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A SYSTEMATIC TREATISE

ON

COMPARATIVE PHYSIOLOGY,

INTRODUCTORY TO

THE PHYSIOLOGY OF MAN,

TRANSLATED, WITH NOTES, FROM THE GERMAN OF

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VOL I.

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THE

TRANSLATORS' PREFACE.

THE object of physiology is to expose the phenomena of life, and the conditions upon which their manifestations depend. To accomplish which it must be first determined what are the phenomena which collectively are denominated life. For this purpose a knowledge of the general properties of organic or living bodies must be acquired, and this can only be attained by comparing the phenomena and actions of organic or living bodies with those exhibited by inorganic or lifeless bodies. Having by such comparative investigation gained a knowledge of the qualities distinguishing living bodies in general, the next principal object will be to ascertain the qualities that respectively characterize the two great sections of the animate world. With this view, a comparison is instituted between plants and animals relative to their composition, configuration, formation, powers, origin, end, and connexion with external influences.

These comparative inquiries lead to the discovery of the qualities which man shares with living bodies in general, or with animals in particular, and to the acquisition of fundamental ideas of life, organization, and the properties of living bodies, as also of the circumstances and conditions under which life is developed.

The next course to be pursued is that of comparing man with other animals, so as to make known the peculiarities of his structure and manifestations of life—to assign him a place in the system of nature, to characterize the races of man, and to follow them in their distribution over the globe.

In researches into the manifestations of activity in man, and the causes on which they depend, the qualities of the body in which these operate are to be considered. These qualities consist in peculiarities of composition, aggregation, texture, and formation. Hence chemistry is employed to detect the matters entering into its solid and liquid parts, to determine their modes of combination, and to indicate and explain the changes occurring therein during life. As respects the structure and form of the body, the parts simply as they are seen, those which are beyond the analysis of the anatomical scalpel, the different tissues, and their several properties, severally require examination and exposition.

The principal inquiry, however, included in the science of human physiology is into the demonstrations of power, which we call the life of man. In this scrutiny the phenomena exhibited, and the properties enjoyed by the different tissues and organs are to be divided into classes, according to their several resemblances and differences ; at the same time that attempts must be made to discover the conditions and powers under whose influences such phenomena are generated and maintained. To establish the laws by which the powers enter into action, and to learn in what manner the life of man, or the sum of all his active manifestations is produced and maintained by the mutual play of the power, also form part of the task. Finally, a consideration of all the vital phenomena, as well in the different organs and isolated apparatus as in their connexion one with another and in their mutual dependance, is the great object of physiology.

One train of phenomena is superadded to the study of human physiology not entering into that of general physiology—the phenomena of intellect. These are, however, to be examined only in part—psycology claims the remainder. The physiologist has to inquire into the dependance of the mental operations on the disposition, organization, and powers of the body, to determine the influence which different functions exert over them—as also to indicate the reciprocity of action between the mind and the corporeal organs and their functions. The regular changes which the human race undergoes in configuration, composition, and activity, from the period of conception to that of death, are subjects of physiological investigation, and are properly treated of, while considering the functions of generation, formation, development of the fœtus, and the various periods of life. Death, with its phenomena and their differences resulting from the mode of death, together with the operation of the causes of these differences, also compose objects of physiological inquiry.

The action of external influences on the body, as of certain degrees of heat, light, and electricity, the qualities of the atmosphere, water and food, the diurnal and annual epochs, the influence of climate, of meteorological and hygrometrical conditions of the atmosphere, are each and all circumstances and agents that should not escape the scrutiny of the physiologist.

Inasmuch as our inquiry should extend to the influence exerted by the mind over the material body, in so much should our study be directed to those circumstances which may modify the habits and tendencies of the mental faculties. Manners and customs, the organization of society, the constitution of the state, and the prevalent religious opinions, compose such circumstances, and are, therefore, worthy the serious consideration of the philosophical inquirer into the life of man.

Such are the subjects entering into the domain of systematic physiology. The mode of arriving at the preliminary knowledge of the attributes of inorganic and organic matter, as well as of the inferior forms of the latter composing the vegetable creation, is by comparison. This mode, which on its announcement may appear novel, is, nevertheless, the one most commonly had recourse to during an investigation of nature and her phenomena; of this any one will be convinced who reflects on the origin of his knowledge of those phenomena. The more numerous the points of view under which we discover that the objects of our researches may be compared, the more fully do we perceive resemblances and distinctions between them, and the more perfectly do we enter into their essence. But neither should deductions be too hastily made from the resemblances or differences of objects, nor should such be allowed too exclusively to fix our attention. Sagacious observers not unfrequently fall into the error of trusting to the former alone, while men of active imagination as easily submit to the latter. This double error was well remarked and expressed by Bacon in his Nov. Organum, Lib. I, Aph. 55. Maximum et velut radicale discrimen ingeniosum, quod philosophiam et scientias, illud est; quod alia ingenia sint fortiora et aptiora adnotandas rerum differentias: alia adnotandas rerum similitudines. Ingenia eínm constantia et acuta figere contemplationes et morari et hærere in omní subtilitate differentiarum possunt; ingenia autem sublimia et discussiva etiam tenuissimas et catholicas rerum similitudines et agnoscunt et componunt. Utrumque autem ingenium facile labitur in excessum prensando aut gradus rerum aut umbras." The former often fail to obtain the essence by paying too much attention to the more unimportant secondary points, whilst the latter, by seizing too readily slight resemblances, are led away by false analogies. The true inductive spirit lies "in medias res," and in proportion to its value is the rarity with which it is observed to be pursued. By closely insisting on this rule the usefulness of comparison, in the study of physiology, may be fairly estimated, and its application judiciously regulated.

Physiology is very commonly considered and represented as an experimental science, although the true meaning attached to the designation is as commonly misunderstood; all that it implies being that the science is based on experiment. The incontestable truths of physiology are the results of observation and experiment, whatever follow must be derivable from the same sources. All our knowledge proceeds from experience; for the objects which impinge on our senses, and which, themselves, produce ideas, or excite the mind to compare, combine, separate, and elaborate other ideas, are the only means whereby the mind is brought to an acquaintance with them, which acquaintanceship is called experience. No knowledge precedes experience; accordingly experiment is the foundation on which all our physiological knowledge, if it be rational, must be erected, and to which it must, if questioned, be referred.

But crude, indeed, would be the pediment without the well-ordered statue—the foundation without the superstructure—the fact without the inference. Vain would be the chaotic accumulation of experiments, and useless the heaps of isolated facts. The mind of man is so constituted as to render very unsatisfactory the possession of mere truisms established by the external senses. Facts, to be useful, must be placed in a tangible position, to be applicable they must be made to bear on specific points. The same relation which the crude and shapeless mass bears to the material when manufactured and brought to its highest utility does practical physiology, or physiology of facts, bear to theoretical physiology. In the former the existence of facts is ascertained, in the latter those facts are arranged and their value certified. The effect of this arrangement is to bring all the facts to their bearings on general points, or, in other words, to generalize, for which it is especially necessary to embrace the objects and phenomena in question, even to their minutest particularities. The more clear and accurate is our comprehension of these individual examples, and the more our attention is concentred on particular points, the more certain are we to discover materials between which a general connexion may be established. On the other hand, the mind should, whilst contemplating the whole with the view of learning what particular quality may be common to numerous objects and phenomena so as to obtain precise ideas of them, and to place them under a category, be capable of rising above particularities.

In the arrangement and classification of facts, and in deductions arising therefrom, we act by analysis, synthesis, and induction. By the former we reduce the compound and complex phenomena of living bodies to the simplest mode of representing them, having, at the same time, a regard to each of the various points of view in which they may be considered. By synthesis we collect similar or analogous phenomena, and attempt to depict, by one idea, whatever is common and essential to a group. Lastly, by induction, we infer from a number of similar or analogous facts general rules and laws.

Having reduced the phenomena and properties of a living body to general traits, and established their several relations, it remains only to assign the causes on which they depend, this being the boundary of research in physical science. In attempting this it behoves us to attribute all phenomena and effects of the same description to one and the same cause, to regard that cause only as the true one which is founded on precise observation, and which is both necessary and sufficient to explain the phenomena, admitting no greater number of causes than there are effects manifestly and essentially different.

From the preceding, it follows that physiology is an experimental science, based on a rational empiricism. Its axioms are conclusions acquired from observation and experiment,—its rules and laws marked by induction; for the phenomena and causes of life only possess a value relative to the observations and experiments whence they are deduced. They are only to be accepted as true after having been submitted to the test of repeated observation. The axioms established in the manner stated are united into one systematic and logically-congruous whole, in which hiatus occur whenever further experiments and observations are wanting, when they are insufficient to enable us to form tenable conclusions, or whenever the reflections and considerations on which these conclusions are based do not comprehend them in their diversified bearings.

The applications of the principles of physiology and the cultivation of the science is of paramount importance to the pathologist. The normal state is the standard whereby is measured the extent or degree of morbid lesion, or in the words of Galen, "Cujusque morbi tanta est magnitudo, quantum a naturali statu recedit; quantum vero recedat is solus novit qui naturalem habitum adamussim tenuerit." How, for example, should the morbid condition of the pulse be distinguished and recognized without a previous knowledge of what constitutes its sane state with all the modifications entailed by age, sex, constitution, the time of year, external temperature, food, mental emotions, &c.? Nor can the causes of disease be ascertained, unless the conditions and circumstances on which the manifestations of life depend, and by which they are maintained in a normal state be understood. Such conditions are either external or internal agents. As regards the former physiology teaches the action of the various states of the atmosphere, of light, water, aliment, poisons, &c., on the body. The latter comprehend the influence of the will over the functions, the mode of life, occupation, profession, &c., all severally determining an increased or diminished activity in different organs. Wherefore it is obvious that, to estimate the part performed by these in the production of disease, a knowledge of their mode of operation on the sound body is requisite. This knowledge is the object of physiology, the means of its attainment constitute the science. We are, therefore, opposed to those who maintain the separation of pathological from physiological science, since the same causes, modified as to state and degree, are capable of inducing both conditions.

Inasmuch as physiological science treats of the sympathies existing between different organs, the manner in which they are affected by external agencies, and the mode in which they react upon such influences through the instrumentality of internal powers, so will the applications of its doctrines be found to be frequent and pertinent in the explanation of the operation and effects of remedial agents, whether externally or internally administered. That portion of medical study denominated the doctrines of therapeia must therefore derive valuable aid from physiology.

Thus at every step of his career the student of medical science will receive that illumination from physiology which, while it dissipates the obscurity investing many of the particular subjects of his investigation, strikingly manifests the general philosophical character of the study of medicine. Those rude and superficial observers who seek nothing in the arrangement of the organs but the most facile means of fulfilling some of the minor practical designs of the art, cannot comprehend, much less appreciate, the scientific turn which the applications of physiology give to the ideas both of the practitioner and the student. It is not to such, however, we should refer as criteria of medical acumen. Let the inquirer into medicine take those extensive but accurate physiological views, those well founded doctrines of life and its laws, which the laboured experiments of later times have originated; let him apply them to the aberrations from, or modifications of those laws, which constitute disease; let him, having thus ascertained the nature of the modifications and of their causes, reason upon the connexion subsisting between such modifications and the agents employed for their correction; and he will then be in a position qualifying him to give a rational explanation of his medical views—to advance a reason "for the faith which is in him," and to establish his claim to the enviable title of a medical philosopher.

It has been from the conviction of its high character as a systematic work embodying all that has been advanced on a subject of that universal application and incalculable value which we have maintained comparative physiology to be to the general science of medicine, and likewise from a desire of more completely attaining the object which originated its publication, that the translators present the accompanying volume to the English students of medicine, to whom the novel mode adopted by the Heidelberg Professor, in pursuing the physiological inquiries, must be particularly interesting. The course prosecuted consists in first comparing organic with inorganic bodies, and afterwards the objects of the organic world with one another, precisely the one which we have instanced as the most rational, simple, and conclusive, and which to every mind reflecting on the science must appear a plan most likely to lead to a near approximation to the truth, and which may, therefore, reasonably create some surprise that a similar scheme has not already been adopted by the physiologists of our own country. The Treatise on the Formation and Development of the Great Nervous Centres, published some years since, by Tiedemann, and translated by Dr. Bennet, is a highly-gratifying instance of the advantages derivable from his manner of studying the anatomical connexions of a complicated organ. No medical inquirer can terminate the perusal of that work, without a conviction, engendered by the accurate ideas it has imparted of the brain's development, that a comparison between man and other animals, relatively to structure and the uses of structure, is the most certain way of acquiring valid information on the organic dependence of function, and a conclusive indication of the particular organs of specific functions. In fact, nothing appears more clear than that functions, the organs for which are not well ascertained, should be determined by a comparison with those animals in which such functions are not manifested, and in which certain organs do not exist; being thus, by discovering the coincidental absence of function and organ, impelled to the conclusion that such organs perform such functions in animals endowed with both. Pursuing a similar inquiry still further, we are ultimately led to an intimate knowledge of the function—which constitutes the object of physiological science.

In this first volume (the only one yet published by the author) a general comparison is instituted between organized bodies. It may be termed in itself a system of comparative physiology, in which the opinions of Tiedemann are so fully explained, the subject so completely investigated and illustrated, and the whole argumentative edifice so beautifully constructed from the premises to the conclusion, by himself, that little remains for his transcibers to attempt in the way of augmentation or elucidation. Their notes will, therefore, be somewhat rare, and necessarily diminutive. Should the translators, however, succeed in bringing the attention of the medical reader to the comprehensive and philosophical manner of studying this fundamental part of his scientific education, they will consider it the best mode of doing just honour to the author, and the most gratifying reward to themselves for the labour of introducing it to their country's language.

GERRARD-STREET SOHO, LONDON.
NELSON-STREET, LIVERPOOL.

1*st September,* 1834.

THE

AUTHOR'S PREFACE.

To my Pupils.

You have so frequently expressed a desire to see my lectures on physiology in a printed form, that I am at length induced to accede to your wishes. In order to further your studies, I have given a greater scope to the contents, communicated as they are in aphoristical sentences, than it would have been possible to do in the brief period dedicated to oral instruction. In publishing this work, I purpose more especially to bring under your view and to arrange the most important results of the observations and experiments that have been made in that department of science which treats of the physiology of man. A collection and review of physiological experiments appeared to me of the first importance, inasmuch as no great attempt of that kind has been made since the appearance of Haller's "*Elementa Physiologiæ,*" and as many of the most valuable researches, scattered throughout the writings of men of learning and periodical publications, are not sufficiently known or regarded. For many years past I have been striving, so far as it lay in my power, to repeat and certify, by ocular proof, the observations and experiments of my predecessors and contemporaries. In presenting and examining them I have endeavoured to employ a short, clear, concise, and easy style.

In order to obtain a proper foundation in studying the physiology of man, I considered it best to determine the properties of living bodies in general, and those of vegetables and animals in particular, in reference to chemical composition, external form and aggregation, and the powers belonging to them, by induction and by a comparison with bodies not endued with life, and likewise among themselves. It is only in this manner that we can acquire a true conception of the phenomena which constitute life, and of the properties of living bodies. As you have been applying yourselves to the physical sciences, natural philosophy, chemistry, mineralogy, botany, and zoology, as well as to the anatomy of man, plants, and animals, with the intention of becoming scientifically-educated men instead of mere *routiniers,* you will easily be able to follow the experiments here laid down.

This work, which is intended for you alone, will not only recall to your memory things which I have heretofore stated, but will serve also as a commentary on the maxims I have already delivered. Much that has been advanced in the lectures is here more fully developed and enlarged upon. Moreover, it makes you acquainted with the works of the distinguished physiologists from which I have borrowed many materials, facts, and ideas, and enables you to go to the actual sources for information. I trust, then, this work, which aims at giving a true and full description of the life of man, its phenomena, causes, and conditions, will be useful to you in the extensive study of medicine and its various branches. In the practice of medicine it will likewise prevent prejudice and rashness in judging and acting, a thing altogether unavoidable without a thorough knowledge of the structure and functions of the human body. Finally, you will meet with hints in every part which cannot fail to be advantageous to you in practical medicine.

TIEDEMANN.

Heidelberg, August 23, 1830.

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ON

COMPARATIVE PHYSIOLOGY,

INTRODUCTORY TO

THE PHYSIOLOGY OF MAN.

PART I.

GENERAL OBSERVATIONS ON ORGANIZED BODIES.

BOOK FIRST.

Comparison between living Bodies and Bodies not indued with Life.(1)

I. The objects capable of making impressions on our senses, the union and reciprocal action of which represents nature,(2) are either large masses concentrated in themselves, moving in the space of the universe—the celestial bodies—or only parts or fragments of one of the stars, such as the bodies which compose our planet. We are informed of the existence of the former by an effect which impresses on our eyes, and has the name of light. That

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(1) The following books on this head may be consulted: G. E. Stahl, De organismi et mechanismi diversitate. Halle, 1706, in 4to.—R. Bradley, Philosophical Account of the Works of Nature. London, 1721, in 4to.—Buffon, Comparaison des animaux, des vegetaux, et des mineraux, in his Histoire naturelle. Paris, 1749, in 4to, v. ii, p. 1.—Charles Bonnet, Considerations sur les corps organisés. Amsterdam, 1762, 2 vols. in 8vo.—J. B. Robinet, Considerations physiologiques sur la gradation naturelle des formes de l'être. Amsterdam, 1768, in 8vo.—Vicq d' Azyr, Exposition des caractéres qui distinguent les corps vivans; in his Discours sur l'anatomie: works, vol. iv, p. 229.—Delaméthérie, Considerations sur les êtres organisés. Paris, an. xiii, in 8vo.—A. Sniadeski, Theorie der organischen Wesen; translated from the Polish. Nuremberg, 1828, in 8vo.—C. G. Carus, Von den Naturreichen, irhem Leben, und ihrer Verwandtschaft; in Zeitschrift für Natur und Heilkunde, published by the Professors of the Medico-chirurgical Academy of Dresden, vol. i, p. 1.

(2) The word *nature* is employed in different acceptations. In the first place, by it are designated the qualities which belong to bodies primarily, in opposition to those bestowed on them by art. We also understand, by the *nature of a thing*, that its qualities and changes of state are determined by laws. The word nature, moreover, indicates the entire of all the objects susceptible of coming under the senses, or the universe, as the sum of all individual things. Such as the senses conceive of it, nature appears to us a chaos of bodies and of infinitely varying phenomena. We designate, also, by this name the totality of perceptions by the senses, inasmuch as we behold in them unity, harmony, and reciprocity of action, and that the qualities and changes of things and of their phenomena are necessarily determined by laws, and are held

of the others is made known to us by two of their more general properties, extent and impenetrability. If we divide these last named according to their material qualities, their manifestations of power and the changes which they present in time and space, we shall behold them ranged in two great groups, accurately separated, namely, inorganic bodies, or bodies not endued with life, and organized or living bodies. The former are the fossils or minerals, liquids, and gases ;(3) the latter are plants and animals.(4)

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together by the bonds of a mutual causality. This knowledge is the work of the mind, which classes the phenomena of the universe, seeks their relations of causality, and discovers the dependence in which they stand to each other. Lastly, we designate by the word nature the first and supreme cause of all the things and phenomena of the universe, that from which all emanate, and by which all exist. The idea of a supreme cause in the universe results from the operation of reason, which sees that everything in nature obeys eternal and immutable laws recognised as conformable to reason. The unity and harmony which reign in the universe, the tendency to one end which reason discovers in the innumerable bodies composing it, (of which man is only with some fragments acquainted,) prove that there can only be one prime cause of it. Reason, which is, by its very self compelled to recognise a complete whole in nature, at once cause and effect of itself, imagines that which acts the part of preserver and creator of the universe, to be the absolute one, the soul of the world, the Deity.* Reason, which generates the idea of a God, has a great tendency to deify itself and to assimilate itself to the reason which reigns in the universe. But, in my view, the reason even of the most profound metaphysician, is scarcely to that of the Deity what the light of the glow-worm is to the noon-day sun. Although reason leads the naturalist to admit a predominating unity in nature, and though her efforts have for their end to refer our knowledge of nature and the phenomena therein perceived, to a primary and supreme principle, which she makes use of to explain them, yet all the attempts which metaphysics have hitherto made to attain a complete knowledge of nature by purely rational ideas, have failed. In order to acquire perfectly the nature of phenomena and their causes, as well as the unity which prevails in them, we should be able to contemplate it with the eye of omniscience, in its first principles and its primitive powers: then we should possess a science of the universe, a cosmology, in which the particular phenomena would be deduced from a supreme rational idea, by embracing the entire of them. But as our faculty of thinking and perceiving is confined, the prudent naturalist is aware he cannot take so high a flight, and is forced to go hand in hand with experiment, in order to ascend the ladder of facts as far as it will bear him. He therefore abandons the solution of this problem to the metaphysician, and only engages in the establishment of an experimental science of nature and her domains. Observations and experiments furnish him with the material which he elaborates by the activity of his mind, for which he seeks principles, and from the collection of which he forms a science at once empirical and experimental.

* It may be questioned whether, strictly speaking, there ever existed such a character as an atheist. The dispute has been rather about the *nature* of the Deity, than about his *existence*—the mass of mankind giving the name of atheist to the few who differed from them in their notions of his nature and attributes. We are, perhaps, too much in the habit of regulating our conceptions of the Deity, by our ideas of his personification, as one after whose image we were made, and hence we hold those to be tainted with atheism who, refusing to say what or where he is, pretend to no knowledge of him beyond what his creation exhibits. If we analyze the doctrines of Spinoza, who has been considered one of the most inveterate atheists of later times, it will probably be difficult not to recognize in them an acknowledgment of a great First Cause. The Spirit whose emanation, Spinoza contends, constitutes the exalted reason of man, the lower degrees of reason and instinct of other animals, and the qualities of matter, is still a spirit of the most exalted order, whose attributes are omnipotent, whose existence omnipresent, whose essence is beyond our comprehension, and which therefore approaches very nearly to the generally received idea of the Deity. There are those who consider that bodies exist by a mutual necessity—that the reciprocity of cause and effect, which all matters manifest to each other, is a sufficient reason for their existence and continuation. Unlike Spinoza, they discard the agency of any spirit, and, in our idea, approximate more closely to atheism than this philosopher. On the other hand, their doctrine leads them to believe and have a firm faith in whatever religious creed they may imbibe, since such belief is a necessity of their nature. The adherents to this doctrine are the St. Simonians, in France, and the followers of Robert Owen, in England.—TRANSL.

(3) Physical science has not yet solved the problem, whether imponderable substances, such as light, heat, electricity, and magnetism, are very subtle matters, having a separate existence or only manifestations of activity of ponderable matters. Perhaps these substances are, as some physical philosophers think, simple phenomena which ponderable matters produce under certain circumstances, such as sound.

(4) Bonnet himself, the most warm defender of a natural scale of bodies, admits a similar difference, since he says, (Loc. Cit. ch. xii, sec. 209,) that " Si le polype nous montre le passage

II. Organic bodies, divided into two great sections, the vegetable and animal kingdoms, do not come into contact at their boundaries, so that the plants most complicated in structure verge upon the most simply constructed animals, and form the passage from one kingdom to the other, as Buffon, (5) Bonnet, Sulzer, and other naturalists have admitted. On the contrary, the most simple vegetables, the cryptogamia, particularly the algæ, the ulvæ, the tremellæ, &c., and the most simple animals, the zoophyta, the infusoria, and polypi, approach the nearest of all, according to the remark of Linnæus and other naturalists. The two kingdoms approach so near to each other in their most simple forms, that there are some of these, regarding which it has not been determined, at least hitherto, whether they are plants or animals. Thus naturalists still dispute concerning the nature of sponges, (6) of corals, (7) of the oscillatoria, (8) &c. One might even be almost tempted to believe that, in certain circumstances, the most simple vegetable and animal forms may pass from one to the other. Conferva are resolved into infusoria, and infusoria produce confervæ by their union. (9)

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du Vegetal à l'animal, d'un autre côté nous ne decouvrons pas celui du Mineral au Vegetal. Ici la nature nous semble faire un saut; la gradation est pour nous interrompue, car l'organization apparente de quelques pierres et des cystallizations ne repond que trés imparfaitement á celle des plantes." However, some naturalists have rejected all idea of a difference between organic and inorganic bodies. Among such is Robinet, in the work which I have cited, and in the fourth volume of his Traité de la Nature. A. F. Schweigger (Handbuch der Naturgeschichte des Skelettlosen Ungegliederten Thiere. Leipsick, 1820, p. 26) also admits a transition from inorganic to organic bodies. He thinks that the animal kingdom passes to the inorganic kingdom by the Lithophyta and the Nullipora, and regards lime as one of the links of the chain which unites these two kingdoms. But to this hypothesis it may be objected, that the lime which is found in lithophyta is always penetrated by an organic matter, a gelatinous mass, and that the reunion of its molecules, whence is made the branch of coral, is produced by polypi.

(5.) *Hist. Nat.*, vol. ii, p. 8. "L'examen nous conduit a reconnaitre qu'il n'y a aucune difference absolument essentielle et generale entre les animaux et les vegetaux; mais la nature descend par degrés et par nuances imperceptibles d'un animal qui nous parait le plus parfait á celui qui l'est moins, et de celuici au vegetal. Le polype d'eau douce sera, si l'on veut, le dernier des animaux et la première des plantes."

(6) Sponges have been ranked in the number of animals by Belon, Imperati, Nuremberg, Peysonnel, Tremblay, Ellis, Solander, Linnæus, Bruguière, Lamarck, Bosa, Lamoureux, Cuvier, Schweigger, Grant, &c.; whilst Bauhin, Kay, Tounefort, Morrison, Seha, Forskael, Targioni, Tarzetti, Spallanzani, Gray, and others, regard them as plants.

(7) To the genus *corallina* of Linnæus approach considerably the pennatulæ, as also the halymedeæ, the galauxeræ, the lygoreæ of Lamoureux, and the flabellareæ and polyphyses of Lamarck.

(8) Guod de Chantran (Recherches chimiques et microscopiqnes sur les conferves, bysses, tremelles. Paris, 1802) regards the confervæ, byssi, and tremellæ as polypi; whilst other naturalists class them among plants. According to G. R. Treveranus, (Vermischte Schriften, vol. i, p. 168,) the confervæ oscellatoriæ, for instance, the *conferva limosa, muralis,* and others, which approach the zoophyta so much in their form and movements, their green colour, and their peculiarity of exhaling oxygen gas in sunshine, but which are altogether of a vegetable nature, are as near to zoophyta as to plants in regard to their propagation by cuttings, suckers, buds, and seeds. Bory de Saint Vincent (Essai monographique sur les Oscillaires. Paris, 1827) has lately erected them, under the name of *psychodiariæ,* into a separate kingdom of living bodies, The nostoch of Vaucher and the diatomes of Fries are among the number of organic bodies, the nature of which is still in doubt.

(9) Thus Ingenhouz (Miscellanea Physico-Medic. Ed. Schrerer, Vienna, 1793) says, he observed that the green matter of Priestley was formed by an union of infusoria, and also was separated into infusoria. This observation has been confirmed by the remarks of G. R. Treviranus, (Biologie, vol. ii, p. 338, 344, 350,) and of Trentepohl, (Roth's Botanische Bemerkungen,

III. The great analogy which exists between the most simple or inferior animals and plants, an analogy which Aristotle heretofore recognised, (1) has led many naturalists, Buffon, Bonnet, (2) Pallas, (3) Darwin, (4) Smellie, (5) Mirhel, (6) to deny any essential difference between animals and plants. G. R. Treviranus, in consequence of this idea, has considered the cryptogamia and zoophyta as an intermediate kingdom between the animal and vegetable. Although some of the most simple forms of living bodies resemble each other so strongly, that it is actually impossible for us to discover, in their structure and manifestations of life, characters sufficient to decide whether they be plants or animals, yet this is not a reason which can authorize us in maintaining that there is no difference in general between these two kingdoms. In fact, the further we rise from the simple forms of plants and animals to the more complex, the more we perceive well pronounced distinctions in structure and manifestations of life. Starting from the cryptogamia and zoophyta, the vegetable and animal kingdoms proceed in different directions from each other, and pass into more complex forms. To the cryptogamia of Linnæus, or a cotyledones of Jussieu, (7) the algæ, mushrooms, lichens, hepaticæ, and mosses, succeed the ferns, the lycopodineæ, &c. Then come the phaneragamia, and first of all the monocotyledones, (8) the aroïdeæ, the typhæ, the cyperaceæ, the graminæ, the palmæ, the asparagi, the liliaceæ, the bromeliaceæ, the narcissi, the tulipaceæ, the irideæ, the musaceæ, the canneæ, the orchideæ, &c.

Leipsick, 1807, p. 180.) Guod de Chantran has also seen confervæ and ulvæ formed by collections of infusoria, and again separated into infusoria. Bory de Saint Vincent has moreover shown that great quantities of confervæ arc dissolved during summer, and that many globules which are seen within them become infusoria animalculæ, which may again unite to form new confervæ. A similar observation has been made by Gaïllon on a species of marine conferva which belongs to the genus *ceramion* of Decandolle, and which Dellwyn has described under the name of *conferva comoïdes.* The filaments of this conferva separate into infusoria, resembling the enchelideæ, cyclidieæ, and other infusoria animalculæ of Muller. Latterly, also, Edwards has observed, in his researches in infusoria, that they can unite to produce vegetable forms, and again separate. Turpin has objected to this, but his objections do not refute the preceding observations. The movements of some infusoria are effected with great slowness, and these bodies fix themselves, one after the other, into the form of confervæ. This almost leads to a difference between the infusoria animals, or the commencement of animal formations, and the infusoria vegetables, or commencement of vegetable formations. The infusoria animalculæ approach sometimes so near to each other, that it is not possible, with any certainty, to establish generic distinctions between them. Nitzch has pointed out this phenomenon to the attention of naturalists (Beitraege zur Infusorienkunde oder Naturgeschichte der Zerkarien und Bacillarien; Halle, 1817.) According to him, the *bacillaria pectinalis*, *viridis*, and other species described by him, act altogether like plants, although they cannot be separated, by any generic character, from the *bacillaria palea* et *fulva,* which perfectly resemble animals in their movements, and are joined very closely to the preceding.

(1) Hist. Aninal., lib. v. c. l.

(2) Contemplation de la Nature, Works, vol. x. p. 514.

(3) Eleuchus Zoophytorum, p. 23.

(4) Phytonomia.

(5) Philosophie der Naturgeschichte, vol. i. p. 3.

(6) Elemens de Physiologie Végétale, vol. i. p. 171.

(7) Richard called them *exembryonatæ*; Lamarck, *plantes agames;* Link, *homonomeæ;* Decandolle, *plantes cellulaires;* Schultz, *plantæ axylinæ*.

(8) *Embryonatæ* of Richard; *phanerogames* of Lamarck; *heteronomeæ* of Link; *plantes vasculaires* of Decandolle; *plantæ xylinæ* of Schutz.

Lastly, the dicotyledones approach, with their numerous subdivisions, namely,

1. The apetalous plants, or those with incomplete flowrets, the coniferæ, the amentaceæ, the laurineæ, the euphorbiaceæ, &c.

2. The monopetalous plants, the labiatæ, the convolvulaceæ, solaneæ, campanulaceæ, ericeæ, &c.

3. The polypetalous plants, the umbelliferæ, ranunculaceæ, papaveraceæ, malvaceæ, leguminosæ, rosaceæ, &c.

In the animal kingdom, after the zoophyta, among which are ranked the infusoria, the polypi, the acalaphi, the entozoa, the echin odermi, come the mollusca, the jointed animals, annelidæ, insects, arachnidæ, and crustaceæ, and lastly, the vertebrated animals, fishes, reptiles, birds, and mammifera, the last class of all, at the summit of which man is placed.

IV. In order to judge of the phenomena and general characters of organic or living bodies, we shall compare them with inorganic, or those not endued with life, in relation to their conformation, configuration, contexture, their manifestations of activity or of power, their origin, and their end. This parallel will bring together the resemblances and differences, and will decide whether we are right in attributing to living bodies particular qualities which belong to them exclusively. (9)

FIRST SECTION.

PARALLEL BETWEEN THE MATERIAL COMPOSITION OF ORGANIC BODIES AND THAT OF INORGANIC BODIES.

CHAPTER FIRST.

On the Chemical Mixture of Substances.

V. All organic and almost all inorganic bodies are composed of simple materials, diversely combined with each other, and which may be separated by chemical operations. However, when we compare the composition of these two groups of bodies, we recognise important differences between them. Thus the first are for the most part assemblages of particular combinations,

(9) G. G. Stahl, De Mixti et vivi Corporis Vera Diversitate; in the Theoria Medica, Vera, p. 65.—T. Berzelius, Essay on the Means of Discovering the Simple and Definite Proportions, according to which the Principles of Organic Nature are combined; in Hisinger och Berzelius A Chandlingar i Fysik, Kemi och Mineralogi, vol. iii. Stockholm, 1810. Also in Thomson's Annals of Philosophy, vol. iv. p. 323, 401, vol. v. p. 93, 174, 360.—Berzelius Treatise on Chemistry, translated from the Swedish by Woehler, Dresden, 1827, book iii. part 1, p. 135.—Gay, Lussac and Thenard, Methode pour Determiner la Proportion des Principes qui Constituent les Substances Vegetales et Animales; in Recherches Physico-chimiques. Paris, 1811, vol. ii. p. 265. A. Ure, on the Ultimate Analysis of Vegetable and Animal Substances; in Philosophical Transactions for the year 1822, vol. ii. G. Patten Emmet, on the Chemistry of Animated Nature. New York, 1822, in 8vo.—E. Chevreul, Considerations Generales sur l'Analyse Organique et sur ses Applications. Paris, 1824.—Robinet, Essai sur l'Affinite Organique. Paris, 1826, in 4to.

which we first meet with when we chemically analyse plants and animals. There are, in the vegetable kingdom, starch, vegetable albumen, gluten, gum, sugar, &c.; in the animal kingdom, animal albumen, fibrin, gelatin, mucus, &c. These matters are called by chemists the immediate or proper matters of organized bodies, or the simple organic compounds. (1)

VI. In submitting anew the immediate principles of organic bodies to chemical analysis, we obtain the mediate principles, or the simple matters, which chemistry has not yet further decomcomposed, and which for this reason are denominated elements. The ponderable mediate principles of organic bodies are:

A. Non-metallic substances; namely, 1 oxygen, 2 hydrogen, 3 carbon, 4 nitrogen, 5 phosphorus, 6 sulphur, 7 iodine, 8 bromine, 9 chlorine, and 10 fluorine.

B. Metallic substances:

a. Alkaline metals—11 potassium, 12 sodium, and 13 calcuim.

b. Earthy metals—14 magnesium, 15 silicium, and 16 aluminum.

c. Ponderous metals—17 iron, 18 manganese, und 19 copper.

Among imponderable substances, those which can in some circumstances be recognised in organic bodies, are, light, heat, and electricity.

All these elements are likewise found in inorganic bodies. Organic bodies, therefore, do not differ from the latter in regard to elementary matters. But great differences exist relative to the number of elements which enter into organic combinations, and in the manner in which they are joined together.

VII. The number of elements which enter into the composition of bodies included in the organic kingdom, is much less considerable than that of the elements which exist in the other kingdom. Organic bodies, as far as we can judge of them from the data hitherto collected by chemistry, do not present, putting aside the imponderable matters, more than the nineteen elements which I have enumerated, (2) while fifty-two have already been found in the other kingdom. All the substances which chemistry regards as simple, do not therefore enter into the composition of organic bodies, which, on the contrary, only contain the smallest proportion of them. From among the substances therein discovered, those which exist in greatest quantity are oxygen, hydrogen, carbon, and nitrogen, in infinitely varying proportions. The rest are by no means abundant in comparison with these.

VIII. Although the number of elements in organic bodies in general

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(1) The French chemists call them "*les principes immediats organiques.*" We may give them the name of organic matters or those adapted to life, because they are essential constituent parts of living beings and the phenomena of life are perceived only in bodies that are composed of such.

(2) The opinion of chemists are divided regarding the existence of some other simple substances in organic bodies. Thus, Becher asserts that he found gold in the ashes of tamarinds.

be small, nevertheless the composition of a living body, a plant, or animal, is much more complicated than that of an inorganic body. Besides the fact that almost always one and the same vegetable or animal presents at the same time, in its different parts, very diverse modes of combination, we observe that all the compound or organic matters proceed from three, four, or more elements. There are three elements at least in them, united together in an immediate manner, without having a preliminary binary combination. Vegetable mucus, sugar and starch, are composed of carbon, oxygen, and hydrogen. Gluten, albumen, fibrin, animal mucus, cafein, &c., contain moreover nitrogen, in addition to these three elements. The ternary or quarternary unions of these four substances in proportions varying *ad infinitum*, give rise to the immediate products of organized bodies; a result clearly proved by the researches instituted by Thenard, Gay Lussac, Berzelius, Prout, Thomson, Berard, Th. von Saussure, Ure, and others.

On the other hand, all the inorganic combinations, as Berzelius has shown, are to be considered as binary compositions, that is, resulting from the union of two elements alone, or as combinations of two binary composed bodies, or lastly, as combinations of a binary compound with a simple substance. Thus oxygen with hydrogen produces water; with sulphur, phosphorus, nitrogen, and carbon, it forms sulphuric, phosphoric, nitric, and carbonic acids; in junction with calcuim, soduim, and potassium it gives lime, soda, and potassa. Chlorine with hydrogen, originates hydrochloric acid; nitrogen and hydrogen produce ammonia. These salts, then, are only double binary compounds.

It is evident, therefore, that nature has given a more complex composition to organic than to inorganic bodies, a remark which Kielmeyer has already made in his course of general zoology.

IX. Organic combinations can easily be reduced to their elements by chemical operations, and principally by the action of fire, but chemists have not hitherto succeeded in reproducing them, as they have done the inorganic compound bodies.(3) Sugar, starch, gum, gluten, fibrin, albumen, &c. have

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(3) Some chemists assert, that they have obtained organic combinations by submitting inorganic compositions to various modes of treatment; but doubts may be entertained on this subject. Thus Berard (Annales de Chimie et de Physique, vol. v, p. 297) says, he obtained a little crystallized fat by passing one measure of carbonic acid gas, ten of olifiant gas, and twenty of hydrogen through a red-hot tube. It is very probable, that the substance resembling fat which he found was held in solution in the olifiant gas, which had been procured from alcohol. Dœbereiner, (Oken's Isis, 1817, art. 5, p. 576,) by passing watery vapour over red-hot charcoal, in an iron tube, got a volatile matter, soluble in water, and having the smell of fat. But it may be objected, that charcoal should be looked on as an organic combination. Besides, Berard and Trommsdorf, (Neues Journal für Pharmacie, vol. ii, art. 2, p. 203,) who repeated the experiment, did not obtain the same result. We only are acquainted with two compound organic bodies, of the simple kind, namely, oxalic acid and urea, which Wœhler first pointed out the mode of procuring from their different components (Poggendorf, Annal. der Physik, vol. iii, p. 177.) If chemists have really succeeded in producing, by means of purely inorganic substances, some combinations in which the elements are associated as in organic combinations, it is only those

been brought down to their elementary principles, but no chemist has yet arrived at the reformation of them in all their parts. The same is the case of all the liquid and solid parts of living bodies. On this account, then, we are authorized in admitting that, in the present state of chemistry, the composition of organic bodies is not the effect of affinity alone, but that it depends on powers peculiar to those bodies, by which powers the chemical affinities are swayed.

X. Between organic and inorganic bodies there exists a difference relative to the mode of combination of the materials which enter into their composition, and this consists in the greater tendency the former have than the latter to undergo changes and decompositions. The combinations of bodies not endued with life, for the most part binary or double binary, are more confirmed, more fixed, and their elements are held together by more energetic affinities than in organic matters, as Chevreul has shown. For the most part they present solid combustible bodies, which strongly resist decomposition from the atmosphere. On the other hand, the ternary, the quaternary, and even the more complex combinations of the organic kingdom, are less compact and less intimate; they are the results of weaker affinities, which causes them to appear more unsettled and variable, because saturation in them is rarely perfected. The principle of combustion, oxygen, does not exist in sufficient quantities in them, to saturate the combustible elements and to prevent the possibility of their yielding to other affinities. This is the reason why all organic combinations are combustible. For they do not contain the proper quantity of oxygen to saturate their carbon and hydrogen. They burn, when heated, in contact with the atmosphere, and then absorb all the oxygen that is necessary to the saturation of the hydrogen and carbon.

XI. As the elements have a greater inclination to produce binary compounds than to continue in ternary and quaternary combinations, there is observed in organic substances a constant disposition to run into binary states of composition. Inorganic bodies having their elements in a kind of perfect equilibrium, these same elements are but little disposed to combine with surrounding matters, or in any other manner. Such is not the case with organic matters, which are more complicated, and retained by less powerful affinities; in them there is observed a constant tendency to resolve themselves. They are mostly composed of oxygen, hydrogen, nitrogen, and carbon, the three

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that are placed on the outer boundary between compound organic and inorganic bodies. Berzelius (Chimie, book iii, part 1, p. 147) expresses himself in the following manner on this subject: "Although it may happen that, eventually, it may be discovered that many of these products of matters purely inorganic have a similar composition to that of organic products, yet this, in complete imitation, is always reduced to a very small foundation for hoping that it would ever be in our power to manufacture organic matters from their components, and thus to confirm analysis by synthesis, as we almost always are able to do in inorganic nature."

first of which are gaseous when in a state of freedom, and strive to abandon the solid form, a tendency which is still more increased by external heat and the heat peculiar to living bodies. The great affinity of the oxygen for the hydrogen and carbon, causes it to combine easily with the first, whence results water, and with the second, which produces carbonic acid. Nitrogen, which has a great affinity for hydrogen, joins with it, and gives origin to ammonia. But, as the carbon and hydrogen do not find sufficient oxygen, in organic combinations, to form water and carbonic acid, they have a disposition to attract that of the atmospheric air. On these circumstances depends the facility with which plants and animals run into decomposition, and which rests on the constant tendency of their elements to contract binary combinations, and to quit a state in which they are maintained only by the powers acting in living bodies. Living bodies suffer, by the atmospheric influence, remarkable changes, which induce the unfixed elements of food, introduced and rendered fluid in their interior, to undergo, as well by the effect of a subtraction of the materials of the latter, as by an absorption of other principles drawn from the air, a change in their respective proportions, designated under the name cf respiration. The manifestations of activity of living bodies themselves, are incessantly modifying organic matters, the composition of which is extremely variable and mobile, and cause them to pass sometimes to a more simple, sometimes to a more complex, state, by changing the numerical relations of their elements, in such a manner, that vegetable combinations may become animal, and these resume the vegetable state.

XII. There is this difference between living and inert bodies, relative to the connexion of the chemical composition with the configuration, that the former, although they resemble each other most in their composition, nevertheless present a much greater diversity in their forms. What an immense variety of forms the vegetable and animal kingdoms exhibit, notwithstanding the inconsiderable number of elements which constitute living bodies in general. We even find that with an analagous composition, the parts of one and the same organic individual differ in a singular degree from each other in point of configuration. I will only mention, as an example, the diversity which petals often present in the same vegetable species, and that which is remarked, among animals, in the configuration of the bones and muscles. Inorganic bodies, on the contrary are remarkable, with very few exceptions, for their great analogy of form and crystallization, when their chemical composition is identical.

There must be, therefore, in living bodies a peculiar power, differing from the chemical affinities which determines the forms of bodies not endued with life, and the action of which produces the diversity which organic forms with similar composition exhibit. Or, which expresses the same idea in a still more clear manner, the configuration of organic bodies is not only the effect of chemical affinity, as in bodies without life, but it is also that of a power of a special, or, it may be, a superior nature.

XIII. Regarding the origin of organic combinations, experience teaches us that they are only produced by the manifestations of activity of living bodies already existing. Albumen, gelatin, mucus, gluten, starch, gum, sugar, &c., do not form spontaneously, by the union of elements, or binary compounds, according to the laws of chemical affinity, but only by the manifestations of activity of organic bodies already possessed of life. Organized beings are produced by their fellow-beings, or owe their origin to the matter of organized bodies in a state of decomposition. The production of organic combinations in these beings, takes the name of assimilation and nutrition, whilst the procreation of beings themselves is called generation. On the other hand, inorganic combinations and bodies never originate but from the remains of other more ancient bodies, fallen into dissolution, and the materials of which, under certain circumstances, reunite, to produce them, according to the laws of chemical and mechanical attraction alone.

XIV. Even the most simple animal and vegetable forms, the infusoria, the green matter of Priestley, the confervæ, mouldiness, &c., in what is called spontaneous generation, proceed, according to the observations and experiments undertaken by Needham, Priestley, Ingenhouz, Monti, Wrisberg, Muller, G. R. Treviranus, &c., not from inorganic matters, but from organic bodies and combinations passed into putrefaction or fermentation. It is true, that J. B. Fray (4) asserts, he has seen infusoria animalculæ developed in pure water. Gruithuisen (5) says, also, that he saw generated, in an infusion of granite, of chalk, and of marble, a gelatinous membrane, in which, after some time, movements were manifested, and ended by the formation of infusoria, of monades, and globular animalculæ. But it is very probable that the bodies subjected to experiment, or the water employed in the infusion, already contained organic matter, though in a very small quantity, for other naturalists have not observed the formation of living bodies in infusions of purely inorganic ones.

XV. In all inorganic bodies, particularly crystals, as soon as their materials are brought together and combined by the laws of affinity, the chemical composition remains quiet, and it is by this very fact that they subsist. It is not so with living bodies, the composition of which is continually undergoing

(4) Essai sur l'Origine des Substances Organisées et Inorganisées. Berlin, 1807.—Essai sur l'Origine des Corps Organisées et sur quelques Phénomènes de Physiologie Animale et Végétale. Paris, 1817.

(5) Ueberdie Chemischen und dynamischen Momente bei der Bildung der Infusorien mit einer Kutik der Versuche Fray's; in Gehlen's Journal der Physik, vol. viii. p. 150.

changes. So long as these bodies act after their manner, that is, so long as they live, they are receiving within them new substances, which they assimilate and introduce into their composition, from which they expel others. It is by the actions of assimilation of food, of respiration, of nutrition, and excretion, that the materials of living bodies are incessantly changing. The composition of these bodies, therefore, is never in a state of quietude. Their tendency to assimilate to themselves new substances, ceases only with the extinction of the manifestations of activity, which we call life. But at the same time their existence is stayed, they are destroyed, and lose their form as well as composition. There is then this essential difference between inorganic and living bodies, that the duration of the former depends on the repose in which their composition remains, whilst the existence and preservation of the latter are conditional on a continual change of composition. The cause of this difference is found in the peculiar circumstances, belonging to living bodies, which induce new affinities, and which can only be maintained in action thereby, whereas, when bodies not endued with life are once formed, no further change takes place in the relations of affinity which themselves produce.

XVI. Although during their existence, living bodies are subjected to continual changes, rapid or slow, and introduce within themselves materials obtained from the atmosphere, from matter and from aliments of various kinds, and also free themselves of certain substances, nevertheless they preserve, during a certain lapse of time, the form and composition which is peculiar to them. They have thus the faculty whilst incessantly changing their composition, of retaining their qualities, and even of resisting, to a certain extent, chemical influences from without. (6) All inorganic bodies, on the contrary, being only the simple products of affinities, the property of substances which constitute them, are deprived of the power of reacting on the external impressions which produce changes in them, and are delivered up to the play of chemical affinities. For instance, when a crystal has been placed in contact with an acid which has an affinity for its base, the latter combines with the acid, in such a manner that the form and composition of the crystal are changed and destroyed.

We can attribute this property which organic bodies possess of resisting, to a certain extent, the purely chemical actions of external things, to no other than peculiar powers which sway the affinities. This results from the consideration, that so soon as their vital powers are extinguished, exterior

(6) Nevertheless, when living bodies are exposed to a very high or a very low temperature, if they be placed in contact with certain kinds of gas, or if concentrated mineral acids or caustic alkalis be made to act on them, they may even then be destroyed by these different agents.

influences, guided by the laws of chemical affinities, produce likewise in them, changes tending to the destruction of the form and composition peculiar to them. After the death of an organized body chemical affinities enter into play, so that its form and composition, which, during an age or more, had frequently braved the destructive action of external things, are done away with in a short space of time.

XVII. The chemical operations of putrefaction and fermentation, which which are established after the extinction of the special powers, whose action counterbalances, during the life of organized bodies, that by which the chemical affinities of external things tend to destroy them, and which change at once their composition and their form, are phenomena of a particular nature, that are not observed in the decomposition of inorganic bodies. They are organico-chemical processes. The decomposition which takes place after death has, in ordinary cases, its limits, and the organized materials do not altogether enter, but only in part, into the inorganic kingdom, since they are neither completely reduced to their elements, nor converted into binary combinations.

XVIII. The organic combinations or matters, albumen, starch, gluten, gum, animal mucus, fibrin, gelatin, &c., as well as the animal and vegetable tissues into which they enter, possess the peculiarity, when placed in favourable external circumstances, exposed to a certain degree of heat, of light, and humidity, and in contact with the asmosphere, of passing to new simple organic forms, as soon as they have been detached from the organic combination of any being. This is what happens in fermentation and putrefaction, where the resolution of organic combinations gives rise, according to the composition of the latter, and external influences sometimes to infusoria, sometimes to the green matter of Priestley or to mouldiness. This property which organic matters enjoy, of taking a new form under certain circumstances, shall be designated provisionally, under the name of aptitude for life or plasticity. It is only extinguished when these matters are reduced to their elements, as whenever fire is made to act upon them. Thus, when the manifestations of activity, called life, are done away with in the matters of the peculiar kind appertaining to organic bodies, and the chemical operations of the special nature which occur in them after death, that is, putrefaction and fermentation, are established, these matters do not enter completely into the inorganic kingdom, but retain the power of putting on a new form, and of showing themselves adapted to the enjoyment of life. Death, then, or the extinction of the manifestations of life only bears upon organic individuals, whilst the organic matters entering into the composition of these beings continue to be capable of taking on form and receiving life.

XIX. The principal result of the comparisons made between the composition of organic bodies and those of inorganic bodies, which comparisons are founded on observations and researches in the chemical composition of these bodies hitherto pursued, is that the former have peculiar matters, which we call organic, for their basis. The changes of composition which take place in bodies endued with life, are not simply the effects of affinities similar to those observed in brute or inorganic bodies; they are the effects of affinities and forces of a special nature. Organic matters are the only ones which exhibit, and for the greater period of time in a particular state of aggregation and form called organization, the manifestations of activity which we designate by the name of life. They are accumulated at one time in bodies actually living, and life is manifested in them; at other times they are exterior to living bodies, mixed with inorganic matters, and then only capable of living. In this latter state they may return to the domain of living bodies, and into the tide of life, either in the shape of aliments, or, in a direct manner, by the aid of certain circumstances, as happens in spontaneous generation. Purely chemical affinities, or the action of simple chemical forces, appear, in the present state of our planet, to produce no organic combination or matter, such as albumen, gelatin, starch, gluten, &c.; at least we possess no facts which go to support the contrary opinion. None but organic bodies themselves are capable of introducing inorganic matters into organic combinations, of which respiration in particular and the nutrition of plants are examples.

XX. If we extend our researches still further, a question presents itself, namely, how organic matters, their different combinations and living bodies, are formed in our planet? The solution of this problem passes the limit of our experience. Should we, however, wish to hazard an answer to it, we fall into the waste of conjecture, and are forced to erect hypotheses, which are but probable, and not at all certain. We suppose that organized bodies have existed in our planet from its commencement; or else we admit that organic matters and living bodies have been produced, under certain circumstances, together with the elements and inorganic matters, by the action of general physical causes; or, lastly, we conjecture that the substance of living bodies was primitively contained in water, as primitive organic matter, having the property of taking on the organic form, that it gave origin to organic bodies of very simple and varied kinds in consequence of circumstances, and that these bodies have passed successively to more complicated forms, until at length the generative organs and their manifestations of activity having appeared in them, they were endowed with the faculty of preserving themselves in a continuous manner, by means of generation, as separate species.

XXI. Geology is opposed to the first hypothesis of the existence, in our planet, of living bodies from the first moments of its creation. Fossils are found only in the exterior crust, that is to say, in the superficial layers of the earth, the formation which is most recent, whilst there are none at all in the primitive earths. Consequently there was a time when no living being existed on the globe. Even supposing we admitted this hypothesis, we should still leave untouched the question, how living bodies were formed, inasmuch as we could say nothing concerning the mode of origin of our planet and of the bodies which constitute it. In reference to this question, it matters little whether we declare for vulcanism or neptunism, since the geologists are under the necessity of leaving the origin of fire and water without explanation, and the biologist is still less able to pronounce any opinion on that of living bodies.

XXII. The difficulties which occur in the second hypothesis, of the dependence of the production of organic matters and living bodies on the action of general physical forces, are, that we are actually in want of facts which would authorize us to conclude analogically that organic matters and living bodies can proceed from inorganic matters, never having observed any thing similar, at least up to this day. Far from this being the case, living bodies are unable to produce, with inorganic substances, the greater number of the materials which enter into their composition, and for such end they require the matter of other organic bodies, which they introduce into themselves. Plants are nourished principally by the remains of dead vegetables or animals: animals likewise preserve their existence by means of vegetables, and even of other animals.

XXIII. The most probable hypothesis is the third, viz., that the substance of organic bodies existed primitively in water, as matter of a particular kind, and that it was there endowed with the plastic faculty, that is to say, with the power of acquiring, by degrees, different simple forms of living bodies, with the concurrence of the general influences of light, heat, and perhaps also of electricity, &c., and of then passing from the simple forms to other more complicated, varying in proportion to the modification occurring in the external influences until the point when each species acquired duration by the production and manifestation of activity of the genital organs. Although we cannot here also answer the question, whence came the water and the organic matter which it contained, yet this hopothesis is the one which accords best with the facts with which geology has latterly been enriched. In fact, we find no organized bodies belonging to what is called the primitive world in the strata of earths which modern geologists consider as the products of fire or of vulcanism. They are only observed in the upper layers of the earth, in those of the latest formation, and in the soils which have evidently been precipitated in the midst of the waters. Aquatic animals existed before terrestrial animals. An argument which favours the hypothesis according to which the organic kingdom has been gradually developed and elevated from simple to more complicated forms, is drawn from the fact that we meet with remains of organic bodies belonging to the most simple species in the secondary and more ancient soils, whilst the most recent strata of the earth contain the remains of more complicated living bodies. The soils which rest directly on primitive rocks, present fragments of corals, radiated animals, and shells. It is only after these that remains of vertebrated animals, fishes, reptiles, and cetacea, are found in the water. Fossil bones of oviparous animals exist in the deep strata of the earth, whereas the viviparous mammiferæ are met with in the superficial layers. We observe the same in the organic complication of vegetables, whose remains are contained in the different layers of the earth. Impressions of cotyledonous plants, especially of ferns, are the first vegetable traces met with in the deep seated strata. Then come the remains of monocotyledonous plants, of arborescent gramina, of palms, &c., and finally those of the coniferæ and other dicotyledonous plants.

There have not yet been found any fossils belonging to apes or man, whose organization has reached the highest degree of complication and development. We may therefore admit, with great probability, that apes and men are the last and the newest products of our planet. (7)

XXIV. Another circumstance favourable to the hypothesis of the gradual development of organic bodies, from the most simple to the most complicated, is that all those bodies, as well vegetables as animals, to this day appear in a simple form, at the period of generation, or when they proceed from the germ, and that it is only by degrees they acquire the most complex form peculiar to each species. To commence in a very simple manner, and to rise thence to the complicated, is the general character of every thing that has life, as well of individuals as of the entire of the organic kingdom.

XXV. These reasons, coupled with the fact that, after the extinction of the life of individuals, the materials of organized bodies are reduced to the

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(7) An additional argument in favour of this hypothesis, is the fact that whenever animal matter shall have lost that power which gave and maintained it in a higher degree of complication in form and functions—no matter how high this degree—it invariably returns to the most simple forms. The noble human form, after the cessation of the functions, possesses only sufficient plasticity to take on the shape of the lowest insects and worms. The same applies to the kingly lion of the forest and the soaring eagle. In fact, the matter composing each of these, after death, is in the same state as the matter which is described by Tiedemann as possessing merely the aptitude for life, and therefore taking on only the most simple form. Again, that external circumstances modify structure, is very well ascertained. The absence of light generally causes a mother to produce a deformed child, as Edwards observed in females confined in dungeons, whilst tadpoles, preserved from the light, became huge tadpoles instead of frogs. Natives of different climes have different parts of their organization prominently in action; the muscular system, for instance, is much more developed in cold than warm climates; on the other hand, natives of the tropics are from birth more excitable than those of northern parts of the globe; in other words, the animal nervous apparatus is more developed. In a pure hypothesis it is not expected that the modus operandi of the circumstances to which Tiedemann alludes should be explained; collateral evidence is certainly in favour of it.—Transl.

most simple organic forms by the action of what is called spontaneous generation, oblige us to admit a primitive organic matter extended on the surface, or in the crust and waters of our planet, concerning the first origin of which matter it is as possible for us to certify any thing as on that of the planet itself. This organic matter, with its different organic modifications, considered as matters of a peculiar species, sometimes is seen active and living in the individuals of vegetable and animal species actually existing, under conditions and in the midst of phenomena, the recital of which will be made hereafter; at other times remains merely capable of enjoying life, and endued with the faculty of taking on, in certain circumstances, the most simple organic forms, whenever it has been withdrawn from the composition of living bodies.

Several naturalists, particularly Buffon (8) and Needham, (9) have allowed the existence of a matter peculiar to living bodies. G. R. Treviranus (1) concludes from his researches on life,

1. That there is in nature a matter which is ever moving, by which all living beings, from the byssus to the palm, and from the infusoria animalculæ to the sea monster, possess life, and which, though immutable in its essence, is notwithstanding variable in its form, and is incessantly changing it.

2. That this matter is deprived of form in itself, but nevertheless ready to take that of life; that it maintains a determinate form under the influence of external causes; that it only continues in that form so long as these causes are active, and that it takes another so soon as new causes influence it.

3. That the matter capable of life, and the living principle, exist reciprocally, and that death is only a passage of certain forms of this matter to certain others. (2)

CHAPTER SECOND.

On the external Configuration and internal Aggregation.

XXVI. Some bodies, the solids, fill space in a durable and uniform manner, whilst others, the liquids, vary in their manner of filling it. These, air and water, are the vehicles which contain the solid bodies. All organic bodies,

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(8) Hist. Nat., vol. ii. p. 420. Il existe une matière organique animée, universellement repandue dans toutes les substances animales ou vegetales, qui sert également à leur nutrition, à leur developpement, et à leur reproduction.

(9) An Account of some new Microscopical Discoveries. London, 1745, in 8vo.

(1) Biologie, vol. ii. pp. 267 and 403.

(2) This has reference only to the power of life inherent in matter, and is a question of science only. The soul is not concerned nor mentioned. It may be necessary to state this, as there are those who would startle at a sentence which, in fact, asserts that life is material and matter eternal, leaving one form only to take on another. The stupid outcry against the phrenological doctrine, and the exclamations concerning its inculcation of materialism, have a foundation in a precisely similar error, that of mistaking the principle capable of life in matter for the soul.—Transl.

as also all minerals, mercury excepted, are solid. Organic bodies at the same time have a regular form, which minerals only present in the state of crystallization. In comparing these two groups of bodies, in reference to their configuration, and aggregation, we are under the necessity of confining ourselves, as far as minerals are concerned, to those which are possessed of a regular form.

XXVII. All organic bodies, plants as well as animals, have a form more or less round and oval, or branched and articulated, and they are confined by curved or undulating lines, as also by convex or concave surfaces. (3) Inorganic bodies, on the contrary, in cases where they have a regular form, as in crystals, are limited by flat surfaces and right lines, by the conjunction of which, at certain inclinations, are produced ridges and angles. This has been sufficiently demonstruted by Romé de l'Isle,(4) Bergmann,(5) but particularly by Haüy,(6) Brochant de Villiers,(7) and by others. It is known that crystals exhibit a great diversity of forms, both simple and complicated: these are cubes, hexaedrals, rhombs, prisms, columns, &c.;(8) but, however various their forms may be, it is possible notwithstanding, according to the connexion of their parts, to reduce them to certain primitive forms and to certain systems of crystallization.(9) Thus these bodies, as was well remarked by Kielmeyer,(1) represent in some degree the effect of an elementary geometry, whilst nature has employed a high geometry in proceeding to the formation of living bodies. It may be also said, and it amounts to the same thing, that the forms of organized bodies are more complicated than those of inorganic bodies.

XXVIII. The organic kingdom exhibits a much greater abundance and

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(3) Several of the immediate organic principles are exceptions to this rule, inasmuch as, after having been taken from living bodies or secreted in them, they crystallize in different manners. Cholesterine, uric acid, and the sugar of milk are, in this respect, among those from the animal kingdom. Many vegetable substances, sugar, different acids, such as the pure sinapic, the benzoic, and others, but especially the salifiable vegetable bases, such as morphine, narcotine, strychnine, brucine, quinine, &c.; in fine, the sub-resinous substances, crystallize. The forms of the latter are, however, for the most part, globular or radiated, like stars or rosettes, according to Bonastre, (Sur la forme cristalline de plusieurs sous-résines ;) in the Annales de la Societé Linnéene, de Paris, Nov. 1827, p. 549.

(4) Essais de Cristallographie, or, Description des Figures Géométriques propres aux differens Corps du regne Minéral. Paris, 1772, in 8vo.

(5) Ueber die Gestalten der Krystalle, 1773.

(6) Essai d'une Théorie sur la Structure des Cristaux. Paris, 1784, in 8vo. Traité de Mineralogie. Paris, 1822.

(7) De la Cristallization Consideree Géométriquement et Physiquement. Strasbourg, 1819, in 8vo.

(8) Whenever the operation of crystallization has been troubled, and the molecules are precipitated suddenly, the regular geometrical form is changed, and very frequently round forms are produced; but these, according to Haüy's very just remark, show a want of perfection in the mineral kingdom.

(9) Weiss, in the Abhandlungen der Physikalischen Klasse der Akademie der Wissenschaften, von Berlin, years 1814 and 1815, p. 289.

(1) In his Course of Lectures on General Zoology.

diversity of forms than that of the bodies not endued with life. The thousands of vegetable and animal species, showing so many differences in their configuration, are proofs of this. According to an estimate made some years ago by Humboldt,(2) there are known nearly fifty-six thousand species of plants, and fifty-one thousand seven hundred animals; but, since that period, besides a great number of new vegetables and animals have been discovered.

XXIX. If we compare living bodies with minerals in reference to their aggregation, we observe that, according to the expression of G. R. Treviranus, (3) organic bodies are distinguished both by the regularity and the heterogeneous nature of their parts, whilst the latter are possessed only of the first character and want the second. All living bodies, vegetables, and animals, are composed of heterogeneous parts. They always contain solid and liquid constituents, which is looked upon by Humboldt (4) as a character essential to them. Besides, we remark in all, except the most simple, a vast number of heterogeneous components; in plants, we see roots, leaves, and flowers; in animals, muscles, nerves, vessels, bones, and viscera of several kinds. These parts, regularly arranged and distributed, are themselves composed of more simple parts; the tissues in organic bodies, on the contrary, are not the result of an assemblage of heterogeneous parts, or if, sometimes, they present this character, the parts are only simply mixed with each other. Generally speaking, crystals are composed only of homogeneous solid parts.(5)

XXX. Inasmuch as organic bodies are composed of liquids and solids, it follows as an immediate result, that they possess but little consistency and rigidity. All of them are soft and flexible, either throughout, or in a great number of their parts. In fact, their consistence varies considerably, as well in vegetables as in animals, and not only in the different groups of living bodies, but even in the different parts of each individual. In general, we remark that the more important parts of these bodies, those parts which perform the principal offices in the accomplishment of their special manifestations of activity, possess the smallest consistence and solidity, such as the fibres of the roots, the sap vessels, the alburnum, the leaves and flowers in plants; the nerves, brain, muscles, the viscera intended for the process of digestion, and of respiration, and those destined to the movement of the humours and to

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(2) Annales de Chemie, vol. 16.

(3) Biologie, v. i, p. 158.

(4) Aphorismen aus der Pflanzen. Physiologie, p. 33.

(5) The drops of water which are met with sometimes in crystals can scarcely be brought forward as an objection, because they are purely accidental. Thus Brewster (Transactions of the Royal Society of Edinburgh, vol. x, p. 1,) found colourless and transparent liquids in some topazes, in the chyrsoberyl, in the Quebec quarz, in the amethyst, &c. Commonly these liquids only in part filled the cavities of the crystals, and besides contained a bubble of air, which disappeared by the action of heat. Neither can the water of crystallization be objected, since it is intimately combined with the very matter of the crystals, and is not distributed in specified spaces, as the humours of living bodies are.

the different secretions in animals. The consistence varies also in proportion to the age. Regarding this, we may lay down the principle, that it is so much the more diminished in vegetables and animals, as those bodies are least distant from their origin, or from the periods of their development and growth, whilst it increases, together with the rigidity, in proportion as they approach the end of their career.

Inorganic bodies, on the contrary, which are composed entirely of solid parts, are remarkable for their great rigidity. In them we do not see parts differing in point of consistence, neither does their rigidity vary with the duration of their existence.

XXXI. Another consequence of the mixture of the solids and fluids, which enter into the composition of living bodies, as well as of their state of softness, is the facility with which they undergo changes in the relations of their structure, that is, with which they move. These two very circumstances render their chemical composition more easily attacked by external influences, as of heat and the atmosphere, which act principally on their liquid parts. Minerals, which are composed of solids, and possess rigidity, do not exhibit these changes in the mutual connexion of their parts, that is to say, they do not move, and are less liable to be varied in their composition by the action of exterior influences, particularly of heat and the atmosphere.

XXXII. All organic bodies do not only exist as a result of an assemblage of solid and liquid parts, but moreover this sort of constitution is indispensably necessary to their existence and preservation, inasmuch as it is the reaction of solid and liquid parts which determines and maintains the manifestations of activity or of life.(2) If the juices of a plant are abstracted, it dies; if the mass of its humours are withdrawn from an animal, and its vessels emptied of the blood contained in them, life is extinguished. Let the solid parts be destroyed in a mechanical or chemical manner, in this case too the manifestations of life cease. It follows, then, that the solids and liquids of living bodies are in a continual reciprocity of action, indispensably necessary to the support of life.

XXXIII. Another cause, too, of the essential and necessary connexion which exists, in organized bodies, between the liquid and solid parts, is that the latter take their origin from the former. Every animal originates from a

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(6) Some vegetables and animals, of the most simple species however, for instance, mosses, infusoria, ratifera, (*vorticella rotatoria,*) vibriones, (*vibrio anguilla,*) &c., survive for some time the loss of their liquid parts; they may be dissected so as to give no sign of life, and when afterwards they are moistened, the phenomena of life are again roused in them, as is shown by the experiments of Needham, (Nouvelles decouvertes faites avec le Microscope. Leyden, 1744,) of Baker, (Employment for the Microscope. London, 1764.) of Spallanzani, (Observations sur les Animaux qu'on peut tuer et ressusciter à son gré; in Opuscules de Physique, vol. ii, p. 261,) and of Fontana, (Sur le venin de la vipère, vol. i.)

liquid, in the midst of which it is formed. Liquids, also, are incessantly furnishing the materials for the nutrition of the solids. These possess the capability of exercising their manifestations of activity only so long as they are nourished. Every substance whatever which enters into organic bodies, under the name of food, should be liquid, or at least susceptible of becoming so. The solids themselves are likewise resolved into liquids. In short, all matters which are elicited and rejected from living bodies, during life, are more or less liquid. But the constitution of the liquids depends, in its turn, on the manifestations of activity of the solids, for these are the chief source of the qualities which distinguish them.

XXXIV. Neither is it difficult to convince ourselves, by an attentive examination with the microscope, that the parts entering into the composition of organic bodies, are of another nature from those which constitute minerals. By this instrument we perceive, both in the liquids and solids of vegetables and animals, globular or oval, and occasionally flattened, bodies. The most simple animals, such as the infusoria, polypi, as well as the most simple plants, the confervæ, tremellæ, the pulverulent mushrooms, the byssus, &c., are composed of globules, as is shown from the results of Trembley's,(7) Schœffer's,(8) Carolini's,(9) and other observations. In the majority of the animal humours, globules have been found; in the blood, chyle, saliva, the pancreatic juice, the fat, the semen, and the milk, by Leuwenhoeck,(1) Hewson,(2) and very recently by Home, Prevost, and Dumas, Rafn,(3) Gottfried Reinhold,(4) and Ludolf Christian Treviranus,(5) &c. have likewise met with them in the proper juices of plants, especially in those of the milky kind. Globules of divers kinds are also seen in the cells of vegetables. Of this sort are those of the starch found in cotyledons; of the albumen of grains of corn and bulbous roots; the resinous globules of chlorophile, in the parenchyma of the leaves, and the coloured globules in the cells of the flowers. Similar globules have also been perceived in the cellular tissue, the serous and mucous membranes, the brain and nerves, the tendons, and the different glands of animals, by Leuwenhoeck, Hooke, Swammerdamm, Della Torre, Prochaska, Fontana, &c., and latterly by Barba, Horne, G. R. Treviranus,(6) Milne Edwards,(7)

(7) Mem. pour servir à l'Histoire d'un genre de Polypes d'eau douce. Leyden, 1744, p. 54.

(8) Von den guinen Armpolypen. Ryensburg, 1755, p. 21.

(9) Ueber Pfanzenthiere des Mittelmeers, p. 56.

(1) Opera omnia seu Arcana Naturæ. Leyden, 1722.

(2) Opus Posthumum, Description of the red Particles of the Blood. London, 1777.

(3) Entwurf einer Pflanzen Physiologie. Translated from the Danish, by Markussen, p. 91.

(4) Ueber die Gefässe und den Bildungsaft der Pflanzen. in Vermischten Schriften, v. i, p. 145.

(5) Ueber den eigenen Taft der Gewäschse; in Tiedemann's und Treviranus' Zeitschrift fur Physiologie, vol. i, p. 147.

(6) Ueber die Organischen Elemente des thierischen Körpers; in Vermischten Schriften, anatomischen und Physiologischen Inhalts. Gœttingen, 1816, vol. i, p. 117.

(7) Sur la Structure Elementaire des Principaux Tissus Organiques des Animaux; in the Archives Generales de Medicine, 1823, vol. iii. Recherches Microscopiques sur la Structure in-

Dutrochet,(8) Prevost and Dumas,(9) Hodgkins and Lister.(1) Lastly, they are discovered also in the embryons of plants and animals that are forming, a fact demonstrated by Swammerdamm,(2) C. F. Wolf,(3) G. R. Treviranus,(4) Sprengel,(5) L. C. Treviranus,(6) Link,(7) Rudolphi,(8) J. F. Meckel,(9) and many others.

XXXV. These globules or corpuscules peculiar to organic bodies, none similar to which are found in minerals, are to be considered as the elementary forms of the former, as the final organic molecules possessing a distinct form which are perceivable in them. Organic matters, in general, appear to have the property of assuming, under certain circumstances, globular forms. This is chiefly remarked when they pass from the liquid to the solid state. G. R. Treviranus saw globules formed during the coagulation of the white of an egg, which he had not distinguished in the liquid albumen. Prevost and Dumas observed the same phenomenon in albumen, whose coagulation they had effected by submitting it to the action of the positive pole of the galvanic pile. It is globular corpuscules, also, which first appear when infusoria are formed in the midst of organic matters in a state of decomposition.

XXXVI. These organic elementary globules, whose volume, colour, and other qualities show so many differences in the liquids and solids of plants and animals, form the basis of the different tissues, the presence of which distinguishes living bodies from minerals, wherein nothing that can be compared to them is perceptible. Animal tissues are the consequence of, or are composed by, different modes of arrangement of the globules. These are ranged in series and lines in the fibrous tissue of the nerves, of the muscles and tendons. They are extended in the form of lamellæ in the cellular tissue and those membranes that are chiefly composed of it, as the serous, synovial, and mucous, as well as in the coats of the vessels. They are found variously united in masses in the glandular organs, the liver, the kidneys, the salivary glands, the pancreas and testicles. The tissues of vegetables have not been hitherto sufficiently examined so as to ascertain the precise arrangement of their elementary globules.

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time des tissus Organiques des Animaux ; in the Annales des Sciences Naturelles, 1826, vol. ix, p. 362.

(8) Recherches Anatomiques et Physiologiques sur la structure intime des Animaux et des Vegetaux, et sur leur Motilité. Paris, 1824.

(9) Bibliothéque Universelle des Sciences et Arts, vol. xvii.

(1) Philosophical Magazine and Annals of Philosophy, No. 8, 1827.

(2) Biblia Naturæ, p. 817. He saw globules on the young bull-head frogs.

(3) Theoria Generationis, vol. ii, pp. 2, 16, 53.

(4) Biologie, vol. iii, p. 233, vol. iv, p. 9.

(5) Von dem Bau und der Natur de Gewäschse. Halle, 1812, p. 71.

(6) Vom inwendigen Bau der Gewäschse, p. 2. Beiträge zur Pflanzen Physiologie, p. 1.

(7) Grundlehren dei Anatomie und Physiologie der Pflanzen, p. 29, Nachträge, p. 3.

(8) Anatomie der Pflanzen, p. 27.

(9) Vergleichende Anatomie, vol. i, p. 40.

XXXVII. The union of tissues, in extremely diversified modes of combination, disposition, and form, gives origin to the parts which we see exercising the different functions in organic bodies, during their life, and which we designate by the name of organs or apparatus for the performance of the different manifestations of life. Parts resembling these are never met with in inorganic bodies.

XXXVIII. Organic bodies, at least the more complicated, have their surface supplied with a covering, which confines them, and which surrounds the different liquid and solid parts, organs, tissues, and combinations of tissues, entering into their composition. This covering is called skin in animals and bark in plants. The different sized openings by which it is pierced, permit living bodies to absorb substances from without and to expel substances from within. We find nothing like this in minerals, whose constituent particles are without any means of separation directly exposed to the surrounding media.

XXXIX. All the parts found in, and whose union constitute, organic bodies, are held together by the bonds of a strict causality. In relation to their origin and formation they are dependent on each other. This proposition does not only follow from what has already been said concerning the connexion of liquids and solids, but also from the manner in which organized bodies are formed in the midst of matters which produce them. The radicle, proceeding from the fertile seed of a plant, determines the growth of the stalk, which afterwards plays the same part with respect to the leaves and flowers. The parts which appear first are the cause of the manifestations of those that succeed. Thus, in the embryos of the more complicated animals, the two most generally extended apparatus, the nervous and vascular systems, are those which are first formed, and from whose formation that of the others proceeds.

A similar relationship of cause and effect does not exist between the parts whose aggregation produces minerals. When a crystal is formed in the midst of a liquid, the particles of which it is composed are united to each other by the laws of affinity and cohesion alone, without the first which congregate exercising a determining action on the formation and arrangement of the others, as happens in the formation of organic bodies.

XL. Once produced and formed, the solid and liquid parts remain, so long as they endure, in a continual state of dependence and reciprocity of action,(1) that is to say, that they are to each other as cause and effect, or,

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(1) The reciprocal action of the parts in living bodies was known to Hippocrates, since he says (lib. de alimento ;) Consensus unus, conspiratio una, consentientia omnia ; and in another place (de locis in homine ;) mihi quidem videtur principium corporis nullum esse, sed omnia similiter principium et omnia finis.

to employ the expression of Kant,(2) as means and end. The liquids contained in defined spaces of different kinds, and spread throughout the solids, combine with them, and pass from the liquid to the solid state. The solids, on the other hand, are redissolved and return to the liquid state. Moreover, the liquids act on the organs which they urge to the production of manifestations of activity, while the organs, in their turn reacting on the liquids, keep them in motion and modify their properties. Every part of a plant or animal contributes, by its manifestation of activity, to the preservation of the individual in the full exercise of its faculties, and indirectly also to the maintenance of the species. The duration of vegetables, with a few exceptions, which will be spoken of hereafter, depends on the root, the stalk, and leaves, which all contribute to it by their special functions. These parts and the flowers, or genital organs, which they produce, assure the duration of the species. The same is the case in animals. The organs of digestion, of absorption, of respiration, of the circulation, and of secretion, assure, by the very fact of their manifestations of activity, both their own preservation and that of their numerous apparatus, of the organs of the senses and of the locomotive apparatus, just as the functions of these latter contribute also to the preservation of the other organs and of themselves. The genitals, the existence and the functions of which depend on the other apparatus of the individual, do not react on them as cause, nor are they necessary to the preservation of the individual, but they certainly are to that of the species by their manifestations of activity. All the parts, then, which enter into the composition of an organic body, together with their qualities and manifestations of activity, are in a mutual dependence on each other and constitute a perfect whole, so that the particular activity belongiug to the individual and to the species is thereby preserved.

The homogeneous particles which constitute a crystal, and which are united by cohesion, have not this reciprocity of action in reference to each other, as Bichat has shown.(3) They do not act mutually the part of conservative agent and cause, relative to their qualities, as is the case in the parts of an organic body.

XLI. As the different solid and liquid parts, existing in an organic body, are in intimate connexion with each other, and as their duration is conditional on the reciprocity of action of the parts which constitute it, the greater number of living bodies, especially all those that are complex, do not suffer division, without being deprived of their existence and of their own proper activity. Organic bodies, then, in the rigorous acceptation of the word, are

(2) Kritik der Urtheilskraft, v. ii, p. 292.
(3) Anatomie generale. Introduction, p. 23.

individuals which cannot be divided, inasmuch as such division annihilates life in them.

It is true there exist several organic bodies, which are susceptible of division to a certain degree, without having their existence compromised by this operation. In this number are many plants, especially perennial plants, and amongst animals, polypi, some radiariæ, and worms. This circumstance does not confute what has been said on indivisibility as a characteristic of living bodies. On one hand, many plants, like polypi, represent an union or collection of several smaller organisms, which may continue to live after they have been detached from their stock. On the other hand, all their parts present a certain uniformity of organization and action, and such an independence, that they are able to exist apart from each other, and produce or regenerate, by their own activity, the parts necessary to the perfection of the species. The character of individuality is the more pronounced, in organic bodies, as their structure is more complicated and their manifestations of activity more varied. On the contrary, a less difference is exhibited by the parts entering into their composition, or the more they are similar, less is the diversity in their actions perceivable, less striking is the character of indivisibility, and more feeble is the connexion of the parts of the same organism, because parts that are similar have the conditions of their existence more in themselves, and are less dependent on each other.

Regarding inorganic bodies, they do not form individuals, because they are the result of an assemblage of homogeneous particles, having no relation of production or preservation with each other, as have the different parts of organized bodies. Inorganic bodies can therefore subsist after having been separated into pieces. Each piece of a broken crystal exists as well as if united to the other pieces.(4) Neither can inorganic bodies reproduce or regenerate, by their own proper power, parts which have been separated from them, as is the case with those simple living bodies that are divisible without loss of existence.

XLII. In reference to the form and composition of bodies, if we examine the changes they undergo during their existence, their duration, their mode of origin, and their relations with external influences, we also here discover considerable differences between those that are organized and those tbat are not.

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(4) Richerand has perfectly explained this in the following terms: " Toutes les parties d'un corps vivant, soit vegetal, soit animal, tendent et concourent à un but commun, le conservation de l'individu et de l'espece ; chacun de leurs organs, quoique doué d'une action particulière, agit pour remplir cet objet ; et de cette série d'actions concurrentes et harmoniques resulte la vie generale, ou la vie proprement dite. Au contraire, chaque partie d'une masse brute ou inorganique est independente des autres parties, aux quelles elle n'est unie que par la force ou l'affinité d'aggregation ; lorsqu'elle en est separée, elle existe avec toutes ses proprietés caracteristiques et ne diffère que par son volume de la masse à la quelle elle a cessé d'appartenir."

The form and aggregation of all living bodies vary during their existence, at stated periods, and according to inherent laws. All vegetables and animals are born with a very simple form, and, at the time of their origin, they are composed, internally, of a very small number of parts having a simple configuration. By degrees, in proportion as their volume augments, their form and aggregation become more complicated. All of them observe a periodicity in their development. Moreover we observe, that the majority suffer by degrees, in the progress of age, a sinking in their form, and changes in the composition of their liquids and solids.

Crystals do not exhibit, in their form and aggregation, changes that can be considered as the results of development or of the epochs of age; they suffer no change whose cause is inherent, and dependent on their duration.

XLIII. All organic bodies, plants as well as animals, in their figure and aggregation, possess a certain duration, varying considerably, according to the genera, species, and individuals, but which, notwithstanding, depends chiefly on circumstances inherent in themselves. The duration of the form and aggregation of inorganic bodies, crystals for instance, is not confined to any determinate period; when they are destroyed it is by the effect of extrinsic circumstances.

XLIV. The origin and production of new organic forms of a species is the result of manifestations of activity in forms already existing. These manifestations of activity, which are called generation, are not the effects of chemical affinity and cohesion, but of a peculiar power, appertaining to organic bodies, exhibited, with specific modifications, in the different species of living bodies, propagated or diffused through the product during the act of generation, and directing the form and aggregation of it, in such a manner that none but beings of the same kind are produced and formed.

The production of new crystalline forms, on the contrary, supposes the destruction, the annihilation, the solution in a liquid, of crystals already existing. Such new crystallized forms, developed as they are according to the simple laws of affinity and cohesion, at the expense of former materials dissolved in a liquid, may differ considerably. Indeed, the researches of Mitscherlich(5) have taught that a body composed of the same principles, in the same proportions, is capable of assuming different forms. The crystalline form, therefore, does not depend on the nature of the atoms, but on their number and mode of aggregation. The same number of atoms, united in a similar manner, produce one and the same crystalline form.

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(5) Königl. Vetens. Acad. Handling, 1821, p. 4.

XLV. The form and aggregation of organic bodies can only subsist and enjoy a certain duration on condition of a reciprocity of action with external things, and more especially on that of a continual change which is going on in their material substance. All organic bodies take from everything around them, and attract the constituent principles of the air, water, and food, which they introduce into their composition and form. At the same time divers matters are eliminating from their composition and form. It is only so long as this change and renewal takes place in the materials, that they continue in the form and aggregation peculiar to them.

On the other hand, the existence and permanency of the form and aggregation of inorganic bodies, crystals for example, suppose their composition to be in absolute repose, and that no change whatever occurs in them. If external things, which have a greater affinity with their materials, should act on them, they combine with them according to the laws of affinity, and thence follows the destruction and annihilation of their form and aggregation. A renewal of matter, therefore, a thing absolutely necessary to the subsistence of organic bodies, exerts a destructive action on inorganic bodies.

XLVI. From the parallel which has been established between the form and aggregation of organic and those of inorganic bodies, essential differences are collected. All organic bodies have a regular form, terminated by undulating lines and surfaces which are not flat. They all proceed from an assemblage of heterogeneous parts, both liquid and solid, having a peculiar mode of arrangement and distribution, and connected so as to produce an harmonious whole; in other words, engaged in a reciprocity of action necessary to the preservation of the individual. The form and aggregation sway each other mutually; the destruction of one leads to that of the other. All organized bodies preserve their form and aggregation by virtue of an internal activity, under the influence of external circumstances, and amid incessant changes in their material substance or their composition. They are developed from each other, produce themselves, are formed and maintained by their own activity, are subject to regular changes, and enjoy a certain durability.

These bodies thus constitute separate beings, whose various parts, with their different qualities, have a configuration and an aggregation of such a nature that unity, harmony, concurrence of actions to a common end, the preservation of the individual and of the species, may, and in fact do, follow as results. They are relatively more perfect than inorganic bodies.(6)

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(6) Absolute perfection belongs to every being whatsoever, since each one is what it ought to be according to the laws of nature. But the different groups of beings present differences as to relative perfection. Bonnet (Contemplation de la Nature, vol. ii, cap. 2) has very clearly expressed himself on this subject, in the following manner: "Tous les êtres sont parfaits, considerés

This superiority of relative perfection is exhibited by the greater number of different parts and matters entering into their composition, as also by the more intimate connexion and more exact reciprocity of action existing between all these parts and matters, so that we cannot but recognise a train of coincidences tending to one end or to unity of end.

XLVII. If, lastly, we put the question, on what rests the property which organized bodies have of exhibiting this disposition, the combination and reciprocity of action, in the parts which compose them, we have no other answer to make, except that it ought to be sought for in their material substance itself, in organic matter. All organisms proceed, as far as we can judge of them by observation, from organic matters, which are presented to us as susceptible of organization. At one time they are formed at the expense of an organized individual in which putrefaction is established, as is seen in the case of spontaneous generation, wherein the organisms developed vary according to the external influences to which the organic matters are submitted. At other times, organisms, or organic tissues, are formed in a determinate manner, and with an equally determinate form, in the midst of liquid organic matters, produced by the manifestations of activity of organisms already existing, as is observed in generation properly so called, and in the acts of development, of formation, and nutrition. Each species of animal and vegetable presents an organization peculiar to itself, and possesses the faculty of preserving itself, notwithstanding the perishable character and the continual renewal of the individuals. Should we seek to discover whence proceeds this quality of animal and vegetable species, we are lost in the regions of obscurity. Neither do we know more touching the origin of the first individuals of any animal or vegetable species, than concerning that of the organic matters on the surface of our planet. Provisionally we shall designate the faculty or power which organic matters have of taking on organic form and aggregation, in certain circumstances, by the name of plastic power, or power of organization, and regard it as a quality peculiar to these matters, so that we shall consider aggregation by means of purely mechanical or chemical attraction as an especial property of inorganic matter.

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en eux-mêmes ; tous repondent à une fin. Les determinations, ou les qualités propres a chaque être, sont les moyens relatifs à cette fin. Si ces determinations changeoient, elles ne seroient plus en rapport avec la fin et il n'y aurait plus de sagesse. Mais à une fin plus noble rèpondent les moyens plus relevés. L'être appellé à remplir cette fin est enrichi de facultés qui lui sont assorties. Considerés sous ce point de vue, les êtres nous offrent differens dégrés de perfection relative. La mesure de cette perfection est dans les rapports que chaqu' être soutient avec le tout. L'être dont les rapports au tout sont plus variés, plus multipliés, plus féconds, possede une perfection plus relevée." We appreciate the relative perfection of an organized body by the multiplicity, the diversity, and the development of its parts. Whenever we observe a great diversity in the organic conformation, we also uniformly see a great variety and combination in the manifestations of life.

SECOND SECTION.

PARALLEL BETWEEN THE MANIFESTATIONS OF ACTIVITY OF ORGANIC AND THOSE OF INORGANIC BODIES.

CHAPTER FIRST.

Of the Manifestations of activity common to organic and inorganic Bodies, and their Modifications in the former.

XLVIII. The manifestations of activity and of power of inorganic bodies are reducible to repulsion and attraction. The first is shown by impenetrability and extension, the second by mechanical attraction, gravity, cohesion, adhesion, and chemical affinity. Physical philosophers designate by the names of attraction and repulsion those inherent causes in bodies on which these phenomena depend. They have discovered a great portion of the laws according to which these forces act, without being able to detect their fundamental cause.

XLIX. Similar phenomena, or manifestations of activity, are observed in living bodies. All of them possess extent and weight; cohesion and adhesion is exerted in all of them, and we see besides, in all, the play of chemical affinities. But these phenomena, although the effects of general physical forces, are modified by the manifestations of activity peculiar to organic bodies, called life, and by powers of a particular kind, viz., organic powers. All the physical and chemical properties of plants and animals, the manner in which they fill space, their extension, their gravity, their cohesion, the chemical affinities which operate in them, depend more or less on the organic powers by which they are animated. A further proof of this is, that plants and animals are produced from other living bodies of the same species as themselves, and that all their qualities, form, peculiarities of weight, of adhesion and cohesion, the form and composition of their parts, in short the mode of showing their own action, are determined by the organic powers of the bodies which originate them. We know of no living body generated by the action of purely physical or chemical forces. All the qualities, therefore, of organic bodies should be looked upon as the effects of life. Even those phenomena seen in them, which they exhibit in common with organic bodies, undergo modifications of their specific action, and should be considered as subordinate to the organic powers.

L. The weight of different living bodies depends on their life, and varies according to the periods of age, the state of the nutritive functions, and divers influences, external as well as internal, which modify the manifestations of activity of these functions. The specific gravity of all their solids and liquids is also subject to continual changes during the course of their existence. The liquids contained in the different spaces, cavities, or vessels of the plants and animals, are not distributed according to the law of gravitation alone: they are frequently moved against their gravity, and their manner of movement and of distribution is dependent on their manifestations of life.

LI. The degree of cohesion, of adhesion, and consistence of organic bodies, of all their liquid and solid parts, varies extremely according to the duration of their existence and manifestations of activity. Plants and animals have but little consistence and cohesion in the first period of their existence. These properties become more pronounced in them in proportion as they are developed, and for the most part they attain their maximum in advanced age. Various influences, which modify their manifestations of life, as heat, light, the atmosphere, water, and food, produce changes in their state of cohesion. This changes even in consequence of their internal action, as is particularly seen in the contraction of the muscles. The same is the case with the chemical affinities met with in living bodies. The composition of these bodies, as well in their entire as in their different parts, together with all the changes which take place during the existence of organic bodies, should be considered as the effects of life.(7)

Neither does heat spread over living bodies in the same manner, nor after the same laws, as in bodies not endued with life. The greater number of animals maintain the temperature peculiar to them, although that of the surrounding media be different.

LII. Even when the life of organic bodies is extinct, we should consider the qualities which they possess, from the time of death to the complete resolution of organization, as results of the organic powers which have been active in them. Besides the powers of life, Bichat(8) admits, in organic bodies, particular qualities, amongst which he classed extensibility, contractility, and elasticity of the tissues, which he regarded as inherent in their texture and the arrangement of the molecules of which they are composed. He thinks them independent of life, because they remain after death, and are only annihilated after the establishment of putrefaction and destruction of the organs. He adds, that life certainly augments their energy, but that it is not the cause of it. These properties are also the effects of forces which life has put into action, for the tissues which possess them have been produced during life and by life. The qualities which still remain inherent in them after death

(7) Berzelius also (Lehrbuch der Chemie, v. 3, part 1st, p. 135) recognises this, when he says, "The elements seem to obey, in living bodies, other laws than those in dead bodies, or bodies not endued with life. The cause of this difference has hitherto been withheld from our inquiries, and we attribute it to a power of a peculiar nature, belonging only to living bodies—the vital power. This something is placed altogether beyond inorganic elements; it is not one of their original qualities, as gravity, impenetrability, electric polarity, &c.; but we can neither conceive what it is, nor how it is generated or finishes."

(8) On Life and Death, p. 43. General Anatomy, v. i, part 1, p. 35.

proceed from their composition and texture, and these are produced by the manifestations of life. So soon as chemical affinities take the upper hand in dead bodies, during fermentation and putrefaction, these properties of the tissues also disappear, and are destroyed as the last remaining effects of life.

LIII. Hence it follows that the qualities of organic bodies, as well those observed in life as those remaining even after death, should be considered as the effects and results of special powers that are exercised in these alone. All the phenomena of these bodies, even those of general physical forces, are produced or modified by life and its powers. Reil, therefore,(9) was right when he said that, in a living organ, nothing is dead, not even elasticity, and that all therein is modified by what we call life.

The manifestations of life, such as we recognize them, are inexplicable by the general laws of physics.(1) Neither the power of repulsion, nor that of attraction, with all their modifications, is sufficient, according to researches hitherto made, to explain life. Already it has been more than once attempted to deduce life from the laws of mechanics, physics, and of chemistry. This error has been committed by the physiologists and physicians of the iatromathematic and iatrochemical schools. In every age distinguished naturalists discovered this error and opposed it. The difficulty of explaining the manifestations of activity of living bodies by the laws of other natural powers, probably depends on the imperfect knowledge which is possessed concerning natural phenomena in general; but so long as we cannot succeed in accounting for them in this manner, we are authorized in attributing them provisionally to powers of a particular species.

CHAPTER SECOND.

Of the Manifestations of Activity proper to organic Bodies.

LIV. All organic bodies, plants, and animals, are in a continual state of activity, and incessantly subject to changes. This is the most general phenomenon observed in them. If we submit it to analysis, we perceive that there are manifestations of activity and changes which take place uninterruptedly

(9) Archiv. für die Physiologie, v. vii, p. 438.

(1) Buffon (Histoire Nat., v. ii, p. 50) says, " J'avoue que je pense bien differemment de ces philosophes ; il me semble qu'en n'admettant qu'un eertain nombre des principes mechaniques, il n'ont pas senti combien ils retrécissoient la philosophie, et ils n'ont pas vu, que pour un phenomene qu'on pourrait y rappeler, il y en avoit mille qui en etoient independens. L'idee de ramener l'explication de tous les phenomenes à des principes mechaniques, est assurement grande et belle : ce pas est le plus hardi qu'on put faire en philosophie, et c'est Descartes qui l'a fait ; mais cette idee n'est qu'un projet. Le defaut de la philosophie d' Aristote etoit d'employer comme causes tous les effets particuliers ; celui de celle de Descartes est de ne vouloir employer comme causes, qu'un petit nombre d'effets generaux, en donnant l'exclusion à tout le reste. Il me semble que la philosophie sans defaut seroit celle où l'on n'employeroit pour causes que des effets generaux, mais où l'on chercheroit en même temps à en augmenter le nombre, en tâchant de generaliser les effets particuliers."

during the whole existence of each organized body; that there are others which only occur once, and never re-appear, and several that are only exhibited at certain epochs.

LV. Among the manifestations of activity which are continually present in each organize dindividual is placed nutrition, or the faculty enjoyed by the individual of maintaining himself in the state of chemical composition, of organization, and activity which is proper to it. If we inquire by what acts individuals are preserved, we find that they are the following:

1. Taking from the external world liquids and solids, entitled aliments, which is performed by absorption, or by particular movements.

2. Absorption of gaseous substances from the media which surround them, and expulsion of their materials in the same form, to wit, respiration

3. Conversion of the food, or gaseous bodies, which they have absorbed, into a mass resembling that of their own humours—assimilation.

4. Movement of the humours between the interstices of the solid parts—the circulation.

5. Conversion of the humours into solids, or combinations of these humours with the solid parts, and preservation of the properties of the latter—nutrition properly so called.

6. Lastly, preparation of particular liquids, at the expense of their humours—secretion.

Such are the operations observed, more or less distinctly, and in a greater or less degree, in all living bodies, plants, and animals, and designated by the name of nutritive functions. By these it is that bodies are maintained, during a certain time, in possession of the properties peculiar to the species of which they are a part. Nutrition, properly so called, the condition of their duration, goes on uninterruptedly in all of them, although frequently it occurs only in a very small degree. The other manifestations of activity which concur in the preservation of the individual frequently suffer more or less lengthened interruptions, as happens during the hibernation of a number of plants and animals. In general, the intervals observed, in the different groups of living bodies, are so much the less frequent, and shorter, as the organization of these bodies is more complicated, and as their manifestations of activity possess greater energy.

LVI. The matters that living bodies take from without to accomplish their nutrition, are the principal constituents of the atmosphere, water and organic matters, sometimes simple, sometimes compound. The organic substances are specially designated under the name of aliment. Living bodies serve for food to themselves, that is to say, they mutually devour each other; or they are nourished by organic excretions; or, in fine, they subsist on matters proceeding from the decomposition and dissolution of dead bodies. Consequently, the compound of particular combinations constituting the material substance of organic bodies, and which we have above designated by the name of organic matter, is the chief source whence living bodies obtain the materials for their nutrition.(2) These organic combinations, which pass from one living body into others, have in themselves the necessary qualities to render them capable of resuming the organic form, and reappearing in life by the manifestations of activity of living bodies. Aliments are matters capable of life, and are continually changing their form by the action of living bodies. There is no sort of aliment for inorganic bodies, or those not endued with life, during whose existence no change or renewal of materials takes place.

LVII. The introduction of aliments is accomplished by particular manifestations of activity of living bodies. The most general of these manifestations, and one which is observed in vegetables as well as animals, is absorption. Plants absorb their alimentary substances only in a liquid form, and the majority of them by means of special organs, namely, the roots. In animals, the taking of food is also chiefly performed by absorption, as long as they are confined in the ovum; but, after their exit from the membranes of the ovum, the mouth becomes the principal opening by which the animal ingests food in a liquid or solid form, and then it is only within the body, in the alimentary sac, that the attraction of the nutritious parts takes place by absorption. But the introduction of alimentary substances into the mouth is accomplished by a series of special movements, to which we shall return hereafter. No mineral receives within itself matters introduced into it by absorption, or by the aid of certain movements concerned in its preservation.

LVIII. The aliments which plants and animals introduce into themselves by absorption, and animals moreover by the mouth, do not pass into the mass of solids in a direct manner and without undergoing preliminary changes. Previous to their combination with organisms into the composition of which they are to enter, and participating in their vital qualities, they acquire, in certain localities, the properties belonging to the liquids or juices which form these organisms. The conversion of aliments into the proper mass of living bodies is known under the name of assimilation.

Several facts seem to favour the assimilation of alimentary matters absorbed by the roots or other organs of plants. We know that plants most distant in regard to formation and budding composition, increase and produce

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(2) Buffon says very truly (Hist. Nat., vol. ii, p. 306,) "La matière qui sert à la nutrition et à la reproduction des animaux et des vegetaux est la même; c'est une substance productive et universelle, composée de molécules organiques, toujours existantes, toujours actives, dont la reunion produit les corps organisés. La nature travaille toujours sur le même fond, et ce fond est inépuisable; mais les moyens qu'elle emploie pour le mettre en valeur, sont differens les uns des autres."

particular combinations in the same soil and under the influence of the same nutritive materials. We also see branches of different varieties of plants covered with leaves, flowers, and fruits peculiar to them, after having been engrafted on the same trunk, although they were nourished, like the trunk itself, by the nutritious liquid imbibed by its roots. It follows from this, that the crude liquid of a wild shrub needs to be assimilated, by the special manifestations of activity of the graft, to the mass of the shrub's humours, before it can combine with its solid parts and share its qualities. Each kind of plant prepares, from alimentary substances, a peculiar nutritious liquid, endowed with specific qualities, and fitted to take on the nature of its solid parts.

Neither is the aliment of animals of such a nature as to be capable of passing directly into their solid parts, and of being exhibited as endued with their organization and manifestations of life. It must undergo divers elaborations and be converted into a liquid, properly so called, in order to enjoy this property. Besides, the most dissimilar animals frequently take the same food, but this does not prevent each one maintaining the organization and composition belonging to it and its peculiar manifestations of life.

LIX. The assimilation of aliments is accomplished in two ways. On the one hand, it is effected by means of liquids which organic bodies add to the aliments, in the localities wherein they are received, and by the influence of which they modify the properties these substances possess, by bringing them nearer to their own. On the other hand, also, it takes place by the exposure of the aliments, mixed with the juices that have been added, to the action of the atmospheric air, of which they absorb a part, at the same time that they supply certain materials to it. The former is called assimilation by the first passages, and the latter assimilation by respiration. These two operations are the special manifestations of activity which living bodies alone can display, and which are totally wanting in bodies deprived of life.

LX. In organic bodies of the most simple kind, which are composed uniformly of cellular tissue, or mucus, as the cryptogamia and some animals that have no buccal openings, the assimilation of aliment in the first passages is directly effected, in the very midst of this tissue or mucus, into which it has been received, in a liquid form, by means of absorption. In more complicated living bodies, on the contrary, there exist particular spaces into which the aliments are directed, where they become assimilated. In plants these are the sap vessels proceeding from the roots: in animals, a cavity of sacciform shape, the alimentary digestive or intestinal canal, in which aliments accumulate, and where, by the addition of secreted humours, their assimilation is effected.

Inorganic bodies do not contain cavities of this description, filled by matters from without, converting them by degrees into a substance of the same composition as themselves.

LXI. All organic bodies, plants, and animals, exercise a reciprocity of action with the media which they inhabit. They withdraw, either directly from the atmosphere or from air mixed with water, materials that combine with the mass of their humours; but on the other hand, they return to these same media certain materials from their liquids. Respiration is the name given to the process by which this change of aeriform or vaporous matter is accomplished. In vegetables and animals of the most simple kind, as the cryptogamia, polypi, medusæ, &c.; there are no special organs for the accomplishment of respiration, which is performed by their entire surface. Those, on the other hand, whose organization is more complex, not only respire by the crust or membrane which envelopes them, but they are likewise provided with organs especially destined for the performance of this function. In animals respiring air, lungs, and air passages are found, and branchi and water passages in those respiring water. It is by respiration that the nutritious liquid, prepared by the alimentary matters in the first passages, acquires the properties necessary for passing, in the shape of formative or nutritive juice, into the mass of solid parts, combining with these parts, receiving their mode of organic aggregation, and enjoying their vital manifestations of activity. Respiration is an organic operation, on the continuance of which the existence of living bodies depends, so that, in this sense, they could not without it be nourished, nor possess the capability of evincing their manifestations of activity.

Reciprocity of action, with the media which surround them, is not necessary for the preservation of inorganic bodies, and in them no change of aeriform materials occurs, on which their existence is conditional. We must, therefore, consider respiration as a manifestation of activity appertaining exclusively to organic bodies.

LXII. In order that the aliment, after being introduced into the different localities and canals of organic bodies, afterwards converted, by the actions of assimilation, into a nutritious and formative liquid, may pass into the solid parts and contribute to their nutrition, it is necessary that they should be guided to these parts, and be distributed throughout the body. Nutrition supposes, therefore, movements in the nutritive liquids. In plants, the absorbed and assimilated liquids are in motion: the rough juice which the roots imbibe, is carried along the stalk, in particular vessels, and thus arrives at the leaves, where, by the influence of atmospheric air, it is converted into nutritive or formative juice, properly so called. Particular vessels again convey this juice from the leaves, distributing it to the various parts of the plant.

In all animals, the aliment, on its arrival at the alimentary sac, or intestinal canal, whither it has been conducted by a series of particular movements, is agitated by the alternate contractions and dilations of the walls of this sac.

Whether it is already in a liquid state, or whether it is liquified, during its stay in this canal, by the humours with which it is mixed, it is, after having undergone assimilation from these humours, absorbed, and in the greater number of animals, as the mammifera, birds, reptiles, fishes, crustacea, arachnides, insects, mollusca, annelidas, and the radiariæ, it passes into vessels of a particular description. These vessels, ramifying in the body of the animal, have communication with every part of it. Their trunks and ramifications are so united, that the liquid they contain can flow from one into the others. The junction of the different trunks is effected, in the majority of animals, by a hollow muscle, which is continually agitated by an alternate movement of contraction and dilatation, and is called the heart.

The liquid prepared from the aliment, and which fills the vascular system, the blood, is in a state of continual motion. On one hand, it proceeds out of the heart and great trunks by particular vessels, the arteries, which ramify throughout the body; on the other hand, it returns by vessels which leave the extremities of the arteries, unite by degrees into larger trunks, and have the name of veins. The liquid contained in the vascular system is continually submitted to the influence of atmospheric air, in a portion of the same system which is distributed to the respiratory organs, whilst that which is in the portion of the vascular system, whose ramifications are spread throughout all the other organs, serves for their nutrition, and supplies many of them with the materials of the particular humours which they secrete. In animals of a simple structure, polypi, entozoa, and some others, in which no vascular system for the movement of the humours has hitherto been discovered, the nutritious assimilated liquid passes directly into the parenchyma of the body, with which it enters into combination.

Thus in all organic bodies we find movements of liquids in certain particular spaces, and in determinate directions, an operation on which the maintenance of their existence depends, because the acts of nutrition are conditional on such movements. No movements of this kind have been yet observed in any inorganic body. On this account we should consider this process as a manifestation of activity belonging in a special manner to living bodies, as a vital phenomenon.

LXIII. Another manifestation of activity, peculiar also to organized bodies, plants, and animals, is the passage of the nutritious liquid into the solid parts, whose composition, organization, and vital properties it assumes. In plants, especially those of a complicated structure, as the monocotyledones and dicotyledones, the formative coagulable juice which has been prepared in the leaves from the crude fluid, is taken up again by particular vessels, distributed through the body, and employed in the nourishment and growth of the solid parts. In animals endowed with special organs for the movement of the humours, the nutritive liquid prepared from the aliment, and converted into blood by respiration, is conducted by vessels to the several organs. Each organ appropriates to itself materials from the blood, which it introduces, by its proper action, into the circle of its composition and aggregation; after which these materials discover the same vital properties as the organs into whose constitution they have respectively entered. In animals that have no circulation of blood, the nutritive liquid passes directly from the alimentary sac, or is conveyed by vasculiform prolongations of this sac, into their substance. The parts of air mixed with water penetrate the soft surface of these animals, and appear to combine with the nutritive liquid, which becomes afterwards identified with their parenchyma.

By nutrition we designate that manifestation of activity which belongs to all living bodies. It is not met with in inorganic bodies. As soon as inorganic matters, submitted to chemical affinity, come under circumstances favourable for crystallization, they are mutually attracted, according to the laws of attraction, and crystals are formed. When the crystallization is finished, everything is again quiet, and no manifestations of activity that can be compared to the nutrition of living bodies are any longer observable.(3)

LXIV. Organic bodies secrete, from the mass of their humours, substances in a vaporous or liquid form, some of which are ejected, as excretory matters, into the media, air or water, which they inhabit; whilst others serve for the assimilation of aliment, or for generation. Vegetables transpire by their leaves, and the greater number of them exhale from the flowers odoriferous matters. In all, the matter destined to form the germ, is secreted in a liquid form; in the majority, the secretion of the pollen, which is necessary to the fecundation of the germ, is also performed. Animals expel matters by several different ways; especially by the skin, the respiratory organs, the alimentary canal, and the urinary passages. In all those provided with an intestinal canal, the internal surface of this apparatus secretes a liquid, the gastric juice, which acts as a solvent and a means for the assimilation of ingesta. Among the liquids which effect the assimilation of aliments, in the complicated animals, are also ranked, the saliva, the bile, the pancreatic juice, and the intestinal liquid. In all animals, the matter, from which a new being of the same species is formed, is likewise secreted from the assimilated alimentary mass. Lastly, in the greater number, particular organs secrete a liquid which is destined to form the generative liquid enclosed in the ovum; this is the seed.

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(3) Blumenbach says, in speaking of nutrition, (Institut. Physiolog, ed. 4, p. 383,) "*Est autem nutritio summum naturæ privilegium, et omnium et singulorum in utroque regno corporum organicorum communis et princeps prærogativa, qua machinas et automata humano artificio confecta, primo statim intuitu mirum quantum longissime superant, &c.*"

Secretion is another manifestation of activity that belongs peculiarly to living bodies. There is no analogous operation to be found in inorganic bodies. If their materials escape, it is ever the effect of a chemical decomposition, produced by external circumstances, causing the destruction of their form.

LXV. The manifestations of activity, of which we have spoken, namely, the reception of alimentary matters, absorption, assimilation, respiration, the movement of the nutritious liquid, nutrition and secretion, are dependent on, or are mutually swayed by, each other. Absorption influences assimilation, inasmuch as it takes up the assimilated aliment; assimilation acts the same part with respect to nutrition, because it prepares the materials, making them fit to nourish and form the organs; the movement of the nutritive liquid is a condition essential to the operations of nutrition, since it conveys to the solid parts the matter which is to nourish them; nutrition, in its turn, also influences assimilation and the movement of the nutritive liquid, because it maintains the parts charged with the accomplishment of these manifestations of activity in a state capable of exercising their functions. Secretion supposes absorption, assimilation, the movement of the nutritive liquid, and nutrition. Absorption itself is a condition necessary for these different manifestations of activity, inasmuch as by preparing the liquids that are added to the aliment, it effects the assimilation of the latter, and by eliminating the secretory matters, it preserves the nutritive liquid in the state necessary for the nutrition of the organs charged with the accomplishment of absorption, assimilation, and the movement of the nutritive liquid. In a word, all the manifestations of activity which conduce to the preservation of organic bodies, are mutually dependent on, and reciprocally sway, each other.

LXVI. So long as organic bodies exercise the function of nutrition, and are thereby maintained in the state of composition, configuration, organization, and activity proper to them, spite of the conflict with external influences whose action tends to their destruction, so long as they resist the laws of chemical affinity, and by their own proper activity, are preserved, and have their duration assured, so long do we say they are living.(4) But, as soon as these manifestations of activity have been extinguished, the matter constituting organic bodies fall under the laws of chemical affinity and the influence of

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(4) Stahl made life to consist (Theoria Medica Vera) in the property which organic bodies possess of preserving their particular composition. *Vita nihil aliud est formaliter, quam conservatio corporis in mixtione quidem corruptibili, sed sine omni corruptionis actuali eventu.* His commentator, Juncker, says, *Illud putredini contrarium quod vitæ nomine salutamus.* John Hunter also asserts, that life is a vast chemical operation, which even continues in the apparent state of repose, resists external chemical influences, and opposes the decomposition of the bodies in which it acts.

external agents, heat, light, and water; they are withdrawn from their combinations, they contract new ones, and the organic composition, configuration, and arrangement disappear. The most general manifestation of activity, then, of living bodies is self-preservation by their own proper activity, in the midst of changes effected more or less rapidly, and of a continual renewal of material substance.(5)

Inorganic bodies are not subjected to continual changes and uninterrupted renewal of substance similar to those observed in living bodies in the operations of their nutrition. Directly contrary is the case; they are in a state of repose and sluggishness, and of themselves operate no change, which is the very reason of their subsistence. Matters united into crystals, according to the laws of chemical attraction, and kept together by cohesion, are permanent in the forms peculiar to them only so long as influences from without bring no change into their composition. Thus, whilst the existence and duration of organic bodies are conditional on changes and continual renewal of their material substance, these very circumstances compromise and destroy the existence of inorganic bodies in the form which is peculiar to them.

LXVII. Independently of these particular manifestations of activity which belong to all living bodies, and allow of their preservation during some time, notwithstanding the external influences which tend to their destruction, we observe, in animals, others also, the remote likeness even of which are not met with in inorganic bodies. Such are the operations of the mind, the faculty of feeling and moving altogether, or partially by the influence of their own proper activity. We shall return to this point in the next book.

LXVIII. The second group of the changes of organic bodies, which only occur once during the existence of each individual, and never reappear, consists in the phenomena that accompany the origin, the development, and the periods of life or of age. In general, these changes are accompanied, in each individual, by the same phenomena, only exhibiting endless differences, according to the species to which the individuals belong. First, regarding the origin, we remark that all vegetables and animals, so far as we can judge from observation, are indebted for their formation to organic matters, which enter into the composition of bodies already existing. The first rudiment of a living body takes its origin from the material substance of an organic body,

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(5) Cuvier is perfectly right (Le Regne Animal, v. 1, p. 12) when he says, "Si pour nous faire une idée juste de l'essence de la vie, nous la considerons dans les êtres où ses effets sont le plus simples, nous aperceveron promptement qu'elle consiste dans la faculté qu'ont certaines combinaisons corporelles de durer pendant un temps et sous une forme determinée, en attirant sans cesse dans leur composition une partie des substances environnantes, et en rendant aux élemens des portions de leur propre substance. La vie est donc un tourbillon plus ou moins rapide, plus ou moins compliqué."

after the extinction of its individual manifestations of activity, or else it originates from the matter of organic bodies with the concurrence of the manifestations of activity of beings yet alive. We call the first mode spontaneous generation, and the second generation, properly so called, or procreation.

LXIX. Although Harvey, Linnæus, and other naturalists have founded the principle, that living bodies can only be propagated by ova and grains, and that animals and vegetables of new formation could be considered only as products of the manifestations of activity of similar beings that were already in existence, this rule has been discovered to be too general. The observations made by Needham,(6) Priestley,(7) Ingenhouz,(8) Monti,(9) Wrisberg,(1) O. F. Müller,(2) G. R. Treviranus,(3) &c. have shown that a number of vegetable and animal forms, placed in the most simple and least elevated ranks of organization, can, in certain favourable conditions, be formed without the concurrence of other living bodies, at the expense of the material substance of dead organized bodies, which have been thrown into a complete state of revolution by putrefaction and fermentation. Of this number are the infusoria or microscopic animalculæ, the green matter of Priestley, the species of byssus, mushrooms, &c. To attribute the origin of infusoria, as Leuwenhoeck their discoverer did, and that of the other bodies which have been named, as Spallanzani,(4) Bonnet,(5) Terechowsky,(6) and others were in the habit of doing, to ova and seeds, is, according to the remark formerly made by Buffon, and for the reasons advanced by the naturalists whose names I have quoted, especially Treviranus, to hold a false and untenable hypothesis, which only rests on hazarded suppositions and mistaken analogies. Observations and experiments lately made by Fray, Gruithuisen, Nitzch,(7) Maerklin,(8) Bory de St. Vincent,(9) and others, joined to the researches of

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(6) An Account of some New Microscopical Discoveries. London, 1745, in 8vo. Nouvelles decouvertes faites avec le Microscope. Leyden, 1747. Nouvelles Observations Microscopiques. Paris, 1750, in 8vo.

(7) Versuche und Beobachtungen uber Verschiedene Theile der Naturlehre, v. i, p. 261.

(8) Experiments on Vegetables. London, 1779. Vermischte Schriften Physisch Medizinischen Inhalts. Vienna, 1784, v. ii, p. 3.

(9) Commentat. Academ. Bononienses, v. iii, p. 145.

(1) Observationum de Animalculis Infusoriis Satura. Gœttengen, 1765, in 8vo.

(2) Historia Vermium, v. i, p. i, p. 1. Animalcula Infusoria Fluviatilia et Marina. Op. Posth. Edit. Cura Ott. Fabricii. Copenhagen, 1786.

(3) Biologie, b. ii, p. 264.

(4) Saggio di Osservazioni Microscopiche Concernenti il Systema Della Generazione di Signori Nudhame Buffon. Modena, 1765. Osservazioni ei Esperienzi Intorno egli Animalculi delle Infusioni; in Opusculi di Fisica Animale é Vegetabile. Modena, 1776, v. i and ii.

(5) In Spallanzani, Opusc di Fisica.

(6) Debhao Infusorio Linnei. Strasburg, 1775.

(7) Beitrag zur Infusiorenkunde oder Naturbeschreibung der Cercarien und Bacillarien. Halle, 1817.

(8) Beobachtungen uber die Urformen der Niederen Organismen. Heidelberg, 1823.

(9) Essais Monographiques sur les Oscillaires. Paris, 1827.

Schweigger,(1) Carus,(2) and of Burdach,(3) speak most favourable for a mode of production, without the concurrence of parents, of a generation taking its source directly from the matter of dead organized bodies. These organic bodies, of the most simple kinds, make their appearance in infusions, as well of the immediate principles of organized bodies, as albumen, fibrin, gelatin, animal and vegetable mucus, starch, and gluten, as of the combinations proceeding from these principles, so soon as decomposition commences in them from the coincidences of heat and air.

LXX. The most simple mode of generation, spontaneous generation, (generatio œquivoca, spontanea, heterogenea, primitiva,) consists in this, that at the commencement of fermentation or putrefaction in dead individuals, the organic matters now separated from their organization preserve, if they be not reduced to their elements or converted into binary compounds, by the action of chemical affinities, the property of reappearing, with the concurrence of favourable external influences, as heat, water, atmospheric air, and light, in more simple animal and vegetable forms, which, however, vary according to the influences to whose action they are submitted.

As a simple modification of this mode of generation we are to consider the first development, in an animal body, of entozoa, which are sometimes met with even in embryons. The reasons alleged by Pallas, Müller, Werner, Bloch, Goeze, Braun, and especially G. R. Treviranus,(4) Rudolphi,(5) and Bremser,(6) forbid our admitting that they come from without the animal, since they are not found out of it, nor in the earth, nor in plants, in which they cannot exist, and since they are met with sometimes in organs, such as the eye, the brain, the muscles, and others, which have no communication whatever with the external parts. We must, therefore, with these naturalists, regard them either as the products of non-assimilated elements, or as morbid productions, which, in certain circumstances, are formed in the humours or the parenchyma of the organs. However, many of them, being once formed, are provided with genital organs, and are reproduced by generation properly so called.

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(1) Handbuch der Naturgeschichte der Skelettlosen Ungegliederten Thière. Leipsick, 1820, p. 256.

(2) Von den Ausseren Lebens ; Bedingungen der weiss, und kaltblutigen Thierc. Leipsick, 1824, p. 37.

(3) Die Physiologie als Erfahrungswissenchaft, v. i, p. 7.

(4) Biologie, v. ii, p. 365.

(5) Entozoorum sine Vermium Intestinalium Historia Naturalis, v. i, p. 370, cap. xviii, De Entozoorum Ortu.

(6) Ueberlebende Wurmer in Lebenden Meuschen. Vienna, 1819, v. iv, p. 1. It is worthy of remark, that moldiness has been observed in the interior of animal bodies, on parts changed by disease, as is proved by the facts mentioned by Mayer, (in Meckel's Archiv der Physiologie, v. i, p. 310,) Jaeger, (Ibid, v. i, p. 354,) and Olfers, (Commentarius de Vegetativis et Animatis in Corporibus Animatis Reperiundis. Berlin, 1816, in 8vo.)

The results of observations and researches on this subject equally impose on us the necessity of admitting the axiom established by G. R. Treviranus, that there exists a matter peculiar to organic bodies, capable of life, and having the property of taking on certain forms, at the same time that it acquires a particular mode of action. The manner in which this property is manifested in the actual development of form, is dependent on the conflict and reciprocity of action existing between organic matter and external or physical influences, according to which circumstances it takes either an animal or vegetable form.

LXXI. All living bodies that have not this mode of origin, proceed from other organisms already existing, by the effect of manifestations of activity peculiar to the latter, which they resemble in structure and phenomena of life. Generation by procreation, or unequivocal generation, presents two differences; it takes place with or without the concurrence of two sexes. In the former case, which is the more simple, parts or segments are detached from organisms already existing, which go on increasing, acquire the form of individuals of the same species, and continue to subsist in this shape.(7) This mode of generation occurs in two ways: sometimes an organic body is divided into several parts, each of which takes the qualities of an individual: sometimes it is confined to the production of parts which, after being detached from the organism, (and this does not the less continue to exist,) are developed, and themselves become individuals. In this mode of generation there is no sexual difference; each individual itself acts the part of the species, and it can, when circumstances are favourable, produce beings of the same species as itself.

LXXII. Generation, by division or scission of an organ into new individuals, (generatio fissipara,) takes place only in very simple bodies, composed of one homogeneous substance. It has been observed by Saussure,(8) O. F. Müller,(9) Nitzch,(1) in infusoria, (bacellæria, paramecia, cyclides, trichodes,) and by Ingenhouz, G. R. Treviranus, Bory de St. Vincent, Girod Chantran, and others in confervæ. It is also sometimes remarked in fresh water polypi, according to Trembley;(2) in them, however, it scarcely ever happens otherwise than accidentally, and in consequence of certain circumstances.

LXXIII. When organic beings are multiplied by means of parts separated

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(7) This mode of generation has been very fully treated of by Burdach (Physiologie, v. i, p. 30.) He calls it solitary generation.

(8) In Spallanzani, Opusc; de Physique, v. i, p. 172.

(9) Vermium Terrestrium et Fluviatilium Historia. Copenhagen et Leipsick, 1773, in 4to. Animalcula Infusoria Fluviatilia et Marina. Copenhagen, 1786.

(1) Beitrage zur Infusorienkunde, p. 72, 81. Perhaps vibriones and monades are sometimes propagated by spontaneous scission.

(2) Mem. pour servir à l'Histoire d'un genre de Polypes d'eau douce. Leyden, 1744, in 4to. Translated by Goeze, pp. 257.

from their bodies, and whose development originates new individuals, the parts thus produced are called germs. Sometimes they represent portions or a more distant organism, anterior to this same organism, and whose structure and substance are the same as their own; sometimes they are exhibited under the forms of globules or grains, which the organic body producing them excretes and ejects from within itself. We give the name of shoots to the former, and that of reproductive corpuscules to the latter.

LXXIV. In the propagation by sprouts, the germ is elevated on the surface of the body producing it, in the form of a small swelling, which gradually increases in size, and ends by being detached, to continue its development and to live as an individual. It is thus that armed polypi and vorticellæ are multiplied, according to the observations of Trembley, of Schæffer,(3) Roesel,(4) &c.; and corals, isis, and other marine polypi, according to those of Cavolini,(5) Schweigger,(6) &c. Propagation by shoots is only met with in plants, in conjunction with other modes of multiplication, for instance, in some filamentous mushrooms, the confervæ, tremellæ, and hepaticæ. In phanerogamic plants, although they are provided with sexual organs, we must refer to this head the formation of creeping roots, shoots, and twigs, (radix repens, stolons, sarmentum.)

LXXV. In multiplication by reproductive corpuscles, an organism produces, at the period of its greatest activity, globules or grains, which are emitted, and from which, after their elimination, new individuals proceed. These corpuscles differ from true ova and seeds, which are ripened by fecundation, inasmuch as the substance of which the new being is formed is not, as ova and seeds are, enclosed in a special envelope, which is separated from them at the moment of the development of the germ, and inasmuch as the formation of the new individual is owing to the entire substance of the reproductive corpuscule. Sometimes the reproductive corpuscules are, at the period of their origin, united to the mass of the body producing them, and from which they are shortly separated; sometimes they proceed from its humours. Differences occur relative to the spot of the body where they are developed, for at one time their production takes place only on a determinate part of it, at other times they are developed in several places, and are spread into its substance. In some zoophytes we observe a production of reproductive corpuscles scattered throughout the organism, which is the head of the family. The vegetable kingdom presents examples of this mode of propagation by repro-

(3) Die Armpolypen in den süssen Wassern. Regensburg, 1754, 1763, in 4to.
(4) Insectenbelustigúngen. Nuremberg, 1746, in 4to, v. iii, p. 433.
(5) Abhandlungen über Pflanzen, Thiere des Mittelmeeres, translated from the Italian by Sprengel. Nuremberg, 1813, v. iv, plate 5.
(6) Handbuch der Naturgeschichte der skeletlosen ungeglierderten Thiere. Leipsick, 1820.

ductive corpuscles, (sporæ, sporidia, germina, gongyli,) in the acotyledonous plants, the confervæ, ulvæ, fuci, pulvurent and filiform mushrooms, hepaticæ, &c.

In a great number of organized bodies, the production of reproductive corpuscules is confined to a certain part of the parent organism, and accomplished by special organs, which should be considered as the first rudiments of female genitals. In the gorgonia, the madreporas, the sertulariæ, the red corals, &c., there is formed, according to Cavolini,(7) in the middle of the substance of the polypus, and not far from its arms, a small membranous sac, which contains the reproductive corpuscles, is detached, bursts and casts the corpuscles into the sea. Pallas (8) remarked something similar in fresh-water polypi. In this instance, the organ which prepares the corpuscules is formed annually, and each time is detached from the body, together with the corpuscules.

The corpuscules are inclosed in tubes or bladders in the medusæ, and in spaces disposed in a fan-like manner in the actiniæ. Lastly, the productive organs of germs resembling the ovaries of the superior animals, exhibit the same disposition in the asterias, the sea hedge-hog, the holothuria, and others. The vegetable kingdom presents, in many cases, collections of germs, in the form of sacs or corpuscules, to which botanists have assigned different names. We must moreover bring under the same mode of multiplication, what is remarked in a number of phanerogamic plants provided with proper sexual organs, which, independently of generation properly so called, are reproduced by knots, tubercles, bulbs, and buds, whence originate new plants, or parts of new plants.

Propagation by germs consists in a periodical exaltation of the plastic activity of the individual, brought on by favourable external influences, which causes the rudiments of new individuals to proceed from its own mass, or be separated from the mass of its humours, to be developed, and give rise to beings of the same species by the concurrence of external conditions.

LXXVI. The majority of animals and plants, whose structure exhibits a higher degree of composition, are propagated by means of two sexes. Such is the case in the mammifera, birds, reptiles, fishes, crustacea, insects, the greater number of mollusca and annelidæ, and some entozoa. Among plants, this mode of propagation is met with in the monocotyledonous and dicotyledonous plants, although they multiply by other ways. In generation by two sexes, there are two different genital matters, one proceeding from the female, the other from the male, and two kinds of organs which separate these matters

(7) Loc. cit., plate 1, fig. 5, 6; plate 2, fig, 6; plate 3, fig. 4, 5; plate 4, fig. 7, 11.
(8) Elenchus Zoophytorum, p. 28.

from the humours of living bodies, at a certain period of their existence. The female genital humour, from which a new being is to take its origin, is enclosed in a special envelope, and has the name of ovum in animals, of seed in plants: the organs that produce it being called ovaries. The ovum and the seed do not become a new being, until the seed of the male has exerted an influence over them which determines their development in a form corresponding to the species that has furnished the genital matter. In animals, the seed of the male is secreted in particular organs, the testicles; in plants, an analagous matter, the pollen, is prepared in the anthers. The action of the male seed on the female genital matter, ovum or seed, is called fecundation, in consequence of which the formation of a new being commences in this matter, and is effected in various manners in the different groups of animals.

Male and female genital organs exist at the same time in one individual, or they are separated in two individuals of the same species. Their union in one individual is most commonly the case in plants: their separation in different individuals is seen, on the other hand, most frequently in animals. Many differences, the explanation of which will be given elsewhere, are exhibited by organic bodies, in relation to the presence of other organs, constituting a part of the male and female genital apparatus, and having for their end either the accomplishment of generation, or the lodgment, development, and nutrition of the germs.

LXXVII. The act of begetting, therefore, is a property belonging to all organic bodies. These bodies are multiplied, because at a given period of their existence and in certain circumstances, they are capable of producing, and themselves are likewise produced by, other beings of the same species, which supposes a series of past generations, whose first link or commencement is unknown to us. Among inorganic bodies there is no generation, no production of bodies from each other. No mineral, no crystal, after being destroyed, is separated into crystals of its own kind, as happens in organic bodies in the fissiparous generation; none give out new crystals, as in the gemmiparous generation, and that by productive corpuscules; in short, crystals never do procreate others like themselves, as occurs in the generation, properly so called, of living bodies provided with a sex. There are, therefore, neither species nor genera in the inorganic kingdom. The production of fresh crystals is nothing more than the effect of chemical and mechanical attraction, exerted according to purely physical laws, between the substances forming the base of their composition. When substances different in nature, but having affinity for each other, are held in solution in a liquid, their atoms unite, under certain external circumstances, and according to fixed laws, into bodies endowed with geometric forms, namely crystals, which are characterized by smooth surfaces and by fixed inclinations of their angles and edges.

It is necessary for the crystallization of a substance that it should first be converted into the shape of a liquid or æriform fluid, and that then the causes which rendered it fluid should be withdrawn. The latter is effected by the cooling or subtraction of the ponderable substance with which the intended crystal had contracted a combination that rendered it fluid.

LXXVIII. All animals and vegetables, as soon as they proceed from the shoot, from the reproductive corpuscule, from the ovum or the seed, appear in a simple form, which they gradually leave, to take a more complicated one; this is accompanied by an increase in the diversity and intensity of their manifestations of activity. All organic bodies, whose life is not curtailed or interrupted in any way, exhibit three distinct periods in their existence—that of gradual growth, or youth, of complete development, or sexual maturity, and that of decay, or old age, which finishes in death. In this manner, the representatives of all the vegetable and animal species are included in a continual series of changes, the duratiou of which varies infinitely in the different groups of living bodies, being extended from the space of a few days to entire ages. To be born, to be developed, to engender, and to die, are acts occurring uninterruptedly in the domain of organic bodies, first calling into existence, then repelling into nothingness the individuals representing the species. These changes, which happen only once in each individual, are dependent on the mode of action of the organic powers, whose activity commences in its minimum of intensity, by degrees arrives at the maximum, is exhausted by the very fact of its exercise, and ends by being extinguished.

In inorganic bodies no changes occur that can be compared to those of the periods of life or the ages. Substances once united into crystals, according to the laws of attraction, and whose molecules are held together by cohesion, remain in their respective forms, without our perceiving in them thenceforward any phenomena presenting even a distant analogy to those of development and the ages of living bodies. Crystals of themselves undergo no changes that terminate in their ruin and destruction in a certain lapse of time. If they last a few hours only, or thousands of years, it is dependent altogether on accidental circumstances, according as they enter into connexion with matters which have a stronger affinity for the substances that constitute them.

LXXIX. In regard to the changes and periodical manifestations of activity of organic individuals, the phenomena are of several kinds. In the first place we remark, in the majority of animals, changes which occur every day, at fixed periods, and which have a certain connexion with the movements of the earth round the sun, as well as with the modifications that follow thence in the influence of external circumstances on animals. These are the states of waking and sleeping. We also remark, in many plants, phenomena whence may be inferred an alternate state of repose and activity. Inorganic bodies fixed in inactivity, that is to say, crystals, exhibit nothing which even in a distant manner can be compared to these states of living bodies.

LXXX. In all vegetables and animals whose life is prolonged beyond one or more years, changes and manifestations of activity are periodically remarked, which appear at different periods of the year, and may be considered as dependent on the annual movement of the earth round the sun. Of this kind are, in plants, the annual shooting of buds, of leaves, and flowers, fecundation, the ripening, and lastly the fall of the fruits and seeds, as also the death and fall of the leaves; in animals, the periodical appearance of the manifestations of activity of the genital organs, the formation of germs and ova, the secretion of the male seed, the generative act, pairing, gestation, laying eggs, the building of nests, hatching, parturition, and the secretion of milk. Under the same category must also be placed the renewal of hair and feathers, that of the skin, the formation of new scales, the shedding and shooting of antlers. In fine, we may also bring under this head the winter and summer sleep of a great number of animals, as also the migrations regularly observed among some of them. These periodical changes have their origin in the action of external influences, of light and heat, on living bodies, which varies according to the situation of our planet in reference to the sun, and modifies the manifestations of activity of organic bodies.

Inorganic bodies present nothing that can be compared with these periodical changes that occur annually.

LXXXI. Moreover we perceive, in organic bodies, changes that only happen in individuals under the sway of certain circumstances. Of these are the restoration of solutions of continuity and the regeneration of lost parts, whenever the lesion has not endangered the duration, nor destroyed the life of the individuals. The majority of long-lived animals and plants repair the solutions of continuity made in their different parts by wounding bodies. We even see parts that have been totally separated reunited. Here likewise we must place the planting of part of one body on others, as grafting slips in vegetables. This transplanting even succeeds sometimes in animals on the skin and other parts.(9)

Regeneration is exhibited in several different degrees. It has the greatest activity in animals and vegetables of the most simple kind, for in them the parts of an individual that has been cut in pieces produce all those necessary to form a complete one. Thus we see detached portions of a lichen continue to grow and acquire the form peculiar to the species. A great number of perennial plants may be multiplied by means of slips which throw out roots

(9) Joseph Baronio (Memorie della Societa Italiana. Vol. i, p. 180) transplanted the spurs of a cock to the comb of another: he even succeeded in transplanting thither the tail of a kitten and the wing of a canary bird.

and become individuals. There are also vegetables that are multiplied by their leaves. Under this head we may bring, among animals, the multiplication of polypi by division. According to the well-known experiments of Trembley, Roesel, and several others, armed polypi may be cut into several pieces, which continue to grow, and each of which becomes a perfect polypus. Similar phenomena have been observed in detached segments of naiades and some other annelidæ.

Parts or members that have been accidentally lost or destroyed, are reproduced in many animals. Thus the actiniæ, the medusæ, the sea-stars reproduce their rays; the teniæ renew the rings taken from the posterior part of them, snails their horns, craw-fish their claws and paws. Aquatic salamanders reproduce several successive times their paws and tails, together with all the bones, muscles, vessels, and nerves that form a part of them; even the eye is reproduced after being destroyed. The tail is regenerated in lizards. As to warm-blooded animals, mammifera, and birds, regeneration in them is confined to the epidermoid and horny parts, hairs, claws, and feathers.

Lastly, we remark, in all living bodies, that when disorder takes place in their functions, that is, when they are seized with disease, they exhibit a tendency to repress this state of uneasiness, and again to introduce order and regularity into the manifestations of activity.

Inorganic bodies absolutely present no phenomenon which we can consider as the effect of regeneration and healing. No crystal reproduces the parts it has lost; none repair the solutions that may have happened in their continuity; none return of themselves to a state of soundness.

LXXXII. These manifestations of activity, which are here only drawn in the outline, the self-preservation of individuals and of species, throughout an uninterrupted series of changes, belong to all organic bodies without exception. We designate the union of them all by the name of *life*, and we denominate *living* the bodies in which we remark them. As we do not remark similar phenomena in inorganic bodies, we are necessitated to consider them as the effects of causes which are not active in these bodies, and which only exist in living beings. These very causes have their foundation in qualities belonging only to organic bodies, and which we call organic powers. In order to become well acquainted with these qualities, we must enter into some details on the chemical composition, the organization, the manifestations of activity, and the changes of plants and animals, and compare these two orders of bodies together in all these relations, which will allow us to judge which those are that belong to them in common, and which those are exclusively peculiar to each series.

BOOK SECOND.

Comparison of Animals with Vegetables.(1)

FIRST SECTION.

COMPARISON BETWEEN THE MATERIAL COMPOSITION OF PLANTS AND ANIMALS.(2)

CHAPTER FIRST.

Of the Chemical Composition.

LXXXIII. Vegetables and animals have great analogy with each other on the score of their chemical composition. In both we find the following elements; oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, iodine,(3)

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(1) J. M. Ciassi, Meditationes de Natura Plantarum. Venice, 1677, in 12mo.—Phile, De Animalium Proprietate. (J. C. de Pauw.) Utrecht, 1730. Feidmann, De comparatione Plantarum et Animalium, Leyden, 1732, denuo edita a J. A. Merck, Berlin, 1780.—P. Camper, Oratio de Analogia inter animales et stirpes, Groningen, 1764, in 4to.—Bonnet, Parallele des Plantes et des Animaux : in Contemplations de la Nature. Amsterdam, 1764.—De la Metherie, Vues Physiologiques sur l'Organization Animale et Vegetale. Amsterdam, 1787, in 8vo.—J. G. Gleditsch, Ueber die Gleichheit zwischen den Thieren und Gewachsen; in his Vermischte Bemerkungen, vol. i, p. 260.—N. Bondt, Verhandeling over de Overeenkomt tweschen dieren en Planten. Amsterdam, 1792, in 8vo.—A. Nitsche præs. E. B. F. Hebenstreit, Momenta quædam Comparationis regni Animalis cum Vegetabili. Leipsick, 1798, in 4to.—A. P. De Candolle, Dissertation sur les Proprietes des Plantes. Paris, 1804, in 8vo.—M. Samelson, præs. A. F. Schweigger, Cogitata quædam de Corporum Naturalium Affinitate, imprimis de vita Vegetativa in Animalibus. Kœnigsberg, 1814, in 8vo.—A. F. Schweigger, Verwandschaft des Thier- und Pflanzenreichs; in Handbuch der Naturgeschichte der Skelettlosen ungegliederten Thiere. Leipsick, 1820, in 8vo.—C. H. Schultz, Ueber die Pflanzen und Thiere in Allgemeinen; die Natur der lebendigen Pflanze. Berlin, 1823, vol. i, p. 62.

(2) J. Z. Cartheuser, Dissertatio Chymico-physica de genericis quibusdam Plantarum Principiis, hactenus plerumque neglectis. Franckfort, 1754, 1764, in 8vo.—Bucquet Introduction à l'étude des corps tirés du regne Vegetal. Paris, 1773, 2 vol. in 12mo.—C. A. Riche, Considerations sur la Chimie des Vegetaux. Paris, 1787, in 8vo.—F. A. von Humboldt, Aphorismi ex Doctrina Physiologiæ Chemicæ Plantarum; in Flor. Fribergensis spec. Berlin, 1793, in 8vo.—W. B. Johnson, History of the Progress and present State of Animal Chemistry. London, 1803, vol. iii, in 8vo.—Th. de Saussure, Recherches Chimiques sur la Vegetation. Paris, 1804.—G. Wahlenberg, De sedibus Materiarum Immediatarum in Plantis, 1806, 1807, in 4to, translated in Gehlen's Journal of Chemistry and Physics, b. 8, p. 92.—H. Davy, Elements of Agricultural Chemistry. London, 1813.—J. Berzelius, Uebersicht der Fortschritte und des Gegenwärtigen Zustandes der Thierischen Chemie. Nuremberg, 1815, in 8vo, translated from the Swedish.—Berard, Sur l'Analyse des Substances Animales; in Annales de Chimie et de Physique, 1817, vol. v, p. 290.—Doebereiner, Zur Pneumatischen Phytochemie. Jena, 1822.—A. Desvaux, Essai d'une Classification des Principes immediats des Vegetaux : in the Journal de Pharmacie, 1826, v. ii, p. 433.

(3) Iodine has not only been found in divers marine plants, in species of fucus, ulvæ, and ceramia, but moreover in sponges, gogonia, doris, and venus, and the covering of the egg of the cuttle fish.

bromine,(4) chlorine, potassium, sodium, calcium, magnesium, silicium, manganese, and iron. Aluminum and copper have hitherto been met with only in plants, whilst fluorine has been shown in animals. Thus there is not any considerable difference between these two groups of bodies, in regard to the elementary matters entering into their composition. Greater differences are remarkable in the relative quantities of these substances, and in their mode of combination.

LXXXIV. Regarding the oxygen, hydrogen, carbon, and nitrogen, they are all four found in plants as well as animals, but nitrogen more frequently enters into the composition of the latter. Some naturalists attempt to convert into distinctive characters of these two series of bodies, that carbon is the predominating element in plants and their different combinations, whilst on the other hand nitrogen is so in animal matters and their combinations. But as all animal matters, with the exception of urea and uric acid, contain much more carbon and nitrogen, this character cannot be admitted. Besides, there are some cryptogamia, especially mushrooms, in which a large proportion of nitrogen enters. In pollen, also, this element is abundant. It enters likewise into the vegetable salifiable bases. On the other hand, a certain number of animal combinations are said to contain a great quantity of carbon. The principal animal substances, albumen, fibrin, gelatin, are charged with this principle; they even contain more of it than some vegetable substances, for instance, sugar and gum, according to the researches of Gay-Lussac and Thenard.(5) Thus, all that we are allowed to say, regarding the presence of nitrogen and carbon, is, that the former enters more frequently and in greater quantities into animal than vegetable combinations, whilst the latter is met with oftener and more abundantly in the vegetable composition.

LXXXV. Phosphorus, which was long looked upon as peculiar to organized animal bodies, is found in a great number of vegetable substances. It has been met with abundantly, in the saline shape, in the farina of wheat, in vegetable albumen and gluten, by Bergmann,(6) Th. de Saussure,(7) and several others. Lately Berthier(8) has found phosphate of lime in the ashes of several kinds of wood. It follows that phosphorus is freely distributed throughout vegetables. Generally, however, it is more abundant in animal than vegetable combinations.

LXXXVI. Sulphur, which some physical philosophers have also considered as a principle belonging exclusively to the animal composition, exists

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(4) Bromine has been discovered in some marine plants, and in the janthina violacea, a species of mollusca.

(5) Recherches Physico-chimiques, vol. i, p. 337.

(6) Opuscul, v. 5, p. 96.

(7) Annales de Chimie, v. 65, p. 189.

(8) Analyses des Cendres de Diverses especes de Bois. Annal. de Chim., v. 32, p. 210.

likewise in vegetables. In the form of sulphates it is found in almost all plants, as is proved by the chemical analysis of their ashes. Moreover it is a constituent part of vegetable albumen and gluten. It is also found in other combinations, as in the sinapic acid, which in all probability does not belong exclusively to the cruciferous but exists also in other plants. Lastly, Planche(9) discovered sulphur in the flowers of the elder, linden, and orange trees, in the stalks of hyssop, of stragon, rue, and melilot, in the seeds of the anis, fennel, cummin, and other vegetables. However, like phosphorus, it is more frequent and abundant in animal than vegetable combinations.

LXXXVII. In regard to the alkalis, the opinion has been broached by some chemists and physiologists that these bodies establish an essential difference between plants and animals. Yet the existence of different alkalis in these two natural kingdoms is a verified fact. It is true potass is more common in plants than animals; but the contrary is the case with soda. Ammonia is, generally speaking, more abundant in the animal kingdom. Chevallier and Lassaigne(1) found carbonate of ammonia in the leaves of the *chenopodium vulvaria.* The former(2) even assures us that he remarked the exhalation of ammonia from them during life. He also says that, with Boullay, he discovered that many flowers which exhale a cadaverous odour, and some, whose perfume is pleasant, gave out ammoniacal gas.

LXXXVIII. With regard to the earths, lime is the most rife in all plants and animals. However, the latter contain more than the former. The contrary is the case with silica: it is more frequently met with, though in small quantities, in vegetables especially, according to Bergmann,(3) in the cerealeæ, and more particularly in the external pellicle of the gramineæ, and cannæ, wherein Humphrey Davy(4) found abundance of it; moreover Th. de Saussure(5) and Berthier obtained some of it also from the ashes of several kinds of woods. Magnesia exists in both kingdoms, especially in the bones and some animal fluids. Vauquelin(6) discovered it in a species of fucus; Saussure and Berthier in the ashes of different woods. Alumina has only been detected in a few vegetables, and, amongst others, in the ashes of the fir-tree, the alcander, and the bilberry.

LXXXIX. The oxides of the heavy metals are found in extremely small quantities in plants as well as animals. In other respects they furnish no peculiar character to one more than the other, since iron and manganese have

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(9) Sur l'Existence et l'Etat du Soufre dans les Vegetaux; in the Journal de Pharmacie, v. 8, p. 364.
(1) Journal de Pharmacie, v. 3, p. 42.
(2) Annales des Sciences Naturelles. Avul, 1824.
(3) Opuscula, v. 5, p. 94.
(4) Scherer, Allgem. Journal der Chimie, v. 3, part 13, p. 75.
(5) Recherches Critiques sur la Vegetation, 328.
(6) Annal. de Chimie, v. 18, p. 79.

been met with in vegetables and animals. Buchholz and Meissner(7) also observed some traces of copper in a few plants.

XC. The organic combinations or immediate principles of animals and plants present more important differences than their elements. These combinations are especially numerous and varied in the vegetable kingdom, although we appear to have discovered only a very small part of them as yet, and though new ones are being almost every day detected. The animal kingdom is infinitely less rich in compounds of this kind. The immediate principles of the two kingdoms are divided into acids and oxides. Plants, moreover, present a group of substances entirely apart, the salifiable bases, of which there is not the slightest trace in animals. The immediate principles of vegetables are for the most part ternary combinations of carbon, hydrogen, and oxygen, whilst those of animals are quaternary, nitrogen being superadded to these three elements.

XCI. If we pay attention to those organic acids which proceed from the three elements, carbon, hydrogen, and oxygen, we see that very few of them exist simultaneously in the two kingdoms. Acetic acid especially belongs to this number. Vegetables are immensely rich in peculiar acids, some of them distributed generally, and others confined to certain kinds. Among the former are ranked the malic, citric, pectic,(8) oxalic, tartaric, benzoic,(9) gallic, and other acids; from the second class I shall only mention the kinic meconic, sinapic, fungic, and strychnic acids. These acids are found in a free state in the fruits particularly, in the cellular tissue, and the leaves. It is very rarely that they are found in the seeds and roots. The liquids and all parts of vegetables contain them, saturated by lime or potass. Among acids proceeding from ternary combinations of the three elements above mentioned, there are but few belonging peculiarly to animals, such as the inorganic, the butyric, and the formic. But animals contain some acids, in the composition of which nitrogen also enters, such as the uric, the cholesteric, and the allantoic.

XCII. In many plants there exists a substance composed of carbon, hydrogen, and nitrogen, and containing no oxygen, but which is notwithstanding ranked among the acids. This is the hydrocyanic acid which has not hitherto been met with in animals, and which is only formed in them under certain circumstances, or in the progress of chemical operations.

XCIII. The non-acid combinations, the organic oxydes, which form the

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(7) Schweigger's Journal, v. 18, p. 340.

(8) Braconnot, Recherches sur un nouvel acide universellement repandu dans les Vegetaux, (Acide Pectique,) in the Annales de Chimie et de Physique. February, 1825, p. 173.

(9) Benzoic and oxalic acids are sometimes found in the urine and its concretions, but in that case they probably proceed from vegetables taken as a food.

principal part of organic bodies, exhibit considerable differences in their composition, according as they belong to plants or animals. Some of them, few in number, are common to both, as albumen, ozmazome, sugar, and oil. Ozmazome, which is so abundant in animals, is very rare in plants; but Vauquelin found it in some mushrooms. Sugar, with all its modifications, being one of the principal materials of plants, is, on the other hand, rarely observed in the animal kingdom. The vegetable kingdom is particularly distinguished by a great richness in organic substances composed of the three elements, carbon, hydrogen, and oxygen. Among these ternary combinations, of which there is so great a variety, and which we may consequently regard as the general immediate principles of this kingdom, are ranged: 1, starch, with its two modifications, inuline and the fecula of licheu; 2, gum and vegetable mucus; 3, sugar, with its modifications, cane sugar, grape sugar, mannite, mushroom sugar, glycyrrhizine; 4, vegetable or ligneous fibre; the highly carbonized and combustible resins, the liquid ones, or balsams, and the dry.

In the number of ternary combinations of the vegetable kingdom, which enter less generally into the composition of plants, are reckoned, 1, the thick oils and all their varieties; 2, the volatile, aromatic, acrid oils, and those containing prussic acid; 3, camphor; 4, extracts and extractive matters; 5, the tannins.

In animals there is only a very small number of ternary organic matters not containing nitrogen. To this number belong, 1, among the sugars, that of urine and of milk; 2, among the resins, the biliary, urinary, and the resinous red matter of the lobster; 3, among the thick oils, fat, and tallow; 4, among the volatile oils, castor, civet, and the camphor of cantharides.

XCIV. The organic quaternary materials, composed of oxygen, carbon, hydrogen, and nitrogen, are very numerous in the animal kingdom, and form the principal basis of the composition of animal bodies. Of those most freely distributed, and which enter with more or less abundance into the composition of almost all animals, we reckon albumen, fibrin, gelatin, animal mucus, and ozmazome. Others are not so common, such as salivary fluid, caseous matter, hematine, urea, and the pigmentum of the eye. The nitrogenated combinations are infinitely more rare and less numerous in the vegetable kingdom. In this class are comprehended, independent of vegetable albumen and ozmazome, the latter of which is exceedingly rare, vegetable glue or gluten, pollenin, indigo, and several other colouring extractive matters. Lastly, in some plants we also meet with combinations of a particular kind, that have been designated by the name of vegetable alkalis, or, more precisely speaking, vegetable salifiable bases, in the composition of which nitrogen enters, besides carbon, and a little oxygen and hydrogen. Of this kind are morphine, narcotine, strychnine, brucine, quinine, cinchonine, veratrine, emetine, delphinine, solanine, &c.

XCV. The chief consequence that flows from what has been said is, that the organic combinations of animals are generally more complex than those of plants, being almost all quaternary, whilst the latter are, on the contrary, for the most part ternary. In the same manner that nature has given a more complicated formation to organic than to inorganic bodies, so also has she made the animal combinations more complex than the vegetable. The manifestations of activity of organic bodies, which we call life, if embraced in their whole extent, exhibit, according to the group they belong to, and the material substance which forms their base, special modifications, from which animal or vegetable life results. In general this difference exists between plants and animals, in reference to the chemical operation that accompanies the exercise of life in them, namely, that (as I shall show in detail in the sequel, when speaking of their functions) in vegetables there is an incessant disacidification and production of combustible substances, whilst in animals a process of oxidation goes on, a sort of burning of combustible materials.

CHAPTER SECOND.

Of the external Configuration.

XCVI. If, in the first instance, we compare animals with vegetables, on the score of volume and mass, we see that the former present, with the exception of some colossal forms, as whales, elephants, rhinoceri, ostriches, the gigantic serpents, crocodiles, different kinds of tortoises and fishes, in general and most frequently less voluminous masses than plants. Almost all trees are remarkable for their considerable size, and, in regard to mass, far exceed animals, even those which have just been mentioned. On the other hand, vegetables, with the exception of the cryptogamia, never present such diminutive forms as those of the classes of infusoria, polypi, worms, mollusca, insects, arachnida, and crustacea. The manifestations of activity, therefore, which constitute life, appear to limit the accumulation of mass in animals, whilst the life of plants is chiefly manifested by the increase of the volume of their bodies.

XCVII. Vegetables and animals resemble each other in regard to their external form, inasmuch as they are both limited by crooked or undulating lines, as well as by uneven and most frequently rounded surfaces. The most simple vegetable and animal forms, for instance, some pulverulent mushrooms in the vegetable, and monades in the animal kingdom, have a great similitude in their globular form. With the exception of these plants and some others lengthened out into filaments, the confervæ, and of divers animals presenting the same form, the vibriones, we see that, in regard to configuration, this difference exists between vegetables and animals, that the former have a predominating tendency to lengthen, and extend, in the shape of branches in two opposite directions,(1) whilst the latter incline to concentration, and their bodies prefer taking a spherical form or that of a cylinder, whose surface projects in a radiated manner.

XCVIII. The bodies of complex organized plants, the phanerogamia, are divisible, by an horizontal line, into two halves, one of which inclines to the solar light, in the shape of a stalk, with divers prolongations, leaves, and flowers; the other, consisting of the root, its divisions and fibrillæ, is pushed into the earth, and avoids the influence of light.(2) In other respects, we are well aware that different plants present an infinite diversity in the number, form, situation, direction, length, breadth, and disposition of these two parts which thus tend to opposite directions. However each family, each genus, and each species has a particular type or habit in this respect.

XCIX. In the animal configuration the globular or cylindrical form always predominates, or, in other words, it forms the basis. Of this we may be convinced in the most simple animals, the infusoria. The monades represent true cylindrical or oval masses. When the sphere is flattened or depressed, the disk shape, which we see in the cyclidia, the paramecia, and the coldoda, is the consequence. If this sphere or ovoid be lengthened in two opposite directions, the cylinder is the result, of which the infusoria at once present an instance in the genus enchelis. The cylinder extremely prolonged produces the filiform, as in the vibriones. In other instances, to the globule or the cylinder, appendages are superadded, as we see in the trichodæ, kerones, and cercariæ. If the sphere, or cylinder, be opened at any point, and thus produce a mouth, and if this aperture be surrounded by appendages in a radiated form, we have the form of polypi, vorticella, hydra, heroes, actinia, &c. When the sphere, or disk, sends out prolongations to its circumference, the radiated form occurs, which we perceive in the medusa, equorea, eudores, pelagia, cassiopea, porpita, &c. Here the buccal aperture situated in the centre of the disk looks downwards.

C. The globular, cylindrical, and radiated form is shown in a complicated shape in the entozoa, the radiaria, the annelides, and mollusca. Hydatids are intestinal worms in a globular form; the ascarides and lumbrici, in a cylindrical one; the tape worms, in the shape of the elongated disk; the

(1) The most simple, or the cellular plants, are those in which this tendency is the least perceived.

(2.) Decandolle, Organographie vegetale, v. 1. p. 249. " Un vegetal est composé de deux cônes (dans les exogènes), ou de deux cylindres (dans les endogènes), appliquès par leur bases, disposés dans le sens vertical, et s'allongeant indefinement par leurs extremitès."

tænia, in the form of an articulated ribbon. Among the radiaria there are some in which there are prolongations or appendages, like rays diverging from a sphere, as in the sea hedge-hog, or from a cylinder, as in the holothuria, or from the circumference of a disk, as in the asteria. The bodies of the annelides are divided by contractions, or segments, resembling rings, either in a cylindrical form, as in the earth worms, the gordii, the sipunculi, or in a ribbon shape, as in leeches and planaria. The cylinder is surrounded by rays at one of its extremities, where the mouth is situated, as in the tubicola; or else we observe, as well in this part as on the body when elongated into a ribbon, lateral appendices, of very various forms, as in the arenicola, or sand worms, the amphinoma, the nereides, amphitrites, and aphrodita. In these animals we distinguish two surfaces, a dorsal and a ventral, and two extremities, the buccal or cephalic and the anal or caudal. The form of mollusca is very various; the body forms a rounded sac, oval or cylindrical, furnished with a mouth and an anus, as in the ascidia and biphora; or else it is oval or oblong, compressed laterally, and furnished on its sides with membraniform prolongations, the most external of which, called the mantle, is covered with calcareous scales, as in the acephala. The shells are symmetrical, as those of pinna, arca, (Miess-und-Teich Muschell,) mytili, anodontes; or non-symmetrical, as in the anomia, hyalea, &c. The body is oval, and furnished with lateral membranes, like fins, as in hyalea; or cylindrical, provided with an upper disk and two appendages in front, as in the gasteropoda. In such the back is sometimes naked and free, as in snails; sometimes covered with tufts, as in the thetis, tritones, and colida; sometimes, in short, enveloped in a calcareous shell, of extremely various form, as in the patella, haliotis, murex, voluta, turbo, nerita, janthina, &c. Lastly, the body is elongated, cylindrical or oval, and it has a head separated by a neck, from which proceed radiated prolongations furnished with suckers, as in the cephalopoda.

CI. In more complex animals, of a superior order, we behold, more or less distinctly, the globular and cylindrical forms, with radiated prolongations, appearing together. The former is exhibited, diversely modified, at one of the extremities of the body, the head. The latter is shown in the trunk, sometimes a regular cylinder, as in serpents and some fishes: sometimes flattened like a disk, in ray, frogs, and tortoises; frequently compressed laterally as in the majority of fishes, lizards, birds, and mammifera. In fine, the prolongations attached to the sides of the trunk represent the limbs, fins, paws, and wings. The head, the trunk, and the limbs externally are separated by hollow spaces; that is, the animals are externally articulated, as in insects, arachnida, and crustacea; or else the division is internal, and is only indicated externally by variously marked contractions, as happens in the mammifera. In the latter, moreover, the head is divided into the cranium and face. The trunk is divided more or less distinctly into neck, chest, belly, and tail. The limbs, too, present different grades in their divisions. In all animals we find three marked antipodes, to wit, a cephalic and caudal extremity, a dorsal and ventral aspect, and a right and left side.

Besides this, natural history teaches to what extent forms, which cannot be more than mentioned here, are modified and combined in the numerous animal species.

CII. Most animals, that is to say, the mammifera, birds, reptiles, crustacea, arachnida, insects, annelides, and even a great number of mollusca, are symmetrical, composed of two similar moieties in regard to form and the longitudinal position of the body. There are a few to be excepted from this rule: such are, among fishes, the pleuronectes, (plaice,) which have two eyes projecting from one side of the body; such, besides, are some gasteropoda, in which the apertures of the respiratory organs, of the anus and of the genitals, are situated on the side; and divers conchifera, whose two valves are not symmetrical. Symmetry is shown in the radiated disposition of the radiaria. It is wanting in most corals whose trunk is ramoze. But even corals, strictly speaking, should be ranked among symmetrical animals, inasmuch as they should be regarded less as simple beings than as unions of numerous individuals, in each of which symmetry may be found.

In plants, likewise, we cannot mistake a certain symmetry which prevails, as Decandolle(3) has lately shown; but it is neither so distinct, nor of the same kind as in animals; their bodies, more particularly, are not composed of two halves possessing the same form, and united in the longitudinal diameter. It is only in some parts of plants, the leaves, flowers, capsules, fruit, and seeds that we frequently perceive a symmetrical arrangement of this sort, just as we almost always behold a radiated one in the organs of reproduction.

CHAPTER THIRD.

Of the Aggregation or Intimate Structure.

1. On the Anatomy of Plants.(4)

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(3) Organographie Vegetale. Paris, 1827, vol. 2, c. 2, Sur la Symmetrie Végétale.

(4.) M. Malpighi, Anatome Plantarum. London, 1675, fol.—A. Grew, Anatomy of Plants. London, 1682, fol.—J. Hill, Construction of Timber. London, 1770, in 8vo.—K. Sprengel, Anleitung zur Kenntniss der Gewächse. Halle, 1802, 1807, in 8vo.—Vom Bau und der Natur der Gewächse. Halle, 1812, in 8vo.—C. F. Brisseau Mirbel, Traite d'Anatomie et de Physiologie Vegetale, 1802.—Exposition et Defense de ma Theorie de l'Organization Vegetale. Amsterdam, 1808, Paris, 1809, in 8vo —Aubert du Petit Thouars, Essai sur l'Organization des Plantes. Paris, 1806, in 8vo.—L. C. Treviranus, Vom Iniwendigen Bau der Gewächse. Gœttingen, 1806, in 8vo. K. A. Rudolphi, Anatomie der Pflanzen. Berlin, 1807, in 8vo.—H. G. F. Link, Grundlehren der Anatomie und Physiologie der Pflanzen, Gœttingen, 1807, in 8vo. Appendix, Gœttingen, in 1809, in 8vo.—T. T. P. Moldenhauer, Beiträge zur Anatomie der Pflanzen. Kul, 1812, in 4to.—D. G. Kieser, Memoires, sur l'Organization des Plantes. Harlem, 1814, in 4to.—Decandolle, Organographie Vegetable. Paris, 1827, 2 vols. in 8vo.

2. On the Anatomy of Animals.(5)

CIII. Animals and plants are both composed of liquid and solid parts; the quantity of liquids, however, in the former is in general more considerable than in plants, and they have consequently more softness.(6) In this respect there is also some difference in different animals, those which live in the air having generally greater consistence than those which exist in water, as we may convince ourselves by comparing the mammifera, birds, and insects with fishes, aquatic mollusca, worms, medusæ, and polypi. This difference seems to depend on the more free evaporation in the air, whilst in the water it is less, or absorption of a large quantity of liquid occurs at the same time.

CIV. The liquid and solid parts of animals and plants exhibit differences in relation to form and composition. The liquids found in complicated animals, chyle, blood, mucus, saliva, pancreatic juice, bile, urine, and the genital fluids, differ from those of vegetables, the sap, the cambium, the liquor of the nectaries, and the gummy as well as resinous liquids which are deposited in different cavities. In general, the number of liquids, especially of the secreted ones, is greater in animals than plants. As to the solids which enter into either composition, they present much greater differences, which I shall briefly describe.

CV. The most simple vegetables, the cellular or acotyledonous plants, algæ, mushrooms, lichens, and mosses, though they present a great diversity in their configuration, are composed of a substance for the most part homogeneous, forming rounded or oblong cells, frequently like a sac, in which liquids or a granular substance are found, without it being possible to distinguish any sort of tissue. Even when there are external parts differing from each other in form, as roots, stalks, and leaves, yet such parts do not exhibit any perceivable heterogeneousness in their texture. The passage of the acotyledonous to more complicated plants is marked by charæ, ferns, shave (equisitæ) grasses, &c., in which we perceive heterogeneous tissues, that become distinctly pronounced in the phanerogamia, monocotyledones, and dicotyledones. All these plants are composed of cellular tissue, of a tubular or vascular texture, spiral and nutritious vessels, and are externally covered by a prominent epidermis. We may, with Decandolle, denominate them vascular plants.

CVI. The cellular tissue, which is first perceived in the formation of a

(5) J. F. Blumenbach. Handbuch der Vergleichenden Anatomie. Gœttingen, 1805, in 8vo. 1824.—G. Cuvier, Leçons d'Anatomie Comparée. Paris, 1809, 5 vols. in 8vo. translated into German by J. F. Meckel, 1809.—G. Jacopi, Elementi di fisiologia e notomia comparativa. Milan, 1808, 3 vol. in 8vo.—E. Home, Lectures on Comparative Anatomy. London, 1814, 4 vols. in 4to.—C. G. Carus, Lehrbuch der Zootomie. Leipsick, 1818, in 8vo.—J. F. Meckel, System der Vergleichenden Anatomie. Halle, in 8vo, 1821.—Ducrotay de Blainville, de l'Organisation des Animaux, ou principes d'anatomie comparée. Paris, 1822, in 8vo.

(6) This rule, it is true, presents some exceptions, in which we may rank plants with fleshy leaves.

plant, or a young part of one, is a soft, homogeneous substance, in which we distinguish, by the microscope, small vesicles or globules, as Malpighi, Grew, Sprengel, the brothers Treviranus, Link, and others have shown. In the fully-developed cellular tissue, on the contrary, are seen vacuities, or proper cells, surrounded by solid membranous walls, having different forms and sizes, and containing divers matters. These cells, according to the researches of Treviranus, Kieser, Dupetit Thouars,(7) Pollini,(8) Amici,(9) Dutrochet,(1) Turpin,(2) and Decandolle,(3) appear to be composed of vesicles placed near each other and connected together. In the trunk and stalk the cellular tissue surrounds the spiral vessels, as in the bark, it also envelopes the nutritious vessels containing the cambium. It represents the pith in the centre of the wood of trees and shrubs. There often exists between the cells, especially of the pith, and, in the gramineæ, between the spiral vessels, oblong conduits, or hollow spaces, which L. C. Treviranus has named the intercellular canals. In the pith, especially in this stalk of umbelliferæ, the straw of gramineæ, and the petiols of aquatic plants, the cellular tissue forms hollows, or spaces filled with air, which are the pneumatic reservoirs of Rudolphi. Lastly, it leaves in the bark and wood of certain plants, closed, oblong, hollow spaces, containing resinous, oily, mucous, or gummy liquids. These are the reservoirs or conduits of the proper juice described by L. C. Treviranus.

CVII. The tubular or vascular tissue, which naturalists particularly engaged in the study of vegetable anatomy have disputed so much, is exhibited in two different forms, the spiral and the nutritious vessels. The former compose the chief part of the wood and ligneous bundles. They are found in the root, trunk, branches, peduncles, and petiols. Thence they spread into the reticulated nerves of the leaves, and also into the veins which are scattered over the petals, as we learn from the researches of Labaisse,(4) Reichel,(5) Comparetti,(6) Schwagerman,(7) Sprengel, and others.

These spiral vessels even penetrate into the filaments of the stamen, and into the pistil as well as the fruit. In the straw of gramineæ they are met with, forming isolated bundles, as also in the stalk of herbaceous plants; whilst in the wood of trees and shrubs they are firmly pressed together, and thus constitute the ligneous body. There is no vestige of them in the bark.

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(7) Essai sur la Vegetation. Ess. 5, p. 66.
(8) Elemen. Botan., v. i, p. 45, fig. 5.
(9) Osservaz. Microscop., fig. 19, 20, 23, 30.
(1) Recherches sur la struct. Vegetale. Paris, 1824, p. 10, 47.
(2) Mem. lu à l'Acad. des Sc. de Paris, 1826.
(3) Organographie Vegetale, v. 1, p. 20.
(4) Diss. sur la Circul. de la seve des Plantes. Bordeaux, 1733, 8vo.
(5) De vasis Plantarum spiralibus. Leipsick, 1738, in 4to.
(6) Prodomo di fisica vegetabile, p. 19.
(7) Verhandl. der Maatschap te Harlem, v. xx, p. 480, v. xxi, p. 118.

We must consider the ligneous tubes described by Malpighi, as well as the sap vessels remarked by Grew, as mere varieties of these vessels. The annular, the retiform, or spiral vessels, the perforated and garland vessels of Mirbel, appear also to be modifications of the spiral vessels.

We see clearly, in the wood of young branches, that the spiral vessels are formed of small fibres, viscous, extensible, elastic, and spirally turned; that these may be unrolled; and that the turns constitute the walls of a canal, furnished with no internal or external membrane, according to the researches of Schwagerman, Comparetti, Link, Rudolphi, L. C. Treviranus, Sprengel, and others. These vessels appear destined principally to contain the liquid which, especially in the spring, rises from the roots to different parts of plants, and has the name of sap.

CVIII. The other vessels are the nutritive vessels, or vessels of the cambium, with the situation, structure, and arrangement of which we are least acquainted. Malpighi, Grew, Hill, and others, have heretofore admitted particular vessels (Vasa propria seu peculiaria) which contain the proper juice, analagous to the blood of animals, intended for nutrition, and which distribute it throughout the vegetable. The experiments of Knight aid the probability that the sap absorbed by the roots and carried by the sap vessels of the wood into the leaves undergoes there, by the influence of respiration, a more complete degree of assimilation, and that, being afterwards re-conducted from the leaves by particular vessels, it is distributed in various parts to answer the wants of nutrition. J. P. Moldenhauer(8) succeeded, in several plants, the Havanah and Indian corn, in discovering particular vessels, filled with a thick and coloured juice, which he called fibrous. G. R. Treviranus(9) has proved the existence of these vessels in the wood and immediately under the bark in various plants; he has given the name of plastic juice to the thick, milky, and globule-filled liquid which they contain, and considers it as the true nutritive liquor perfected by elaboration. Schultz(1) has the credit of having demonstrated, in a great number of plants, the presence of these specific vessels for the return of the juice from the leaves. He called them vital vessels, and gave the name of vital juice to the liquor they contain. M. Schultz assured me of the existence of these vessels.

These very delicately constructed vessels are situated, in the shape of bundles, along the spiral vessels of the leaves, stalks, and petals, in herbaceous plants. In plants of a wooden body and a prominently distinct bark, as in the root and trunk of trees and shrubs, they are found in the soft internal

(8) Beiträge zur Anatomie der Pflanzen, p. 130.
(9) Ueber die Gefässe und den Bildungssaft der Pflanzen, in den Verischten Schriften, v. 1, p. 145.
(1) Von der Natur der Lebendigen Pflanzen, v. 1, p. 515.

layer of the bark, or in the cortical substance; thence they spread into the wood and cellular tissue. Their sides are formed of an homogeneous pellicle, which is thin, white, and transparent. These it is which contain the formative or nutritive liquid. This is produced by the influence of the atmosphere and light on the sap, which, rising from the roots and trunk into the leaves, is distributed to the different parts, to perform therein the offices of nutrition, growth, and secretion.

CIX. These elementary tissues, combined and disposed in an infinite number of manners, compose the bodies of all vascular plants, with their different parts, roots, trunk, stalk, leaves, flowers, and fruits, however great or numerous the differences may be which their external forms exhibit, and by which their families, genera, and species are distinguished(2.) If we regard the manifestations of activity these parts display, we remark that they are confined to those whose design is the nutrition, growth, generation, and formation of plants, that is, the absorption of alimentary matters, their assimilation, respiration, movement of the liquids, nutrition, secretion, and, lastly, the acts of generation. The parts may be divided, in reference to function, into those whose manifestations of activity accomplish the preservation of the individual, and those which, by effecting generation, tend to the maintenance of the species. In the first are comprehended the root, trunk, or stalk, and the leaves; to the latter belong the flowers, fruit, seeds, buds, tubercles, and bulbs. It will be more convenient to examine their structure in the next section, which is dedicated to the explanation of the manifestations of activity or vital phenomena of plants.

CX. The tissues and parts which enter into the composition of animals are infinitely more numerous than in vegetables, and are at the same time of a nature entirely their own. As to the tissues generally distributed in animal organisms, and met with in all, except the most simple animals, infusoria, polypi, medusæ, and several other zoophytes, which consist of a gelatinous or mucous mass, they are the cellular, vascular, nervous, and muscular tissues. These may be considered as elementary constituents, whose combinations and dispositions compose the different organs. We may, moreover, add to these some other tissues less generally distributed, such as the tendinous or fibrous, the bony, the cartilaginous, and the horny. I shall rapidly sketch the nature and qualities of these tissues.

CXI. From the zoophytes to man, the cellular or mucous tissue is the most universally distributed of those which enter into the composition of all animals. It is exhibited in the form of an homogeneous, whitish, semi-trans-

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(2) Decandolle (Organographie Vegetale, v. i, p. 5) says, "La texture intime des vegetaux, vue aux plus forts microscopes, offre peu de diversité. Les plantes les plus disparates par leurs formes exterieures se ressemblent à l'interieur à un degrê vraiment extraordinaire."

parent, soft, almost mucous, extensible substance, endued with a certain degree of viscosity, and slightly contractile during life. It absorbs liquids with facility, and is also permeable by aeriform matters. Originally it contains neither hollows nor excavations; but it is easily distended by air or liquids so as to produce cells. According to the remark first made by Rudolphi,(3) there is this difference between the cellular tissue of plants and animals, that the former exhibits cells more or less regular, with strong and consistent walls, whilst nothing of the kind is discoverable in the latter. On one hand the cellular tissue fills the interstices of the organs; on the other, it enters into the texture of the same organs, and there keeps together or includes all the other tissues. The enveloping cellular tissue contains a watery and transparent liquid, the serum. In more complex animals, we often find within it, in various parts, opaque white or yellow substance, which is inclosed in round sacs of various sizes. This is fat, which, according to the researches of Chevrel, is composed of stearine and elaine.

CXII. The cellular tissue, condensed and extended into surfaces, forms the basis of the common integuments, as also of the membranes which secrete the mucus, serum, and synovia. Condensed into chorion, it forms the ground of the common integument, and thus includes all the organs of the animal body within itself. It is reflected by divers principal apertures into the cavities of the body, where it is continuous with the mucous membranes. In many animals the skin produces ramose or foliated appendages, the gills, which effect respiration in water. The skin, which in the majority of animals is supplied with a vast number of vessels and nerves, maintains a reciprocity of action with surrounding media. On one hand it absorbs aeriform or liquid matters; on the other, an excretion of gaseous matters by transpiration, or of liquid substances in the form of sweat, mucus, or fat, is proceeding from it. The nerves entering into the skin give to it a greater or less degree of sensibility to mechanical or chemical impressions, as well as to variations of temperature.

CXIII. The mucous membranes, formed of condensed cellular substance, most of them provided with numerous nerves and vessels, and secreting liquids by their internal surface, line all the cavities which end externally, or communicate with the external surface of the body, the alimentary sac or intestinal canal, with the excretory ducts of the glands which end in them, the bronchi and lungs, the urinary organs, and the cavities of the genital organs. They also form the basis of the different organs which serve the taking and assimilation of food, to aerial respiration, the secretion of humours, and the preparation and emission of the genital liquids.

(3) Anatomie der Pflanzen, p. 26.

CXIV. The cellular tissue, condensed into membranes and strewed with small vessels, also forms the base of more or less considerable sacs, closed on all sides, and denominated serous and synovial membranes. The smooth and polished internal surface of these sacs secretes an aqueous humour, holding albumen in solution, and continually undergoing re-absorption. The outer surface is joined to different organs by a loose cellular tissue. These membranes favour, by means of their free, secreting internal surfaces, the movements of the organs which they cover.

The serous membranes inclose organs in which the involuntary or automatic movements are effected. They envelope the heart, the lungs, the intestinal canal, with its glandular appendages, and the organs whose office it is to prepare the generative fluid. The brain and spinal marrow, with the origin of the nerves, are also surrounded with a delicate serous membrane, whose existence is in relation with the movements which the circulation and respiration communicate to them.

Synovial or joint membranes are found in animals possessing an internal articulated skeleton, at the ends of the bones which are moveable on each other, as also in many places between the tendons, chiefly in the points where they pass over osseous grooves. These membranes, with their secreted product, synovia, are designed to facilitate the voluntary movements.

CXV. The vessels we meet with in the great majority of animals, in the mammifera, birds, reptiles, fishes, crustacea, arachnida, insects, mollusca, annelides, and radiarii, and which contain the nutritive or plastic juice prepared from the food and assimilated, are canals ramified throughout the body whose trunks are continuous with each other, in an immediate manner, or communicate together by the intermedium of the heart's cavities. Their base is a thin membrane, smooth on its internal surface, washed by the nutritive fluid, and composed of condensed cellular tissue. This membrane, entering also into the cavities of the heart, forms, in different parts and sections of the vascular system, certain folds, the valves, to regulate the direction of the blood, as it is moved onward by the muscular walls of the heart, or by the contractile coats of the vessels. Externally it is furnished with a tissue of a specific kind. The portion of it that is spread through the cavities of the heart and unites together the vascular trunks, is covered by muscular fibres arranged in layers. As to the walls of the greater number of vessels, they exhibit a particular tissue, fibrous, yellowish white, or pale red, which may be called vascular fibre. This tissue, surrounding the vessels sometimes in a circular manner and sometimes longitudinally, is endued with a proper contractile power. Vessels are divided, in complex animals, into three orders, arteries, veins, and lymphatics.

CXVI. The vessels which ramify towards the periphery of the body, departing for the most part from the cavities of the heart, are called arteries. They are distinguished by the thickness of their vascular tissue, which surrounds them in a circular direction. Their smooth internal membrane forms valves only at their exit from the heart, in order to prevent the reflux into this organ of the liquid which they convey. On one hand, the blood they contain is carried to the different organs which extract the nutritive matters, and, on the other hand, it is the source whence the various humours are eliminated. In a particular section of the arterial system, which ramifies throughout the respiratory organs, the conversion of the crude nutritive juice into blood is effected, in consequence of the reception of substances obtained from the atmospheric air and an elimination of carbonic acid and water.

CXVII. Other vessels which originate from the organs, and are in immediate connexion with the most minute arteries, are united into branches, from these into trunks which afterwards open into the cavities of the heart, or are intimately joined with the arterial trunks. These are the veins. Their smooth internal membrane forms, in the major part of animals, valves looking towards the trunks and the cavities of the heart. Their vascular tissue is delicate and almost entirely disposed lengthways on the vessels. The veins return to the heart and arterial trunks the remnant of the blood which has not been employed in the nutrition of the organs and the secretion of particular fluids. They also serve to absorb certain substances. Finally, one of the sections of this system, commencing at the respiratory organs, brings to the heart and arterial trunks the blood prepared from the crude nutritive juice.

CXVIII. The lymphatics constitute a third order of vessels, which have been hitherto only met with in mammifera, birds, reptiles, and fishes. They originate in the different mucous, serous, and synovial membranes, and the dermoid tissue, whose basis is condensed cellular texture, as also from the cellular tissue distributed in the interstices and parenchyma of the organs. It has not yet been properly demonstrated that these vessels arise from membranes or any other tissue, by gaping orifices, so as to render it probable that they proceed immediately from the mucous or cellular tissue. They unite into twigs, branches, and trunks, and anastomose with the veins in such a manner that we may consider them as an appendage to the venous system. Their smooth internal membrane is furnished, in the majority of animals, with numerous valves directed towards the trunks. The existence of a fibrous tunic has not been clearly established. Their function is to absorb the liquid prepared from the aliments in the intestinal canal, as also the fluid substances that are in contact with the common integuments and mucous membranes. They likewise take up the fluids secreted into the serous and synovial membranes, and they also perform the absorption of the constituent materials of the organs which have again become fluid in the substance of the same organs.

The arrangement of their valves and their dilatation beyond a ligature placed round them in a living animal, prove that the liquids they contain proceed from branches to trunks, and consequently from the organs to the venous trunks in which they terminate.

CXIX. Another tissue peculiar to animals is that of the nerves. The existence of these organs in mammifera, birds, reptiles, and fishes, was long since known to the Greek naturalists. The anatomical researches of Swammerdamm, Willis, and Redi, have effected the discovery of them in crustacea, insects, mollusca, and annelides. But it was reserved for the modern spirit of observation to establish their presence in many of the most inferior animals, the star fish, actinia, pyrosoma, ascidia, and some entozoa, in which their existence was denied in Haller's time. The infusoria, polypi, medusæ, various other zoophyta, and the majority of entozoa, are the only animals in which we have not yet succeeded in showing their existence by the anatomical scalpel. But as we perceive, in these animals, phenomena which take place by the medium of nerves in animals of a more elevated order, that is to say, sensibility and voluntary motion, it is not improbable that in them the nervous substance is mixed with their gelatinous or mucous mass, without being demonstrable as a particular tissue.

CXX. As far as we can judge from the researches hitherto made, the tissue of the nerves consists, in all animals, of a soft, white, slightly consistent mass, the nervous pulp. This mass is composed of small globules, placed in the midst of a semi-fluid substance, in a delicate mucous or cellular tissue, which serves to unite them together; this is the result of microscopical observation made on this point. The globules are mostly arranged in longitudinal rows, and represent the medullary or nervous fibres. These fibres are surrounded by condensed cellular tissue, forming tubes or canals, which are denominated the neurilema. In animals possessing a vascular system, minute vessels penetrate the covering of the nerves and the medullary substance. In those which have a lymphatic system, lymphatic vessels are also perceived in the neurilema. The vessels effect the nutrition of the nervous substance and the changes of composition which its manifestations of activity induce during life.

CXXI. The nervous substance is connected together throughout the whole animal frame. Part of it is disposed like rays, and designated by the name of nerves, whose minute ramifications enter into the composition of almost all the organs and tissues: another part is concentrated in masses more or less voluminous, nervous ganglions, medullary centres, and cords. The union of the latter produces the brain and spinal marrow. In the parts where the medullary substance is accumulated another substance is observed, soft, of a yellowish or reddish grey, likewise composed of globules and a quantity of mucous tissue, in which numerous vessels ramify ad infinitum; this is the gray substance.

CXXII. The nervous apparatus presides, during life, over the intellectual activity, or operations of the mind, sensation, perception, consciousness, and the will, phenomena which eminently distinguish animals from vegetables. The nerves which penetrate the different tissues, impart to them the capability of being affected by excitants. The nervous system itself, by producing excitement, brings into action the muscles under the influence of the will. Moreover it possesses an automatic and unrevealed power over the organs and apparatus whose functiôns maintain the body in the form and composition that are proper to it, and render it capable of displaying its manifestations of vigour. It regulates the taking of food, influences the digestion and the preparation of chyle, gives an impulse to the respiratory movements, and, through the movements of the blood, effects nutrition and secretion. The functions relating to the preservation of the species, or genital functions, are also placed in dependence on the nervous system. In short, this system is the most important apparatus of the animal body, that to which, during life, the manifestations of activity of all the other parts and organs are linked, that for which the organs which are more or less influenced and determined by it as to their mode of action exist. Distributed throughout the whole animal body, it is the bond that unites the organs, that draws them into unity, that maintains them in this reciprocity of action and this harmonious concordance, the principal result of which is the preservation of the individual and the species.

CXXIII. Muscles exist in animals of all classes, from the mammifera to the radiaria. They have been discovered in a great number of entozoa. Even in the activia, some medusa and other zoophyta, muscular fasciculi interwoven with the external skin, have been perceived. The infusoria, polypi, and several other gelatinous animals are the only ones in which muscular tissue has not been seen. The muscles of all animals are composed of white, yellowish, or red bundles, soft, united by cellular tissue, and themselves formed of delicate fibres, the nature of which has been much disputed by anatomists. All that we can state with certainty at present is, that they are not hollow, but solid. Several naturalists assert they have discovered them, by their microscopes, to be composed of globules, which appear arranged in rows, and united by their extremities. The muscles have an animal matter, fibrine, for their base, which, when deposited from the blood, takes a filamentous form. In animals advanced in age, nerves penetrate these organs and spread their delicate ramifications between the fasciculi and the fibres. Moreover, the muscles of all animals provided with a sanguineous vascular system, receive a great number of vessels, which bring blood to them and regulate their nutrition, thus rendering them capable of exerting their proper manifestations of activity.

CXXIV. During life, muscles have the power of shortening themselves, of condensing and contracting, whenever excitants act on them or their nerves; and when the action of these stimuli ceases, of relaxing and resuming their former situation. This power has the name of irritability. The excitants which induce the contractions of muscles are either volitions, that is to say, stimuli generated in the masses of nervous matter whence they are passed to the muscular organs by the nerves; or they are influences which the blood and different secreted liquids exert over the hollow muscles; or, lastly, excitements occasioned either by the food or air which enters the cavities of animals, or by mechanical or chemical causes which act externally on their bodies. The muscular parts endowed with irritability accomplish the majority of the movements which animals perform.

CXXV. The arrangement of muscles varies considerably in animals. Some, forming a thick and firm mass, are applied to the internal surface of the common integuments, as in entozoa, radiaria, annelides, and some mollusca; connected with calcareous shells, as in the univalve, bivalve, and multivalve mollusca; or are inserted on horny or earthy parts externally articulated, as in insects and crustacea. In animals possessing an internal articulated skeleton, fishes, reptiles, birds, and mammifera, the greater part of the muscles are attached to the bones. These muscles produce the movements of the limbs and of the whole body. They are found also in the mouth, in the organs of mastication, of the senses, of respiration, the voice, and of copulation, the motions of all which parts they execute. Another portion of the muscular tissue is extended over the internal surface of the membranes. The fleshy fasciculi, of varied thickness, which envelope the smooth internal membrane of the sanguineous vascular system, at the places where the veins are united with the arterial trunks, represent the heart, the chief organ of circulation of the blood. Muscular expansions are also found on the external surface of all the mucous membranes. That of the mucous membrane of the intestinal sac effects the motions of the alimentary substances introduced into that cavity, and of the liquid secretions which are mixed therewith to assist digestion. That of the mucous membrane of the lungs and bronchi is a party to the renewal of air in these organs. The portion which covers the ureters and the bladder, produces the movement of the urine prepared by the kidneys. Finally, the layer spread over the mucous membrane of the genital apparatus of both sexes, regulates that of the seminal fluid and of the ova.

CXXVI. The bones and cartilages, the hardest and most dense of all the parts of animals, do not differ essentially from each other in reference to the substances that enter into their composition. Both contain a combustible animal substance and several inorganic matters. The former is soluble in water, and is converted into glue by boiling. It constitutes their base and takes their organic form during life. It is imbued with inorganic matters—phosphate of lime, carbonate of lime, and divers other salts, which are therein deposited from the mass of the humours, in the acts of nutrition and formation. It is the proportion of these matters with the animal substance that causes one part to be bone and another cartilage. All the bones commence from cartilage, and these again, at the period of their appearance in the fœtus, are composed of a semi-fluid substance, analogous to the cellular or mucous tissue, in which a substance capable of coagulating and becoming hard, probably albumen, and which only appears to acquire the properties of gelatine by boiling, is deposited. As soon as the cellular tissue is imbued with it, it appears in the form of an almost homogeneous mass rather resembling coagulated albumen, which is the cartilaginous substance. In proportion as earthy matters are deposited in it, hard and reticulated fibres, which represent the bony system, make their appearance. These fibres are sometimes loose and distinct, forming then the internal, cellular, or spongy tissue of the bones; sometimes disposed in plates or layers, which, pressed together, are retained by fibres, and constitute the compact external or cortical tissue. Every bone deprived of its earthy matters by the action of acids re-appears with the qualities of a cartilage, so far as these depend on chemical composition, but, notwithstanding, preserves the organic form of the bones.

CXXVII. The bones, in which minute blood vessels are distributed that regulate their nutrition, vary considerably in animals, in regard to their configuration, arrangement, and connexions. In mammifera, birds, reptiles, and fishes, they are situated in the internal part of the body, separated from the common integuments by muscles. But the skin immediately covers them in a great number of points, on the head of fishes and reptiles, as also on the pectoral and dorsal shields of tortoises. By their quality of hardness and solidity they furnish a protecting envelope to the central mass of the nervous system, the brain and spinal marrow, on which they are moulded in the fœtus, wherein they appear at a period posterior to them. The spinal marrow is surrounded by annular bones, moveable on each other, the vertebræ, the number of which is, in a certain degree, proportioned to that of the nerves proceeding from the marrow itself, and whose external surface affords points of attachment to muscles by means of prolongations with which they are furnished. Other bones, in which some further traces of the form of vertebræ are recognised and which are united in their sutures by cartilage, produce the cranium or the covering of the brain and the origins of the nerves. A great number of bony pieces, taking their origin from the cranium, and leaving hollows between them, give rise to the cavities in which the organs of the senses are lodged. Some being articulated so as to preserve their mobility, form the buccal cavity. The teeth, whose office it is to divide the food, are implanted in these bones, to which the muscles, whose action effects the reception, the diminution, and the deglutition of alimentary substances are attached. With the bones of the trunk are articulated, in mammifera, birds, and the majority of reptiles, the ribs, which are arched, and whose extremities, almost always forming separate bones, join the pieces of the sternum. The ribs envelope and protect the respiratory organs, the heart, and the organs of digestion. In tortoises, where they are broad and united by sutures, as are also the sternal bones, they form the breast and back shield. In fishes we find curved bones, moveable, and resembling ribs, which are articulated with the head, and give support to the gills.

The bones of the limbs represent levers of different kinds, which are retained in their articulations by firm though flexible organs, the ligaments, and which, the contraction of the muscles inserted in them, renders capable of performing movements whose direction and extent vary according to the articular surfaces. The bones of the posterior extremities, which are articulated with the vertebral column in the majority of animals, produce by their union a cavity called the pelvis, where the genital organs, the reservoir of the urine, and the lower end of the alimentary sac are situated.

CXXVIII. Bones are also met with in the organs of sense of many animals, wherein they act as supports and points of attachment to muscles. Of this kind are the pieces of the hyoid, the bony ring and scales in the eyes of many birds and various fishes, and the ossicules of the ear. Bony plates, likewise, contribute to the increase of the olfactory membrane. In the hearts of many ruminating animals a bone is found, to which muscular bundles are attached. In some animals the penis and clitoris possess a bony support. Lastly, there are some also which exhibit bony plates in the skin; of these are the armadillo, the crocodile, and many fishes, the mail and trunk fishes, sturgeons, &c.

CXXIX. Of the cartilages some are elastic discs, which cover the ends of moveable, articulated bones; others serve to unite bony pieces that execute no movements. Many assist in forming certain cavities, such as the ribs, the sternal pieces, and the bones of the pelvis. Lastly, same support and determine the form of softer organs, as the cartilages of the nose, the eye, eyelids, larynx, and trachea.

CXXX. The manifestations of life in the bones and cartilages, are reducible to the simple phenomena of nutrition and formation, which keep them in the possession of their form, and the other qualities essential to the performance of their offices.

CXXXI. The bones of vertebrated animals may be compared, on the score of chemical composition, structure, and destination, to the coverings and shells of mollusca and crustacea, which are either mixed with the common integuments, or deposited between them and the epidermis, and to which the majority of the muscles are attached. The shells of mollusca, which present so many differences in the form and number of their pieces, as well as in their size and mode of union with the body, are composed, according to Hatchett, of lamellar, membranous layers, like coagulated albumen, in which the earthy matters, (chiefly carbonate, and sometimes also phosphate of lime,) are deposited. The hard parts of the crustacea, which represent a skeleton externally articulated, are formed, according to the analyses of Hatchett, John, Merat Guillot, and Chevreul, of an animal substance resembling albumen, of a great quantity of carbonate and a little phosphate of lime, with traces of phosphate of magnesia and chloride of sodium. In insects the horny integuments supply the place of the bones, and furnish points of attachment to the muscles. They are composed of coagulated and dried albumen, some traces of salts, and a peculiar matter lately discovered by Odier, chitine. The jointed and moveable parts, shaped like vertebræ, as seen in the asterias, are analogous to the bones, as also the sutured pieces of the sea hedgehog, which contain an animal matter, with abundance of carbonate, and a little phosphate of lime. Lastly, we may also bring corals under the same head, which sometimes form a trunk that supports the soft and gelatinous mass consequent on the union of many polypi, as in the gorgonia, sertularia, and isis; and sometimes contain polypi in their cells and interstices, as is remarked in the madrepora, tubipora, &c. The horny or earthy corals are themselves composed of a coagulated animal substance, similar to albumen, and of carbonate of lime in various proportions.

CXXXII. Tendinous and fibrous parts, putting on different forms and arrangements, are chiefly met with in the animals of the four superior classes, the vertebrata. The tissue that forms its base exhibits, silvery, brilliant, hard, firm, and flexible filaments, which appear to be composed of a very condensed cellular tissue, penetrated with coagulated albumen, By long maceration in water, they are resolved into a flaky substauce resembling cellular tissue. Boiling converts them, as it does cartilage, into gelatin. A portion of the fibrous tissue is extended into membranes, and adheres to the external surface of the bones and cartilages, where it receives the name of periosteum and perichondrium. Other fibrous membranes, constituting what is called aponeurosis, envelope the muscles, which are thus maintained in the respective situations best suited to the performance of their several movements. Variously figured fibrous organs fix the bones in their articulations, as the articular ligaments, or else fill the vacancies that are left between them, as the interosseous ligaments. At the ends or origins of the muscles, fibrous cords, or tendons, are observed, by means of which the bones are drawn during the contraction of the muscular fibres. Finally, nature has made use of fibrous membranes to envelope and protect the delicate and soft parts; instances of which are presented in the brain and spinal marrow, the sclerotic of the eye, the fibrous membrane surrounding the vascular net-work of the penis and clitoris, that of the spleen with its reticulated appendages, and the tunica albuginea of the testicle. A combination of fibrous and cartilaginous tissue originates the fibrous or ligamentous cartilages found in different parts of the body. Fibrous parts generally receive only a small number of vessels, which regulate their nutrition. Life is only manifested in them by their nutrition and continuance in the form and chemical composition which are proper to them, together with the qualities depending on these.

The fibrous parts of vertebrated animals may be compared to the ligamentous masses of mollusca, which keep the valves in their hinges. The parts which are observed in crustacea and insects joined with the muscles, are likewise hard, white, and brilliant, but they are not, properly speaking, fibrous.

CXXXIII. Lastly, the horny tissue forms the basis of parts, some of which are situated on the external surface or skin of animals, whilst others are placed on the surface of the mucous membrane of the digestive and genital apparatus. It is exhibited in the form of a perfectly homogenous, transparent substance, more or less solid, and variously coloured, without either vessels or nerves. In all vertebrated animals, it produces, on the common integuments, a layer of varied thickness, frequently composed of several lamellæ, called epidermis, (epidermis seu cuticula,) and which is the outermost boundary of the animal body. In animals that live in the air, the epidermis is dry like horn, and thicker in places which are subject to friction, such as the sole of the feet, the palm of the hands, the bending surface of prehensile tails, the callosities of the buttocks, &c. In those which exist in water, the cetacea, betrachia, tritones, and fishes, it is soft, almost mucous. A true epidermis is also seen on the calcareous shells and horny crusts of crustacea, insects, mollusca, and echinodermata, as also on the naked skin of snails and annelides. It is only in the soft and gelatinous animals that it is not distinctly perceptible. The horny tissue, likewise, forms the basis of the different parts that serve to cover or protect animals, as hair, bristles, prickles, scales, feathers, shields, nails, hoofs, as also the covering of horns and beaks.

The mucous membrane of the alimentary sac is also covered, in many places, by a similar pellicle, which then takes the name of epithelium. In the tongue it not unfrequently is raised into points and scales. It is very well marked on the internal surface of the œsophagus, as well as on that of the first stomach or paunch of ruminating animals, of the stomach of the manis or pangolin, of the gizzard of almost all birds, the stomach of some crustacea, &c.

The horny tissue is seen sometimes on the surface of the genital mucous membrane, especially on that of the penis, in the shape of prickles or scales, which is observed in cats, many rodentia, serpents, &c.

CXXXIV. These tissues, some of which are generally distributed and met with in all animals, except the most simple, whilst others, confined to certain classes only, produce, by association, in greater or fewer numbers, and by their different modes of combination and arrangement, the parts which are met with on dissecting an animal, and which are called organs, for the exercise of certain functions. Among these are the intestinal canal, the liver, salivary glands, the heart, the lungs, the gills, the kidneys, the testicles, ovaries, brain, tongue, the eyes, the muscles, bones, &c. None of these organs result from a single tissne, several uniting to form it. Those tissues that enter more or less abundantly into the composition of almost all organs, are the cellular tissue, the vessels, and the nerves, different parts of which form a continuous whole in the entire animal body. Of those which, together with the preceding tissues, contribute to the production of certain organs only, are the muscular, fibrous, cartilaginous and bony tissues, which do not form a continuous whole in the body, but are more or less isolated or confined to certain organs. The organs produced by the association of different tissues, exhibit different degrees of composition ; the intestinal canal, the lungs, glands, the organs of the senses, the brains, genitals, &c., in short all that are called viscera, are very complex ; the muscles, bones, cartilages, ligaments, and the different membranes are less so.

CXXXV. In animals, the organs are united into groups that, during life, possess the faculty of exerting, by their united activity, a principal function. The name of apparatus may be given to these groups. Thus, we distinguish apparatus for digestion, respiration, the movement of the blood, sensation, locomotion, generation, &c. All the superior or perfect animals are consequent of a collection of different apparatus, which are linked together by the generally distributed tissues of the body, nerves, and vessels, and whose number and composition is so much more considerable as the manifestations of activity, or life, that are observed in these beings themselves are numerous.

If we attend to the functions that are accomplished by the apparatus, we shall be convinced that, as in plants, some relate to the preservation of individuals and others to the maintenance of the species. In the former are ranked digestion, or assimilation of food in the intestinal canal, absorption, respiration, circulation of the blood, nutrition, and secretion. The functions of the genital apparatus belong to the latter. Independent of these functions, others are also found, in animals, which consist in the exertion of manifestations of activity that are altogether wanting in vegetables, to wit, the operations of the mind. The apparatus that officiates in the accomplishment of these particular functions, is the nervous system. In the periphery of the nervous apparatus smaller organs or apparatus, the organs of the senses, are found, which, being exposed to impressions from the external world, are capable of determining divers states of excitements on the nervous system. Moreover, the nerves have exceedingly numerous connexions with the muscles that are attached to the skin, or to the horny or earthy articulated and moveable parts, and which constitute, together with these parts, the locomotive apparatus. By means of excitements generated in its nervous system, the animal is capable of producing different movements, by which it reacts with its own activity on the external world, adapts it to its inclinations, its sensations, its wants, its ideas, and obtains the external conditions that are essential to the maintenance of life, as well in the individual as in the species. The animal is also able, by movements, to withdraw itself from, or resist, external influences that would be hurtful.

CXXXVI. Animals, therefore, are organic bodies of a particular kind, having proper tissues for their basis, which are more numerous and diversified than in plants. These tissues represent varied organs and apparatus, whereas vegetables have less prominent organs and apparatus. Simultaneous with a great complication and diversity in organization, we also remark, in animals, a larger sum of different manifestations of activity than in plants. The phenomena of their life do not consist, like those of vegetables, simply in the functions of nutrition, of generation, and formation; but they exhibit others peculiar to themselves, namely, those of of sensation, of perception, and voluntary motion, which we are used to unite under the collective name of phenomena of animal life.

Besides these differences between animals and plants, some others exist, which we shall now rapidly glance over.

CXXXVII. In the organization of animals, we remark a distinct tendency to produce a great number of different parts, either single or at most double, and, in this latter case, of a form altogether similar, that is, to make the greatest number of organs coincide with the greatest diversity of conformation, as J. F. Meckel has shown.(4) Among the azygous organs, we reckon the brain and spinal marrow, the heart, the intestinal canal, the bones situated in the medial line, or in the axis of the body, namely, those in the base of the skull, the vertebræ, and sternal pieces, and, finally, the sphincter muscles, which are not numerous, and the diaphragm. Although a vast number of bones enter into the composition of the vertebral column, yet each of them, for the most part, has so characteristic a form, in complex animals, that they may be all considered as unique. By the duplicates are comprehended the majority

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(4) System der Vergleichenden Anatomie, vol. i, p. 18.

of the organs of the senses, the jaws, teeth, salivary glands, the lungs, and gills, the kidneys, the testicles, and ovaries, the lateral bones of the head and trunk, those of the limbs, in short, the greater number of the muscles, which are double, if we look to their form, but exhibit this great difference, that they can be recognised as belonging to the right or left side of the body. Hairs, feathers, and scales are the only parts that are in immense numbers with the same form. In animals of a simple structure, particularly in the radiaria, we often see external or internal parts several times repeated in the same form.

In plants, on the other hand, the tendency to multiply parts resembling each other in form, predominates, even to hundreds and thousands of times, as the leaves, flowers, and fibrillæ of roots prove.

CXXXVIII. Vegetables and animals are the reverse of each other with regard to the arrangement and situation of their organs. In plants, all the parts recognised as special organs, the roots, leaves, and flowers, the calyx, the stamina, and pistil, are situated externally, while in their interior there are no special organs distinguishable, as G. R. Treviranus has shown.(5) In animals, on the contrary, all the important organs, those which are necessary to the preservation of the individual and the species, and those which perform the animal manifestations of activity, occupy the interior of the body. The digestive and, for the most part, the respiratory organs, the heart, the different secreting organs, the nervous system, the muscles, and the organs that prepare the genital liquids, are placed in the interior, mostly enclosed in particular cavities, and surrounded by proper membranous coverings. It is only the less important organs, whose end is the immediate preservation of the body, the organs of the senses, frequently also those of copulation, and the different parts connected with the common integuments, as the hair, feathers, scales, nails, and the horny parts, that are situated externally.

A disposition is observed in plants to push outwardly, and to expand their organization towards the circumference, as Aristotle heretofore remarked. But in animals the inclination to keep the parts within, and to concentrate the organs in the interior predominates. It is on this account that plants have been said to be animals turned inside out, and animals to be plants turned outside in.

CXXXIX. With this opposition observed between the situation and arrangement of the parts of animals and vegetables, is connected, in the former, the existence of central organs, as Bichat denominates them, that are not seen in plants. In all complicated animals, and this is so much the more perceptible as their organization is the more complex, we perceive organs situated in the interior of the body, in the median line or the axis, and for the most

(5) Physiologie, vol. i, p. 169.

part azygos, whence radiated prolongations originate, which are spread throughout the body in proceeding towards the periphery. This class of central organs includes the brain and spinal marrow, the collections of nervous matter, called nervous ganglions, and the hollow muscle, the heart, which is connected with the sanguineous vascular trunks. From the brain, spinal marrow, and nervous ganglions radiated nerves proceed, which enter into the composition of all the organs, and connect them with central organs. The vascular trunks which communicate with the cavities of the heart, and include the nutritive or formative liquid, the blood, are divided into successively decreasing branches, the minute ramifications of which terminate at the periphery of the body, in the different organs.

The central organs being connected with all the organs of the animal by their radiated prolongations, the nerves and blood vessels act on them during life, link them together, and are the sources of the reciprocity of action that exists between them. The more marked and multiplied the phenomena of life are in animals, the more also the manifestations of activity of the organs and apparatus situated on the periphery, are dependent on those of the central organs.

In plants there are no central organs that send prolongations throughout the whole body, and place its different parts in an intimate union; this has been lately demonstrated by Schulz.(6) Hence it happens, that the different parts of a vegetable are not so intimately connected and so dependent on each other, in their manifestations of activity, as the organs and apparatus of animals are. Plants have no centres, no central organs, that can be compared with the brain and heart of animals.

CXL. In the majority of animals, especially in all those which have a complex organization, the mammifera, birds, reptiles, fishes, crustacea, arachnida, and annelida, there presides, in the intimate structure, particularly in the apparatus of animal life properly so called, a well marked symmetry, and of such a kind, that these organs are formed of two equal halves, or are repeated in each half of the body. This arrangement is eminently visible in the brain and spinal marrow, which are composed of two similar halves, meeting on the median line. It is even found, according to the observations of Autenrieth, (7) in the pleuronectes, spite of the partial defect of symmetry seen externally in these animals. All the nerves and the organs of the senses, the locomotive organs, the skeleton, and the muscles have likewise a symmetrical conformation. This symmetry is remarked too in several organs implicated in nutrition and generation, the masticatory apparatus, and the salivary glands, in the organs of the circulation, the heart, the kidneys, and the genital organs.

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(6) Die Nätur der lebendigen Pflanze, vol. i, p. 98.
(7) Wiedeman's Archiv für Zoologie und Zootomie, v. i, p. 4.

Even the intestinal canal, although generally not symmetrical in regard to situation, is composed of two equal halves. This internal symmetry seems to apply chiefly to the nature and particularly to the mode of formation and development of the nervous system; at least this system is the first of all the symmetrical apparatus that appears in the fœtus. The symmetry of the other apparatus is in close connexion with this one, which also appears to be the cause of that which is perceived externally. In animals, whose external form is radiated, the nervous system and internal parts have also a radiated disposition.

Plants that have no central symmetrical organ, exhibit no trace, either externally or internally, of this division into two equal halves, which seems to be the law of animal organization.

CXLI. The character of individuality, which only belongs to living bodies, is more pronounced in animals than vegetables. The more complex the structure of animals, the more numerous and varied will be their organs and apparatus, the more pronounced and developed will be the central organs, the brain, and heart, the more will the vitality of these individuals be endangered by the loss of any parts, and the more applicable to them will be Kant's idea, that organic bodies are beings whose parts act, in reference to each other, the part of cause and effect, of means and end. On the other hand, the more uniform and simple their structure, the less perceptible are central organs, and more readily can they be divided without losing life, as is the case with many annelides, entozoa, radiaria, and polypi.

Plants which lack central organs, whose different parts bear a greater resemblance with respect to structure, and are neither subject to so precise a reciprocity of action, nor so intimately linked as to form a compact whole, appear to be less concentrated in themselves than animals. Perennial vegetables, trees, and shrubs are divisible, and parts detached from them are capable of becoming new plants, as is proved by the multiplication from slips, and even that of some vegetables from their leaves.(8) The parts of vegetables easily exchange their forms and functions, and can become vicarious of each other.(9) They are not, therefore, so distinct as those of

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(8) In the following works we find numerous examples of plants proceeding from leaves: Augustin Mandirola, Manuale de gardinieri. Venice, 1652, in 12mo.—G. A. Agricola, Versuch einer Allgemeinen Vermehrung aller Baume, Stauden und Blumengewächse. Ratisbon, 1716, in fol. Thuemmig, De acboribus ex folio Educatis. Halle, 1721.—Wildenow, Grundriss der Gewächskunde, p. 487.—Thouin, (Ann. du Museum d'Hist. Nat. v. xii, p. 226, v. xiv, p. 101,) even reared young plants from the annual leaves of the *cactus opuntia.*—Schweigger (Naturgeschichte der Skelettlosen Thiere, p. 52) got ten young plants from one leaf of the *verrea crenata.*—Hedwig (Sammlung Zersteuter Abhandlungen, v. ii, p. 125) and Brandis (Versuche über die Lebenskraft, p. 105) saw bulbs produced from detached leaves of the *fritillaria regia.*

(9) A tree planted in the earth, after being turned, throws out leaves from its roots, and roots from its branches, which has been established by the experiments of Agricola, Magnol, Hales, Duhamel, (Physique des Arbres, v. ii,) and others.

animals. On this account, plants, especially the perennial, should be considered, as Darwin,(1) Du Petit-Thouars, and Decandolle,(2) have described them rather as aggressions of individuals than as individuals properly so called. By grafting we even succeed in uniting different individuals on the same stock.

CXLII. The sexual character establishes a striking difference between animals and plants, which Hedwig first caused to be noticed.(3) It is, in fact, permanent in all animals provided with genital organs, whilst in plants it is transitory, and confined only to a short period of their existence. In general the genital organs of animals are not destroyed after having fulfilled their function, and in animals whose life lasts more than a year in the adult age, they may act repeatedly. All plants, on the contrary, annual as well as perennial, are provided with only temporary genitals. These organs are destroyed by the very fact of accomplishing their function, and the plants then relapse into a neutral state, like that of animals in the first periods of their embryonic existence. Every year perennial plants throw out new flowers, and it is only at that time they exhibit completely the character of the species.

CXLIII. The organs that prepare the genital matter, male as well as female, are, in the majority of animals, mammifera, birds, reptiles, fishes,(4) crustacea, arachnida, insects, almost all the mollusca, especially the cephalopoda, the ascarides from among the entozoa, &c., divided between two different individuals, and the species is represented by being furnished with different sexual organs. In a few of the inferior animals, the organs of the two sexes are found united in the same individual, which is then called hermaphrodite. This is the case among the mollusca, in the gasteropoda of the genus *helix*, *limax*, and others, and, according to the researches of E. Home,(5) in the *lepas*. The two sexes are also united, in the class of annelides, in leeches, and earth worms, and in that of the entozoa in teniæ. Although in these each

(1) Phytonomia. London, 1800, in 4to, v. i. He regarded buds and the branches proceeding from them as distinct individuals.

(2) Organographie Vegetale. Paris, 1827, v. ii, p. 238. "Nous considerons comme un individu tout germe développé, savoir; 1, tantot une graine, en supposant que, comme cela a lieu dans quelques plantes annuelles, elle produit une tige sans ramifications; 2, tantot une branche considerée comme un germe quelconque développé. Ainsi dans ce sens, un arbre est un agregat de l'individu primitif provenu de la graine et de tous les individus provenus de germes non fécondés, et qui se sont developpés les uns sur les autres, et ont formé les prolongemens ou les ramifications de l'individu primitif."

(3) Leipziger Magazin zur Naturkunde; edited by Leske and Hindenburg, 1784, art ii, p. 215.

(4) It has not yet been satisfactorily demonstrated that there are hermaphrodites among fishes, that is, individuals uniting the two sexes, as Cavolini asserted (Erzeugung der Fische, p. 82) in regard to some kinds of perch, and very recently E. Home (Phil. Trans. 1825, v. 2, p. 267; 1823, v. i, p. 120) in regard to lampreys, myxines, and eels. Jacopi (Elementi di fisiologia e natomia comparata, v. iii, p. 128) express doubts concerning perch. Bojanus says he found a male lamprey.

(5) Philosoph. Transact. for the year 1823, v. i, p. 140.

individual represents the species, yet there are but few of these animals that can impregnate themselves; for the most part the reciprocal influence of the genitals of two individuals, that is to say, a double copulation, is necessary to accomplish the work of generation, as occurs in the gasteropoda above mentioned, and earth worms (lumbricus.)

In the greater number of plants, on the contrary, the male and female genital parts are united in the same flower, thus presenting hermaphrodites; or else the sexual organs are met with on the same trunk, but in different flowers, as occurs in monæcious plants. This is the case among the monocotyledones, in plants belonging to the families of the aroideæ, (arum calladium,) the typhaceæ, (typha, sparganium,) the cyperoideæ, (carex, scleria,) palmæ, (areca, cocos, caryota,) gramineæ, (zea, coix;) among the dicotyledones, in vegetables entering into the families of the coniferæ, (pianus, casuarina, thuya, cupressus,) the myrificeæ, (hernandia,) urticæ, (urtica,) euphorbiaceæ, (croton, jatropha, ricinus, buxus,) amentaceæ, (fagus, carpinus, betula, quercus, corylus, juglans,) &c. The genital organs are distributed in different individuals of the same species, (divecia,) among the monocotyledones, in plants belonging to the families of the pandaneæ, (pandanus,) palmæ, (phœnix,) asparagi, (smilax, dioscorea, ruscus;) and among the dicotyledones, in plants forming part of the families of the coniferæ, (juniperus, araucaria,) myristiceæ, (myristica,) urticæ, (cannabis, humulus,) amentaceæ, (salix, populus, broussonetia, myrica,) euphorbiaceæ, (mercurialis,) chenopodeæ, (atriplex,) terebintaceæ, (pistacia,) &c.

The union of the two sexes in themselves, thereby representing the complete species, at the same time constituting, an union of individuals, occurs more frequently in vegetables than in animals, since they often bear a multitude of flowers, whereas in animals, the number of testicles and ovaries in one individual never exceeds two. According to G. R. Treviranus,(6) the union of the organs belonging to two sexes, and an indefinite number of such organs in one flower, are the characters of the maximum of vegetable organization, whilst the converse is that of the minimum of the same organization. In animals, on the contrary, the separation of the genital organs into two individuals is a proof of more perfect or complete organization.

CXLIV. In the majority of animals that possess two sexes the difference between the male and female, is not alone confined to the genitals, but is also extended to other parts, which have no immediate connexion with the functions of generation. The males and females, in animals, exhibit as great differences in the conformation of the body, relative to volume, to the existence of particular organs, and the more or less extensive development of

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(6) Biologie, v. i, p. 432.

some others, as in the manifestations of life; this has been shown by J. F. Meckel (7) in a very detailed manner, when surveying the different classes of animals. On the other hand, in plants with distinct sexes, this difference does not exist at all, or at least is not so well pronounced. Thus, in a shrub of Cochin-china, the *pselium heterophyllum, Lour.*, the male individuals have cordiform, round, and obtuse leaves, whilst those of the females are oval and pointed. H. F. Autenrieth(8) says, he observed female plants to have, on the whole, more branches and leaves, as well as larger leaves. He adds, moveover, that seeds from which female trunks proceed are rounder and lighter than those whence the males proceed. But these differences are not always visible.

CXLV. The chief conclusion which results from the reseaches and comparisons in which we have been engaged in reference to the structure of animals and vegetables is, that the former possess a more complicated, more developed, and on that account a more perfect organization. The number of tissues, organs, and apparatus intended for the exercise of the different manifestations of life, is evidently greater in the majority of animals than in plants. They not only exhibit more numerous and diversified, but also better developed or more prominent parts. All these parts are united by the bonds of a more intimate reciprocity of action; they are more dependent on each other, and more concentrated into a single whole. The animal organization has, moreover, a tendency to divide the species into different individuals, each furnished with genital organs. In vegetables, on the contrary, there are fewer tissues and parts, the different organs project in a less prominent manner, and they have not so well marked a reciprocity; in short, individuality is not so well pronounced. Plants represent more generally the species and the union of several individuals on the same stock. Finally, the sexual character is more transitory, more evanescent, and vegetables are deprived of it during the greater part of their existence.

SECOND SECTION.

COMPARISON BETWEEN THE MANIFESTATIONS OF ACTIVITY OF PLANTS AND ANIMALS.(9)

CXLVI. Let us now examine, by means of analysis, induction, and comparison, the manifestations of activity which constitute the life of animals and

(7) System der Vergleichenden Anatomie, v. i, p. 229.

(8) De discrimine sexuali jura in seminibus plantarum dioicarum apparente. Tubingen, 1821, in 4to.

(9) H. L. Duhamel, de Monceau, La Physique des Arbres. Paris, 1758, v. ii, in 4to.—Van Marum, Dissert. qua disquisitur, quousque motus fluidorum et ceteræ quædam animalium plan-

vegetables. Let us reduce them to the most simple phenomena, then let us inquire how far they correspond in these two groups of living bodies, and in what respects they differ. Let us, in continuation, study the connexions they have with each other and the cause on which these connexions depend. Let us then apply the name of powers to the conditions of the manifestations of activity, and give them that of special powers, if we cannot do away with or combine the differences they present. Lastly, let us observe the reciprocity of action, and the mutual dependence of the powers in the production of the phenomena of life.

CXLVII. The manifestations of activity of organic bodies in general may be brought directly under two great classes, according as they relate to the individual or to the preservation of the species. Of the former some maintain the individual in the enjoyment of its chemical composition, form, organization, and proper activity; the others consist of the exercise of the manifestations of the mind. To the former belong the nutritive functions, the taking of food, absorption, assimilation, respiration, the movement of the humours, nutrition, and secretion. Hither also we may refer the evolution of imponderable substances, heat, and, in certain circumstances, light and electricity. In the second, or manifestations of the mind, are comprehended sensation, perception, and consciousness, as also instinct, the desires, the will, and the motions caused by it. The functions relating to the preservation of the species are those of procreation, production, formation, maturation, and expulsion of the offspring. There are, moreover, vital phenomena, which occur at regular periods during the existence of the organic individual, as the changes resulting from development, the epochs of age, and the daily and annual changes.

We are convinced by our senses of the existence of the functions of nutrition and generation, of motion, of the phenomena relative to development, the epochs of age, and changes which daily and annually occur in living bodies. On the other hand, the operations of the mind, of which we have no consci-

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tarumque functiones consentiunt. Groningen, 1773, in 4to.—Mustel, Traite theorique et pratique sur la Vegetation. Rouen, 1781, in 8vo.—Ed. Fryar, De Vita Animantium et Vegetabilium. Leyden, 1785, in 4to.—Ch. Dumas, Essai sur la vie, ou Analyse raisonnée des facultés vitales. Montpelier, 1785.—A. Comparetti, Prodromo di Fisica Vegetabile. Padua, 1791, in 8vo.—C. F. Kielmeyer, Ueber die Verhältnisse der Organischen Kräfte unter einander in der Reihe der verschiedenen Organisationen, und die Gesetze und Folgen dieser Verhaltnisse. Stuttgard, 1793, in 8vo, Tubingen, 1814.—Fr. Al. von Humboldt, Aphorismen aus der Physiologie der Pflanzen, translated by Fischer, Leipsick, 1794, 8vo.—Brera, Programma de vitæ Vegetabilis et Animalis analogia. Pavia, 1796, in 4to.—C. G. Rafn, Entwurf einer Pflanzen-Physiologie. Translated from the Danish, by J. A. Markussen. Copenhagen, 1798.—J. Senebier, Physiologie Vegetale. Geneva, 1800, vols. 5, in 8vo.—E. Darwin, Phytonomia. London, 1800, v. ii, in 4to. Translated by Hebenstreit. Leipsick, 1801.—Carradori, Sulla vitalita della piante. Milan, 1807, in 8vo.—G. G. Kieser, Aphorismen aus der Physiologie der Pflanzen. Gœttingen, 1808, in 8vo.—L. C. Treviranus, Beitræge zur Pflanzen—Physiologie. Gœttingen, 1811, in 8vo.—P. Keith, System of Physiological Botany. London, 1816, v. ii, in 8vo.

ousness but by the internal sense, internal perception, can never be an object of immediate observation to us when they are executed by other bodies. It is by analogy alone that we admit their existence in those bodies, whenever we see in them instruments similar or analagous to those by means of which we ourselves perform these operations, or whenever we behold actions which our consciousness tells us are the result of the mind's activity, or of an impulse communicated by it.

By comparing the manifestations of activity of living bodies in this light, we arrive at the conclusion that both vegetables and animals possess the faculties of nutrition and generation, as well as evidence the periods of development and age, but that, judging from the organs and the actions of organic bodies, the manifestations of mind belong exclusively to animals, and do not exist in plants.

CXLVIII. The phenomena of life, and the powers on which they depend, will form the subject of as many distinct divisions. The first comprehends the manifestations of activity that relate to nutrition. The second treats of the evolution of the imponderable matters, heat, light, and electricity. In the third we examine the movements. The fourth embraces the functions of the nervous system, and of the organs of the senses. The fifth is dedicated to the functions of generation. In the sixth, we direct our attention to the periods of development and age. Finally, in the seventh, we study the organic powers and their mutual dependence. Various periodical changes, such as the daily ones, sleep and waking, and the annual ones, hibernation, summer sleep, the emigration of animals, &c., will be more in their proper place in the succeeding book, which treats of the connexions of living bodies with the influences from without, or the external conditions of life, because they are dependent on periodical, daily, and annual changes. It is in that place, also, that the alterations which the domain of living bodies has suffered in consequence of the development and revolutions of our planet, are to be explained.

In tracing the manifestations of activity of living bodies, we shall make it a point to form as condensed a picture as possible, for in this our design can only be to place before the view of the young physician the more general traits of the vital phenomena, and of their connexions with each other.

FIRST DIVISION.

OF THE FUNCTIONS OF NUTRITION.

CXLIX. The general qualities of living bodies belonging to all animals and vegetables, is, as I have already shown, (sec. LV,) that of preserving themselves, during a certain period, by the fact of their own activity, at the same time that they are undergoing continual changes in chemical composition and organization. From all around them they obtain materials, food, and the constituents of the atmosphere, which they convert into their own substance, and they expel others in a liquid or vapourous form. So long as there exists in organic bodies an attraction and expulsion of matters, without their form being thereby changed, they are said to be living bodies; but whenever this exchange ceases, they no longer possess life. In the latter state, the material substance entering into their composition is, by the concurrence of external influences and according to the laws of chemical affinity, destroyed. The organic association that united their parts is broken, and organization no longer exists.

The manifestations of activity, by means of which individuals are maintained, are called acts or functions of nutrition. Of this kind are the ingestion and absorption of aliments, respiration, assimilation, the movement of the nutritive fluid, the passage of the matters of the humours into the solid parts, and secretion. We will examine each of these functions in animals and vegetables, indicating at the same time the resemblances and differences they present.

CHAPTER FIRST.

Of the Aliments.

CL. I have already said (sect. lvi) that living bodies chiefly obtained organic matters, to assist in their nutrition, from the external world. These matters must either be already liquid, or capable of being liquified by the addition of divers humours. All solid organic substances which the addition of the liquids of a living body is unable to convert into a fluid state, cannot, as such, serve for food.

1. Aliments of Vegetables.

CLI. Plants obtain their alimentary matters, in a liquid form alone, from earth or water, with which they have a continual connexion by their roots. Some cellular vegetables, however, seem to be nourished by watery vapour contained in the atmosphere. Earth and water are the two great magazines and depôts of organic matters, into which the remains of all dead vegetable and animal bodies are cast. These remains, after dissolution and decomposition, are taken up by plants which return them to organization and to life. The upper layer of the earth, which is charged with organic substances, vegetable earth, allows the entrance of air and water into it; and, taking oxygen from the atmosphere, allows of the formation of carbonic acid in it. Water containing this acid, as well as organic matters and different earthy, saline, and metallic substances in solution, is the principal food of plants. On all sides we behold vegetation flourishing in places where there are organic bodies in a state of decomposition, as in cemeteries, on battle fields, and other situations where animal excrements or vegetable remains are rotting. The improvement of land by manure is also designed to prepare this nutritive liquid.

CLII. Several of the older physical philosophers, Vanhelmont,(1) Boyle,(2) Duhamel,(3) Eller,(4) Tillet,(5) and others, asserted that plants could be nourished by pure water, and they rested this assertion on experiments which, they thought, proved it. Wallerius(6) even thought he could prove from his own researches, that all the saline, earthy, and other matters found in plants, are formed from water. But Bergmann(7) has shown that the earths which are found in plants that have been reared in water, were already contained in the water, or proceeded from the vehicles holding the liquid. Kirwan(8) has, moreover, remarked, that rain water, which these physicians frequently made use of in their experiments, contains certain substances that are found in plants. In short, all vegetables whose seeds or organs grow in pure water, are chiefly nourished, as is well certified, by the mucous or albuminous matters in these bodies and which are dissolved in the liquid.(9)

CLIII. Carbon, the most abundant principle in the composition of plants, is not, as Crell(1) supposed, a product of the exercise of their vital activity, with the concurrence of light and heat, on matters introduced into them; for the experiments of Saussure,(2) and Goeppert(3) show that it proceeds from without, partly raised by the roots with the aliment, partly extracted by the leaves from the carbonic acid contained in the atmosphere. Moreover the inorganic combinations that are found in plants on incinerating them, as salts, earthy matters, and metallic substances, are not produced in their interior, as

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(1) Ortus Medicinæ. Amsterdam, 1654, p. 55, 82, 116.
(2) Chymista Scepticus, vel dubia et paradoxa Chymico-physica. Rotterdam, 1668, p. 96.
(3) La Physique des Arbres, v. ii, p. 198.
(4) Mem. de l'Acad. de Berlin. 1752, p. 17.
(5) Mem. de l'Acad. de Paris. 1774.
(6) Agriculturæ fundamenta chemica, p. 35.
(7) Opuscul Chim. v. ii, p. 15; v. v, p. 92.
(8) Transactions of the Royal Irish Academy, v. v, p. 160.
(9) Bulbs, for instance those of the hyacinth, the tulip, the narcissus, and others, throw out roots when placed in distilled water, and these roots are covered with a mucilaginous or albuminous matter proceeding from the bulbs themselves. This phenomenon has been observed by Duhamel, (Physique des Arbres, v. is p. 86;) Gautier d'Agoty, (Observ. sur l'Hist. Nat., v. viii. p. 160;) Senebier, (Physique Vegetale, v. i, p. 315;) and others. J. Murray (the Edinburgh Philos. Journal. No. 14, p. 328) has also very lately observed, that carbonic acid was disengaged from the fibrillæ of the bulbous root of the hyacinth growing in water.
(1) Chemische Annalen, v. ii, p. 110. Nov. Commentar. Soc. Gœtting, 1818, v. i.
(2) Rech. Chimiques sur la Vegetat, ch. ii.
(3) Nonnulla de Plantarum Nutritione. Berlin, 1825, in 8vo.

Schrader,(4) Einhof,(5) and Braconnot(6) asserted, but are rather absorbed with water, which holds them in solution, as follows from the experiments of Saussure,(7) Davy,(8) Lassaigne,(9) and Berthier.(1) There is absolutely no proof that living bodies in general, and vegetables in particular, are so situated as to form elements.

CLIV. Although Ingenhouz,(2) Percival,(3) Schrader, Braconnot, and others have found that there are plants which vegetate in substances totally insoluble in water, as sand, glass, &c., provided they only contain water charged with carbonic acid, yet it follows, from experiments made by Hassenfratz,(4) Th. de Saussure,(5) Giobert,(6) Link,(7) and others, that in a soil altogether free from organic matters, plants vegetate wretchedly, or even do do not shoot at all, rarely have flowers, and still more rarely fructify. We cannot therefore deny the importance of organic matters held in solution in water, for the nutrition of plants. The difference established between vegetables and animals by Mirbel(8) and Smith,(9) viz., that the former live on inorganic and the latter on organic matters, is untenable, as the instance, among others, of parasitical plants proves, which live at the expense of the juices of the body to which they cling.

2. Aliments of Animals,

CLV. The aliments of animals are infinitely more varied and compound than those of vegetables. Besides water, which is the vehicle of some nutritive matters, they consist of vegetable and animal substances.(1) Minerals

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(4) Zwei Preisschriften über die eigentliche Beschaffenheit und Erzeugung der erdigen Bestandtheile in den verschiedenen inländischen Getreidearten von C. C. Schrader und J. S. B. Neumann. Berlin, 1800.

(5) Gehlen, Neues Allgem. Journal der Chemie., v. iii, p. 563.

(6) Annales de Chimie, v. lxi, p. 187.

(7) Loc. cit., p. 281.

(8) Elements of Agricultural Chemistry.

(9) Observations sur la Germination des Graines dans le soufre; in the Journal de Pharmacie, v. vii, p. 509.

(1) Analyse des cendres de diverses especes de bois; in the Annales de Chim. et de Phys., July, 1826, p. 240.

(2) On the Food of Plants. London, 1797.

(3) Philosophical Transactions, No. 253, p. 193.

(4) Ann. de Chim., vol. xiii, p. 179.

(5) Loc. cit., p. 28.

(6) Physiologie Vegetale, by Senebier, v. ii, p. 34.

(7) Kritische Bemerkungen zu Sprengel's Werk über den Bau und die Natur der Gewächse, p. 36.

(8) Traite d'Anatomie et de Physologie Vegetale, v. ii, p. 19.

(9) Introduction to Botany. London, 1809, p. 5.

(1) Rondelet (De Piscibus, b. i, ch. xii) speaks of marine animals that can live on water alone. He observed a fish that lived during three years in a vase full of spring water, and which nevertheless grew to such a size that the vase became too small for it. This phenomenon is also observed in the gold fishes of China. But it does not prove that animals are nourished by water alone, since it almost always contains organic matters dissolved, though in small quantity, as the formation of Priestley's green matter in the midst of it proves.

are not alimentary, although divers animals often take them mixed or combined with organic matters.(2) Animals exhibit vast differences in regard to the nature of their food. The majority of them, and particularly almost all the aquatic ones, live only on animal substances; others again, the greater number of land animals, are nourished by vegetable matters, and some by both. We can, however, draw no strict line of demarcation, because many animals change their nourishment according to the seasons, and various other circumstances.

CLVI. Regarding the nature of the substances which form the food of animals, they are either liquid or solid, or both. Animal humours are the nourishment of entozoa, of many parasitical apterous insects, and of different dipterous ones. The animal substances which the various animals of any class prefer, are either substances still living, or in a state of decomposition. The nature of aliments also exhibits many differences. Some animals live only on vegetable juices, as many insects. These juices are either already secreted and contained in the nectaries, whence animals, such as bees, butterflies, and some flies, suck them; or they are sucked after making a wound in the plant by means of a sting, as by many hemiptera. But the greater number of animals eat vegetable substances in a solid form; some feed on the leaves, others on the flowers, others again on the fruits or seeds, &c. Another source of difference is, that there are many animals which eat many different plants, and others that live only on a single kind.(3)

CLVII. Animals, therefore, are organisms of a more perfect kind than plants, not only because they live on more diversified and compounded food, but because they are not like plants, confined to a liquid nourishment,(4) which is not a thing of necessity to all except in the fœtal state, and of which mammifera are under the necessity of taking for some time after birth.

CHAPTER SECOND.

Of the reception of Aliment by Absorption,

CLVIII. All plants imbibe their liquid nourishment by absorption, which is performed at the periphery. Liquid alimentary matters are likewise

(2) No animal is known that is nourished by mineral substances. If some, for instance earth worms, devour soil, it is for the purpose of getting the organic matters that are mixed with it; the earthy particles themselves are ejected with the excrements.

(3) Two divisions of the herbivorous animals may be made; those which live on a great number of plants and those which feed on a single kind. Yet the former reject, according to Linnæus's remark, several plants of a genus or family. Thus the ox will neither touch the labiatæ nor the veronicæ; the horse passes by all the cruciferous plants. Oxen, horses, sheep, pigs, and goats scarcely eat any of the solaneæ, whereas they are very greedy of the graminæ, the leguminosæ, and the compositæ. The majority of insects feed only on a single species, or at least on plants belonging to one genus or one family,

(4) G. R. Treviranus (Biologie, v. iv, p. 295) speaks at great length of the food of animals.

absorbed by organs placed in the periphery of the bodies of animal embryons *in ovo:* but, after breaking through the coverings of the ovum, animals take their food by a particular aperture, the mouth, which vegetables do not possess, and they pass it into a canal, also peculiar to them, of a saccular shape, the intestinal canal, wherein the parts that are constitutionally liquid, or have become so by the addition of humours proceeding from the body itself, are absorbed. We are now about to speak of absorption in plants and animals: the next chapter will be appropriated to the reception of food which is effected by the mouth.

1. Absorption of Aliment in Vegetables.

CLIX. The organs by whose means vegetables, surrounded by, and implanted in, the aliment itself, absorb the matters that are capable of nourishing them, are sufficiently well known. The roots of cellular plants, of many mosses, of some lichens and mushrooms, are filiform or capillary, and sometimes ramose prolongations, which, like the plant itself, are composed of cellular tissue, frequently containing sacciform cavities, into which the absorbed liquid rises. In the roots of vascular plants, especially the dicotyledones, a body with ramifications and appendages is distinguished. In the gramineæ we remark a knot whence radical threads proceed. The body of the root is composed of wood and bark. The former which, in some plants, contains pith, is the result of an assemblage of cellular tissue and vessels. Some anatomists, Duhamel,(5) Comparetti, Bell,(6) Link,(7) and others, say they perceived true spiral vessels in the ligneous part, but the existence of these is denied by others. The bark contains a great quantity of cellular tissue, as well as nutritive vessels essential to the growth of the roots. These are not possessed of epidermis, properly so called, either among the monocotyledones or dicotyledones, according to the researches of Kieser(8) and L. C. Treviranus.(9) The radical fibrillæ, which are mostly cylindrical, have their most minute ramifications furnished with capillary or spongy appendages, which Treviranus found to be composed of cellular tissue only. According to the experiments of Senebier, Carradori,(1) and Decandolle,(2) it is the final extremities of these appendages that chiefly perform the act of absorption. Orifices, or pores, by which the nutritive liquid penetrates, have not yet been remarked. If they exist, they must be excessively small, since,

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(5) Physique des Arbres, v. i, p. 82.
(6) Mem. of the Manchester Society, v. ii, p. 403.
(7) Grundlehren der Anatomie und Physiologie der Pflanzen, p. 125.
(8) Grundzüge der Anatomie der Pflanzen, sec. 350.
(9) Ueber die Oberhaut der Gewächse; in Vermischten Schriften, v. iv, p. 35.
(1) Degli organi assorbenti delle radice; osservaz. present. alla Societa Georg. di Firenza.
(2) Mem. sur le developpement des racines; Ann. des Sc. Nat. de Geneve, 1826, p. 1.

from the experiments of Sprengel(3) and Link,(4) the radical fibrillæ only take up colouring matters when very finely divided and dissolved in water, leaving behind those which are in larger molecules, which are only absorbed when the roots have been damaged.

CLX. It follows, from the experiments of Labaisse,(5) Hales,(6) Senebier, and others, that absorption by the roots is exceedingly active, especially in the spring. Some physiologists have attributed to these organs the faculty of selecting parts from the liquid substances that are placed in contact with them, and only taking up those which can best conduce to their nutrition. This is an error which numerous recent experiments have fully refuted. Th. de Saussure found that plants absorbed sea salt, nitrate of lime, sulphate of potass, sal ammoniac, acetate of lime, sulphate of copper, sugar, gum arabic, &c. G. J. Jaeger(7) confirmed the deleterious action of arsenic, on plants whose roots are plunged into water containing only a small quantity of this substance; they withered and perished. C. J. F. Becker,(8) Schreibers,(9) and Goeppert.(1) saw hydrocyanic acid produce a similar effect. To the younger(2) Marcet we are indebted for interesting and numerous experiments, the result of which is, that plants absorbed different mineral substances dissolved in water, as the arsenious acid, chloride of mercury, salts of lead and copper, as also the extracts of opium, belladonna, nux vomica, and hemlock, distilled water of the cherry laurel, prussic acid, alcohol, &c., and that this absorption exerted a deleterious influence over them. Similar experiments have been made by Macaire-Prinsep,(3) and also by Schuebler and Zeller(4) with the same result.

CLXI. The absorbing power belongs also to leaves. That plants absorb liquids by means of their leaves, and for the purpose of nutrition, is proved by the beneficial action which dew, rain, and watering the leaves exert,—circumstances that all favour their growth. Many vegetables with insignificant roots, but thick and succulent leaves, for instance the *cactus*, are preserved chiefly by the absorption which is effected by means of these latter

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(3) Anleitung zur Kenntniss der Gewächse, p. 100.
(4) Grundlehren, p. 72.
(5) Diss. sur la circulation de la seve des plantes, p. 53.
(6) Statique des Plantes.
(7) Diss. de effectibus Arseniei in varios Organismos. Tubing., 1808.
(8) De Acidi Hydrocyanici vi Perniciosa in Plantas. Jena, 1803.
(9) De Acidi Hydrocyanici vi Perniciosa in Plantas. Jena, 1825.
(1) De Acidi Hydrocyanici vi in Plantas. Breslau, 1827, in 8vo.
(2) Mem. sur l'Action des Poisons sur le regne Vegetal; in the Mem. da la Soc. de Physique et d'Hist. Natur. de Geneve, 1824. Bibl. Universelle, v. xxxi, p. 244. Ann. de Chim. et de Physique, vol. xix.
(3) Sur l'Influence des Poisons sur les Plantes douces de Mouvemens excitables. Ibid., 1825-26, v. i, p. 1, 2.
(4) Enquiry into the Effects of different Matters of the Organic and Inorganic Kingdoms on Vegetable Life; in Schweigger's Jahrb. der Chemie und Physik, 1827, art. 5, p. 54.

organs, which even remain fresh for some time after being detached from the plant. Many cellular plants, marine algæ, ulvæ, confervæ, mushrooms, lichens, and especially mosses, obtain abundance of liquids by the whole of their surface, and even some, as the majority of lichens, which have, properly speaking, no roots, appear to be nourished solely by the absorption going on at their surface. Hales proved experimentally that vegetables increase in weight in a humid atmosphere. Mariotte, Duhamel, Merret, and particularly Bonnet,(5) have also confirmed the absorption accomplished by the leaves. The latter has remarked that leaves placed on water, not only are themselves preserved, but are moreover capable of maintaining the life of the branches and twigs to which they are attached. The absorption of liquids seems to be effected by both surfaces of the leaves of herbs, but chiefly by the inferior one in shrubs and trees. It is probable that their elongated pores regulate the absorption, as Humboldt,(6) Kroker,(7) Sprengel,(8) Schrank, G. R. Treviranus,(9) and L. C. Treviranus admit. In cellular plants, however, which have no pores, this operation is performed.

CLXII. Here a question presents itself for solution; namely, whether the introduction of liquid alimentary matters into the interior of plants, is a simple result of the capillary action of porous bodies, the same as that which causes a narrow glass tube, when placed in the midst of a liquid, to draw it into its interior until it reaches the level of the fluid without, or if absorption be not rather a particular vital phenomenon. Many physiologists, Malpighi, Grew, Borelli, Delahire, Bradley, and others, admitted the former hypothesis, and considered the radicles as capillary tubes, whose office it was to suck up and propel the nutritive liqnid by their attractive power. It is not impossible that such a power contributes its part to the production of the phenomenon; but it can by no means be the only cause, as the following reasons will show. The absorption of the nutritive liquid varies according to the state of the plants, the periods of their development and growth, and the seasons of the year. During the formation and increase of the leaves, the absorption and progression of the sap go on with so much more rapidity as the leafing itself is rapid. Besides, it is at the periods of flowering and the formation of the fruit and seeds that plants draw the greatest quantity of nourishment from the soil. We know, too, that the absorption and progression of the absorbed liquid are dependent on the influence exerted by heat and light over plants; so that absorption, generally more active in spring and summer than at any other time, is diminished in autumn, and very weak, if not altogether stopped,

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(5) Recherches sur l'Usage des Feuilles. Geneva, 1754, sec. 4.
(6) De Plantarum Epidermide. Halle, 1801,
(7) Einleitung zu Ingenhouz über die Ernährung der Pflanzen, p. 24.
(8) Biologie, v. iv, p. 38.
(9) Vermischte Schriften, v. iv, p. 79.

in winter. These phenomena cannot be regarded as the pure effects of capillary action, this being neither modified by the seasons, nor by the influence of heat. Lastly, there is this difference between capillary absorption and that of plants, that a capillary tube does not expel by its upper aperture the liquids it has sucked up, whilst the fluid absorbed by vegetables flows from the vessels when they are wounded. These are sufficient reasons for obliging us to follow the opinion of Senebier, Saussure, Desfontaines, Decandolle, and others, who regard the absorption of vegetables as an organic or vital phenomenon.

2. Absorption in Animals.

CLXIII. Animals, which are not, as plants are, placed and fixed in the midst of their aliments, introduce them into the intestinal canal chiefly by the mouth. Here the alimentary substances are mixed with the secreted liquids of the part, whose action renders them fluid, should they be solid. Thus in animals the absorption of food takes place in the internal surface, which supposes previous manifestations of activity of a special kind, whereas in plants it occurs in the periphery. However, many animals absorb, likewise, by their surface, the skin; but this mode of absorption is rarely sufficient to maintain their existence.

CLXIV. Regarding the parts which perform the absorption of alimentary matters, either already liquid or liquified by the dissolving action of the intestinal juices, it would appear that this function belongs principally to the cellular tissue forming the base of the alimentary sac, and which has the property of imbibing liquids. Particular vessels, the lymphatics, are found in the mucous membrane of the intestinal canal of the animals which compose the four higher classes, mammifera, birds, reptiles, and fishes. Since their discovery by Aselli, the existence of these vessels has been fully demonstrated by the researches of Vesling, Th. Bartholin, Stenon, Rudbeck, Pecquet, and many others. They have been seen in the intestinal canal of birds by Hewson,(1) A. Monro secundus,(2) myself,(3) and very lately by Breschet,(4) and E. A. Lauth.(5) The first two of these anatomists, Cruickshank,(6) and Fohmann,(7) observed them in reptiles and fishes. These vessels, taking

(1) Philos. Transact., 1768, v. lviii, p. 217; 1769, v. lix, p. 204.

(2) State of Facts concerning the Paracenthesis of the Thorax, an Account of Air effused, and Lymphatic Vessels in Oviparous Animals. Edin., 1770—Anatomy of Fishes.

(3) Anatomie der Vögel, v. i, p. 533.

(4) Note sur la Recherche des Vaisseaux Lymphatiques des Oiseaux; in the Bulletin des Sciences Medicales. Oct., 1824, p. 105.

(5) Mem. sur les Vaisseaux Lymphatiques des Oiseaux; in the Ann. des Sciences Nat. Paris, 1825.

(6) Geschicte der Saugarden, p. 62.

(7) Das Saugadersystem der Wirbelthiere, erstes Heft, das Saugadersystem der Fische. Heidelberg, 1827, in fol.

their origin from the intestinal mucous membrane, are united into twigs and branches, and by their anastomosis with the lymphatics coming from other organs, form trunks which are called thoracic canals. These open into the subclavian veins, and other large venous trunks in the neighbourhood of the heart. Besides the opening of the lymphatics into the great veins, they are also united at intervals with the veins of the intestinal canal, which anastamosis more particularly happens, among the mammifera, in the mesenteric glands, as Fohmann(8) has demonstrated. In fishes, reptiles, and birds we also observe a vast number of communications between the lymphatics of the intestinal canal and other parts of the body, and different veins, without reckoning those which the thoracic canals form. The lymphatics of the intestinal canal are chiefly filled, in animals, with an abundant liquid which has a milky colour, in mammifera after the introduction of food into the intestinal canal. We must, therefore, admit that they take from the mucous membrane of the alimentary sac the food that has become liquid, receive it into their cavities, and convey it towards the sanguineous vascular system.

CLXV. Lymphatics are found in the mammifera, not only in the intestinal canal, but also in all the organs whose interior is lined by a mucous membrane, as the lungs, the urinary organs, and those of generation. They have likewise been seen in the external surface of the common integuments or the skin, in the gills of fishes, in the serous and synovial membranes, the different glands, the cellular tissue that envelops the muscular and nervous substance, the external surface of the bones, &c., in short, wherever there is cellular tissue. The phenomena of the absorption of secreted humours, and other fluids placed in contact with these different parts, having been remarked very repeatedly, we are authorized in allowing that the function of absorption belongs chiefly to these vessels.

CLXVI. In other animals having blood vessels, mollusca, crustacea, arachnida, insects, annelida, and radiaria, in whose bodies no lymphatic vessels have hitherto been discovered, the absorption of alimentary matters, at the surface of the intestinal canal, is performed either by veins which have the property of absorbing, or perhaps likewise by lymphatics terminating abruptly in veins. It is true, that it is difficult to show what the arrangement really is, as well from the smallness of the animals, as from their blood not being red, except in the annelida, and consequently, if lymphatics do exist, which are immediately united with the veins, they could not be distinguished from the latter by the colour of the liquid.(9) Very probably we shall attain

(8) Anatomische Untersuchungen über die Verbindung der Saugadern mit den Venen. Heidelberg, 1821.

(9) Viviani (De Phosphorescentia Maris. Geneva, 1805, in 4to, p. 14) saw in the *sabella*

the discovery of lymphatic vessels in the invertebrated animals. Lastly, in animals which have no blood vessels, such as the entozoa, medusæ, and polypi, the cellular tissue alone fulfils the office of absorption, and takes up the alimentary matters of the intestinal canal.

CLXVII. In all animals with naked skins, an absorption of liquid also takes place at the surface of this organ. The experiments of Leuwenhoeck, Baker,(1) Fontana,(2) and Spallanzani(3) have proved that infusoria ratifera, vibriones, &c. absorb water. Polypi, medusa, radiaria, and worms, likewise, absorb rapidly by the skin. Entozoa, which live immersed in animal humours, absorb them by the skin, as Zeder and Rudolphi assert.(4) Spallanzani(5) found that snails absorb an abundance of water, for their weight increases rapidly when they are placed in it. Jacobson(6) has lately made experiments on the absorbing power of the vine-snail (*helix pomatia.*) A solution of prussiate of potass, which was poured on the surface of animals belonging to this species, was absorbed with rapidity and passed into the mass of the blood. The blood can take up such a quantity, as afterwards to acquire a deep blue colour when sulphate of iron is added. The absorption of water by frogs, toads, and salamanders, which takes place by the skin, and especially by that on the lower surface of the body, is shown by the valuable experiments of R. Townson,(7) from which it appears these animals can absorb, by this medium, a quantity of water equal to the weight of their own bodies. Finally, Edwards(8) has certified, by numerous experiments, that a very active absorption takes place by the skin in frogs, toads, and lizards. When these animals have lost much of their weight by a long exposure to the air, where their cuticular transpiration is very active, and are then immersed in water, so rapid an absorption of it goes on, that it very soon makes up the deficiency they had suffered. The absorption of water takes place more rapidly in warmth than cold.

CLXVIII. When we wish to account for the activity with which absorption is accomplished in animals, we meet with the same difficulty which impeded us when speaking of absorption in vegetables. Several physiologists,

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naispiro, Cuv. (Spirographis Spallanzanii, Viv.) besides the two vascular trunks of the intestinal canal carrying blood a third vessel, filled with a yellow liquid, which he calls the *vas lymphaticum*. Is this a lymphatic trunk?

(1) Employment for the Microscope. London, 1764.

(2) Vom Viperngift, v. i, p. 62.

(3) Opuscules de Physique, v. ii, p. 264.

(4) Entozoorum Historia, v. i, p. 252, 275.

(5) Mem. sur la Respiration, p. 137.

(6) Oersted. Oversigt over det kon. Danske Videnskab. selsk Forhandlung, 1825.

(7) Observationes Physiologicæ de Amphibiis. Gœttingen, 1795, in 4to. Pars Secunda de Absorptione Amphibiorum.

(8) Influence des Agens Physiques sur la Vie; de l'Absorption dans l'eau, p. 90, p. 345.

Magendie,(9) Blainville,(1) and Fodera(2) regard absorption as the pure effect of capillarity, and to the cellular and also to the animal tissues they attribute the property of imbibing liquids, acting, as they conceive, in the manner of a sponge. Certainly the cellular tissue, the mucous and serous membranes, the common integuments, and, according to the researches of Emmert and Lebkuchner,(3) the walls of the vessels, possess the property of admitting fluids through them, or being permeable to liquids that are placed in contact with them, a subject to which we shall return in speaking of absorption in man; but this property does not constitute absorption, and only explains the penetration of the tissues. Absorption is also shown by the reception of fluids into certain spaces, namely, into the arteries in the four superior classes of animals, and by the impulse which is given to them in directions equally fixed.

The cellular tissue, as well as the mucous and serous membranes, possess this penetrability as much after death as during life; but this is not the case in the passage of the liquids. Besides, as we behold the reception and propulsion of fluids, during life, vary exceedingly according to the manifestations of activity, or of the life of animals, that absorption is more rapid in early than advanced age, and, finally, that divers influences and excitements are capable of modifying it, we are bound to consider it, as well as the propulsion of the liquids, as a vital phenomenon, and we cannot reckon it among the purely mechanical effects of the capillarity of the tissues.

Absorbing Power.

CLXIX. From the preceding it follows, that all living bodies, plants as also animals, possess the property of absorbing alimentary matters and other liquid substances. We cannot regard absorption as an effect of the capillary action, because it is sometimes more, sometimes less energetic, according to the state of the living individuals and the influences to which these are subjected, circumstances which cause no change in the capillary attraction of bodies not endued with life. We should, therefore, consider it as a manifestation of life, dependent on a special quality, or power of living bodies, since hitherto it has been impossible for us to explain it by any of the other forces whose action goes on in these bodies. This special manifestation shall be provisionally designated by the name of absorbing power or faculty, inasmuch as we have

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(9) Mem. sur le Mecanisme de l'Absorption, in the Journal de Physiologie Experimentale, v. i, p. 1.

(1) Analyse des principaux travaux dans les sciences physiques publiè, 1820.

(2) Recherches experimentales sur l'exhalation et l'absorption. Paris, 1823.

(3) Diss. qua experimentis eruitur, utrum per viventium adhuc animalium membranis atque vasorum parietes materiæ ponderabiles illis applicatæ permeare queant, nec ne? Tubingen, 1819, in 8vo.

not referred it to any other organic power. Its effects will be spoken of in detail, when we are on the subject of absorption in man.

CHAPTER THIRD.

Of the reception of Aliment by the Buccal Aperture.

CLXX. All animals, with very few exceptions, are furnished with one, or even several great apertures, for the purpose of introducing aliment into them. The majority of infusoria, some zoophyta, and various entozoa, have no such openings, and it is probable that their liquid aliments are introduced solely by means of absorption, performed at the surface of the body. However, there are some infusoria that do possess mouths; of these are the ratifera, according to Spallanzani,(4) and some cercaria, according to Nitzch,(5) polypi, the greater number of entozoa, all the echinodermata, annelida, mollusca, insects, arachnida, crustacea, and vertebrata have only one mouth. On the other hand, many suckers are found in teniæ, and several mouths in different medusæ. The mouth, the organ of the ingestion of food, presents a vast number of differences in its arrangement, described in comparative anatomy, and intimately connected with the nature of alimentary substances.

CLXXI. Animals that live in fluids have suckers, whose structure and mechanism vary considerably. A membranous contractile trunk is seen in the aphrodita, among the articulated worms, in some gasteropoda, *(doris, buccinum, voluta, murex,)* among the mollusca, and in the majority of dipterous insects. Butterflies have a long extensible proboscis, which can be rolled up by muscles when the animal is not making use of it, *(lingua spiralis.)* In insects and arachnida, which suck their liquid nourishment from the vessels of living vegetables and animals, the proboscis is furnished with pricking organs, fit for perforating these ducts, as we see in the aptera, *(pediculus, pulex, acarus,)* hemiptera, and others. In some diptera, *(culex, tipula,)* the trunk is composed of several hard bristles, concave in their internal surface, which form a sucker *(haustellum)* when closely collected together. In diptera and butterflies, furnished with a muscular proboscis, we perceive moreover an extensible and contractile vesicle, which communicates with the pharynx, and whose dilatation produces the suction, as G. R. Treviranus has shown.(6)

Animals that are nourished with solid food sometimes introduce it in large masses into the alimentary sac by a very extensible and contractile buccal aperture, as the polypi, actinia, asteria, holothuria, &c.; sometimes they

(4) Opuscules de Physique, v. ii, p. 212.
(5) Beiträge zur Infusorienkunde. Halle, 1817, p. 8.
(6) Ueher das Saugen der Insekten; in Annalen den Witterauer Gesellschaft, v. iii, p. 147; Vermischte Schriften, v. ii, p. 95.

have horny or calcareous parts, bills and jawbones, placed around the mouth, capable of movement in several directions by means of muscles, of which they make use to seize their food as if with forceps. This arrangement exists in sea hedge-hogs, sepia, coleoptera, orthoptera, neuroptera, and vertebrated animals. The jaws are commonly furnished with teeth, as in the majority of mammifera, reptiles, and fishes; or else they are covered with a horny coat, as in birds and tortoises. Lastly, mammifera exhibit, about the jawbones, moveable folds of skin, the lips, which may also assist in suction.

CLXXII. In animals, the ingestion of food by the mouth takes place at certain periods, separated by longer or shorter intervals, whilst in plants the absorption of alimentary matter seems to go on in a continuous manner. Further, animals, as soon as they have broken though the membranes of the ovum, if we may judge by what they enact, are forced, by an internal action going on in the nervous system, and called a necessity for food, or hunger and thirst, to seek matters for their nutrition, and introduce them into their alimentary sac. Plants exhibit no phenomenon which can allow us to admit, with any show of probability, the existence of this inclination in them. It is the necessity for food which most powerfully impels animals of all classes to action and motion. This necessity is renewed at longer or shorter intervals, the period varying according to the structure of the animal, its manifestations of activity, its age, habit at the season, and other circumstances. In general, warm-blooded animals, mammifera, and birds, which have the most complicated organization, and present greater variety and intensity in the phenomena of life, especially in reference to the animal functions, feel, at shorter intervals than others, the necessity of eating. At the period of their full and entire activity they commonly eat once or several times in the day. The necessity for taking food returns less frequently in cold-blooded animals, reptiles,(7) fishes, crustacea, arachnida, insects in their perfect state, mollusca, worms, and radiaria, whose manifestations of activity possess both less energy and diversity. Among these animals, the most voracious are those which have the greatest degree of mobility, as insects. By the experiments of Redi, it has been proved, that the mammifera, birds, and insects sink from want of food more than reptiles fishes, mollusca, worms, &c.

CLXXIII. In all animals the necessity for food is most vehement and frequent at the period of youth, or of development and growth, and the more so as the growth itself is rapid. Young mammifera and birds are almost continually engaged, when awake, in seeking for food. As soon as insects, especially caterpillars, leave the ovum; they eat almost incessantly. Young

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(7) A serpent, sixteen feet long, observed by Prout, (Thomson's Ann. of Philos., v. 5, p. 443,) only ate once a month.

animals, too, perish more quickly than old ones when they are in want of food. Several insects, particularly the lepidoptera, take no nourishment whatever in their perfected state.

Animals that live in the air consume, in general, more aliment than those residing in water. In the greater number of animals, heat likewise greatly influences the necessity for food. Many mammifera, the marmot, the dormouse, hedgehog, the cheiroptera, and others, reptiles, insects, and mollusca, cease to take any nourishment as soon as the temperature approaches zero, and their vital manifestations are diminished in energy from this cause.

Lastly, all the influences and circumstances which exalt or accelerate the phenomena of life in animals, render the movements stronger and more prolonged, augment the tension of the organs of sense and of the nervous system, and cause a larger consumption of the powers, generally increase the necessity for nourishment, whilst those influences which produce a contrary effect lessen this necessity.

CLXXIV. Animals do not take indiscriminately by the mouth, as plants do by their roots and leaves, whatever food is presented to them. They select from them, and in this also they are determined by a special action of the nervous system, an inherent inclination—instinct. Of this we have a proof in an experiment made by Galen.(8) This physician took a full-grown fœtal kid from the womb of its mother and placed it in a spot where vases stood containing milk, honey, oil, corn, and fruits; the young animal smelled at the vases, and chose the milk. The instinct which determines animals in the choice of aliment varies infinitely according to their organization and the degree of vital energy in the nervous system. Animals seem to take only those substances which have an agreeable effect on their nervous system, either by vaporous exhalations, or by effluvia communicated to water. It cannot be denied that smell plays the chief part in the regulation of the action which these effluvia exert on the nervous system. In animals of the inferior classes that have no olfactory organs, the soft and eminently nervous membrane which lines the mouth appears adapted for perceiving and discriminating the impressions of the effluvia.

CLXXV. The ingestion of food by the mouth is accomplished by movements which animals perform spontaneously. The muscles attached to the mouth are put into action by the living influence of the nerves. Hence it follows, that this ingestion is performed by particular manifestions of power, that we do not observe in plants in the attraction of aliment by the roots and leaves. These manifestations are the effects of the nervous and muscular power.

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(8) De locis affectis. Lib 6, c. 6.

CHAPTER FOURTH.

Of the Assimilation of Aliment in the first Passages.

CLXXVI. In all living bodies, the alimentary substances, after their reception into certain localities, undergo changes, the design of which is to render them similar to the mass of humours in these bodies. This is what is understood by assimilation in the first passages. We shall consider first in plants and then in animals, the operations that refer to it.

1. Assimilation in the first Passages in Plants.

CLXXVII. The liquids absorbed by the roots, and constituting the sap, rise along the stalk or trunk to the leaves, where, by the influence of the air and light, they are converted into the proper formative or nutritive juice. Let us sketch shortly the structure of the stalk, point out the spaces in which the vegetable juice moves, and finally examine the nature of this juice, as also the changes it undergoes in its ascent to the leaves.

CLXXVIII. In adopting the determinations of Decandolle,(9) we perceive, that all vascular plants are furnished with a stalk, (caulis,) that is, with a part arising from the root, verging towards the light, bearing leaves and flowers, and varying considerably, as well in its proportions as in its forms. There is but a small number of vegetables in which it is very short and concealed under ground. The excellent remarks of Desfontaines(1) have certified the fact, that in monocotyledones and dicotyledones, it presents differences in regard to structure, nature, mode of origin, and growth. It has a less complicated organization in the former than in the latter.

CLXXIX. The stalk of trees and shrubs is composed of the ligneous body and bark. The former, in its ascent, is extended into branches and twigs, and is formed of concentric layers. Each layer contains bundles of ligneous fibres, and a thin layer of cellular tissue. In the centre of the stalk, the cellular tissue almost always represents the spongy pith, composed of a great number of membranous and rounded cells, which is sometimes continued uninterruptedly in the trunk and branches, commencing at the root, and sometimes, as in some trees, is divided by partitions corresponding to the annual shoots. On the external surface of the medullary canal, sometimes in the pith itself, isolated fibres are perceived in some vegetables.(2) The functions of the pith, on which physiologists have built many hypotheses, are

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(9) Organographie vegetale, v. i, p. 142.
(1) Mem. de l'Institut. Nation, v. i, p. 478.
(2) Hedwig mentions them as *vasa fibrosa;* Decandolle calls them *fibræ medullares.* These fibres, and not the cells of the pith itself, are sometimes coloured, according to the researches of Labaisse, when the young branches are immersed in coloured water.

not yet well known. It appears, however, to play an important part, especially in young plants, where it is filled with juice, and where it contains, perhaps, the nutritive matters intended for the buds and young shoots, as Decandolle and Du Petit Thouars(3) assert. In aged plants it is sapless and dry, and can then be destroyed without endangering the life of the subject. Horizontal rays of condensed cellular tissue proceed from this pith, which passing between the ligneous bundles, reach the circumference and bark, thus forming the medullary rays.

After the central pith come the ligneous layers, which are concentric and united by condensed cellular tissue. The layers situated directly over the pith contain almost all the spiral vessels, whereas in the succeeding layers perforated vessels alone are found. The outermost are soft, tender, have but little density, and are mostly whitish. They constitute the alburnum, which, gradually hardening, becomes wood. A new layer of alburnum is formed annually, whence result the concentric circles observable in wood, the number of which indicates the age of the plant, and the thickness the energy with which it has shot forward each year.

CLXXX. The bark, or cortical body, forming the covering of trees and shrubs, is composed of the cortical substance, for the most part green and succulent, and of the hardened epidermis. The former is the product of many other superposed layers, each being successively converted into an internal fibrous and an external cellular layer. Between these layers, medullary rays similar to those of the ligneous body, only less distinct, are spread. Each year a new layer is formed on the internal surface of the bark. The name of *liber* is given to the soft and tender layers. It is in the internal soft and succulent layers of the cortical substance that the nutritive vessels which contain the sap already elaborated in the leaves under the influence of air and light, and which distribute it through the body of the plant, as Schultz has shown, appear to be found. Lastly, extensive and particular spaces are frequently met with in the cortical layers, filled with different secreted matters, and called reservoirs of the peculiar juices. The cellular tissue, situated on the external cortical layer, made up of an assemblage of rounded cells, and exposed to the air and light, is condensed and hardened, whence arises a coloured epidermis. The existence of this epidermis is, however, only capable of confirmation in the young branches, and green shoots of trees and shrubs, as L. C. Treviranus has pointed out.(4) In old vegetables the exterior layers of the bark gradually acquire a deeper colour; they crack, burst, die, and are separated from the trunk, in proportion as they are pushed out by the

(3) Essais sur la Vegetation, v. i, p. 52.

(4) Ueber die Oberhaut der Gewächse; in Vermischten Schriften anatomischen und physiologischen Inhalts, vol. iv, p. 1.

growth of new layers forming underneath, and as the narrowness of their calibre renders them unable to contain such layers.

CLXXXI. The stalk, bearing branches, leaves, and flowers, which comes forth and dies, either altogether, as in annual herbaceous plants, or only to the neck of the root, as in perennial herbaceous plants, in the course of the same year, is likewise formed of a ligneous and cortical system. The bundles of wood, or ligneous fibres, situated internally, and which, almost always, include the pith or a medullary canal filled with air, contain the spiral vessels arising from the root. These bundles are united by cellular tissue, in which intercellular ducts exist. The nutritive vessels proceeding from the leaves are found in the bark, which is commonly green and succulent, and is made up of an assemblage of fibres united by cellular tissue. The green and fleshy stalk of the cactus and stapelia filled with the substance of the leaves, likewise performs their office and is furnished with pores.

CLXXXII. The stalks of monocotyledones, which vary according to the families, generally differ from that of dicotyledones, inasmuch as they present more of a homogeneous mass, being never composed of a distinct ligneous and cortical body, growing in the inverse ratio of each other. Neither do they contain medullary rays. In them the oldest fibres are situated externally and the youngest internally. The transverse scission of palm trunks only shews scattered longitudinal fibres united by cellular tissue, the most external of which are hard and of a compact texture, whilst the internal are, on the other hand, soft and similar to the alburnum. Each bundle of fibres contains spiral and perforated vessels united by cellular tissue. The stalk *(culmus)* of gramineæ is distinguished by being composed of more or less numerous segments, united by swellings or knots, from which sheathing leaves proceed. These interknots are composed of longitudinal and parallel fibres, inclosing a loose cellular tissue. In the knots these fibres are pressed together and interlaced in the horizontal direction, so that the canal filled with pith is interrupted by transverse partitions, &c.

CLXXXIII. The stalk of cellular plants, when it does exist, as in mosses (surculus), some lichens (thallus, podetium,) and a few mushrooms (thallus, peridium, cormus), is composed solely of a homogeneous cellular tissue, even without bark. The cellular tissue sometimes contains elongated cells or sacciform cavities. In most hepaticæ (marchantia, riccia) nothing is seen but a leafy disk (frons,) which fulfils at the same time the office of stalk and leaves, and is composed only of rounded and oblong cells. Water algæ exhibit an union of small sacs. All these plants are without the true epidermis, the development of which only commences with the mosses.(5) In cellular

(5) L. C. Treviranus, Von der Oberhaut der kryptogamischen Gewächse; in den Vermischte Schriften, vol. iv, p. 54.

vegetables, the liquid absorbed either by the root or the capillary prolongations situated at the bottom of the thallus, or by the surface, arrives at the cellular tissue, and rises into the sacciform spaces. The ascent of coloured liquids along the stalks is frequently very easily seen in mushrooms. This phenomenon is also perceived in ulvæ, fuci, lichens, and mosses. It is in the cellular tissue that the assimilation of the sap and its conversion into the proper substance of the vegetable is performed.

CLXXXIV. In vascular plants, the liquids absorbed by the roots traverse the stalk or trunk, the branches and twigs, to arrive at the leaves. This is proved by the fact that if incisions be made down to the wood, in the spring, at different altitudes, on the stalk of trees or shrubs, the sap flows first from the lower and afterwards from the upper ones. Duhamel and Bonnet, also, saw, in their experiments on coloured liquids placed in contact with the roots, that they made their appearance gradually from below upwards. But physiologists are divided regarding the facts that regulate the progress of the sap. Some admit that the sap rises through the ligneous body; others think it is the alburnum that contains the sap vessels; and others again maintain that the ascent goes on at once in the pith, the wood, the alburnum, and the bark. The first opinion, that the sap rises in the ligneous body of trees and shrubs, and in the ligneous bundles of herbs and gramineæ, is every day becoming more and more probable, and the following reasons are quoted in its favour:

1. It is proved by Coulomb's,(6) Knight's,(7) Wahlenberg's,(8) Walker's,(9) and other experiments, that in spring the wood, ligneous bundles and alburnum, contain a vast quantity of sap, which arrives by degrees at the leaves from the roots, passing through the stalk, the branches, and twigs.

2. The experiments of Magnol,(1) Labaisse,(2) Duhamel,(3) Bonnet,(4) Reichel,(5) Comparetti,(6) Knight, Cotta,(7) and others, on coloured liquids placed in contact with roots or cut branches, show that these liquids are spread over the wood, and even frequently reach the veins of the leaves and flowers.

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(6) Experiences relatives à la circulation de la seve dans les arbres, in Mem de l'Inst. Nat. des Sc., vol. ii, p. 246—Rozier's Journal de Physique, vol. xlix, p. 392.
(7) Philos. Transactions, 1801, p. 36—1808, vol. ii, p. 313.
(8) Magazin der Naturf. Gesellsch. in Berlin Jahrg. 6, quart. i, p. 25.
(9) Transact. of the Royal Society of Edinburgh, vol. i, p. 3.
(1) Mem. de l'Acad. de Paris. 1709, p. 105.
(2) Sur la circulation de la seve des plantes. Bordeaux, 1733, in 8vo.
(3) Physique des Arbres, vol. ii, p. 286.
(4) Recherches sur l'usage des feuilles, p. 212.
(5) De vasis plantarum spiralibus. Leipsick, 1758.
(6) Prodromo, p. 60.
(7) Natur Beobachtungen über die Bewegung und Function des Safts in den Gewächsen. Weimar, 1806, in 4to.

3. It has been sufficiently demonstrated that trees come into leaf even after their bark, both outer and inner, has been circularly cut down to the wood.

As the wood of trees and the ligneous fasciculi of herbaceous plants are chiefly composed of spiral vessels reaching from the root to the leaves, and passing through the trunk, branches and twigs, as these vessels probably form a cavity which is uninterruptedly continuous, and which especially contain the colouring matters in all experiments made with coloured fluids, it is very likely that the sap rises with them, as Ray, Labaisse, Duhamel, Bonnet, Reichel, Schwagerman, Knight, Link, G. R. Treviranus,(8) Dutrochet,(9) Schultz,(1) and others, believe. Kieser, Amici,(2) Decandolle,(3) and some others think, on the contrary, that it rises by the intercellular ducts, and admit that its progression is caused by the cellular tissue, which has the property of imbibing liquids.

CLXXXV. The sap, which rises from the roots in great quantity, especially in spring, and less abundantly in summer, or the lymph, as Duhamel called it, has hitherto been gathered from the perforated trunks of trees. That of the birch, of the beech, the maple, the elm, the vine, &c., is, according to the researches of Hales,(4) Deyeaux,(5) Vauquelin,(6) Proust,(7) and Scherer,(8) a colourless and limpid fluid, having a specific gravity a little greater than water. It has a sweetish taste which tickles the tongue. It always contains an acid, frequently a free one, which is the carbonic or acetic. The former, from the observations of Coulomb,(9) is often disengaged in the shape of bubbles at the time the sap flows from the wound in the tree. The acids are mostly combined with lime or potass. Different vegetable matters, sugar and mucus, are also found in the sap. The quantity of sugar contained in the sap of the maple (acer saccharinum) amounts to about five or six per cent. of its weight. Albumen, also, and a substance analogous to gluten, are met with in the sap. It does not appear that organic forms, globules, have been as yet seen in it; at least G. R. Treviranus(1) and Schultz(2) have not perceived

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(8) Biologie, vol. iv, p. 20. Ueberdie Gefässe und den Bildungsaft der Pflanzen; in Vermischten Schriften, vol. i, p. 145.

(9) Recherches sur la structure vegetale. Paris, 1824.

(1) Die Natur der lebendigen Pflanze, vol. i, p. 483.

(2) Osservazioni microscopiche.

(3) Organographie vegetale, vol. i, p. 28.

(4) Statique des Plantes.

(5) Mem. sur la seve des plantes et principalement sur celle de la vigne et du charme, avec une analyse de ce fluide; in Mem. presentès á l'Instit., vol. i, p. 83. He examined the sap of the birch (carpinus betulus.)

(6) Experiences sur les seves des vegetaux. Paris, An. 7 (1789,) in 8vo.; Ann. de Chimie, vol. xxxi, p. 20. He examined the sap of the ulmus campestris, fagus sylvestris, carpinus sylvestris, betula alba.

(7) Annals of Philosophy, vol. i, p. 109. He analysed the sap of the vine.

(8) Schweigger's Journal, vol. iv, p. 362, contains an analysis of the sap of the acer campestre.

(9) Journal de Physique, vol. xlix, p. 392.

(1) Vermischte Schriften, vol. i, p. 155.

(2) Natur der lebenden Pflanze, vol. i, p. 466.

them. Schultz says he only discovered some vestiges of them in sap taken from a considerable height up the stalk. The collected sap passes into fermentation under the influence of atmospheric air; carbonic acid gas is disengaged, the mixture becomes thick, whitish flakes are precipitated, and the liquid turns sour. If it contain much sugar, vinous fermentation ensues. It is not only trees that contain sap in the spring, but a similar liquor is also found at the same period in the ligneous fibres of other plants. It is exceedingly abundant in palm trees, among the monocotyledones. The sap of herbs has not yet been examined in a pure state. The analysis of the juices obtained from different plants by expression can furnish no certain conclusion, because the sap procured in this manner is mixed with other fluids.

CLXXXVI. The crude nutritive matters which the roots absorb appear to undergo a certain degree of assimilation by their mixture with a liquid, secreted by the radical fibres. What proves that a secretion of this kind takes place in the radicles of hyacinths, tulips, and other bulbs that are immersed in water is, that they are surrounded by a mucilaginous or albuminous fluid, which Duhamel, Bonnet, Senebier, and others have described. The liquid which the roots of a plant shed into the soil, seems even to hurt the vegetation of other plants, in support of which fact Brugmans(3) and Mirbel (4) have brought forward observations.

The sap is further assimilated as it ascends higher up the stalk. According to the researches of Knight(5) and Wahlenberg,(6) the specific gravity augments in the ratio of its elevation. At the same time it contains more muco-saccharine matter. The sap of the maple taken from the upper part of the trunk is more rife of sugar than that which comes from the lower part. But a profound obscurity as yet reigns over the mode in which this assimilation is effected, and how the matters which the roots absorb together with water, acquire by degrees the qualities of sugar, mucus, albumen, and an azotized substance analogous to gluten. On this point, Knight has ventured an opinion which appears probable; he thinks that annual plants, being arrived at the limit of their development, deposit, at the end of summer, the superfluous nutritive matters in the alburnum and roots, where it remains until the following spring, at which period it is combined with the new ascending sap, whose assimilation it effects by mixing with it. The non-perennial plants proceeding from seeds, bulbs or tubercles, already contain in these organs sufficient nutritive matter for their development, added to their germ by the vegetables whence they proceed. Lastly, in both groups of vegetables it

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(3) Coulon, Diss. de mutata humorum indole a vi vitali derivanda, p. 77.
(4) Phys. Veget., v. i, p. 148.
(5) Philos. Transac., 1803, v. 1, p. 90, 1805, v. 2.
(6) De sedibus materiarum immediatarum in plantis. Upsal, 1806, 1807.

appears that a part of the cambium, prepared by respiration, passes directly from the nutritive vessels into the sap, to the assimilation of which it contributes. Without this addition it cannot very well be seen how the sap could be assimilated in the course of its ascent from the roots to the branches and twigs.

2. Assimilation in the first Passages of Animals.

CLXXXVII. The aliments of animals, although of a more simple kind, and a composition approaching nearer to that of the beings they nourish than the food of vegetables does, do not on that account pass immediately into the mass of solid parts. Previously to being adapted for this purpose, they are obliged to undergo certain changes, which vary according to the organic complication of animals, as also according to the sum and energy of the manifestations of activity they exercise. In the most simple animals, that are formed of an homogeneous substance, of mucus, as the majority of infusoria, the reception of aliment seems to take place only at the surface of the body, by absorption. As soon as the alimentary matters have reached their substance, they are immediately assimilated, and capable of answering the wants of nutrition, because there are no particular organs set apart for the accomplishment of assimilation. In other animals there is a special cavity, the alimentary sac or intestinal canal, in which the aliment is assimilated after its ingestion. Plants do not possess this receptacle for food, which Aristotle considered as an animal characteristic.

CLXXXVIII. The alimentary sac and the organs attached to it are called the digestive apparatus. This apparatus exhibits an astonishing diversity in the different groups of animals with respect to arrangement, to structure, and the number of organs entering into its composition. We remark in general, that from its first appearance in some infusoria and in polypi up to warm-blooded animals, birds, and mammifera, that is to say, the classes of medusa, entozoa, radiaria, annelida, mollusca, insects, arachnida, crustacea, fishes, and reptiles, it is so much more complete, more rich in diversity of parts, in short more developed, as the manifestations of activity possess more energy and diversity, and as the necessity for food is felt at shorter intervals. We cannot be mistaken in the fact that the complication of the digestive apparatus has close connexion with the development of the nervous system, of the organs of locomotion, and of the number of the organs of the senses. The manifestations of activity of these organs especially contribute to hasten the consumption and renewal of matter which obliges the exercise of life. Consequently, the more the phenomena of animal life are multiplied and strong in animals, the greater necessity is there for a powerful and well pronounced action of the digestive apparatus for the preparation of new materials to preserve the organs of animal life, and to maintain their uninterrupted play.

Moreover, we remark that the complex nature of the digestive apparatus has an intimate connexion with the nature of the very aliment with which instinct impels animals to nourish themselves. Those which subsist on liquids have a less complex digestive apparatus than those whose nourishment is composed of solid food. The harder and more distinct are the aliments from the nature of the body which they are to maintain, the more complex are the organs of digestion. On the contrary, the softer and more similar the food is to the animal in point of composition, the more simple also is the structure of the assimilating organs. This is the reason why these organs are more complex in animals living on plants and chiefly on raw herbs, than in those which are nourished by animal food.

By referring, therefore, to these different circumstances, we may determine, à priori, whether the digestive apparatus of an animal is simple or complicated.

CLXXXIX. The alimentary sac of the most simple animals, of those which are composed of a gelatinous homogeneous substance, represents a simple cavity, included in the mass of the body, neither figured nor limited by particular membranes, and to which an aperture called a mouth conducts.—Nitzsch(7) observed, in cercaria, a sucker leading to a branched vessel, which was lost in the substance of the body. From the observations of Spallanzani(8) and Dutrochet,(9) it follows that rotifera have an extensible and contractile buccal opening, leading to a sac shaped like a stomach, into which they take infusoria. In polypi, as well of fresh water, hydra, as of the sea, which form corals, there is likewise only a ventral sacciform cavity, with an aperture by which they take in other small aquatic animals (which they seize with their arms,) and eject the indigested remnants of their food; whence it follows that this aperture serves at once for mouth and anus. In polypi living on a fixed and common coral-trunk, also in pennatulæ, we almost always see a small canal proceeding from the ventral cavity of each polypus, and traversing its pedicle, to reach the common mass, so that the nourishment of each individual is profitable to the entire trunk.(1) The medusa exhibit differences in regard to the organs of digestion. In one division of them, which Peron(2) called agastric (medusæ agastricæ, eudora, berenice,) absorbent vessels alone

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(7) Beiträge zur Infusorienkunde oder Naturgeschichte der Cercarien und Bacillarien. Halle, 1817, p. 8.

(8) Opuscules des Physique, vol. i, p. 214.

(9) Sur les Rotiferés (Furcularia et Tubularia Lam.,) in the Ann. du Museum d'Hist. Nat., vol. xix. p. 355. It is very doubtful, however, whether a short intestinal canal proceeds from this cavity, and terminates by a particular anal aperture.

(1) Cavolini (Loc. cit., p. 56, 91) saw these canals in the sertiolaria filled with a milky fluid, in which were small granules that were in motion.

(2) Annales du Museum, vol. xiv, p. 325.

exist, spreading in a radiated manner from the middle of the internal surface of the animal throughout all its substance. In others again, a spacious ventral cavity is observed in the midst of the body, to which many absorbent canals sometimes lead, as in Cuvier's Rhizostoma; at other times it ends in a large buccal aperture, often prolonged into a tube, as in medusa properly so called. The stomach sometimes has lateral dilations or cul-de-sac appendages, as in the cyanæa of Cuvier, and from this organ or these appendages vessels proceed, which ramify towards the periphery or disk of the animal, and convey the nutritive juice. The actinia (actiniæ, zoanthes, Cuv. Lucernaria Müll.) have a large ventral cavity, to which a spacious buccal aperture leads, by which different marine animals are introduced, as crustacea, mollusca, and small fishes, whose soft parts are rapidly dissolved, whilst the hard, that are not digested, are ejected by the same opening. Among the radiaria a similar arrangement is found in the asterias, in which there is likewise only one large mouth, situated in the centre of the lower surface of the animal, and leading to a spacious sac, whence ramose and cul-de-sac appendages proceed, which enter into the rays. By means of their tentaculi, and frequently by turning their stomach inside out, they seize on marine animals, actinia for instance, which they rapidly digest and eject by the mouth the parts that are insoluble in the digestive juice.

CXC. The arrangement of the organs varies exceedingly in the entozoa, which exhibit such diversified forms in reference to the degree of organic complication. The cavity intended to receive the aliment is sometimes arranged as a vessel, and sometimes as a true sac. The vasculiform intestinal canal proceeds from apertures or bulgings, performing the office of suckers, and consists of simple canals, which traverse the body longitudinally, as in worms of the bladder (echinococcus, cœnurus, cysticercus;) or else four canals coming from four suckers are united into two tubes, as in the tenias, and traverse all the links, in which they are mostly connected by a transverse canal; or lastly, the vessels, proceeding from the sucking mouths, ramify throughout the body, frequently anastomosing with each other, as in sucking worms (polystoma, tristoma, distoma, amphistoma.) Round worms have a sacciform intestinal canal, sometimes provided with a single opening, as in filaria; sometimes with a distinct mouth and anus, as in the genus ascaris, oxyurus, cucullanus, &c.

CXCI. In other animals, whose organization is more complicated, the holothuria and sea hedgehogs among the radiaria, annelidas, mollusca, insects, arachnida, crustacea, fishes, reptiles, birds, and mammifera, the alimentary cavity presents a sac of various length, formed of several superposed membranes, and is called the intestinal canal. An aperture, situated at the forepart of the animal's head, the mouth, leads to this sac, which terminates by another aperture, almost always situated at the opposite extremity of the body, the anus, through which the undigested remnants of the elements, mixed with excrementitious humours, are ejected. The basis of the intestinal canal is a cellular membrane, well supplied with vessels and nerves, lined on its internal surface by a membrane secreting mucus. Externally this cellular membrane is covered by a muscular tunic, composed of longitudinal and circular fibres. Finally, the greater part of the intestinal canal is covered by a serous membrane. The mucous membrane of the alimentary sac frequently describes folds and valves, which cause the retention, during some time, of the ingested aliment in different portions that are the most extensive; while in consequence of the stimulating power which the alimentary matters exert on it, the mucous membrane secretes fluids that have a solvant and stimulating influence on the food. At the surface of this membrane the absorption of liquified aliment also takes place. Excited to contraction by the alimentary substances, it forces them along the intestinal canal. Lastly, the serous coat, enveloping the alimentary sac, placed in a particular cavity of the body, the peritoneum, approaches in plates and folds, the mesenteries and epiploons towards the canal, with the mucous membrane of which it is united by its external surface. On one hand, the peritoneum forms attachments for the alimentary canal, and on the other, by the liquid it secretes, or the peritoneal serosity, it favours the vermicular and automatic movement of this organ.

The mucous and muscular tunics vary considerably in animals, in regard to their arrangement, and it is chiefly on the modifications they exhibit on this score, that the differences existing in the alimentary sac, and which comparative anatomy exposes, depend. They produce projecting valves and constrictions, which divide the canal into compartments, as the stomach and the small and large intestines, in which alimentary matters remain some time, in order to undergo particular changes by the action of the digestive juices secreted therein.

CXCII. The most general action which the intestinal sac exerts, in animals that have one, on food admitted within it, is the secretion of fluids which the stimulus produced on its internal surface, by the presence of foreign matters, provokes. These juices have a dissolvant and liquifying influence on the aliment, whose assimilation they at the same time effect by mixing with it.—In all animals, from polypi to the mammifera, we behold aliment endued with any consistence, become softer, pulpy, and finally liquid, in consequence of its stay in the alimentary sac. The agent by which the digestive juices effect the solution is partly the water they contain, and in which a great number of simple organic combinations, composing alimentary matters, as albumen in its uncoagulated state, gelatin, sugar, vegetable mucus, and starch, are soluble.

It also partly consists in the acids, particularly the acetic and hydrochloric, which the gastric juice of mammifera, birds, reptiles, fishes,(3) and probably, also, other animals, contain, by which the other organic compounds, such as solid albumen, fibrin, cheesy matter, gluten, &c., are dissolved. The vegetable and animal food, composed of more or fewer of these simple combinations are by these means reduced to a state of solution.

In all animals, even polypi, the aliment is kept in motion by the re-action which the contractile walls of the sac produces at the time of their contraction, from the stimulus which the food occasions. The matters dissolved and moved by the digestive sac are absorbed by its internal surface, whilst the insoluble parts are ejected, as indigestible, either by the mouth or anus.

CXCIII. In the majority of animals that take solids, and in which it is necessary for their preservation that the act of digestion and assimilation should go on with rapidity, nature has moreover joined to the alimentary sac different organs, whose movements or secretions assist in the preparation of the nutritive juice. To this class belong the organs of mastication, and different glands which secrete liquids, and pour them through canals into different portions of the alimentary sac, as the saliva, the pancreatic juice, and the bile. We shall only point out in a preliminary manner the part they take in the work of assimilation.

CXCIV. Animals that live on food still organized, or even still living, possess organs for the destruction of its organization and life. These are the masticatory organs, which vary more than any other part of animal organization in regard to the parts entering into their composition, to their number, form, arrangement, and connexions. They exhibit at the same time, in the different classes, orders, genera and species, such prominent and constant peculiarities, that zoologists have used them as characters adapted to the division of animals. These organs are found in mammifera, birds, reptiles, fishes, crustacea, many insects, especially the coleoptera and orthoptera, in the cephalopoda and several gasteropoda, in the mollusca, in the nereides among the annelida, and even in sea hedgehogs among the radiaria. They consist of bones attached to the cranium, or of calcareous or horny pieces called jawbones and bills, to which muscles are fixed that move them in different directions. In mammifera, reptiles and fishes, with very few exceptions, the jawbones are furnished with hard parts, denominated teeth. These also vary, ad infinitum, according to the nature of the aliment animals use. The teeth of carniverous animals are mostly sharp, cutting, angular or hooked, for the purpose of seizing and slaying animals. Herbivora, on the contrary, have smoother teeth, which admit of their crushing and grinding their food. Instead of teeth, the

(3) Tiedemann und Gmelin. Versuche über die Verdauung. Heidelberg, 1826, in 4to.

jaws of birds and tortoises are furnished with a horny covering, called a beak. The movements of the jaws, likewise, exhibit differences. In mammifera, birds, amphibia, fishes, cephalopoda, and many gasteropoda, they move perpendicularly; whereas their motion is in an horizontal manner in crustacea and crabs. In the class mammifera, among the carnivorous species, the food is torn and crushed by the elevation and depression of the lower law. In animals that divide their food by gnawing with scissor-shaped teeth, the lower jaw is moved from behind forward, and vice versâ. Ruminantia, that feed on herbs and very tough substances, move it laterally, which allows them to crush the matters seized between the teeth. Lastly, in apes and pachydermata, that live on various kinds of food, the lower jaw moves in several directions at once.

CXCV. The movements the masticatory organs execute when obeying the orders of the will, extinguish life in the aliment, if it possess it, and destroy more or less their organic texture, without which processes they would resist the solvant action of the digestive juices. The division of the food into small pieces also renders it fit to be carried into the alimentary sac by the vermicular motion. It likewise allows the solvant substances to penetrate and liquify it with greater facility,

Animals differ essentially, in these movements, from vegetables, which are nourished only by dissolved organic combinations more or less decomposed, which they take by absorption. As vegetables never take living food, they never have either living power or organic texture to overcome in the work of assimilation, the sole end of which is to change the innate affinities of liquid aliment. Animals on the contrary, which feed on animal and vegetable substances, have first of all to put down the resistance of life and of the organization of solid parts, and it is only after having accomplished this, that they are capable of modifying, by their digestive juices, the affinity of organic matters. In this respect, therefore, the act of assimilation is more complex in animals than vegetables.

CXCVI. It is worthy of remark moreover, that some animals which have no masticatory organs to divide their food and reduce it to a pultaceous mass, possess in the sac itself, organs by which they are able to soften it so as it shall be penetrated by the digestive and solvant juices. Thus, in the armadillo (manis) which lives on insects, we find an exceedingly muscular stomach, by whose powerful contractions the nourishment is crushed. Granivorous and insectivorous birds are furnished with a very strong muscular stomach, the internal surface of which is callous and crushes the aliment, which action they favour by swallowing small stones. An analogous stomach is met with in the crocodile. There is a similar one, in the class mollusca, in the onchidia, and in the class annelida, in the aphrodita. Lastly, the stomach of some animals, is fortified with hard calcareous or horny parts, which attenuate the food, as in the beetle, (blatta) the dytiscus, forficula, locusts, and others, in the class of insects, and, among the mollusca, the bulla, the aplysia, and the nereides among the annelida.

CXCVII. Finally, the different humours, such as the spittle, the pancreatic juice, and the bile, which certain organs obtain from the nutritive fluid of animals, and mix with the food in different portions of the intestinal canal, are of the first importance in the act of assimilation.

In the first place, regarding saliva, this liquid is mixed in many animals with the aliment received into the mouth. Glands which secrete it are found in all the mammifera, (cetacea, probably, not excepted,) birds, and reptiles, among which last they are particularly large in serpents. Hither we must refer, also, the glands that secrete a poisonous humour in many ophidia, and which communicate with the inside of the poisonous fangs.(4) In the class of fishes there are several that have glands analogous to the salivary ones. Of this kind are, among others, according to Rathke,(5) carps, eels, pikes, siluri, &c. Spallanzani(6) also considered the liquid secreted by the internal surface of the pharynx in carps, barbels, and pikes, analagous to saliva. Among the mollusca, salivary glands exist in the cephalopoda, pteropoda, (clio,) and some gasteropoda, (limax, helix, doris, aplysia, tritonia, onchidium, bulimus, murex, &c.) (7). Insects have organs in the shape of a sac, which secrete the spittle, and open into the buccal cavity. Ramdohr,(8) Posselt,(9) G. R. Treviranus,(1) Rengerr,(2) Leon Dufour,(3) and others found these vessels in butterflies, bees, most diptera, libellula, cicada, many hemiptera, orthoptera, and some coleoptera, in different aptera, (pulex,) lastly, in spiders, scorpions, and centipedes.

The saliva, a watery fluid, for the most part slightly alkaline, is composed, in the mammifera, of water, a peculiar animal matter called salivary matter, of mucus, ozmazome, perhaps a little albumen, and several salts. In some animals it also contains the sulpho-cyanuret of potassium. Its effects on the food are various. By the water and carbonates, acetate and hydrochlorate of potass and soda it contains, it assists in softening and dissolving the alimentary matters. It likewise destroys the phenomena of life in the food,

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(4) Fontana, Traité sur le venin de la vipère. Florence, 1781, in 4to. T. H. Smith, on the Structure of the Poisonous Fangs of Serpents, in the Philosoph. Transact. for 1818, v. i, p. 471.

(5) Ueber den Darmkanal und die Zeugungsorgane der Fische. Halle, 1824, in 4to, p. i.

(6) Versuche über das Verdauungsgeschaft, p. 41, 49, 71.

(7) Cuvier, Mem. pour servier à l'Hist. et l'Anatomie des Mollusques. Paris, 1817, in 4to.

(8) Abhandlung über die Verdauungs—Werkzeuge der Insekten. Halle, 1811, in 4to.

(9) Diss. sistens tentamen circa anatomen forficulæ auriculariæ. Jena, 1800. Beiträge zur Anatomie der Insekten. Heidelberg, 1804, art. 1.

(1) Biologie, vol. iv, p. 323.

(2) Physiologische Untersuchungen über die Insekten. Tübingen, 1817, in 8vo, p. 8.

(3) Annales des Sciences Naturelles. June, 1825, p. 155. Salivary vessels of cicada.

which is especially the case in poisonous serpents, whose bite kills animals rapidly. Moreover it seems to favour the assimilation of the aliment by the azotized substances, the salivary and albuminous matters, which it adds to the food. In favour of its assimilating action, it may be alleged that animals which live on vegetables have larger salivary glands than those which feed on animal substances. Lastly, the addition of saliva, by moistening and softening the food renders it more easy to be swallowed.

CXCVIII. In many animals, when the aliment, now dissolved by the acid gastric juice, leaves the stomach and passes into the small intestine, two liquids of a particular kind are mixed with it, namely, the pancreatic juice and the bile. The former is secreted, in mammifera, birds, and amphibia, as also in rays and sharks among cartilaginous fishes, by a conglomerate gland, resembling the salivary, and called the pancreas. The simple, double or multiplex duct of this gland, sometimes opens directly into the first division of the small intestine; sometimes unites with the biliary ducts; occasionally one of its branches anastomoses with these ducts, whilst the other terminates in the intestine. In most bony fishes, the pancreas of the superior animals seems to be replaced by cul-de-sac appendages, more or less numerous, of the small intestine, of which Swammerdamm(4) gave the first exact description under the name of pyloric appendages (appendices pyloricæ,) and which in sturgeons (accipenser) are united and mixed into a mass resembling a gland. In regard to mollusca, Grant(5) has lately perceived in some cephalopoda (loligo sagittaria) two glands of a bright red colour and lobular form united to the biliary canal, which he thinks are analogous to the pancreas. He also considers the glandular appendages that communicate with the stomach in the aplysia and doris, as analogous to the pyloric appendages of fishes. The researches of Ramdohr(6) inform us that among insects the intestinal canal is furnished, in many coleoptera, (carabus, cicindela, dytiscus, staphylinus, tenebrio, sylpha, nicrophorus, hister, and attelabus,) with cul-de-sac appendages similar to those of fishes.

The slightly acid pancreatic juice of mammifera, of the dog, the sheep, and horse, is composed, according to the researches I have made together with L. Gmelin,(7) of water holding abundance of albumen in solution, a matter resembling casein, ozmazome, and different salts, whence it follows that there is no identity between it and saliva, as some physiologists have allowed.—

(4) Observat. Anatomicæ Selectiores Collegii Privati Amstelodam. Amst. 1667, in 12mo, p. 2. Lately, Rathke (Ueber den Darmkanal der Fische, p. 85,) has mentioned the pyloric appendages.

(5) On the existence of the pancreas in some species of the cuttle-fish tribe, and on the existence of a pancreas in the Doris Argo, in the Edinb. Philos. Journal, July, 1825, p. 197.

(6) Ueber die Verdauungswerkzeuge der Insektén, p. 20.

(7) Die Verdauung nach Versuchen, vol. i, p. 42.

This liquid appears to be of use, chiefly by its richly azotized animal nature, which it imparts to the aliment dissolved in the stomach, in assimilating the food and bringing it into the condition of the animal chemical composition. It may be said in favour of this opinion, that the pancreas is much larger in mammifera and herbivorous birds than in carnivorous animals, and that if it be judged by its volume it supplies a more copious secretion. The pancreatic juice of birds, amphibia and cartilaginous fishes, has not yet been submitted to chemical analysis. The very abundant liquid contained in the pyloric appendages of fishes is whitish, viscous, mucilaginous, and mostly slightly turnsole reddens. We may presume that by its mixture with the chyme it also effects its assimilation.

CXCIX. The bile, the other fluid, which, poured in abundance into the intestinal canal, is mixed with the aliment after it has been dissolved in the stomach, is secreted by a large gland, having the name of liver, and remarkable for the peculiar arrangement of its blood vessels. It is found in all mammifera, birds, amphibia, and fishes, as also among the invertebrated animals, in all the mollusca and crustacea, in which latter it is often composed of a great number of branching canals. In the class of insects, it appears to be replaced by more or fewer vessels, ending in a cul-de-sac, which open into the intestinal canal, contain a yellowish liquid, of a bitter taste, and have been considered by Cuvier,(8) Posselt,(9) Ramdohr,(1) Treviranus,(2) Carus,(3) and J. F. Meckel,(4) as the secreting organs of the bile. Similar vessels are met with in aphrodita, in the class of annelida.

The bile of vertebrated animals is composed of water, mucus, and several peculiar animal matters, the resin of the bile, cholesterine, picromel, cholic acid, a colouring matter, and probably salivary matter, ozmazome, casein, and many salts. In these animals it is chiefly taken from venous blood, carried to the liver by a large venous trunk, the vena portæ, which is distributed within this gland like an artery. Its secretion seems designed, on one hand, to keep the mass of the blood in such a state, in regard to chemical composition, as to enable it to operate in nutrition, and, on the other hand, to co-operate in the accomplishment of the assimilating act of the alimentary matters.

The majority of the materials of the bile, the resin, fat, colouring principle, mucus, and salts, are ejected with the undigested remnants of alimentary

(8) Anatomie Comparée, v. 4, p. 158.
(9) Beiträge zur Anatomie der Insekten, p. 11.
(1) Verdauungs-Werkzeuge der Insekten, p. 43.
(2) Biologie, v. iv, p. 417.
(3) Zootomie, p. 649.
(4) Ueber die Gallen, und Harn-Organe der Insekten ; Archiv für Anatomie und Physiologie, v. i, p. 21. At the same time he considers them urinary organs, an opinion already advanced by Rengger and Wurzer.

matters, in conjunction with which they constitute the excrements. From this it appears then, that this secretion has a design relative to the maintenance of the chemical composition of the blood. As to the part it acts in digestion, it not only consists in exciting, by its bitter resin, the mucous membrane of the alimentary sac to furnish a more abundant secretion, and the muscular tunic to perform more vehement movements, but also, by the azotized principles it contains, as picromel, ozmazome, and cholic acid united with the dissolved aliment, in assimilating and reducing it to the animal chemical composition. What speaks for the re-absorption of these principles, with the dissolved alimentary substances, is that they are not discovered in the excrements.

CC. The changes the aliments undergo in the alimentary sac, in order to become fit to be absorbed, consist, therefore, in general, in the destruction of qualities which they may yet preserve from their organic origin, and in the communication of other properties, which make them capable of becoming constituent parts of the body of the animal that takes them. If they are yet living and organized, their life and organization are destroyed. Moreover, the chemical composition, which had been given them by other living bodies, changes, and they are resolved into their simple organic elements. Finally, they are converted into a liquid resembling in chemical composition the mass of the liquids of the animal that has received them; this liquid is called chyle, and is absorbed. This change is effected partly by movements, and partly by the addition of secreted liquids. An ejection of excrement, which takes place in most animals, is the final limit or consequence of this series of operations. The manifestations of activity or life which cause these changes in alimentary substances are designated by the name of digestion or assimilation in the first passages.

No proper digestion, division, solution, and fluidification of solid aliment, is observed in plants,(5) which can only take up liquid food by absorption. There appears to be in them nothing more than assimilation of these alimentary liquids by the juices that mingle with them. Neither do plants give out excrement. Thus digestion is designed to take from aliments the particular qualities that have been communicated to them by other living bodies, and to impress new ones upon them which allow of their becoming constituent parts of the nutritive juice and solid parts of the being that feeds on them.

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(5) Some botanists have compared the roots of vegetables to the stomach of animals, and assert that they digest the food taken by absorption. This opinion, which was held by Theophrastus, is erroneous. Duhamel (Physique des Arbres, v. ii, p. 189) has objected to it, that slips elaborate the liquids they absorb, as well as entire plants that receive them by their roots.

CCI. In animals furnished with a lymphatic system to receive and convey the chyle, the nutritive juice continues to be elaborated whilst passing through this system. Secreted fluids are joined to the chyle and to the lymph of the blood, which bring them more and more near to the condition of the blood. Among the organs which act in the secretion of these liquids, we reckon glands of a particular kind, the lymphatic, as also the spleen, the supra-renal capsules, and the thyroid gland. The chyle and lymph approach the nearer to the blood in regard to colour, coagulability, and constituent principles in proportion as assimilative liquids are added to them, as I shall hereafter show when speaking of the assimilation of absorbed substances in the lymphatic system of man. These glands, which, in fishes and amphibia, appear with the lymphatic system itself, increase in number and volume, in birds and mammifera; whose more intense manifestations of activity, require a more rapid preparation of blood for their support.

3. Properties of Assimilation.

CCII. The property which all organic bodies, vegetables, as well as animals, have of assimilating the aliments taken from without, or of converting them into a liquid whose chemical composition approaches their own, is manifested in each body, in a particular manner, that is, with special modifications. Every living body prepares from the most dissimilar aliments a particular and appropriate nutritive liquid for its own preservation, just as different organized bodies produce, from the same sort of food, nutritive liquids that do not resemble each other. It cannot be mistaken that assimilation is an operation exclusively the property of living bodies, and is in no way to be compared with the changes of composition which general physical forces and the play of chemical affinities are capable of producing in inorganic matters. It must be considered as a vital act, as an effect of life. Let us examine in what this property consists.

Assimilation seems to be attributable to the action of liquids which living bodies secrete and add to the alimentary matters, in whose chemical composition these liquids produce particular changes.

In animals, different fluids, containing strongly azotized principles, saliva, gastric juice, intestinal fluid, pancreatic juice, and bile, are mixed with the food, which, after being dissolved by them, is absorbed with them. The addition of these liquids renders the chemical composition of the dissolved food more nearly resembling that of the animal body that has submitted it to digestion, and gives it the qualities of the animal. In vegetables, the sap which the roots imbibe seems to be assimilated by its mixture with liquids proceeding from the nutritive vessels, and containing particular vegetable combinations, freely charged with carbon, such as sugar, vegetable mucus, and starch.

The liquids endowed with particular properties that are mixed with the food may be compared to ferments that cause, in alimentary substances proceeding from organic combinations, changes which make these substances become similar in regard to properties. It may be admitted that every living body, when it comes to be maintained by its own activity, and by virtue of its special organic composition, also possesses in some degree its particular ferment, by means of which it effects the assimilation of the food it introduces into its body.

The assimilative action of the liquids, added to the food, may further be compared to that of the male seminal liquor on the productive liquor of the female, in the act of generation. Just as the specific vivifying influence of the seed on the genital matter determines particular changes of form and composition, by virtue of which the germ comes to resemble in every thing the vegetable or animal species, the individuals of which possess the power of producing it; so also aliments acquire the properties that are special to, and compatible with, those of the individuals that take them.

Lastly, the modus operandi of the assimilative liquids may be compared to a phenomenon observed only in animals, namely, infection by contagion. In the same manner that infectious matters, that of small-pox for instance, after being developed in an animal under certain circumstances, give rise, when transmitted into another living body of the same species, to an exactly similar disease, and to the production of a similar infectious matter, so likewise do the assimilative liquids communicate their special qualities and properties to the food received into living bodies.

All the phenomena here spoken of, and which are only observed in living bodies, appear to rest, as to their foundation, on the vital property organic liquids possess of producing, under certain circumstances, in other organic matters or bodies, similar changes or fermentations that cause these bodies to acquire the properties themselves are endowed withal.

CCIII. Does the assimilative property of the liquids which living bodies add to the aliment, depend on a special force, or can it be referred to the action of any other organic power? Galen,(6) long ago, admitted a peculiar power of assimilation, and other physiologists, amongst them Grimaud,(7) from the moderns, have been of the same opinion. They rested this opinion chiefly on the fact that assimilation cannot be considered as the effect of any other power of nutrition and formation, with which in other respects it has the

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(6) Galen (De. nat. facult. L. 3, 6, 1.) attributed assimilation (εξομοιωσις, ομοιωσις) to a special power, *facultas* assimilatrix (δυναμις ομοιωτικτη.) Bacon also admitted a special *motus assimilationis.*

(7)Grimaud (Cours complet de Physiologie, v. 1, p. 229) called the power of asssimilation *the power of vital affinity, the digestive power or faculty.*

greater analogy, because its end is to produce an homogeneous substance from heterogeneous aliments, whereas the power of nutrition or formation from the homogeneous nutritive liquid produces mixtures widely different from each other, to wit, the materials of the solid parts. However, it does not appear necessary that we should admit a specific assimilative power, the more so as this hypothesis does not make us better acquainted with assimilation itself. The assimilative liquids owe their different qualities to the manifestations of activity of the solid parts, that is to say, they are prepared from the general nutritive liquid by the action of these parts, in which, consequently, their secretion presupposes the power of nutrition and formation, whose diversities again modify it.

In the same manner that the solid parts, by virtue of this power, obtain from the general nutritive fluid matters which they receive into their composition and organic structure, and to which they communicate their vital properties, so also do the organs which prepare the assimilative liquids from the general nutritive fluid appear to communicate to them, by the same act and by virtue of the same power, qualities that give them the faculty of acting on the aliment so as to effect their assimilation. The power of formation which, in the generation of each animal or vegetable species, produces chemical compounds, organic forms, and a mode of development conforming with that of the generating bodies, is the same power which, in preparing the assimilative liquids and their action on the aliment, is incessantly producing a fluid adapted to the particular mode of composition, organization, and activity of these bodies.

As the origin of the animal and vegetable species capable of reproduction by generation, is not in the number of things within the range of our perception, and as the effects of the power of formation are prolonged throughout generations in a series whose limit the human mind will never be able to attain, such also is the case of the manifestions of this power in nutrition and assimilation. We only behold in individuals the effects of the formative power pronounced in generation, nutrition, and assimilation, in the midst of certain phenomena and conditions, of which we strive to attain a knowledge, without being able to account for the primary cause on which they depend.

CHAPTER FIFTH.

Of Respiration.

CCIV. The liquid prepared from the alimentary matters, by the functions of the first passages, is not yet adapted to the nutrition of the solid parts. To become so, it must be exposed to the action of atmospheric air, which causes it to undergo changes, that are consequent on an interchange of gaseous materials occurring between them. The crude nutritive liquid takes certain principles from the air, and throws out others. Its composition is thereby changed, and it acquires the qualities necessary for its combination with the solid parts in the act of nutrition. We give the name of respiration to the function by which this crude liquid is converted, through the influence of atmospheric air, into a nutritive liquor. As the acts concomitant with respiration differ in animals and vegetables, we shall, in the first place, consider them separately in each of these groups of living bodies.

1. Respiration of Plants.

CCV. All living plants, during the course of their full and complete activity, withdraw materials from the immediately circumambient air, or take them from air contained in water, when they happen to be aquatic plants. But at the same time they also exhale matters in the shape of vapour or gas. The more complex or perfect plants, the vascular plants, monocotyledones, and dicotolydones, are furnished with particular organs, the leaves, which accomplish this change of aeriform matters. However, the green bark, especially in aphyllous vegetables, such, among others, as the cactus,(8) seems to be capable of maintaining respiration. In more simple vegetables, the cellular plants, algæ, lichens, mushrooms, and mosses, there are no special respiratory organs, and respiration seems to be effected by the whole surface of the body.

CCVI. The leaves which present so many differences in their size, number, form, composition, and situation, may be considered in some sort, according to Malpighi's remark, as prolongations, continuations, and expansions of the stalk and branches. Fibres from the trunk are prolonged into each of them, which are spread over its surface. During the complete development and perfect exhibition of the manifestations of activity of the leaves, there is a direct passage from the parts of these stalk into the organs. Sometimes the fibres are united into a bundle, and represent a foot-stalk, as in the petiolated leaves; sometimes the fibres of the stalk expand immediately, as in sessile leaves. Leaves also exhibit a species of articulation with the stems and branches, as in most trees or shrubs, or else they are direct prolongations of it, and have the form of sheaths surrounding the stalk, as in the gramineæ, &c. The leaves themselves are simple or composed of several leaflets. Fibres that are either prolonged into the foot-stalk, or directly into the sides

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(8) The green bark, whose organization resembles that of the leaves, and has oblong pores, also fulfils the office of these organs in the *stapelia*, as well as in the genera *ceropegia*, *xylophylla*, *casuarina*, and others. Many aphyllous parasitical plants, as the cuscutæ, cassytes, and others, seem to live at the expense of the nutritive juice of the vegetables which support them.

and veins, and whose ramifications produce more or less compact nets, are composed of the spiral vessels of the trunk. Besides the vessels which convey the sap from the roots and trunk, there are also particular ones, whose existence Schultz has demonstrated.(9) They are found likewise in the sides and veins of the leaves, whence they convey the nutritive juice, now prepared and completely elaborated by respiration, into the bark of the trunk. The vessels which convey the sap, and those which return the cambium, appear to communicate directly with each other in the fine net-work of the leaves. The intervals of these meshes is filled more or less abundantly with cellular tissue. The parenchyma of the leaves, composed of vessels and cellular tissue, is covered entirely by the epidermis, which is formed, according to the researches of L. C. Treviranus,(1) of the outermost thin layers of the cellular tissue, either simple or double. The cells of this epidermis differ from those which are seen in the rest of the cellular tissue, by the absence of all juice and the deficiency of colour.

CCVII. There are seen on the surface of leaves oblong pores (pori exhalantes, spiracula, stomata,)(2) which have been discovered by Grew,(3) and whose arrangement has been carefully examined by Kroker,(4) Rudolphi,(5) Moldenhawer,(6) L. C. Treviranus,(7) and others. Most of these pores are situated on the internal surface of the leaves; but they occupy the upper one in leaves that swim on the water. Both surfaces exhibit them in the majority of monocotyledones, gramineæ, scitamineæ, palmæ, liliaceæ, &c. Among the dicotyledones this arrangement is made, especially in those plants whose leaves are thick, coriaceous, or succulent, as in coniferæ, the New Holland mimosa, &c. Lastly, there are no oblong pores at all in plants that are always covered by water, such as the *zostera* and *ceratophyllum*.

According to the researches of Mirbel, Moldenhawer, and L. C. Treviranus,(8) the pores run between the cells of the leaves, in which there is green juice, containing small grains or globules. It has not yet been proved that any direct communication exists between them and the intercellular vessels or ducts themselves, as Comparetti and Kieser thought.

CCVIII. The leaves of cellular plants, as most mosses, that have a green colour, are commonly without veins. They consist of an homogeneous cellular

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(9) Die Natur. der lebendigen Pflanze, v. i, p. 272.

(1) Ueber die Oberhaut der Gewächse; in Vermischte Schriften Anatomischen und Physiologischen Inhalts, v. i, p. 1.

(2) Guettard (Mem. de l'Acad. des Sci., 1745) calls them miliary glands. H. B. de Saussure, (Sur l'Ecorce des Feuilles et des Petales. Geneva, 1762,) Glendulæ corticales.

(3) Anatomy of Plants, b. iii, p. 1, c. 2.

(4) De Plantarum Epidermide. Halle, 1801.

(5) Anatomie der Pflanzen, p. 94.

(6) Beiträge zur Anatomie der Pflanzen, p. 94.

(7) Loc. cit.

(8) Ueber die Ausdüngstung der Gewächse; in Vermischten Schriften, v. i, p. 182.

tissue, and have no oblong pores. Whenever veins are observed in them, they are formed by elongated cells, whose junction produces the appearance of veins which the leaves of vascular plants exhibit. The leaves of most hepaticæ are without veins and composed of round cells. In those of many algæ, veins, produced by oblong cells, are observed. There are none in ulvæ. The leaves of cellular plants are simple prolongations of the stalk which they resemble perfectly on the score of texture, according to Decandolle.(9)

CCIX. The operations by which the sap now brought to the leaves is converted into the cambium, consist in the elimination and rejection of certain materials, and the reception of other principles from the air, which are combined with it. Malpighi(1) was aware that the leaves exhaled, and this fact has been well shown by the experiments of Mariotte,(2) Woodward,(3) Hales,(4) Duhamel,(5) Bonnet,(6) Bierkander,(7) Senebier,(8) Martino,(9) and others. The quantity of matter that escapes in this manner is considerable, as is fully proved by Woodward's valuable experiments. Exhalation is in no case more rapid than in the tender leaves that are beginning to shoot. As autumn approaches it gradually diminishes, in proportion as the tissue becomes harder and drier. At last it ceases altogether when the leaves turn yellow; then the vessels by which the leaves communicated with the stalk dry up and are closed. The quantity of exhaled matter also varies according to the time of day. Exhalation is very abundant during the day, under the influence of the solar light, as Hales, Guettard,(1) Senebier,(2) and Th. de Saussure,(3) have shown. If two plants of the same size are covered with two glass bells, and one exposed to the sun's light, whilst the other is left in the shade, the inner surface of the former bell will soon be covered with drops of water, but that of the second will remain dry. Exhalation is scarcely appreciable in the night. In other respects it is particularly modified by various influences, especially by temperature, rain, and the degree of dryness or humidity of the atmosphere. Considered in a general way, it is more abundant, as Duhamel well remarked, in proportion as the life of plants is

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(9) Organographie Vegetale, v. i, p. 374.
(1) Anatome Plantarum, v. i, p. 14.
(2) Essai sur la Vegetation, p, 98.
(3) Philosoph. Transac., 1699, p. 193.
(4) Statik der Gewächse, p. 3.
(5) Physique des Arbres, v. i, p. 135.
(6) Recherches sur l'Usage des Feuilles. Geneva, 1754, in 4to.
(7) Schwed. Abhand, 1773, p. 66.
(8) Physiol. Veg., v. iv, p. 73.
(9) Voigt's Magazin. v. vii, art. 2, p. 18.
(1) Mem. de l'Acad. des Sc. de Paris, 1748, p. 569, 1749, p. 265.
(2) Exp. sur l'Action de la lumiere solaire dans la vegetation. p. 72.
(3) Recherches Chimiques sur la Vegetation. Geneva, 1804, p. 54.

more energetic, in favourable circumstances, and as the actions dependent on it are more active. Lastly, it is so much the more copious in a plant as the number of leaves is great, as these leaves present an extensive surface, and as the elongated pores are numerous.

CCX. The transpirable matter of plants is in great part vaporous, but at times also liquid. To the latter dew belongs, which is frequently seen on leaves. According to Hales and Senebier it consists chiefly of water which exhales the particular odours of plants. The latter author says he has sometimes met with a matter analogous to gum or resin in it, together with carbonate and sulphate of lime.

CCXI. Regarding the changes plants produce in the atmosphere, it is proved by the observations and experiments of Priestley,(4) Scheele, Ingenhouz,(5) Spallanzani,(6) Senebier,(7) Humboldt,(8) Th. de Saussure,(9) H. Davy,(1) Woodhouse,(2) Gilby,(3) Grischow,(4) and others, that green and healthy leaves, exposed to the influence of the solar light, decompose the carbonic acid contained in the air, that the carbon, with a certain quantity of its oxygen, combines with the plants, the greater part of the oxygen being returned to the air in a gaseous form. In the night, on the other hand, or when they are withdrawn from the light, as also when they begin to wither in autumn, or lastly when they become diseased and take another colour than green, plants take a portion of the oxygen of the atmosphere, and exhale carbonic acid gas, in much smaller proportion than the quantity of carbon they acquired during the day. They then also retain a certain quantity of oxygen, which is exhaled by the sound leaves during the sunshine of the following day.

CCXII. Priestley first discovered the property which plants have of purifying the air by their respiration. He saw vegetables continue to live in confined air, and when after some time he introduced a lighted taper into this air, it still went on burning. Ingenhouz showed that this change in the air is owing to the disengagement of oxygen gas, which is effected by the leaves when exposed to the influence of solar rays. Senebier proved that the oxygen

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(4) On air, v. i, p. 284.
(5) On vegetables, v. i.
(6) Journal de Physique, v. i, p. 135.
(7) Encyclopedie Method. Physiologie Vegetale, p. 184. Recherches sur l'influence de la lumiere solaire pour metamorphoser l'air fixe en air pur par la vegetation. Geneva, 1804.
(8) Aphorismen aus der chemischen Physiologie der Pflanzen. Freiberg, 1794.
(9) Recherches chimiques sur la vegetation. Geneva, 1804.
(1) Researches Chemical and Philosophical, chiefly concerning nitrous oxide and dephlogisticated nitrous air and its respiration. London, 1800.
(2) Nicholson's Journal, v. ii, p. 150.
(3) On the Respiration of Plants; in Edinburgh Philos. Journal, 1820, v. vii, p. 100.
(4) Physikalisch-chemische Untersuchungen über das Athmen der Gewächse. Leipsick, 1819.

proceeded from the decomposition of the carbonic acid of the air by the leaves. Th. de Saussure showed that plants soon perish in pure carbonic acid gas, and even when it is mixed in a great proportion with atmospheric air; but that when it exists in small proportion in the atmosphere, far from injuring them, it, on the contrary, favours their growth, under the influence of the sun's light; and that, on the other hand, if plants be not exposed to the light, carbonic acid gas is injurious. He(5) has also certified the fact that vegetables cannot live in air altogether deprived of this gas. Percival(6) and Henry(7) have likewise confirmed the necessity of the absorption of this gas for the nourishment of plants. Whence it follows that the disengagement of oxygen gas by the leaves, under the influence of the sun's light, depends on the decomposition of the carbonic acid gas they withdraw from the air, and the carbon they retain, whilst they exhale the oxygen. Confervæ, algæ, and lichens, which have a green hue, exhale, according to the observations of Ingenhouz, Scherer, and Senebier, oxygen gas when they are exposed to the air.

Saussure is said to have observed, that plants also exhale a little azote; but Gilby perceived nothing like this in his experiments. The quantity of carbonic acid that plants absorb, and of oxygen that they exhale, varies exceedingly according to the vegetables. All external circumstances being equal, these quantities depend on the nature of the leaves. Thin-leaved plants take more carbonic acid and give out more oxygen than plants with thick and fleshy leaves.

CCXIII. The converse is the case with plants in reference to the atmospheric air, either during the night, or when they are withdrawn from the action of the sun's light. Their leaves then absorb oxygen, and many exhale carbonic acid gas, as the experiments of Spallanzani, Th. de Saussure, Gilby, Gough,(8) and others have certified. Vegetables exhibit differences in the quantity of oxygen absorbed, and of carbonic acid exhaled. Those with thick, fleshy leaves, absorb the least oxygen, and do not exhale any carbonic acid. Then follow the evergreens, the coniferæ, and afterwards the trees and shrubs which shed their leaves in autumn. The latter receive the most oxygen, and also give out the greatest quantity of carbonic acid. Moreover, plants absorb more oxygen in the spring than during autumn. Further, the quantity of oxygen they imbibe is always more considerable than the carbonic acid they exhale. The portion of oxygen they absorb during the night is also less, than what they give out in the day, as the numerous

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(5) Ann. de Chimie, v. xxiv. p. 145.
(6) Hunter, Geological Essays, v. v, p. 17.
(7) Transact, of the Manchester Academy, v. ii, p. 341.
(8) Nicholson's Journal of Natural Philosophy, v. iii, p. 1.

experiments of Saussure have verified. It appears that the oxygen they absorb during the night is combined with the materials of the sap, to produce carbonic acid, and that it is in this state emitted. The carbonic acid gas exhaled during the night is again absorbed in the day, and escapes in the shape of oxygen gas, through the influence of the solar light. Saussure instituted an experiment confirmatory of this fact; he covered a plant, placed over a quicksilver bath, with a bell containing atmospheric air, mixed with a tenth of carbonic acid. At the end of six days, during which the plant had been exposed alternately to the light of the sun, and to darkness, the air contained no longer any carbonic acid, but the quantity of oxygen was augmented. It is proved, moreover, that the quantity of carbonic acid gas in the leaves, decomposed by the influence of solar light, far exceeds what they produce during the night.

CCXIV. If we compress into a small space the phenomena of the respiration of plants, we see that they consist in the exhalation of water in the vaporous form, and of oxygen gas during the day, under the influence of the sun's light. The water comes from the sap which the roots send, by the sap vessels, into the parenchyma of the leaves, and from the moisture these absorb in the night-time. The primary effect of the evaporation of this water is the condensation of the organic matters contained in the sap. The oxygen gas is in great part taken from the carbonic acid absorbed during the day, and from the water impregnated with this gas, which the roots bring from the soil, together with the organic matters; these are the sources to which Senebier,(9) Woodhouse,(1) and Saussure assign it. Possibly, it also partly arises from the oxigenated organic combinations contained in the sap, that is, from the acetic acid, the sugar and the matter analagous to gum. It is not certain that the water of the sap is decomposed by the respiration of plants, as Berthollet and Thomson have supposed, and that a part of the oxygen proceeds thence; Saussure rejects this decomposition as by no means probable. The exhalation of oxygen increases the proportion of carbon relatively to the other elements of the sap, just as its absolute quantity becomes greater by the absorption of the carbon contained in the carbonic acid of the atmosphere. In support of this hypothesis, the experiments of Chaptal,(2) Hassenfratz,(3) and Senebier, may be quoted, from which it follows, that plants which have increased in the shade contain much less carbon, than others which have been exposed to the light.

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(9) Recherches sur l'influence de la lumiere solaire pour metamorphoser l'air fixe en air pur par la vegetation. Geneva, 1783.
(1) Nicholson's Journal of Nat. Philosophy, v. ii, p. 150.
(2) Mem. de l'Instit. Nat. des Sc., v. i, p. 288.
(3) Ann. de Chimie, v. xiii, p. 188.

CCXV. The question, which of the two surfaces, the superior or inferior, of a leaf, officiates in the exhalation of water, and in the absorption and emission of gaseous matters, has been a subject of controversy. Guettard, Duhamel, and Bonnet supposed, from experiments on leaves whose surfaces they had varnished, that the exhalation of water is effected chiefly by the upper surface, because the application of varnish on it interrupted in a great degree the manifestation of this phenomenon. Knight,(4) on the contrary, from his experiments on vine leaves placed in contact with glass plates, and during the course of which he saw the lower surface alone become covered with dew, when the sun acted on the leaf, concluded that exhalation takes place by the inferior surface. L. C. Treviranus repeated the experiments of Knight on a great number of plants, and found that, in membranous leaves, the exhalation takes place wherever the oblong pores are found. Some vegetables transpire by the upper surface, others by the lower, and a few by both. Exhalation only takes place under the influence of solar light, at which time the oblong pores are most open, whereas in darkness they seem to be constricted. Otherwise, it is immaterial whether the light of the sun falls on the upper or lower surface. In consequence of this, Treviranus considers the elongated pores as the passage through which the watery part of the sap is dissipated, an opinion which Decandolle, Sprengel, Link, and Rudolphi have also advanced. At the same time he considers them to be the organs by whose means the taking of materials from the air is effected. G. R. Treviranus(6) had previously said that the respiration of vegetables takes place by the elongated pores. In support of this hypothesis, we may quote the observations of Jurine(7) on leaves immersed in water under the receiver of an air pump, from which small bubbles of air were seen to proceed from the surface exhibiting the elongated pores.

CCXVI. The reception and decomposition of carbonic acid by the influence of the sun, as well as the absorption of oxygen gas and the production of carbonic acid during the night, are to be considered as so many organic actions of living leaves, which take place in the substance of these organs. These actions continue so long as the leaves are fresh and perfect, and even after they have been cut into pieces. But when the leaves are crushed, so as to destroy their organization and life, carbonic acid gas is no longer decomposed under the influence of the solar light, neither does the absorption of oxygen in darkness any longer take place. The vegetable mass then only

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(4) Philos. Trans., 1803.
(5) Ueber die Ausdünstung der Gewächse und deren Organe; in Vermischten Schriften Anatom. and Physiol. Inhalts. v. i, p. 173, v. iv, p. 3,
(6) Biologie, v. iv, p. 37.
(7) Journal de Physique, v. lvi, p. 185.

converts a small quantity of the oxygen of the air into carbonic acid, as dead organic matters do.

CCXVII. The acts of respiration which living leaves execute under the influence of light, are of the highest importance to the life of plants. If plants be deprived of their leaves, or if they lose them by cold or the destructiveness of insects, their nutrition and growth are stopped, the development of the flowers, the act of fecundation of the fruit and seeds cease to occur, and the already formed fruit does not ripen. It is true, that perennial plants then shoot out new leaves, because the buds which should not open until the year after are developed, but this loss does not on this account less frequently cause the death of vegetables.

If we inquire in what respect respiration is necessary to the life of plants, we can find no other use for it than to produce the nutritive juice, properly so called, or the cambium, from the sap sucked by the roots. The sap, which reaches the leaves colourless, not coagulable, without globules, and composed of water holding in solution carbonic and acetic acids, a gummy-saccharine matter and divers salts, is in them converted into a greenish liquid, partly coagulable and filled with globules, which the nutritive vessels return into the trunk of the plant, where it serves for the proper nutrition, as also to the formation, the development, and growth of the parts. It is from this liquid that, in perennial plants, the matter necessary to the production of new ligneous and cortical layers is deposited; it is this which furnishes the materials of which new shoots are formed.

CCXVIII. The juice expressed from the leaves contains the green fecula, which is precipitated as a sediment. In this fecula are perceived green grains or globules, which do not exist in the sap. From the experiments of Rouelle,(8) Einhof,(9) Proust,(1) Vauquelin,(2) Pelletier, and Caventou,(3) it follows that it is composed of a green resinous matter, soluble in alcohol and ether, and combustible, called chlorophylle, of starch, or matter like gluten, and vegetable albumen. When the juice is heated, it partly coagulates in flakes, and acids precipitate it. Senebier and Gough(4) clearly demonstrated that the green colour of plants depends on respiration, subservient to the influence of light. The conversion of the matters contained in the sap, of the carbonic acid suspended in water, of the acetic acid, of the sugar, and the gum, into more compound organic combinations, such as they exist in the green fecula, are to be considered as an effect of respiration for

(8) Crell. Beiträge zu den Chem. Ann., v. i, art. iii, p. 87.
(9) Gehlen's Neues allgemeines Journal der Chemie, v. lvi, p. 67.
(1) Ann. de Chim. et de Physique, v. x, p. 31. Journal de Physique, v. lvi, p. 97.
(2) Ann. de Chim., v. lxxxiii, p. 42.
(3) Ann. de Chim, et de Physiq., v. ix, p. 194. Journ. de Pharmacie, v. iii, p. 486.
(4) Manchester Memoirs, v. iv, p. 501.

which no satisfactory theory has yet been given. From the facts hitherto obtained concerning respiration, the following is the least strained explanation of it. The matters existing in the sap, the acetic acid, and particularly the gummy saccharine principle, are organic combinations of an inferior kind, containing a vast quantity of oxygen relative to the carbon. Again, in the fecula are found starch, a substance approaching to gluten, and albumen, in the composition of which matters less oxygen enters in proportion to the carbon. It is precisely these changes in the respective proportions of the two elements, which seems to be the result of respiration, since the absorption of carbonic acid from the air augments the mass of carbon, either absolutely or relatively to the oxygen, and the quantity of the latter is perhaps diminished by exhalation. From this it follows, that the organic combinations of a lower degree, that exist in the sap, are converted into others of a higher degree, which are found in the green fecula.(5) Lastly, in regard to the azote contained in the glutinous matter and albumen of this fecula, it is probably taken from the humours, and is already existing in the sap, wherein some chemists have found an azotized substance. With the formation of organic combinations of a higher degree which accompanies respiration, seems also to be connected the first appearance of the organic materials of aggregation or globules.

CCXIX. The nutritive juice which is prepared in the leaves, by the act of respiration, under the united influence of light and heat, and which contains organic combinations of a superior kind, starch, resinous matters, albumen, and gluten, is the liquid which particular vessels carry out of the leaves and transport to the different parts of the vegetable, to serve for their nutrition. We shall return to this point when speaking of the circulation of the nutritive juice and nutrition. In other respects the nature of the cambium appears to vary according to the species, as may be imagined from the differences remarked in the composition of vegetables and their products. Notwithstanding the resemblance of the alimentary matters imbibed by the roots, and the equality of the external influences which maintain respiration, a phenomenon of which chemistry has hitherto been unable to give an explanation, however imperfectly satisfactory, its diversity can only be considered as an effect of the plastic activity which is manifested in a special manner in the different species of plants, and by virtue of which each vegetable species prepares a nutritive juice adapted to its necessities.

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(5) Common gum is composed, according to Berzelius' Researches, of 41·906 carbon, 6,788 hydrogen, 51·306 oxygen. Starch contains, 43·481 carbon, 7,064 hydrogen, 49·455 oxygen. In woody fibre is found, according to Gay-Lussac and Thenard, 52·53 carbon, 5,69 hydrogen, 41·78 oxygen. In albumen there is, 52,883 carbon, 7,540 hydrogen, 3,872 oxygen, 16·705 azote.

CCXX. To come to an end, we shall just glance over the changes produced in the atmospheric air by the roots, the flowers, and the fruit. It is proved that these organs do not occasion the same changes as those effected by the green parts of vegetables, especially by the leaves. Roots that have recently been dug from the soil, when placed in a receiver full of moist atmospheric air, from which the stalk and flowers project, and the ends of which alone are immersed in water, absorb oxygen and exhale a little carbonic acid gas during the day, according to the experiments of Th. de Saussure. They therefore act like the leaves during the night. When he introduced nitrogen, hydrogen, or carbonic acid gas into the receiver containing the roots, the plants soon perished.

CCXXI. The action of the flowers on the atmosphere likewise differs from that which the leaves exert. Th. de Saussure(6) found, in his experiments, that all, even those of aquatic plants, absorb oxygen gas, and that they are not developed in media deprived of this gas. They faded in a vacuum and in nitrogen gas. When a flower is placed under a receiver full of atmospheric air, and stopped by a bath of quicksilver, the quantity of air is but slightly diminished, or even is not at all diminished, so long as there remains any oxygen gas. The flower absorbs the oxygen and replaces it by a nearly equal quantity of carbonic acid gas. The operation is accelerated by the influence of solar light and heat, whereas it is much more slow in the shade. In general, equal weights of flowers produce more carbonic acid gas than green leaves disengage in darkness in the same space of time. The absorption of oxygen gas, and the production of carbonic acid gas, take place chiefly by the genital organs. Formerly Saussure(7) supposed, and Grischow(8) also thought he remarked, that flowers exhale nitrogen. But in his later experiments, he was convinced they gave out neither azotic nor hydrogen gas.

CCXXII. Regarding the changes which the fruit occasions in the atmospheric air, Th. de Saussure(9) found green fruit determine similar ones to those produced by the leaves. Exposed to the air, they absorb, according to him, carbonic acid gas and exhale oxygen, in smaller quantity, however, and less freely as they approach the period of ripeness. Berard,(1) again, assures us, that he remarked, in his experiments on the ripening of fruit, that green fruits, raspberries, pears, apples, apricots, figs, cherries, gooseberries, grapes, &c. do not act like the leaves at any period of their growth, under the influ-

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(6) De l'Action des Fleurs sur l'Air, in Ann. de Chimie et de Physique, v. xxi, p. 279. Nov. 1822.

(7) Recherches Chimiques sur la Vegetation, p. 127.

(8) Ueber das Athmen der Gewächse, p. 154.

(9) Recherches sur la Vegetation, pp. 57, 129.

(1) Ann. de Chimie et de Physique, v. xvi, p. 157, January, 1821.

ence of solar light; that they do not absorb any carbonic acid gas, nor do they exhale oxygen. He maintains that their sole action on the atmosphere, as well in light as shade, consists in the absorption of oxygen and the exhalation of carbonic acid. This contradiction determined Saussure(2) to undertake fresh experiments, and he has shown that green fruits, cherries, plums, pears, and grapes disengage oxygen and absorb carbonic acid, in the solar light, as well in air containing carbonic acid as in water holding this acid; that, on the other hand, in darkness, they absorb oxygen and exhale carbonic acid gas, and that consequently they act on the air in the same manner as the leaves, although in a less powerful degree. If their growth go on tardily, they destroy the purity of the air under any circumstances, but less in light than in darkness. Lastly, he thought he found that, in the immature state, and at the time they began to get sour, they also absorb a part of the oxygen of the air, which might consequently contribute to the development of their acidity.

2. Respiration in Animals.

CCXXIII. In all animals, the crude nutritive fluid, prepared from alimentary matters by the activity of the organs of digestion, must be submitted to the influence of atmospheric air, in order to acquire the qualities without which it could not answer the necessities of nutrition. By this influence, parts of the air mingle with the nutritive juice, which gives out other parts into the air. It thus becomes more allied to the animal body in its chemical composition, and acquires a fitness for combination with the solid parts in the act of nutrition, and exhibiting their composition, organization, and vital manifestations of activity. The necessity to the preservation of life, of an interchange of matters between the air and the crude nutritive fluid follows from the fact that all animals perish more or less rapidly when placed out of communication with the air, when they are immersed, for instance, in a vacuum or in various gases, such as the carbonic acid, hydrogen, &c. Death takes place so much the more rapidly, or the maintenance of life is so much more dependent on respiration, as the organization of animals is more complicated, as the manifestations of activity or life present greater diversity or intensity. This is the reason why there exists an intimate connexion, not to be mistaken, between the necessity for respiration they feel, and the degree of development of their nervous system and locomotive organs, as G. R. Treviranus(3) and A. F. Schweigger(4) have shown. The more

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(2) De l'influence des fruits verts sur l'air avant leur maturité; in Mem. de la Societe de Physique et d'Hist. Nat. de Geneve, v. i, p. 245. Ann. de Chim. et de Phys., v. xix, p. 143.

(3) Biologie, v. ii, p. 463.

(4) Naturgeschichte der skelettlosen Thiere, p. 138.

blood the manifestations of activity of these organs consume in an animal, the greater necessity has the animal, for its own preservation, that the apparatus for the preparation of the crude nutritive juice should be complex, and the reciprocity of action of this fluid with the air should be close, so that it may be converted into blood fit for replacing the continual losses that are occurring.

CCXXIV. The atmospheric air, which alone is capable of maintaining in a durable manner the act of respiration, operates immediately on animals, as in those which respire air, or is mixed with water, through the medium of which respiration is effected, as in the majority of animals that live in this element. As to intestinal worms which inhabit the bodies of other animals, respiration in them appears to be maintained by the humours that are secreted from the arterial blood and bathes them.

CCXXV. In the lowest animals, that live in water or in the animal humours, the action of air goes on at the surface of the body, without there being special organs of respiration. In such case are infusoria, polypi, medusa, entozoa, in short the nereides, the gordia, and planaria among the annelida. In them the liquid prepared from the aliment, and which has passed directly from the alimentary sac into the very substance of the animal, is assimilated, at the surface of its body, by the influence of the air, which thus communicates to it the faculty of converting itself into the mass of the body, and identifying itself with it. In other animals there exist particular organs for the accomplishment of respiration. The basis of them is either the external skin, prolonged in the shape of lamellæ, branches, or tufts, or a mucous membrane dipping into the interior of the body, where it produces hollow vesicles, sacs, or tubes.(5) The respiratory media, air or water, are placed in contact with these membranes, by means of which they exert their action on the nutritive juice of animals, which are for the most part contained in vascular net-works. The more extensive surfaces these membranes present to the respiratory media, the more vehement, rapid, and considerable is the exchange of gaseous matters between them and the humours. We will endeavour to give a general glance of the disposition and structure of the respiratory organs in animals.

CCXXVI. The respiratory organs of animals that breathe air, are lungs or air tubes. The lungs of vertebrated animals, mammifera, birds, and amphibia, are hollow, vesicular sacs, situated in the chest, which communicate, by a canal, the windpipe and larynx, with the back of the throat, and through it with the nasal and buccal cavities. This canal is based on a mucous membrane which, commencing at the trachea, divides into branches,

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(5) J. J. Fouquet de organi respiratorii in animalium serie evolutione. Halle, 1817, in 8vo.

ramifications, and ramusculi, and finally ends in round and closed bladders, called pulmonary cells. These cells are most numerous and small in mammifera and birds, because life, in them, much more than in reptiles, depends on the influence the air exerts over the blood. In reptiles, on the contrary, the mucous membrane frequently produces, just where the trachea enters the lungs, capacious vesicles, which likewise serve as a reservoir for air when the animal is immersed in water. In birds, the lungs, moreover, communicate, by apertures, with membranous sacs situated in the chest and abdomen, which again are prolonged into most of the bones, whose interior is hollow and without marrow. From this arrangement it follows, that the air not only acts on the blood which is circulating in the lungs, but exerts besides an influence on the organs themselves. Along the body and branches of the trachea, the mucous membrane is furnished with entire cartilaginous rings, or segments of rings; but in proportion as the trachea is divided in the substance of the lungs, the cartilages become more and more small and thin, until they disappear altogether. In most amphibia, however, the cartilages cease to be perceived from the spot where the trachea penetrates into the lungs. These cartilages keep the mucous membrane of the lungs extended and accessible to the air that should act on it. Between them, as also on the mucous membrane itself, where they cease to be visible, a layer of muscular fibres, arranged in a circle, is almost always seen. These fibres are distended by air during inspiration. The ramifications of the trachea and the cul-de-sac cells, in which they terminate, are filled in inspiration, and are partly emptied in expiration.

To the ramifications of the trachea is joined, in mammifera, birds, tortoises, lizards, and ophidia, an artery proceeding from the heart, the pulmonary artery, whose distribution follows precisely that of the air canal, and which ends by forming a very minute net-work on the pulmonary cells, called the capillary system of the lungs. In frogs, toads, salamanders, and tritons, the arteries of the lungs are branches of the aorta. From the net-work in which the pulmonary artery terminates, veins arise, which unite into branches and trunks, and end in the heart. Numerous branches of the pneumo-gastric nerve (vagus) go to the larynx, which are distributed to the muscles, the mucous membrane, and the coats of the arteries of the respiratory organs.

The venous blood which arrives at the heart, mixed with the chyle and lymph, traverses this organ to reach the pulmonary artery, either altogether, as in mammifera and birds, or only in part, as in amphibia. Arrived at the ultimate ramifications of this artery, it is there converted into arterial blood, by the influence of the inspired air. In this new shape it returns by the pulmonary veins to the heart, which by the artery of the body called aorta, distributes it to all parts, to officiate in their nutrition.

CCXXVII. Many mollusca of the order of gasteropoda likewise breathe air by a lung. Of this number are snails, (limax,) testacella, parmacella, helices, pupa, clausilia, and others, as also most of those which live in the water, planorbes, onchidea, lymnæa, physa, &c. Their lung consists of a cavity in the shape of a sac, to which a round hole leads, surrounded by a sphincter, by which the animals alternately inspire and expire air. The cavity is internally lined by a very delicately folded mucous membrane, in which blood vessels are spread in a retiform manner. The blood which returns from the body is collected into one venous trunk, the vena cava, that is distributed like an artery through the lung. After being submitted to the influence of the air, this fluid is reconducted to the auricle of the heart by the pulmonary vein.

These lungs may be compared to the air cells, or membranous vesicles, which some annelida, earth worms, and leeches exhibit on the lateral parts of the body, which communicate with the external world by a small aperture, and in the sides of which vessels ramify.

CCXXVIII. Insects breathe air by small rounded or oblong apertures, that are arranged in rows, on each side, on certain segments of their bodies, and which are called stigmata. These stigmata exhibit a different form, according to the abode of the animal, and are often guarded from foreign bodies which might attempt entrance, by valves, bristles, or hairs, as C. Sprengel(6) has shown Certain muscles officiate in opening and closing them. Small ramose and very delicate tubes proceed from the stigmata, which ramify in all the organs and parts of insects, and are called tracheæ. Their sides are formed of three superposed tunics, the middle one consists of spiral fibres, of a silvery white, brilliant and very elastic. These fibres bring the organs themselves to the air, which there exerts its influence directly on the nutritive fluid. In insects that live in water, the tracheæ are found at the anus, and are often dilated into the shape of a sac, in order to serve as a reservoir for air.

The arachnida likewise breathe air by stigmata, which end in sacs in the shape of lungs, or in tracheæ.

CCXXIX. Respiration which is accomplished in water, takes place by branchiæ, or tubes, receiving this liquid into their interior. The gills of most fishes represent organs in the shape of plates, situated at the hinder part of the head, fixed to particular bones or cartilages, which are similar to ribs, and called branchial arches. These arches are articulated above with the head, below with the hyoid bone, and can be put in motion by muscles.

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(6) Commentarius de partibus, quibus insecta spiritus ducunt. Leipsick, 1815, in 4to.

Each gill, and they mostly reckon four or five, is composed of numerous lamellæ, which allow of its presenting a large surface to the water.

The gills adhere by their superior border only, as in bony fishes; or by both borders, as in the rays and shark. In the former, they are covered by moveable bony pieces, the operculum and the enveloping membrane of the gills, beneath which a large aperture gives passage to the water introduced into the mouth. In the latter, on the contrary, there is no operculum, and we find several holes, called branchial holes, (foramina branchialia,) which serve as a passage for the water.

In some fishes, such as the hippocampus and syngnathus,(7) the gills have the shape of a bunch of grapes; or else they form, as in many sucking fishes, lampreys, (petromyzon,) and the myxine glutinosa, according to Gunnerus,(8) Bloch,(9) and Home's(1) observations, vesicular sacs, into which the water is introduced by means of a canal coming from the buccal cavity, through which it is emptied by several holes situated on the sides.

The gills are composed externally of a delicate mucous membrane, a continuation and prolongation of that of the mouth and pharynx. To this membrane a large artery, arising from the single ventricle of the heart, the branchial artery, proceeds, which first divides into as many branches as there are branchial plates or sacs. Each branch sends numerous branches to the branchial plates, in the mucous membrane of which they form minute networks. The veins communicate with the ultimate ramifications of the arteries. They unite into small, then into larger branches, and form, at the lower surface of the cranium, a thick arterial trunk, the artery of the body, the aorta. The branchial artery takes the blood, mixed with the chyle and lymph, from the heart to the gills. The water containing air, which is introduced by the mouth or the branchial holes, coming in contact with the gills in many points, acts on the venous blood that is traversing the vascular net-works, and arterialises it. The arterial blood then passes into the aorta, which conveys it to all the organs.

CCXXX. Most fishes possess, besides their gills, another organ analogous to a lung, which is the swimming bladder. This organ is situated in the abdominal cavity, along the under surface of the vertebral canal, and it commonly communicates with the pharynx, or stomach by a membranous canal. Numerous blood vessels, as well as branches of the pneumo-gastric nerve and the great sympathetic, are spread through its coats.(2) The air it

(7) Meine Untersuchungen über der Kiemenbildung der Nadelfische; in Meckel's Archiv. für die Physiologie, v. ii, p. 210.

(8) Schriften der Drontheimer Gesellschaft, v. ii, p. 230.

(9) Naturgeschichte der ausländischen Fische, v. ix, p. 67.

(1) Philosoph. Transact. for the year 1815, part ii, p. 256.

(2) Weber, Anatome comparata nervi sympathici. Leipsick, 1817, p. 58.

contains is composed, according to the researches of Priestley,(3) Fourcroy,(4) Brodbelt,(5) Biot,(6) Erman,(7) Configliachi,(8) Provençal and Humboldt,(9) Geoffroy,(1) and Delaroche,(2) of the same elements as air, that is to say, of oxygen, nitrogen, and carbonic acid, but in proportions that are very subject to variation, Erman found in fresh water fishes less oxygen gas than exists in atmospheric air, whilst according to Biot, the proportion of this gas is more considerable in sea fishes, and more particularly in those which remain at great depths. Lacepede(3) thought he also met with hydrogen in them, but no other physician has confirmed this assertion.

Very probably the swimming bladder plays the part of an accessory organ in respiration, as Fischer,(4) Nitzch,(5) G. R. Treviranus,(6) and many others have admitted. Fishes that are remarkable for very vehement and prolonged movements, are the chief of those which breathe by the aid of this organ. They seem to accumulate in it respirable air under circumstances where they take more of it than they can consume, and to employ this reserve in other circumstances where they have occasion for a great quantity of air. What supports this opinion is, that flying fishes, as the *triglæ*, and, according to Humboldt's researches, the *exocœtus volitans*, are provided with very capacious swimming bladders. Delaroche also saw this organ of a great size in the *scorpæna volitaens*, whereas the species of the same genus which do not fly (scorpæna porcus, scrosa, dactyloptera, &c.) are commonly without it. A large swimming bladder is also found in the species of the salmon genus, the sword fish, the pike, the perch, the herring, the *polypterus niloticus*, &c., which are distinguished for the rapidity of their swimming; whilst, on the other hand, there is none in fishes accustomed to remain deep in the water and in the mud, and whose movements are slow, as raies, lophii, lampreys *(petromyzon,)* many mud fishes, *(blennii,)* tænia, echineis, bull-heads, *(cotti,)* pleuronectes, &c. It is yet doubtful whether this bladder should be considered at the same time as an organ assisting, in an accessory way, in swimming, allowing fishes, by its distension or collapse, to raise them-

(3) Versuche und Beobachtungen über verschiedene Thale der Naturlehre, v. ii.
(4) Ann. de Chimie, v. i, p. 47.
(5) Nicholson's Journal of Nat. Philos., v. i, p. 284.
(6) Mem. de Physique et de Chim. de la Societ. d'Arcueil, v. i, p. 253, v. ii, p. 487.
(7) Gilbert's Annalen der Physik, v. xxx, p. 113.
(8) Memoria sull' analysi dell' aria contenuta nella vesica natatoria dei pesci. Pavia, 1809.
(9) Mem. de la Societé. d'Arcueil, v. ii, p. 400. Humboldt's Reise in die Æquinoctial. Gegenden, v. i, p. 306.
(1) Ann. du Mus. d'Histoire Naturelle, v. xiii, p. 460.
(2) Ann. du Mus. d'Histoire Naturelle, v. xiv, p. 184, 245.
(3) Hist. Nat. des Poissons. v. i, p. 102.
(4) Ueber die Schwimmblase der Fische. Leipsick, 1795.
(5) De respiratione animalium. Wirtemberg, 1808, p. 16.
(6) Annalen der Wetterauer Gesellschaft für die gesammte Naturkunde, v. iii. p. 142. Vermischte Schriften, v. ii, p. 156.

selves or dive into the water, as Borelli supposed.(7) As many fishes that have it not, are nevertheless good swimmers, as it does not always communicate with the pharynx and the stomach by a canal which allows the exit of air, and as finally it is sometimes enclosed, as in the *cobitis fossilis*, for instance, in a bony capsule, which therefore prevents its dilatation or contraction, this opinion does not appear probable. It may be also alleged, that fishes whose swimming bladder has been cut out maintain the power of elevating themselves and diving in water, a fact which Humboldt and Provençal found to be true in their experiments.

Many fishes also breathe by the intestinal canal, by the air they swallow, which the valuable experiments of Erman(8) on the *cobitis fossilis* show. The air comes out by the anus in the shape of carbonic acid gas. The electric eel, likewise, comes to the surface of the water, according to Humboldt's observations, to swallow air. Sylvestre(9) also showed that fishes enclosed in vessels come to the surface of the liquid to take in some air, when that which was mixed with the water has been consumed by respiration. From the experiments of Edwards(1) it follows, that the necessity for respiration augments when the temperature becomes more elevated, which causes many fishes to swallow air during the summer.

CCXXXI. As most fishes have, besides gills, accessory respiratory organs, so also in some amphibia we find lungs and branchiæ together. This is the case, according to the researches of Schreiber,(2) Cuvier,(3) Configliachi,(4) and Rusconi, in those remarkable animals the proteus and siren, which are, on the score of structure and manifestations of life, between reptiles and fishes. They possess true bunchy gills, like those of fishes, to which the branches of the aorta pass. The water that bedews these organs, maintains their respiration in the ordinary circumstances of their existence. But when the necessity for respiration increases in them, they force air into their lungs. The bull-head frogs, salamanders, and tritons are likewise furnished with branchiæ, to which, according to Rusconi's inquiries, branches of the aorta also proceed.(5)

CXXXII. Among the animals that breathe by gills, are reckoned the crustacea, as also most mollusca, and annelida. In the former the branchiæ,

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(7) De motu animalium, cap. 23.
(8) Gilbert's Ann. der Physik, v. iii, p. 140.
(9) Bulletin des Sc. de la Societ. Philomatique, v. i, p. 17.
(1) De l'Influence des Agens Physiques sur la vie. Paris, 1824, p. 118.
(2) Philos. Transact. for the year 1801, p. 255.
(3) Recherches Anatomiques sur les Reptiles regardes encore comme douteux. Paris, 1807, in fol.
(4) Del proteo anguino di Laurenti, Pavia, 1819.
(5) Descrizione anatomica degli organi della circolazione della larva della Salamandre acquatiche. Pavia, 1817, in 4to.

which have either the shape of tufts or plates, are sometimes at the exterior of the body, as in *squilla* and brachiopoda, the *apus*, the *limulus*, &c., where they are fixed to the internal surface of the tail, sometimes under the dorsal shield, as in the decapoda, the lobster, properly so called, and in the crab. The venous blood is carried to them by vessels which are formed by the venous trunks of the body, after which it is passed into the heart. According to the observations of Audouin and Milne Edwards, these branchiæ can not only maintain respiration in water, but likewise in air, so long as they do not become dry from evaporation.

CCXXXIII. Of the mollusca, the cephalopoda, the pteropoda, the acephala, the branchiopoda, and very many gasteropoda breathe by gills. These exhibit great variety in their arrangement. The cephalopoda have two branching gills situated within the muscular sac of their body. In the pteropoda, the clio, pneumadermon, hyalea, &c. present branchiæ at the surface of the body, either forming membranes like fins, or small lamellæ. The acephala, as oysters, mussels, *anodonta*, the cardium, *chama*, *danax*, *tellina*, *venus*, the *mya*, *anatina*, and *solenaceæ*, have four very large lamellar branchiæ, situated within the shell and the cloaca, and perforated by numerous blood vessels. In the brachiopoda, such as the genera *lingula*, *terebratula*, *orbicula*, &c., the branchiæ consist of lamellæ fixed to one of the sides of the cloak. In the gasteropoda, which breathe by branchiæ, they are sometimes in the shape of tufts, fans, or combs at the surface of the body, as in the genera *doris*, *tritonia*, *thetys*, *scillæa*, *glaucus*, &c.; sometimes in the shape of a lamella and concealed under the edge of the cloaca, as in the genus *phyllidia*, *pleurobranchus*, *aplysia*, and those with a shell, *patella* and *chiton*; at other times in the form of numerous lamellæ, holding by a kind of membranous sac situated under the last winding of the shell, as in the genera *turbo*, *paludina*, *trochus*, *janthina*, *nerita*, *conus*, *cypræa*, *voluta*, &c. among the shell-covered gasteropoda.

Lastly, in many, the edge of the cloaca is prolonged into a respiratory tube, by which water enters and leaves the branchial cavity, an arrangement which is remarked in the genera *murex* and *strombus*. In the mollusca, the venous blood that returns from different parts of the body is brought to the branchiæ by the vena cava, which is divided like an artery. Returning from these organs, the blood passes by the branchial veins into the heart, which distributes it to all the organs of the body. In the cephalopoda, however, there exist two muscular ventricles at the place of junction of the two venæ cavæ with the branchial arteries.

CCXXXIV. Those annelida which live in water breathe by branchiæ, in which numerous blood vessels are spread like nets. They are found at the anterior extremity, or head, in tubicolous worms. They have the form of fanlike tufts, as in *serpula* and *sabella;* of a comb, as in the *amphitrita* ; or finally of small trees on the neck, as in *terebella.* In annelida that move freely in the water, they are spread over the body, in its longitudinal direction, and in the shape sometimes of a tuft, as in the *amphinoma* and *arenicola;* or of a comb, as in the *eunices;* or they are placed on scales, as in the *aphrodita.*

CCXXXV. Among the echinodermata, the *holothuria* breathe by a hollow organ which communicates with the cloaca, is divided, in the interior of the body and along the intestinal canal, into branches, ramifications, and ramusculi, and ends in rounded, cul-de-sac vesicles. On this organ the ramifications of the sanguineous vascular system are spread. The water is alternately absorbed and rejected by the cloaca. The asterias, the sea hedge-hogs, and actinia introduce the water by small tubes into their body, where it directly washes the viscera. It is possible that the vesicles observed at the side of the stomach in the several medusa *(physophora, rhizophysa, physalia, medusa)* are in lieu of respiratory organs.

CCXXXVI. The functions performed by the respiratory organs are accomplished, in most animals, by movements which renew the breathing media, air or water, within or around these organs. All animals that have lungs, mammifera, birds, and reptiles, so soon as they leave the ovum and come into contact with the air, perform movements by which the air is made to enter into and leave their lungs at certain intervals. In mammifera, these movements are the consequence of the contractions of the diaphragm and of other muscles that are attached to the larynx as well as the ribs, which are themselves moveable on the vertebral column. Their end is to alternately enlarge and diminish the respiratory passages, and to renew the air in the lungs. The same takes place, in birds, by means of the muscles of the larynx and the pectoral cavity. Amphibia, on the contrary, draw the air into the larynx by a kind of deglutition, which the muscles of the tongue and the hyoid bone accomplish. Fishes take in air by the mouth and push it between the plates of their branchiæ, whence it comes out below the operculum or by the branchial holes.(6, 7.) The impulse which puts the muscles of the organs of respiration into play, is produced in an automatic manner in the nervous system of all animals, or, more correctly, in the spinal marrow, whence the nerves, that spread their ramifications in these muscles, arise. In ordinary circumstances, as for instance during sleep, the respiratory movements are involuntary. They may, however, be rendered active and be accelerated at the will of the animal, whenever the necessity for respiration becomes more

(6) Gouan. Historia Piscium, p. 32.
(7) Dumeril sur le mecanisme de la respiration des poissons ; in Mem. de Zoologie et d'Anat. comparée. Paris, 1807, p. 17.

pressing, as when the temperature of the air or water is augmented, or in violent movements of the body and in excitements of the nervous system.

In insects, movements take place in the stigmata and tracheæ, as observations made by Comparetti,(8) Vauquelin,(9) Hausmann,(1) Sorg,(2) and G. R. Treviranus(3) show. In the mollusca that breathe with lungs, the air is renewed in these organs by the alternate contractions and relaxations of muscles situated round the pulmonary sac. The cephalopoda alternately take in and eject water by a tube. The shell acephala renew the water about their branchiæ by opening and shutting their valves. Lastly, we see the holothuria alternately take in and reject water.

CCXXXVII. This dependance of movements, the excitation to which in the nervous system takes place in an automatic or voluntary manner, establishes a difference between the respiration of animals and that of vegetables, which is performed without muscles and without nervous influence.

Moreover, in all animals, we remark a tendency to maintain themselves, by their own activity, in the media where their respiration can continue to be performed. Respiration, then, like the susception of aliment, is under the empire of an inclination which has the preservation of the body for its end, and which depends on the nervous system. There are no similar manifestations of activity in plants.

CCXXXVIII. As to the changes which occur in the media in contact with the respiratory organs, it is proved, by numerous chemical experiments, that certain constituent principles of these media combine with the humours of animals, which yield others in exchange. Long ago Mayow discovered that the respiration of animals effected changes in the air similar to those produced by the flame of a burning body. Priestley, Scheele, and Lavoisier have since proved that atmospheric air is composed of two elastic fluids, one of which, oxygen, is capable of maintaining the life of animals and flame, whereas flame and the life of animals are extinguished in the other, nitrogen. They have also shown, that in respiration, as in combustion, oxygen disappears and carbonic acid is produced. Finally, the latest researches of chemists have established, that atmospheric air results from a mixture of twenty-one parts of oxygen and seventy-nine of azotic gas; and that moreover it almost always contains a small, but variable, quantity of carbonic acid gas. The air which the respiratory movements inhale into the lungs and tracheæ, undergoes therein the same changes in all animals; that is, its proportion of oxygen is diminished, whilst carbonic acid

(8) De aure interna, p. 290.
(9) Ann. de Chimie, v. xii, p. 273.
(1) De animalium exsanguium respiratione. Hanover, 1803, p. 8.
(2) Disquisitio Physiol. circa respirationem insectorum et vermium. Rudalstadt, 1805, pp. 27, 46, 66.
(3) Biologie, v. iv, p. 160.

gas and aqueous vapours are ejected. This has been shown, in regard to mammifera and birds, by Lavoisier's(4) first experiments, as also by Seguin's,(5) and the chemical researches of Menzies,(6) Spallanzani,(7) H. Davy,(8) Berthollet.(9) The experiments of Spallanzani,(1) Sylvestre,(2) Carradori,(3) Humboldt,(4) and others, on the respiration of amphibia, were followed by the same results.

Further, the air undergoes a similar change in the lungs of garden and road snails, according to experiments made by Spallanzani,(5) Varquelin,(6) Hausmann,(7) and Sorg,(8) also in the trachea of insects, from the observations of Scheele,(9) and of the naturalists before named.

CCXXXIX. The respiration of animals living in water and having branchiae, takes place by air mixed with the water. The water exposed to air contains its elements, oxygen and nitrogen, as well as a little carbonic acid gas, which it takes from the air. The air combined with water is, however, more rich in oxygen than the atmosphere, according to the researches of Humboldt and Gay Lussac,(1) for it contains 32-hundredth parts, whereas there are only twenty-one in the latter.

The respiration of aquatic animals causes the air that is mixed with the water to undergo the same changes which it suffers when introduced into the tracheæ and lungs; oxygen gas is absorbed and carbonic acid expelled. Priestley,(2) Spallanzani,(3) H. Davy,(4) Sylvestre, Carradori,(5) Humboldt, and Provençal,(6) have shown this in fishes; and Spallanzani, Hausmann, and

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(4) Experiences sur la respiration des animaux et sur les changemens qui arrivent à l'air en passant par leur poumon. Mem. de l'Acad. des Sc. de Paris, 1777, p. 185, 1780, p. 401.
(5) Idem, 1689, p. 572.
(6) Diss. de Respiratione. Edinb., 1790.
(7) Senebier, Rapports de l'air avec les êtres organisés, tirés de Journaux d'Observations et d'Experiences de Spallanzani. Geneva, 1807, v. ii, pp. 5, 133.
(8) Researches Chemical and Philosophical, chiefly concerning nitrous oxide and its respiration. London, 1800.
(9) Mem. de la Soc. d'Arcueil, v. ii, p. 454.
(1) Loc. cit., v. ii, p. 278. He made experiments on frogs, salamanders, tortoises, lizards, and serpents.
(2) Bullet. des Sc. de la Soc. Philomat, v. i, p. 17.
(3) Esperienze e Osservazioni sulle Respiratione delle Rane e dei Girini, in Brugnatelli Annali di Chemica, v. xii, p. 112.
(4) Annales du Mus. d'Hist. Nat., v. ii, p. 305. Experiments on a young Crocodile.
(5) Mem. sur la Respiration. Geneva, 1803, p. 191.
(6) Observations Chimiques et Physiologiques sur la respiration des insectes et des vers; in Ann. de Chimie, v. xii, p. 273.
(7) De animalium exsanguium respiratione. Hanover, 1803.
(8) Disquisitiones Physiologicæ circa Respirationem Insectorum et Vermium. Rudolstadt, 1805.
(9) Abhandlung von der Luft und dem Feuer, p. 118.
(1) Journal de Physique, v. lx, p. 129.
(2) Experiment on Air, v. iii, p. 312.
(3) Loc. cit., v. i, p. 132. Mem. sur la respiration. Geneva, 1803, p. 161.
(4) On Heat and Light; in Contributions to Physical and Medical Knowledge, collected by Beddoes. Bristol, 1799, p. 1.
(5) Brugnatelli, Annali di Chimica, v. v, p. 53.
(6) Mem. de la Soc. d'Arcueil, v. ii. pp. 98, 359.

Sorg in crustacea, the bivalve mollusca, and annelida. It is erroneous to suppose that the water itself is decomposed in the respiration of these animals, as Darwin asserted.

CCXL. Whether the other constituent part of the air, nitrogen, undergoes changes during respiration, and whether it is absorbed, as Priestley concluded from his experiments, and as Davy, Spallanzani, Henderson, Humboldt, Provençal remarked; or whether it is ejected, as Berthollet, Nysten, Despretz, and Dulong thought they observed; or, lastly, whether it is, as Edwards thinks, sometimes absorbed and sometimes given out, according to circumstances, are questions still in dispute, to which I shall return when I treat of respiration in man.

CCXLI. In most, if not in all, animals, the skin likewise performs the functions of a respiratory organ. The air which comes into contact with the common integuments, either simple, or mixed with water, suffers the same changes as that which enters into the organs of respiration; its oxygen disappears and carbonic acid is substituted. This is chiefly remarked in the naked skin of the frog-like amphibia, (batrachia,) frogs, toads, salamanders, and tritons. At a low temperature, at ten degrees of the Celsian or centigrade thermometer, these animals remain whole weeks and months in the water, without breathing by the lungs; they then breathe by their naked and abundantly vascular skin, particularly in autumn and winter. It is only when the temperature is elevated to ten degrees above zero, that they breathe by the lungs also. Cutaneous respiration, in these animals, is even more important than the pulmonary to the preservation of life; for they live longer when the latter is interrupted, provided the air be respirable, than when the former is stopped, although in the last case the lungs continue to act. The experiments of Spallanzani give proof of this.(7) Frogs whose lungs had been excised, lived longer than those whose skins had been rubbed with oil, or had been immersed in an atmosphere of irrespirable gas. Edwards obtained the same results from similar experiments. Frogs and salamanders whose trachea had been tied, or the head enveloped in a bladder, or even whose lungs had been abstracted, still lived a long time, especially at a low temperature. In leaf-frogs, the pulmonary respiration alone was not sufficient for the maintenance of life.

Respiration by the skin likewise takes place in lizards, ophidia, and tortoises, according to the researches of Spallanzani and Edwards, and acts in concert with that of the lungs in preserving their life. In serpents and tor-

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(7) Mem. sur la respiration. Geneva, 1803, pp. 72, 115.
(8) Influence des Agens Physiques sur la vie, p. 10.
(9) Idem. p. 227.

toises, respiration by the lungs is sufficient during the summer, when the temperature is not too high; but lizards are besides necessitated to breathe by the skin, and in summer they perish in the course of a few hours, when reduced to respire by the lungs alone.

Fishes also breathe by the skin, according to the experiments of Humboldt and Provençal(1). The air mixed with water contained in the vessels wherein they had immersed the hinder part of the bodies of several tench, *(cyprinus tinca,)* underwent the same changes as if the fishes had respired by their gills. The air, however, is not so rapidly changed as by respiration by gills.

Even in birds and mammifera, the air in contact with the skin suffers similar changes to those it undergoes in the lungs, only not so well marked. Spallanzani(2) inclosed animals belonging to these classes in vessels, out of which their heads protruded, and, after some time, he discovered that oxygen gas had been consumed, and carbonic acid produced.

CCXLII. From the details I have entered into concerning the respiration of animals and vegetables, it follows as a main result, that these bodies occasion opposite changes in the atmospheric air. The carbonic acid which the respiration of animals produces is decomposed, through the influence of light, by plants which take the carbon and exhale the oxygen. The latter again is absorbed by animals, which throw out carbonic acid. Thus, the respiration of vegetables is accompanied with a disacidification, and that of animals with a decarbonization.

CCXLIII. Animals consume oxygen so much the more rapidly and abundantly in a given time, and produce so much more carbonic acid, as their organization is more complex, their manifestations of activity more varied and intense, and the renewal of matter induced by the exercise of life more rapid. Mammifera and birds consume more oxygen, and produce more carbonic acid, than amphibia and fishes,

Among the invertebrated animals, insects, which breathe air, and are endued with great vivacity of motion, crustacea, mollusca, and worms, which breathe water, and have less rapid motion, are distinguished by a more rapid consumption of oxygen, and a more abundant production of carbonic acid. The degree of sensibility, of irritability of animals, the vigour and continuation of movements, the energy of the digestive act, the velocity of the circulation of the blood, the alacrity of nutrition and secretion, are generally in a direct ratio with the quantity of oxygen animals consume in respiration, and with the carbonic acid they expire.

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(1) Mem. de la Soc. d'Arcueil, v. ii, p. 393.
(2) Loc. cit. p. 116.

CCXLIV. With regard to the changes respiration produces in the mass of the humours of animals, these are only ascertained in a few of them, and only in those which have red blood, mammifera, birds, reptiles, and fishes.

Lower, Needham, Thruston, and Mayow saw, in mammifera and birds, the black blood carried from the heart to the lungs by the pulmonary artery, and return of a bright red colour to the heart by the pulmonary veins. Goodwyn observed the same phenomenon in the blood of reptiles, in its passage through the lungs. This change of colour has also been fully shown by the experiments of Duverney, J. Hunter, Hewson, Bichat, and others. It has also been demonstrated, that the chyle, which is mixed with the venous blood, returns from the lungs converted into true blood. From all this it must be admitted that the lungs are the organs of hæmatosis.

That the change in the colour of the blood is produced by the inspired air, and especially by the oxygen it contains, has been proved by Cigna, Priestley, Goodwyn, and others. They saw the black blood received into vessels filled with atmospheric air, or oxygen, become of a bright red colour, and they ascertained that oxygen was combined with it. They likewise showed that venous blood suffers no change in colour in irrespirable gases, such as carbonic acid, hydrogen, and azote, and that, so far from this, the scarlet blood itself becomes black when it is immersed in these gases. Moreover, numerous experiments teach us, that the scarlet colour of the blood which circulates in the lungs is, in animals, in direct ratio with the quantity of oxygen they consume in their respiration. Mammifera and birds, whose consumption of oxygen in a given space of time is the most considerable, have also the most scarlet blood; whereas the blood of amphibia and fishes, which do not absorb so much oxygen, has a less red colour. If we cause animals to breathe carbonic acid, hydrogen or nitrogen, their blood becomes black. On the reception of oxygen from the air, therefore, and on its action on the blood, depends the scarlet colour it has in these animals.

The venous blood that flows in the pulmonary vessels, loses carbonic acid and water, which are disengaged in the form of vapour, constituting the matter of pulmonary exhalation, and it returns to the heart more coagulable, more loaded with fibrine. At the same time, it contains more globules, or elementary organic forms. The coagulability and quantity of globules existing in arterial blood are, in animals, in relation to the quantity of oxygen they take during respiration, and to that of the carbonic acid and water they throw out. The blood of mammifera and birds is richer in coagulable principles than that of amphibia and fishes.

Physiologists and chemists are still divided on the question, whether the carbonic acid disengaged in respiration, is produced by a kind of combustion of the carbon of the venous blood and the chyle, by the influence of the inspired oxygen, or whether it should not rather be admitted that it already exists quite formed in this blood and chyle, from which it is then merely separated. We shall return to this point, in speaking of respiration in man.

Such are the changes which, as far as regards the essential circumstances, respiration produces in the blood of vertebrated animals, as much as we have been able to ascertain of them by experiment. No researches have been hitherto made on the changes this junction causes in the humours of invertebrated animals.

CCXLV. Lastly, we arrive at this question; is the chyle, that is, the liquid taken from the aliment in the digestive apparatus, by means of solvent and azotized juices, mixed with the food, changed into arterial blood by the effect of respiration? To me the least strained solution of this problem appears to be that of Hallé, Thomson, and Cuvier, who think that the proportion of nitrogen to the other principles is increased in the blood by the subtraction of water and carbonic acid from the chyle and venous blood, and it is precisely this which brings the alimentary substances to the conditions of the animal chemical composition. In favour of this theory it may be alleged, that the ejection of carbonic acid is particularly abundant during digestion and the flowing of the chyle into the blood, and that two organic matters, into whose composition there enters a considerable quantity of azote, albumen, and fibrine, are essential parts of the blood. As a final effect, therefore, in the preservation of life, respiration will play the important part of completely assimilating the chyle and converting it into arterial blood, which effects depend on an absorption of oxygen, and an ejection of hydrogen out of the, in itself very variable, composition of the organic compounds constituting the food. It is even possible, in certain circumstances, that animals take from the air they breathe some nitrogen which combines with the materials of the chyle, as many chemists thought they observed in their experiments on respiration. It is by the changes effected in the respective proportions of the elements, and the increase of nitrogen relatively to the others, that the organic combinations of the simple kind, particularly the ternary ones, appear to be converted into others more compound, animal, or quarternary. It moreover appears that the carbonic acid produced by the change of composition effected in the solid parts, in consequence of their manifestations of activity, is taken up by the veins and separated from the venous blood in the respiratory organs.

CCXLVI. The arterial blood prepared by respiration, from the dissolved aliment, arrives in the arteries of the body, whose numerous ramifications distribute it to different parts of the body, as their nutritive fluid. These parts are preserved by taking one or more of its materials into their own particular form, composition, and vital qualities, by which they are rendered capable of accomplishing their manifestations of power. The acts of nutrition, formation, secretion, and generation, as also the manifestations of muscular power and nervous energy, are therefore dependent on respiration and the preparation of arterial blood. All these vital phenomena are extinguished as soon as those of respiration are entirely stopped.

Qualities of Respiration.

CCXLVII. Thus in all living bodies the phenomena of respiration are observed to consist in an interchange of matters between the media in which they exist, and their imperfectly assimilated humours. Its design is to prepare the nutritive or formative liquid in which all the parts find the materials necessary for their continuance in the enjoyment of their vital qualities during a certain space of time. There is no necessity for supposing a peculiar power in order to explain it, for the nature of the crude nutritive juice, prepared from the food by the addition of assimilative liquids, is to undergo, in certain circumstances, changes in its composition and in the mode of combination of the elements which compose organic matters. These co-operating circumstances are, in the respiration of plants, external, namely, heat and light, by the influence of which the nutritive sap and carbonic acid taken from without, undergo such a change that, by the exhalation of water and of the principle of combustion, oxygen, and by the attraction of the carbon, ternary combustible combinations are formed, which are fit to enter into the composition of the solid vegetable parts. In animals, on the contrary, oxygen is absorbed, which combines with the chyle, and carbonic acid and water are exhaled, by which the mass of humours is decarbonized and azote is accumulated. The consequence of this is the production of the quarternary or organic animal combinations, albumen, and fibrine, which are adapted to the nutrition of the solid parts.

In animals, the acts of respiration that are necessary for the preservation of life, are simultaneously dependent on two forces belonging to them, the muscular and nervous forces. This is the case, because in most animals, the renewal of the respiratory media in the organs of respiration, is accomplished by the movements of muscles, the excitement to which consists in an impulse generated in the nervous system. Moreover, the numerous nerves which enter the respiratory organs and surround the arteries, also exert an influence on the venous blood, which tends to favour the changes in its composition which it is destined to undergo by respiration. It is possible this influence resembles that of light in the respiration of plants. We shall return to this subject in our inquiry into the respiration of man.

CHAPTER SIXTH.

Of the Movement of the Nutritive Fluid.

CCXLVIII. The nutritive fluid prepared from the aliment is carried to all the parts of animals and plants, to be there employed in their nutrition. We will examine the movements it performs. It appears to me more convenient to study them in animals, where they are well known, before saying what they are in vegetables, where they are less accurately understood.

1. Movement of the Nutritive Fluid in Animals.

CCXLIX. Most animals, mammifera, birds, amphibia, fishes, mollusca, crustacea, arachnida, even insects, according to the recent observations of Carus, annelida, and among the radiaria, the holothuria, sea hedge-hogs, and asterias, contain particular spaces, in which the blood moves in a circular manner. The lower animals, on the other hand, have vessels provided for the circulation of the blood. In the medusa, lucernaria, &c., there only exist branching appendages of the digestive cavity, which are distributed in the body, and, after receiving the blood, carry it to the parts. In some entozoa, also, there are, according to the researches of Rudolphi, minute canals which branch off from the intestinal tube. Bojanus(3) saw, in the ascaris lumbricoides, two vessels winding along the sides of the body, which appeared to unite at the cephalic extremity. Perhaps these are the first rudiments of a vascular system for the circulation of the blood. Most intestinal worms, however, as also actinia and polypi, are altogether without branching and vasculiform appendages to carry the nutritive juice from the digestive cavity, this fluid seeming to be directly absorbed by the coats of the alimentary sac and spread throughout the homogeneous substance of their bodies.

CCL. We call the spaces in which the blood moves circularly the vascular system. It is composed of canals ramifying in the interior of the body, and always filled with blood, (cxv.) Its trunks communicate freely, so that the blood can pass from one into the other, or else their communication takes place through the medium of a hollow muscle, the heart, whose cavity alternately receives blood from one trunk and throws it out by another. In one division of vessels, the arteries, (cxvi,) the blood moves from the trunks, passing through branches, ramifications, and ramusculi, towards the periphery and the organs. In another class of vessels, the veins, (cxvii,) it returns from the periphery and the organs to the trunks, passing through the ramusculi, ramifications, and branches. These two divisions of vessels communicate

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(3) Oken's Isis, 1818, sec. viii, p. 1431.

together by their ultimate ramifications, the capillaries, in such a manner that the blood can be poured from the arteries into the veins.

CCLI. In the greater number of animals, mammifera, birds, reptiles, fishes, mollusca, and crustacea, the communication between the venous and arterial trunks takes place, either altogether or partly, by one heart, or even, in some animals, by two or three. The walls of a heart are composed of thick, fleshy bundles, which extend in different directions, are interlaced in a very close manner, and generally form several superposed layers. Externally the heart is enveloped in a sacciform serous membrane, closed on all sides, called the pericardium, which favours its movements, by the liquid it secretes. The cavity of the heart is lined by the smooth internal membrane of the sanguineous vascular system, extended from the venous trnnks to its walls, to which it is united by cellular tissue, and afterwards prolonged into the arterial trunks. At the orifices of the vascular trunks, this membrane forms diversely figured folds, frequently fixed to prominent muscular fasciculi, which folds are called valves of the heart, and which determine the direction in which the blood, driven forwards by the contraction of the heart's walls, is moved. The walls themselves of the heart receive ramifications from the aorta, which conveys to them the blood necessary for their nutrition, Numerous and very delicate nerves, spread in the muscular substance of the heart, seem to regulate its nutrition, and, through that, its susceptibility to the excitement the blood affords, as well as its contractile power.

CCLII. The presence of one or more hearts, their situation and composition, the arrangement of their valves, and their mode of union with the vascular trunks, are circumstances which vary considerably in animals. They are connected by close relations with the divers combinations of their structure, their abode, their mode of respiration, the intensity of the phenomena of life, and their dependence on the acts of nutrition, themselves placed under the influence of the sanguineous circulation. We shall briefly point out the composition of the heart in the different groups of animals.

The heart sometimes contains only one cavity and sometimes two, three, or four. When there is only one, in its dilatation it receives the blood from the venous trunks, and by its contraction it impels it into the arterial trunks. The reflux of the blood into the veins when the heart contracts, or from the arteries into the heart when it dilates, is prevented by valves. This most simple of all forms, exists in crustacea, in which the heart is placed between the branchial veins and the arteries of the body. The cephalopoda have three of these hearts, two between the veins of the body and the branchial arteries, and the third between the branchial veins and the aorta.

When there are two cavities in the heart, one receives the blood from the venous trunks, during dilatation, and propels it, during contraction, into the second, which in the same manner transmits it into the arterial trunk. Its return from the second into the first is prevented by valves situated at the point of junction. This first cavity always has thin walls, and is termed the auricle, *(sinus, atrium.)* The latter, on the contrary, is furnished with thicker and denser walls; and is denominated ventricle, *(ventriculus.)* The contractions and expansions of these two cavities are never effected simultaneously, but alternately. A heart thus formed is called simple. Sometimes we find a similar one between the venous trunks of the respiratory organs and the arteries of the body where it regulates the movement of the blood, as in most mollusca; this is called an aortic heart. Sometimes there is one between the trunks of the veins of the body and the arterial trunk of the respiratory organs, within which it regulates the course of the blood, as is seen in fishes; this is called a respiratory heart. There is also a simple heart between the venous trunks of the body and the organs of respiration, and between the arteries of the latter and those of the body, to regulate the circulation of blood in the body and respiratory organs, an arrangement which is met with in amphibious batrachia. In other reptiles, tortoises, lizards, and ophidia, the heart has two auricles, one of which receives the blood of the veins of the body, and the other that of the pulmonary veins. These two auricles pour the blood, by two openings, into a single ventricle, which is frequently divided, by a commencing partition, into several compartments imperfectly defined, whence arise the arterial trunks of the lungs and of the body, which receive the blood at the period of the ventricle's contraction. This is the demi-double heart. Lastly, the heart exhibits two auricles and two ventricles, one auricle and ventricle of which communicate by an opening, whilst a complete partition separates them from the two corresponding cavities of the opposite side. This is the truly double heart, which exists in birds and mammifera. The right half of the organ receives the venous blood returning from the body, mixed with the lymph and chyle, and projects it into the pulmonary artery. The left half, on the other hand, receives the blood returning from the pulmonary veins and sends it into the aorta.

CCLIII. The liquid contained in the vascular system, or the blood, has a greater specific gravity than water. It is slightly viscous, presents a peculiar odour, has almost always a somewhat salt taste, and exhibits a different colour according to the animals. That of mammifera, birds, amphibia, fishes, and annelida, is red. In mollusca it is white, or approaching to blue; in crustacea and insects, it is limpid and clear like water. The blood of holothuria, asterias, and sea hedge-hogs, is yellowish or orange.

CCLIV. If blood, just drawn from the veins, or that is yet inclosed in the veins of transparent parts, be examined by a microscope, we perceive a liquid containing coloured corpuscules, which are called globules of the blood.

These bodies, the discovery of which is due to Leuwenhoeck and Malpighi, have been observed in the blood of mammifera, birds, amphibia, and fishes, by Baker, Haller, Della Torre, Hewson, Fontana, Spallanzani, and others; and very recently by Villar, Home, and Baur, Doellinger, Prevost, and Dumas, Dutrochet, and others. Lister, Baker, Prevost and Dumas, Milne, Edwards, and Carus, saw them in the blood of mollusca; Leuwenhoeck in that of squillæ, and Carus in that of the common lobster. Lyonet saw them in the fluid of the dorsal vessel of caterpillars; Gruithuisen in the wings of the green grasshopper, and Carus observed them in the vessels of the larval libellulæ. Globules, therefore, appear to exist in the blood of all animals.

Their size and form, in animals, exhibit differences. In the blood of amphibia and fishes, their volume is greater than they present in birds and mammifera. In the latter they have a round form, and are slightly flattened. They appear oval in the blood of reptiles and fishes. They are round in the snail and common lobster, according to Carus and Prevost and Dumas. They have an oval shape in the larvæ of libellulæ.

The quantity of globules also varies. The greatest quantity is found in the blood of birds and mammifera. They are less numerous in that of amphibia and fishes; the blood of mollusca also contains less than that of vertebrated animals. Their number is more considerable in the blood of well-fed animals, than in those exhausted by hunger. The globules of red-blooded animals are composed of a colourless nucleus and a coloured cortical layer, which is separated during the coagulation of the blood. This layer does not appear to exist in the blood globules of invertebrated animals.

The globules of the blood doubtless proceed from the organic matters of the aliment dissolved by digestion, which in certain circumstances have the property of taking on a globular shape. They are found in the chyle, but as yet without a coloured coat. The latter seems to be formed only in the vessels of the respiratory organs.

CCLV. The blood which flows from the vessels coagulates; and the globules which were separated from each other during life, unite into one mass and leave the watery part. The coagulated portion of the blood, which is heavier, and falls to the bottom, has the name of clot, (crassamentum sanguinis,) whilst the watery part, which flows over it, has that of serum. The respective quantity of these two parts varies in animals. The blood of mammifera and birds contains more coagulable parts than that of reptiles and fishes. There appears also to be less of them in the blood of invertebrated animals, than in that of the before-named animals. The serum is composed of a solution of albumen, a little fat, salivary matter, and different salts. The clot, on the other hand, is formed of fibrine, and, in red-blooded animals, a peculiar colouring matter, the cruor, which contains a little iron.

CCLVI. The blood of vertebrated animals presents differences, in the different portions of the vascular system, which are better marked in mammifera and birds than in amphibia and fishes. The blood contained in the veins of the body, from all parts of which it returns, and which flows into the respiratory heart, mixed with lymph and chyle, has a red colour approaching to black, contains much water, but a small quantity of coagulable parts, and has the name of venous blood. That found in the arterial trunks of the respiratory organs is of the same kind. That which returns from the respiratory organs by the veins, as also that of the aortic heart, and the arteries of the body, is distinguished by a scarlet red hue. It is very rich in globules, and contains less water. This blood, prepared by the act of respiration, and called arterial, is a fluid absolutely necessary to the maintenance of life. It includes the materials for the nutrition of the solid parts, which receive it by the arteries spread through their tissue, attract them in the act of nutrition and combine with them. By nutrition all the parts of an animal body are retained in the state of chemical composition and organization which peculiarly belong to them, and in the conditions which render them fit to exert their different manifestations of power or activity. The arterial blood furnishes, moreover, numerous secreted liquids, some of which are essential to the preservation of life, either by flowing into the alimentary sac, where they effect the solution and assimilation of the food, or by moistening the internal surface of the serous and synovial membranes, and facilitating the exercise of the automatic or voluntary movements, whilst others have reference to the production of new beings.

The blood is the liquid in which all matters coming from without and entering into the composition of the solid parts exist, and into which all the materials of organs which regain the fluid form by their own manifestations of action, and are taken up by absorption, return. From it the different excrementitial matters are derived, the elimination of which is designed to maintain the chemical composition peculiar to it. Some of these excretions, as of those of the respiratory organs and the bile, emanate from the venous blood, whilst others, for instance, the urine and the exhaled matters of the skin, proceed from the arterial blood.

CCLVII. The blood, as the source of all the acts of nutrition, formation, and secretion, is in a reciprocity of action with all parts of the body. It keeps up the changes of composition which accompany the manifestations of life of the organs, and is the indispensable condition of the existence of animals. The subtraction of it or the destruction of its properties by various external influences or poisonous substances, causes the loss of life. Being necessary to the accomplishment and exercise of all the animal operations and all the manifestations of activity of animals, of digestion, absorption, respiration, nutrition, of the secretions, motions, nervous and generative actions, the blood is subjected to continual changes. Its quantity, composition, and qualities are modified by the acts of nutrition and secretion. What it loses in quantity, it recovers by the susception and assimilation of aliment. The changes it undergoes in its composition, are repaired by respiration and by the rejection of excrementitial matters. Thus, continually varying, the blood is the source of all the changes of composition which accompany the exercise of the life of animals, and the indispensable condition of the maintenance of their existence.

CCLVIII. The blood is agitated by an incessant movement during life. It flows from the heart by the trunks, branches, and ramifications of the arteries, arrives by these at the organs, whence it returns into the cavities of the heart, by the radicles, branches, and trunks of the veins, then again passes into the arteries. This uninterrupted movement, on which the continuance of life depends, is called the circulation. That which occurs in the vessels of the organs of respiration, has the name of the lesser or respiratory circulation, whilst that which takes place in the remainder of the body, takes the denomination of the great or aortic circulation. In vertebrated animals, mammifera, birds, amphibia, and fishes, a third circulation, perfomed by vessels only, goes on in the liver. The veins of the stomach and intestinal canal, of the pancreas, and the spleen unite into a single trunk, the vena portæ, which is distributed through the liver like arteries, and communicates with the lower vena cava by the hepatic veins. In amphibia and fishes, the vena portæ, moreover, receives the veins of several other organs. This movement of the venous blood through the liver, is intended for the secretion of the bile, a fluid in part excrementitial, and the elimination of which maintains the mass of the blood in the condition of chemical composition necessary for the accomplishment of nutrition.

CCLIX. As to the cause of the blood's circulation, a subject on which physiologists have considerably disputed since Harvey's discovery, it may be regarded as proved, that it is owing as well to the manifestations of activity of the walls of the spaces in which the blood is contained, as to the inherent property of the blood itself, in other words, of its organic globules, moving by their own impulse. It seems, too, that the organs, whose substance is subjected to an incessant change, exercise an attractive power over the blood, by which also the movement of the blood is favoured. We will examine rapidly these different conditions of the circulation. We shall speak more fully of them when considering the circulation of the blood in man.

CCLX. The living heart, whose arrangement and structure result from the plastic activity manifested in the fecundated germ, is endued to a great extent with a contractile faculty, called muscular power, or irritability. This power subsists in the heart of an animal so long as the nutritive vessels convey arterial blood to its substance and nourish it. It quickly diminishes and is soon altogether extinguished in a heart separated from the body. The stimulus which excites the irritable walls of the heart to contract, is the blood, as Haller fully established by numerous experiments. It flows from the venous trunks into the auricles when these relax and dilate; their muscular walls then contract and drive the blood they compress into the ventricles, which dilate to receive it. The reflux of the blood from the auricles into the venous trunks is prevented by the contraction of circular muscular fasciculi which surround the latter, or by valves. The distended walls of the ventricles, stimulated by the blood they have received, also contract in all directions, according to the arrangement of their fleshy bundles, with great force and rapidity, and throw the blood, by jets or gushes, into the arterial trunks. The blood would return from the ventricles into the auricles, if strong valves did not oppose it. Just as the ventricles contract, the auricles, which are empty, again dilate and admit other blood coming from the great venous trunks, which they drive into the ventricles, whose expansion coincides with their contraction. The contractions and expansions of the auricles and ventricles continue thus alternating during the whole of life; whence it follows that blood is incessantly being received from the venous trunks, and thrown into the arterial trunks. Whilst the trunks of the veins pour the blood into the auricles, which dilate, it returns from twigs and branches into the trunks. The blood thus thrown with great impetus into the arteries, is carried to the organs by branches, twigs, and ramifications of these vessels, at whose extremities it re-enters the veins (but not till its properties are changed) which take it back to the heart.

The course of the blood in the aforesaid direction, and in circular paths, has been demonstrated by the experiments of Harvey on the effects which the compression and ligature of arteries produce on its movement, as well as by the conclusions resulting from them. Compressed or tied arteries swell above the impediment, on the side next the heart, whereas they remain flaccid and contracted below it. On the contrary, veins, submitted to the same treatment, are distended below the impediment and shrink above it. Moreover, the circular movement of the blood has been observed in living animals by the aid of the microscope, by Malpighi, Leuwenhoeck, Baker, Haller, Spallanzani, and many other naturalists.

CCLXI. In the arteries, the blood flows by jets or gushes from the trunks to the branches, and from these to the twigs and ramusculi, until at last it moves uniformly in the most minute ramifications. This motion is produced by the vehement contraction of the ventricles of the heart, whence it follows, that the blood thrown by gushes from the ventricles into the arteries, drives before it what was already contained in the trunks, so that at each contraction of the ventricles, the column of blood which fills the arterial trunks is pushed on towards the peripheric ramifications by a fresh wave. At each contraction of the ventricles, there is felt, on compressing the artery, a beating which depends on the afflux of the projected fluid column, and which even raises the finger when the pressure is not strong. In pricking an artery we also see the blood flow by jets synchronous with the contractions of the ventricles. Lastly, the motion imparted to the blood by the heart's action is easily perceived by the aid of the microscope in the arteries of transparent parts, of the mesentery, the lungs, and the swimming membrane of small living animals.

Thus the irritable heart is the principal agent of the flux of blood into the arteries, from the vehement contraction of its ventricles and the jaculatory movement thereby impressed on the fluid. This cause, however, as some physiologists assert, is not the only one; the coats of the arteries also taking a part in it.

CCLXII. The arteries, which consist of a peculiar fibrous membrane, are extensible, elastic, and indued with a vital power of contraction; but this faculty is not identical with muscular irritability, as some physiologists suppose. When mechanical or chemical agents are applied to living arteries, they do not contract like muscles subjected to the same treatment, as I shall hereafter explain when speaking of the properties of these vessels in man. However, every artery cut across and exposed to the influence of the air, in a living animal, contracts somewhat on itself, which does not occur in a dead body, and cannot, consequently, be attributed to elasticity alone. The existence of a living contractile faculty in the coats of arteries follows also from the fact that, after losses of blood, their calibre diminishes in proportion to the quantity of blood that has been drawn from the animal. This power which arteries have of straitening their calibre, independently of elasticity, we shall designate provisionally by the name of organic contractility, or tonicity.

At the moment of the vehement contraction and emptying of the ventricles, the arteries, which are extensible and ever filled with blood, by the influx of a fresh quantity of the latter, are dilated somewhat beyond their medium diameter, but very slightly. Their elastic and contractile coats then strive to return to this medium diameter, and this takes place whilst the ventricles are dilating and receiving a fresh wave of blood from the auricles. As the valves situated at the base of the arterial trunks do not allow the blood to flow back into the ventricles, it is necessitated, in consequence of the diminution the arteries suffer in regaining their medium diameter, to proceed on to the more minute ramifications. This reaction of the elastic and contractile arteries, which has been observed by many physiologists, has been improperly rejected by some, or not less falsely attributed to elasticity alone. In the small arteries, the blood no longer flows by jets, but uniformly, as most physiologists have ascertained by the aid of the microscope. This difference depends on the force of the contracting ventricles, and the pushing impulse they give to the column of blood being weakened by the distension of the arterial coats. The movement of the blood in the smallest twigs cannot be attributed to the heart alone, but should rather be considered as an effect arising from the contractility of the arterial coats, and to the property the blood possesses of moving by its own impulse. The best proof of this is, that the blood flows in the arteries of animals which have no heart.

CCLXIII. The blood passes from the most minute arterial ramifications into the veins. Besides that it has frequently been proved by injections of thin substances in dead animals that there is a communication between these two orders of vessels, the same fact has been observed, by means of the microscope, in the transparent parts of living animals, by very many naturalists, Malpighi, Leuwenhoeck, Cowper, Molyney, Cheselden, Baker, Hales, Haller, Reichel, Spallanzani, and others. These authors saw the blood flow from the arteries into the veins. Dœllinger and Pander(4) have lately made the same observation in the venous figure (structure) of the hatched hen's-egg. Villar(5) saw the blood in the tails of bull-frogs pass from the arteries into the veins. J. Thomson(6) found the same in the swimming membranes of frogs. Erman(7) saw rows of blood globules, in the fringed branchi of fully developed frogs, pass from the small arteries into the veins. The same was observed by Cuvier(8) in the gills of larval water salamanders, and by Configliachi and Rusconi(9) in those of the proteus. Dœllinger(1) saw the blood in the embryons of fishes flow along the minute convoluted arteries into the veins. Lastly, Carus(2) remarked an arterial and venous current in the plates of the tail of the larval libellula, and ascertained that the former was convoluted to form the latter. From these testimonies, we cannot doubt the conversion of the minute arteries into veins, and the passage of the blood from the first into the second. The communication between the two orders of vessels is, for the most part, so narrow as not to allow more than a single

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(4) Beiträge zur Entwickelungs-geschicte des Hühnchens im Eye. Wurtzbourg, 1817, in fol.

(5) Journal de Physique, v. lviii, p. 406.

(6) Lectures on Inflammation. Edinb., 1813, p. 75.

(7) Schriften der Berliner Akademie, 1816—17, p. 213.

(8) Recherches sur les amphibies douteux, p. 22.

(9) Del proteo anguino, p. 72, tab. 4, sec. 18.

(1) Vom Kreislaufe des Bluts; in the Denkschriften der Münchner Akademie, 1818—20, v. vii, p. 169, plates.

(2) Blutumlauf in den Larven Netzflügeliger Insekten. Leipsick, 1827, p. 12.

row of blood globules to pass ; more rarely two or three globules are seen to pass at once. Further, the current of blood is uniform, not by shocks, which militates against the opinion of physiologists who think the blood traverses the capillary vessels by virtue of the heart's contraction. But it still remains in doubt whether the small sanguineous currents are inclosed in the vascular coats at the time of their passage from the arteries into the veins, as Leuwenhoeck Haller, Spallanzani, and others, suppose and assert to have seen, or if they are merely contained in hollow ducts within the mucous tissue, as Gruithuisen, Dœllinger, Carus, and others presume. It may be considered, however, as a determined fact, that at its first appearance in the vascular figure of the hatched bird's-egg the blood is not as yet surrounded by vascular coats.

CCLXIV. The blood proceeds in the veins from the ramifications towards the branches and trunks, where its course is more regular and slow than in the arteries. It moves in the trunks by gushes, which are synchronous with the distension of the auricles. Its progress in the veins is the result of the continual flow of blood from the arteries, of the elasticity and vital contractility of the venous coats, and of the alternate expansions of the auricles. The blood poured from the arteries distends the veins ; these react on the fluid, and partially contract, by virtue of the elasticity and contractility of their fibrous coat, in which they resemble the arteries, and to which I shall return hereafter in speaking of the properties of the veins. Hence, the blood advances from the twigs towards the branches, during which progress the valves prevent its retrogade movement, and support the column of fluid thus divided into numerous sections. The flow of the blood towards the heart is, moreover, favoured by the distension of the auricles, for it rushes from the trunks into the vacuum produced by this distension, whilst at the same time that in the twigs and branches arrives in the trunks that are being emptied. Haller, Wilson, Platner, and Blumenbach supposed that the auricles by their dilatation acted like a sucking pump on the blood contained in the veins. This may be said to be demonstrated by the arguments of Carson, Jugenbuehler, and Schubarth, as well as by Dœllinger's observations, who, in studying the embryo of a bird, saw the blood advancing along veins, whilst the trunks poured it into the auricles at the moment of their dilatation.

CCLXV. Besides the movements communicated to the blood by the alternate contractions of the irritable heart, which hereby acts like a repelling and sucking pump, independently of those caused by the elastic and contractile coats of the arteries and veins, it possesses the property of moving itself. This property has been attributed to it by several physiologists, whilst others have doubted its reality. Harvey, Glisson, Bohn, and others assert that the blood is a living fluid, and capable of a motion which particularly belongs to it ; and Albinus, Wilson, John Hunter, Gallini, &c., have advanced weighty reasons in favour of this doctrine. Heidmann,(3) in the examination of fresh drops of blood by the microscope, saw a reticular tissue form in the midst of the fluid during its coagulation, which performed during some minutes movements that resembled feeble contractions and expansions of muscular fibres. G. R. Treviranus(4) observed by the microscope two sorts of motion in the blood running from the vessels of a living animal. One consisted of a whirling movement of the sanguineous globules, whilst the other shewed itself during coagulation by a convulsive contraction of the whole clot. Cavollini(5) even saw a liquid in the tubes of the trunks and ramifications of the horny skeleton of sertularia, containing granular bodies that had a rotary motion. Haller(6) Spallanzani, Wilson Philip,(7) G. R. Treviranus,(8) and others, remarked, by the microscope, that the blood continued to move in the vessels of different animals, chiefly of frogs, for some time after the great cardiac vessels had been tied, or the heart itself extracted, which I have myself several times witnessed. C. F. Wolff, Dœllinger, and Pander, Prevost and Dumas and others saw, even before the formation of the vessels and the heart, blood globules appear in the hatched bird's egg, which were in motion. John Hunter, Gruithuisen, Kaltenbrunner, &c., saw in the mucous tissue, in inflamed parts, in regenerating tissues, and during the cicatrisation of wounds, sanguineous puncta, placed in order after each other, thus forming small streams, which represented new vessels, and united with the already existing ones. All these phenomena testify that the blood globules in their quality of organic parts, possess the faculty of moving, which Wolff formerly attributed to them. But, though this power cannot be denied to the blood, and though the first movements it performs, before the formation of the heart and the vascular coats, can be only a force inherent in itself, yet in animals furnished with a heart its progression is chiefly the result of the action of this organ, after the extinction of whose energy the circulation is immediately stopped. Finally, the blood remains liquid, and preserves its power of moving, only so long as it is connected with living bodies. Once out of the vessels, it coagulates, and quickly loses its movements.

CCLXVI. The organs appear to exert a vital attraction on the arterial blood on the action of any part being increased, whether in consequence of an internal or external excitement, or by the influence of the nervous system, more blood arrives at that part. Let an external part, the conjunctiva for

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(3) Reil's Archiv. für die Physiologie, v. x, p. 417.
(4) Biologie, v. iv, p. 654.
(5) Abhandlungen über Pflanzenthiere des Mittelmeers, p. 56.
(6) De Motu Sanguinis; in Oper. Min., v. i, p. 115, sec. 8. Sanguinis motus, qui alias præter cor causas, habere videtur.
(7) Philos. Trans., 1815, part ii, p. 224. Med. Chir. Trans., v. xii, p. 2.
(8) Vermischte Schriften, v. 1, p. 102.

instance, or a part of the skin, be subjected to a mechanical stimulus, let it be rubbed, exposed to a high temperature, let an electric spark fall on it, or place it in contact with both poles of a galvanic pile, immediately the blood rushes thither in greater quantity, and the part reddens. The same happens in the case of a wound. All the membranes that secrete mucus or serum, all the secretory and other organs likewise receive more blood when they have been stimulated. This cannot be attributed to a redoubling of the heart's action, since this only exerts an influence on the movement of the blood in general, and could not change the quantity of it that is sent to each part of the body. It seems rather to rest on the fact that the organ whose action is increased, undergoes more than ordinarily rapid changes in its material composition, and by that more quickly and abundantly attracts the arterial blood, which alone is capable, by its influence on nutrition, of making the part able to put on an increased energy. When I treat of the circulation of the blood in man, I shall detail the arguments which speak in favour of an attraction being exercised on the blood by the living organs.

CCLXVII. The arrangement of the sanguineous vascular system, its degree of complication, and the direction the blood therefore takes, are intimately connected, in the different groups of animals, with the degree of complication of their structure and of diversity and intensity of their vital phenomena. In mammifera and birds which have the most complicated organization, and in which we observe the most varied and intense manifestations of activity of the nervous system, as well as the most energetic and durable motions, the movement of the blood through the respiratory organs, and the whole body is controlled by particular divisions of the heart. The course marked out for it in the lungs and body are so distinct from each other, that a single drop of chyle or blood cannot arrive at the parenchyma of the organs, without previously being subjected to the action of the air in the lungs.

In amphibia, which are less excitable, and whose motions have not so much vehemence or duration, the circulation of the blood through the lungs is not so distinctly separated from that through the rest of the body as in the first mentioned animals, for the arterial and venous blood are mixed together in the heart. Still this organ is the principal agent in the movement of the blood in its double course. In fishes, crustacea, and mollusca, whose nervous systems present a less degree of activity, and whose muscular systems execute less vehement motions, the two currents of the blood are fully separated from each other by the respiratory organs and the body, but its movement is only maintained in one of them by a heart, namely, a branchial heart in fishes, an aortic heart in crustacea and most mollusca. In annelides and radiaria, the two routes of the blood are not so accurately divided as in the preceding animals; the heart, the chief impelling agent of the blood, disappears, and the vessels alone perform the sanguineous circulation.

CCLXVIII. The volume of the heart in proportion to the mass of the body, the force with which it keeps up the movement of the blood by its contraction, and the velocity of the blood's circulation, are, in animals, likewise, closely connected with the complication of their structure and the intensity of the manifestations of action of their nervous and muscular systems. In mammifera and birds the blood moves with the greatest rapidity and strength in its double course; more slowly and heavily in amphibia and fishes, and most tardily of all in crustacea, mollusca, annelides, and radiaria. The influences and circumstances which exalt the phenomena of life in animals mostly accelerate the movement of the blood, whereas those which depress them render the circulation slower and less energetic. Finally, the duration of life is so much more dependent on the circulation of the blood in animals, as the phenomena which characterize them, namely, the actions of the nervous system and the voluntary motions, possess greater intensity. The life of mammifera and birds is extinguished, if the circulation be interrupted only for a few minutes. On the contrary, amphibia, fishes, mollusca, and worms continue to live for many hours, and even, in some circumstances, during whole days, though the movement of blood in them be suppressed, their heart extracted, or the continuity of their great vascular trunks destroyed.

In support of what has just been said, let us glance over the arrangement of the sanguineous vascular system in the different classes of animals.

CCLXIX. In fully-developed warm-blooded animals, mammifera, and birds, which have the most complicated structure, the most developed nervous system, the most intense nervous actions, and most durable animal motions, which feel the want of food at the shortest intervals and digest with the greatest rapidity,—in which life most eminently depends on the renewal of air in the lungs,—in which the renovation of the materials of the organism is effected with the greatest celerity, and which exhibit the most varied and copious secretions,—in which, in short, the manifestations of life exhibit at the same time the greatest diversity and intensity,—in such animals is the vascular system most fully developed. Their voluminous heart is composed of two halves, divided by a partition, or of two hearts closely joined together. Each half of this heart has a thin-coated cavity communicating with the venous trunks, called auricle, and another with thick walls, communicating in one direction with an auricle and in the other with an arterial trunk, called ventricle.

The black blood returned from the different organs is poured into the auricle of the right half of the heart by the venous trunks of the body, the venæ cavæ. With this is mixed the chyle and the lymph, conveyed by the lymphatic trunks.

By the contraction of the auricle the blood is driven into the right ventricle, whose contraction then causes it to proceed into the pulmonary artery. This artery, spread throughout the lungs, and changed into a minute net-work on the surface of the small and vastly-numerous pulmonary cells, exposes the venous blood mixed with the chyle to the action of the atmospheric air, which converts it into arterial blood. The scarlet blood, taken up by the veins of the lungs, which gradually unite into trunks, is by them carried to the left half of the heart, which has thicker and stronger walls. From the left auricle it passes into the corresponding ventricle, whence it is driven with great force into the aorta, whose ramifications convey it to all the parts, which are nourished and maintained thereby in the exercise of their vital properties. From the arterial blood are extracted all the humours, with the exception of the bile. Whatever part of it has not been used in nutrition or secretion, passes from the minutest arteries of the organs into the veins, which unite successively into twigs, branches, and trunks, and pour the now black blood into the right auricle. The veins of the stomach, the intestinal canal, of the spleen and pancreas form the vena portæ, which ramifies in the liver, like an artery, and is chiefly instrumental in the secretion of the bile. The veins that bring back the blood from the liver enter into the lower vena cava.

The circulation of the blood occurs in a very rapid manner in birds and mammifera. Prevost and Dumas(9) reckoned a hundred and ten pulsations in a minute in a crow and duck, a hundred and thirty-six in a pigeon, a hundred and forty in a hen, and nearly two hundred in a heron. The number of pulsations in a minute is, according to Parry(1) and Greve,(2) from thirty-eight to fifty-two in the horse, and from sixty-four to seventy in the ox. Prevost and Dumas remarked fifty-six pulsations in the sheep, eighty-four in the goat, ninety in the dog and ape, a hundred in the cat, a hundred and twenty in a rabbit, and a hundred and forty in a guinea-pig.

CCLXX. In amphibia, the pulmonary and general circulation are less distinct than in mammifera and birds. The hearts of tortoises, lizards, and ophidia are composed of two auricles, divided by a partition, and a ventricle containing, in tortoises and lizards mostly three, in ophidia two cavities communicating with each other, from which the pulmonary arteries and those of the body arise. The venous blood returning from the body mingled with the chyle and lymph, is poured into the right auricle by the venæ cavæ, whilst the arterial blood coming from the lungs is carried by the pulmonary veins into the left auricle. When the two auricles contract, the two sorts of blood

(9) Bibliotheque Universelle, v. xvii, p. 294.
(1) An Experimental Inquiry into the Nature, Causes, and Varieties of the Arterial Pulse.
(2) Bruchstücke zur Vergleichenden Anatomie und Physiologie, p. 29.

are driven into the compartments of the cardiac ventricle, where they mingle together, after which the contraction of this cavity sends the fluid into the pulmonary arteries and into those of the body. This has been demonstrated by the researches of Caldesi,(3) Duverney,(4) Mery,(5) Buissiere,(6) Morgagni,(7) Wrisberg,(8) and others on the heart of tortoises; Duverney(9) and Cuvier(1) on that of the crocodile, and Schlemm(2) on that of serpents.

The heart of frogs, toads, salamanders, and tritona is formed only of a single auricle and ventricle. The former receives the blood from the lungs and heart, which passes thence into the ventricle and afterwards into the artery of the body.(3) The pulmonary arteries are only simple branches of the aorta. A similar arrangement is found in the heart of reptiles furnished with branchiæ, the siren and proteus. In the *siren lacertina*, according to Cuvier's researches,(4) the artery arising from the ventricle is ramified entirely in the branchiæ, and the branchial veins form the aorta by their union, as in fishes. In the *proteus anguinus*, on the contrary, the artery proceeding from the cardiac ventricle divides, according to the researches of Configliachi and Rusconi,(5) into two trunks, which give branches to the gills, to the head, and lungs, and then unite to form the descending aorta. The branchial veins partly join with the arteries of the head and partly with the descending aorta, whilst the pulmonary open into the venous trunks of the body. Rusconi(6) met with a similar disposition in the larvæ of aquatic salamanders.

In amphibia, as in mammifera and birds there is found a vena portæ system, only much more extensive, since, from the researches of Bojanus,(7) not only the veins of the stomach, the intestinal canal, the spleen, and pancreas, but, moreover, those of the posterior extremities and integuments of the belly, contribute in forming the venæ porta.

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(3) Osservazioni Anatomiche intorno alle tartarughe maritime, d'aqua dolce e terrestri. Florence, 1687, in 4to, p. 59, tab. 7.

(4) Mem. de l'Acad. des Sc., 1699, p. 227. Description du cœur de la tortue, de la grenouille, de la vipere, des poissons, &c.

(5) Ibid., 1703, pp. 355, 403, 437, 451, 457. Description du cœur d'une grande tortue terrestre de l'Amerique.

(6) Anatomical Description of the Heart of Land Tortoises from America in Philos. Trans. 1710, p. 170.

(7) Adversar. Anat., v. v, p. 24.

(8) Observationes Anatomicæ de Corde testudinis marinæ Mydas dictæ, in Comm. Soc. reg. Gœtting., v. xvi, p. 18.

(9) Description du cœur du Crocodile in Mem. de l'Acad. des Sc. de Paris, 1703, p. 390.

(1) Anat. Comparée, v. iv, p. 222.

(2) Tiedemann's und Treviranus Zeitschrift für Physiologie, v. ii, p. 101.

(3) Swammerdamm has described the heart and vascular system of the frog in his Biblia Naturæ, and gives a plate of it. Tab. 49, fig. 3, 4.

(4) Recherches sur les Amphibies Douteux, p. 21.

(5) Del proteo anguino, p. 69, tab. 4, fig. 8.

(6) Descrizione Anatomica degli organi della circolazione delle larve delle Salamandre aquatiche. Pavia, 1817, 4to, fig. 6.

(7) Anatome testudinis Europæ, p. 129, tab. 25.

Judging from the movements of the heart, the circulation of the blood takes place in a less rapid and vehement manner in reptiles than in mammifera and birds. The temperature of the media in which these animals live, and the interruption of the respiratory movements, exert a vast influence on the celerity and slowness of the heart's contractions. The heart of tortoises only contracts from thirteen to twenty in a minute, according to Caldesi's observations, and even ten times only from those of Fontana. Wilford counted from fifteen to twenty-five pulsations in a minute in the heart of a boa;(8) Fontana seventy and odd in a frog's heart. When animals are exhausted by hunger, the movements of the heart become very slow. Fontana saw the heart of a turtle that had not taken food for a long time, beat only ten times in the space of twenty-two minutes; a frog's heart ten times in the same circumstances. The life of amphibia does not depend on the circulation of the blood so much as that of mammifera and birds, for tortoises, serpents, and frogs move for a long time after the heart has been extracted.

CCLXXI. In fishes the circulation of the blood in the gills is accomplished by a heart, but in the body by vessels only. The heart, which is small in proportion to the mass of the body, isplaced behind the branchiæ, and is composed of an auricle and ventricle.(9) The former receives the black blood from the veins, which returns from the different parts of the body with the chyle and lymph, and passes it into the ventricle. The ventricle drives it into the branchial artery, which, at its origin, forms a contractile dilated space. It ramifies in the gills, on the multitudinous lamellæ of which it is reduced to a minute net-work, where the venous blood is changed into scarlet. All the branchial veins unite into one large trunk placed along the under surface of the vertebral column, the aorta, in fact, which carries to the organs the blood necessary for their nutrition, by its numerous ramifications. The major part of the veins returning from the organs form the superior and inferior venæ cavæ, which enter the single auricle. The veins of the stomach, of the intestinal canal, and the spleen, as also, in many fishes, according to Rathke's(2) observations, of the genitals and swimming bladder, convey the blood to the liver.

The circulation is less rapid than in mammifera and birds, for the heart only contracts from twenty to thirty times in a minute. According to Fontana's observations the heart of the eel beats twenty-four times, or only twice or thrice when exhausted by hunger.

CCLXXII. In the mollusca there are two circulations, one in the respi-

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(8) Thomson's Ann. of Philos., v. ii, p. 26.
(9) Tiedemann's Anatomie des Fischherzens. Landshut, 1809, 4to.
(1) Du Verney in the Mem. de l'Ac. des Sc. de Paris, 1699, p. 240, fig. 16.
(2) Ueber die Leber und das Pfortader-system der Fische, in Meckel's Archiv. für Anatomie und Physiologie, 1826, p. 126.

ratory organs, the other in the body. The first is maintained by the heart, the second accomplished by the vessels. The heart is generally formed of an auricle and ventricle. Its situation varies according to the arrangement of the respiratory organs. When they are placed on each side of the body, the heart occupies the median line, as in the genera *scyllæa, tethys, tritonia,* and others. If they are on one side only, the heart is on the same side. In the gasteropoda with twisted shells, the heart has a place opposed to the direction of the body. The blood returned to the respiratory organs by the veins, flows into the auricle, whence it passes into the ventricle, which disperses it over the body by the ramifications of the aorta. It is then collected from the different organs into the great venous trunks of the body, which again ramify like arteries in the apparatus of respiration.(3) In other respects the sanguineous vascular system presents a few peculiarities in the different groups of mollusca. Thus, the cephalopoda have no auricle, and at the transformation of the two branches of the vein of the body into branchial arteries, there is found in them a special heart, on each side, for accomplishing the movement of the blood in the branchi. In some acephala, for instance, in the genera *arca* and *pinna,* the ventricle is divided into two segments, from each of which an aorta arises, which is also the case in the *teredo,* according to Home.(4) The naked acephala, and the genus *lingula,* are without an auricle. In the the shell acephala,(5) and among the gasteropoda, those of the genera *patella* and *haliotis,* have, on the other hand, two auricles, which receive the blood from the branchi and transmit it into the ventricle.

The circulation is slowly performed in mollusca. Gaspard(6) saw the heart of a vineyard snail (helix pomatia) beating, in the summer, twenty-five to twenty-eight times in a minute. That of a pond-mussel contracted, according to Pfeiffer,(7) fifteen times in the minute. Further, the vivacity of the heart's movements is very variable, according to the temperature of the air or water in which they remain.

CCLXXIII. The existence of the circulation of the blood in crustacea was known long ago to Harvey(8) and Willis.(9) One saw the movements

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(3) As Swammerdamm first ascertained in the genus *limax.* (Bibl. Nat., tab. 5, fig. 4, 5.) The same thing occurs in acephalous mollusca, according to Bojanus. (Ueber die Athmen und Kreislaufswerkseuge der Zweischaligen Muskeln. Jena, 1821.)

(4) Philos. Trans., 1806, p. 184.

(5) Poli Testacea utriusque Siciliæ, tab. 9, fig. 11, 12, tab. 10, fig. 16.

(6) Magendie, Journal de Physiologie, v. ii, p. 295.

(7) Naturgeschichte der Deutschen Land-und-Süss-Wasser Mollusken. Abth. 2, p. 22.

(8) De motu cordis et sanguinis in animalibus. Frankfort, 1628, in 4to, p. 49. Est hic apud nos minima squilla (quæ Anglice dicitur a shrimp, Belgicé en Gerneel) in mari, et in Thamesi capi solita, cujus corpus omnino pellucidum est. Eam aquæ impositam sæpius præbui spectandam amicissimis quibusdam meis, ut cordis illius animalculi motus liquidissime perspiceremus, dumexteriores illius corporis partes visui nihil officerent, quo minus cordis palpitationem quasi per fenestram intueremur.

(9) De anima brutorum. Amsterdam, 1674, in 12mo, p. 48, tab. 3, fig. 1.

of the heart in a *squilla*, and the other described the heart and vessels of the common lobster. The heart of *crustacea decapoda*, which Rœsel(1) likewise described, is situated on the dorsal shield, behind the stomach, and is a body or aortic heart. The following is the manner in which the circulation is performed, according to the observations of Audouin and Milne Edwards.(2) The blood leaves by six vessels of the heart, which is voluminous and furnished with thin muscular walls. Three of these vessels convey it to the anterior parts of the body, the eyes, the antennæ, &c.; two others conduct it to the liver; and the last, which has a large calibre, the aorta, passes through the chest and belly, whence it sends branches to the limbs. The veins(3) which have extremely thin coats, unite into two or three trunks or reservoirs, inclosed in the calcareous pieces of the thorax. From these trunks vessels arise which proceed to the branchi. These conductor vessels of the blood to the branchial organs, therefore, are in lieu of arteries, and ramify in the branchial lamellæ. From the gills other veins proceed which open into the heart. At the junction of the two principal venous trunks with the heart there are valves, which prevent the blood from retrograding during the heart's contraction.

There is likewise a circulation in the other crustacea. Degeer(4) and O. F. Mueller(5) saw two currents running in opposite directions in the antennæ and paws of squillæ. Schœffer(6) observed a cardiac canal in the *limulus lacustris* (Muel.) exhibiting alternate contractions and dilatations.(7) Jurine, the younger, witnessed the circulation of the blood in the *argulus foliaceus*. He and Ramdohr(8) found a cardiac canal in the *daphnia*, performing vivacious movements. Finally, G. R. Treviranus(9) also found a similar canal in the *oniscus*, the *armadillo*, and the *idotea*. The blood appears to go, as in the decapædous crustacea, from the heart to the organs, and to return from these to the heart by the branchi.

CCLXXIV. In arachnida, spiders, *phalangia*, and scorpions, Cuvier,(1) J. F. Meckel(2) and G. R. Treviranus(3) ascertained the presence of a vas-

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(1) Insektenbelustigungen, v. iii, tab. 58, fig. 9, 14.
(2) Recherches Anatomiques et Physiologiques sur la Circulation dans les Crustacées: in Ann. des Sc. Nat., v. xi, July, 1827, p. 283.
(3) Lund (Isis. 1825, sec. 5, p. 593) was deceived in denying veins in the crustacea. G. R. Treviranus (Zeitschrift für Physiologie, v. ii, p. 152) has, however, started some objections on this point.
(4) Mem. pour servir à l'Hist. Nat. des Insectes, v. vii, p. 512.
(5) Zoologia Danica, v. ii, p. 48.
(6) Der krebsartige Kiefenfuss, p. 64.
(7) Ann. du Musée d'Hist. Nat., v. vii, p. 431. Hist. Nat. des Monocles. Geneva, 1820.
(8) Mikrographische Beiträge zur Entomologie und Helminthologie, v. i, p 22.
(9) Vermischte Schriften, v. i, p. 58, 78.
(1) Anat. Comparée, v. iv, p. 419.
(2) Beiträge zur vergleichenden Anatomie, v. i, part 2, p. 108, in the scorpion.
(3) He describes the cardiac canal and its vessels in the *aranea domestica* and *atrox* (Ueber den inneren Bau der Arachniden. Nuremberg, 1812, p. 28, tab. iii, fig. 28, 30) and *aranea*

cular system for the movement of the nutritive fluid. The heart traverses the body in the shape of an oblong sac, contracted at the extremities, and is provided with a delicate layer of muscular fibres. From this sac vessels proceed which are distributed through the body and the respiratory organs. During life it is in a state of alternate contraction and expansion. Probably, during its expansion, it receives the blood from the respiratory organs, and, by its contraction, sends it to the different parts of the body. Perhaps the vessels returning from the organs ramify in the respiratory apparatus, as in the crustacea. Leeuwenhoeck(4) Baker(5) and Degeer(6) perceived, by the microscope, a current of blood in two opposite directions, as if it were passing through arteries and veins, in the transparent parts of spiders.

CCLXXV. There is also a circular movement of humours in insects. Malpighi(7) first observed, in the silk worm, as well as in other caterpillars and butterflies, a canal extended along the body, underneath the skin of the back, filled with a liquid and agitated by strong pulsations, which he called a heart. Swammerdamm(8) and Lyonnet convinced themselves of the existence of the canal; but as they could discover no ramifications diverging from it and distributed in the body, they hesitated to consider it a heart. Cuvier,(9) Marcel de Serres,(1) J. F. Meckel,(2) Herold,(3) and others have not succeeded any better. J. Mueller(4) saw the dorsal vessel send branches to the head, and a great number of delicate and hollow filaments to the ovarian tubes. Although this vessel, in its situation, arrangement, and manifestations of life, has the greatest analogy to the heart of crustacea and arachnida, physiologists, nevertheless, refuse to attribute the functions of one to it.

Movements of humours in different parts of insect bodies have been observed, by aid of the microscope, by an anonymous author,(5) Nitzsch,(6)

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diadema (Vermischte Schriften, v. i, p. 4, tab. 1, fig. 4;) of the scorpion in the former work, (p. 9, tab. 1, fig. 4,) and the *phalangium* in the latter work, (v. i, p. 31, tab. 3, fig. 16, 18.

(4) Arcan. Naturæ, v. iv, p. 331.

(5) On the use of the Microscope, v. i, p. 130.

(6) Loc. cit.

(7) Oper. Omnia, v. ii, De Bombycibus, p. 20, 42.

(8) Traite Anatomique de la Chenille, qui ronge le bois de Saule. The Hague, 1762, in 4to, p. 104, pl. 4, fig. 4, p. 425.

(9) Mem. de la Soc. d'Hist. Nat. de Paris, An. 7, p. 34.—Anat. Comparée, v. 4, p. 417.

(1) Observations sur les Usages du Vaisseau Dorsal, in Mem. du Muséum d'Hist. Nat. v. iv. p. 149, 313, v. v, p. 59.

(2) Ueber das Rückengefäss der Insekten, in Archiv. für die Physiologie, v. i, p. 469.

(3) Physiologische Untersuchungen über das Rückengefäss der Insekten. Marburg, 1823, in 8vo.

(4) Ueber die Entwickelung der Eyer un Eyerstocke bei den Gespenster. Heuschrecken und eine neu entdeckte Verbindung des Rückengefässes mit den Eyerstöcken bei den Insekten, in the Nov. Act. Acad. Nat. Cur., v. xii, part 2, p. 555.

(5) Brief eines Ungenannten in Baker's Beiträgen zu nützlichem und vergnügendem Gebrauch und Verbesserung des Mikroscops. Augsburg, 1754, p. 506.

(6) Commentatio de Respiratione Animalium. Wittenberg, 1808, p. 27. In larva tipulæ plumosæ quæ tracheis caret, vasa sanguifera ipse mihi animadvertisse videor.

Gruithuisen,(7) Ehrenberg, and Hemprich.(8) Carus(9) first proved the existence of a complete circulation, commencing and terminating at the dorsal vessel. In the transparent parts of the plates of libellula and ephemera, he saw an arterial peripheric current and a venous returning one, and he recognised the inflexion and immediate passage of blood globules from one into the other. The movement of the mass of humours goes on uninterruptedly, but with a rapidity evidently accelerated by gushes, proceeding from the dorsal vessel. The liquid driven onwards by the contractions of this vessel is conveyed by branches into the head, antennæ, and limbs. The most minute arterial currents change into venous currents, and these pour their currents into a vessel situated at the ventral surface, which unites with the dorsal vessel, or cardiac canal, towards the posterior part of the body. Consequently, it appears that the fluid prepared from the food in the intestinal canal, arrives by unknown routes at the cardiac canal, whence it is carried to the different parts, to answer the necessities of nutrition. The air brought to the organs themselves by the tracheæ, uudoubtedly communicates to the crude nutritive fluid the qualities which may enable it to combine with the solid parts in the act of nutrition. The remainder of the nutritive juice seems to return to the cardiac canal.

The pulsations of the insect heart occur with various rapidity. According to Herold's observations, the dorsal vessel beats more quickly in young caterpillars than in adult ones. Thus he remarked from forty-six to forty-eight pulsations in a minute in silk-worms, after the first moulting, at a temperature of 22·50 C., and only thirty-six in the same caterpillars when adult. The pulsations are much more rapid and vehement in heat than cold.

CCLXXVI. Although there is in annelides a vascular system, containing a red, coagulable liquid moving in currents, the arrangement of this system is not yet perfectly understood, notwithstanding the researches made on different sorts of worms by Cuvier,(1) Viviani,(2) Thomas,(3) Spix,(4) Home,(5)

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(7) Salzburger Medic. Chir. Zeitung, 1818, No. 92. He saw the circulation is the larvæ of aquatic insects.

(8) Von Humboldt's Bericht über die Naturhistoriche Reise der Herren Ehrenberg and Hemprich, p. 22. They saw the movement of the blood in the wings of a species of mantis.

(9) Entdeckung eines einfachen vom Herzen aus beschleunigten Blutkreislaufes in den Larven netzflüglicher Insekten. Leipsick, 1827, in 4to. He also saw the circulation of the nutritive fluid in the epidermis of the wings of some coleoptera, especially of the genus lampyris.

(1) Anatomie Comparée, v. iv, p. 410.

(2) De phosphorescentia maris. Geneva, 1805, in 4to, p. 14. On the vessels of the sabella.

(3) Mem. pour servir a l'Hist. Nat. des Sangsues. Paris, 1806, in 8vo.

(4) Ueber den inneren Bau des gemeinen Blutegels, in Denkschriften der Münchner Akademie, 1813, p. 183.

(5) An Account of the Circulation of the Blood in the Class Vermes of Linnæus, in Philos. Trans., 1817, part 1, p. 1.

Kunzmann,(6) Bojanus,(7) and Leo.(8) These naturalists are agreed on one point only,—that the blood moves in several vascular trunks, which traverse the body and anastomose together, without there existing any particular muscular dilatation resembling a heart. In the leech, whose structure, of all the annelides, has been most studied, three trunks, one median and two lateral, traverse the body in its longitude. At each ring of the body, the lateral trunks communicate with each other and the median one, by anastomatic vessels. According to J. Muellor's(9) microscopic observations the circulation is effected in the following manner: at one time one of the lateral trunks and the median, as also the anastomatic vessels passing between them, are filled with blood, whilst the other lateral trunk and its branches are empty and shrunk. In a moment after the latter is full and the other empty. During the contraction of one of the lateral trunks, the blood passes to the other side, traversing the intermediate vessels, and in the second period it returns to the side whence it first started. The contraction, however, and the current begin at the hinder part, and advance gradually forward, as it were by undulations. The lateral and median trunks then are first emptied behind, and the trunk which was empty previously, begins to fill at its anterior part. From this it appears, that in annelides between the skin, which maintains respiration, and the other parts of the body, there is only one circulation accomplished by vessels.

CCLXXVII. The radiaria, such as the asterias, the sea hedge-hogs, and the holothuria, have a system of vessels in which a liquid moves in a circle, but which is confined to the alimentary sac and ovaria alone.(1) In the asterias numerous thin-coated veins, coming from the stomach, the cœcal appendages, and ovaries, unite into a single trunk. This produces a dilatation analagous to a heart, and then ramifies like an artery. In sea hedgehogs are found, on both sides of the circumvolutions of the intestinal canal, two vascular trunks, the external of which seems to be a vein and the internal an artery. These two trunks communicate by a dilatation similar to a heart, or by their minutest ramifications. The intestinal canal of holothuria likewise exhibits an arterial and venous trunk connected with each other by their smallest ramifications as well as by a large vascular net-work spread over one branch of the respiratory organ.

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(6) Anatomiseh-physiologische Untersuchungen über den Blutegel. Berlin, 1817.

(7) Vom Gefäs-system des Blutegels, in Oken's Isis, 1818, p. 2,089.

(8) Diss. de Structura Lumbrici Terrestris. Kœnisberg, 1820, in 4to.

(9) Ueber den Kreislauf des Bluts bei Hirudo vulgaris, in Meckel's Arch. für Anat. und Physiol., 1828, No. 1, p. 22, tab. 1, fig. 1, 2.

(1) My Anatomie der Roehren-Holothurie, des pomeranzfarbigen Seesterns und Stein-Seeigels. Landshut, 1816, in fol. The sanguineous vascular system of the holothuria is represented in plate 3; that of the asterias in plate 8, and of the sea hedge-hog in plate 10, fig 1.

Besides this vascular system there is another in the radiaria, of a particular kind, which has reference to the exercise of locomotion. It is composed of vessels which commence from a canal placed around the mouth, and spread in rays over the internal surface of the skin, as in holothuria, or proceed to the chalky covering, as in sea hedge-hogs and asterias. These vessels open in the hollow tentacula and their vesicular dilatations. They contain a limpid fluid, which is shed over the tentacula during the animal's motions, and causes their increase or shrinking. When the animal draws in his tentacula, the contraction of their muscular coats forces the liquid again into the vessels. The fluid contained in this vascular system is not, therefore, agitated by a circular movement, but only flows outwards from within, *et vice versâ*. This liquid, which is probably derived from the blood, seems at the same time to serve for the nutrition of the skin, of the chalky covering, and the locomotive organs.(2)

2. Movement of the nutritive Fluid in Vegetables.

CCLXXVIII. Few points in botany have been so much disputed as the movement of the nutritive fluid. Botanists were soon agreed on one point, that the sap imbibed by the roots arrives at the leaves, and there acquires by the influence of light, heat, and air, the qualities necessary for its office of nutrition. But the question whether there exists a retrograde current from the leaves towards the other parts, and in what organs it takes place, has not yet been resolved. Grew and Malpighi, the founders of vegetable physiology, trusting to the analogy between plants and animals, conjectured that a movement of the nutritive fluid, similar to the circulation of the blood, does exist in vegetables. Malpighi,(3) thought that the sap raised to the leaves is assimilated by the evaporation of its watery parts, and then returns by particular vessels which convey it to the different organs of vegetables, to the growth of which it serves. Major, Perrault,(4) Parent, Mariotte,(5) Delabaisse,(6) Duhamel,(7) Van Marum,(8) Carradori,(9) and others declared in favour of the hypothesis of a circulation in plants. Other physiologists of equal authority,

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(2) This vascular system of the holothuria is represented in plate 2, fig. 4; that of the asterias in plate 8, and of the sea hedge-hog in plate 10, fig. 2, 3.

(3) Anatome Plantarum, v. i, p. 54.

(4) Observation sur la Circulation de la sève dans les Plantes, in Mem. de l'Ac. de Paris, 1709, p. 44. Œuvres de Physique et Mechanique, vol. i, p. 69.

(5) Mem. de l'Ac. de Paris, 1709.

(6) Diss. sur la Circulation de la sève dans les Plantes. Prix de l'Ac. de Bordeaux, 1733, in 8vo.

(7) Physique des Arbres, v. i, p. 85.

(8) Diss. qua disquiritur, quo usque motus fluidorum et cæteræ quædam animalium et plantarum functiones consentiunt. Groningen, 1773.

(9) Sulla circolazione del sugo nelle piante, in Atti della Societa Econom. di Firenza, v. iii, p. 211.

Dodart, Magnol, Hales, Duclos, Bonnet, &c., reject this idea, and only admit an ascending and descending flow of sap in the same vessels.

Latterly Knight(1) has forcibly supported the idea of a current of vegetable sap from the leaves to the parts. His opinion, which is founded on experiments, is that the sap which rises into the leaves through the young wood of trees, becomes richer by the evaporation of its watery parts, in combustible materials, and afterwards flows by particular vessels of the petiole, into the internal layer of the bark and into the alburnum. Thence it is again sent out to the trunk and root, and cherishes the growth. A part of the nutritive juice accumulates in the alburnum towards the end of summer, and contributes, together with the sap, which, in the spring, rises from the roots, to form new leaves and flowers. Knight brings the following experiments in support of his opinion. If a ligature be applied to a young tree, which penetrates the bark, the tree grows more above than below the spot. The same effect takes place when two circular incisions are made around the trunk, and the portion of bark which is between them be withdrawn. Knight showed, moreover, that the roots, as other naturalists have also observed, particularly Duhamel, increase longitudinally by their minute ramifications, which presumes the descent of the sap. These and many other experiments determined him in admitting the return of the sap from the leaves to the trunk. Bell(2) and others likewise have endeavoured to prove this retrograde movement of the vegetable juice.

CCLXXIX. A movement of the nutritive fluid in plants is observed by aid of the microscope. Moving grains or green globules are perceptible in the transparent parts of confervæ, as was seen by Ingenhouss,(3) Vaucher,(4) Girod-Chantran,(5) and L. C. Treviranus.(6) B. Corti(7) first recognized a fluid in an aquatic plant, (probably the *caulinia fragilis*, Willd.,) containing globules, and forming regular ascendant and descendant currents. It moves in the partitioned spaces, where it appears to be enclosed in vessels; on one side it rose to the knot or swelling, then, turning on itself, descended on the other, again to rise. He asserts to have seen similar movements in several other aquatic and land plants, in the water-cress, in the leaves of the

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(1) On the motion of the sap of trees, in Philos. Trans., 1801, p. 336; 1803, part 2, p. 273; 1804, part 1, p. 183; 1805, part 1, p. 88; 1808, part 2, p. 313.

(2) Manchester Memoirs, v. ii, p. 402.

(3) Vermischte Schriften, v. i, p. 218.

(4) Hist. des Conferves d'eau douce.

(5) Recherches Chimiques et Microscopiques sur les Conferves, Bisses, Tremelles, &c. Paris, 1802, p. 88.

(6) Beobachtungen über die Bewegungen des Körnigen Wesens in verschiedenen Wassergewächsen; in Beiträgen zur Pflanzenphysiologie. Gœttingen, 1811, p. 73.

(7) Osservazioni microscopiche sulla Tremella e sulla circolazione del fluido in una pianta acquajola. Lucca, 1774. Lettera sulla circolazione del fluido scoperta in varie piante. Modena, 1775.

sagittarium, and also in divers curcurbitaceæ. Fontana(8) confirmed Corti's observations. L. C. Treviranus(9) likewise saw the circular ascending and descending movement of a liquid containing green grains, in the pouches of the internodal spaces of charæ (chara flexilis vulgaris et hispida.) A movement of vegetable sap resembling this, has been remarked not only in charæ by Gozzi(1), Amici,(2) Schultz,(3) Kaulfuss,(4) and G. G. Bischoff,(5) but also in caulinia by Amici, in nitellæ by Agardh,(6) and in the cells of the *vallisneria* and *hydrocharis* by Meyen.(7) Heat accelerates this movement, cold impedes it, and at length altogether stops it. Acid liquids, also, which act on plants, suspend it. If the growth of the vegetable proceed well, so also will the sap move more rapidly. It has not hitherto been observed to arrive at the internodal spaces from the roots, nor that it rose from one of those spaces to the other through the partition. Probably the thinest part of the sap alone passes through the transverse partitions, and it is only in the intervals between these that it takes on the globular form.

CCLXXX. Schaltz(8) recognized the existence of the movement of the nutritive juice in plants of a more complex organization, or proper vascular plants, especially in the *chelidonium majus*, the *rhus typhinum*, the *angelica*, in the fig and mulberry trees, &c. From his microscopical observations it follows, that the sap arrived at the leaves from the roots, and there converted into nutritive juice by the action of the air, passes into the vessels of nutrition (sec. cix) by numerous anastomoses, which the minute net-work in the leaves contains, and that thence it is conveyed into the bark of the twigs, branches, and trunk, through the petiolus. The vessels in the bark anastomose frequently, and spread into the liber, the alburnum, and the wood, as also to the roots, to which parts they carry the proper nutritive fluid to aid their growth. Schultz supposes that the juice having left the leaves is never carried

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(8) Rozier, Journal de Physique, 1776, v. ix, p. 285.

(9) Loc. cit. Fernere Beobachtungen über die Bewegung der grünen Materie im Pflanzenreiche in Vermischten Schriften, v. ii, p. 73.

(1) Brugnatelli Giornale di fisica, 1819, v. i, p. 199. He says he observed that the ascent and descent of the sap continued in every part after the ligature of the internodia.

(2) Osservazioni Microscopiche sopra varie piante, in Memorie della Societa Italiana in Modena, 1820, v. xviii, p. 183; 1823, v. xix.

(3) Die Natur der lebendigen Pflanze, v. i, p. 345.

(4) Erfahrungen über das Keimen der Charen.

(5) Die Chareen und Equiseten. Nuremberg, 1828, p. 17. Bischoff had the kindness to show me the movement of the sap in the *chara hispida*.

(6) Verhandlungen der Leopold-Carolinischen Akademie der Naturforscher, 1827, v. xiii, part 1, p. 113.

(7) Ueber die eigenthümliche Säfte-bewegung in den Zellen der Pflanzen. Ibid. p. 2, p. 841.

(8) Ueber den Kreislauf des Safts im Schöllkraut und in mehreren andern Pflanzen. Berlin, 1824. Nachträge über die Cirkulation des Safts in der Pflanzen. Berlin, 1824. Die Natur der lebendigen Pflanze, v. i, p. 557. In the autumn of the year 1827, at the assembly of naturalists and physicians at Munich, M. Schultz had the goodness to show M. Decandolle and myself the movement of the vegetable juice in the leaves of the fig-tree.

back to them. Savi(9) says he observed a similar movement of the vegetable juice. Meyen(1) also saw it in the *musa, zea, canna, maranta, arum, calla, campanula, papaver, chelidonium, rhus, ficus,* and other plants.

CCLXXXI. If these observations are correct, it follows, that the movement of the juice in plants takes place throughout the whole vegetable in vessels of different kinds, and in two different directions, from the roots to the leaves, and from these to the various parts of the plant. The two sorts of vessels are not, however, so united as that the vegetable fluid moves, like the blood of animals, in routes circularly enclosed. The vascular system of plants differs, moreover, from that of animals, inasmuch as there is no vascular trunk in it, no organ for effecting the movement of the liquid, no heart, nor any organ in lieu of it. Further, in most animals there are double currents of blood, in the arteries and veins, through the respiratory organs, and through the whole body; and the ramified trunks of the arteries and veins unite into closed circles, since they are joined together both by the most minute vessels and the trunks themselves, which last communication is almost always made by the cavities of the heart. In vegetables, on the contrary, currents of fluid are only met with in very numerous vascular ramifications, analagous to the capillary vessels of animals, and without trunks which pass into each other. The vessels that conduct the sap from the roots to the leaves by the trunk, and thence to the parts, are united in the leaves by anastomoses, which, however, do not form, properly speaking, circular routes, nor yet closed in all directions. Consequently the parts and tissues entering into the composition of a plant, are less closely connected by the vascular system and the movement of the juice, and less concentrated into a single organic whole than is seen in animals whose parts are more intimately united by the connexion of the vascular trunks with hearts specially intended to maintain the movement of the blood, and the existence of which seems dependent on the manifestations of action of this organ. It is doubtlessly partly on this account that the character of organic indivisibility is more prominent in animals than plants. Whereas in animals furnished with a complete sanguineous system and a heart, parts separated from the body die, because the movement of the blood, which is the condition of their life, is stopped in them. Parts torn from a plant may continue to live, because the movement of the fluid which regulates their nutrition is not so concentrated, and does not depend on a central organ. as in animals.

CCLXXXII. The fluid which the nutritive vessels bring back from the leaves, and convey to the parts, seems to differ in its properties from the sap

(9) Nuovo Giornale dei Letterati, 1825, No. 19.
(1) Ueber die Cirkulation des Lebenssaftes in den Pflanzen, in the Linnæa, 1827, v. ii, p. 632.

which rises from the roots to the leaves. It is the *succus proprius* ascribed to plants by Malpighi, who compared it to the blood in animals, and considered it as the nutritive liquid, properly so called, of plants. Most vegetable physiologists, and very lately L. C. Treviranus, (2) have beheld in it a secretory liquid poured into particular spaces of the cellular tissue. G. R. Treviranus(3) has given the name of plastic juice of vegetables to this specific liquid which differs from the other vegetable humours in its colour and consistence. Schultz(4) likewise distinguishes it from the fluids secreted in some spaces, and bestows the name of vital juice, because being employed in the nutrition of plants, it thereby maintains their life. This juice, therefore, might be compared to the arterial blood which returns from the respiratory organs of animals to proceed to the different parts of the body, and, like it, appears intended, from its complete assimilation, for the nutrition and growth of plants.

The nutritive liquid, or the plastic juice, differs from the sap which rises to the leaves, and which is almost always limpid, in having a different colour, with greater consistence and specific gravity, in containing more globules, and being more highly coagulable. In other respects it exhibits a great number of differences in the divers families, genera, and species of vegetables. In regard to the colour, it is white or milky in the asclepiadeæ, euphorbiaceæ, campanulaceæ, *(campanula, lobelia, phyteuma,)* chicoraceæ, *(lactuca, scorzonera, leontodon, cichorium,* &c.,) in the genera *rhus, morus, ficus, papaver, carica, galactodendrum,* &c.; yellow, in various degrees, in the genera *chelidonium, œnanthe, aloe, ornithogalum,* &c.; red, in the *sanguinaria, bocconia,* &c. It likewise presents many diversities in regard to its composition and the elements that predominate therein. It is rife of sugar in the sugar cane, maize, the carrot, and the beet-root. It contains a great quantity of vegetable mucus in the malvaceæ. A great deal of vegetable mucus is found in it in the *carica, Hevæa caoutchouc, Galactodendrum trichotomum, Jatropha elastica,* &c. That of the oak and the sumac contains tannin; that of the coniferæ, resinous, balsamic, and terebinaceous substances. In this juice, likewise, seem to be contained the narcotic and acrid principles belonging to different vegetables, as also the vegetable alkalis or vegetable salifiable bases.

The nutritive juice differs principally from the sap by the presence of globules. Fontana(5) saw these globules, by aid of the microscope, in the milky juice of the *rhus toxicodendron,* and compared them to blood globules. Rafn(6) recognized globules in the juice of the euphorbiæ, of the *musa,* of

(2) Ueber den eigenen Saft der Gewächse, seine Behälter, seine Bewegung und Bestimmung; in Tiedemann und Treviranus Zeitschrift für Physiologie, v. i, p. 147.
(3) Vermischte Schriften, v. i, p. 156.
(4) Die Natur der lebendigen Pflanze, v. i, p. 530.
(5) Ueber das Viperngift, p. 56.
(6) Pflanzen Physiologie, p. 87. Danmark's Flora, 1796.

the *chelidonium majus*, the *potentilla anserina*, &c. G. R. Treviranus confirmed their existence in that of the *rhus cotinus* and *vinca major*. Schultz observed them in the juice of the chelidonium and other plants. L. C. Treviranus remarked the granular structure of the juice of the *Chelidonium*, *Leontodon*, *Bocconia frutescens*, *Lobelia longiflora*, *Rhus typhinum*, &c. It is probable these globules are composed of *grains* of fœcula.(7)

CCLXXXIII. Though physiologists are divided in opinion regarding the movement of the vegetable juice and the parts in which it goes on, they are still more at issue concerning the causes and powers on which it depends. Notwithstanding the observations and experiments made by men of worth, these causes are not yet ascertained. Different conjectures have been advanced concerning them. Some botanists make the juice to move by the capillary attraction of the vessels; others ascribe to the vessels a vital contractility, and even an irritability which makes them capable of alternate contractions and dilatations; and others again seek the cause of the movement in the fluid itself and its property of self-motion, through a power peculiar to it, under the influence of external excitements. Let us submit these opinions to a rapid examination.

CCLXXXIV. Most of the older vegetable physiologists, Grew, Mariotte, Delahire, Tournefort, and others, who made the absorption of liquids depend on the capillary attraction exerted by the roots, regarded also the capillarity of the vessels as the motor cause of the juice. Although it cannot be denied that the vessels which contain the juice of plants seem, by the resemblance of their structure to that of capillary tubes, adapted for raising the fluid to a certain height, since even dead vegetable parts exercise an attraction on liquids, receive, and transmit them, yet capillary attraction does not explain the ascent and movement of the juice in a satisfactory manner. Van Marum(8) demonstrated by calculations that the fluid can only rise to an elevation of eight inches by capillarity alone. Further, the experiments of Hales,(9) Walker,(1) and others have proved that its movement is too rapid in the spring, and too forcible to be considered as a simple effect of capillarity alone, as Knight has very judiciously remarked. Besides, it is not easy to reconcile the influence of light, heat, and other external excitements which accelerate the movement of the vegetable juice, with capillarity. Lastly, according to

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(7) Raspail Mem. sur le Developpement et l'Analyse Microscopique de la Fecule ; in Ann. des Sc. Nat., v. vi, p. 388.

(8) De motu fluidorum in plantis experimentis et observationibus indagato. Groningen, 1773, in 4to.

(9) Vegetab. Statik, v. i, p. 105. Hales found that the force of the ascending sap in a vine cut in the spring was equal to a column of mercury of thirty-three inches in height.

(1) Trans. of the Edinb. Society, v. i, p. 7. The movement of the fluid in young plants is much more rapid than in old vegetables.

the theory Laplace has given of this phenomenon, the juice which rises into plants, ought not to flow by any opening made in the vessels, which, however, is the case. These reasons oblige us to reject the theory which goes to explain the movement of the vegetable juice by capillary attraction.

CCLXXXV. Modern physiologists, Saussure,(2) Brugmans, Coulon,(3) Decandolle,(4) Carradori,(5) and others, seek the cause of the movement of the vegetable sap in a living contractile power inherent in the coats of the vessels, and analagous to, if not identical with, muscular irritability. The fluid absorbed by the roots, according to them, excites the vessels to contraction, which drives it onwards. Brugmans and Coulon bring, in favour of this theory, experiments relative to the action astringent substances have on wounded vegetables. They assert that the flow of juice is stopped by the application of a solution of sulphate of iron, or of alum, to a wound inflicted on a plant, (for instance an euphorbia,) which appears to show that a contraction has been effected in the spot. However, Van Marum,(6) Link,(7) and L. C. Treviranus,(8) on repeating the experiment, did not observe this effect of astringent substances. Carradori says he observed a high degree of irritability in the common lettuce, *(lactuca sativa,)* at the period of its flowering. It was sufficient to touch lightly with the finger the small leaves lying along the stalk, or the calices, to perceive a milky juice ooze, in consequence of the irritation, from the spots which had been touched. L. C. Treviranus, who observed a similar phenomenon in the calices of lettuce, of sow thistle, *(lactuca sonchus,)* &c., attributes the irritability to the receptacles of the milky juice, which irritability is more marked in young parts than in those of advanced age, which is shown more in heat than cold, and which is put into action by touching, partial tearing, and other similar stimuli.

It is very probable that the coats of the spaces in which the juice is contained aid, as in animals, the movement of this liquid, although contractions that can be compared to those of living muscles have never been perceived in the vessels, even with the aid of a microscope. Moreover the arrangement and nature of vessels inclosed in wood and bark do not seem to allow of the same contraction as in muscles endued with life. If the vessels of plants are really endued with a living contractile faculty, it is probably only analogous to the organic contractility or tonicity which is shown in the

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(2) Encyclopedie Methodique, Physiologie Vegetale, p. 267.

(3) Diss. præs. Brugmanns, de mutato humorum in regno organico indole a vi vitali vasorum derivando. Leyden, 1789, p. 12.

(4) Mem. de l'Instit. Nation., 1807, v. viii, p. 68.

(5) Mem. di Mathematica e Fisica della Societa Italiana, v. xii, part 2, p. 30.

(6) Journal de Physique, v. li, p. 217. Gren's Journal der Physik, 1792, v. vi, p. 360.

(7) Grundlehren, p. 271.

(8) Loc. cit., p. 174.

cellular tissue, the coats of arteries, of veins, and lymphatics, as well as in various animal membranes, under certain circumstances, by a slight contraction, without, however, being identical with muscular irritability. According to the judicious remark of Van Marum, the abundant flow of milky juice from the upper part of an euphorbia stalk, or from the leaf of a fig or mulberry tree, held in a vertical situation after cutting it across, may be alleged in favour of a living contractile power belonging to the vessels of plants. If the vessels maintained the same diameter they previously did, we see not why the juice should flow out. This oozing has some analogy with the exit of the lymph through a prick made in a lymphatic vessel, or to that of the blood by a wound inflicted on a vein, when the opening looks upwards, and the liquids flow against their own gravity.

CCLXXXVI. Physiologists who seek the cause of the movement of the vegetable juice in the juice itself, admit the influence of external agents on it which force it to rise from the roots, or they ascribe a proper mobility to it. The former, in the number of whom are ranked Malpighi, and partly, also, Grew, Delahire, Linnæus, Hales, Bonnet, Dupetit-Thouars, and others think that the juice absorbed by capillary attraction, is dilated, or even vapourised by the external heat which acts on plants, and that it rises to the leaves in consequence of this expansion. Mustel(9) supposes that the vessels are expanded by heat, and the juice rushes into the vacuum consequent on it. Supposing the ascending movement of the fluid, from the roots to the leaves, was really effected in this manner, and it is not proved, it is impossible at all to explain, by this hypothesis, its descending movement from the leaves, or its distribution in the bodies of vegetables to serve for their nutrition.

CCLXXXVII. Some physiologists attribute a proper motor power to the juice itself, or rather to its globules, and consider the movement it performs as a vital manifestation in it. Kielmeyer(1) first suspected the existence of a power in the fluid of vegetables similar to that in the blood. G. R. Treviranus(2) observed movements in the juice of some plants. In examining, with the microscope, the milky juice which flows from the top of a branch of the *Rhus cotinus*, or the *Vinca major*, he saw the globules it contained executing slow movements. Schultz(3) says he also ascertained, by the microscope, that the nutritive fluid that is poured from the vessels of a living plant, is composed of particles which exhibit movements, often continuing a minute after the flow. This phenomenon, therefore, appears to have a striking

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(9) Traite de la Vegetation, v. ii, p. 264.

(1) Ueber das Verhältniss der organischen Kräfte unter einander in der Reihe der verschiedenen Organisationen. Tubingen, 1814, p. 12.

(2) Vermischte Schriften, v. i, p. 157.

(3) Der Lebensprocess im Blute. Berlin, 1822. Die Natur der lebendigen Pflanze, v. i, p. 534.

analogy with the movement of blood globules that have just left the veins of a living animal. Schrank(4) and L. C. Treviranus(5) assert, however, that they never remarked proper movements in vegetable juices. But as the microscope discovers the globules of the vegetable fluid in movement, as well in the internodal spaces of charæ, caulinіæ, and nitellæ, as in the cells of the vallisneriæ, in this case, therefore, out of the vessels, this phenomenon appears to favour the hypothesis of a movement peculiarly belonging to these globules. The latter, likewise, flow in different directions into the petioles of the leaves by the anastomotic vessels, without any observer hitherto being able to perceive any contractions in the vessels.

CCLXXXVIII. Whether the movement of the juice in vegetables depends on a proper motor faculty inherent in the juice, or is consequent on the living contraction of the vascular coats endued with a power analogous to, or resembling, either tonicity or muscular irritability, or whether possibly it be the effect of these causes united, it cannot be denied that heat, light, electricity, or other exciting causes from without, exert a vast influence on it. Duhamel(6) saw the sap flow very abundantly in hot weather from holes made in trees, come out in smaller quantity when the air was cool, and cease to flow altogether in cold weather. The movement of the fluid was executed more slowly even when the sky was clouded. Bonnet and Walker likewise ascertained this influence of the variations of temperature. Hales proved by his experiments that the rapidity of the sap's ascent is in direct ratio with the evaporation, and that the heat which favours the latter also accelerates the former. The experiments of Van Marum,(7) Willdenow,(8) Barton,(9) Humboldt, Coulon, Schnurrer,(1) G. R. Treviranus,(2) and others, in reference to the influence of different excitements on plants, also show that moderate external excitations quicken the movement of the juice, whereas too vehement ones exhaust it.

CCLXXXIX. The rapidity and even the direction of the current of fluid seems to depend chiefly on the acts of formation and growth of plants, and on external circumstances which influence these acts, in such a manner that the

(4) Ueber die Kügelchen im Blute und in den Pflanzen-Säften; in Landshut'schen Nebenstunden zur Erweiterung der Naturgeschichte. Landshut, 1802, art i, p. 75. He saw the bodies that exist in the juice of the *chelidonium majus, glaucium, trogopogon picroides,* and *rhus typhinum,* in a state of motion.

(5) Zeitschrift für Physiologie, v. ii, p. 147. He saw no movement in the milky juice of the *leontodon taraxacum, rhus typhinum, chelidonium majus, lobelia longiflora, euphorbia cespitosa,* &c.

(6) Physique des Arbres, v. i, p. 71.

(7) Journal de Physique, v. xli, p. 218.

(8) Grundriss der Kräuterkunde, p. 327.

(9) Pfaff's and Scheele's Nordisches Archiv für Naturkunde und Arzneiwissenschaft, v. i, p. 274.

(1) Observata de materiarum quarundam oxydatarum in germinationem efficientia. Tubingen, 1805.

(2) Biologie, v. v, p. 230.

parts that are forming and growing exert a vital attraction on the juice. The spring, when the temperature of the air is increased, when the action of the solar light becomes stronger and prolonged, when the development and evolution of leaf and flower buds is going on, is the period wherein the vegetable fluid exhibits the most rapid movement, and is most forcibly directed towards the periphery. Afterwards, in trees and shrubs, a current of this fluid proceeds towards the trunk and roots; new ligneous and cortical layers, as well as radical fibres are formed. In the month of August a second ascent of juice, less abundant than the first, occurs in the trees and shrubs of our climate, when the leaf and flower buds of the following year commence forming, which, according to Th. Saussure and Decandolle,(3) is neither evidently accelerated nor slackened by heat or cold, humidity or moisture, from which fact the latter writer concludes that the buds attract the juice necessary for their formation, by a faculty peculiar to themselves. During winter the movement of the juice appears to be altogether interrupted in perennial plants, at the same time that the phenomena of formation in them are suspended, without, however, any injury being thereby done to their existence.

A well-known fact speaks in favour of the dependance in which the movement of the juice is placed by the formation and development of the vegetable parts, namely, that a vine-shoot conveyed into a warm chamber throws out leaves and flowers, even in winter, whereas the buds of the rest of the stalk exposed to the cold are not developed. To effect this, the fluid essential to development and growth must have been attracted by the buds after they have been subjected to the influence of heat, and by it actuated to a double activity. The known experiments, on reversing the positions of trees, also proves that the direction the juice takes depends on the influence of light and heat on the vegetable parts.(4) When the top of a young tree is placed in the earth and its roots exposed to the air, to heat, and to light, the twigs and branches produce roots, whilst the former roots throw out leaves and flowers. Here, then, the movement of the fluid takes place in opposite and inverse directions, corresponding to the external influences which determine the

(3) Rapport sur un memoire de M. Decandolle, intitulè, Tableau de la nutrition des vegetaux, par Chaptal, Labillardiere, and Cuvier; in Mem. de l'Instit., v. viii, p. 68. L'auteur remarque que l'ascension de la sève s'effectue au moment où les boutons de l'année suivante commencent à pondre, comme celle de la sève du printemps au moment où les boutures de l'année tendent à se developper; et qu'il semble que ces boutons animés d'une force vitale, que leur est propre, attirent alors à eux toute sève environnante.

(4) As the experiments of Leuwenhoeck, (Arcan. Nat., v. ii, p. 265,) Beal and Tongue, (Philos. Trans., No. 43, p. 853,) Perrault, (Œuvres de Phys., v. i, p. 85,) Magnol, (Mem. de Paris., 1709, p. 36,) Hales, (Vegetable Statis., p. 78,) Duhamel, (Phys. des Arbres, v. ii, p. 310,) and others prove. Knight, however, (Philos. Trans., 1804, part 1, p. 188,) observed that the growth of trees, in a reversed position in the earth, is much slower than that of trees that have kept their natural position. Annuals cannot be treated in this manner without dying, according to Link's experiments, (Zusatz zu Willdenow's Kräuterkunde, v. i, p. 388.)

formation and development of vegetable parts. Lastly, it is known that the juice flows in abundance to those parts of plants that have been irritated to the formation of unnatural excrescences. Thus it is that galls are seen to grow when some species of cynips deposit their eggs in the leafy parenchyma of the oak, the rose tree, the beech, the willow, &c., and that morbid growths are perceived in a very short time in the spots where such deposits have been made. From all this it follows that there is no circulation, properly so called, in plants as in animals, and that the movement of the juice is not so regular in them as in the latter. The formative fluid is chiefly carried by numerous nutritive vessels, spread throughout the body, and communicating together, to the parts whose activity is exalted, and formation rendered more energetic by the external influences of heat and light.

Movement of the Nutritive Fluid as a Property of Living Bodies.

CCXC. The movement by which the fluid, prepared from assimilated food, arrives at the different parts, and tissues of living bodies, to aid their formation, their growth, and nutrition, is therefore a property belonging to all organic bodies, and one on which the preservation of these bodies depends. No inorganic body presents within it any spaces containing liquids in motion. This movement is not explicable by the principles of mechanics, and it can only be considered as a vital phenomenon. The powers that accomplish it are organic powers; they are shown both in the nutritive fluid itself, and in the coats of the spaces that contain it. The inherent mobility of the nutritive liquid itself appears to belong to its organically formed elements, the globules of the vegetable juice and the blood. These enact movements whose direction is probably determined by the acts of formation and nutrition of the solid parts, and by the attraction these parts exercise. They only retain the faculty of self-motion so long as they are in connexion with the living body. We shall call this mysteriously-acting power, whose existence cannot be doubted, and which C. F. Wolff, as also Kielmeyer(5) admitted, the propelling power. The power which manifests itself, in the coats of spaces containing liquids, in the vessels of animals, and probably also of plants, by the contraction and diminution of these spaces, however feeble it be in degree, will receive from us the name of organic contractility or tonicity.

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(5) Loc. cit., p. 12. Kielmeyer says on this subject, " I make use of this word only because it first presented itself to me, and another perhaps would do better. In other respects it expresses the phenomenon here referred to, and which consists in a pushing forwards of liquids, without our knowing the cause of it sufficiently well, for which reason it is designated by the name of power, until the phenomenon shall have been resolved."

In the greater number of animals there exists likewise a muscular organ united with the vascular trunks, the heart, which possesses, so long as life lasts, the property of contracting by the excitement the blood produces in it, and of thus driving into the arteries the blood it had received from the veins during its dilatation. The power which is resident in the muscular substance of the heart is called muscular power, or irritability. This it is which in animals constitutes the chief agent of the movement of the blood, without which there is no circulation in complex organized animals; for the propelling power of the blood globules, and the tonicity of the vascular coats, are not themselves capable of effecting the passage of the nutritive fluid. In embryons, however, at the first appearance of the blood, its movement must be attributed immediately to the force of the propulsion of the globules. In animals that have no heart, the circulation of the nutritive fluid is consequent on the motor faculty inherent in the blood globules, and on the vital contractility of the vascular coats.

CHAPTER SEVENTH.

Of Nutrition.

CCXCI. Inorganic bodies maintain their particular form and special mode of aggregation only so long as the equilibrium between their different constituent parts is kept up, and new affinities are not brought into action by external influences. The existence of living bodies, on the contrary, is connected with continual changes, but of varied rapidity, in the form and composition of their parts; and these changes depend both on the influence of external stimuli on the parts, producing new affinities, and on the pace of their development, or even on the bent of the internal activity they are endued withal. All living bodies give out matters in a vaporous or liquid form, and take others from the external world. The materials received into particular cavities are converted into a nutritive fluid by assimilation and respiration, and this fluid is conveyed to the different parts of organized bodies. The solids withdraw certain constituent principles from this fluid, combine with them, enlist them into their composition and organic complication, and communicate to them the vital properties with which they are themselves endowed. The activity exhibited in living bodies, and which not only enables them to keep possession of their proper characters during a certain space of time, but also to resist external influences which tend to their destruction, takes the name of nutrition. Its effects are easily demonstrated, though the minute process of nutrition is still covered by a thick darkness. We will first mention the phenomena of nutrition in plants and animals, and then give an account of the power which produces and is a condition of it.

1. Nutrition of Plants.

CCXCII. The nutrition of vegetables is shown by the increase of size, and by the formation and development of parts in the young plant that proceeds from the germ. The activity of every plant, from the first moment of its appearance, is designed for its increase, for the formation of new parts, and their development conformably with the species to which it belongs. The augmentation of volume is in length and thickness. The longitudinal growth takes place in two opposite directions, for the radicle of the germinating plant, avoiding the influence of light, pushes into the earth or water to form a root therein, whilst the plumula, growing towards the light, rises in the shape of a stem. The stem of vascular plants, having a tendency to the vertical direction, sends out fresh shoots, which sometimes, as in annuals, are formed on each other at short intervals, and sometimes grow during a series of years, as in perennial plants, trees, and shrubs. The development and growth of annuals is accomplished when the leaves, flowers, fruit, and seeds are once formed. Trees and shrubs, on the other hand, renew these organs every year. The root immersed in earth or water, also grows longitudinally. The growth always takes place at the extremities, to which new masses are added, which causes the radical fibrillæ to be lengthened, and thrust more deeply into the soil, as Duhamel,(6) Meyer,(7) Knight, Decandolle,(8) and others have proved by their experiments.

CCXCIII. The growth in thickness in trees and shrubs, which are the plants in which it has been best observed, is effected at the expense of the liquid which the descending nutritive or formative juice deposits between the bark and ligneous body. The deposition of this liquid, coagulable as it is, and susceptible of taking on organization, and which Grew and Duhamel called the *cambium*, occurs chiefly at the end of summer, or in autumn. According to Mirbel's researches(9) globules and fibres first appear in it, which have the appearance of a young tissue. From the cambium, as was shown by Senebier,(1) Mirbel,(2) Mastel,(3) L. C. Treviranus,(4) Rudolphi,(5)

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(6) Physique des Arbres, v. i, p. 84, v. ii, p. 108.
(7) Naturgetreue Darstellung des Wachstums der Pflanzen, p. 249.
(8) Memoire sur les Lenticelles des Arbres; in Ann. de la Soc. Natur., 1826, p. 1.
(9) Mem. sur l'origine, le developpement, et l'organization du liber et du bois. Mem. du Musée d'Hist. Nat. Ann. 8, p. 190.
(1) Loc. cit., p. 161.
(2) Observat. Anatomiques et Physiol. sur la croissance et le developpement des Vegetaux; in Mem de l'Instit., v. ix, p. 303.
(3) Traité de la Veget., v. i, p. 49.
(4) Vom. inwendigen Bau der Gewächse, p. 143. Beiträge, p. 60.
(5) Loc. cit., p. 228.

Cotta,(6) Dutrochet,(7) Decandolle,(8) and others, new layers composed of cellular tissue and vessels, are formed, some of which are applied to the outer surface of the ligneous body to constitute the alburnum, the others to the inner surface of the bark, to originate the liber; hence the annual circles of wood and the new cortical layers. The plastic liquid deposited between the bark and the wood, also appears to produce the new leaf and flower buds. In the stem of arborescent monocotyledones, especially of palms, a new soft substance is deposited along the axis of the trunk, analogous to the alburnum, and which is developed from within outwards, so that the shoots of the new leaves and flowers protrude at the summit of the plant.

CCXCIV. From the phenomena that have been thus briefly mentioned, we are authorized to admit a nutrition in vegetables, by which each plant not only increases in size and produces the parts that are formed during the course of its development, but is likewise maintained for some time in the possession of the qualities that are peculiar to it in regard to composition, organization, and vitality. The nutritive juice peculiar to each kind of plant, and conveyed by the nutritive vessels to the parts, is the fluid from which the vegetable tissues that are nourished develope and grow, take materials which they include in their mass and their organic connexion. It is imbibed from the external world by means of absorption, in the form of sap. The materials existing in it are among the most simple kind of organic combinations, and these again are changed into organic combinations of a higher or more complex order, by the acts of assimilation and respiration, under the influence of heat, air, and light. The formative juice contains all the materials that are necessary for the nutrition, the formation, and growth of the different parts of plants, certainly not yet organized, but capable of becoming so by the manifestations of activity which occur during the work of nutrition. The parts that are formed and grow appropriate to themselves the products obtained from the aliment by assimilation, the saccharine matter, the gum, fecula, vegetable albumen, gluten, &c., transform them into their own composition by their activity, and thus cause them to penetrate their tissue, and enter their organic connexion.

CCXCV. On the subject of the material changes which vegetable parts undergo in nutrition, chemistry has hitherto given us no satisfactory information, simply because, being effects of life, such changes are beyond the domain of chemical science. All that we are authorized to admit is, that the changes

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(6) Naturbeobachtungen, p. 68.

(7) Rech. sur l'accroissement et la reproduction des Vegetaux; in Mem. du Mus. d'Hist. Nat., Ann. 4, v. vii, p. 379.

(8) Organographie Veget., v. i, p. 201.

of composition that occur during the nutrition of vegetables are the consequence of vital manifestations of activity, and not the mere effects of chemical affinities, such as are observed in inorganic bodies. In support of this opinion, the fact may be alleged of vegetables of different species, which grow in a perfectly similar soil, furnishing different products, whilst plants of the same species, planted in dissimilar soils, give identical products. Thus the vegetable species maintain the character of composition peculiar to them, in all soils, similar or different. Although it is a peculiarity in vegetables not to be dependant in general on the nature of the aliments they receive, yet it cannot be denied that the composition of the soil and water by which they are nourished, exercises some influence on the materials found in them. The presence of marine salt and soda in plants that grow on the sea shores, and in a soil impregnated with salt, is beyond dispute, as well as the passage of copper into them. The experiments of Th. de Saussure,(9) moreover, confirm the influence of the soil on vegetables, for they exhibit some differences in their chemical composition and properties, according as they grow in a granitic or calcareous earth.

The valuable experiments of Decandolle(1) on the medicinal properties of plants, compared with external forms and natural classification, also prove that their composition depends on their vital powers. Generally speaking, the same parts or the same juices of plants, belonging to the same genus, produce similar effects, and even the same parts or juices of vegetables of one natural family resemble each other in their mode of action. As, then, we cannot mistake the existence of a close relation between the organization and the composition and medicinal effects of plants, we are under the necessity of admitting that one and the same power must produce the organization and determine the composition.

CCXCVI. Every species of plant seems to change, by its own activity, the crude elements it imbibes from without by absorption, into organic combinations of the most simple class, whether these elements consist of organic bodies in a state of dissolution, or even of inorganic bodies. The subsequent acts of assimilation and respiration then transform the organic combinations of this inferior order, (which are very variable in the composition of their elements,) into those of a superior order. Lastly, these matters, passing into the nutritive or formative juice, are converted, by the vital acts of nutrition of each kind of vegetables, into the material substance of the solid parts which form them. If then we are not unwilling to admit that living plants have the

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(9) Recherches Chimiques sur la Vegetation.

(1) Essai sur les proprietes medicales des plantes comparées avec leurs formes exterieures et leur classification naturelle. Paris, An. 12 Translated into German by Perleb. Aarau, 1818.

power of producing inferior organic combinations by a vital activity, we are not nevertheless obliged to hold the opinion of physiologists and chemists who think that living vegetables are capable of producing, with water or air alone, by the influence of light and the effect of a vital power, substances which are chemically considered as simple or elementary, such as carbon, the earths, and the metals. The experiments made by Vanhelmont, Boyle, Tillet, Crell, Schrader, Einhof, Braconnot, and others, do not at all prove any such production.

2. Nutrition of Animals.

CCXCVII. In animals, as in plants, a formation and growth of parts in the fecundated germ takes place. The embryo that is formed exhibits its different organs and apparatus in a certain order and succession; these augment in mass and attain a certain degree of development. Even after the fœtus has quitted the coverings of the ovum, the development of its body proceeds uninterruptedly to the meridian of life. During all this time, animals convert the food they take into the nutritive fluid, and this passes into the composition and course of the organs in the acts of formation and growth, at the same time taking on their vital properties. Nutrition is likewise shown by the rapid or tardy changes which occur in the materials of organs. Some of these materials become unfit, in consequence of their manifestations of activity, to remain any longer in the organic course. They leave the solid state to return to the liquid, and are again taken up by absorption. The living organs, on the other hand, withdraw new materials from the nutritive fluid that is brought to them, which they incorporate into their texture.

The acts of formation, of development, and growth of the organs and entire animal body, as also the changes of material composition that occur in each individual organ, the alternate reception and ejection of materials which they perform, their solidification and fluidification, in short, the formation and unmaking which is incessantly going on in the tissues and organs of the animal body, constitute the vital operation designated by the name of animal nutrition, which renders each organ and the whole organism capable of maintaining themselves, under favourable external circumstances, during a definite space of time, in the enjoyment of their proper manifestations of activity.

CCXCVIII. Regarding the means, instruments, and acts which nature makes use of to accomplish nutrition, we observe, in the various groups of animals, numerous diversities on this point, which have been already mentioned under the head of digestion, respiration, and the movement of the nutritive fluid. The apparatus for these functions are so much the more complicated, and the functions themselves appear so much the more complex, as the manifestations of life peculiar to each animal are more diversified and vehement. In the lowest or most simple animals, the infusoria, the alimentary matter obtained from the water by absorption, at the surface of the body, appears to be directly converted into their substance, in such a manner, that the reception, the assimilation, and transformation of the aliment into the organic mass, are conjoined in one and the same vital act. The nutrition of infusoria is proved by the observation which Nitzch(2) made on the growth of bacillaria, as also by the rapid increase of paramaceia, bacillaria, vibriones, and volvoces, which are divisible into several animals that very soon reach their full growth, as Spallanzani,(3) Saussure,(4) O. F. Mueller,(5) Goeze,(6) and others ascertained. In animals furnished with a simple alimentary sac, polypi, actinia, &c., the liquid prepared from the food and introduced into the body by absorption, is sometimes directly converted into and combined with their mass, so as to resemble cellular tissue, at other times is conveyed by branching and vasculiform appendages of the alimentary sac to the different parts, and is identified with them, as in medusa, pennatula, many entozoa, &c. The respiration necessary to assimilation is performed at the surface of the body. It is a well-known fact that all these animals grow and augment in mass with great rapidity.

In animals whose organization is more complicated, the radiaria, annelides, mollusca, insects, arachnida, crustacea, fishes, amphibia, birds, and mammifera, we find an apparatus, which, after receiving the aliment, adds certain liquids to it, in order to fluidify, assimilate, and prepare the chyle from it. These animals are further provided with respiratory organs, by which, with the influence of the atmospheric air, the absorbed chyle is transformed into blood. Lastly, in all these animals a vascular system is found, containing the fluid intended for nutrition and growth. The blood forms unceasing currents in the different sections of this system, and in the circularly closed paths through which it flows. After being mixed with the chyle it arrives at the organs of respiration, where it is converted into arterial blood. This again is conveyed to the internal structure of all the organs, which derives from it the materials necessary for their nutrition. The blood, altered in its composition by the acts of nutrition, having lost a great part of its coagulable principles, and having undergone a change of colour, once more returns to the respiratory organs, and there regains the qualities it previously possessed.

CCXCIX. The arterial blood, in its quality as a nutritive fluid, contains the materials of nutrition of all the tissues and the organs, and from these

(2) Loc. cit., p. 83, 89.
(3) Opuscules de Physique, v. i, p. 175, 249.
(4) Ibid, v. i, p. 172.
(5) Hist. Verm., v. i, p. 8.
(6) Mikroscopische Untersuchungen über Essigaale; Naturforscher, art. 1, p. 1; art. 9, p. 177.

materials are formed the cellular tissue, membranes, vessels, nerves, muscles, glands, bones, cartilages, and ligaments. There is no actual proof that the globules so abundantly existing in the blood, combine with the parts during the process of nutrition, and take their organic texture, as some modern physiologists admit.(7) If it were so, the blood would necessarily contain different globules for the nutrition of different tissues, a fact that still remains to be proved. Be this as it may, it cannot be admitted that the vessels which ultimately ramify in the parenchyma of the organs simply deposit or secrete the materials of nutrition, which in that case would combine with the organic texture as they were given out, merely from juxtaposition, or according to the laws of aggregation. On the contrary, each tissue and organ seems to attract, by a proper activity, the molecules that have the greatest affinity with the organic combinations entering into its composition, as was very properly remarked by Buffon.(8)

The materials attracted to the organs and tissues by their specific activity, are, still by the actions of the same organs, incorporated into their composition and organic connexion. It is in this choice of proper materials from the midst of the arterial blood, and the conversion of these materials by them into their own texture and composition; that the act of nutrition, properly speaking, consists—an act which is altogether different from every mechanical, chemical, and physical effect, such as they are seen in lifeless or inorganic bodies. In ordinary circumstances each tissue and organ, so long as it is

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(7) Dutrochet says, (loc. cit., p. 214,) "Ce que nous venons de voir touchant la similitude de la composition organique des solides et des fluides du corps vivant, pourrait faire penser que les globules vesiculaires contenus dans le sang s'ajouteraient au tissu des organes et s'y fixeraient pour les accroître et les reparer, en sorte que la nutrition consisterait dans une veritable intercalation des cellules toutes faites, et d'une extrême petitesse. Cette opinion, toute étrangère qu'elle puisse paraître, est cependant très fondée ; car l'observation parle en sa faveur. J'ai vu plusieurs fois les globules sanguins sortir du torrent circulatoire, s'arrêter et se fixer dans le tissu organique. J'ai été temoin de ce phinomène, que j'etais loin de soupçonner, en observant le mouvement du sang au microscope dans la queue fort transparente des jeunes têtards du crapaud accoucheur. Des artéres formant des courbures nombreuses se repandent dans la partie transparente de la queue des têtards ; ces artêres sont immédiatement continues avec les veines, en sorte qu'il n'existe ici aucune distinction, aucune ligne de démarcation entre les deux circulations arterielle et veneuse ; le sang, dont on aperçoit parfaitement les globules, qui sont assez gros, offre un torrent, dont le mouvement n'éprouve aucune interruption depuis son départ du cœur jusqu'à son rétour à cet organe. Entre les courbures que forment les vaisseaux, il existe un tissu sort transparent, dans lequel on distingue beaucoup de granulations de la grosseur des globules sanguins ; or, en observant le mouvement du sang, j'ai vu plusieurs fois un globule seul s'echapper lateralement du vaisseau sanguin, et se mouvoir dans le tissu transparent. Or, en le comparant aux granulations que contenait ce même tissu, il était facile de voir qu'il n'en differait en rien, en sorte qu'il n'était pas douteux que ces granulations transparentes ne fussent aussi des globules sanguins precédemment fixés. Par quelle voie ces globules sortent ils du torrent circulatoire ? C'est ce qu'il n'est pas facile de determiner." Dœllinger says he observed similar phenomena.

(8) Hist. Nat., v. ii, p. 63. "Comme toute la masse du sang passe plusieurs fois dans toute l'habitude du corps, je conçois que, dans ce mouvement de circulation continuelle, chaque partie du corps attire à soi les molécules organiques les plus analogues, et laisse aller celles qui le sont le moins. De cette façon, toutes les parties se developpent et se nourrissent, non pas, comme on le dit ordinairement, par une simple addition des parties et par une augmentation superficielle, mais par une pénétration intime, produite par une force qui agit dans tous, les points de la masse."

united to the entire body, so long as the external and essential conditions of life exist, and so long as it is not exposed to anormal irritations, is maintained by the nutrition it effects, in the composition, the organization, and vital properties peculiar to it, and undergoes thereby, during the period of its existence, the changes incidental to its different epochs of development and age. Nutrition, therefore, presents a specific modification in each organ, which is the source of the qualities belonging to the organ itself. The name of proper vitality (vita propria) may be given to the particular modus of this process, which exists in all the functions, and determines the vital properties observable in them.

CCC. The minute operations which accompany formation and nutrition have hitherto escaped the recognition of our senses, and are as yet altogether unknown. We only judge from their effects, from the growth and diminution of parts, from the changes of their form and composition; but we neither know what the changes are which the materials of the blood, attracted by the living organs, undergo, nor how these materials come to be organized and endowed with the vital properties belonging to the organs. It is unknown in what manner they are converted, during nutrition, into muscles, nerves, bones, and viscera. Nutrition resembles, as Ent said,(9) a continued generative act in each living being and in all his parts, over which nature has spread the thickest veil. Could we but raise it, the secrets of life would be in great part revealed to us.

CCCI. The duration of animals and of the exercise of their manifestations of action, which we call life, goes along with a continual change of the materials of their solid parts. The materials constituting the organic junction of different parts are changed in composition by the exercise of life, and become incapable of remaining there any longer. Those that are past use, that have lost their form, and are returned to the liquid state, are absorbed, which, in mammifera, is effected by the lymphatic vessels. They regain the vascular system, whence they are eliminated by the excretory organs. In lieu of these molecules, now somewhat wasted by the functions of the organs, new ones arrive, formed by the act of nutrition from materials taken from the arterial blood. We are authorized to admit a similar renewal of substance, an uninterrupted internal movement, an incessant formation and unmaking in the organs, from the changes which we observe in all the parts, and in the entire body of an animal during its existence. The extent, the mass, the consistence, the composition, configuration, the structure, and texture of the animal body and all its parts, of the cellular tissue, the membranes of the vessels, of nerves,

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(9) Op. omnia medico-physica, Leyden, 1657, p. 462. Nutritio sane videtur esse veluti continuata quædam generatio.

muscles, cartilages, bones, tendons, ligaments, &c., undergo incessant and more or less rapid changes. All animals live in a certain uninterruptedness of formation, disformation, destruction, and reconstruction. In support of the occurrence of a change and wearing away of the parts in the organs, it may be alleged, that the mass of the animal diminishes rapidly in weight, and we behold the parts disappearing quickly when animals are placed in circumstances where they can take no food. The diminution of their body is accompanied with an exhaustion of their powers, which finally are altogether extinguished. Let animals receive food after being deprived of it, their weight rapidly augments, the organs take on their former volume, and the strength is re-established. We will mention some laws relative to the renewal of the materiel of the organism.

CCCII. The rapidity of the renewal of the materials in solid parts, which accompanies the life of animals, is in a direct ratio to the degree of complication of their structure, and the variety of their vital manifestations, itself dependent on the former circumstance. To the support of this proposition, we may bring the phenomena of the ingestion of food, of digestion, respiration, the movement of the nutritive fluid, and secretion, which are referable to the preparation of the nutritive liquid, as well as to the act of nutrition, and the renewal of materials. Animals take, as I have previously shown, so much more aliment, feel the necessity for it at so much shorter intervals, and their life is so much the more dependent on this ingestion, as their organization is more complex, their manifestations of life more numerous, their growth more rapid, and the performance of their animal functions more energetic. The digestive organs in animals are so arranged as that the food introduced into them can be quickly broken down by movements, dissolved, assimilated by the addition of divers juices, and converted into chyle. It is these animals which breathe at the shortest intervals, consume the greatest quantity of oxygen, exhale the most carbonic acid, in which the change of venous into arterial blood is effected with the greatest celerity, and whose life, in short, most eminently depends on the uninterrupted continuity of respiration. Their sanguineous vascular system is moreover disposed in such a manner that the arterial blood arrives so much purer and more quickly at the organs as the intensity of their manifestations of activity renders a rapid renewal of the material substance more necessary, in order that the preservation of their vital properties may be effected by the act of nutrition. The number of excretory organs, and the abundance of the various excretions of animals, are likewise in a direct ratio to the degree of complication of their texture and the sum of the manifestations of action they perform. Should these become more vehement, the activity of the secretory organs is also redoubled, and the excreted matters are more copious. The reverse takes place in the state of repose and inaction. These phenomena clearly show that the renewal of materials coincident with the manifestation of activity of the solid parts, is effected with so much more rapidity in animals, as the sum of these manifestations themselves is more considerable, and as they are exerted at once with the greatest energy, and in the most continuous manner.

CCCIII. The celerity in the renewal of the materials of the organism is further intimately connected with the nature and the number of external impressions whose influence animals have to undergo. Heat, air, water, aliment, light, sound, electricity, odoriferous, and sapid substances, and mechanical impressions of divers kinds, act on animals and incite them to action, wherefore they are called stimulants, or excitants, (stimuli, incitamenta.) The number and nature of the stimulants which act on animals will vary according to the place they inhabit. Those that live in air are exposed to much more numerous excitements than those which pass their lives in water. The excitements which act on the former vary, moreover, considerably in degree and power, as happens in the heat, light, and electricity; and these variations are the consequence of changes in the situation of our planet in reference to the sun, during its annual and daily revolutions. This is the reason why air-breathing animals, which are exposed to multiplied and stronger excitements, possess also more rapid vital manifestations than aquatic animals. All the external influences which act on animals appear to produce changes in the materiel of their organism, by the impression they make on the living organs, and by the reaction they occasion in the latter. The renewal of materials coincident with the exercise of life, is evidently more accelerated in animals that live in air, than in those having their usual abode in water. The former consume more aliment, their life is more dependent on the ingestion of fresh food at smaller intervals, their digestion is quicker, and their respiration more frequent; they decompose the air with greater celerity, and their existence is more linked with the uninterrupted continuity of respiration; the movement of the nutritive fluid goes on with greater velocity in them, and they give out more excrementitious matters than aquatic animals. Consequently, the rapidity of renewal of the materials of solid parts, which accompanies the exercise of life in animals, appears proportioned to the sum and energy of the excitants that act on them and provoke them to exhibit manifestations of activity.

CCCIV. Finally, the rapidity of renewal of the organic materials in the different groups of the animal kingdom, is proportional to the degree of development and action of their apparatus for the exercise of the manifestations of animal life, of the organs of the senses, of the nervous system, and the organs of voluntary motion. The nervous system of an animal suffers more numerous and various excitations, as the number and delicacy of the senses on which the different influences from without act are more considerable. The more developed the nervous system is, particularly the brain, as the centre of sensation, the more numerous, diversified, and energetic, are the manifestations of activity it is capable of producing, either in consequence of impressions proceeding from the senses, or by its spontaneous action. The degree of development of the locomotive organs is also in proportion to that of the nervous system and the number of the senses. By the movements they voluntarily execute, animals react on the external world, in order to place themselves for a longer period under the influence of things which act on them in an agreeable manner, or, on the contrary, to avoid the hurtful impression they might suffer from them. Lastly, the degree of development of the organs of the senses, of the nervous system and the locomotive organs, and the variety and energy of their manifestations of activity, are closely connected with the structure and arrangement of the apparatus whose office it is to perform the nutritive functions and effect the renewal of the materials of the organism.

CCCV. Let us now inquire what changes occur in the materiel of the organs during the performance of their vital manifestations; and here we shall find ourselves obliged to confess that the operations accompanying this act are yet far beyond the reach of our observations and experiments. We can only hazard some conjectures on this most minute and hidden operation of life. The physiologists of the iatro-mathematical school thought the change of organs consisted in the mechanical wearing down of their molecules by motion. Besides that the materiel of the organism is likewise incessantly changing in organs that exhibit no sensible movements, consisting in contraction and expansion, as the nerves, bones, cartilages, ligaments, &c., it is impossible to conceive how the organic combinations forming the bases of the organs could change so much, in consequence of mere friction, as to become incapable of remaining any longer in the organic junction.

The physiologists of the modern iatro-mathematical school admit a sort of acidifying, or burning process, to be going on in the living organs, in which process the principle of combustion, oxygen, leaving the arterial blood, unites with the organic combinations of the parts, and raises a kind of combustion in them. The nature of the excrementitious matters seems to show that an operation proceeds in the organs by which the superior or more complex organic combinations are converted into inferior or more simple ones, or even into inorganic combinations. Thus a great quantity of carbonic acid is continually exhaled by the respiratory organs and skin. The fluid excretion which occurs from the skin of some mammifera, or the sweat, contains free acetic acid, chloride of sodium, a little phosphate of lime and iron, and an animal matter. The ternary combinations belonging to the bile individually, biliary resin and cholesterine, are expelled, as excrementitious matters of the blood, by the intestinal canal, together with the various salts and the undigested residue of the food. The most compound excrementitious fluid is the urine, in which, besides two highly-azotized specific organic matters, urea and uric acid, a vast number of different salts is found. Hence it appears, that the complex animal combinations, which the act of assimilation prepares from the matters received from without, and which the process of nutrition conveys to the organic junction, are decomposed by the vital manifestations of the organs, and thus changed into organic combinations of the lowest class, or even into inorganic ones. This operation seems to consist in a specific process, analogous to combustion. The production of animal heat, which, in animals, is exactly proportioned to the rapidity of renewal of the organic materials, should also be considered as a result of this act. Finally, it is not improbable that an agent generated in the nervous system plays a prominent part in this operation.

CCCVI. There is this difference between vegetables and animals in regard to nutrition, that in the former there is only a formation and application of fresh substances and a growth of those already existing, the organs once produced being no longer subject to a renewal of materials, and preserving their composition and texture, during some time, unchanged. At all events no continual change in the materiel of the root, the wood, or the bark, has been hitherto observed. What has been once formed no more returns to the liquid state, to be re-absorbed. In animals, on the contrary, an uninterrupted and variously rapid renewal of materials takes place in their solid parts, and they undergo continual changes by means of their activity. This difference is undoubtedly dependent on the fact that animals possess manifestations of activity that produce changes in the materiel of the organs, into which process the action of the nerves seems to enter.

Plastic Power, Power of Nutrition.

CCCVII. The operation of primary existence, of formation, growth, and nutrition, by which living bodies are distinguished from all natural productions not endued with life, and from all artificial products, are not the simple physical, mechanical, or chemical effects, such as are observed in lifeless bodies. The act of origination, formation, and nutrition consists neither in a precipitation, according to laws of gravity, of the organic molecules contained in the fecundated generative liquid and in the nutritive fluid, nor in mechanical attraction of these particles, nor, lastly, in a simple chemical affinity and combination, as in crystallizing inorganic matters. All the attempts of the iatro-mechanicians and iatro-chemists to reach this point have failed, and it is well ascertained that such ideas are both unsatisfactory and erroneous. We are therefore under the necessity of regarding them as effects sui generis, as vital manifestations, founded on a power proper to, and inherent in, organic bodies.

Distinguished physiologists and physicians of all ages have attributed a peculiar power to living bodies, which they considered as the cause of formation and nutrition. They have designated this force by different names. The ancients, especially Galen,(1) called it *facultas formatrix, nutrix, auctrix.* Vanhelmont gave it the epithet of *blas alterativum.*(2) Bacon denominated it the *motus assimilationis,* or *motus generationis simplex.*(3) It was the *facultas vegetativa* of Harvey ;(4) the *anima vegetativa* of Stahl;(5) the *puissance du moule interieur* of Buffon.(6) C. F. Wolf(7) gave it the name of *vis essentialis,* and Blumenbach(8) that of *nisus formativus.* Modern physiologists call it the power of nutrition, power of formation, power of reproduction or vegetation. However different may be the names chosen by physiologists and physicians to designate this power, and various the ideas they attach to it, yet all are agreed on the essential point, that of regarding it as intended to maintain living bodies, and all their parts, during a certain space of time, in a state of integrity, in the composition, organization, and vital properties that are proper to them, and to render these bodies capable, at a certain period of their existence, of producing beings of the same species as themselves, which beings, like, in this respect, to those by which they were engendered, are confined to a determinate mode of formation and development, and exhibit similar phenomena. Let us bring forward the facts which speak in favour of this assertion.

CCCVIII. A living body, considered as an object of chemical examination, is, as Berzelius expresses it,(9) a laboratory in which many chemical

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(1) Oper. omnia. Lib. de facultatibus.
(2) Oper. part 1, p. 258.
(3) Novum Organon, lib. ii, aph. 48.
(4) De generatione animalium. London, 1651, in 4to, p. 170.
(5) Theoria medica vera. Halle, 1708.
(6) Hist. Nat., v. ii, p. 41. " Le corps d'un animal ou d'un végétal est une espèce de moule interieur dans lequel la matière qui sert à son accroissement se modele et s'assimile au total. Il nous parait certain que le corps de l'animal ou vegetal est un moule interieur, qui a une forme constante, mais dont la masse et le volume peuvent augmenter proportionellement, et que l'accroissement, ou, si l'on veut, le developpement de l'animal ou du végétal ne se fait que par l'extension de ce moule dans toutes ses dimensions exterieures et interieures, que cette extension se fait par l'intusousception d'une matière accessoire et étrangère, qui penêtre dans l'interieur, qui devient semblable à la forme et identique avec la matiére du moule."
(7) De generatione. Halle, 1759.
(8) Ueber den Bildungstrieb und das Zeugungsgeschäft. Göttingen, 1781, 1794, in 8vo. Comment. Soc. Gôtting., v. viii, Institut. Physiol., sec. 591. Inesse corporibus organicis vivis ad unum omnibus peculiarem vim, ipsis connatam, et quamdiu vivunt, perpetuo activam et efficacem, statutam ipsis et destinatam formam generationis negotio primo induendi, nutritionis posthac functione perpetuo conservandi, et si forte mutata fuerit, quantum fieri potest, iterum restituendi.
(9) Chemie, v. iii. Abthl. 1, p. 138.

operations are going on, finally designed to produce all the phenomena the collection of which we designate by the name of life, and to keep the laboratory itself in such a state as that it may be developed, as it were, from an atom to the highest perfection it is capable of attaining, after which it retrogrades, and is at last destroyed. It cannot be refuted that life is accompanied by continual changes in its composition. These changes, however, differ, as to their causes and effects, from the chemical operations that take place in lifeless bodies. As I have previously remarked, chemistry may possibly dissolve the organic combinations and their elements, but it is impossible for it to reproduce them from the latter. What, therefore, in living bodies, retains the elementary matters in the organic combinations necessary to the continuance of their existence, and determines the particular changes of composition which accompany life, is a specific power, altogether different from the chemical affinities acting in inorganic bodies.

The particular changes of composition that occur in living bodies, are the result of the power of nutrition or of assimilation, which regulates the chemical affinities of substances drawn from the external world, and uses them for its own purposes. The various alimentary matters consisting of water, organic substances, and air, are so changed, in their chemical connexions, by the power of formation manifested in a specific manner in each living body, as to be transformed into the peculiar organic combinations of its nutritive fluid. As, moreover, we are aware that plants and animals form, from aliment, the varied organic combinations that are proper to them, such as albumen, fibrin, gelatin, mucus, gluten, fecula, gum, sugar, &c., which we cannot always demonstrate as such in their alimentary substances, we are authorized to admit that this power has the property of so changing the elements of the food, in their associations and respective proportions, as to enable them to pass from one combination to another. Hence results the great variety of organic combinations, with their multiplicity and variableness in the acts of assimilation and nutrition. In fine, it is more than probable that living bodies, especially plants, possess the faculty of converting inorganic or binary combinations into organic or ternary. It even appears that the chief purpose of plants, in the economy of the organic kingdom, is to be continually transforming the inorganic matters of the earth, water, and air, into inferior organic combinations, which taken afterwards by animals, under the name of aliment, become, in them, more complicated animal combinations.

CCCIX. The power of formation not only regulates the composition of living bodies, but also effects their organization. It is it which, in the fecundated germinative liquid, brings the molecules of the organic combinations to the solid form, and calls the first lineaments of the vegetable and animal embryo into existence. All the parts and tissues that are formed in it, according to a definite order of succession, are products of the power of formation, and on this they depend in all that relates to their first appearance, their development, aggregation, configuration, and arrangement. The phenomena exhibited in the act of formation of an embryo, are placed far above all the mechanical and chemical acts we observe in bodies not endued with life. It is the power of formation that produces the growth of all the organs, because it is it which induces the attraction of the nutritive molecules contained in the nutritious fluid, which combines these molecules with the parts already formed, and which thus produces the augmented size of the latter. It is this power, in short, which, in the renewal of materials, attracts new molecules from the formative liquid, and inserts them in the organic junction, in lieu of those which have been used and rendered worthless by the vital act of the organs. This continual attraction of molecules, and their conversion into the texture of the organs constitutes the difference between animate and inanimate bodies. The molecules of crystals, which are united at the period of crystallization by chemical affinity, and retained near each other by cohesion and adhesion, do not change of their own accord, nor exert any attraction that can operate beyond the collection of which they are a part, as happens in organs that, in the whole duration of their existence, never cease attracting molecules from the nutritive fluid, and assimilating them. The acts of formation and nutrition, the never-ceasing organic crystallization, as Reil called it, cannot be alone explained by the chemical properties of organic combinations entering into the composition of organized bodies. Albumen, fibrin, gelatin, mucus, gluten, fecula, gum, sugar, &c., are the matters which compose the different tissues, and the extremely varied parts of animals and plants. From these organic combinations, when external circumstances are favourable, vegetables and animals of the most simple kind are generated, such as infusoria, mouldiness, confervæ, &c., but organs similar to those met with in more complex vegetables and animals never proceed from them. Neither has any chemist ever succeeded in forming a plant or animal from organic matters, by any of the operations art has put in his possession. These consequently are only the substance from which living bodies produce and form their organs, and this occurs by means of the power of formation or nutrition, which exerts a special activity in every kind of vegetable and animal. This same proper and inherent power of living bodies, determines the organic configuration and conformation in every and all the parts. It forces organic matters into the junction of living bodies, fixes them there, and uses them for their several purposes. It preserves these bodies during a certain period of time, spite of the external influences which tend to destroy them.

CCCX. The power of formation should be considered as a force which not only produces the composition and organization of living bodies, but moreover calls all the other powers into existence that are manifested in organized beings, and renders their different tissues and parts capable of exerting special manifestations of activity. This is consequent on the fact of all the parts endowed with particular vital properties which we behold gradually generated in the fecundated seed and ovum, being productions of the powers of formation caused by the generative act. The manifestations of action of the tissues and organs have their origin in the peculiarities of composition and organization that are communicated to them by the act of formation. It is not until the parts and tissues are in existence that their manifestations of activity are present. The phenomena of muscular irritability only begin to be seen in the embryo when the muscular substance is formed. Various humours, the bile, the saliva, the urine, are only secreted at the time of production of the organs that prepare them. The phenomena of sensation are not perceived previous to the formation of the nerves. Even the manifestations of mental power only begin to be pronounced when the organs connected with them are formed and have acquired the necessary degree of development. Thus the power of formation shows itself to us as the creator and regulator of all the other powers, since itself produces the organs in which they are manifested, and renders them fit for exerting their proper activity.

CCCXI. The parts of plants and animals produced by the power of formation, together with their particular vital properties, are preserved for some time by this power, which never ceases to act throughout the period of their existence, and which, on that very account, maintains them continually in the aptitude for exhibiting their manifestations of life. The power of nutrition puts them in a proper state for entering into action under the influence of excitants. The aptitude of the organs to be affected by stimulants and to react on them, which aptitude some physicians have made the basis of life, giving it the name of excitability, can only be considered as an effect of the power of formation. It is evident that any part must be formed before it can show itself to be excitable. Each organ is maintained in the possession of its proper characters by nutrition, and being so maintained, is rendered fit for producing its particular effects. The vital properties penetrate as it were the materials taken by the organs from the nutritive fluid, at the same time they enter the organic junction of the latter in the act of nutrition. A perfect relation exists between the intensity of the manifestations of life and nutrition. Well-nourished organs are capable of executing energetic actions. Ill-nourished ones, on the contrary, act with less power and for a shorter space of time. In short it is the act of nutrition which brings back to their former state the organs that are exhausted by their manifestations of activity.

CCCXII. The power of formation which calls organic bodies into existence in generation, which produces all their tissues and parts, together with their vital properties, in the germinative liquid, which developes, completes, and maintains them during their life, should be considered as the primitive and fundamental power of these bodies, as the creator and preserver of all the powers that belong to living bodies, either in their ensemble, or in their different parts. Hence physiologists and physicians who seek the principle of life in any other power than it, in excitability, irritability, or sensibility, commit a great error, since the parts in which these powers are manifested, are only products of the power of formation, and such secondary powers could not possibly show themselves before the existence of their organs.

CCCXIII. The power of formation shows itself active in all the parts and points of living bodies. In the solids, it causes, by nutrition, the attraction of the materials of the nutritive fluid into them, changes these materials into their organic junction, and communicates to them the same vital properties as to the solids. It is manifested even in the formative liquids by the production of organic materials having a form, the globules. We are bound, therefore, to consider the activity which presides over these different acts, as a power inherent in all the parts of living bodies, and we cannot assume that, either in vegetables or animals, it is limited to any one tissue or apparatus. All the parts of a plant, the roots, stem, branches, leaves, flowers, wood, and bark, are nourished. Nutrition takes place in all the tissues and organs of animals, in the cellular tissue, the membranes, nerves, vessels, muscles, ligaments, tendons, cartilages, bones, and viscera. The continual tendency of this power to preserve the individual and all its parts, forms the prominent character of individual life, and is presented to us as the most important internal condition of life. This power not only converts the alimentary matters, drawn from without, into nutritive fluids, endued with special properties and assimilated by it, but it also introduces them into the solid organic form, determines and regulates the composition, the organization, and the vitality of the parts, and maintains them in their vital qualities. Every living body is exposed to external influences which tend to its destruction; its composition changes in the conflict with these influences, which urge it to manifestations of activity. Every one, however, under certain external circumstances, to which we shall afterwards return, retains its form, its composition, and activity. Whatever has been changed in the materiel of living bodies, by external impressions and excitements, or by the manifestations of action, or the reactions of their organs themselves, is again established by the power of nutrition or formation. Certain external impressions, however, of a mechanical or chemical nature, and divers organic matters, vegetable and animal poisons, are able to annihilate this power, and thus cause the death of the living bodies on which they operate.

CCCXIV. The power of formation which preserves individuals during a certain space of time, is by degrees exhausted by its own action. Death and the annihilation of the individual are consequent on its extinction. Yet it gives duration to animal and vegetable species, by producing, at its highest degree of activity, the germs or commencements of new beings of the same species, and originating the conditions in which they can be developed so as to produce new individuals. The power of formation of individuals, is as it were expended in their productions, the germs, and establishes the stock of new beings, in which it is afterwards manifested in the same manner. Bodies actually living formed a part of other similar bodies, from which they are detached to continue their existence as distinct individuals. The power of formation of the preceding generation of a vegetable or animal species founded the existence of present generations, and so on in tracing the past, the beginning of which is unknown to us. The current of life arises from a source of which we are ignorant, and is continued to infinity from generation to generation. By generation, by that act of the plastic power which produces new beings of the same species, in which the same power is afterwards manifested in like manner as in the generative individuals, the power of formation of the species is preserved and maintained.

The liquid drop of the germinating vesicle and the fecundated seed contains, virtually but not actually, a being of the same species, endowed with all the same qualities of composition, of form, and life, without excepting the possibility of one day engendering, as the being which called it into existence. The power of formation in the fecundated germ, produces the different tissues and parts, with all their vital properties, regulates their configuration and conformation, and determines the mode and period of appearance of the organs, in conformity with the species of the generating bodies. It produces the organs for absorption, assimilation, respiration, the movement of the nutritive fluid, secretion, the motions, sensation, and generation, and places them all in the requisite state of reciprocal action. In this manner the creative power of formation is maintained in the species, whilst, in individuals, it is present only as a passing and perishable phenomenon.

CCCXV. It is the power of formation which, after the extinction of the individual life of organized bodies, renders the organic matters, separated from their organization by fermentation and putrefaction, capable, provided they have not been reduced to their elements by external physical or chemical actions, of assuming new and more simple organic forms, and of being transmuted, by what is called spontaneous generation, into infusoria, confervæ, mouldiness, &c., according to the diversity of external influences, such as heat, light, water, &c., which determine them in taking on this new form. This power appears, therefore, to be a property inherent in organic matters in general, rendering them able to take other more simple configurations, when detached from the combination of living bodies. In the act of assimilation and nutrition of individuals also, those organic materials of the aliment endued with an aptitude for formation and life, are chosen by the plastic power of each individual, to contribute to the augmentation of its volume, to the growth and preservation of its body, and are employed in the secretion of the assimilating and generative fluids.

CCCXVI. The formative power further determines the course of life, the vital periods of organized bodies, and the change of composition, organization, and manifestations of action that coincide with such periods. It grounds the possibility of the duration of life, various as this is in organized bodies. This power effects the reunion and healing of wounded or detached parts, and it is even capable of producing new ones in place of those that have been lost. Lastly, it is this which quiets the disturbances or diseases that occur, in various circumstances, in the organs and functions; and this effect is consequent on its determining and regulating the reactions by which the natural course of the manifestations of life are re-established, a tendency of organized bodies which physicians have denominated the *vis medicatrix naturæ.*

CCCXVII. The power of nutrition or formation, the power which exhibits its action in all organized bodies, in the pulverulent mushroom and the confervæ, as well as in the palm-tree and adansonia, in the infusoria and polypi as in the elephant and whale, presents the greatest diversities and varieties in regard to its manifestation, as the incalculable richness of our planet in different vegetable and animal forms fully proves. Each vegetable or animal species has a specific configuration and organization, each one exhibits vital acts that are peculiar to it, each produces specific germs, each one is developed in a manner of its own, each one in short pursues a path in its course of life that belongs to it alone. " Here," as Kielmeyer said,(1) " this power creates colossal masses whose extent the eye with difficulty measures; there it is confined to diminutive points that are scarcely perceivable with the aid of the microscope; here it appears eternally the same, and there, it is seen as a fairy of ever varying aspect; here, it endures for ages, there, a fraction of time includes all its operations; here it outlives almost every cause of destruction, and there the slightest breath suffices to extinguish it." The plastic power not only is exhibited in a fixed and particular manner in each vegetable and animal species, but further, each individual shews it in its individuality of action.

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(1) Ueber die Verhätnisse der organischen Kräfte unter einander in der Reihe der verschieden Organisationen, die Gesetze und Folgen dieser Verhätnisse, p. 27.

CCCXVIII. The plastic power inherent in all living bodies presents an admirable harmony in its effects, and proceeds according to laws whose conformity with reason cannot but be recognised by a reflecting man. In this respect it even surpasses human reason, as Harvey properly remarked.(2) How diminutive appear all the works the human mind has invented, when compared with the products of this power! Organic formation is, so to express it, the greatest masterpiece of nature, that which solves the problem of a series of living bodies possessing duration notwithstanding the irritability and transitory nature of their forms and phenomena. Many naturalists have called this power the *anima vegetativa,* and have considered it as an emanation of Plato's "soul of the world," the *natura naturans,* the ultimate cause of the universe, the absolute or first cause.(3) Whilst we allow that, like other powers, it proceeds from a superior cause, we may likewise confess that this emanation of the plastic power, from an absolute entity, presents something incomprehensible and that it exceeds the limits of our conception. Moreover we look upon every attempt to derive this power from the absolute existence, as an illusion of the heated imagination, inasmuch as the human mind is incapable of raising itself to absolute wisdom.

CCCXIX. The plastic power which proceeds in its operations so harmoniously, is not an absolute power. It is rather dependent on certain external conditions, and, like all other powers, it has its limits and boundaries in the circle in which it acts. The acts of generation and nutrition occur only in certain external circumstances, when the temperature is at a certain degree, under the influence of air, of water, and light, and when aliment is presented. Each vegetable and animal species keeps itself at a certain external temperature, which, however, is extremely various in the different kinds of living beings. Excessive heat or cold curtails the generative power, the development of germs, and nutrition, and finally annihilates them. Each vegetable and animal species exists in a determinate sphere of external influences, in the earth, in the water, or the air, and is confined to a larger or smaller

(2) De generatione, p. 170. "Si ex operationibus fas est de facultatibus judicium ferre, vegetativæ operationes potius videntur arte, electione et providentia institui, quam animæ rationalis, mentisve actiones; idque etiam in homine perfectissimo.

(3) So says Harvey loc cit. "Superior itaque et divinior opifex (quam est homo) videtur hominem fabricare, et conservare; et nobilior artifex (quam gallus) pullum ex ovo producere. Nempe agnoscimus Deum, creatorem summum atque omnipotentem, in cunctorum animalium fabrica ubique praesentem esse; et in operibus suis quasi digito monstrari; cujus, in procreatione pulli instrumenta sunt, gallus et gallina. Constat quippe, in generatione pulli ex ovo, omnia singulari providentia, sapientia divina, artificioque admirabili, et incomprehensibili, exstructa et efformata esse. Nec cuiquam sane hæc attributa conveniunt, nisi omnipotenti rerum principio; quocunque demum nomine id ipsum appellare libuerit; sive mentem divinam cum Aristoteli; sive cum Platone, animam mundi; aut cum aliis, naturam naturantem; vel cum Ethnicis, Saturnum, aut Jovem; vel potius (ut nos decet) Creatorem, et Patrem omnium quæ in cœlis et terris; a quo animalia, eorumque origines dependent, cujusque nutu, sive effato, fiunt et generantur omnia."

portion of the earth's surface, as is proved by the geographical distribution of living beings. Whenever plants or animals are placed out of the primitive relations that nature has assigned them, a curtailing of their generative act, and of their nutrition ensues. What further proves that the power of formation is, to a certain degree, susceptible of variation in its effects, by the action of external circumstances, is, that animal and vegetable races degenerate in consequence of changes in the influences they come under. We likewise remark that the acts of generation and nutrition are dependent on the seasons, that hot weather favours them, whereas cold contracts, suspends, or altogether stops them. According to the excitements applied to the organs, their nutrition changes, is rendered active, or slackens, or even alters its modus operandi, as is proved by the numerous morbid and anormal changes that occur in the organs, whose functions are thereby disturbed. There are influences which rapidly annihilate nutrition, extinguish the plastic power, and destroy life; such is the case with poisons. When we come to speak of the external conditions of life, we shall see how far the results of the power of nutrition or formation are dependent on external influences.

CCCXX. Another proof of the facility with which the plastic power varies its mode of action, is furnished by the anomalies organic bodies frequently exhibit in their formation, configuration, aggregation, and arrangement, or by what are called monstrosities. Each kind of living body is capable of exhibiting, when developed and formed in the fecundated germinative liquid, variations and changes, which, however, are limited. Sometimes a deficiency in the regular development or the absence of some part is observed; sometimes, on the other hand, there is a superfluity in the formation. Here, parts that should be united are separated, and there, other parts that ought to be distinct, are confounded together. Nevertheless, how far soever monstrosities stray from the rule, the species to which they belong may always be recognised. This circumstance clearly proves they only occur within the limits assigned to the laws of formation proper to each species, and that they do not extend ad infinitum. Besides, we remark, that although, in the case of monstrosity, it often happens that harmony in the arrangement of the parts is no longer perceivable, yet in the majority of cases it is impossible to mistake the existence of a state approaching to it, and that, consequently, even then the plastic power preserves one of its most prominent characteristics.

CCCXXI. The preceding considerations lead to this chief result, that the power of formation inherent in all living bodies, and whose action is exerted conformably with the laws of harmony, which is transmitted from generation to generation, and in engendered beings has its action subjected to the influence of certain external conditions and circumstances, should be considered, if judged of by its effects, as a power sui generis, and different from all other known powers. So far as we are informed by experience, it is only manifested in organic matters, and in bodies composed of such matters, which differ from inorganic bodies in their composition, configuration, and mode of aggregation, as also in their properties. This power appears then to be a force inherent in organic matters, and dependent on their specific material constitution, one whose effects are seen without our being able to say any thing concerning its first cause and mode of action,(4) as is also the case with all the other powers. Sometimes its effects in organic matters are shown in a free and independent manner, but only differing according to the external influences to which the matters are exposed, as in equivocal or spontaneous generation; at other times they exhibit particular modifications, and are inclosed within defined limits, as in vegetable and animal species propagated by organisms anterior to them, or by unequivocal generation. If it be asked whence organic matters proceed, how they are produced, together with the power of formation inherent in them, we are necessitated candidly to confess our ignorance on the subject, inasmuch as the first origin of organic matters and living bodies is altogether beyond the range of experiment, as is also that of inorganic bodies and of matter in general. The final cause of the existence of the plastic power is, like that of the other powers, of attraction, of repulsion and their modifications, mechanical attraction, gravitation, cohesion, and adhesion, like also that of chemical affinity, a secret whose profundity, as Buffon said,(5) we shall never be able, from all appearances, to reach. In the present state and arrangement of our intellectual faculties, we are under the necessity of admitting these powers without the capability of giving an account of the cause that called them into existence and produced them.

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(4) Buffon Hist. Natur., t. 2, p. 45. "Quelle peut-être la puissance active qui fait que la matière organique penêtre le moule interieur et se joint, ou plutôt s'incorpore intimement avec lui? Il paraît, qu'il existe dans la nature des forces, comme celle de la pesanteur, qui sont relatives à l'interieur de la matière, et qui n'ont aucun rapport avec les qualités exterieures des corps, mais qui agissent sur les parties les plus intimes et qui les pénêtrent dans tous les points; ces forees ne pourront jamais tomber sous nos sens, parceque leur action se faisant sur l'intèrieur des corps, et nos sens ne pouvant nous représenter que ce qui se fait à l'exterieur, elles ne sont pas du genre des choses que nous puissions apercevoir; il faudrait pour cela que nos yeux, au lieu de nous representer les surfaces, fussent organisées de façon à nous représenter les masses des corps, et que notre vûe pût pénètrer dans leur structure et dans la composition intime de la matière; il est donc évident qui nous n'aurons jamais d'idée nette de ces forces pénétrantes, ni de la manière dont elles agissent; mais en même temps il n'est pas moins certain qu'elles existent, que c'est par leur moyen que se produisent la plus grande partie des effets de la nature, et qu'on doit en particulier leur attribuer l'effet de la nutrition et du développement, puisque nous sommes assurés qu'il ne se peut faire qu'au moyen de la pénétration intime du moule intérieur; car de la même façon que la force de la pesanteur pénétre l'intérieur de toute matière, de même la force qui pousse ou qui attire les parties organiques de la nourriture, pénètre aussi dans l'intérieur des corps organisés, et les y fait entrer par son aetion."

(5) Hist. Natur., t. ii, p. 3. "La faculté de produire son semblable, qui rèside dans les animaux et les végétaux, cètte espéce d'unité toujours subsistante et qui parait éternelle, cette vertu procréatrice qui s'exerce perpétuellement sans se détruire jamais, est pour nous un mystère dont il semble qu'il ne nous est pas permis de souder la profondeur."

CCCXXII. The power of formation, though a sole and single primitive power, appears gradually to be so modified in its action by circumstances that have reference to the mode of development of our planet, as thereby to produce the different vegetable and animal species, in which it is ever manifested in the same manner, and gives origin to germs of similar species, so long as external circumstances or conditions are the same in the essential particulars. What speaks in favour of this assertion is the fact that, (judging from the remains of animals and vegetables scattered through the different strata of the earth,) there has been a certain order of succession or gradation in these, and that in comparing the remains of a former world with the species now existing, we ascertain that a great number of them have disappeared, probably in consequence of changes in the cosmic relations. We are also certified, that each vegetable and animal species exists only in the circle of certain external circumstances, and that nature has assigned to each one a definite dwelling on our planet. But what are the changes which the earth has undergone in the lapse of time, and on what causes they depend, is a problem which geologists are endeavouring to solve. Though they are able to show different changes produced by fire and water, yet the final cause of these revolutions is not less profoundly lost in the region of things beyond our investigation (6)

CCCXXIII. As we are not able to ascertain either the first origin of the power of formation, or the final cause of its action, any more than of the other powers, and are consequently obliged to admit that it is inexplicable in its cause, physiology can, in such a state of affairs, offer no other question than the study of the phenomena and effects of this power in the different kinds of living bodies, the search into the causes on which they depend, and the establishment of the laws of their action, so far as we can do so by pursuing the path of observation, of experiment, and of sound reflection.

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(6) As Swammerdamm says very justly, (Biblia Naturæ, t. ii, p 867,) Cum Dei Opera iisdem omnia regulis inniti, verasque eorum causas, aut primitivas origines, nobis absolute imperscrutabiles esse, neque hinc revera, nisi extimam simplicis duntaxat umbræ divinorum miraculorum superficiem, a nobis cognosci, manifestissimum sit: hinc pro certissimo habeo, quod omnis Philosophorum cognitio ac sapientia solummodo in accurata perceptione elegantium illorum phænomenorum sive effectorum, quæ a causis primis producuntur, notabilesque vicissim aliorum sæpe effectorum causæ sunt, unice sita sit. Qua propter omni etiam studio ac industria in id incubendum foret, ut isthæc tandem phænomena exactissime pernoscamus, et ex his dum firmas positiones, regulas, conclusiones et ratiocinia, legitime deducamus. Alioquin enim facillime a veritatis tramite aberramus; si quando de Natura quæ prorsus inexhausta est, disputantes sufficientibus destituimur experimentis, quæ sola viam nobis, in spissima ignorantiæ nostræ caligine, haud aliter ac bacillus cæco præmonstrari possunt et debent. Imo vel nostra ipsorum culpa tunc contingit, ut, quæ in rerum natura levi negotio cognoscenda offerunt, non solum obscura nobis, sed etiam inexplicabilia fiant, nostramque hinc inscitiam ac cæcitatem potius, quam scientiam, magis magisque augeant.

CHAPTER EIGHTH.

Of the Secretion of the Humours.

CCCXXIV. The secretion of vaporous or liquid matters is a property belonging to all living bodies. It is of equal importance for the preservation of individuals as of the species. The secreted liquids are added to the aliment and effect its assimilation, or they are thrown out as true excrementitious matters, in order to prepare the nutritive fluid from the food, and to keep this fluid in the necessary state of composition for the continued performance of the act of nutrition. Organized bodies, moreover, during a certain period of their existence, prepare generative liquids which perpetuate the duration of the species.

Let us rapidly review the secreted liquids of vegetables and animals; let us point out their properties and uses, and demonstrate the structure of the organs that officiate in their preparation.

1. Secretion in Plants.

CCCXXV. The secretions of vegetables are divided into external and internal. The former, which are the most numerous, consist chiefly in the ejection of a vaporous matter by the leaves, in order to aid in the assimilation of the sap. Further, excrementitious liquid matters of various kinds are eliminated by glands and hairs. In the number of external secretions, those of the generative liquids and the nectaries of flowers may also be reckoned. Regarding the internal secretions, they refer to humours that are poured into sacciform spaces, into what are called the reservoirs of the humours. Considered generally, the secretions of vegetables have reference only to the preparation of the nutritive fluid and the act of generation.

CCCXXVI. The principal organs of vaporous excretion are the leaves, as has been already stated in speaking of the respiration of vegetables (ccvi.) Mariotte, Hales, Duhamel, Bonnet, Martino, Woodward, Knight, L. C. Treviranus, and others, have shown this excretion by experiments, but have very differently calculated the quantity in vegetable species.(7) It is certain, however, that the transpiration is maintained by the influence of light, and that it is never so active as when an abundant absorption of liquids by the roots is going on, in warm weather and in the sun's rays. It is intimately connected with the growth and energy of plants, on whose life it exerts

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(7) Hales says he observed a sun-flower, three feet and a half high, which transpired about sixteen ounces in twelve hours, during the day; a small vine tree, five; a young apple tree, nine; a lemon tree, six; a medium sized cabbage, three. Martino calculated the quantity of transpiration in a cabbage at twenty-three ounces in the space of twenty-four hours; of a young mulberry-tree, at eighteen ounces; and of a maize plant, at seven drachms.

an essential influence. When it becomes too abundant, it checks development and exhausts life; if it have been suppressed, diseases ensue.

The transpirable matter of leaves exposed to the light, is composed of oxygen and water (ccli.) According to Chevallier's observations,(8) the *Chenopodium vulvaria* also exhales ammonia, and G. Sprengel(9) is said to have remarked that certain plants, growing on the sea shore, give out chlorine. Several poisonous trees, the *Antiaris toxicaria*, the *Hippomane biglandulosa*, and other euphorbiaceæ give acrid exhalations, or even exert a narcotic action. Lavini(1) found carburetted hydrogen gas, together with an acrid principle, in the transpirable matter of the *Rhus toxicodendron*, collected in the night. The matter of transpiration, especially that which is exhaled in the sun, is sometimes also precipitated in the shape of small drops, to which the dew of the leaves is owing.

CCCXXVII. The leaves of some plants also secrete water in a liquid form; this is sometimes the case in the leaves of the pisang, according to Miller,(2) and Bierkander's observations,(3) Munting saw the same thing in the leaves of an *Arum*,(4) Habenicht(5) in those of the *Calla æthiopica*, and L. C. Treviranus in those of the *Ludolfia glaucescens*(6) In some plants of the species *Nepenthes*, *Sarracenia* and *Cephalotus* a copious secretion of limpid and pure water is constantly going on in the sacciform appendages of the leaves that are frequently covered with an operculum; as was observed by Grimm(7) and Rumph(8) in the *Nepenthes distillatoria* and *phyllamphora*. We learn from the researches of L. C. Treviranus, that the coats of the sac at the extremity of the leaf of the former of these plants, contains a great number of true spiral vessels, together with small glandiform elevations which have minute openings, and he thinks it probable the secretion of water is effected by these organs. J. F. Smith(9) and Elliot(1) say that the water found in the hollow leaves of the sarracenia is secreted by them. It is likewise the opinion of Brown,(2) that the sweet-smelling water met with in the utriculæ of the cephalotus, is partly exuded from the coats of the air bags.

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(8) Journal de Pharmacie, v. x, p. 100.
(9) Kastner, Archiv. für die gesammte Naturlehre, p. vii, p. 161.
(1) Recherches sur les emanations deléterés que s'exhalent du Rhus Toxicodendron, in Journal de Chimie Medicale, June, 1825, p. 249.
(2) Duhamel, Physique des Arbres, v. i, p. 141.
(3) Abhandl. der Schwed. Akad, 1773.
(4) Oeffening d. Planten, p. 274.
(5) Flora. 1823, p. 34.
(6) Ueber die wässerigen Absonderungen blättriger Pflanzentheile; in Zeitschrift für Physiologie, v. iii, p. 72.
(7) Ephem. Nat. Cur. Ann. 1, Dec. 2.
(8) Herb. Amboin, v. v, p. 122.
(9) Introduct. to Botany, p. 195.
(1) Sketch of a Botany of South Carolina and Georgia, v. ii, p. 12.
(2) Vermischte Schriften, v. i, p. 147.

Lastly, L. C. Treviranus observed a secretion of water in the flower-ear of the *Amomum zerumbet:* the liquid contained a small quantity of mucus, with a matter resembling fibrin. A similar secretion occurs in the flower-buds of the *Nicandra physaloides.*

CCCXXVIII. The leaves of many trees, of the maple, the lime-tree, the poplar, the willow, the olive, &c., during the warm periods of the year, when the air is very dry and the sun powerful, secrete a viscous matter, containing mucus and sugar, and designated by the name of *melligo.* This secretion was formerly attributed to an insect (aphys,) (3) but the researches of L. C. Treviranus(4) have certified that it should be considered as a product of the leaves. Under the same head must also be placed the secretion of manna from the ash *(Fraxinus ornus.)* The resinous matter of the *Populus balsamica* and the wax of the *Myrica cerifera* are also reckoned among the liquid secretions of the leaves. It is worthy of remark, that vegetables which have absorbed different organic or inorganic hurtful matters by their roots, strive to get rid of them by the leaves, as Schuebler and Zeller(5) ascertained in their experiments on several salts.

CCCXXIX. Among the organs intended for the secretion of very various liquids, are certain parts, commonly composed of small cells pressed against each other, and mostly penetrated by vessels, and denominated by botanists glands. As instances of these, the small fleshy elevations which secrete a viscous humour, and are seen on the petiole of the leaves of the cherry-tree and other amygdaleæ and rosaceæ, and the wartlike elevations of the ice-plant *(Mesembryanthemum crystallinum)* may be cited. The glands are frequently connected with the hairs, which are often articulated, are formed of one or more cells raised above the surface of the vegetable, and contain a canal in their axis. There are two kinds of secretory hairs; those in which glands exist, *Pili glanduliferi,* and those which can be considered only as excretory ducts of glands, *Pili excretorii.* To the former sort belong the *Pili cupulati,* representing small filaments terminating in a concave gland, as the hairs of the *Cicer arietinum.* These, according to Deyeux(6) secrete a sour juice composed of acetic, malic, and oxalic acids. Not unfrequently, however, this last named acid is altogether wanting, according to the researches of Dulong d'Astrafort.(7) The same kind further includes the *Pili capitati,* simple filaments with a globular glandular swelling, as in the *Dictamus albus,* and the *Pili polycephali,* in which each branching filament is

(3) Réaumur, Hist. des Insectes, v. iii, p. 2, p. 46.
(4) Vermischte Schriften, v. iv, p. 89.
(5) Schweigger's Jahrbücher der Chemie und Physik. 1827, art. v, p. 54.
(6) Journal de Pharmacie, v. i, p. 131.
(7) Ibid., v. xii, p. 110.

terminated by a small glandular head, as in the *Croton penicillatum*. Among the hairs that are excretory ducts of glands situated at their base are described those of the nettle, and of the *Malpighia urens;* the liquid is acrid; it probably contains a very concentrated vegetable acid, and it only appears externally when the glands are stimulated, touched, or pressed by a foreign body. Very likely the hairs of the *Hieracium amplexicaule*, of the *Madia viscosa*, of the *Nicotiana glutinosa*, the *Hibiscus*, &c., which give out viscous and oleaginous liquids, come under this class.

CCCXXX. Flowers secrete vaporous and liquid matters. When exposed to light, they absorb oxygen and exhale carbonic acid gas, according to Saussure's experiments. Hydrogen and azote are not excreted, as some physiologists assert. In most vegetables the transpirable matter of flowers carries with it a peculiar odour, probably proceeding from an essential oil, which is sometimes evaporated with the pollen, and is sometimes secreted by glandiform warts or follicles of the petals.

Among the fluid secretions of flowers, besides the generative liquids, to which we shall return hereafter, a juice containing sugar, and secreted by the glandiform organs called nectaries, is ranked. From the observations of Soyer-Willemet,(8) it seems that similar organs, but variously pronounced, exist in all vegetables provided with stamina and pistils. They assume very different forms, as of small round glands, tubercles, pits, pores, grooves, &c., on the ovarium, on the calix, and at the base of the petals or stamina. The juice they secrete contains sugar, often in such a quantity as to crystallize, as Odhelius(9) remarked in the flowers of the *Impatiens balsamica,* and G. Jaeger(1) in those of the *Rhododendron ponticum.* The secretion of this humour is so copious in some plants, such as the *Musa paradisiaca* and *Hoya carnosa,* as to flow out of the flowers. It is yet unknown whether it participates in the fecundative act of plants, as Christian Conrad Sprengel,(2) Perroteau,(3) Smith,(4) Soyer-Willemet, and others have endeavoured to prove, or whether it has no connexion with this act, as Desvaux(5) concludes from his experiments on the effects of the destruction or abstraction of the nectaries. To me it appears that the liquid secreted in the nectaries, (and this the more abundantly as the air is warmer or drier,) is intended to moisten the

(8) Mem. sur la Nectaire; in the Ann. de la Soc. Linnêene de Paris, March, 1828, p. 1.

(9) Abhandl. der schwed. Akad., 1774, p. 363.

(1) Tiedemann and Treviranus, Zeitscrift für Physiol., v. ii, p. 173.

(2) Das entdeckte Geheimniss im Bau und in der Befruchtung der Blumen. Berlin, 1793, in 4to. He thought that the juice secreted in the nectaries aided the fecundation of plants, by attracting insects, as bees, butterflies, some diptera, &c., which fed on it, and by sucking it carried the pollen to the pistil. Kurt Sprengel has also defended this opinion.

(3) Analyse des travaux de la Soc. d'Emulation de Poictiers pour 1803, p. 29.

(4) Recherches sur les appareils sécrétoires des nectaires; in the Ann. de la Soc. Linnéene de Paris. March, 1826, p. 53.

(5) Introduction to Botany, ed. 3, p. 256.

genital parts by its evaporation, and thus keep them in the state requisite for the performance of the act of fecundation. Possibly, also, it is the vehicle by whose means the vapour of the pollen acts on the stigmata.

CCCXXXI. Of the internal secretions that of air deserves to be first examined. Many vegetables, when full grown, have spaces filled with air, which Grew has described under the name of medullary cavities, Mirbel as lacunæ, and Rudolphi as air vessels. In these the globular cavities, divided by a partition, and lined with a dry pellicle, which are found in the stem of gramineæ, are ranged. They are also seen of divers shapes and sizes, in the pith of trees and shrubs. They exist too in the herbaceous stem, the leaf and flower stalks of a great number of dicotyledones, for instance, in the stem of umbelliferæ, the peduncles of dandelion, *(Leontodon taraxacum,)* the petioles of the acacias, &c. They are particularly large in the stems, leaf, and flower stalks of several aquatic plants, of the *Nymphæa*, the *Potamogoton*, the *Trapa natans*, &c. All these hollows in the cellular tissue are not seen in young plants, because at that period of life the cellular tissue is filled with juices. It is not until a certain age that the juices disappear, and are replaced by air in the cells, which at the same time become larger. It is not ascertained whether the air reservoirs are formed solely by the extension or rupture of the cells, caused by the growth of plants, or whether their production and the accumulation of air in their interior, have reference to the acts of nutrition and development. Neither do we know whether the air is introduced from without, or secreted by vessels. Malpighi thought it was conveyed by the spiral vessels; others say it is consequent on the decomposition of the liquids contained in the cellular tissue. The spaces filled with air, or the intercellular ducts, of some plants, with loose cellular tissue, contain within them small, hard bodies, adhering to their coats, which Decandolle calls *raphides.*(6) Sprengel found these bodies in the cellular tissue of the *Piper magnoliæfolium;* Rudolphi, in the air-vessels of the *Tradescantia* and *Musa;* Kieser, in the *Calla æthiopica* and *Aloe verrucosa;* the elder Decandolle, in the *Tritoma uvaria, Littæa geminiflora*, and the *Crinium latifolium;* the younger Decandolle,(7) in the *Nyctago jalappæ* and the garden balsam. Probably they are small crystals formed in the juices.

CCCXXXII. The internal liquid secretions exhibit a great diversity. They comprehend the volatile and fatty oil found in divers plants, the gum, balsams, and resins, which have been often confounded with the nutritive juice of vegetables. They are always found in spaces contained in the cellular tissue, which form their walls, as Mirbel(8) and L. C. Treviranus(9) have

(6) Organographie Végétale, v. i, p. 126.
(7) Mem. de la Soc. de Physique de Genève, v. iii, p. 2.
(8) Exposition et Defense de ma Théorie de l'Organisation Végétale. Amstm., 1808, p. 17.
(9) Beiträge zur Planzenphysiologie, p. 42. Zeitschrift für Physiologie, b. 1, p. 147.

shown. The form of these reservoirs is not everywhere the same. Sometimes they are small cells, bags, or sacs; sometimes they have the shape of tubes, ducts, or pouches of various length and terminating in a cul-de-sac. Round sacs, cells, or vesicles, containing volatile or fat oil, are situated under the epidermis, in the parenchyma of the leaves of myrtles, aurantiaceæ, of the *Metrosideros* and *Melaleuca* species, of the coniferæ and many other plants, as also in the bark and fruit of the orange and lemon tree. In similar cells of the leaves of the *Laurus camphora*, camphor is formed. Short tubes, closed at their extremities and filled with volatile oil, are found in the seed covering of a great many umbelliferæ, of the cummin, anise, and fennel. The vessels that secrete gum represent canals. Such are found in the pith of the linden; in the pith and bark of malvaceæ; in the stalk of the *Atroma angusta* and the petioles of the *Hybiscus*, Similar ducts, containing gum, are met with in the species of *Rhus*, of *Cacalia*, *Aloe*, &c. Balsamic and resinous liquids are found in long sacs or tubes, formed of very condensed cellular tissue, called by Grew turpentine vessels, in the bark of the genus *Pinus*, *Larix*, *Juniperus*, *Thuja*, and *Pistacia*.

All these juices appear to be secreted from the nutritive fluid in the reservoirs which inclose them, in order to keep it in the requisite state of composition for the continued accomplishment of nutrition. There they neither move, nor are moved. They do not seem to be at all consumed in the growth of the plant, neither do they suffer any essential changes. By the progress of age in the vegetable, they lose their aqueous parts, and are finally dried up.

2. Secretion in Animals.

CCCXXXIII. The secretions of animals are more numerous and diversified than those of vegetables. We behold their number increasing, from the foot to the summit of the animal scale, with the complication of structure, and with the multiplicity and intensity of the manifestations of life. In order to maintain this assertion we will enumerate the animal secretions.

CCCXXXIV. The fluid secretions, in reference to form and consistence, are divided into vaporous, aeriform, and liquid. The transpirable matters of the common integument and of the respiratory organs, as also the air of the swimming bladder of fishes, are ranked among the two former. The variously consistent liquids form the extensive remnant of the secretions. The serosity of the cellular tissue, of the serous membranes, of the chambers of the eye, and of the labyrinth of the ear, is very thin, although its specific gravity exceeds that of water; the tears, the urine, and sweat follow. The saliva, the pancreatic juice, the bile, the mucus, the synovia, the semen, the milk, &c. have more consistence, and are often thready. The fatty substances, the suet and fat of the cellular tissue, the marrow of the bones, the wax of the ears, and the different secreted matters of the dermoid cryptæ, are of still greater consistence, and only possess fluidity at a certain degree of heat.

CCCXXXV. The fluids secreted in a liquid form are referable to six classes, according to the chief ingredients of their composition.

1. Serous liquids, resembling the serum of the blood, and composed of a great quantity of water, a little albumen dissolved, and salts existing in the latter. To this class belong the serosity of the cellular tissue, the liquors of the serous and articular membranes, of the chambers of the eye, of the capsule of the lens, and of the labyrinth of the ear.

2. Albuminous liquids, distinguished by a great quantity of albumen. These are the pancreatic juice, the semen, the liquor of ova of Degraaf, the fluid of the thyroid and thymus, and the milk, which besides contains serous matter, fat, and several salts.

3. Mucous liquids, in which animal mucus is the predominating principle, such as the mucus of the mouth, of the pharynx, of the stomach, and intestinal canal, of the nose and air passages, of the urinary and genital organs, and the liquid secreted at the surface of the skin in most animals that live in water.

4. Fatty or oily liquids, as the suet and fat of the cellular tissue, the marrow of the bones, the liquids secreted in the cryptæ of the skin, the cerumen of the ears, the liquor of the Meibomian glands, the fatty fluid of the prepuce, and of the entrance of the female genitals, such as castor, civet, musk, the fluid of the anal glands, the oil of the coccigeal gland of birds, bees'-wax, &c.

5. The saliva, bile, urine, tears, &c., are matters containing many salts, and mostly particular animal substances.

6. Liquids in which acids predominate, as the sweat, the poison of bees, the liquid which ants and many other insects throw out, &c.

CCCXXXVI. If we regard the secretions, according to the ends they fulfil in the animal economy, we see that they are important in many respects in the preservation of life and the performance of divers functions. It is not impossible to divide them into two great classes, those which are necessary for the preservation of the individual, and those for the maintenance of the species. The former remain entire during the existence of every individual; the latter, on the other hand, are only effected during a certain period of life, and even then are generally connected with certain periods of the year.

CCCXXXVII. The secretions relative to the preservation of the individual, include two divisions; those which eliminate liquids from the mass of the humours to eject them, and those which pour liquids into cavities, whence, after having performed different offices, or assisted in functions, they are taken up by absorption and returned to the mass of the humours.

The former products are called excreted liquids, *(fluida excreta,)* and the latter secreted fluids, *(fluida secreta.)*

There is this difference between the excreted and secreted liquids, that the latter contains simple organic constituent parts, of definite form, or globules, which have, in fact, been found in the saliva, the pancreatic juice, the semen, and the milk; whereas none are seen in the urine, the bile, the tears, &c.

CCCXXXVIII. To the class of excreted liquids, by the elimination of which, on the one hand, certain non-assimilable matters that have passed from the aliment into the mass of the humours, are got rid of; on the other hand, the useless materials taken from the organs by absorption, and through which the nutritive fluid is therefore kept in a state which allows of the continuance of nutrition, belong:

1. The exhaled matter of the organs of respiration, the constituent principles of which have been mentioned above.

2. The cutaneous transpiration, the sweat, and the fatty, oily, or mucous matters of the common integuments.

3. The urine.

4. Several elements of the bile, as the resin, the fat, the colouring principle, and salts.

5. Several humours by which animals defend themselves from the attacks of their enemies; as the ink of the sepia, the purple, the liquids of several insects, and the poison of divers arms, especially of the sting of the bee, of the scorpion, &c.

6. Lastly, the humour of spiders and some mollusca, with which they form their webs.

CCCXXXIX. The secreted liquids may be distributed into several groups, according to their purposes and the parts they take in the animal economy:

1. Liquids that are added to aliment received into the alimentary sac and effect its solution and assimilation; as the digestive liquids formerly mentioned, the gastric and intestinal juice, the saliva, the pancreatic juice, and, in part also, the bile.

2. Liquids that relate to the assimilation of the chyle and lymph in the lymphatic system: among those I reckon the humours secreted in the lymphatic glands and in the glands without an excretory duct, the spleen, the thyroid, and supra-renal capsules, which liquids are taken up by the lymphatics and mixed with the fluid they contain.

3. Liquids poured into cavities, where they facilitate automatic or voluntary movements, as the secretions of the serous and articular membranes: here also may be placed the serosity deposited in the cellular tissue, inas-

much as it favours the contractions and relaxations of the muscles within cellular sheaths.

4. Liquids that serve as media in the organs of the senses, and by which external objects are conveyed to the nerves, to produce excitement therein: of this kind are the humours of the eye and of the labyrinth of the ear, the mucus of the nose, and, in part also, the saliva.

5. Liquids deposited at different points of the cellular tissue, where they are afterwards re-absorbed, either when the animal lacks food, or when, having their manifestations of life exalted, they require a greater quantity of aliment. Such a liquid is the fat: its quantity diminishes during hunger, hibernation, the secretion of semen, gestation, and the secretion of the milk.

CCCXL. To the second class of secreted liquids belong those that are necessary for the preservation of the species:

1. The female genital matter contained in the vesicle of the ovum, or of the germ, as also the fluids that many animals give out with the germ, to serve for its nutrition, as the white and yolk of egg.

2. The semen.

3. The fluids secreted by the prostate and Cowper's glands, and mixed with the seed.

4. The liquids contained in the membranes of the fœtus.

5. The milk secreted in the breasts of mammifera.

6. Lastly, the different liquids of which insects make coverings and reservoirs for their eggs, to protect them from baneful influences from without. Here likewise may be reckoned the fluids which caterpillars and other larvæ of insects use in forming their webs, as also wax.

CCCXLI. If we turn our attention to the organs which secrete these widely different humours, and the conditions under which secretion is performed, we should first of all make a distinction between those animals which have no vessels and those which possess a vascular system. In the former, certain infusoria, polypi, medusa, and most entozoa, secretion consists in a simple transudation or exhalation, at both surfaces of the body, of materials of the nutritive fluid contained in their homogeneous mass, without the possibility of pointing out any special secreting organ. The external surface which also performs respiration, appears to elicit excretory matters only, either in the shape of vapour or of mucus, which renders these animals slippery. At the internal surface of the alimentary canal, which is placed in contact with the aliment introduced into the body, a secretion of a solvent and assimilative juice is, on the other hand, effected in consequence of the excitement produced by the food.

CCCXLII. In animals furnished with blood vessels the blood is always the source of secretion, and contains the materials of the different humours:

vessels conveying it to the secreting organs. Sometimes certain of these materials are separated from the minute vessels which penetrate the secretory organs; at other times there are particular organs, having a very diversified structure, which are called glands, and effect the separation of liquids from the blood which has reached them in the circulation. Secretion from the minute vessels is called exhalation, and that from the glands, glandular secretion. The former seems to consist in a separation and elimination of certain parts of the blood, for the liquids produced by exhalation approach the nearest to the blood in composition. In the secretion by glands, the blood certainly furnishes the materials of the liquids to be produced; but these fluids undergo such changes in composition, from the vital manifestations of the glandular parenchyma, that they cannot be considered as simple extracts from, but as true productions of, the blood.

CCCXLIII. The exhalation performed by the capillary blood-vessels mostly takes place at the free surface of membranes, either externally, internally, or in cavities of the body. The cutaneous transpiration which occurs in the majority of animals is an external exhalation, as is also that of carbonic acid from the appendages of the skin, the branchiæ. In the number of internal exhalations are the perspiratory matter of the lungs and trachea, the secretion of a watery, not mucous liquid, which goes on at the inner surface of all mucous membranes, and that of the liquids produced by the serous and synovial membranes. The secretion of the humours of the eye and labyrinth is likewise effected by exhalation. Finally, this mode of secretion also occurs in the cellular tissue, where, in fact, it is the agent in the formation of the serosity and fat.

CCCXLIV. The glands present numerous differences in their structure. They may be divided into simple cryptæ, follicles, or blind cavities, into hollow, cylindrical, or convoluted vessels, and into glands properly so called, or glands in the closest acceptation of the word.

The cryptæ represent pits or small excavations *(folliculi, cryptæ)* of various form and size, in the sides of which close net-works of very minute blood-vessels ramify, which act in nutrition. The secreted fluid remains some time within them, and leaves them by small apertures when they are stimulated. These cryptæ are found in all the mucous membranes. They have the name of muciparous glands, or mucous follicles, *(glandulæ muciparæ, folliculi mucosi,)* because they secrete the mucosity of these membranes. They are sometimes single, and sometimes accumulated together. The former, or simple ones, are found, having the shape of small oval cavities, flattened and provided with one orifice, in the palate, tongue, trachea, œsophagus, stomach, and intestinal canal of most animals. They are also met with in the mucous membrane of the biliary and gall ducts, in the ureters and bladder, and in the mucous membrane of the vagina. The conglomerate cryptæ are the tonsils, the stomachal glands of the castor and pangolin, those of the glandular stomach of birds, and the glands of Peyer scattered over the intestinal canal. Hither, too, the prostate and Cowper's glands must be referred.

These small cavities, or sacs, are very numerous in the genital integument: they secrete a fatty or oily matter, which they pour out, and are therefore called sebaceous cryptæ or glands. To these belong the sebaceous follicles of the eyelids, the ceruminous glands, the anal follicles, the fat secreting cavities found in the genitals, the secretion of the musk, and of the castor, as also the cryptæ that secrete the civet, &c.

CCCXLV. Narrow sacs, of various lengths, or branching canals officiate in the secretion of liquids in insects. The secretory vessels of the saliva and bile are only simple appendages of the alimentary canal. The seed vessels, the ovaries, and the spinning vessels have a similar form. That these cavities receive the materials of the liquids they secrete, by their terminations, from the nutritive fluid, which is spread over the interior of their body through the coats of the intestinal canal, as Cuvier endeavoured to prove, is improbable, since a complete circulation has been discovered in these animals. We should rather suppose that the capillary ramifications of the blood-vessels are connected with these excretory canals, as J. Mueller(1) observed in the ovarian ducts of the mantis species. The seminiferous vessels and ovarian ducts of some worms are analagous to the secretory sacs of insects. The hollow pyloric appendages of bony fishes may also be reckoned here.

CCCXLVI. The glands, properly so called, or the conglomerate, *(glandulæ conglomeratæ,)* as the salivary glands, the kidneys, &c., which, in vertebrata and mollusca, act in the secretion of humours, exhibit numerous diversities in their form, colour, consistence, and texture. In general, they are hollow organs, more or less round and lobular, having a branched mucous membrane for a basis, and ramifications of numerous arteries, veins, lymphatics, and nerves distributed in them. At the point where the arteries arrive at their most minute branchings and are converted into veins, they mostly form, by their netlike convolutions, kinds of nodosities and small peculiarly formed masses that are called glandular grains, *(acini.)* From these very small vessels the radicles of the secretory ducts arise, which are in immediate connexion with the finest ramifications of the arteries, if we may judge from what is proved in regard to the liver and kidneys. These vessels, proceeding from the glandular grains, and which carry off the liquid secreted from the blood, unite into twigs, branches, and trunks, and are joined to a mucous

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(1) Ueber eine unentdeckte Verbindung des Rückengefässes mit den Eyerstöcken bei den Inseckten in Nov. Act. Acad. Nat. Cur., v. xii, p. 12.

membrane, or to the common integument, with which they are in such close connexion as to warrant their being considered as branching appendages of them. The salivary glands, the pancreas and liver, are glands whose excretory ducts pour the secreted liquids on the surface of the mucous membrane of the intestinal sac, of which they appear as so many ramified appendages. The excretory ducts of the kidneys have a particular mucous membrane for a basis, which is united with the lower part of the intestinal canal, or with the mucous membrane of the genitals. The seed secreted in the testicles, and the germinating vesicles formed in the ovaria, are given out upon a special mucous membrane which, in many animals, likewise communicates with the alimentary sac. The breasts and salivary glands, together with the conjunctiva of the eye, are glands whose excretory ducts open on the outer skin, and whose mucous membrane is continuous at its orifice with the general integument. In some secreting apparatus, the excretory ducts also form particular dilatations or reservoirs, wherein the secreted liquors accumulate and remain for some time. The gall and urine bladders, the seminal vesicles, and the lacteal sacs, are reservoirs of this kind. The excretory ducts and their dilatations have always a mucous membrane for a basis, moistened by the secreted liquids. On its outer surface there is either a true muscular membrane, or a tissue analogous to the fibrous coat of the blood-vessels, which, by its irritability and contractility, propels the secreted fluids.

CCCXLVII. A class of glands without excretory ducts, the lymphatic glands, may also be formed; they result from an interlacing of afferrent and efferrent lymphatic vessels, between which blood vessels divide into extremely minute ramifications. It is probable that during the passage of the chyle and lymph through these convolutions, materials of the arterial blood are mixed with them, and aid in their assimilation. Among the glands of the lymphatic system I include the spleen, which is eminently stored with lymphatics, blood vessels, and nerves, and in which a coagulable liquid is prepared from the arterial blood, to be then taken up by the lymphatics and poured into the thoracic canal. Perhaps the supra-renal capsules, the thyroid, and thymus, should be ranked among these glands.

CCCXLVIII. The arrangement of the arteries in the glands presents a vast number of differences. The vessels are nearly strait in some, whilst in others they are considerably convoluted. In one part they represent kinds of small trees, in another hair pencils, and, in a third, starry or radiated expansions. Their diameter, also, is very various. As the distribution of vessels in the different glands seems to be connected with the nature of the liquids they secrete, it is not at all improbable that it influences the act of secretion itself, although nothing certain on this head is yet known. The veins of the glands, likewise, present diversities. In some they are almost straight, and in others much twisted, and divided into net-works. In some glands, the communication of the veins with the arteries is shown by fine injections, the injected mass easily passing from one into the other, whereas in others it is with difficulty demonstrated. This mechanical arrangement is very likely not unimportant in secretion, inasmuch as it influences the rapidity or slowness with which the blood reaches or leaves the glands. The varying quantity of lymphatics which enter into the texture of glands, and the abundant absorption of the watery or other principles of the secreted liquids, may also influence the quality of the latter. Lastly, in regard to the nerves that are distributed in the glands, and which mostly arise from the nervous ganglions, a powerful though hitherto unknown sway over the process of secretion, should also be attributed to them. Perhaps an imponderable agent, (resembling galvanic electricity,) is generated in the nerves, which causes changes in the blood, passes through the delicate vascular net-works of the glands, and renders them capable of secreting, as has been supposed by Wollaston, Berzelius, Brodie, Wilson Philip, and others. It is at least proved that nervous irritations, and the state of the nervous system, in mental affections and diseases, make considerable changes in the activity of the glands, and in their products. We shall return to this in speaking of secretion in man.

CCCXLIX. After these general remarks on the secretion of liquids, and the organs that officiate in it, we will glance over the excreted liquids, which exhibit so many peculiarities, that each animal species may be regarded as a sort of workshop of changes and combinations accompanying its manifestations of life. The secretion of the digestive juices, as well as the part they take in the act of assimilation, have been already spoken of, and the generative liquids will be mentioned hereafter. Besides the exhalation of the respiratory organs and the bile, the excretions comprehend the fluids thrown out on the general integuments, the urine, the ink of sepiæ, and the purple, the matters which divers insects and mollusca make use of in forming webs, and, lastly, several poisons. These liquids are elicited either from venous or arterial blood. The former chiefly gives out the exhalation of the respiratory organs and the bile of mammifera. The urine and the other excreted liquids are furnished by the arterial blood. In animals that live in air there is an abundant excretion by exhalation from the respiratory organs and the surface of the skin, whereas in aquatic animals there is a proportionate evacuation of excretory matters from the liver and kidneys.

CCCL. The skin of the mammifera, birds, and amphibia that live in air, of land mollusca, and probably also of insects, when it is soft, exhales water with carbonic acid. According to Edwards' experiments,(2) exhalation is

(2) Influence des Agens Physiques sur la vie, pp. 84, 131.

particularly abundant in naked-skinned amphibia, frogs, toads, and salamanders, so that if they remain long exposed to a very dry air their life is quickly exhausted, in consequence of the immense loss of fluids they suffer. In general the cutaneous transpiration of animals augments with the dryness and heat of the air, as also from its renewal, and in such circumstances they lose more of their weight than in a cool, moist, and still air. The diminution of atmospheric pressure induces an increase of cutaneous transpiration, as Edwards proved by placing frogs under the recipient of an air-pump.

Moreover liquid matters are thrown out from the skin of animals living in air. Of this kind is the sour liquid sweat in mammifera, many apes, ruminantia, pachydermata, and solipeda, which mostly contains free acetic acid and divers salts, and is excreted when the air is very warm, or when the animals practice violent movements. Animals covered with fur, or those which, together with long hairs, have also short, soft, and downy ones, as the beasts of prey, and the rodentia, &c., do not sweat at all. Neither is any sweat excreted by birds or by amphibia that are covered with scales or shields. In mammifera, birds, and reptiles, fatty or oily liquids are also thrown out on the skin.

CCCLI. Fatty excretions exhaling more or less strongly odoriferous matters, which spread a peculiar atmosphere around animals, are thrown out by the skin of all mammifera that live in air, and are produced by single or conglomerate follicles, as was first shown by Tyson.(3) Besides that the blood appears by these excretions to be maintained in a composition which allows of its officiating in nutrition, they also aid in preserving the integuments, and in defending them from the moisture that would otherwise penetrate them. Moreover the volatile odorous exhalations which are frequently spread through the air over a great space, render animals able to scent and find each other at a distance. Their excretion is particularly copious at the rutting season, and it is not improbable that the animals are excited to commit the generative act, by the influence which the volatile matters exercise over the nervous system through the organ of smell. The variously-smelling transpired matters seem, too, according as they affect animals agreeably or disagreeably, to determine the sympathies or antipathies that exist between them. In short, many animals are protected by their transpiration from the attacks and pursuits of their enemies. Glandular follicles, secreting matters of this kind, are met with in different parts of the skin; we will examine them somewhat in detail, on account of the remarkable products of their secretion.

CCCLII. Many mammifera have glandular crypts on the head. In both male and female elephants, in the temporal space, under the skin, there is a

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(3) In Plott's Natural History of Oxfordshire, chap. ix, p. 325.

large, flat, and roundish gland, composed of a spongy mass, and furnished with a great number of blood vessels. Some blind cavities are found in this mass, which unite into a common excretory duct, whose orifice is in the temple, between the ear and the eye.(4) These glands secrete a viscous, fatty, and ill-smelling liquid which, as Strabo, Arianus and others formerly said, flows copiously at the rutting time, but in greater quantity, however, in the male than female.

In the skin of the face of the bat, especially of the *Vespertilio murinus Noctula,* there is, on each side near the nose and beneath the orbit, a flattened, brownish yellow glandular sac, which is internally divided into several small cells by lamellæ. Externally a small oval aperture is seen, whence a fatty, yellowish-brown liquid, giving a strong smell of musk, flows, when the sac is compressed. From this fluid the peculiar odour of bats arises. Thane met a similar gland, having the same locality, in the two-fingered ant-eater, *(Myrmecophaga didactyla.)* I have seen in the skin of the face of the marmot several small sebaceous follicles, which secreted a fatty liquid, giving out a very strong alliaceous smell. The animal spreads this smell when it is irritated, as I have observed in tame marmots.(5)

In many ruminantia, especially those of the genus *Cervus* and *Antilopes,* there is a pit on each side beneath the internal angle of the eye, leading to a chink, and having its skin furnished with follicles, which secrete a somewhat thick, viscous, and fatty liquid. The very inapplicable name of lachrymal fossæ has been given to these pits.

CCCLIII. On the back of the *Dicotyles torquatus* and *labiatus* there is an oval sac with glandular sides, whose round orifice opens externally between the bristles, as was first made known by Tyson.(6) According to Azara,(7) the fatty liquid secreted in these sacs exhales the smell of the carnation.

CCCLIV. Some mammifera have glandular follicles situated on the sides of the trunk, or on the chest. In the shrew mouse, *(Sorex,)* at the sides of the body, under the skin, and hidden by the hairs, a secretory organ is seen which was first mentioned by Pallas,(8) and which Geoffroy Saint-Hilaire has since examined more minutely.(9) It forms a large, oval, and flattened mass, which is composed of a great number of glandular grains. Externally it is strewed with short and stiff hairs. The fluid it secretes gives a very

(4) Perrault (Mem. pour servir à l'Histoire Naturelle des Animaux, vol. iii, p. 3, p. 138,) and P. Camper (Description Anatomique d'un Eléphant mâle. Paris, 1802, in fol. pl. 10 and 11, fig. 1) have described it.

(5) Meckel's Deutschem Archiv. für die Physiologie, v. iii, p. 112, tab. ii, fig. 9 and 10.

(6) Philos. Transact., 1683, p. 359, tab. 1, fig. 3, 4. Daubenton, in Buffon Hist. Nat., v. v. Seifert, in Spicileg. adenologie. Berlin, 1823, tab. 2.

(7) Voyage, v. i, p. 248.

(8) Act. Ac. Petropolit, 1781, v. ii, p. 343.

(9) Sur les glandes odoriférantes des musaraignes; in Annal. du Mus., v. xxi, p. 299, pl. 15.

penetrating odour, approaching that of musk, and seems to exhale through several pores. Similar glands exist in the skin of the mole, which also smell of musk. The opossum *(Didelphis marsupialis)* has a yellow spot on the chest, whence a reddish and fatty liquid exudes, which is secreted in the cutaneous follicles.

CCCLV. In most animals belonging to the carnivora, rodentia, and marsupialia, round or oval follicles, called anal glands, exist at the extremity of the rectum, underneath the skin and sphincter muscles of the anus. Grew(1) described and delineated those that are met with in several carnivora. They secrete a variously consistent, fatty, or sebaceous, whitish or yellowish matter, which flows out by a small orifice, on the edge of the cutaneous folds of the anus. The evacuation of this liquid occurs chiefly during the exit of the excrements; some animals, however, can force it out at will, when they are irritated. It commonly has a strong odour, which varies according to the species. Most animals of the cat,(2) dog,(3) marten,(4) civet,(5) ichneumon,(6) coati,(7) white bear,(8) and otter(9) genera, have two of these glands. Among the rodentia, anal glands are found in the porcupine,(1) *cavia*,(2) marmot,(3) &c. They have likewise been observed in divers marsupialia. Cowper(4) saw them in the Virginian opossum, in which they were also discovered by Daubenton(5) and Vicq d'Azyr.(6) The two anal glands give a yellowish green liquid, of a very disagreeable smell, which the animal

(1) The Comparative Anatomy of Stomachs and Guts, tab. 23, of the cat, the dog, pole cat, &c.

(2) They secrete a yellowish and very fœtid liquid in the lion; (Daubenton, in Buffon, Hist. Nat., v. ix, p. 32, pl. 4, fig. 1;) in the tiger; (Perrault, Mem., v. iii, p. 3, p. 10, pl. 2;) in the panther; (Daubenton, loc. cit., p. 183, pl. 16;) in the couguar. (Ibid. p. 225.)

(3) The fluid is whitish and has a disagreeable smell; it gives a peculiar odour to dogs.

(4) In the *Mustela foina* and *martes*, it is a thick and yellowish liquid, giving an odour like musk, of which the excrements of these animals also smell. (Daubenton, v. vii, p. 170, pl. 19, fig. 1.) In the *Mustela putorius, furo, and erminea*, it is a pale lemon yellow, and exceedingly fœtid.

(5) Perrault, loc. cit., v. iii, p. 1, p. 163.

(6) Cuvier, Anat. Compar., v. v, p. 258. Here it is a large pouch surrounding the anus, into which a great number of follicles, which secrete a liquid partly white and partly yellow, open.

(7) I have found a fatty and very fœtid whitish liquid in the brown coati.

(8) The liquid is yellow and exceedingly foul scented.

(9) Daubenton, v. vi, p. 278, pl. 42, 43. I have found in the two large anal glands of the common otter, a dirty-white liquid, the smell of which approached that of foul fish-oil.

(1) In the common porcupine there is nearly a dozen small glands at the anus. (Perrault, Mem., v. iii, p. 2, p. 41.) Their contained liquid is whitish, of great consistence, and, according to my observations, smells like box-tree oil.

(2) The *Cavia aguti* has two large follicles, which open at the anus, and secrete a yellowish-green fluid, having an extremely disagreeable alliaceous smell. One of these animals, that belonged to me, spirted the liquid out, whenever it was frightened. I have found similar sacs in the *Cavia capybara, cobaya,* and others.

(3) I have seen two anal glands in the marmot, which secreted a whitish, stinking fluid. I have repeatedly remarked that when this animal was tormented or vexed, it gave out a disgusting smell, at the same time pushing his anus out, so as to render the anal glands apparent.

(4) Philos. Transact., 1704, p. 1568, fig. 3.

(5) Buffon, Hist. Nat., v. x, p. 324, pl. 49.

(6) Anatomie du Sarigue; in Œuvres, v. v, p. 335.

excretes when tormented. The cayopollin *(Didelphis philander)* posssses similar ones.

CCCLVI. In hyænas, male as well as female, between the anus and tail, there is a transverse cleft which leads into a pouch. This is surrounded with a muscular membrane, which likewise includes four large glands resembling a bunch of grapes. The anterior glands communicate with the pouch by two excretory ducts, according to Daubenton's researches,(7) whilst the posterior ones open by numerous orifices. The liquid contained in the pouch is grey, about the thickness of pomade, and smells like rotten cheese. The badger has a similar pouch, only smaller, into which many lenticular glands open,(8) which, according to my own observations, pour a fatty and yellowish fluid into it, diffusing a smell like new honey. In the fox's tail, at some fingers' breadth above its base, a place is observed, which Caspar Bartholin(9) formerly saw, where the hairs smell of violets; in this spot a fatty liquid, to which the smell is owing, is secreted in several small follicles. In the Russian desman, *(Mygale muscovitica.* Cuv.) which spreads a strong civet smell, Pallas(1) found two series of fourteen or sixteen glands, at the origin of the tail, between the scales, which secreted a thick fat, the cause of the odour.

CCCLVII. Some mammifera have glandular pouches between the anus and genitals. Male and female civets *(Viverra)* show a cleft in this part of the body, leading into a pouch; from this two sacs proceed, into which a great number of follicles open, that are composed of small hollow glands, as Perrault,(2) Th. Bartholin,(3) Morand,(4) Daubenton,(5) and others ascertained. The liquid secreted in this organ and called civet, according to Boutron-Charlard's(6) researches, is composed of free ammonia, a fatty substance, (elain and stearin,) mucus, resin, volatile oil, a yellow colouring matter, and some salts. Here also is reckoned the sac which is similarly situated in the *Mephitis,* and in which, according to Mutis,(7) the excretory ducts of two large glands formed by an assemblage of numerous and small follicles terminate. Externally, they are covered by a thick muscular membrane, so as to give the animal the power of shooting the liquid to

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(7) Buffon, Hist. Nat., v. ix, p. 287, pl. 28, 29.
(8) Ibid., v. vii, p. 118, pl. 8, 9, fig. 7.
(9) Act. med. Hafniens, v. iii, p. 32, obs. 21. De caudæ vulpinæ odore violaceo.
(1) Act. Petropol., 1781, v. ii, p. 329.
(2) Mem., v. iii, p. 1, p. 162, pl. 24.
(3) Anatome civette; in Hist. Anat., cent 4, hist. 1, p. 199.
(4) Observations sur le sac et le parfum de la Civette; in Mem. de l'Acad. des Sc., 1728, p. 568.
(5) Buffon. Hist. Nat., v. ix, p. 323, pl. 32.
(6) Journal de Pharm., 1824, v. x, p. 357.
(7) Abhandl. der Schwedischen Akad., v. xxxii, p. 68.

some distance, when irritated; the liquid is dark yellow, and has an exceedingly foul alliaceous smell. Lassaigne,(8) found it to be composed of a volatile oil and strong smelling fat, a colouring matter; a little sulphur, and a small quantity of hydro-sulphate of ammonia.

CCCLVIII. In all the mammifera, a fatty or sebaceous matter, mostly exhaling a peculiar odour, is secreted on the surface of the gland of the penis and clitoris, underneath the prepuce. This humour, prepared in small single follicles, spreads also between the lips of the vulva, in females. But some mammifera have, in addition to these, large follicles with glandular sides, which secrete fatty or oily substances, and pour them upon this part by excretory ducts. These follicles either belong exclusively to the males, or exist in both sexes.

To the follicles which are met with in males only, belongs the musk-pouch, an exact description of which has been given by Pallas.(9) It is a large oval sac placed under the skin of the belly, behind the navel. Its lower surface admits the anterior extremity of the penis into a sort of groove. It is composed of three superposed membranes, an external cellular one in which some fleshy bundles are scattered, a middle coat furnished with a great number of blood vessels, and an internal one, soft, and forming many folds and wrinkles. The orifice of the pouch, which is small, round, and encircled with stiff hairs, is placed directly before the aperture of the penis: some sebaceous follicles are situated around it. In adult animals, the sac contains a brown, very consistent, dry, and granular matter, called musk, which, according to the chemical researches of Blondeau and Guibourt,(1) and especially of Geiger,(2) is chiefly composed of a particular volatile, strongly-smelling substance, which appears to be an essential oil, and is joined to some cholesterine, a little resin, stearin, and different salts.

Follicles are found in both sexes. Castors, male as well as female, as Rondelet formerly observed, have four large glandular sacs, two of which are on each side near the cloaca, where the genitals and anus open, below the muscular layer of the skin, as Perrault,(3) Gattwaldt,(4) Kuhnus, Sarrasin,(5) Mortimer,(8) Daubenton,(7) and very lately A. C. Bonn,(8) have shown. The anterior follicles, which are larger and oval, open by separate

(8) Ann. de Chim. et de Physique, 1821, v. xvi, p. 384.
(9) Spicilegia zoologica. Fasc. xiii, p. 30, tab. 6, fig. 4, 8, 9, 10.
(1) Journal de Pharmacie. Mars 1820, p. 105.
(2) Magazin für Pharmacie, v. xxi.
(3) Mem pour servir a l'histoire naturelle des animaux., p. i., p. 141, pl. 20.
(4) Physikalisch anatomische Bemerkungen über den Biber; aus dem Latein übersetzt Nürnberg, 1782, 4to.
(5) Mem. de l'Ac. des Sc., 1704, p. 48.
(6) Philos. Transact, Nro. 430, p. 172.
(7) Buffon Hist. Natur., vol. vi, p. 317, pl. 40.
(8) Anatome Castoris atque chemica castorei analysis, Lugd. Bat., 1806, 4, tab. 1.

orifices into the prepuce which envelopes, like a sheath, the gland of the male and the clitoris of the female. Their coats are thick and composed of three membranes, a cellular, a vascular, and an internal dense one which forms numerous folds. The liquid secreted in this cavity is consistent, of a dark-brownish grey, and has a very strong odour; it is the castoreum, properly so called, which, according to the analyses of Boun, Bouillon-Lagrange,(9) and others, contains fat, a matter like resin, and a volatile oil. It seems to be shed during the act of generation. The posterior follicles are smaller, are pear-shaped, and are each composed of three small sacs, which open by very narrow orifices into the cloaca, near the anus. The sacs are formed of three membranes, and contain a great number of small hollow glandular grains, which are open towards the surface of the internal membrane. In these follicles, which resemble the anal glands of other animals, an oily liquor, of a whitish yellow, the castor oil, is secreted. Part of it seems to be shed into the cloaca, each time the animal passes its excrement,

The Canadian musk-rat or civet-mouse, *(Fiber zibethicus ondatra,)* according to Sarrasin's observations (1), has two pyriform sacs situated underneath the skin, anterior to the pubis, the internal membrane of which, forming a great number of folds and small tubes, secretes a liquid resembling milk in colour and consistence, but having a strong smell of musk. The two excretory ducts run towards the penis, and terminate near the gland, in the shape of minute papillæ. In the female they proceed along the urethra, and open on the inside of the lips of the vulva.

In the hamster, the rat,(2) the mouse, and other rodentia, there are two glandular follicles under the prepuce, which secrete a fatty, whitish fluid, and shed it over the gland, by narrow excretory ducts.

The hare has an oval gland on each side of the external genitals, in a bald space; each gland having an orifice. Behind it, between the penis and anus, or between the anus and vagina, there is a pit, which contains a yellowish, fatty, and very fœtid liquid, secreted in the gland.(3)

CCCLIX. Some antelopes have large sebaceous follicles in the neighbourhood of the mammæ. Perrault(4) found, in the male and female of the *Antilope oryx,* two follicles, situated beneath the teats, in the inguinal region, and furnished with glands opening into them by small orifices. Daubenton(5) recognised two similar follicles in the gazelle *(Antelope dorcas,)*

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(9) Journal de Physique, v. xlvi. p. 65.
(1) Sur le rat musqué; in Mem. de l'Ac. des Sc, 1728, p. 323.
(2) Daubenton in Buffon Hist. natur. t. vii, p. 290, pl. 38, fig. 1.
(3) Wepfer in Ephem. Natur. Curios. Dec. 1, Ann. 3, Obs. 167. Daubenton loc. cit, v. vi. p. 278, 282, pl. 42, 43.
(4) Mem., v. iii, part 1, p. 98.
(5) Buffon, Hist. Nat., v. xii, p. 251, plate 24, fig. 1.

containing a whitish fatty matter. The pouch of the opossum, according to Tyson(6) and Vicq d'Azyr's(7) researches, is furnished with small sebaceous follicles, which secrete a yellowish fluid, having an exceedingly disagreeable smell, when fresh, but approaching to that of musk, when dried.

CCCLX. Lastly, the feet of some ruminantia present minute sebaceous follicles, situated beneath the skin, and having their internal surface studded with fine hairs. In their sides, a great number of small glands are found, which secrete a fatty and viscous liquid. This is shed, through a hirsute aperture, between the clefts of the hoof, in the intermediate skin of which, small glands are mostly found. Such glands of the hoof were first noticed by Daubenton(8) in the hind-feet of a gazelle. P. Camper(9) found them in the rein-deer, in which there was a yellowish, oily, fœtid liquid. Smith(1) saw them in the hind feet of the elk. He remarked that the liquid secreted by them was oily and very stinking, and that it increased at the rutting season. Livingstone,(2) J. F. Meckel,(3) and Niemann(4) also saw these glands in the sheep. The oil probably flows when the animal is walking, contributes to the preservation of the hoof, and gives a peculiar odour to the footsteps of the animal, so enabling it to discover others of its own species.

CCCLXI. With the follicles of the skin in mammifera may be compared the gland situated on the coccyx of birds, the excretory ducts of which open at the top of two small tubercles. Its oily liquid maintains the pliancy of the feathers and renders them impermeable to moisture. To this is chiefly owing the peculiar odour diffused by birds. Besides this gland, which is larger in aquatic birds than others, many of them, such as herons, water-hens, divers, &c., have a great number of similar small follicles scattered over the skin. A small pouch, with glandular sides, which opens into the cloaca, and is called after Fabricius ab Aquapendente, seems to be in place of anal glands in birds. The liquid it secretes is unctuous, and in many birds, especially the heron, gives a very strong smell.

CCCLXII. Animals of the class amphibia exhibit glands in different parts of the body, that secrete fatty or oily liquids. Crocodiles of the old and new world, especially when exposed to the sun, exhale a strong smell of musk, which the Arabs Addamir and Abd-Allatif heretofore remarked in the crocodile of the Nile, as also Petrus Martyr ab Angleria in the cayman of

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(6) The Anatomy of an Opossum; in Philos. Transact., 1698, p. 120.
(7) Œuvres, v. v, p. 334.
(8) Buffon Hist. Nat., v. xii, p. 252, pl. 24.
(9) Naturgeschichte des Rennthiers. Dusseldorf, 1791, in 4to, p. 102.
(1) New York Med. Reposit., 1729, p. 173.
(2) Transact. of the Soc. of New York, vol. ii. p. 120.
(3) In the translation of Cuvier's comparative anatomy, v. iv. p. 690.
(4) Taschenbuch für Hausthierärzte, v. ii, p. 87.

the West Indian islands. Vesling, Perrault, Hasselquist, Sonnini, Geoffroy, and others also remarked it in the Nilotic crocodile; Dampier, Sloane, Plumier, and others, in the sharp-snouted crocodile; Ximenes, Azara, and others, in the jacarre; the Jesuits, in the helmetted crocodile, and Fra Paolino in the *Mudela or gavial.* This smell proceeds from a fatty matter which two glandular follicles situated in the skin, at the inner part of the lower jaw, shed upon the exterior of the body by an aperture;(5) these follicles have been lately described by Th. Bell.(6) Similar ones are likewise found at the anus. According to the observations of Prince Maximilian of Neuwied,(7) the smell of the jacarre is strongest at the coupling season.

Several lizards, among others the iguana, have a row of small follicles with round orifices, at the inner side of the thigh, which secrete, especially at the coupling season, a fatty liquid, the smell of which is not disagreeable, and almost resembles that of dried hay.(8) In the *Tachydromus quadrilineatus* Daudin(9) discovered two small vesicles placed between the anus and the upper part of the thigh.

CCCLXIII. Snakes have two long follicular and pointed sacs, at the tail, behind the cloaca, which are covered with skin, and situated between the muscles. Each of them opens on a tubercle placed at the edge of the posterior lip of the cloaca. Tyson(1) first observed them in the rattlesnake; Redi (2) and Morgagni(3) saw them in the viper. I have not only found them in these snakes, but also in the adder, the boa, and phyton, and even in the *anguis.* A fatty, yellowish or greenish liquid, of a penetrating and disagreeable smell, is secreted in them, which is particularly abundant at the coupling time, if we judge by the stronger scent at that period. The liquor of the anal follicles of indigenous adders and angues has an alliaceous smell, almost like assafœtida. The exceedingly disgusting emanations from snakes were heretofore remarked by Martial, Ælian, Aldrovand, Gessner, Castelli, and others. Kalm(4) likewise observed this odour in living rattlesnakes, which exhaled it more especially when exposed to the sun or irritated. The smell of these ophidia is often sufficient to indicate their presence, and to put horses and oxen to flight. R. Povall(5) and Garden(6) also observed the fœtid and

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(5) Tiedemann and Oppel, Naturgeschichte des Krokodils. Heidelberg, 1817, in fol., p. 34.
(6) Philos. Transact., 1827. P. 2, p. 132.
(7) Beiträge zur Naturgeschichte Brasiliens. V. 1, p. 84.
(8) Hist. Nat. des Reptiles. V. i, p. 121.
(9) Ibid. V. 3, p. 253.
(1) The Anatomy of a Rattlesnake; in Philos. Trans., 1683, page 25, fig. 2.
(2) Obs. de Viperis; in Exp. circa varias res Naturales, p. 221.
(3) Adversar. Anat., v. iv, p. 53.
(4) Historia Caudisonæ; in Amœn. Transalp., v. ii, p. 490.
(5) London Med. Repos., Jan., 1819. He quotes general cases in which even men had been vehemently affected by the exhalations from rattlesnakes.
(6) Chapman, Philadelphia Journal, May, 1824. Himself found a collection of rattlesnakes under some stones, and was invaded by a stupor from their excessively fœtid exhalations, and nearly fell into a syncope.

almost stupifying smell of rattlesnakes; they attribute to it the pretended power of charming which these animals are said to exert on the smaller mamifera and birds, an opinion against which Barton(7) has advanced some weighty reasons. Several venomous serpents have, moreover, particular fossæ in the face, which have been described by P. Russel and Home(8). But it is not known whether they secrete a liquid.

CCCLXIV. Naked-skinned reptiles, particularly toads and salamanders, have a great number of glandiform follicles opening on the skin. Glands of this kind, united into two masses, are found behind the head. When the animal is excited, they secrete a large quantity of liquid, which in the brown toad smells of garlic. The fluid in salamanders is milky, and I have ascertained that it gives the odour of jasmine,(9) especially during the hibernal torpor. The animal is able to project it to some inches, as Wurfbain,(1) Maupertius,(2) and Laurenti(3) observed.

Lastly, many tortoises exhale a smell of musk, according to Daudin's observations, especially the *Testudo odorata* and *pensylvanica*. The origin of this smell is not known; perhaps it proceeds from follicles that are connected with the cloaca, and which have been mentioned by Caldesi, Perrault, and others.

CCCLXV. Many insects secrete vaporous or liquid fluids for the most part having a strong odour, and which they shed over their general tegument, in various circumstances, but chiefly when they are disturbed, to defend themselves from the attacks of their enemies. Among the odoriferous exhalations of insects which affect the olfactory organ of man agreeably, I may mention the rose-scent of the *Callichroma moschatum*, and of the *Staphylinus suaveolens* which approaches the smell of a ripe pear. The scent of the *Oxytalus morsitans* resembles that of the water lily flower; the *Oxytalus rugosus* smells of water cress; the *Dytiscus marginalis*, of liquorice wood; the *Lygæus hyosciami*, of thyme;(5) the *Musca cynipsea*, of balm,(6) The *Crabro flavus* diffuses a pungent æthereal smell.(7) The *Trichius eremita* smells like Russia leather, and some kinds of *Andrena*, like garlic. Many *Carabi* exhale a very disagreeable odour, like rancid butter, owing to a fatty matter that transudes from their abdomen.(8) The species of *Blaps*, *Tenebrio*, *Omalium*, *Blatta*,

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(7) A Memoir concerning the fascinating faculty which has been ascribed to the rattlesnake and other American serpents. Philadelphia, 1814, in 4to.
(8) Philos Transact., 1804, p- 70.
(9) Deutsch. Arch. für die Physiologie. V. 2, p. 115.
(1) Salamandrologia, Nurimberg, 1683, p. 50.
(2) Mem. de l'Acad., des Sc. de Paris, 1727, p. 27.
(3) Synopsis Reptilium. Vienna, 1768, p. 51.
(4) Loc. cit., v. ii, p. 29.
(5) De Geer, Hist. des Insectes, v. iii. p. 249, 274.
(6) Ibid, v. vi, p. 135.
(7) Kirby, Monographia Apium, v. i, p. 136.
(8) Loc. cit., v. iv, p. 86.

Gyrinus, Cimex, &c., also affect our smell in a disagreeable manner, The *Formica fuliginosa, fœtens, analis*, and others, diffuse a stinking odour. The exhalation of the *Hemerobius perla*, and of the *Formica fœtida*, altogether resemble that of human excrement.

CCCLXVI. The secreting organs of odoriferous fluids, which Kirby and Spence(9) call *osmateria*, have been discovered in several insects. They consist of small hollow vesicles, situated in the interior of the body, and which, when being evacuated, can be partly protruded by the animals. The *Staphylinus brunnipes* has branching vessels in the abdomen, which project from the body in the shape of vesicles, and shed, when the insect is pressed, an aromatic smelling liquid.(1) *Cicada*, according to Leon Dufour's(2) observations, are provided with two secretory organs, situated in the rectum, and composed of a great number of small oblong sacs. The *Meloe* pours a yellow liquid, which is secreted in follicles, from the joints of its trunk and limbs. The same is observed in the *Pimelia collaris* and *Coccinella bipunctata*. Many caterpillars and larvæ have similar secretory organs. The caterpillar of the *Papilio machaon* has a follicle on its back, at some distance from the head, which projects like a horn when pressed, and emits a liquid smelling of fennell.(3) Similar projections are observed in the caterpillars of the *Papilio apollo* and *anchyses*. The larva of the *Chrysomela populi* has black, hollow tubercles on the back, from which a white, milky, and strong smelling liquid is darted when touched. This is also the case with the larva of some saw-flies, (*Teuthredo.*)(4) The larva of a species of this genus has large sacs, between the five anterior pairs of feet, the extremities of which are pierced like a watering-pot, which, when the animal is tormented, project outwards and diffuse an extremely disagreeable smell.(5)

CCCLXVII. The secretions of the skin of aquatic animals are infinitely less diversified than are those of animals that live in the air. They are almost altogether confined to an excretion of mucus. The skin of fishes secrete in varied abundance, a slippery slime, which is prepared in particular vessels or canals, and poured out by apertures, upon the naked skin or scales. Stenon first observed the muciparous vessels in the head of rays, sharks, and eels.(6) Lorenzini(7) described them more minutely from

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(9) Introduction to Entomology, ed. 3. London, 1818, v. 1, lett. 21.
(1) Ibid.
(2) Ann. des Soc. Natur., June, 1825, p. 155.
(3) De Geer, Loc. cit, v. v, p. 96.
(4) Reaumur, Hist. des Insectes, v. v, p. 96.
(5) Ibid., v. ii, p. 989, pl. 37, fig. 6.
(6) De Musculis et Glandulis Observat. Specimen. Amstel, 1664, v. xii, p. 54, beim Rochin; Elementorum Myologiæ Specimen, cui accedunt Canis carchariæ dissectum caput et dissectus piscis ex canum Genere. Amstel, 1669, pp. 93, 189, beim Hayen.
(7) Osservazioni interno alle Torpedini. Firenze, 1678, 4.

the electric ray. An anonymous author(8) has shown those which exist in the head of the pike and carp. Perrault(9) showed that mucous ducts proceeding from a gland in the head descended along the lateral lines of fishes, and sent minute branches between the scales in which there are orifices, as was seen by Petit(1) in the carp. These mucous ducts have likewise been described by Lamorier,(2) Alexander Monro,(3) Koehlreuter,(4) Gunner,(5) Forster,(6) and others.

The skin of mollusca, annelides, medusa, &c., also secretes a mucus, which is acrid in the latter animals.

CCCLXVIII. All vertebrated animals secrete urine, a very complicated and variable fluid, which consists of water, having many different matters dissolved in it. The principle element of the urine of mammifera is a peculiar animal substance, urea, which may be extracted frôm the urine by alcohol, after concentration by evaporation. It crystallizes in colourless, transparent, four-sided columns and leaves, which neither react like acids nor alkalis, and of all animal matters contains the most azote. J. Davy,(7) Prevost, and Dumas,(8) also met with it in the urine of some kinds of frogs. The urine of carniverous mammifera contains moreover a particular acid, the uric acid, which is deposited by cooling in the form of a grayish powder, and produces small crystals of a pearly brightness. This acid is given out with the excrement of birds as a white matter, which is rapidly converted by the action of the air into a very friable powder.(9) Wollaston(1) and Chevreul(2) found it in particular abundance in birds that feed on meat. It is excreted, in the same form, from the anus of the common lizard,(3) the cameleon,(4) the iguana,(5) the crocodile,(6) the boa,(7) and tortoises.(8)

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(8) Observatio anatomica circa poros in piscium cute notandos; in Act Eruditorum. Leipsick, 1683, p. 160, tab. 3, f. 2-4.
(9) Œuvres de Physique. Amster. 1724, 4, t. 3, p. 478, pl. 20, fig. 2.
(1) Mém. de l'Ac. des Sc., 1733, p. 291, pl. 12, fig. 2.
(2) Ibid., 1742, p. 32, beim Hayen.
(3) Anat. and Physiology of Fishes. ch. 3, beim, Kabeljan, pl. 5, bei Rochen, pls. 6, 7.
(4) Novi Comment. Petropol., t. 9, p. 430, bei Cyclopterus.
(5) Schriften der Drontheimer Gesellschaft, b, ii, s. 248.
(6) Beiträge zur Natur., und Völker-Kundi, b. 3, s. 269, bei Catostomus.
(7) Philos. Trans., 1821, part 1, p. 95.
(8) Analyse de l'Urine des Grenouilles; in Biblioth. Univers., Feb., 1822, p. 115.
(9) Fourcroy and Vauquelin, in Ann. du Muséum d'Hist. Nat., v. xvii, p. 310.
(1) Philos. Trans., 1810, p. 223.
(2) Annales de Chimie, v. lxvii, p. 305.
(3) Scholz, on the Urine of Lizards; in the Jahrbüchern des österreichischen Staats, v. ii, p. 185.
(4) Prout, in Annals of Philosophy, v. xiv, p. 471.
(5) Prout, in Ann. de Chim., v. i, p. 198.
(6) J. Davy, in Philos. Transact., 1818, p. 303.
(7) Prout, in Ann. of Philos., 1815, p. 413. Davy, in Philos. Magaz., October, 1819. Pfaff, in Schweigger's nuem Journal für Chemie und Physik, 1822, v. v, p. 344.
(8) John, in Meckel's Deutschem Archiv. für die Physiologie, v. iii, p. 358; the urine of the *Testudo tabulata*. Stoltz, ibid., v. vi, p. 349; the urine of the *Emys europæa*.

The salts existing in the urine are very numerous; they consist of chalk, magnesia, ammonia, potass, and soda, combined with uric, carbonic, phosphoric, and even sulphuric and hydrochloric acids. Phosphates are generally met with in the urine of carniverous animals. With the urine certain colouring and resinous non-assimilable substances leave the body, which have been taken along with the aliment, and received, together with the different salts and acids, into the mass of the blood, to the latter of which, the benzoic acid, existing in the urine of herbivorous animals, belongs.

CCCLXIX. The organs of the urinary secretion represent an apparatus situated in the abdominal cavity, composed of the kidneys, glandular secreting organs, and of their excretory ducts, the ureters. Many have also a reservoir, the bladder, in which the urine accumulates, and whence it departs by a canal called the urethra. The kidneys, generally double in mammifera, birds, and reptiles, and almost always collected into one mass in fishes, are connected with the vertebral column, outside the peritoneum. In general, they are larger in aquatic animals than in those living in air, these being freed from a vast number of excrementitial matters by the lungs and skin. Birds have likewise larger kidneys than mammifera.

The kidneys of mammifera, which in some are shaped like a bunch of grapes, or are made up of several masses, are composed of two substances, possessing a different colour and texture. The exterior substance, called cortical, is red and softer; large arteries coming from the aorta, ramify in it to an excessive degree, and it besides contains very tortuous small canals, called urinary ducts. These ducts form plexuses by twisting with the minute blood-vessels, and receive the urine. The internal substance, denominated tubular or mamillary, represents conical masses, varying in number, and having their base directed outwardly and covered by the cortical substance. The summits of the cones which are directed inwardly, form kinds of projecting nipples, perforated like a sieve with a great number of holes. The tortuous urinary ducts of the cortical substance, after being prolonged into the mamillary substance, immediately take a strait course. As they proceed, they unite at acute angles to produce tubes of a larger calibre, and open on the surface of the nipples. These are encircled by the calices of the kidneys, species of sacs intended to receive the urine. All the calices unite to form the funnel-shaped pelvis of the kidneys which is continuous with the ureter.

The kidneys of birds, amphibia, and fishes are formed of one substance only, analogous to the cortical of mammifera, without either nipples or calices, as Ferrein(9) and Galvani(1) have shown. The tortuous urinary ducts unite

(9) Mem. de l'Acad. des Sc. de Paris, 1749, p. 489.
(1) Comment. Bononiens, v. v, part 2, p. 501.

into twigs and branches, and thus give origin to the ureter. According to Jacobson(2) the urine of these animals comes from the blood of the venous trunks of the posterior half of the body, which ramify in the kidneys like the vena portæ—an assertion for which there is no proof.

CCCLXX. In all mammifera, the ureters transmit the urine into the receptacle situated in the abdominal cavity, the bladder, which is composed of mucous membrane, of a cellular or vascular, and a very thick muscular one. By the contraction of the latter, the liquid is expelled through the urethra. In birds, on the other hand, the ureters open into the cloaca and mix the urine with the fœces. In the ostrich, however, and the cassowary, the cloaca which receives the urine is separated from the rectum by a circular valve, formerly described by Perrault,(3) and lately more accurately demonstrated by Geoffroy Saint Hilaire.(4) In amphibia, the ureters likewise end in the cloaca. Notwithstanding, many of them have a bladder situated at the under surface of the cloaca, and communicating with it by a large orifice, in which the urine collects. It is found in frogs, toads, salamanders, the proteus and tortoises, as also among the lizards, in the iguana, the cameleon, the dragon, many agamæ and geckos, the common lizard,(5) and among snakes, in blind-worms, and amphisbænæ. On the other hand, it is wanting in crocodiles, many lizards, and the majority of ophidia.(6) Townson supposed that this sac was not an urinary bladder,(7) but a receptacle for the water from the cloaca and skin, which, however, is refuted by the fact of Lassaigne and Boissel(8) having discovered uric acid in the fluid contained in the bladder of the Indian tortoise, and Vauquelin having fouud a true urinary calculus in it.

In fishes, the ureters open into a canal placed behind the anus, into which seminal ducts and oviducts also open. In some fishes, the frog-fish, *(Lophius,)* the sea-hare, *(Cyclopterus,)* the burbot, *(Gadus,)* the carp, the pike, the salmon, &c., the two ureters form by their union a dilatation resembling a bladder.

CCCLXXI. There is an excretion of a fluid analogous to urine in insects and mollusca. Brugnatelli(9) found in the excrements of the mulberry-butterfly, shortly after leaving the chrysalis, urate of ammonia, carbonate and

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(2) Bulletin de la Soc. Philom., 1813. Meckel's Deutsches Archiv. für die Physiologie, v. iii, p. 147. J. U. H. Nicolai, Disquisitiones circa quorundam animalium venas abdominales præcipue renales. Berlin, 1823.

(3) Mem. pour servir á l'Histoire Nat. des Animaux, part 2, p. 154, pl. 56.

(4) Composition des appar. genitaux, urinaires et intestinaux, á leurs points de rencontre dans l'Autruche et le Casuar ; in Mem. du Mus. d'Hist. Nat., v. ix, p. 438.

(5) Emmert and Hochstetter in Reil's Archiv. für die Physiologie, v. x, p. 114.

(6) Fink, de Amphibiorum Systemate uropoetico. Halle, 1717, in 8vo.

(7) Observat. Physiol. de Amphibiis, part ii, p. 21.

(8) Journal de Pharmacie, v. vii, p. 381.

(9) Giornale di Fisica, 1815, v. viii, p. 12.

phosphate of lime, and phosphate of magnesia, Herold(1) and Rengger(2) regarded the ducts that are connected with the intestinal canal, and to which zootomists attribute the secretion of the bile, as the source of fluid. In fact, Wurzer(3) remarked urate of ammonia in the liquid of these vessels. It is probable, as J. F. Meckel(4) has shown, that these vessels prepare both excrementitious fluids, the urine and the bile.

Among the mollusca, Jacobson(5) recognised uric acid in the calcareous pouch or gland of snails, which Swammerdamm,(6) Poli,(7) and others considered as intended for the formation of the earthy materials of the shell. This liquid is particularly abundant in the pouch during the hybernation of the animals. G. R. Treviranus(8) likewise found uric acid in the chalk-pouch of snails and mussels. Blainville(9) supposes the ink-bag of sepia and the organs that prepare the purple are also organs for the secretion of urine.

CCCLXXII. Several mollusca secrete coloured liquids which appear to be allied to the urine. Of this kind are the ink of sepia and the purple of some gasteropoda. The former is a black or dark brown liquid, devisible to the utmost degree in water, which, according to Kemp,(1) coagulates by boiling, as also by the action of mineral acids, alcohol, ether, and tincture of nut-galls. Prout(2) and L. Gmelin(3) found in it a richly-carbonized pigment, some animal substance, approaching to mucus, some calcareous and other salts, and mostly a little iron.

According to Swammerdamm,(4) Lamorier,(5) and Cuvier's and other researches, this fluid is prepared in a bag attached to the liver, the interior of which has many folds, and the coats contain glandular grains pierced by numerous blood-vessels, its excretory canal opening into the anus. By contraction of its muscular integuments, the animal can at will project its ink by the same tube which serves as a passage for the excrement. As this fluid

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(1) Entwickelungs-geschichte der Schmetterlinge, sec. 18.

(2) Physiologische Untersuchungen über die thierische Hauhsaltung der Insekten. Tubingen, 1817, p. 27.

(3) Deutsches Archiv. für die Physiologie, v. iv, p. 213.

(4) Archiv. für Anatomie und Physiologie, v. i, p. 21.

(5) Journal de Phys. de Chim. et d'Hist. Nat., 1820, v. xci, p. 318. Wohnlich, however, had already considered the chalk-pouch as the secretory organ of the urine, (De Helice pomatia.) Wurburg, 1813, 4to, p. 23.

(6) Bibl. Naturæ, tab. 5, fig. 4, 5. *Sacculus calcarius* of the *Helix pomatia.*

(7) Testacea utriusque Siciliæ, v. ii, tab. 20, fig. 6 of the *Venus chione*, tab. 26, fig. 11, 13, of the *Arca pilosa*.

(8) Zeitschrift für Physiologie, v. i, p. 52.

(9) In the Journal de Physique, loc. cit.

(1) Schweigger's Journal, v. ix, p. 371.

(2) Thomson's Ann. of Philos., v. v, p. 417.

(3) Schweigger's Journal, v. x, p. 533.

(4) Bibl. Nat., v. ii, p. 890, tab. 51, fig. 1, 5. Monro also (Anatomy and Philosophy of Fishes, chap. 12, tab. 41, fig. 1) has described and delineated the ink-pouch; but he was wrong in considering the fluid it contains as a secretion of the liver.

(5) Mem. de la Soc. de Montpellier, 1766, p. 293.

soon makes the surrounding water turbid, it would seem, as Plutarch(6) remarked, to be a means of protecting the animal from the pursuit of its enemies. According to Meckel's(7) observations, a similar glandular organ exists in the *Doris*, the excretory ducts of which open into the rectum.

The purple, concerning which Fabius Columna,(8) Cole,(9) Normann,(1) Réaumur,(2) Duhamel,(3) Bring,(4) Peyssonnel,(5) Stroem,(6) Olivi,(7) Bossi,(8) Cortinovis,(9) and others have instituted inquiries, is secreted in several species of the genera Murex, *(M. brandaris, trunculus,)* Buccinum *(B. echinophorum, lapillus,)* Ianthina, Aplysia, &c., in a glandular cavity, situated beneath the mantle, in the neighbourhood of the rectum, and the secretory sac of the urine or the chalk-pouch, with which it has probably direct connexion.(1) The excreted fluid, which has not yet been submitted to an accurate analysis, is, according to Lesson, changed to a green colour by alkalis. It is infinitely divisible in water like the ink of sepia, and probably protects the animals from the attacks of their pursuers.

CCCLXXIII. Among the secretions of insects there is another fluid which should be mentioned, namely, that from which they weave their webs and nets. The caterpillars of twilight and night butterflies, and also of some day ones, form a covering for themselves, in which they are changed into chrysalides. The materials of these are secreted as a viscous liquid, in two long tortuous tubes, situated in the course of the intestinal canal, and called spinning vessels, which Malpighi(2) examined in the silk-worm, and Lyonnet(3) in the willow caterpillar. They end by very narrow ducts in the moveable spinning-tube, which is fastened to the under-lip. The liquid, which dries in the air, is composed in the silk-worm, according to Board's(4) researches, of a matter approaching to gelatin, of a little wax, and a small quantity of oil.

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(6) He says, that as the gods of Homer concealed their favourites in clouds, in order to protect them from their pursuers, the sepia can do the same with its liquid.

(7) Beiträge zur veigleichenden Anatomie, v. i, art. 2, p. 1.

(8) De Purpura. Rome, 1616.

(9) Observations on the Purple Fish; in Phil. Trans., v. xv, No. 178, p. 1,278.

(1) Diss. resp. El. Bask, de Purpura. Upsal, 1686, in 8vo.

(2) Mem. de l'Acad. de Paris, 1711.

(3) Ibid., 1736, p. 49.

(4) Diss. de Purpura. Lund., 1750, in 4to.

(5) Philos. Transact., v. 50, p. 585.

(6) Purpur-Snegeln; in Kiöbenh. Selsk. Skrifter, v. xi, p. 1, translated by Chemnitz in the Trans. of the Berlin Soc. of Naturalists, v. iv, p. 241.

(7) Della scoperta di due testacei porporiferi, con alcune riflessioni sopra la porpora degli Antichi; in Opuscoli Scelti, v. xiv, p. 361, suppl. p. 303.

(8) Opuscoli Scelti, v. xvi, p. 130.

(9) Sopra di Alcuni Sperimenti da farsi sulle Chiocciole Porporifere. Ibid., v. xvii, p. 50.

(1) Leiblein, in Heusinger's Zeitschrift für die Organische Physik, 1827, v. i, p. 1.

(2) De Bombyce. in Oper. Omnia, v. ii, p. 24, tab. 5, fig. 11.

(3) Traité Anatomique de la Chenille qui ronge le bois de Saule. The Hague, 1762, p. 54, pl. 5, fig. 1, pb. 14, fig. 10, 11, pl. 2, fig. 1, L.

(4) Ann. de Chim., v. lxv, p. 44.

The larvæ of the genus *Phryganea*, which remain in water surrounded in a case formed of small stones, close the orifice of this tube with silky threads which they secrete by the anus. In the larva of the *Myrmeleon formicarum*, the silky matter is found in the rectum, according to Ramdohr.(5) In spiders, the glutinous fluid, with which they form their variously shaped webs, is deposited by four tubercles placed at the posterior part of the body. A canal proceeds from each tubercle, and divides into numerous very minute tubes, as is shown by the researches of Leeuwenhoek,(6) Réaumur,(7) Degeer,(8) and G. R. Treviranus.(9) According to Halle, Kirby, and Spence,(1) Teed,(2) and Murray's observations, spiders are able to dart the liquid, in a filiform shape, towards distant bodies, by which means they form a kind of bridge, so as to enable them to pass from one spot to another.

In the number of secreted products peculiar to insects, is reckoned the wax with which bees build the cells for their posterity. It follows from the observations of Hornbostel,(4) Thorley,(5) J. Hunter,(6) F. Huber,(7) and G. R. Treviranus,(8) that it is secreted in small membranous cavities, situated at the lower part of the abdomen, underneath scales, in the form of very thin white plates, which the animal elaborates by mixing saliva with it.

Among the mollusca, the species of *Mytilus*, *Pinna*, and others, like many insects, prepare a silky matter.(9) This is secreted in a gland discovered by Cuvier,(1) to be situated under the sole of the foot, which being pressed during the motions of the linguiform foot, gives out the liquid, and fastens it to the rocks.

CCCLXXIV. We shall finally mention some different excreted venomous fluids. Among mammifera, only one animal is known that is armed with an organ for the secretion of a poisonous liquid. This is the *Ornithorhynchus paradoxus*.(2) The males have a horny spur on the hind feet, furnished with a

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(5) Ueber die Verdauungs-Werkseuge der Inseckten, p. 58.
(6) Hoole's edition. London, 1791, v. i, p. 41, pl. 2, fig. 20 22.
(7) Mem. de l'Ac. de Paris, 1710, p. 386.
(8) Hist. des Insectes, v. vii, p. 187.
(9) Ueber den inneren Bau der Arachniden, v. i, p. 41.
(1) Introd. to Entomology, v. i, p. 415.
(2) Journal of Nat. Philos., v. iii.
(3) Mem. of the Wernerian Society, v. v, p. 2.
(4) Hamburgische vermischte Bibliothek, 1744, v. ii, p. 45.
(5) An Inquiry into the Nature, Order, and Government of Bees. London, 1765.
(6) Philos. Trans., 1792, 143.
(7) Nouvelle, Observations sur les Abeilles, v. ii, pp. 35, 54, 463.
(8) Zeitschrift für Physiologie, v. iii, art. 1, p. 62.
(9) Chemnitz, in Natur-forscher. art. 10, p. 1.
(1) Anat. Comp., v. v, p. 264.
(2) In March, 1817, a letter was read at the Linnæn Society of London, from John Jameson, from Macleay, which contained the first account of the poison-spur, of the ornithorhynchus. Jameson wounded one of these animals slightly by a shot; a man who accompanied him took

small opening through which they can eject a liquid that acts like poison. According to Blainville,(3) Rudolphi,(4) and J. F. Meckel's,(5) reseaches this orifice leads to a small canal which runs through the spur and is the passage to a minute bladder communicating with a large gland which is situated in the thigh and secretes the poison.(6) The female has only a small pit, in which the rudiment of a spur is found. The *echnida* has also a spur, and probaby a similar gland.

In birds no instance is known of a poisonous secerning organ.

CCCLXXV. Many reptiles secrete poison. The glands which secern it in serpents, and whose excretory ducts open at the sharp and axe-shaped teeth, may be reckoned among the salivary glands, of which mention has already been made, (CXCVII.) Toads secrete an acrid liquid in the glandular follicles of the skin, which they eject in their defence when pursued by an enemy. Several glands are united into two masses at the posterior part of the head, and others are scattered about the back. According to the researches of Pelletier(7) and J. Davy(8), the fluid is yellowish, oily, and has a very bitter taste. It acts as an acrid and corrosive on the delicate parts of the skin, and excites pain. A similar liquid appears to be secreted by the cutaneous glands of the geckos.

CCCLXXVI. Scorpions, spiders, and many insects, generate liquids that act as poisons. Nature has, for the most part, placed the preparing organs of poisons in connexion with arms, as is seen in scorpions, bee-insects, (apiariæ), ants, &c. The poison-organ of scorpions is found in the last knotted swelling of the tail, which ends by a sharp and curved sting. Above the point and on each side, a slit orifice is seen, through which the poison flows, as Redi,(9) Leeuwenhoek,(1) Maupertius,(2) Mead,(3)

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hold of it, and was wounded in the aim by the spur; the limb inflamed immediately, and all the phenomena that occur when men are bitten by serpents, followed. The mischief, however, yielded to the external use of oil, and the internal administration of ammonia. The wounded man was for a long time subject to pains in the arm, and it was only after a month had elapsed that he recovered the use of his limb. Hill (Linnæan Trans., 1832, v. xiii, p. 2) saw a drop of a thin fluid trickle through the orifice of the spur. He remarks that no case is known in which the poison exerted a mortal action on man.

(3) Journ. de Phys., 1817, v. lxxxiv, p. 318.

(4) Schriften den Berliner Akad., 1820-21, p. 232, tab. 3. Seifert, Spicilegia Adenologica. Berlin, 1823, in 4vo, tab. 1, fig. 5.

(5) Ornithorhynci paradoxi descriptio Anatomica. Leipsick, 1828, in fol., p. 54, tab. 6, 8, fig. 7, 8.

(6) This gland appears to have been discovered at the same time by Meckel, Rudolphi, Clifft, and Knox.

(7) Leroux, Journal de Médécine, v. xl, p. 75. The poison of toads reddens the tincture of turnsole, and forms an emulsion with water. It contains an acid partly free and partly combined, as also a very bitter fatty matter.

(8) Philos. Transac., 1826, part 2, p. 127. Davy found the poison neither acid, nor alkaline, and that it was soluble in water.

(9) Generazione degli Insetti, p. 15.

(1) Continuatid arcan. Natur. Epist. 123, p. 167.

(2) Mem de l'Acad. de Paris, 1731, p. 223, pl. 16, fig. 1, 2.

(3) Oper. Med., v. 2, p. 77, tab. 13, fig. 1, 2.

L. J. Mueller,(4) have demonstrated. According to the researches of J. F. Meckel,(5) Treviranus,(6) and Mueller, the poison is secreted by two glands enveloped by a muscular membrane. Each gland contains a small vesicle, from which a very narrow excretory duct proceeds and enters the sting. Among bees, the females and busy ones are furnished with poisonous arms, which have been described by Hooke,(7) Swammerdamm,(8) and recently by Kunzmann.(9) The sting, situated at the upper part of the rectum, and provided with small hooks directed forwards, is enclosed in a horny sheath. It is composed of two hollow divisions that are united in their longitude, and thus produce a canal, and terminate in a projecting point. Two pairs of muscles inserted into the sheath effect the projection and retraction of the sting. The poison is contained in a small pouch, probably furnished with a muscular membrane, and is secreted in two long and narrow tubes. An excretory duct conveys it from the vesicle into the sheath, whence it is poured into the tube of the sting. It is a clear and limpid fluid, which, according to Fontana, has a great analogy to that of serpents.

Ants have a poison-bag in the abdomen, in which is secreted a peculiar acid. They wound with their jaws, and dart the poison from the bag into the wound by standing on their hind feet. According to Gould's observations,(1) they sometimes turn the pouch out. In the species of the genus *Myrmica*, the poison-bag is connected with a true sting. *Carabi* eject an acrid fluid, as Degeer heretofore remarked,(2) which is secreted by vessels situated along the rectum. The *Brachinus crepitans* and *displosor* which are so remarkable, also the *Harpalus brasicus*, when irritated, throw out, with some noise, a bluish liquid from the end of the abdomen. Leon Dufour(3) remarked, that this vapour in the former species has a pungent odour, bearing a striking resemblance to that of aquafortis. It is caustic, reddens white paper, and blisters the skin.

Several caterpillars secrete acrid liquids in pouches situated underneath the skin, and dart them at their pursuers. This is the case, according to Rœsel's observations,(4) with the caterpillar of the great peacock, (Bombyx pavonia major, Fabr,) and, according to Degeer,(5) in some others.

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(4) Meckel's Archiv. fuer Anat. und Physiol., 1828, p. 29, tab. 2, fig. 1.
(5) Beiträg. zur vergl. Anat., v. i, art. 2, p. 116.
(6) Ueber den Inneren Bau der Arachniden, p. 14.
(7) Micrographia. London, 1668, in fol. obs. 34.
(8) Bibl. Nat., v. i, p. 184, tab. 18, fig. 1, 2, 3; tab. 19, fig. 3.
(9) Hufeland's Journal der Prakt. Heilkunde, September, 1820, p. 119.
(1) Account of English Ants. London, 1744, p. 34.
(2) Hist. des Insectes, v. iv, p. 86.
(3) Ann. du Museum Nat., v. xviii, p. 70.
(4) Insekten-Belustigungen, v. iv, p. 162. When the bristles with which they are covered are touched, they shoot out, by small holes in the skin, a clear and acrid liquid.
(5) Loc. cit., v. i, p. 324.

Degeer and Latreille have remarked that the species of *julus* give out a very bad odour. Savi(6) ascertained that, when touched or rolled together, a pungent smelling fluid trickles from the body, which is reddish, caustic, soluble in water or alcohol, reacts like the acids, and gives the skin a permanent red hue like that from the nitrate of mercury and chloride of gold. The sources of this fluid are vesicles, of which there is one on each side of every ring, opening externally by a point like a stigma.

In many insects, such as *tipula*, gad-flies, *oestrus*, bugs, particularly the *Rhynchoprion persicum*, and others, the saliva has acrid or even poisonous qualities. *Scolopendra* have a secretory organ in the jaw, whence a venomous liquid flows through a cleft, according to Leuwenhoeck (7) and Mead's(8) observations. The same occurs in spiders and tarantula. Among the mollusca, the aplysia secrete a caustic liquid from a gland, the excretory duct of which opens near the orifice of the oviduct.(9)

Properties of Secretion.

CCCLXXVII. It follows from the preceding facts, that the secretion of liquids is a vital phenomenon belonging to all organized bodies, vegetables as well as animals, immediately connected with the acts of nutrition and generation, and on that account equally necessary for the preservation of individuals and maintenance of the species. Animals secrete more diversified fluids, more copiously and incessantly than vegetables; and this is so much the more remarkable as their organization is more complex, and as their manifestations of life exhibit greater diversity and intensity. Doubtless, this peculiarity depends on their not being limited, as vegetables are, to the acts of formation, development, and growth, on continued variation of the composition of all their organs and tissues through the same manifestations of activity, and on the destruction and renewal of part of the materiel of their organism. The changed and shapeless materials taken from the organs by absorption, pass into the sanguineous vascular system, whence they are eliminated, by numerous organs in different forms. On the other hand, the aliment which serves to repair the losses and comes into the digestive apparatus in great quantities, is liquified, and assimilated to the blood by several secreted liquids of different kinds. In vegetables, on the contrary, secretion seems to be confined to the preparation of the formative juice by the elimination of certain materials, and to the production of the generative fluids, without any

(6) Opuscoli Scientifici di Bologna, 1817, v. 1, p. 321.
(7) Continuatio Arcanorum, epistle 24, p. 116.
(8) Loc. cit., v. ii, p. 76, tab. 3, fig. 2.
(9) The sea lobster (Cancer astacus of Browne) of the Carribean seas, especially in the hotter seasons of the year, has a poisonous bite; there is no description extant of the apparatus by which this is effected. See Mem. of the London Medical Society, p. 5.—Trs.

evacuation of excretory matters originating from a change of materials belonging to the organs that have been once formed. In plants, the acts of secretion, like those of absorption, respiration, and growth, are more dependent on external influences, on light, heat, and air, and on daily and yearly periods; whereas in animals, they rather depend on internal stimuli, produced in an automatic manner in the nervous system.

CCCLXXVIII. The secretions, as operations peculiar to organic bodies, admit of no explanation founded on the principles of mechanics or chemistry, as the imaginary theories of the iatromathematical and iatrochemical schools fully prove. They are acts of life, which can only be considered as effects of organic powers.(1) Some physiologists suppose a special power that effects

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(1) It is somewhat remarkable that our author does not more fully develope his notions of the secretorial function. When describing secretion to be an effect of certain organic powers, he merely represents what is pretty generally accredited, without instituting any inquiry into the precise nature of these powers. All that can be inferred from the text is, that the author considers secretion to partake of the nature of a chemical process, as he speaks of it consisting, in some instances, of "simple evaporation of liquids." There is no single secretion in the animal body which could be supposed to be the product of evaporation, for the simplest fluid separated from the blood contains one or more ingredient which is not susceptible of vaporization, as the salts, &c. From Dr. Hunter Lane's paper on the Animal Secretions, (Liv. Med. Gaz. vol. i. p. 305) which contains a review of the various opinions entertained of this function, we extract the following passages, in which some hypothetical suggestions regarding the nature of this organic power are promulgated.

"The blood being a compound fluid, composed of different elements held together by different degrees of force of chemical affinity, it is evident that, as various degrees of decomposing power are applied, there will be separated the different elements united by the corresponding forces. To illustrate this position, we may suppose a solution of three salts in a given quantity of water: by applying heat to the solution a certain portion of the water will be evaporated, when the remaining quantity being insufficient for the solution of one of these salts, this will therefore be crystallized; the farther addition of caloric will evaporate another part of the fluid, so that the quantity remaining will then be rendered incapable of holding the second salt in solution; it is therefore deposited: by continued evaporation the third salt will be obtained. So with the blood, by applying different degrees of the same decomposing agent, we shall have its different elements liberated,—those united by the least chemical force yielding to the lesser degree, while those combined by the greatest affinity will require the highest powers for their separation. With respect to the agency by which the decomposition of the blood is effected, I should consider it to be, if not identical with, at least closely approximating to, the nature of galvanism. It may be unnecessary to state, that galvanism has been excited by the contact of the nerve and muscle of an animal recently dead, and that a galvanic pile may be constructed of alternate layers of nervous and muscular substance, or of nervous and other of the animal tissues; so that every secreting organ, which is liberally supplied with ganglionic nerves, is naturally, in its anatomical and physical structure, a galvanic organ. Dr. Davy's late anatomical inquiries into the nature of the electrical apparatus of the Raia Torpedo* give some strength to this conjecture. From these inquiries it would appear, that the class of nerves connected with this peculiar property of the torpedo correspond with the ganglionic nerves in the human body. It is principally distributed to the organs of digestion and secretion, and would seem to be especially instrumental in these processes, for, when frequently excited to give shocks, digestion appeared to have been completely arrested, so that after the animal's death, fishes, which had been swallowed some time previously, were found unchanged. The respiratory organs, the branchiæ, are as plentifully furnished with these electrical nerves as are the human lungs with ganglionic nerves; and what still further confirms the view I have suggested is the fact, which Dr. Davy believes he has witnessed, of the branchiæ, by their galvanic apparatus, decomposing the water in which the fishes were confined to appropriate its oxygen to the purposes of respiration. Being, therefore, justified by our knowledge of the anatomical structure of secreting organs, as well as by analogy in assuming the capability of these

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* Philos. Trans. Part II. 1832.

secretion. There is no necessity for this hypothesis. When the secretions do not consist in a simple evaporation of liquids (in which case, however, they still depend on the vital activity of the ducts in which the fluids are contained) they should be considered, as G. R. Treviranus has well observed,(2) as the effects of the same power which produces organized bodies and maintains them in the possession of their properties, that is to say, of the power of formation, under the control of which all the conditions of composition that accompany life are placed. The acts by which the solids are formed and nourished, and the secretions of liquids, are essentially effects of the same kind. In nutrition and secretion, the organs exert an attractive power over the materials of the nutritive fluid which reaches them, and which they alter in a particular manner, according to their vital properties. The only difference between these two functions is, that in one the materials of the fluid become part of the solid organic form, whereas in the latter they are converted into special organic combinations, and given out by organs. One secreted fluid, however, the female generative matter, is capable, under certain circumstances, of taking on a solid organic form, so, that in regard to it even this difference is wanting.

The acts of secretion, like those of formation and nutrition, tend to the preservation of the individual and the maintenance of the species. Just as the formative activity is manifested in a special manner in each kind of organized body, at the time when new individuals are produced, and just as each organ is kept by nutrition in its proper organization and vital properties, so also have the secretions their particular character in each species of living bodies, and each secreting organ prepares a distinct liquid, according to the difference existing in its structure and life. Each secreting organ is rendered

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organs to manifest powers corresponding to galvanism, we are next led to inquire in what manner this individual agent can, by everywhere operating on the same fluid, generate such diversified compounds. This problem is not difficult of solution, when we remember that it is only necessary so to regulate the action of galvanism or any decomposing power to enable it to separate different elements, at different periods, from the same fluid. On comparing the anatomical structure of the secretorial organs we see one having, to the same proportion of ganglionic nerve, a given quantity of other parenchymatous tissues; a second having a superior or inferior relative proportion of the nerve, and so throughout the whole system. The combination of these various relative proportions, we should expect to produce several modifications of the one power; so that in one place it will be capable of separating a certain number of the elements of the blood, and in others the various other constituents of this fluid, according to the different powers exerted. In assuming the ganglionic nerves to be those engaged in the function of secretion, we have not only the reasons already detailed in its support, but it is also not exposed to those objections so fatal to the hypothesis of Wilson Philip, that acephalous children, and children born without either brain or spinal marrow, have their secretions performed in every respect naturally, for there is no case on record of a fœtus being organised, not to say being born, without the ganglionic system of nerves. Hitherto the hypothesis has only proceeded so far as to account for the decomposition of the blood; so much being explained, the synthetical process may be easily understood. The very existence of these products of decomposition, in the same place and in close approximation, will entail an union of their particles. But why it does so can only be attributed to the law of chemical affinity." – TRS.

(2) Biologie, v. iv, p. 624.

active by particular stimulants, which are partly dependent on the nature of the nutritive fluid, and vary according to the quality of the aliment. External stimulants, that act on the secretory organ, are also capable of modifying the secretions. In fine, divers circumstances, which alter the activity of these organs, both in health and disease, determine changes in the quality of their products. I shall return more fully to this point in treating of secretion in man, and shall then adduce facts in support of these assertions.

THIRD SECTION.

OF THE EVOLUTION OF IMPONDERABLE MATTERS.

CCCLXXIX. The manifestations of activity of living bodies, by which they are maintained during a certain period of time in a determinate state of composition, organization, and action, are, in many of them, accompanied by an evolution of imponderable matters, heat, light, and electricity, which is for the most part to be considered as a consequence of the material changes connected with the nutritive functions. It is not our place to enter into the discussion on which physical philosophers are divided, whether imponderable substances are really matters of a particular kind, or only states of activity of other matters. It is sufficient for us to sketch the phenomena they exhibit in organized bodies, to make known the circumstances on which they are conditional, and to fix their importance in the animal economy.

CHAPTER FIRST.

Of the Evolution of Heat in Living Bodies.

CCCLXXX. The organic bodies, as physics inform us, show warmth during the action of solar light, in combustion, very frequently by compression, friction, and concussion, whenever a change takes place in their state of aggregation and in their composition, and by the influence of electricity. After having been warmed, they all grow cold by the radiation or withdrawal of their heat, and their temperature is placed by these means in an equilibrium with that of surrounding bodies. The greater number of living bodies are, on the contrary, endued with the faculty of engendering heat by their own activity, and of keeping their temperature within certain limits amid the vicissitudes of external temperature. This property is an effect of life. It is only when the proper powers of organized bodies are extinguished, that their temperature is placed in an equilibrium with that of surrounding bodies. Let us in the first place see what organized bodies generate their own heat.

1. Heat of Vegetables.

CCCLXXXI. It is yet an undecided question whether plants give out heat. Some physical philosophers, John Hunter,(3) Senebier,(4) Schœpf,(5) Salomé,(6) Hermbstaedt,(7) Schrank,(8) and others, attribute to them the faculty of retaining a temperature which is proper to them, and of generating heat. Others, on the contrary, Fontana,(9) Nau,(1) G. R. Treviranus,(2) Schuebler and Halder,(3) deny them this faculty. The former rest on the observation that vegetables continue to live under the influence of very different external temperatures. Trees and shrubs of northern countries frequently bear a cold of 30°C without freezing, whilst those of the tropics are often exposed to a heat of from 35° to 40° C without perishing. Moreover, they assert to have remarked, that thermometers placed in holes made in living trees, did not agree with those that were exposed freely to the air, or were introduced into dead trees, and that they neither rose nor fell, by the changes of external temperature. According to Schœpf and Salomé's observations, the temperature of vegetables is midway between the highest and lowest degree of the circumambient air, so that their temperature is lower than that without, during summer, and higher during winter. Birkander(4) also says he found, in Sweden, the trees warmer than the air in winter. According to the views of the naturalists just named, the continuance of the life of plants during cold, is the result of an internal evolution of heat, whilst the faculty of producing cold, when the external temperature is high, depends on evaporation. They add, that the death of vegetables only occurs when the external temperature is excessive. Some physiologists suppose the heat to be disengaged during the conversion of the humours into solids. Th. de Saussure thinks it probable, that heat is generated, as in the respiration of animals, when oxygen is absorbed during the night by the green parts of vegetables, and carbonic acid disengaged.

CCCLXXXII.—Against these assertions Fontana's experiments appear, which indeed were not conducted with much care, but from which it follows that vegetables have no proper heat, and that what is remarked in them is only communicated from without. G. R. Treviranus having examined the

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(3) Experiments on animals and vegetables with respect to the power of producing heat; in Philos. Trans., 1775, p. 116. On the heat of animals and vegetables, ibid., 1778, p. i, p. 6.
(4) Journal de Physique, v. xl, p. 173.
(5) Naturforscher., art. 23, p. 1.
(6) Ann. de Chimie., v. xl, p. 113.
(7) Magazin der Naturforschenden Gesellschaft zu Berlin, v. i, p. 316.
(8) In Denkschriften der Münchner Akademie, 1809-10, p. 81.
(9) Efemeride chemicho-mediche, 1805, p. 236.
(1) Schriften der Wetterauer Gesellschaft, v. p. 27.
(2) Biologie, v. v, p. 4.
(3) Ueber die Temperatur der Vegetabilien. Tubingen, 1826.
(4) Svenska Akadem. Handl., 1790, p. 136.

N.B. For the convenience of surveying the assertions of naturalists concerning the degrees of heat, which are sometimes given according to Fahrenheit's, sometimes according to Réaumur's, or according to De Luc's thermometer, I have reduced them all to the thermometer of Celsius, or the centigrade.

experiments made by the naturalists above mentioned, showed that the only fact that can be deduced from them is, that plants are bad conductors of heat. This circumstance, and their union by the roots with the earth, whose temperature the seasons affect only to a small depth, are, according to him, two means by which vegetables maintain a certain medium temperature, and resist the extremes of atmospheric heat. The recent experiments of Schuebler and Halder seem to favour this theory. They placed corresponding thermometers in holes which they bored down to the axis of the living trunks of common and coniferous trees. They did the same with the trunk of a dead tree. The thermometers were placed towards the north side of the tree, and screened on the sides, so as not to be affected by the sun's rays. They compared them at various periods of the day and year with others fully exposed to the air; the following were the results:

1. Trees have always a higher temperature than the air, in the morning, at sunrise, and when the sky is clear; their temperature is, on the contrary, lower at mid-day, and in the evening, during the hottest part of the day. This difference is not only observed in summer, but also in the middle of winter.

2. The temperature of the interior of trees differs so much the more from that of the circumambient air in the morning and at mid-day, as the trees are thicker, and as the thermometer is placed more in the lower part of the trunk or that which is nearest to the earth.

3. The difference of temperature between the air and trees is so much greater as the changes in the temperature of the atmosphere are more rapid and considerable. Hence it is never more evident than in serene weather, when the daily difference of the temperature in our climate is often from 12° to 18° C, between sun-rise and two o'clock in the morning. The daily extremes of heat and cold do not commonly affect trees, because being bad conductors of caloric, the temperature of the external air is but slowly propagated in their internal parts, and that of the open air commonly remains for a short time only at the daily extremes. The longer the atmospheric temperature is uniform, the nearer is that of trees to it.

4. Trees of different species do not exhibit, cæteris paribus, any appreciable difference in their temperature.

5. The temperature of trees may be considerably lowered without being hurtful to them. During the long continued cold of January, 1826, when during three months the temperature never rose, even at noon, above zero, the thermometers placed in the trees were always below the freezing point. They not unfrequently even descended from six to ten degrees below zero, without the trees suffering therefrom. A few, however, such as the *Phormium tenax, Vitex agnus, castus, Coriaria myrtifolia*, &c., perished. The interior of trees is actually frozen in excessive cold.

6. In summer, the temperature of trees rises sometimes to 18° or 20° above zero, though more slowly than the atmosphere. This is also more evident in small than in large trees.

The principal result from these experiments is, that plants maintain a certain medium temperature, but that this cannot be considered as the consequence of heat developed within them, and that it admits of perfect explanation by the weakness of the conducting power of the vegetable fibre and wood, whence the temperature of the ambient strata of air can only slowly penetrate the interior of vegetables.

CCCLXXXIII. Plants then do not appear to be endowed with the faculty of generating heat, or at most possess it only in a very feeble degree. Nevertheless, caloric is disengaged during germination, as was observed by Thomson(5) in barley. There are likewise circumstances in which vegetables exhibit a high degree of heat. Lamark(6) first made the observation that in the expanded flowers of the *Arum italicum*, heat is disengaged, which is not only sensible to the thermometer, but also to the touch. Senebier(7) remarked the same in the *Arum maculatum*, and found that it was chiefly when the spathæ leave their sheaths that they disengage heat. The thermometer rose in the flowers about 8.70° C above the point it was at in the open air. This phenomenon has been remarked by Hubert, on the authority of Bory de Saint Vincent,(8) in the *Arum cordifolium*, in the Isle of France. The flowers attained such a heat at sunrise, that the thermometer rose from 23.33° to 56.67° C. The male flowers give out less heat than the females. Bory de Saint Vincent likewise remarked the production of heat, but in a less degree, in the flowers of the *Pandanus utilis*. Th. de Saussure has lately made experiments on the *Arum maculatum*.(9) He covered a spatha with a glass bell, the inner surface of which was so lined with dew as to make the flower no longer perceptible. At the end of twenty-four hours the air contained in the bell had not diminished in quantity, but a fifth of its oxygen had disappeared, and was replaced by carbonic acid gas. By enclosing the different parts of the arum separately, Saussure ascertained that the genitals consumed the greatest proportion of oxygen. He also observed an evolution of heat in the flowers of the *Cucurbita melo* and *pepo*, of the *Bignonia radicans*, and the *Polyanthus tuberosa*. He thinks this evolution is owing to a rapid

(5) System of Chemistry, ed. 5, v. iv, p. 344. He saw malted barley which had not been turned, shoot radicles 13 millimetres long in one night, by which the temperature was raised to 38° C.

(6) Encyc. Method. v. iii, p. 9, art. Aron d'Itale.

(7) Physiologie Véget., v. iii, p. 314.

(8) Voyage dans les quatre principales îles des mers d' Afiique, v. ii, p. 66.

(9) Ann. de Chimie et de Phys., Nov., 1822. v. xxi, p. 286. The quantity of air in the recipient was 1,000 cubic centimetres. In the space of time mentioned, 200 cubic centimetres of oxygen were consumed, and replaced by as much carbonic acid gas. Flowers that no longer disengage heat cause no opacity of the glass by vapour.

combination of the oxygen with the carbon of vegetables. The abundant formation of carbonic acid gas certainly appears to be connected with the high temperature of flowers; but researches are still required to discover whether the former is the cause of the latter, or if both are not results of one and the same organic power, the simultaneous effects of an organic operation, a thing which does not appear improbable. The observations that have been mentioned prove at least that we cannot deny vegetables the power of generating heat. They are, moreover, supported by those lately made by Murray(1) on the heat of differently coloured flowers. At an atmospheric temperature of 26.11° C, the flowers of a white lily showed the same heat; at 25° of atmospheric heat, those of a blue *Tradescantia* showed 26.11°; at 24.44° of the former, the yellow flowers of a *Cistus* gave 26.11°; at 27.22° of air heat, the scarlet flowers of a *Geranium* showed 30.56°

2. Heat of Animals.

CCCLXXXIV. All animals seem to possess the property of evolving heat, and of maintaining themselves within certain limits, at a degree of temperature peculiar to them, whatever changes occur in that of the atmosphere at the different periods of the day and year. Under ordinary circumstances, the media in which they live, the entozoa excepted, abstract heat from them which they quickly reproduce. But if the external temperature fall considerably and remain so for a long time, their power of evolving heat becomes weakened, their temperature is more and more diminished, and at last they freeze. When, on the contrary, they are exposed to a heat which exceeds their own and caloric is communicated to them from without, a tendency is seen in many of them to keep themselves at the proper temperature. For this purpose they remove the heat that flows into them by an evaporaration of fluids, and so produce cold. The degree of heat belonging to animals is very various, according to the classes, orders, genera, and species. Differences are even perceived in regard to the periods of development, the seasons, and divers other circumstances, which modify their manifestations of life. Further, the limits within which they are capable of maintaining their proper warmth at high degrees of external heat and excess of cold are likewise different. Animal heat is most sensible in beings of the first two classes, mammifera and birds, since it can be perceived by the touch. In these animals also the tendency to maintain themselves at a certain temperature, and to resist external cold, is most remarkable. But the others, amphibia, fishes, crustacea, insects, mollusca, and worms, improperly called by naturalists cold-blooded animals, although cold when touched, have a

(1) Experimental Researches. Glasgow, 1826, p. 9.

proper temperature, appreciable by the thermometer, though it varies more with the vicissitudes of the external temperature. In support of this assertion, we will detail observations and experiments which alone can decide in this matter.

CCCLXXXV. Mammifera, soon after birth, manifest a temperature higher than that of the atmosphere, and which, with few exceptions, they uniformly maintain during their whole life, as is proved by the experiments performed by Martine,(2) J. A. Braun,(3) J. Hunter,(4) Pallas,(5) Edwards,(6) J. Davy,(7) and others. The new-born animals, however, of carnivora and rodentia, are not in a state to produce of themselves the degree of heat necessary for the continuation of their existence, and the mother is obliged to communicate it to them. According to the valuable experiments of Edwards,(8) the heat of new-born dogs, cats, and rabbits is so low, that they resemble cold-blooded animals. Placed near their mother, they have a warmth only one or two degrees lower than her's. But if separated from her, with an external temperature of 10° or 20° C, they rapidly grow cold, and in the course of a few hours their warmth is equal to that of the air.

The warmth of mammifera varies according to the orders and classes, as is shewn by the following tables:

Names of the Animals.	Atmospheric Temperature.		Heat of the Animal.	Place where the heat was measured.	Observers.
Simia aygula	+30° C.	Ceylon	+39,7° C.	Armpit	J. Davy.
" sabæa			35,5	Blood	Prevost & Dumas(9).
Pteropus vampyrus	21	Ceylon	37,86		J. Davy.
Vespertilio noctula		Summer	38,89		Pallas.
" pipistrellus		"	40,56 to 41,11		"
"	22		31	Chest near the Heart	Saissy(1).
"	18		29,75	" " " "	"
"	7		14	" " " "	"
"	1,25		5	" " " "	"
Erinaceus europæus		Awake	35 to 36,11	" " " "	J. Hunter.
" "	22		36	on the Heart	Saissy.
" "	18		34	" " "	"
" "	7		15	" " "	"
" "	1,25		5	" " "	"
Mygale muscovitica			36,67		Pallas

(2) Martine, Medical and Philosoph. Essays. London, 1740. Martini, de similibus animalibus, et animalium calore. Libri duo. London, 1740, in 8vo.

(3) Nov. Comment. Act. Petropol, v. xiii, p. 419.

(4) Philos. Trans., 1775, part 2, p. 446; ibid., 1778, part 1, p. 7.

(5) Novæ species quadrupedum e glirium ordine. Erlangen, 1774, in 4to.

(6) De l'influence des agens physiques sur la vie. Paris, 1824, ch. 14.

(7) Observations on the Temperature of Man and other Animals; in Edinb. Philos. Journ., January, 1826.

(8) Loc. cit., p. 82. De la chaleur des jeunes animaux.

(9) Bibliotheque Universelle, v. xvii, p. 294.

(1) Recherches Experimentales sur la physique des animaux mammiféres hybernans. Paris, 1808.

Names of the Animals.	Atmospheric Temperature.	Heat of the Animal.	Place where the heat was measured.	Observers.
Ursus maritimus	+ 2,8 Port Bowen	37,8	directly after death	Cap. Lyon[2].
“ “	11,6 “ “	37,8	“ “ “	“
“ “	−18,3 “ “	37,5	“ “ “	“
Mustela putorius		38,36		Pallas.
“ erminea		40,25		“
Herpestes ichneumon	27 Ceylon	39,4		J. Davy.
Felis catus		38,50		Braun.
“ “		37 to 39		Martine.
“ “		38,3	Blood	Prevost & Dumas.
“ “	15,15	39,78		Despretz[3].
“ “	15,5 England	38,3		J. Davy.
“ “	26 Ceylon	38,9		“
“ tigris	26,5 “	37,2		“
Canis domesticus		37,39		Martine.
“ “		38,50	Rectum	J. Hunter.
“ “	Ceylon	39,3		J. Davy.
“ “		37,4	Blood	Prevost & Dumas.
“ “		38,33	“	Turner.
lupus		35,24	“	Pallas.
“ “	−32 Port Bowen	40		Lyon.
“ lagopus	− 7,2 “ “	40,5		“
“ “	−13,8 “ “	41,1		“
“ “	−33,3 “ “	40		“
Phoca vitulina		38,39		Martine.
Hypudæus œconomus	in Winter	36,11		Pallas.
Myoxus nitela	+22	37,5	on the Heart	Saissy.
“ “	18	36	“ “ “	“
“ “	7	23	“ “ “	“
“ “	1,25	4	“ “ “	“
Mus musculus	15,56	35 to 37		J. Hunter.
“ “	−10,56	25,56 to 26,67		“
“ “	in Winter	41,12 to 42,78		Pallas.
“ rattus	26,5 Ceylon	38,8		J. Davy.
Cricetus vulgaris	in Summer	39,44		Pallas.
Arctomys marmotta	+22	38	on the Heart	Saissy.
“ “	18	37,50	“ “ “	“
“ “	7	34,25	“ “ “	“
“ “	1,25	5	“ “ “	“
“ bobac	in Summer	37,38 to 38,89		Pallas.
“ citillus	“ “	39,44		“
Sciurus vulgaris		40,56		“
“	27 Ceylon	38,8		J. Davy.
Lepus	26,5 “	37,8		“
“ glacialis	−21,1 Port Bowen	38,9		Lyon.
“ “	−21,8 “ “	38,9		“
“ “	−28,3 “ “	38,9		“
“ variabilis	in severe cold	39 to 40		Pallas.
“ pusillus	“ “ “	40		“
“ cuniculus		37,48	Rectum	J. Hunter.
“ “		38	Blood	Prevost & Dumas.
“ “		38 to 40		De la Roche.
Cavia cobaya		38	“	Prevost & Dumas.
“ “		38,89		De la Roche.
“ “	+15,15	35,76		Despretz.
Manis pentadactyla	26,67 Ceylon	32,22		J. Davy.

(2) He accompanied Parry in his second voyage in search of a northwest passage. Temperatures de quelques animaux du nord, prises au port Bowen; in Ann. de Chim. et Phys., February, 1825, p. 223.

(3) Ann. de chim. et de physique. August, 1824, v. 26, p. 337.

Names of the Animals.	Atmospheric Temperature.	Heat of the Animal.	Place where the heat was measured.	Observers.
Elephas indicus	+26,7 Ceylon	37,5		J. Davy.
Sus scropha jun.		40	inward parts & blood	Braun.
" "	23,9 "	40,5		J. Davy.
Equus caballus		36,8	Blood	Prevost & Dumas.
" "		36,11	"	Turner.
Moschus moschiferus		38,89		Pallas.
Capra		38,33	inward parts & blood	Braun.
"		39,2	Blood	Prevost & Dumas.
"	26 "	39,5		J. Davy.
Ovis		38,9	inward parts & blood	Braun.
"		38	Blood	Prevost & Dumas.
"		38,89 to 39,44	"	Turner.
"	in Summer in England	39,1		J. Davy.
"	27 Ceylon	40		"
Bos taurus		37,28	Rectum	J. Hunter.
" "		37,78 to 38,33	Blood	Turner.
" " vitulus		40	inward parts & blood	Braun.
" "	in Summer in England	37,8		J. Davy.
" "	26 Ceylon	38,9		"
Delphinus phocæna	18 Air, 17 Water	35,50	Blood	Broussonet[4].
"	23,7 on the Sea	37,5		J. Davy.
Monodon monoceros		35,56		Scoresby[5].
Balæna mysticetus		38,89		"

According to J. Hunter and J. Davy's(6) observations, the heat of the different organs of the mammifera presents diversities. The former found the temperature of a dog's rectum to be 37° C; that of the substance of the liver, 38°; of the stomach and right ventricle of the heart, 38,33°. The latter ascertained that in a lamb the heat of the brain was 40° C; of the rectum, 40.56°; of the right ventricle of the heart, the substance of the liver and of the lungs, 41.11°, and of the left ventricle, 41.67°.

CCCLXXXVI. The faculty of generating heat and maintaining it in a cold atmosphere exhibits an astonishing diversity among mammifera. In some of them, as the marmot, *(Arctomys,)* dormouse, *(Myoxus,)* hedgehog, bats, &c., the warmth is so much diminished when the external temperature approaches the freezing point, as to make them resemble cold-blooded animals and to freeze at 10° or 12° below zero, as is shown by the experiments of Pallas, J. Hunter, Spallanzani, Reeve, Mangili, Prunelle, Saissy, and others, and to which we shall revert in speaking of hibernation. Other animals, on the contrary, as those of the polar regions, support a cold of 40° below zero, and maintain their proper degree of heat. Thus, according to Parry's observations, the temperature of Melville Island is so low during five whole months, as to congeal mercury at 39.5°, and even sometimes falls

(4) Mem. de l'Acad. de Paris, p. 192.
(5) An Account of the Arctic Regions. Edinburgh, 1820, v. i, p. 477.
(6) Philos. Transact., 1814, part 2, p. 597.

as low as 46° below zero; yet in this island, musk-oxen, rein-deer, white hares, polar foxes, and white bears are found.

When mammifera are exposed to a temperature exceeding their own, their heat is increased about 6° or 7°, but not in the same proportion as the external heat rises, as is evident from the experiments of Duntze,(7) Delaroche, (8) and Berger. The heat of dogs exposed by Duntze to a temperature of 60° rose only to the 43d or 47th degree, and the animals sunk in a few hours. Delaroche and Berger placed rabbits and guinea-pigs in a temperature raised from 50 to 90 degrees; their warmth was only increased a few degrees; if they were not quickly taken into a colder medium, they died. Animals, therefore, possess the power of producing cold in a medium whose heat exceeds their own. This depends on a doubly profuse transpiration of the mass of humours, an act which is altogether vital, and by which the heat they receive from without is eliminated in a latent form. This phenomenon is not owing alone to the bad conducting power of caloric possessed by the animal body, as was formerly supposed, for dead mammifera exposed to a high temperature imbibe caloric, and are placed in a state of equilibrium with surrounding objects.

CCCLXXXVII. The heat of birds exceeds by some degrees that of mammifera. It is greater in the small than the large species, as is proved by the following tables:

Names of the Animals.	Atmospheric Temperature.	Heat of the Animal.	Place where the heat was measured.	Observers.
Vultur barbatis		+44,94° C.		Pallas(9).
Falco ossifragus		10,28		"
Falco nisus		42,22		"
" palumbarius		43,18		"
" lanarius		42,92		"
Strix passerina		40,82		"
" aluco	+15,15° C	40,91		Despretz.
"	15,6	40		J. Davy.
Psittacus pullarius	24,4 Ceylon	41,1		"
Picus major		39,44		Pallas.
Merops apiaster		40		"
Corvus	29,4 Ceylon	42,1		J. Davy.
" corax	15,15	42,91		Despretz.
Turdus	15,5 "	42,8		J. Davy.
Emberiza nivalis (7 Ex.)	15,15	42,92 to 43,47		Pallas.
Emberiza		42,88		Despretz.
Loxia pyrrhula	in severe cold	42,22		Pallas.

(7) Experimenta calorem animalium spectantia. Leyden, 1754.

(8) Experiences sur les effects qu' une forte chaleur produit dans l'économie animale. Paris, 1806; Delaroche, in the Journ. de Physique, v. lxxi, p. 289.

(9) According to some excellent manuscript remarks, from which Rudolphi (Grundriss der Physiologie, v. i, p. 171) has given extracts.

Names of the Animals.	Atmospheric Temperature.	Heat of the Animal.	Place where the heat was measured.	Observers.
Fringilla carduelis		42,92		Pallas.
" domestica foem.		41,67		"
" " mas.		42,78		"
" "	15,15	41,96		Despretz.
" linaria mas.		44,03		Pallas.
" " foem.		43,47		"
" spinus		43,19		"
Parus major		44,03		"
Hirundo lagopus		44,03		"
Caprimulgus europæus		43,47		"
Columba		41,5	Blood	Prevost & Dumas.
"	15,15	42,98		Despretz.
"	15,5	42,1		J. Davy.
"	25,5 Ceylon	43,1		"
Gallus		39,44 to 39,88	Cloaca	J. Hunter.
Gallina		39,44 to 39,88	"	"
"	at breeding time	40		"
"		41,5	Blood	Prevost & Dumas.
"	+4,5° C. England	42,5		J. Davy.
"	25,5 Ceylon	43,3		"
Meleagris gallopavo	25,5	41,94		"
" "		42,7	Entrails, Blood	Braun.
Tetrao tetrix		42,22		Pallas.
" lagopus		41,67		"
" perdrix (7Ex.)		41,81 to 42,92		"
" albus	—21,1 Port Bowen	38,9		Lyon.
" "	—23,8 " "	38,9		"
" "	—26 " "	38,9		"
" "	—28,3 " "	38,9		"
Ardea stellaris		39,44		Pallas.
"		41	Blood	Prevost & Dumas.
Tringa pugnax		42,22		Pallas.
Scolopax limosa		42,22		"
Hæmatopus ostralegus		41,11		"
Fulica atra		40,56		"
Anser		41,94	Entrails, Blood	Braun.
"	+25,5 Ceylon	41,7		J. Davy.
Anas		42,5	Blood	Prevost & Dumas.
"	25,5 "	43,9		J. Davy.
" acuta		40,56		Pallas.
" clypeata		42,22		"
" penelope		41,11		"
" strepera		41,11		"
Colymbus auritus		41,67		"
Pelecanus carbo		41,11		"
Larus	2,8	37,8		Lyon.
Procellaria æquinoctialis	26 on the sea	40,3		J. Davy.

CCCLXXXVIII. Young birds that leave the egg when very small, naked, their eyes not yet opened, and but little developed, such as birds of prey, climbers, singing-birds, and pigeons, possess less warmth than adults. When taken from the nest they quickly grow cold, and are incapable of keeping up the temperature that is necessary to their preservation. This follows from Edwards.(1) In a nest of young sparrows, that had left the egg 8 days, the thermometer rose from 35° to 36°, with an external temperature of 17 degrees. After taking the young ones from their nest, he saw them cool down to 19° in the space of an hour. He observed the same in young swallows and sparrow-hawks. These consequently resemble cold-blooded animals, and are not able to keep themselves from cooling, except by the high temperature of the spring and autumn, and by their assemblage in a nest composed of substances that are bad conductors of heat. Moreover, the mother sits on the nest during the night and on cold days. In order to ascertain whether the rapid cooling of young birds depended on their nudity, Edwards compared their temperature with that of a full-grown sparrow, whose feathers he had plucked. This maintained its temperature at 18 degrees of atmospheric heat, whilst young birds already in part covered with feathers, cooled down to 19 and 20 degrees. The diminution of temperature is not therefore to be attributed to the want of feathers; the cause of it must be sought in an internal condition of the body.

Full-grown birds maintain their temperature in intense colds that are even sufficient to congeal mercury, as Lyon's experiments on the heat of the *tetro albus* prove. However, the faculty of generating heat at a low temperature seems to be somewhat modified by the influence of the seasons. Edwards(2) placed five sparrows, in the month of February, in a vessel in which the thermometer stood at zero. At the end of an hour, the heat of the body appeared the same as before in some, whilst in others it had fallen a half or a whole degree. Having exposed birds of the same species, in July, to a similar cold artificially produced, he found that their temperature had fallen about 3.62° in an hour, and even 6° after three hours.

When birds are exposed to an artificial heat that far exceeds their own, the latter is only increased from about 6 to 7 degrees, according to the experiments of Delaroche and Berger; it does not, however, become equal to that without, but always remains much lower, and the animals are cooled by evaporation. The heat of a pigeon exposed to a temperature from 66.56° to 74.69°, only rose about 7.5 degrees. Nevertheless, birds soon perish in a heat exceeding their own, as was observed by Braun in a sparrow, which he had placed in a temperature of 63.33°, and whose life was extinguished at the end of seven minutes. Tillet remarked the same in his experiments on birds.

CCCLXXXIX. Some naturalists have doubted whether reptiles have the power of generating heat. Braun said he observed in his experiments on

(1) Loc. cit., p. 138.
(2) Loc. cit., p. 162.

frogs, that their temperature equalled that of the media in which they lived. Martine and J. Hunter, on the contrary, found frogs, tortoises, and snakes warmer by some degrees than the media. It follows from the experiments of J. Davy and of Czermak(3) on animals belonging to all the orders of this class, that they do possess this calorific faculty. Their temperature, however, is very various, according to that of the media which surround them. This is particularly evident in frogs *(batraca)* and tortoises, but is less so in lizards and ophidia. We will mention the necessary proofs from the different orders.

	Heat of the Media.	Heat of the Animals.	Place where the Heat was measured.	Observers.
Rana esculenta	Water + 7,5° C.	+9°		Prevost & Dumas.
" "	Air 14 to 15	15,50 to 17		Edwards.
" "	Water — 5	3,12	Pericardium	Czermak.
		1,41	abdominal cavity	"
" "	" + 6,88	9,34	Pericardium	"
" "	" 8,12	8,44	"	"
" "	Air 17,50	20,83	Stomach	"
		20,94	Pericardium	"
" "	" 20	22,50	"	"
Proteus anguinus	Water 15 } Air 16 }	18,60	Pharynx	Rudolphi.[4]
" "	Water 12,81	18,44	Region of the Heart	Czermak.
" "	" 14,37	19,38	" " "	"
" "	" 15,31	20,41	" " "	"
" "	Air 13,12	17,50	Throat	"
" "	" 17,50	20,15	Region of the Heart	"
" "	" 20	19,99	Throat	"
" "	" 22,50	21,25	Region of the Heart	"

Whence it is obvious that the heat of these animals varies according to the media they inhabit. J. Hunter remarked the rapid changes of their warmth when exposed to artificial cold or heat. He exposed a frog to artificial cold, and its heat, which was 6.67° in the stomach, fell to 0.56°. Having placed frogs in air heated to 42.22°, he saw their heat rise to 33.89°, but it did not become any higher. The following experiments, however, prove that, notwithstanding the variableness of their temperature, frogs possess the power of maintaining it to a certain degree. During the winter I took a frog by an iron spoon from a glass vessel filled with water, the temperature of which was 7.50° below zero, and exposed it to the air which had the same temperature. The thermometer applied to the frog, rose to one degree below zero, and the abdominal cavity gave the like indication. Having taken another frog, I exposed it in a vase full of water to the air, in

(3) Baumgaertner und Ettingshausen, Zeitschrift für Physick, 1824, v. iii, p. 385.
(4) Rozier, Journal de Physique, v. lxxi, p. 289.

which the thermometer fell to 13° below zero. The water froze during the night, and the glass broke. I found the animal in the mass of ice, its eyes closed and limbs drawn up to the body. The water around it was not frozen, and its heat was 0.56° above zero; it moved very slowly when touched. It was again exposed in a vessel full of water to the cold, which during the following night, was 15.56° below zero. In the morning it was completely frozen and dead. Frogs, therefore, seem, at a low degree of atmospherical temperature, capable of generating heat, whilst an observation of Blagden and experiments made by John Hunter and Delaroche prove that they have likewise the property of keeping themselves at a low temperature in warm air. The former saw a thermometer, placed in a frog's throat on a hot summer's day, fall several degrees. J. Hunter exposed frogs to air heated to 42.22°, but their warmth only rose to 33.89°. Delaroche inclosed a frog in a space heated to 45°; after an hour the heat of the animal only stood at 29°. In another frog, the external temperature being 46.67°, the heat of the animal only rose to 28.33°. Dead frogs on the contrary were in an equilibrium with the external media. The property these animals possess of reducing their temperature is doubtlessly owing to evaporation, which is very copious in them on account of their naked skin.

CCCXC. Tortoises evidently engender heat, especially in the region of the heart. Their temperature, however, varies according to the external warmth.

Tortoises.	Temperature of the Media.	Heat of the Animal.	Place where the heat was measured.	Observers.
Testudo mydas	Air +26° on the sea	+28°		J. Davy.
" "	" 30 Ceylon	29,4		"
" "	" 26,11 on the sea	32,78	Blood	"
Testudo geometrica	" 16 Cap	30,5		"
" "	" 26,11 Ceylon	32,78		"
Emys europæa	" 16,25	17,81	Æsophagus	Czermak.
		18,34	Heart	"
" "	" 23,12	26,66	Throat	"
" "	Water warmed +41,25	23,75	abdominal cavity	"
Chersine græca	Air +15,30	13,44	Heart	"
		12,81	Lungs	"
" "	" 17,91	18,91	Blood	"
" "	" 22,81	18,75	Heart	"
		18,12	Lungs	"
" "	" — 3,12	3,75	abdominal cavity	"
		4,06	Throat	"
" "	" — 6,25	2,81	abdominal cavity	"

CCCXCI. According to the observations made by Wilford(5) on a boa three feet and a quarter long, at Sierra Leone, the heat of snakes varies with

(5) Annals of Philosophy, v. ii, p. 26.

the temperature of the air. Czermak's experiments, however, do not give us ground to suppose that heat is communicated to them from without alone.

Snakes.	Temperature of the Air.	Heat of the Animals.	Place where the heat was measured.	Observers.
Boa	+22,2°	+23,9		Wilford.
"	22,8	24,4		"
"	23,3	24,4		"
"	23,9	23,9		"
"	24,4	24,5		"
"	24,4	24,9		"
"	25,0	25,5		"
"	25,1	25,4		"
"	25,5	26,3		"
"	25,7	25,9		"
"	26,1	26,6		"
"	26,6	26,3		"
"	26,6	26,3		"
"	28,1	27,3		"
	28,3	27,8		"
A green Snake	27,5 Ceylon	31,4		J. Davy.
A brown Snake	28,1 "	29,2		"
Natrix lævis	16,88	19,37	full stomach	Czermak.
		19,37	Heart	"
" "	18,12	21,72	great trunks of the heart	"
" "	20,31	26,66	Region of the Heart	"
		22,81	abdominal cavity	"
" "	24,16	25,41	Heart	"
" "		24,37	Throat	"
" torquatus	16,88	18,12	abdominal cavity	"
		19,06	Throat	"
		20,62	Heart	"
" "	18,12	18,44	abdominal cavity	"
		19,16	Œsophagus, Heart	"
" "	20,31	21,56	Throat	"
		22,50	Heart	"
		22,91	full stomach	"
" "	25,3	23,44	abdominal cavity	"
		24,06	Heart	"
Anguis fragilis	18,44	18,91	abdominal cavity	"
		20,84	Heart	"
" "	19,06	20,31	Throat	"
		20,62	Heart	"
" "	19,69	20,31	between the skin and the muscles	"
		20,62	Throat	"
		22,08	Heart	"
" "	20,31	22,08	full stomach	"
		22,66	Heart	"

The experiments which John Hunter made on vipers, as he says, but most likely on adders, prove that living snakes are not placed in equilibrium with a very high or very low temperature. The temperature of the air being 14,44°, he introduced the bulk of a thermometer into the throat and cloaca, whereon it rose to 20°. When he exposed serpents to an artificial cold of 12,22°, their heat fell to 2,78°, and at last to 0,56°. He adds that serpents lose their warmth in cold much more slowly than frogs do. Another of these animals was placed by him in an artificial heat of 42,22°, after which the heat of the stomach and anus rose to 33,83°, but no higher. Hence it is evident, that if the heat of snakes varies with the external temperature, such variations never go beyond a certain extent.

CCCXCII. Lizards also generate heat which, in ordinary circumstances, exceeds that of the atmosphere.

Lizards.	Temperature of the Air.	Heat of the Animals.	Place where the heat was measured.	Observers.
Iguana	+27,8° Ceylon	+28,0		J. Davy.
Lacerta maculata	12,2	15	Pharynx	Rudolphi.
		18,78	Chest	"
" viridis	16,25	20,25	Abdomen	Czermak.
		21,25	Region of the Heart	"
	22,81	28,75	Abdomen	"
		30,15	Region of the Heart	"
" agilis	23,75	28,12	Full Stomach	"
		28,91	Heart	"
	21,88	26,88	Abdomen	"
		30,00	Heart	"
	12,50	16,56	Mouth	"
		19,16	Heart	"
	11,56	12,81	Abdomen	"
		14,16	Heart	"
	5,31 artificial heat	0,63	Abdomen	"
	6,41 "	1,56	Heart	"

Murray ascertained by a very sensible thermometer, that the heat of the cameleon is from 22,78° to 23,33°, the temperature of the air being 22,24°, and that the changes of colour of the animal are accompanied by a slight diminution of the heat.(6)

CCCXCIII. Some naturalists have denied that fishes have the power of producing heat. Braun says he found the temperature of pikes, carps, eels, and lampreys always the same as that of the water in which they were then living. Neither did Humboldt and Provençal(7) perceive any appreciable difference between the warmth of fishes and the water. On the other hand, Martine, J. Hunter, Broussonet,(8) Buniva,(9) Perrins,(1) and J. Davy,(2) ascertained that, under ordinary circumstances, their temperature is one or several degrees higher than the water they live in. According to Martine's observations, the blood of many marine fishes only show one degree more than sea-water. Broussonet saw the thermometer rise only half or three-fourths

(6) Experimental Researches. Glasgow, 1826, p. 89.
(7) Mem. de la Soc. d'Arcueil, v. ii, p. 598.
(8) Mem. de l'Ac. des Sc. de Paris, 1785, p. 191.
(9) Mem. de l'Ac. de Turin, v. xii.
(1) Nicholson's Journal, January, 1804, p. 13.
(2) Loc. cit.

of a degree above the heat of the water in the bodies of fishes; carps alone had mostly a temperature higher by a degree or a degree and a half than the water.

Names of Fishes.	Heat of the Water.	Heat of the Fishes.	Place where the heat was measured.	Observers.
Esox lucius	+ 0,56° C.	+ 4,44°	Abdomen	Krafft.
" "	9,44	10,50	"	"
Cyprinus carpio	18,83	20,56	Stomach	J. Hunter.
" "	10,83	11,69		Despretz.
tinca		11,54		"
Squalus	24,44	25,56	Mouth	Perrins.
"	23,7	25	Blood	
Exocœtus	25,3	25,6		J. Davy.
Salmo fario	13,3	14,4		"
Sparus auratus	23,56	25	Heart	"

The heat of fishes varies with the temperature of the water. J. Hunter exposed an eel, whose warmth was 2.78° in the stomach, to an artificial cold; its heat fell to 0.56°, and it appeared dead, but on the following morning it was found still living. A tench, whose warmth was 6.67°, was exposed to a considerable cold; its temperature sunk to 0.56°, and it froze. The warmth of an eel, whose heat was 6.67°, rose to 18.33° in water heated to this degree. A tench, whose warmth was 5°, being immersed in water at 18.33°, only showed a temperature of 12.78° in the stomach and rectum. Fishes that live in the tepid water of Barrèges, have, according to Audirac,(3) a lower temperature than the water.

From these observations, it may be concluded that the faculty of generating heat cannot be refused to fishes. Their temperature, however, varies with that of the water. Further, by their sojourn in water they are better defended from the changes of temperature connected with the seasons than animals which live in air are, inasmuch as they can abscond to deep waters, where the heat, especially in the sea, is not changed by the influence of the seasons, and in the same manner but little changed in deep lakes and rivers.

CCCXCIV. Insects generate heat, as Swammerdamm, Maraldi, Martine, and Réaumur certified in bees collected in hives. Martine(4) found a temperature of 36.11° in the hives. Réaumur,(5) in the month of January, introduced a thermometer into a hive placed in a room where the temperature was 3.33°; it rose to +12.78°. In the month of May again, it indicated a heat of 38.89°. According to Huber,(6) the heat of a populous hive rises

(3) Bulletin de la Soc. Philomat., v. i, p. 136.
(4) Medical and Philos. Essays, p. 331.
(5) Hist. Nat. des Insectes, v. v, part 2, p. 360.
(6) Mem. sur les Abeilles, v. i, p. 305.

in the winter to 30° or 32°, even when the temperature of the air is below zero. During summer it rises to 33° and 36°, and, at the swarming season, it stands above 40°. In an ant-hill, also, the heat is greater than in the air, for Juch(7) saw the thermometer in one of them rise to 20°, the external heat being 13°, and to 18° when the atmosphere was at 24.44°. Martine remarked, that the heat of caterpillars mostly exceeds that of the atmosphere by one or two degrees. Hausmann(8) and Rengger(9) observed a rise in thermometers placed in strait glasses, in which beetles and other insects had been collected. J. Davy has specified the heat of some insects.

Names of Insects.	Heat of the Atmosphere.	Heat of the Animals.
Scarabæus pilularius	24,30°	25°
Lampyris	22,8	23,3
Blatta orientalis	23,3	23,9
Gryllus	16,7	22,5
Scorpio afer	26,1	25,3
Julus	26,7	25,8

Rudolphi found the thermometer rise to 12.50° in the body of a river crab, (*Astacus fluviatilis,*) and to 15° in another, whilst the heat of the water was 11°.

CCCXCV. Mollusca also have the property of generating heat, though their warmth varies with the atmospheric temperature. J. Hunter observed that four black snails, (*Limax ater,*) inclosed in a vessel, made the thermometer rise from 12.22° to 13.89 C. Spallanzani(1) likewise remarked that the thermometer rose a little when he inclosed several animals of the genus limax and helix in vessels. Gaspard(2) found that twenty-four garden snails, (*Helix pomatia,*) inclosed during the summer in a pot placed in a cellar, where the temperature was 13°, caused the heat to rise about a degree in the pot. According to Berger's experiments,(3) the heat of the *Helix pomatia* varies exceedingly with that of the atmosphere. Its medium warmth was 8.33° during eleven months, the minimum 2,22°, and the maximum 18.33°. In summer it was mostly at 4.44° at sunrise, and at 12.22° towards 2 o'clock in the afternoon. The heat of bivalve mollusca is, according to Pfeiffer,(4)

(7) Ideen zu einer Zoochemie, v. i, p. 90.
(8) De animalium exsanguium respiratione, p. 65, 69.
(9) Physiologische Untersuchungen über die Insekten, p. 40.
(1) Mem. sur la Respiration, p. 257.
(2) Magendie, Journal de Physiol., v. ii, p. 295.
(3) Mem. du Mus. d'Hist. Natur., 1828, art. 9, p. 231.
(4) Naturgeschichte deutscher Land-und Süsswasser Mollusken, Abthl. 2. Weimar, 1825, p. 22.

nearly the same as the temperature of the water in which they live. He found the water in which they were kept to stand at 11,25°, whilst the bulb of the thermometer, placed between the belly and the branchial lamellæ, rose only to 11.56°. J. Davy says he never remarked any difference between the heat of oysters and of the water in which they were.

J. Hunter made some experiments on the heat of annelides. Several earth-worms, *(Lumbricus terrestris,)* inclosed in a glass, caused a rise in the thermometer from 13.33° to 14.94°. Having placed three leeches *(Hirudo medicinalis)* in a glass, the thermometer rose on one occasion from 12.22° to 13.78°, and on another from 13.33° to 13.90°.

CCCXCVI. With respect to the cause of the production of heat in animals, there are few vital phenomena on which so many different theories have been built as this. The iatro-mechanicians taught that heat was produced in living bodies as in those which possess no life, by the friction which takes place both between the fluids and the coats of the vessels, and in the organs themselves, in consequence of their internal movements.(5) The physicians of the ancient introchemical school regarded it as a result of the mixture of the supposed acid chyle with the alkaline blood, which they said caused an effervescence, accompanied by an evolution of heat. The partisans of the new chemical doctrines believe the cause of animal heat to be found in the act of respiration, which they compare to a combustion going on between the materials of the venous blood and the oxygen of the inspired air, in whom the caloric evolved combines with the arterial blood, and is distributed over the body. Other physiologists seek the source of it in digestion, in nutrition, secretion, or even in the nervous system. Without stopping to examine these theories, of which we shall treat more fully when at the production of heat in man, we shall merely mention here what is certain, namely, that none of them offer a satisfactory explanation. Even the doctrine of Crawford and Lavoisier, according to which heat is a product of respiration, although it has the suffrages of most

(5) Thus Haller, " We may also ask whether the heat of the blood does not also proceed from its motion; seeing we observe heat to arise from the motion of all kinds of fluids, even of air itself, in our experiments; but much more does this attrition produce heat in the inflammable animal juices, which are denser than water, and compressed with a considerable force by contractile and converging tubes. Is not the truth of this sufficiently evinced by the blood being warm in those fish which have a large heart, and cold in such as have a small one? the generation of heat being in proportion to the size of their bodies: from the more intense heat of birds that have a larger heart, and more frequent or quick pulsations? from the increase of animal heat that ensues from exercise of all kinds, and even from bare friction of parts?——Nor must we explain an evident appearance by the action of such an obscure being as the *vital power;* and though sometimes the heat may be greater when the pulse is slow, and less when it is more frequent, the difference may arise from the different disposition of the blood, from the different densities of the vessels, or the increase or diminution of perspiration?"—(Physiology, sec. 181, éd. Wrisberg.) It is curious to find these unstable analogical proofs trusted to by the philosophic Haller, whilst he contemns what he calls the obscure but in fact evident (in operation if not in essence) vital power. To this latter, under the more appropriate term of nutritive power, Tiedemann attributes the calorific process.—Trs.

naturalists, has been found insufficient by Dulong and Despretz, who endeavoured to ascertain by experiment how far the quantity of oxygen gas consumed in respiration, sufficed to produce all the heat which animals are continually losing, and who, after this, were induced to allow other sources of heat, which are unknown to us.(6)

The only point that can be regarded as placed beyond doubt is, that the evolution of heat is a vital act which depends immediately on the process of nutrition, the conditional and preservative cause of life. The taking of alimentary matters, and their assimilation by digestion and respiration, the circulation of the fluids, nutrition, and secretion, the renewal of materials that accompanies the exercise of life, and the incessant changes of composition in the solids and liquids, all which are under the influence of the nerves, also act a part in the production of heat, and it is erroneous to seek the cause of it in any one of these acts only. The intensity of the evolution of heat and the property of maintaining itself at a certain temperature proper to each species, are, in animals, in direct ratio with the composition of their organization, and with the sum and intensity of their manifestations of activity. Birds and mammifera, which take aliment at the shortest intervals, which

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(6) Dr. Crawford maintains that the caloric is generated during the conversion of part of the inhaled atmospheric air into fluid—as well as during the mutation of the circulating fluids into solids—that this caloric is imbibed by the arterial blood, in which it remains latent until the arterial is changed to venous blood, whereby its capacity for heat being diminished a certain portion of caloric is evolved. This theory explains whence caloric may proceed, and how it may be diffused; but the quantity of caloric referrible to these sources would not seem adequate to the maintenance of the animal temperature when it is remembered that processes precisely the converse of these, are constantly carrying on in the economy, and whose effects must completely counteract these calorific operations. Thus in the lungs, while there is the assimilation of air, and consequent evolution of caloric, there is also the exhalation of aëriform secretions, and the necessary abstraction of heat; so in the other organs of the body and throughout the whole secretorial and absorbent capillaries at the same time that there is the conversion of aëriforms to fluids, and fluids to solids, with their attendant extrication of heat—there is the change of solids to fluids—fluids to aëriform substances—and the secretion of vapours and airs—all of which imply the production of cold sufficient probably in degree to neutralise the heat resulting from the opposite processes. Where this theory fails to explain the generation of caloric sufficient to preserve the animal temperature, Dr. Carson's hypothesis supplies a problematical source which may, when added to the chemical and vital operations already detailed, explain the evolution of that heat which is to preserve the temperature of the animal, the other caloric having been neutralised by the frigorific processes alluded to. Dr. Carson, in his Inquiry into the Causes of Animal Heat, &c., p. 333, says, "The air thus introduced, by a thousand minute passages, into the blood becomes intimately mingled with it. Partly by mechanical, and partly by chemical agency, a portion of this air, while the blood with which it is commixed is still in the lungs, is converted from the aërial into the fluid state. The consequence of this conversion is well known to be an evolution of heat. But all the inspired air is not converted into liquid in the pulmonary veins. After the passage of the blood out of the lungs, a portion of it still retains the gaseous condition; it is mingled with the blood in the form of small globules, and in this state is transmitted by the heart into the aortic system. In its passage through the system to all parts of the body, it is gradually converted into a liquid form; as this conversion takes place, giving out heat. As, therefore, the stream of blood proceeds on its course from the heart to the extremities, it receives from itself a new supply of heat, and is thus enabled to preserve the same temperature throughout a course in which its heat is rapidly conducted from it into the surrounding substances. When the blood has reached the capillary arteries, the conversion of air into liquid may be supposed to have been completed."—Trs.

digest with the greatest rapidity, which consume the most oxygen, and give out the most carbonic acid, whose circulation is most rapid and energetic, which exhibit the greatest pertinacity in their movements, in which we observe the strongest effects of the nervous system, which secrete the greatest quantity of diversified humours, and in which, in short, all the phenomena proclaim that the renewal of matters takes place in the most speedy manner; these have the highest degree of heat, and are able to maintain it with the greatest uniformity at the temperature proper to each of them. Amphibia, fishes, insects, mollusca, and worms, whose structure is less complex, whose vital phenomena exhibit less diversity, and in which the above-named actions of life have less intensity, have also a lower degree of heat, are more subject to variation in their temperature, and have their faculty of generating caloric confined to smaller limits.

Further, the generation of heat resulting from the renewal of matter, and the changes of composition ever accompanying life, varies in animals, within certain limits, according to the development, the periods of age, the nature of aliment, and the manner of performing digestion, according to the respiration, the circulation of the blood and the nervous influence, the seasons, even according to the periods of the day, during waking and sleeping, according to the external stimuli that affect animals, and finally, according to diseases, medicinal remedies, and poisons. The proofs in support of this assertion shall be given when we treat of the heat of man.

In plants, an evolution of heat seems to occur, though only to a small degree, during the acts of respiration, nutrition, and secretion, as also during fecundation and germination. But vegetables do not appear to undergo continual changes in consequence of their internal activity, in their solids when once formed, as is observed in animals, in which the matter of the different tissues is incessantly changing; neither do they execute voluntary movements, nor does the entire group of nervous functions belong to them, so that they lack the chief sources of the generation of heat.

CHAPTER SECOND.

Of the Evolution of Light in Organized Bodies.

CCCXCVII. Many organized bodies, vegetables and animals, emit light. Previous to naming them, and mentioning the conditions in which they diffuse light, I think it proper to make a few remarks on the phosphorescence of bodies in general. All bodies are denominated luminous whose existence is made known to us, even at immeasurable distances, by the sense of seeing. The sun and fixed stars appear to be the only absolutely luminous bodies. All others become visible by reflecting light, or only are so in certain circumstances.

As a body, in becoming visible to us, affects the nerves of our eyes, a medium must exist between these nerves and it. On the nature of this medium, physical philosophers are divided in opinion. Some think there is an exceedingly thin elastic fluid between luminous bodies and the eye, which fills all the mundane space, and which they call ether. According to them, this fluid, by the activity of luminous bodies, as air by the effect of sound, suffers undulatory vibrations, which are propagated with immense rapidity and produce the sensation of sight, when they arrive at the nervous membrane of the eye. This theory Huygens established, and Euler has defended and developed it. Others suppose that minute material particles emanate from luminous bodies, that these particles traverse space in right lines with extreme velocity, and that on arriving at the interior of the eye, they occasion the sensation of sight. These are called light, or luminous matter. It is the emanation-system formerly advanced by Epicurus and developed by Newton. Both theories present great difficulties, most of which, however, are more easily overcome in the second than the first.(7) Almost all physical philosophers are decided on the existence of a peculiar matter, exceedingly thin, eminently expansible and imponderable, which emanates from luminous bodies. All ponderable bodies appear to receive within them a portion of the solar light that reaches them, and to admit the more of it as they are less transparent, or as their surface is more dark and rough. The degree in which a body is warmed by the solar light is in proportion to the quantity of light it absorbs. Several distinguished chemists, moreover, consider it likely that light is chemically combined with ponderable matters, and may afterwards, in different circumstances, be separated from them.

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(7) The former of these doctrines was also ably maintained by Descartes. The objections that rise against it are, that according to it, night is inexplicable, as is also the non-appearance of an object when an opaque body intervenes; for if light, like sound, acts by vibrations, why should an opaque body more particularly interrupt vision? Nor can the change of direction which light undergoes in passing from one medium to another be explained by this hypothesis. Concerning the theories of Epicurus and Newton, it may be asked, how the sun still supplies the immense torrents of light which it is incessantly shedding? how the sun impels the molecules of light with the extreme rapidity they exhibit? and how so many luminous rays reflected from millions of bodies cross each other without confusion? These may be answered by alleging the extraordinary minuteness of the luminous molecules and their distance from each other. According to Newton's theory, the division of the prismatic rays is rationally explicable; not so, however, (or at least with equal probability,) by the doctrine of Huygens, which attributed the diversity of colours to the diversity of vibrations which the coloured bodies were supposed to impress on the ethereal fluid. It is known that different rays have different effects upon the thermometer. Thus the experiments of Herschell, Wollaston, and Berard show that the red portion of the spectrum causes the thermometer to rise the most, then the orange, then the yellow, &c. It may hence be inferred that the red is a more potent calorific ray. To apply this to the evolution of light from organised bodies:—The animals that possess the property of eliminating light also give out variously coloured rays; some are red, others yellow, others orange, greenish, and so on. Hence it is not unreasonable to suppose, that according to the degree of evolution of calorific rays is the exaltation of function essential to that degree; the more as it is well ascertained that the secretion of heat is ever in a ratio with the complexity of organization or exaltation of functional power.—Trs.

CCCXCVIII. Inorganic bodies exhibit the phenomenon of an evolution of light in the following circumstances and conditions:

1. Many inorganic bodies, transparent as well as opaque, colourless or slightly coloured, but never black ones, have the property, when they have previously been exposed to the glare of solar light, or even of any other light, of shining for a time in the dark, as Beccaria, Canton, Dessaignes, Grotthuss, Heinrich, and others, have shown. The substances that exhibit this phenomenon in the greatest degree are the diamond, arragonite, strontia, marble, calcareous spar, lime, and divers phosphoric stones. Sal-ammoniac, alabaster, saltpetre, basalt, and zalena shine less; iron ochre, celestine, beryl, &c., shine still less. Silica, amethyst, chrysolite, emerald, &c., shine the least, and frequently not at all. Water, and all liquid bodies, sulphur, graphyte, barytes, chalk, and metallic reguli, diffuse no light. As the preceding bodies shine in all transparent media by which they are not decomposed, even in gases that are not supporters of combustion, and in vacuo, and this with an evident evolution of heat, the light they absorb by feeble affinity during insolation, would seem to abandon them in darkness.

2. Most bodies that shine by insolation, but also various others, as chalk, barytes, strontia, magnesia, &c., almost all earthy fossils, as rock crystal, asbestos, quartz,(8) topaz, cyanite, mica, and the filings of many metals, as of zinc, antimony, iron, silver and gold, diffuse light in the dark, when heated, as follows from the experiments of Wedgwood, Haüy, Dessaignes, Heinrich, Brewster, Children, and others. The degree of heat necessary for the evolution of light varies, however, exceedingly. It appears that in these bodies their combination with light is more intimate, and that it can only be destroyed by the influence of heat.

3. The contact of inorganic bodies by friction, percussion or concussion, produces in many instances an evolution of light, according to observations

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(8) A species of fluor spar found in the granite rocks of Siberia was exhibited by M. Becquerel to the Philomathic Society in August, 1826. It shines in the dark with a very remarkable phosphoric light which increases when the temperature is raised. Its light augments when it is plunged into water. In boiling water it is so luminous that the letters of a printed book can be seen near the transparent vase which contains it. In boiling oil the light is still greater; and in boiling mercury it emits such a light that we may read by it at a distance of five inches. Of a similar kind must be the stones mentioned by Sir John Mandeville, as surmounting two columns placed at the entrance of a town in Great Tartary, and which shine brightly in the dark. Patren observed the phosphorescence by friction to be very remarkable in blend or sulphuret of zinc. In that which he saw in the silver mines of Zmeof, in Siberia, the phenomenon was elicited by the simple friction of a pen on the surface of the mineral. The same is remarkable in the blends of Scharffenberg, in Misnia. All kinds of quartz, especially those called greasy quartz and grammatite, are highly phosphorescent by friction. Some slight degree of luminous appearance may be seen by rubbing the diamond with a brush in the dark. Among the more familiar objects the phosphorescence by friction of sugar and the chloride of calcium may be easily ascertained. According to Bayle, Dufay, Margraff, Beccaria, &c., the phosphorescence of minerals by friction is in a ratio inverse to that of their humidity. Phosphorescence by collision is seen (besides the minerals named in the text) in carbonates of barytes and strontia, tremolite, wernerite, several phosphates of lime, harmotome, &c.—Trs.

made by Homberg, Bergmann, Macquer, Pelletier, Dolomieu, Gillet-Laumont, Saussure, and Dessaignes. For the most part these are bodies which shine by insolation or heating, as the diamond, ponderous spar, chlorate of potass, quartz, fluor spar, arragonite, dolomite, blend, sublimate, &c. Fluids, water, and air give out light when suddenly compressed. It is not certain whether in this case the disengagement of light is the effect of motion, or of the excitation of electricity, as Dessaignes and Becquerel suppose.

4. An evolution of light sometimes accompanies changes of cohesion, and it then seems to be allied to an excitation of electricity. Luminous phenomena have been observed by Pickel, Schœnwald, Schiller, Giobert, Hermann, Berzelius, Woehler, and Pfaff, in various salts, at the time of crystallisation in the water which held them in solution, especially in the sulphate of potass, and the fluate of soda.

5. An evolution of light and heat is seen during the reaction of a great number of different ponderable matters. This is nowhere more evident than in the combination of oxygen with other matters, as in the process of combustion. The quantity of light disengaged during combustion is in proportion to the nature of the combustible body. Phosphorus disengages a great deal, carbon less, and hydrogen least of all. The light is the more vivid as the combustion is rapid. Its colour depends on the nature of the burning body. A disengagement of light also takes place in the combination of chlorine, iodine, selenium, sulphur, and phosphorus with other matters. Some compound bodies likewise present this phenomenon when they combine together, as sulphuric acid and magnesia, lime and water, barytes and water. The light disengaged during the combination of these bodies exists in one or other of them, or in both at once, and is separated from them whilst they are being united. Or else it is produced from the combination of ponderable with imponderable matters contained in them, or, as Berzelius thought, by the concurrence of two opposite electricities.

6. An evolution of light frequently accompanies electric phenomena. As soon as electricity is produced with only a little energy, it appears in the shape of a spark. Electricity is capable of generating luminous phenomena in many bodies. Bodies that shine by insolation also acquire the property of shining when traversed by an electric discharge, as was demonstrated by the experiments of Dessaignes, Heinrich, Grotthuss, and Seebeck. Is the light a part of the electricity? or is it composed of both electricities? or, lastly, is it driven by the action of electricity from the media and bodies on which it acts? are questions which the science of physics has not yet decided.

CCCXCIX. After these preliminary remarks, we will pass to the luminous phenomena of organized bodies. Some of these bodies are only luminous during their full activity or in the state of life, and others, on the contrary, when life is extinguished in them. Let us first examine the latter.

Lifeless organic bodies or substances give out light in several circumstances wherein inorganic bodies are luminous.

1. Many organic substances shine by insolation. According to Heinrich's experiments,(9) seeds, flour, starch, gum arabic, and others among vegetable matters manifest this property; among animal substances, feathers, horn, corals, snail shells, pearls, teeth, bones, leather, yolk of egg, tendons, muscles, fish glue, and dried glue. Wood, most gums, silk, and undried animal matters give out little or no light by exposure to the solar rays. The fresh parts of vegetables are not luminous.

2. Wax, volatile and fatty oils, sugar and wood, the sulphate of cinchonine, according to Pelletier,(1) and the sulphate of quinine, according to Callaud,(2) evolve light by the action of heat. As organic matters, according to Dessaignes'(3) observations, only shine in the air, and as the evolution of light is augmented in oxygen gas, the phosphorescence of organic bodies under the influence of heat may be reckoned among the phenomena of combustion.

3. Mechanical contact, friction, causes common sugar, manna sugar, and the sub-resins, gum elemi and gum *arbol a brea* to shine, according to Bonastre's(4) observations, probably in consequence of an excitation of electricity.(5)

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(9) Die Phosphorescenz der Körper. Nuremberg, 1811-20.
(1) Journal de Pharmacie, v. vii, p. 579.
(2) Ibid.
(3) Journal de Physique, v. lxviii, p. 444; v. lxix, p. 5; v. lxxiii, p. 41; v. lxxiv, p. 101.
(4) Journal de Pharmacie, April, 1825.
(5) There is a phosphorescence elicited on certain occasions from the hair of certain animals. A well known example of this is the production of sparks from a cat's back by friction in the dark. Such phosphorescence is electrical. It has been noticed in man. Thus Homer describes the hair of Achilles as brilliant when rage had filled his breast:

" Αμφι δε οι κεφαλη νεφος 'εστεφε δια θεαων
Χρυσεον, 'εκ δ' αυτȣ δαιε φλογα παμφανοωσαν.
* * * * * * *
Ως απ Αχιλλησς κεφαλης σελας αιθερ' ἱκανε."

Which Pope translates,

"Around his brows a golden cloud she spread;
A stream of glory flam'd above his head,
* * * * * *
So from Achilles' head the splendours rise."
Bk. 18.

* * * * * " αυταρ Αχιλλευς
Ως ειδ', ως μιν μαλλον 'εδυ χολος· 'εν δε οι 'οσσε
Δεινον υπο βλεφαρων, ωσει σελας, εξεφαανθεν."

Rendered by Pope,

* * * "the hero kindles at the show,
And feels with rage divine his bosom glow;
From his fierce eye-balls living flames expire,
And flash incessant like a stream of fire."
Bk. 19, *lines* 20 *et seq.*

Volatile and olive oil disengage light, especially when shaken in vacuo. Dessaignes asserts that animal matters do not shine under these circumstances.

4. All organic bodies, in their combustible character, diffuse light during combustion.

5. An evolution of light, together with excited electricity, is seen in resins that are rubbed.

In regard to these modes of phosphorescence, dead organic bodies resemble the inorganic. But very many of them likewise diffuse light during their decomposition, and when undergoing putrefaction.

CCCC. In dead vegetables, an evolution of light is most frequently seen in the wood, particularly that of the root, but also of the trunk and branches, when it is decomposed by a moderate heat, moisture, and without full exposure to the air. According to Dessaignes and Heinrich's experiments, the phosphorescence only occurs at a medium temperature. It disappears in frosts and great heat. Hot water puts a stop to it, as also desiccation. The evolution of heat takes place in atmospheric air. It becomes stronger, but does not last so long, in condensed air. Dessaignes says it gradually disappears in a vacuum. Wood does not shine more in oxygen gas than in atmospheric air, as Heinrich, Dessaignes, Gaertner,(6) and Bœckmann(7) ascertained: from the experiments of the last two, however, it follows, that phosphorescence continues longer in it. It only exists for a few hours in nitrogen, hydrogen, and phosphuretted hydrogen; but it recommences when atmospheric air is introduced into the vessel. It ceases after a few minutes in carbonic acid gas, sulphuretted hydrogen, nitrous gas, ammoniacal gas, and hydrochloric acid, as Spallanzani, Hulme,(8) Humboldt,(9) and others observed. It disappears at from six to twenty-four seconds in water not boiled and in fatty oils; it shines still more vividly in alcohol, ether, lime water, in diluted acids, and saline solutions. It ceases immediately in sulphuric acid. Wood that shines in air, or oxygen gas, consumes oxygen, and produces carbonic acid, without the volume of air being sensibly diminished.

Judging from the phenomena that have been enumerated, one is led to think, with L. Gmelin,(1) that during the decomposition of wood an eminently

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So also Virgil mentions the flame which he describes as playing round the head of the young Ascanius:

"Lambere flamma comas et circum tempora pasci."

Something of the same light appears to be produced on rubbing down the fore-hair of the horse's mane. The spontaneous combustion of excessively fat persons and inveterate spirit drinkers may also, probably, be referred to the same category. All are most likely owing to the elimination of electricity.—Trs.

(6) Scherer's Journal der Chemie, v. iii, p. 14.

(7) Ibid., v. v, p. 8.

(8) Philos. Trans., 1801, p. 483.

(9) Versuche über die Chemische Zerlegung des Luftkreises, p. 200.

(1) Hanbuch der Theoretischen Chemie, v. i, p. 90, 3d edition.

combustible organic combination of carbon, hydrogen, and oxygen is produced, which, like phosphorus, burns and gives out light at the ordinary temperature. Possibly phosphorus itself is an agent in it, since the researches of Berthier(2) have shown the existence of phosphate of lime in the ashes of very many woods.

An evolution of light has likewise been observed in the valerian and tormentilla roots,(3) in potatoes,(4) pumpkins, and during the putrefaction of various mushrooms.(5)

CCCCI. The phenomenon of phosphorescence is much more common in dead animals than vegetables. Theodore Bartolin,(6) Boyle,(7) Beale,(8) Redi, and others observed it in the flesh of mammifera, birds, and amphibia a short time after death. Light is most frequently and most evidently seen during the incipient putrefaction of fishes. Bartholin,(9) Jacobæus,(1) Redi, Spallanzani, Tilesius, &c., saw dead sepia, bivalve mollusca, entozoa, and medusa shine. I have also observed the same in dead sea-stars. The most numerous experiments on the phosphorescence of fishes are those of Canton,(2) Martin,(3) Spallanzani,(4) Hulme,(5) Heinrich, and Dessaignes. Sea fishes shine most frequently; but fresh water fishes, as was remarked by Heinrich in pikes and siluri, have the same property. For the most part it begins a day or two after death, when the body is exposed to moisture in atmospheric air or oxygen gas, at a temperature from 12° to 18°. A temperature beneath zero puts a stop to it. However, fishes that have been frozen, again become luminous when thawed. A boiling heat, and especially boiling water, destroys it irrevocably. It does not occur in vacuo, in carbonic acid gas, hydrogen,

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(2) Ann. de Chemie et Physique, v. xxxii, p. 210.

(3) Kortum remarked phosphorescence in valerian root, (Voigt's neues Magazin, v. vii, p. 67,) and tormentilla root, (Berliner Jahrb. der Pharmacie, v. i, p. 174.)

(4) Journal de Physique, v. xxxiii, p. 225; Voigt's Magazin, v. vii, p. 74; Edinb. Philos. Journal, July, 1824, p. 232.

(5) Linseed oil, shaken in a barometric or pneumatic vacuum, emits a phosphorescent light. Friction of the stalk of the "calamus rotang" causes a luminous appearance; it is not unlikely that in this case it may be owing to the presence of silica in the fibre of the plant. Putrefaction occasions phosphorescence to a great degree in the byssus violacea or hyperoxylon. The pith of most plants and the ligneous portion of others shine. Of the latter, the most remarkable are those that have a soft and-spongy wood, as the willow and poplar. Some trees with hard wood, however, have likewise a shining wood; instances of such are the elm, the beech, and the oak. Josephus mentions a luminous root under the name of "baharas;" which, if it ever existed, is now unknown. The phosphorescent property of the fungus of olive trees has lately been remarked by M. Delile, anatomical professor at Montpellier. He found it the same when reduced to minute particles.—Trs.

(6) De luce animalium. Copenhagen, 1669, in 8vo.

(7) Works, v. iii, 304.

(8) Philos. Trans., v. 11, p. 599.

(9) De animalibus vivis, quæ in corporibus animalium vivorum reperiuntur. Amsterdam, 1708, p. 15.

(1) Act. Hafn., v. 5, p. 283.

(2) Philos. Trans., v. 59, p. 446.

(3) Schwed. Abhandl., 1761, No. 7.

(4) Chimico essame degli esperimenti del Sign. Gœttling. Modena, 1796.

(5) Philos. Trans. 1800, part 1, p. 161; 1801, p. 483.

sulphuretted hydrogen, or nitrous gas, and, if it have already commenced, it ceases immediately on the introduction of the fishes into these media; but is renewed so soon as the fishes are replaced in atmospheric air. Lime-water, alcohol, ether, concentrated solutions of alkalis and salts, and the acids, extinguish it; but it returns when the liquids are diluted with a great quantity of water. The evolution of heat is not accompanied with phosphorescence, according to Hulme's observations, though Dessaignes asserts that carbonic acid is produced. During phosphorescence in the air, a clear, liquid, mucilaginous matter is perceived on the surface of fishes, which becomes a little turbid, consistent and luminous. This phosphorescent substance may be abstracted by washing, being by this means made to combine with the water, which is thereby rendered luminous. If fishes are put into glass vessels with water, a glittering circle soon appears at the surface of the liquid; if the water is shaken, it becomes luminous. The light disappears in water that has been boiled and is freed from the contact of air, but reappears as soon as the air reaches it. Phosphorescence ceases immediately on the commencement of fetid putrefaction. From all these facts it follows that the phosphorescence of dead animals is preceded by a decomposition effected by the influence of heat and air, whereby a luminous fluid is produced and given out. Probably it contains phosphorus, which is disengaged from the organic combination and is consumed by a slow combustion.

1 Phosphorescence of Living Plants.

CCCCII. It is said that the flowers of several plants disengage light, like sparks, in serene and warm summer evenings. This phenomenon, of which former writers speak,(6) was observed by Linnæus' daughter(7) in the nasturtium *(Tropæolum majus)* Linnæus is said only to have observed it in flowers whose petals have an orange colour. Haggren(8) thought he perceived luminous emanations from the marigold, *(Calendula officinalis,)* the *Lilium bulbiferum*, and the Indian pink, *(Tagetes patula, erecta,)* and therefore from yellow flowers, a little after sunset, when the air was still and warm, but not when it was humid. Johnson(9) says he saw sparks emitted from the flowers of several vegetables, the *Calendula, Lilium bulbiferum*, chalcedonicum, tagetes, helianthus, and polyanthus. The common white tuberose, *(Polyanthes tuberosa,)* became luminous in a sultry summer evening, and on looking at it closely, he perceived three flowers that were beginning to fade emit sparks of a yellowish, turbid light, giving an extremely strong odour;

(6) The ancient authorities are collected by C. Gesner (De lunariis, Zurich, 1555.)
(7) Abhandl. der Schwedischen Akademie, 1762, v. xxiv, p. 291.
(8) Neue Abhandl. der Schwedischen Akademie, 1777, v. ix, p. 59.
(9) Edinburgh Philos. Journ., v. vi, p. 415.

with all his attention, however, he was unable to hear any crepitation resembling the electric spark. The flowers of other vegetables are said to give out, during the night, a feeble and uniform light, of a greenish colour, approaching to blue, as Szuets(1) says he remarked in the *Phytolacca decandra.* Some naturalists have doubted the phosphorescence of flowers, because they have not seen it in their experiments. Thus Ingenhouss(2) saw no trace of light in the flowers of the nasturtium, either at twilight in the evening, or in summer nights, or in complete darkness. Senebier(3) and the younger Saussure(4) were not more successful. Neither could L. C. Treviranus(5) perceive any phosphorescence, in complete darkness, in the flowers of the Indian pink, of the tithonia, *Coreopsis tinctoria* and *Gonteria pavonina.* He therefore thinks, with Goethe,(6) that the light believed to have been seen in these flowers at twilight, was a pure illusion. Further, some naturalists say they have remarked an evolution of light from the flowing juice of an euphorbia, growing in Brazil. Murnay(7) first mentioned this phenomenon. Martius(8) who speaks of the plant under the name of *Euphorbia phosphorea,* says he once observed it.

CCCCIII. An evolution of light has been observed in several cryptogamia. Linnæus mentions the phosphorescence of the *Byssus phosphorea, (Dematium violaceum, Pers.)* Ducluzeau(9) saw confervæ shine. The same was exhibited to Funk and Brandenburg(1) by the *Schistotega osmundacea.* Brewster(2) observed phosphorescence in the *Chara vulgaris,* and *hispida,* particularly when placed on a warm iron. Derschau and Noeggerath(3) observed an evolution of light in a cryptogamic plant found on the surface of old wood in coal and other mines, and described under the name of *Rhizomorpha.* Bischof (4) discovered the circumstances in which the phosphorescence takes place. It is perceived in all parts of the plant, but chiefly in the young white shoots. It is more vivid in young than in old plants. Further, the light is stronger in such as grow in the moist and warm localities of mines, than in those placed in dry and cold situations. When the temperature is at 40°, the phosphorescence is stronger. The rhizomorphæ do not shine in vacuo,

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(1) Trommsdorff's Journal der Pharmacie, v. viii, p. 54.
(2) Versuche mit Pflanzen, v. ii, p. 273.
(3) Physiol. Végétale, v. ii, p. 21.
(4) Recherches Chim. sur la Végétation, p. 129.
(5) Zeitschrift für Physiologie, v. iii, art. 2.
(6) Zur Farbenlehre, v. i, p. 21.
(7) Gilbert's Annalen, v. lvi, p. 367.
(8) Reise in Brasilien, v. ii, p. 726.
(9) Essai sur l'Hist. Natur. des Conferves des Environs de Montpellier, p. 18.
(1) Gilbert. Annalen, v. xxx, p. 242.
(2) Edinburgh Philos. Journal, July, 1823, p. 194.
(3) Verhandlungen der Leopold Carol. Akad. der Naturforscher, v. xi, p. 2.
(4) Schweigger's N. Journal, für Physik und Chemie, v. ix, p. 259.

nor in any gases which have not oxygen in their composition. The light of the plants reappears in the atmosphere, even after they have remained some hours in vacuo, or in azotic gas. They shine more in oxygen than in air; the oxygen disappears and carbonic acid is produced, part of which seems to be absorbed, for it does not completely fill the space which the consumed oxygen occupied. Phosphorescence appears to vanish with the life of rhizomorpha.

CCCCIV. The causes of phosphorescence in vegetables are not yet ascertained. Pultney and Volta(5) regarded it as an electric phenomenon, produced by the idio-electric pollen. But against this may be advanced the fact of Haggren having seen the light proceed from the petals and not from the filaments of the stamina. Probably it is owing, if it occurs at all, to the emanation of a combustible matter, perhaps a volatile oil, which enters into a kind of combustion under the influence of the air. The *Dictamnus albus* is said to spread around it, during the warm summer evenings, an atmosphere that takes fire on the approach of a candle, and gives a brilliant blue flame.(6) The phosphorescence of cryptogamia appears likewise to be owing to a slow combustion, if we may judge from the foregoing experiments.

2 Phosphorescence of Living Animals.

CCCCV. Luminous phenomena are exhibited by many animals, aquatic as well as those living in air. They are more common, however, in the former than the latter; most animals of the inferior classes that inhabit the sea, infusoria, medusa, radiaria, annelides, many crustacea, several mollusca, and even some fishes, evolve light. To them is owing the phosphorescence of the sea, which has been observed in every zone, but most frequently between the tropics, by Loeffling, Ternstroem, Osbeck, Kalm, Hasselquist, Banks, Solander, Forster, Legentil, Labillardière, Peron, Humboldt, Krusenstern, Tilesius, and others. When a vessel ploughs the ocean, during the night, in a fresh wind, the agitated waves diffuse a glittering and reddish light which darts along the sea, similar to lightning.(7) Quoy and Gaimard saw the sea luminous as far as the 60° of south latitude; and M'Culloch observed it on the coasts of the Shetland and Orkney islands. Naturalists differ concerning its cause. Boyle(8) thought it was produced by the rapid rolling of the sea on itself, whereby a strong friction of the air on the surface of the

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(5) Meteorologische Briefe., v. i, p. 24.
(6) Edinburgh Philos. Journal, July, 1824, p. 232.
(7) I saw this beautiful object in September, 1811, in the Adriatic sea. It was owing to luminous infusoria which I perceived in the water by the aid of a microscope.
(8) Works, v. iii.

water was induced. Bajon,(9) Legentil,(1) Delaperriere,(2) Waesstroem,(3) and others, regarded it as an electric phenomenon, produced by the friction of the sea and of its saline particles. Beal,(4) Bourzes,(5) Leroy,(6) Godeheu de Riville,(7) Martin,(8) Canton,(9) Hulme,(1) and others, attribute it to the putrefaction of animal bodies, preceded by a decomposition of a peculiar kind, whereby a mucous-oily phosphorescent matter is generated. Silberschlag,(2) Borch,(3) and others take it for an effect of phosphorus existing in the sea. Mayer,(4) Helwig, Brugnatelli, and others, think that animals absorb, during the day, the light they exhale in the dark.

Vianelli(5) and Griselini's(6) observations in the Venetian marshes show that the phosphorescence of the sea is owing to living animals. Nollet(7) and Fougeroux de Bondarroy(8) also saw animals in the same place give out light. Moreover, it is placed beyond all doubt by the researches of Linnæus,(9) Forskael, Donati, Banks, Forster, Spallanzani, Viviani, (1) Péron, (2) Macartney,(3) Mitchell,(4) Tuckey,(5) Tilesius, M'Culloch, Quoy and Gaimard,(6) Murray,(7) and others. We will mention the animals in which phosphorescence has been observed.

CCCCVI. Among sea infusoria, many have been found phosphorescent by Baster,(8) Rigaud,(9) Labillardière,(1) Tilesius, M'Culloch, Quoy, and Gaimard. These chiefly belong to the genera *Cercaria*, *Volvox*, and *Vibrio*;

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(9) Mem. pour servir à l'Hist. Nat. de Cayenne. Paris, 1777. Rozier, Journal de Physique, v. iii, p. 106.
(1) Voyage aux Indes, v. i, p. 685.
(2) Mechanisme de l'Electricité, v. i, p. 111.
(3) Vetenskaps Akad. Nya Handling, 1798. p. 241.
(4) Philos Trans., v. xi, p. 599.
(5) Voyage aux Indes. Paris, 1704. Philos. Trans., 1713, p. 230.
(6) Mem. de Mathém. et Physique, v. iii, p. 143.
(7) Mem. sur la Mer Lumineuse. Ibid., v. iii, p. 269.
(8) Schwed. Akad. Abhandl., 1761, p. 224.
(9) Philos. Transact., 1769, p. 446.
(1) Ibid., 1800, p. 161.
(2) Sendschreiben über das im Jahr, 1720, Beobachtete Nordlicht. Berlin, 1770.
(3) Memoria sopra il fosforo marino ; in Atti dell' Acad. di Siena, v. vi, p. 347.
(4) In Schriften den Böhmischen Gesellschaft der Wissenschaften. 1785, Abthl. ii, p. 3.
(5) Nuove scoperte intorno de luci notturne dell' acqua marina. Venice, 1749, 8vo.
(6) Observations sur la scolopendre marine luisante. Venice, 1750, in 8vo.
(7) Mem. de l'Acad. de Paris, 1750, p. 57.
(8) Ibid., 1767, p. 120.
(9) De natura pelagi ; in Amœnitat. Acad., v. v, p. 72.
(1) Phosphorescentia maris quatuordecim animalculorum novis speciebus illustrata. Genoa, 1805, in 4to.
(2) Voyages aux terres Australes, v. i, p. 41.
(3) Observations on luminous animals, in Philos. Trans., 1810, p. 2, No. 15.
(4) New York Medical Repository, v. iv, p. 375.
(5) Account of an Expedition to Zaire, 1818.
(6) Annal. des Sciences Naturelles, January, 1825, v. iv, p. 1.
(7) Experimental Researches. Glasgow, 1826, p. 71.
(8) Opuscul. Subsciv. Haarlem, 1759, book i, p. 31.
(9) Mem. de l'Acad. de Paris, 1769, Hist., p. 26.
(1) Voyage, v. i, p. 63.

of this kind are also the *Trichoda granulosa,* and *triangularis,* the *Lincophea echinoides,* &c. Tilesius observed the phosphorescence of animals placed in a glass cylinder, filled with water, every time he moved the water, or shook it by striking the vessel. M'Culloch remarked the light to be extinguished on the death of the animals. Quoy and Gaimard poured diluted sulphuric acid into a vessel of sea water containing phosphorescent infusoria; they gave a very brilliant and sudden light, which quickly disappeared. The addition of pure sulphuric acid or wine vinegar killed the animals, and the phosphorescence immediately ceased. Peron(2) saw sertularia, gorgonia, alcyonia, sponges, and ises that had been taken from a great depth of the sea on the coast of new Holland, shine. The phosphorescence of sea-feathers, *(Pennatula phosphorea, grisea, rubra, argentea,)* was observed by Linnæus, Shaw,(3) Spallanzani,(4) and others. According to the researches of the latter, it is only the polypi situated at the end of the feather that emits light when moved. The phosphorescence lasts for a long time after death, and a mucous liquid flows, which Spallanzani regards as the source of the light.

CCCCVII. All the medusa, and especially those of tropical seas, appear to be phosphorescent in certain circumstances, according to observations made on many species *(Medusa noctiluca, pelagica, scintillans, hemisphærica, aurita, ovata, capillata, lucida,* &c.*)* by Forskael,(5) Banks, Dicquemare,(6) Spallanzani,(7) Macartney, Humboldt,(8) Tilesius,(9) M'Culloch, and others. The phosphorescence takes place, particularly around the tentacula, during the movements of the animal. Macartney saw it increased in the *Medusa lucida,* when he warmed the water. The light also became more vivid in alcohol; the animals, however, quickly perished in it, and their light was extinguished. Spallanzani remarked the trickling of a viscous fluid from the surface of medusa, which had a burning taste, and produced an itching sensation on the skin. This liquid, mixed with water or milk, renders them phosphorescent for some hours, particularly when they are warmed and agitated. Dead animals, whose light was extinguished, again became phosphorescent by the addition of a quantity of spring water, and by movement at a heat of 26° to 37°. Humboldt observed his fingers to shine for some time after he had touched medusa; he also saw the light become stronger

(2) Annal. du Mus. d'Hist. Nat., v. v, p. 133.
(3) Travels in Algiers and Barbary.
(4) Memorie di Matematica e Fisica della Societa Italiana, v. ii, p. 603.
(5) Descriptiones Animalium quæ in itinere orientali observavit. Copenhagen, 1775, p. 109.
(6) Rozier, Journal de Physique, v. vi, p. 319.
(7) Memorie sopra le meduse fosforiche; in Mem. della Soc. Ital., v. vii, p. 271.
(8) Reise in die Æquinoctial-Gegenden des neuen Continents, v. i, p. 109.
(9) Annalen der Wetterauer Gessellschaft, v. iii, p. 567.

when the animals were galvanized. The light of medusa to which Macartney applied an electric shock, was extinguished for an instant, but afterwards reappeared more vividly than previously. The phosphorescence of beroes *(Beroe fulgens, ovatus, pileus)* was observed by Bosc,(1) Macartney, and others. It is so much more vivid as they move rapidly. Animals, from the genera *Physalia, Rhizophora, Stephanomia,* and *Physophora,* have also been seen to be luminous. Viviani observed a small phosphorescent asterias, and Peron(2) found ophiura *(Ophiura telactes, phosphorea)* on the rocks of Bernier island, which gave out light.

CCCCVIII. Luminous phenomena have been observed in sea-worms, nereides, *(Nereis noctiluca, phosphorans, cirrigera, mucronata, &c.)* and planaria, *(Plenaria retusa,)* by Auzout,(3) Delavoye,(4) Vanelli, Griselini, Linnæus,(5) Viviani, and others. Even earth-worms, *(Lumbricus terrestris,)* according to Flaugergues(6) and Brugière's(7) observations, diffuse a light at the period of copulation. Among mollusca there are also some luminous ones, as the *Pholas dactylus,* whose phosphorescence Pliny(8) was long since acquainted with, and on which Reaumur(9) and the academy of Bologna(1) made many experiments. Its bluish white light is the more sensible as the animal is lively, fresh, and supplied with its fluids. It is more powerful in summer, and at the period of propagation, than at other times. It is not only the external parts, and particularly the respiratory tubes, but also the internal parts, that shine. The water that flows from these animals, and a viscous mucus they excrete, also afford light. They communicate phosphorescence to the fingers of those who touch them, as likewise to the mouth and spittle of others that eat them. The light disappears in vacuo, but reappears in the air. A moderate heat increases its brightness, whilst cold and the boiling heat extinguish it. If the pholades are sprinkled with tepid water, or milk, the light is more vivid, and the water and the milk become luminous. The phosphorescence lasts for some time in oil. A weak solution of sea-salt and of saltpetre and spirit of ammonia makes it more intense. On the other hand, concentrated solutions, vinegar, wine, alcohol, sulphuric acid, and cor-

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(1) Hist. Nat. des Vers., v. ii, p. 147.
(2) Voyage, v i, p. 121.
(2) Sur les vers luisans dans les huitres; in Mem. de l'Ac. de Paris, v. x, p. 453.
(3) Lettres sur les vers luisans; ibid., p. 455.
(4) Diss. res. Adlas. De Noctiluca Marina. Upsal, 1752.
(5) Lettre sur le phosphorisme des vers de terre; in Journal de Physique, v. xvi, p. 311.
(6) Sur la qualité phosphorique des vers de terre dans certaines circonstances; in Journal d'Histoire Nat., v. ii, p. 267.
(7) Hist. Nat. l. 9, c. 61
(8) Des merveilles des dails, ou de la lumière qu'ils repandent; in Mem. de l'Acad. de Paris, 1723, p. 198.
(9) De luce dactylorum; in Com. Ac. Bon., 1745, v. ii, part 1, p. 248. Beccaria, Monti, Galeati, and Balbi performed the experiments.
(1) Hist. Nat. des Vers., v. ii, p. 174.

rosive sublimate rapidly extinguish it. It continues for some days after death, and is put an end to at the commencement of putrefaction. When animals dry, the property of shining disappears, but it is renewed for some time if they are rubbed or moistened with water, particularly if it be tepid.

Among phosphorescent mollusca are the biphora, according to the observations of Bosc,(2) Tilesius, and others, and the pyrosoma, *(Pyrosoma atlanticum, giganteum,)* according to Peron, Desmarets, and Lesueur.(3)

CCCCIX. Many crustacea are phosphorescent. Thulis and Bernard(4) observed phosphorescence in the *Gammarus pulex*, during the summer, in the south of France, and Hablitzl,(5) in the Caspian sea. Banks, Macartney, Tuckey, and Tilesius, saw some crabs shine, especially the *Cancer fulgens*. This phenomenon has also been remarked in several species of the genus astacus,(6) palæmon, crangon, penæus, squilla, limulus,(7) lynceus,(8) &c.

Phosphorescence has also been said to have been observed in fishes. Loeffling and Bajon(9) saw dorades *(Coryphæna hippuris)* in multitudes, shining, and Riville, troops of the *Scomber pelamys*. M'Culloch quotes, as phosphorescent, a species of leptocephalus. However the phosphorescence of fishes may depend on the movements they cause, while swimming, among infusoria, and other shining animals in the sea, Tilesius attributes it, in many, to their scales.(1)

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(2) An. du Mus., v. iv, p. 441.
(3) Bulletin des Sciences, May, 1815.
(4) Obs. sur les crevettes de rivière phosphoriques ; in Rozier's Journ., v. xxviii, p. 67.
(5) Pallas, Nordische Beiträge, v. iv. p. 396.
(6) Tilesius has described and partly figured many phosphorescent crustacea, in his atlas to Krusenstern's voyage.
(7) Macartney, loc. cit.
(8) Riville in Mem. etrang. de l'Ac., v. iii, p. 269.
(9) Mem. pour servir à l'Hist. de Cayenne, v. ii.
(1) The phosphorescence of the sea was attributed by the ancients to the agency of Castor and Pollux. Besides Boyle, the Abbé Nollet was one of the first to mention its production from the friction of the particles of sea water. Leroy was not among those who assigned putrid animal matters as the cause ; he accused the collision of the particles of dissolved marine salt, (Mem. sav. etrang., v. iii.) Sir J. Pringle thought it arose from putrefaction, because he ascertained that the muriates of soda and lime hastened that process in sea water by giving it a greater solvent power. Among fishes, some dolphins, (as *Coryphæna hippuris)* are phosphorescent. Of the *Pholas dactylus* alluded to, Pliny says that they shine in darkness, and the more as they are supplied with water ; they shine when in the mouth, when being eaten, when held in the hands, and the drops that fall on the hands and habiliments are brilliant. Thomas Bartholin (De luce animalium, 1647, in 8vo) and Oligerus Jacobæus (Acta Haf., v. v) found on opening cuttle fish *(Sepia octopus)* that their viscera shone. After Vianilli, Francisco Grisellini, and Linné had established the origin of marine phosphorescence from animalculæ, the following observed the fact in the various situations :—Fougeroux de Bondarroy saw it in the lagunes of Venice ; Forster in Cook's voyages, 1772 and 1775 ; Ternstroem, a pupil of Linnæus, in the Chinese seas ; Dagelet in the bay of Antongil, Madagascar, and off the Cape of Good Hope, and Rigaud in the seas of the Antilles. The *Medusa noctiluca* was first observed by Forskahl ; the *Medusa scintillans* by Macartney, off Margate ; the *Medusa pellucens* by Sir J. Banks, in Cook's voyages. Sir J. Banks observed the *Cancer fulgens*, between Madeira and Rio Janeiro. Blood-red sea water, one of the plagues of Egypt, but which now and then occurs in these days, is owing to the propagation of innumerable quantities of blood red marine lice, *(Daphnia pulex.)* Capt. Parry, in his voyage to the North Pole, saw red snow ; it became redder by pressure, as when the sledges

CCCCX. Among animals living in the air, many insects are remarkable by their phosphorescence. Of these, in the order of coleoptera, are the shining worms, (*Lampyris noctiluca, splendidula, italica, ignita, phosphorea, nitidula, lucida, japonica, pennsylvanica,* &c.,) the source of light is in the abdomen.(2) Some beetles (*Elater*) also shine, particularly the cucujo (*Elater noctilucus*) of the West India Islands and South America, whose glittering and emerald-like light is mentioned by Sloane,(2) P. Browne,(3) and Fougeroux.(4) The elater ignitus, phosphoreus and different other species mentioned by Illiger,(5) are likewise shining. In the *Elater noctilucus,* the light proceeds, according to Curtis' observation, from two eye-formed elevations of the breast and the base of the abdomen. He thought they excited and extinguished it at will. Having taken away the luminous matter immediately after the death of an insect he beheld the phosphorescence maintained for some time subsequently.

Luce,(7) describes a species of beetle (*Scarabœus phosphoricus*) of the south of France, the abdomen of which shines. According to Afzelius,(8) the hollow and globular-formed antennæ of the *Paussus spheroceros* emit a phosphoric light. Latreille(9) reports an observation of one of his friends, who is said to have seen the eye-spots of the *Buprestis ocellata,* shining. Sutton(9) says that of the orthoptera, the mole-cricket is phosphorescent, (*Acheta gryllotalpa.*) In the order hemiptera the lantern-carrier, *Fulgora laternaria,*(2) and *serrata,* of South America, *F. pyrrhorhyncus* of the East Indies, and *F. candelaria*(3) of China, are brilliant. The luminous part of

crushed it. Captain Ross observed the same. Could this appearance depend on animalculæ? Milky seas have been seen on the western coasts of India and about New Guinea; they are caused by immense masses of mollusca, whose ova and embryons float at certain seasons on the surface of the sea, frequently covering many square miles.—Trs.

(2) The female of the *Lampyris noctiluca* excels all the rest in the beauty of its light. It is of a light bluish or greenish colour, and seems to envelope the whole of the insect. The male fly has a soft and delicate bluish light. It requires a temperature of about 55.7° for its appearance. The light of the female glow-worm is of a light topaz colour, with rather a tinge of green. The hour upon a watch may be distinguished by it. The light of the male is of the same colour. The fire-fly produces two degrees of light, the one fainter than that of the glow-worm, but without intermission. The second is a vivid white light, intermitting instantaneously, like vivid sparks of fire suddenly extinguished. Its power of illumination exceeds that of the glow-worm and all other animal light. The intermitting light gives the appearance of a membranous veil being removed from the surface of the organ, and suddenly drawn over it. The glow-worm requires a mean temperature of 50.7° for its appearance.—Trs.

(3) A Voyage to Jamaica. London, 1707, v. ii, p. 206.

(4) Nat. Hist. of Jamaica. London, 1756, p. 432.

(5) Mem. de l'Ac. de Paris, 1766, p. 340.

(6) Berliner Magazin der Naturforschenden Freunde, Jahrgang i, p. 141.

(7) Zoological Journal, 1827, No. 11, p. 379.

(8) Description d'un insecte phosphorique qu'on rencontre dans une partie du district de Grasse, Depart. du Var; in Nouv. Jour. de Physique, v. i, p. 300.

(9) Linnæan Transact., v. iv, p. 261.

(1) Hist. Nat. des Insectes, v. x, p. 262.

(2) Kirby and Spence, Introduction to Entomology, v. ii, p. 421.

(3) Merian, Insecta Surinam, p. 49. Richard and Count Hoffmannsegg (Ueber das Leuchten der Fulgoren; in Berlin Magazin, Jahrg. i, p. 152) have raised a doubt concerning the phosphorescence.

their body is the anterior portion of the head, which forms a vesicular protuberance.(4) Olivier says that cicada shed light. Of the lepidoptera, the abdomen of the *Pyralis minor* is slightly luminous, according to Brown. Of the myriapoda, the *Scolopendra electrica, phosphorea* and *morsitans,* according to Garman,(5) Reaumur,(6) Linnæus,(7) Fougeroux,(8) and Macartney's(9) observations are distinguished by a phosphoric light. M'Culloch remarked the same in the species of julus, and among the arachnida in the *Phalangium.* Macartney says, the *Scolopendra electrica* emits a luminous matter, which, taken up in the fingers, gives a phosphoric light for several seconds.

CCCCXI. The phosphorescence of insects has occupied much of the attention of naturalists. A vast number of experiments, in order to ascertain its conditions and causes, have been made on shining worms; on the *Lampyris splendidula* by Templer,(1) Waller,(2) G. Forster,(3) Guenau de Montbeillard,(4) Razumowsky,(5) Macartney,(6) and G. R. Treviranus;(7) on the *Lampyris noctiluca,* by Hermbstædt,(8) Heinrich,(9) and Murray;(1)

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(4) This fly is of a very considerable size, measuring nearly three inches and a half from the tip of the front to that of the tail, and about five inches and a half from wing's end to wing's end, when expanded; the body is of a lengthened oval shape, and divided into several rings or segments; the head is nearly equal to the length of the rest of the animal, and is oval, inflated, and bent slightly upwards; the ground colour is an elegant yellow, with a strong tinge of green in some parts, and marked with numerous bright red-brown variegations, in the form of stripes and spots; the wings are very large, of a yellow colour, most elegantly varied with brown undulations and spots, and the lower pair is decorated by a very large eye-shaped spot on the middle of each, the iris or border of the spot being red, and the centre half red and half yellow, with longitudinal red stripes. This beautiful insect is a native of Surinam, and many other parts of South America, and during the night diffuses so strong a phosphoric splendour from its head or lantern, that it may be employed for the purpose of a candle or torch; and, it is said, that three or four of the insects tied to the top of a stick, are frequently used by travellers for that purpose. The celebrated Madam Mereau, in her work, "on the insects of Surinam," gives a very agreeable account of the surprise into which she was thrown by the first view of the flashes of light proceeding from these insects. "The Indians once brought me," says she, "before I knew that they shone at night, a number of these lantern flies, which I shut up in a large wooden box. In the night they made such a noise, that I awoke in a fright, and ordered the light to be brought, not knowing whence the noise proceeded. As we found it came from the box, we opened it, but were still much more alarmed, and let it fall to the ground in a fright, at seeing a flame of fire come out of it; and, as many animals as came out, so many flames of fire appeared. When we found this to be the case, we recovered from our fright, and again collected the insects, highly admiring their splendid appearance."—Trs.

(5) Donovan, An Epitome of the Natural History of the Insects of China. London, 1798.

(6) Scolopendræ lux innata; in Misc. Acad. Nat. Curios., Dec. 1, Ann. 1, 1670, p. 307.

(7) Mem. de l'Acad. de Paris, 1723, p. 204.

(8) Abhandl. der Schwed. Akademie, 1746, p. 62.

(9) Mem. de l'Acad. de Paris, 1766, p. 339.

(1) Some observations concerning glow-worms; in Philos. Transact, 1671, v. vi, No. 72, p. 2177; No. 78, p. 3035.

(2) Observations on the *Cicindela volans,* or flying glow-worm, ibid, 1684, v. xv, No. 167, p. 841.

(3) Göttingisches Magazin der Wissenschaften und Literatur., Jahrg. iii, art. 2, p. 80.

(4) Mem. sur la lampire; in Nouv. Mem. de l'Ac. de Dijon, 1782, sem. ii, p. 80.

(5) Mem. sur le ver luisant; in Mem. de Lausanne, v. ii, part 1, p. 240.

(6) Philos. Transact., 1810, part 2, p. 275.

(7) Ueber das Leuchten der *Lampyris splendidula;* in Vermischten Schriften, b. 1, p. 87.

(8) Magazin der Naturforschenden Freunde in Berlin, Jahrg. ii, p. 248.

(9) Ueber die Phosphorescenz der Körper. Abhandl., v. iii, p. 375.

(1) Experimental Researches. Glasgow, 1826, p. 9.

on the *Lampyris italica*, by Nollet,(2) Spallanzani,(3) Carradori,(4) Brugnatelli, and Grotthuss.(5) Macaire(6) experimented on the *Lampyris noctiluca* and *splendidula*, and Tweedy John Todd(7) on all the three species. The results of these researches are contradictory in several points, and the theories erected to explain the phenomenon bear more or less the stamp of the chemical opinions which prevailed at the period the experiments were made. We will expose the principal points.(8)

The source of the light is chiefly situated in the last rings of the abdomen. The luminous points, however, exhibit differences according to species, and are generally of greater extent in females than males. The greenish yellow light of the *Lampyris splendidula* proceeds from yellow spots, situated at the under surface of the last three rings. In males, to which some naturalists refuse a phosphorescent quality, there are only two small luminous points. The *Lampyris noctiluca* sheds a bluish or greenish light, proceeding from between the two penultimate segments, and from two spots on the sides of the last ring. The fourth ring has only one small brilliant point on its posterior border. In the *Lampyris italica*, the last two rings of the abdomen shine all over, and their light is a bright blue. Not only the perfect insects of the two

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(2) Observations sur la mouche luisante d'Italie, (Luceiola;) in Mem. de l'Ac. de Paris, 1750, p. 57.

(3) Chimico Essame degli Experimenti di Sig. Goettling sopra la luee del fosforo. Modena, 1796, p. 119.

(4) Brugnatelli Annali di Chimica. Pavia, 1797, v. xiii, 1808, 1809.

(5) Ann. de Chimie, v. lxiv, p. 19.

(6) Mem. sur la Phosphor. des Lampyres; in Journ. de Physique par Ducrotay de Blainville, July 1821, v. xciii, p. 46; Ann. de Chemie, v. xvii, p. 151.

(7) An inquiry into the nature of the luminous power of some of the Lampyrides, viz., *Lampyris splendidula, italica*, and *noctiluca*; in Journ. of Science and Arts. London, 1826, No. 42, p. 241.

(8) Animal phosphorescence is more remarkable among insects, and especially among coleoptera; of these, the genera elater, lampyris, and paussus are especially distinguished. The *Elater noctilucus* or *cucujo* of the Americans, or fire-fly of the British, according to Patrick Brown, (Hist. of Jamaica,) withdraws its phosphorescent organs when frightened. Its light is so brilliant, that with eight or ten of them a book may be perused as if by the light of a candle. The Indians carry them as a lantern, and the women ornament their hair with them. We should suppose this doubtful, as such usage would inspire the fear which makes them extinguish the light. Two other phosphoric moles are known: the *Elater phosphoreus*, of Geer, and the *Elater ignitus*, of Fabricius, belonging to South America and the Isles of the Antilles. The *Lampyres*, or glow-worms, have their light aroused by movement; the luminous matter may be obtained, and remains phosphorescent either in the air or vacuo, as long as it remains moist. The females are most brilliant, in order to attract the male. The *Lampyris noctiluca* and *splendidula* are the glow-worms commonly observed in this country. The *L. italica* is the *Lucciole* of the Italians. There are also the *L. ignita, phosphorea, nitidula, lucida, japonica, pennsylvanica*, &c. Gueneau de Montbeliard observes that, after copulation, these insects lose their brilliancy "as if they extinguished the torches of their loves by marriage." Afzelius describes another coleoptera of phosphorescent power. Its two antennæ are swelled at their extremities into small globules, which are brilliant lanterns, lighted at night. The insect is the *Paussus spherocerus*, and is described in Linn. Transact., vol. iv. The nocturnal butterfly, *(Pyralis minor,)* which Patrick Brown says is phosphorescent, shines feebly and at intervals. It is not improbable that many moths, which so often burn themselves in the candle, recognise their females in the night by feeble lights not cognisable to our eyes; for all nocturnal insects which thus fall into the flame, instead of avoiding it, show that they are seeking each other by means of light. Scolopendræ not only shine by night, but also avoid open day. Flaugergues maintains the phosphorescence of some earth worms in certain circumstances, particularly when about to copulate.—Trs.

sexes, but the larvæ also shine, as was observed by Swammerdamm,(9) Degeer,(1) Schmidt,(2) Macaire, and Todd. Macaire saw two small luminous points on larvæ that had just quitted the egg, and were not a line in length. The eggs themselves shed a feeble light, resembling that of phosphorus. Hence it would seem that the disengagement of light is not strictly connected with the generative act, although, according to Mueller,(3) it is greater during copulation than at any other time, that it remains bright in the female at the period of laying eggs, and that it diminishes in the male when the copulation is finished.

Naturalists are divided on the subject of phosphorescence being produced by special organs. Macartney believed he saw the light emanate from the fatty body, situated immediately beneath the transparent integuments of the luminous parts. He saw, moreover, in the last abdominal ring, two small oval sacs, formed of elastic spiral threads, like tracheæ, and containing a soft, yellow substance. Carradori, Mueller, and Murray, likewise admit that the luminous matter is contained in the vesicles or small sacs. Treviranus denies the existence of special organs for the disengagement of light, and considers the internal genital parts as the seat of the light. After having removed the thin, horny, transparent, and soft integuments, Macaire remarked, at the luminous points, a semi-transparent, yellowish-white substance, which, examined by the microscope, appeared to be formed of a multitude of ramose fibres, whilst nervous filaments spread throughout it, and a granular matter adhered to the fibres. This substance manifests a vivid phosphorescence in the dark, while humid; drying renders it opaque, and puts an end to its shining. In air and water it continues to cast a greenish yellow light for two or three days. Heat and galvanic action renew the phosphorescence, as long as the matter is not dry. Spallanzani and Carradori also ascertained that the shining parts of the *Lampyris italica* only shed light so long as they were moist. Spallanzani, Heinrich, and Todd say, that after separating these parts of the body, and while they were not dry, they succeeded in making them give a phosphorescent light by touching or pricking them with a pin. When Macaire exposed the substance to a heat of 41°, its brightness became more vivid; but if he persisted in heating it, the light diminished, and had a reddish hue; at 52° it was totally extinguished; the matter was then white, opaque, and like coagulated white of egg. Murray's experiments agree with these in the essential points. The light was extinguished in vacuo, and

(9) Bibl. Naturæ, v. i, p. 283.
(1) Mem. presentés à l'Ac. de Paris, v. ii, p. 261.
(2) Versuche über die Insekten. Gotha, 1803, b. i, p. 245.
(3) Illiger's Magazin für Inseektenkunde, b. 4, p. 175.

renewed on replacing it in the air. Carradori and Brugnatelli, on the other hand, assert that they saw it in vacuo; but this is doubtful. It disappears in irrespirable gases, and reappears both in air and oxygen gas. Murray says the matter continues to shine in carbonic acid gas, hydrogen and azote. Chlorine, nitric and sulphuric acids, irrevocably destroy its phosphorescence. Exposed to fire, it ceases to shine, burns, and emits an ammoniacal odour. Concentrated mineral and vegetable acids coagulate the luminous substance, thus causing the extinction of its light. The former with the aid of caloric dissolve it. Sulphuric acid produces a bluish-green colouring. The glitter of the luminous matter disappears in oil and fatty substances, which neither dissolve it with heat nor cold. Macaire supposes the light to cease then, because the fat prevents the air from reaching the luminous matter. Carradori, Brugnatelli, Murray, and Todd, say they have seen the phosphorescence continue in oil. Ether and alcohol cause it to cease directly, rendering the luminous matter white and opaque. The light is likewise, according to Sheppard's experiments, extinguished in camphorated alcohol.(4) Pure potass destroys the phosphorescence, and completely dissolves the matter, becoming of a yellow hue. A solution of corrosive sublimate and salts of copper destroys the light but coagulates the matter. The latter is not soluble in boiling water, and acquires a firmer consistence in it.

From these experiments, Macaire is led to infer the existence of a special shining matter, composed chiefly of albumen in a semi-transparent state, phosphorescent under the influence of moderate heat and atmospheric air, but ceasing to emit light as soon as it is completely coagulated.(5)

CCCCXII. Regarding the circumstances under which living animals shine, the following are deduced from experiments. Phosphorescence ordinarily commences at the close of twilight, when the shining parts appear like some points, which gradually increase. If animals are confined in a dark place before sunset, they begin to shine a long time before twilight. If they be exposed to the light whilst shining, their brilliancy is sensibly diminished, but always returns in darkness. The light is extinguished at the dawn of day, except in two points of the last ring, which continue to shed a feeble light, as was observed by Razumowsky and Macaire. Macartney remarks, that insects do not shine in the evening, if they have been withdrawn from the sun's rays during the day. Macaire made the same observation, at least on the first day of the experiment. On the other hand, Todd and Murray

(4) Kirby and Spence, Introduction to Entomology, v. ii, letter 25.

(5) Todd says, this matter is granular and organized; Macaire asserts that it is penetrated by nerves. According to the former, when it has lost its vital properties it is incapable of affording light. Vide Institution Journal, August, 1826.—Trs.

found that all the species, although kept during the day in dark places, did shine less in the evening, and even much sooner than when they had been exposed to the day light.

Carradori, Brugnatelli, Macartney, Treviranus, and others observed that the emission of light is at the will of animals. Mueller and Murray think that phosphorescence is voluntary only, inasmuch as animals can retire and conceal the luminous organs behind the opaque parts. Treviranus explains the phenomenon by the faculty which insects have of accelerating or retarding respiration, and by the influence which he asserts the air exerts over the intensity of the light. Macaire thinks the power of the will on the production of light cannot be denied, because any noise or a blow on the animal sometimes causes it to cease shining, and the light then disappears, except in the two points of the last ring. He attributes the cause of the phonomenon to the influence of the nerves. It is moreover certain that the light is augmented by the movements of the body.

The phosphorescence of living animals is dependent on the temperature of the air. In ordinary circumstances, animals, according to Macaire's experiments, only shine at an atmospheric temperature exceeding 12°. If a living insect, not shining, be immersed in water at 13°, light appears when the liquid is heated to 25° or 31°, and goes on increasing to 41°; at this point the animal perishes, without the cessation of the phosphorescence, but it disappears at 57°. If the water be left to cool, the light fails when the heat falls below 25°. If living insects be thrown into water, having a temperature from 43° to 51°, they immediately die, but at the same time emit a brilliant light. At 62° the light is extinguished, and it is not possible to revive it. When animals are warmed in the air, the same phenomena take place, except that a lower temperature is required to extinguish the phosphorescence. Solar rays, directed on an insect through a glass lens, also excite a light. If animals that are shining be exposed to an artificial cold, their brilliancy gradually diminishes and disappears as soon as the temperature falls below 12°. At zero the animals perish, but a heat of 21° may reproduce the light. These experiments agree with those made by Spallanzani and Carradori. According to the observations of Hulme, Spallanzani, and Heinrich, phosphorescence ceases when lampyri are congealed, but reappears when they are thawed, though the animals do not return to life.

Phosphorescence is moreover in dependence on the atmospheric air. Macaire placed shining worms under the receiver of an air-pump, and saw the light disappear as he withdrew the air. When the air was allowed suddenly to return, the phosphorescence was vividly renewed. In this manner he could extinguish and revive the light by alternately withdrawing and readmitting the air. He enclosed a lampyrus in a glass tube, and abstracted the air, which soon killed the insect. When, subsequently, he heated the tube to 50°, the phosphorescence did not reappear, yet it became sensible when air was introduced into the tube. These experiments have been frequently repeated with the same result.

Lampyri become very lively in oxygen gas, and when the heat is increased they emit a very brilliant light, which is stronger than in atmospheric air. When Macaire placed shining beetles in oxygen, their phosphorescence was augmented, but ceased after a short time. The same phenomenon was observed by Forster, Lichtenberg, Spallanzani, Carradori, and Sorg. Hulme, Davy, Hermbstaedt, Heinrich, and Murray, on the contrary, say they did not see the light become more intense in this gas. According to Macaire, nitrous oxide gas produced nearly the same effect. Insects perish immediately in chlorine, but with a little heat a reddish light is developed instead of a yellowish green; this soon disappears. The phosphorescence ceased rapidly in hydrogen gas; the animals perished, and their light could not be renewed by heat. Carbonic acid, sulphuretted hydrogen, carburetted hydrogen, and nitrogen gases produced precisely the same effects, as Hulme, Spallanzani, Razumowsky, Macartney, Hermbstaedt, Grotthuss, and Heinrich observed. H. Davy(6) and Murray saw the phosphorescence supported in hydrogen gas. Murray says it has also continued in carbonic acid gas. If shining beetles are plunged into water their light disappears after a few minutes. This should be attributed to cold, according to Macaire's experiments, for the light is extinguished the more rapidly as the temperature of the water is lower, whereas the phosphorescence remains a long time in water heated to 31°. It ceases in alcohol at the end of two minutes, and cannot be renewed by heat. In concentrated mineral acids the light is extinguished immediately, but not until after some minutes in diluted ones, and cannot afterwards be recalled.

Macaire exposed non-phosphorescent lampyri to an electric current without any sensible effect. On applying a spark from a Leyden jar to some insects of this genus, no disengagement of light was effected. A living lampyrus, which did not shine, being placed in a galvanic circle, began to shed a feeble light. Having moistened an insect with a little water, and conducted the galvanic fluid on it by means of two platina wires, he saw it immediately shine. The disengagement of light was maintained so long as the animal was exposed to the influence of galvanism, and its temperature increased about half a degree. A single pole did not excite any phosphorescence. A lampyrus was decapitated, and a conducting wire forced into the trunk, as far as the shining rings, whilst the other was applied to the slightly moistened

(6) Philos. Transact., 1810, p. 287.

surface of the insect, the chain being formed, a brilliant phosphorescence took place. Lampyri, that could not be made to shine by the electric spark, became directly luminous under galvanic action. Galvanism does not excite phosphorescence in vacuo, but causes its development as soon as air is admitted. From Todd's experiments, it would appear that all mechanical and chemical agents that cause pain in lampyri excite light. According to him, divers poisons, an alcoholic solution of iodine, the tincture of black hellebore, of nux vomica, the cyanuret of mercury and ammonia, kill lampyri, but their phosphorescence remains for some time after death. When the head of a living insect was separated from its trunk, or the luminous rings cut, the light was extinguished after five minutes; the body and rings, after some time, moved, and the phosphorescence then reappeared, though feebly, but became more vivid by heat.

CCCCXIII. Naturalists are divided in opinion concerning the cause of phosphorescence of lampyri. Beccaria and Monti compared it to that of the minerals that shine after being exposed to the sun. Carradori and Brugnatelli that light, combined with organic substances, is ingested by insects with their food, and is disengaged in a form perceptible to us in consequence of a vital operation in them. Spallanzani and Grotthuss regarded shining as the effect of a combustion maintained by the influence of the oxygen of the atmospheric air. H. Davy, Heinrich, and Treviranus attribute it to a matter containing phosphorus, which is separated from the humours of the animal during life, combines with the oxygen of the atmospheric air introduced by respiration, and, like phosphorus, becomes luminous on combustion. This opinion is founded on the presence of phosphoric acid in the animal humours, on the great resemblance between phosphorus burning slowly and the animal light, on the fact of the phosphorescence of insects occurring in the same circumstances as that of phosphorus, on heat and oxygen gas rendering it more vivid, whilst cold and the non-respirable gases extinguish it. Macartney and Todd consider it as an immediate operation of life, as a vital action, as an effect or manifestation of vital power. They think that external influences, heat, atmospheric air, oxygen, and other exciting gases, are only capable of producing phosphorescence, inasmuch as they excite the vitality of the animals, particularly the sensibility of the luminous organ, and that they can diminish or extinguish it by diminishing or annihilating the vital activity. This hypothesis is scarcely admissible, because the luminous parts, and the matter that sheds the light continue to shine, even after being separated from the body of the animal, and after the extinction of the manifestations of life, when they are placed in the conditions above cited,—a fact set beyond doubt by the multiplied experiments of Murray and Macaire. Weighing well all the circumstances, phosphorescence would seem to depend on a matter, the product of the changes of composition accompanying life, and, to all appearance, secreted from the mass of humours by particular organs. This liquid probably contains phosphorus, or an analagous combustible substance, which combines with the oxygen of the air, or of aërated water, at a medium temperature, and thus produces the disengagement of light. The preparation and secretion of this substance are acts of life, which change, augment, or decrease by the influence of external stimulants, whose action on the animals modifies their manifestions of life. But the phosphorescence itself depends on the composition of the secreted matter, and cannot be regarded as a vital act, because, on certain occasions, it continues for whole days, even after the death of the animal. All that can be said on the utility of the light in the economy of shining insects, is that probably the preparation and secretion of the luminous matter is important to the preservation of life in these animals. Neither do we deny that this light may aid the sexes in finding each other at the epoch of copulation; at least it is observed that the males are attracted by the brilliant objects. Perhaps it may serve to protect them from the aggressions of enemies.

CCCCXIV. Phosphorescence is a rare phenomenon in aërial animals of the higher classes. Gruendler,(7) Sturm,(8) and others, saw an emission of light from the eggs of the grey lizard. It also appears from Rolander's observations,(9) that a species of toad or frog inhabiting Surinam, is luminous. The urine is phosphorescent in some mammifera, in the *Viverra mephitis,* and *putorius,* as Azara(1) and Langsdorf(2) assert from information. The same happens sometimes in the urine and sweat of man, under circumstances which I shall explain hereafter.

Some naturalists, F. A. A. Meyer,(3) Pallas,(4) Heinrich, and G. R. Treviranus, have ranged under this category the glittering of the eyes of some mammifera, of cats, dogs, wolves, foxes, martens, and other carnivora, as also of sheep, cows, and horses. Pallas thought the light of these animals emanated from the nervous membrane of the eye, and considered it as an electrical phenomenon. B. Prevost(5) observed the glittering eyes, not only in cats and dogs, but also in the sheep, the cow, and the horse, generally, in fact, in animals whose eyes possess a *tapetum lucidum.* He likewise saw it in the

(7) Von dem Leuchten der Eidechsen-Eyer im Finstern; im Naturforscher, part 3, p. 218.
(8) Deutschlands Fauna, Abth. iii, p. 2.
(9) F. Boie (Oken's Isis., v. xx, parts 8, 9, p. 726) speaks of a passage taken from a manuscript having the following title: *Diarium Surinamicum, quod sub itinere exotico conscripsit Dan. Rolander.*
(1) Essais sur l'Histoire Natur., des. Quadrupedes de Paraguay. Paris, 1801, v. i, p. 215.
(2) Reise, v. ii, p. 184.
(3) Ueber das nächtliche Leuchten der Katzenaugen; in Voigt's Magazin, v. viii, part 3, p. 105.
(4) Zoographia Rosso-Asiatica, v. i, p. 14.
(5) Considerations sur le brillant des yeux du chat et de quelques autres animaux; in Bibliot. Britannique, 1810, v. 45.

eyes of different ophidia, and some insects, particularly of the *Sphinx atropos.* The shining never took place in complete darkness, and was neither produced voluntarily nor in consequence of moral emotion, but proceeded solely from the reflexion of the light which fell upon the eye. Gruithuisen,(6) in his experiments, also found that no light proceeds from the eyes in totally darkened places, and that this emission only occurs when the light, after arriving at the eye, though feebly, is reflected. He ascertained, too, that cats' eyes, living as well as dead, glistened. I have myself observed this phenomenon in the head of a cat that had been separated from the trunk for twenty-four hours, and it only disappeared when the optical humours had become turbid. Very lately, Esser(7) has made experiments on the glistening, which have led to the same conclusions. The eyes of cats, dogs, rabbits, sheep, and horses, do not glitter in totally dark places. Reflexion of light took place in the eyes when dead, after the removal of the cornea, of the iris, and the crystalline lens. The phenomenon in this case cannot therefore be placed in the number of phosphoric effects.(8)

CHAPTER THIRD.

Of the Electrical Phenomena of Living Bodies.

CCCCXV. In order to a more full understanding of what follows, I shall first of all briefly lay down the fundamental propositions regarding electricity, and shall develope, in as few words as may be, the circumstances under which bodies in general exhibit electrical phenomena.

By the word electricity it is known that physical philosophers understand the property which bodies have, in certain circumstances, of attracting and repelling light bodies of various kinds, that approach them. The ordinary means employed to place bodies in the electric state is friction. If a glass tube be rubbed with wool, it attracts from certain distances slips of paper, hairs, small feathers, thin metallic leaves, balls of cork or elder-pith attached

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(6) Licht der Katzen-augen; in Beiträgen zur Physiognosie und Eautognosie. Munich, 1812, p. 199.

(7) Ueber das Leuchten der Augen bei Thieren und Menschen; in Kastner's Archiv. für die gesammte Naturkunde, v. viii, p. 394.

(8) It is nevertheless certain that cats, wolves, and, in fact, almost all the higher animals, when either enraged or fearful, have a more than usual splendour of the eyes. Indomitable anger produces the same in man: thus Homer.

> "His flowing eye-balls roll with living fire."—*Bk.* 18.
> "While anger flash'd from his disdainful eyes."—*Bk.* 22.

Many of the ancient philosophers, Plato, Epicurus, &c., believed that light was darted from the eyes and produced the effects of love, envy, ire or fascination in others.

> "Nescio quis tenuos oculus mihi fascinat agnos."

This probably is the origin of the creeds concerning the fascination of serpents exercised over their prey; as also of the power of the basilisk to kill with its look.—Trs.

by silken thread, and afterwards repels them. If the friction be increased, brilliant sparks, accompanied by a crackling noise and a peculiar odour, proceed from the body. When these sparks touch the skin, they cause a tingling sensation. Besides glass, sulphur, amber, porcelain, and among organic substances, resin, sealing wax, paper, silk, wool, and hair, exhibit similar phenomena. All bodies that become electric by friction have the name of electrics, whilst those in which this action does not cause sensible electric phenomena, such as metals and liquids, are denominated non-electrics.

To account for these phenomena, physical philosophers have assumed that a subtle, imponderable, and peculiar matter, the electric fluid, proceeds from bodies that are in an electric state, and that this matter is communicated to other bodies. According to Grey's discovery, the electricity is only propagated through certain bodies, with great but variable rapidity. Bodies are divided, according to the facility of conveying electricity, into conductors and non-conductors. Those which receive the electric matter and give it out when they approach bodies that have been rubbed, or communicate with similar ones, are called conductors, whereas those which retain it take the name of non-conductors, or isolators. All non-electric bodies, metals in the state of regulum, coal and graphite, are good conductors of the electric fluid. Expanded air, vapours, water, acids diluted by water, alkalis, saline solutions, and moist organized substances, are imperfect or demi-conductors. Electrics, such as, among inorganic matters, glass, gems, diamond, phosphorus, sulphur, selenium, iodine, jet, many metallic oxides, common atmospheric air and the gases, and, among organic bodies all the resins, fatty oils, tallow, wax, camphor, dry vegetable fibre, linen, silk, hair, wool, feathers, leather, are non-conductors or isolators. No strongly marked line of demarcation, however, can be strictly established between conductors and non-conductors, because some substances are sometimes conductors and sometimes not, according to their degree of warmth, moisture, aggregation, &c., otherwise the electric matter accumulates in various quantities in bodies, whether conductors or isolators, and when charged with it they are never found to have their weight increased, even when the most accurate balances are used.

Electricity presents, as Du Fay first observed, according to the divers bodies in which it is excited, two striking differences that have been designated by the names of vitreous and resinous electricity. The former is put into action by the friction of glass, rock crystal, diamond, and hair; the latter is produced by that of resins, amber, silk, and paper. The existence of two electric states opposed to each other has been confirmed by the researches of Boulonger, Wilke, Symmer, Wilson, Cigna, Aldini, Ritter, and others.

When two bodies are rubbed together, both the rubber and that which is rubbed, become electric, but in an opposite manner, one taking the vitreous electricity and the other the resinous. Bodies having the same electricity are mutually repulsed, whilst those that are endued with different electricities are reciprocally attracted. The repeated contact of two bodies possessing contrary electricities causes the neutralization and destruction of these electricities: repose, or electric indifference being the consequence of their reunion. The opposition which exists in electrical phenomena has been designated by Lichtenberg under the names of plus and minus electricity. Vitreous electricity has also been called positive, and the resinous, negative. The difference which exists between the two electricities is likewise made known by that of the luminous phenomena which they occasion in the dark, by the production of different figures in the powder of resins, by the chemical effects they determine, and by the different influence they exert on the senses of the living man.

CCCCXVI. The inherent quiescent electricity in bodies may be excited by other means than friction, and be decomposed into positive and negative electricities. There is scarcely an operation in nature during which two heterogeneous bodies or matters enter into mutual action, without a greater or less derangement of the electric equilibrium and consequent manifestation of electrical phenomena. The derangement of the electric equilibrium is discovered, according to the diversity of the conditions under which the action occurs, either by placing the electricities in the state of free tension, or by their flow in a continuous current, which again causes their neutralization, a fact which may be ascertained by the aid of minute electrometers or galvanometers. We will mention the principal conditions in which the equilibrium of the two opposite electricities is destroyed.

1. Several bodies, particularly calcareous spar, topaz, mica, rock crystal, island spar, turmolin, &c., according to Coulomb, Dessaignes, Haüy, Becquerel's, and other experiments, become electric by simple compression of their parallel surfaces between the fingers. If a plate of cork be pressed against elastic gum, amber, copper, zinc, silver, &c., it is positively electrified, whilst the latter bodies take the negative electricity. On the other hand the cork acquires negative electricity when it is pressed against dry animal substances, or on gypsum, heavy spar, fluor spar, which then show positive electricity.

2. Certain bodies exhibit electric phenomena when their state of aggregation is changed. When water is converted into vapour in vessels, this assumes the negative electricity. Grotthuss found, in his experiments, that water congealing rapidly acquires positive electricity, and that when quickly evaporated at a high temperature, it takes the negative. Perhaps the

phenomenon of light which is observed in the crystallization of different salts is also electric: at least the electricity shows itself at the electrometer immediately after the crystallization is effected. Grotthuss remarked no constant rule in regard to the nature of electricity. The phenomenon observed by Buechner during the sublimation of benzoic acid is also probably an electric effect, dependent on the change in the state of aggregation.

3. Many crystals, when warmed, exhibit contrary electricities at the opposite extremities of their axes a fact which occurs, according to the experiments of Aepinus, Canton, Brand, Haüy and Brewster, in the turmolin, topaz, axinite, boracite, mesotype, diamond, heavy spar, calcareous spar, fluor spar, celestine, strontian, sulphate of magnesia, amethyst, granite, sulphate of iron, &c.

4. If two wires of the same metal are placed in contact with each other, one of which is more heated than the other, the hotter wire takes the negative electricity, and the cooler one the positive, according to Dessaignes, Seebeck, and Becquerel's observations.

5. When heterogeneous solid and fluid bodies enter into immediate contact, opposite electricities are mutually excited in them, the tension of which is more powerful as the matters are more heterogeneous. This phenomenon is nowhere more sensible than in the contact of different metals, and it is on it that electricity by contact, or galvanic electricity, is founded.

6. Lastly, a disengagement of electricity takes place during the chemical changes of ponderable matters, according to the experiments of Lavoisier. Laplace, Becquerel, Pouillet, and others.

CCCCXVII. Let us now inquire which are the living bodies that exhibit electric phenomena, and what are the circumstances and conditions in which they take place. It is known that cats, foxes, martens, hares, and other animals covered with fur, give out electric sparks, accompanied by a crackling noise, when their fur is rubbed. The down of birds is also very electric, according to the observations of J. F. Hartmann,(9) and J. Meyer.(1) These phenomena cannot be considered as dependent on life, since the hairs and feathers are equally electric after death, when they are warmed or rubbed.

Abstractedly from this circumstance, it may be presumed that all living bodies develope electricity, although in a feeble degree, because all the conditions which are accompanied, in inorganic bodies, by electric phenomena, are met with in them. Of these are the evaporation of fluids, the change in the state of aggregation, and the changes of composition that take place

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(9) De electricitate plumæ psittaci notata quædam; in Nov. Act. Nat. Curios., v. iv, p. 76; Neues Hamburger Magazin, sec. 20, p. 129.

(1) Anmerkungen über die Elektricität der Vögel; in den Abhandlungen einer Privat-Gesellschaft in Böhmen, v. iv, p. 82.

in the acts of assimilation, of respiration, nutrition, and secretion, of which they are an essential part. Vegetables and animals at the period of their full vigour, are continually imbibing heterogeneous substances, which are assimilated by the exhalation of certain materials into the surrounding media and the absorption of constituent parts of the atmosphere; when assimilated and formed into nutritive fluid, they combine with the solid parts, and, in animals, these again pass into the liquid state. Moreover, in all these acts, heterogeneous fluid and solid parts enter into mutual contact and react on each other. Homogeneous matters are converted into heterogeneous, and these into homogeneous. According to analogy with the phenomena which inorganic bodies present in similar circumstances, we may suppose that in all these operations in living bodies, there is sometimes manifestation, sometimes saturation, of opposite electricities. Various experiments made on living animals, the results of which will be mentioned, speak in favour of this conjecture. Few have as yet been made on vegetables, to examine their electrical state. Pouillet(2) however asserts, that he observed a disengagement of electricity during the germination of plants. He placed several pots filled with earth, and containing different seeds, on an isolated stand in a chamber, the air of which was kept sufficiently dry by quick lime. The stand was placed in connexion with a condensor. During germination, no mark of electricity was manifested, but the seeds had scarcely sprouted when signs of electricity were distinctly perceived; and when the young plants were in a complete state of growth, they gave to the condensor a charge which separated the two leaves of gold half an inch from each other. Moreover, Pouillet(3) supposes that plants develope electricity when they exhale carbonic acid gas, because the latter gives marks of electricity at the time of its formation. The action of vegetables on the air appeared to him one of the principal sources of atmospheric electricity.

CCCCXVIII. Electricity by contact, or galvanic electricity, is manifested in living animal parts, when uncovered nerves and muscles are brought into contact, and is then shown by the production of contractions or convulsions in the muscles. This phenomenon was first observed by Galvani.(4) After decapitating a living frog, separating the fore limbs, and quickly drawing the skin off, he separated the vertebral column, and only left the spinal marrow communicating with the posterior limbs by the lumbar nerves; he

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(2) Bulletin general des Sciences, Sept., 1825; Physique, p. 236.

(3) Mem. sur l'electricité des fluides elastiques, et sur une des causes de l'electricité de l'atmosphere; in Annales de Chim. et Phys., August, 1827, p. 401.

(4) De viribus electricitatis in motu musculari; in Comm. Ac. Bononiens, v. vii, 1792. Dell' uso e dell' attivita dell' arco conduttore nell contrazioni dei Muscoli. Bologna, 1794. Memorie sull elettricita animale di L. Galvani al celebre Abbate Lazaro Spallanzani. Bologna, 1797.

then took with one hand one of the animal's thighs, seized the vertebral column with the other, and bent the former on the latter until the crural muscles touched the lumbar nerves. At the moment of contact the muscles were strongly convulsed. The experiment also succeeded after having isolated the frog on glass cylinders. It has been repeated with the same result by Volta,(5) Valli,(6) Aldini,(7) Pfaff,(8) Von Humboldt,(9) Fowler,(1) Ritter,(2) and others. Aldini says he observed convulsions in the muscles, as a consequence of the mutual contact of muscles and nerves, not only in the same frog, but in two different ones. He adds, that he has remarked them when he placed the nerves of a frog in contact with the muscular flesh of the nucha of a recently killed ox. Humboldt made numerous experiments of this kind on frogs. He saw convulsions induced when he placed on a dry glass plate a posterior extremity, the crural nerves of which had been exposed, and touched the nerves and muscles with a piece of fresh muscular flesh isolated at the end of a stick of sealing wax. Convulsions also commenced, when, instead of one slip of flesh, he employed in the formation of the chain three different pieces, one of which touched the nerve, the other the thigh, and the third the two others. Similar and analagous experiments made by Pfaff, Ritter, and others, produced the same results. But they only succeed so long as the frogs possess vital activity in full play, especially in the spring, after copulation, when performed on animals that are not too small, and when the preparatory steps are rapidly executed.

These different experiments prove sufficiently that animal parts are capable of forming galvanic chains and producing a galvanic effect, without any mechanical excitement causing contractions of muscles. The following are the laws they obey in reference to the manifestation of convulsions, to their strength and to their duration:

1. The nerves of the muscles in which it is proposed to excite convulsions must make part of the chain.

2. The nerve or portion of nerve which is to make part of the chain must

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(5) Memorie sull Elettricita Animale, 1792. Brugnatelli, Annali di Chimica, v. xvi. Gilbert's Annalen, v. li, No. 4, 12 Darstellung Volta's Untersuchungen über die galvanische Elecktricität Pavia, 1814. Bibliotheque Brittannique, v. lviii, No. 4.

(6) Sull' Elettricita Animale. Pavia, 1792. Experiments on Animal Electricity, with their application to Physiology. London, 1793. Lettre du Docteur Valli à M. Brugnatelli sur l'electricité animale; in Journ. de Phys., v. lxxxi, p. 77.

(7) Dissertationes duæ de Animali Electricitate. Bologne, 1794. His latest researches are found in the Bulletin des Sciences, an. xi, No. 68, p. 156. Van Mons, Journ. de Chim. et de Physique, v. iii, p. 20. Gilbert's Ann., v. xiii, p. 459.

(8) Dissert. de Electricitate sic dicta Animali. Stutgard, 1793. Ueber thierische Elektricität und Reizbarkeit. Leipzig, 1795.

(9) Versuche über die gereizte Muskel-und Nerven-Faser. Posen und Berlin, 1797.

(1) Experiments and observations relative to the Influence lately discovered by M. Galvani, and commonly called animal electricity. Edinburgh and London, 1793.

(2) Beweis, dass ein beständiger Galvanismus den Lebensprocess in dem Thierreiche begleite. Weimar, 1798. Beiträge zur nähern Kenntniss des Galvanismus. Jena, 1800.

be isolated as completely as may be, and no other conductor must produce derivation in this portion of the chain, so as to oblige the electric current, when developed in the chain, to take a course through the nerves.

3. Cæteris paribus, the convulsions are so much stronger, and are manifested over a greater extent, as the nervous portion, acting as a conductor, enters into the chain.

4. The convulsions are so much more powerful, and last the longer, as the chain is quickly formed, and the surface with which the parts constituting it are in contact, is extensive.

CCCCXIX. Although, according to the preceding researches, the power which animal parts placed in a chain possess of exciting contractions in the muscles by means of the nerves cannot be doubted, physical philosophers have nevertheless been divided in opinion regarding the agent that is effectual in such cases.

Galvani considered the contractions which he observed in the muscles of recently killed frogs, the nerves of which were laid bare, and placed in contact with them in the manner above mentioned, as effects of an electric power of a peculiar kind belonging to living animals, and called by him animal electricity. This power, according to his views, is produced in the nervous system, particularly in the brain, and distributed by the nerves, throughout the body.

Carminati, Carradori, Valli, and Aldini, warmly supported this opinion. Humboldt, Fowler, and others, also considered the phenomena in question as the result of a special agent, dependent on the power of living animals. Volta was the first who perceived the resemblance of these phenomena to those of general electricity, and who denied the existence of a special force, animal electricity. He regarded the convulsions which occur in living muscles as the effects of the influence of electricity on the nerves, an influence which is excited by the mutual contact of heterogeneous animal parts, disposed so as to form a chain. He was confirmed in this opinion by the electrical phenomena which he beheld to arise from the contact of different metals with each other, and with humid bodies, and which produced precisely the same effects on living nerves and muscles. The valuable researches of Pfaff have also demonstrated the identity of electricity excited by chains of animal parts, with that which is produced by the contact of heterogeneous inorganic bodies. Circles composed of animal parts act, in reference to their conditions and the laws for the manifestations and intensity of convulsions in living muscles, exactly in the same manner as those that are formed of heterogeneous inorganic bodies, in which, according to the nature of their constituent elements, the excitation of electricity by contact, or galvanic electricity, cannot be doubted. A similar coincidence between effects obliges us therefore to admit that animal circles are truly galvanic, and that their action, when they are enclosed, is likewise galvanic, that is to say, that electricity by contact is then excited and put into action. These animal circles also exert their activity when an inorganic body, a metal, is introduced as an exciter of galvanism. Convulsions are still more strong when the muscles, and nerves are furnished with metallic leaves or plates, commonly called armatures, and when the metals are made to communicate by means of a metallic wire, a galvanic arch or exciter, as the experiments of Volta, Humboldt, Ritter, Pfaff, Rossi,(3) Nysten,(4) and others prove.

The excitation of electricity by contact, or galvanic electricity, in circles of animal parts should not therefore be considered as a vital act, and it is only its effects, the contractions it causes in the muscles, that depend on their vital conditions and those of the nerves. However, it may be presumed, that electricity excited in circles of heterogeneous animal parts may be modified and strengthened by organic forces. Further, organs are met with in animals, the disposition of which is such as to excite electricity by their vital action, which is particularly the case in electric eels.

CCCCXX. Vasalli-Eandi(5) and Bellingeri(6) have experimented on the electrical properties of the animal fluids, the blood, the urine, and the bile. The former thought he found the blood to possess generally positive electricity, and only to become negative in slightly inflammatory states. Bellingeri has very lately made numerous experiments to ascertain the electric state of these liquids. For this purpose he made use of a frog's thigh, furnished with heterogeneous metals, after a method of his own invention.(7) The following considerations are necessary in order to understand these experiments and the conclusions drawn from them. All bodies, simple as well as compound, are in a certain electric state, of such a kind that though electricity or electric tension is not observed in them, yet when two of them are united, an electric excitation of varied strength is manifested, which in general belongs to electricity by contact, or voltaic electricity, and is the more powerful as the two bodies are at a greater distance from each other in the series traced after the manner in which they act in regard to their electricity. Bellingeri, backed by his experiments, disposed the metals of the electric train in the following manner:—zinc, lead, mercury, antimony, iron, copper, bismuth, gold, platina. He then compared the manner in which the animal liquids act in reference to electricity with that of the above different metals, for which experiments he made use of frogs' thighs as electrometers. He says, he thus found that the electricity of the blood of the jugular vein of calves, oxen, lambs, fowls,

(3) Mem de l'Acad. de Turin, v. vi.
(4) Nouvelles Experiences Galvaniques. Paris, an. xi.
(5) Commentarii Acad. Taurinens, v. v. Journ. de Physique, v. v, p. 336.
(6) In electricitatem sanguinis, urinæ et bilis animalium; in Mem. della R. Academ. delle Science di Torino, v. xxxi.
(7) Ibid., v. xxiii.

turkeys, and ducks, in the healthy state, remains the same under almost all circumstances. In the electric series of bodies, the blood almost always showed that of iron, even when it it was coagulated and separated into clot and serum. The electricity of the blood of old animals was a slight degree weaker than that of iron. That of arterial blood has not been found so constant. In lambs, rams, horses, and birds, it was mostly less strong than that of venous blood; sometimes it was equal to it, but never exceeded it. Arterial blood also preserves the same degree of electricity for a long time after its exit from the vessels. The electric state of the urine of calves, oxen, sheep, and rams, varies exceedingly. It never equalled that of the blood, being for the most part stronger or weaker than the latter. Bellingeri likewise found the electricity of the bile very variable, not agreeing with that of the blood and urine, being sometimes stronger, sometimes weaker than these.

CCCCXXI. The most palpable and remarkable electrical phenomena are seen in several kinds of fishes, which, on this account, are called trembling or electric fishes. They give men and other animals shocks resembling those afforded by a Leyden bottle or voltaic pile. Some live in the sea, and others in rivers, and they belong to different orders, families, and genera.

From among the cartilaginous fishes, the following come under this category:

1. Rays, (*Torpedines*, according to Risso,) especially the *Torpedo vulgaris*, and *marmorata*, of the south of Europe, and different other tropical seas. Those on which Kaempfer, experimented in the Persian gulph, Todd at the Cape, and Humboldt at Cumana, were probably particular species, differing from those of Europe. The ancients,(8) long ago, mentioned the property which these fishes have of giving shocks; the first exact observations on them were those of Redi.(9) After him, Kaempfer,(1) Reaumur,(2) Walsh,(3) J. Pringle,(4) Ingenhouss,(5) Cavendish,(6) Spallanzani,(7) Galvani, and Aldini,(8) Humboldt and Gay-Lussac,(9) Volta and Configliachi,(1) and

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(8) Plato in his Dialogue Meno. Aristoteles Hist. Animal, l. 2, c. 13; l. 9, c. 37. De part. Animal, l. 4, c. 13. Plutarch, De industria animal, p. 246. Plinius, Hist. Natur., l. 32, c. 1. Aelian, De Animal. Natura., l. 1, c. 36. Oppian, Halieit., l. 1, c. 104. Galen and others.

(9) Esperienze intorno a diverse cose Naturali. Florence, 1671, 4to. Experimenta circa res diversas naturales, speciatim illas, quæ ex Indiis adferuntur. Amsterdam, 1675, 8vo.

(1) Torpedo sinus persici; in Amœnitat. exotic. Lemgo, 1712. Fascic. 3, obs. 2, p. 509.

(2) Des effets que produit le poisson appellé Torpille sur ceux qui le touchent, et de la cause dont ils dependent; in Mem. de l'Acad. des Sc. de Paris, 1714, p. 344.

(3) Of the electric property of the Torpedo; in Philos. Trans., 1774, v. lxiii, p. 461.

(4) A Discourse on the Torpedo. Lond., 1775. Six Discourses pub. by A. Kippis. Lond., 1783.

(5) Experiments on the torpedo; in Philos. Trans., 1775, v. lxv, p. 1.

(6) An account of some attempts to imitate the effects of the Torpedo by electricity. Ibid, v. lxvi, p. 196.

(7) Opuscoli scelti di Milano, 1783. Memorie di Matematica e Fisica della Societa Italiana, v. ii, p. 603. Journ. de Physique, v. xxiii, p. 218; v. xxviii, p. 261.

(8) Essai Theorique et Experimental sur le Galvanisme. Paris, 1804, v. ii, p. 61.

(9) Sur la torpille; in Ann. de Chimie, v. lxv, p. 15.

(1) Annali de Chimica de Brugnatelli, v. 22, p. 223. L'identita Elettrico del fluido col cosi detto Galvanico. Pavia, 1814, in 8vo.

Todd,(2) made numerous researches on the properties with which they are endowed.

2. The *Rhinobatus electricus* (of Schneider) of the Brazilian seas, which Marcgraf(3) first mentioned by the name of *puraque*. Bony fishes also exhibit several electric species.

1. The electric eel *(Gymnotus electricus tremulus)* of the South American rivers, Humboldt found it in the Colorado, the Guarapiche, the Oronoco, and the Amazon river; and they are particularly abundant in the stagnant waters of the environs of Colabozo. Richer first mentioned the property it has of giving shocks.(4) Berkel,(5) Condamine,(6) Bajon,(7) Fermine and others have also spoken of it. Experiments have also been made on it by Ingram,(8) S'Gravesande,(9) Gronov,(1) Van der Lott,(2) Schilling,(3) Williamson,(4) Garden,(5) Walsh, Le Roy,(6) Ingenhouss,(7) Bryant,(8) Collins Flagg,(9) Fahlberg,(1) Guisan,(2) and Von Humboldt.(3)

2. The *Silurus electricus, (Malacopterurus electricus, lacepeda)* of the Nile, Senegal, the Congo and other rivers of Africa. Adamson(4) first observed its exhibition of electric phenomena. Forskael,(5) and Broussonet,(6) have given an exact description of it.

3. The Indian sword-fish *(Trichiurus indicus)* of the Indian seas, of which mention has been made by Willoughby,(7) and Nieuhof. (8)

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(2) Some observations and experiments made on the Torpedo of the Cape of Good Hope; in Philos. Trans., 1816, part 1, p. 120.

(3) Hist. Brasil, p. 151.

(4) Mem. de l'Acad. des Sc. de Paris, 1677, v. i, p. 176; v. vii, p. 325.

(5) Voyage to the Rio de Berbice.

(6) Voyage dans Amerique Meridionale. Paris, 1745.

(7) Mem. sur Cayenne, v. ii, p. 287.

(8) In "The Student of Oxford," No, 2, translated into the Hanoverian Scientific Observations, 1750, sec. 21, p. 83.

(9) Allamand Van de uit werkzelen, welke un Americaanse Vis veroorsaakt op de geenen, die hem aanraken; in Verhand. van te Maatsch. te Haarlem, v. vi, p. 372. Neu Hamburger Magazin, sect. 20, p. 178.

(1) Gymnoti tremuli descriptio, atque experimenta cum eo instituta; in Act. Helvet, v. iv, p. 26.

(2) Bericht van den Conger-Aal, of te Drilvish; in Haarlem Verh., v. iv, p. 87.

(3) Observatio Physica de Torpedine pisce. Utrecht, 1770.

(4) Experiments and observations on the Gymnotus electricus; in Philos. Trans., 1775, vol. lxv, p. 94.

(5) An account of the Gymnotus electricus; ibid., p. 102.

(6) Lettre á l'Auteur du Journ. de Physique, v. viii, p. 331.

(7) Vermischte Schriften. Vienna, 1782, p. 272.

(8) Account of an electrical eel, or the Torpedo of Surinam; in Trans. of the American Society, v. ii, p. 166.

(9) Observations on the numb-fish, or torporific eel; ibid., p. 170.

(1) Vetensk. Acad. Nya Handlingar, 1801, part 2, p. 122. Gehlen's Jour., v. xiv, p. 456.

(2) De gymnoto electrico. Tubingen, 1819, in 4to.

(3) Observations sur l'anguille electrique; in Recueil d'Observations de Zoologie. Paris, 1805, p. 81.

(4) Hist. Nat. du Senegal. Paris, 1757, p. 134.

(5) Descriptiones animalium quæ in itinere orientali observavit., p. 10.

(6) Mem. sur le trembleur, espece peu connue de poisson electrique; in Mem. de l'Acad. des Sc. de Paris, 1782, p. 692.

(7) Ichtyologie. Append., v. iii, fig. 3.

(8) Zee on Lant Reize door West-en Ost-Indien. Amsterdam, 1682, p. 270.

4. The electric prickle-belly, (*Tetrodon electricus.*) Paterson(9) discovered it in the midst of the coral banks of the island of St. John, in the Indian seas.

It is very probable that several other fishes of tropical seas possess similar electrical properties.

CCCCXXII. Electric fishes have nothing in common externally, except a naked skin without scales, and being furnished with numerous mucous glands, which secrete abundance of mucus. All are distinguished by particular organs, of various structure, very rich in nerves, and for the most part connected with the common integument, and called electric or electromotors, on account of their resemblance to a voltaic pile. We will describe the structure of these organs in the different species.

Those of rays, which have been examined by Redi, Lorenzini,(1) Oliger Jacobæus,(2) Reaumur, J. Hunter,(3) Girardi,(4) and Geoffroy,(5) are double. They are found on both sides of the head, between the cranium, the gills and the great semi-circular cartilages of the pectoral fins, in the shape of flattened oblong masses, the upper and lower surfaces of which are covered by the skin. After removing the common integuments, a reticulated membrane, formed of tendinous fibres is met with. Each organ is composed of a great number of membranous, perpendicular columns, generally irregularly hexagonal, pentagonal, or tetragonal, united by cellular tissue, blood vessels, and nerves. The size and number of these columns vary according to the size and age of the fish. J. Hunter counted four hundred and seventy in a small torpedo, and eleven hundred and eighty-two in a very large one. Their coats are formed of a thin tendinous membrane. Each column is intersected by fine membranous horizontal partitions or plates, the number of which, varying according to age, reaches one hundred and fifty or two hundred, and are kept together by fibres. Between these plates is a small space filled with gelatinous or albuminous fluid. Arteries and veins, forming exceedingly fine net-works, are spread through their substance. Moreover, very large nerves, branches of the par vagum, which is voluminous, and proceeds from particular swellings of the medulla oblongata, ramify through the electric organs, previous to which they pass between, and send branches to, the gills. Each branch that penetrates into a column gives out twigs in

(9) An account of a new electrical fish; in Philos. Trans., 1786, vol. lxxvi, p. 382.
(1) Osservazioni intorno alle Torpedini. Firenze, 1678.
(2) Anatome piscis torpedinis motusque tremuli examen; in Bartholini, Act. Med., v. v, p. 253.
(3) Anatomical observations on the torpedo; in Philos. Trans., 1773, v. lxiii, p. 481, pl. 20.
(4) Saggio di osservazioni anatomiche intorno agli organi ellettrici della torpedine; in Mem. della Societa Italiana, v. iii, p. 553.
(5) Mem. sur l'anatomie comparée des organes electriques de la raie torpille, du gymnote engourdissant, et du silure trembleur; in Ann. du Mus., v. i, p. 392, pl. 26.

it, which terminate in the partitions. The columns also receive branches from the third branch of the fifth pair, which wind along the external border of the electric organ.

The electric organs of the Surinam eel, whose structure has been studied by J. Hunter,(6) Geoffroy, Von Humboldt,(7) and recently by Knox,(8) are much larger than those of rays, and constitute the greater portion of the extremely long tail of the fish. There are two on each side, which are separated from each other by a long ligament, and by the upper muscles of the vertebral column. A voluminous organ is found directly underneath the skin, along the superior muscles of the back, and extends along the two posterior thirds of the tail, at the extremity of which it finishes in a point. A smaller and more deeply seated organ is separated from this by a thick tendinous membrane, a layer of fat, and muscles. Both are composed of tendinous membranes in the form of plates, some of which are superposed, whilst others are perpendicular to and cross them. These plates produce a great number of cells, which are filled with a liquid. The nerves of the spinal marrow send numerous branches to the electric organs, which are reduced into very delicate twigs in the coats of the cells. It is not correct that these have ramifications from the great sympathetic.

In the *Silurus electricus,* the electric organs are situated beneath the common integuments, according to Geoffroy's assertion, and Rudolphi's(9) more accurate researches. After opening and reversing the skin, a peculiar membrane, composed of small rhomboidal cells, is perceived on each side of the fish, which extends from the head to the back of the ventral fins. These cells contain an albuminous fluid. At its internal surface, this membrane is furnished with tendinous silvery white fibres, which intersect each other in different directions. A large branch of the par vagum passes through it on the median line, and sends branches in all directions, which, after piercing the membráne, divide ad infinitum in the external cellular mass. The nerves are accompanied by a considerable artery, which spreads into a multitude of branches. The vein proceeding from this membrane is emptied into the vena cava, not far from the heart. The muscles are moreover enclosed by another membrane, formed of spongy cellular tissue, into which branches of the spinal nerves penetrate.

The electric organs of other fishes have not yet been examined. From

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(6) An account of the Gymnotus electricus; in Philos. Trans., v. lxv, part 2, p. 395.

(7) Observations sur l'anguille electrique; in Recueil d'Observations de Zoologie et d'Anatomie comparée p. 81, pl. 10, fig. 3.

(8) Observations on the general anatomy of the Gymnotus electricus, and on the anatomy of the electric organs; in Edinburgh Journal of Science, 1824, No. 1, p. 96.

(9) Ueber den Zitter-Wels; in den Denkschriften der Berliner, Akademie, 1824, p. 187, tab. 123.

all this it follows, that the electric organs have the common character of being composed of tendinous membranes, having the form of plates, supplied with blood vessels as well as numerous nerves, having cellular spaces between them filled with a gelatinous or albuminous fluid. In this structure some analogy may be seen with the arrangement of a voltaic pile.

CCCCXXIII. Electric rays and eels are the only fishes on the electric faculty of which experiments have been made, a collection of which Pfaff(1) has lately given. We will confine ourselves to the principal results.

Regarding the sensations occasioned by the contact of living electric fishes, Redi(2) described them before the effects of electricity were known, from his observations on the torpedo, in a manner which established their analogy with those effects. When Reaumur touched animals of this kind, he felt a stupifying sensation, which spread quickly along the arm to the shoulder, frequently to the head, and was accompanied by a dull pain. Adamson, Gravesande, Walsh, and others, compared this sensation to the shock produced by a Leyden bottle; so also do Gay-Lussac and Humboldt, only they consider it more strong and painful. Since that, Humboldt and Configliachi have found it to resemble rather that which the contact of two poles of a voltaic pile causes. The effects of the electric eel, which has larger electromoter organs, are stronger than those of the torpedo, and, according to the observations of Williamson, Flagg, Fahlberg, and others, are similar to the shock of an electric battery. Bryant felt the shock, not only in the hands and arms, but through the whole body. Humboldt saw the horses under whose bellies Surinam eels had given out shocks, fall into the water, overwhelmed with stupor. The intensity of the shock varies with the mode of contact. If the skin of a torpedo be touched with the finger alone at the spot where the electric organs are situated, the stroke is feeble. It is stronger if the hand be applied to the organ, and is most powerful if one hand be placed above and the other below it; by this means a shock is felt in both hands, stronger in the former than the latter. The shocks, moreover, are still stronger when the skin of the fish is at the same time squeezed, rubbed, pinched, or in any manner irritated. The Surinam eel also affords more intense shocks when touched by both hands at once. The most violent of all is when one hand seizes the head and the other the tail of the animal.

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(1) See the article, Electric Fish, in Gehler's Physikalischem Wörterbuche, new edition, by Brandis, Gmelin, Horner, Muncke, Pfaff. Leipzig, 1827, v. iv, p. 275.

(2) Loc. cit., p. 61. *Vix torpedinem manu constrictum tetigeram, cum formicare manus, brachium, et omnis humerus cepit, cum tremore usque adeo fastidioso, necnon dolore afflicto et acuto, in mucrone cubiti, ut statim, manum abducere cogerer: idque toties mihi accidit, quoties eundem diutius tangere obstinate volebam. Verum quidem est, me tanto minus doloris atque tremoris sensisse, quanto morti proprior torpedo erat: quin sæpius nihil istiusmodi sensi; et cum plane mortua esset, neque enim ultra tres horas vixit, tractare eandem secure, et sine omni fastidio poteram.*

CCCCXXIV. A multitude of phenomena speak in favour of the opinion advanced for the first time by Adamson, and Gravesande, and since supported by Walsh, that the shock produced by electric fishes is of an electric nature. Strokes are even felt without immediately touching the fishes, if there be connexion with them by other bodies. Redi reported the saying of fishermen, that when they caught torpedos, they felt a shock both from the cord of the fishing-net and the fork with which they struck the fishes. Reaumur received a slight shock on touching a torpedo with his stick. Walsh felt strong ones in both hands when he applied a piece of iron to a torpedo covered with water, the other hand being immersed in the fluid at some distance from the animal. Spallanzani also experienced shocks on touching similar fishes with conductors of electricity. Threads and stuffs conducted strokes when moist, but not when they were dry. On the other hand, Gay-Lussac and Humboldt say they felt nothing in the simple contact with metallic conductors. Having placed a torpedo by its inferior surface, on a metallic plate, the person who held the plate in his hand experienced no stroke; but if he touched the upper surface of the electric organ with the other hand, he immediately felt a violent shock in both arms. Water alone does not, according to them, conduct the electric effect, for they experienced no shock in water when the hand only approached the fish; it only occurred in consequence of direct contact. The phenomena of propagation of electricity by intermediate bodies are more prominent in the Surinam eel than the torpedo. The fish affords shocks, even when the hand approaches it in the water, without touching it, as was observed by Williamson, Fahlberg, Guisan, and others. It is capable of stupifying and killing, with the shocks it aims, small fishes passing at some distance from it. Its shocks are propagated by metals, even by wood placed in contact with it, but not by common wax or sealing wax.

The electric shock may be experienced by several persons at once when they form a chain by joining hands, the last of which is in immediate contact with the electric organs of a fish or connected with them by an electric conductor. If the circle is interrupted by non-conductors of electricity, the effects cease. This experiment, more adapted as it is than any other to prove the electric nature of the agent produced by living fishes, was first made by Walsh on rays, and subsequently repeated, with the same result, by Spallanzani, Gay-Lussac, Humboldt, and others. It succeeds in a still more striking manner when made on the Surinam eel. In an experiment performed by Walsh, the shock was felt by twenty-seven persons united into a chain, the two ends of which touched the fishes.

Sparks, during the passage of the electric fluid of rays through conductors, have not been observed either by Walsh, Spallanzani, Gay-Lussac, Humboldt, or Configliachi. Gardini(3) alone asserts he saw them, on the occasion of receiving a violent stroke from a torpedo lying on an isolated board. But the electric spark has been remarked in experiments on the Surinam eel. Walsh having taken one of these eels out of the water, and made the shock pass through a strip of laminated tin attached to a pane of glass, saw the spark start from one half of the metal to the other. The same was observed by Fahlberg, by connecting, by the hands of two individuals, or by other conductors, the two extremities of a strip of laminated tin, fixed to glass, and separated by a small interval, with the fish lying in the open air; but when the animal was in the water he could perceive no sparks. Guisan also witnessed the same phenomenon.

Lastly, and it is worthy of remark, Galvani saw skinned frogs' thighs, which he placed on the back of a torpedo, become convulsed when the animal gave a shock, a fact which favours the idea of an electric shock. Notwithstanding these palpably electrical phenomena, it has been hitherto found impossible, either in torpedos or Surinam eels, to discover any trace of free electric tension, or of polarity, or attraction and repulsion of light bodies, or action on the most sensible electromoters, even with the aid of the best condensors, or, finally, of a bottle or battery charge. H. Davy(4) made experiments on the influence of the electric shocks of the torpedo on the decomposition of water, and on the magnetic needle. He repeatedly made the animal's shocks pass through an arch of silver thread and water, without being able to discover the slightest decomposition of the fluid. He also caused the shocks to pass several times through the arch of an exceedingly sensible multiplier, without observing the smallest deviation of the magnetic needle. Schilling was wrong in saying that the electrical phenomena of the Surinam eel have some connexion with the magnet, for Walsh, Ingenhouss, and Humboldt found this fish altogether insensible to every magnetic influence, whilst the same was remarked by Spallanzani in reference to the torpedo.

CCCCXXV. Regarding the state in which electric fishes are when they discharge shocks, and the dependence of this phenomenon on life, observations have taught the following facts. When these animals give a shock, they are not inactive, and their electric organs cannot be discharged at will, like a Leyden bottle or voltaic pile. The discharge is an act of their own will, as Reaumur remarked, and as the observations of Walsh, Williamson, Spallanzani, Gay-Lussac, Humboldt, Todd, and others confirm; for it often happens that a vigorous fish, held by both hands, gives no shock, whilst at other times the slightest touch is sufficient to cause one to be felt. Hence, electric

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(3) De Electrici Ignis Natura. Mantua, 1792, sec. 71.
(4) Philosophical Transactions, 1829, part 1, p. 15.

fishes appear to effect the discharge, and probably also the charging of their organs, by the influence of the will. Humboldt even thinks he may conclude from his experiments, that the Surinam eel is capable of giving what direction it pleases to its shocks. According to Walsh, Fahlberg, and Guisan's remarks, it appears that this fish possesses an exquisite sense for appreciating the circumstances in which these shocks may be given; in fact, it seems to recognise whether the bodies that approach it are or are not of a nature to receive them, that is, whether they are conductors or isolators, since in the former case it discharges a shock, whilst in the latter they refrain from it. Thus the neighbourhood of metals in the pond in which it is, agitates it and causes it to discharge its electric fluid on them.

Concerning the phenomena which precede the discharge and those which accompany it, observers are not agreed. Some say the discharge of torpedos is ever connected with a muscular effort. Thus Reaumur says he remarked the rounded back of the fish become flattened or even concave, when it gave a shock, and that immediately afterwards it resumed its convex form. Gay-Lussac and Thenard thought they observed the pectoral fins affected with a convulsive movement at the instant of the discharge. Todd likewise found the communication of the stroke generally accompanied by muscular efforts, and that the fishes drew in their eyes. This was also remarked by Walsh, but was not observed by Spallanzani. Regarding the Surinam eel, it is ascertained that movements of the body do not necessarily coincide with the discharge; for the fish often moves with great vigour, when held in the hands, without giving shocks, whilst, on the contrary, it frequently affords them when in perfect repose.

CCCCXXVI. Electric fishes, after giving a shock, possess the power of recharging their organs with great rapidity, and of communicating a series of shocks. In general the strength of the strokes is in the direct ratio of their vivacity and the intensity of their vital phenomena. The frequency of the act enfeebles them and renders their strokes less powerful. They are freshened by repose, and the intensity of their shocks is augmented. When they are gradually exhausted, the shocks are also gradually enfeebled. Just previous to death they succeed each other very rapidly, but are so weak as to be scarcely felt. Torpedos, whose electric organs have been abstracted, no longer afford them; they can, however, live a long time after this excision, and even longer than those in which frequent discharges are excited. If one organ is removed the other mostly remains active.

CCCCXXVII. The nerves proceeding to the electrical organs play a very important part in the excitation of electricity and the communication of shocks. Spallanzani, Galvani, Humboldt, and Todd, found that fishes lose the faculty of giving strokes when these nerves are tied. If the nerves of one organ be divided, the other maintains its activity. Todd destroyed the brain, and thus caused the cessation of the shocks, which no excitement could afterwards renew. The power of discharging shocks remains some time after the excision of the heart. It is also remarkable that electric fishes, like other animals, are convulsed by electricity, by rubbing, and galvanism, a fact which Aldini ascertained in rays, and Humboldt in the Surinam eel.

CCCCXXVIII. From the researches on electric fishes which have been hitherto made, there can be no doubt that the shocks they give during life are of an electric nature and more resembling the effects of a voltaic pile than any other phenomenon. The electrical organs, peculiar to these animals, also exhibit, in their structure, a great resemblance to one of those piles of the second class, since they are composed of alternate layers of moistened conductors of different natures, to wit, of membranous partitions and of gelatinous or albuminous fluid. It cannot be admitted, however, that their effects are solely consequent on their structure, on the mechanical disposition of the parts entering into their composition, and that by it alone electricity is produced on touching, to the extent which has been observed in living animals; for after section of the nerves going to the electric organs, the latter immediately lose the power of affording shocks, though the heterogeneous layers constituting their organs have undergone no change at all. In this state of the case we are under the necessity of considering the electric charging and discharge of the organs as a vital act, immediately dependent on the influence of the nerves on these organs, and of regarding the latter only as apparatus concurring, in a secondary manner, in the production and discharge of electricity by contact, with the vital co-operation of the nerves. Meantime we are ignorant of the modus operandi of the nervous power itself, therefore we can give no precise account of the manner in which the nerves act in exciting electricity. A complete theory of these remarkable electrical phenomena can only be acquired by fresh observations and researches on the manifestations of life in the nerves. From his experiments, H. Davy supposes animal electricity to possess more analogy with common than with voltaic electricity, and it appeared to him still more probable that it is a species of electricity distinct from any other.

CCCCXXIX. Electric phenomena excited by simple contact, and equally palpable with those exhibited by the fishes of which we have spoken, have not been hitherto observed in other animals with a certainty which leaves no doubt on the subject. It is true that Cotugno(5) says he received an electric shock from a living mouse, which he was about to dissect, when the animal's

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(5) Lichtenberg's Magazin für das Neueste aus der Naturkunde, v. viii, p. 121.

tail touched his finger. Molina(6) and Vidaure(7) give an account of a six-footed spider benumbing the hand of the individnal that touched it. Kirby and Spence(8) say that General Davies felt an electric shock on taking a *Reduvius serratus* into his hand. Lastly, it is said that the *Leonice gigantea,* one of the great marine annelida, that was thrown alive on the coast of the Antilles, gave an electric stroke to the person that touched it, whose body was afterwards covered with an eruption(9.) But these assertions appear very doubtful, and demand further confirmation.

CCCCXXX. Several other phenomena in the animal economy render it probable, that the nerves are capable, by means of an inherent force, of exciting and conducting electric currents resembling those which the union of the poles of a galvanic pile produce. Under this head the action of living nerves, on muscles in the act of contraction, may be ranged. Humboldt(1) broached the conjecture that each contraction of muscles is accompanied by a kind of electric discharge of the nerves. Prevost and Dumas,(2) and also Edwards,(3) subsequently endeavoured to show that such is actually the case. We shall return to this point in proper time and place. Meantime, we are to consider the excitation of electricity by living nerves, in all circumstances as a phenomenon subordinate to life, and dependent on the actions of the nervous power.

THIRD DIVISION.

Of the Movements.

CCCCXXXI. Movements take place in organized bodies, and form one of the principal characters of life. The acts of nutrition and formation, which have been before described, the ingestion of aliment, absorption, assimilation, respiration, passage of the nutritive fluid, fixation of the constituents of this fluid in the act of nutrition, and, lastly, the secretion of the humours, on which the maintenance of living bodies in the condition of composition, organization, and activity peculiar to them, are all connected with movements. Besides the movements which accompany the act of nutrition and formation, others are also perceived. Leaves move in vegetables and in many of them the genital organs also. Animals move their limbs and change their locality at will. In

(6) Naturgeschichte von Chili, p. 175.
(7) Geschichte Chil's, p. 63.
(8) An Introduction to Entomology, v. i, p. 110.
(9) Silliman, American Journal of Science, v. xv, No. 2, p. 357.
(1) Annales de Chimie, August, 1819, v. xi, p. 437.
(2) Memoire sur les Phenomenes qui accompagnent la contraction de la fibre musculaire. Paris, 1824, 8vo.
(3) De l'influence des agens Physiques sur la vie. Paris, 1824, p. 551.

short, every living body may be compared to a perpetual movement, more or less perceptible and of varied rapidity and force, dependent on an inherent power.

Let us endeavour to trace the movements of organized bodies, and to show the causes and conditions,—an inquiry forming one of the most difficult problems of physiology. The surest mode of attaining this end seems to be, to enumerate, seriatim, the movements that are observed in animals and vegetables, to point out the parts and organs which execute them and make known the circumstances in which they occur. We shall afterwards compare the movements of the two groups of living beings, in order to discover how far they are similar, analogous to, or different from, each other. We shall thus arrive at the search after the causes and powers on which they depend, and the discussion as to whether they are produced by the same or different powers. I think it better to commence by the movements of animals, which are more manifest and better known.

CHAPTER FIRST.

Of the Movements of Animals.

CCCCXXXII. We distinguish, in animals, movements of solids and of fluids. The former are generally shown by alternations of contraction and extension, either of sensible oscillations as in muscles, or without perceptible oscillations, as in the mucous and other non-muscular tissues. The movements exhibited by liquids are in a great measure communicated to them by the walls of the cavities which contain them. The globules, however, entering into the composition of the formative liquids possess the faculty of self-movement in certain circumstances, as occurs in blood globules and those called spermatic animalculæ. Movements are likewise seen proceeding from an afflux of fluids towards parts which are thereby rendered swollen and turgid. These are the movements of turgescence, which are more particularly observed in the genitals of both sexes. There also exist movements connected with the acts of formation, growth and nutrition, which, though not hitherto remarked by the senses, we are authorized to admit, judging from the effects of formation, growth and nutrition. We shall call these the movements of formation and nutrition. Finally, the manifestations of activity peculiar to the nerves probably accompanied by movements, which are also imperceptible to immediate observation, but the reality of whose existence is supported by many arguments. Let us examine more closely these different classes of movements.

Movements produced by the Muscles.

CCCCXXXIII. Animals execute their most palpable and energetic movements by means of flesh or muscles. The latter, as has been already stated, (CXXIII,) have a particular tissue, the muscular fibre, for a base. Cellular tissue combines the fibres into fasciculi, and these into bundles, between which the larger blood vessels and nerves, in most animals, are ramified down to the most minute. During life, so long as the muscles are nourished and are fully connected with the vascular and nervous systems, they possess the property of shortening themselves or of contracting, under the influence of what are called stimuli, after the cessation of which they again extend and return to their primitive station.

CCCCXXXIV. The exciting influences to muscular contraction present vast differences in their nature. Sometimes they are nervous excitations, or manifestations of activity produced in the living nervous apparatus, and which, transmitted by nerves entering into the composition of muscles, determine contractions, a fact occurring in movements performed in animals by the will, such as those of the limbs, of the organs of sense, of the parts of the mouth, of the masticatory organs, of those of deglutition and of the voice. There are other movements induced by nervous influence which are not subject to the will in ordinary circumstances, but are performed in an automatic and rhythmic manner, such as those that accompany respiration, which renew the respiratory media in the organs of respiration or their neighbourhood. Sometimes liquids of different kinds, by their stimulus, determine the contraction of hollow organs that are externally covered with muscular layers. Thus the blood poured from the venous trunk into the heart's cavity during the expansion of its muscular parietes, is the stimulus which excites it to contraction. The digestive fluids secreted in the alimentary sac, the saliva, the gastric and intestinal fluids, the bile, the pancreatic juice, occasion an excitation in its mucous membrane, inducing it to contract. Urine collected in the bladder is the stimulus which influences it to contract. Matters introduced from without into hollow organs provided with muscles, likewise determine movements in the latter. To this head belong the food and drink which enter the alimentary canal, as also the air introduced into the lungs(4) and trachea. Light arriving at the eye must also be reckoned among the external excitants, since, by acting on the nerves, it produces movements in

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(4) This must be an oversight of the learned author. It is not the air which enters the lungs that produces the muscular movements of the thorax; on the contrary, the movements are the cause, not the consequence of the entrance of aeriform fluid. The origin of such movements is to be found in the accumulation of venous blood, and in the sympathies excited by its presence between the absorbing and secreting surface of the lungs and the external muscles, whose action permits the entrance of air to effect a change in that blood.—Trs.

the iris. The same applies to sound, which, by stimulating the tympanum, excites the muscular fibres of this membrane to contraction.

CCCCXXXV. When muscles of a living animal are laid bare, or examined immediately after being detached from a body enjoying life, their bundles, disposed in parallel lines to each other, appear straight. But when any excitement, a mechanical action, a chemical impression, or the afflux of electricity, causes them to become active, they contract. The bundles and fibres of these organs, representing solid masses, fixed to bones, shells, or other parts, shorten, bend, form undulating lines, and the muscle, in its totality, appears wrinkled, shortened, thicker and harder at its middle. Hollow muscles, such as the heart and those constituting membraniform expansions, such as the membranous coat of the alimentary canal and of the bladder, contract, when stimulated, in the direction of their fibres, so as more or less completely, to destroy the cavity. When excitants cease to act on the muscles, they relax and extend; they become soft, the undulations of their fibres disappear, their extremities become more distant from each other, and they resume their former situation. Hollow muscles extend in the circumference. Every muscle that has remained for some time in a state of contraction, in consequence of the continued action of a stimulating agent, also eventually relaxes.

CCCCXXXVI. The question whether muscles, in contracting in consequence of the application of an exciting cause, change their volume and density, has furnished a subject for numerous controversies. Some physiologists maintain they do increase in volume; others, on the contrary, assert that they become smaller and at the same time increase in cohesion and specific gravity; others again say that neither of these effects takes place, and think that muscles only gain in thickness, during contraction, what they lose in length. When I treat in detail of the manifestations of life of the muscles in man, I shall return to the examination of the experiments which support these different opinions. It is probable, that the contraction of muscles is accompanied with an actual increase of cohesion, and one of the principal arguments in favour of this hypothesis is, that the contracted muscles are capable of bearing, without laceration, heavier weights than dead muscles. The cohesion of muscles appears, on the other hand, to diminish, when they relax and are extended.

CCCCXXXVII. Haller, on the foundation of his instructive experiments, erected the power which living muscles have of contracting under the action of stimuli into an organic force of a special kind, which he called irritability. Other physiologists have given the name of myotility or muscular contractility(5) to this power. Its effects differ from all the movements induced

(5) Chaussier and most subsequent anatomists of the French schools.

by mechanical or chemical causes. The partisans of the iatromathematical school frequently confounded them with those of elasticity, which is shown by a simple reaction inverse to a mechanical action exerted on an elastic body, and the consequence of which is never greater than the cause which produced it. Muscular contraction exhibits very different results. When the excitement which induces it is mechanical, the effect far exceeds the cause, and there exists between them no physical connexion resembling that which is observed in the phenomena of elasticity. The slightest contact of a muscle with the point of a needle often produces more vehement contractions than a great exterior violence. Another and stronger argument against this doctrine is taken from the very energetic effects produced in muscles without any mechanical cause, as the influence of nervous and chemical excitations testify.

CCCCXXXVIII. In regard to the conditions in which muscular irritability enters into play, the following is what observation and experiments have discovered on this point;

1. The muscles must be nourished, which supposes the free influx of nutritious fluid into them.

2. They must be in connexion with the nervous system.

3. They must meet with external stimulating causes.

CCCCXXXIX. The afflux of nutritious fluid to the muscles, in all animals provided with a sanguineous vascular system, is effected by numerous vessels which ramify in them. In animals, having no vascular system, the nutritious fluid seems to be conducted to the muscles by cellular tissue. The arteries which go to the muscles and convey arterial blood to them, divide in the cellular tissue, which runs between the fleshy bundles, and are resolved into very minute nets, surrounding the muscular fibres, whose arrangement with regard to the latter has not been yet discovered, on account of their exceeding minuteness. All that can be said is, that the living muscles are nourished by the blood, which reaches them by an innate activity, attracting the constituents of the fluid and combining them with the muscular fibres, whose characters they take, while, meantime, the arterial blood becomes venous. The size of the arteries and the quantity of blood conveyed to the muscles are proportionate to the bulk of the latter, as also to the force and duration of the contraction, which stimuli, acting on them, excite. Veins convey from the muscles the blood which has been thus modified in its composition.

The afflux of arterial blood is the more necessary to the retention of the power possessed by muscles of contracting on the application of stimuli, as these organs are nourished, in consequence of a special activity, and are thus maintained in the conditions of composition and organization, which render them fit to exercise their proper manifestations of activity. Arterial blood appears also to re-establish in muscles whatever has been changed by contraction. If there be any impediment to its free afflux thither, if the vessels of muscles are tied or cut across, they speedily lose the power of contracting under the influence of stimuli, as the experiments of Stenon, Haller, Fowler, and others certify, thus proving that this power is dependent on nutrition.

CCCCXL. As the preparation of arterial blood necessary to the maintenance of muscular irritability depends on the ingestion of aliments, the secretion of the digestive fluids, the assimilation of food in the organs of digestion; on the absorption of fluidified and assimilated alimentary matters, on respiration and circulation, all these functions participate indirectly in the preservation of the vital faculty which muscles possess of contracting whenever a stimulus acts on them. If an animal is deprived of food, if, therefore, nutritive fluid is neither prepared nor absorbed, the quantity of blood is diminished, the consequence of which is the impoverishment of the nutrition of the muscles, the diminution and finally the exhaustion of their contractility, as is observed in animals that die of hunger.

If animals are placed in circumstances when there is interruption or stoppage of respiration, either by the destruction of the respiratory organs, or by their impermeability to air, or by the withdrawal of the respiratory media, or, lastly, by immersion in irrespirable gases, the formation of arterial blood is stopped, and the living contractile faculty is extinguished in the muscles. The vigour and duration of the movements of animals are in direct ratio with the arterialization of the blood, the degree and development of their respiratory organs, the quantity of oxygen they consume in respiration, and of the carbonic acid they exhale.

If the blood of animals be withdrawn by opening the great vascular trunks, or if the heart be torn out, or the free communication of the divisions of the vascular tree, indispensable to the maintenance of the circulation, be interrupted, the muscular power is likewise shortly extinguished. It is also annihilated when the specific composition of the blood necessary to the continuance of nutrition is destroyed by poisons.

It is plain, therefore, that muscular contractility is dependent on hæmatosis and on all the functions that assist in it.

CCCCXLI. The muscles of all animals in which a nervous system has hitherto been discovered, as the mammifera, birds, reptiles, fishes, crustacea, arachnida, insects, mollusca, and annelida, contain nerves. The same thing seems to occur in several entozoa and radiaria. In actinia alone it is doubtful whether the fibres, analogous to muscles and found in the skin, are provided with nerves, since no nervous system has been as yet discovered in these animals. The nerves pass between the muscular bundles, ramify and are reduced to very minute net-works, which are interwoven with the muscular fibres. The most delicate ramifications do not appear to be free at the extremity, but to anastomose together into arches and form bundles, as Prevost and Dumas, have lately discovered by aid of the microscope.

CCCCXLII. Violent disputes have been raised as to the part which the nerves proceeding to muscles take in the movements, and whether they essentially contribute to the maintenance of the contractile faculty. Haller and his disciples, Fontana, Metzger, Bichat, and others, considered this power to be *sui generis*, inherent in the living muscular fibres, altogether independent of nervous influence, and only subjected in muscles governed by the will, to the action of the nerves, which in this case serve as conductors of the stimulus intended to excite contraction. They found their opinion on the fact of the muscular power being altogether different from that of living nerves in its manifestations, which consist in manifest and visible oscillations and movements, that are not perceivable in nerves; also on the circumstance that after the destruction of the brain and spinal cord, or after having communication with the nervous system, stopped, either by tying or cutting their nerves, or even when, after being separated from the body, the muscles continue for some time to contract, under the influence of divers stimulants to whose action they are submitted.

Other physiologists, Whytt, Monro, Unzer, Prochaska, Legallois, &c., who regard the nervous power as the prime principle of the life of animals and of all their movements, did not see in muscular contractility a power *sui generis*, existing independently, but considered it dependent on the influence of the nervous system, and communicated to the muscles by the nerves. They thought themselves authorised to presume it, because nerves enter into the composition of all muscles, as well those which obey the will as those which, free from its dominion, act in a purely automatic manner; because muscles contract quite as well when the nerves are irritated as when the stimulus is applied to themselves; because muscular contractility is extinguished after the employment of narcotics and other substances destructive to the nervous power; lastly, because, after the destruction of the brain and spinal cord, after the section or ligature of their nerves, muscles cease to contract by the influence of excitants.

CCCCXLIII. Both parties have gone to extremes in this dispute, and the truth appears to be between the two opposite opinions, so far as observation and experiments allow us to judge. Haller and his disciples were wrong, and went counter to the idea of organism, in which all the manifestations of activity and the powers are mutually connected, in attributing to the muscles a faculty altogether independent of the influence of the nervous system. But his opponents committed the fault of denying the existence of a special power inherent in muscles and causing them to contract when subjected to stimulants; of attaching too much importance to the part which the nervous power plays in the nervous phenomena of muscular contractility; and of considering as a cause of the contraction of muscles what is only a simple condition of it.

We must certainly, with Haller, regard the faculty which muscular fibres have of contracting, as a special force inherent in the fibres, but the maintenance of which depends on nutrition and the nervous influence, as Gautier, Scarpa, Hildebrandt, Pfaff, and others, endeavoured to show, because nerves enter into the composition of all muscles, as well those which obey the will as those which act without its impulse; whence it may be concluded, that the part of nerves is not simply to conduct stimuli for the purpose of producing contractions, as in muscles subject to the dominion of the will, but that they are, moreover, an essential condition in the very vital manifestations of those organs. This condition, doubtlessly, consists in the communication by the nerves which ramify in the muscles, of an aptitude to be affected by excitants, to be excitable; or in the action of the stimuli which affect the muscles and cause them to contract, being immediately on their nerves, and only inducing the contraction of the muscular fibres by means of an action in the latter. Perhaps, also, the nerves act an essential part in the nutrition of muscles at the expense of the arterial blood, and in this manner may be a necessary condition for the maintenance of muscular contractility.

In favour of the former part attributed to the nerves in the excitement of muscular contraction, it may be advanced, that when stimulants are directly applied to the nerves which ramify in the muscles, they determine convulsions as certainly, and for the most part even more vehemently, than when they act on the muscles themselves. In this case it also seems impossible to exclude the action of nerves, because they are divided into the most minute threads in the very substance of the muscle, and should, consequently, be affected by the stimulus acting on the exposed muscle. As a stimulus which acts on the surface of a muscle, frequently the slightest touch with the point of a needle, produces a rapid contraction of all the bundles and fibres; but as these are only situated near each other and do not form one body, and as they are only connected together by nerves and blood vessels, it is probable that the nerves are the means of the rapid propagation of the stimulus. Moreover, the stimuli that determine contractions in muscles not under the influence of the will, as the different fluids, do not act immediately on the muscular substance itself, but on a membrane which lines the interior of hollow muscles; in the heart this is the membrane which lines the sanguineous vascular system: in the alimentary canal, the bladder, and other hollow organs, it is a mucous membrane. Hence it may be presumed, that the action of the fluids, exerting a stimulating power over the muscular fibres, is directly induced by the living nervous fibres of these membranes, and that it produces in the fibres a change whose result is the contraction of the muscles. Finally, it may be alleged in favour of this opinion, that narcotic substances and many other poisons which destroy the nervous energy, also annihilate the faculty which muscles have of contracting under the influence of stimulants, when the naked nerves are only bathed in liquids of that kind.

It is, therefore, probable that the excitations which produce contractions in the muscles act in the first place on the nerves, and that a change in these precedes the movements or convulsions of the muscular fibres, or that the nerves communicate to the muscles the power of being affected by stimulants, and that these act through the medium of the nerves. But though the contractile muscular fibres appear to require the nervous influence in order to enter into action, it is impossible to deny in them a special power of contraction, and to consider the contraction as a pure effect of the nervous energy, for the living nerves cannot communicate to them a faculty which they themselves do not possess.

The opinion that the nerves may, moreover, contribute to the maintenance of muscular contractility, by causing the nutrition of the muscles at the expense of the arterial blood, rests on the fact of muscles whose nerves have been divided speedily shrinking, diminishing in volume, at the same time that their manifestations of contractility are weakened.(6)

We shall return to this controversy when speaking of muscular contractility in man, and shall discuss more in detail the arguments *pro* and *con.* that have been advanced on either side.

CCCCXLIV. Although the duration and persistance of the power possessed by muscles of contracting under the influence of excitants depend on their connexions with the sanguineous vascular system, on the free afflux of arterial blood, as also on their junction with the nervous system and nervous influence, yet this faculty is known to remain for some time, though weakened, in muscles which have been separated from the animal body. The heart torn from the chest, portions of the alimentary canal, and of the detached muscles, contract under the influence of excitements of various kinds. This effect takes place, either when the muscles are directly irritated, or when irritants are applied to their isolated nerves.

Among these excitements are reckoned,

1. Mechanical contact of a muscle, or of its nerves, with the point of a needle or scalpel, or the act of pricking or pinching.

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(6) This is only a proof that the nerves *indirectly* influence the nutrition of the muscles. In the case alluded to, the latter diminish in volume and function because *one* of the conditions to their functional activity is abstracted; the consequence is, that their office is not performed, and then, like every other organ, they become flaccid and diminished. We incline to think, that the *immediate* conditions of nutrition exist in the organised muscle itself, and that the nerves only indirectly, or as stimulants to the exercise of function, influence the increase, by their presence, or the decrease by their absence, of the nutrition of the muscular tissue. In fact, to say otherwise would be to agree with Whytt and the other partisans of nervous influence, who attribute even the contractility of the muscle to it.—Trs.

2. If a muscle or its nerves be moistened with alcohol, ether, acid, alkali, salts, metallic oxides, or various other vegetable or animal matters, it contracts.

3. Even air, coming in contact with a recently exposed muscle, often excites oscillations in it.

4. Heat, acting on the muscles or their nerves, likewise induces contractions.

5. Electricity, both that elicited by friction and that proceeding from contact, is one of the strongest excitants in bringing muscles into action. If the electric fluid be made to flow, by a metallic wire, from a muscle or its exposed nerves, or if an electric spark be made to fall on it or them, the muscles suddenly contracts. If the two poles of a galvanic pile be placed in contact, either with different parts of a muscle, or with the muscular substance and its nerves, directly or by the medium of a conductor, violent contractions take place. Electricity for the most part excites muscles to contract, when other stimulants have ceased to act on them.

CCCCXLV. The duration of the living contractile faculty, in muscles separated from the body, varies according to the classes of animals and the muscles themselves. It is sooner extinguished in warm-blooded animals, mammifera, and birds, than in cold-blooded animals, reptiles, fishes, crustacea, insects, mollusca, and worms, in which it often remains for several hours. Of the different muscles of an animal, contractility generally persists longer in the heart, the alimentary canal, and the diaphragm, than in the muscles fixed to the skeleton. The duration of this property also varies according to the age and states of life of animals, as likewise, according to the seasons, the temperature, and a number of other influences, which act upon animals and modify their conditions of vitality. The muscles of young animals contract for a longer period than those of old ones, when irritated. Animals exhausted by hunger lose their contractile power sooner than those which are well fed and in the full exercise of their faculties. When an animal has been killed by the irrespirable gases, carbonic acid, azote, carburetted hydrogen, sulphurous vapour, &c., its muscles contract but feebly, or do not contract at all, when irritated. Some poisons also totally annihilate muscular contractility. The persistance of this faculty is also changed by very many influences which act on the muscle, even when separated from the body. It remains longer in air moderately warm than in that which is very hot or cold. The muscles remain longer contractile in atmospheric air and in oxygen than in the irrespirable gases. Caustic alkalis, concentrated acids, narcotic substances, strong electric shocks, made to act on muscles or their nerves, very rapidly annihilate in them the power of contracting when irritated. The persistance of muscular contractility, therefore, varies considerably according to different circumstances.

CCCCXLVI. These vital phenomena of muscles detached from the body are to be considered as the consequences of particular conditions of organization and of composition on which muscular contractility depends, and which still remain for a short time. Haller and his disciples have adduced them as a main proof in favour of their doctrine that the muscles are endued with a special force, independent of the rest of the body and of the nervous system. In doing this they started with an assertion without any proof, namely, that the nerves which are disconnected from the entire nervous system, particularly from the brain and spinal cord, lose immediately their vital property of responding to excitations. It is, however, probable, that the nerves which enter into the composition of muscles preserve their excitability for some time, as well as the muscular fibres their contractility; it is also probable, that in muscles separated from the body stimuli act, by means of the nerves, on the muscular fibres which they thus determine to contraction. An additional circumstance authorizing us to conclude that excitability exists in the nerves distributed to muscles, after their section and separation from the body, is that a simple touch or stimulation by chemical agents on the nerves, suffices to produce convulsions in the muscles. Moreover, the action of narcotic substances and of a great number of poisons which annihilate nervous energy may be adduced. If the nerves of muscles separated from the body of an animal living, and still possessing great irritability, be plunged into a solution of opium, or into hydrocyanic acid, it is impossible subsequently to excite convulsions, whatever irritation is directly applied to the muscles. We are, therefore, under the necessity of admitting that the convulsions observed in muscles, separated from the body, are connected with the persistance, during some time, both of contractility in the muscular fibres and of excitability in the nerves which are distributed to the muscles.

CCCCXLVII. In studying muscular movement, we are led to the following questions:—Upon what depends the power which muscles have of contracting when irritated, or what is the cause of muscular irritability? What are the intimate changes that are effected in muscles when they contract, and how do excitants then act? Notwithstanding the multiplied efforts of skilful physiologists, and spite of the numberless hypotheses that have been imagined, these questions are as yet unresolved. In this place, when it is only my intention to sketch the manifestations of life in the muscles, I do not propose to state these hypotheses and submit them to discussion, the more as I shall treat of them in speaking of muscular contractility in man. I shall content myself with announcing the opinion in favour of which the majority of facts speak, and which I regard as the most probable.

The property possessed by muscles of contracting under the influence of excitants doubtlessly depends immediately on the peculiar material constitution of the living muscular fibres, on their chemical composition and their organization, conditions in which they are maintained by nutrition, like the rest of the body of which they are a part. In favour of an intimate connexion between the material state of muscles and their contractile power, it may be alleged that all the influences which modify their chemical composition and organization also produce changes in the effects of contractility.

Every contraction of a muscle supposes an excitement, which appears in the first instance to produce a manifestation of activity in its nerves, and determines, in the living muscular tissue, a change, the consequence of which is contraction. In our present knowledge, the only exact idea we can have of the phenomena of life in muscles, is that the change occurring in the muscles is accompanied by an approach or contraction of the particles constituting the muscular fibres, an approach which differs in its phenomena and causes, from all other kinds of attraction, such as are seen in inorganic, dead matters. The great vehemence with which irritated muscles contract, and the ponderous nature of the bodies which, in this state, they are capable of raising, whilst after death a slight weight will very easily lacerate them, render it probable that the shortening of the fibres at the moment of their action is the result of an augmentation of cohesion, of density, and of attraction of the particles constituting them.

Although it is proved, that the nervous system produces stimuli excitant of the contraction of muscles subject to the command of the will, and that feasible reasons exist for admitting that those of the muscles, independent of such command, likewise act through the medium of the nerves, the mode and agent by which the nerves change the muscular fibres and induce them to contract, are still unknown. It is not known whether the nerves, when producing a change in the muscular fibres, deposit any particular matter in them, either ponderable or imponderable, or whether the change which is followed by contraction, is not effected by a mutual reaction of the nerves and nourished muscular substance. It is probable, that the nerves furnish an imponderable agent to the muscular substance, or perhaps they act on the muscles by an electrical discharge, whence the change essential to contraction is produced. Ignorant of the mode of action of nerves on muscles, we are not better acquainted with the changes that occur in the latter when they contract. It may be presumed, either that the fibrine forming the base of the muscular fibres is brought by the nervous influence to a greater degree of density, or that perhaps a coagulable matter, albumen, passes from the blood into the fibres, and there becomes coagulated. In favour of this hypothesis it may be advanced, that the blood, in coagulating, exhibits phenomena of concentration and condensation of its coagulable parts, and that many influences which determine its coagulation are similar to the excitants which induce contractions in living muscles. But as muscles which are contracted return to the state of extension after the removal of the stimulus, some change opposite to that which caused their contraction must occur, putting an end to the state induced by the exciting influence of such stimulus. This is a point on which there is a total obscurity.

CCCCXLVIII. From the preceding it follows, that by the word muscular power, we designate the unknown cause of known effects, a cause which is inherent in the specific matter of living, nourished muscles. The continuance of this power depends both on the acts of nutrition by which muscles are maintained, at the expense of the nutritious fluid, in their special conditions of composition and organization, and on the nervous influence which communicates to them the aptitude to be changed and brought into movement by excitants.

CCCCXLIX. The great majority of animal movements, both those of the whole body and limbs, and of the internal organs, together with the liquids contained in their cavities, are produced by muscles. Though when excited they contract and are shortened, yet the mechanism by which the movement is effected varies according to their configuration and mode of application. The muscles representing thick masses, the bundles of which are laid in straight lines by each other, are for the most part connected with solid parts, variously formed and jointed together so as to be capable of moving like levers. Sometimes muscles are applied exteriorly to these parts, as is the case in the bones of mammifera, birds, reptiles and fishes; sometimes, as in crustacea and insects they are situated within hollow, calcareous or horny parts; sometimes they are inserted on earthy shells, as in bivalve and multivalve mollusca. In such muscles a head, a middle part or body, and extremity are recognised. The head and extremity are always fixed to two or more different bony, calcareous or horny parts, whilst the body passes over one or more articulations. When a muscle of this kind contracts, by the stimulus of the will through the medium of its nerve, the head and extremity approach each other, and the moveable parts on which they are inserted move likewise towards each other, provided they are equal in mass. But if the part whence a muscle originates is fixed and immoveable, or if it be larger than the part in which the muscle ends, the latter is moved, during contraction, towards the former which is less moveable or is immoveable. In this case the part where the muscle commences is called the fixed point and that where it terminates, the moveable point.

Other muscles originate from solid parts or bones, and are inserted into soft or moveable parts, as those of the lips, of the palate, of the pharynx, of the tongue, of the external part of the nose, of the outer ear, the globe of the eye, and the genital organs. When such muscles are acting, the soft parts, which are moveable, approach the hard parts, which are not so.

All these muscles antagonize each other, that is to say, if the contraction of one causes the movement of a limb or part in one direction, there is another which in contracting moves the limb in a contrary direction. Antagonist muscles are in opposite states to each other as regards their activity. When a muscle contracts under the influence of the will, its antagonist is relaxed and extended. The movements of animals and of their limbs exhibit the greater diversity and complication as the number of articulations is greater, as their form renders them more moveable in different directions, and as the number of antagonist muscles is greater.

Movements are effected in a different manner by muscles that are hollow and spread over the internal membrane of the vascular system, as also over the mucous membranes. Of these muscles, some, as the heart, are made up of an assemblage of several layers of fleshy fibres, which are interlaced in all directions, others are formed of a layer of longitudinal and circular fibres, as the muscular coat of the alimentary sac, of the bladder, oviducts, and vesiculæ seminales. When these enter into action, contractions take place in all the directions of their constituent fibres, and the hollow organ becomes shorter, at the same time that its transverse diameter is diminished. In consequence of this contraction the internal hollow space disappears, and the liquid occupying the cavity, or any other substance contained in it, is driven out. After this expulsion, when consequently the stimulus to contraction is no longer present, the muscular layers return to their state of extension and their cavity again becomes filled. These muscles do not exhibit any antagonism resembling that which is observed in muscles that are stimulated to action by the influence of the will.

CCCCL. It remains to point out the importance, in the animal economy, of movements accomplished by muscles, and to show how far the continuance of life, in animals, depends on muscular movements. The muscular parts produced by the plastic force in a certain order of succession in the growing animal, and endued with a living contractile faculty of a specific nature, exert, by the movements they perform, an influence essential to the preservation of life. In the first place, these movements are important to the nutritive functions, digestion, respiration, circulation, nutrition itself, and secretion. By the muscles which surround the mouth and jaws, animals seize their food and triturate it when it is composed of solids. Muscles effect deglutition and the progress of alimentary matters in the digestive sac. The necessity for food, made manifest by the nervous system, in the first instance affords the impulse to these movements, though afterwards they are also produced at will. Food arrived at the alimentary sac excites the secretion of the digestive fluids and induces the vermicular movement of the stomach and of the intestinal canal, in consequence of which, after being mixed with the digestive juices, which exert a dissolving action on it, it is moved on towards the absorbing surface of the alimentary sac. Muscles also expel the undigested remnant of the food in the form of excrement. Thus, digestion and chylification, that function so indispensable to the preservation of life, are in dependence on muscular movements. The conversion of the chyle absorbed in the intestinal canal into blood, supposes respiration. This, in most animals, is accompanied with movements executed by muscles, which renew the respiratory media in the lungs, in the trachea, and about the branchiæ. The stimulus which brings the muscles of respiration into play is engendered, in an automatic manner, in the nervous system. But animals may also, at will, accelerate or render slow their respiratory movements, according to their necessities. As respiration, all necessary as it is to the preservation of life, is accompanied with muscular movements in the majority of animals, the maintenance of life would seem to be in this view conditional on these movements.

The movements of blood in the ramifications of the vascular system is chiefly effected, in all animals possessing a heart, by the contraction and expansion of the muscular parietes of this organ. The cavities of the heart, during dilatation, receive blood from the venous trunks, and this produces in them a stimulation which leads them to contract, the consequence of which is the passage of the blood into the arteries. The heart which, during a whole life, executes continual and rhythmic movements, is one of the conditions of the continuance of life, inasmuch as it sends to all the organs the fluid necessary to their nutrition, and whence they obtain the materials essential to the preservation of their composition, their organization, and vital properties. The elimination of humours from the blood in the secretory organs, also supposes an afflux of blood to these organs caused by the heart. Moreover, the heart returns to the respiratory organs the venous blood, mixed with chyle and lymph, to be in them converted into nutritive fluid. Thus it is that the continuance of the life of animals depends on the movements of the muscular heart.

It will be plain, after these details, that muscular movement acts an indispensable part in the preservation of life in animals provided with muscles, since without it the nutritive functions could not be executed.

CCCCLI. Animals move spontaneously and freely in the media they inhabit. Even those which, like oysters, remain fixed at the bottom of the sea, on rocks or other spots, and which are, in fact, unable to change their locality, have nevertheless the power of executing movements of their bodies in different directions, which changes they effect and cease to perform by their own activity. It is in consequence of such movements that we are in the habit of saying that an organized body is an animal. The majority of animals are furnished with special organs for movement, which consist of muscles which are sometimes attached to the common integuments the skin, as in some medusa, radiaria, entozoa, annelida, and most mollusca; sometimes are inserted in horny or calcareous parts mixed with skin and articulated, as in insects, arachnida, and crustacea; sometimes are attached to bones concealed within the body and moveable by articulations, as in fishes, reptiles, birds, and mammifera. Comparative anatomy shows, that the structure of locomotive organs exhibits, according to classes, orders, genera, and species, an infinite variety in its disposition, and that the mechanism connected with the movement corresponds in a wonderful manner with the physical constitution of the media which animals inhabit. Here, again, it is the plastic force which produces and continues the harmonious disposition of the organs of movement in different animals.

Each kind of movement executed by animals, standing, walking, running, leaping, creeping, clasping, digging, flying, and swimming, supposes a particular structure and a specific mechanical arrangement of the locomotive organs, the effects of which have been profoundly studied and mathematically calculated by Borelli, Mayow, Barthez, and others. These movements, the analysis of which exceeds the limits of the general considerations in which I am at present engaged, are of the utmost importance in the preservation of the life of animals. By their aid they procure the conditions necessary to their existence, go in search of their food and obtain it. By them they are maintained in circumstances which render the prolongation of life possible, by avoiding the influences and impressions which affect their nervous system in a disagreeable and painful manner, or compromise their existence, by resisting the attacks of their enemies, and by procuring for themselves whatever aids their subsistence. By them, in short, animals react on the external world, and modify it according to their wants.

Moreover, we observe, in the organs of sense of most animals, movements accomplished by muscles, whose end is either to favour the reception of impressions, to exclude or avoid them. Many animals are thus enabled, by movements performed by muscles, to produce in the air during expiration, changes which give rise to different sounds, whose use is mutually to communicate their intellectual and moral states.

CCCCLII. All these movements are important, in more than one respect, for the preservation of the life of individuals. But there are likewise others, also performed by muscles, which are indispensable to that of the species. Among these may be reckoned the movements accompanying the exercise of the sexual functions. In all animals which have these organs developed in distinct individuals, the approach of individuals, which supposes locomotion, is necessary to the accomplishment of the generative act. The organs of copulation are necessarily brought into contact with each other by movements. Movements produce, during the copulative act, in the genital parts, changes the result of which is the outpouring of the generative fluids from their reservoirs. The exit of seed from the seminiferous ducts and seminal vesicles, the progress of ova detached from the ovarium along the oviducts, hatching and parturition, are all enacted by movements of muscles. The receptacles which animals build for their eggs, their nests, the arrangements and different tissues necessary to the maturation of the germ, are likewise executed by muscular movements.

2. Movements produced by the Cellular and other Tissues.

CCCCLIII. All the movements of animals are not produced by muscles. There is a set of animals entirely composed of cellular or mucous tissue, in which, even by the microscope, neither muscular fibres nor any thing analogous to them, are discovered, and which, nevertheless, are capable of moving. Of this kind are infusoria, polypi, most radiaria, and some entozoa. Even the most complicated animals exhibit movements in the cellular tissue, in the membranes formed by this tissue, and in different other non-muscular tissues. We will first examine the movements of gelatinous animals, after which we will point out those of the tissues of superior animals which are not muscular.

CCCCLIV. The most simple infusoria, the monades, *(Monas termo, atomus, punctum,)* representing only small round globules move vivaciously in water in all directions. Wrisberg(7), O. F. Mueller(8), Spallanzani(9) Schranck(1) and others, observed in them, during the movements neither change of form, nor contraction nor expansion of substance. Volvoces *(Volvox globator, punctum, conflictor, granulum, socialis, globulus, &c.)* also perform divers movements; they swim, turn on their axis, turn over, and avoid each other. Yet neither expansion nor contraction has been observed in them, though Mueller(2) saw the small globules of which they are composed move.

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(7) Observationum de animalculis infusoriis satura. Gœttingen, 1765, 8vo.

(8) Vermium terrestrium et fluviatilium seu animalium infusoriorum, helminthorum, et testaceorum non marinorum succincta historia. Copenhagen and Leipsick, 1773, in 4to. Animalcula infusoria fluviatilia et marina. Copenhagen, 1786, in 4to.

(9) Observations et experiences faites sur les animalcules des infusions; in Opuscules de Physique Animale et Vegetale. Geneva, 1787, v. i, p. 1.

(1) On the manner in which infusoria perform their movements; in Denkschriften der Münchner Akademie, 1809-10, p. 3.

(2) Vermium terrestrium et fluviatilium historia, p. 29. Volvox conflictor. Dextrorsum sinistrorsumque lente per intervalla rotatur, loco tamen raro movetur. Moleculæ innumeræ inter circulum contentæ in continuo motu et quasi in conflictu vehementi absque omni ordine, hinc pro majori confligentium in alteram concursu sphæra aliquantisper dextrorsum vel sinistrorsum rotatur, moleculis eandem directionem sequentibus.

The flat infusoria *(Cyclidia, Paramecia, Colpoda and Gonia)* proceed for the most part slowly, in a straight line, and this they effect by turning sometimes to one sometimes to the other side, extending and shortening themselves, and causing changes in their form. This is particularly remarked in the infusoria which Mueller(3) refers to the genus *proteus* and which at one time appear round, at another angular. Here contraction and expansion seem to take place in the different parts of the body. Of the cylindrical and filiform infusoria, some dive to the bottom of the water by alternate contractions and expansions of their body, as the enchelis *(gliscens, deses, punctifera)* and some vibriones, *(Vibrio vermicularis, truncatus, tripunctatus,)* others swim by undulatory movements of the body, as the *trachelius* and some vibriones *(Vibrio lineola, fluviatilis, serpentulus, aceti.)* The movements of flat and cylindrical infusoria are seen together in cercaria, *(Cercaria inquieta, lemna, ephemera, minuta,)* according to Nitzsch's observations (4) The thickest part of the body of these animals, whose inferior surface has a sucker, serves for crawling, and they swim by undulations of their tail.

Rotifera, *(Furcularia,)* which are also composed of cellular tissue, and whose oval body is anteriorly furnished with a part surmounted by appendices or fringes, swim by agitating these appendices as quickly as possible. There is no proof that these movements are effected by muscular fibres, as Dutrochet thinks.(5)

CCCCLV. Polypi, composed of a soft and gelatiniform membranous mass, in which, by the aid of the microscope, nothing but small grains or globules, without any muscular fibres, is perceived, move with varied velocity. Hydra fix themselves to bodies bathed with water, to stones, plants, and shells, by means of a sucking surface existing at their pedicle. Their body is moveable, as well as their filiform arms. The former extends, is shortened, and can bend in all directions. The arms may be extended, withdrawn, and moved every way; with them hydra seize the small animals, which serve for their nourishment, and carry them to their mouths. According to Trembley,(6) Roesel,(7) Schaefer,(8) as well as the observations of some others,

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(3) Animalcula infusoria. Proteus diffluens, crystallinus, tenax, tab. 2. Rœsel Insekten-Belustigungen, v. iii, tab. 101.

(4) Beiträge zur Infusorienkunde, oder Naturbeschreibung der Zerkarien und Bazillarien. Halle, 1817, p. 15.

(5) Sur le mecanisme de la rotation chez les rotiferes; in Annales du Museum d'Hist. Natur., v. xix, p. 351, v. xx, p. 369.—The Rotifera in which Dutrochet discovered muscular apparatus are the *Rotifer quadricircularis*, *R. albevèstilus*, *R. confervicola*, and *R. redivivus*. The three former, a species discovered and named by him; the latter was known to, and experimented upon by, Leuwenhoeck. They all differ from the animals called Brachionæ, inasmuch as the latter swim whither they please, whereas the others are fixed to one place.—Trs.

(6) Memoires pour servir à l'histoire d'un genre des polypes d'eau douce a bras en forme de corne. Leyden, 1744, 4to, translated into German by Goeze.

(7) Historie der Polypen des süssen Wassers; in Insekten-Belustigungen, v. iii, p. 433.

(8) Die Armpolypen in den süssen Wassern. Ratisbon, 1754-1765, 4to.

hydra can change their locality, by fixing their arms on neighbouring bodies, disengaging their pedicle, and applying it again to other objects. Sometimes they allow themselves to be carried along with the stream. Crystatellæ proceed in the same manner.

Other polypi, resembling hydra in structure, and adhering to bodies immersed in fresh or sea water, are not capable of locomotion. This is the case with those that are united by a soft contractile tube, which is sometimes naked, as in the genera *Vorticella* and *Corine*, sometimes covered with a horny envelope, as in the genera *Sertularia* and *Tubularia*. Here movements are chiefly confined to the tentacula that surround the mouth. Nevertheless, the body can only be shortened and extended; it may also in most sertularia, according to Cavolini's observations,(9) enter the horny sheath, and again leave it. Polypi of the genera *Lobularia, Athelia, Xenia,* and *Amothea,* which have shrivelled tentacula adhering to a common tube, are also incapable of changing their locality. Their movements consist in contractions and expansions of the body and tentacula. Neither does the power of locomotion belong to the tubipora, which, according to Quoy and Gaimard's researches,(1) inhabit calcareous tubes, to which they are united by a contractile membrane. The observations of these naturalists,(2) and those of Rapp,(3) show the same to be the case with polypi of the madrepora, which are fixed in stiliform depressions of the calcareous case. These polypi move their tentacula, leave the depressions of the case, and re-enter them.

The polypi, which produce ramified calcareous or horny corals, adhering to rocks, as the genera *Corallium, Isis, Gorgonia,* &c., lie scattered in a thick crust, which envelopes the common axis of the polypus case. Between this crust and the axis is a thin layer, furnished with vessels, by which the polypi are united to each other. The latter are provided with eight tentacula, fringed, and capable of executing vivacious movements. They are able to leave the crust and return to it.

Sea-feathers (*Pennatula, Scirpearia, Pavonaria, Renila, Veretillum, Umbellaria*) represent an aggregation of many polypi having eight fringed tentacula, resting on a common symmetrical axis, and united externally by a contractile membrane, internally by a calcareous peduncle. They are not fixed to marine bodies, but only have their foot inserted in the sand. Each polypus can move its tentacula independently of the others. It may be remarked, however, that an irritation applied to one of them is soon propagated to the

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(9) Memorie per servire alla storia di polypi marini. Naples, 1785, 4to, translated into German by W. Sprengel. Nuremberg, 1813.

(1) Freycinet, Voyage autour du monde. Partie Zoologique, p. 634.

(2) Annales des Sciences Naturelles, July, 1828.

(3) Ueber die Polypen im Allgemeinen und die Actinien insbesondere. Weimar, 1829, p. 38.

others, since, according to the observations of Bohadsch,(4) merely touching one causes all the others to contract. It would appear from this, that all polypi are organs or parts of the same individual, as Pallas, Cavolini, Olivi, Cuvier, and Schweigger admit. But it is by no means proved, as some naturalists assert, that they swim by simultaneous movements of their arms, acting, as it were, like ours.

CCCCLVI. Acalepha, which are formed of a soft gelatinous substance, easily reducible in water, execute exceedingly active movements. They all swim with facility in the sea. The acalepha discophora, or medusa, the animals of the genera *Cassiopea, Rhizostoma, Cephea, Medusa, Cyanea, Pelagia, Ephyra, Æquorea*, &c., move by means of the clock-shaped disk, forming the chief bulk of their body. By a sudden contraction of this disk, and chiefly by the curling of its inferior edge downwards and inwards, the animal presses on the mass of water contained in the excavation, and by this is moved onwards. As a medusa, in a quiet state, falls to the bottom of the water, frequent movements of the disk are necessary to keep the body at a certain height in the liquid, and these are only effected by contraction of the cellular tissue. The muscular fibres which Gaede(5) believed he saw in the disk of medusa, do not exist, according to the researches of Schweigger,(6) Rosenthal,(7) Eschscholtz,(8) and others.

Animals of the order of *Acalepha ctenophora*, those belonging to the genera *Cestum, Cydippe, Callianira, Eucharis, Mnemia, Beroe, Medea, Pandora*, &c., swim by movements of small foliaceous organs, situated one above the other, forming close rows along the body, and acting as fins.

The *Acalepha syphonophora*, as the genera *Eudoxia, Physalia, Rhizophysa, Physophora*, &c., swim by means of membranous prolongations of the body, forming hollow surfaces. On the contraction of these prolongations, the water is driven from the cavities, and the animal is pushed backwards. In several animals of this order, as in the genera *Rotaria, Velella*, and *Porpita*, there are bladders filled with air, which assist in swimming.

Most of the acalepha are furnished moreover with tentacula of various length, variously shaped, hollow, full of fluid, very extensible and exceedingly contractile. These for the most part communicate with bladders or vessels situated within the body. Muscular fibres arranged in a circle and lengthways are perceived in the parietes of the bladders and tentacula of some acalepha. When the bladders contract, the fluid is driven into the

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(4) De quibusdam animalibus marinis. Dresden, 1761, p. 120.
(5) Beiträge zur Anatomie und Physiologie der Medusen. Berlin 1816, 8vo. p. 22.
(6) Naturgeschichte der skelettlosen ungegliederten Thiere. p. 485.
(7) Beiträge zur Anatomie der Quallen; in Tiedemann and Treviranus Zeitschrift für Physiologie, v. 1. p. 318.
(8) System der Acalephen. Berlin, 1829, 4to, p. 5.

hollow tentacula, which dilate and become strait. When, on the other hand, the tentacula contract, the fluid re-enters the bladders and the external appendices are shortened. The tentacula serve the animals in seizing their food.

CCCCLVII. Of the entozoa, the majority of which, as the *Nematoidea*, the *Acanthocephala* and the *Cestoidea*, move by muscular fibres lying along and across the inner surface of the skin, there are some in which these fibres have not been discovered and whose body is composed of a mucous contractile tissue, analogous to the gelatine of zoophyta. This, according to Rudolphi's(9) researches, is the case with the *Trematoda*, the animals of the genera *Distoma* and *Amphiostoma*, the *Scolex* among the *Cestoidea* and the *Echinococcus* among the *Vesicularia*. Neither did Dugés(1) perceive muscular fibres in *Planaria*, which strongly resemble *Distoma* in their external form. Nevertheless these animals possess the power of extending and shortening themselves, of bending and stretching in different directions, in short of creeping like snails.

CCCCLVIII. Thus we see many animals that execute movements composed of a simple mucous matter. It is worthy of remark, that these movements may, like those of muscles, be excited, changed, and suspended by external influences and excitement,—a fact which was observed in infusoria by O. F. Mueller, Wrisberg, Spallanzani, and others. These animals move vivaciously with a moderate heat; but in cold, their movements become slower, and at length stop. Spallanzani(2) saw infusoria animalculæ, which he had exposed to the vapour of camphor, move in a rapid way, and retire to the bottom of the water; when the vapour was made very strong the movement ceased and the animals perished. The addition of acids, of salts, or alcohol, to infusoria, likewise suspended their movements and caused them to perish. The same effect took place, according to Spallanzani's experiments, when infusoria were exposed to the vapour of turpentine spirit, tobacco-smoke, and sulphurous vapour. Gruithuisen(3) found that assafœtida, added to an infusion, threw the infusoria into excessive agitation for several minutes; they afterwards became gradually quiet, and continued to live. A saturated infusion of wild chesnut bark produced the same effect on them. An infusion of Spanish tobacco changed their ordinary movement into a rapid rotation on their longitudinal axis, which, however, did not prevent their fixation at the same point, and which ceased after 15 or 20 minutes, when the animals again began to swim in all directions as before. A drop of

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(9) Entozoorum sive Vermium Intestinalium Historia Naturalis. Amst., 1808, v. i, p. 217.
(1) Froriep's Notizen aus dem Gebiete der Natur-und Heilkunde. Feb., 1829, No. 501, p. 258.
(2) Loc. citat., p. 120.
(3) Beiträge zur Physiognosie und Eautognosie. München, 1812, p. 122.

camphor solution placed in an infusion full of animalculæ, killed them all in a few minutes after making them turn round. The tincture of opium diluted, stupified them and caused them to fall. Pure laudanum killed them in a few seconds. Rotifera existed for a long time in a solution of opium; they fell into a stupor, but soon recovered when fresh water was supplied to them. Acids, common salt, alkaline solutions, sugar, syrup, alcohol, and infusion of gall-nuts, killed infusoria rapidly.

If an electric current be passed through an infusion, the animalculæ do not die; but by a strong spark they are killed, as Saussure, Moscati, and Spallanzani observed.(4) Gruithuisen saw infusoria stagger in their movements after the discharge of a Leyden bottle into an infusion. He also saw them die in drops of water, into which the poles of a galvanic pile were introduced, especially when they approached either of the poles. They finished by leaping and tumbling over. It is a fact, recognised and proved by numerous experiments, that the movements of polypi, of medusa, of entozoa, mentioned above, and of planaria, may be excited by heat, by mechanical or chemical stimulants of different kinds, and by common or galvanic electricity.

But as these animals likewise move in a spontaneous manner, as their movements are not excited only by external influences, and as the direction of these movements is regulated by themselves, it follows that internal stimulations are equally capable of producing them. Yet no nervous any more than a muscular system has been discovered in these animals. Physical philosophers say that the nervous matter is mixed and compounded with the mucous tissue. We are altogether ignorant of the mode in which stimuli, that excite to movements, are produced in them.

CCCCLIX. The changes that occur in the mucous tissue during the production of movements are as yet unknown. It is probable, that they consist in a condensation and augmentation of cohesion effected by the stimuli. But it is not known how or by what process this effect results from external or internal stimulations. It appears, that in the contraction of the mucous tissue, a liquid which this tissue contains, either in its intimate nature or in particular ducts, is driven into the parts that are not contracted, in which it causes an intumescence, that has been observed in such a distinct manner in the arms and tentacula of polypi and medusa. In medusa, and also in actinia, which, however, have muscular fibres, we also meet with a vascular system containing fluid, communicating with the tentacula, as I discovered in asterias, sea-hedgehogs and holothuria, and by means of which the diminution and intumescence of these animals' feet are effected. Physical researches afford no aid in determining whether the property possessed by the mucous

(4) Loc. cit., p. 125.

tissue, of contracting by the influence of a stimulus, is identical, in essence, with the contractility of the muscular fibres of other animals, or if it is only a modification of it; or, lastly, whether it should be considered as a force of a special kind. Perhaps the exciting stimuli of movements produce in the atoms of the mucous mass, a condensation resembling that which the nervous influence determines in the globules of the muscular fibres of other animals. It is certain, that the contractility of the mucous tissue is induced by excitations, as muscular contractility is, and that both these vital phenomena are altogether different from the effects of electricity and all other mechanical movements.

CCCCLX. Long disputes have been raised between physiologists on the question, whether the cellular tissue which enters into the composition of other animals furnished with muscles, is endued with a vital power of contraction. It cannot be denied, that the cellular tissue of living animals has the property of contraction and condensation, although frequently very slowly and scarcely perceptibly. If it is in a distended state and full of liquid, and the cause of distension be removed or the liquid elicited, it gradually returns to itself and regains its previous position. It also exhibits the phenomena of contraction in wounds. These are likewise observed in membranes formed of cellular tissue, the serous, synovial, and mucous, but chiefly in the excretory ducts of glands, whose secreted liquids cause their distension, whilst on the evacuation of these humours they return to themselves and are diminished in calibre. The phenomena of contractility are not less evident in the dermoid tissue. The same are observed in the parietes of arteries, of veins, and lymphatics, the diameter of which depends on the degree in which they are filled with fluids; if these fluids are evacuated during life, the canals diminish and contract; when they are cut across, both ends separate in different directions and more forcibly than after death. These phenomena of contraction which are remarked in very many non-muscular tissues, have been regarded by some physiologists as the pure effects of elasticity. But the proof that they ought not to be referred to such a cause, is their disappearance immediately or very shortly after death. Other physiologists see in them the effects of muscular contractility. To this hypothesis it may be objected, that the contraction is not determined by the same stimulants as those which induce it in muscular tissue, and that it is not accompanied, as in the latter case, with oscillations followed by a palpable extension. Several physiologists, who distinguished the movements perceived in these tissues, as well from the effects of elasticity as from movements produced by muscles, regard them as specific vital phenomena, and give them the name of tonic movements; the force which produces them they call tone, tonicity, and insensible organic contractility. I shall fully examine this point of doctrine when speaking of the manifestations of life in man. All that I can state here is, that the cellular tissue, the membranes which are formed of it, and the coats of arteries, veins, lymphatic vessels, and of the excretory ducts of glands, are each possessed of a contractile faculty, differing from elasticity. Analogy supports this assertion, since it is by a similar power that animals altogether composed of mucous tissue move.

3. Movements of Globules, or Organic Molecules, in the Humours.

CCCCLXI. The liquids contained in the different spaces found in the bodies of animals are principally moved by the contractile parietes of these spaces; but a movement peculiar to the globules constituting such liquids cannot be denied. I have already shewn (CCLXV) that the globules of the blood have the power of self-movement. C. Mayer(5) has very recently observed by the microscope, the movements of the globules of blood flowing from vessels, particularly in that of frogs, eels, of the *Daphnia pulex*, of the *Gammarus pulex*, the *Ostrea edulis*, and of the fœtus of the sheep.

CCCCLXII. The corpuscules contained in the seed of male adults, which many naturalists have regarded as distinct animals, by the name of spermatic animalculæ, likewise move spontaneously. By the assistance of the miscroscope movements in the organic molecules contained in the seed of mammifera, birds, reptiles, fishes, mollusca, and insects, varying according to species, both in form and size, have been observed by Leuwenhoeck,(6) Hartsoeker,(7) Vallisnieri,(8) Buffon,(9) Ledermueller,(1) Gleichen,(2) Spallanzani,(3) Bory St. Vincent,(4) and others. They saw this phenomenon, both in the seed ejaculated by the animal, and in that taken from its ducts and receptacles. The observations recently made by Prevost and Dumas(5) on the seeds of different mammifera, birds, reptiles, and mollusca, prove that these supposed spermatic animalculæ are to be considered as essential parts of the matured seed, just as the blood-globules are of the blood, and that they perform spontaneous movements. Needham, Buffon, Daubenton, and

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(5) Supplimente zur Lehre vom Kreislaufe. Bonn., 1827, 4to, p. 67.
(6) Opera omnia. Epist. 113; Philos. Trans., 1677, No. 141.
(7) Journal des Savans, 1678.
(8) Opera, v. ii, p. 105.
(9) Hist. Natur., v. ii, p. 255.
(1) Physikalische Beobachtungen über die Samenthierchen. Nuremberg, 1778, 4to.
(2) Abhandlung über die Samen—und Infusions—Thierchen. Nuremberg, 1778, 4to.
(3) Description des petits vers spermatiques de l'homme et de divers animaux; in Opuscules de Physique Animale et Vegetale, v. ii, p. 1.
(4) Diction. d'Hist. Natur., v. iii, p. 35.
(5) Essai sur les animalcules spermatiques des divers animaux; in Mem. de la Société de Physique et d'Hist. Natur. de Geneva, v. i, p. 180.

Lieberkuhn say they have also seen similar mobile corpuscules in the fluid found in the ovarian vesicles of some animals.

CCCCLXIII. The movements of globules contained in the formative liquids, differ from those observed in the tissues and solid parts, inasmuch as they are not accompanied by palpable contractions and expansions, at least nothing of the kind has been hitherto observed. In this respect they resemble the movements of the most simple infusoria, monades, and volvoces, in which neither contraction nor expansion have been observed. They differ, however, as regards the external influences or stimulations that act on them; this is particularly demonstrated in the case of the supposed spermatic animalculæ. Spallanzani remarked their movements to exist longer in heat than cold. When they had been put a stop to by a low temperature, they were subsequently renewed by the stimulus of heat. The influence of solar light stopped them. Prevost and Dumas remarked that electricity from a Leyden bottle suspended the movements of the spermatic animalculæ of the frog, and that galvanic fluid did not produce the same effect. It has not been as yet decided by experiments, whether the movements of blood globules vary with excitants; it is, however, probable.

CCCCLXIV. Under this head of movements should also, perhaps, be ranged those of the ova or shoots of some polypi and of the germs contained in the ova of mollusca. Grant(6) saw, by the microscope, the shoots of the *Lobularia digitata* of Lamarck (*Alcyonium lobatum* of Pallas) resembling globules, transparent on the edge, and surrounded by a circle of delicate fringe; they changed situations and swam in all directions. He even thought he saw contractions during their progress. He likewise remarked that ova move in the bodies of polypi. Similar movements have been observed by him(7) in the ova of other species of polypi, of the *Virgilaria mirabilis,* of the *Campanularia dichotoma* and the *Gorgonia verrucosa.* Swammerdamm(8) found, on opening a *Paludina vivipara,* young ones enclosed in their membranes, which turned somewhat rapidly in the water of the amnios, although, as he says, they were not larger than pin-heads. The turning of the globules of the yelk on their own axis, in the white of the ovum of the *Lymnæus stagnalis* has been remarked by Stiebel,(9) Hugi,(1) and Carus.(2) Hugi saw the yelk with the embryon, as yet exceedingly small, turn nearly forty times in a minute

(6) Brewster's Edinburgh Journal, No. 15, June, 1828.
(7) Ib., No. 20, April, 1829.
(8) Bibel der Natur., p. 77.
(9) Ueber die Entwickelung der Teikhornschnecke, (*Limnæus stagnalis*), in Meckel's Archiv. der Physiologie, v. ii. p. 557.
(1) Oken's Isis, 1823, p. 213.
(2) Vonden äusseren Lebensbedingungen der weiss-und kaltblütigen Thiere. Leipsick, 1824, p. 31.

on itself; whereas Carus saw it turn only seven or eight times. The latter(3) also observed the turning of the embryon with the yelk in the ova of the *Paludina vivipara*; he beheld a current of the white proceeding towards the determining points of the embryon, and he thinks the movement proceeds from the attraction and repulsion of this fluid. Lastly, Leuwenhoeck(4) observed a gyratory movement within the membranes of the ovum, in the very small embryons of mussels.

4. Movements of Turgescence.

CCCCLXV. Besides the movements effected by the constriction of contractile parts, there are others in which the humours are importantly concerned. These are the movements of turgescence. According to Hebenstreit(5) and G. R. Treviranus's(6) observations, they consist in an expansion and intumescence of soft parts, accompanied with an increased afflux of blood, consequent on excitations applied to the parts. There is no part of the animal provided with vessels, which is not liable to swell when stimulated. The movements of turgescence are most particularly pronounced in the male and female genital organs, especially those of copulation, the penis, clitoris, and vagina, during the existence of venereal desires. However the internal genital parts, the testicles, the ovaries, the oviducts and the womb, also become turgescent. The vessels are always gorged with blood during expansions. The nipples are erected when touched or rubbed. In gallinaceous and other birds, the combs and carunculæ are seen turgescent when the animal copulates, or is enraged. The papillæ of the tongue are likewise susceptible of a certain degree of turgescence.

The skin and internal membranes, the serous, mucous, and synovial, also swell when irritated, and a greater quantity of blood is then poured into their vascular nets. If the skin be rubbed, or an irritating substance applied to it, the blood flows towards it, and it becomes red, swollen, and stretched. Heat and cold, especially when the transition from one to the other is rapid, always cause a change in the afflux of blood. More blood is also sent to mucous membranes when irritated. This is very well seen in the mucous membrane of the alimentary sac, which reddens, and is tumefied after the excitement which ingested food produces. If a serous or synovial

(3) Neue Beobachtungen über das Drehen des Embryos im Ey der Schnecken, in Nov, Act. Acad, Cæsar, Leopold,.Carolin., Natur., Curios., v. xiii. P. 2, p. 763. Tab. 34-

(4) Opera omnia seu Arcana Naturæ. Leyden, 1722. Continuatio Arcanorum, p. 14. Epist. 95.

(5) Doctrinæ physiologicæ de turgore vitali expositio. Leipsick, 1793, 4to.; translated with notes in Reil's Archiv. für die Physiologie, v. i, p. 159.

(6) Ueber Lebens Turgescenz, in his Physiologischen Fragmenten, p. i, p. 57.

membrane be exposed to the air, or irritated in any mechanical or chemical manner, a greater quantity of blood rushes towards its vascular congeries and it becomes of a deep red or is swollen. Similar phenomena are observed in glands that have been stimulated. Muscles, nerves, and other parts, furnished with nerves, tumefy in the same manner, in consequence of the influx of a greater quantity of blood into their vessels, when they are exposed or irritated.

CCCCLXVI. All parts, which in ordinary circumstances are capable of undergoing palpable turgescence, as the penis, the clitoris, the internal genital parts, the nipples, &c., have all the peculiarity of possessing numerous blood vessels in their texture, interlaced into a network, and between which large nerves run. The admission of a special erectile tissue is unsupported. A stimulus proceeding from the nerves appears to be always the determining cause of intumescence. This is sometimes produced by external excitants, by touch, by friction, or heat; sometimes by internal excitations, by voluptuous ideas, or by mental emotions, anger, and shame. No movement of this kind is induced by volition, as in the contraction of a muscle which is under the control of the will. When an organ capable of entering into a state of intumescence has been stimulated by any of the above influences, a greater quantity of blood comes to its vessels; it extends, swells, and becomes erect and tense. Gradually the turgescence disappears, the blood flows off, the part becomes flaccid, and regains its former dimensions.

CCCCLXVII. Physiologists are divided in opinion concerning the cause of the phenomena of turgescence. They, however, agree in thinking that it cannot be an effect of the impulse given to the blood by the contraction of the heart, inasmuch as the latter only projects the whole of the blood to all parts in a uniform manner, with varied rapidity and force, but cannot possibly make it flow in greater abundance to any given part than to others. Some physiologists attribute turgescence to an increase of the movement of contraction in the vessels, consequent on excitations acting on the organs, and causing the influx of more blood to them. This cannot be the case, inasmuch as a more vehement contraction of the vessels, which would diminish their calibre, would rather be an impediment to the afflux of blood. Others give the vessels the faculty of dilating in consequence of nervous excitements, so as to cause the blood to pour more plentifully into them. It may be objected to this hypothesis, that such an active expansion of vessels has not been observed, and no phenomena exist which authorize us to think that the contractile parietes of spaces expand when excited; the direct contrary is the case on all occasions. It is therefore probable that the excitants which act by the medium of the nerves exert an influence on the movement of the blood itself, determining its progress towards the parts, or that the nervous excitations produce in the vessels of the stimulated organs, a state whose result is the increase of the vital attraction which they exercise on the blood.(7)

5. Movements of Formation and Contraction.

CCCCLXVIII. In all animals there are movements connected with the phenomena of origin and the formation of animal organisms and their parts, with those of nutrition, of growth and decrease, and also with those of the continual renewal of materials which is a condition of the continuance of life. Such movements have not hitherto been immediately recognised by the senses, but we are bound to believe their existence from the changes of consistence and composition, of augmentation and diminution of mass, of structure, and texture which animals exhibit in general and in all their parts during the continuance of life, all which cannot be imagined without continued internal movements of the matter constituting them.

CCCCLXIX. The first manifestations of life, when an animal is born, are accompanied by movements in the matter of the germ, for the constituent parts of this matter unite in a determinate matter, corresponding with the species which has produced the germ, and thus represent an organic coalition. The first movements of this kind occur before the formation of the blood, of the blood-vessels, the heart, the muscles, and the nerves, and cannot, therefore, be the effect of all these organs. On the contrary, we ought rather to consider these as the products of the movements of formation. Once formed, they contribute their part to the ulterior development of the germ, by virtue of the vital powers which have been given to them by the plastic activity. Each

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(7) The last sentence of this paragraph is a modification of the preceding opinions of the author on turgescence. The phenomena of turgescence can by no means be attributed solely to the movement of the blood-globules to a particular part. In this, as in every other operation of the animal body, the solids also play a part; what such part is, we opine to be the question—the self-motion of the globules is undoubted but conditional. They who say that turgescenee is the consequence of stimnli applied to the minute vessels, producing stronger contraction of them, are very possibly correct as to the fact of contraction, though, as Tiedemann observes, such contraction would have the effect of impeding the influx of blood. They, too, who suppose an active dilatation of vessels suppose a thing which has neither analogical nor actual proof. Still, though both are wrong, and they may also both be right, there is primary contraction and subsequent dilatation. Take the instance of the skin, susceptible as it is of ocular proof. In rubbing the skin, the first effeet observed is paleness or absence of blood; this soon passes off, and redness and a partially erectile state ensues. If the friction be again applied, paleness again takes place, to be succeeded by even greater afflux of blood than before. This would seem to show that the redness consequent on the paleness is also in proportion to it. Now the latter can only be caused by contraetion of the minute vessels, and the faet of the application of mechanical pressure, as in friction, countenances this view. As the absence of blood then is accompanied by the vascular contraction, so are we authorized to conclude that the turgor and redness are dependent on a state of the vessels opposite to contraction or expansion, which expansion, for the reasons advanced in the text, cannot be active, but may be so far passive as to admit a more full torrent of self-moving globules within their calibre, and thus constitute the state of turgescence. This theory will be found to apply to the effects of heat, cold, and mental emotions on the skin; for more or less paleness always precedes the rubor of that surface in summer or winter, and of the act of blushing.—Trs.

tissue, each organ, each apparatus of an animal body has its own mode of generation, and is developed in determinate directions, a fact which supposes movements in the molecules during the work of formation. These movements are not communicated from without to the organic matter of the germ, which is capable of performing them of itself, and by a spontaneous activity.

Neither can we imagine the growth and increase of organs once formed without movements, since in these acts they attract the particles of the formative fluid brought to them by the vessels, combine with them and cause them to enter into their texture and structure. Moreover, all the animal parts undergo, during their existence, changes in their volume, form, chemical composition, and texture. In the process of nutrition, and during the change which their substance undergoes, constituent principles of the nutritive fluid pass into their organic composition and are solidified, whilst molecules of the latter return to the liquid state.

The movements of formation are, as is shown in CCCVII, different from all those observed in bodies not endued with life, and cannot be explained by any mechanical or chemical cause. It is on this account we considered them as effects of a special organic force, the force of formation and nutrition. Among these we have also reckoned the movements which accompany the preparation and secretion of the humours.

CCCCLXX. The movements in question are performed, in the different species of animals, in each part and organ, with special and determinate modifications, which maintain them in action during a certain space of time. In all complicated animals, the first impulse is given to plastic movements by the act of generation. Although this act gives a specific direction to their effects, yet they also depend, on external conditions and influences, on a certain degree of heat, on the air, moisture, and alimentary matters. These may even modify them, but within certain limits. Thus we see parts that are exposed to a continual stimulation exhibit changes in their formation and nutrition. Such is particularly the case in the phenomena of inflammation which are developed in consequence of mechanical, chemical, and other irritations; as also of a number of other pathological formations, which proceed from unaccustomed irritations. Here, likewise, may be mentioned the plastic phenomena which follow wounds.

CCCCLXXI. The movements which accompany the act of formation and nutrition in animals in general, and of their parts, are the condition of all the other visible movements, of the contraction and expansion of irritated muscles, of the phenomena of the contractility of the cellular and other non-muscular tissues, of the movements of the fluids, of the movements of turgescence, inasmuch as the parts in which these are observed, are productions of the plastic force, and only maintain the aptitude for the movements peculiar to them so long as they are nourished and nutrition continues them in the possession of their vital properties.

6. Movements of the Nerves.

CCCCLXXII. Finally, movements appear also to accompany the manifestations of activity of the nerves. In order that an external object, acting on the peripheric extremity of a nerve in an organ of sense, shall excite a sensation, it is necessary that the change produced in the nerve by the object should be transmitted to the brain. If the immediate communication of the sensitive organ with the brain by the nerves be interrupted, if the nerves are divided, tied, or compressed, the excitation of the organ of sense is not followed by sensation. Hence it is clear, that the impression received by the peripheric extremity of the nerve should be propagated to the brain. Now this is not conceivable without movement in the nerves. When a nerve which has been distributed to a muscle has been irritated the muscle contracts. In this case also, a change produced in the nerve by the irritation must be propagated from the irritated point to the muscle, which could not occur without movements. Erasmus Darwin supposed the nervous membrane of the eye to be composed of mobile fibres, which were excited to contractions as irritated muscles are. He also said the other nerves were composed of mobile fibres. But hitherto no movements have been perceived in stimulated nerves, except those which depend on the contractility of the cellular tissue. The phenomena, however, which have been mentioned oblige us to admit movements in the nervous substance, either that itself suffers some displacement, or that a subtle matter, perhaps of the imponderable kind, moves in it in the manner of a current. In short, without change of locality, that is, without movements, we can form no idea of the action of living nerves.

CHAPTER SECOND.

Of the Movement of Vegetables.

CCCCLXXIII. Plants also execute movements, and motility cannot be considered as a property exclusively belonging to animals, as some naturalists have asserted. It is true that vegetables, being fixed to the earth by roots, do not change their locality at will like animals; but we perceive automatic movements in them, which accompany their formation, their growth, and nutrition. Many plants, moreover, exhibit periodical movements connected with the portions of the day, such as the erection and depression of the leaves, and the expansion and closing of the flowers. In several of them the organs of generation move in order to approach each other. Lastly, the flowers, the leaves, and the fructifying organs of some vegetables perform movements in consequence of external excitants. We will examine more in detail the movements of plants, and shall point out the circumstances in which they occur.

1. Movements of Tremellæ, Confervæ, and Oscillatoriæ.

CCCCLXXIV. Movements have been observed by many naturalists in confervæ, tremellæ, and oscillatoriæ. Adanson,(8) Corti,(9) Fontana,(1) O. F. Mueller,(2) J. A. Scherer,(3) H. B. de Saussure,(4) Collomb,(5) and Olivi(6) saw them in various species of confervæ and tremellæ. Girod de Chantran,(7) Vaucher,(8) Roth,(9) G. R. Treviranus,(1) Nees von Esenbeck,(2) L. C. Treviranus,(3) and others saw them in the above vegetables, and in oscillatoriæ. This has induced several of the physical philosophers that I have quoted, Fontana, Saussure, Scherer, and Girod de Chantran, to reckon them in the number of animals. Their movements consist in a more or less rapid fluctuation of the fibrils in their erection or depression, or in serpentine inflections, incurvations, spiral twistings, or oscillations. Often a palpable elongation of their extremity is seen, which appears to be a phenomenon of growth. The rapidity of the movements varies according to the nature of external circumstances and excitements. Under the influence of heat and solar light, they are stronger than at a low temperature and in the shade. The movements of oscillatoriæ were remarked by L. C. Treviranus to be more pronounced in warm than in cold water. Scherer found they were checked by the addition of acids, alkalis, metallic salts, alcohol, and

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(8) Sur un mouvement particulier decouvert dans une plante appellée Tremella, (conferva glutinosa, omnium teuerrima et minima, aquarum simo innascens. Dillen. Hist. Musc., p. 15,) in Mem. de l'Acad. des Sc. de Paris, 1767, p. 564.

(9) Observazioni Microscopiche sulla Tremella. Lucca, 1774, 8vo.

(1) Sur le Tremella Journal de Physique, v. vii, p. 47.

(2) Schriften der Berliner Gesellsch. Naturf. Freunde, v. iv, p. 171.

(3) Beobachtungen und Versuche über das pflanzenähnliche Wesen in den warmen Carlsbader und Töplitzer Wassern; in Abhaud. der Böhmischen Gesellsch., 1786, p. 54, (an tremella thermalis Dillen ?)

(4) De deux nouvelles especes de Tremelles douées d'un mouvement spontané; in Journal de Physique, v. xxxvii, p. 401, (an conferva fontinalis ?)

(5) Observations sur quelques phénomènes particuliers à une matière verte; in Journal de Physique, v. xxxix, p. 169.

(6) Delle conferve irritabili, e del loro movimento di progressione verso la luce, esame fisicochimico, specialamente diretto a stabilire la vegetabilia della loro natura; in Mem. della Societa Italiana, v. vi, p. 161. Scoperta e spiegazione del fenomeno del movimento progressivo d'una conferva infusoria (materia verde di Priestley) verso la luce; in Usteri Annalen der Botanik, part 6, p. 30.

(7) Recherces chimiques et microscopiques sur les conferves, Bysses Tremelles. Paris, 1802.

(8) Histoire des Conferves d'eau douce. Geneva, 1803, 4to.

(9) Catalog. Botan., Fasc., iii, p. 198.

(1) Biologie, v. iii, p. 283.

(2) Die Algen des Süssen Wassers. Bamberg, 1814, p. 18.

(3) Bemerkungen über die Bewegung der grüner Materie im Pflanzenreich; inden Vermischten Schriften, v. ii, p. 73.

sugar. Their cessation however, was frequently preceded by a sort of trembling. Saussure observed a similar action of acids and alkalis. Moreover, it may be remarked that, as was seen by these last named naturalists, the movements of infusoria that were in the same water as the plants, were also suspended by the same substances: whence it would appear that the principle of movement is the same in both these groups of living bodies.

2. Movements of Formation and Nutrition of Phanerogamia.

CCCCLXXV. All vegetables, during their development from the grain, perform movements of growth in different directions. However situated the grain may be in germination, the root always forces downwards into earth or water; whilst the plumula, about to become the stalk, rises and points towards the light. The aerial roots proceeding from the trunk or branches of some vegetables, for instance of the *Ficus elastica* and *religiosa*, of the *Clusia rosea*, of the species of *Rhizophora*, *Epidendrum*, *Cactus*, &c., also have a tendency to descend. The same is the fact, according to Schultz's observations,(4) in the young plants that grow from the indented borders of the leaves of the *Cotyledon calycinum (Bryophyllum.)*

Most botanists have sought for the cause of the direction of these movements in external agents, in the action of light, heat, air, and humidity on plants. Dodart(5) thought the radicle was actuated to movement by humidity, and the plumula by the dryness of the air, and that this was the reason why the former points towards the earth, and the latter to the atmosphere. Delahire(6) and Astruc(7) attributed the downward tendency of the radicle to the greater weight of the sap charged with earthy matters, and to its precipitation to that part of the vegetable; whilst the elevation of the plumula appeared to them to depend on the attenuation and ascent of the sap by the influence of heat. Bazin(8) says the radicle is attracted by the humidity of the earth. E. Darwin asserted that the radicle is induced to action and determined to extension by humidity, whilst the plumula is similarly affected by the air.

CCCCLXXVI. These opinions have been fully refuted by the experiments

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(4) Die Natur der lebenden Pflanze, v. i, p. 159.

(5) Sur l'affectation de la perpendiculaire, remarquable dans toutes les tiges, dans plusieurs racines, et autant qu'il est possible dans les branches des plantes; in Mem. de l'Ac. des Sc. de Paris, 1700, p. 47.

(6) Conjecture sur le redressement des plantes inclinées à l'horizont; in Mem. de l'Ac. des Sc., 1708, p. 463. Mem. de la Societé de Montpellier, v. i, p. 373.

(7) Explication physique de la direction verticale et naturelle des tiges des plantes et des branches des arbres, et de leur racines; ibid., 1708, p. 231.

(8) Observations sur les Plantes. Strasburg, 1741, p. 100.

of Duhamel,(9) Link,(1) Dutrochet,(2) H. Johnson,(3) and others. Duhamel inclosed bulbs and other seeds in a germinating state in glass tubes, filled with earth, which he placed in a horizontal position, and saw the radicle tend downwards, while the plumula reached the upper part. When he changed the posture of the tubes to the perpendicular, he always saw these parts change their mode of growth, and still take the direction they previously had. This took place alike in darkness and when they were exposed to light. Neither can the direction of growth be changed by heat or humidity. Link obtained the same results on repeating and varying Duhamel's experiments. Dutrochet filled a vessel, pierced at the bottom, with moist earth, then introduced several beans by the holes, and suspended the vessel from the ceiling of a chamber. The roots from the seeds came out by the holes, whilst the plumulæ rose through the moist earth. Now if the direction of the growth of the radicles were determined by darkness and humidity, and that of the plumula by the influence of light and heat, as some naturalists say, the latter should have proceeded downwards, and the former upwards, which was not the case.

CCCCLXXVII. Experiments have also been made to ascertain whether the direction which the radicle and plumula take might be changed by a mechanical movement given to the seed while germinating. John Hunter placed a bean in the middle of a small barrel full of moist earth, which he then turned horizontally on its axis; but he observed no change in the direction of the growth of these parts. Knight(4) fixed and made beans germinate on the lateral surfaces of a small wheel, eleven inches in diameter, placed perpendicularly, moved by a rivulet and making about 150 turns in a minute. After some days he saw the radicles of beans, which had been driven in all possible directions, all separate in rays from the circumference of the wheel, while the plumulæ proceeded towards its centre. The same experiment was made with a wheel moved horizontally, which turned 250 in a minute on its axis. The radicles still tended outwardly and the plumulæ inwardly; the former being inclined towards the earth at an angle of 10 degrees, and the others to the surface at a similar degree. The slower the rotation, the more did the radicles point downwards, and the plumulæ upwards. At the rate of 24 turns in a minute, the angle of inclination of the radicles to the earth, and of the plumulæ to the air was 45 degrees. Although these

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(9) Physique des Arbres, v. ii, p. 138.

(1) Grundsätze der Anatomie und Physiologie, p. 126. Nachträge, p. 39.

(2) Des directions speciales qu'affectent les diverses parties des vegetaux; in Recherches anatomiques et physiologiques sur la structure des animaux et des vegetaux et sur leur motilité. Paris, 1824, 8vo, p. 92.

(3) Edinburgh Philosophical Journal, No 12, January; April 1822, p. 312.

(4) Philosophical Transactions, 1806, part 1, p. 99.

experiments prove that the direction of the movements of growth may be changed by a rotatory motion of germinating seeds, we cannot, as Smith(5) and L. C. Treviranus(6) properly remark, conclude from this that the tendency of the roots downwards is determined by the centripetal force or gravitation, and that of the radicle upwards by the centrifugal force. If this were the case, the roots in the experiments above quoted, should have been turned inwards towards the centre, and the plumulæ outwards, which did not occur. Experiments of a similar kind have been recently made by Dutrochet(7) and have presented the same results. He took a hollow glass ball, in the middle of which a germinating seed was placed, turned it on its axis, and during its rotation gave it slight blows with a hammer, which always fell on the same side of its periphery. All the plumulæ pointed towards the spot where the shocks were received, and the radicles to the point directly opposite. By augmenting the number and force of the blows in a determinate proportion, he saw both products of the seed gradually take a perpendicular position, that is, a direction perpendicular in reference to the movements of the shocks. It follows, hence, that the movements of growth of the radicle downwards, and of the plumula upwards, may be somewhat changed by movements given to them, but that, as far as we can judge from experiments hitherto made, they are primitively neither produced nor determined by external movements.

CCCCLXXVIII. The experiments which have been quoted, therefore, afford proof that the movements of growth in two opposite directions which accompany the development of plants, are not originally determined by external influences, by light, heat, air, humidity, or gravitation. They only depend on them, as we shall hereafter see in speaking of germination, inasmuch as such influences furnish the conditions for the manifestations of the plastic force. We must, therefore, consider them as the effects of a force inherent in the germ itself, which determines and regulates the formation and growth of plants. This force is none other than the plastic power, in which appears to exist the sufficing, though, in mode of action, unknown, cause of the movements of growth. It may, moreover, be advanced, that this force does not act herein according to laws applicable to movements produced by mechanical causes. The opinion of Dutrochet that the movements of plants are determined by an activity analagous to the nervous energy, (*nervimotilité des végétaux*,) under the influence of external agents, is an hypothesis devoid of all proof.

Although we regard the plastic force as the internal cause of the movements

(5) Introduction to Botany, p. 95.
(6) Beiträge zur Pflanzen-Physiologie, p. 191.
(7) De l'infiuence du mouvement de rotation sur les directions speciales qu'affectent les diverses parties des vegetaux ; Loc. cit , p. 138.

of growth, and of the development of their tendencies, it cannot be denied, that internal agents, by their influence on plants, may produce a greater activity of it, and determine its effects within certain limits. Thus it is known that roots laid bare and placed near to a sponge filled with water, approach it. It is also sure that roots are elongated chiefly in the direction where a greater abundance of nutritious matters is to be found. This appears to be the consequence of a stimulating power which these matters exert over the radicle fibres, and which produces in them an exaltation of nutrition and growth. We see, moreover, the pushing and growth of branches, leaves, and flowers, take place more palpably on the side where a stronger light falls on the plants, and that in green-houses or caverns they invariably progress towards the light. This is also doubtlessly an effect of the irritation of the light, which excites the plastic power of vegetables to a greater activity. Lastly, it is well known, that morbid productions are developed in plants, in parts that are exposed to unusual stimulations, of which the formation of excrescences after the bite of insects is a familiar example.

CCCCLXXIX. Among the sensible movements of formation and growth the twisting of many vegetables may be reckoned, which procures for them a firm support in rising, by the spiral turns they make round bodies. The trunks and stalks of very many plants tend, according to Dupetit-Thouar and Decandolle's(8) observations, to form spiral turns in their growth. The leaves of most vegetables are likewise disposed in spiral lines, as was observed by Calandrini in pines and fir-trees, and by Jussieu in the *Araucaria.* Cassini showed(9) that leaves are ranged in five spiral lines in many plants. Further, Decandolle(1) demonstrated that leaves arranged in the *Quincunce* form a spiral line, whilst those of the *Pandanus* and *Dracæna* represent three spiral parallel lines, and those of some other species of *Euphorbia* and *Pinus,* five or six spiral lines. These lines turn to the right in some vegetables, and to the left in others. The arrangement of a spiral line is remarked in some flowers. The scales of pine-apples and the capsules of the genus *Medicago* also take on this form. Vaucher disovered a spiral arrangement of fibres in the stalk of the *Equisetum fluviatile.* Lastly, the spiral vessels which exist in most vessels likewise exhibit this phenomenon.

But nowhere is the spiral form more remarkable than in the twisting stalks *(Caulis volubilis)* of some plants, which in this manner are twisted upon themselves and round their support. Such an arrangement is particularly

(8) Organographie Vegetale, v. i, p. 154.
(9) Journal de Physique, May, 1821.
(1) Loc. cit., v. i, p. 338. Toutes les dispositions des feuilles peuvent se reduire à deux classes, savoir, 1° les feuilles verticilles qui, quand le verticille est reduite au minimum deviennent opposées; 2° les feuilles en spirale qui, quand la spirale est reduite au minimum, deviennent alternes.

common in tropical vegetables; it is more rare in those of temperate zones and does not exist at all in cold climates. It is principally exhibited in the stalks of the families *Convolvulaceæ* and *Leguminosæ*. Regarding the direction which the stalk takes, it has been remarked to be most frequently from right to left, as in the genera *Cocculus, Menispermium, Nissolia, Dolichos, Abrus, Cuscuta, Convolvulus, Calystegia, Ipomœa, Thunbergia, Clitoria, Passiflora, Periploca, Momordica, Lithsomia, Banisteria, Asclepias, Cynanchum, Tragia*; but sometimes also from left to right, as in the genera *Calyptrion, Basella, Lonicera, Tamnus, Humulus, Polygonum, Morinda, Dioscorea*. The cause of this diversity of direction is unknown. But it is certain, that the direction belonging particularly to each plant cannot be changed, and that by attempting it the growth is stopped. Some vegetables are broken, and wither when another direction is given to them, as was shown by Broussonet.(2)

CCCCLXXX. According to the valuable experiments made by Palm,(3) twisting plants show no trace of spiral movement at the time of their first exit from the earth, and it only begins to be manifested in them after the formation of one or more internodia. The contortions occur at first with exceeding slowness, so that the vegetables scarcely describe a circle in the space of twenty-four hours. But as the growth increases, they become more rapid, and make from four to eight circles in the day; but much depends on external influences favouring the growth of plants, as warm weather, light, moisture. The torsion is more rapid in day than night; in bright sunshine than in gloomy weather. If a plant, during its circular movement, meets a perpendicular or only slightly inclined body, it attaches itself to it, surrounds it, and rises in spiral turns up it. The nature of supports, their form, colour, their matter, do not influence the movements; neither do they exert any attraction over the vegetables. It is said, however, that some plants never approach nor twist round certain others. It is not known whether this phenomenon is connected with the transpiration of vegetables. Further, the *Cuscuta* only twists round living plants. If twisting vegetables find no support near to them, they point downwards and twist round each other. The spiral torsion stops with the cessation of growth, which mostly corresponds with the budding of the flowers. External influences, light, heat, air, and moisture, only excite to this torsion, inasmuch as they are necessary conditions of growth, and they accelerate it by favouring nutrition and growth. Light, though the agent which exerts the greatest influence on the movements of twisting plants, by accelerating their increase, has not the power of changing the direction of the spiral turns. Electricity,

(2) Mem. de l'Ac. des Sc. de Paris, 1784, p. 612.

(3) Ueber das Winden der Pflanzen; a prize essay bestowed by the medical faculty of the University of Tubingen. Stutgard, 1827, 8vo.

galvanism, and magnetism do not appear to influence this kind of movement. Galvanism alone seems to hasten it, according to Palm's experiments, by favouring growth. The cause of the torsion does not seem to depend on the structure of the plants, for this does not essentially differ from that of other plants; it differs in different genera, and in genera containing both twisting species and such as are not, no difference between them is exhibited. As torsion commences in the young parts of the plants, before as yet there is any trace of perfect tissues, before the spiral vessels are formed, it cannot be attributed to these, which, moreover, are wanting in some twisting plants, the *Cuscuta* for instance, and when met with in them, does not belong exclusively to them.

From these researches, it follows, that the torsion is a manifestation of life which does not depend on purely mechanical causes, as Senebier maintained, and that it cannot be attributed to muscular contractility, as Fontana thought, since the movement is neither accompanied by sensible contractions nor determined by stimulating causes producing contractions in living muscles. It is plainly, according to the very judicious remark of Broussonet and Palm, the consequence of movements effected by external influences which are favourable to development and growth. It appears to be accompanied by a more copious afflux of humours, by a movement of turgescence excited by the stimulus of light, and producing an increase of tension and movement.

CCCCLXXXI. Another movement of plants is executed by particular organs, the tendrils, *(Cirrhi,)* by means of which, in their growth, they attach themselves to, and, as it were, climb up surrounding bodies. Tendrils are only found in a small number of genera, and they exhibit differences. In some plants they originate from the groin of the leaves, and are rolled up like a snail, as in the genera *Cucumis, Cucurbita, Passiflora,* and *Smilax.* In others they are seen opposite the petioles, and in such case they are undeveloped and barren peduncles, as in the genera *Vitis* and *Cissus.* These latter are commonly ramose, and have a small incurvation at their extremity, like a hook, by which they hold by, and twist round, bodies. Some vegetables, as the *Vicia* and *Cobœa,* have tendrils at the extremities of their pinnate petioles. Lastly, petioles take on the form of tendrils in the *Adlumia cirrhosa,* and in some species of *Clematis.* From Palm's researches it follows, that tendrils have two kinds of movement which do not take place in fixed directions and become more sensible by the contact of foreign bodies, previous to the cessation of their longitudinal growth. Some tendrils, such as those of the *Cucumis* and *Cucurbita,* are contorted from their commencement, afterwards are extended and only gradually take the spiral form in an opposite direction. If the tendril meets an object in its second roll, it twists round it. The tendrils of leguminosæ twist in different directions round foreign bodies, such as wood, threads, glass, metals, silk, and living plants without distinction, ivy *(Hedera helix)* alone excepted, to which the tendrils seem to have an aversion. The movement of tendrils proceed in a ratio with the longitudinal growth, and cease with it. With regard to the influence exerted over them by imponderable bodies and humidity, they resemble precisely the twisting plants. The circumstances which favour growth also accelerate the rolling of tendrils. No trace of a contractile faculty analagous to muscular contractility is perceptible. Tendrils do not exhibit anything in their structure differing from that of other parts of the same plant and other plants of the same genus. Here also the spiral form is already pronounced before perfect tissues and spiral vessels are formed.(4)

CCCCLXXXII. We are bound to consider all the movements of nutrition and growth which accompany the formation and development of the different parts of plants as vital phenomena that are produced and regulated, not by mechanical causes, but solely by an internal principle, the plastic force. External influences or stimulations applied to living vegetables, are, it is true, necessary to the manifestations of movement, but are only so, inasmuch as they induce the plastic force; they do not determine the direction of the movements of formation, which is consequent on the specific character of the plastic force in each species of plant, which itself depends, in its active state on the operation that produces the vegetable grain by the organisms that gave origin to it. Moreover the movements of development and growth are arrested by divers external influences which annihilate the plastic force, as by a very high degree of heat or cold, by violent electric shocks, and by poisons.

In each plant, the plastic force is manifested in a specific manner, conformably with the species to which it belongs, and it determines, in reference to time, form, and chemical composition, the phenomena of formation which are connected with the development and growth of the different parts, which phenomena cannot be changed in their essence by the sum or the nature of

(4) The petiolar tendrils are merely prolongations of the petiols. The leafy tendrils are rare, and are not true limbs of the leaf, but rather foliaceous petiols without limbs, as in the *Flagellaria indica*, (Decandolle,) *Menthonica gloriosa*, and *Fritillaria verticillata*. The stipular tendrils are also rare, and their existence may even be doubted; such so called are seen proceeding from the axilla of the cotyledons and lower edge of the stalk of the *Trapa natans;* sometimes they occupy the place of a stipula as in the cucurbitaceæ. Peduncular tendrils are more frequent than the preceding kinds, and are found in the genus vitis, passiflora, (the tendrils of which do not proceed from the leaf axilla, as mentioned in the text—see Decandolle Organograph. Vegetal,) and cirrhiflora, (Juss. Ann. Mus. 6, p. 41.) They are probably, and particularly in the latter species, abortive peduncles. The pedicellæ of the base of the clusters of the cardiospérma and other sapindaceæ are almost always transformed into tendrils, as are also some species of smilax.—Trs.

the excitations, but are only capable of being modified by such a cause in a slight degree and within fixed limits.

3. Movements of Globules in the Formative Fluids.

CCCCLXXXIII. The globules contained in the formative or nutritive fluid of plants have, like those of the blood of animals, the property of self-movement, as follows from the observations of G. R. Treviranus and Schultz (CCLXXXVII) already mentioned. With the microscope, C. Mayer(5) also saw diversely tending movements in the globules of the liquid which flowed from incisions made in the leaves of the *Vallisneria spiralis*, of the *Chara vulgaris*, the *Anthericum rostratum*, and the *Tropæolum majus*. He also observed movements in the juice contained in the cells and vessels of the *Vallisneria*, the *Chara*, and the *Lemna polyrhiza*. These movements were more rapid under the influence of light. Further, Mayer(6) remarked the movements of the globules of the juice in the cells of the *Chara*, the *Vallisneria, Hydrocharis, Stratiotes, Sagittaria, Cucurbita, Cucumis*, and *Potamogeton*. They were accelerated by heat, retarded by cold, and arrested in vacuo. Acrid substances suspended them. In favour of the special and proper movements of the sap-globules the movements of the green grains in the articulations of confervæ may be advanced, which have been observed with the microscope by Ingenhouss,(7) Girod de Chantran,(8) Vaucher, and L. C. Treviranus.

CCCCLXXXIV. Movements have also been observed in the spherical corpuscules of the grains of pollen, which have lately given rise to disputes. Needham and Gleischen had already ascertained that when the pollen grains burst, small corpuscules proceed from them which upon being thrown into water move like infusoria. Schmiedel(9) even saw that the small globules which cover the twigs of the *Jungermannia pusillu*, and which are regarded as male generative organs, gave out minute corpuscules which oscillated vivaciously in water. A similar phenomenon was remarked by the younger Nees(1) in the globules of the anthers of *Sphegnum capilliforme*. Rotatory movements have been observed by Amici(2) in the pollen

(5) Loc. cit., p. 31.
(6) Nov. Act.. Ac. Nat. Curios., v. xiii, p. 2. Anatomische-physiologische Untersuchungen über den Inhalt der Pflanzen Zellen. Berlin, 1828, 8vo, p. 70.
(7) Vermischte Schriften, translated by Molitor, v. i, part 78, p. 218.
(8) Recherches Chimiques et Microscopiques sur les Conferves, Bisses, Tremelles, &c. Paris, 1802, p. 88.
(9) Icones Plantar. et Anal. Part., fasc. i, p. 83, tab. 22, fig. 8.
(1) Flora oder Botanische Zeitung, 1822, No. 2.
(2) Memorie della Socièta Italiana della Scienze residente in Modena, vol. xix, 1823.

globules of the *Portulaca spinosa.* Guillemin(3) likewise remarked that when the pollen grain burst, a liquid escapes which does not mix with water, and contains a multitude of very small globules that continue for a long time in motion. These globules he compared to the spermatic animalculæ. Alexander Brogniart(4) saw small spherical or elliptic corpuscules in the pollen grains of the *Pepo macrocarpus,* of several malvaceæ, and a great number of other plants; and he observed the movements of these corpuscules after the grains had been emptied of them into water. These movements were manifested in the *Pepo,* by a slow oscillation, accompanied by displacement. In the *Hibiscus palustris* and *syriacus,* the *Sida hastata* and the *Rosa practeata* they were exceedingly vivacious, and the globules, when executing them, sometimes changed their shapes and became bent. These corpuscules, called by him "*Granules spermatiques,*" and varying in volume and form in different genera of plants, appeared to him also analagous to the spermatic animalculæ. To them, as to the latter, he attributed a spontaneous movement, not communicated by anything extraneous. Their movement is stopped by alcohol.

Robert Brown(5) saw particles, of a shape between cylindrical and spherical, proceed from the pollen grains of the *Clarkia pulchella* when they burst, which moved in water. The movement of these particles did not consist of a simple change of their relative situations, but not unfrequently in a change of form, inasmuch as an inflexion or bending was visible in them. He convinced himself that the movements proceeded neither from currents existing in the water, nor from its slow evaporation. He remarked similar particles, or, as he calls them, molecules, in the pollen grains of very many plants of the different families belonging to the two great divisions of phanerogamic vegetables. They had sometimes an oblong shape, sometimes spherical, and their movements were always accompanied by a displacement and occasionally by a change of shape. Several plants of different families, chiefly of the gramineæ, whose pollen grains are transparent, exhibited molecular movements in the grains themselves. He likewise observed mobile molecules in those organs of cryptogamic vegetables, mosses, and particularly equiseta, which some botanists consider as stamina. He recognised movements, not only in the particles of fresh pollen grains, but also in those of

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(3) Recherches sur la generation et le developpement de l'embryon dans les vegetaux phanerogames; in Ann. de la Soc. Nat., v. xii, p. 14. Nouvelles recherches sur le pollen et les granules spermatiques des vegetaux; in Ann. des Sci. Naturelles, Nov., 1828, p. 381.

(4) Recherches microscopiques sur le pollen; in Mem. de la Soc. d'Hist. Naturelle de Paris, 1825, No. 2.

(5) A brief account of microscopical observations made on the particles contained in the pollen of plants; and on the general existence of active molecules in organic and inorganic bodies. London, 1828, 8vo. Also in the Philosophical Magazine and Annals of Philosophy, new series, Sept., 1828, p. 161. Additional remarks on active molecules by R. Brown, July, 1829.

the pollen of plants which had been preserved 120 years in an herbarium. In like manner he saw spherical and mobile molecules in other parts of plants which he had crushed in water.

At first he took these particles for the elementary molecules of organized bodies described by Buffon, Needham, Wrisberg, Mueller, and others, because he discovered them in vegetable as well as animal tissues that were crushed, either alive or dead, in water, and were reduced into very minute fragments. But he abandoned this opinion, when, on examining inorganic bodies with the microscope, he observed similar molecules, spherical in form, and executing movements, not only in fossil wood, but even in glass, granite, obsedian, lava, pumice stone, manganese, nickel, bismuth, arsenic, and other inorganic substances reduced to fine powder and diluted with water. The cinders of burnt organic matters, of wood, linen, paper, cotton, wool, silk, hair, and muscular fibre, exhibited the same when thrown into water. On this he founded the assertion that all solid bodies of the organic and inorganic kingdoms are composed of active molecules. The smallest mobile particles have a spherical form, and their volume is from $\frac{1}{20000}$ to $\frac{1}{30000}$ of an inch. Dispersed in water, and swimming in it, they perform movements which are not communicated to them by currents; neither do such result from evaporation, but are accomplished by a power proper to, and inherent in, the molecules.

According to these researches, the movements of the particles contained in the pollen grains would appear not to belong to organic or vital phenomena. Raspail(6) also thinks it may be concluded from his observations, that the corpuscules in question cannot be considered as spermatic animalculæ, but that they are minute drops of a resinous substance, which, after their ejection from the grains, separate from each other in consequence of the weak attraction they possess for water.

Further researches, therefore, chiefly referring to the operation of different stimuli on the particles of pollen, appear necessary in order to decide whether their movement should or should not be considered as manifestations of life.(7)

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(6) Observations and experiments tending to demonstrate that the granules which are discharged in the explosion of a grain of pollen, instead of being analogous to spermatic animalculæ, are not even organized bodies; in the Edinburgh Journal of Science, Jan., 1829, p. 96.

(7) The movements of the pollenic particles were observed by Brown in several species of the natural families, *Onagrariæ*, *Gramineæ*, *Asclepiadeæ*, *Periploceæ*, *Apocineæ*, *Orchideæ*, &c., during the life of the plants. The same he saw in the minute spherical bodies found on the surface of the four spalhulate bodies surrounding the naked ovulum of *Equiseta*, and other cryptogamic plants, as mosses. Such movements were also observable in specimens of several phanerogamic plants that had been dried and preserved in an herbarium for upwards of a century; and of mosses after a lapse of the same period. The pollen grains are likewise capable of discharging their contents after months of immersion in weak spirit and water; those of the *Viola tricolor*, according to Brown, did so even after immersion in nitric acid.—Trs.

CCCCLXXXV. Lastly, mention must be made of the remarkable movements effected by the germinating grains of divers confervæ, which after separation from the vegetable that produced them, move like infusoria. Movements of this kind have been observed by Nees von Esenbeck,(8) in the reproductive corpuscules of Nostoc and the *Ectosperma clavata* of Vaucher. G. R. Treviranus and Dittmar saw them in those of Vaucher's *Batrachospermum* and Roth's *Conferva compacta.* Bory de St. Vincent(9) observed propagation by self-moving and living grains *(Zoocarpes)* in the numerous group of plants resembling confervæ, the Zoocarpeæ, of the family of Arthrodicæ. Gruithuisen(1) found the reproductive corpuscules of a small species of conferva, *(Conferva ferax,)* move freely like infusoria. Carus(2) witnessed a similar phenomenon. Nees of Esenbeck,(3) has united the genera whose germinative grains present movements, into a family which he designates by the name of *Hydronemateæ,* and which corresponds in many respects with the Arthrodicæ of Bory. F. Unger(4) has also very recently examined the reproductive corpuscules of the *Ectosperma clavata.* He saw small green globules grow as filaments, and subsequently become detached, and swim in water like infusoria; when they ceased to move they showed themselves as filaments of confervæ. Gaillon(5) and Demaziéres(6) had previously thought they remarked globules which performed movements, placed themselves in a series, and thus produced the new filaments of confervæ. Ingenhouss,(7) G. R. Treviranus,(8) Girod de Chantran, and others have advanced an analogous opinion, namely, that the green matter of Priestley is formed by an union of infusoria, and is afterwards resolved into infusoria.

These different observations seem to show, almost to a certainty, that the reproductive corpuscules of certain confervæ execute movements resembling those of infusoria, and that these corpuscules, after enjoying this mode of life for some time, germinate in the same manner as seminal grains of other cryptogamia, and then represent filaments of confervæ.

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(8) Die Algen des saüssen Wassers. Bamberg, 1814.
(9) Diction. Classique d'Hist. Nat., v. i, Art. Arthrodicæ.
(1) Nov. Act. Ac. Leopold. Carolin. Nat. Curios., v. x, p. 437.
(2) Ibid., v. xi, p. 491.
(3) Ibid., v. xi, part 2, p. 518. He divides the Hydronemateæ in the following manner: A. *Tremelloideæ,* Nostoc, *Syncollesia,* Nees. B. *Oscillantia, Baccillaria, Oscillatoria,* Thunberg, *Diatoma,* Nees. C. *Confervoidea,* and *Saprolegnia,* Nees, *Achlya, Pythium, Zoocarpea, Ectosferma.*
(4) Die Metamorphose der *Ectosperma clavata.* Vaucher. Ibid, v. xiii, part 2, p. 780.
(5) Annales des Sc. Natur., v. i, p. 309.
(6) Ibid., v. x, p. 42.
(7) Vermischte Schriften, v. ii, p. 218; v. iii, p. 33.
(8) Biologie, v. ii, p. 338, 344, 350.

4. Movements of the Sap Vessels.

CCCCLXXXVI. Several physiologists, Saussure, Hedwig, Gahagan, Brugmanns, Coulon, Townson,(9) Carradori, and others conclude, from their observations and experiments, that the sap of vegetables is moved by a vital reaction or contraction of the coats of the sap vessels. Some have considered the contraction as the effect of organic contractility or tonicity, *(tonus;)* others, as analogous to muscular contractility, as is elsewhere stated.(CCLXXXV.) Very recently, Don(1) and Barbieri(2) maintain that they have observed vital contractions in the sap vessels. The former remarked, what had been already perceived by Malpighi, that the spiral vessels of herbaceous plants enter into movement when they are separated. This movement persisted some seconds, in his experiments, and did not appear to be attributable to a simple mechanical effect. On holding a small piece of the Urtica nivea, just detached from a living stalk, between his fingers, he observed a spiral movement which seemed to him the manifestation of a contractile force of living fibres. Barbieri says he perceived, with a solar microscope, in transparent charæ, tubes composed of exceedingly fine pellicles, in which the sap circulates. According to him, these minute tubes communicate in the knots with the hollow fibres of the roots, which perform the absorption of liquids. He says he observed, moreover, that the filaments of the roots contract and relax alternately in spiral lines, and he thinks a movement is thereby communicated to the sap. These observations, provided they are correct, seem to sustain the opinion that the sap-vessels react on the sap, and communicate a movement to it, a point which has been denied by many physiologists.

5. Movements of the Leaves.

CCCCLXXXVII. Leaves perform movements under various circumstances. In most plants they have not only a determinate situation and direction, the consequence of development and growth, but they also return to these when any mechanical influences may have changed them. The leaves of many plants change their direction during the day. In several, they are induced to movement by external actions and varied excitations. Lastly, there are some which are in a state of incessant oscillation. We will examime these movements more in detail.

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(9) Transactions of the Linnæan Society, v. ii, p. 211.

(1) On the general presence of spiral vessels in vegetable structure, and on the peculiar motion observable in detached pieces of the living bark of Urtica nivea; in the Edinburgh Philosophical Journal, Oct., Dec., 1828, p. 21.

(2) Osservazioni ed esperienze intorno la circolazione della linfa in alcune spezie di Cara. Mantua, 1828.

CCCCLXXXVIII. The leaves of almost all plants are so situated as that one of their surfaces, the most highly coloured one, looks upwards, and is exposed to the influence of light, whilst the less strikingly coloured one looks downwards. If a leaf be disturbed from this position and turned, it very soon renews its former direction, as Bonnet(3) proved by numerous experiments. The torsion occurs in the foot-stalks and their knots and joints, and takes place with greater rapidity in the leaves of herbs than trees. Otherwise, it is remarked both in plants existing in air and those inhabiting water, and is even active in the former when their branches are immersed in water. It also takes place in vacuo. It is effected by day or night alike, but more rapidly under the influence of solar light. The season of the year affects it, for it is more quick in warm, dry, and serene weather than in cold, moist, and lowering. Its rapidity is never greater than in full sunshine. If the leaves have been turned frequently, torsion is then effected more tardily. The frequent repetition of the experiment is hurtful to the life of the leaf. Should the foot-stalk be transfixed at its knot, the movement takes place slowly, and after several wounds it ceases altogether. It is further worthy of remark, that the leaves of the branches which Dutrochet exposed to a rotatory motion in a glass balloon, turn their upper surface towards the centre of rotation, and the lower one towards the periphery. This occurred in consequence of a torsion in the foot-stalks.

CCCCLXXXIX. The tendency of leaves to preserve the situation and direction that are given to them by development and growth, and to renew this when they have been turned by any external mechanical action, seems owing to an afflux of sap into their vessels, and to a state of turgescence resulting therefrom, on which state their position and spreading depend. In support of this hypothesis is the fact that the leaves of plants, deprived of water, become relaxed, soft and flaccid; but as the plant absorbs liquid, the leaves quickly return to their firmness and expand. It may be further alleged, that these movements of leaves are active in a purely special manner through the influence of solar light, which favours the afflux of sap towards the leaves and maintains exhalation, and the exchange of gaseous matters in respiration. They are likewise more rapid in young plants during development, in the spring, when the sap flows more quickly, than in aged vegetables, in autumn, when the current of sap to the periphery diminishes. The petioles, however, with their vessels or cellular tissue, appear to possess a certain degree of contractility, by which, after distraction they endeavour to return to their former position. The leaves of plants that have been exposed to the action of poisonous substances lose this property.

(3 Recherches sur l'usage des feuilles dans les Plantes. Gœttingen and Leyden, 1754, 4to, sec. 2. Supplement dans ses Œuvres, v. ii, p. 460.

CCCCXC. The leaves of a great number of vegetables exhibit changes in their direction corresponding to different periods of the day. This phenomenon was known, in some degree, to Theophrastus and Pliny. Acosta(4) and Prosper Alpini(5) observed it in the pinnate leaves of some plants of warm countries. Linnæus(6) paid particular attention to it, and gave it the inappropriate name of the sleep and waking of vegetables. Deeper researches on this subject have been made by J. Hill,(7) R. Pulteney,(8) R. A. Vogel,(9) Zinn,(1) and others.

During the day the leaves are expanded, and their upper surface, exposed to the influence of solar light, is mostly concave, or somewhat grooved. Those of divers herbaceous plants, for instance, of the *Helianthus annuus*, the *Helianthemum annuum*, the *Croton tinctorium*, &c., even follow the sun's course in their position.

Towards the evening the leaves take another direction. Simple leaves that are opposite to each other sometimes shrink so as to touch by their superior surfaces, as in several species of *Atriplex* and *Asclepias;* at other times, they cling to the stalk, as in the *Sidon abutilon*, and the *Œnothera mollis*. Some form a funnel which envelopes the flowers, such as those of the *Malva peruviana*, the *Iva annua*, and several species of *Parthenium, Amaranthus*, and *Datura*. In other plants, again, the leaves drop their points and cover the flowers like a vault, as in the *Hibiscus sabdariffa*, the *Impatiens noli tangere*, the *Sigisbeckia orientalis*, the *Millera quinqueflora*, &c. More palpable movements are perceived, in the evening, in compound and pinnate leaves, whose petioles bend downwards towards the stalk, and whose leaflets take another direction. In many of these plants, the leaflets are applied to each other by their upper surfaces, as is seen in the *Colutæa arborescens*, the *Hymenæa courbaril*, the *Lathyrus odoratus*, the *Psoralea pinnata*, and the species of *Bauhinia*. In others, such as the *Tamarindus indica*, the *Gleditsia triacantha*, the *Hœmatoxylon*, &c., the closed leaflets fall at the same time like tiles upon the foot-stalk. In the *Lotus tetragonotus* and *Trifolium incarnatum*, the points alone of the fallen leaflets touch. Lastly, in many vegetables the leaflets bend towards the earth, and have their inferior surfaces in contact, as in the *Robinia pseudacacia*, the *Ipomœa ægyptiaca*, the *Glycine abrus*, and several species of *Lupinus, Cassia, Glyzirrhiza, Oxalis*, &c.

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(4) Aromatum et medicaminum in Orientali India nascentium liber. Antwerp, 1593, p. 216.
(5) De Plantis Ægyptïæ, ed. Vesling, cap. 10, p. 35.
(6) Diss. de somno plantarum, resp. P. Bremer. Upsal, 1755, 4to. Amen. Academie, v. iv, p. 333.
(7) The sleep of plants and the cause of the motion in the sensitive plant explained. London, 1757, 12mo, 1762, 8vo.
(8) Observations upon the sleep of plants, and an account of that faculty, which Linnæus calls Vigiliæ florum; in Philos. Trans., v. l, p. 506.
(9) De statu plantarum quo noctu dormire dicuntur. Gœttingen, 1759, 4to.
(1) Von dem Schlafe der Pflanzen; in the Hamburgh Magazine, v. xxii, p. 40.

To these movements, which vary according to the time of day, may be also referred the periodical expansion and closing of the foot-stalk cavities of the *Nepenthes destillatoria* and of the *Phyllamphora Madagascariensis*.(2)

CCCCXCI. Most writers on vegetable physiology have looked for the determining cause of these movements, in the influence of external agents on plants, and in the variation with which this influence is exercised at different times of the day. Some have believed them to be dependent on light; others have attributed them to vicissitudes of temperature, and others again to the different states of the atmosphere's humidity. It has been said that the presence of certain stimulants during the day induces the activity of the leaves, and thus occasions their expansion, whilst the absence of these excitations during the night causes them to fall into repose and flaccidity. The different direction of the leaves according to the diurnal periods, as well their erection and expansion during the day, as their sinking and folding during the night, must be considered as the consequence of a state of activity in both cases. Linnæus heretofore remarked, that the sleep of leaves cannot be attributed to a relaxation, and that it is altogether distinct from the flaccidity observable in them when they fade or are deprived of water. On the contrary, this state involves a certain degree of tension. If an endeavour is made to change the situation of a leaf thus closed, it resists, and if then left to itself, forcibly regains the position from which it had been disturbed: this has been observed by many botanists.

In favour of the hypothesis that the periodical movements of leaves depend on internal vital conditions, it may further be advanced, that they vary according to the progress of nutrition, growth, and development. In young, strong plants, which vegetate vigorously, and are in their epoch of growth, they are seen to be more vivacious than in vegetables that are old, unhealthy, or have already flowered.

CCCCXCII. The changes of situation and direction experienced by the leaves, according to diurnal periods, are to be traced, like those of growth and formation, to an internal activity of plants under the influence of external agents, light, and heat. They appear to be immediately produced by variations in the afflux of sap, and the degree of turgescence dependent thereon. By solar influence existing during the day, and that of heat, which is at that time more elevated, the movements of nutrition and growth become increased, and that of the sap accelerated. (CCLXXXVIII) It rises more copiously,

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(2) Pliny observed the erection of the leaves of trefoil on the approach of a storm; he says "Trifolium quoque inhorrescere et folia contra tempestatem subrigere certum est," (Hist. Nat., lib. xviii, cap. 35.) Linnæus says the same is observable in almost all plants with delicate stamina, (Flor. Luphon., p. 222.) The *Trifolium pratense album*, or common white flowered meadow trefoil, is a barometer to the Swedes, and warns them when to prepare for a storm.—Trs.

spreads through the vessels of the leaves, and puts them into a state of turgescence, which is accompanied by an unfolding and expansion. The operations of respiration, exhalation, and the change of aeriform materials, are then performed in the leaves more actively and rapidly. (CCCIX.) When, on the other hand, in the night, in the absence of solar light and the decrease of atmospheric temperature, vegetable growth becomes less energetic, the movement of the sap slower, and respiration less active, a smaller quantity of liquid arrives at the vessels of the leaves and they close. The sap then appears to accumulate more in the knots and swellings of the petioles, and possibly that which the vessels of the leaves contained retires thither. A turgescence and certain degree of tension thence ensues, and has the effect of changing the direction and situation. The reason why the leaves and leaflets of some plants fall during the night against the knots and swellings of the foot-stalks, whilst in other vegetables they fold up, is probably dependent on the different modes of disposition of the vessels in the knots and swellings, a point, however, on which no anatomical researches have been hitherto made. In favour of the dependence in which the movements of the leaves are supposed to be on the variations of afflux of the sap, and the different degrees of turgescence arising therefrom, under the influence of heat and light, it may be stated that certain plants, for instance, the *Euphorbia lathyris*, the *Ocymum fructicosum*, the *Asclepias curassavica*, the *Solanum bahamense*, &c., exhibit, during the winter, a change in the direction of their leaves similar to that which the vegetables called sleepers present at night, and that the pinnate leaves of very many plants are neither erected nor expanded, or very slightly, in cold days. Adanson(3) and Bonnet remarked that leaves, on the approach of a hot or red iron to their upper surface, became erect, as they do when they feel the influence of the sun's rays. Plants that have been long withdrawn from the action of solar light, lose the power of unfolding and expanding their leaves. Moreover, some observations of Hill and Zinn exist, which go to show that leaves droop in daytime when placed in a dark place, and again rise and expand when returned to the light. The leaves of some vegetables have even been seen to rise and expand at night by the artificial light of lamps.

CCCCXCIII. The change which occurs in the afflux of the sap, and in the turgescence of the different parts of the leaves dependent on it at different periods of the day, appears to be accompanied at the same time by a varied degree of contraction in their sap vessels and cellular tissue, as well as of their foot-stalks. In proof of this is the effect produced by divers substances

(3) Famille des Plantes, v. i, p. 55.

imbibed by the roots, which change the mode of vitality of vegetables, and thereby modify or destroy their mobility. Schuebler and Zeller(4) found in their experiments on this point that the leaves of different species of *Acacia, Cassia,* and *Mimosa,* after the absorption of narcotic substances, whether extract of opium, or nux vomica, or distilled laurel water, *(Aqua laurocerasi,)* were deprived of the power of moving their leaves, of dropping or folding them at night, for they remained expanded, and gradually fell, frequently after very few days, although green. After the absorption of a solution of camphor, the leaflets approached each other as at the commencement of night, but they never afterwards expanded. If branches, whose leaves were closed, were immersed in solutions of narcotic substances, the latter remained in that state without opening in the day, and gradually perished. Goeppert,(5) saw the leaves of the *Coronilla securidata, Tamarindus indica, Acacia farnesiana,* and *Poinciana pulcherrima,* cease to move according to the diurnal periods, after their branches had been placed in water containing prussic acid or prussiates, or in bitter almond water, cherry laurel water, and similar poisons. The action of these substances can only be explained by admitting that they annihilate the contractility with which the sap-vessels of plants seem to be endued, and that after such extinction, the movement of the sap in the leaves ceases, together with the turgescence dependent on it.

CCCCXCIV. The leaves of certain plants move, not only at diurnal periods, but also in consequence of external influences or excitants of divers kinds. This phenomenon has been remarked in several plants of warm countries, but particularly belonging to the family of leguminosæ, such as *Mimosa (pudica, sensitiva, casta, viva, asperata, humilis, pellita, dormiens,* &c,) *Desmanthus, (diffusus,) Schrankiaa (aculeata,) Smithia, (sensitiva) Æschynomena, (sensitiva, indica, pumila,) Oxalis (sensitiva,) Dionæa (muscipula)* and *Averrhoa (carambola.)* Numerous experiments and observations concerning this subject have been made on *Mimosæ,*

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(4) Schweigger, Jahrbücher der Chemie und Physick, 1827, sec. 5, p. 62.
(5) De Acidi Hydrocyanici vi in Plantis commentatio. Breslaw, 1827, 8vo, p. 26.
(6) Observations on the humble and sensible plants, in Micrographia. London, 1667, folio, p. 116.
(7) Disquisitiones Botanicæ de Herba Minosa. Tubingen, 1688.
(8) Hist. de l'Acad. des Sc. de Paris, 1729, p. 35.
(9) Observations sur la sensitive; in Mem. de l'Acad. de Paris, 1736, p. 87.
(1) Physique des Arbres, v. ii, p. 158.
(2) Beschäftigungen der Berliner Gesellsch. Naturforsch. Freunde, v. ii, p. 79, v. iii, p. 138.
(3) Mem. of the Society of Manchester, v. ii, p. 114.
(4) Observations on the irritability of plants; in Duncan's Medical Commentaries, 1790, Dec. 2, v. iv, p. 375.
(5) Nouvelles recherches sur la structure organique relativement à la cause des mouvemens de la sensitive commune; in Mem. de l'Acad. de Turin, 1790-91, v. v, p. 209.

especially the *Mimosa pudica,* by Hooke,(6) Mauckart and Cammerer,(7) Mairan,(8) Du Fay,(9) Duhamel,(1) Oehme,(2) Thomas Percival,(3) Gahagan,(4) Comparetti,(5) Lindsay,(6) G. C. Sigwart,(7) Dutrochet,(8) Burnett and H. Mayo,(9) the principal results of which I shall briefly enumerate.

CCCCXCV. In the *Mimosa pudica,* a plant of South America, with which Clusius first made us acquainted, there are mostly two or three pairs of leaves on a common foot-stalk, at whose point of union with the branch there is a knot or swelling, four lines in length, and covered with short hairs. Each leaf is pinnate, and likewise forms a minute swelling at the union of its particular foot-stalk with the common one. The opposite leaflets also exhibit one at each of their pedicles. In these protuberent points alone does the movement take place.

At daytime all the common foot-stalks describe an almost right angle with the stalk. The particular foot-stalks are also erect and separated from each other. All the leaflets are expanded horizontally. At sunset the leaves change their direction. At first the leaves rise in an insensible manner, incline towards each other, and join by their upper surfaces. They next descend with their anterior border towards the foot-stalk; then the individual petioles approach each other, and bend downwards; lastly, the common petioles bend towards the branch. It appears from Sigwart's observations, that, subsequently, the latter gradually recover themselves whilst the leaves approach nearer to each other until towards midnight they lay quite straight along the stalk. At sunrise the movements are in the inverse order. The petioles first recover their former situation, then the leaves rise and spread into a fan, and lastly, the leaflets separate and return to the horizontal direction. When the weather is lowering and cold, the leaflets remain closed.

CCCCXCVI. The foregoing movements take place both in the air and in vacuo. Dufay and Duhamel placed not only cut branches, but whole plants in pots under the recipient of an air pump, and saw the leaves rise and spread in the morning, and descend and fold in the evening; the movements, however, were effected less vivaciously than in air. They also saw branches and entire plants, which they had immersed in water, continue to perform, but feebly, alternate movements, corresponding with the diurnal periods.

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(6) In a MS preserved in the library of the Royal Society of London, and mentioned by Smith, (Introduction to Botany, p. 29,) Burnett, and Mayo.

(7) Bemerkungen über die Bewegungen der *Mimosa pudica;* in Reil's Archiv. für die Physiologie, v. xii, p. 13.

(8) Observations sur les mouvemens de la sensitive, *(Mimosa pudica;)* in Recherches Anatomiques et Physiologiques sur la Structure intime des Animaux et des Vegetaux. Paris, 1824, sec. 2, p. 52.

(9) Quarterly Journal of Science, July—September, 1827.

Variations of temperature influence the mobility, as was remarked by Dufay and Duhamel. The movements were not so strong in cold as in warm days; the leaflets did not open so rapidly nor so completely, and, in closing, they were not so accurately applied to each other as when the weather was warm. Dutrochet found the movements cease altogether at a temperature of +7° R. A very hot air likewise arrests them. But the external cause of the phenomenon is not to be sought for in the vicissitudes of temperature alone, for Dufay and Duhamel observed a sensitive plant that was in a room, the temperature of which was +15°, close its leaflets and drop its leaves in the evening, and in the morning open the one and erect the other, though the thermometer then stood about two degrees lower. Transferring a plant, towards the evening from a temperature of +20° to one of +28°, it still regularly closed its leaves. Similar experiments have been made by Zinn on the *Desmanthus virgatus*.

CCCCXCVII. Observers have arrived at different conclusions regarding the influence of light on the movements of sensitive plants. Mairan saw the leaves of those which he had placed in a dark place move at certain times, like those in the open air, in ordinary circumstances. Dufay and Duhamel, on the contrary, say, that although they saw the leaves of mimosæ that had been shut up for two days in perfectly darkened cellars, open, yet they did not close again, but remained expanded and unfolded. They assert that they observed the same effect on a plant which was inclosed in a box. In the night, when the light of a candle was made to fall on a mimosa whose leaves were closed, the latter did not expand. Hill, on the other hand, says he saw the leaflets close in the daytime, when the light was prevented from penetrating the place wherein the plant was. Zinn sometimes observed the same. Decandolle(1) placed a *Mimosa leucocephala* in a dark cellar, and another of the same species in a cellar strongly lighted by lamps. The plants opened and shut their leaves at the usual time, but the folding did not take place in the evening so completely as in the open air. Two plants of *Mimosa pudica*, on the contrary, that were during the day in a dark place which was lighted in the night with lamps, gradually so changed the time of what is called their sleep, that, on the third day the leaves opened in the evening, and closed in the morning. When returned to the open air they renewed their former mode of action. Ritter(2) observed that the *Mimosa pudica* opened and closed its leaves as regularly in the total absence of light as before, but not to the same extent. If the plant was covered whilst its leaves were extended,

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(1) Experiences relatives à l'influence de la lumiere sur quelques vegetaux; in Mem. presentés à l'Institut., v. i, p. 329.

(2) Gehlen's Journal für Chemie, Physik, und Mineralogie, v. vi, p. 470.

the leaflets somewhat approached each other. Dutrochet has made several experiments concerning the action of light on the *Mimosa pudica.* Plants in a dark place, at a temperature of $+20°$ to $+25°$, R., dropped their petioles in the evening, and brought together their leaflets; in a morning they spread the latter and erected the former. On the third day, the periodical movements occurred in a less sensible and complete manner, and, on the fourth day, the mobility had altogether disappeared. It was then impossible to excite movements, even by different stimuli. On the sixth day, when the plants were again exposed to the sun, the movements gradually reappeared. Hence, it follows, that the maintenance of the mobility of sensitive plants is attributable to the influence of light, inasmuch as the latter is an essential condition of the continuance of that living state of these plants on which their moving faculty depends.

CCCCXCVIII. Similar movements to those performed by mimosæ in the evening, and, in ordinary circumstances, may be excited during the day by stimuli of various kinds. Mechanical irritations, a blow, a shock, or any contact accompanied with agitation put the leaves into motion. If a leaflet be pinched, or cut with scissors, it rises together with that placed opposite to it. The same occurs in the next pair, and those following, until all the leaflets inserted in the foot-stalk are closed, after which the petiole itself descends. Shortly after, the neighbouring foot-stalks close. At length, and generally after twelve or fifteen seconds, the common foot-stalk bends. If the shock has been excessive, all the leaves of the plant enter into movement. Hence it is plain, that the irritation is transmitted from one leaflet to all those of a leaf and even to several leaves and divisions of leaves. The movements generally commence in the leaflet which has been irritated, then extend to the nearest ones, from the point to the base of the leaf; after which the irritation is propagated by the foot-stalk to the next leaf, whose leaflets close one after the other from the base to the point, &c. Sometimes the stimulation only excites a few leaflets or leaves, or portions of leaves, and their movements are performed more slowly. This phenomenon seems to depend on a varied degree of susceptibility. It is generally remarked, that the irritation is transmitted and propagated the more extensively as the plants are more healthy and are vegetating with greater vigour.

If the touch of a leaflet is light, and not accompanied by agitation, no movements are observed. A slight shaking, the section of a leaflet with a sharp instrument, causes only that one and its opposite to rise. A needle may also be struck into a leaf, if done with care, without any motion of it, as Dufay, Percival, and Sigwart observed. When, on the other hand, the bulb of a foot-stalk is irritated, the latter immediately bends. Wind and rain also induce folding of the leaves and sinking of the foot-stalks. It is further remarkable, that the *Mimosa pudica* becomes accustomed to shocks. Desfontaines took a sensitive plant with him in a carriage; the leaflets first closed, but gradually they opened and remained erect, notwithstanding the continuation of the shocks. Meyer,(3) also found in his experiments that the leaflets at length expanded when the agitation was continued for some time.

CCCCXCIX. Chemical irritations, of different kinds, also put the leaves in motion. Hooke saw the leaflets rise and apply themselves to each other, when he allowed a drop of aquafortis to fall on a foot-stalk, and the movement occur not only in that but in the other leaves. The following morning the leaves were again expanded, except those underneath the point where the aquafortis had been applied, which were faded. Dufay observed the movement after the contact of aquafortis, caustic, ammonia, and vapour of burning sulphur. Ammoniacal vapours also act as violent stimuli, according to Dufay, Gahagan, and Sigwart. The latter remarked that chlorine, more than any other substance, induced the strongest movements. Hydrogen gas, vapour of alcohol, and spirit of turpentine produced no effect. Meyer also tried the action of acids, alkalis, essential oils, and ethers, of all which the most volatile, and particularly the ethers, acted most forcibly. When the last two leaflets of a single foot-stalk were moistened with one of these liquids, they approached each other, as did the succeeding ones, down to the base of the foot-stalk; the movements were then propagated to the other leaves of the common petiole, proceeding from the base to the summit, and at last the foot-stalk itself bended. The bulbs of the foot-stalks were the parts most sensible to the irritation of chemical agents. Although no movements have been perceived in the stalk, branches, flowers, and roots, these parts are, notwithstanding, capable of receiving stimulations, and of transmitting them to the mobile leaves. Desfontaines saw all the leaves and the leaflets fall after he had poured sulphuric acid on the roots. Dutrochet produced the same effect by moistening a flower with this acid.

D. The imponderables, heat, light, and electricity, as stimulants, likewise excite the movements of the leaves of mimosæ. Hooke and Dufay having caused luminous rays to pass through a burning glass and fall on leaflets, saw these close and the footstalks bend. The same happens when a red hot iron is placed near the leaflets or leaves. Dufay and Sigwart burnt leaflets with the flame of a candle, when movements ensued more strong and rapid than after the employment of purely mechanical excitants. Here, also, we see the irritation propagated as in the preceding case, since the burning of a

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(3) Versuche über die Irritabilität einiger Pflanzen; in Froriep's Notizen aus dem Gebiete der Natur-und Heilkunde, May, 1824, No. 141.

leaflet induces movements in all the others, and even in several leaves and divisions of leaves. A rapid variation in the atmospheric temperature caused the leaflet to close, and the foot-stalks to descend. Hooke, Dufay, and Duhamel ascertained that when a plant has remained for some time covered with a glass bell and exposed to the sun's heat, and the bell is then withdrawn carefully without touching the plant, all the leaflets close, and all the foot-stalks bend. Duhamel also tried the action of artificial cold. He introduced a branch, which communicated with a plant, into a hollow glass ball, which he surrounded with a mixture of ice and salt; the leaflets at first bent downwards, but afterwards closed rapidly.

Young and very irritable plants, according to Ritter's experiments, close their leaflets, when suddenly exposed to a very strong light, and do not afterwards expand them until the light is enfeebled. Sigwart, too, observed, that when a plant had been kept in the shade for some time and then exposed suddenly to the glare of the sun, the foot-stalks fell, and the leaflets closed as after a mechanical shock.

DI. Naturalists are divided in opinion concerning the influence of electricity on sensitive plants. Ledru, called also Comus,(4) who first experimented on the subject, touched the leaflets lightly with a piece of glass, and remarked that they did not close. After he had made the glass electric, they approached each other by reiterated touches. A charged Leyden bottle, which he placed near the leaves, caused the closing of the leaflets and the bending of the foot-stalks. Having discharged the bottle several times, he saw the leaflets apply themselves to each other, and the petioles bend downwards. The simple electric bath produced no effect. Repeated electrization for several successive days weakened the mobility of the plants so much that the leaves no longer closed when touched. Ingenhouss and Schwankart(5) repeated these experiments and obtained the same results in the chief particulars; but they attributed the movements of the leaves to the mere shaking. Such was also the opinion of Dandriani,(6) Delamethrie,(7) and Cavallo.(8) Percival, however, ascertained, that it was sufficient to approximate a stick of electric sealing wax in order to produce the folding of the leaflets. Van Marum(9) found that the conductors, whether charged with positive or negative electricity, act no more than the electric bath, when placed near the

(4) Rozier, Journal de Physique, Nov., 1776, v. viii, p. 395.
(5) Ibid., Dec., 1785, v. xxvii, p. 462.
(6) Ibid., p. 468.
(7) Ibid., 1787, v. xxx, p. 26.
(8) Vollständige Abhandlung der theoretischen und praktischen Lehre von der Elektricität. Leipsic, 1797, p. 319.
(9) Seconde continuation des experiences faites par le moyen de la machine électrique Teylerienne. Haarlem, 1795, p. 160.

leaves of the sensitive plant; but when the conductors gave out sparks, the leaflets closed, and the foot-stalks bended. This effect he also attributed to the agitation caused by the electric shock. Ritter's(1) experiments on the action of electricity, developed by friction, seem to show that electric currents directed on the plants through metallic wires, produce the closing of the leaflets and the inflexion of the foot-stalks.

Galvanism has been likewise applied to these plants. Schmuck,(2) Iberti,(3) Fowler,(4) Cavallo,(5) Von Humboldt,(6) Creve,(7) Rafn,(8) and Giulio,(9) obtained no effect from a simple chain. Giulio, however, says he saw the leaflets close and the foot-stalks descend when he applied the pile. He furnished the bulbs of the petioles of a branch with small plates of tin and lead, and the following morning, on placing one of the armatures in communication with the zinc pole of a voltaic pile, and the other with the copper pole by means of a gold wire, he perceived the leaves frequently incline towards each other at the moment when the circle was closed.

DII. On the subject of the phenomena which supervene upon the withdrawal of the irritation by which the movement has been determined, observations give us the following information: The footstalks invariably remain depressed for some time and the leaflets closed. At the end of a half or quarter of an hour, sometimes even ten minutes, a period varying according to the vigour and age of the plants, as well as the season and time of the day, the leaflets begin gradually to spread out, the foot-stalks recover themselves, and the leaves take a diverging direction. The order in which these phenomena occur is subject to variation. Sometimes the common foot-stalks are the first to recover, at others, the individual ones; sometimes, also, the leaflets first of all separate from each other. The general condition of these movements is the withdrawal of the external impression that had occasioned those in the contrary direction. They appear, moreover, to be favoured by the solar light. This, however, is not an essential condition, since the leaves are seen to rise during the day, when, after receiving excitement, they are withdrawn from the sun's light. Nor can the movements be forcibly provoked by doubling the glare of the solar rays, or by using artificial light.

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(1) Electrische Versuche an der *Mimosa pudica;* in Denkschriften der Münchner Akademie, 1809-10, p. 245.

(2) Ludwig, Scriptores nevrologici minores selecti, v. iii, p. 31.

(3) Esprit des Journaux, March, 1794, v. iii, p. 210.

(4) Experiments and observations relative to the influence lately discovered by M. Galvani, and commonly called Animal Electricity. London, 1793.

(5) Loc. cit., v. ii, p. 319.

(6) Versuche über die gereizte nerven und muskelfaser, v. i, p. 249.

(7) Schriften der Berliner Gesellsch. naturforschender Freunde, v. xi, p. 141.

(8) Entwurf einer Pflanzenphysiologie, p. 150.

(9) Journal de Physique, 1803, v. lvii, p. 460.

The rising of the foot-stalks and the expansion of the leaves cannot be considered as the effect of electricity, as Sigwart very justly remarked, since they only take place at a varied interval after the withdrawal of the external influence. Besides there is a vast difference between the rapidity of the movements produced by the irritation and those which occur after its withdrawal, the former being much more rapid than the latter. Elastic bodies, on the contrary, that have been forced from their position by external violence, recover it with the same force and quickness when such violence ceases to act, which is not the case with the movements performed by the leaves of sensitive plants.

DIII. The mobility of the leaves of mimosæ is dependent on external and internal conditions and varies with these. The most important of the internal conditions is the normal exercise of the nutritive functions. The more robust a plant is, the more vigorously it pushes, the more easily are movements induced by external irritations, and the more lively are these movements. Young plants are more mobile than old ones. The mobility is greatest before flowering, and it palpably diminishes after that period. Mimosæ are more mobile in the morning than in the afternoon. Dufay and Duhamel remarked that those reared in hot houses have much slower movements in winter than summer. Among the external conditions of the moving power are heat, light, atmospheric air, and alimentary matters. A medium atmospheric temperature is the state in which the movements produced by excitation are manifested with the greatest facility and strength. When the heat rises to + 7° R., the plant, according to Dutrochet's experiments, cannot be roused to motion by any stimulation, not even that of burning. A very hot air, or the burning rays of the sun likewise diminish the mobility. It has been said above that mimosæ continue for some time to execute their periodical movements according to the diurnal periods, when placed in dark situations, but that they soon lose their faculty of sensibility to impressions, and in the end become incapable of movement. It is worthy of remark, that this takes place more quickly, according to Dutrochet's experiments, in a high than a medium temperature. In darkness, mimosæ lose their mobility at a temperature of + 20° to + 25° after four days, and at a temperatnre of — 10° to — 15° not until after fifteen days. Atmospheric air and the respiration it supports under the influence of light, are necessary to the persistance of mobility. Although mimosæ continue for some time to execute their periodical movements in reference to the diurnal epochs, in vacuo, yet, according to Dufay, Percival, and Sigwart's experiments, they gradually lose the faculty of moving on the application of mechanical stimulants. The dependence of the motor power on respiration has also been proved by experiments made by Ingenhouss,(1) and Humboldt(2) of the mode of action of mimosæ in different gases. Their mobility diminished and was extinguished in carbonic acid and azotic gases, whereas it was preserved in oxygen gas. If the mimosæ are without water or alimentary matter, their nutrition suffers and their mobility is enfeebled, and the latter altogether disappears when the plants fade. If they are again watered, the mobility is revived. When the stalk is wounded so as to suffer the escape of a great quantity of sap, the motor faculty is extinguished. Lastly, it may be added that this faculty is destroyed by certain poisons and narcotic substances when such are absorbed by the roots, or placed in immediate contact with the leaves and the bulbs of the footstalks. Hope,(3) Wilson,(4) and Link(5) say they observed the mobility to be destroyed by the action of opium. G. F. Jaeger(6) saw the leaves of mimosæ cease, even before losing their green colour, to be sensible to the action of excitants, if they had been subjected to that of arsenic. The same occurred in the experiments of Becker(7) and of Goeppert,(8) after the application of prussic acid. Macaire-Prinsep(9) placed mimosæ in contact with weak solutions of oxide of arsenic, arseniate of potass, of corrosive sublimate, opium, and prussic acid, and saw that these substances deprived them of the power of moving on excitation. Similar experiments with the like results have been made by Mulder.(1)

These phenomena manifestly denote a certain analogy with the laws which preside over the manifestations of muscular irritability in animals, and certify to us the play of a vital contractile faculty in the leaves of mimosæ.

DIV. Regarding the parts or organs that produce the movements in the circumstances mentioned, all observers agree in saying that they are the bulbs situated at the base both of the common foot-stalks and the individual ones and leaflets. A certain degree of tension is manifested in these parts during the movements induced by excitants, and the leaves, once that they are bent, resist when an attempt is made to return them to their primitive position. They break rather than yield, as Gahagan remarked. Other physiologists have made the same observation. The first experiments made on the influence exerted by the bulbs of the foot-stalks upon the leaves are

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(1) Versuche mit Pflauzen, v. ii, part 2, p. 235.
(2) Aphorismen aus der chemischen Physiologie der Pflanzen. Leipsic, 1794, p. 95.
(3) Diss. quædam de plantarum motibus et vita complectens. Edinburgh, 1787.
(4) An experimental inquiry on the manner in which opium acts in the living animal body. Edinburgh, 1795.
(5) Salzburger medicinisehe Zeitung, 1810, v. ii, p. 15.
(6) De effectibus arsenici in varios organismos. Tubingen, 1808.
(7) Diss. de acidi hydrocyanici vi perniciosâ in plantas. Jena, 1823.
(8) Loc. cit., p. 25.
(9) Mem. sur l'influence des poisons sur les plantes douées de mouvemens excitables; in Annales de Chemie et de Physique, Sept., 1828, p. 85.
(1) Beytragen tot de Naturkundige Wetensehappen, v. ii, No. 1.

due to Lindsay. He took away a portion of the lower surface of the bulb of a common foot-stalk, and the petiole rose after the operation. From another foot-stalk he cut off a portion of the upper surface, and immediately the leaf shrunk. He submitted the bulbs of the individual foot-stalks to the same mutilation, and obtained the like results. Hence he concludes that the power which erects the foot-stalks has its seat in the lower part of the bulb, and that which bends it, in the upper portion.(2)

DV. Comparetti and Dutrochet studied the structure of the bulbs of the footstalks. They are composed of a delicate, soft, and flexible cellular tissue, containing, together with small globules, a great number of minute rounded cells, full of coagulable liquid, the whole being externally covered with a very thin epidermis. Internally to this tissue analogous to the mucous matter of gelatinous animals, and which Dutrochet considers as a special development of the parenchyma of the bark, there is a minute net-work of sap and spiral vessels. No fibres have been seen that could be compared to muscular fibres. In order to be assured whether the movement was produced by the soft cellular tissue or by the net-work of vessels contained within it, the former was carefully withdrawn, whereby the foot-stalks were deprived of the power of moving on the application of stimulants. Hence it is clear that this tissue is the seat of the movements. Moreover, Dutrochet repeated Lindsay's experiments, with which he does not appear to have been acquainted. He constantly saw the common and particular petioles rise after the excision of a part of their upper surface, and shrink when their lower surface had undergone a loss of substance. When he withdrew a small piece of the lateral surface, the leaf turned to the side where the substance of the parenchyma had been taken away. Having detached longitudinal slips of foot-stalk bulbs, and placed them in water, he saw them immediately curl inwardly, in the direction they would have taken in reference to the axis of the foot-stalk, whilst they became convex on their external surface.

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(2) Lindsay found that when the petiole is depressed, the under part of the bourrelet assumes a deeper colour. It is to be remarked, that in the subleaflets the upper part of the swelling corresponds, in one respect, with the lower portion of the petiolar swelling; it is the part shortened when the leaf is folded. Burnett and Mayo found that it likewise changes colour at the moment when the subleaflet rises, while the under surface of the swelling of the subleaflet does not change hue. When the plant is not in its most lively state, the under surface of the subleaflet and upper surface of the petiolar swelling may be pricked with a needle without producing action. But if the opposite surfaces (those which change colour and are shortened when the petiole is depressed and the subleaflets are touched) are touched with a needle, these actions are immediate, and if only lightly touched, the leaflet itself is raised, and its fellow remains expanded, and in proportion to the rudeness of the touch is the degree of sympathy exhibited. The needle may be applied to the solar surface of the petiolar swelling without effect, but when applied to the under part, the petiole is depressed. Hence it would appear that each swelling has a surface especially adapted to receive mechanical impressions, which surface is that side of the intumescence opposite to that by which the consequent motion is produced. This would give some ground for establishing an analogy with the nervous functions of animals, did not other and insuperable objections present.—Trs.

When he immersed pieces that he had detached in acids or a solution of potassa, their curling immediately ceased, and they became straight. He considers the inflexion of the substance of the petiolar bulbs as a vital phenomenon, and gives the name of vegetable irritability to the power which this substance possesses of bending in a determinate direction. From his experiments on the manner in which the movements of the leaves of mimosæ are performed in opposite directions, he concludes that they occur solely by the inflexion of the cellular parenchyma of the foot-stalks, which is applied, like living elastic springs in a state of antagonism, to the different sides of the foot-stalk. The upper spring which bends the foot-stalk downwards is urged into action by most external irritations, especially by mechanical shocks, sudden cold, great heat, and chemical stimulants. The inflexion of the lower spring, on the other hand, which erects the foot-stalk, is effected in the absence of those excitants, and by the influence of light. When there is no light the upper spring has its activity increased, and the foot-stalk is depressed. He attributes the alternating action of the living opposed springs to a distinct afflux of sap towards the superior and inferior portions of the petiolar bulbs in such a manner that when the leaves are upraised by the inferior spring, the latter becomes turgescent, whilst when they are depressed by the superior spring, the turgescence occurs in that spring. What seems to prove that these movements depend on the sap is, that want of water diminishes the mobility of the leaves, and watering doubles its energy.

Lastly, Dutrochet made some experiments on the transmission of irritations from one foot-stalk to another. In order to discover by what tissues this is effected, he destroyed the cortical tissue, the petiolar bulbs, the pith, and the vascular fasciculi, separately. The consequence was, that transmissions are not by the bark, nor the cellular tissue, nor the pith, and that the ligneous part alone, with the vessels and sap, is adapted for this purpose. Moreover, he found that the maximum rapidity of this internal movement of transmission is as much as fifteen millimetres a second in the foot-stalks, and only three millimetres in the body of the stalk, in the same space. The degree of temperature does not appear to exert any influence in this respect.(3)

DVI. In repeating Lindsay and Dutrochet's experiments, L. C. Treviranus,(4) Burnett, and Mayo, likewise ascertained that the movement in the leaves of mimosæ is produced by an antagonizing activity which

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(3) Dutrochet gives the name of incurvation to the elastic power of the swellings of the sensitive plant. According to this, the vegetable irritability consists only in an elastic incurvation which is sometimes fixed and sometimes oscillatory. For example, it is fixed in the tendrils of vegetables, in the valves of the ovarium of the balsamine, &c.; it is oscillatory in vegetables that are named irritable—those that present alternate incurvation and straightening. The sympathy of the leaves is attributed by him to the sap of the tubes, he calls "corpusculiferous."

(4) Tiedemann und Treviranus Zeitschrift für Physiologie, v. i, p. 175.—Trs.

resides in the petiolar bulbs. Some of the observations mentioned above may be advanced in support of the opinion held by Dutrochet, that the activity of these bulbs, brought into action by irritations, is owing to the afflux of sap into them. Hooke had, beforehand, attributed the depression of the foot-stalks, in consequence of the application of stimuli, to a reflux of the sap of the leaves to the petiolar bulbs. Bellardi and Beccari also thought that the movements of the foot-stalks in different directions proceeded from an unequal distribution of sap in the parenchyma of their bulbs, so that if more fluid arrives at their upper portion, the footstalks descend, whereas an inverse movement takes place when the inferior part receives a greater quantity of sap. Lindsay saw the petiolar bulbs take on a deeper colour underneath during the inflexion of the leaves. Ritter(5) remarked, that when the leaflets closed and the foot-stalks bended downwards, an afflux of sap took place towards the petiolar swellings. These swellings, which are white and semi-transparent during the expansion of the leaves, then become opaque, more coloured, more full and turgid. He further says, he saw with the microscope the sap rush into the petiolar bulbs. As the leaflets again expanded, and the foot-stalks descended, the sap appeared to flow from the swellings into the leaflets. Burnett and Mayo(6) have likewise remarked a change of colour in the petiolar bulbs during movement.

These observations, therefore, render it very probable that the movements of the leaves, after excitations are owing to the turgescence of the petiolar bulbs produced by an afflux of sap.

DVII. There are two important points on which the experiments just related throw no light. Why does the sap flow into the swellings of the leaves after excitations, and wherefore is the afflux towards the lower portion of the foot-stalks when they rise, and towards the upper when they sink? Dutrochet did not propose these questions, and neither his anatomical researches nor his experiments afford any data to answer them. I will allow myself to advance the following hypothesis on this point. The erection of the foot-stalks, the expansion of the leaves and the unfolding of the leaflets in the day are probably the consequence of the afflux of sap into the vessels of the foot-stalks, leaves, and leaflets, under the influence of solar light, and those agents that induce movements of that fluid towards the periphery, by which means they are rendered turgid. The sap that is accumulated in the vessels, and the cellular tissue of the upper surface of the petiolar swellings produces therein a turgescence, the result of which is the sinking of the foot-stalks. The reason why, at the time of turgescence, the sap accumulates in

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(5) Denkschriften der Münchner Akademie; Loc. cit., p. 397.
(6) Brewster's Edinburgh Journal, January, 1829, p. 186.

certain points of the swellings, is very probably owing to a particular disposition of sap-vessels which anatomical researches have not yet ascertained. The movements that occur after irritations applied to the leaves likewise depend on a reflux of sap from the peripheric vessels of the leaves to the upper portion of the petiolar bulbs. Either the stimulants exert on the sap itself an influence which determines a retrograde movement of it, or, what is more probable, the vessels are endued with a vital power of contraction which the stimulants bring into play. By the contraction and narrowing of the vessels, the sap is driven to the swellings which enter into a state of turgescence and tension whence results a change in the direction of the leaves. As soon as internal excitants cease to act, the sap gradually renews its course towards the vessels of the leaves, especially with the influence of solar light; the leaves are then seen to rise and again unfold. This hypothesis is quite reconcileable with the effects of the influences which determine the movements. All those influences that favour the progress of the sap, as, its abundance, solar light, and heat, increase the mobility of the leaves of mimosæ. Such, on the contrary, as render the movement of the sap more tardy and languid, as its scantiness, cold, excessive heat, hyper-excitation by the electric fluid, diminish or annihilate the mobility. In favour of the opinion that a vital power of contraction plays an essential part in these movements, the effects of narcotic substances and poisons may be advanced, which undoubtedly only arrest the movements by destroying the contractility of the vessels. The transmission of excitations from one leaf to another is probably effected through the medium of the sap vessels which are first put into a state of contraction by stimulants, a state that is then propagated to various distances according to the degree of susceptibility and stimulation. More ample anatomical researches into the disposition of the vessels in the petiolar swellings, followed by experiments on living mimosæ, are necessary in order to ascertain how far this hypothesis is correct.(7)

DVIII. We will mention some other plants whose leaves may be excited to motion by stimulants. That which is most closely analogous to the mimosæ is the *Oxalis sensativa*, which grows in Java. Its leaves are pinnate, and consist of eight or ten pairs of oval leaflets, whose magnitude augments from the base to the summit of the leaf. According to Rumph(8) and

(7) In this hypothesis the self-movement of the sap is but slightly alluded to and not endued with any considerable influenee in the phenomenon; the author appears to prefer the explanation by the action of the vessels on their contractility. The phenomenon is that of turgescence. It will be seen by reference to our note on animal turgescence, that in that operation, we incline to attribute the chief movement of the blood towards the turgid parts to the containing vessels. For reasons similar to those therein adduced, we also regard the vessels as the cause of vegetable turgescence, agreeing (to repeat the words of Tiedemann) as such an hypothesis does with the effects of the influences which produce the movements.—Trs.

(8) Herbarium Amboinense, v. v, p. 302.

Garcin's(9) observations, the leaflets are expanded horizontally during the day. At sunset they fall and are applied to each other by their lower surfaces. When touched they take the same position as in the night. It is even sufficient for this purpose to approach near to them or disturb the soil. They are likewise depressed in rainy and stormy days. The more warmed they are by the sun, the more active are their movements. In the morning they are in their fullest state of erection and expansion, and are not then so easily closed by mechanical excitations as towards noonday, at which time merely blowing upon them suffices to produce their depression. After being irritated and depressed, they gradually rise again in the sunshine, and this probably depends on the afflux of the sap into the vessels of the leaves.

DIX. R. Bruce(1) observed movements produced by excitations in the foot-stalks of the *Averrhoa carambola,* a tree which grows in Bengal. The pinnate leaves of this plant are extended horizontally in the day; but the direction of all the leaflets is not the same, some being more erect than others. In the space of an hour they often change their situation, and rise or sink without any determinate order. After sunset all the leaflets incline downwards, and are joined by their lower surfaces. When the leaves are much agitated by the wind and pushed against each other, they sink. If a branch be bended, without shaking the leaves, no movement occurs; but if the bending is effected roughly, and is accompanied with agitation, the leaflets gradually sink until they touch at their surfaces. The young leaves then often glide over each other and cross. All the leaflets inserted on a common foot-stalk move at once, when the latter is rubbed with the nail or any other hard body. But each leaflet may also individually be brought into motion by giving it a slight shock; in this manner all the leaves of one side may be made to sink one after the other, whilst those of the opposite side remain erect. The leaflets also of either side may be urged into movement. But if the shock be great, they all fall at one time, and sometimes the neighbouring foot-stalks with them. The depression is performed gradually, and in a quarter of an hour the parts rise again. The seat, properly speaking, of the movement is in the individual foot-stalks of the leaflets. If one of these be pressed, crushed, or cut with scissors, without shaking the foot-stalks, no depression take place. When the foot-stalk is irritated with a needle point, the leaflets sink. Bruce made a hole through a leaf with a burning glass without any motion of the leaflets; but as soon as he concentrated the luminous rays upon the foot-stalks, he saw them all sink. On removing a circular piece

(9) Description of a new species of the plants called Oxyoïdes; in the Philos. Transac., 1729, v. 36, p. 377.

(1) An account of the sensitive quality of the tree Averrhoa carambola; in the Philos. Transact., 1785., v. lxxv, part 2, p. 356.

from a branch down to the wood, so as altogether to interrupt the continuity of the vessels of the bark, the leaves no longer changed their position. An electric shock, though feeble, produced an immediate movement of the leaves.

It is probable that these movements are occasioned by stimulants, which change the course of the sap in the foot-stalks.

DX. The leaves of the *Dionæa muscipula* are endowed with a high degree of mobility. This plant, which grows in the shady and marshy parts of North Carolina, was first described by J. Ellis.(2) All around its stalk are many thick leaves, composed of two pieces. The larger piece, which is attached to the branch and acts as a foot-stalk, is flat and shaped like an oblong heart. The outer, smaller, and properly so called, leaf is roundish and itself composed of two equal lobes united in a median line, and furnished with stiff hairs on its edge. On the superior surface, a multitude of small glands are perceived, which secrete a saccharine fluid. Further, each half of the leaf presents three small thorns arranged perpendicularly, When an insect, attracted by the honied sugar, lights on the upper half of the leaf, the two segments approach each other, seize it, and pierce it through. According to Bonnet's experiments, the leaves of this plant are also urged into motion by any other mechanical excitation. Their lobes press against each other so forcibly that it is not easy to separate them without tearing them. The mobility depends on the vigour of the plant, and augments when the air is warm.

DXI. The leaves of the *Hedysarum gyrans*, a Bengalese plant, discovered by Lady Monson, and those of the *Hedysarum cuspidatum*, present two kinds of movements, one periodical, regulated by diurnal periods, the other having no connexion with them. Each foot-stalk, when completely developed, supports three leaves, (one middle, large, and lanciform, and two lateral ones, smaller, narrow, placed opposite to each other,) which are fixed to the principal foot-stalk by shorter petioles. The common foot-stalk is furnished as far as particular ones, with hairs arranged in two rows. This, and the great leaf, as also the leaflets, according to the observations of the younger Linnæus,(3) Pohl,(4) Broussonet,(5) J. S. Kerner,(6) Hufeland,(7) Gahagan, and others, execute particular movements, independently of each other. The middle leaf is, in daytime, horizontal and motionlesss. By the action of

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(2) Dionæa muscipula descripta: in Nov. Act. Societat. Upsaliens, v. i, p. 98. A Botanical Description of the Dionæa Muscipula. London, 1770, 4to.

(3) Supplementum plantarum. Brunswiek, 1781, 8vo.

(4) Sammlungen der Physik und Naturgeschichte. Leipsic, 1779, v. i. p. 502.

(5) Description d'une espece de Sainfoin, dont les feuilles sont dans un mouvement continuel; in Mem. de l'Ac. des Sc. de Paris, 1784, p. 616.

(6) Beobachtung über die beweglichen Blätter des *Hedysarum gyrans*; in Vorlesungen der Kurpfälzichen physikalisch-ökonomischen Gesellschaft. Mannheim, 1785, v. i, p. 391.

(7) Ueber die Bewegungen des *Hedysarum gyrans* und die Wirkung der Elektricität auf dasselbe; in Voigt's Magazine, für das Neueste aus der Physik und Naturgeschichte, v. i, p. 3, p. 5.

strong solar light it leans towards the stalk. At twilight it bends downwards, and lies along the stalk. The sun reappearing in the horizon, it gradually rises again. This movement is so much dependent on the light, that if the plant be in the shade only a few minutes, a manifest depression of its middle leaflet is produced. In the noonday sun, and under the action of light concentrated by a burning-glass and directed on the leaf or its foot-stalk, it takes on a trembling motion. Moonlight and that of candles have not, according to Hufeland's experiments, any influence on this movement, any more than have mechanical stimulants and the electric bath. But if an electric spark be made to fall on a leaf, it gradually sinks and does not rise again that day; its erection even occurs later the next day. Electrization continued for a few minutes, totally destroys its mobility: it droops, and at length dies. Incisions in the foot-stalk likewise deprive it of the power of motion.

The small lateral leaves are incessantly in motion. They describe an arch forwards towards the great leaf, then another backwards towards the foot-stalk, and this by revolving on their articulation with the common foot-stalk. They pass over the space mentioned in thirty or forty seconds, and then remain quiet for nearly a minute, after which the movement recommences. The inflexion downwards is always performed somewhat more rapidly than that upwards. The sinking occasionally takes place by starts, but the rising is uniform. The leaflets, for the most part, move in opposite directions, one rising while the other is sinking, and vice versâ. Sometimes a leaflet stops and the other continues to move. These motions only go on when the leaflets are fully developed, but after that they continue uninterruptedly, night and day. They are slower, however, in cold nights than in daytime, according to Kerner's observations. When the sun is very powerful, the leaflets often remain tranquil. The movements are always more rapid in warm and moist weather, as in a warm rain. The period of their greatest vivacity is that of flowering and fructification. After that time they become slower, and at length stop altogether. Broussonet observed the movement of the leaves to remain two or three days in branches that had been cut and kept immersed in water. Hufeland saw the leaflets continue to move even on foot-stalks which had been depressed by the electric spark. Mechanical irritations, touching, heat, moistening with volatile oils and spirits, exerted no influence; nor did the magnet. Electricity produces the following effects: positive and negative sparks and shocks made no change in the movements; nor did anything result from the contact, of a negatively or positively electrified body. The simple electric bath alone, whether negative or positive, which had no influence whatever on the large leaves, always produced a more rapid waving of the lateral leaflets, which not only persisted during the whole of the electrization, but remained for sometime afterwards. Giulio observed no sensible effect from the use of the poles of a voltaic pile, on the *Hedysarum gyrans.* It is worthy of remark, that the movements became weaker and slower after Hufeland had cut off the small hairs of the foot-stalks.

The oscillatory movements of the leaves appear to be, as Ritter(8) thinks, the consequence of a varied afflux of sap, which produces an alternation of turgescence and emptiness in the vessels of the leaflets.

6. Movements of the Flowers and Genital Organs.

DXII. In the first place, movements connected with the time of day, are observed in flowers, similar to what are noticed in leaves. Of this kind are the elevation and depression of the flower-stalks, and the opening and closing of the flowers. According to Linnæus's observations, the *Euphorbia germanica,* while in flower, sinks its umbels at night and raises them again in the morning. The *Geranium striatum,* the *Ranunculus polyanthemus,* the *Draba verna, Verbascum blattaria,* &c., also droop their flowers in the night. The flowers of the *Nymphæa, Lotus, Stratiotis, Potamogeton, Myriophyllum,* &c., rise out of the water in the daytime, and sink under it in the evening.

In most vegetables the flowers only open once and remain expanded until they fade. Many flowers, on the other hand, open and close several times, and this at certain periods of the day. The closing of certain flowers on the approach of night was known to Bacon, who compared it to the sleep of animals. Linnæus(9) made very careful observations on this subject. All flowers that open in the day and close at night he called *Flores solares,* and he founded his *Horologium Floræ* on those which expanded at certain hours. Pulteney, David de Gorter,(1) and Thomas Martyn,(2) have also investigated this subject.

Plants exhibit multitudinous differences as to the times at which they open and close their flowers. In many the flowers unfold at sunrise, and do not close until sunset, as in the *Hemerocallis fulva,* the *Leontodon taraxacum,* the *Bellis perennis,* the *Papaver nudicaule,* &c. Some close their flowers in the afternoon, as the *Mesembryanthemum barbatum,* the *Alyssum sinuatum,* the *Alyssum alyssoides,* the *Anthericum album,* the *Hieracium pulmonaria, fructicosum, rubrum,* and *latifolium,* the *Cichorium intybus,* the *Hypochœris hispida,* and *pratensis,* the *Crepis rubra,* the *Calendula officinalis,* and

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(8) Gehlen's Journal, v. vi, p. 478; Beiträge zur nähern Kenntniss des Galvanismus, v. ii, part 3, p. 268; part 4, p. 349.

(9) Philosophia Botanica, p. 272.

(1) Beschryving van un Bloem-Horologie; in Verhandel van het Genootstch. te Rotterdam, D. i, p. 477.

(2) Observations on the flowering of certain plants; in Transactions of the Linnæan Society, v. iv, p. 158.

africana. Others again fold them between ten o'clock and mid-day, as the *Tragopogon luteum* and *pratense,* the *Crepis tectorum* and *alpina,* the *Scorzonera tingitana,* the *Sonchus arvensis, oleraceus, alpinus, palustris, lapponicus,* and *repens,* and the *Lapsana glutinosa.* Many plants only expand their flowers between eight and ten o'clock, and close them towards mid-day, or shortly after, as the *Dianthus prolifer,* the *Malva helvola* and *caroliniana,* the *Portulaca hortensis* and *oleracea,* the *Mesembryanthemum crystallinum, neapolitanum,* and *nudiflorum,* the *Calendula arvensis,* the *Arenaria purpurea,* the *Hieracium pilosella,* the *Hypochœris chondrilloides,* the *Drosera longiflora,* and the *Moræa undulata.* Some do not unfold themselves until mid-day, as the *Mesembryanthemum spectabile;* or towards the evening, as the *Ixia cinnamomea;* or even in the night, as *Œnothera tetraptera* and *molissima,* the *Silene noctiflora,* the *Mirabilis longiflora,* the *Gladiolus tristis* the *Cactus grandiflorus* and *triangularis.*

Linnæus divided the flowers which expanded in the day into meteoric, tropical, and equinoctial. He called those meteoric whose unfolding and closing varied with external influences, light, heat, humidity, and the general state of the atmosphere. Thus the flowers of the *Calendula pluvialis* and *africana,* of the *Anagallis arvensis* and of several *Oxales* remain closed in lowering weather. Those of the *Sonchus sibericus,* on the contrary, do not close at night, when it threatens rain. In tropical flowers, the time of unfolding and closing the leaves depends on the length of the days. The *Convulvuli,* the *Mesembryanthemum,* and the *Oxales* open their leaves earlier in long than in short days. Lastly, the equinoctial flowers are confined, in their expansion and closing, to a determined and invariable time of day.(3)

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(3) Alpinus mentions among sleeping plants the Acaciæ, Abrus, Absus, Lesban, and Tamarindus (Prosp. Alp'in. de plant. Ægypt. cap. 10.) Cornutus observed the sleeping property in the *Pseudo-acacia Americana.* To the list of Linnæus Miller added (Med. arborcæ. Lin. Sp. Pl. Plate 778) the common kidney bean *(Phasiolus vulgaris)* and clover grass *(Trifolium pratense purpureum majus.)* In one of our common plants, *Tragopogon luteum,* this property is so evident as to obtain for it the vulgar appellation of *John-go-to-bed-at-noon.* The following are a few species indigenous in this country whose flowers open and close at fixed periods of the day:

Anagallis arvensis	male pimpernel	flowers open at 8 a.m. & close at 8 p.m.
Anagallis monelli	blue flowered pimpernel	ditto.
Convolvulus cæruleus	bindweed	flowers open at 6 a.m. & close at 6 p.m.
Phalanjium ramosum,	branched spiderwort	open at 7 a.m. and close at 3 or 4 p.m.
Hemerocallis fulvus	day lily	open at 5 a.m. and close at 8 p.m.
Alisma ranunculoides,	lesser water plantain	open at noon.
Portularia oleracea	common purslain	open at 9 a.m. and close an hour after.
Nymphæa alba	white water lily	open at 7 a.m. and close at 4 p.m. The stalk is first erected to the surface of the water, and then sinks and retires.
Papaver nudicaule	yellow wild poppy	open at 7 a.m. and close at 7 p.m.
Tragopogon pratense,	yellow goat's beard, or go-to-bed-at-noon	open at 3 p.m. and close at 9 or 10 a.m.
Sonchus arvensis	tree sowthistle	open at 6 a.m. and close at 12 a.m.
Sonchus oleraceus	hare's lettuce	open at 5 a.m. and close at 12 a.m.
Lactuca sativa	garden lettuce	open at 7 a.m. and close at 10 a.m.

DXIII. These diurnally periodical movements of flowers appear to depend, like those of leaves, on a change in the vitality of plants, accompanied, through the influence of external agents, with differences in the afflux of sap to, and in the degree of turgescence of the flower leaves. The erection of the flower-stalks and the unfolding of the flowers is doubtlessly owing to more copious flow of sap, and a consequent turgescence. The drooping of the flower-stalks, on the contrary, and the closing of the flowers seem to be the result of a diminution of the influx of sap and the cessation of the turgid state. This may be dependent, on the one hand, on a diurnally periodical change in the contractility of the sap vessels, and, on the other hand, on a modification of the external agents determining the state of vitality, and the flow of the sap. What proves the variableness of the vital condition is, that the movements of the leaves are in a precise ratio with nutrition and growth, and are performed more rapidly in healthy and vigorous plants than in sickly and fading ones. Plants deprived of water do not expand, or at least very slightly open their flowers. After the period of fecundation, the periodical movements of flowers altogether cease. They are also destroyed by divers narcotic and poisonous substances, which appear to annihilate the contractility of the sap vessels. Light and heat also exert great influence over them. They do not take place when the atmospheric temperature is very low or much elevated. When plants are withdrawn for a long time from the influence of light, the periodical movements of the flowers cease, and they do not expand. Decandolle(4) found in his experiments on plants preserved in a cellar which at night was lighted with lamps and in the day kept dark, that the period of unfolding and closing of the leaves changed in several of them. Some vegetables, which opened their flowers in the day, expanded them at night and closed them in the morning. Others which open at night, unfolded in the morning and closed in the evening. This was the case with the *Ornithogalum umbellatum*, the *Convolvulus purpureus*, the *Mesembryanthemum noctiflorum*, the *Hieracium amplexicaule*, and the *Anthemis maritima*. The flowers of the *Ornithogalum umbellatum*, which open towards eleven in the morning and close at three o'clock, closed immediately

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Leontodon taraxacum,	dandelion	open at 5 a.m. and close at 8 or 9 a.m.
Leontodon hispidum ..	rough dandelion	open at 4 a.m. and close at 3 p.m.
Hieracium murorum..	golden lungwort	open at 6 a.m. and close at 2 p.m.

Various other species of hieracium are sleepers, as *Hieracium umbellatum*, *sabandum*, *paladosum*, *aurantiacum*; also the *Crepis tectorum*, *alpina*, *rubia*—the flowers of all which open between 4 and 7 a.m. and close between 10 a.m. and 3 p.m.

Cichorium intybus....	wild succory	open at 8 a.m. and close at 4 p.m.
Calendula officinalis ..	wild marygold	open at 9 a.m. and close at 3 p.m.
Calendula pluvialis ..		open at 7 a.m. and close at 3 p.m.

Trs.

(4) Mem. presentés á l'Institut., v. i, p. 329.

on being withdrawn from the light, and again expanded when exposed to the light. In other vegetables, the periodical movements of the flowers were not changed by light and darkness.

DXIV. In some plants the corollæ also perform movements on being irritated. This is the case, according to Turpin's(5) observations, with the *Ipomœa sensitiva*. The membranous tissue of the bell-shaped corolla of this plant is supported by threads or vessels, which on the slightest touch bend, shorten themselves, and cause the closing of the flowers. The irritating cause removed, it again unfolds. Swagerman(6) and Bartolozzi(7) also say they perceived movements in the flowers of the *Apocynum androsæmifolium*, occasioned by irritations. According to Roxburgh's(8) observations, the flowers of the *Amaryllis saltatoria*, an East Indian plant first described by Sims,(9) possesses a high degree of mobility. On the slightest touch of an insect, on the slightest mechanical excitement, or on the most gentle breeze, they execute oscillatory movements in different directions. It can scarcely be doubted that this depends on a living contractile faculty. This property is said to be wanting in plants reared in hot-houses.

DXV. The movements of the organs of generation are more distinct than those of the flower leaves. In many vegetables, at their complete development, and during the fecundative act, they perform movements which bring into contact with each other parts often placed at a great distance. In some plants the stamina and anthers erect themselves and lean towards the stigmata; in others the pistil approaches the anthers; and in a third series, both organs make mutual advances.

The movement of the stamina towards the pistil seems to have been first observed by Vaillant(1) in the *Parietaria*. Linnæus(2) saw the stamina in the *Parnassia palustris*, and the *Ruta graveolens*, one by one approach the stigmata, shed the pollen, and then return to their former situation; whilst in the *Saxifraga tridactylites*, they all leaned simultaneously towards the pistil. Similar movements have been remarked by Stieff(3) in the *Amaryllis formosissima*; by Staehelin(4) in the *Parietaria*; by Koel-

(5) Dutrochet. Loc. cit. tp. 64.

(6) Waarneeming omtrent une byzondere Eigenschap van de Apocynum, in hed dooden van sommige soorten von vliegen; in Verhandeling van de Genootsch te Vlissingen, v. v, p. 281, v. ix, p. 1.

(7) Memorie sopra la qualita che hanno i fiori d'Apozynum androsæmifolium di prender le mosche; in Opuscoli scelti, v. ii, p. 193.

(8) Asiatic Researches, v. xi, p. 359.

(9) Botanical Magazine, tab. 1310.

(1) Discours sur la structure des fleurs. Leyden, 1718, 4to.

(2) Fundameuta botanica. Amst., 1735; Flora Suecica, p. 98; Disquisitio de sexu plantarum, p. 25.

(3) De vita nuptiisque plantarum. Leipsic, 1741, 4to.

(4) Theses miscellaneæ medico-anatomico-botanicæ. Bale, 1751, 4to.

reuter(5) in species of *Ruta, Antirrhinum,* and *Scrophularia;* by J. F. Gmelin(6) in a great number of syngenesiæ, the *Cactus opuntia,* and the *Cistus helianthemum;* by Leske(7) in species of *Aguilegia* and *Saxifraga.* The most numerous observations on this subject have been made by F. C. Medicus(8) and Desfontaines.(9) From them it follows, that at the time of fecundation the stamina rise and incline themselves towards the pistil, the anthers open and shed the pollen on the stigmata, and that the stamina then return to their former situation. Sometimes the stamina lean to the pistil one after the other, as their pollen becomes ripe, as in the *Hyoscyamus aureus,* the *Fritillaria persica,* the *Butomus umbellatus,* the *Polygonum orientale,* the *Scrophularia nodosa, aquatica, canina, lucida,* the *Tamarix gallica,* &c.; sometimes they move by pairs or triplets, as in the species of *Saxifraga, Stellaria, Veronica,* and *Kalmia,* the *Alsine media, Moerrhingia muscosa, Swertia perennis, Rhus coriaria,* &c.; at other times they all proceed simultaneously to the pistil, as in the *Zygophyllum fabago,* the *Agrimonia eupatoria,* the *Ricinia humilis* and *lævis,* the *Atropa physaloides,* &c. Of the ten stamina of the *Sedum telephium* and *reflexum,* only five at first rise, and subsequently the five others commence their movements.

The stamina of the *Delphinium, Aconitum,* and *Garidella,* which closely surround the pistil, retire from it as soon as the pollen is shed. In many plants, the anthers alone erect themselves, lean on the stigmata, allow the escape of the pollen, and then retire, as in the *Lilium superbum,* the *Amaryllis formosissima,* the *Pancratium illyricum, maritimum,* &c. Humboldt(1) ascertained that the stamina of the *Parnassia palustris* approach the pistil one by one, at first by starts, and then suddenly and at once, and that after shedding their pollen at three intervals, they return to their former situation until they are curled over the corolla.

DXVI. It is not so usual to perceive movements in the female genital organs as in the male. Linnæus saw the pistils and stigmata incline towards the stamina and anthers in the *Nigella arvensis,* the *Passiflora,* and the *Tamarindus.* Medicus remarked the bending of the pistils and the application of the stigmata to the stamina in the following plants: *Nigella sativa* and *orientalis, Sida americana* and *umbellata, Passiflora vespertilio,*

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(5) Voräufige Nachricht von einigen das Geschlecht der Pflanzen betreffenden Versuchen und Beobachtungen. Leipsic, 1761.

(6) De generatione vegetabilium. Leipsic, 1773, p. 19.

(7) Irritabilitas vegetabilium in singulis plantarum partibus explorata. Tubingen, 1768, 4to.

(8) Von der Neigung der Pflanzen sich zu begatten; in Act. Acad. Theodoro-Palatin, v. iii, p. 116; Pflanzen-physiologische Abhandlungen. Leipsic, 1803, v. i, p. 3.

(9) Observations sur l'irritabilité des organes sexuels d'un grand nombre des plantes; in Mem. de l'Acad. des Sc. de Paris, 1787, p. 468.

(1) Beobachtungen über die Staubfaden der *Parnassia palustris;* in Usteri's Annalen der Botanik, 1792, part iii, p. 7.

suberosa, minima, and *cœrulea, Œnothera repanda, molissima, biennis,* and *fructicosa, Hibiscus malvaviscus, manihot, abelmoschus, africanus, phœniceus,* and *trionum, Cactus hexagonus* and *grandiflorus,* and the *Turnera ulmifolia.* Desfontaines found that a movement of pistils and stigmata towards the stamina and anthers takes place chiefly in plants whose short stamina are situated lower than the pistil. The latter he saw lean towards the stamina, both in several of the preceding plants, and in the *Lilium candidum, martagon,* and *chalcedonicum,* the *Epilobium angustifolium* and *spicatum,* and the *Callinsonia canadensis.* This leaning also occurs in the species of the genera *Gloriosa, Cymbidium,* &c. Both sets of organs approach each other, according to the observations of Medicus, in the *Boerhaavia diandra,* and several species of *Malva, Althœa, Alcea,* and of *Lavatera.*(2)

DXVII. Desfontaines considers these movements as the effect of the irritability of the stamina and pistils, and thinks that emanations from the generative liquids are the stimulus which induces the contraction. Against this hypothesis it may be said that the stamina of several plants with male flowers, as those of species of *Urtica,* likewise move, and that their anthers project the pollen. The movements of the genital parts, which occur with so much regularity, must doubtlessly be considered as the immediate consequence of the internal movements of growth, originating from the progress made by plants towards their complete development, which movements are accompanied by a state of turgescence produced by the afflux of sap, and by manifestations of a vital contractile faculty. External influences do not excite the movements in the character of stimuli, but only exert a mediate influence over them, inasmuch as they are one of the conditions of the growth of plants in general. The injurious effects of poisons seem to testify to the part which a vital power of contraction takes in the movements that are manifested in matured generative organs. Goeppert(3) remarked that the stamina of the *Ruta graveolens, angustifolia,* and *divaricata,* the *Saxifraga aizoon, sarmentosa, longifolia,* and *punctata,* the *Polygonum orientale,* and of the *Zygophyllum fabago,* lost the power of approximating to the pistil, of casting the pollen, and of returning to their former situation, when the plants had been plunged into prussic acid or bitter almond water, and that the absorbed poison reached the flowers. Direct moistening of the stamina with poisonous liquids immediately destroyed their mobility, and they faded.

DXVIII. The genital organs of several plants are also urged into motion by external excitants. The male parts, either stamina and anthers conjointly, or the latter alone, are those in which this mostly happens. Among plants of

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(2) Philosophia Botanica, p. 91; Amœnitat: Academ., v. i, p. 360.
(3) Loc. cit., p. 23.

this kind are ranged species of *Cactus, Centaurea, Cisbus, Berberis, Scabiosa,* this *Cichorium, Onopordon, Serratula, Hieracium, Ventenatia,* &c. Linnæus(4) Duhamel,(5) and Adanson,(6) observed the mobility of the stamina of the *Cactus opuntia.* When the numerous stamina of these plants were touched, which are at some distance from the pistil after the bloom of the flowers, they quickly approached it, and partly came into contact with it; subsequently they generally returned to their former places. A second excitement again urges them to motion. Similar phenomena have been observed by Koelreuter,(7) in the *Cactus tuna,* and by Medicus in the *Cactus hexagonus* and *grandiflorus.*

Count Covolo(8) observed that the stamina of the *Centaurea calcitrapoides,* which, at the unfolding of the flowers, are arched outwards, proceed rapidly towards the pistil when they are irritated with a pin, and that the anthers let fall their pollen. He thought he perceived palpable contraction of the stamina in this movement. He even says that the stamina, under the influence of stimulants, continue to move for some time after being cut. Koelreuter observed similar movements in the *Centaurea spinosa, cineraria, ragusina, eriophora,* and *salmantica.* The stamina that had been irritated returned after some time to their former place. They might be made to move several successive times. Their mobility varied with the atmospheric temperature.

In the species of the genus *Cistus,* the stamina directly surround the pistil. When touched or shaken, they slowly leave it and fall back to the sides of the corolla, which they approach the nearer as they have been more vehemently stimulated. They then rapidly return towards the pistil and the anthers, which open, discharge their pollen upon the stigma. Shocks given by the wind suffice to cause movements of the stamina. These movements are most vivacious in the morning. When the air is very hot and dry, the stamina are motionless. These movements have been observed by Duhamel in the *Cistus helianthemum,* by Koelreuter in the *Cistus appenninus,* and by Medicus and Desfontaines in the same species, as also in the *Cistus ledifolius.*

DXIX. The most numerous experiments, regarding the mobility of stamina under the influence of stimuli, that have been made are those on the *Berberis vulgaris* by Linnæus(9) Duhamel,(1) Adanson,(2) Koelreuter,(3)

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(4) Sponsalia plantarum; in Amœnitat. Academ.
(5) Physique des Arbres, v. ii, p. 167.
(6) Famille de Plantes, v. i, p. 59.
(7) Loc. cit.
(8) Discorso della irritabilita d'alcuni flori, nuovamente scorpeta. Florence, 1764, 4to.
(9) Flora Suecica, ed. 2, p. 311.
(1) Traité des arbres et des arbustes, p. i, p. 22.
(2) Famille des Plantes, v. p. 59.
(3) Nouvelles observations et experiences sur l'irritabilité des etamines de l'Epine-vinette (*Berberis vulgaris;*) in Nov. Act. Ac., Petropol., v. vi, p. 207.

Smith,(4) Medicus, Desfontaines, Humboldt,(5) Ritter,(6) Nasse,(7) Descemet,(8) Macaire Prinsep,(9) and Goeppert.(1) It is well known that the flowers of this shrub have six stamina, which in the day are separated from the pistil and arched outwards in the expanded flowers. In the night the flowers close, and the stamina are applied to the pistil; when in the daytime the stamina have been mechanically irritated at their base or inner side, either by insects, or the point of a needle, they rapidly proceed towards the pistil and discharge the pollen on the stigma. If the needle be driven into the stamina, the movement is still more quickly executed and sometimes slight oscillations are observable. At a low temperature the movement is slow, and sometimes a few moments elapse before the irritated stamina approach the pistil. In a short time afterwards they slowly return towards the petals, which have a concave form. To perform this movement several minutes and sometimes a quarter of an hour are necessary, varying however with the state of the plant and the atmospheric temperature. The return of the stamina to their former position being extremely slow, compared with the quickness with which they hurry to the pistil, proves that the movements cannot be the effects of elasticity. The mobility of the stamina remains after the excision of the corolla, calyx, and pistil, being then only less rapid and complete. When the extremities of the stamina have been cut off, their filaments are still susceptible of being urged to motion by mechanical stimulants.

The action of divers other stimulants on the stamina have also been made the subject of experiment. Koelreuter saw the solar light concentrated by a burning-glass, and electric shocks, cause movements in them. Humboldt ascertained that the irritated stamina certainly sometimes returned towards the corolla in flowers to which violent electric shocks had been applied, but that they had not afterwards the power of again approaching the pistil when the stimulus was continued. Nasse excited the movement by using the galvanism of a voltaic pile. On flowering branches that were immersed in water heated to 32 or 35 centrigrade degrees, the stamina proceeded immediately or in a short time towards the pistil; but in water of a temperature not above

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(4) Some observations on the irritability of vegetables. Philos. Trans., v. lxxviii, part 1, p. 158.

(5) Ueber die gereizte Muskel-und Nerven-Faser, v. ii, p. 193.

(6) Gehlen's Journal für die Chemie und Physik, v. vi, p. 456.

(7) Untersuchungen über den Einfluss der Wärme auf die Staub-gefäss Bewegungen einiger Pflanzen; in Reil's Archiv. für die Physiol., v. xii, p. 251. Versuche über den Einfluss der Elektricität auf die Staubfaden der *Berberis vulgaris* in Gilbert's Annalen der Physik, v. xli, p. 393.

(8) Recueil periodique de la Societé de Medicine de Paris, v. ii, No 15.

(9) Mem. sur l'influence des poisons sur les plantes douées de mouvemens excitables; in Annales de Chemie et de Physique, Sept. 1828, p. 85.

(1) Ueber die Reizbarkeit der Staubfaden der *Berberis vulgaris* in der Zeitschrift *Linnea* July, 1828.

10 or 14 degrees, they failed to do so. In Ritter's experiments the stamina were not urged to motion by moistening with alcohol or tincture of opium. Nasse and Goeppert, on the contrary, excited movement by ether, alcohol, essential oils, spirits of turpentine, acetic and hydrochloric acids; but the parts in this manner lost the power of subsequently answering to mechanical excitants. The same occurred when prussic acid, bitter almond water, and canella water were introduced into the flowers. Macaire-Prinsep immersed the flowering branches in diluted prussic acid, when the stamina lost the power of moving on the application of external stimulants. The vapour of prussic acid produced a similar effect. The mobility was likewise destroyed by the aqueous tincture of opium, and by diluted solutions of oxide of arsenic, arseniate of potassa, and corrosive sublimate. Goeppert placed flowering branches in different liquids in order to ascertain the action which the absorbed substances exercised on the mobility of the stamina. In prussic acid, bitter almond water, liquid ammonia, alcohol, ether, volatile oils, spirits of turpentine, acetic and hydrochloric acids, solution of metallic salts, of oxide of arsenic, acetates of lead and copper, nitrate of silver, and sulphate of zinc, the stamina lost their mobility, as soon as the absorbed substances reached the flowers. This effect did not take place in the solution of opium, and the infusions of Saint Ignatius' bean, belladonna, and other narcotic subtances, so long as the branches retained their freshness.

It is worthy of remark, that the filaments of the stamina preserved their mobility under vessels that had been withdrawn for three days and a half from the influence of light.

The stamina of other species of *Berberis*, such as the *Berberis humilis, canadensis, emarginata, cretica,* and *cristata*, according to Link(2) and Goeppert's observations, likewise possess the faculty of moving when irritated.

DXX. In several plants the stamina begin to move, when perfectly developed, without being incited thereto by external excitants, whereas the rupture of the anthers may be caused by mechanical irritation. This phenomenon is observed in the species of *Parietaria, Spinacia, Atriplex, Urtica,* and some other genera. J. Bauhin(3) seems to have been the first who remarked it in the *Parietaria officinalis* whose anthers discharged pollen whenever he attempted to take away the stamina from the flowers. Morison,(4) Ray,(5) Vaillant, Staehelin, Linnæus, and others, likewise saw the anthers of the *Parietaria* burst from mechanical excitement. The hermaphrodite and male flowers of this

(2) Grundlehren der Anatomie; Ueber Physiologie der Pflanzen, p. 259.
(3) Historia Plantarum Universalis, v. ii, p. 976.
(4) Plant. Oxon., v. ii, p. 600.
(5) Hist. Plant, v. i, p. 206.

plant have four stamina inclosed in the corolla, which gradually rise and bend outwardly; if touched in this situation they shed their pollen. The same happens when the anthers of the five stamina of the *Atriplex patula* are irritated. In the species of the genus *Spinacia*, wherein the genital organs occupy different organs, the five stamina rise at the period of maturity, and bend outwardly, at which time, if their anthers be irritated, they burst. The four stamina of the male flowers of the species of *Urtica* are at first bent inwardly; as they ripen, they rise and project out so as to have almost an horizontal position. As soon as the anthers are touched they suddenly open and discharge their pollen. This was observed by Staehelin, Haller,(6) Alston,(7) Gmelin, Medicus, and others, in the *Urtica dioica, canabina, pilulifera*, &c. Similar phenomena have been seen in the anthers of several species of *Morus, Chenopodium, Forskohlea, Orchis, Stachys, Anemone,* and others.

DXXI. The stigma of several plants may be urged to motion by external irritations. Linnæus(8) was the first who mentioned the closing of the open stigma of the *Gratiola* on being touched by the pollen, a fact which was also remarked by Adanson.(9) In the *Martinia annua, perennis,* and *proboscidea,* and the *Bignonia catalpa* and *radicans,* whose stigma is composed of two lobes wide asunder at the full bloom of the flowers, these lobes approach each other, according to observations by Adanson, Koelreuter, and Medicus, as soon as the pollen falls on the stigma, or when the stigma is irritated with a needle, the lower portion then proceeding rapidly towards the upper. This takes place more readily as the air is warmer. When the temperature is low, and the weather rainy, the stigma remains motionless. Similar movements were observed by Medicus in the stigma of the *Lobelia syphilitica, erinus,* and *erinoides*; of the *Antirrhinum albescens* and *glaucum,* of the *Cliome arabicum,* the *Justicia ciliaris* and *hysopifolia,* the *lavandula latifolia, multifida,* and *spica,* and of the *Scrophularia lucida.* The stigma of the *Mimulus guttatus* is also very mobile, when irritated, according to Kielmeyer's experiments,(1) as also that of the *Mimulus glutinosus,* according to Braconnot's. The pistil of the *Stylidium graminifolium* is possessed of a high degree of mobility.(2) In the expanded flower it is arched over the curled lip of the corolla, so that the stigma comes into contact with the anthers. Touched slightly at its base, it suddenly erects itself. After some time it returns to its former situation.

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(6) Enumeratio method, p. 674; Hist. stirp. indigen Helvet, v, ii, p. 265.
(7) Tyrocinium Edinburgh, p. 31.
(8) Hortus Clifort, p. 9.
(9) Famille des Plantes, v. i, p. 122.
(1) Autenrieth's und Bohnberger's Blätter für Naturwissenschaft und Arzneikunde, v. i, part i, p. 92.
(2) Account of the sensitive properties of the *Stylidium graminifolium*; in the Edinburgh Journal of Science, January, 1829, p. 185.

When again irritated, the movement is reiterated; but frequent excitations diminish its vivacity and vigour.

Goeppert(3) found, in his experiments on the action of prussic acid on plants, that the stigma of the *Bignonia catalpa*, of the *Martinia proboscidea*, and of the *Mimulus glutinosus*, and *guttatus*, lost its mobility after the application of this acid, whether the plant was immersed in it, or only exposed to its vapour.

DXXII. The movements induced by stimulation in the male and female genital organs, cannot be otherwise considered than as the effects of one and the same vital contractile faculty inherent in the organs and brought into play by excitants of various kinds. The influence of poisons in the extinction of this power argues in support of our idea. Probably such power is seated in the cellular tissue.

DXXIII. The ripe capsules of some plants, of the genera *Balsamina*, *Cardamine*, *Dentaria*, *Momordica*, *Impatiens*, &c., execute very palpable movements when touched, as was remarked by Tournefort,(4) bursting and discharging to some distance the seeds, whilst the flaps of the capsules turn over in a spiral manner. Though these movements have been considered by the majority of writers on vegetable physiology as simple phenomena of elasticity, they also seem to depend on a vital contractile faculty of the cellular tissue. In favour of this opinion is the extinction of the property in question by poisons. Carradori(5) immersed balsamine capsules in cherry-laurel water, and found they thereby lost their power of bursting under the influence of mechanical stimulus, whereas those which he had plunged into cold water remained motionless. According to Goeppert's(6) experiments on the capsules of the *Cardamine pratensis*, and the *Dentaria enneaphylla*, they lost their mobility in prussic acid. He likewise considers the movement as a manifestation of life produced by the contractility of the cellular tissue. Dutrochet attributes them to the property which the vegetable tissue possesses of bending, when in a certain state of turgescence. According to his researches, each valve of a capsule is formed of concentric layers of minute vesicles, diminishing from the periphery to the centre. He says that the tendency to bend depends on the inequality of swelling between the layers composed of large and of small vesicles, whenever any cause determines a state of turgescence. This mechanical theory is not consistent with the mode of action of poisons.

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(3) Loc. cit., p. 24.
(4) Memorie della Societa Italiano delle Scienza, residente in Modeno, v. xviii, No. 1.
(5) Loc. cit., p. 25.
(6) Loc. cit., p. 67.

7. Movements of Plants dependent on the Hygrometric State of the Atmosphere.

DXXIV. Finally, there are movements observable in plants both during life and after death which are dependent on the hygrometric state of the atmosphere and its influence on the vegetable tissue. Of this, the *Carlina vulgaris* presents, according to Bierkander's observations,(7) a remarkable instance. It dries up after flowering, and remains with its leaves and calyxes until the succeeding year. During this interval the calyx contracts when the weather is damp and dull; but when a dry air and a clear sky prevail, it opens and spreads in an horizontal direction. Analogous phenomena are presented by the *Anastatica hierochantina*. The movements of the bristles of the *Funaria hygrometrica*, of the beards of the *Stipa pennata* and *Avena fatua*, and also of several *Gerania*, are hygrometric, and these parts have been used as hygrometers.(8) Perhaps, too, the movements of the compound leaves of the *Porliera hygrometrica*, which press against each other at the approach of rain, may be ranged under this category. Those of the capsules of mosses, and of the grains of the *Jungermannia* and *Marchantia* must be referred hither.

CHAPTER THIRD.

On the Causes and Powers which determine the Movements of living Bodies.

DXXV. All living bodies, vegetables as well as animals, perform movements, as appears from the facts cited in the preceding chapters. Each act of life appears to be accompanied by changes of place, some of which are directly perceptible by the senses, whilst we are necessitated to infer the existence of others from phenomena that are conceivable without movement, such as those of formation, nutrition, growth, and the functions of the nerves. The movements of living bodies can neither be considered as the effects of gravitation, nor as the results of a mechanical impulse from without. Nor has it been hitherto satisfactorily explained by the attractions and repulsions exerted in the play of chemical affinities. Distinguished naturalists and physicians therefore consider them as phenomena *sui generis*, as products of powers of a specific nature, having their foundation in the special constitution

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(7) Neue Abhandlungen der Schwedischen Akademie, 1728, p. 80.

(8) J. M. F. Lodemann, Ueber den Gebrauch des geranneten samens vom *Geranium gruinum* zum Hygrometer; in Annalen der ökonom: Gesellschaft zu Potsdam, v. iii, p. 5, p. 55. A. Soares Barbosa. Observaçoes sobre hum hygrometro vegetal (Geranium moschatum et malacoides:) in Memorias da Acad. da Lisboa, v. i, p. 262.

of the bodies in which they are observed. But if we seek to learn what these powers are, on what conditions they depend, and by what laws they act, we raise a question concerning which the most opposite opinions and theories have been advanced, and which has given rise to warm controversies. Previous to announcing my own ideas on the subject, I propose to give a brief exposition of the more important hypotheses that have been erected in order to account for the moving powers of living bodies, and to subject them to examination, so that the truths therein which are agreeable to experiment may be put forward and their errors pointed out.

DXXVI. Glisson(9) was the first physiologist who absolutely attributed the movements of animals to a specific power. To this power he gave the name of irritability, because it is called into action by influences of various kinds, which he called irritating causes, *(causæ irritantes.)* He distinguished in it the faculty of recognising these irritating causes, or of being changed and affected by them, and the tendency to react upon such excitants by means of movements which consist in contraction.(1) The perception of irritating causes appeared to him different from sensation, because the heart and the intestinal canal move on the application of exciting agents without any sensation being developed. These parts, as also the muscles, are urged into motion by divers stimulants, even some time after their separation from the body. Perception of an irritation, however, may be accompanied by sensation, as in the stimulation of a nerve. Glisson admitted three sorts of perception of irritating causes and of irritability, the natural, the sensitive, and that dependent on the will.(2) The first or natural belongs to the animal fibre in general, even to the blood and humours. In the sensitive, the action of external impressions or irritations on the irritable fibres is effected by the medium of irritated nerves. The third kind is caused by the *appetitus animalis,* or the will, the brain inducing the muscles to motion by an irritation *ab interno.* To these he added valuable remarks on the degrees of irritability and on its variableness in different circumstances.(3)

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(9) De natura substantiæ energetica, seu de vita naturæ. London, 1672, 4to. De ventriculo et intestinis. London, 1677, 12mo. Tractatus posterior, cap 7. De irritabilitate fibrarum.

(1) Loc. cit., p. 163. Actio fibræ proprie dicta sive motus ejus activus consistit in contractione, vigoratione, molitione et labore ejusdem. Quando enim fibra contrahitur, vigoratur, nititur, tenditur, laborat, et tractu temporis defatigationi atque lassitudini abnoxia fit. Dividitur actio in naturalem et præternaturalem, sive in sanam et læsam; utraque admittit gradus. Estque vel remissa, vel intensa, vel media. Hi gradus oriuntur a gradibus roboris, tum irritabilitatis, tum causarum irritantium.

(2) Loc. cit., p. 168. Perceptio naturalis ea est, quâ fibra alterationem sive illatam, sive gratam, sive ingratam percipiens, ad eam appetendam, vel fugiendam, et conformiter ad sè movendam excitatur. Secunda sensitiva, est ea qua fibra sensu alterationem in externo organo factam advertens, ad aliquid appetendam, seque conformiter movendam, impellitur. Tertia, ab appetitu animali regulata, ea est, quâ cerebrum fibras musculorum ad ea quæ appetit exequenda, ab intus commovet. Loc. citat., p. 194. Ex dictis elucescit, dari revera tres irritabilitatis species, naturalem, sensitivam externam, et a phantasia imperatam.

(3) Loc. citat., p. 195. De irritabilitatis differentiis.

Glisson's theory regarding an organic or vital motor power, inherent in animals and urged into action by external irritations, or internal ones engendered in the living body itself, found no supporters among his contemporaries, blinded as they were by the systems of chemistry and iatro-mechanics, and was only justly appreciated in the following century.

DXXVII. Stahl,(4) who had the great merit of showing the difference that exists between living beings, particularly animals, and bodies not endued with life, and of fixing attention on the peculiarites exhibited by the former in their structure and intimate composition, considered the soul to be the fundamental cause of life and of the movements attached to it. It is true, Descartes and Vanhelmont had previously advanced an analogous opinion, and it had been maintained in a still more precise manner by the two celebrated iatro-mathematicians, Borelli and Perrault, who considered the soul as the generator of the movements of animals, and endeavoured to demonstrate its influence over all the functions. Still it was Stahl who maintained and developed this theory with the greatest zeal, and in the most able manner, so much so as to entitle him to be regarded as the veritable founder of the system of animism in physiology. With him, the animal body, as such, does not possess the power of moving, but is urged into motion by an immaterial essence, the soul, which acts through the medium of the nervous system. The soul also generates and forms the body, and maintains it in the possession of its properties. All movements performed by the muscles, voluntary as well as involuntary, are produced by the soul, the former with consciousness and reflection, the latter unconsciously. Besides muscular movement, he admitted movements in the other soft parts, that were the product of tension and relaxation; these he called tonic movements. By such it is that the blood flows in the vessels and the humours in the excretory ducts of the glands and in the cellular tissue, aiding in nutrition and the secretion of humours. These also he considered as the effects of the soul. Every external irritation which acts upon any organ, first determines a change in the soul and urges it to a reaction on the irritated part, a reaction manifested by movement. The action of some irritations on the soul is obscure and vague, so that their impression is not perceptible; for the same reason the reaction of the soul is equally obscure, so that no consciousness is roused. The most zealous supporters of this system were, in Germany, Carl,(5) Coschwitz,(6) Gohl, Platner,(7) and others; among the English, Porterfield, R. Whytt,(8)

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(4) Theoria Medica vera, physiologiam et pathologiam sistens. Halle, 1708, 4to.
(5) Synopsis Medicinæ Stahlianæ, 1724, 8vo.
(6) Organismus et mechanismus in homine vivo obvius et stabilitus. Leipsic, 1725, 4to.
(7) De principio vitali Leipsic, 1777. Repetitio brevis et assertio doctrince Stahlianæ de motu vitali. Leipsic, 1781. Questiones physiologicæ. Leipsic, 1794, 8vo.
(8) Essay on the vital and other involuntary motions of animals. London, 1751, 8vo.

and Erasmus Darwin,(9) and in France, Boissier de Sauvages,(1) by whom it was slightly modified.

Against this theory, which represents the animal body, its composition and material part, as deprived of all power and energy, forcible objections present themselves. Stahl erroneously asserted the identity of the soul, or of one of the causes which occasion the movements, with the motor powers themselves. Though it cannot be denied that animals enter into certain movements in a spontaneous manner by virtue of the principle which is the source of sensation and perception in them, yet it does not follow that the soul itself also accomplishes them, and that the impulse should be given by it to all the movements. We can only regard it as a cause by which the motor powers are brought into play, and it is impossible to find in it the power itself which produces the movements. A proof that this power and the soul differ essentially is, that the muscles, the heart, and all parts furnished with muscles, the stomach and intestinal canal, continue to perform their movements, when irritated, for some time after their separation from the body. In such case, were the motor power identical with the soul, we must suppose the divisibility of the latter at the moment the part is separated from the body, which contradicts the fundamental idea of its unity and indivisibility. Further, movements and manifestations of life are perceived in plants, which, however, present no phenomenon that can be considered, with any probability, as the effect of the soul. Stahl and some of the partisans endeavoured to get over this objection by saying that the vital manifestations of plants are the result of mechanism. But this mode of defence cannot be recognised, inasmuch as we see properties in plants and animals that are common to both and essentially distinguish them from bodies not endued with life. Darwin, relying on appearances, has not scrupled even to consider plants as sensible beings.(2)

DXXVIII. The doctrine of Glisson relative to an inherent power in organized bodies, which, under the name of irritability, induces their movements, was brought forward by De Gorter.(3) He extended the field of this

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(9) Zoonomia, translated by J. B. Brandis. Hanover, 1795.

(1) Nosologia methodica. Amsterdam, 4768, 8vo.

(2) Moreover, several physiological as well as pathological states were perfectly inexplicable by this theory. If the soul, acting through the nerves, orginate and continue the phenomena of life, any suspension of the palpable office of the nerves and nervous masses must be accompanied by suspension or extinction of the other functions. Thus to the animist, the continuance of digestion, respiration, circulation, secretion, and absorption during sleep are inexplicable, for the nervous masses, actuated by the soul, are arrested in function. Reverie and catalepsy call forth the same remarks. Sleep walking, wherein sensation and consciousness are wanting, but where movements are effected, must have been a grievous stumbling block in the way of a Stahlian partisan.—Trs.

(3) Exercitationes medicæ quatuor. Amsterdam, 1737, 4to. Exercit. medicæ quinta de actione viventium particulari. Amsterdam, 1748, 4to.

power by asserting that not animals only, but plants also, have the property of being induced to movements by irritating causes. Gorter upheld a principle as existing in all parts of living bodies, which produced movements under the influence of excitants, and he distinguished this from elasticity as well as from all other physical forces, that cause mechanical or chemical phenomena. Inasmuch as movements exist in plants, which are induced by irritations, this internal principle of action cannot be confounded with the soul or with the nervous power, neither of which are found in plants. Gorter further treated in a more particular manner of the irritations which excite vital movements.

F. Winter(4) and Lups(5) trod in his footsteps. The former considered irritability as a power inherent in each fibre of the animal body, which may be put into action not only by the influence of the nerves, but also by irritations of various kinds. The second, on the other hand, endeavoured to show that irritability belongs equally to plants, since they, on being irritated, execute sensible movements. It was thus, for instance, that he explained the movements of the anthers by irritability. Gaub(6) also attributed a motor force to the living solids, muscles, nerves, and cellular tissue, and, like Glisson, made a distinction between the faculty of being affected by irritating causes and that of reacting against them. Though he supposed the mobile faculty to be in the solids, he nevertheless allowed that it does in some degree also exist in the fluids from which the solid parts are formed.

DXXIX. Although the movements of organized bodies have been considered by the physiologists and physicians just cited as effects of a special power, inherent in living parts, and properly distinguished by them both from general physical forces and from the soul; yet they had made the movements which occur in living bodies and their different parts under the influence of irritations, and the manner in which they are performed, so little the subject of observation, that the irritability which they erected as the principle of all organic movements was rather regarded as an occult quality, hypothetically advanced, than as an organic fundamental faculty, the existence of which was demonstrable. This determined Haller(7) to undertake observations and experiments on the action of irritating causes on the different animal parts and on the changes induced by them. He laid bare some muscles, nerves, the heart, vessels, membranes, tendons, ligaments, cartilages, bones, glands,

(4) De Certitudine in medicina practica. Franeker, 1746, fol.
(5) De Irritabilitate. Leyden, 1748, 4to.
(6) Institutiones Pathologiæ. Leyden, 1758, 8vo, p. 169.
(7) Primæ lineæ physiologiæ. Gœtting., 1747, p. 224. Elementa physiologiæ, v. iv, lit. 11, sec. 2, p. 11. Commentat. Societat. Gœtting.. v. ii, p. 114. Memoire sur la nature sensible et irritable des parties du corps animal. Lausanne, 1756, 8vo. Oper. Min., v. i, p. 333. Nov. Comment. Soc. Gœtting., v. iii, part 1, tab. 4, p. 1.

and viscera, in living animals of different classes, and subjected them to the action of numerous different agents, mechanical or physical, in order to ascertain the effect thereby produced on the parts. From his numerous and varied experiments he considered himself authorized in establishing the following propositions. The organic fibre in general, and in all the solid parts of animals and plants, possesses in varied degree the property, on the application of an external force within certain limits, of returning to its primitive situation, when the cause that acted upon it has been withdrawn. This property, which he called contractility, *(contractilitas,)* depends solely on the material constitution and organic texture. It cannot be considered as a power of living bodies since it is manifested in the parts after the extinction of life. Haller therefore, looked upon it as a dead force, identical with elasticity. The separation of the lips of a wound of the blood-vessels, and their retraction, appeared to him to be the simple effect of contractility. With him the muscles alone of living animals possess the property of contracting and passing into oscillatory movements when subjected to irritating causes of different kinds. These movements are phenomena of life, because at the death of an animal, or shortly afterwards, the muscles can no longer be provoked to action by irritations. The property inherent in living muscles of contracting, when irritated, Haller called irritability, *(irritabilitas,)* and he regarded it as a power inherent in the living muscular fibre alone, different from all other powers, and hidden in its cause. All the other parts, nerves, vessels, membranes, glands, tendons, ligaments, cartilages, and bone, are not irritable because in the course of his innumerable experiments he observed no movements in them. Besides movements in the living, irritated muscles, he perceived manifestations of feeling and pain when he irritated parts furnished with nerves or made the irritating causes act on the nerves themselves. He considered sensation as a vital property peculiar to nerves and nervous tissues, and gave it the name of nervous power or sensibility, *(sensibilitas.)* He could not perceive any movement in irritated nerves, yet he allowed that possibly a very thin fluid, the nervous fluid or spirit, was in motion during sensation and the manifestations of life in nerves. Thus, in Haller's theory, movements occurring in irritated organic parts, and manifested by contraction and expansion, were the sole criterion by which the existence of irritability could be recognised, and this power was confined to muscular fibres.

Although Haller's merit in studying and distinguishing the effects of irritating causes, by observation and experiment, and in a more complete manner than his predecessors had done, cannot but be appreciated, yet it cannot be denied that he regarded his subject in too confined a view, when he admitted no other effect, from the application of these causes to living bodies, than sensation by the medium of nerves, and movement by the medium of muscles, and considered sensibility and muscular irritability as the only powers of life. There are many parts in the animal body which, when irritated, seem neither to be sensible nor irritable in the Hallerian meaning of the terms, but in which the existence of life cannot be therefore denied, since the phenomena of formation and nutrition are perceptible in them. Were the two powers established by him the sole conditions of life, plants, which do not possess them, must necessarily be excluded from the number of living bodies. The first manifestations of life in the germs of animals consist of the simple phenomena of formation and growth, which are accompanied by movements, without the possibility of discovering any muscular fibres in them. On the operations of formation, the appearance of muscles and nerves, in which muscular contractility and sensibility are manifested, depends. Moreover, the acts of formation and nutrition in animals and plants are seen to depend on external influences or irritations, and are subject to variations within certain limits. The secretory organs, the glands, mucous, serous, and synovial membranes, though possessing no muscular fibres, are equally brought into play by the action of irritating causes upon them. Again, Haller was wrong in attributing the contractile phenomena of the cellular tissue, the vessels, excretory ducts, and membranes to elasticity. Thus animals altogether composed of mucous tissue move when they are irritated. Moreover, some plants exhibit movements, though possessing no muscles. The property which animals and vegetables have of being affected by irritating causes, and exhibiting activity by motion, cannot, therefore, be traced to the Hallerian irritability, the idea of which is cramped by too confined a limit. Irritability, in the extent of the word, does not belong to muscles alone, but to all the parts of organized bodies, differing in this from the irritability taken in the sense maintained by Haller.

DXXX. With Haller's doctrine, a controversy arose which was warmly maintained for half a century, and the disputed points of which are not yet entirely cleared up. Whilst Zimmerman,(8) Oeder,(9) Battie,(1) Pozzi, Cigna, Fontana,(2) and others obtained results from their experiments on living animals, agreeing in their principal points with those of Haller, and maintained his opinions regarding irritability and sensibility as fundamental forces of the life of animals, Whytt,(3) Bianchi, Lorry, Arrigori, Cullen,(4) De Haen, Unzer,(5) J. A Schaeffer,(6) and others were strongly opposed to the

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(8) De Irritabilitate. Gœttingen, 1751, 4to.
(9) De Irritabilitate. Copenhagen, 1752, 4to.
(1) De principiis animalibus. London, 1757, 4to.
(2) Atti dell'Academia delle scienze de Siena, v. iii, p. 209. Ricerche filosofiche sopra la fisica animale. Florence, 1775, 4to.
(3) Physiological Essays. Edinburgh, 1755, 12mo.
(4) First Lines of the Practice of Physic. Edinburgh, 1784.
(5) Erste Gründe einer Physiologie der eigentlich thierischen Natur. Leipsic, 1771, 8vo.
(6) Ueber Sensibilität als Lebensprinzip. Frankfort, 1793, 8vo.

theory. These attributed irritability not only to muscles, but also to cellular tissue, membranes, vessels, and nerves. They even were inclined to admit the identity of irritability with the nervous power, or that the former is only the consequence or effect of the latter. They maintained that irritations which induce movements in animal parts act solely by the nerves, and that these must also produce the movements, and indeed all the functions of the animal body. This doctrine, which elevates the nervous power into a fundamental force of animal life, approximates to Stahl's system. It differs from the latter essentially, inasmuch as its supporters granted to exciting causes the power of impressing on the nerves independently of the soul, and without producing sensations, as also of producing movements in these parts without the concurrence of the soul. Neither sufficiently founded on experiment nor applicable to plants, it was only coldly received by physiologists and physicians, and was speedily supplanted by fresh theories.(7)

DXXXI. Some naturalists, in studying the properties of animals and plants, and comparing them with those of inanimate bodies, became convinced that the movements and all the other manifestations of activity of organic bodies differ from those of inorganic bodies, both in their causes and their mode of accomplishment. They protested against every attempt to explain them by the general physical powers. The powers admitted by the physiologists I have quoted, the soul, the irritability of Glisson, the irritability and sensibility of Haller, did not appear to them sufficient. They therefore had recourse to the admission of a fundamental power, on which depend all the manifestations of life, which exerts its activity in plants as well as animals, and which they designated by the name of the vital power or principle. According to them, this inherent power of organized bodies produces all the phenomena of life, acting in different manners and in various directions. As a formative or plastic force it is the foundation of the power possessed by individual animals and vegetables of preserving themselves by nutrition, and by the species of maintaining themselves by generation. Like irritability, it gives the contractile parts of plants and animals the fitness to be affected by irritating causes, and of reacting against such by movements which consist in contraction and abbreviation. In animals alone it manifests itself in the nerves as sensibility or as the faculty of receiving and transmitting impressions,

(7) Yet, supported by Cullen, it formed the basis of his pathological theories concerning the spasmodic nature of almost all diseases. These theories, as is known to all the medical world, were predominant until a recent date, and even to this day his pathological works are the text book at more than one school in this kingdom. Though, therefore, curtailed in influence, this doctrine of physiology may be said to exist even in our own times; its partisans are, however, few. At the same time none can study the general physiological ideas of Cullen without being convinced of the shrewdness of observation and profundity of thought of the once great leader of the European medical community.—Trs.

or even as the faculty of producing excitements which induce movements in contractile parts, and other effects in other parts. Besides these various manifestations of the vital force, its supporters admit, in animals, a spiritual principle, the soul, which, in concurrence with the vital force, gives origin to the intellectual phenomena.

The vital force, as a property common to all living bodies, manifests itself with specific modifications, or in a particular manner, in each vegetable or animal species, and thence proceed their special organization and composition, as also their vital phenomena. The warm upholders of this theory of the vital principle are Barthez,(8) Fryer,(9) Blumenbach,(1) Hufeland,(2) Sprengel,(3) Brandis,(4) Roose,(5) and others. In establishing a vital force, they thought the demands of reason which tends to refer to a principle of unity, the numberless diversities observed in the phenomena of life, would be satisfied. But, in scrutinizing, it will be seen that this vital force is only an occult quality, regarding which, they give no account either of its existence, or its mode of action, or of the reason why it manifests itself at one time as a plastic, at other times as a motor, and again, as a sensitive principle.

In their researches into the cause of the vital force, these physiologists fell into most contradictory conjectures. Some considered it as a simple, immaterial force, altogether beyond investigation, associated with matter in certain circumstances, and causing it to produce effects of a peculiar kind. Others regarded it as the result of a specific combination of the materials that enter into the composition of living bodies, and of their chemical and mechanical forces, or, in a word, of their general physical forces, and made life dependent on commixture and form. Finally, others thought oxygen or electricity should be received as the principle of life. It will appear from this that the adoption of the vital force, as the proximate cause of the movements which occur in living bodies, cannot be satisfactory.

DXXXII. Towards the end of the last century the doctrine of the vital force, as it had been erected by these physiologists, was shaken by John Brown.(6) Brown saw more clearly than his predecessors the dependence of life on the action of external agents, as heat, air, water, aliment, and light. He consequently considered it as a state conditional on external

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(8) De Principio vitali. Montpellier, 1773, 4to. Nouveaux elemens de la science de l'homme. Montpellier, 1778. Paris, 1806, 8vo.
(9) De vita animalium et vegetantium. Leyden, 1785, 4to.
(1) Institutiones Physiologicæ. Gœttingen, 1788, 1821, 8vo.
(2) Ideen über Pathogenie. Jena, 1795, 8vo.
(3) Handbuch der Pathologie. Leipsic, 1795, 1814, 8vo.
(4) Versuch über die Lebenskraft. Hanover, 1795, 8vo.
(5) Grundzüge der Lehre von der Lebensckraft. Brunswick, 1803, 8vo.
(6) Elementa Medicinæ. Edinburgh, 1780. Elements of Medicine. London, 1788, translated into German by C. H. Pfaff. Copenhagen, 1804.

influences, and, as it were, forced. He sought the reason why external influences, which he called stimulants, *(incitamenta, stimuli, potentiæ irritantes,)* induced living bodies to activity, in the property possessed by the latter, of being affected by irritations and of reacting on them. To this property he gave the name of irritability, and attributed it exclusively to the solid parts, the muscles, nerves, and all the organs. The fluids did not appear to him to be either excitable or living, and he regarded them only as internal excitants, among which he also ranked the manifestations of the soul. He considered excitability, as the principle of life, to be a fundamental force, inherent in organized bodies, of the nature of which we can know nothing, and the existence of which can only be concluded from the action of stimulants, that is, from excitements. Each living being receives a certain quantum of this force at his birth, which all the excitants acting upon, destroy sooner or later, according to their energy, and the annihilation of which brings death, which may also be the result of want of excitement.

Inasmuch as Brown's ideas of the external conditions of life, and of its dependence on external circumstances were clear and precise, insomuch were his views regarding the internal conditions, the organization and powers, vague and inexact. He degraded living bodies to the rank of simple machines that are put into action by external influences, and denied them all internal principle of spontaneous determination. Living bodies, it is true, exist only by an incessant conflict between them and external influences, and the latter cause them to enter into action; but in this they exert an activity peculiar to themselves, for excitation, like reaction against stimuli, is dependent on the state of their powers. Hence the relation between the organisms and the excitants is not only passive, but active. Brown overlooked altogether the essence of organized bodies, when he considered the solids alone as living and the fluids as dead, as only acting the part of stimulants: whereas all the parts that enter into the composition of a living body mutually react on each other, and by that alone is life maintained. Moreover, the fluids are the matters at the expense of which the solids are formed, and which support the state of excitability of the latter in the act of nutrition. In erecting excitability as the fundamental force of life, he only regarded its proportions as to quantity, which is insufficient of itself to explain the differences exhibited by living bodies in their composition, configuration, organization, and manifestations of power. Although living excitable bodies only develope their activity on the application of external influences, it would be impossible to conceive, from the nature of these influences, which are nearly alike for all bodies, nor from the quantum of excitability dealt out to them, the modifications which they present in their formation, organization, composition, and actions. Each vegetable, each animal species produces exciting causes, is formed and developed in its own way, and manifests its activity in a specific manner, the cause of which cannot be in the proportionate quantity of excitability, nor in the sum of external excitants, but solely in the quality or nature of their own powers. Brown does not even appear to have suspected the differences existing in the internal activity of which the life of the varied organized beings is the product when influenced by external agents, or excitants. Another defect of this system is the admission of a general uniformity in the excitability of the whole organism and of all its parts, whereas each part accomplishes a function proper to itself, is urged to action by influences or excitements purely special, and thereby assists in the preservation of life. According to this system it is hard to determine the utility of different tissues, organs, and apparatus in a living body.

When Brown made excitability the fundamental force of life, he made no inquiry as to the state of organized bodies on which it depends, how and in what circumstances bodies endued with irritability are produced together with their solid and fluid parts; what part the different liquids, and solids, the tissues, organs, and apparatus, take in the preservation of irritability; nor why, in general consideration, they are necessary to certain states of life. Nor does it appear by what means living bodies, surrounded by external excitants which tend to their destruction, maintain themselves and remain excitable during a certain period of time. Brown left altogether untouched the question, what passes in the organs during the action of external stimuli, and wherefore excitation diminishes, and finally even annihilates excitability. The reaction of living parts, and their excitability, are diminished by the operation of excitants, but rest re-establishes them. How this happens he did not attempt to inquire, or explain. In short, he paid no attention to the internal condition necessary for the maintenance and preservation of excitability.(7)

(7) The doctrine of Brown, in a few words, is as follows: that excitement is the cause of life; that it is produced by the operation of exciting powers upon the excitability; that the effect of this operation is to wear out the property to which it owes its effect of producing excitement; that therefore the more excitement the more excitability is wasted; and that, consequently, increase of excitement and diminution of excitability are terms that may be interchanged for each other, signifying increase of vigour. Again, as the operation of the exciting powers upon the exciteability wastes the latter in proporiton to the degree of excitement which it produces, it follows, that the less the exciting powers have been applied, the less, in proportion, will either the excitability be wasted, or the excitement increased; consequently, an under-proportioned application of the exciting powers and an over-proportion of languid excitability are terms which may be used indiscriminately to signify a state of debility. Excitement is bounded by two circumstances, the one, excess of exciting power exhausting excitability, the other, the want of exciting power to prevent the accumulation of excitability. Though Brown's theory does not give any answer to the question put by Tiedemann above, "How does sleep re-establish excitability?" yet something may be inferred, from Brown's account of sleep, which bears upon the subject. "The excess of stimulant power exhausting the excitability," says Brown, (Elem. Med., sec. 29,) "may be temporary, as in sleep." As herein sleep is said to be the consequence of exhausted excitability from excessive stimulus, so may we infer that the excitability of the brain and body are renewed by sleep in consequence of stimuli ceasing to act on the excitability, which therefore accumulates.—Trs.

The supporters of Brown's doctrine have certainly endeavoured to correct some of its defects, by regarding excitability as the product of two factors, the faculty of perceiving excitements (*receptivity*) and that of acting, (*spontaneity*,) and by seeking the connexions with each other and the different states of the organisms and stimuli. They have further supposed a modification of the excitability and of its factors in the apparatus, the organs, and the tissues, and marked the differences exhibited in the action of stimuli upon them, without, however, removing the objections I have above advanced. We refrain, therefore, from raising new ones against a system which is now nearly forgotten, and in which some physicians have too long hoped to find the true foundations of the healing art.

DXXXIII. How widely different soever the preceding physiological doctrines may be in their principles, they still all agree in one point, that of considering the movements and manifestations of activity of organized bodies as the effects of special forces which come into action on the application of external agents or stimuli. The forces proceeding from the particular constitution of organized bodies must be regarded as the internal condition of life, whilst the excitants that urge them to action are its external conditions. We will first give the facts which establish the dependence of life on external agents. We will then examine the manifestations of action that occur in living bodies under the influence of these agents, and will, proceeding on the rules of analogy, refer them, as far as is possible, to more general facts. This will lead to the decision whether the forces that have been imagined by the physiologists and physicians, quoted in order to explain the phenomena of life, are sufficient, and how far the ideas formed of them are too general and comprehensive, or too contracted and partial.

DXXXIV. Organized bodies are only active when certain connexions exist between them and external objects, or entire nature; in other words, external influences and agents are necessary to the manifestations and preservation of their activity. All the movements of living bodies, as well those that accompany formation and nutrition as those of the fluids and solids, of which mention has been made in the two foregoing chapters, require the concurrence of external conditions and influences, among which are a certain degree of heat, atmospheric air, aliments, and, for the most part, light. Once they cease to be connected with these influences, or are withdrawn from their operation, their organic activity, sooner or later, is extinguished. In vacuo, as also in the irrespirable gases, vegetables and animals soon cease to live. They likewise lose their organic activity when water and aliments are withheld. Life is sustained only at a certain degree of heat. If the external temperature is very high, or very low, it is extinguished. Plants and most animals die if light be withdrawn. All the vital phenomena of plants and animals, the operations tending to their preservation, the reception of aliments, respiration, assimilation, the movement of the nutritive fluid, nutrition, growth, and secretion take place with the condition of external influences, which are essential to the exertion of their functions. The manifestations of force peculiar to animals, sensation and voluntary motion, also suppose these external conditions.

Regarding the dependence of life on external agents, organized bodies present numberless differences. Each vegetable or animal species subsists only in certain external conditions, and when these are confined within certain limits. In the following book we shall speak at length of the external influences necessary to the preservation of life and of their importance to the accomplishment of the different functions.

Excitability.

DXXXV. To the external influences which affect living bodies the name of excitants *(stimuli, incitamenta, potentiæ irritantes)* may be given, inasmuch as they urge them to action, and determine their special mode of action. The property which these bodies have of being affected by excitants, of being sensible to the impressions they receive from them, and thence entering into action, we shall denominate susceptibility or excitability. All vegetables and animals are endued with this property, and we may infer its existence from the phenomena that are observed to follow upon the operation of excitants. The cryptogamia, the confervæ, tremellæ, mushrooms, mosses, &c., and phanerogamic plants, monocotyledones and dycotyledones, are determined in their formation, nutrition, and growth, by external influences, whose impression supposes the aptitude to be affected by excitants. All animals are excitable, from the animalcula infusoria to man, for not only is their preservation ensured by the influence of external impressions, but they are moreover put into motion by excitants of various kinds. The fecundated germ, the seed, and the egg already possess excitability. The formative germs only commence the act of formation and development, which are accompanied by movements, when they are placed under influences from without, in a certain degree of heat, and in certain ambient media, air or water. Even the germs that are developed in the body of the mother, require certain external impressions to be made upon them, in order to effect formation.

All the solid parts are excitable in the preceding sense, and can only be brought into a state of activity by impressions of various kinds, external to them, while the manifestations of this activity, varying with the differences of constitution impressed on them by the operation of formation, at the period of their development, consist in a change in the mode of nutrition, or in visible movements, or in sensations. The globules contained in the formative fluids must also be considered excitable; at least the movements of those found in the male seed, the spermatic animalculæ, vary with the excitants that act on them. The movements of animals that swim in infusions are distinguished from those of the molecules of inorganic bodies, to which R. Brown first called the attention of physical philosophers, by their capability of being modified by certain excitants, which, in my experiments, have no influence over the latter.

Excitability, therefore, in the most extended sense of the word, is a property inherent in all organized bodies, which should not be confined to any single group of living bodies, or to certain tissues of those bodies, or only to the muscular fibre, as Haller did. The property of being determined to manifestations of power by external influences does not only belong to all the organic solids that are nourished and endued with the plastic force, and to the globules contained in the formative fluids, but even appears to be inherent in organic matter in its amorphous condition, and susceptible of taking on form. In proof of this, is the fact, that in equivocal generation, organic matters, albumen, fibrine, gelatine, animal mucus, amidon, gluten, gum, &c., are seen to take on organic forms under the influence of external agents, and from them organized beings of the most simple kinds, infusoria, confervæ, and mouldiness arise, which vary according to the differences exhibited by these external influences.

DXXXVI. The property possessed by living bodies of being susceptible of excitation exhibits great differences, judging from the circumstances in which they exist. Each vegetable and animal species lives within a certain limit of external influences. It remains in a determinate medium, is confined to a certain zone and climate of the earth, continues to live in a certain temperature, is subjected to a fixed atmospheric pressure, and depends on particular aliments. Should a plant or animal be withdrawn from the circumstances in which nature has placed it, the change of external influences, that is, of the conditions of its life, annihilates all activity in it, or modifies that activity by exaltation or diminution of it. A certain degree of heat, sufficient for the life of one plant or animal is too high or too low for another plant or animal, in which it would extinguish life. Such an event can only be explained by admitting differences in the quantity and quality of the excitability imparted to plants and animals. Excitability further varies in degree, according to ages, and effects produced by exitants are seen to differ with the length of existence of living bodies. The parts also entering into the composition of an organized body have different degrees and different characters of excitability. Each organ, each tissue of a plant or animal, is determined to action by certain excitants. Excitability, therefore, presents great diversities in the various species of organized bodies, as also in their different tissues, and these diversities are quite as numerous as those that are observed in the manifestations and effects of the plastic force.

DXXXVII. Dividing the external influences which operate upon living bodies, and excite them to action, according to their nature, they form two kinds, the inorganic and organic. The former includes heat, air, water, and light, and a great variety of external things; to the latter, aliments, taken from the organic kingdom, are referred.

Inorganic influences or agents act, under the circumstances usual to living bodies, sometimes in a continuous manner, as the external temperature, air, (which not only affects plants and animals living in the air, but also, by its mixture with water, those which reside in the latter element,) and also water itself, or the state of humidity of the air and earth; at other times, only at certain intervals, as light.

DXXXVIII. The external agents of the inorganic kingdom, from their nature, can only impress on living bodies in a mechanical or chemical manner. They act mechanically, when by the general qualities possessed by all bodies, such as gravity, density, hardness, and form, they make pressure upon, or give a shock to, the organism, and tend to produce changes in the continuity and cohesion. They act chemically whenever their action tends to change the composition of living bodies and the specific direction of their affinities, in order to subject them to the laws of chemistry, as heat, light, electricity, atmospheric air, gases, acids, caustic alkalis, various salts, metallic oxides, and other substances do. All manifest a tendency to derange the chemical composition, either by striving to reduce the ternary, quaternary, or other organic combinations to the elementary condition or to inorganic binary compositions, as is the case with fire, air, caustic alkalis, and mineral acids; or by themselves entering into the composition or displacing some of the matters forming part of it.

DXXXIX. Although the external agents of inorganic kind must be considered as external conditions of life, inasmuch as the activity of living bodies depends on their influence, on that of light, of water, air, and heat, and as other influences can likewise, in certain circumstances, excite them to action, yet the effects proceeding therefrom are not, in bodies endued with life, purely mechanical or chemical, as might be supposed judging from their origin, but organic or vital. External things only induce living bodies to become active, and the latter resist any mechanical or chemical action they might threaten to exert on them. The action produced in an organized body by an external object, or excitation, is a vital act consisting in the reaction of the living body against the mechanical or chemical impression which is thereby arrested. Thus, that an external substance should be named an excitant and produce excitation, the organized body on which it exerts its influence must possess an organic activity. All external things that act on organized bodies with sufficient violence to destroy their activity, cease to be excitants. An external mechanical violence, which destroys the organization and annihilates the activity of which this organization is the condition, can no longer be termed an excitant. Concentrated mineral acids, caustic alkalis, fire, and the electric fluid, especially lightning, are no longer excitants, when, in acting on living bodies, they overthrow the specific composition and arrest the activity attached to that composition. The vital activity of an organic body being extinct, the action of externals upon it is now only mechanical or chemical, and they cease to be excitants. With regard to the changes produced by external objects, there exists this difference between inorganic and organized bodies, namely, that the changes produced in bodies not endued with life, by agents from without, are invariably mechanical or chemical, whereas those that occur in organized bodies form a series of themselves, and suppose the existence of organic forces of which they are the consequences. The connexion of externals with living bodies, with reference to excitation, is, therefore, organic or vital. The physical properties of externals are, as it were, in a constant struggle with the vital properties of organized bodies, and these react upon those. Living bodies only maintain the character of being living so long as they resist physical impressions by their reaction.

The manifestations of life, and the organic phenomena that occur in consequence of external influences differ, therefore, essentially from the movements communicated to inorganic bodies in the non-existence of a purely mechanical or chemical connexion between them and the causes determining them, or the excitants. When we say that organic movements are caused by excitations, we do not admit that they are the immediate effects of mechanical or chemical impression, but that they are ever those of the powers of the organism, which the external impression only induces to become active. The movements of living bodies, provoked by externals, are not, therefore, communicated, but are spontaneous, or self-produced, and external objects only present the opportunity for their manifestation. Lastly, in proof that the excitations generated in organized bodies by externals are products of the organic activity, or the powers of the organism, is the fact, that such do not occur in bodies not endued with life.

DXL. As the effects of external agents on living bodies, that is, excitations, are vital acts or products of their organic forces, they are not to be calculated according to the absolute scale of the power with which externals act, but always according to the relative state of the forces belonging to the organisms in which actions are induced by external agents. In other words, the mode of excitement produced in a living body by an excitant does not depend on the intensity of the action exerted by the latter, but on the state and degree of the forces of the organized body itself thus determined to action. Excitability and the organic forces present, as regards their quality and intensity, many differences in different living bodies, and hence the phenomena produced by excitants also exhibit such diversities, with reference to the facility with which they are manifested, and the intensity shown in their reaction. Thus, for instance, pressure on a tree produces no sensible effect, whilst in an animal it may cause violent movement, and in a polypus or medusa the slightest touch suffices to induce such. The effect of excitants on organisms, varies therefore considerably, according to the state and intensity of their forces. But the effects which external influences cause in the different tissues and organs of an organism, likewise exhibit variations coequal with the differences of vital properties imparted to them at the period of formation. The same excitant applied to a nerve produces sensation; to a muscle, causes a contraction; to a gland, a change in its secretion. It further modifies the act of nutrition in each organ. If, then, an external influence produces one effect in one organ, and another in a second, and if this effect itself varies in its intensity according to the living condition of the excited organ, the cause must be sought in the different constitution of the powers. Hence, it follows, that the effects produced by exciting causes, in living bodies and their different tissues, can only be calculated from the particular constitution of these bodies and of their tissues, from the forces that are inherent in them, from the various living conditions in which they are, and not solely from the nature and intensity of the excitants themselves, whose effect is always relative to, or dependent upon, the state of the organic powers.

DXLI. The mode of action of the externals which living bodies take from the organic kingdom itself by their own activity, and for their own preservation, or the alimentary matters, is neither purely mechanical nor chemical. All such act on organized bodies, and cause them to become active, not by their mechanical qualities and chemical constitution, but chiefly by the organic properties they possess—properties that are inherent in them as organic matters, and vary infinitely, according to the kind of living bodies into whose composition they enter. Hence it is, that the effects they produce in living bodies that have received them by absorption or movements, vary exceedingly. In the first instance, as excitants, they induce the coats of the excitable spaces wherein they are introduced, to perform movements and secrete liquids, which causes them to acquire properties that render them fit, as matters capable of taking on forms, to pass into the formative fluids of the organisms, and to become constituent parts of those fluids. As such, they act on the excitable solids according to their specific constitution, and maintain them in action during the operations of nutrition and secretion.

If the living body is unable to convert, by the act of assimilation, the aliments it has taken from without, into its own proper fluids; if it is unable to destroy the properties of organization and composition, and to reduce them to the special conditions and chemical composition of its own formative fluids, they cause divers reactions. An increase of movement, and an augmentation of secretions, takes place in the alimentary passages, in order to expel them as foreign and non-assimilable matters. If, by absorption, they have passed into the mass of the humours, the excretory organs labour to elicit them. When mixed with the formative fluid, they produce various disorders in the functions of the solid parts on which they act.

Many of the organic matters received by living bodies from without, are so unchangeable in their chemical composition, that the living activity of organized bodies sinks in the efforts to neutralize or eliminate them, and life is extinguished. Certain substances, as the poisons of the vegetable and animal kingdoms, even annihilate the forces of the organism. For the rest, the venomous part, enacted by a vegetable or animal substance on an organized body, does not depend alone on the qualities of the poison itself, but also on the condition of the forces of the living body into which it is introduced. Hence the same substance is poisonous to one vegetable or animal and not to another. But the actions of poisons differs also with the living condition of one and the same organic body.

DXLII. From these inquiries it follows, that external influences or excitements that urge living bodies to action, whether of the inorganic or organic kingdom, are the cause of their preservation and their persistence in the state of life, but do not produce life itself. Their action supposes the previous existence of an organic activity which they only excite and determine to action. That an external should act as an excitant on an organized body, and urge it to a development of power, the body must possess the property and capability of being affected by external things, and of acting by a proper force, whenever their influence is exerted over it. The excitement produced by an external object in a living body is not, therefore, a passive state but an active one, is an act of life, which supposes the existence of organic forces. Inasmuch as these forces are diversified in living bodies, insomuch are the effects of excitants varied. This throws light on the fact, that the phenomena of life are manifested in a specific and uniform manner in each organized being, notwithstanding the diversity of excitements, and that different living bodies develope a different activity in a similarity of external things.

Excitability, or the faculty of being affected by excitants and placed by them in a state of excitement is communicated, like the plastic force, to the germ of organized bodies, by the activity of the generator organisms, which produce the specific constitution of their organic materials, and the quantitative division of these materials. It is manifested in each germ in a specific manner corresponding to the species of the generator bodies, and under the influence of fixed excitants. The plastic force of germs endued with excitability gradually produces all the tissues and organs, together with their different organic or vital properties, observing, at the same time, the track of formation and development of the species, and in concurrence with the excitants, which induce it to become active. Subsequently we see other manifestations of force developed, according to the varied nature of the organs that have been produced by formation.

DXLIII. Regarding the dependence of organized bodies on external agents, it is founded directly upon the fact, that the latter furnish both the stimulus and the materials by which the acts of formation and nutrition, of which the existence and preservation of living bodies is the consequence, are executed. Heat causes the plastic force inherent in vegetable and animal germs to enter into action, urges it to formation, and places the organic matter of the germ and the ovum, with which it combines, in the condition essential to development. No germ is developed without a certain degree of heat. Its influence is necessary to the continuance of the operation of nutrition of all vegetables and animals, because the assimilation of aliments, respiration, the acts of nutrition in the solid parts, and the secretion of fluids, are accompanied with organic changes in the composition, which can only take place at certain temperatures. All the other manifestations of force of living bodies, movement, sensation, generation, are only effected at determinate temperatures, as I shall afterwards show under the head of heat, as an external condition of life. The stimulus of light also in plants, and even in most animals, is an important agent for the maintenance of the acts of formation, and for the excitement of all the acts of life.

The other externals on which the maintenance of organized bodies depends, such as atmospheric air, water, and aliments, act as excitants to parts with which they are placed in contact, and from these matters it is that living bodies, in the act of assimilation and respiration, prepare the formative and nutritive fluid by the activity peculiar to them. This fluid is absolutely necessary to the preservation of the activity of the organisms, inasmuch as being an excitant, it determines the action of the solids, and furnishes the materials by which they are maintained, by the act of nutrition, in possession of their organization and vital properties. Hence, the necessity of these external agents, for the continuance of organized bodies and the maintenance of their activity, will appear. Without them, no vital phenomena, no action of the organic powers, are developed. Withdrawn from their influence, the life of organized bodies is infallibly extinguished.

DXLIV. Besides the external agents necessary to the preservation of organized bodies, as heat, light, air, water, and aliments, there are moreover internal excitants inherent in living bodies, which themselves produce, and which maintain them in activity. Of these are the exciting fluids of all vegetables and animals which are the products of their own activity. In the fecundated matter of the germ of each plant and animal, a liquid, containing globules that move under the influence of heat, is formed. Solid parts proceed from the constituent principles of this fluid, and take an organic texture. In the vegetable and animal embryo, during development, organs are formed which, by the vital properties imparted to them in the formative act, take up by absorption the alimentary matter furnished by the parent body to the grain or ovum, and convert it to their own nutritive fluid or blood, by the acts of assimilation and respiration. Spaces are marked out in which the formative liquid flows, and this furnishes the stimulus that urges the contractile parietes of the spaces to perform movements. Thus it is, that in embryons that are gradually, rapidly, or slowly developed at fixed periods, and in determinate order, organs are produced from the formative fluid, which themselves elaborate, which, from their vital properties, are enabled, under the exciting influence of the formative liquid, to fulfil the functions essential to the preservation of the newly organized being.

DXLV. All vegetables and animals continue, during life, to introduce into themselves aliments, air, water, and organic substances, from which they prepare fluids that are stimuli, and new materials for formation and nutrition, which acquire, by means of assimilation in each vegetable and animal species, the specific properties necessary to the preservation of its activity. The excitant fluids regulate the acts of nutrition. The solid parts give an impulse to automatic movements which procure their progression in the spaces they fill. Driven into the organs, these fluids urge them to accomplish the act of nutrition. In thus regulating, by nutrition, the spontaneous preservation of organized bodies, and all their different parts, the nutritive fluid is the condition of their vital properties and renders them fit for all the other varied manifestations of force. In animals, the nervous system, the organs of the senses and those of movement are prepared to produce the effects peculiar to them by the act of nutrition, under the influence of excitement occasioned by the fluids. The nutritive fluid solicits the nourished secretory organs to secrete, and the liquids prepared by these organs act at the same time as stimulants to the contractile parietes of the excretory ducts and canals into which they are poured, and which they bring into motion. Thus the preservation of all living bodies, during a certain time, depends on the existence of fluids which, under the influence of external agents, are prepared from those agents, and place the living bodies in a state of internal excitement. When organized bodies are placed in such circumstances as render them unable to make nutritive fluid, or when this fluid has been withdrawn by a wound, or when it loses its properties, their life becomes extinct.

DXLVI. Another important source of internal excitations in animal organisms is the nervous apparatus. So long as it is nourished, it produces stimulations that are essentially necessary to the preservation of animals. Hither are referred the excitations causing the contractions of the muscles, and by which animals move in a spontaneous manner, in consequence of ideas. Hither, too, must be referred the desires arising from the state of the animal body and its nervous system, and urging them to certain actions, accompanied with movements, and intended for their preservation. Moreover, the nerves exert over all the organs into whose composition they enter, an automatic and unconscious influence, which is indispensable to the acts of nutrition and secretion, as well as to the excitement of involuntary movements. Plants are altogether deprived of this source of internal excitements produced by the nourished nervous apparatus, inducing muscles to action in an automatic and arbitrary manner, and by the excitement causing a series of other effects in the organs.

DXLVII. Every living body only shows its activity in a certain circle of external agents, and under the influence of certain internal excitements produced by itself. Each tissue, each organ, demands for the excitement of its activity, particular excitants, exactly corresponding to its specific constitution and excitability. The alimentary canal is urged to action by aliments introduced within it, and by the digestive fluid poured out in it. For the heart the blood is the specific stimulus. Each gland is stimulated by particular agents to the enactment of its secretion. Each organ of the senses enters into action on the application of certain external influences alone. The eye is excited by the impression of light, the ear by sounds, the olfactory organ by odoriferous matters, the tongue by sapid substances. The brain is induced to act by external or internal impressions, which reach it by means of irritated nerves. The muscles attached to the skeleton, to the organs of the senses and of respiration, are brought into play by the excitements of the nervous apparatus. The various parts of an organized body are incessantly mutually exciting and reacting on each other, so that the activity of one part reacts as an excitant which determines the action of another. On this mutual reaction of the organs, and from the production of internal excitements for the maintenance of the activity, depends the necessity of their individuality, in order to their continued existence, and this it is that distinguishes organisms from the simple inorganic aggregates, in which this reciprocal dependence of congregated parts is not observed.

DXLVIII. Besides the external and internal excitants necessary to the preservation of the activity of organized bodies, there are many other impressions of a mechanical, chemical, or organic kind, which, in certain circumstances, act on organized bodies. Such, likewise, are capable of determining them to manifestations of activity, when they do not destroy their organization and forces by mechanical violence, or by the powers of chemical affinities. They may occasion anomalous and unusual excitations or reactions. There is ever observed in living bodies affected by unaccustomed excitations a tendency to react against them, and to ward off their baneful influence. In the action which they determine, reference is not only to be had to the quantum of the impression and excitation produced, but its kind, and the quality of the reaction it causes must also be taken into consideration.

DXLIX. If we now inquire on what the property possessed by organized bodies of showing themselves susceptible to excitements, and of being urged to action thereby, depends, we find that it appears to be owing immediately to the particular state of the organic matter constituting them. This state is communicated to other germs of all vegetables and animals by the plastic activity of the generator organisms, and renders them fit for formation and development under the influence of external agents and excitants. It is true that the particular state of the matter of the germs which renders them excitable and fit for formation has not yet fallen under the cognisance of our senses, and that it has been hitherto impossible to subject it to observation or experiment; yet we are bound to entertain its existence, inasmuch as we behold the phenomena of formation, that take place in the germs in consequence of excitements, vary with the diversity of the generator of the vegetable, and animal species, and according to the differences they present in their organization and composition. Formation is manifested in the germs of each species of living beings in a specific manner, corresponding to the constitution of the parent bodies that communicated the formative faculty to them. The plastic force or excitability differ in germs according to the specific nature of the organic matter which renders them capable of formation.

DL. The parts that are developing germs, by the influence of external agents or excitants, in a given order and determinate progression, are variously irritable and active, each in its own manner and agreeably to the differences of organization and composition given to them by the act of formation. The gradual seed-proceeding roots, leaves, flowers, and fecundating organs, the cellular tissue and sap vessels of plants are determined to action and to the fulfilment of their specific functions by different external and internal excitants. In animals, the muscles, nerves, cellular tissue, vessels, glands, organs of sense, and all the viscera produced by the formative act, exhibit a varied susceptibility to excitements, and are placed, by excitants of different kinds, in a state of activity varying with the organization, composition, and vital properties that have been communicated to them by formation. The cause of the formation of different parts, endued with different vital properties, in developing germs, cannot be attributed to the influence of external agents or excitants urging the germs to formation; but we must seek such cause solely in a force inherent in the matter capable of formation, in a force which regulates the acts of formation, in fact, in the plastic force. The effects produced by the action of this force on the germs, under the influence of external agents, are as varied as in the species that produced the germs capable of development. As each organ, each tissue, each part, is endued with a specific susceptibility of certain excitements, and manifests its action in a manner peculiar to itself, this must depend on the properties communicated to it by the act of formation and development. But since these properties are effects of the plastic and nutritive force, in it alone can we endeavour to discover the cause of the differences observed in the excitability and activity of parts.

DLI. A condition necessary in order that organisms, with all their parts, once formed, may for a certain time remain excitable and manifest their activity in a specific manner, under the influence of external and internal excitants, is, that the act of nutrition shall maintain them in their organization, composition, and vital properties. Each part of an organized body, animal or vegetable, remains excitable in a manner agreeable to its proper constitution and being, and manifests its specific activity only so long as it is nourished. A muscle is only sensible to excitations and only contracts under their influence, so long as the act of nutrition maintains it in the conditions of organization, composition, and vital properties peculiar to it. It is only nerves that are nourished that are sensible. Each organ of the senses is only capable of exciting particular sensations on the presentation of irritants from without, so long as its special constitution is preserved by the operation of nutrition. Excitants cannot urge a gland to secrete its humour, unless it be nourished. In the same case are the manifestations of life in all the other organs. Likewise in vegetables, movements are only enacted on the application of stimulants, so long as the mobile parts are nourished. The fundamental internal condition of excitability and of the faculty of reacting in a specific manner against excitants is, therefore, to be found in all organisms and their parts, in the state and peculiar character of their organization, composition, and vital properties, which are communicated to them by the force of formation or nutrition, and in which they are maintained by the same force.

DLII. But the kind and degree of susceptibility of living bodies and of all their parts, as also the mode and energy of activity they exhibit on the application of excitants, the condition of a fit nutrition always understood, depend also on the nature of external agents, aliments, water, and air, from which organized bodies prepare their nutritive fluid and the materials which serve both for their formation and nutrition. These matters possessing the necessary qualities for the supply of a fit nutritive fluid, and the living parts remaining thereby in a proper state of nutrition, the latter manifest their excitability and activity in their own manner. Well nourished plants and animals preserve most fully their excitability and activity, and exhibit the greatest energy when they act. On the other hand, if the aliments are bad, the nutritive fluid is altered in quality, the operation of nutrition suffers, and the excitability and activity of the parts are also changed. Should nutrition languish or change, either from want of aliments or from their bad quality, from sojourn in vitiated respiratory media, or from other hurtful influences that disturb and derange it, a change also invariably takes place in the excitability and power of action.

DLIII. The excitability and activity of living bodies and of their parts may likewise be changed by divers external matters which do not always, but only in certain circumstances, act on them. Among such are medicines. Most of them are absorbed and added to the nutritive fluid. Sometimes they change its organic composition and qualities; at other times they are conveyed with it to the solid parts in which they produce changes that are recognised by the exaltation or diminution of their excitability and activity and by a modification of their manifestations of life. Their operation, as explained by the Brunonians to be confined to the various degrees of excitement they occasion in the parts, is too limited. All of them, on the contrary, act in the first place by modifying the material constitution and kind of nutrition of the organs on which susceptibility and power of action is founded, and by that alone they effect a change in the excitability and forces of those organs.

The action of medicines varies much, according to their kind. Some, by changing the state of nutrition of the nerves, exalt or diminish their susceptibility. Others have a similar influence over the muscles, others over one gland or other, others modify the vitality of the membranes or of other tissues. This effect is not always explicable by the mere degree of excitement produced by medicines. It can only be explained by the admission of a varied qualitative action on their part, and a consequent modification of the state of nutrition. The addition of various materials, electricity, heat, alkalis, acids, narcotics, &c., to the organic substance of the parts works divers changes, exalts, diminishes, or altogether inversely modifies their excitability and faculty of action, as Von Humboldt(8) and G. R. Treviranus(9) show in their experiments on the application of divers matters to the nerves and muscles of living animals, and to which I return in another place. It is plain, that a change effected by medicines in the state of nutrition and in the forces dependent on it, must also induce modifications in the effects of the ordinary excitants that are essential to life.

DLIV. Excitability, and the special manifestations of activity exhibited by living bodies under the influence of excitants, may be annihilated by divers external influences, by a certain degree of heat, of cold, or electricity, and by certain mechanical and chemical impressions. Such present numerous diversities as regards the degree at which they do this, dependent on those which exist in the constitution of living bodies and their state of life. All of them cause death by destroying the internal condition and specific constitution of the organic materiel of living bodies, in which they extinguish the circumstances that are the conditions of their plastic and nutritive activity, and on which their susceptibility to excitants and their living action are dependent. To this class of influences, destructive of the excitability and organic forces, lastly, belong the organic poisons, whose action is always relative or according to the different constitution of living bodies. Neither do these poisons act on vegetables and animals otherwise than by changing the particular properties of the nutritive fluid, and destroying those conditions of it that are necessary to the maintenance of nutrition, or by extinguishing nutrition in the solid parts themselves, an event which induces the annihilation of their excitability and forces, of which nutrition is the indispensable condition.

The opinion of certain physiologists and physicians who hold that poisons immediately destroy the nervous or muscular force and in this manner cause death, is narrow and erroneous. As there are many poisons which destroy the life both of plants and animals, it is not possible that their action can be other than the cessation of nutrition and the annihilation of the nutritive force which belong alike to plants and animals, and it cannot consist in the abolition of the muscular or nervous power, which plants do not possess. Nevertheless, it must be admitted, that in animals some poisons annihilate immediately the nutrition of the nerves, and consequently the nervous power; whilst others destroy primarily the nutrition of the muscles, and with it the muscular

(8) Versuche über die gereizte Muskel-und Nervenfaser. Berlin, 1797, v. ii, pp. 70, 171. Versuche über die Stimmung de Erregbarkeit durch chemische Stoffe.

(9) Physiologische Fragmente. Hanover, 1797, v. i, p. 70. Biologie, v. v, p. 303.

force, so that death may commence at one time in the nerves, at another in the muscles.(1)

DLV. The susceptibility of living bodies to excitations, and the intensity of their reaction against them, varies moreover with the periods of developement and age. Young plants and animals are very excitable, and are put into action by slight excitants; but more powerful excitants soon exhaust their powers. In the lapse of time, when life has arrived at its highest pitch of organic activity, the susceptibility to excitements gradually diminishes, though the reaction induced by a sufficient degree of stimulation is effected with great energy. Excitability and the active power, moreover, are not at this period so easily destroyed by excitations. In advanced age, when organized bodies have reached beyond the term of their greatest development, susceptibility to excitants has not only sunk, but the force of reaction is also no longer so energetic. This variableness of the excitability and forces of the organism according to age, is owing to the change which takes place in the material constitution of living bodies and in their nutritive power at the different epochs of their development and life. Each living body has a certain span of existence, according to the species to which it belongs, and each passes through life in fixed periods, exhibiting infinite differences, according to species, as regards their duration and their acts of formation. The cause of these changes, and those which follow in their excitability and

(1) The truth that medicinal substances produce their effects by modifying the nutrition of tissues is one which leads to philosophical views, both in the pathology and therapeia of disease; in this respect this physiological point is particularly interesting to the medical readers. Nothing is more frequent than to hear that narcotics "suspend the nervous and muscular powers," that certain stimulants excite them, and so on. The same persons who state this refuse all theory concerning the modus operandi of medicines; forgetting that even their own expressions include a theory, a sorry one truly, being founded on powers whose existence is at best apocryphal. That of the nutritive power is certain, and a simple syllogism proves that it is in modifications of it that the operations of medicinal agents consist; for as the body itself and its functions are the consequences of nutrition, anything modifying the former must primarily effect changes in the latter. We have heard it objected to such a doctrine that the effects of some medicines and poisons are too instantaneous to be consequences of modified nutrition. Without resting on the assumption contained in this objection, namely, that the intimate nature of nutrition is ascertained, it may be remarked that many facts demonstrate the extreme rapidity of the nutritive process and every function shows its incessant enactment. The rapid changes in the colour of the surface, the changes of secretion (which imply changes of nutrition) as of the lachrymal glands, mouth, kidneys, &c., show that an operation, the suspension or alteration of which can induce such rapid changes in its effects must necessarily be itself of surprising velocity, which, added to its continuous nature, makes the instantaneous action of certain medicines, especially on a tissue so highly nourished as is the nervous, a fact easily to be credited when attributed to nutrition. In this manner, for instance, the action of prussic acid, which causes instantaneous death in a large dose, is perfectly intelligible, without recourse being had to the vague explanation included in "the annihilation of nervous power." In pathological doctrine the fact of the action of medicines on the nutrition of parts would lay open another fact, that disease is the consequence of modifications of the the nutritive process. Following on this would be the abolition of the division which gives organic and functional diseases; if nutrition be modified, so is the organism, so also is the function; but all must be referred to the modification of the organism, that is, of nutrition, and the epithet "organic" must be the only one applicable to disease.—Trs.

activity is referable to the differences exhibited by their plastic force, differences whose origin must be sought in the natural circumstances that called living bodies into existence. These are yet unknown to us; so that no explanation of them can be given in the present state of physical science.(2)

DLVI. Excitability, and the manifestations of force of living bodies vary according to the diurnal periods and present periodical alternations of exaltation and exhaustion. The susceptibility and activity of the nervous apparatus, of the sensitive organs and muscles of all animals are changed and diminished by the operation of irritations upon them, and by the effects produced therefrom, and a period of rest and inactivity arrives, a state of sleep, the cause of which is to be sought in a suspension of the powers of those parts. In sleep during which the nutritive functions continue uninterruptedly, the susceptibility of these organs is gradually exalted and their forces obtain renewed energy, so that they may again be put into action by external and internal excitants. These phenomena are referable to changes effected in the material constitution of the nervous apparatus, sensitive organs and muscles, in consequence of excitations which bring them into play, and, by reason of their own proper reaction, changes which render them unfit for the permanent exercise of their functions. During sleep, the necessary conditions of this material constitution are renewed by the operation of nutrition, as also the external and internal excitants that maintain them. Hence, the forces of these parts get renovated energy and recover the power of acting under the influence of excitants that urge them to activity. It is the force of nutrition, therefore, which not only originates excitability and activity of the nerves, sensitive organs and muscles, but also renovates them when they are exhausted by exertion. Similar phenomena of a varied state of excitability and mobility, according to the diurnal periods and the kind of excitants, are observed in the leaves, flowers, and genitals of plants, in which they are also only an index of the changes they undergo in the state of their nutrition according to the periods of the day and the excitants they meet withal.

It is, therefore, the force of nutrition tending to the preservation of organized bodies, which renews the excitability of plants and animals when lessened by the action of excitants and the fact of excitement, and which renders them able to come into play. The phenomenon of variableness of excitability in

(2) The excitability of animal bodies in regard to *external* agents appears at the highest pitch in their more youthful state. Food, air, light, and water are now more immediately essential; the want of them compromises more directly the preservation of the individual. In middle age, the habits of brutes and the intellectual cogitations of man, both acts of the nervous centres and among *internal* stimuli, come more into play, and teach them to bear with the diminution of the external stimuli. This, however, can only be resisted for a time; still there seems some ground for such a general rule as the above. In old age, when nutrition is throughout impaired, the excitability both to external and internal stimuli is far below the standard of former years, and the conflict, called life, at last ceases; excitability can no longer come "to time."—Trs.

animals, according to the diurnal periods, was well known to the excitability-theorists; but they knew not how to account for it. To the renewal of the excitability and activity of organisms by the act of nutrition, the reception of fresh aliments, organic materials, water, and the components of air, on which the preservation of living bodies is dependent, is referable, inasmuch as they prepare from these new materials, fresh nutritive fluid, by which each organ is maintained in its state of excitability and activity, and renews whatever has been changed by excitants and reaction against them.

DLVII. It follows from these researches, that we designate by the word excitability the property or faculty possessed by all living bodies, animals, and plants, by all their parts, and even by their germs, of being susceptible to external agents or influences, as also to excitations produced within themselves, and of being thereby determined to continued manifestations of action and changes. Reil(3) and Hufeland(4) heretofore employed the word excitability in this general signification. We are not, however, to imagine it as an isolated force, merely attached to organisms and objectively different from their organic constituent matter, capable of change, of exaltation, or diminution, without a simultaneous change in that matter. On the contrary, we are to regard it as a quality founded in the specific state of the organic matter and the organization, altogether dependent on these and as diversified in the different species of living beings as their organic constitution is. As much as the organs produced by the plastic activity of the germs, according to the mode of development peculiar to each species, vary, so much also does their excitability vary. Each tissue, each organ is urged to action by specific excitations, according to equally specific constitution bestowed on them by the act of formation.

We are bound to admit, in animals, as many kinds of excitability as they have different parts, therefore an excitability of the cellular tissue, of the muscles, of the nerves, of the bones, of the fibrous organs, &c. Each organ, each viscus, each gland, each sensitive organ, according to the differences of structure and constitution communicated to it by the act of formation, has its peculiar and specific susceptibility to excitations and is excited to its manifestations of activity or life by particular kinds of stimulants. The cellular tissue, the different sorts of vessels, the roots, leaves, secretory organs, genital parts, flowers, pistil, and stamina are variously excitable, according to the difference they exhibit in the structure and properties bestowed on them by the acts of formation and development, and are urged to their functions by different excitations.

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(3) Von der Lebenskraft; in Archiv. für die Physiologie. v. i, p. 1.
(4) Pathogenie, Jena 1795, p. 77.

Excitability is communicated, by the formative activity of parent organisms, to the plastic matter of the germs, together with the property of taking on a form under certain external influences. The excitability of organisms and of all their parts also persists while they are nourished. All influences that change the state of nutrition in general, or in part, cause changes in their excitability also. A change of excitability accompanies those which occur in the state of nutrition of the whole body or of its parts during the development of different living bodies and during the periods of their age. All influences that arrest nutrition and annihilate the force of formation or nutrition destroy excitability.

Since excitability cannot be considered as a particular power of organized bodies, but only as a property of formative germs and organisms and their parts originated by those germs in their development, which is previously communicated to them by the plastic force, and which is likewise maintained in them by this force, it will appear how erring the physicians and physiologists have been who created it as a fundamental force of life, or the principle of life. They have mistaken for the cause of life a simple property of organized bodies, which is the consequence of the plastic force.

DLVIII. After demonstrating the necessity of external and internal excitants for the preservation of organized bodies, that the activity and vital acts of those bodies also depends on them, and lastly that excitability is a property of organisms founded on the force of formation or nutrition, we now proceed to examine the effects produced by excitants. When external agents produce an excitation in an organized body, this, as I have before shown, (DXXXIX,) is not owing solely to the excitants, but likewise supposes the existence of forces in the living body that may thereby be urged to action. The effects consecutive on excitations are, moreover, neither mechanical nor chemical, but organic or vital, that is, are products of forces inherent in organized bodies and determined to action by excitants. We can only know that an organic body is excitable, or that an excitant impresses on it and gives rise to an excitement, from the manifestations of activity that take place, and from these alone can we conclude the occurrence of excitement. The impression caused by the excitant, and the consequent manifestation of activity cannot be distinguished by the senses as two separate acts, inasmuch as they are resolved into one act, the impression of the excitant on the living organ bringing into play the force inherent in it.

DLIX. The manifestations that succeed the impression of excitants vary considerably in organized bodies and their parts, and we must hence conclude, that there is a difference between the forces put into action. In observing the effects produced by exciting agents it will be found they are reducible, to the following. In the first place we perceive phenomena of formation, nutrition, and secretion occurring in consequence of excitements. Phenomena of formation take place in the fecundated germs of plants and animals at a certain degree of heat and with the presence of air. The acts of nutrition are in all living bodies effected through the influence of excitants. All nourished parts may undergo divers changes in the state of their nutrition by the action of excitants, as exposed, wounded, or diseased organs give us the opportunity of observing. In the secretory organs, the glands and membranes furnish a secretion, the activity induced by excitants is manifested by the secretion of liquids and occasionally by a change in their composition and properties. In other organs the activity thus excited by stimulants is discovered by movements of various kinds. In irritated muscles we observe oscillations accompanied with alternate contraction and expansion of their fibres. In the cellular tissue and the membranes formed from it, in the coats of the vessels and excretory ducts of glands, and even in the fibrous organs, a slow contraction and condensation of their tissue is observed. The blood or nutritive fluid flows in greater quantity to parts rich in vessels that have been stimulated, and they become turgescent. In other organs again the activity roused by excitants is recognised by sensations which accompany the action of our spiritual principle, of our own consciousness, as happens in irritations applied to the organs of the senses or to the nerves, or to organs supplied with nerves. Analogy alone follows the admission of these manifestations of activity in other organs, partly because they possess nerves and organs of sense similarly or analogously constructed, partly because we witness actions in them which, in us, are enacted in consequence of nervous excitations.

DLX. Let us inquire how or in what manner living bodies and their parts discover their activity when impressed by excitants, or in what the effects manifested consist? In general, the excitement occasioned by excitants, or the state of activity consequent on the impression of excitants, seems to consist of movements of the excited parts, or to be accompanied by movements. The movements, however, present differences corresponding with those exhibited in living bodies and their parts, their organization, and the forces inherent in them. In many parts, such as the muscles and all the other contractile tissues, the movements elicited by excitants are visible. When no movements are perceptible, we are equally necessitated to admit the existence of phenomena which we are unable to imagine without changes of locality, such as those of formation, of growth, of nutrition, and secretion, or as the internal operations enacted in irritated nerves, which are followed by sensations and movements of the muscles. Inasmuch as living bodies and their parts possess the faculty of moving by a proper activity, under the influence of excitants, we are bound to attribute motor powers to them. These we can only estimate from the kind of movement caused by them. We will now proceed to investigate the causes or forces which effect the movements of animals and vegetables, detailed in the two preceding chapters, and we will designate them by particular names whenever it is impossible to trace them to each other.

Activity of Formation or Nutrition as the Effective Cause of the Movements that accompany Formation, Nutrition, and Secretion.

DLXI. The first manifestations of activity that occur, under the influence of external agents, in the fecundated germs of animals and vegetables, are those of formation. They are accompanied by extensive but slow internal changes of the organic matter of the germs, and without such it is impossible to conceive of them. Formation, however, does not consist solely in movements, for it is simultaneous with changes in the chemical composition of the organic matters that are not explicable by movements alone. The movements that accompany formation, though caused by excitants, are not by them communicated to the germs. On the contrary, they are enacted and regulated by a force inherent in the germs themselves, and on this the particular mode of formation and the movements associated with it depend. Formation, and its accompanying movements are performed in a specific manner in each vegetable and animal species, so that the parts which compose them and which appear in a fixed order, at determinate periods, resemble in form, chemical composition, organization, and vital properties, the organisms that called the germs into existence.

We have designated by the name of formative movements (CCCCLXVIII and CCCCLXXV) the movements that accompany formation. The manner in which they are effected is as yet beyond our sensible observation. Their wonderful effects strike our sight, although we are unacquainted with the internal operations whence they proceed. They appear to depend on the same internal principle, inherent in the plastic matter of the germs, which produces the composition and organic texture, and to which we have applied the denomination of plastic force. We are not at all authorized to admit a specific force regulating the movements of formation, and we are not prepared to assign a character by which the existence of a special force, different from the plastic, can be established. Aptness for taking a form, and mobility for its acquisition, are properties inherent in the organic matter of the germs, of which we can give no explanation in the existing state of physiology, and the existence of which we are necessitated to admit, without a knowledge either of the manner in which they act, or of their absolute cause.(5) The same applies to a great many other forces, whose effects are perfectly known, but whose mode of action is yet buried in obscurity.

DLXII. The unknown operations of formation and their accompanying movements are the condition of all the other movements of liquids that occur in organized bodies, under the influence of excitants, inasmuch as all these are products of the formative act, and as it is formation that bestows on them the property of moving on the application of excitants. The globules contained in the formative and nutritive fluid, together with their mobility, are the products of formation. All the contractile parts that are generated in the germ, the mucous tissue in animals, and the cellular tissue in plants, the different vessels endued with contractility, the contractile membranes, are products of the plastic force, and are indebted to it for the property of being contractile. The same is the case of the muscles and their living contractile power. The nerves and their aptness for internal movements by means of stimulants,

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(5) Dutrochet (L'Agent immediat du mouvement vital, vesicle dans sa nature et dans son mode d'action chez les vegetaux et chez les animaux. Paris, 1826, 8vo, ch. 4, p. 105) accidentally ascertained that the seed capsules of certain mouldiness became filled with water through their sides, whilst a thicker substance contained within them flowed out. This phenomenon attracted his attention and suggested to him a series of experiments. The cœca of fowls, which he placed in water, filled with fluid, though their open extremity was tied. When left open, the water penetrated their coats and displaced the contained matters, as chyme or milk. These phenomena continued so long as the matters in question were not putrid, but immediately that putrefaction occurred, the contrary took place, the water within the intestine being driven out, and the intestine itself shrunk. Dutrochet then introduced the lower end of a tube filled with gum-water into the cœcum and plunged this half way into water. The ambient fluid passed through the coats of the intestines with so much impetus that the gum-water was raised and ran out by the upper end of the tube. From these and other similar experiments he concluded, that so often as two liquids of different densities are separated from each other by an organic membrane, the less thick one is vehemently directed to the place where the more thick is situated, and that the cavity which contains the latter fills and becomes turgid as often at least as the chemical nature of the fluid does not prevent it, for in certain cases alkalinity produces the same effect as a lower density. Dutrochet calls the tendency of a liquid to penetrate the interior of a cavity *endosmosis* and the opposite tendency *exosmosis*. He thinks the explanation of this phenomenon is found in the observation made by Porrett, that when two liquids are separated from each other by a membrane and one of them is electrified, it rushes forcibly towards the non-electrified one, in a manner agreeable to the general law of galvanic electricity to which Becquerel has called attention, and according to which, when two bodies of different densities come into contact with each other, one takes a positive and the other a negative electricity. In this manner he was led to the conclusion, that electricity is the immediate agent of vital movements. Dutrochet does not hesitate to consider not only the absorption of liquids by the roots and the ascending and descending currents of the sap, but also the nutrition and formation of vegetables, as simple effects of the endosmosis and exosmosis of fluids of different densities through the parietes of the sap globules and the cellules of plants. He says, (p. 184,) "Il resulte de tout ce que vient d'etre exposé que la vie de nutrition des vegetaux consiste toute entiere dans l'endosmose et dans l'exosmose; et comme ces actions physico-organiques reconnaissent pour cause l'agent electrique, il resulte, en derniere analyse, que cet agent est le principe de la vie de nutrition des vegetaux." But then, whence do the first globules proceed in the formation of vegetables, which should certainly precede endosmosis and exosmosis? How do new ones originate, and how are these added to the different tissues of plants, which possess their particular character in each vegetable species? Until he shall have resolved these questions, we can only consider his doctrine as an hypothesis altogether hazarded and without proof, which does not explain the phenomena of formation. —TRS.

are also dependent on this force, which calls them, together with their properties, into existence. The nature of the movements produced by the impression of excitants on the organs, and the reaction of these by virtue of an activity proper to themselves, exhibit as many differences as there are varieties in their organization and vital properties, which are communicated by the plastic activity and the act of formation.

DLXIII. All organized bodies, with their different parts, which are formed in a fixed order of succession, maintain the faculty of moving in a specific manner after excitation, only so long as they are nourished. But nutrition, as I have already shown, is accompanied by continual changes in the organization and composition, and by equally incessant internal movements, which take place both between the nutritive fluid and solid parts and the particles or molecules of the tissues themselves. Although these movements are not cognizable by the senses, we are forced to infer their existence from the changes we observe in all the parts in regard to composition, consistence, configuration, and increase and diminution of volume during their being, changes which could not occur without movements. These movements also are owing to the plastic or nutritive force, and on it is founded the continuance of the mobility of the different parts, of the cellular tissue, the membranes, vessels, muscles, and nerves of animals. To nutrition also and its movements is owing the property possessed by the parts of vegetables of moving by excitants of different kinds. All excitants that are in a condition to provoke visible movements in the organic tissues, appear to determine primarily movements of nutrition or molecular organic movements, and it is only subsequently to these that the other movements observed in irritated parts are manifested.

DLXIV. The operations of nutrition, and the molecular movements associated therewith, may be modified in all the solid parts by influences of different kinds, and these are connected with changes in their state of nutrition and vital properties. In animals, the cellular tissue, the different membranes, the muscles, nerves, bones, fibrous tissues, the glands, in short all the viscera and organs undergo, by excitants and impressions of unusual kinds, changes in their state of nutrition and their organization, as we with others have had the opportunity of observing. Parts that receive an anormal or morbid irritation, swell, are augmented in mass, and changed in structure or texture. Disturbances in the process of nutrition take place in diseased conditions, in hardening and softening, and in many other morbid conditions of nutrition, degenerations, scirrhus, cancer, tubercles, &c., which are accompanied by an anormal state of composition and structure of the organs, and in which the morbid excitement is, in the first instance, only manifested by a disturbance and modification both of the act of nutrition and its molecular movements. The change of the nutritive process in morbid states is ever accompanied by a change in the vital properties belonging to the organs, in their excitability, their mobility, and in the movements they enact through excitants. The parts of plants may likewise be urged, in numerous ways and by divers influences, to anormal and morbid formations, in which case the change that takes place is first effected in the operations of nutrition and their accompanying movements.

DLXV. Among the organic molecular movements produced by the force of formation or nutrition, those, lastly, are included which accompany the secretion of the humours. Components of the nutritive fluid conducted to the secretory organs are employed in their parenchyma, for the preparation of fluids of a specific kind, endued with particular qualities, and poured into different spaces. It is impossible to consider the preparation of the humours in the secretory organs other than an effect of the force which regulates the changes of composition in living bodies in general. The preparation and secretion of the humours must be accompanied by internal or molecular movements, without which they are not conceivable. These movements, then, which divers excitants cause in the secretory organs endued with excitability and formative activity, we also consider as effects of the force of formation and nutrition. They vary according to the secretory organs and the plastic activity they are endued withal. The activity of the secretory organs and the constitution of the secreted humours, also undergo numerous modifications from internal and external excitants, from the different matters taken up by absorption and introduced into the mass of the fluids, and from mechanical, chemical, and nervous irritations, which, acting on the organs of secretion, alter their activity and the nature of their fluids Violent excitants may throw them into a state of inflammation, and modify the act of nutrition in them.

DLXVI. All the phenomena accompanying formation, development, growth, nutrition, and secretion, which take place in organized bodies and their parts, in consequence of excitants, and with which internal or molecular movements are associated, we therefore consider as effects of the plastic activity. It is they which furnish the conditions of all the other visible movements that occur in the organs and tissues, in consequence of excitations, both because they call into existence the mobile parts, together with their properties, and give them another kind of mobility, and because they maintain them, by nutritive acts, in possession of the faculty of executing movements by means of excitants. We now proceed to detail the different kinds of motor forces depending on the structure of parts.

Motor Faculty of the Globules in the Fluids and in Generating Seeds.

DLXVII. The globules contained in the blood of animals and in the nutritive fluid of vegetables possess the property of moving spontaneously, (CCLXV, CCLXXXVII, CCCCLXI, CCCCLXXXIII.) The corpuscules of the matured seed of animals, the so called animalculæ, (CCCCLXII,) also perform spontaneous movements. Such are likewise observed in the shoots of some polypi (CCCCLXIV) and confervæ (CCCCLXXXIV.) These movements are vital, and must be distinguished from those executed by very minutely divided bodies swimming in water, to which Robert Brown has recently called attention. In order to avoid the false conclusions which some naturalists might perhaps draw from these microscopical observations, and which they would introduce into physical science, I shall proceed to make an examination of them and point out some results of my own observations on this subject.(6)

DLXVIII. In the first place, Brown's position, that solid inorganic bodies contain minute spherical particles, as organisms, is not founded in nature. The spherical parts or particles which he observed in very minutely divided inorganic bodies, such as glass, granite, obsedian, pounce, manganese, nickel, arsenic, sulphur, fossil wood, and other pulverized inorganic substances suspended in water, do not exist as such, but are artificial productions, as was demonstrated by C.A.S. Schultze.(7) The spherical form does not belong to the aggregated particles previous to the mechanical division, and is only produced by friction. In proof of this, when the parts of these bodies are broken and then examined by the microscope, they always appear more or less angular. It is only by continued friction in the water that they take on a globular form, which is clearly the consequence of the wearing of the angles. The non-existence of spherical molecules in mineral bodies is moreover proved by the fact, that inorganic matters in solution never show that form in the act of crystallization. On examining drops of saline solutions by the microscope during the time of their crystallization by heat and the evaporation of dissolvent liquid, the particles which become solid are always angular, or they resemble needles, the shape of which varies according to the substances crystallized, as appears from Ledermueller's(8) numerous

(6) Mr. Robert Brown had the politeness, at the assembly of naturalists and physicians in Heidelberg, to communicate his observations to me, and perform several experiments before me, These I repeated with my colleague, Professor Muncke, by the aid of an excellent microscope, made at Vienna, by Ploessel, and I shall publish them more fully on another occasion.

(7) Mikroskopische Untersuchungen über des Herrn Robert Brown Entdeckung lebender, selbst im Feuer unzerstörbarer Theilchen in allen Körpern. Carlsruhe and Frieburg, 1828, 4to.

(8) Ledermueller caused different solutions of inorganic matters to crystallize by the application of heat, and observed the act of crytallization with the aid of the solar microscope and other powerful glasses. In his "Mikroskopischen Gemüths-und Augen-Ergötzung. Nuremberg, 1763, 4to," he has represented the forming crystals of verdigris and sal sedativum, (tab. 3, fig. 1, 2,) of common salt, (tab. 6, fig. 3, tab. 7,) of the salts of urine, (tab. 15,) of sal ammoniac, (tab. 23,) of saltpetre, (tab. 3,) of the saline particles of Burgundian and French wines, (tab. 43,) of alum, (tab. 57,) of sublimate, (tab. 69,) and of solution of silver, (tab. 99.)

microscopical observations. The particles of inorganic and organic bodies, therefore, do not possess the same form. The spherical form is characteristic of organic bodies only, (XXXIV, XXXV, XXXVI)

But the globules, contained in the formative fluids of animals and vegetables, and the spherical particles of organic solids which very many observers, and Brown himself, perceived by the microscope, cannot be regarded as the elementary molecules of organic matters, as several natural philosophers have supposed. Needham, Buffon, Bonnet, O. F. Mueller, Wrisberg, and different recent observers, Milne, Edwards, &c., were guilty of a great error in asserting that all the tissues of vegetables and animals are composed of minute homogeneous spherical bodies or organic molecules; that the particles discovered by the microscope in the muscular fibre, the cellular tissue, glands, &c., are identical in kind; that the globules existing in the nutritive fluid of plants and the blood of animals are the same as those found in the tissues; and that even the most simple infusoria are to be considered as molecules of that kind detached from organic bodies during putrefaction, and reconstructing them by their union in the generative act. If this were the case, it does not appear how tissues and organs so different, that are endued with specific forces and properties, proceed from spherical molecules, homogeneous and identical in kind. The globules perceived by the microscope in the fluids and solids of organized bodies ought not to be considered as the elementary molecules of the organic matter, which latter have not hitherto come within the range of our senses though artificially armed. We should rather regard them as already organized particles of organic matter, from which they are formed. Themselves present great diversities in the fluids and solids according to their constitution, and are the varied products of organic matters subject to the laws of formation. In support of this is the fact, that they have very diversified magnitudes, according to micrometric measurement. Moreover, the form and size of blood globules in animals vary exceedingly, which would make it appear that they are not the elementary particles of organic matter. The globules seen in the nerves, muscles, glands, and cellular tissue of animals, and likewise in the various tissues of plants, also differ in their nature. None have yet been perceived in liquid albumen, vegetable mucus, sugar and amylum. Lastly, neither does the matter which is soluble in water, at the dissolution of an aged organic body, contain any. In such they only appear in the shape of the most simple infusoria and monades, when the dissolved matter begins to be reorganized and formed under the influence of favourable external circumstances.

The particles perceived in organic and inorganic bodies are subjected to minute division, and have not, therefore, the same form, that is, the spherical form. This belongs only to organic tissues, whilst the angular form is peculiar to the particles of minerals. Globules even exhibit great diversities in the tissues of organized bodies.

DLXIX. The movements which Brown saw performed by the water-swimming particles *(actives molecules)* of inorganic and certain organic bodies, which movements, by their irregularity and apparent spontaneousness, appeared to him like those of the most simple infusoria, differ widely from such, as Gliechen(9) had previously remarked. From my own observations it follows, that the movements of infusoria are essentially distinct from the minute and water-swimming particles, inasmuch as they always proceed from an internal self-active principle, and are not communicated. They may be altered or even quickly arrested by divers impressions or excitants which have no influence on the movements of the particles of inorganic bodies, or of Brown's, so called, active molecules. The movements of monades, volvoces, ciclydia, &c., are instantaneously suspended by nitric, sulphuric, acetic, prussic, and other acids, also by common salt, the sulpho-prussiate of potassa, the acetate of lead, the nitrate of mercury, &c., and the animalculæ perish. On the contrary, those of the particles of triturated granite, cinnabar, pounce, &c., continue uninterruptedly in such fluids. If a little alcohol, ether, spirit of turpentine, caustic, or carbonated ammonia, be added to a drop of water containing infusoria, their movements become slower, sometimes circular, tremulous, and in a short time they cease altogether. Even the same ensues when the vapour of these substances is given out in the neighbourhood of a drop full of infusoria. But these fluids do not suspend the movements of Brown's active molecules; but, on the contrary, they give them greater rapidity, and the molecules are drawn into currents by the evaporating movements that take place. When a small quantity of water containing musk is added to a drop full of infusoria, their movements at first become more rapid, but after the space of a minute they relax, the animalculæ turn in a circular manner, and at length cease to move. The aqueous tincture of opium renders their movements slower, and finally stops them. After the addition of camphor gyratory movements commence, the animalculæ turn over and die. These substances have no influence on the movements of the molecules of inorganic bodies; camphor causes evolutions only by its evaporation. I have

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(9) Abhandlung über die Samen-und Infusions-Thierchen. Nuremberg, 1778, 4to, p. 7. An observer who is accustomed to the examination of fluids with magnifying glasses, will not take all the corpuscules he may see swimming, for living beings. Some light bodies, dry pollen for example, when mixed with strong alcohol, might be considered as animalculæ by an observer who has not seen sufficiently frequently spermatic and infusoria animalculæ, and who has not remarked that they avoid each other, or, as I have sometimes seen, that they seem to play with each other. As the movement of these grains is quite of a different kind from the animal movement, that is, extremely rapid and by starts, and as the corpuscules turn on their axis like globules, and even frequently strike against each other and rebound, it cannot be supposed that an experienced eye could be deceived by a phenomenon of this kind.

also observed that the movements of infusoria are arrested by an electric current passing along the wires of a voltaic pile, which had been inserted into a drop full of infusoria. The electric spark directed on such a drop also kills the animalculæ. These agents do not arrest the movements of the inorganic molecules described by Brown : nor do they even visibly alter them.

From all this we must conclude, that the cause of the movements of infusoria, modified, quickened, retarded, or even arrested, as they are by divers impressions or excitants, which have no influence on those of the particles of finely divided inorganic bodies suspended in water, differs from that which induces movements in the latter. The movements of infusoria are besides more vivacious, are more varied, and are made in ever varying directions. They traverse the sight under the microscope with a velocity which is never observed in the particles of inorganic bodies. They move in all directions, swim here and there, turn on themselves, tumble over, and go in a circle with varied rapidity. Sometimes they remain quiet, at others they perform exceedingly rapid movements. The movements of inorganic and lifeless particles, on the contrary, are mostly very slow, feebly revolving, and confined to a small extent of sight.

The movements observed by Brown in the molecules are partly owing to currents and movements of the liquids in which they are contained. They are also owing to an attraction and repulsion between the molecules and to an hygrometric and capillary action, or are even produced by the air which escaping during the solution of the particles in the water, imparts a movement to them. If a liquid drop, containing such molecules, and near to which is a drop of any volatile fluid, as alcohol or ether, be examined with the microscope, the first drop is remarked to be moved by the vapour of the other, just as if a current of air had passed over it. What favours the influence which an evaporation of the water itself exercises over the movements of the particles is that these are more rapid when the temperature of the ambient air is high than when it is low. By the addition of some very volatile fluid, as alcohol, ether, or camphorated spirit, to a drop full of molecules placed under a microscope, their movements were considerably accelerated. Brown, it is true, objected that the movements of the molecules continued even when the drop of water was covered with a layer of oil, which prevented the evaporation from taking place. The same remark was made by David Brewster(1) and Hollard.(2) But in proof that the drop of water also evaporates under the oil, though slowly, is its gradual diminution

(1) Observations relative to the motions of the molecules of bodies; in the Edinburgh Journal of Science, April, 1829, p. 215.
(2) The Quarterly Journal of Science, July to September, 1829, p. 162.

and final disappearance. Certain volatile molecules, such as those of powdered camphor when placed in water, move rapidly in it, in consequence of the evaporation.

In wetting or moistening dry particles, such as the grains of dry pollen, cinders of burnt bodies, finely-powdered salts, movements are induced which are owing to the penetration of the water by means of their capillarity, and the disengagement of air from their pores. In examining with the microscope the solution of sugar, of common salts, and other pulverized salts, in water, the drop of water gave out bubbles of air which carried off molecules with them until the latter were dissolved. The movements observed by Brown in the molecules of arsenic, and of the saline particles of the cinders of burnt organic and inorganic substances, must more especially be referred to the movements of solution. When two heterogeneous fluids are mixed together, as water with alcohol, ether, or acids, movements are always observed which are communicated to the particles of organic or inorganic bodies suspended therein.

All these facts warrant us in concluding that the movements of infusoria animalculæ are different from those of minutely divided water-swimming particles, and that they should be regarded as organic or vital, whilst the latter are caused altogether by forces denominated dead or physical forces.(3)

DLXX. The preceding researches oblige us to consider as vital movements those which are seen in the globules contained in the nutritive fluid of animals and plants, as also in the spermatic animalculæ and germs of polypi and confervæ. These organic particles, as the primary products of the formative activity of organic matter, which are employed in the formation, nutrition, and growth of the solids of every individual, and in the production of new beings, which acts they precede, possess organic mobility. They appear to be endued with excitability from the very instant of their production, for their movements are modified, accelerated, retarded, or even arrested, by divers sorts of excitants which bave no influence whatever on the molecular movements observed by Brown. The variableness of the movements according to the excitants, may, with respect to spermatic animalculæ, (CCCCLXIII,) and the globules of the nutritive fluid of plants, be considered as proved (CCCCLXXXIII,) and, as very probable, as regards the blood globules.

(3) Besides even were the movements described by Brown ascertained to be spontaneous, they possess no other property that can establish an analogy between them and those of organic globules. No circumstances of moisture, heat, air, light, &c., however favourable, will produce in them those hidden movements whose end is the formation of organized bodies, with all their properties. Indeed the object of such experiments as those of Brown on inorganic molecules, and the application of any discovery arising from them, is far from being clear—a remark, however, which does not attach to his account of active organic molecules. (Sec. 483.)—Trs.

So long as the globules of the nutritive fluid of plants and of the blood are contained within the living spaces of the vessels, they appear to exert a repulsive influence against each other, and remain distinct. But when the fluids leave the vessels, the globules speedily coalesce, and the phenomenon of coagulation takes place. It has been remarked, that, on the addition of acids, slight convulsive movements occur in the globules during their coagulation.

How these organic particles of the simplest kind perform their movements is altogether unknown. Perhaps they are effected by a slight contraction and expansion of their organic matter, which it has hitherto been impossible to perceive on account of the minuteness of the corpuscules, but which, it is true, also needs to be explained. Dutrochet endeavoured to account for them by the endosmosis and exosmosis produced by electric currents. Against this it may be objected, that it rests on an opinion divested of proof, namely, that the globules are vesicles filled with fluids. The blood globules at least evidently possess a nucleus, of solid matter. Neither is it proved that an electric current exists in the globules. We shall therefore pass by the question, whether they possess, as some physiologists assert, a particular motor power, which Kielmeyer has denominated the force of propulsion.

Organic Contractility.

DLXXI. We shall designate, in general, by the name of organic or living contractility, the property possessed by animal and vegetable solids of performing, in certain circumstances, and under the operation of excitants, movements that are manifested by a contraction, curtailing, and condensation of the tissue which is the basis of those solids. It is distinguished from elasticity in not arising from mechanical causes, but being founded by the organic nature of the nourished solids, and by the organic changes in the parts on the application of influences that bring it into action. When contractile parts are no longer nourished, their contractile power is extinguished; whereas, electricity remains in lifeless parts so long as putrefaction does not destroy the organic texture bestowed on them by life.

Organic contractility exhibits differences in the solids of animals and vegetables, which have reference both to those observed in their texture and vital properties, and to the influences or excitants which urge them into action. We will examine the different kinds of contractility in their phenomena and manifestations and give them their different names.

1. Muscular Contractility.

DLXXII. The property inherent in muscles of being put into motion by very varied excitants (CCCCXXXIV, CCCCXLIV) has the name of muscular contractility, or myotility. It corresponds to Haller's irritability an appellation we cannot preserve, because excitability is a property belonging to all living parts and can by no means be attributed to the muscles exclusively. The movements of muscles are distinguished from those produced by elasticity, and every other kind of contractility, by rapid oscillations, accompanied with a shortening, condensing, folding, and winding, to which extension, relaxation, and elongation of the fibres and bundles succeed. (CCCCXXXV) The excitants of oscillations, however diversified, and the movements that take place in the muscles in consequence of their operation, appear invariably to be conditional on the living influence of the nervous system. (CCCCXLIII, CCCCXLVI) It is sufficiently proved, that the excitants which put into play the voluntarily acting muscles, are produced in the nervous apparatus, in the aggregations of nervous substance, and are propagated by means of nervous ramifications entering into the composition of the muscles. As the muscles that are urged to contract in an automatic manner by secreted excitants, such as the heart and muscular membranes, likewise receive nerves, it is probable that in this case also excitants act through the nerves, or at least, that simultaneously with the excitation, a change is effected in the nerves, without which the oscillation could not take place. Moreover, of all the kinds of organic contractility, the muscular is the most easily brought into play by electric shocks applied to the nerves or muscles, either in living animals, or such as have been recently killed.

DLXXIII. Muscular contractility is founded on the innate constitution, organization, and organic composition of the muscles, which are communicated to them by the plastic activity in their formation. The muscles once formed, the continuance of this force in them depends on nutrition, assimilation, respiration, and the movement of the fluids, as also on the living influence of the nervous system, and varies with the circumstance heretofore stated, (CCCCXXXIX, CCCCXL, CCCCXLIII.) It is yet unknown how this force acts and how it is determined to action by excitants. Mere hypotheses alone (CCCCXLVII) have been hitherto advanced on this subject.

DLXXIV. Muscular contractility is an exclusive property of the muscles of living animals. It does not exist in plants, in which neither muscular fibres nor tissues analogous to nerves are found. This force makes animals having a complicated organization capable, by excitements produced in the living nervous apparatus, of moving voluntarily, of bringing themselves to movements which vary according to the structure and arrangement of the locomotive organs, (CCCCLI.) The contractility of the muscles which enter into the composition of the digestive, respiratory, secretory, and generative apparatus, is brought into play in an automatic manner by fluid and nervous excitations. Hence, movements take place that are necessary for the performance of the nutritive and generative functions, and on which both the preservation of individuals during a certain time, and the continuance of the species depend, (CCCCL, CCCCLII.)

2. Contractility of Infusoria and Gelatinous Animals.

DLXXV. The movements of infusoria, (CCCCLIV,) and gelatinous animals, fresh and salt water polypi (CCCCLV,) medusæ (CCCCLVI,) and among entozoa, of sucking and some vesicular worms (CCCCLVII,) seem to be accomplished by slight alternations of contraction and expansion of their mucous substance.(4) With the aid of a microscope, and using a very strong magnifying glass, I perceived traces of contraction and expansion in several of the simplest infusoria, volvoces and cyclidia. All these animals are excitable, and may be urged to movements by external stimuli of various kinds, mechanical or chemical, and by the electric fluid. Although they do not possess any nervous substance drawn out into a system of nervous threads, they are in a condition to move by an internal activity, and in consequence of excitations which themselves produce. Such of these animals as are not fixed, as the infusoria, rotifera, pennatula, and medusæ, are able, without external impulses, to change their locality by swimming or crawling. Hydræ also possess locomotiveness. Other polypi, as vorticellæ, sertulariæ, lobulariæ, tubiporæ, madrepora, gorgones, &c., which adhere to a fixed, common, horny, or calcareous stock, cannot certainly change their locality, but they move their bodies and parts, by an internal impulse, in various directions, and with varied rapidity. By movements of their seizing arms they take their food and convey it to the mouth. The movements they execute spontaneously, and with exceeding vivacity distinguish these animals from confervæ, tremellæ, and oscillatoriæ, which do not possess the faculty of moving from an internal motive and in chosen directions. They differ from muscular movements inasmuch as they are not accomplished by contractions and relaxations of fibres, nor accompanied by visible oscillations or rapid incurvations and extensions. We will designate this kind of contractility by the name of contractility of gelatinous animals.

3. Contractility of Confervæ, Tremellæ, and Oscillatoriæ.

DLXXVI. Confervæ, tremellæ, and oscillatoriæ, execute feeble movements, consisting in a slow erection and shrinking, a swinging from side to side, incurvations, twisting and spiral torsions of their fibres. (CCCCLXXIV.) The movements are modified by external influences. Heat and solar light accelerate them : cold and want of light retard them. They are arrested by

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(4) Dutrochet (Loc. cit., p. 182) has not scrupled to deny the character of animality to infusoria and to consider their movements as the mere effects of endosmosis and exosmosis produced by electric currents. Had he examined with greater care the so varied movements of infusoria, he would not have ventured to advance an opinion so totally devoid of proof.

the addition of acids, salts, alkalis, or alcohol, to the water in which the simple plants in which they are observed, exist. It cannot, therefore, be denied, that these vegetables possess excitability, and this, together with the variableness of their movements, according to their excitants, distinguishes them from the molecular movements of Brown, which are not affected by influences of the above kind. We are, therefore, authorized to consider them as vital movements. It is not known how they are accomplished, but they may be supposed to consist in a slow alternation of contraction and expansion of the homogeneous substance of the vegetable, or of the globules which constitute it. They differ from the movements of infusoria and gelatinous animals by being apparently induced solely by external excitants, and by exhibiting no trace of spontaneity which cannot be denied in the latter. They are unable to change their locality by an activity peculiarly belonging to them. We will designate this kind of organic mobility by the name of vegetable contractility of the most simple plants.

4. Contractility of the Cellular Tissue, the Vessels and other Non-muscular Tissues of Animals with Complex Organization.

DLXXVII. Movements manifested by a slow contraction, alternating with a very slight or scarcely existant expansion, and unaccompanied with sensible oscillations, as in irritated muscles, occur in many animal parts that are not of a muscular nature, (CCCCLX.) To these belong the cellular tissue and all the tissues based on it, the skin, the blood-vessels, lymphatics, excretory ducts of the glands, and even the fibrous tissues. All these parts are endued, during life, with the power of contracting and drawing together, whenever they have been distended, and the cause of their distension is removed. The arteries and veins filled with blood, the lymphatics gorged with their absorbed chyle and lymph, the excretory ducts of the glands distended with secreted humours, strive to contract and diminish their calibre, and thus communicate movement to the liquids they contain. The degree of distension of the fluid-filled canals is proportionate to the quantity of fluids. If there be abundance of fluids the diminished vessels and excretory ducts are exceedingly distended. If the quantity of fluids is diminished the vessels show a diminished calibre. In all animals the capacity of the blood-vessels changes as the mass of blood augments or is diminished. If they are pricked or cut, they forcibly eject their contained liquids, and their diameter is lessened. These phenomena are more palpable if, previous to pricking the vessels, they are tied, so that the fluids may distend them to a high degree.

The property which the cellular tissue, the different membranes, the vessels, excretory ducts, and fibrous tissues possess, during life, of contracting after being distended, and the tendency the vessels have to shrink and eject their contained fluids, have been observed by many physiologists. Some have erroneously considered it as the effect of elasticity, others as the consequence of muscular contractility.

DLXXVIII. Haller, who very clearly distinguished the contraction and shrinking of these parts from the effects of muscular irritability, committed the mistake of regarding them as the mere results of elasticity, and he went so far as to attribute a similar faculty of contraction to dead bodies, such as leather, hempen ropes, and gut-cords. Against this, which many of his disciples have maintained, it may be said that the property which the cellular tissue, the vessels of excretory ducts, possess, of contracting and shrinking as they do during life, disappears in death, and when nutrition ceases to be enacted. The cellular and dermoid tissues never contract in corpses when these are cut, and the lips of the wound in such cases gape, as is the case in wounded living animals. In death the arteries remain gaping, and do not contract in their diameter when cut across, as happens during life. When arteries, veins, and lymphatic trunks are divided, their ends start asunder, as in living animals. Nor is anything of the kind observed in excretory ducts, when cut across, for they remain flaccid; whereas during life they contract, and their extremities separate from each other. All these parts possess elasticity alone in dead animals. When disturbed from their proper situation they quickly return to it; but they are no longer endued with a living contractile faculty: they no longer shorten and shrink by a proper activity, and independently of mechanical power. The elasticity they possess after death, and which is owing to the organic texture of the tissues, disappears when putrefaction has destroyed their organic commixture.

DLXXIX. Some physiologists, Van Dœveren, Verschuir, Zimmerman, &c., considered the contracting and shrinking of vessels and other contractile parts as phenomena of muscular contractility. They were lead into this error by the mode of action of some chemical agents, especially acids and minerals, on the vessels. Haller(5) had previously and with reason considered the experiments made with mineral acids among those which did not prove the existence of muscular contractility, inasmuch as whether the organs, the cellular tissues, vessels, nerves, tendons, and membranes, on which these acids acted, possessed life or not, they always produced movements in them by the chemical changes they caused therein. We owe the most precise researches on this subject to Bichat.(6) He found that animal tissues, either dead or alive, when exposed to fire or to the action of concentrated mineral acids, sulphuric,

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(5) Oper. Min., v. i, p. 403, sec. 17. Experimenta quæ nihil pro irritabilitate demonstrant.
(6) Anatomie Generale, v. i, sec. 1, p. 36.

nitric, or hydrochloric acids, contracted in consequence of the corrosion they suffered, and curl and shrink in various manners, but that these movements can by no means be regarded as manifestations of life. I have also ascertained that arteries, veins, nerves, and membranes that had been preserved for several years in alcohol, contract when sulphuric acid is poured on them, and execute movements resembling those of muscles.

Putting aside this chemical action of fire and mineral acids, it is proved by numerous experiments that the parts possessing a living contractile faculty, the cellular tissue, the tissues originating from it, the vessels, the excretory ducts of the glands, the dermis and tendinous parts, are not rendered active by all the excitants which produce contractions in living muscles. Mechanical excitants, as touching with a needle's point, and moistening with alcohol, diluted alkalis, and acids, do not induce contractions in the cellular tissue, vessels, excretory ducts, and tendinous parts, resembling those which they cause in bared muscles. Neither does electricity elicited by friction or contact, produce any sensible effects. We should not, therefore, confound the contractile phenomena of these parts with the movements of stimulated muscles.(7)

DLXXX. Several physiologists who distinguished the movements performed by the above-named parts, both from the effects of elasticity and from muscular contractility, consider them as vital phenomena of a peculiar kind. Stahl(8) named the motor faculty of these parts, tone *(Tonus.)* By the same name, or others analogous to it, it is mentioned by Whytt,(9) Cullen, Bordeu,(1) Grimaud,(2) Barthez,(3) Chaussier,(4) and others. Blumenbach,(5) called it tonicity or contractility of cellular tissue. Bichat(6) considered some of these movements as manifestations of a property inherent in the organs, different from elasticity, and consequent on the arrangement of the molecules in the tissues, or on the texture of the organs, but independent

(7) Were this view of the contractility of blood vessels more generally taken, much of the disputation with which physiologists, of this country more especially, have amused themselves concerning the muscularity of arteries, might have been avoided. The error has been in their being fascinated by the word "contractility," a term so commonly used as applied to muscular power that at length the idea of other contractility than the muscular has never once entered the heads of the disputants. On the other hand, the opponents of the muscularity of arteries, aware that some contraction *does* occur in their coats, have been unable, from the cause above named, to find any other reason for it than the physical power "elasticity." The arguments of Tiedemann place the question in the right light, showing that neither muscular tissue nor contractility is engaged on the one hand, nor the attribute of lifeless bodies, elasticity, on the other.—Trs.

(8) Dissertatio de motu tonico vitali. Jenal, 1692-4. Theoria medica vera.

(9) Essay on Vital and Voluntary Motions, sec. 1. Sec. 3, Natural Contraction.

(1) Recherches sur le tissu muqueux, sec. 70.

(2) Cours complet de Physiologie, v. i, p. 358.

(3) Physiologie, v. i, p. 144. Des forces toniques.

(4) Table synoptique de la force vitale. He calls it, Force tonique, tonicité, contractilité fibrillaire, organique, force du tissu areolaire, elasticité contractile.

(5) Institut. Physiologiæ, sec. 40-58.

(6) De la vie et la mort, v. i, p. 40. Anatomie Generale, v. i, sec. 1, p. 36.

of life. Death, he says, does not destroy this property, since it adheres to the organs so long as they do not fall into putridity. Its energy, however, is increased by life. Bichat called it *contractilité de tissu.* Other movements belonging to the class in question he viewed as effects of a vital property, which he distinguished from muscular contractility, and called *contractilité organique insensible, contractilité par defaut d'extension.* According to him, it is by this force that the organs act on the blood, which is conveyed to them in nutrition and secretion. By it the blood in the capillaries is moved, and the movements of the secreted fluids through the excretory ducts are executed. Bichat frequently confounds the effects of these two supposed properties with each other and with those of elasticity.

The adoption of a contractility differing from elasticity in the tissues and organs, after the utter extinction of life, is inadmissible. But it is not less erroneous to consider, as some modern physiologists, Bostock,(7) among others, do, all the phenomena of contraction and shrinking, not produced by muscles, in living parts, as the mere effects of elasticity.

DLXXXI. It cannot be denied that movements take place in several parts of animal bodies, which can neither be considered as mere effects of elasticity, nor as the operations of muscular contractility. We shall call these peculiar movements tonic, and the force which produces them tonicity, or contractility of cellular tissue and non-muscular organs. In general this organic force is manifested by a slow contraction, shrinking, and condensation of the tissue of the parts that possess it, without oscillations similar to those that occur in irritated muscles being perceptible. It differs, too, from muscular contractility, inasmuch as it is not urged, in a palpable manner, to action by the electric fluid and nervous excitements. It may, however, be excited by divers impressions, especially by heat or cold, the influence of light, and even by some other excitants. Further, it varies according to the age of animals, the influences that alter the state of nutrition, and in disease.

DLXXXII. The contractility of the parts in question, and the movements determined thereby, are of the first importance in the exercise of several functions, and for the preservation of life. The tendency of the coats of the lymphatic vessels to contract on the absorbed liquids causes them to pass from their ramifications into the sanguineous vascular system. The contractility of the arteries (CCLXII) and veins (CCLXIV) act an essential part in the circulation, and it is even by the contraction of the muscular coats of the arteries that the blood is moved onwards in animals that have no heart, (CCLXXVI, CCLXXVII.) All the secreted humours that are poured into the

(7) Elementary System of Physiology, v. 1, p. 35.

excretory ducts of glands are put into motion by the contractile coats of the canals, by which means they flow from the roots to the trunks, and from these to the surface of the membranes that line the canals into which they are emptied. Without a living reaction of the coats of the excretory ducts on the fluids they contain, manifested by their contraction and shrinking, it is impossible to imagine what could put them into motion, and force them to flow frequently against their own gravity. The tonicity of the fibrous organs, the ligaments, fibro-cartilages, and true cartilages facilitate the movements of the joints.

5. Contractility of Vegetable Vessels.

DLXXXIII. All vascular plants are endued with excitability. By excitants they are urged to development, nutrition, and the internal movements attached to those processes. The vessels of plants, as well as those that absorb sap by the roots and convey it to the leaves through the stalk or trunk, as those that take up in the leaves the nutritive fluid prepared by respiration and convey it to the different parts, appear to be possessed of a living contractile power. They fill with sap imbibed by the roots and probably react on it by a slow contraction succeeded by shrinking, by which a movement of the liquid is effected. The proof of this is found in the copious flow of the ascending sap after a section of the stalk and branches, which, according to experiments made by Hales, Walker, Mirbel, Chevreul, and others, (CCLXXXIV,) goes on with such rapidity and vehemence, that it is impossible to err as to its dependence on a living reaction of the vascular coats and an impulse thereby given to the sap. Don and Barbieri (CCCCLXXXVI) even maintain that they saw movements in the coats of the vessels, which were manifested by contractions. Moreover it is certain, that the movement of the sap is augmented by divers external influences or excitants which act on plants and whose mode of action is in nowise mechanical, (CCLXXXV, CCLXXXVIII.) Lastly, in support of this theory the action of different poisons on plants which arrest the flow of the sap may be advanced. Thus Goeppert(8) remarked that no sap flowed from wounds made in the branches of the *Euphorbia esula, villosa, uralensis,* and *glaucescens,* the *Chelidonium majus,* the *Rhus typhinum,* the *Chondrilla juncea,* the *Hypochoeris radicata,* the *Lactuca perennis,* the *Leontodon taraxacum,* &c., which had been immersed in the prussic acid; whence he concludes that the vessels had lost their contractility and power to impel the sap, by the action of the poison. Hence, we cannot regard the cause of the movement of the sap in vegetables as the effect of capillarity or of any other purely physical force, since poisons have no effect on such. Nor can we do otherwise

(8) Loc. cit, p. 15.

than consider Dutrochet's(9) opinion, which makes the movement of the sap to be performed by endosmosis and exosmosis, as an hypothesis totally devoid of proof, and incongruous with the mode of action of poisons. We are therefore necessitated to regard the movement of the sap as a vital act which, judging from the experiments above cited, is manifested by a slow contraction of the vessels, in consequence of which their calibre is diminished and an impetus imparted to the sap.

DLXXXIV. The movements of the leaves, the faculty they have of returning to their station after being turned away by mechanical violence, (CCCCLXXXVIII, CCCCLXXXIX,) their erection, their unfolding and expansion during the day, their sinking and folding (CCCCXC, CCCCXCI) during the night, (CCCCXC, CCCCXCI,) accompanied with a change in the course of the sap and the state of turgescence, through the influence of light and heat, (CCCCXCII,)—likewise appear to be consequences of a certain degree of contractility of their vessels and cellular tissue (CCCCXCIII.) Something like a proof of this we have in the tension and rigidity of the leaves. In support of this opinion the experiments of Schuebler, Zeller, and Goeppert (CCCCXCIII) may be advanced, which show that the motor power of leaves is annihilated by poisons, by prussic acid, prussiates, cherry-laurel water, narcotic substances, opium, nux vomica, &c., when presented for absorption by the roots. The movements enacted by the so-called sensitive plants (CCCCXCIV to DII) under divers influences and excitants, which are accompanied by a change in the afflux of sap and the degree of turgescence and tension of the petiolar ducts (DIV, DV, DVI) seem to be immediately owing to the contraction of the sap-vessels and cellular tissue, in consequence of the operation of excitants, (DVII.) On this point may be quoted the effects of opium, prussic acid, arsenic, corrosive sublimate, and other poisons, (DIII,) observed by Hope, Wilson, Linck, Jaeger, Becker, Goeppert, Macaire-Prinsep, and Mulder,—effects which deprive vegetables of the power of moving when irritated, after the absorption of these poisons by the roots, or their direct application to the leaves and the petiolar bulbs. The movements of the leaves, according to the diurnal periods, the erection and sinking of the peduncles, the unfolding and closing of the leaves (DXII, DXIII) also seem to depend on a change in the afflux of sap, caused by contractions which excitants produce in the sap-vessels. Finally, the movements of the stamina and anthers, (DXV, DXVIII, DXIX,) and of the pistil and stigma, (DXVI, DXXI,) which take place after the development of plants and the application of excitants to these organs, should also be regarded partly as the effects of the afflux of sap, and of the consequent

(9) Loc. cit., p. 160

turgescence, itself dependent on the contraction of the sap-vessels, and partly as caused by the living contractility of the cellular tissue of those parts, brought into play by excitants. This is proved by the arrestation of these movements by various poisonous substances, as in the experiments of Macaire-Prinsep, Goeppert, and others. The same is the case of the movements performed by the seed capsules of several plants, (DXXIII.)

DLXXXV. As on the application of divers influences and excitants, movements occur in animals which are accompanied by a change of the situation and direction of the stimulated parts, and which cannot be referred to the effects of elasticity, we are necessitated to agree with De Gorter, Lups, Bonnet,(1) Broussonet, J. E. Smith,(2) Koelreuter, Medicus, Desfontaines,(3) Hedwig,(4) Gahagan, Von Humboldt,(5) Saussure, Brugmans and Coulon, Van Marum, Decandolle, Carradori,(6) G. R. Treviranus,(7) and others, that vegetables possess excitability and a living or organic motor faculty. But we do not agree with several of these physiologists in thinking that this faculty is identical with Haller's irritability, because nowhere in plants are fibres perceived that can be compared to the muscular fibres of animals, and because the movements excited in them by stimuli are unaccompanied by oscillations resembling those that are observed in irritated muscles. With Unzer(8), J. F. Gmelin and Oettinger(9,) Farr(1,) L. C. Treviranus(2,) Rudolphi(3,) and others, we regard the motor faculty of plants, which is manifested by contraction and condensation of the cellular tissue, as a faculty different from muscular power, and as originating in the mode of nutrition of those bodies. In its mode of action it has the strongest analogy with the contractility of the cellular tissue and non-muscular parts of animals, if it be not even identical with it. The excitability and contractility of vascular vegetables vary in their degree and manifestations according to the state of the development of plants, the annual and diurnal periods, the temperature, the influence of light, the

(1) Œuvres, v. iv, p. 199.

(2) Some observations on the irritability of vegetables; in Philosophical Transactions, v. lxxviii, p. 158.

(3) Loc. cit. La force contractile, qui nous offre dans les animaux des phénomènes si etonnans et si variés, n'est point comme on le croit communement, un attribut particulier qui les distingue; un grand nombre de plantes donne aussi des signes d'irritation plus ou moins sensibles, selon leur age, leur vigueur, la partie qu'on touche ou qu'on irrite, Les loix physiques et mecaniques communes n'en rendront jamais mieux raison que de l'action musculaire des animaux.

(4) De fibræ vegetabilis et animalis ortu. Leipsic, 1789, p. 27.

(5) Aphorisms, p. 57.

(6) Loc cit., and in Continuazione degli atti dell 'Accademi aeconomico-agraria dei Georgofili di Firenza, v. iv, 1825.

(7) Biologie, v. v, p. 234.

(8) Physikalische Schriften, v. i, p. 242.

(9) De irritabilitate vegetabilium. Tubingen, 1768.

(1) Philosophical Inquiry into Animal Motion. London, 1771.

(2) Zeitschrift für Physiologie, v. ii, p. 174.

(3) Grundriss der Physiologie, v. i, p. 240.

atmospheric constitution, the aliments and other influences conditional of nutrition; and they may undergo modifications from all these. Lastly, many substances, as certain poisons, and the electric spark, annihilate them. All the movements of plants are automatic: they are the consequences of a blind necessity, and refer to the operations of formation, development, nutrition, and generation. No vegetable has the power of moving spontaneously and voluntarily, by excitants resembling nervous excitements, according to determinations proceeding from within itself, and with interruptions regulated by itself.

FINIS.

ADDITIONAL NOTES.

Note to sec. lviii.

It is not ascertained what change the sap undergoes in its passage from the root to the leaves : indeed there is no proof that it undergoes any. Tiedemann appears to think the same, for he constantly calls the sap the "rough juice," (ropen Nahrungsaft,) and in LXIII it will be seen that he speaks of the "formative coagulable fluid prepared in the leaves from the rough nutritious juice." But it is well known that a change *does* occur in it during its sojourn in the leaves, and that this change renders it fit to deposit the peculiar fluids and cellular tissue of the plant, (the ligneous matter being only the ancient spiral vessels compressed.) In this view there occurs only one species of digestion in plants, to wit, respiration. In the case of a graft, therefore, the sap, arrived at the leaves of the graft, does certainly undergo modifications dependent on their organization, and produces flowers and fruits of its own kind, though tributary to the roots of a plant alien to it in nature. The knowledge, therefore, of which we already stand possessed, may account for this phenomenon in grafting. Should it be asked how the budding leaves come to be formed, the answer is found in that fact being an extraordinary and temporary effort of the vegetable irritability, aroused from its winter torpor by the vernal solar warmth. Once pushed forward, the leaves take upon themselves the office of assimilation.

Note to sec. lxv, after "capable of exercising their functions."

This is an important physiological maxim. In the application of physiology to pathology, it is not less so. It may prove instructive to those physicians who are in the practice of attacking every disordered symptom as it arises, whether in the two digestions, the circulation or the secretion, by teaching them that the disorder of one may and does eventually influence and disorder the others, and that the application of remedial means to one is the more rational method of overcoming all. It is only astonishing that such a proposition and its consequences should have been overlooked by any member of a learned profession.

Note to sec. lxx, after "are reproduced by generation properly so called."

The same observations likewise give plausibility to the hypothesis advanced by the learned Tiedemann in the previous part of this volume, regarding the origin and progress to perfection of organic matter (XXIII, XXIV, XXV.) Here we have the fact of spontaneous generation of entozoa, to which the progressive energy of the plastic power adds genitals, when spontaneous generation gives place to procreation, or true generation.

With regard to the nature of the cause of this generation of entozoa, it is hazardous to advance any opinion, as it can only touch the verge of probability. To take those of the intestinal canal; they occur simultaneously with a varied degree of inflammation of the canal; there is also great emaciation of the body, and chyle is observed in the intestinal evacuations, together with disordered fœces. The inflammatory state is here accompanied, as it ever is, with anormal secretions; the highly animalized chyle is mixed with these secretions. Now it is not unlikely that the diseased state of the latter may consist in their too great animalization, which is moreover augmented by the addition of chyle. From this conjunction with the influence of heat, that species of generation in question, would readily occur. The emaciation countenances the idea of the existence of a secretory process, which drains the pabulum of its more animalized constituents; the non-absorption of chyle no doubt also aids in it. These effects of the presence of entozoa are more visible when such exist in the intestinal canal; first, because their number and volume are greater there than in other parts where they are found; and secondly, because the surface which they irritate is more extended, and bound by stronger sympathies to the rest of the body than those parts. Au reste, disordered deposit goes far to explain their appearance in the liver, bladder, eye, brain, and muscles.

Note to sec. lxxxi, after "have been made on their parts by wounding bodies."

The reparation of solutions of continuity is a palpable fact, especially in animal bodies. It must be remarked, however, that some respectable authorities have maintained that such junctions in animals are a simple glueing together of the separated parts, by the cohesive fibrinous matter thrown out, in the same manner that the glueing of inorganic matter is effected. Granting this, the question still remains, whence proceeds the glueing material? With respect to partial regeneration in the human frame, instances are recorded, of reproduction of the glans penis, and of the phalanx of the finger. Can we consider the growth of a third set of teeth, in old age, as a regeneration of lost parts, since two sets only are usual? also of their sockets? Some instances of this are quoted by Dr. Mason Good, Study of Medicine vol. 1, page 55, from the German Ephemerides, Medical Commentaries, &c.

Note to sec. lxxxvi, after " does not belong exclusively to the cruciferæ."

Sulphur is particularly developed during the natural analysis or putrefaction of the tretradyamic cruciferous plants: during that process the sulphur uniting with the hydrogen of the fluid, which is indispensible to the putrefaction, forms sulphuretted hydrogen, so prominent in the odour of cabbage-water, &c. Sulphate of lime is found in clover. The albuminous parts of animal bodies particularly contain sulphur : the albumen or white of egg is an instance ; the yolk of egg, however, contains more sulphur than the white, and being united with an oil, (or rather elaine,) whose hydrogen unites with the sulphur, the strongly fœtid smell of putrefying eggs is the consequence.

Note to xcii.

The sulpho-cyanic acid, which contains no oxygen, was discovered, however, by Tiedemann and Gmelin, in the salivary secretions of man : it was more particularly perceived during digestion.

Prussic acid, free or combined, has been found in human urine, under the following circumstances :—Brugnatelli discovered it free in the urine of a dropsical patient; Moyon and Julia-Fontanelle saw prussiate of iron in that of a person with no morbid symptoms; Cantu, of Turin, in that of a young girl, who experienced no feelings save some cholicky pain previous to voiding it. Besides these instances, Reisel observed prussiate of iron in the sputa of a woman affected with inflammation of the lungs, accompanied with frequent vomiting. The same presented itself to Dolxi, Mogi, and Julia-Fontanelle, in the respiration of other individuals, labouring under nervous affections.

Note to sec. cii.

The idea of vegetable symmetry entertained by Decandolle would seem to refer both to the intimate organization and external appearance, as appears from the following quotation from his chapter on vegetable symmetry :—" L'arrangement des plantes en ordres naturels suppose, selon moi, qu'on pourra un jour etablir les caracteres de ces ordres sur ce que fait la base de leur symetrie, et rapporter les formes varieés des especes ou des genres a l'action des causes qui tend á alterer la symetrie primitive. Ainsi chaque famille des plantes, comme chaque classe de cristaux, peut etre representée par un etat regulier tantôt visible par les yeux tantôt concevable par l'intelligence; c'est que j'appelle son type : des soudures, des avortemens, des degeneresences, des multiplications separés ou combinés ensemble modifient ce type primitif de maniere à faire naitre les caracteres habituels des êtres que les composent. Ces modifications sont constantes entre certaines limites comme les formes secondaires des cristaux. Mais chaque genre, chaque espece est par sa nature propre plus ou moins soumises à chacune des causes que les determinent; car les plantes qui ont le meme type ne sont pas plus identiques que les cristaux que ont de molecules primitives semblables."

Cryptogamic plants exhibit only feeble marks of symmetry in their organization; so slight, that in the present state of our knowledge, it is impossible to detect its laws in them.

The Pleuronectes a genus of fishes comprehending what were formerly named *passer, rombus, buglossa,* &c., differ from other vertebrated animals, by wanting the symmetry of the two sides in respect to size, though not in regard to actual existence of parts, ; for all the parts are found on each side of the fish, but so much larger on one than the other, as to make a prominent character in the genus. This irregularity is more pronounced in the head than the body. The eyes are both placed on the same side, and are always uppermost; hence the fish of necessity swims on the same side, and it is from this circumstance that they derive their name, it being πλευρα, a side, and νυχτης, a swimmer.

Note to sec. ciii, after " therefore they are more soft."

The quantity of fluids in the body forms 9-10ths of its weight. Chaussier introduced a human body, weighing 120 lbs., into a stone, dried it perfectly, and found on its removal that it weighed only 12 pounds. Egyptian mummies are also instances of the prevalence of fluids in the mass of the body: as also the dead bodies of travellers over Arabian deserts, where the excessive heat, unaided by moisture, effects desiccation rather than putrefaction.

Note at the end of sec. cxvi.

The proper arterial tunic of arteries is thicker in the lower limbs than in the upper; it is more particularly thin in the vertebral, carotid, and hepatic arteries. The external tunic, according to Beclard, consists of two layers: it is wanting in the cerebral arteries. The inner coat is always the seat of disease. In muscles arteries run between fibres, in the brain between convolutions, in the glands between lobes. They convey the greatest quantity of blood to the brain, spinal cord, glands, muscles, mucous membrane and skin. Arteries have not been anatomically traced in cartilage and arachnoid membrane; but the processes of nutrition and secretion therein necessitate their existence in those textures.

Note to sec. cxvii.

The vascular tunic of veins is, according to Bichat, more palpable in venous branches than in the trunk; and in superficial than deep-seated veins. Magendie says this tunic is fibrous. The internal lining of the veins is exceedingly distensible, not fragile; in this differing from the arteries. Bichat says it is continued throughout the black blood circulation. It is the only tunic in the veins of the liver, kidneys, bones, and sinuses. The venous valves consist of both tunics folded inwards (Bichat.) Hunter and Gordon deny this, and say they are tendinous. The transverse cords of sinuses are said to supply the place of valves.

Veins for the most part accompany arteries; instances of the contrary are those of the brain, the azygos, vena cava and portæ. The number of veins in the stomach, kidney, and testicles is equal to that of the arteries. They are two to one in the penis, clitoris, gall-bladder, and umbilical cord.

Note to sec. cxviii.

The mode of origin of lymphatic vessels is unknown. Their valves are 1-20th of an inch from each other, but are less numerous in the large lymphatic trunks. According to Cruickshank, Schreger, and Sœmmering they are muscular. Mascagni, Meckel, Rudolphi, Bichat, Beclard, and Gordon deny their muscularity. The lacteals are called a portion of the lymphatic system; they differ from the latter, however, in having a different and palpable commencement, in the fluid they convey, &c. Tiedemann says that in the seal the lacteals do not reach the thoracic duct, but terminate separately in veins.

Note to sec. cxxi.

Scarpa says the neurilema is a continuation of the dura mater; Reil, that it is composed of cellular substance and vessels; Bichat, that it consists of pia mater. It appears to become more delicate as it approaches the minute nervous branches. It is wanting in ganglionic nerves.

The substance of nerves is composed of many filaments, each one inclosed in neurilema. It is doubtful whether they are, as Tiedemann asserts, mostly longitudinally placed. Fontana says they cross each other in all directions, and that the ultimate fibres, which he calls "canaliculi," contain a gelatinous fluid. Della Torre and Home say, the ultimate structure of nerves is globular; whilst Reil and Monro maintain its fibrous nature.

That disposition of nerves called a "plexus" is found almost altogether in the interior of the body, and generally in the immediate neighbourhood of large arterial trunks, as the carotid, pulmonary, cœliac, superior and inferior mesenteric, &c. They possess neurilema, but it is much thinner than in large and single branches.

Nerves cannot be anatomically traced in lymphatic glands, cartilaginous, fibrous, or fibro-cartilaginous textures. Both the substance and neurilema are more vascular and comparatively more developed in the fœtus than the adult.

With regard to the spine, and its appendage, the brain, the following particulars may be given:—The pia mater is the sole agent in the growth of them. The gray substance appears after the white, the former being at the sixth month globular immediately below the pia mater, and the latter, still lower, fibrous.

The canal of the spinal cord is found only in the fœtus, in mammalia. It is found in all reptiles, fishes, and birds. Occasionally, however, it has been found after birth in mammifera, instances of which are given by Bauhin Malpighi, Morgagni, Portal, and Haller.

The globules of the cortical part of brain matter have been estimated at from $\frac{1}{2300}$th to $\frac{1}{4000}$th of an inch: in the medullary portion, at $\frac{1}{4000}$th of an inch: in the corpus callosum, at $\frac{1}{2400}$th of an inch. In the restiform, pyramidal, and olivary eminences the globules are large. According to to Della Torre the globules are largest in the brain, smaller in the cerebellum, and least of all in the spine.

The matter in which they exist is generally supposed to be gelatinous: Prochaska, however, says it is very fine cellular membrane. The distinction is probably no difference, for cellular membrane is gelatinous during life, and is only cellular when inflated. It predominates over globules in the cortical substance, is more tenacious and in smaller quantity in proportion to globules in the medullary, and is in equal quantity with the globules in the corpus callosum.

Note to sec. cxxiii.

The minute muscular filament has been estimated as $\frac{1}{4000}$th of an inch in diameter: their union forms fasciculi. Prochaska says that 200 fasciculi form a bundle: these are from 1-8th to 1-10th of an inch in diameter. The fibrine of muscles is found to be most abundant in old age.

Note to sec. cxxvi.

The bony texture of quadrupeds is not so fine and delicate as that of man; it is particularly loose and coarse in the cetacea, where the distinction of the fibres is very manifest, even on the external surface. The bones of birds consist of a thin, firm, elastic substance, formed of layers apparently fastened on each other. The bones of reptiles and fishes have a very homogeneous appearance, the earthy matter and the gelatine appearing to be mixed uniformly; in cartilaginous fishes the latter predominates. The shells of testaceous animals are formed of a calcareous substance, which is sometimes laminated, sometimes as hard as marble; the earth is not disposed in fibres or laminæ, but is uniformly expanded through the animal substance.

Bones are slow in their formation, in proportion to the remoteness of the period at which the growth of animals is finished. In some animals it is always cartilaginous, as in the chondropterygii. Although the bones of other fishes, reptiles, and serpents acquire a greater hardness, they ever remain more flexible, and retain a larger proportion of gelatine in their structure than those of warm-blooded animals.

The colour of bone is not always white. In some genera the bony structure differs; thus in the garpike *(Esox belone,)* the bones are green, and in some varieties of the common fowl, they approach to a black colour.

The common cuttle-fish *(Sepia officinalis)* has a white, firm, calcareous mass, commonly known by the name of the cuttle-fish bone, contained in the substance of its body. It has no connexion with any soft part; no vessel or nerve can be perceived to enter it; nor does it receive the attachment of any tendon. In the calmar *(Sepia loligo)* it resembles horn; it is transparent, hard and brittle.

Note to sec. cxxix.

Bichat says, that cartilage consists of longitudinal fibres, intersected by oblique and transverse ones. No blood vessels are seen in it, but, on cutting it serum appears on the surface: it is also coloured in jaundice. In young subjects, however, there is a muscular net-work perceivable in cartilage on the verge of newly-forming bone: it is the "circulus articuli vasculosus" of Hunter.

Note to sec. cxxxv.

On this is founded the instinct of self-preservation, properly called the first law of nature. This instinct, and the means of exerting it which fall to the lot of each animal, are in exact proportion to the complexity of its organization; in other words, to the variety of apparatus it has to preserve. The nervous system more particularly bears this relative proportion. In the lower animals, this instinct of defence is discovered by various movements, by the secretion of various poisons, by the formation of a vacuum, &c., as in reptiles, mollusca, and some insects; by the secretion of coloured fluids, as in some fishes; by the evolution of light, as in phosphorescent insects and reptiles; in the higher orders by the secretion of odorous matters, as in some mammalia, (rodentia and ruminantia;) of electric fluid, as in some fishes; by the presentation of a rigid surface, as in the hedge-hog; and lastly, by the operations of the mind of man, as displayed in the endless contrivances of art to improve the defenceless condition in which nature presents him. Man, who has the most complex organs to defend and preserve, has also a series of functions, those of the mind, superadded, the results of whose operations enable him, though unprovided with the strength of some animals and the swiftness of others, not only to defend himself from such, but also to subdue them to his will. Nothing can be more beautiful than the adaptation of means to ends, of power to defend to parts to be defended, exhibited in this law of of animal nature!

Note to sec. cxxxix, after "depend on central organs."

So great is the connexion between the centralization of organs and the activity of vital manifestation that it even influences the comparative vital phenomena of animals, in which the two hearts form one mass, and those in which they are separate. In the former, the mammifera, all the manifestations of life are most intense: whereas, in fishes and reptiles, where the heart is not so compactly central, the sympathies between, and the vital manifestations of, the parts are considerably fewer and weaker. In still lower animals, worms, for instance, where no central organ of circulation exists, the manifested vital activity is almost at its lowest ebb, while, at the same time, their individuality is less distinct, and sections of them live and have their being.

To the medical student this law of dependence between the peripheric and central organs becomes worthy of the first attention. To it, for instance, all the morbid phenomena of the pulse are owing, phenomena which may vary in degree or quality, according to the diseased portion of the circulatory periphery sympathizing with the central heart; the hard pulse being generated on one occasion, the small one on another, &c.

Note to sec. cxliii, after " terebintaceæ," &c.

The sexual division of plants has been more than once questioned. In order to set it beyond a doubt, Gaertner undertook a series of experiments, of a few of which we now give a sketch. They relate to the fecundation of the plant naturally or artificially by its proper pollen; to fecundation by another plant; to the action of pulverized sulphur, magnesia, lycopodium, &c; and to the duration and mode of action of the pollen of one plant upon the ovaria of another. A microscopic quantity of pollen proper to a plant being placed on its pistil destroys the action of a large mass of pollen of another plant even though of a near species. The proper pollen of a plant applied by a pencil to a stigma becomes so exactly attached to it that it is difficult to remove it without injuring the stigma. The result is very different with the pollen of another plant; the stigma then appropriates the pollen with difficulty and slowly, and this in proportion as the species differ. When the fecundation of one plant is occasioned by the pollen of another, the pollen applied to the stigma disappears in a time which, *cæteris paribus,* varies as the affinity between the species is greater or less. When once the pistil is saturated with fecundating matter, that which is subsequently applied undergoes no change either of colour or form. In natural fecundation the stigma loses its fulness and freshness as soon as it is saturated with fecundating matter; in cross fecundation the stigma remains unchanged for a much longer time, and even sometimes seems to be renewed in vigour. In this latter case the pollen which is reapplied disappears until the stigma loses its freshness. The foreign pollen retards rather than accelerates fecundation.

Note to sec. cxliii, after " in the lepas."

In 1806, Home ascertained that *teredines* had double generative organs. In 1815, he remarked the same in the lamprey. In 1823, the same arrangement was shown by him in the common eel, the conger eel, and the barnacle.

In earth worms there are two slits, or suckers, a little way from the head, on each side of the belly. Lower down there is a pair of hooks corresponding to each pair of suckers. In the copulative act, two worms proceed from respective holes in the soil sufficiently to reach each other; their heads remaining in the holes. The hook of each is then attached to the sucker of the other, which sucker becomes filled with mucus. The act takes up a long space of time.

Note to sec. clix.

Decandolle says, roots should unite the offices of absorption and prehension, otherwise they are only suckers on the one hand, or claws on the other. Absorption is effected solely by the spongy extremities of each radical fibril. The experiments of Senebier, alluded to in the text, to prove this fact are as follow: placing one carrot root completely under water, and another with its fibrillous extremity only immersed, he found that equal absorption had taken place in both. Again he placed the fibrillous extremity of a carrot-root under water, and immersed the whole bulk of another one, *except* this extremity, in the same fluid; the former absorbed quickly, the latter not at all. Duhamel long previously had remarked, that young trees exhaust the soil near the trunk; while old trees with horizontal roots, such as old elms, exhaust it at a distance from the trunk proportionate to their age.

In roots, it is for the most part a law that the fewer spongy fibrils they possess the greater contrivance there is for depôts of nutriment previously prepared. Thus bulbous roots, though possessing scarcely any spongelets, are far from being delicate, inasmuch as they possess a depôt of mucilaginous nutriment.

Note to sec. clxxviii.

The upward perpendicular tendency of the caulis of vascular plants is wanting only in some parasites, or those plants which live on sap prepared by others, as in the mistletoe and cuscuta.

Perennial caules have either a green bark, and are then called "succulenti," as in stapelia; or woody, *(caules lignosi, fructicosi,)* or have a medium character, and are termed "sublignosi." The caulis, moreover, is either fixed to other plants by claws, as in ivy; (Sowerby, English Botany, pl. 126;) by tendrils, as in peas; by long hanging branches, as in the *Solandra;* by hooked hairs, as in the *Galium operine;* by prehension, like true roots, as in the *Ficus scandens,* ferns and climbing orchideæ; or by spiral torsions, as in cuscutæ.

Note to sec. ccxviii, after "vegetable albumen."

Chlorophylle, which acts so important a part in the organization of vegetables, has been classed, sometimes among the resins and sometimes among the fatty matters, because it is soluble in the same menstrua in which they are. But the fact of its being converted into a soap by postash forbids it, accord-to Raspail's opinion, (Nouv. Syst. de Chemie Organique, sec. 1101,) being any longer classed apart from the vegetable fatty bodies. It is, in fact, a variety of wax. It is bleached by exposure to the sun, and also by the action of chlorine and the alkalies. Sulphuric acid dissolves it at first, and receives a green colour from it; but ultimately it, as well as all other acids, destroys this coloured matter. It must be remarked, that the shades of colour resulting from the action of acids and alkalies on this matter are various, according to the kind of plant from which it has been obtained and the period of its extraction. It is seen to pass spontaneously by the progress of vegetation through all the hues of the prism, generally terminating with a yellow, thus corresponding with the birth and death of the leaves,—the spring displaying them in their liveliest green, and the autumn showing their yellow garb.

Note to sec. ccxxviii, after "to open and shut them."

Dr. Carson, jun., in the "Monthly Archives of the Medical Sciences" for January, 1834, has made use of this arrangement as an analogical support to a theory which he advances, viz., that the muscular fibres of the trachea in mammifera are intended both to extend the passage for the entrance of air, and by their contraction to diminish the calibre, and thus retain the air in the lungs during the interval between inspiration and expiration. Whether this be the case or not in mammifera, and the theory is sufficiently ingenious, it is more than probable that the muscular arrangement alluded to in the text, as existant in insects, effects such ends as those mentioned by Dr. Carson, jun. The very simple cul-de-sac stigma seems to require some such means to insure the full action of the air upon its interior, and *vice versa*.

Note to sec. ccliv, after "the larvæ of the libellula."

In man the globules (according to Raspail) are from $\frac{1}{100}$ or $\frac{1}{150}$ to $\frac{1}{200}$ of a millimetre in size and of a circular and flattened form. Other mammifera possess globules of somewhat the same size and form. The blood globules of birds, fishes, and oviparous quadrupeds are elliptic. Those of the frog are as much as $\frac{1}{40}$th of a millimetre, and of the salamander $\frac{1}{30}$th. These are the largest known. The same author supposes the blood globules to be only albuminous muscle precipitated from the serous menstruum in which they were dissolved. Under what circumstances does this precipitation take place? For there are always globules but their quantity varies at different times. The globules are always scanty when the serous fluid is abundant, and *vice versa*, which gives a colour to the hypothesis of precipitation from the menstruum.

Note to sec. cclxii.

In the circulation of the blood another agent is involved, according to an original writer of the day. He supposes that the blood is absorbed by the parietes of the vessels through which it passes; and that it likewise receives from them the refuse of their functional effects. The former he calls aspiration or attraction, the latter expiration. As these imply movement of the fluid and moreover an uniform movement, (inasmuch as the double operation is inherent in each molecule,) he maintains that its continuous effect must be the grand agent in causing the sanguineous circulation, and, according to him, therefore, resemble the circulation of vegetables.—(*Raspail Nouveau Systeme de Chimie Organique*, p. 364.)

But this is straining at trifles. The effect of such aspiration, supposing it to be more than an hypothesis, must be exceedingly diminutive; and the shock given to the sanguineous column by the heart, together with the rapidity with which the blood moves onward must render such an agent next to nugatory, and altogether improbable in its asserted character of *sole* agent in the circulation.

Nor are we inclined to attach great consideration to the agency of the attraction of tissues as regards the circulation. That they exert a discriminative affinity with reference to the blood presented to them is sufficiently plausible, because it answers the purposes of their deposition, certain tissues being deposited in certain situations only. But that such operation on the nutritious fluid presented, implies an attraction or, as some call it, a *vis sugendi*, capable of even aiding in the circulation, is conjectural and without plausibility. The self-movement of the blood globules must materially assist in the capillary circulation, expended as the impetus from the heart must have been by the innumerable subdivisions of the torrent which it propels from its own cavity.

Note to sec. cclxxxi.

The double circulation of the *Chara hispida* has been maintained during more than an entire month, in the interval between two ligatures placed at a short distance from each other on a stalk; this stalk was separated from the mother plant and could, not, therefore, receive any influence from that quarter. The experiment was first made by Gozzi, and lately repeated by Raspail (Nouv. Syst. de Chim. Organ. p. 319.)

Note to sec. cclxxxii, " vegetable alkalies or salifiable bases."

The different kinds of descending sap may be divided into the *saccharine*, from the sugar cane, the grape, the beet-root, the mushroom, the chesnut, the liquorice root, &c.; the *gummy*, from the Arabian and Senegal Acacia, the cherry and plum trees, linseed, althæa root, &c.; the *milky* or *glutinous* from different lettuces, and particularly the "palo de vaca" or cow-tree, growing in the Caraccas, at an elevation of 1,200 ft. from the sea, the sap of which is used by the natives for all the purposes of milk; the *oleaginous*, from the *quillaia smegmadermos;* the *resinous*, from most coniferous plants; the *gummo-resinous*, from the papaver somniferum (common opium) pastinaca opoponax, the euphorbium officinarium, the juniperus lycia, and thurifera, the assafœtida, &c.; the *oleagino-glutinous*, from the *castilleja elastica.*

Note to sec. cccxlii.

From the distinction here made between secretions from minute vessels and secretions from glands, one might be led to suppose that the latter are not products of the blood contained in capillaries. So long as experiment demonstrates the continuation of arterial capillaries into venous radicles and the secretion of matters from the blood in the former, other than deposits from minute vessels cannot be maintained. The difference is dependent on the distribution of vessels in the several parts. This distribution on plain surfaces begets vaporous or exhaled matters; on ramified surfaces varied fluids. Nor though acini are seen in the liver, for instance, is it experimentally ascertained that they are the secretory points of that gland. On the other hand, and in the absence of positive facts, some analogies speak in favour of biliary secretion from the mucous base of the gland. These are found in the secretion of a matter in the gall bladder (a ramification of the same mucous membrane which lines the liver ducts and alimentary canal) which adds considerably to its bitterness; in the varied nature of the mucous secretion of the cryptæ of the digestive apparatus, according to their localities, these, in the stomach secreting the gastric fluid, in the cœcum, the fœces, &c. These cryptæ are in miniature what the salivary glands, liver, and pancreas are in replete character; appendices of the mucous lining of the alimentary canal, and taking into account the simplicity of their ramification as compared with that of the liver, their secretions differ quite as much from the vaporous exhalations of the smooth surfaces, as do those of the liver. Why, therefore, should not the bile be secreted from the complex ramifications of the latter gland?

If this hypothesis be of any value in regard to the liver which we have adduced as an instance, it will plainly also apply to the ramifications of other mucous surfaces, taking on the attributes of glands; as also to those cryptæ of the skin which give out the sebaceous secretion.

Note to sec. ccclxviii, after "some species of frogs."

These are the bull frog *(Rana taurina, Cuvier)* and the brown toad *(Bufo fuscus, Laurenti)*. The urine of the former is almost transparent, insipid, but not without smell, the odour it emits resembling that of the serum of the blood. After evaporation there remains a small quantity of brownish extractive, having the smell of urea; and the specific gravity 1.003. That of the brown toad is 1.008, resembles human urine in smell and in taste also, though more faint. Evaporation gives more of the brown extract, urea, than the preceding kind. It also contains a great quantity of subcarbonate of ammonia. Hence it would appear, that the urine of frogs and toads is very similar, but that it differs from the urine of other amphibia. Besides the acids and alkalis here mentioned, sulphur, silica, and fluoric acid combined and free exist in the urine. Lactic acid combined with ammonia is also a constituent, and, according to Berzelius, gives the odour peculiar to urine. The urine of the horse, rabbit, and cow, are milky, from the great quantity of carbonates (lime and magnesia) they contain. With regard to the predominance of uric acid in carnivorous animals, Wollaston found that the gannet, fed only on fish, discharged no solid matter except uric acid, and Prout found it in the proportion of 90 per cent. in the excrement of the boa constrictor. On the other hand, Vauquelin ascertained its absence from the urine of the lion and tiger, though these animals were fed on flesh, and passed urine containing abundance of urea.— *Thomson's Ann. v.* 5, *p.* 413.

Note to sec. ccclxix, after " bunch of grapes."

In bears, for instance, in which there are upwards of fifty distinct portions or lobuli connected by vessels and ducts. This many-lobed kidney is chiefly found in aquatic animals, in which, as the author remarks, they form a greater mass than in land animals. In the seal and porpoise there is no common pelvis, but each lobule sends its individual duct to the ureter. The single-lobed kidney is generally found in land animals, especially those which secrete fluid by the skin.

Note to sec. ccclxx, " after a true urinary calculus in it."

Townson's reasons for the assertion were—that the sac has no connexion with the ureters, the latter ending in the posterior part of the rectum, whereas the sac is placed on the fore part, that the fluid it contains is pure water: and that it is out of proportion with the kidney, exceeding its volume twenty or thirty times. (Townson's Tracts and Observations, p. 66). The analysis of Lassaigne and Vauquelin however outweighs these considerations.

Note to sec. ccclxxxvi.

It will be evident that many of these calculations of heat must be approximations only. If we go along with Tiedemann in maintaining that the heat of animals is the production of their own vitality, we must also be convinced that causes which modify the vital conditions, will likewise modify the evolution of caloric in them. This will be the more the case in those animals whose organization and consequent vitality are of that exalted character enjoyed by mammifera; and it is to these that the preceding tables refer. Accordingly, the violence which must necessarily have been employed, and the lesions that must have been effected in the vital conditions, during the experiments on which those tables are founded, cannot but render the results somewhat distant from the actual fact, though the doubtlessly close approximation to it gives them an interest which is not a little enhanced by the concomitant accounts of localities wherein, and the temperature at which, they were taken.

Note to sec. ccccxxii.

The most recent experiments on the relative powers, and the latest observations on the anatomical structure, of the electrical organs of the raia torpedo are those made by Dr. Davy and reported in the volume of the Philosophical Transactions for the year 1832, page 259. From the facts and observations detailed in that paper it appears very difficult to resist the conclusion that the electrical organs of the torpedo are not muscular, but columns formed of tendinous and nervous fibres distended by a thin gelatinous fluid. Their situation, too, surrounded by and exposed to the pressure of powerful muscles, shows that, if condensation is required for the exercise of the electrical function, they may experience it without possessing any muscular fibres in their own substance. The arrangement of the muscles of the back and of the fins, and of the very powerful cross muscles situated between the under surfaces of the electrical organs is admirably adapted to compress them. Without entering into any minute anatomical examination of these muscles and their uses, it is only necessary to compare them in the torpedo and in any other species of ray to be convinced that they are adequate to and designed for the effect mentioned.

Dr. Davy, although he has distinctly seen the same appearance presented, still concurs in the opinion expressed by Mr. Hunter, (Philos. Trans., 1773,) that the columns of the electrical organs are composed of cells containing a fluid, divided by their horizontal partitions which he was able to count.

In examining the brain, proceeding from the anterior to the posterior portion after passing the first, second, third, and fourth pairs of nerves, the fifth is described as seen issuing from the medulla oblongata or posterior tubercle of the brain. After quitting the cranium (confining the description to one side) it proceeds upwards, divided into two large branches, which go to clusters of mucous glands situated in the front of the head and at the anterior margin of the electrical organs, and they appear to be confined to these parts. The next pair, the first electrical, rises close to the preceding just behind it, and in passing out of the cranium, is firmly connected with it, and also where it passes out, a portion of medullary matter proceeds from it into a cavity filled with fluid, in the cartilage adjoining, which there is reason to consider as the cavity of the organs of hearing, and the medullary matter the nerve of hearing. After this, in passing outwards, it divides into three small branches and two large ones. Of the former, one proceeds to the gills, another to the adjoining muscles, and the third to the mouth. Of the great branches, one ascends and, sweeping round the margin of the electrical organs, is distributed to the mucous glands which abound there, and where some of its twigs inosculate with twigs of the former nerve.

The other great branch, which is inferior, enters the electrical organ and ramifies through its superior portion. The next pair of nerves, the second electrical, rises a little beyond the preceding. On leaving the cranium it divides into two great branches; these, with the exception of the nervous twigs, supplying the adjoining branchiæ, are distributed entirely in the substance of the electrical organ, and ramify in all directions through its middle portion. The third electrical rises close to the last, divided only by a very thin plate of cartilage; the principal portion of it passes into the electrical organ and ramifies through its inferior part, and, besides, gives off three small branches, which are sent to the adjoining branchiæ, to the gullet and stomach, and to the tail. The branch which supplies the stomach appears to be the principal nerve of this organ; it descends along the inner and inferior portion of the gullet and ramifies in the direction of the great arch of the stomach. The caudal branch descends in a straight line under the peritoneal lining of the abdomen and under the spinal nerves, without giving off a branch till it reaches the tail, in the muscular substance of which it is lost.

Dr. Davy has not yet been able to discover any connexions of the electrical nerves besides those pointed out. It is an interesting fact, that the gastric nerves are derived from them. Perhaps superfluous electricity, when not required for the defence of the animal, may be directed to this organ to promote digestion. In the instance of a fish which Dr. Davy had many days alive in his possession, and which was frequently excited to give shocks, digestion appeared to be completely arrested. When it died a small fish was found in its stomach, much in the same state as when it was swallowed. No portion of it had been dissolved.

Though Dr. Davy has not found the temperature of the electrical organs higher than that of any other part of the fish, or the temperature of the fish generally different from that of the water in which it has been confined, yet it seems probable that, as the branchiæ are liberally supplied with twigs of the electrical nerves, there may be some connexion between its respiratory and electrical function; and he ventures to offer the conjecture that, by means of its electricity, it may have the power of decomposing water and of thus supplying itself with air, when lying covered with mud or sand in situations in which it is easy to conceive pure air may be deficient; and in his experiments Dr. Davy has often fancied that he has witnessed something of the kind. After repeated discharges of its electricity, the margin of the pectoral fins has acquired an appearance as if very minute bubbles of air were generated in it and confined. Besides the electrical nerves, there is a plexus of nerves, deserving attention, of great magnitude, formed by the junction of the anterior and posterior, or upper and under cervical nerves; of the former, about sixteen on each side, of the latter about fourteen. It makes its appearance as one trunk just below the transverse cartilage, which is interposed betwixt the thorax and abdomen. It sends a recurrent branch to the muscles and skin of the under surface of the thorax; but its main trunk ascends along the inner margin of the pectoral fin and is distributed through it. On this plexus the sentient and motive powers of the parts connected with the electrical organs seem to depend.

The electrical nerves at their origins are enveloped in a very thick fibrous sheath. As the branches subdivide in the substance of the organ the neurilema becomes thin and semi-transparent. On examining a minute branch with a powerful lens, its internal and medullary substance is not seen in a continuous line, but interrupted, as it were dotted, as if the sheath contained a succession of partitions with a little space between each.

In the anatomical structure of the torpedo the mucous system forms a very conspicuous part; it consists of several clusters and chains of glands distributed chiefly around the electrical organs, at different depths beneath the cutis; and of strong transparent vessels of various lengths and sizes, opening externally in the skin, for the purpose of pouring out the thick mucus secreted by the glands and destined for lubricating the surface. This system has not been noticed by Mr. Hunter, and it has been but imperfectly described by Lorenzini. Though it is not peculiar to the torpedo, it is much more strongly developed in this fish than in any other species of the ray, and the situation of the glands and the distribution of their vessels are different. Whether it is concerned in any way with the electrical function of the torpedo is deserving of consideration. That it is thus concerned in some way, seems to be indicated, not only by the situation of these glands, between and surrounding the electrical organs, but still more so by the manner in which they are supplied with nerves, either from the first electrical, or from the fourth pair, which is connected with the nerve. As the thick transparent mucus, which these glands secrete, is probably a better conductor of electricity than the skin alone, or than salt water, this mucous system may serve as a medium of communication between the electrical organs. Dr. Davy states, as corroborative of this idea, that when one contact wire was placed underneath an active torpedo just anterior to the mouth, and the other at the extremity of the back, out of the circle of the mucous apparatus, the shock of the fish had no effect either on the multiplier or on needles in the spiral. But when the upper contact wire was made to touch the back of one electrical organ, the under wire being placed as in the preceding experiment, both these effects were simultaneously produced; and they were also produced when both the wires were brought very close to each other, one being kept as before, and the other moved immediately over it, in front, each about a quarter of an inch from the margin, and not connected with the electrical organs, except by the common integuments and this mucous apparatus. It is worthy of remark, that this little space in front, intermediate between the two electrical organs, so abounding in glandular structure, and so amply provided with nerves, appears from experiment to possess very little sensibility; this was denoted in these trials in which the fish though exquisitely sensible of pressure on the margin of the pectoral fins, seemed indifferent to it when applied in front, as if the fourth pair, which supplies this part, were destined rather for secretion than for the purposes of sensation.

The connexion between the electrical nerves and the mucous system, even more remarkable than between the former and the stomach, may perhaps warrant the conjecture, that the electrical function may be not only aided by, but also aid the secretion of mucus; and that as was supposed in regard to the stomach, when the electricity is not employed in repelling an enemy in violent efforts it may be exercised gently in increasing the activity of these glands. In support of this notion it may be maintained, that in fishes in which digestion was arrested, the secretion also of mucus seemed to be stopped or considerably diminished.

Mr. Hunter, from the examination of a torpedo whose vascular system was injected, states that the electrical organs of this fish are abundantly supplied with blood-vessels. From what Dr. Davy has witnessed in the living fish and the fresh fish recently dead, he is compelled to conclude that the quantity of blood which circulates through them is very inconsiderable. The blood-vessels which pass into them with the electrical nerves are small; the organs are colourless and very few branches carrying red blood are perceptible extending through them. The integuments of these organs, and the pectoral fins and the lateral clusters of mucous glands, are indeed abundantly supplied with blood-vessels. The contrast of the vascularity of these parts and of the electrical organs is so strongly marked as to suggest the idea that the latter can possess very little ordinary vital activity, and that in accordance with the common analogies of living parts they must be rather passive than active.

The experiments on the electricity of the torpedo, detailed by Dr. Davy, confirm those made by Mr. Walsh, in 1772, shewing its resemblance to common electricity. They moreover shew, that, like common electricity and voltaic electricity, it has the power of giving magnetic polarity to iron, and of producing certain chemical changes. In these, its general effects, it does not seem to be essentially peculiar, but as much allied to voltaic electricity as voltaic electricity is to atmospheric, or atmospheric electricity is to that produced by contact or friction.

When we examine more minutely its phenomena or effects, in relation to these different kinds, or varieties ef electricity, certain points of difference occur. Compared with voltaic electricity, its effects on the multiplier is feeble; its power of decomposing water and metallic solutions is inconsiderable; but its power of giving a shock is great, and so also is its power of magnetising iron.

Compared with common electricity, it has a power of affecting the multiplier, which, under ordinary circumstances, common electricity does not exhibit, its chemical effects are more distinct; its power of magnetising iron, and giving a shock appear very similar; its power of passing through air is infinitely less, as is also (if it possess it at all) its power of producing heat and light. There are other points of difference.

How are these differences to be explained? Do they admit of explanation similar to that advanced by Mr. Cavendish in his theory of the torpedo; or may we suppose, according to the analogy of the solar ray, that the electrical power, whether excited by the common machine or by the voltaic battery, or by the torpedo, is not a simple power, but a combination of powers, which may occur variously associated and produce all the varieties of electricity with which we are acquainted.

As regards the mode of production, or the cause of the electricity of the torpedo, it is unavoidably enveloped in great mystery. Like animal heat and the light emitted by certain animals, like the secretions of animals generally, it appears to be a result of living action, and connected with a peculiar and unusually complicated organization. All the attempts made to obtain electrical excitement in the fish, after it has been deprived of life, have been vain. The observations which have been detailed relating to anatomical structure show a complicated adaptation of parts, nerves of unusual magnitude, ramified between apparently insensible columns, saturated with a bad conducting fluid; muscles surrounding these columns and fitted to compress them; and a system of mucous glands and tubes adjoining, well adapted to be the medium of electrical communication between the two organs and their opposite sides.

Note to sec. cccclxxx.

Most plants have more or less of a spiral turn in their developement. Thus it is not unfrequent to see trees having few branches, as the fir, in which this direction is very plainly exhibited, when they have been deprived of their bark for some time, and the ligneous portion has been exposed to the air; spiral fissures in the latter are then visible. M. du Petit Thouars (Hist. d'un Morc. de Bois. p. 71) and Theophrastus before him (Hist. Plantar, Lib. 3. cap. 18) remarks that the ablation of the bark of smooth trunked trees, as the cherry-tree, or the *Hydrangea arborescens,* is more easily effected in a spiral than in any other direction. Again, the primitive direction of the leaves of endogenous plants (monocotyledones) is spiral, and very many of the exogenous (dicotyledones) have this disposition, either from a natural or accidental developement. That there is some connexion between this spiral tendency of straight trunks and the twisting branches usually so called, is in some degree confirmed by the observation of M. Leopold de Buch, who says that in several species of the former, the direction of the spiral torsion is as constant as that of the latter. Thus, for instance, the Indian or horse-chesnut tree, and the common chesnut, twist in contrary directions.

The spiral torsion of some plants exists all their life however ligneous their trunks and branches become, as those of the *Misteria fructescens et Periploca græca;* whilst in others this tendency is only visible in young branches, and disappears in the ligneous branches or trunks of several ipomœæ with ligneous trunks.

END OF THE ADDITIONAL NOTES.

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