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THE SEA-SERPENTS OF SCIENCE. *See Preface.*

LEISURE-TIME STUDIES

CHIEFLY BIOLOGICAL

A Series of Essays and Lectures

BY

ANDREW WILSON, PH.D., F.R.P.S.E., ETC.

LECTURER ON ZOOLOGY AND COMPARATIVE ANATOMY IN
THE EDINBURGH MEDICAL SCHOOL; LECTURER ON PHYSIOLOGY, WATT INSTITUTION
AND SCHOOL OF ARTS, EDINBURGH;
EXAMINER IN BOTANY AND NATURAL HISTORY, FACULTY OF MEDICINE,
UNIVERSITY OF GLASGOW, ETC.

WITH NUMEROUS ILLUSTRATIONS

THIRD EDITION

WITH A NEW PREFACE

London
CHATTO AND WINDUS, PICCADILLY
1884

1738

"Beholding the bright countenance of truth in the quiet and still air of delightful studies."—MILTON.

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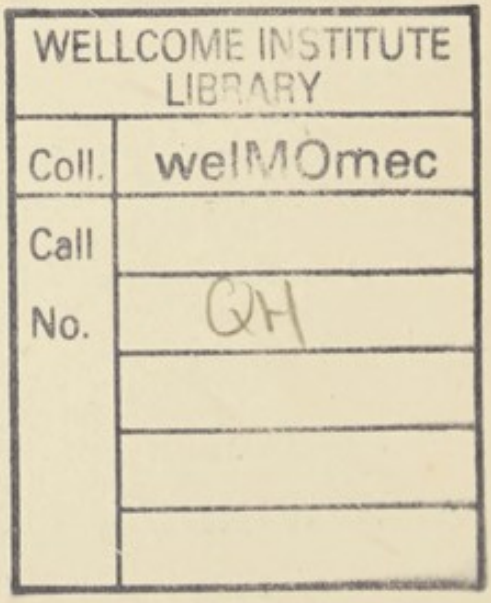

TO

JOHN CAIRD, D.D.,

PRINCIPAL AND VICE-CHANCELLOR OF THE UNIVERSITY OF GLASGOW

This Volume is Inscribed,

IN ADMIRATION OF HIS GIFTS AS

A SCHOLAR AND PREACHER,

AND NO LESS SO AS AN ACKNOWLEDGMENT OF HIS INFLUENCE

IN PROMOTING TRUE CULTURE AND

A LIBERAL RELIGION.

PREFACE.

THE present volume has at least one merit: it is strictly what its title-page announces it to be—a volume of essays and addresses, written and delivered for the most part in the leisure-time of a busy professional life. To collections of articles written at various times, and it may be under varying moods and phases of thought, there is usually brought the objection that the interest of the papers is of passing kind, whilst their relationship to each other may be by no means stated or clear. To both objections the author would fain offer a reply in the facts, firstly, that if the essays themselves be of transient nature, their subjects for the most part bid fair to find a place in the "foremost files" for many days to come; and secondly, that a thread of connection binds the various articles in a series, inasmuch as they are mainly devoted to an exposition of phases of living nature,

upon which most thoughtful persons amongst us find it interesting to reflect.

In this latter view, the author would hope that the essays on the relations of biology to common education may receive their due meed of attention from both educationists and scientists. Of these efforts to state the case for biology as a mighty influence in modern culture, the author would only say that they are the direct products of a long experience in biological teaching, and the sincere expression of a strong belief in the value of a knowledge of nature in producing a true and liberal culture in all departments of human thought.

The great bulk of the essays deal with some of the more important questions of biology and with their explanation, in so far at least as the true meaning of such phases of life and nature are susceptible of elucidation by our present knowledge. The paper entitled "The Sea-Serpents of Science" is an attempt to rescue an interesting subject from the domain of the ludicrous, and to show that the personality of the "Great Unknown" is at least worthy of a reasonable amount of attention. A holiday spent amongst the river lands of Oxfordshire suggested the current of thought which led to the

production of "A Summer's Day"—a trifle which will more than serve its purpose if it may show the possibility of spending many pleasant hours amongst familiar home scenes. The essay on "Science and Poetry" was suggested by Principal Shairp's charming volume "On Poetic Interpretation of Nature;" and the tenor of my remarks may be taken as an endeavour to combat the too common idea that a knowledge of the facts of nature modifies or destroys the poetic sentiment. The author ventures confidently to appeal to his scientific brethren in support of his assertion, that an understanding of the causation of nature, can never of itself destroy our sense of beauty and joy in the fairness of the universe.

The author's best thanks are due to Mr. G. J. Romanes for the loan of several illustrations used in the essay on "The Origin of Nerves," and to Messrs. Longmans and Co., Messrs. Smith, Elder and Co., and Messrs. Daldy, Isbister and Co., for permission to reprint articles from *Fraser's Magazine*, the *Cornhill Magazine*, and *Good Words*, respectively.

The frontispiece is intended to embody the chief representatives of the various theories of the "sea-serpent" question. A giant tape-fish is represented

at the right-hand side, and a large turtle at the left-hand side of the foreground. The extinct plesiosaurus, with its swan-like neck, is also depicted; a weed-laden log of wood, often mistaken for a living animal, being descried beyond the turtle on the left. A giant and true marine snake is seen in turn beyond the plesiosaurus, and the detached fins of porpoises or sunfishes swimming in line—the fins appearing as those of a single animal—are depicted in the distance.

A. W.

EDINBURGH, *November*, 1878.

AUTHOR'S PREFACE TO THE THIRD EDITION.

A THIRD edition of this volume of essays having been called for, the publishers have asked me to supplement by a few words the Introduction which has done duty in the case of the first and succeeding issues of the work. It is with feelings of satisfaction that I respond to their invitation, because the demand for the book constitutes, in itself, a pleasing proof that the aim and purport of the work have been fully realized.

The evidence that there exists a growing interest, on the part of the public, in topics, which, even a few years ago, were regarded as lying wholly within the province of the professed naturalist, is no longer doubtful. And the demand for works which instruct while they interest, is a feature of modern literary life, which is pleasing to none more than to scientific men themselves. After all, the interests of culture are identical, under whatever guise they may be presented; and I can only hope that the office of the present volume, as a collection of essays dealing with some of the broader and more interesting aspects of the world of life, may continue to be discharged as pleasantly in the future, as its functions have apparently been served in the past.

A. W.

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LEISURE-TIME STUDIES.

THE PLACE, METHOD, AND ADVANTAGES OF BIOLOGY IN ORDINARY EDUCATION.

THE task of an educational apologist is one which, in these days of the widespread recognition of the teacher's office and power, may be accounted as being almost of superfluous kind. Whatever need the past may have had of educational reformers, the present requires no apologist to advocate the extension of knowledge as a humanizing and elevating influence in man's estate. Contented with the three "R's," our predecessors might, and probably would, have needed some forcible arguments to convince them that their limitation of the branches of knowledge was injurious. And it would have needed an exercise of much apologetic skill to show them that the utter absence of sympathy between their educational code and the after-life of the pupil, was a most glaring fault and error in their system of mind-training. Whilst, however, we may safely congratulate ourselves upon the progressive character of the movement of liberality in matters educational, it may not be out of place to guard against the idea that further progress is unnecessary. We have gained a solid advance in the necessary branches of education; it now remains for us to further develop and differentiate these branches, accord-

ing as we may hold them to be more or less essential. And in what follows I shall endeavour to show that Biology may claim to hold, not merely and as usually regarded an incidental, but an essential and necessary place and power in ordinary school-training.

A simile of biological kind may, perhaps, serve in some degree to illustrate the position on which I take my stand. A very important principle, known as that of the "specialisation of functions," assists the naturalist in determining the place of different organisms in the scale of being. By the aid of this principle he is led to assign to each organism a position of high or low grade, according as the functions of its body are of a more or less complicated kind. Complication of functions in the living organism results from their specialisation or differentiation; in other words, the higher the organism, the more thoroughly specialised or broken up into minor parts is each function of its frame. In any low microscopic Protozoön—such as the *Amœba*—the functions are not specialised at all. When such a being eats, for example, it grasps food by any portion of its body, which is composed of a speck of almost structureless protoplasm. And any part of the soft protoplasmic frame serves equally with any other part, for the digestion of that food. But when we regard the higher animal, we notice that not only are distinct organs set aside or *specialised* for the function of taking in food, but every part of the great function of digestion is subserved by separate organs, allocated each for its special work. Thus, we say that, in the latter form, "specialisation of functions" exists; and the animal is a higher animal than the Protozoön, because, in the latter, any part seemed to subserve any function—just as the "maid-of-all-work" represents in herself the specialised labours of the numerous staff of servants belonging to the great mansion. Conformably with this principle would I argue of the study of Biology in its relations to commonplace education. As the specialisation in functions advances with the rank and value of the organism, so, I

maintain, should we endeavour to differentiate the nature and extent of biological training as education advances towards perfection. The study and recognition of Biology by educationists, is at present in a non-specialised condition. Its general utility is an admitted, because an apparent, fact; but I should wish with all honesty of purpose to press home the further value and higher application of the science, as entitling it to a definite place in the specialisation of the functions and subjects of the educational reformer.

By the term Biology, we mean to collectively indicate those branches of science, commonly known as Botany and Zoology, which deal with living beings, or with the great organic series of objects which the world presents to our view. My subject naturally divides itself into a threefold consideration of the place, method, and advantages of this study; and it is needful for the appreciation of all three points that the study itself should in the first instance be clearly defined.

It may thus be found to involve three, if not four, distinct yet connected branches of inquiry; which, as the result of their investigations, place us in possession of full information regarding any individual organism or series. Biology has thus firstly a *Morphological* side or aspect, through which we investigate the *structure* of living things; and Morphology in its turn includes not only *anatomy*, or the department of science investigating the structure of the fully-formed being, but the study of *development*, and that of *taxonomy* or *classification* also. Through Morphology we, in fact, become acquainted with every aspect of the structure—adult and embryonic—of the organism; and by comparing the structure of various organisms, we are also enabled to relate them together in a scheme of classification. Then, secondly, the study of a living being necessitates our looking at it from a *physiological* point of view. Morphology taught us the structure and disposition of the vital machinery. Physiology shows us how that machinery acts and works in maintaining the life of the organism. Thus physiology is

the science of *functions;* and its study includes the consideration of the many processes whereby the organism nourishes itself, reproduces its species, and through its nervous system maintains relations with and reacts upon its surroundings. The three great functions of *Nutrition*, *Reproduction*, and *Innervation*, thus fall to be considered under the head of Physiology. The third department of biological science is that of *Distribution.* We now regard the living being in its relations to its environments, past and present. The study of Geographical Distribution, or that in space, leads us to note its *habitat* in the existing world; whilst Geological Distribution, or that in time, elucidates for us the conditions under which it existed in past periods of the earth's history, and seeks to make us acquainted with the relations of living beings to their surroundings in epochs anterior to our own day. A fourth department of biological inquiry, which in one sense may be said to unite the interests of the preceding branches, is that to which the name of *Ætiology* has been given. Through this latter department, which may be viewed as the result of the promulgation of the modern theories of Evolution and Descent, we investigate, as far as is possible, by the light of hypothesis and development, the probable derivation of living beings; and we thus seek to unite by a thread of continuity the various and diverse relationships so clearly to be discerned in either kingdom of living nature. Such a work assists us in framing a feasible plan of classification, based upon the development of living forms, and presents a highly attractive field for investigation.

Having thus noted the essential features comprised in the modern study of living beings, we may next look at the wider and incidental relations which the study of Biology may be shown to possess to other branches of inquiry. The work of the biologist cannot be carried on in a successful and satisfactory manner without aid from many other, and, in many cases, apparently dissociated sciences. The inquiry into the most common phenomena of animal and

plant life, leads us to deal with problems which, for example, belong more or less completely to chemical science. The nature of foods, the reaction of animals and plants upon the atmosphere—nay, the very differentiation or separation of the one series of living organisms from the other, and the nature of life itself, are all so many questions in the discussion of which a knowledge of chemical science is absolutely necessary. The investigation of the products of plant or animal life, and of the functions whereby these products are produced, render the chemical aspects of both botany and zoology an essential study for the modern biologist.

In a less important but still feasible manner may the studies of the natural philosopher or physicist be brought into the field of biological inquiry. The characters of the inorganic, as distinguished from the organic, world; the investigation of phenomena of such importance in the life of plants and animals as endosmose and exosmose; the relations which nerve-action bears to electrical and magnetic forces; and even the comparatively simple study of how a fish rises or sinks in the water through the agency of its "swimming-bladder" or "sound," are so many processes in the satisfactory elucidation of which, an acquaintance with at least the principles of natural philosophy will prove of great service to the biologist. The consideration of animal mechanics may similarly relate the domain of mathematical science to that of biology; and with geology and mineralogy the science of life possesses relations of a very intimate kind. One of the most fascinating departments of biological inquiry is unquestionably that of investigating the conditions under which life existed in the past. Without a knowledge of the distribution in time of living organisms, as already remarked, the biologist's information would be very far from satisfactory or complete; and an acquaintance with the facts and laws of geological thought is very necessary in the active practice and work of the student of life-science.

Thus the study of life-science may be shown to relate

itself on every side to other departments of purely physical inquiry. I need not discuss at any great length the equally obvious manner in which biology merges, in one aspect at least, into the domain of the metaphysician. The consideration of a colony of social insects, and the investigation of the wonderful phenomena presented to us in the daily life of an ant or bee-community, introduce us to the study of mental physiology, and open up to us the department of psychology when we endeavour to compare the acts of the insect with those of higher forms. To omit from physiology, as a branch of biology, the due consideration of the phenomena of mind, would be to imperfectly appreciate what the study of physiological science involves. Whilst the pursuit of the department of psychology to its ultimate and practical end, brings us face to face with problems and matters of the deepest social interest—such as are well exemplified in the relations of religious belief to mental disposition, and in those which the psychologist may be led to deduce between the mental and social disposition of individuals, sects, or of the nation at large.

The discussion of these preliminary points now leads me to speak of the *place* which the study of biology may reasonably hold in an ordinary school-curriculum. I may be told by some that the place of biology is already recognized, and that educationists are alive to its value and power. My reply to this observation must be that I have failed to obtain evidence that biology is recognized as a branch of education proportionably to its value, or that it is taught even in a small proportion of schools, as it should be taught. I am fully aware that in some of our secondary schools some one branch or other of biological science is included in the list of studies. I know for example that botany forms a summer study in many instances; and that, in the form of elementary book-lessons, physiology is attempted to be taught to school-boys and school-girls. I admit that in some of the larger endowed schools of this country, and in a few private schools of large extent,

the study of biology is carried on in a truly scientific and satisfactory manner. And yet I may be pardoned, I think, if I state with some force, that I doubt emphatically if biology has yet received any due recognition at all. So far as the teaching of biology in the schools of this country is concerned, that work may be said to present itself in the most unspecialised state in which it is possible for any study to exist. Its cultivation is for the most part left to chance; or, what is much the same thing, to the predilections of the governing body of the school—individual or collective. From my own experience as a biological teacher, I can state, that in very few cases have I been asked to lecture in schools on this subject. In general the need or advantages of such instruction had, in the first instance, been pressed home upon the head of the school; and of the instances in which the advantages of the study were so urged and admitted, only a proportion of such cases eventually adopted the study.

My strong complaint, therefore, is, that the educational world as a whole has yet to learn the place and power of biological training. Teachers of the science have still to combat the old notion that "science" consists only in dry bones and abstruse technicalities. It is wonderful to find how widely, even amongst otherwise intelligent people, this idea of science prevails; and until it is exploded or thoroughly combated, no real progress in the fuller recognition of science-teaching of any kind can be hoped for or expected. Until science-teachers obtain an earnest, helpful co-operation on the part of those who hold the reins in matters educational; until we succeed in convincing such that science should form an essential item in an ordinary education, demanding their fostering care and protection in its early growth; and until we can impress by practical work and demonstration, the benefits and advantages which can be shown to result from its study, science-teaching can never obtain its true place beyond the walls of universities, nor can it exist in any other fashion than as the feeble

sapling, depending for nourishment upon mere chance kindness, and which can hardly hope ever to assume the proportions of a goodly tree of knowledge. I know of cases where a science-teacher has succeeded in drawing a class around him in an ordinary public school; the numbers attending the class, however, being, in respect of their paucity, out of all proportion to that exhibited by the roll of available attendance. On making inquiry into such cases, I have invariably found that whilst the head-master or mistress, as the case might be, sanctioned and approved of the class, he or she took no further interest in its welfare. "You may attend the science-class if you choose," was the understanding which existed between the pupils and the responsible head of the school, who in some cases was, nevertheless, liberal enough to make the science-class one open to the entire school without extra charge. Yet the pupils themselves were left the sole judges as to the advantage or necessity of attending the class. I need say nothing of the wisdom of the practice of accrediting pupils with the power of judging for themselves what they should or should not study. Nor need I do more than point out that if science-teaching be admitted and recognized in any school-curriculum, the pupils should no more as a matter of reason and logic be left to decide the question of attendance for themselves, than they should be allowed to select or reject the other branches which are also admitted into the programme of the school. The pupils might equally and as feasibly be allowed to attend or reject an English or an arithmetic class as they pleased, as to be allowed the option of attending or not their science-class. Once let educationists recognize the science-teacher and his work, and they do him the grossest injustice if they allow his success to be determined by the tastes or dispositions of the pupils. It is the true office, I should imagine, of the principal of a school to foster and encourage a love for science-instruction, as well as for other branches which are usually deemed of more essential nature. And I hold that science-teachers

have their hardest battle to fight in cases where this non-recognition of their subject is a settled idea in their employers' minds.

This aspect of the subject leads me now to say something of the exact place which biology should occupy in the curriculum of the school. The question, "At what stage of the pupil's progress should biological teaching be introduced?" may be answered by maintaining its educative value to pupils of every age above that of mere infant or primary school-children. I do not hesitate to affirm that a boy or girl of, say, ten years of age may receive a certain amount of elementary biological instruction, which will be of the greatest service in the training of the child's mind, and which will assist the due appreciation of its other studies. As Sir James Paget well remarks, "The askings of children seem to indicate a natural desire after a knowledge of the purposes fulfilled in nature;" and even where this desire is most feebly developed, the plain, interesting teaching of the grand yet simple facts of biology, will tend to arouse the latent curiosity of the child, and to early awaken its sympathies with the things of living nature. Dr. Carpenter, in his evidence before the English Public Schools Commission, lays great stress upon the importance of enabling children to begin the study of physical and natural science at an early age. He says, "The training of the observing faculties by attention to the phenomena of nature, both in physical and in natural science, seems to me to be the natural application of time at the age of say from eight to twelve." Dr. Carpenter further exemplifies, by citing his own case, the value of an early training in science as tending to cultivate the observant habits more thoroughly than when the study is entered upon at a later period. The evidence of the late Sir Charles Lyell goes to support Dr. Carpenter's views in relation to the advantages of training the observant faculties in early youth; the age of nine or ten, the late distinguished geologist maintained, being that at which the powers of observation are sufficiently developed; and when,

if pupils be taught natural science, "they learn a vast deal of other things in consequence."

No science can pretend to give to the child information of so simple, interesting, and useful a nature as that which biology supplies. Since the thoughts of the child naturally run most in the direction of the objects which meet his gaze in the world around him, and especially, as any one may note in the questionings of the intelligent boy or girl of the age I have mentioned, as the interests of children are bound up in the *living* things with which their daily life brings them into contact. Thus biology assumes in the education of the observant faculties of the child a thoroughly *natural* place; and a position which no other science can pretend to occupy, from the fact that the subject-matter of biology is essentially that of the child's own thoughts, as he speculates on the how and why of his natural environments. The late Canon Kingsley was a most powerful and earnest advocate of the extension of this description of biological knowledge amongst the youngest of children. And I know of no happier example of the true mode of conveying the broad truths of science to the young than may be found in his charming series of papers entitled "Madam How and Lady Why," in which, with a connecting thread of narrative, a vast quantity of interesting and useful knowledge is given in a form readily appreciable by the very young pupil.

From pupils of ten or twelve years of age who have been properly instructed in the elements of biology, one may obtain a surprising accuracy in the answers given to both written and oral questions. The chief idea, however, to be borne in mind in teaching pupils of this early age, is that the instruction must be limited to broad and general details, and, save in very exceptional cases, must not include attempts at specializing the science. The general phenomena of plant and animal life; the broad relations of the organic and inorganic worlds; and the general details of the structure and life-history of the more familiar groups

of animals and plants, present subjects which may be made, with sufficient means of illustration, to convey a great amount of solid information to the youngest pupil who is able to think for himself or herself. For example, I do not see that an intelligent teacher, with a good set of diagrams and a few specimens, should have the slightest difficulty in interesting a very youthful auditory in the structure and metamorphosis of Insects, and in the general course of insect-life. He would find in the details furnished by the common observation of his pupils, a ready assent to and illustration of most of the facts he would set before them; and he would send them back with renewed interest from his class-room to study the caterpillars in the garden, or the development of the silkworm's eggs, which formerly had been kept as mere playthings. A lecture on Shells and their inmates would in like manner be readily illustrated; and with the aid of a few microscopes and some stagnant water, the wonder and interest of the pupils might be excited over the description of lesser worlds than ours.

With pupils of more advanced age and intelligence, the sphere and labours of the teacher of biology may be greatly extended. There is no reason why, for example, a regular systematic course of lectures on zoology or botany should not be given to pupils who make up the greater bulk of the population of secondary schools. My own experience in this respect goes to prove that average school pupils may, if required, be trained to a pitch of excellence in zoology equal to that—so far as the test of a written examination may be deemed satisfactory proof—demanded from candidates for honours in art examinations, or for the natural history part of the first professional examination in medicine in the Universities of Edinburgh and Glasgow. To pupils of this age the teacher may enter into considerable detail, and may even, if necessary, touch upon the hypothetical questions which environ the modern study of biology, and which may in some degree facilitate, through their suggesting the comparison of views, the comprehension of other parts and

details of the science. In short, I claim for biological science a place at every part of the pupil's career beyond the purely infantile stage of training, and I hope to justify this claim by what I now proceed to say of the method, and afterwards of the advantages, of the study.

The question of the *method* in or through which biological science is to be successfully taught in schools, necessarily assumes somewhat of a compound nature. It includes the consideration of the teacher, of his special qualifications, and of the appliances and apparatus which the due study of biology demands. Firstly, then, let us consider the teacher himself, and the qualifications which specially fit him to discharge his important office. That an adequate knowledge of biology demands a singleness of aim in the teacher, is a statement the truth and importance of which cannot be doubted or over-estimated. The teacher of biology, in his most typical development, cannot afford to be a teacher of aught else. He exhibits, in his own person, the condition of an organism whose functions exhibit the highest possible degree of specialisation. The biologist of to-day requires to keep himself heartwhole in his scientific aspiration and as regards other pursuits, if he would successfully discharge his duty to his science and to himself. The ever-widening limits of biological inquiry, extending, as we have already seen, into many other and diverse paths, necessitate on the part of the biologist the closest attention to his own department if he means to keep pace with the times. And, therefore, when we speak of the professed teacher of biology, we should bear in mind that we can only so regard him who specialises biology as his subject, and who devotes himself to biological work alone. This is the aspect in which the modern biological teacher must be viewed; since a plurality of aims is utterly incompatible with the true performance of his office and functions.

Such being the description of the teacher's requirements who may aspire to fill the office of a recognized instructor, it clearly follows that his training and education must have

been of a special kind. The professional training necessary to develop such a teacher can only be acquired in the course of such a thorough curriculum of studies as is undertaken by the student of medicine or by the student of pure science. To the medical profession and to the ranks of the professed scientists we must accordingly look for the recruits who are alone qualified by their training to fulfil in all its details the task of biological instructors. And it may also be noted that such an instructor is qualified in virtue of his training to instruct pupils of all ages in his special subjects. Indeed, as experience teaches, such a professed scientist is likely to be far more successful than any other in interesting and instructing the youngest pupils; since his full acquaintance with his subject and its surroundings enables him to draw very copiously upon all its parts for the illustrations and comparisons so necessary for the successful teaching of science to the young. And the confidence such knowledge gives, is the most favourable condition to his playing the *rôle* of an intellectual crushing-mill, in grinding down the harder and more inexplicable details into fragments adapted for the youngest and feeblest of mental digestions.

But I do not limit the teaching of science to the professed biologist, with his special training, and his technical education. There are circumstances in which the employment of the services of such a teacher may be an impossibility, or a very inconvenient matter; and in such cases it may be asked how his place may be most suitably and ably supplied. In the case of primary schools, I see no reason why an intelligent master or mistress should not be able to introduce to the notice of their pupils the elementary facts of biology. The amount of knowledge required to pass even the primary stage of the biological subjects in the Government examinations held under the auspices of the Science and Art Department, and certainly that which enables the candidate to pass in the advanced grade, may be taken as fair and readily appreciable tests of

the kind and amount of knowledge which should fit its possessor for imparting elementary instruction in biology. Such a teacher must not of course attempt too much; and in any case he or she can never be considered a perfect substitute for the professed biologist. But the way for higher teaching may thus be prepared; and an intelligent teacher, possessing himself a love for natural science studies, and having an interest in imparting that love to his pupils, may accomplish no light or insignificant labour in thus cultivating the scientific tastes and habits of the young. Such a teacher may thus fill the place of, though he can never absolutely supplant, the trained and professed scientist already described.

The exact mode in which school-studies in biology should be conducted, has formed in my own case subject-matter for much consideration. The method of imparting knowledge in the form of the *lecture* is, I think, after all, the most advantageous manner of teaching biology in schools. But lectures, like most other good things, have their abuses. A biological lecture is worse than useless when it consists of a quantity of disconnected matter poured forth without due order, and without consideration of preceding or succeeding details. And equally are the functions of a lecture abused, in my opinion, when the lecturer, however brilliant and well-informed he may be, gives his thoughts to his audience either in such quantity or at such a speed as renders the mental digestion of the knowledge by his pupils, an utterly impossible procedure. Professor Huxley, in his address "On the Study of Zoology," conveys his opinions and practice on this matter by stating that he condenses "the substance of the hour's discourse into a few dry propositions, which are read slowly and taken down from dictation; the reading of each being followed by a free commentary, expanding and illustrating the proposition, explaining terms, and removing any difficulties that may be attackable in that way, by diagrams made roughly, and seen to grow under the lecturer's hand."

But such a mode of conveying instruction, however

admirably it may serve advanced students, or those of an age willing and able to pay close attention to the subject-matter of the discourse, cannot, in my opinion, successfully answer the requirements of the biological teacher in average schools. The preliminary statement of dry facts or propositions, and the subsequent explanation, appear to me to form the mode of instruction exactly suitable where both time and means exist for after-demonstration; or, in other words, where the pupils are subsequently brought face to face with the actualities of which the lecturer has treated. Then, also, in teaching science to schoolboys and girls, the first care and duty of the teacher must be to excite the interest of the pupils; since, if his instruction awakens no feeling even of ordinary curiosity as a stepping-stone to a real interest being taken in the study, his labours will prove but fruitless and unthankful in the extreme. Through abundant illustration, and by telling his audience the history of natural things much as he would tell an interesting narrative, the biological teacher can alone hope to successfully fulfil his mission in the school. He stands on a very different footing from the university professor, or school of medicine lecturer. He has to cater for various tastes, and to create, as well as to foster, a love for his study; and in the exercise of his imperative duties he cannot tie himself to the systematic routine of propositions and explanations suitable for the older student, on whom the study devolves generally as a plain necessity.

In my experience as a school-lecturer, I have usually found that a lecture of one hour's duration, on a subject however interesting, will tend to weary the pupils. Unaccustomed to bear such a lengthened and continuous strain on their powers of hearing and appreciating, one cannot wonder that to young pupils the latter half of many a lecture must prove a weariness to the flesh and mind as well. Even older people, in the majority of cases, find it a hard matter to pay continuous and undivided attention to a speaker, however eloquent he may prove himself to

be, for a single hour—*vide*, the idea of a long sermon,—and we cannot wonder that a boy or girl should grow listless and fagged under the uninterrupted flow of scientific talk in a science-class. Before long, however, I managed to vary the routine of the science-lectures by lecturing for forty or forty-five minutes only, and by devoting the remainder of every lecture-hour to an oral examination on the subjects under explanation. I found that this plan not only relieved the tedium of the lecture, but awoke a healthy interest and stimulated the attention of the pupils; whilst another and very valuable result of the examination consisted in its affording the teacher, through the answers of the pupils, sure information regarding the points which they individually seemed to have appreciated best or least. And in the latter event, he could by a few hints set the pupils right, and advance their knowledge of the more abstruse parts of the subject.

The subjects of books, note-taking, and definite examinations as tests of the knowledge of the pupils, are naturally included in the consideration of the methods of teaching. Note-taking is a labour I have seen every reason to encourage, from its practical bearings on the progress of the pupils. From the mere employment of the eyes and fingers that note-taking involves, the practice would commend itself to the favourable notice of the teacher; but he should not, in my opinion, neglect to show his pupils the most suitable way in which their notes should be taken. The practice of taking very frequent notes, each, however, of limited extent, is the true principle on which note-taking in schools should be conducted. The notes should be copious as to numbers, but short in their individual extent. The nearer the notes approach in character to mere jottings, the better will they fulfil the true end and aim of the practice. For if the notes be each of very copious extent, the pupil must of necessity lose, as he or she writes, many of the succeeding remarks of the lecturer; whilst a series of mere jottings, will, if attention be paid to the lecture, serve

amply to recall to mind the more salient features of the discourse. And it must also be borne in mind that the note-takers in schools are not, in the vast majority of cases, so very deft with pen or pencil that great things in the way of quick writing can be expected of them. But the youngest may make a jotting; and in the rewriting of the notes—which, by the way, should be almost a *sine quâ non* in the practice of science-lecturers,—facts and ideas stored up in the mind by attention to the lecturer's words and supplemented by reference to books, will grow around the jotting, and increase its proportions to a goodly extent. Through this practice of oral examination, of making many jottings, and of subsequently extending and verifying the information given in the lecture, the powers of the memory are braced, strengthened, and improved. And this last forms, of itself, no mean result of science-teaching in schools, from its obvious bearing upon the other studies and general intellectual progress of the pupil.

It is impossible, of course, that science should be studied in schools without the aid of books; but I would rank the help of works of reference as very subsidiary to that of active teaching by lectures, questions, and verbal explanation. Too frequently, however, do we find a tacit adherence to the text of books to be a characteristic of lectures of professedly higher grades than those of schools. Nothing can be more injurious to the real interests of science-teaching, and to the progress of the pupil, than to make his dependence on books a necessity. He thereby loses confidence in the statements of his teacher, and comes to regard the book as his chief authority in matters of dispute or doubt. Books should therefore ever have a secondary place in the teaching of science. The pupil should be taught to see, to observe, and to judge for himself; and to form those habits of self-reliance, the cultivation of which is to be regarded as one of the chief benefits of science-training.

Periodical written examinations, conducted by the

teacher, with or without assistance, and relieved by being invested with a practical element in the shape of specimens placed before the pupil, to be described and referred to their place in the series, are, after all, the surest tests of the progress of the pupils in any branch of physical or natural science. The extension of their notes, and the oral examinations, act as convenient and effective preparation for these periodical competitions; and thus the much-to-be-detested practice of "cramming" should be entirely avoided in the practice of biological school-teaching.

I have incidentally spoken of the *illustration* of biological instruction, and it will readily be allowed that this topic forms one of the chief points for consideration in discussing the general method of teaching biology. It is an admitted fact that all biological teaching is nothing if it is not illustrative and demonstrative in its nature. Touching, and handling, and seeing, are the essential and necessary preliminaries to understanding the things of biology; and in its most typical and advanced aspect, biological teaching must be largely, or almost wholly, demonstrative in its character. Every educated and intelligent boy or girl will not in these days rest content with having microscopic objects described for example, but will expect that they may be shown where to find, how to see, and how to prepare the objects for themselves. Thus the demonstrative aspect of biology opens up to us a means for the actual and practical cultivation of observing habits, quick perceptions, and neat-handedness in many ways. The means at the disposal of even the amateur biologist for the demonstration of his studies are now so cheap and so widely diffused, that no excuse for the imperfect illustration of his teaching on the ground of cost or elaborateness of apparatus can be maintained. In a humble but effective enough manner, when aided by a little experience, the teacher, with his microscope, his scalpel, and a few common type-specimens which the fishmonger's shop, his seaside stroll, or his inland walks will furnish, may demonstrate to his boys and

girls some of the most important structures and functions of animals and plants.

It is in this illustrative aspect that the distinct position of the trained biological teacher must tell with increased effect. For it must be his business and his aim to accumulate around himself the apparatus necessary for the illustration of his lectures. In virtue of his training and pursuits, he will thus possess not only the knowledge wherewith to use the apparatus, but also the time and means for forming a museum or collection adapted for illustrating his teaching. He will be draughtsman enough to design and draw his own diagrams and pictures; his histological studies will have made him skilled in the use of the microscope; he will be able to procure, dissect, and display structures, not only in the fresh state, but for preservation on his museum shelves; and the formation of his apparatus thus constitutes a task inseparable from his actual work as a teacher of biology. The professed scientist thus claims a place and advantage above that of the ordinary and non-specialised teacher, in virtue of his facilities for the illustration of his subject—facilities these, which may only be imitated in a faint degree by others. His example should also encourage the formation by his pupils, in their respective schools, of that most necessary and instructive aid, even in ordinary teaching—the school-museum. And it is wonderful to note how a collection will grow through the efforts of many gatherers, when once its nucleus has been formed.

Thus, practically and personally, I found little difficulty in illustrating my prelections, according to the age and intelligence of my pupils. A convenient box—to come to actual details—afforded ready means for the conveyance, without risk of breakage, from place to place of specimens and microscopes; and in due time this labour on the part of the teacher, if his work be duly appreciated, should be obviated by the formation within the school of a collection of specimens, as well as the purchase of one or two microscopes and other apparatus.

From these remarks on the method of biological teaching, I may now pass to consider very briefly the *advantages* of the study. I apprehend I have the sympathy and support of the majority of thinking men and women with me so far as I have gone, in detailing the place and method of biology in ordinary education. But I am well aware that many who may concur with me in my description of theoretical details, may differ from me, or, at least, require some more practical argument to convince them when I maintain that biology should form, not merely an incidental, but an essential study of the youth of both sexes. I know well that the educational mind is not prepared to give an unqualified assent to my demand for the universal recognition of biology. "There is no absolute need for it," may be the response of many, who will agree with much of what I have said of its place and method. Wherever taught, all will agree that biological study should be conducted as I have indicated, or, what is the same thing, as thoroughly as it can. But this is quite a different matter from accompanying me a step further, when I demand that biological training should be included as a compulsory subject in our educational code. And it is to the attempt to illustrate and make good my position that I now proceed.

I would firstly address myself, in speaking of the advantages of biological study, to the question of our *need* of it.

No better or more forcible exposition of the want and need of biological instruction in the world at large can well be found than in the evidence of Dr. Hooker given before the English Public Schools Commission, when he states that "sometimes two or three letters a day come to us requiring information with regard to well-known fibres, which the slightest habit of observation, or the slightest knowledge, would assure the persons who send them that they cannot in any way be used for cotton." Dr. Hooker also speaks of the universal regret expressed by his numerous applicants, that they had neglected the study of natural science; whilst he himself says that the neglect of this important study is a

matter of national regret. Professor Owen similarily testifies to the deficiency of natural history knowledge, and to the necessity for the nation's awakening to the duty of science culture in schools. This evidence, now of some years' date, stands as typical of the need of biological instruction at the present time, as when it was originally given.

We have not, however, to look far in order to find those who will require much argument to convince them that this world, generally speaking, is a world of ignorance and doubt; and that, with its increasing wealth and prosperity, our own country among others has an ever-recurring need of humanising, educating, and elevating influences. There are also many who seem inclined to enter a chronic protest against the importation into the studies of the young of anything which in their opinion is to be of "no use." "Whatever you study," says a shrewd writer, "some one will consider that particular study a foolish waste of time." This utilitarian cry, this process of estimating the importance of any branch of knowledge by a certain incomprehensible standard of "use" and "no use," belongs to a class of policy which is simply synonymous with narrow-minded limitation and dangerous conservatism. A strict utilitarianism in matters educational usually implies a stubborn obstructiveness. For, to dogmatise from our knowledge of the present, what the requirements of the future will or will not be, is a course of procedure utterly at variance with the true work of the reformer and with the tendencies of an advancing age. The future may well wonder at many a present-day policy; but I am sure at none more so than that which arrogates to itself the right of deciding and limiting educational progress according to preconceived or traditional ideas of what is useful and what is unnecessary.

Yet the question of science-teaching in schools is too frequently thus treated in the present day. "What," says the writer I have just quoted, "when it is not your trade, can be the good of dissecting animals or plants?" He well answers the supposed utilitarian query by the retort, "To

all questionings of this kind there is but one reply. We work for culture. We work to enlarge the intelligence, and to make it a better and more effective instrument." And he wisely adds: "It is always difficult to say beforehand exactly what will turn out in the end to be most useful."

I am afraid a chief element in the work of the educational reformers of modern times must consist in the task of showing the actual need of science-culture to those who might be expected to know fully and well the benefits and advantages of such studies. That the educational leaven has much hard work yet before it, ere ignorance in the lump be wholly leavened, is self-evident. And that the leaven of the future will be chiefly scientific in its character, is a prediction which the present aspect of educational matters and the spirit and tendency of the age together give full warrant for stating boldly. If we think of the rapid and astonishing extension of scientific tastes, knowledge, and appliances, which has taken place within even the past few years, it will readily be owned that the demands of modern culture at least, will insist on the distinct incorporation of the scientific element into the body educational. That boys or girls should leave school ignorant of the grand facts of biology; unable to give any intelligent account of the constitution of the world in which they live, and unlearned in the phenomena of their own existence, is a fact in the present history of education for which the future will have good cause to blush. The ordinary modern school-boy or school-girl, I make bold to say, leaves school, in the majority of cases, as liable to drift into errors, moral and physiological, as did his or her predecessor of fifty years ago. And hence the growth to manhood or womanhood proceeds, without adding to the knowledge of school-days any other than may be purchased in the battle of life, sometimes at the highest and dearest price which experience can pay. The errors of life and thought; the abuse of foods and drinks; much of the vice and immorality of modern times, represent, I think, in greater part, so many consequences of the deficient train-

ing of the school. As professedly giving to the child what will stand it in best stead on its entry into the world at large, educationists, I think, are bound to regulate their work and labour in sympathy with its future life and interests. It is exactly this want of connecting sympathy in modern education, this break of continuity between the education of the school and that of the world, that, in my opinion, most clearly shows our need of biological training. I look in vain in the list of ordinary school-studies; I seek vainly to recall in my own school history any study, save perhaps that of English literature, which can carry the pupil in healthy sympathy from his school directly into the arena of active life. The study of the lives and works of great writers undoubtedly connect the young with the history and doings of their own and of other days, but in an indirect and abstract manner only. Our ordinary modern list of school studies is thus almost as deficient in truly humanising resources as was the educational *répertoire* of the ancient Greek. The education of Alcibiades, as described by Socrates, consisted of letters—reading and writing—wrestling, and music. I can discern in the modern category of ordinary school resources but little, if any, advance on the philological, caligraphic, gymnastic, and musical pursuits of the ancient Greek. The wisdom of the ancient educator consisted in the endeavour to make his pupils really learn the few subjects he possessed. From the multiplicity of our modern subjects, we can only make an attempt to master them. And it is to be noted that amongst all this multiplicity, entailing a too powerful strain upon the intellect of the average pupil, we have not one study which has any power or charm to weld together the school with the world—to bridge over the gulf which, strangely enough, should be regarded as existing between the battle-field of life and the armoury in which the weapons we therein use are forged.

If, however, the study of life-science has one prominent advantage over all other studies, it is that in its nature it acts most powerfully in bringing the present world and its con-

stitution plainly and vividly before the eyes of boys and girls. It excites their interest in life and living things; it suggests trains of thought which extend almost into every department of knowledge which has a claim on human sympathy and regard. And it can provide the young with that knowledge of themselves which is the surest safeguard against the numerous pitfalls that in this exhausting age threaten the physical and mental health at every epoch of life. Thus, if the knowledge and observation of how the every-day and widespread life of the world pursues its course, and that of how life is affected by its environments, cannot bring the young into sympathy with that outer world into which they must sooner or later enter, every other branch of knowledge must assuredly fail in attempting to fill what admittedly is the great blank in our educational mode.

Dr. Youmans, quoting the words of Mr. Wyse, remarks that empiricism reigns very widely throughout the educationist's domain. The capabilities of the child, he complains, are not duly noted and registered so as to afford a basis for the proper direction of educative efforts. And Dr. Youmans maintains that "the art of observation, which is the beginning of all true science," and "the basis of all intellectual discrimination," is "universally neglected." The teacher's preparation, he says, is "chiefly literary; if they obtain a little scientific knowledge, it is for the purpose of *communicating* it, and not as a means of tutorial guidance. Their art is a mechanical routine, and hence, very naturally, while admitting the importance of advancing views, they really cannot see what is to be done about it. When we say that education is an affair of the laws of our being involving a wide range of considerations . . . . that complete acquaintance with corporeal conditions which science alone can give . . . . we seem to be talking in an unknown tongue, or, if intelligible, then very irrelevant and unpractical."

Then, also, I need hardly point out that the mind-training which the study of biological phenomena involves, forms another powerful aid in lifting the pupil out of the dull

mechanical routine of abstract studies, to an intelligent appreciation of his work and place in the world. The effort to train pupils to think for themselves, is confessedly the hardest task of the intelligent teacher; and I have said enough of the method of biological study, I imagine, to show how the science, founded on observation, must induce habits of thought, which should affect the whole educational life of the pupil.

I might also point out how, especially in the case of girls, the study of biology, in its effect of interesting them in the world around, should act as an important means of furthering the after-education of their lives. The boy, with his future destiny as a tradesman or professional man, has less need than the girl of some solid study whereon the mind may rest, and to which it may fly for the intellectual occupation that it must inevitably feel the need of some time or other. As Mr. Hamerton has well said, "To have one favourite study, and live in it with happy familiarity, and cultivate every portion of it diligently and lovingly, as a small yeoman proprietor cultivates his own land, this, as to study at least, is the most enviable intellectual life." And if a study should be sought for which shall most pleasantly aid in the cultivation of the inner life just described, it will assuredly be found more readily within the domain of biology than in any other department of human knowledge. To act as such a mental stimulant; to effectually prevent the occurrence of that miserable disease of female mental existence—*ennui;* to give the mind breadth and tone from the beginning of its cultivation—such are the benefits I claim for the school study of biology, carried in its natural development into the after-life of the pupil of either sex.

That we need biological teaching, therefore, in our schools, I think I may fairly maintain; and that this need should assert itself by demanding the necessary supply, I must also boldly submit. It is for practical educationists—for those engaged in the daily labour of teaching, and of observing what are the necessities of modern culture in its

effects upon the future life of the pupils—to create this demand; to set forth the honest claims of biology to the world at large; and to act as the accredited pioneers of an advance in education which, in the world's school at large, and amongst thinking men and women, has already sown intellectual wealth and freedom broadcast, and with an unsparing hand. My plea is that this advance merely represents the call of the age for school-training in things biological; and that the exigencies of modern life demand the enrolment of the science amongst the means whereby the true end of educative effort may be fulfilled. To aid, encourage and foster the demand for this training, should constitute no unimportant duty of the earnest reformer in educational matters. His labour in this respect will assuredly earn the gratitude of future years; for the effects of the teacher's work tend to perfect the most noble part of man's nature—that "mental lighte" of Spenser, which

> . . . . is heavenly borne and cannot die,
> Being a parcell of the purest skie!

SCIENCE-CULTURE FOR THE MASSES.

An Opening Lecture at a "People's College."

THE opening of a class for the study of zoology in this institution, which may emphatically rank as a "People's College," may be regarded in one sense as marking a significant era in the growth and extension of science-teaching among the people. The great majority of the pupils who attend this class must, from the nature of their daily avocations, take up the study of natural history from reasons other than those which animate the ordinary school-boy or school-girl, or which lead the medical or scientific student to enter a zoology-class. Your aim in enrolling yourselves as pupils, I take to be represented chiefly by an eager and laudable desire to know something of the living beings which are our co-tenants of the world, and which possess relations of various kinds and degrees with ourselves. Some of you may even look beyond the mere acquirement of this knowledge, and possess the idea that, in the abstract, such information will serve as a means for the attainment of what is to be regarded as an infinitely higher aim of mankind—I mean the acquirement of *culture*, or the means whereby we form large-minded, liberal, and, at the same time, correct ideas of the universe, and of the relations of ourselves and our neighbours thereto.

Looking at my position as your teacher, in the second place, I find myself compelled to consider in this discourse

the relations of our studies, firstly, to that training of the mind and intellect we usually denominate by the general term Education; and secondly, to certain plain aspects of every-day life. My colleague, the lecturer on chemistry, would require to offer no such apology or explanation, since the relations of chemistry to the improvement of the arts and manufactures are too obvious to need comment. Nor need you demand from the lecturer on physiology an estimate of the value of the information he imparts to working men and working women. Whoever values that health, which to all men is the best kind of wealth, and which is to very many their chief stock-in-trade; whoever desires the wisdom wherewith to know how to live wisely and well in a physical sense, can require no argument to bring home conviction as to the utility of a knowledge of the laws of life and health. Your studies in English or foreign literature; your close attention to the study of mechanics and natural philosophy, are not only to be commended, but represent, in many cases, absolutely essential details in your daily life and labours. With my own department of study, however, the case is different. You may reasonably inquire what use zoological study can subserve in the case of general students, and what profit can its cultivation ensure? It is to the task of answering these most natural queries that I now purpose to address myself.

Let me, firstly, note, that those who object to study any subject which they themselves deem unconnected with their own special life and avocation, commit the illogical, and I must say illiberal, mistake of seeking to limit their intellectual progress from a very unreasonable motive and cause. Because such persons consider any particular study of no use, or, what is still more absurd, because they think that it cannot be of any future service to them, the study is rejected. But one is naturally tempted to ask of such persons how, without pretending to possess a special gift of prophecy, they can attain to any knowledge of what will or what will not be of service to them in the future? Who can, in the

first place, and as a matter of common sense detail, reasonably assert that they will never be in any position, or placed in any circumstances in which a knowledge of the despised branch will not come handy, and even be of valuable nature to them? Human policy in this respect, and especially that which would take upon itself the office of educational censor, and of deciding according to its narrow lights what should or should not be studied in view of the unknown future, is of a very shortsighted kind. The study we prosecute from a liking for it, and in our leisure time, may in the days of the future become the prop and mainstay of our physical and intellectual life, and may unfold sources of pleasure and gratification to us undreamt of until the occasion calls them forth.

But probably you will agree with me that this mode of arguing for the limitation of studies is not a feasible argument, or one worth while attacking. It carries with it its own condemnation, and in this light we can well afford to leave it. Zoology, however, has more positive and direct aspects in which to present herself for your mental acceptation. For if you ask me now to explain the benefits of its study, I reply, firstly, that its cultivation forms one of the most valued means of mental training that can be found, and that as such it should form an essential part of every liberal educational programme; secondly, that its study has important bearings on commerce and the health of nations; and thirdly, that it involves considerations connected with religion and morality which appeal to every man and woman who counts it a privilege to be able to think and reason as intelligent beings, with minds to cultivate, bodies to conserve, and hopes and beliefs to strengthen and defend. Such a category of aims and attributes cannot be accepted by you unreservedly or without questioning; nor would I wish you to simply take them for granted and without proof or illustration of any kind. Let me, therefore, exemplify to you the chief aspects in which zoological study fulfils the undoubtedly high ends I have just enumerated.

Its study—and indeed I may extend my remarks to include the cultivation of all other branches of natural science—acts, I have said, as an important aid in mental training; that is, in bringing the mind into orderly habits of thought, and in inducing in the mental powers results analogous to those acquired by the powers of the body after a judicious course of physical training. It will not be disputed, I fancy, that the mind, like the body, requires to be trained to its due work—the work of thinking in a reasonable, judicious, and trustworthy manner. Nor will it be denied that, in proportion to the efficacy of this mental training, our minds will more or less effectively perform the work whereunto they are called. We may train the bodily powers judiciously and well, to enable us to undergo the fatigue of ordinary life with less languor and weariness than before. A system of gymnastics may be lawfully and reasonably undertaken by any one, without the slightest intention of qualifying for an acrobatic life. And so with the mind. We may as reasonably hold that the task of mental training is no less a part of every one's duty and lawful labour, than that of ensuring the health of the body by due exercise, daily ablution, or by attention to any of the plain common-sense rules which regulate our physical life.

This system of mind-gymnastics is one which is imperative on all ages and conditions. In no age can its advantages be more thoroughly understood than in this controversial epoch, when the oldest and most respected of ideas are ruthlessly deposed from their niches, and supplanted by new and advanced codes of opinion. To have our young trained to "think," and our elders to judiciously weigh and consider all the matters of life; to teach men and women how to use their reason; to enable them successfully to grapple with the great difficulties of trade and labour, of science and art, of morality and religion—such are the objects which this system of mind-training has in view. And the study of natural science accomplishes these great ends chiefly by inducing orderly habits of thought. The very

essence of this study lies in the cultivation of the observant faculties, and in the true culture of the senses to appreciate, and, through appreciation, to understand and enjoy the objects which are set before the mind.

To observe rightly and truly, and as science teaches us to observe, is a habit which lies at the foundation of all order in mental things; and without this habit of looking at things in their due sequence, thoughts and thinking can only appear as acts and processes which exist but to confuse and bewilder the thinker. And to the young, in their responsible duty—too little thought of in its serious nature both by pupil and teacher—of laying up stores of mental wealth for future use, how great a boon must be the acquirement of these orderly habits in the work of the mind! The great difficulty, I presume, of every educator of youth is not to arouse his pupils' thoughts, not to incite them to think, but to train them so to think that they shall understand, appreciate for themselves, and in due order arrange, for future use, the material which their education furnishes. For the well-balanced mind is like a duly arranged storehouse, where the fruits of each year's industry are not only duly arranged within, but are capable of being brought forth for use in good order and at the proper season and time. I have no intention of depreciating in the slightest degree the value of mathematical and allied sciences as means whereby this mind-training may be effected. I fully recognise the value of such studies; but I make bold at the same time to maintain that in their universality of application, and in their suitability for both sexes, and for minds of all ages, the natural sciences present means of wider application and of fuller use than are included in the studies of exact science. And withal, what argument is needed to enforce the pleasantness of natural-science studies, which bring us into contact with the fairest aspects of this great world, and with all that is lovely and attractive in the surroundings of our lives? If we have no appreciation of the beautiful in nature—which, by the way, we are supposed to seek in our

Highland tour, our sea-side stay, in our holiday time wherever spent—it is high time we should be taught to see the fairness and fulness of the earth. For no more humanising influence than that of the beautiful and good in nature can operate on man. And to remain as one of the dull, unperceiving objects of this world, with no sense of aught beyond the narrow round of our daily life, were surely a practice unworthy the name of humanity and reason. Whilst when we contrast with this latter state that of the mind aided by science to peer into the secrets of Nature's working; when we imagine the never-ending sources of delight and instruction, which in the study of plant or animal life, or in the world itself, are continually appearing, we may well maintain that such a mind must live its short life over and over again, in the fulness of its enjoyment and in its contemplation of the wonders of the universe.

In thus pleading for natural-science studies as initiating a feasible and pleasant system of mental gymnastics, do not, I pray you, mistake the meaning I attach to the term "natural-science studies." By the sciences of natural objects I do not mean the dry bones, and bare, hard details of any scientific system. I do not in any sense wish you to think of science only as a collection of dry, hard facts, arranged in a certain order, and as presenting nothing more attractive than this. No! There is an aspect of science commonly present to the popular mind, in which it appears like the dry skeleton of the museum—uninteresting and unintelligible, save to the initiated few. But science has also its warm, living aspect. The dry facts form, like the skeleton, the mere framework which gives support to the active, pulsating, life-retaining parts of the scientific organism. And if science be taught to you as it should be, you will be led to its valued facts through their connection and relations with the interesting and captivating body of the study. Generalisations will act as the ligaments and muscles to bind the parts together; and throughout the scientific, as throughout the actual living organism, you will be led to

feel how real are the interests, and how wondrously exact in their relations are all the harmonies, of a scientific system.

The science of some, I know, is that involved in the idea of Wordsworth's Peter Bell, whose observation of Nature, as we all know, resulted in the dogma that—

> "A primrose by the river's brim,
> A yellow primrose was to him—
> And it was nothing more."

As Huxley has remarked, it would not have roused Peter a whit from his apathy had he been informed that "the primrose is a Dicotyledonous Exogen, with a monopetalous corolla and a central placentation." Whilst if the botanist continued his encyclopædic chant, he might afford Peter the additional satisfaction of knowing that the flower belongs to the natural order Primulaceæ; that it has oblanceolate, wrinkled, radical leaves; an inferior, gamosepalous calyx; pentandrous stamens; and a syncarpous, superior pistil! As an actual and not merely supposititious criticism upon this mode of regarding scientific method, I may quote a newspaper paragraph, now of some years' date, which says:—"In the Charterhouse examination questions for this year, under the head of botany, the scholar is told to explain the following terms:—Malva has a gamosepalous calyx; a polypetalous hypogynous corolla; polyandrous, monadelphous, epipetalous stamens; and a superior, syncarpous pistil." The reporter adds no observation upon the information he gives his readers; but if we may judge from his silence, the Charterhouse boys had his utmost sympathy and commiseration in their hard estate.

Now all this, I frankly admit, sounds ludicrously enigmatic, and affords a text whereon a sophist might inveigh against the abstruse nature of science and its terminology. But to teach botany merely as a modernised repository of classical roots and derivations, is not the aim or intention of the true botanist. His technical language is as necessary and as useful to him as are the privileged terms of any trade

to the workers therein; but to learn botany does not mean that you shall learn names merely. What the skilful botanist would teach you to look at, to observe, and to note, would be the structure of the flower; the teachings of the microscope with regard to it; the revelations of physiology about it; and its relations to the world in which it is placed. From these points he would lead you further to see how the silent inner life of the plant proceeded from day to day; you would note its growth and its decline; in short, you would find that through the true study of your primrose, you would gain glimpses of worlds and catch gleams of thoughts, too wonderful in the one case for description, and too grand in the other for realisation. You would through this study come to realise the true force of Wordsworth's lines—

> "To me the meanest flower that blows does bring
> Thoughts that do often lie too deep for tears."

Of such a character, also, would be the teaching of the true zoologist. He would lead you to look at animal life and existence, not as a mere collection of dry details, but in all its many and varied phases; and he would thus awaken within you an interest in the world, its tenants—nay, and even in yourselves—that would afford you instruction and delight throughout an entire lifetime.

When, therefore, you think of science, do not picture it to yourself as composed of nothing save the dry-as-dust technicalities of popular notions. Do not think of it, either, as those do, who, as the author of the "Ingoldsby Legends" remarks, see something ridiculous in any one who—

> "Would pore by the hour,
> O'er a weed or a flower,
> Or the slugs that come crawling out after a shower.
> * * * * * *
> Still poking his nose into this thing or that,
> At a gnat, or a bat, or a rat, or a cat;
> Or great ugly things,
> All legs and wings,
> With nasty long tails, armed with nasty long stings."

Think of true science as a living reality; as a faithful expounder of all that is worth knowing and that can be known; as an existing power, ever anxious in its unwearied march for the good and welfare of mankind; and best of all, perhaps, as an ever-willing instructor of all who will come to be taught. I cannot conclude my advocacy of this my first proposition, without expressing the earnest wish that the future may see, in greater detail than the present shows us, natural science taught broadcast in our schools. Let us bend the educational twig in its early growth, that our efforts may be perceptible on the fully grown tree. Let us send our boys and girls out into the world, knowing something of the world, of its wonders, and of themselves, as well as of the proprieties of life, or of the dead languages and modern tongues. I think Carlyle well expresses himself regarding the want of such information, when he says, "For many years it has been one of my constant regrets that no schoolmaster of mine had a knowledge of natural history—so far, at least, as to have taught me the grasses that grow by the wayside, and the little winged or wingless neighbours that are continually meeting me with a salutation that I cannot answer as things are. Why," he continues, "did not somebody teach me the constellations, and make me at home in the starry heavens which are always overhead, and which I don't half know to this day?"

The second point involved in my commendation of natural-science studies, lies in the fact that such studies have important bearings on the prosperity of commerce, and on the health of nations. This proposition admits of proof of the easiest and most direct kind. For if we will only think of the many sources of commercial industry which either take origin from or are very intimately dependent upon the natural objects by which we are surrounded, the cultivation of the knowledge of these objects will at once be admitted to be of the greatest importance from a technical point of view. The extension of botanical science has made us familiar, as Friar Lawrence says, with the "wondrous grace" that lies

hidden and stored up within the tissues and cells of vegetable life; and has ferreted out for us many a valuable aid to the art of the physician in the alleviation and cure of disease. But the case of zoology presents even stronger aspects than that of botany. For I have but to remind you of the multifarious objects of commercial gain and speculation which are derived from the animal world, to show you how zoology relates herself to trade. Our furs and fisheries, our pearls and shells, our fats and oils, our daily food, and our many luxuries, come wholly, or in greater part, from the zoologist's domain. Incidentally, therefore, and in a wide glance, we see how the extension of zoological knowledge may become one with the widening of commerce, and the increase of many branches of profitable industry.

But wider, more typical, and far more striking, are the aspects in which zoology may become related not only to the conservation and protection of our much-cherished industries, but to that highest of all human aims—the conservation and saving of human life itself. Did time permit, I could lead you in an historical ramble backwards to the middle of the seventeenth century, and southwards in imagination to the still beautiful city of Florence, where a certain philosopher-physician, by the name of Francesco Redi, started a controversy, the part fruits of which you and I are reaping in this nineteenth century, and the fuller benefits of which our descendants will assuredly in their turn gain. Redi directed his attention to the solution of the question, whether or not it were possible that living beings could come from things that were dead or inorganic; and gave it as his opinion, and as the result of much careful investigation, that every living form must have originated from something living which preceded it—in other words, that every animal must have had a parent, and that every plant must have come from a pre-existing plant. Prior to Redi's time it had been believed that living things might and did spring from lifeless material. The ancients and his predecessors, for example, believed that the maggots appearing in putrifying meat were generated *de*

novo from the meat itself; whilst Redi, on the contrary, showed his contemporaries, by the simple experiment of placing gauze over the meat, that the maggots in reality were developed from eggs which had been deposited in the meat by parent-flies. Thus a case of what was termed "spontaneous generation"—a stout belief in which was, by the Churchmen of Redi's days, emphatically "nail'd wi' Scriptur'"—was disposed of in the simplest possible manner by the quiet observation of a single student of life-science. We can trace the progress of Redi's doctrine, "*omne vivum ex vivo*," along the line of the intervening centuries, as marked by many a foray and many a stout contest. We follow it from the time of Needham and Buffon, and that of Spallanzani with his "universal germ theory," promulgated to account in his day, as we do in ours, for the production of living organisms in all sorts of out-of-the-way places. And we can best of all witness in our own day, at our very doors, and in our own persons, the beneficial effects of the reform movement begun by the physician of Florence some two hundred or more years ago. For to-day, and in the midst of the great centres of civilization, our sick are being successfully treated on the principles which are essentially those of Redi and his disciples. We find Professor Lister and his followers busied with the "antiseptic system" of treatment, which takes as its keynote and standpoint the fact that the germs of lower animal life and plant life—existing unseen in the air around us but visible to the scientific gaze—are the prime causes of much suffering and frequent death after surgical operations. And proceeding to exclude the germs, as did Redi of old, we now can attempt, and successfully perform, operations for the cure of suffering humanity, which operations, prior to the inauguration of the antiseptic system, would have been deemed in many cases of unjustifiable character. This principle of recognising the "particulate" or material and organic origin of many diseases—or in other words, the "germ theory of disease"—underlies the practice of the most advanced school of modern medical thought.

And if, as I trust I have shown you, these great results of saving and prolonging life have sprung from, and been perfected by zoological observation, you will not require much further illustration of my second proposition, that zoology has something to do with the health and well-being of communities.

But every time you see a child vaccinated, you are also beholding a tacit recognition of the "germ theory," and of the value of biological study and research. The vaccine lymph contains the particles or germs of the mild fever which has so valuable a protective influence on the child. And you are thus simply and intentionally, and with good result, exposing the human organism to the attack of the lower organisms which in more virulent form cause the dreaded small-pox epidemic. In following up the proposal to "stamp out" infectious disorders, we are simply treading in the footsteps of Redi and his successors; and if in the future we are privileged to reach this higher perfection of the physician's art, and to see epidemic disorders finally trodden underfoot, we shall have to thank the labours of biologists and physiologists for thus saving the people from perishing by the fulness and worth of their knowledge.

If also you will read the account—and I know of no subject more attractive to the ordinary reader, as well as to the student of zoology—of Pasteur's researches into the nature and cause of the great silkworm-disease, known as *Pébrine*, which decimates that insect-species, as cholera slays its human thousands, you will discover how a zoological study saved the commercial prosperity of France. Prior to Pasteur's researches, the silkworms died in multitudes from the mysterious epidemic, and blank ruin stared the silk-growers and cultivators in the face. When, however, by careful study of the causes and conditions of the disease, Pasteur had made himself master of the situation, and had found that a minute plant-organism, propagating itself within the bodies of the silkworms and readily conveyed from one to the other, was the cause of the disorder.

his countrymen fully realised the truth of the proverb that "knowledge is power," and that to scientific research was due the salvation of their commerce, and the rescue of their happiness and prosperity.

Allied to the subject of the suppression of the silkworm-epidemic, we may find some details more nearly concerning ourselves, and which also illustrate the value of zoological research in the protection of commercial interests. The vines in France have been literally devastated by the attack of a minute insect known as the *Phylloxera;* and the minds of vine-growers have been much exercised to obtain a certain cure for this pest. The researches of French entomologists are at length being crowned with success, and in a short time we may expect to hear of the repression of this unwelcome visitor. The existence of the well-known "Colorado potato beetle" possesses for our American neighbours and for our own agriculturists a high degree of interest; seeing that in this insect, we have added another to the many foes which already claim the valued tuber as a natural prey. American farmers, however, possess in the State or Government entomologists, allies of the most valuable kind; and the patient study of the insect's structure, and above all of its development, has been rewarded by the knowledge of the best means for its destruction. Our Government might well, I think, take a leaf from the American book in this respect, and institute regularly appointed officials, who, as far as zoological knowledge is concerned, would be qualified to protect our commerce from the inroads and attacks of lowly organised, but occasionally potent, enemies.

If you further wish to see how biology or natural science becomes related to the social welfare of the human race, and if you feel interested in the arguments of those who think that such studies form one of the chief bases for the cultivation of social science and for bettering the condition of the masses, you should read Mr. Herbert Spencer's interesting work on the "Study of Sociology." Whether or not you may agree with all that Mr. Spencer advocates, you

cannot but admire his deft way of showing how the welfare of a nation depends unconsciously on the use it makes of scientific and other kinds of knowledge. No one can doubt the innate truth and applicability of Mr. Spencer's argument, that the life of every organism, the human being included, is strangely analogous to that of the compound organisation we know as society at large; and that the fuller knowledge we possess of the former, the better shall we be able to legislate for the welfare of the latter. In other words, the better a biologist any social reformer is, the more likely will his influence and work in society be of a beneficial kind.

As Mr. Spencer ably remarks, "all social actions being determined by the actions of individuals, and all actions of individuals being vital actions that conform to the laws of life at large, a rational interpretation of social actions implies knowledge of the laws of life." In the second place, "society as a whole, considered apart from its living units, presents phenomena of growth, structure, and function like those of growth, structure, and function in an individual body; and these last are needful keys to the first." Or again, "that everything thought and felt and done in the course of social life, is thought and felt and done in harmony with the laws of individual life, is also a truth—almost a truism, indeed; though one of which few seem conscious." "The Science of Life," he concludes, "yields to the science of society certain great generalisations, without which there can be no science of society at all."

With these remarks I dismiss, and think I may fairly claim to have illustrated and proved, my second proposition, namely, that natural-science studies become correlated in the most intimate manner with the health, and also with the commercial well-being and social interests, of mankind.

I have left myself but a few moments in which to hurriedly dispose of my last proposition, namely, that my subject has important bearings on matters connected with those varied beliefs which, under the common term of religion, belong to the natural estate of man, wherever that

estate is found, and whatever degree of culture it may present. You will probably think I am about to touch on ground which to the footsteps of most men should be labelled "dangerous." But I have no fear that, in anything I may say, I shall offend the susceptibilities of any one who extends to others that liberality of thought and expression he or she must demand for himself or herself. That science of all kinds has intimate relations with religious beliefs, is a statement which none may deny, were they inclined so to do. It needs but a glance at the literature and daily events of our time, to show that the controversial element in modern intellectual life is one which therein attains, if not its maximum, at least a very high phase, of development. And it requires but a British Association meeting, and a speaker free of thought, and plain of speech as well, like Huxley or Tyndall, to set the world at large in a ferment which takes years to subside, if indeed some of the particles concerned can come to rest at all. If, therefore, science and religion have nothing in common, why the disturbance? The fact is, that religious beliefs are too intimately connected with scientific method and scientific affairs, to passively suffer even an attempt at divorce. The religion of our minds is, in truth, based more or less completely on the particular interpretation of nature at which we have arrived, and these two closely connected interests must stand or fall together.

When, therefore, the disturbing elements of scientific assertion and inquiry shock the religious beliefs of the individual, the sect, or the nation at large, what procedure or line of conduct does it become every earnest and cultured person to follow? Certainly not that of bewailing the destruction, apparent or real, of his temples of belief; not that of bemoaning the razing to the ground of those tents wherein he has so long and comfortably dwelt; and not that, assuredly, of asserting that, because his fathers worshipped in this mountain or in that, he must therefore and of necessity do the same. No; if our beliefs are attacked, and if they are worth defending at all, let us be up and doing. Meet your

opponents with their own weapons. Do not go forth with old dogmas to meet scientific truths, as with the armour of mediæval times against the weapons of to-day. Study science for yourselves; meet scientific fact and assertion by counter-assertion and counter-fact. You will find that in science, more, perhaps, than in commonplace things, there are always two sides to every great question; and you will never fight or gain your battle more readily, or more honestly, than by testing every point by your own knowledge, and by opposing to the advance of your adversaries a barrier of like kind to that which forms their most potent means of offence. Thus, if for no other reason than to defend and establish the beliefs dear to you and yours, you should cultivate science-studies; and in no province more than in that of the biologist and zoologist can you successfully labour in this way. From the biological citadels of our day, with their numerous disturbing and perplexing theories regarding matter and mind, have proceeded the attacking parties, whose sallies have most perplexed the camp of orthodoxy; and I could not, therefore, invite you to a better field for study, or to a better place for demonstrating the "other side" to the great questions of the day, than by asking your earnest attention during the session we inaugurate to-night.

Lastly, let me say a closing word in defence of earnest, honest, and sober scientific inquiry in the direction of the subjects I have just been proclaiming as those of vital interest to common religion. I say "defence," for some appear to think that the inquiries of honest science, made in all cases for the intellectual and social benefit of mankind, are fit objects for criticism, not always of the most charitable or just nature. To charge the scientific inquirer with "Atheism," "Materialism," or any other of the numerous "isms" of so-called heterodoxy, which are always ready at the beck and call of the theologian, is generally deemed not only a light, but a very right and just procedure. I am not here to defend unwarrantable speculation, but I do strenuously advocate freedom of inquiry in all cases. I

am continually tempted to remember the remark that, in the battle of the "doxies," "orthodoxy" is too frequently regarded as each man's special possession; "heterodoxy" being somebody else's "doxy." I know that ignorance and superstition are the steadfast parents of misery and unbelief; but I never yet heard it proved that honest inquiry into the ways and works of nature made, or could make, any man or woman the worse for their labour. And a thorough examination of any disputed point will generally do more to clear away the difficulties and dangers of any untoward religious position than any other form of procedure.

Let us, therefore, boldly, yet with all humility, proceed to the investigation of every point, or fact, or theory that comes before us. Let our knowledge grow and increase, setting aims of real worth and value before us, in the spirit of George Herbert's quaint remark—

". . . who aimeth at the sky
Shoots higher much than he that means a tree."

Let the Church and religion, as a noted preacher of our time* remarks, "Take hold of Science and the Arts, and the new facts," and "recognise and regulate the modern appliances of luxury." For Goethe says truly, when he maintains the unity of art, science, and religion—

"Wer Wissenschafft und Kunst besitzt,
Hat auch Religion;
Wer jene beiden nicht besitzt,
Der habe Religion." †

In proportion as religion avails herself of the help of science and its labours to strengthen her position and power, so will she most typically and admirably fulfil her great office in ruling wisely and well the inner and higher life of man. As science progresses, so let religion advance

* Rev. H. R. Haweis's "Speech in Season," p. 18.

† "Whoso has art and science found,
Religion, too, has he;
Who has not art nor science found,
His should Religion be."

with her,—for the world, we shall find, is daily awakening to new beliefs, to the fuller knowledge of itself. The great irresistible tide of human knowledge is sweeping away the old landmarks and resting-places with rapid force. And wise, indeed, are they who, recognising the extension of knowledge as from God, betake themselves with the tide to higher levels of thought, and there construct their dwelling-places anew.

If, therefore, to gain the knowledge which shall make us truly wise in our day and generation, and which may, in turn, affect those who come after us, be a high and honourable calling in all, let us with honesty of heart and purpose try to walk worthy of the vocation wherewith we are called.

[As this volume is passing through the press, Dr. Spottiswoode's presidential address to the British Association Meeting (1878) has come under review. The following paragraph is well worthy the attention of "exclusives" in educational matters, and of persons who refuse to encourage the growth and culture of science in ordinary education :

"To recognise the common growth of scientific and other instincts until the time of harvest, is not only conducive to a rich crop, but it is also a matter of prudence, lest in trying to root up weeds from among the wheat, we should at the same time root up that which is as valuable as wheat. When Pascal's father had shut the door of his son's study to mathematics and closeted him with Latin and Greek, he found on his return that the walls were teeming with formulæ and figures, the more congenial product of the boy's mind. Fortunately for the boy, and fortunately also for science, the mathematics were not torn up, but were suffered to grow together with other subjects. And, all said and done, the lad was not the worse scholar or man of letters in the end. But, truth to tell, considering the severance which still subsists in education and during our early years between literature and science, we can hardly wonder if when thrown together in the afterwork of life they should meet as strangers, or if the severe garb, the curious implements, and the strange wares of the latter should seem little attractive when contrasted with the light companionship of the former. The day is yet young, and in the early dawn many things look weird and fantastic which in fuller light prove to be familiar and useful. The outcomings of science, which at one time have been deemed to be but stumbling-blocks scattered in the way, may ultimately prove stepping-stones which have been carefully laid to form a pathway over difficult places for the children of 'sweetness and of light.'"]

A STUDY OF LOWER LIFE.

As has well been observed, the phrase *Omne ignotum pro magnifico* is not more appropriate or true than its reverse or opposite. Applying the apothegm to zoological science, one of the greatest advantages of natural-history study may be shown to exist in the fact that it directs our attention to new and curious features in the commonest living forms around us, and by aiding both our mental and physical perceptions, largely extends the range of the most commonplace observation. The "sight" of the natural historian is, in fact, anything but "unassisted." On the contrary, it discerns beauty and grace where vision of the latter description could perceive nothing worthy of attention or study. If Pope's dictum, that "the proper study of mankind is man," be accepted as literally true, and as tending to limit human observation to the investigation of its own peculiarities, the zoologist may fitly remind the poet, that the study of lower forms not only assists our appreciation of human affairs, but sometimes actually explains and elucidates points in man's history which otherwise would remain utterly obscure. Thus the spirit of a liberal science is most decided in its opposition to any exclusiveness in the objects submitted to its scrutiny; since, recognising the interdependence of the various branches of knowledge, we learn that the advance of one study really means the improvement of all.

No better illustration of the manner in which a simple study in biology may be made to form a text for the illustration of some facts and points interesting to the world at large, can well be selected, than that comprised in the life-history

of the little animal known as the *Hydra*, or "Common Fresh-water Polype" (Fig. 1). The examination of this common denizen of our pools and ditches may convince the most sceptical that the issues of scientific study are not only varied and interesting, but that they also sometimes lead us to contemplate phases of life and growth not very far removed from some of the most important problems which can well occupy the consideration of the human mind.

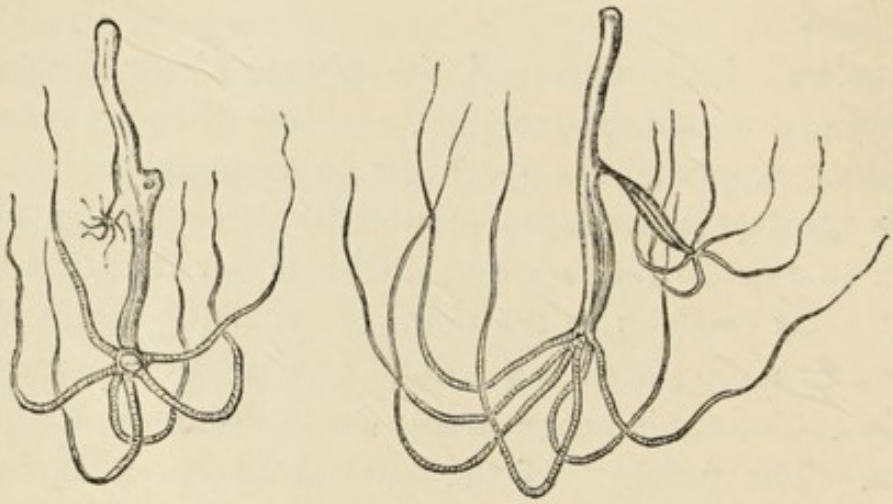


FIG. 1.—Hydræ. (In both figures young hydræ are represented budding from the side of the parent.)

The hydra of the zoologist by no means recalls to mind, as regards its form at any rate, the famous being of mythological lore; although, as will hereafter be noted, in certain of its features, the modern hydra may bear comparison with its mythical namesake. If we take some water from

"The green mantle of the stagnant pool,"

which has become overgrown with lower plant-life and water-weeds flourishing apace under the kindly influences of the summer sun, and place this water along with a small quantity of the weeds in a clear glass vessel exposed to the light, we may be almost certain to find that in due time several small bodies of greenish colour have attached themselves to the sides of the vessel. These bodies will congregate chiefly on the side of the vessel next the light; and, as regards their size, the beings referred to are seen to be by no means large. A length of about a quarter of an inch may

be regarded as a fair statement of their average dimensions; although occasionally a specimen may greatly exceed the proportions of its neighbours, and exhibit a length of half an inch, or more. Examined by aid of a hand-lens, each of these little organisms or hydræ is seen to possess a tubular or cylindrical body, which is attached by one extremity to the glass or duckweed, and which exhibits at the opposite and free extremity, a mouth-opening, surrounded by a circle of arms and tentacles. These latter are delicate thread-like organs, which, in the undisturbed and natural state of the animal, remain outstretched in the water. In the common or green hydra, the tentacles are not disproportionately developed as regards the body; but in certain other forms or species, in which the body is coloured brown (*Hydra fusca*), the tentacles are very long, and the animal obtains, in consequence, the distinctive name of the "Long-armed Hydra" (Fig. 1).

The observation of the common incidents of the hydra's life reveals certain interesting features, which assist us in some degree in the appreciation of the nature and structure of these organisms. When the tentacles are touched, they at once contract and shorten, and the body also shrinks or shrivels up into a somewhat rounded mass. This simple fact proves to us that the hydra is sensitive to outward impressions—a feature in its history which is of high interest when we endeavour to understand the nature and relations of the nervous system of higher animals. That the hydræ are also sensitive to more delicate impressions, is proved by their clustering most thickly on that side of the glass vessel which is next the light. If the hydra is left in an undisturbed condition after being thus irritated, the body and tentacles will become elongated and expanded, and will once more resume their normal condition. That the polypes are not permanently rooted or attached to the weeds on which they are commonly found, may be proved by the simple observation of their habits. They may be seen to detach themselves from fixed objects, and to move slowly about in leech-like

fashion, or, like the "looping" caterpillars, by alternately fixing and extending the mouth and root-extremity of the body; whilst occasionally they may be seen to float listlessly, with extended tentacles, amid their native waters.

When any minute animal, such as a water-flea, or some similar organism, comes in contact with the tentacles of the hydra, an interesting series of acts is witnessed. The tentacles are then observed to act as organs for the capture of prey; the victim being seized and conveyed by their contraction towards the mouth of the animal, within which cavity it finally disappears from view. That the hydra, therefore, possesses instincts common to all forms of animal life, high and low alike, and which lead it to supply the wants of its frame, cannot be doubted; and Schiller's maxim, that hunger is one of the powers that rule the universe, may thus be aptly illustrated within the small domain and in the simple life-history of the hydra.

As might be expected, the prey at first struggles violently to escape from the clutches of its captor; but after a short period the struggles become less marked, and the captured animal may be noted to become somewhat suddenly helpless and paralysed. The observation of these details leads us to expect that the hydra possesses some offensive apparatus, through the action of which the capture of prey is facilitated. And an examination, by aid of the microscope, of the tentacles of the polype, and in fact of its body-substance as well, would reveal the presence of numerous minute capsules, named "thread-cells," which are developed in the general tissues of the body. Each of these curious little cells consists of a tough outer membrane, within which a delicate thread or filament lies coiled up amidst fluid. When one of these structures is irritated, as by pressure, the cell is observed to rupture, the thread being thrown out or everted, and the fluid at the same time escapes. A thread-cell of the hydra in its ruptured condition appears as an oval capsule, having attached to one extremity the thread, which is provided at its base with three little spines or hooks. The

consideration of the structure and functions of these thread-cells clearly indicates their offensive nature. Each may in fact be regarded as representing a miniature poison-apparatus; the "thread" being the dart or sting, and the fluid constituting the venom. The prey of these polypes has little chance of escape from the attack of these cells; since, wounded by the threads, which doubtless become attached to its body by the hooks, and poisoned by the fluid, even animals of tolerably large size when compared with the hydra, may be seen to succumb to its attack. The polypes are thus noted to be singularly well provided as regards offensive apparatus, the particular form of action of which reminds one, in some degree, of the famous "lasso" of Western nations. And it is, at the same time, interesting to note that thread-cells of essentially similar nature to those found in hydræ confer on the jelly-fishes and allied forms the stinging powers which render these beings the terror of tender-skinned bathers.

The internal structure of our polype is of the simplest possible description. It may seem strange to talk of an animal body which lives and grows without any of the structures or machinery we are accustomed to associate with higher animals. Yet the hydra exemplifies the former condition, since we might accurately enough describe its body as consisting of a simple tube (Fig. 2), the interior of which contains no organs of any kind, and which communicates with the outer world through the mouth (*d*). If we further suppose that the walls of this tubular body are composed of two closely applied layers or membranes (*a*, *b*)—the outer somewhat dense and tough, and the inner of more delicate nature—we shall have formed a broad but accurate idea of the physical constitution

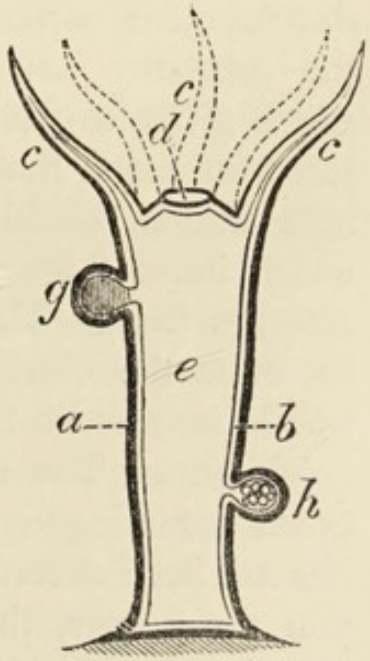


FIG. 2.—Diagrammatic section of hydra.

of these polypes. When the prey or food is swallowed, it therefore passes into the interior (*e*) of the tubular body, which evidently serves as a stomach-sac. Here the morsel is digested or dissolved, and as the result of this process, a fluid perfectly adapted for the nourishment of the polype is formed. This fluid, or blood, is kept circulating throughout the interior of the simple body by the constant movements or vibrations of numerous minute processes named *cilia*, which exist like a fringe on the lining membrane of the body-cavity, and which therefore perform the functions of the heart of higher animals. Thus it may be said that every part of the hydra's body is brought directly into contact with this nutritive fluid; since we note that the fluid is transmitted from membrane to membrane and from cell to cell by the process of imbibition. In this manner, then, does the hydra repair the continual waste of its parts, this process of waste being the inevitable result of the acts and functions of every living being, and the invariable concomitant of life itself.

It is interesting to note that the green colour commonly seen in the bodies of these animals is produced by the development, within the cells of their tissues, of particles of the substance named *chlorophyll*. This substance is that which gives to plants their green hues; and it forms a subject for remark, that the body of the hydra, a true and veritable animal, should be coloured with the same substance which imparts the green hue to the duckweed to which it attaches itself. The recognition of this fact may also serve to show the close resemblance in chemical composition which may exist between some animals and their plant-neighbours. The exact use or function of these particles of green colouring-matter found in the tissues of the hydra, has not been determined. But it is not at all improbable that the polype, through the possession of this green substance, may, like plants, be able to utilise certain of the waste matters of its body, and notably carbonic acid gas, and to elaborate such matters into useful nutriment.

We have already noted that the hydra possesses the power of appreciating sensations, since it shrinks when touched, and exhibits other proofs of its sensitiveness. In the possession of this power, the polype resembles some plants, and most, if not all other animals, including man himself. Broadly stated, this power which the hydra possesses may be regarded as presenting us with the idea of a nervous system in its simplest phase. The functions of such a system may be summarised in the statement that it is adapted for bringing the animal into relation with its surroundings. We thus say that the nervous system exercises the function of "Relation;" whilst, from the fact that the animal performs this function through impressions being made upon it, we are also accustomed to speak of the nervous power as exercising the function of "Irritability." This power, in fact, stands mediately between the animal and the world in which it lives. The higher we ascend in the animal scale, the more perfectly do we find the nervous system adapted for placing the animal in possession of a knowledge of its environments; although, as will be presently remarked, the differences between the nervous powers of higher and lower animals are to be considered rather differences of degree than of kind.

But as an examination of the hydra demonstrates to us, the view just taken of the nervous functions can hardly be considered of complete kind. For we find that the polype, when touched, is enabled to act upon the "knowledge" or "sensations" which the touch conveys; since its tentacles contract and its whole body shrinks as if in irritation and alarm. The reception of a sensation by the nervous system is therefore accompanied by a power of acting upon "information received;" and it cannot be doubted that a certain and definite correspondence must exist between the impression and the act it evokes. Indeed, amongst lower forms of animal life this correspondence is not only exceedingly well marked, but constitutes in itself the sum total of the nervous functions in such beings. But the

highest animals, including man himself, may be said to acquire a knowledge of their surroundings in an exactly similar manner. When we talk of exercising our senses, or when, to use the comprehensive term, we speak of "feeling,"—we are simply expressing the idea of obtaining a certain knowledge of our environments, and as a result, we are further enabled to act upon that knowledge in ways and fashions relative thereto.

Some such ideas as those just stated, have given rise to the conception—widely known and discussed in these latter days under the name of the "automatic doctrine"—that the acts of all animals, including those of man, "the paragon of animals," as Hamlet terms him, bear in reality a much closer relation to their surroundings than they are generally supposed to possess. The simple acts of a hydra's life, and the most intricate operations of the human mind; the nervous action which enables a polype to obtain a particle of food, and the nerve-changes evolving thoughts which emanate from minds like those of Goethe, Shakespeare, Newton, and Milton, and which will re-echo in the minds of men throughout all time, are thus held to present, when analysed out to their fullest extent, a striking community of origin. The polype is said to be really an "automaton," in that it simply acts through its nervous powers as these powers are first acted upon by outer impressions; and man must also be held as sharing this automaton nature, since his acts are determined in like manner by outward circumstances, and simply by the succession or order in which these circumstances have been impressed upon his nervous centres. "The question is," as Dr. Carpenter has expressed it, "whether the Ego is completely under the necessary domination of his original or inherited tendencies, modified by subsequent education; or whether he possesses within himself any power of directing and controlling these tendencies." Or as the case is put by Professor Huxley, "Descartes' line of argument is perfectly clear. He starts from reflex action in man—from the unquestionable fact

that, in ourselves, co-ordinate purposive actions may take place without the intervention of consciousness or volition, or even contrary to the latter. As actions of a certain degree of complexity," continues Huxley, "are brought about by mere mechanism, why may not actions of still greater complexity be the result of a more refined mechanism?"

As may readily be noted, this theory of the physical origin of man's mental powers necessarily carries with it a special and peculiar interpretation of man's moral nature and obligations. For it implies the belief that we cannot act in any other fashion than is determined by our character; and this latter in its turn results from or is developed by the action of outer and physical circumstances upon the organism. Consciousness, or that knowledge of Self, which most people hold lies at the root, foundation, and direction of our mental existence, except as a secondary matter, is thus put altogether out of court; and the powers of mind come in this view to represent so many effects of the long-continued action of experience and custom in inducing various mental states, as the result of certain combinations of outer impressions.

The fierce conflict to which the discussion of this automatic doctrine has given rise can be readily understood and explained. It is no light matter to assert that the mental powers and intellect of man are after all simply material in their nature and origin, and that they merely represent a high development and modification of the simple nervous impressions seen in lower states of existence. Yet there is a latent truth in this view of the matter, which, when recognised and brought into relation with facts and ideas external to such a theory, presents us with a rational explanation of the origin of man's mental nature. Whatever may have been the origin of man's intellect, there can, firstly, be no question of the wide nature of the gulf which exists between the human type of mind and the instincts of all other forms of life. Even if man's total origin from a lower form or forms were a

proved fact, the recognition of the fact could never lessen by an iota our estimation of the immense superiority of man, regarded as a thinking, intelligent being, over his nearest allies. But such recognition would be by no means synonymous with the admission that the gulf between the human and animal type is impassable. Preconceived notions and ideas might, and probably would, revolt against such an idea of the origin of man's mind; but the spirit of a liberal science would content itself with the fact that no considerations regarding its origin and development can detract from the high superiority of the human over every other type and form of nervous functions.

As the Duke of Argyle remarks, in an interesting article entitled "On Animal Instinct in its relation to the Mind of Man" (*Contemporary Review*, July, 1875), "If it is no contradiction in terms to speak of a machine which has been made to feel, and to see, and to hear, and to desire, neither need there be any contradiction in terms in speaking of a machine which has been made to think and to reflect and to reason. . . . It seems to me that the very fact of the question being raised whether man can be called a machine in the same sense as that in which alone the lower animals can properly be so described, is a proof that the questioner believes the lower animals to be machines in a sense in which it is not true. . . . The notion that, because these (mental) powers depend on an organic apparatus, they are therefore not what they seem to be, is a mere confusion of thought. On the other hand, when this comes to be thoroughly understood, the notion that man's peculiar powers are lowered and dishonoured when they are conceived to stand in any similar relation to the body, must be equally abandoned, as partaking of the same fallacy."

Turning next to inquire into the existence of automatic or instinctive acts amongst animals, we may in the first place be surprised to note that in the hydra, sensitive although the polype is seen to be to outward impressions, no traces of a nervous system, or of analogous organs, can

be discerned. The polypes are thus literally sensitive, without possessing any appreciable or visible apparatus for exercising that sense. The hydra is, however, by no means alone in this respect. The sea-anemones (Fig. 3), animals nearly related to the hydra, are equally, if not more sensitive than the latter; since the anemones may be seen to

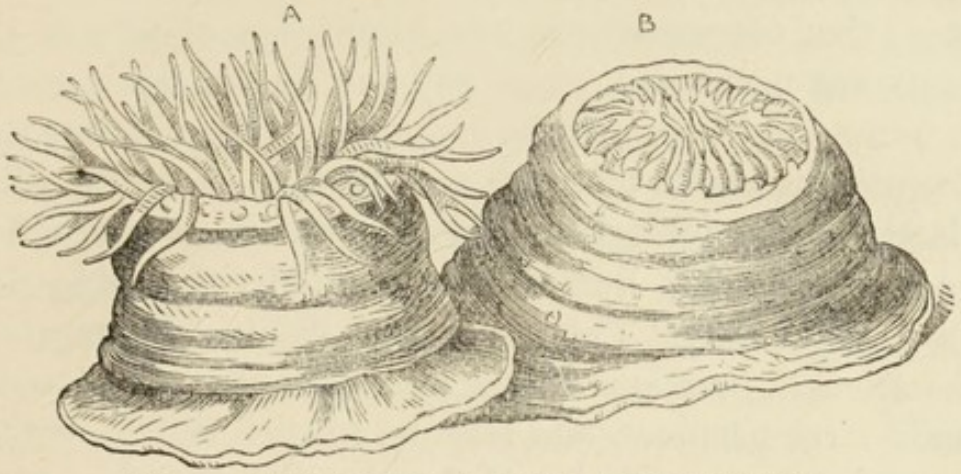


FIG. 3.—Sea-anemones: A, expanded; B, contracted.

withdraw their tentacles and to contract their bodies if the light falling upon them be suddenly intercepted, as by the shadow of a passing cloud. Yet the anemones, like hydræ, want a definite nervous system. But certain plants may also not only exhibit symptoms of irritation or sensitiveness when touched, but may act upon their sensations,—features well exemplified by the drooping leaflets and leaf-stalk of the sensitive plant; by the closure of the leaf of the Venus' fly-trap; and by definite movements of contraction observed in other plants, resulting from alterations in temperature. In plants, it is almost needless to remark, no nervous system has been demonstrated to exist; and no botanist has even suggested the possibility of the existence of nervous tissues within the limits of the vegetable creation. Yet, tested by the acts of their lives, one might truly say to such plants with Shakespeare,

"Sense you have,
Else could you not have motion:"

and judging from the sensitiveness of the plants just mentioned, the conclusion appears inevitable, that plants

possess means for receiving and for acting upon sensations, and that, in this light, they may be fitly compared with the hydræ and all lower animals in which a nervous system has not been demonstrated to exist.

It is perfectly clear that the acts of these plants, and of such animals as the hydræ and sea-anemones, must be considered of purely automatic kind. We cannot reasonably suppose that consciousness, or a knowledge of why or how the acts are performed, plays any part in the life-history of such forms. And even if it be maintained that mere sensation and consciousness in this case are identical or closely allied, the latter quality must be so far removed in its nature from the consciousness of humanity, as to render the comparison quite inadmissible. The hydra and its neighbours are in truth automata pure and simple, in that they are stimulated by outward circumstances, and respond to such stimuli, without possessing any appreciation of the why and wherefore of any act of their lives.

But that automatic acts may represent the whole life, or a very large share of the actions of animals much higher than these polypes, can readily be demonstrated. A centipede, for example, when cut in halves, will exhibit lively and independent movements in each half of its body,—a fact readily explained when we note that each joint of the animal's body possesses a nerve-centre, which supplies the surrounding parts with sensation. And if the central portion of the nervous system of the animal be destroyed whilst its body remains intact, the front portion of the body and the front legs may stop at the sight of an object, whilst the legs belonging to the portion lying behind the division of the nerves, will continue to push the animal forwards. Here the action of the hinder legs is purely automatic. But in the insect-class we find many examples of automatic acts, performed naturally, and which at first sight actually seem to suggest the development of a high intelligence. The young insect, liberated from its chrysalis state, and necessarily destitute of all experience, performs at once and perfectly all

the operations of its life. Even in the case of the wonderful operations exemplified by the ants, bees, and their allies, we find pure examples of automatism (see note, p. 70). The acts of these insects are in reality determined by surrounding conditions; and each insect, destitute of all previous knowledge, enters upon its duties and discharges them with unerring skill, immediately after its birth, and when it has attained its full development. Here, therefore, there is no guidance by experience, and there can be no intelligent appreciation or consciousness of the nature of the duties performed. Indeed, as Dr. Carpenter has well remarked, in speaking of the adaptation of the insects to their duties, "the very perfection of the adaptation again, is often of itself a sufficient evidence of the unreasoning character of the beings which perform the work; for if we attribute it to their own intelligence, we must admit that this intelligence frequently equals, if it does not surpass, that of the most accomplished Human Reasoner."

Amongst the higher animals, automatic acts are also readily exemplified. The young of many aquatic birds—*e.g.* the dippers—take to the water and swim and dive with as great facility on their first immersion, as after a prolonged experience. Whilst no less extraordinary is the instinctive or automatic manifestation by young birds of certain traits of character, such as those of counterfeiting helplessness or a wounded state, or of remaining still and motionless, and protected by its colour, under the very eye and nose of the enemy.

Turning, lastly, to the investigation of man's actions, as a type of those of higher animals generally, we find that physiology makes us acquainted with the presence of many automatic acts and movements in the common existence of humanity. The earliest nutritive acts of the infant are purely automatic; they are performed without the slightest appreciation of their meaning, and without any intelligent conception of their order and succession,—that order and succession being really determined by the outward or physical conditions of the infant's life. The person who walks along the street absorbed in a reverie or day-dream, but who, nevertheless,

and all unconsciously to himself, avoids his neighbours and the lamp-posts, is so far an automaton in that the complicated muscular movements of his limbs, and the general equilibrium of the body are being co-ordinated independently of his knowledge and will. And very many other examples might be cited in support of the allegation that automatic acts and movements play a very important part in the existence of higher animals.

Thus we may hold it to be fully proved that automatism has a veritable existence, and really forms the basis of all nervous acts. That in itself it constitutes the essence of all the intellectual acts of man is, however, a conclusion by no means involved in the preceding statement. That the "physical" act of executing any movement—such an act being exemplified by the change which nerve-tissue undergoes, even in the act of thinking—is connected and associated with another action, the "mental" act, cannot be doubted, if it be admitted that we possess a rational cognisance of ourselves and our actions. And that the "mental" act in the higher animal may represent the actual source, origin, and direct or indirect cause of the physical act, is also, as far as human cognisance can assure us, an undoubted fact. Hence, we are forced to conclude that, however this mental act has originated in man, it has really come to assume a place, dominion, and power in the constitution and working of his nervous system which is utterly unrepresented in any lower form. If man may be proved or believed to be "the slave of antecedent circumstances," it must also be admitted that a new power has arisen or has been developed out of the action upon his nervous system of these same circumstances, this power being represented by the formation of the conscious, self-knowing Ego or Mind.

That hereditary influences and inherited constitution possess a powerful influence in moulding the mind, as they undoubtedly operate in producing a certain conformation of body, is but a reasonable belief. The formation of the character of the child—and, through the development of the latter,

that of the man also—must accordingly depend to a certain extent upon influences for which neither are in any way responsible, and over which, in the first instance, neither can have any control. That automatic acts, derived from and moulded upon preceding acts of like character, make up the chief part of human existence in a savage state, is a statement of readily proved kind. Man in his primitive condition can hardly be supposed to speculate much concerning himself, but has his acts directed and controlled to a greater or less extent by outward circumstances, and by the exigencies which his physical surroundings induce. But, as in the highest phases of man's physical development, so in his mental nature, new features appear; and explain it how we may, we are forced to recognise that out of the mere instinct and pure automatism of his earlier state, has been developed the fuller knowledge and command of Self, which brings with it the moral sense and all the noble conceptions of his race;—a progress of mental development this, imitated by the mental advance of man as he emerges from the savage to the civilized state; and typified in a closer fashion still by the growth and progress of the infant's mind, from the indefinite mist of unconsciousness, to the clearer light of a rational intelligence. The development of the child's intellect in this view, presents us with a panoramic picture of the stages through which we may conceive the mind of man to have passed in its progress, from the condition of pure or hydra-like automatism to the higher phase in which he obtains a knowledge of himself. And it seems to me that only through the ideas involved in some such theory of the origin of man's mental powers, can we reasonably explain the possession by lower animals of many qualities and traits of character which we are too apt to regard as peculiar to man. The community of instincts in man and lower animals, affords a powerful argument in favour of the idea that the higher intellect of humanity has originated through the progressive development of lower instincts.

Our survey of the relations and origin of nervous acts

has led us far afield into the domain of metaphysics, and has in some measure alienated us from our more sober study of the commonplace hydra. We have, however, noted that our polype forms a text for the illustration of some points highly interesting to humanity at large; and in what remains to be told of its life-history we shall find exemplified several other features of highly interesting, if not of most remarkable kind.

Of these latter features, probably the most notable relate to the various modes in which the hydra may reproduce its kind. We have already noted how the animal makes provision for the wants of its own existence, and how it repairs the local and continually occurring death of its parts by the reception and digestion of food, and by the circulation of the products of nutrition from cell to cell of its body. Such a view of the polype's organisation, however, presents us, after all, with only a one-sided aspect; and, like most partial and incomplete surveys of things, our ideas of the polype's life-history are apt to become erroneous and liable to misconstruction. Every living being, in addition to the duty imposed upon it of repairing its individual loss of substance, has to bear a share in the reparation of the losses which death is the means of inflicting on its species or race. Through the processes of reproduction and development, new beings are ushered into the field of active life, to take part in carrying on the life of the species, just as the process of nutrition made good the wants and supplied the exigencies of the single form.

The Harveian motto, *Omne ex ovo*, holds good in the case of the hydra, inasmuch as we find that animal, in summer more particularly, may be seen by aid of special organs (Fig. 2, *g*, *h*) to produce eggs, from which, through a process of regular and defined development, new hydræ are produced. But we may concern ourselves less with this normal phase of development, than with certain strange and out-of-the-way features which our polype may be observed to exhibit. There are very few persons, outside the ranks of biologists, who would be inclined to associate a veritable process of

"budding" with the functions of an animal organism. Yet in the hydra, in a large number of its immediate neighbours, and in a few other groups of the animal world, a veritable process occurs, whereby from a parent-body certain portions are gradually budded out, to assume in due time the form and likeness of the being which has produced them.

Thus when the hydra is well nourished, little projections may be observed to sprout from the side of the body. As these projections increase in size, each is seen gradually to develop a mouth and little tentacles at its free end, and in due time presents us with the spectacle of a young hydra which has budded from the parent (Fig. 1), to which, save in size, it bears a close resemblance. Sometimes, also, it so happens that this young bud grows and multiplies like its parent, and produces a bud in its turn. So that we meet in such a case with a veritable genealogical tree, presenting us with three generations of hydræ, adhering to each other and connected by the closest ties of blood-relationship. Not only, therefore, is our hydra coloured like a plant; it also closely imitates the plant-creation in certain aspects of its life-history, and, by the process of budding, converts itself from a single into a compound animal. So long as the young buds remain attached to the parent, so long does communication exist between the simple body-cavities of the connected individuals; and the compound organism is thus nourished by as many mouths as there are animals in the colony. But this connected and compound state is not permanent in the hydra,—although, as seen in the zoophytes, it presents us with a complicated and enduring fabric, numbering, it may be, many hundreds of included animals, which have been produced by a process of budding. Sooner or later the young hydra-buds will break contact with the parent-body, and will float away through the surrounding water on their way to root themselves to fixed objects, and to begin life on their own account.

More astonishing by far, however, is it to find that we possess the means for propagating hydræ at will. We may

actually imitate the experiment performed of old by that redoubtable demi-god Hercules; since, by the artificial division of our polype, we may give origin to new beings, and may multiply the species through the destruction of a single individuality. These curious results, also obtained by experimentation on the sea-anemones, were first made known to the world at large by Trembley, an Englishman, who was tutor to the two sons of Count Bentinck, and who, whilst resident at Geneva about the middle of last century, contrived to find time and opportunity for experimentation upon these polypes. In 1744 Trembley published his memoir on the hydra, and we shall leave the ingenious naturalist to detail in his own language the method and results of his experiments. Surprised at the curious life-history and plasticity of these creatures under almost every condition, Trembley resolved to ascertain if the reproductive powers of hydræ were further allied to those of plants, in their ability to reproduce their like by being divided into "slips." Having divided a hydra crosswise, and nearer to the mouth than to the root-extremity, he put "the two parts into a flat glass, which contained water four or five lines in depth, and in such a manner that each portion of the polyp could be easily observed through a strong magnifying glass. . . . On the morning of the day after having cut the polyp, it seemed to me that on the edges of the second part, which had neither head nor arms, three small points were issuing from these edges. This surprised me extremely, and I waited with impatience for the moment when I could clearly ascertain what they were. Next day they were sufficiently developed to leave no doubt on my mind that they were true arms. The following day two new arms made their appearance, and some days after a third appeared, and I now could trace no difference between the first and second half of the polyp which I had cut."

Experimenters, since Trembley's time, but following in the track of that ingenious observer, have cut and divided the hydra in almost every possible fashion, with the result of

finding that the polype possesses an unlimited power, not only of resisting injuries, the least of which would be sufficient to ensure the death of any ordinary organism—plant or animal—but of utilising the results of mutilation in the multiplication of its race. As a final feature in the hydra's history, we must allude to one point which perhaps we should deem as even of a more extraordinary kind than the traits of character just described; this point being exemplified by experiments of Trembley's, in which he actually succeeded in turning these polypes inside out, without in the slightest degree interfering with their ultimate vitality. In 1742 Trembley first succeeded in his endeavour to place the polype *hors de combat*, and his plan of procedure was of so ingenious a nature, that we may again let him speak for himself. He tells us that he commenced operations "by giving a worm to the polyp, and put it, when the stomach was well filled, into a little water which filled the hollow of my left hand. I pressed it afterwards with a gentle pinch towards the posterior extremities. In this manner I pressed the worm which was in the stomach against the mouth of the polyp, forcing it to open,—continuing the pinching pressure until the worm was partly pressed out of the mouth. When the polyp was in this state, I conducted it gently out of the water without damaging it, and placed it upon the edge of my hand, which was simply moistened in order that the polyp should not stick to it. I forced it to contract itself more and more, and, in doing so, assisted in enlarging the mouth and stomach. I now took in my right hand a thick and pointless boar's bristle, which I held as a lancet is held in bleeding. I approached its thicker end to the posterior extremity of the polyp, which I pressed until it entered the stomach, which it does the more easily since it is empty at this place and much enlarged. I continued to advance the bristle, and, in proportion as it advanced, the polyp became more and more inverted. When it came to the worm by which the mouth was kept open on one side, and the posterior part of the polyp was passed through the mouth, the creature

was thus turned completely inside out; the exterior superficies of the polyp had become the interior."

The operation thus described was occasionally frustrated in a manner by the hydræ; since, in less than an hour, Trembley observed some specimens to succeed in restoring themselves to their natural position. This observer prevented the latter result in one or two instances, by spitting the polype,—a needle being passed through the body close under the mouth; and when thus impaled, the animal, with wisdom which humanity might sometimes advantageously imitate, accommodated itself without murmur to the exigencies of its position. Trembley appears to have taken the state of the appetite of his polypes, as a very natural and rational test of their state of health after being operated upon. He remarks that a hydra which had been turned inside out ate "a small worm two days after the operation;" whilst to conclude, he tells us that "the same polyp may be successively inverted, cut in sections, and turned back again, without being seriously injured." After the recital of these experiments—to which, seeing that the hydra possesses no traces of a nervous system, the most tender-hearted anti-vivisectionist could offer no objection—we may well question whether the hydra of zoology is not, after all, a more wonderful animal than its mythical and fabulous namesake.

The attentive consideration of these features in our polype's biography, naturally suggests some remarks on the nature of beings which possess powers so wondrous of resisting and of recovering from serious mutilation and injury. In virtue of what description or amount of vitality, it may be asked, or on what supposition, can we account for the amazing reparative powers of the hydra? The answer to this question may be prefaced by the remark that the hydræ are not singular in respect of their fertility under apparently disadvantageous circumstances. As already remarked, the sea-anemones may be subjected to the ordeal of trial by slicing and chopping, with favourable results as far as the artificial increase of the race is concerned. But animals occupying

a much higher place in the scale of animal society may also exhibit reparative powers of a singular and extensive kind. A star-fish, for example, need not in the slightest be disconcerted by the loss of its rays. For these astronomical beings may be met with on the sea-beach in the condition of grim old warriors who have left portions of their organisation on numerous battle-fields, and possessing, it may be, but a single intact ray,—the other four rays having most likely served voracious cod-fishes, as dainty, if somewhat tough, morsels. Or again, the crabs and lobsters may be cited as examples of animals to whom the loss of a limb less or more makes but little difference. Indeed, the lobsters seem to part with even the largest of their members on very slight provocation; for a sudden noise, such as the report of a cannon, has been known to serve as the exciting cause of dismemberment. Or lastly, to select animals of a higher grade still, it is well known that our familiar eft or newt may lose half of its tail without suffering any permanent loss; the process of reparation and growth in the star-fish, in the crab and lobster, and in the newt, in due time providing new members for old ones. Man, in one sense, may well envy his inferior neighbours these reparative powers; since even in the comparatively small matter of teeth, he has to place himself under the tender mercies of the dentist in the event of loss, and must view with hopeless gaze the disappearance of the last joint of a finger or a toe.

Although the physiologist is unable in the present state of his science to explain the exact and intimate manner in which the hydra and other animals reproduce their tissues, we may, nevertheless, by a very homely simile, contrive to gain a broad idea of the nature of these reparative powers. We must thus firstly note that the process is simply one of nutrition or nutritive growth, carried out to a high degree of development. We are dealing, in fact, in such cases, with an increase of the ordinary powers and processes whereby, as we have already seen, the bodily waste is made good. But at the same time, we observe that such powers and processes

vary in extent throughout the animal world, doubtless in obedience to some law, which determines the closer interdependence of the different parts of animals, the higher we advance in the zoological scale. To put the matter in its plainest light, we may compare the organisation of the hydra and its neighbours to that of a "republic." The essential feature of this form of human association, I take to be comprised in the broad statement that one man or member of the republic is as good as any other man or member; and that each man (theoretically) has an equal voice with his neighbour in the conduct and rule of the state. In that form of government to which the name of "limited monarchy" is applied, the levelling, equalising tendencies of the republic are wanting. Every one person is not equal in rank or value to every other person, but, although each has theoretically his definite place and voice in the rule and management of the state, some assume a higher rank and power than others. Applying the comparison to the case before us, we can at least form an intelligent conception of the relative nature of the powers of the lower and higher animal. The hydra emphatically represents an animal democracy—a veritable republic. One part is as good as any other part, when demands are made upon it for reparation and growth; and this quality of self-support and independence, this power of existing separate from other parts, forms the especial feature in virtue of which the organisation of the hydra becomes so plastic under the most trying conditions, and so well adapted in virtue of its inherent powers to rebuild the disorganised fabric. In man and higher animals, on the other hand, we find exemplified a form of vital government represented most nearly by the limited monarchy. Here, whilst each portion of the organism possesses a certain share in the constitution and management of affairs, some parts—and notably the nervous system—take precedence of, and serve to unite the others. The principle of regulation and interdependence thus involved, simply renders it impossible for all parts to possess equal reparative powers. Hence, lost

parts are not commonly replaced in higher animals, for the reason that the loss has entailed a separation from other parts possessing no inherent powers of reproduction within themselves, but deriving their sustenance and life—as did the lost parts—from the entire, connected, and interdependent system.

The process of growth and the harmonious relation of organs and parts observed in hydræ and in most other living beings, suggests, as a final feature worthy of note, the consideration of what is implied in the growth and increase of living organisms generally. The body of the hydra was seen at an early stage of our investigation to be composed of definite layers or tissues, and these tissues again to be made up of minute elements or "cells." The general growth of the hydra, therefore, in reality means the increase of each of its minute parts, and when we reflect on the law of growth thus evolved, we may be puzzled to account for or explain the nature of the mysterious power which is seen to operate in controlling and directing in so remarkable a manner the functions of this humble organism. In the hydra, then, as representing a single organism,—or still better in the zoophyte, which consists of a colony of animals, numbering it may be many hundreds, united in a close structural relationship,—or in the bodies of higher animals still,—we find the principle of the perfect co-operation of many different parts to one harmonious end,—namely, the maintenance of the organism,—beautifully exemplified.

In most of the grave affairs of life, man strives to secure the co-operation of his fellows, but humanity, unfortunately for the success of man's schemes, exhibits many little weaknesses and failings; and the common tendency of one mind to assert its supremacy over the others may result in the entire demolition of the co-operative idea. Man might, therefore, well strive to imitate the unselfish union of aims and ends which a zoophyte-colony exemplifies, or which the vital mechanism of his own tissues illustrates. When the political economist shall have succeeded in inaugurating a

scheme of human co-operation for any purpose on the successful model of nature's colonies in lower life, he will have good cause to congratulate himself and his fellows on having solved one of the paramount difficulties which beset his day and generation.

But, lastly, the true nature of the growth of a living being can only be fully understood if we for a moment compare that process with the increase of a lifeless body. No better, truer, or more eloquent description of the differences between the growth of the living and that of the non-living, could well be found than in the following passages, culled from an essay* by one of the most liberal thinkers and advanced scholars of our day, and intended to illustrate the progressive nature of philosophic science. "There is one kind of progress," says the writer, "which consists simply of addition of the same to the same, or of the external accumulation of materials. But increase by addition, even though it be ordered or regulated addition, is not the highest kind of advancement. Pile heap on heap of inorganic matter, and you have a result in which nothing is changed; the lowest stratum of the pile remains to the last what it was at the first,—you keep all you ever had in solid permanence. Add stone to stone or brick to brick, till the house you have built stands complete from foundation to copestone; and here, though in order and system there may be a shadow of something higher than mere quantity, there is still only addition without progress. You have here also what the superficial mind covets as the sign of value in its possessions—permanent results, solid and stable reality. Every stone you place there remains to the last cut, hewn, shaped, in all its hard external actuality, what it was at the first; and the whole edifice, in its definite outward completeness, stands, it may be, for ages, a permanent possession of the world.

"But when you turn from inorganic accumulation or addition of quantities to organic growth, the kind of progress

* "Progressiveness of the Sciences," by John Caird, D.D., Principal of Glasgow University. Maclehose, Glasgow, 1875.

you get is altogether different. Here you never for a single day or hour keep firm possession of what you once had. Here there is never-resting mutation. What you now have is no sooner reached, than it begins to slip away from your grasp. One form of existence comes into being only to be abolished and obliterated by that which succeeds it. Seed or germ, peeping bud, rising stem, leaf and blossom, flower and fruit, are things that do not continue side by side as part of a permanent store, but each owes its present existence to the annulling of that which was before. You cannot possess at one and the same time the tender grace of the vernal woods and the rich profusion of colour and blossom of the later growth of summer; and if you are ever to gather in the fruit, for that you must be content that the gay blossoms should shrivel up and drop away. Yet though, in organic development you cannot retain the past, it is not destroyed or annihilated. In a deeper way than by actual matter-of-fact presence and preservation, it continues. Each present phase of the living organism has in it the vital result of all that it has been. The past is gone, but the organism could not have become what it is without the past. Every bygone moment of its existence still lives in it, not indeed as it was, but absorbed, transformed, worked up into the essence of its new and higher being. And when the perfection of the organism is reached, the unity of the perfectly developed life is one which gathers up into itself, not by juxtaposition or summation, but in a far deeper way, the concentrated results of all its bygone history. And by how much life is nobler than dead matter, by so much are the results and fruits of life the manifestation of a nobler kind of progress than that which is got by the accumulation of things which are at once permanent and lifeless, and permanent *because* they are lifeless."

The hydra equally with the higher animal, and the lowliest plant equally with the lordly oak, presents the distinctions and differences thus forcibly expressed as existing between living and non-living matter. There is thus a con-

stant replacement of old particles by new ones, and this change is not, after all, a mere substitution, but also includes and carries with it a process of growth and increase. Of this latter process, as seen in the living being, perhaps the most wonderful feature is that whereby, amid all the constant change which the acts of living and being involve, the animal or plant should preserve and retain the impress in which it was, so to speak, originally limned.

A study of the denizens of a stagnant pool may thus be shown to lead up, unconsciously it may be, but also naturally, to some matters of weighty consideration and interest, even to the most unscientific of observers. And it will be found not the least characteristic and valuable feature of all such studies, that they serve as literal starting-points and as vantage-grounds, whence we may shape an intellectual course, leading us by many and diverse radii from limited perceptions and finite aims, outwards and upwards to the Infinite itself.

[The following interesting communication with reference to the bee's cell appeared in the *Times*, in reference to an address by Mr. G. J. Romanes, at the British Association Meeting, 1878, on "Animal Intelligence." The writer, Mr. Lacy (Rector of Allhallows, London Wall), very clearly shows that the conditions under which the bee's cell is formed are simply of a mechanical nature, and do not in any sense depend on powers allied to those of consciousness or will.

"In your excellent article on Mr. Romanes's lecture on animal intelligence at the British Association, you allude to the case of the bee's cell, and say, in reference to the mathematical properties of the hexagon, 'we must either admit that every bee solves a difficult mathematical problem or else that this problem has been solved for all bees in the construction of their nervous centres.' Either of these admissions implies that the bee itself makes its cell in a hexagonal form. There is, however, a simpler explanation. The hexagonal form is, quite independently of the bee itself, the necessary mechanical result of the mode in which the bees work, and the cell could not by possibility be in any other form.

"The case is this:—The instinct of the bee is to make a cell in a cylindrical form by the circular motion of its head, just as a silkworm makes its cocoon, or a burrowing animal its hole. This is shown by the outer cells of every honeycomb, which are always semi-cylindrical where

there has been no pressure from the inside. If a bee, therefore, worked alone, its cell would be cylindrical. Another instinct of bees, however, is to swarm and crowd together in everything they do. They thus work at their cells side by side, and every bee as it works away at its cylinder is surrounded by as many others as can get close to it. That number is exactly six, neither more nor less. Any one may ascertain this for himself by placing a coin on a table, and then putting round it as many similar coins as he can. He will find that six such coins will exactly touch each other, and each exactly touch the central one. This is the geometrical law which produces the hexagonal form of the cell. Each bee is pressed upon by six others (excepting, of course, the extreme outside ones), and thus the interstitial curves of the cylinders get squeezed out as they are made, become straight lines by the mutual pressures, and every cylinder necessarily becomes a hexagon as its ultimate form.

"The same cause produces the peculiar prismatic form at the bottom of each cell. The instinct of the bees is not only to cluster together side by side, but also to work at their cells in a double plane, head to head. Each bee, therefore, as it works its head round from a hemispherical end to its cell has six other heads pushing round it in the opposite direction, trying to do the same thing. The necessary result is the prismatic form we see.

"The formation of the hexagonal cell is thus as entirely mechanical as when a horse tethered to a peg describes a mathematical circle by being put into a gallop. He is trying all the time not to describe a circle, but to go off in a straight line; but the restraining cord, tightened by his efforts, becomes a radius, and a circle is the necessary result.

"In both cases alike, the effect is entirely geometrical, and the will of the animal has nothing whatever to do with it."]

SOME FACTS AND FICTIONS OF ZOOLOGY.

When the country swain, loitering along some lane, comes to a standstill to contemplate, with awe and wonder, the spectacle of a mass of the familiar "hair-eels" or "hair-worms" wriggling about in a pool, he plods on his way firmly convinced that, as he has been taught to believe, he has just witnessed the results of the transformation of some horse's hairs into living creatures. So familiar is this belief to people of professedly higher culture than the countryman, that the transformation just alluded to has to all, save a few thinking persons and zoologists, become a matter of the most commonplace kind. When some quarrymen, engaged in splitting up the rocks, have succeeded in dislodging some huge mass of stone, there may sometimes be seen to hop from among the *débris* a lively toad or frog, which comes to be regarded by the excavators with feelings akin to those of superstitious wonder and amazement. The animal may or may not be captured; but the fact is duly chronicled in the local newspapers, and people wonder for a season over the phenomenon of a veritable Rip Van Winkle of a frog, which, to all appearance, has lived for "thousands of years in the solid rock." Nor do the hair-worm and the frog stand alone in respect of their marvellous origin. Popular zoology is full of such marvels. We find unicorns, mermaids, and mermen; geese developed from the shell-fish known as "barnacles;" we are told that crocodiles may weep, and that sirens can sing,—in short, there is nothing so wonderful

to be told of animals that people will not believe the tale. Whilst, curiously enough, when they are told of veritable facts of animal life, heads begin to shake and doubts to be expressed, until the zoologist despairs of educating people into distinguishing fact from fiction, and truth from theories and unsupported beliefs. The story told of the old lady, whose youthful acquaintance of seafaring habits entertained her with tales of the wonders he had seen, finds, after all, a close application in the world at large. The dame listened with delight, appreciation, and belief, to accounts of mountains of sugar and rivers of rum, and to tales of lands where gold and silver and precious stones were more than plentiful. But when the narrator descended to tell of fishes that were able to raise themselves out of the water in flight, the old lady's credulity began to fancy itself imposed upon; for she indignantly repressed what she considered the lad's tendency to exaggeration, saying, "Sugar mountains may be, and rivers of rum may be, but fish that flee ne'er can be!" Many popular beliefs concerning animals partake of the character of the old lady's opinions regarding the real and the fabulous; and the circumstance tells powerfully in favour of the opinion that a knowledge of our surroundings in the world, and an intelligent conception of animal and plant life, should form part of the school-training of every boy and girl, as the most effective antidote to superstitions and myths of every kind.

The tracing of myths and fables is a very interesting task, and it may, therefore, form a curious study, if we endeavour to investigate very briefly a few of the popular and erroneous beliefs regarding lower animals. The belief regarding the origin of the hair-worms is both widely spread and ancient. Shakespeare tells us that

> "Much is breeding,
> Which, like the courser's hair, hath yet but life,
> And not a serpent's poison."

The hair-worms certainly present the appearance of long, delicate black hairs, which move about with great activity

amidst the mud of pools and ditches. These worms, in the early stages of their existence, inhabit the bodies of insects, and may be found coiled up within the grasshopper, which thus gives shelter to a guest exceeding many times the length of the body of its host. Sooner or later the hair-worm, or *Gordius aquaticus* as the naturalist terms it, leaves the body of the insect, and lays its eggs, fastened together in long strings, in water. From each egg a little creature armed with minute hooks is produced, and this young hair-worm burrows its way into the body of some insect, there to repeat the history of its parent. Such is the well-ascertained history of the hair-worm, excluding entirely the popular belief in its origin. There certainly does exist in science a theory known as that of "spontaneous generation," which, in ancient times, accounted for the production of insects and other animals by assuming that they were produced in some mysterious fashion out of lifeless matter. But not even the most ardent believer in the extreme modification of this theory which holds a place in modern scientific belief, would venture to maintain the production of a hair-worm by the mysterious vivification of an inert substance such as a horse's hair.

The expression "crocodile's tears" has passed into common use, and it therefore may be worth while noting the probable origin of this myth. Shakespeare, with that wide extent of knowledge which enabled him to draw similes from every department of human thought, says that

> "Gloster's show
> Beguiles him, as the mournful crocodile
> With sorrow snares relenting passengers."

The poet thus indicates the belief that not only do crocodiles shed tears, but that sympathising passengers, turning to commiserate the reptile's woes, are seized and destroyed by the treacherous creatures. That quaint and credulous old author—the earliest writer of English prose—Sir John Maundeville, in his "Voiage," or account of his "Travaile,"

published about 1356—in which, by the way, there are to be found accounts of not a few wonderful things in the way of zoological curiosities—tells us that in a certain "contre and be all yonde, ben great plenty of Crokodilles, that is, a manner of a long Serpent as I have seyed before." He further remarks that "these Serpents slew men," and devoured them, weeping; and he tells us, too, that "whan thei eaten thei meven (move) the over jowe (upper jaw), and nought the nether (lower) jowe: and thei have no tonge (tongue)." Sir John thus states two popular beliefs of his time and of days prior to his age, namely, that crocodiles moved their upper jaws, and that a tongue was absent in these animals.

As regards the tears of the crocodiles, no foundation of fact exists for the belief in such sympathetic exhibitions. But a highly probable explanation may be given of the manner in which such a belief originated. These reptiles unquestionably emit very loud and singularly plaintive cries, compared by some travellers to the mournful howling of dogs. The earlier and credulous travellers would very naturally associate tears with these cries, and, once begun, the supposition would be readily propagated, for error and myth are ever plants of quick growth. The belief in the movement of the upper jaw rests on an apparent basis of fact. The lower jaw is joined to the skull very far back on the latter, and the mouth-opening thus comes to be singularly wide; whilst, when the mouth opens, the skull and upper jaw are apparently observed to move. This is not the case, however; the apparent movement arising from the manner in which the lower jaw and the skull are joined together. The belief in the absence of the tongue is even more readily explained. When the mouth is widely opened, no tongue is to be seen. This organ is not only present, but is, moreover, of large size; it is, however, firmly attached to the floor of the mouth, and is specially adapted, from its peculiar form and structure, to assist these animals in the capture and swallowing of their prey.

One of the most curious fables regarding animals which can well be mentioned, is that respecting the so-called

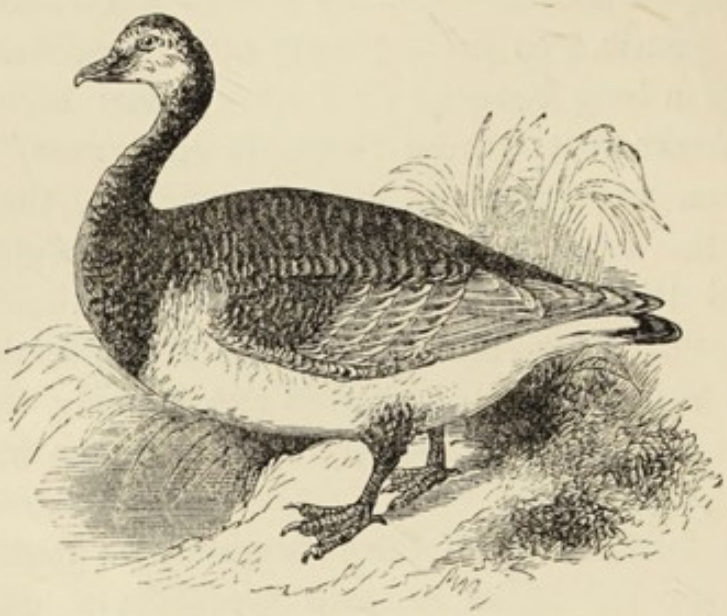


FIG. 4.—The bernicle goose.

"Bernicle" or "Barnacle Geese" (Fig. 4), which by the naturalists and educated persons of the Middle Ages were believed to be produced by those little Crustaceans named "Barnacles." With the "Barnacles" (Fig. 5), every one must be familiar who has examined the floating drift-wood of the sea-beach, or who has seen ships docked in a seaport town. A barnacle is simply a kind of crab enclosed in a triangular shell, and attached by a fleshy stalk to fixed objects. If the barnacle is not familiar to readers, certain near relations of these animals must be well known, by sight at least, as amongst the most

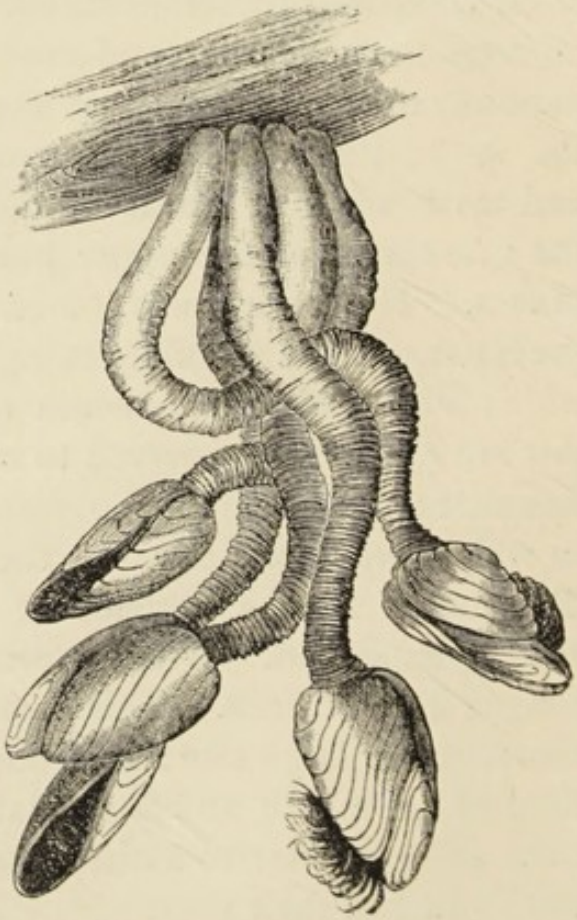


FIG. 5.—Group of barnacles.

familiar denizens of our sea-coasts. These latter are the "Sea-Acorns" or *Balani*, whose little conical shells we crush by hundreds as we walk over the rocks at low-water mark; whilst every wooden pile immersed in the sea becomes coated in a short time with a thick crust of these "Sea-Acorns." If we place one of these little animals, barnacle or sea-acorn—the latter wanting the stalk of the former—in its native waters, we shall observe a beautiful little series of feathery plumes to wave backwards and forwards, and ever and anon to be quickly withdrawn into the secure recesses of the shell. These organs are the modified feet of the animal, which not only serve for sweeping food-particles into the mouth, but act also as breathing-organs. We may, therefore, find it a curious study to inquire through what extraordinary transformation and confusion of ideas such an animal could be credited with giving origin to a veritable goose; and the investigation of the subject will also afford a singularly apt illustration of the ready manner in which the fable of one year or period becomes transmitted and transformed into the secure and firm belief of the next.

We may begin our investigation by inquiring into some of the opinions which were entertained on this subject and ventilated by certain old writers. Between 1154 and 1189 Giraldus Cambrensis, in a work entitled "Topographia Hiberniæ," written in Latin, remarks concerning "many birds which are called *Bernacæ:* against nature, nature produces them in a most extraordinary way. They are like marsh geese, but somewhat smaller. They are produced from fir timber tossed along the sea, and are at first like gum. Afterwards they hang down by their beaks, as if from a sea-weed attached to the timber, surrounded by shells, in order to grow more freely." Giraldus is here evidently describing the barnacles themselves. He continues: "Having thus, in process of time, been clothed with a strong coat of feathers, they either fall into the water or fly freely away into the air. They derive their food and growth from the sap of the wood or the sea, by a secret and most

wonderful process of alimentation. I have frequently, with my own eyes, seen more than a thousand of these small bodies of birds, hanging down on the sea-shore from one piece of timber, enclosed in shells, and already formed." Here, again, our author is speaking of the barnacles themselves, with which he naturally confuses the geese, since he presumes the Crustaceans are simply geese in an undeveloped state. He further informs his readers that, owing to their presumably marine origin, "bishops and clergymen in some parts of Ireland do not scruple to dine off these birds at the time of fasting, because they are not flesh, nor born of flesh," although for certain other and theological reasons, not specially requiring to be discussed in the present instance, Giraldus disputes the legality of this practice of the Hibernian clerics.

In the year 1527 appeared "The Hystory and Croniclis of Scotland, with the cosmography and dyscription thairof, compilit be the noble Clerk Maister Hector Boece, Channon of Aberdene." Boece's "History" was written in Latin; the title we have just quoted being that of the English version of the work (1540), which title further sets forth that Boece's work was "Translatit laitly in our vulgar and commoun langage be Maister Johne Bellenden, Archedene of Murray, And Imprentit in Edinburgh, be me Thomas Davidson, prenter to the Kyngis nobyll grace." In this learned work the author discredits the popular ideas regarding the origin of the geese. "Some men belevis that thir clakis (geese) growis on treis be the nebbis (bills). Bot thair opinioun is vane. And becaus the nature and procreatioun of thir clakis is strange, we have maid na lytyll laboure and deligence to serche ye treuth and verite yairof, we have salit (sailed) throw ye seis quhare thir clakis ar bred, and I fynd be gret experience, that the nature of the seis is mair relevant caus of thair procreatioun than ony uthir thyng." According to Boece, then, "the nature of the seis" formed the chief element in the production of the geese, and our author proceeds to relate how "all treis (trees) that ar cassin in the seis be proces of tyme apperis first wormeetin (worm-

eaten), and in the small boris and hollis (holes) thairof growis small worms." Our author no doubt here alludes to the ravages of the *Teredo*, or ship-worm, which burrows into timber, and with which the barnacles themselves are thus confused. Then he continues, the "wormis" first "schaw (show) thair heid and feit, and last of all thay schaw thair plumis and wyngis. Finaly, quhen thay ar cumyn to the just mesure and quantite of geis, thay fle in the aire as othir fowlis dois, as was notably provyn, in the yeir of God ane thousand iii hundred lxxxx, in sicht of mony pepyll, besyde the castell of Petslego." On the occasion referred to, Boece tells us that a great tree was cast on shore, and was divided, by order of the "lard" of the ground, by means of a saw. Wonderful to relate, the tree was found not merely to be riddled with a "multitude of wormis," throwing themselves out of the holes of the tree, but some of the "wormis" had "baith heid, feit, and wyngis," but, adds the author, "they had no fedderis (feathers)."

Unquestionably, either the scientific use of the imagination had operated in this instance in inducing the observers to believe that in this tree, riddled by the ship-worms and possibly having barnacles attached to it, they beheld young geese; or Boece had construed the appearances described, as those representing the embryo stages of the barnacle geese.

Boece further relates how a ship named the *Christofir* was brought to Leith, and was broken down because her timbers had grown old and failing. In these timbers were beheld the same "wormeetin" appearances, "all the hollis thairof" being "full of geis." Boece again most emphatically rejects the idea that the "geis" were produced from the wood of which the timbers were composed, and once more proclaims his belief that the "nature of the seis resolvit in geis" may be accepted as the true and final explanation of their origin. A certain "Maister Alexander Galloway" had apparently strolled with the historian along the sea-coast, the former giving "his mynd with maist ernist besynes to serche the verite of this obscure and mysty dowtis."

Lifting up a piece of tangle, they beheld the sea-weed to be hanging full of mussel-shells from the root to the branches. Maister Galloway opened one of the mussel-shells, and was "mair astonist than afore" to find no fish therein, but a perfectly shaped "foule, smal and gret," as corresponded to the "quantity of the shell." And once again Boece draws the inference that the trees or wood on which the creatures are found have nothing to do with the origin of the birds; and that the fowls are begotten of the "occeane see, quhilk," concludes our author, "is the caus and production of mony wonderful thingis."

More than fifty years after the publication of Boece's "History," old Gerard of London, the famous "master in chirurgerie" of his day, gave an account of the barnacle goose, and not only entered into minute particulars of its growth and origin, but illustrated its manner of production by means of the engraver's art of his day. Gerard's "Herball," published in 1597, thus contains, amongst much that is curious in medical lore, a very quaint piece of zoological history. He tells us that "in the north parts of Scotland, and the Ilands adjacent, called Orchades (Orkneys)," are found "certaine trees, whereon doe growe certaine shell fishes, of a white colour tending to russet; wherein are conteined little living creatures: which shels in time of maturitie doe open, and out of them grow those little living foules whom we call Barnakles, in the north of England Brant Geese, and in Lancashire tree Geese; but the other that do fall upon the land, perish, and come to nothing: thus much by the writings of others, and also from the mouths of people of those parts, which may," concludes Gerard, "very well accord with truth."

Not content with hearsay evidence, however, Gerard relates what his eyes saw and hands touched. He describes how on the coasts of a certain "small Ilande in Lancashire called Pile of Foulders" (probably Peel Island), the wreckage of ships is cast up by the waves, along with the trunks and branches "of old and rotten trees." On these wooden

rejectamenta, "a certaine spume or froth" grows, according to Gerard. This spume "in time breedeth unto certaine shels, in shape like those of the muskle, but sharper pointed, and of a whitish colour." This description, it may be remarked, clearly applies to the barnacles themselves. Gerard then continues to point out how, when the shell is perfectly formed, it "gapeth open, and the first thing that appeereth is the foresaid lace or string"—the substance described by Gerard as contained within the shell—"next come the legs of the Birde hanging out; and as it groweth greater, it openeth the shell by degrees, till at length it is all come foorth, and hangeth only by the bill; in short space after it commeth to full maturitie, and falleth into the sea, where it gathereth feathers, and groweth to a foule, bigger than a Mallard, and lesser than a Goose, having blacke legs and bill or beake, and feathers blacke and white . . . which the people of Lancashire call by no other name than a tree Goose."

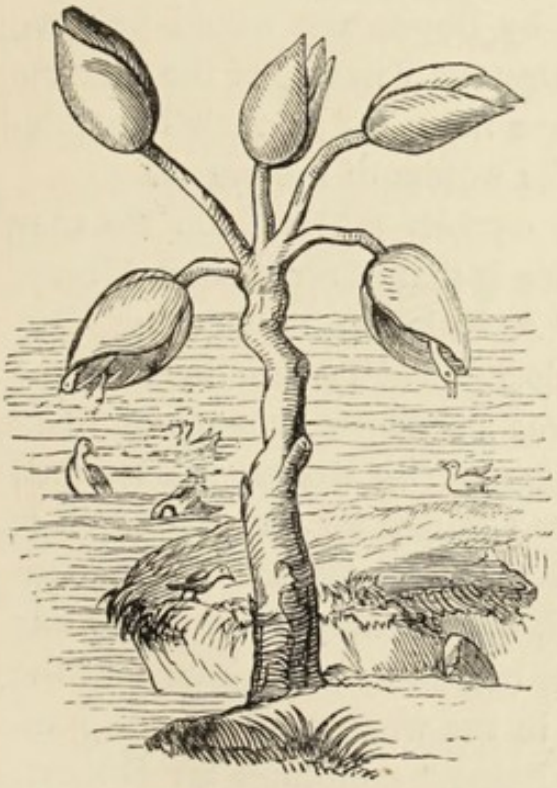


FIG. 6.—The barnacle tree (from Gerard's "Herball").

Accompanying this description is the engraving of the bernicle tree (Fig. 6) bearing its geese-progeny. From the open shells in two cases, the little geese are seen protruding, whilst several of the fully fledged fowls are disporting themselves in the sea below. Gerard's concluding piece of information, with its exordium, must not be omitted. "They spawne," says the wise apothecary, "as it were, in March or Aprill; the Geese are found in Maie or June, and come to fulnesse of feathers in the moneth after. And thus hauing,

through God's assistance, discoursed somewhat at large of Grasses, Herbes, Shrubs, Trees, Mosses, and certaine excrescences of the earth, with other things moe incident to the Historie thereof, we conclude and end our present volume, with this woonder of England. For which God's name be euer honored and praised." It is to be remarked that Gerard's description of the goose-progeny of the barnacle tree exactly corresponds with the appearance of the bird known to ornithologists as the "barnacle goose;" and there can be no doubt that, skilled as was this author in the natural-history lore of his day, there was no other feeling in his mind than that of firm belief in and pious wonder at the curious relations between the shells and their fowl-offspring. Gerard thus attributes the origin of the latter to the barnacles. He says nothing of the "wormeetin" holes and burrows so frequently mentioned by Boece, nor would he have agreed with the latter in crediting the "nature of the occeane see" with their production, save in so far as their barnacle-parents lived and existed in the waters of the ocean.

The last account of this curious fable which we may allude to in the present instance is that of Sir Robert Moray, who, in his work entitled "A Relation concerning Barnacles," published in the "Philosophical Transactions" of the Royal Society in 1677–78, gives a succinct account of these crustaceans and their bird-progeny. Sir Robert is described as "lately one of his Majesties Council for the Kingdom of Scotland," and we may therefore justly assume his account to represent that of a cultured, observant person of his day and generation. The account begins by remarking that the "most ordinary trees" found in the western islands of Scotland "are Firr and Ash." "Being," continues Sir Robert, "in the Island of East (Uist), I saw lying upon the shore a cut of a large Firr tree of about 2½ foot diameter, and 9 or 10 foot long; which had lain so long out of the water that it was very dry: And most of the shells that had formerly cover'd it, were worn or rubb'd off. Only on the parts that lay next the ground, there still hung multitudes of

little Shells; having within them little Birds, perfectly shap'd, supposed to be Barnacles." Here again the description applies to the barnacles; the "little birds" they are described as containing being of course the bodies of the shell-fish.

"The Shells," continues the narrator, "hang at the Tree by a Neck longer than the Shell;" this "neck" being represented by the stalk of the barnacle. The neck is described as being composed "of a kind of filmy substance, round, and hollow, and creassed, not unlike the Wind-pipe of a Chicken; spreading out broadest where it is fastened to the Tree, from which it seems to draw and convey the matter which serves for the growth and vegetation of the Shell and the little Bird within it." Sir Robert Moray therefore agrees in respect of the manner of nourishment of the barnacles with the opinion of Giraldus already quoted. The author goes on to describe the "Bird" found in every shell he opened; remarking that "there appeared nothing wanting as to the internal parts, for making up a perfect Sea-fowl: every little part appearing so distinctly, that the whole looked like a large Bird seen through a concave or diminishing Glass, colour and feature being everywhere so clear and neat." The "Bird" is most minutely described as to its bill, eyes, head, neck, breast, wings, tail, and feet, the feathers being "everywhere perfectly shaped, and blackish-coloured. All being dead and dry," says Sir Robert, "I did not look after the Internal parts of them," a statement decidedly inconsistent with his previous assertion as to the perfect condition of the "internal parts;" and he takes care to add, "nor did I ever see any of the little Birds alive, nor met with anybody that did. Only some credible persons," he concludes, "have assured me they have seen some as big as their fist."

This last writer thus avers that he saw little birds within the shells he clearly enough describes as those of the barnacles. We must either credit Sir Robert with describing what he never saw, or with misconstruing what he did see. His description of the goose corresponds with that of the

barnacle goose, the reputed progeny of the shells; and it would, therefore, seem that this author, with the myth at hand, saw the barnacles only with the eyes of a credulous observer, and thus beheld, in the inside of each shell—if, indeed, his research actually extended thus far—the reproduction in miniature of a goose, with which, as a mature bird, he was well acquainted.

Annexed is a woodcut, copied from Munster's "Cosmography" (1550), a very popular book in its time, showing

FIG. 7.—Barnacle tree (from Munster's "Cosmography").

the tree with its fruit, and the geese which are supposed to have just escaped from it.

This historical ramble may fitly preface what we have to say regarding the probable origin of the myth. By what means could the barnacles become credited with the power of producing the well-known geese? Once started, the progress and growth of the myth are easily accounted for. The mere transmission of a fable from one generation or

century to another is a simply explained circumstance, and one exemplified by the practices of our own times. The process of accretion and addition is also well illustrated in the perpetuation of fables; since the tale is certain to lose nothing in its historical journey, but, on the contrary, to receive additional elaboration with increasing age. Professor Max Müller, after discussing various theories of the origin of the barnacle myth, declares in favour of the idea that confusion of language and alteration of names lie at the root of the error. The learned author of the "Science of Language" argues that the true barnacles were named, properly enough, *Bernaculæ*, and lays stress on the fact that bernicle geese were first caught in Ireland. That country becomes *Hibernia* in Latin, and the Irish geese were accordingly named *Hibernicæ*, or *Hiberniculæ*. By the omission of the first syllable—no uncommon operation for words to undergo—we obtain the name *Berniculæ* for the geese, this term being almost synonymous with the name *Bernaculæ* already applied, as we have seen, to the barnacles. Bernicle geese and bernicle shells, confused in name, thus became confused in nature; and, once started, the ordinary process of growth was sufficient to further intensify, and render more realistic, the story of the bernicle tree and its wonderful progeny.

By way of a companion legend to that of the barnacle tree, we may select the story of the "Lamb Tree" of Cathay, told by Sir John Maundeville, whose notes of travel regarding crocodiles' tears, and other points in the conformation of these reptiles, have already been referred to. Sir John, in that chapter of his work which treats "Of the Contries and Yles that ben bezonde the Lond of Cathay; and of the Frutes there," etc., relates that in Cathay "there growethe a manner of Fruyt, as thoughe it were Gowrdes: and whan thei ben rype, men kutten (cut) hem a to (them in two), and men fynden with inne a lytylle Best (beast), in Flessche in Bon and Blode (bone and blood) as though it were a lytylle Lomb (lamb) with outen wolle (without wool). And men eten both the Frut and the Best; and that," says Sir John,

"is a great marveylle. Of that fruit," he continues, "I have eten; alle thoughe it were wondirfulle"—this being added, no doubt, from an idea that there might possibly be some stay-at-home persons who would take Sir John's statement *cum grano salis*. "But," adds this worthy "knyght of Ingelond," "I knowe wel that God is marveyllous in His Werkes." Not to be behind the inhabitants of Cathay in a tale of wonders, the knight related to these Easterns "als gret a marveylle to hem that is amonges us; and that was of the Bernakes. For I tolde hem hat in oure Countree weren Trees that beren a Fruyt, that becomen Briddes (birds) fleeynge: and tho that fellen in the Water lyven (live); and thei that fallen on the Erthe dyen anon: and thei ben right gode to mannes mete (man's meat). And here had thei als gret marvayle," concludes Sir John, "that sum̃e of hem trowed it were an impossible thing to be." Probably the inhabitants of Cathay, knowing their own weakness as regards the lamb tree, might possess a fellow-feeling for their visitor's credulity, knowing well, from experience, the readiness with which a "gret marvayle" could be evolved and sustained.

Passing from the sphere of the mythical and marvellous as represented in mediæval times, we may shortly discuss a question, which, of all others, may justly claim a place in the records of zoological curiosities—namely, the famous and oft-repeated story of the "Toad from the solid rock," as the country newspapers style the incident. Regularly, year by year, and in company with the reports of the sea-serpent's reappearance, we may read of the discoveries of toads and frogs in situations and under circumstances suggestive of a singular vitality on the part of the amphibians, of more than usual credulity on the part of the hearers, or of a large share of inventive genius in the narrators of such tales. The question possesses for every one a certain degree of interest, evoked by the curious and strange features presented on the face of the tales. And it may therefore not only prove an interesting but also a useful study, if we endeavour to

arrive at some just and logical conceptions of these wonderfull narrations.

Instances of the discovery of toads and frogs in solid rocks need not be specially given; suffice it to say, that these narratives are repeated year by year with little variation. A large block of stone or face of rock is detached from its site, and a toad or frog is seen hereafter to be hopping about in its usual lively manner. The conclusion to which the bystanders invariably come is that the animal must have been contained within the rock, and that it was liberated by the dislodgment of the mass. Now, in many instances, cases of the appearance of toads during quarrying operations have been found, on close examination, to present no evidence whatever that the appearance of the animals was due to the dislodgment of the stones. A frog or toad may be found hopping about amongst some recently formed *débris*, and the animal is at once seized upon and reported as having emerged from the rocks into the light of day. There is in such a case not the slightest ground for supposing any such thing; and the animal may more reasonably be presumed to have simply hopped into the *débris* from its ordinary habitat. But laying aside narratives of this kind, which lose their plausibility under a very commonplace scrutiny, there still exist cases, reported in an apparently exact and truthful manner, in which these animals have been alleged to appear from the inner crevices of rocks after the removal of large masses of the formations. We shall assume these latter tales to contain a plain, unvarnished statement of what was observed, and deal with the evidence they present on this footing.

One or two notable examples of such verified tales are related by Smellie, in his "Philosophy of Natural History." Thus, in the "Memoirs of the French Academy of Sciences" for 1719, a toad is described as having been found in the heart of an elm tree; and another is stated to have been found in the heart of an old oak tree, in 1731, near Nantz. The condition of the trees is not expressly stated, nor are we afforded any information regarding the appearance of the

toads—particulars of considerable importance in view of the suggestions and explanations to be presently brought forward. Smellie himself, whilst inclined to be sceptical in regard to the truth or exactness of many of the tales told of the vitality of toads, yet regards the matter as affording food for reflection, since he remarks, "But I mean not to persuade, for I cannot satisfy myself; all I intend is, to recommend to those gentlemen who may hereafter chance to see such rare phenomena, a strict examination of every circumstance that can throw light upon a subject so dark and mysterious; for the vulgar, ever inclined to render uncommon appearances still more marvellous, are not to be trusted."

This author strikes the key-note of the inquiry in his concluding words, and we shall find that the explanation of the matter really lies in the clear understanding of what are the probabilities, and what the actual details, of the cases presented for consideration. We may firstly, then, glance at a few of the peculiarities of the frogs and toads, regarded from a zoological point of view. As every one knows, these animals emerge from the egg (Fig. 8), in the form of little fish-like "tadpoles," provided with outside gills, which are soon replaced by inside gills, resembling those of fishes. The hind legs are next developed, and the fore limbs follow a little later; whilst, with the development of lungs, and the disappearance of the gills and tail, the animal leaves the water, and remains for the rest of its life an air-breathing, terrestrial animal. Then, secondly, in the adult frog or toad, the naturalist would point to the importance of the skin as not only supplementing, but, in some cases, actually supplanting the work of the lungs as the breathing organ. Frogs and toads will live for months under water, and will survive the excision of the lungs for like periods; the skin in such cases serving as the breathing surface. A third point worthy of remembrance is included in the facts just related, and is implied in the information that these animals can exist for long periods without food, and with but a limited supply of

air. We can understand this toleration on the part of these animals when we take into consideration their cold-blooded habits, which do not necessitate, and which are not accompanied by, the amount of vital activity we are accustomed to note in higher animals. And, as a last feature in the purely scientific history of the frogs and toads, it may be remarked that these animals are known to live for long periods. One pet toad is mentioned by a Mr. Arscott

FIG. 8.—Metamorphosis of the frog.

as having attained, to his knowledge, the age of thirty-six years; and a greater age still might have been recorded of this specimen, but for the untoward treatment it sustained at the hands, or rather beak, of a tame raven. In all probability it may be safely assumed that, when the conditions of life are favourable, these creatures may attain a

highly venerable age—regarding the lapse of time from a purely human and interested point of view.

We may now inquire whether or not the foregoing considerations may serve to throw any light upon the tales of the quarryman. The first point to which attention may be directed is that involved in the statement that the amphibian has been imprisoned in a *solid* rock. Much stress is usually laid on the fact that the rock was solid; this fact being held to imply the great age, not to say antiquity, of the rock and its supposed tenant. The impartial observer, after an examination of the evidence presented, will be inclined to doubt greatly the justification for inserting the adjective "solid;" for usually no evidence whatever is forthcoming as to the state of the rock prior to its removal. No previous examination of the rock is or can be made, from the circumstance that no interest can possibly attach to its condition until its removal reveals the apparent wonder it contained, in the shape of the live toad. And it is equally important to note that we rarely, if ever, find mention of any examination of the rock being made subsequently to the discovery. Hence, a first and grave objection may be taken to the validity of the supposition that the rock was solid, and it may be fairly urged that on this supposition the whole question turns and depends. For if the rock cannot be proved to have been impermeable to and barred against the entrance of living creatures, the objector may proceed to show the possibility of the toad having gained admission, under certain notable circumstances, to its prison-house.

The frog or toad in its young state, and having just entered upon its terrestrial life, is a small creature, which could, with the utmost ease, wriggle into crevices and crannies of a size which would almost preclude such apertures being noticed at all. Gaining access to a roomier crevice or nook within, and finding there a due supply of air, along with a dietary consisting chiefly of insects, the animal would grow with tolerable rapidity, and would increase to such an extent that egress through its aperture

of entrance would become an impossibility. Next, let us suppose that the toleration of the toad's system to starvation and to a limited supply of air is taken into account, together with the fact that these creatures will hibernate during each winter, and thus economise, as it were, their vital activity and strength; and after the animal has thus existed for a year or two—no doubt under singularly hard conditions—let us imagine that the rock is split up by the wedge and lever of the excavator. We can then readily enough account for the apparently inexplicable story of "the toad in the rock." "There is the toad and here is the solid rock," say the gossips. "There is an animal which has singular powers of sustaining life under untoward conditions, and which, in its young state, could have gained admittance to the rock through a mere crevice," says the naturalist in reply. Doubtless, the great army of the unconvinced may still believe in the tale as told them; for the weighing of evidence and the placing *pros* and *cons* in fair contrast are not tasks of congenial or wonted kind in the ordinary run of life. Some people there will be who will believe in the original solid rock and its toad, despite the assertion of the geologist that the earliest fossils of toads appear in almost the last-formed rocks, and that a live toad in rocks of very ancient age—presuming, according to the popular belief, that the animal was enclosed when the rock was formed—would be as great an anomaly and wonder as the mention, as an historical fact, of an express train or the telegraph in the days of the patriarchs. In other words, the live toad which hops out of an Old Red Sandstone rock must be presumed, on the popular belief, to be older by untold ages, than the oldest *fossil* frogs and toads. The reasonable mind, however, will ponder and consider each feature of the case, and will rather prefer to countenance a supposition based on ordinary experience, than an explanation brought ready-made from the domain of the miraculous; whilst not the least noteworthy feature of these cases is that included in the remark of Smellie respecting the tendency of uneducated

and superstitious persons to magnify what is uncommon, and in his sage conclusion that, as a rule, such persons in the matter of their relations "are not to be trusted."

But it must also be noted that we possess valuable evidence of a positive and direct kind bearing on the duration of life in toads under adverse circumstances. As this evidence tells most powerfully against the supposition that the existence of those creatures can be indefinitely prolonged, it forms of itself a veritable court of appeal in the cases under discussion. The late Dr. Buckland, curious to learn the exact extent of the vitality of the toad, caused, in the year 1825, two large blocks of stone to be prepared. One of the blocks was taken from the oolite limestone, and in this first stone, twelve cells were excavated. Each cell was one foot deep and five inches in diameter. The mouth of each cell was grooved so as to admit of two covers being placed over the aperture; the first or lower cover being of glass, and the upper one of slate. Both covers were so adapted that they could be firmly luted down with clay or putty; the object of this double protection being that the slate cover could be raised so as to inspect the contained object through the closed glass cover without admitting air. In the second or sandstone block, a series of twelve cells was also excavated; these latter cells being, however, of smaller size than those of the limestone block, each cell being only six inches in depth by five inches in diameter. These cells were likewise fitted with double covers.

On November 26, 1825, a live toad—kept for some time previously to ensure its being healthy—was placed in each of the twenty-four cells. The largest specimen weighed 1185 grains, and the smallest 115 grains. The stones and the immured toads were buried on the day mentioned, three feet deep, in Dr. Buckland's garden. There they lay until December 10, 1826, when they were disinterred and their tenants examined. All the toads in the smaller cells of the sandstone block were dead, and from the progress of decom-

position it was inferred that they had succumbed long before the date of disinterment. The majority of the toads in the limestone block were alive, and, curiously enough, one or two had actually increased in weight. Thus, No. 5, which at the commencement of its captivity had weighed 1185 grains, had increased to 1265 grains; but the glass cover of No. 5's cell was found to be cracked. Insects and air must therefore, have obtained admittance and have afforded nourishment to the imprisoned toad; this supposition being rendered the more likely by the discovery that in one of the cells, the covers of which were also cracked and the tenant of which was dead, numerous insects were found. No. 9, weighing originally 988 grains, had increased during its incarceration to 1116 grains; but No. 1, which in the year 1825 had weighed 924 grains, was found in December, 1826, to have decreased to 698 grains; and No. 11, originally weighing 936 grains, had likewise disagreed with the imprisonment, weighing only 652 grains when examined in 1826.

At the period when the blocks of stone were thus prepared, four toads were pinned up in holes five inches deep and three inches in diameter, cut in the stem of an apple tree; the holes being firmly plugged with tightly fitting wooden plugs. These four toads were found to be dead when examined along with the others in 1826; and of four others enclosed in basins made of plaster of Paris, and which were also buried in Dr. Buckland's garden, two were found to be dead at the end of a year, their comrades being alive, but looking starved and meagre. The toads which were found alive in the limestone block in December, 1826, were again immured and buried, but were found to be dead, without leaving a single survivor, at the end of the second year of their imprisonment.

These experiments may fairly be said to prove two points. They firstly show that under circumstances even of a favourable kind when compared with the condition popularly believed in—namely, that of being enclosed in a *solid* rock

—the limit of the toad's life may be assumed to be within two years; this period being no doubt capable of being extended when the animal gains a slight advantage, exemplified by the admission of air and insect-food. Secondly, we may reasonably argue that these experiments show that toads when rigorously treated, like other animals, become starved and meagre, and by no means resemble the lively, well-fed animals reported as having emerged from an imprisonment extending, in popular estimation, through periods of inconceivable duration.

These tales are, in short, as devoid of actual foundation as are the modern beliefs in the venomous properties of the toad, or the ancient beliefs in the occult and mystic powers of various parts of its frame when used in incantations. Shakespeare, whilst attributing to the toad venomous qualities, has yet immortalised it in his famous simile, by crediting it with the possession of a "precious jewel." But even in the latter case the animal gets but scant justice; for science strips it of its poetical reputation, and in this, as in other respects, shows it, despite fable and myth, to be zoologically an interesting, but otherwise a commonplace member of the animal series.

THE SEA-SERPENTS OF SCIENCE.

"There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy."

Hamlet.

In the dull season of the year, when there is a decided lack of interesting or startling events, and when newspaper editors are at their wits' end for material, three objects derived from the domain of the biologist have been credited with the task of reviving the tide of public interest, and of restoring peace and composure to the editorial mind. It need hardly be said that the three objects alluded to are: "the frog from the solid rock," "the gigantic gooseberry," —occasionally supplemented by the discovery of "an egg of marvellous proportions,"—and last, though by no means least, comes the announcement—made as if the being were some eminent tragedian returning to the scene of former triumphs—of the "reappearance of the great sea-serpent!" People have come in fact to regard the annual advent of the "Great Unknown" as a sure and settled event; and doubtless there are many who would confess to a feeling of disappointment did the season slip past without an announcement of the mysterious stranger's visit.

Notwithstanding the interest which the discussion of the sea-serpent question inevitably evokes, there are comparatively few persons to be found who regard the question from other than a purely sceptical point of view. The intelligence that the sea-serpent "has been seen again," is

usually reckoned as equivalent to the statement that some grog-laden mariner has been exhibiting that phenomenon known to physiologists as "unconscious cerebration;" or that some observer has been interpreting an unusual appearance in the sea by the light of the serpentine myth. Occasionally the subject affords an opportunity for the display of the anything but scientific use of the imagination of some feeble jokers, who succeed in imposing upon the credulity of editors, and in seeing their absurd descriptions of fictitious animals in all the prominence of large type. I have before me at the present time a most circumstantial account of the "capture of the sea-serpent at Oban," in which the animal is described as having been attacked by a file of volunteers armed with rifles, and by a perfect flotilla of yachts and boats. The animal was, according to this account, happily delivered over to the tender mercies of the native talent. After causing stones to fly in showers by the sweep of its tail as it lay on the beach, it was secured, and a list of zoological characters such as belong to no one known animal is duly given. It can hardly be deemed astonishing that a non-scientific London *entrepreneur*, on reading the account of the monster's capture, at once telegraphed to secure it for exhibition. History, it need scarcely be said, does not record the sayings of this gentleman on learning that, as one of the credulous public, he had been duly hoaxed.

The literature of the subject is in one sense a huge record of mistakes and errors in observation, and the ordinary public, as well as the scientific world, have long been accustomed to accept the erroneous side as representative of the entire subject, and as if no element or substratum of probability and fact was included in the whole matter. Thus, for example, because on one occasion an alleged sea-serpent on closer investigation was proved to consist of a long train or tail of sea-weed, with some heterogeneous material serving for the head,—or since, on other occasions forms described as being of serpentine size have resolved

themselves into shoals of porpoises swimming in line,—readers of such detached statements are apt to rush to the settled conclusion that all sea-serpent tales are explicable on some analogous footing. The relegation of the subject to the sphere of fable is therefore to be accounted a perfectly natural result of the almost invariable construction put upon a few ill-founded tales and mediæval myths—to be presently alluded to—and also of the indifference with which zoologists themselves have treated the subject; whilst ignorance of the existence of a great body of perfectly reliable evidence supporting the view that large serpentine forms have been seen, together with a common incompetence to weigh evidence and to decide upon the merits of the case, may also be cited as two important factors in inducing a general disbelief in the personality of the modern Leviathan.

Of the older chroniclers of sea-serpent lore, perhaps the most noteworthy is Olaus Magnus, the worthy archbishop of Upsala, who devotes a whole chapter in the course of his writings to the sea-serpent, and discourses most volubly upon the marine snake, and other monsters of the deep, such as krakens, whales, and the like. Speaking of some sea monsters, the exact nature of which it is zoologically impossible to define, Magnus writes that "their forms are horrible, their heads square, all set with prickles, and they have sharp and long horns about, like a tree rooted up by the roots. They are ten or twelve cubits long, very black, and with huge eyes, the compass whereof is about eight or ten cubits. The apple of the eye is of one cubit, and is red and fiery coloured, which in the dark night appears to fishermen afar off under waters as a burning fire, having hairs like goose feathers, thick and long, like a beard hanging down. The rest of the body, for the greatness of the head, which is square, is very small, not being above 14 or 15 cubits long. One of these sea monsters will easily drown many great ships, provided with many strong mariners."

The sea-serpent of this writer appears to have been a

terrible animal, worthy of a place in the records of those knightly encounters with strange beasts which mark our earlier literature. The marine snake of Magnus was 200 feet long, twenty feet thick, and appeared "like a pillar" when he elevated his head in mid-air. His hair was a cubit long, his scales were sharp and his skin black; and his eyes were like flaming fire. The appearances of such monsters were naturally regarded in the light of grave portents of coming disasters. One old writer, relating the capture of a marine monster, says that "in 1282, there was a fish taken in the sea, in all respects like unto a lyon." The fishermen reported that "the fishe gave many frighfull scrikes and cries when it was taken, and at this time," continues the narrative, "there fell a great discord between the Englishmen that were students in Paris and those of Pycardy that studyed there likewise. Their division was so terrible that it could hardly be appeased." Starting thus with a basis of myth, it is little to be wondered at that modern ideas have continued to invest the "sea-serpent" and its kind with an atmosphere of the ridiculous.

The simple and attentive consideration of the matter, however, reveals certain aspects and features, in virtue of which it can hardly be dismissed from the sphere either of popular or of scientific thought, and which commend the subject to the intelligent mind, as a study of both a curious and highly interesting kind. Can we, for example, after perusing the mass of evidence accumulated during past years, dismiss the subject *simpliciter*, as founded on no basis of fact? The answer to such a question must be an emphatic negative; since the evidence brought before our notice includes the testimony of several hundreds of sane and reasonable persons, who in frequent cases have testified on oath and by affidavit to the truth of their descriptions of curious marine forms, seen and observed in various seas. The second supposition, that all of these persons have simply been deceived, is one which must also be dismissed. For, after making all due allowance for exaggeration, and

for variations in accounts arising from different modes of expression and even from mental peculiarities in the witnesses, there remains a solid body of testimony, which, unless there is some special tendency to mendacity on the part of persons who travel by sea, we are bound, by all the rules of fair criticism and of evidence, to receive as testimony of honest kind. As I have elsewhere observed, "There are very many calmly and circumstantially related and duly verified accounts of serpentine, or at any rate, of anomalous marine forms, having been closely inspected by the crews and passengers of vessels. Either, therefore, we must argue that in every instance the senses of intelligent men and women must have played them false, or we must simply assume that they are describing what they have never seen. The accounts in many instances so minutely describe the appearance of such forms, inspected from a near standpoint, that the possibility of their being mistaken for inanimate objects, as they might be if viewed from a distance, is rendered entirely improbable. We may thus, then, affirm firstly that there are many verified pieces of evidence on record, of strange marine forms having been met with,—which evidences, judged according to ordinary and common-sense rules, go to prove that certain hitherto undescribed marine organisms do certainly exist in the sea-depths."

The first issue I must therefore submit to the reader, as representing one of a large and impartial jury, is, that the mass of evidence accumulated on the sea-serpent question, when weighed and tested, even in a *primâ facie* manner, plainly shuts us up to the belief that appearances, resembling those produced by the presence in the sea of huge serpentine forms, have been frequently noted by competent and trustworthy observers. Unless we are to believe that men and women have deliberately prevaricated, and that without the slightest excuse or show of reason, we must believe that they have witnessed marine appearances, certainly of unwonted and unusual kind. That "something" has assuredly been seen, must be the verdict on this first

issue. What that "something" is or was, and whether or not the evidence will support the opinion that the appearances described bear out the existence of a "sea-serpent" in the flesh, form points for discussion in the next instance.

In the consideration of this second issue, two chief aspects are presented. We have thus, firstly, to assure ourselves that the evidence, the character of which has just been discussed, will support the assertion that the appearances noted were produced by *living organisms*. And provided this point be decided in the affirmative, we must assure ourselves, in the second place, of the probable *kind* and *nature* of these beings.

Allusion has already been made to erroneous observations, which have subjected the stories of sea-serpents to almost universal ridicule, and in which various *lifeless* objects were at first credited with the representation of the marine monster. That a long and connected string of sea-weed, extending for some fifty or sixty feet along the surface of a sea, slightly disturbed by a rippling breeze, may be moved by the waves in a manner strongly suggestive of the movements of a snake in swimming, is a statement to the correctness of which I can bear personal testimony, and to the truth of which even observant sea-side visitors may testify. The movements of an unusually long frond or group of fronds of tangle, attached to a rock, and set in motion at low water, by a light swell, has before now, and when seen indistinctly, suggested the idea of the existence at the spot of some large denizen of the sea, browsing on the sea-weeds, with the fore part of its body, represented by the tangle fronds, occasionally appearing at the surface of the water. Floating trunks and roots of trees (see Frontispiece), serving as a nucleus around which sea-weed has collected, and to which barnacles and sea-acorns—producing a variegated effect by reason of their light colour—have attached themselves in great numbers, have also presented appearances closely resembling those of large marine animals, swimming slowly along at the surface of the water.

In one instance of this latter kind, related to me by a friend who was an actual spectator, the floating piece of timber assumed a shape imitating in the closest and most remarkable manner the head of some reptile,—by the same rule, I suppose, that in the gnarled trunks and branches of trees one may frequently discern likenesses to the human face and to the forms of other living things. In this latter instance, the floating object was perceived at some miles' distance from the deck of a yacht; and even when seen through a telescope, and carefully scrutinised by men accustomed to make out the contour and nature of objects at sea, the resemblance to the head of some animal was so close that the course of the vessel was changed and the object in due time overhauled. This latter, therefore, presents an example of a case, the details of which, when related, tempt people to maintain without further parley, that sea-serpents always resolve themselves into inanimate objects of one kind or another. And so great in some minds is the fear of popular ridicule regarding this subject, that one ship-captain related that when a sea-serpent had been seen by his crew from the deck of the vessel, he remained below; since, to use his own words, "had I said I had seen the sea-serpent, I should have been considered to be a warranted liar all my life after!"

But the natural supposition and remark of the inanimate nature of objects seen at sea is at once noted to be anything but universal in its nature and application, when the records of sea-serpent history are examined in detail. Numerous cases exist in which the object, presumed to be a living being, has been scrutinised so closely that, save on the supposition that senses have played their owners false, or that minds have given way to an unaccountable impulse for lying, we must face and own the belief that living animals have been seen. Let us briefly examine one or two of the accounts of this kind which have been duly and faithfully recorded, with the view of ascertaining whether or not we may detect any inherent or implied elements of improba-

bility, and whether the evidence as to living things having been seen is of trustworthy kind.

One of the most circumstantially recorded and best-known reports of the appearance of a sea-serpent is that of Captain M'Quhæ, who commanded H.M.S. *Dædalus*, in 1848, and whose case, originally published and commented upon in the *Times* of that year, may be almost unknown to the present and rising generation of readers. The first announcement in the *Times* appeared in the form of a paragraph on October 9, 1848, stating that when the *Dædalus* was on her passage home from the East Indies, and when between the Cape of Good Hope and St. Helena, the captain and most of the officers and crew, saw an animal, which from its form and shape they assumed to be a sea-serpent. Captain M'Quhæ's own statement, contained in his reply to an official inquiry from the Admiralty, gives the date of the marine monster's appearance as 6th August, 1848, and its exact habitat, at 5 p.m. of that day, as latitude 24° 44′ S, and longitude 9° 22′ E. The captain simply states it to be "an enormous serpent, with head and shoulders kept about four feet constantly above the surface of the sea, and, as nearly as we could approximate by comparing it with the length of what our maintop-sail yard would show in the water, there was at the very least sixty feet of the animal *à fleur d'eau*, no portion of which was, to our perception, used in propelling it through the water, either by vertical or horizontal undulation." The animal, Captain M'Quhæ states,—and the observation is important, as bearing on the question of the living nature of the object described,—passed the ship, "rapidly, but so close under our lee quarter, that had it been a man of my acquaintance I should easily have recognised his features with the naked eye." The further dimensions of the animal are given as 15 or 16 inches in diameter "behind the head, which was," continues Captain M'Quhæ, "without any doubt, that of a snake," whilst the colour is described as being "a dark brown, with yellowish white about the throat." No fins

were visible, but it appeared to possess "something like the mane of a horse, or rather (like?) a bunch of sea-weed, washed about its back." Lieutenant Drummond, of the *Dædalus,* who was officer of the watch on the memorable occasion, states in his report that the animal had a "back fin," which was "perhaps twenty feet in the rear of the head." This fin evidently corresponds to the structure described in the captain's report as "something like the mane of a horse," and which the introduction of the word "like" (as I have inserted it in parentheses after the word "rather" in his description) serves to correlate with the "bunch of sea-weed" which "washed about its back."

So far as an exact and circumstantial description, attested by the narrative of other witnesses, can testify to the actual nature of an object, viewed, it must be remarked, by educated and observant men, the instance just given would appear to admit of not the slightest doubt that a truly living and actively moving animal was observed, and also that its appearance was decidedly serpentine. It is noteworthy that in the whole course of the discussion which followed upon the publication of Captain M'Quhæ's observation, no one was found even to suggest that the appearance was other than that of a living animal; although, as will afterwards be remarked, opinions varied greatly as to the nature of the being which thus afforded so tantalising and insufficient a glimpse of its structure and identity.

Passing over many interesting reports of sea-serpents' appearances now of some years' date, I find in the daily newspapers, almost of the date at which these words are penned, statements, both made on oath and before legal authorities, regarding the "great unknown." The first of these statements I shall give in the words of the newspaper reports, which present a clear, unvarnished statement of the narrative, and of the circumstances in which it was offered for public investigation.

"The story of the mate and crew of the barque *Pauline,* of London, said to have arrived in port from a twenty months'

voyage to Akyab,—about having seen 'a sea-serpent' while on a voyage in the Indian seas, was declared to on oath before Mr. Raffles, the stipendiary magistrate, at the Liverpool Police-Court. The affidavit was made in consequence of the doubtfulness with which anything about the 'sea-serpent' has hitherto been received; and to show the genuine character of the story it has been placed judicially on record. The following is a copy of the declaration, which will be regarded as unprecedented in its way:—

BOROUGH OF LIVERPOOL, IN THE COUNTY PALATINE OF LANCASTER, TO WIT.

We, the undersigned, captain, officers, and crew of the barque *Pauline* (of London), of Liverpool, in the county of Lancaster, in the United Kingdom of Great Britain and Ireland, do solemnly and sincerely declare that on July 8, 1875, in lat. 5° 13′ S., long. 35° W., we observed three large sperm whales, and one of them was gripped round the body with two turns of what appeared to be a huge serpent. The head and tail appeared to have a length beyond the coils of about thirty feet, and its girth eight or nine feet. The serpent whirled its victim round and round for about fifteen minutes, and then suddenly dragged the whale to the bottom, head first.

GEORGE DREVAR, *Master.*
HORATIO THOMPSON.
JOHN HENDERSON LANDELLS.
OWEN BAKER.
WM. LEWARN.

Again, on July 13, a similar serpent was seen about two hundred yards off, shooting itself along the surface, the head and neck being out of the water several feet. This was seen only by the captain and one ordinary seaman, whose signatures are affixed.

GEORGE DREVAR, *Master.*
OWEN BAKER.

A few moments after it was seen elevated some sixty feet perpendicularly in the air by the chief officer and the following able seamen, whose signatures are also affixed.

HORATIO THOMPSON.
WILLIAM LEWARN.
OWEN BAKER.

And we make this solemn declaration conscientiously, believing the same to be true, and by virtue of the provisions of an Act made and passed in the sixth year of the reign of his late Majesty, entitled 'An Act to repeal an Act of the present Session of Parliament, entitled an

Act for the more effectual abolition of oaths and affirmations, taken and made in various departments of the State, and to substitute declarations in lieu thereof, and for the more entire suppression of voluntary and extra-judicial oaths and affidavits, and to make other provisions for the abolition of unnecessary oaths.' Severally declared and subscribed at Liverpool aforesaid the tenth day of January, one thousand eight hundred and seventy-seven.

GEORGE DREVAR, *Master.*
WILLIAM LEWARN, *Steward.*
HORATIO THOMPSON, *Chief Officer.*
J. H. LANDELLS, *Second Officer.*
OWEN BAKER.

Severally declared and subscribed at Liverpool aforesaid, the tenth day of January, one thousand eight hundred and seventy-seven, before T. S. Raffles, J.P. for Liverpool."

The second and final piece of evidence I shall cite, is that obtained from an article entitled "Strange Sea Monsters," by Mr. R. A. Proctor, which appeared in the *Echo* of the 15th January, 1877. In this communication, Mr. Proctor makes reference to some of the views which I have promulgated on this subject, and by way of illustration, gives the following interesting particulars of a recent sea-serpent narrative :—

"Soon after the British steamship *Nestor* anchored at Shanghai, last October, John K. Webster, the captain, and James Anderson, the ship's surgeon, appeared before Mr. Donald Spence, Acting Law Secretary in the British Supreme Court, and made affidavit to the following effect :—

On September 11, at 10.30 a.m., fifteen miles north-west of North Sand Lighthouse, in the Malacca Straits, the weather being fine and the sea smooth, the captain saw an object which had been pointed out by the third officer as 'a shoal!' Surprised at finding a shoal in such a well-known track, I watched the object, and found that it was in motion, keeping up the same speed with the ship, and retaining about the same distance as first seen. The shape of the creature I would compare to that of a gigantic frog. The head, of a pale yellowish colour, was about twenty feet in length, and six feet of the crown were above the water. I tried in vain to make out the eyes and mouth; the mouth may, however, have been below water. The head was immediately connected with the body, without any indication of a neck.

The body was about forty-five or fifty feet long, and of an oval shape, perfectly smooth, but there may have been a slight ridge along the spine. The back rose some five feet above the surface. An immense tail, fully one hundred and fifty feet in length, rose a few inches above the water. This tail I saw distinctly from its junction with the body to its extremity; it seemed cylindrical, with a very slight taper, and I estimate its diameter at four feet. The body and tail were marked with alternate bands of stripes, black and pale yellow in colour. The stripes were distinct to the very extremity of the tail. I cannot say whether the tail terminated in a fin or not. The creature possessed no fins or paddles so far as we could perceive. I cannot say if it had legs. It appeared to progress by means of an undulatory motion of the tail in a vertical plane (that is, up and down).

Mr. Anderson, the surgeon, confirmed the captain's account in all essential respects. He regarded the creature as an enormous marine salamander. 'It was apparently of a gelatinous (that is, flabby) substance. Though keeping up with us, at the rate of nearly ten knots an hour, its movements seemed lethargic. I saw no eyes or fins, and am certain that the creature did not blow or spout in the manner of a whale. I should not compare it for a moment to a snake. The only creatures it could be compared with are the newt or frog tribe.'" *

Placing these two latter narratives side by side with that of Captain M'Quhæ, we may firstly remark the singular coincidence that in all three narratives mention is made of the head of the animal being elevated above water,—this feature in the animal's mode of progression having evidently struck the observers as a noticeable point; whilst the coincidence, viewed as a piece of internal evidence, speaks strongly in favour of the implied truthfulness of the narratives. I think one may fairly assume that the supposition that the parties concerned were deceived into mistaking

* It is just possible that the "flabby" or "gelatinous" creature mentioned in this narrative was a giant cuttle-fish, whose manner of swimming, colour, absence of limbs, etc., would correspond with the details of the narrative. The "immense tail" might be the enormous arms of such a creature trailing behind the body as it swam backwards, propelled by jets of water from the breathing "funnel."

a lifeless for a living object, cannot for a moment be reasonably entertained. Laying aside for the present all questions as to the zoological position and rank of the animal, we may take it for granted, as based on evidence of reasonable kind, that the "something" seen in each of these cases—which, be it remarked, are but types of many other authenticated records of similar kind—was an active living animal. And we may also affirm that, from the circumstances in which the statements were made, as well as from the character of our witnesses, from their evident desire and from the trouble taken by them to place on record a faithful account of what they had seen, we have ample evidence to prove that part of our second issue which dealt with the question of the living or lifeless nature of the objects seen. If internal evidence is to be trusted at all, the present case strongly exemplifies its worth and value.

We have, however, still to deal with a point in our second proposition, which brings us within the scope of truly scientific inquiry,—namely, that devoted to the consideration of the kind or nature of the animals observed by narrators of sea-serpent tales. In the elucidation of this topic we may incidentally discover implied proofs of the correctness and truth of the narratives on which the history of the sea-serpent is literally founded. The discussion of the question from a zoological point of view may be fitly prefaced by an allusion to certain readily explained cases of serpentine appearances caused by well-known and common forms of marine life assuming peculiar attitudes in the water, and of being indistinctly seen by observers. The instance already alluded to, of a shoal of porpoises swimming in line, with their backs and dorsal fins appearing now and then, with a kind of regular alternating motion above the surface of the water, presents an example of a deceptive appearance brought about by a somewhat unusual habit of familiar animals. I well remember being struck with surprise at an unwonted spectacle I beheld in the Frith of Forth some years ago, of an apparently long

animal swimming rapidly through the water, and showing several widely detached black fins. Being alone in a small skiff at the time, I confess to the feeling of caution prompting me to restrain my curiosity and to remain at a safe distance from the animal. My curiosity was, however, speedily dispelled by beholding the apparently long and single animal resolve itself into a few sun-fishes (*Orthagoriscus*), which happened to be rolling over and over in the water in line; their motions, viewed from a distance, together with the imperfect glimpse I had at first caught of the animals, rendering my former idea of the presence of an elongated moving body all the more realistic. Such cases are, however, not to be placed side by side with the plain accounts of unknown animals of large size having been distinctly seen in latitudes favouring the growth of animals with which we are less familiar, and to the explanation of the affirmed and verified accounts of which we may next direct attention.

As was naturally to be expected, zoologists began to overhaul their lists on the narration of these tales, with the view of attempting to discover some *known* form which would correspond with the details and appearances observed and described in the sea-serpent accounts. Could the zoologist point with reason to any single form or to a few animals which might, without any undue liberties being taken either with the animals themselves or with the sea-serpent tales, be regarded as the representatives of the marine monsters? Such was the question propounded for the solution of naturalists in former years, and such emphatically is the chief question for consideration in the subject as it at present stands.

The only group of animals to which our attention may be specially directed with the view of finding a zoological solution of the problem, is that of the *Vertebrata*,—the highest group of animals, which possesses the fishes as its lowest, and man and quadrupeds as its highest representatives. Laying aside the class of birds, as including no forms at all allied to our present inquiry, we are left with, speaking generally, three

groups of animals, from the ranks of which various forms may be selected to aid us in solving the sea-serpent mystery. These three groups are the fishes, reptiles, and mammalia, and it may be shown that from each of these classes, but more notably from among the fishes and reptiles, various animals, corresponding more or less closely with the descriptions given of strange marine monsters, may be obtained. An important consideration, however, must not be overlooked at this stage, namely, that too frequently the attempt to reconcile the sea-serpent with some *known* animal of serpentine form and nature, has limited the perceptions and foiled the labours of naturalists. Starting with the fixed idea that the unknown form must be a serpent, and not widening their thoughts to admit of the term "serpentine" being extended to groups of animals other than the reptilia, naturalists soon exhausted the scientific aspect of the subject, and the zoological solution of the problem was almost at once given up. Then, also, as far as I have been able to ascertain, zoologists and other writers on this subject have never made allowance for the *abnormal and huge development of ordinary marine animals.* My own convictions on this matter find in these two considerations, but especially in the last idea, the most reasonable and likely explanation of the personality of the sea-serpent, and also the reconciliation of such discrepancies as the various narrations may be shown to evince. If we thus fail to find in the ranks of ordinary animal life, or amongst the reptiles themselves, the representatives of the "sea-serpents," I think we may nevertheless build up a most reasonable case both for their existence and for the explanation of their true nature, by taking into account the facts, *that the term "sea-serpent," as ordinarily employed, must be extended to include other forms of Vertebrate animals which possess elongated bodies; and that cases of the abnormally large development of ordinary serpents and of serpent-like animals will reasonably account for the occurrence of the animals collectively named sea-serpents.*

The case related by Captain M'Quhæ formed, as has been remarked, subject-matter for much discussion. As Mr. Gosse records in his charming work, the "Romance of Natural History," the various suggestions thrown out regarding the nature of the "serpent" seen by the crew of the *Dædalus*, included and advocated its correspondence with a gigantic seal,—this idea emanating from Professor Owen; with a *Plesiosaurus*—an extinct reptile, which possessed a very long swan-like neck, and which attained a usual length varying from eighteen to twenty or more feet; with other and allied forms of extinct reptilia; and with a large species of shark, the basking shark (*Selache maxima*). The idea of Professor Owen does not in the least correspond with Captain M'Quhæ's circumstantial account of the appearance; and to Owen's views the captain contributed a courteous but firm reply, refusing absolutely to admit that his description was susceptible of such modifications as would bring Professor Owen's idea of a gigantic seal and the serpent of the *Dædalus* into close correspondence. Mr. Gosse and others support the suggestion that the animal seen on this occasion was a kind of *Plesiosaurus* (see Frontispiece). And this idea received apparent support from the fact recorded by Captain M'Quhæ that no motion was observed in the portion of the animal above water; it being thus concluded that the movements were produced by limbs existing in the form of swimming-paddles, such as the *Plesiosauri* possessed, and which would in their natural position be concealed below the surface of the water. The suggestion of a huge shark is simply untenable from the utter want of correspondence between any feature of the shark's conformation and the account of Captain M'Quhæ.

The idea that the animal observed in this instance was a huge serpent, seems to have been simply slurred over without that due attention which this hypothesis undoubtedly merits. Whilst to my mind, the only feasible explanation of the narrative of the crew of the *Pauline* must be founded on the idea that the animals observed by them were gigantic snakes.

The habits of the animals in attacking the whales, evidently point to a close correspondence with those of terrestrial serpents of large size, such as the boas and pythons; whilst the fact of the animal being described in the various narratives as swimming with the head out of water, would seem to indicate that, like all reptiles, they were air-breathers, and required to come more or less frequently to the surface for the purpose of respiration. The difficulties which appear to stand in the way of reconciling the sea-serpent with a marine snake, in this or in other cases, are two in number. The great majority of intelligent persons are unaware of the existence of serpents of truly and exclusively marine habits; and thus the mere existence of such snakes constitutes an apparent difficulty, which, however, a slight acquaintance with the history of the reptilia would serve at once to remove. Mr. Gosse speaks of these marine snakes,—the *Hydrophidæ* of the naturalist,—which inhabit the warmer seas, possess compressed fin-like tails adapted for swimming, and are frequently met with far out at sea.* Whilst, as regards the claims of the "sea-serpent" to belong to the true serpent order, naturalists have dismissed this idea, simply because it has never occurred to them that a gigantic development of an ordinary species of sea-snake would fully correspond with most of the appearances described, and would in the most natural manner explain many of the sea-serpent tales. Suppose that a sea-snake of gigantic size

* It is interesting to note that frequent mention of the occurrence of large "sea-serpents" is made by the crews of vessels which have sailed through the Indian Ocean. An instance of a large sea-snake being seen in its native seas is afforded by the report of the master of the barque *Georgina* from Rangoon, which (as reported in the newspapers of September 4, 1877), put into Falmouth for orders on the 1st September. On May 21, 1877, in latitude 2° N. and longitude 90° 53′ E., a large serpent about forty or fifty feet long, grey and yellow in colour, and ten or eleven inches thick, was seen by the crew. It was visible for twenty minutes, during which time it crossed the bow, and ultimately disappeared under the port-quarter. There can be little doubt that this sea-serpent was simply a largely developed marine snake.

is carried out of its ordinary latitude, and allow for slight variations or inaccuracies in the accounts given by Captain M'Quhæ, and I think we have in these ideas the nearest possible approach to a reasonable solution of this interesting problem.

It will be asked how I account for the apparent absence of motion in the fore part of the body, and for the existence of a dorsal or back fin. I may suggest, in reply, that the simple movements of the laterally compressed tail, altogether concealed beneath the surface, would serve to propel the animal forward without causing the front portion of the body to exhibit any great or apparent motion; whilst the appearance of a fin may possibly be explained on the presumption that sea-weed may have become attached to the animal, or, that the upper ridge of the vertically compressed tail extended far forward and appeared as a fin-like structure.

The most important feature in my theory, however, in which I may be desired to lead evidence, and that which really constitutes the strong point of this explanation, is the probability of the development to a huge or gigantic size of ordinary marine serpents. This point is one in support of which zoology and physiology will offer strong and favourable testimony. There is no single fact, so far as I am aware, which militates in the slightest degree against the supposition that giant members of the sea-serpents may be occasionally developed. The laws which regulate human growth and structure, and in virtue of which veritable "sons of Anak," like Chang the Chinese giant, and the Russian giant, differing widely in proportions from their fellow-mortals, are developed, must be admitted to hold good for the entire animal kingdom. There is, in fact, no valid reason against the supposition that a giant serpent is occasionally produced, just as we familiarly observe almost every kind of animal to produce now and then a member of the race which mightily exceeds the proportions of its neighbours. But clearer still does our case become when we consider that we have proof of the most absolute and direct

kind of the giant development of such forms as cuttle-fishes, which have thus appeared as if in realisation of Victor Hugo's "devil-fish," which plays so important a part in that strange weird tale, the "Toilers of the Sea." The huge polypus of Pliny; the kraken of Bishop Pontoppidan, which that learned Churchman described as "*similior insulæ quam bestiæ;*" the "poulpe" of De Montfort, which was large enough to swallow a three-decker; and lastly Victor Hugo's cephalopodous creation, were deemed, not so very long ago, to belong entirely to the domain of myth and fancy. A few fragments of cuttle-fishes of large size had been now and then cast up on various coasts, it is true, but these instances were not regarded as at all sufficient to establish the existence of giant members of the group. At the present time, however, we are in full possession of the details of several undoubted cases of the occurrence of cuttle-fishes of literally gigantic proportions,—developed, in fact, to an extent justly comparable to that of the supposed "sea-serpent," when the latter is compared with its ordinary representatives of the tropical oceans. An illustration (copied from a photograph) of the head and tentacles of one of these cuttle-fish monsters is annexed (Fig. 9). This creature was cast ashore on the Newfoundland coast, a few years ago. The length of each of the long arms or tentacles coiled round the extremities of the support is twenty-four feet. The eight shorter arms are each six feet in length and ten inches in circumference at the base, and the eyes measured each four inches in diameter. Other giants of the cuttle-fish race are known to science, and no residuum of doubt now remains in the minds of naturalists regarding the existence of prototypes of Victor Hugo's "devil-fish." Many zoologists might hesitate greatly before assigning these monsters to new genera or species, and would simply regard them as giant developments of ordinary and already known cuttle-fish forms. Is there anything more improbable, I ask, in the idea of a gigantic development of an ordinary marine snake into a veritable giant of its race—or, for that matter, in the existence of distinct species of monster sea-serpents—

than in the production of huge cuttle-fishes, which, until within the past few years, remained unknown to the foremost pioneers of science? In the idea of gigantic developments of snakes or snake-like animals, be they fishes or reptiles, I hold we have at least a feasible and rational explanation of the primary fact of the actual existence of such organisms.

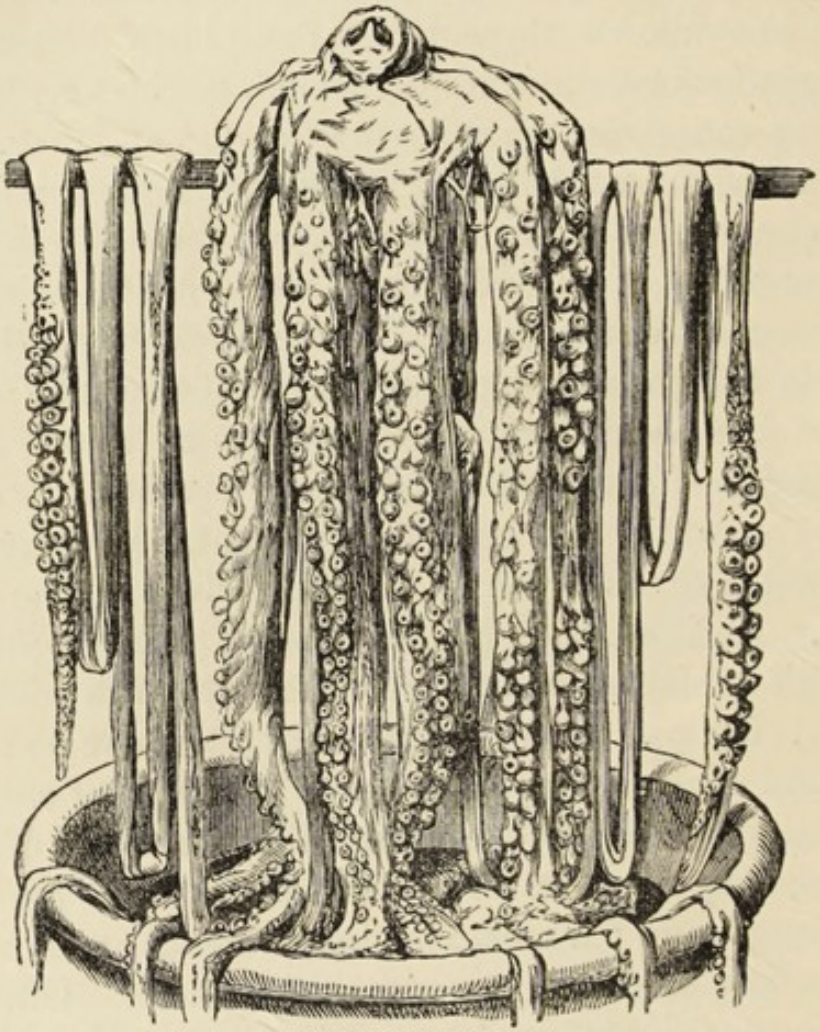


FIG 9.—Giant cuttle-fish's head. The arms, ten in number (two being longer than the others), are represented coiled round a support.

The differences regarding details of appearance and structure described in the sea-serpent tales, leads us next, and lastly, to point out certain considerations which may serve to explain away some of the difficulties which beset the question. That many of the appearances described, may have been produced by animals other than true serpents, cannot be doubted. It, therefore, constitutes an important part of our task to indicate the probabilities of

various other animal forms "doing duty," so to speak, for sea-serpents on some occasions.*

Amongst the fishes, we may find not a few examples of snake-like animals, which, admitting the fact of the occurrence of gigantic developments, may be supposed to mimic very closely the appearance of marine serpents. Any one who has watched the movements of a large conger-eel, for example, in any of our great aquaria, must have remarked not only its serpentine form, but also the peculiar gliding motion, which seems frequently to be produced independently of the active movements of the tail or pectoral fins. I do not doubt, however, that a giant eel might by most persons be readily enough referred to its proper place in the animal sphere, although, when viewed from some distance, and seen in an imperfect and indistinct manner, the spectators—all unprepared to think of an eel being so largely developed—might report the appearance as that of a marine snake.

A visit paid to the Newcastle Museum of Natural History, on which occasion I had the pleasure of inspecting a dried and preserved ribbon or tape-fish (see Frontispiece) of large size, forcibly confirmed an idea that such an animal, developed to a gigantic size, and beheld from a distance by persons unskilled in natural history,—and who would, therefore, hardly dream of associating the elongated being before them with their ordinary ideas of fish-form and appearance,—might account for certain of the tales of sea-serpents which have been brought under our notice. I had been specially struck with the mention, in several accounts of sea-serpents, of a very long back fin, sometimes termed a "mane," and of a banded body covered with tolerably smooth skin; whilst in several instances the description given of the heads of the sea monsters closely corresponded with the appearance of the head of the tape-fishes. These fishes have further been described by naturalists as occasionally having been seen swimming with an undulating or serpentine motion close to the surface of the water, the head being

* See note, p. 125.

somewhat elevated above the surface,—this latter feature, as we have observed, forming a remark of frequent occurrence in sea-serpent tales. I found, on making inquiry into the history of these fishes, that their serpentine form had struck previous observers, but, as far as I could ascertain, their merits as representatives of sea-serpents had never before been so persistently advocated.

These views and the dimensions of the specimen at Newcastle, I communicated to the *Scotsman* and *Courant* newspapers in June, 1876. The measurements of the ribbon-fish at Newcastle are given as 12 feet 3 inches in length, the greatest depth being 11¼ inches, and the greatest thickness only 2¾ inches; the small dimensions in thickness, and the relatively long length and depth, giving to these fishes the popular names of ribbon and tape-fishes. The species was the well-known *Gymnetrus* or *Regalecus Banksii* of naturalists; and by the museum-attendant at Newcastle, I was informed that a still larger specimen of the same species was recently obtained off the Northumberland coast, the length of this latter being 13½ feet, the depth 15 inches, and the thickness 5 inches. These fishes possess a greatly compressed body. The breast fins are very small, and the ventral or belly fins are elongated and spine-like. The first rays of the dorsal or back fin are very long, whilst the fin itself extends the whole length of the back, and attains an average breadth of about three inches.

Curiously enough, the publication of these views regarding the ribbon-fishes drew forth from the head of a well-known firm of fish merchants in Edinburgh, a remarkable confirmation of the idea that gigantic specimens of these fishes might be occasionally developed. The gentleman in question wrote to inform me that about thirty years ago he engaged the smack *Sovereign*, of Hull, Baillie commander, to trawl in the Frith of Forth for Lord Norbury, then residing at Elie Lodge, Fifeshire. Whilst engaged in their trawling operations, the crew of the *Sovereign* captured a giant tape-fish, which, when spread out at length on the deck, extended

beyond the limits of the vessel at stem and stern. The smack was a vessel of forty tons burthen, and the length may therefore be safely estimated at sixty feet,—this measurement being exceeded by the ribbon-fish. The breadth of the fish measured from five to nine inches, and the dorsal fin was from six to seven inches in depth. Unfortunately, Lord Norbury seemed inclined to view the giant he had captured with distrust, and ordered the fish to be cut in pieces and thrown overboard; but it is also worthy of remark that the trawlers seemed to express no great surprise at the size of Lord Norbury's specimen, since they asserted that they had met with one much larger, this latter being coloured of a dirty-brown hue.

It is interesting to note that the details furnished in the following account—taken from the *Times* of June 14, 1877—of a marine monster having been seen in the Mediterranean Sea, appear to be explicable on the ideas just mentioned regarding the tape-fishes. The account is furnished by observers whose veracity it would simply be impertinent to question:—"The *Osborne*, 2, paddle royal yacht, Commander Hugh L. Pearson, which arrived at Portsmouth from the Mediterranean on Monday, and at once proceeded to her moorings in the harbour, has forwarded an official report to the Admiralty, through the commander-in-chief (Admiral Sir George Elliot, K.C.B.), respecting a sea monster which she encountered during her homeward voyage. At about five o'clock in the afternoon of the 2nd instant, the sea being exceptionally calm, while the yacht was proceeding round the north coast of Sicily towards Cape Vito, the officer on the watch observed a long ridge of fins, each about six feet long, moving slowly along. He called for a telescope, and was at once joined by other officers. The *Osborne* was steaming westward at ten and a half knots an hour, and, having a long passage before her, could not stay to make minute observations. The fins were progressing in an eastwardly direction, and as the vessel more nearly approached them, they were replaced by the foremost part of

a gigantic sea monster. Its skin was, so far as could be seen, altogether devoid of scales, appearing rather to resemble in sleekness that of a seal. The head was bullet-shaped, with an elongated termination, being somewhat similar in form to that of a seal, and was about six feet in diameter. Its features were only seen by one officer, who described them as like those of an alligator. The neck was comparatively narrow, but so much of the body as could be seen developed in form like that of a gigantic turtle, and from each side extended two fins, about fifteen feet in length, by which the monster paddled itself along after the fashion of a turtle. The appearance of the monster is accounted for by a submarine volcano, which occurred north of Galita, in the Gulf of Tunis, about the middle of May, and was reported at the time by a steamer which was struck by a detached fragment of submarine rock. The disturbance below water, it is thought probable, may have driven up the monster from its 'native element,' as the site of the eruption is only one hundred miles from where it was reported to have been seen."

I thought the opportunity a favourable one for offering a reasonable explanation of the circumstance, and I communicated my views to the *Times* in the following terms, the latter appearing in that journal for June 15, 1877 :—

"About a year ago I ventilated in the columns of several journals the idea that the 'sea-serpents' so frequently seen, were in reality giant tape-fishes or ribbon-fishes. While not meaning by this statement to exclude the idea that other animals,—such as giant sea-snakes themselves,—may occasionally personate the 'sea-serpent,' I am, as a zoologist, fully convinced that very many of the reported appearances of sea-serpents are explicable on the supposition that giant tape-fishes—of the existence of which no reasonable doubt can be entertained—have been seen. The report of Captain Pearson, of the royal yacht *Osborne*, appears, as far as zoological characters are concerned, to be fully explained on the 'ribbon-fish' theory. The long back fins, the scale-

less skin, the rounded head, and, lastly, the two great side (or pectoral) fins, each measuring many feet in length, all form so many details corresponding exactly to the appearance of a great tape-fish. I offer these observations with the view of showing that, given a recital founded, as I believe the present narrative to be, on fact, we possess in the lists of living and of well-known animals adequate representatives of the 'great unknown.'"

The imperfect view obtained of the body renders the expression contained in the report, that the body was "like that of a gigantic turtle," somewhat problematical as to its correctness; and in the absence of more defined information, does not necessarily invalidate the views expressed above as to the personality of this strange tenant of the Mediterranean Sea.

In an article entitled "Strange Sea Creatures," which appeared in the *Gentleman's Magazine* for March, 1877, Mr. R. A. Proctor, speaking of my views regarding the sea-serpent, remarks that I offer "as an alternative only the ribbon-fish." This observation being hardly correct, I may point out that in the article in *Good Words*, from which Mr. Proctor quotes my views, I distinctly refer to the probability of giant sea-snakes being occasionally developed and appearing as the modern sea-serpent. The use of the word "only" in Mr. Proctor's remark is misleading; since I offer the ribbon-fishes simply as explanatory of certain sea-serpent narratives, and not as a sole and universal representative of the modern leviathan.

Thus, then, with the ribbon-fishes at hand, and with the clear proofs before us that these and other animals may be developed to a size which, compared with their ordinary dimensions, we can only term enormous, I think the true and valid explanation of the sea-serpent question is neither far to seek nor difficult to find. To objectors of a practical turn of mind, who may remind me that we have not yet procured even a single bone of a giant serpent, I would point out that I by no means maintain the frequent development

of such beings. The most I argue for and require is their occasional production; and I would also remind such objectors of the case of the giant cuttle-fishes which, until within the past few years, remained in the same mysterious seclusion affected at present by the great serpentine unknown. I need only add that I have as firm faith in the actual discovery of the giant serpent of the sea, as that in the giant tape-fish we find its representative, or that in the huge development of ordinary forms we discover the true and natural law of its production.

To sum up my arguments by way of conclusion, I respectfully submit, as does a pleading counsel to his jury,—

Firstly: That many of the tales of sea-serpents are amply verified, when judged by the ordinary rules of evidence; this conclusion being especially supported by the want of any *primâ facie* reason for prevarication;

Secondly: That, laying aside appearances which can be proved to be deceptive and to be caused by inanimate objects or by unusual attitudes on the part of familiar animals, there remains a body of evidence only to be explained on the hypothesis that certain gigantic marine animals, at present unfamiliar or unknown to science, do certainly exist; and

Thirdly: That the existence of such animals is a fact perfectly consistent with scientific opinion and knowledge, and is most readily explained by recognising the fact of the occasional development of gigantic members of groups of marine animals already familiar to the naturalist.

Since the foregoing remarks were penned, details have been published (*Nature*, February 21, 1878), respecting "A New Underground Monster," which have a very decided bearing on the sea-serpent question, as tending to show that even in the land-fauna of remote districts, there may be included animals of a size and nature utterly undreamt of by the scientific world. The details alluded to are forwarded by the well-known naturalist Fritz Müller, and are related of

the appearance and doings of the "Minhocao," a creature supposed to be a "gigantic earthworm," and which inhabits the highlands of the southern provinces of Brazil. The account as given in the pages of *Nature* is of similar nature to the stories told us of the existence and appearance of sea-serpents. There is the same simplicity of narrative, united to an absence of all reason or cause for exaggeration or invention. We are therefore bound, as already remarked, either to accept such stories as true,—as relating to observed facts,—and to examine them impartially with the view of detecting discrepancy and of possibly modifying details; or, on the other hand, to unhesitatingly and simply reject them. This latter procedure would of course be founded on an unwarrantable supposition,—such as in the ordinary affairs of life would not for a moment be tolerated,—namely, that deliberate lying and meaningless deception are vices of commoner occurrence than humanity at large has been led to suppose. The marks or tracks of the animal, of whatever description it may be, are a valuable source of evidence which, unfortunately, the "pathless deep" cannot offer to the inquirers into the personality of the "sea-serpent." Pending further research, one may only remark that the details given are in all respects of a very circumstantial and clearly related kind, and are such as would lead us to be exceedingly hopeful, now that scientific attention has been directed to the matter, of new and extraordinary additions being made to the lists of zoologists. The following is the account of the animal in question :—

"The stories told of this supposed animal," says Fritz Müller, "sound for the most part so incredible that one is tempted to consider them as fabulous. Who could repress a smile at hearing men speak of a worm some fifty yards in length, and five in breadth, covered with bones as with a coat of armour, uprooting mighty pine trees as if they were blades of grass, diverting the courses of streams into fresh channels, and turning dry land into a bottomless morass? And yet, after carefully considering the different accounts given of the

minhocao one can hardly refuse to believe that some such animal does really exist, although not quite so large as the country folk would have us to believe.

"About eight years ago a minhocao appeared in the neighbourhood of Lages. Francisco de Amaral Varella, when about ten kilometres distant from that town, saw lying on the bank of the Rio das Caveiras a strange animal of gigantic size, nearly one metre in thickness, not very long, and with a snout like a pig, but whether it had legs or not he could not tell. He did not dare to seize it alone, and whilst calling his neighbours to his assistance, it vanished, not without leaving palpable marks behind it in the shape of a trench as it disappeared under the earth. A week later a similar trench, perhaps constructed by the same animal, was seen on the opposite side of Lages, about six kilometres distant from the former, and the traces were followed, which led ultimately under the roots of a large pine tree, and were lost in the marshy land. Herr F. Kelling, from whom this information was obtained, was at that time living as a merchant in Lages, and saw himself the trenches made by the minhocao. Herr E. Odebrecht, while surveying a line of road from Itajahy into the highlands of the province of Santa Caterina, several years ago, crossed a broad marshy plain traversed by an arm of the river Marombas. His progress here was much impeded by devious winding trenches which followed the course of the stream, and occasionally lost themselves in it. At the time Herr Odebrecht could not understand the origin of these peculiar trenches, but is now inclined to believe that they were the work of the minhocao.

"About fourteen years ago, in the month of January, Antonio José Branco, having been absent with his whole family eight days from his house, which was situated on one of the tributaries of the Rio dos Cachorros, ten kilometres from Curitibanos, on returning home found the road undermined, heaps of earth being thrown up, and large trenches made. These trenches commenced at the source

of a brook, and followed its windings, terminating ultimately in a morass after a course of from 700 to 1000 metres. The breadth of the trenches was said to be about three metres. Since that period the brook has flowed in the trench made by the minhocao. The path of the animal lay generally beneath the surface of the earth under the bed of the stream; several pine trees had been rooted up by its passage. One of the trees from which the minhocao in passing had torn off the bark and part of the wood, was said to be still standing and visible last year. Hundreds of people from Curitibanos and other places had come to see the devastation caused by the minhocao, and supposed the animal to be still living in the marshy pool, the waters of which appeared at certain times to be suddenly and strangely troubled. Indeed, on still nights a rumbling sound like distant thunder and a slight movement of the earth was sensible in the neighbouring dwellings. This story was told to Herr Müller by two eye-witnesses, José, son of old Branco, and a stepson, who formerly lived in the same house. Herr Müller remarks that the appearance of the minhocao is always supposed to presage a period of rainy weather.

"In the neighbourhood of the Rio dos Papagaios, in the province of Paranà, one evening in 1849 after a long course of rainy weather, a sound was heard in the house of a certain João de Deos, as if rain were again falling in a wood hard by, but on looking out, the heavens were seen to be bright with stars. On the following morning it was discovered that a large piece of land on the further side of a small hill had been entirely undermined, and was traversed by deep trenches which led towards a bare open plateau covered with stones, or what is called in this district a 'legeado.' At this spot large heaps of clay turned up out of the earth marked the onward course of the animal from the legeado into the bed of a stream running into the Papagaios. Three years after this place was visited by Senhor Lebino José dos Santos, a wealthy proprietor, now

resident near Curitibanos. He saw the ground still upturned, the mounds of clay on the rocky plateau, and the remains of the moved earth in the rocky bed of the brook quite plainly, and came to the conclusion that it must have been the work of two animals, the size of which must have been from two to three metres in breadth.

"In the same neighbourhood, according to Senhor Lebino, a minhocao had been seen several times before. A black woman going to draw water from a pool near a house one morning, according to her usual practice, found the whole pool destroyed, and saw a short distance off an animal which she described as being as big as a house moving off along the ground. The people whom she summoned to see the monster were too late, and found only traces of the animal, which had apparently plunged over a neighbouring cliff into deep water. In the same district a young man saw a huge pine suddenly overturned, when there was no wind and no one to cut it. On hastening up to discover the cause, he found the surrounding earth in movement, and an enormous worm-like black animal in the middle of it, about twenty-five metres long, and with two horns on its head.

"In the province of São Paulo, as Senhor Lebino also states, not far from Ypanema, is a spot that is still called Charquinho, that is, Little Marsh, as it formerly was, but some years ago a minhocao made a trench through the marsh into the Ypanema river, and so converted it into the bed of a stream.

"In the year 1849, Senhor Lebino was on a journey near Arapehy, in the State of Uruguay. There he was told that there was a dead minhocao to be seen a few miles off, which had got wedged into a narrow cleft of a rock, and so perished. Its skin was said to be as thick as the bark of a pine tree, and formed of hard scales like those of an armadillo.

"From all these stories it would appear conclusive that in the high district where the Uruguay and the Paranà have

their sources, excavations and long trenches are met with, which are undoubtedly the work of some living animal. Generally, if not always, they appear after continued rainy weather, and seem to start from marshes or river-beds, and to enter them again. The accounts as to the size and appearance of the creature are very uncertain. It might be suspected to be a gigantic fish allied to *Lepidosiren* and *Ceratodus;* the 'swine's snout,' would show some resemblance to *Ceratodus*, while the horns on the body rather point to the front limbs of *Lepidosiren*, if these particulars can be at all depended upon. In any case, concludes Herr Müller, it would be worth while to make further investigations about the minhocao, and, if possible, to capture it for a zoological garden!

"To conclude this remarkable story, we may venture to suggest whether, if any such animal really exist, which, upon the testimony produced by Fritz Müller, appears very probable, it may not rather be a relic of the race of gigantic armadilloes which in past geological epochs were so abundant in Southern Brazil. The little *Chlamydophorus truncatus* is, we believe, mainly, if not entirely, subterranean in its habits. May there not still exist a large representative of the same or nearly allied genus, or, if the suggestion be not too bold, even a last descendant of the Glyptodonts?" *

*Dr. Joseph Drew details, in *Nature* of September 5, 1878, a case of serpentine appearance in the English Channel, produced by a mass of birds, probably shags, in rapid motion; the aspect of the moving column being described as resembling "an immense serpent, apparently about a furlong in length, rushing furiously along at the rate of fifteen or twenty miles an hour." In the same journal for September 12 one correspondent relates the case of a sea-serpent which resolved itself into "a bamboo, root upwards," and having weeds attached thereto. Another correspondent rightly doubts, however, "whether *all* sea-serpent stories can be thus explained;" and the correspondence in question once again illustrates the necessity for carefully distinguishing "between cases in which serpentine appearances have been assumed by ordinary animals, and those in which *one* animal form has presented itself in the guise of the 'great unknown.'"

SOME ANIMAL ARCHITECTS.

One of the most interesting departments of natural history study is that which devotes itself to the elucidation of the manner in which living beings utilise the various materials of the universe in which they exist, for purposes of protection, for offence or defence, or for food, raiment, and the common necessaries of life. Whilst man, in virtue of his superior powers of adapting himself to his surroundings, may excel lower forms in respect of the variety of means and substances he calls to aid in the advancement of his interest and comfort, it must at the same time be admitted that he is frequently surpassed by the unerring skill with which a particular product is utilised and manufactured by his lower neighbours. Indeed, as a rule, the elegance and quality of the products of animal life at large are found to be apparently out of all proportion to the means by which they were elaborated. And in very many instances the lower animal accomplishes, in the way of direct and unassisted manufacture, a work which man may, after all, but imperfectly imitate by the aid of cunning artifice and mechanical contrivance. The production of a silken thread by the "spinnerets" of the spider or caterpillar is apparently an act of the simplest possible character, viewed in regard to the apparatus and actions which engage in its manufacture; but placed in relation to human contrivance, we may well fail to conceive the delicacy of the spinning-jenny or more modern machine which could evolve a product of like nature. The instinct of the animal, blind and automaton-like as it may be, certainly holds its own in respect of the perfection

and results of its work, when compared with the fruits of intelligence, and with the highest exercise of experience and acquired art.

In no phase of their operation do the vital acts and functions of animals present us with greater profusion of detail than in the consideration of the ways and means adopted for the construction of various portions of their bodies from materials derived from the outer world. The power possessed by living beings, not only of laying hold of such materials, but of duly selecting and appropriating such substances as are best adapted to the work in hand, constitutes, after due reflection, one of the marvels of life at large. Nowhere can we see this marvellous power of selection better exemplified than in certain of the lowest forms of animal life, as representing one extremity of the scale of being, and in man as illustrating the highest grade in the ranks of animal society. The waters of our oceans, both at the surface and in their depths, are inhabited by beings of microscopic size, and of a marvellous simplicity of body. Each of these minute animals consists of a speck of structureless, jelly-like substance,—the protoplasm or sarcode of the physiologist. Placed under the microscope, these living particles may be seen to live and move, to eat and digest, as do their higher neighbours. Compared with the latter, they may be noted to present singular and paradoxical exceptions to the ordinary rules of living and being, since they are thus observed to live, literally without possessing any apparent structures to carry on the functions of life. Such are the beings known to naturalists as the foraminifera and the radiolarians (Figs. 10, 11, 12). Between these two groups no absolute distinction, as far as their living substance is concerned, can be drawn. Yet that distinctions may and do exist is perfectly obvious, if we consider the results of the life in each case. The particle of living jelly we term a foraminifer (Fig. 12), takes from the water of the sea a proportion of the lime which exists dissolved in that medium, and from this lime moulds and forms a shell, in which it protects its

soft, semi-fluid body. The neighbour-particle we name a radiolarian (Fig. 11), existing side by side with the foraminifer, selects flint as its special material from its native waters, and builds a shell of this substance, exhibiting in many

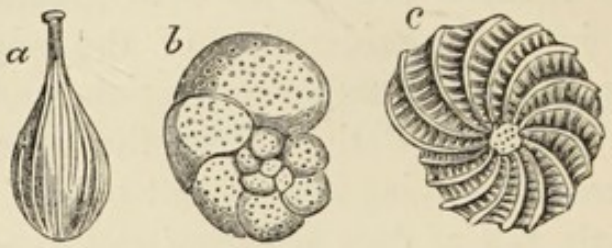


FIG. 10.—Shells of foraminifera, all magnified: *a*, *Lagena*, or "flask animalcule;" *b*, *Discorbina*; *c*, *Polystomella*.

cases, outlines of mathematical nature, and shapes of the most graceful and elegant kind. Thus there must exist, even

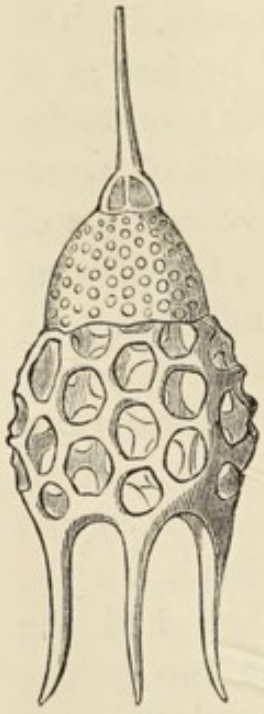


FIG. 11.—A radiolarian shell (*Podocyrtis*).

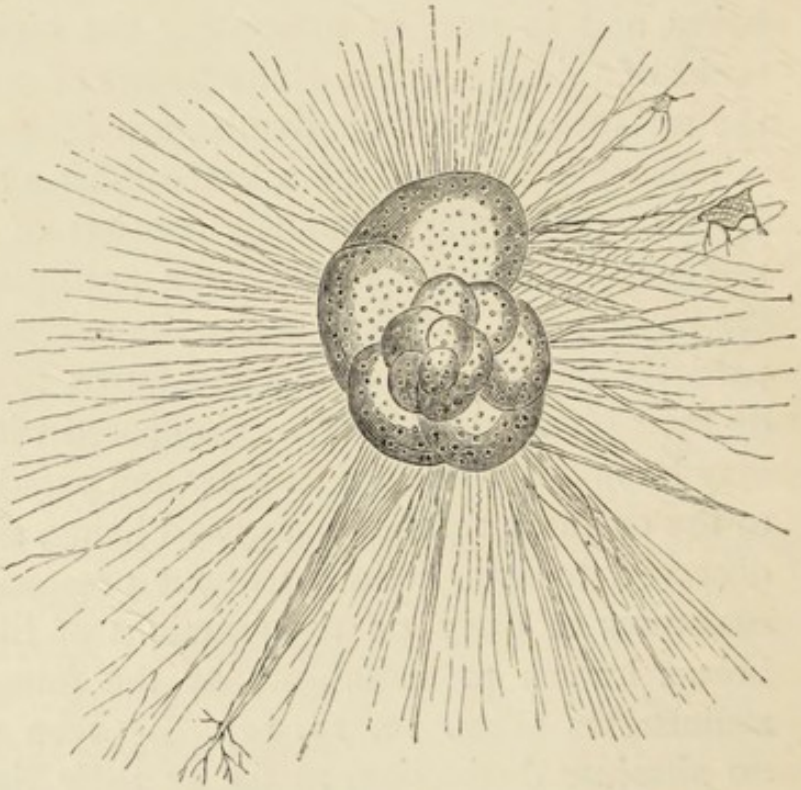


FIG. 12.—A living foraminifer (*Rotalia*), showing the living matter protruded from the shell.

in such simple and primitive organisms, not only a selective principle of the exact nature of which we are utterly ignorant, but a further exercise, in the building of a shell, of a power of whose exact direction and extent we know absolutely nothing.

But if the puzzle of life and of animal architecture is so difficult of solution in these lower forms, it is found to present no plainer aspects when offered for investigation in the personality and frame of even the highest being. Regarded from an aspect similar to that in which the denizens of the depths have just been studied, man's existence is seen to comprehend phases of equally puzzling nature. No law of life rests on a firmer basis than that which maintains that the act of living and being is associated with constant change and alteration, and that the wear and tear of life demand proportional repair. Through each tissue of the body, the life-renewing blood is therefore continually being distributed. The muscle, wearied in the actual work of the body, recruits itself from the supply of nourishment thus afforded it; nerves renew their strength from the same source; and even thought itself thus becomes related in a distinct manner to the material blood from which the thinking brain derives the wherewithal to carry on its work. Nor is this all. It is not only the case that each tissue derives from the blood the necessary matter to replace that which has been lost and expended in the work of life. Each tissue, it must be likewise noted, also takes from the common stream of nourishment the materials necessary for the building up of new substance. From the blood, bone selects the materials necessary for the formation of new bone; nerve from the same source gathers matter for the production of new nerve-tissue; muscle therefrom elaborates new muscle; cells of wondrously diverse kind, like buyers of many nations in a common market, select from the blood the special food or pabulum suited to their wants, and therefrom manufacture new cells:—in short, the process of growth in man and in all animals of higher grade, exemplifies the results of many varied operations effected by the tissues and organs of the body upon the common material offered to them, in the shape of the nutrient blood. How this property of "selection" is exercised, or what is its exact nature, science knows not as yet. But the possession of this remarkable property of

selecting and using appropriate material in the actions of life, explain it how we may, constitutes one of the most consistent and clearly defined distinctions which can be drawn between the world of life and the great encompassing universe of non-living matter.

The foregoing remarks may serve to elucidate in some degree the essential nature of a process whereby certain animal forms not only build up structures of massive kind in modern seas, but through which they have been enabled to effect change and alteration of no ordinary extent on our earth, in past epochs of its history. With the coral-animals every one must be familiar as far as the mere name of these beings is concerned; and doubtless few people are unfamiliar with some variety or other of the substance manufactured by the animals just named. As presenting a subject for a brief investigation into some curious phases, not only of animal life but of physical history also, the coral-animals stand possibly without a rival; and as illustrative of a veritable race of animal architects, these beings have no equal, either in respect of the variety or the magnitude of their operations.

Probably no portion of the domain of the naturalist has been more plentifully overrun with error than the special territory which includes the coral-polypes as its tenants. To begin with, errors in name are of plentiful occurrence; the most common instance of this kind being found in the erroneous designation of "insects" often bestowed on the coral-animals. The name "insect" was no doubt applied in a very loose and general sense in bygone days. But it is the first duty of science to be correct in its nomenclature, and as suggestive of a relationship to the familiar "insects" the use of this term, as applied to the coral-architects, is of grossly erroneous nature. Ere now, also, the fishes of the sea have been credited with the work of building coral-reefs, and the vague term "animalcules" was used in former days to indicate the nature of the workers in coral. Nor have poets been behind in propagating erroneous ideas concern-

ing the nature and work of the coral-animals. As Professor Dana remarks, Montgomery's "Pelican Island" contains statements which a scientific man at least can hardly excuse on the ground of poetical licence. "The poetry of this excellent author," says Dana, "is good, but the facts nearly all errors,—if literature allows of such an incongruity. There is no 'toil,' no 'skill,' no 'dwelling,' no 'sepulchre,' in the coral-plantation, any more than in a flower garden; and as little are the coral-polypes shapeless worms that 'writhe and shrink their tortuous bodies to grotesque dimensions.'" The coral-animals, in short, manufacture or secrete the coral-substance as a part of their life-action and nature, just as a flower manufactures its colour, or as a higher animal forms its bones. The living acts of the coral-animal include the formation of coral as an essential and natural duty, and not as a work of a merely accidental or occasional kind.

It is noteworthy that the animal nature of coral was first discovered only some hundred and fifty years ago. Such an assertion may appear somewhat strange to the ordinary reader, considering the universally admitted animal nature of the substance. But it must be remembered that the distinctions between animals and plants have only in comparatively late years been duly investigated; and the habit of placing reliance upon external form and outward appearance as a means of distinction, certainly tended to place the plant-like and rooted corals as veritable plants before the eyes of naturalists in past days. The appearance of a piece of red coral, or of the nearly allied *Isis* or "mare's-tail" coral, in its living state (Fig. 13), for example, is decidedly plant-like. We see a branching structure, consisting

FIG. 13.—"Mare's-tail" coral: (*Isis hippuris.*)

of a hard, central axis of coral, covered over with a soft skin or living bark, imbedded in which numerous little beings, each possessing a circle of eight fringed arms or feelers, are to be noted. These little beings are the "coral-polypes." That they are sensitive is proved by their habit of shrinking within the living bark of which they form part, when irritated or alarmed; and as the appearance of the polypes is flower-like to a high degree, it is not surprising to find that the Count de Marsigli should have described and figured the sensitive "flowers" of the coral "plant" in his celebrated work entitled "La Physique de la Mer," published in 1706. The ideas which prevailed at that date regarding the exact structure of the supposed coral "plant," however, were of improved kind as compared with prior conceptions of its nature. Ovid states the popular belief of the classic period when he relates that the coral was a sea-weed which existed in a soft state so long as it remained in the sea, but had the curious property of becoming hard on exposure to the air. Messer Boccone, in the 17th century, was the first to refute this idea, and showed that, although the coral "plant" possessed a soft outer bark, it was in reality a permanently hard structure even in its native waters. It so happened, that about 1723 a pupil of Count Marsigli's, Jean André de Peysonnel by name, obtained a commission from the French Academy of Sciences to study the coral "plants" in their native seas. Proceeding to Marseilles and to the North African Coast, Peysonnel soon found reason to alter the views with which he had been indoctrinated respecting the nature of the living parts in the coral. Studying the red coral attentively, this observer said that the coral "flowers" of Marsigli were true animals, and were in fact closely related to the familiar but plant-like "orties" or sea-anemones, which Réaumur in 1710 had shown to be animals. In his remarks on the coral-polypes, Peysonnel compared the coral-animals to "une petite ortie ou poulpe." And that the comparison of the coral-polype to the "ortie" or anemone is a perfectly just one, is proved by the fact that

the zoologist of to-day selects the latter animals as the type of the great class of coral-producing animals.

It is no easier task to root out and supplant long-established beliefs in science than in the ordinary affairs of life; and Peysonnel found to his cost that to play the *rôle* of a conscientious observer and reformer is by no means a labour of easy or enviable kind. Réaumur, whose discovery of the animal nature of the sea-anemones might have been supposed to have given him a peculiar aptitude for criticising Peysonnel's observations after a just fashion, was one of the first to condemn the young student of Marseilles; and other Academicians followed in wholesale condemnation of the revolutionary tendencies of Peysonnel's discovery. Disgusted with the treatment shown towards him by the Academicians whose accredited emissary he was, Peysonnel sailed for the Antilles, engaged in the profession of a naval surgeon, and forwarded to the Royal Society of London the results of his further researches on the coral-polypes. To this day, Peysonnel's observations remain in manuscript in the library of the Natural History Museum at Paris; but it is satisfactory to learn that the ill-treated *savant* lived long enough to find the truth and worth of his discoveries fully admitted. Certain experiments of Trembley, published in 1744, upon those peculiar fresh-water polypes, the hydræ, led to the recognition of these plant-like beings as true animals. The lists of plant-like forms were next overhauled, with the result of demonstrating the animal nature of many organisms which were formerly included within the botanist's domain, and amongst these new-found animals were the coral-polypes, whose exact nature Peysonnel had demonstrated many years before.

The animal nature of the coral-producing beings having thus been demonstrated, their place in the animal series may in the next instance be briefly referred to. As already remarked, the common sea-anemone of our coasts may be selected as the type of the coral-animals,—as far as the structure of its soft parts is concerned. The anemones, as every sea-side visitor knows, do not manufacture or secrete

any hard skeleton; but if we suppose that such a power existed in these familiar denizens of our coasts, and that, taking lime from the sea-water, they elaborated such material into hard parts of various kind, we should possess a broad but essentially correct idea of the nature of any coral-polype. We thus note the incongruity of applying such a name as a coral "insect" to these animals; whilst we can also realise the justness of Peysonnel's descriptions. The coral-polype is a little lime-secreting anemone, possessing a central mouth surrounded by arms or tentacles, the latter capable of withdrawal on being irritated. Peysonnel's name of "poulpe," also given to the coral-animals, is seen to be equally applicable; this name "poulpe" being derived, like the English "polype," from the Latin "polypus," a term meaning "many-footed." The name "poulpe" or "polype" was also given to the cuttle-fishes,—these latter animals, like the anemones and coral-polypes, having numerous arms arranged around a central mouth.

Such being the relations of the coral-polypes to the sea-anemones, certain of the more important differences they exhibit from their familiar representatives may be noted. The common groups of sea-anemones exist, like most other animals, in a single and simple condition, that is to say, each animal is entirely independent of and disconnected from its neighbours. The reverse, however, is the case with the coral-polypes; for amongst these animals there exists a marked tendency to produce compound "colonies" or aggregated masses of animals, which, curiously enough, originate from single and simple forms by a veritable process of budding. Some coral-polypes are, like the sea-anemones, single in their nature. No better example of a solitary coral-polype could be cited than the little Devonshire "cup coral" or *Carophyllia* (Fig. 14), one of the few lingering remnants of British coral-life. The cup coral appears before us as a veritable anemone, possessing the power of elaborating an internal living skeleton; and the foreign mushroom corals or *Fungiæ* may also be cited as representatives of

simple corals. The branch of red coral and the vast majority of reef-building and other corals exhibit, however, the true characteristics of their race, in that they are of compound nature, and form, in the reef-building corals, by a process of continuous and connected growth, masses of immense size and extent. Indeed, it is this feature of constant and connected production which gives to these animals their characteristic power of forming huge monuments of stable and enduring kind on the surface of the earth. It may appear somewhat strange to speak of budding in connection

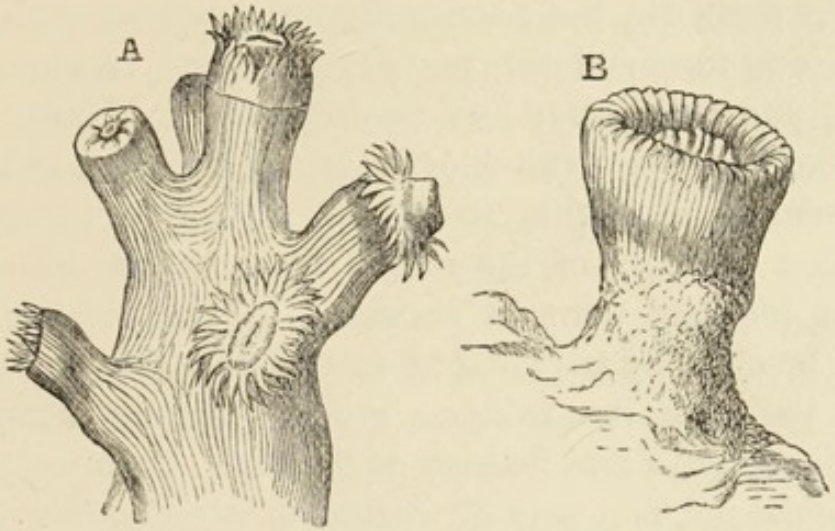


FIG. 14.—Corals. A, *Dendrophyllia*, one of the "tree corals;" B, *Carophyllia*, the "cup coral."

with the animal form. The process, however, not only occurs in the class of coral-polypes, but is represented in the nearly allied zoophytes, and in several other groups of animals. The history of a great mass of coral may be thus traced from its earliest stage, when an egg, liberated from some member of an already-formed colony, settled down, attached itself, and produced a single anemone-like polype. This solitary polype next began to bud, and so produced a series of new and connected beings; and if we suppose the budding process to be in turn repeated by each member of the colony, we can readily understand how the compound organism should attain in due time a growth of almost unlimited extent. Many corals also provide for their increase

by a process of *fission*, that is, of simple division of the body-substance into new individuals. The occurrence of this process in the corals is not surprising when we consider that the common sea-anemone may be divided artificially, like the hydra, with the result of producing one or more new individuals. Some of the star corals or Astræas, of the Pacific, grow into great stony hemispheres through this method of increase, these masses frequently possessing a diameter of from ten to fifteen feet. Life and death in the living coral, to use Mr. Dana's words, may be regarded as "going on together, *pari passu*." As new living parts are developed, the older parts die, but necessarily leave behind their coral-substance to form enduring parts of the mass. In some cases, according to the author just quoted, "a polyp, but a fourth of an inch long, or even shorter, is finally found at the top of a stem many inches in height. . . . The tissues that once filled the cells of the rest of the corallum have dried away, as increase went on above. . . . The coral-zoophyte may be levelled by transported masses swept over it by the waves; yet, like the trodden seed, it sprouts again, and continues to grow and flourish as before." Thus the fertility of the coral-polypes may be regarded as of double nature, since we find that each member of a coral colony is capable —first, of giving origin to eggs, each of which when duly developed represents the initiatory stage in the production of a new colony; and secondly, of increasing each individual colony by an unlimited process of budding or fission.

As features in the general structure of corals, which deserve a brief notice by way of conclusion to their personal history, we may refer to the main differences observable in the coral-structure, and to certain variations in the chemical composition of the coral. A piece of red coral, or mare's-tail (Fig. 13), exemplifies one of the two chief varieties of coral; the coral-substance forming in this instance a solid central axis, on the outside of which the living bark consisting of numerous polypes is situated. In this and similar cases, all traces of the separate coral-polypes dis-

appear when the living matter is washed away. But in the second variety of coral-structure, well exemplified by the Carophyllia and the great reef-building corals (Fig. 14), the coral-substance is outside the living parts, each little polype being contained within a cell which it has secreted and formed. This latter mode of growth produces the massive solid corals, on the presence and increase of which the formation of reefs depends; the more delicate and branching species being formed after the type of the red coral and its neighbours. That lime is the chief element represented in the coral-substance may be readily inferred from the preceding remarks. A few corals, however, exhibit a composition in which lime plays an altogether secondary part. Thus the *Isis* or mare's-tail coral (Fig. 13) of the Indian Ocean and elsewhere, consists of alternate joints of horny and limy matter; whilst in another group, represented by the *Gorgonias* or "sea-fans," the coral is entirely composed of horny material. The essential details comprised in the general history of the coral-polypes may be briefly summarised by way of introduction to the investigation of their actual work in reef-formation, by asserting each coral-animal to be in all essential details of structure a sea-anemone; and by the further statements, that the coral-polypes differ from the anemones in respect of their ability to form an internal or external skeleton usually consisting of limy matter, and that they increase indefinitely by a process of budding or of division, and thus give rise to connected colonies. Bearing these details in mind, the further history of the operations of these animals will be readily understood.

Two important points in the life of the coral-polypes demand attention by way of introduction to the general history of their architectural operations. Like all other living beings, the coral-animals require certain special conditions as those of their normal existence. In the case before us, the two conditions demanded are a certain *temperature* and a certain *depth* of sea; these conditions constituting the environments, as it were, of coral life. The

question of temperature is a highly important one, inasmuch as the condition of the sea as to warmth will be found to regulate the distribution in space of the corals. The geography of these animals, in short, is bounded by well-defined lines or degrees of temperature; and the statement that reef-building corals will not as a rule flourish and grow in seas the temperature of which falls below 68° Fahr., may be taken as a summary of what has been ascertained on this point. We must, therefore, look to equatorial seas, as those in which the typical development of reef-building corals occurs; and a ready mode of stating the broad facts of the distribution of coral life consists in our selecting the equator as a natural centre of our globe, and in measuring off a band of 1800 miles in breadth on each side of that line. A broad band or area some 3600 miles in breadth, encompassing our globe, and having the equator for its centre, will thus be found to include in its course the chief regions of coral growth. But, as Mr. Dana remarks, whilst the distribution of corals depends to a very great extent upon temperature, "regional peculiarities" also "exist that are not thus accounted for."

Whilst the Pacific and Indian Oceans form great repositories of coral-reefs existing within the limits just mentioned, and whilst the Red Sea, the N.E. coast of Australia, and the coast of Florida also exemplify great areas of coral development, certain other oceanic tracts exist, from which coral-reefs are wholly absent. Mr. Darwin thus informs us that "no coral-reefs were observed during the surveying voyages of the *Beagle* on the west coast of South America south of the equator, or round the Galapagos Islands. It appears also," he continues, "that there are none on this coast north of the equator." The western coast of Africa is singularly free from coral-reefs; and it may be laid down as a rule of the widest possible kind, that coral-reefs are not found near the estuaries of great rivers, a result clearly due to the mixed or brackish character of the water in such situations. It may be shown that the absence of reefs on the western

coasts of South America and Africa is due to the lower temperature which prevails in these areas, but it is possible that other causes—to be hereafter noted—less dependent on temperature or on the sea itself, may more feasibly explain the non-development of coral life in certain regions.

The condition included under the head of *depth* is, if anything, a more important item in the maintenance of coral life and growth than that of heat. If we cite evidence on this point, we may ascertain that the subject of the depth at which corals live received attention from more than one naturalist in past days. The French explorers Quoy and Gaimard, in their report of observations published in 1824, were probably the first who ventilated the opinion that the living reef-building corals existed in *limited depths of sea*. Foster and the earlier navigators assumed that, as coral-reefs were found in depths of literally unfathomable kind, the coral-polypes grew from the abysses of ocean. But Quoy and Gaimard concluded, from observations made in two voyages, that a depth of from thirty to thirty-six feet represented the zone of coral life. Ehrenberg set the limit from which living coral was fished at six fathoms, and Mr. Stutchbury, another observer, maintained that a depth of sixteen or seventeen fathoms might be regarded as the furthest limit of the living reef-forming corals. Mr. Darwin concludes "that in ordinary cases, reef-building polypifers do not flourish at greater depths than between twenty and thirty fathoms, and rarely at above fifteen fathoms." And Mr. Dana remarks that "there is hence little room to doubt that *twenty fathoms* may be received as the ordinary limit in depth of reef-corals in the tropics." In answer to a suggestion that "reefs may possibly rise from very great depths through the means of small corals first making a platform for the growth of the stronger kinds," Mr. Darwin says, "this, however, is an arbitrary supposition; it is not always remembered that in such cases there is an antagonistic power at work, namely, the decay of organic bodies when not protected by a covering of sediment or by their own rapid growth. We have,"

he adds, "moreover, no right to calculate on unlimited time for the accumulation of small organic bodies into great masses. . . . As well might it be imagined that the British seas would in time become choked up with beds of oysters, or that the numerous small coral-lines off the inhospitable shores of Terra del Fuego would in time form a solid and expansive coral-reef."

The causes of the limitation in depth of corals may be summed up by recognising the necessity of a due supply of light and air for maintaining the vitality of the living animals. The living polypes require light as a condition for the exercise of their vital functions, and they no less imperatively demand a due supply of the vivifying oxygen; these essentials for vitality being obtainable only in surface-waters, or within a limited depth in the ocean. Recognising the settled and affirmed nature of these two conditions of coral life, we may next proceed to examine the curiously complicated problem which the condition of limited depth especially imposes upon the naturalist. How, in other words, when we take into account the limitation in depth of living corals, can we explain the erection of coral-reefs and islands existing in abyssal or unfathomable depths of sea?

It is a striking characteristic of scientific procedure that no new or strange fact is long left without an explanation. That the first explanation may not necessarily be correct, but is, on the contrary, more likely to prove untenable when a wider knowledge of the fact or facts is obtained, are statements which the history of scientific hypotheses and their verification fully endorses, and which the fate of the first-offered theories of the erection of coral-reefs fully confirms. To appreciate the points which the theories of the erection of coral-reefs include, it becomes necessary to glance, in the first instance, at the various forms which coral-reefs may assume. These reefs may be divided into fringing reefs, barrier reefs, and atolls or lagoon reefs. The nature of the first-named erections is explained by their name. They simply fringe or skirt the margins or coasts of lands, and appear to be mere

coral-extensions of the ordinary beach. A typical reef of this description is seen to surround the island of Mauritius, and another skirts the coast of Cuba. A sounding-lead allowed to descend on the seaward face or edge of a fringing reef would strike the true sea-bottom at a depth not exceeding twenty-five fathoms. Its outer edge is formed of true reef-building corals, which seem to thrive best amid the spray and surf. Near the shore, different and less hardy corals live; and in the shallow water which intervenes between the reef and the shore, a whitish mud, consisting of the *débris* of the dead corals, is found, together with blocks of coral which have been torn from the reef and cast up on the shore by the violence of storms. "A fringing reef," says Mr. Darwin, "if elevated in a perfect condition above the level of the sea, would present the singular appearance of a broad, dry moat, bounded by a low wall or mound." The breadth of a fringing reef depends on the slope of the beach; the more gradual the slope, the further seawards will the reef extend; whilst a steep beach, preventing a great depth of water nearer the shore than the sloping form, will proportionally limit the seaward growth of the corals. On very steep coasts, fringing reefs may not exceed fifty yards in width, that measurement representing the distance from the shore at which the coral-polypes reach their furthest limit of depth.

The barrier reef is an erection of a very different kind from the preceding variety of reef. In its most typical form, well seen on the north-east coast of Australia, or on the western coast of New Caledonia, a barrier reef appears as a great bank or reef of coral, separated from the adjoining land by a belt of water named the "inner channel." Sometimes an island—like Tahiti—is surrounded by a barrier reef, which stands like a great wall around the land, but is separated from the latter by a channel. In the latter case the barrier reef receives the appropriate name of "encircling reef." Some of the barrier reefs are of immense extent. The great barrier reef on the north-east coast of Australia extends uninterruptedly for 1000 miles, and in nearly a straight line,

and varies from ten to ninety miles in breadth. If transferred to European seas and extended round European coasts, this reef would reach from Brest across the mouths of the Irish Sea and English Channel, round the western coast of Ireland to Iceland; whilst if extended in another direction, it would pass round the coasts of Scotland and the Shetland Isles, and terminate on the Norwegian shores. Soundings taken on the seaward face of a barrier reef reveal immense depths and a state of matters very different from that existing in the fringing reef. The seaward aspect of the latter was seen to exist within the limit of depth of the coral-polypes. The barrier reef, on the contrary, is found to rise from depths altogether beyond the sphere of coral life. And whilst the face of the fringing reef is covered with living coral, that of the barrier reef possesses a living incrustation only in its upper part, and to a depth of 100 feet or more; all its substance below this limit consisting of dead coral.

The third variety of reef is named the atoll or lagoon reef. This latter form of reef exists as a more or less circular ring of coral of varying breadth, enclosing a sheet of still water—the lagoon. These coral islands are common in the Indian and Pacific Oceans. Keeling or Cocos Atoll, in the former ocean, measures 9½ miles in its greatest width. Bow Island is 30 miles long and 6 miles wide; whilst in the Maldive Archipelago, atolls of very large size are met with; one island measuring 88 geographical miles in length, its greatest width being under 20 miles, and its least width 9½ miles. Beholding a great coral ring, bearing on its surface a low island soil with vegetation, and protecting a quiet lake-haven from the restless ocean without, it is little to be wondered at that the earlier voyagers recorded their surprise that the apparently insignificant architects of such an erection are able to withstand the force of the waves and to preserve their work amid the continual attacks of the sea. Pyrard de Laval, writing in 1605, well remarks, "It is a marvel to see each of these atollons surrounded on all sides by a great bank of stone—walls such as no human hands could build

on the space of earth allotted to them. . . . Being in the middle of an atollon, you see all around you this great stone bank, which surrounds and protects the island from the waves; but it is a formidable attempt, even for the boldest, to approach the bank and watch the waves as they roll in and break with fury upon the shore." Soundings on the seaward side of an atoll reveal abyssal depths as in the case of barrier reefs; and, as in the latter instance, the living corals exist only at the surface margins of the reef, extending downwards merely to their natural limit of depth. The massive living corals, as before, flourish best where the surf is of the heaviest description, whilst more delicate kinds grow within the quiet waters of the lagoon; and it must be borne in mind that the living corals, of whatever variety, require to be constantly immersed in their native waters. Exposure, even for a limited period, to the rays of the sun, is fatal to their vitality. From this observation it becomes clear that the labours of the coral-polypes are inadequate to raise the reefs above the surface of the water; other agencies, as will be presently noted, completing the erection, by the addition of foreign matter for the elevation of the reef. The depth of the central lagoon varies, a depth of forty-nine fathoms being of maximum kind; and the bottom of this central lake consists usually of sand and soft clay, or fine calcareous mud, the latter resulting from the grinding-down process to which the coral is subjected by fishes and other enemies. The coral ring of the atoll is broken at one or more points by an opening, often large enough to admit the passage of large ships into the quiet haven within. This passage into the lagoon invariably occurs on the leeward aspect of the atoll; this fact possessing a practical interest for the navigator who has succeeded in safely avoiding the dangerous swell and surf of the seaward side.

Noting these three varieties of coral-reefs, we may now proceed to inquire into the chief theories which from time to time have been constructed with the view of explaining their mode of formation. Just as the nature of the coral

itself formed, as we have seen, a subject of debate amongst the earlier writers, so the "reason why" the coral-polypes aggregated themselves together in the form of atolls and barrier reefs, constituted one of the knotty points of early biological science. The same mysterious "instinct," which was supposed to be the cause of their secreting lime, was credited with being the directing impulse in causing the selection of admirable sites for the coral-reefs. They formed a great protecting reef, according to Flinders, that they might work in safety under its shelter, and that the leeward aspect of the reef might form a kind of nursery-ground, whence "their infant colonies might be safely sent forth." In this case the coral-polypes are credited with the possession of intelligence of no mean order, and are presumed to co-operate together for an end and in a manner utterly unknown to be represented in any other group of animals. Such a theory, moreover, leaves untouched the essential question of the causes in virtue of which coral-reefs should assume the characteristic forms observed in the atolls and barrier reefs, and the want of an explanation of the latter points suggested a theory whose simplicity is unfortunately its only recommendation. It was believed that, taking into account the imitation in depth of living corals, these animals obtained a basis and foundation in land which lay submerged some 120 or 150 feet in the sea; so that every coral-reef was regarded as simply presenting us with a coral top to solid land. The circular form of the atoll was ingeniously accounted for on the supposition that the coral-polypes had built around the rim of a volcanic crater, and that the break in the coral ring affording entrance to the lagoon was represented by a fissure of greater or less extent in the continuity of the crater's margin. The plausibility of this theory becomes sadly weakened if we subject its supporters to the cross-examination of the physical geographer. For the stability of the ideas thus ventilated, it would require to be proved firstly that submarine plateaus or ridges existed not only in great profusion in the coral regions, but also that

these plateaus existed at a uniform depth, so as to afford the necessary basis for the operations of the polypes. That physical geography affords not the slightest justification or foundation for such a belief, is a fact known to every schoolboy; and now that we are tolerably familiar with the nature of the bed of more than one great ocean through recent sounding and dredging expeditions, this theory might be simply relegated to the limbo of impossible beliefs on the ground of its entire inconsistence with plain fact.

But its improbability might also be argued from the fact of its assuming the existence, in the coral areas of the ocean, of sunken land, which could not—except on the most arbitrary of suppositions—be supposed to be limited to these areas alone. And as ridges of land within 150 feet of the surface are unknown in other seas and areas, the theorist would have to explain the singularity of submarine plateaus existing so plentifully in one region and their entire absence in another. Geological science, if appealed to in this matter, would own that it knew of no support which could be given to the assumption of local elevations in the sea-bed; whilst it would suggest that the levelling tendency of the waters of the sea in smoothing down the ocean-bed would weigh greatly against the theorist's views. Thus, if the existence of submarine ridges be disproved, this first theory must necessarily fall to pieces and be wholly put out of court. The suggestion that atolls exist on a volcanic foundation meets with a similar fate when tested by the facts of geology and the logic of common sense. It may thus be remarked, that the mere shape and configuration of many of the atolls is entirely inconsistent with this explanation, no volcanic crater possessing, for instance, the form of Bow Atoll, "which is five times as long as it is broad." And the mere question of size is at once seen to prove the utterly untenable nature of the suggestion of the origin of atolls. Since it might be asked if reason could support a theory which on its own showing must postulate the existence of a volcanic crater eighty-eight miles long by twenty miles broad

at its greatest width, the latter being the measurements of one of the Maldive atolls. As in the previous case, this theory demands the recognition of the existence of numerous volcanic chains all existing within a limited depth of the surface; and, in view of the utter want of evidence to show that any such immense volcanic area ever existed, this supposition must be unhesitatingly rejected. One further idea emanating from Chamisso may be lastly noted. This author held that, as the reef-building corals love the surf, the outermost parts of the reef will tend first to reach the surface and so assume a circular form. But this idea assumes that the foundations of the reef in such a case consist of a flat bank, and the existence of such foundations is, as we have already noted, inconsistent with fact. The origin of barrier reefs did not receive from the naturalists and geologists of the past the same amount of attention as the question of the nature and origin of atolls,—a result due to the apparently more recondite character of the latter problem. The great Australian barrier reef was alleged to be founded "on the edge of a submarine precipice parallel to the shore." This idea may be dismissed with the remark that no evidence is afforded that any such precipice or plateau exists.

It may be affirmed that until the year 1842 no theory of the origin of coral-reefs which stood the test of scientific cross-examination was promulgated. In that year Mr. Darwin gave to the world his views on this subject, and enunciated a theory which has firmly stood its ground against the most severe examination and criticism, and which at the present time remains as the only feasible theory of the origin of coral-reefs. If it be taken as a test of the truth of a hypothesis that it intelligently explains all the facts of a case and is found to be inconsistent with none, then Mr. Darwin's ideas may be regarded as constituting a theory of the most perfect kind. And it may be fearlessly affirmed that, had Mr. Darwin accomplished no further investigation than his researches on coral-reefs, he would have been entitled to the admiration and gratitude of all who regard the advance-

ment of knowledge as of supreme consequence to man's welfare. Mr. Darwin spent some five or six years of his life (1831–36) as naturalist on board H.M.S. *Beagle* under Captain Fitzroy, and was thus enabled to study the coral-polypes and their work in the most direct and advantageous manner; whilst Mr. Dana, representing the scientific leader of an American circumnavigating expedition (1838–42) under Captain (now Admiral) Wilkes, may be regarded as an authority of equal rank with Mr. Darwin on the subject of coral-reefs. It is worthy of remark that, whilst Mr. Darwin's observations were published in 1842, Mr. Dana's report on coral-reefs was then in manuscript, but the conclusions at which these observers arrived, independently of one another, were of essentially identical kind, and the fact speaks powerfully for the implied correctness of the views promulgated by these explorers. Mr. Darwin's theory, besides offering a consistent explanation of all the facts of coral life, serves in the most direct manner to correlate and connect in the most natural fashion the various forms of coral-reefs. Starting with the assumption, already seen to rest on the most solid evidence, that coral life is limited to 150 feet as a maximum depth, Mr. Darwin rests his theory of the origin of reefs on the fact that land subsides.

The recognition of the geological phenomena known as the subsidence or sinking of land forms the key-note of Mr. Darwin's views; and it may therefore be viewed as a pardonable digression, if the nature of these phenomena is in the present instance briefly explained. That land rises and sinks is a fact well known to the geologist, who can point to many areas of the earth's surface in proof of his statement. Every one conversant with the elements of geology knows that the majority of the rocks composing the crust of the globe have been formed under water, and that a process of elevation must be assumed to account for their present position. Thus, true chalk is a rock composed of the remains of the minute foraminiferous shells already noticed. The cretaceous rocks were deposited in the sea-beds of the

past, just as the shells of modern foraminifera fall to the bottom of existing oceans to form a chalky layer which may be destined, when elevated, to form the chalk of the future. Elevation of the earth's surface, thus exists as a primary fact of geological science. But it may be conclusively shown that, whilst at the present day certain areas of our earth's surface are undergoing this process of upheaval, other areas as surely exhibit an opposite or subsiding tendency. The fact that land subsides must, however, be regarded in the light of the obvious relations which exist between the sea and the land. The subsidence of land is ascertained and calculated by its fluctuations as regards the sea-level. Hence it is necessary that the burden of the change should be laid upon the shoulders of the land, and that the sea should be shown to be a factor of constant and unvarying nature in this process. That the water of the ocean obeys the same laws as the fluid in a vessel, is a stable fact. Practically, we may regard the sea-level as invariable; and although theories of the influence of a polar ice-cap as tending to disturb the oceanic equilibrium are not wanting, such widely operating causes, even if proved to exist, would affect areas of so wide an extent that their influence would be of the most slight and meagre kind. On the contrary, where the changes between the level of land and sea are of a markedly local description and limited to a certain defined area, the alteration is clearly seen to have its seat in the land and not in the sea, the level of which, outside the defined area of change, can be shown to be absolutely unaltered. For example, on the coasts of Devon and Cornwall the remains of submerged forests are met with, the roots of the trees being still fixed in the soil. As these trees must have grown on land, it follows that the incident reveals the submergence of a land-surface. If we credit the sea with having risen, and suppose that the land has been stationary, we must be able to show not only that the whole southern coast of England has been similarly invaded by the sea, but that the opposite coasts of France, and all the coasts bordering the

North Sea and Atlantic, have been inundated. It is needless to point out that no such evidence is forthcoming, and that we are dealing with a subsidence of land, and not with a rising of the sea. Ample evidence of the existence of large areas of land-subsidence is afforded by the geological survey of the southern coasts of Sweden; the lower streets of the seaport towns of Scania, formerly inhabited, being now under water. The coasts of Greenland are similarly being depressed, and very marked alterations in climate may be shown to result from the existence of these movements on the part of what can no longer be regarded as the "stable land."

Bearing in mind the fact that land may subside completely beneath the surface of the sea, we may return from this necessary digression to the consideration of Mr. Darwin's theory of coral-reefs. Beginning with the fringing reef, well seen in the island of Mauritius, it is shown that such an erection forms the initial stage of coral-formation. Here we find a natural foundation for the work of the living coral-polypes; the animals having fixed upon a natural coast-line, and having, at a suitable depth for themselves, constructed a belt or fringe of coral, the seaward depth of which, as we have seen, does not descend below the fifteen-fathom line. So long as the land skirted by the fringing reef remains stable and stationary, so long will the reef remain essentially in its primitive condition. According as the shore slopes abruptly or gently, so will the breadth of the reef be limited, or be extended out to sea. No increase in depth is possible, seeing that the polypes have already attained, or have built upwards from, their lowest depth; and if the land remains in the condition in which it was when the fringing reef was first formed, the latter erection will also remain *in statu quo*. But, in accordance with the evidence of the geologist, land may sink. If we suppose that the land on which a fringing reef has grown slowly subsides, changes of great extent may be shown to occur within the attached zone of coral life. The lowermost corals, being carried out of their

depth, must of necessity die; a new sphere of operation being at the same time afforded by the subsiding operation for the uppermost corals. These latter will therefore continue to produce new polypes, and an upward growth of the coral will accordingly accompany the downward movement of the land. If the land-subsidence continues, the increase of the sea-wall or outer aspect of the reef will be greater than that of its shore side or inward portion, seeing that on the former surface the conditions of life are more suitable for the growth of the massive reef-building corals. The inner part or shore aspect of what was once the fringing reef thus becomes deeper and deeper as subsidence proceeds, and in due time we find a great coral-ridge growing up in front of the sinking land, and separated therefrom by a belt of deep water. In this way, the barrier reef is evolved by the subsidence of the fringing reef. But the land may be depressed to a still greater extent, and as before, the upward coral-growth will keep pace with the subsidence. If we suppose that we are dealing with the case of an island or with land of limited extent, we may conceive that in time the last island peak or surface of original land will sink beneath the waves. The coral-growth has, however, been proceeding uninterruptedly as before; and the lost land becomes ultimately surrounded by a great wall or cup of coral, enclosing a quiet lake,—the atoll or lagoon of the Pacific voyager.

The formation of coral-reefs may be readily understood from an inspection of the appended theoretical figures (Figs. 15 and 16), by the late Mr. Jukes. The sea-levels are represented at S S; and in the first figure A B and C D are two shores sloping seawards at different inclinations or angles. On these shores corals grow at their own limited depth, represented by the line F F, and thus form a fringing reef (R E G). The greater growth of the reef at E G, that is, furthest from the land, may produce a sheet of water between R and E; and the breadth of the reef is seen to be greatest where the sea-bed slopes least abruptly. If the shores (A B and C D)

begin to subside, the sea will flow in upon the land, and the width of the reef (R E) will be increased, especially on the outer face (E G) by the upward growth of the coral, so that in time the belt or sheet of water between R and E

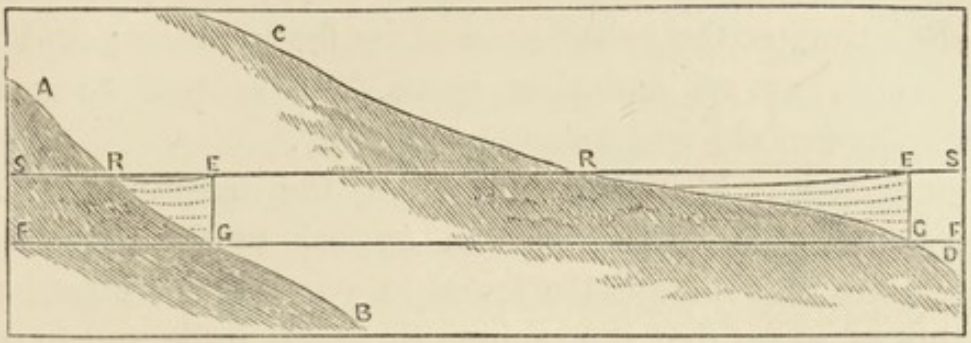
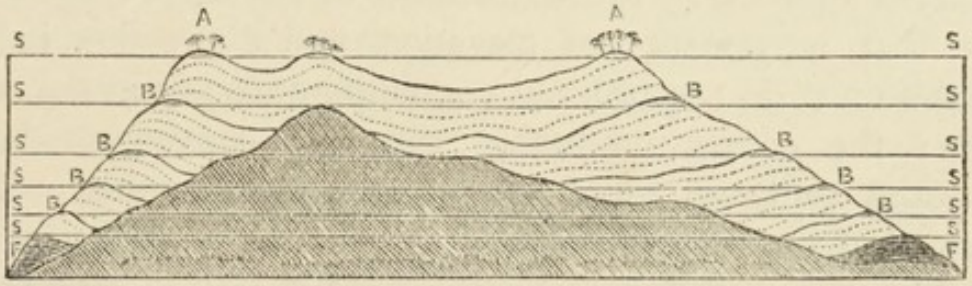


FIG. 15.—Diagram of coral-reefs (Jukes): A B, fringing reef; C D, barrier reef.

becomes of considerable extent, and a barrier reef is formed. In the case of land of limited extent, the formation of an atoll readily takes place as represented in the second figure. The various lines (s s) represent the unaltering sea-level. The shaded central portion represents the original land. The letters B B indicate the successive upward growth of


A
A
S
S
S

a fertile soil in which seeds carried by the winds will take root and grow; and ultimately some race of nomads may be found to colonise this strange sea-born land. Thus we observe that a fringing reef affords evidence of either the rising or stationary character of its land; the barrier reef clearly intimates the subsidence of its foundations; and the atoll exists as an enduring monument erected over the burial-place of old and forgotten territory.

Such being Mr. Darwin's views, the feasibility of his theory may be proved by an appeal to the facts and deductions of geological science in particular. First, is it capable of proof that the regions in which atolls and barrier reefs mostly abound, constitute areas of land-subsidence? One vast area of this kind, extending in the Pacific Ocean for 7000 miles from Pitcairn's Island and the Low Archipelago to the Caroline and Pellew Islands, is a region wherein the work of coral-erection proceeds apace; and between India and Madagascar another area of depression measuring 1500 miles in length has been clearly mapped out. A counter-proof of the correctness of Mr. Darwin's views is afforded by the deductions of geology in ascertaining that movements of elevation and depression in the earth's crust do not proceed contemporaneously in the same area; the causes producing the one movement being opposed to those which give origin to the other. Thus volcanic force invariably tends to produce elevation of the earth's crust, and the geologist would therefore esteem it a proof of the correct nature of Mr. Darwin's theory, could it be shown that active volcanoes were absent from the areas in which atoll and barrier reefs exist. Mr. Darwin's reply to this criticism is illustrated by an elaborately prepared map of the distribution of volcanoes, and may be given in his own words. It may "be considered," he says, "as almost established, that volcanoes are often present in the areas which have lately risen or are still rising, and are invariably absent in those which have lately subsided or are still subsiding:" whilst he has conclusively shown that the areas of

active coral-formation exist as regions destitute of active volcanoes, and in some instances as areas possessing no volcanoes at all. "The regions occupied by fringing reefs may be said to be those in which volcanic matter every now and then bursts forth," and tends to elevation. The areas of barrier reefs and atolls are "wide spaces sinking without any volcanic outbursts; and we may," concludes Mr. Darwin, "feel sure that the movement has been so slow as to have allowed the corals to grow up to the surface, and so widely extended as to have buried over the broad face of the ocean every one of these mountains, above which the atolls now stand like monuments marking the place of their burial."

These ideas are strongly supported by the observations made on *raised* coral-reefs. That sinking must take place in the course of the formation of reefs is proved by the examination of some raised coral-rocks, "as at the island of Mangaia in the Hervey Group," where the elevated reef rises 300 feet above the sea-level. These rocks must have been formed in water; and as we know the limit of coral life to have been 150 feet, it follows that such elevated reefs could not have been made "without a sinking of many scores of feet during their progress." Another explorer tells us that he can vouch for the existence of raised coral-reefs at Timor and Java, these coral-rocks existing at heights varying from 100 to 200 feet above the level of the sea.

The subject of coral and coral-reefs, like most other studies in natural science, becomes related in an intimate manner to other branches of knowledge, and to other trains of thought. In the case before us, it may prove interesting if, by way of conclusion, we endeavour to point out one of the many subsidiary subjects on which a study like the present is adapted to throw some degree of light. The most sublime idea of nature which man can well obtain is that of the uniformity and constant character of natural operations and laws. To the student of nature, the idea of capriciousness exists only as the result of an erroneous interpretation of some violated course of law and order; and in the

modern study of earth-science, the geologist is led to recognise in the principle of the uniformity of nature the means whereby all physical actions are bound together in one harmonious whole. It so happens that the evidence capable of being adduced from the growth of coral-reefs goes far to prove the constant and uniform state of our earth throughout immense periods of time. The testimony of Mr. Dana with regard to the rate at which coral grows is to the effect that the massive corals on which the increase of reef depends are of very slow growth; the branching and certain other kinds growing at a faster rate. One-eighth of an inch per year is given by this author as "the average upward increase of the whole reef-ground per year;" and the estimate appears to be a perfectly just one, when judged by the evidence afforded us of the rate of growth in corals. All authorities agree in stating the growth of massive corals at a very low rate, and the time which has been occupied in the formation of a reef 2000 feet thick must, therefore, on Mr. Dana's estimate, be set down at 192,000 years. This computation, it must be remembered, is one dealing with the work of modern corals. In the far-back past, coral-reefs existed similar in every respect to their modern representatives; these fossil-reefs in many cases evincing an immense thickness. Hence we are led to believe that, notwithstanding the alteration which our earth has undergone, it has had prolonged periods of rest; and the existence of a modern coral-reef may therefore afford evidence, not only of the immensity of past time, but also of the uniformity of nature's ways and works during periods compared with which the furthest limits of history and even of man's own age, are but as yesterday. The deductions from a study like the present may be fitly expressed in Laugel's words, as giving us "a higher conception of the universe than that entertained by the ancients;" since science "no longer regards the material world as the plaything of mere caprice," but "embraces the past, the present, and the future in a magnificent unity, outside of which nothing can exist."

THE GENESIS OF LIFE.

SOME two hundred years or more ago, the *savants* of Florence were somewhat startled by the declaration of one of their number that he had found cause to disagree with the universally received ideas regarding the origin of living beings,—ideas, the correctness or validity of which had till then been unquestioned and undoubted. The man who played in Florence the part of a seventeenth-century reformer was Francesco Redi, a well-known philosopher-physician, esteemed in his day and generation as an able and conscientious observer of biological phenomena. The subject to which he especially directed the attention of his scientific brethren was that of the origin and production of insects, and more especially of those insects which, like the familiar maggots, appear in animal and vegetable substances undergoing changes of a putrefactive nature. From the investigation of an apparently trifling and unsavoury subject, as we shall presently note, results of the highest importance may sometimes spring; and it may be truly affirmed that the subject mooted in Florence two hundred years ago has come to constitute one of the most important scientific questions, if not the paramount one, of the nineteenth century. Prior to Francesco Redi's day, the opinion of philosophers regarding the origin of many lower animals was perfectly uniform and consistent. They held not only that it was possible for living things even of tolerably high grade to spring from non-living material, but that nature frequently produced both animals and plants in this way. Selecting,

for example, the case to which Redi directed the attention of his contemporaries, the scientific men of the seventeenth century did not hesitate to affirm and believe that the maggots which appeared in putrefying meat were generated in some fashion or other by the process of decay in the meat. How this process operated, or in virtue of what laws the non-living matter gave origin to living beings, they did not profess to explain. Sufficient for those early philosophers was the evidence of their senses; and the experience of daily life apparently tended to establish, on the surest of grounds, the belief in what came ultimately to be termed the "spontaneous generation" of living beings.

The belief thus entertained by the scientists of Redi's time, it must be remarked, had been duly transmitted to them from the classic philosophers; just as, but for Redi's interference, it might no doubt have descended to our day as an article of scientific faith. None of the Latin poets has expressed more forcibly the general belief in the spontaneous origin of living things than Lucretius, of whose atomic theory modern science has heard so much. Well might the earth receive the name of mother, says this poet, for out of the earth all things originate. These earth-productions include living things; for, to use Lucretius' own words, in his *De Rerum Natura*, "many living creatures, even now, spring from the earth, being formed by the rains and by the heat of the sun." The influence of a belief transmitted through a long line of centuries may not be lightly estimated; and it has been very fairly argued that even the great Harvey himself, with his powers of original research, was a supporter of the ancient ideas to a greater extent than is generally supposed. It is true that our great countryman concerns himself, in his well-known work, less with the origin of living beings than with that subsequent process of "development" through which they attain the adult state. Even into the opinions of Harvey himself regarding the latter subject, much that is crude and fanciful may be found to enter; although, with regard to the ultimate source or cause of living actions, the

great physiologist thus expresses himself: "It is most apparent that in the generation of the chicken out of the egg, all things are set up and formed with a most singular providence, divine wisdom, and an admirable and incomprehensible artifice."

Thus, practically, the origin of living beings from non-living matter was unquestioned prior to Redi's day. With a boldness worthy of his cause, that experimenter turned his attention to the case of the production of maggots in tainted meat. He showed the Florentine philosophers by the experiment of placing meat in a jar protected by a gauze cover, that the process of meat-decomposition might be observed to take place in perfection, without the appearance of a single maggot. If these animals originated from the meat, why, asked Redi, do they not appear in the jar? The answer was not difficult to find; for one phase of daily experience, hitherto overlooked, came to the aid of the bewildered philosophers. The presence of numerous flies, hovering round the jar, and prevented by the gauze from gaining access to the meat within, supplied the answer to the query. And thus it became clear that one case of spontaneous generation at least could no longer be upheld; since the maggots in meat were noted to be developed from eggs laid in the meat by the flies; the subsequent growth of the maggots into the mature insects forming the conclusive proof of the correctness of Redi's observation.

The overthrow of a long-established belief is no light matter either for the reforming party or for its opponents. Redi accordingly found that his experiments and opinions were not only discredited in many quarters, but were pronounced antithetical to the tenets of religion and subversive of the highest interests of man. For the Churchmen of Redi's day were not slow to inform the philosopher that an appeal to Scriptural authority was, in their opinion, sufficient to prove his opinions incorrect. But Redi contented himself with an appeal to the inexorable logic of facts, and the repetition of his subsequent experiments—

extended in their sphere from that which demonstrated the origin of the maggots in meat—soon turned the balance of opinion in his favour. The inevitable tendency of the human mind to "close with the truth" was thus exemplified, and Redi's famous aphorism and motto, "*Omne vivum ex vivo*," may be said to have formed the watchword of scientists for many years after the recognition of his doctrines. It has, however, been well remarked, that whilst Redi gave his unhesitating and unqualified support to the idea that living beings can originate only from pre-existing life, he admits, in his works that he is unable to explain, according to this theory, many cases of animal developments. For example, when Redi discovered a caterpillar or grub in the heart of a fruit, or buried within the familiar gall or excrescence growing on a tree, he appears to have had no idea of explaining the origin of such insects from the outside world, that is, from parent-insects, which punctured the bark of the tree, depositing an egg in the puncture, and causing thereby the gall to appear. The Florentine philosopher apparently preferred, in the absence of more definite knowledge, to credit the plant itself with the production of the animal, and asserts his belief that the galls and fruits are developed by the trees as special provisions for the growth of the contained animal. Even admitting this latter belief, however, it can hardly be maintained that Redi meant thereby to illustrate a case of spontaneous generation. Doubtless, he would have indignantly denied any such assertion, and would have maintained that the production of the insect in the gall or fruit as the produce of a living tree, fully illustrated the aphorism that life proceeds only from pre-existing life, in which statement, as we have seen, his whole teaching was succinctly comprehended.

After Redi's time, and until the middle of the eighteenth century, the opinions he had advocated regarding the origin of living beings, held their place as accredited maxims of life-science. Probably the fact that these opinions were thoroughly consistent with the visible order of nature, tended

to ensure their favourable reception. Animals and plants, as far as everyday experience could discern, were in no case propagated *de novo*, but sprang invariably from living predecessors. The old maxim, *Ex nihilo nihil fit*, expresses after all a very just conception of the order of nature at large; and, in its application to living things, the aphorism might well be paralleled by Redi's assertion that nothing living could arise from a dead or inorganic source.

As time passed, however, the microscope was being perfected. From the days of simple magnifiers to those of compound microscopes, the optician's art slowly but surely progressed. Leuwenhoeck, the Dutch naturalist, for example, attained great excellence in the art of grinding microscope-glasses, and as a result of perfection in this art was enabled to discern in 1702 the first rotifers, or "wheel animalcules," in the rain-water which had collected in a gutter on his house-top. Lower forms of life, unknown in Redi's day,—animalcules of a size which, for minuteness, were undreamt of in the seventeenth century,—were thus brought to light during the eighteenth; and such discoveries in animalcular life naturally came to possess a very distinct and important bearing on the subject of the origin of life at large. Philosophers in the eighteenth century smiled at the credulousness of their predecessors, who believed in the "spontaneous generation" of animals of such highly organised nature as flesh-flies, gall-flies, and other insects. But the origin of the living specks collectively named "animalcules" was a matter which assumed an entirely different aspect. The animalcule might possibly be propagated in ways 'and fashions impossible to the higher insect. The rule of life and development for the highly organised being might prove to be utterly different from that regulating the genesis of the animalcule. Hence the scientists of the eighteenth century, finding new materials to work upon in the fields of life which the microscope had revealed, were led to attempt anew the solution of the problem to which Redi had apparently given an exhaustive answer. Driven from

the higher fields of life, the contest regarding spontaneous generation was, as the sequel will show, destined to be fought again in the arena of lower and microscopic existence.

The experimenters who first appeared, a century after the Florentine philosopher, to work out the subject of animalcular origin, were Needham and Buffon. With the name of the latter every one must be familiar, as that of a naturalist who added largely to the zoological and botanical knowledge of his time; whilst the former, an English experimenter, comparatively unknown outside the records of scientific discovery, was assisted by Buffon in much of his work. Needham himself speaks with some surprise of the almost universal acceptance with which Redi's views had met, and, as we shall presently note, found cause to disagree most strongly with the opinions of the latter. Writing at the middle of the eighteenth century, Needham says: "Modern naturalists unanimously agree in holding it as a certain fact that every plant originates from a specific seed, every animal from an egg, or from some analogous thing, pre-existing in the plant or in the animal of the same species which has produced it." And as regards the origin of the animalcules themselves, another sentence, translated from Needham's "Observations," written in French, will serve to show the ideas entertained by his contemporaries on this head. "Naturalists have generally believed," says Needham, "that microscopic animals were generated from eggs carried by the air or deposited in still waters by insects."

The population of stagnant waters and putrescent fluids was thus supposed to be produced by the development therein of the minute eggs or germs of the animalcules; and Needham, with a laudable desire to place his own belief on a scientific and experimental basis, began to experiment on fluids in which the lower and minute forms of life were likely to be developed. Provided with a fluid which previous experience had proved to be capable of containing and supporting animalcules, Needham adopted exactly the principles of Redi, exhibited in the experiment on the de-

composing meat. Placing this infusion of putrefying matter in a flask, Needham applied heat thereto, and after boiling the liquid, and carefully corking and sealing it, contended that he had adopted a mode of procedure well adapted to furnish evidence for or against spontaneous generation. As Redi had excluded the flesh-flies by the gauze he placed over the meat, so Needham aimed at protecting his fluid by carefully corking his flask; whilst he also assumed that the heat applied to its contents would effectually destroy any living beings it might originally have contained. Ensured, thus, in his ideas, from outward contamination, and guarded equally from any inherent or internal source of life-development, the fluids experimented upon were left to subside. The appearance of animalcules in his protected fluids would form, to Needham's mind, a clear proof that they must have been generated *de novo*, or from dead matters contributed by the fluid; for had he not destroyed all living things within, and excluded all life proceeding from without? The opposite result of barrenness in the fluid would, of course, weigh powerfully in the opposite direction, and determine a belief in Redi's idea, that, having destroyed and excluded all sources of life-development, no living things could appear in the flasks. The result of Needham's experimentation was affirmative in character. Sooner or later, the boiled liquids became turbid and muddy from the development of organisms, and microscopic examination showed an abundance of animalcular life in the flasks. That Needham should, therefore, have become a staunch advocate of spontaneous generation cannot be accounted other than a natural result of his interrogation of nature. Repeated experimentation seemed to place his belief on a still surer basis, and it thus appeared that Redi's doctrines were in some danger of being overthrown by the march of inquiry, and by investigation directed in new lines of research.

It is both curious and instructive to note that Needham's experiments appeared to afford support to a singular theory of the nature and origin of living bodies, which was enun-

ciated by his coadjutor, Buffon. On this theory—known to modern physiology as that of "organic molecules"—it was held that the essential parts of living beings consisted of infinitesimally minute atoms or molecules, these particles being invested with an indestructible vitality, and with extraordinary powers of development and reproduction. These organic molecules, according to Buffon, form all living beings by their temporary combination, and are set free by the death of the organism, to assume other shapes and forms of living things. This conception, in short, existed as a kind of physical metempsychosis; so that, holding the doctrine of the French philosopher, we might believe that the atoms of which our own bodies are composed were derived from other, and it might be much lower, forms of life; whilst, when liberated by the death of the human organism, they would enter into new combinations, and might appear in any form, from that of the animalcules or lower plants in the stagnant pool, to that of the highest living thing. Thus Hamlet may be said to enunciate the essential features of at least one aspect of the theory of organic molecules when he says—

> "Imperious Cæsar, dead and turned to clay,
> Might stop a hole to keep the wind away:
> Oh, that the earth, which kept the world in awe,
> Should patch a wall to expel the winter's flaw!"

Such a theory applied to explain the origin of living beings may fitly demonstrate the use of the imagination and fancy in science, whilst it may also illustrate the "groundless hypotheses" regarding the origin of living beings which existed in such profusion some two centuries ago. One Drelincourt took the trouble to enumerate no fewer than two hundred and sixty-two such "groundless hypotheses:" Blumenbach quaintly remarking that "nothing is more certain than that Drelincourt's own theory formed the two hundred and sixty-third."

Amongst the scientists who followed the experiments of Needham with a jealous care, was the celebrated Abbé

Spallanzani, who was appointed to the professorship of natural history in the University of Pavia in 1768. A man of wide scientific as well as literary culture, Spallanzani was eminently qualified to undertake a series of independent researches in connection with a subject which had, previously to Needham's experiments, engaged his attention. Accordingly, we find him preparing to investigate the subject in an independent fashion, his initiatory work being devoted to a practical criticism of the experiments of Needham. It is evident that Spallanzani was duly impressed with the ideas of Redi, and with the assertion that, judging from all the analogies presented by nature at large, living things could originate only from pre-existent vitality. But to meet the counter-assertion and experimental facts of Needham, evidence of like nature was required; and we find Spallanzani setting to work to institute a series of investigations, the method of which exhibited a decided improvement on that of Needham. The vessels employed by the Abbé to contain the fluids or infusions to which the tests were to be applied, were provided with slender necks, so that the aperture of each vessel could be readily and hermetically sealed by fusing the glass. Contrasted with Needham's method of merely corking and sealing his flasks, the Abbé's plan appears immeasurably superior and exact; and, as the results proved, such a belief is fully warranted. Spallanzani, it must be remarked, exposed his fluids to much more rigorous conditions in the matter of heat, than those to which Needham subjected his infusions. The Abbé kept his fluids at the boiling-point for periods varying from half an hour to three-quarters of an hour; thus placing the possibility of destroying any contained life on surer and more feasible grounds than that afforded by Needham's shorter period of exposure to a lower temperature. The results of these experiments fully justified the expectations of Spallanzani. Allowed to stand for varying periods of time, the liquids in his flasks remained perfectly clear, and when examined by the microscope gave no indications of life. Therefore, argued the

Abbé, Needham's experimentation was of faulty kind; since, by the exercise of care in sealing the flasks, and by prolonged exposure to heat, we see that life within the flasks is exterminated, and outward vitality hindered from gaining admittance to a field wherein its fertility might be exemplified. Once again, therefore, and in Italy, the balance of scientific opinion, backed by demonstrative proof, goes down heavily weighted against the doctrine of "spontaneous generation."

But Spallanzani did not rest content with a simple refutation of the results of Needham's experiments. He perceived the necessity which had arisen for a positive deliverance on the subject of experimentation, and for an explanation of what in Needham's case had produced the development of life, and of what in his own case had been excluded. Out of Spallanzani's necessity grew the hypothesis which in modern days is widely known as the "germ theory." According to this idea Spallanzani held that the atmosphere and fluids of all kinds were charged with the germs or eggs of the lower forms of animal and plant life. Under certain conditions—such as that of extreme dryness—these germs remained sterile and unproductive. Once introduced, however, into a medium adapted for their development—such a medium being exemplified by an infusion of organic matter—the germs, like seeds placed in a suitable soil, developed into the adult forms of animalcules. The germs in the fluids, according to Spallanzani, were destroyed by heat; those contained in the atmosphere were prevented from gaining access to his infusions, and hence the fluids remained permanently barren. The day of the actual demonstration of the existence of germs was not yet; but the germ theory of Spallanzani at once sprang into favour as a reasonable hypothesis,—taking the latter appellation to indicate a theory which explains all the facts of a case, and is, at the same time, contradictory to none,—of the origin of lower life in closed vessels. The supporters of this theory were formerly known as "Panspermatists," and the theory itself as that of "Panspermy." The old term "spontaneous,"

or "equivocal generation," was replaced by the name "Heterogeny," or "Heterogenesis;" whilst in these latter days, disciples of Redi and Spallanzani are said to support "Biogenesis," against the theory of "Abiogenesis," or that which maintains that living beings may and do, under certain circumstances, originate from non-living matter.

The statement that no branch of science is independent of its neighbour-departments, and that the growth and progress of one science in reality means the advance of the whole scientific *coterie*, receives an apt illustration from those phases of the present subject which succeeded the experimentation of Spallanzani. From amongst the myths of alchemy, the science of true chemistry was, at the date of Spallanzani's experiments, just beginning to be evolved; and shortly after his day, men began to know something definite regarding the composition of matter and respecting the laws in virtue of which elements combined to form the compound substances met with in the world at large. It has been well said that the science of chemistry was founded on the discovery of oxygen and its properties; and it so happened that through the investigation of the relations borne by oxygen to living beings, the subject of "biogenesis" *versus* "spontaneous generation" received an accession of new life, and the old controversy was, in consequence, revived with renewed vigour. Chemical alarmists subjected Spallanzani's work to scrutiny on the ground that they deemed it possible for the fluids in the flasks to have been altered by the applied heat so as to utterly prevent the development therefrom of living beings. The chemical alteration of the liquids, in other words, was a result which had not been bargained for by Spallanzani or his contemporaries, and was, moreover, a condition which, provided its existence could be proved, would unquestionably operate to falsify the results of experiments. "If you literally kill (through chemical alteration and change) the organic molecules in the infusion," said the supporters of Needham and Buffon, "of course you will obtain a negative result; but your conditions of experimen-

tation are too severe, and your experiments must count for nothing in the balancing of evidence, until you prove the stability of the chemical conditions to which the fluids and the matter thereof have been subjected." Hence the new generation of investigators which succeeded the Italian Abbé, had to assure themselves that the conditions necessary and adapted for the production of life were kept intact and unaffected as regards chemical influences.

The first experiments of note which were undertaken under these latter auspices were those of two German observers, Schulze and Schwann, who, about 1836 and 1837, conducted some investigations on the fertility of liquids. An infusion, which had been duly boiled, was thus placed in a flask to which atmospheric air could gain admittance; the air, however, being first made to pass through certain chemical substances. Air was thus literally filtered through glass tubes heated to a high degree, such a condition of great heat being capable of destroying germs, but leaving the oxygen of the air, so necessary for the development of life of all kinds, perfectly unaltered. In other investigations, these experimenters filtered the air through vitriol and caustic potash, two substances well known as destroyers of organic or living matter, but which possess no effect on the oxygen of the atmosphere. The results of these experiments were highly satisfactory to the biogenesists. No traces of life appeared in these protected infusions, and the doubts regarding the deprivation of life-bearing conditions which chemists had raised, were thus effectually dispelled. When the protective chemicals were withdrawn, and unfiltered air allowed to gain access to the flasks, a full development of animalcular life appeared; this positive result serving as an important counter-proof to the negative results previously obtained.

Meanwhile, microscopic science had been making important advances. In 1843 De la Tour discovered the fact that the essential element in yeast is a microscopic plant, and that fermentation must be regarded as a definite result of the growth and propagation of these minute organisms.

This observation bore a clear relation to the production of life in an infusion of decaying animal matter; since it was urged, if fermentation can be shown to depend on microscopic plant-growth, why should not the processes of ordinary putrefaction and decomposition be regarded as of like origin and nature? And the researches of the late Master of the Mint in England, and of various Continental observers, demonstrated in time the reasonable nature of the latter idea. A fluid capable of undergoing putrefaction was completely separated, in Graham's experiments, into two portions by a soft bladder or membrane, through which the fluid could strain, but which would present an obstacle to the passage of solid bodies, however minute the latter might be. Decomposing matter added to the fluid on one side of the membrane produced putrefaction and an abundant development of animalcular life. But whilst the decomposing fluid strained through the membrane to mingle with the pure fluid on the other side, the latter fluid exhibited none of the phenomena of decomposition, and remained perfectly clear and free from all traces of life-development. Thus, once again, but in a more exact fashion than that in which Spallanzani had demonstrated the fact, were scientists led to conclude that the solid and material germs or particles of one kind or another, kept back by the membrane from entering the pure fluid, were the cause of the putrefying action in the companion fluid. A similar result and conclusion to that obtained and arrived at by Spallanzani, had in short been attained through investigation which had proceeded along a different and more complicated line of research.

The demonstration of the "material" nature of the infecting germs or particles was advanced a stage further when Schroeder and Dutsch, experimenting between the years 1854 and 1859, showed that a very effective mechanical filter might be formed of simple cotton-wool; putrescible fluids, contained in flasks the mouths of which were stopped with closely packed wool, remaining perfectly clear and barren of life. And Tyndall, taking up the line of research

at the point where Schroeder and Dutsch had ceased their experimentation, demonstrated that, as far as the atmosphere itself is concerned, it may be described as a "stirabout" of minute particles. These particles are of varying nature; some are living, others inorganic; they are disguised and unperceived in diffuse daylight, it is true, but are revealed by the brilliant lights at the command of science, or, in more homely fashion, by the sunbeam streaming through the chink of a shutter into a darkened room. Nor may the name of Pasteur, the distinguished French chemist and physicist, be omitted from the list of experimenters on the causes and origin of life developed in fluids. It was left for Pasteur to supply the missing link in the evidence regarding the nature of those particles contained in fluids or borne by the atmosphere, which research, from the days of Spallanzani and onwards, had disclosed. Microscopic examination of the cotton-wool used to plug the mouths of flasks, as described in the experiments of Schroeder, revealed to Pasteur the presence of numerous small particles which the wool had filtered off from the air passing into the infusion. These particles, on being sown in fitting solutions and duly watched thereafter under the microscope, were seen to develop into adult forms of animalcules and of lower plants. The identity of the atmospheric particles with the germs of animalcular life was thus fully proved; and the innate truth of the "germ theory" may be regarded as having in this manner been demonstrated.

The first proposition which at this stage of our inquiries may therefore be submitted, is that the germ theory,—which holds that lower forms of life, developed in infusions of organic matter, proceed from the germs originally contained in the fluid, or which have gained access thereto from the atmosphere,—may be regarded as fully proved. As we shall presently note, it matters not, so far as the truth of this proposition is concerned, if "spontaneous generation" also be ultimately proved to occur. The actual demonstration of the fact that some forms of life could be produced *de novo*,

or without the existence of pre-existent life, would not in any degree lessen the truth or alter the significance of the fully demonstrated fact that germs borne by the air or contained in fluids constitute the common cause of life-development in putrefying and decomposing solutions. The two theories, as a matter of logical consistency, may coexist; and should spontaneous generation be ever demonstrated to occur—a fact from the clear demonstration of which we appear as yet to be very far removed indeed—we shall find the truth of the germ theory to be in no sense impugned. In the absence of definite proof on the other side, the scientific mind will not hesitate to regard biogenesis as an explanation of the genesis of life, of which the great merit consists in its perfect harmony and analogy with the observed laws of living nature.

It might be imagined that the controversy between these two theories of life-genesis had well-nigh been contested to its furthest limits, and that the motto "*Omne vivum ex vivo*" might be inscribed over the portals of natural science as expressive of a fundamental article of scientific faith. But a little inquiry shows that of late years the doctrine of abiogenesis has been gaining ground, and that its supporters have been both anxious and willing to join issue with their opponents. The contest, in truth, has not ceased; the battle-field has simply been changed. New aspects of controversy have appeared; and, driven from the consideration of the nature of atmospheric germs, the litigants have girded themselves anew for a contest the issues of which extend to wider and more important spheres of thought than those embraced by the mere question of the existence or non-existence or of the vital powers of germs. Recent science has thus speculated with great persistence regarding the origin of life at large. How did life originate at first on the globe? Human reason and scientific belief would seem to suggest that life must have had a beginning; and geological science negatives the idea that the present condition of the earth has been eternal. If, then, we consider that our earth

has been, according to astronomical deductions, evolved from fiery vapours, and has settled down into its present prosaic state from a primitive nebulous condition, we must also conceive of definite beginnings of life having taken place. Science accordingly inquires how this primeval vitality originated; whence it came; and through what conception or theory its beginning may be legitimately realised.

In answer to these natural queries, more than one suggestion or theory may be offered. Many, for example, will prefer the belief in a creative fiat which in the beginning created the varied forms of life, and left them to exercise their productive vitality through succeeding ages. Once created, life is thus regarded as capable of producing life *ad infinitum*. There is no need to assume the occurrence of new creations in this hypothesis, the first springs of created vitality having swollen in the course of ages into mighty streams with numberless offshoots and branches. Others profess to discredit such a theory of the genesis of life on the ground that it implies a break in the uniformity and unbroken sequence of nature. A creative effort is hence regarded as a break in an otherwise continuous cycle. Hence the supporters of the second theory regard inorganic or non-living matter as potentially containing in the present, as it did in the past, the principles and essence of vitality. Life results, they say, from some subtle and inexplicable conversion of the non-living into the living. When the earth attained a stage of permanency of form and composition, its own matter evolved living things, and as this power is regarded as having existed in the past, why, it is asked, should we object to extend its operations into the present? The lower forms of life may thus, it is believed, originate in the present from non-living matter, and spring spontaneously into vitality. And as a sequel to this belief in the unbroken sequence which connects the living and the non-living world, it is maintained that from lower forms of life, and by a like process of evolution, beings of higher grade may be duly developed. There are some scientists who,

whilst declaring for biogenesis in the present, and whilst assuming that in the present life invariably proceeds from pre-existing life, assent to the statement that in the beginning life arose from non-living matter; although, indeed, the advocates of spontaneous generation do not hesitate to charge such persons with scientific and logical inconsistency, in that they admit the possibility of life-development occurring *de novo* in the far-back past, but deny the operation of any such action in the present.

It is obvious that the point at issue centres around the old question whether at present life may or may not be produced spontaneously. Could this question be definitely answered in the affirmative, then the idea that a natural process may have operated in the past becomes not only of feasible but of highly probable nature, and exemplifies an *à posteriori* argument of likely kind. The issues of the question have thus become broadened out to include, as it may be shown, even the subject of man's origin and development; and in view of the more than passing interest which must therefore attach to the modern phases of this inquiry, we may shortly inquire into the present aspects under which the theories of biogenesis and abiogenesis respectively stand related to each other.

Within recent years various series of experiments, the results of which are cited in support of abiogenesis, have been performed, amongst other investigators, by Dr. H. C. Bastian, of London; this investigator appearing as the foremost advocate, in this country at least, of spontaneous generation. The gist of Bastian's early experiments consisted in the fact that, when certain fluids were employed in experimentation, living beings were produced, notwithstanding the presence of conditions which were ordinarily supposed to be unfavourable or entirely opposed to the development of life. The two great conditions aimed at in experiments on spontaneous generation are, firstly, the complete exclusion of all atmospheric or external influences from the experimental fluid; and, secondly, the thorough

destruction of any living particles contained in the fluid itself. Isolation and destruction are the two chief ideas involved in such experiments; and it may be freely admitted that, if both of these conditions be perfectly carried out in any experiment, such procedure may be deemed a crucial test, and the results so obtained may be regarded as of stable and satisfactory kind. But to procure the perfect isolation of the fluid, and the complete annihilation of germs,—*hic labor, hoc opus est.* The very nature of the experimentation renders it an exceedingly difficult matter to ensure that either condition is perfectly carried out. The manipulation involved is of the most delicate kind, and the sources of error are not only singularly numerous, but are also difficult of detection. An undetected flaw or crevice in the apparatus, a moment of inattention on the part of the experimenter, and the results of a whole series of experiments may be unwittingly vitiated. So that, although the conditions aimed at are themselves perfectly clear and defined, their perfect attainment forms one of the most difficult tasks which the modern investigator can have set before him.

On being first published, some years ago, Dr. Bastian's experiments naturally attracted the attention of the biological world, and revived a controversy which had, to say the least, been in a smouldering condition for some time previously, and which, moreover, in the minds of many observers, had been regarded as practically settled in favour of the germ theory, and of biogenesis at large. The facts asserted by Dr. Bastian, dealing with a problem of such important nature, were not of course to be tacitly accepted by scientists, or without due questioning and verification at the hands of independent observers. Accordingly, Dr. Bastian's experiments were repeated by other physiologists, the method of procedure respecting Bastian's mode of procedure being thus detailed by Dr. Burdon Sanderson. An infusion of turnip was prepared and divided into two portions, one portion being neutralised to correct its acidity

by the addition of potash. Four retorts, the tubes of which were drawn out to almost capillary fineness, were charged with the infusion, two with acid and two with neutralised liquid. "A small quantity of pounded cheese was then added to one of each pair (of retorts). A fifth retort was charged with unneutralised infusion diluted with its bulk of water. As soon as each retort was charged, the open end of its beak was heated in the blow-pipe flame, and drawn out. The drawn-out part was then severed, and the retort boiled over a Bunsen's burner, after which it was kept in a state of active ebullition for five minutes. During the boiling, some of the liquid was frequently ejected from the almost capillary orifice of the retort. At the end of the period named it was closed by the blow-pipe flame, care being taken to continue the ebullition to the last. The success of the operation (*i.e.*, the production of a perfect vacuum within the flask) was ascertained in each instance by observing that, by wetting the upper part of the retort, the ebullition was renewed." Three retorts of similar kind were charged with hay infusion, and "the eight retorts were placed, immediately after their preparation, in a water bath, which was kept at a temperature of about 30° C." Three days afterwards the flasks were examined, with the result of finding that (1) in the unneutralised turnip infusion with cheese, (2) in that without cheese, (3) in the neutral turnip infusion without cheese, and (4) in the diluted turnip infusion—in all four cases—no living forms were observed. One retort (5) containing diluted hay infusion, had been accidentally cracked, and was laid aside as futile, although it is recorded that its contents swarmed with organisms. Of the remaining three retorts, one (6) a neutral turnip infusion with cheese, ascertained to be hermetically sealed at the time of being opened, was found to contain many organisms; a second (7) an undiluted hay infusion, also entire, contained living beings; and (8), an infusion of the same nature as the last, contained organisms, but in fewer numbers than its predecessor (7). These experimental

details will afford some idea of the method of procedure adopted by experimenters, and of the care taken to ensure the perfection of the rigorous conditions of isolation and annihilation of any life contained in the substances infused. It will thus be noted that, whilst negative results were obtained in four out of the eight cases, three afforded evidences of the production of living organisms *in vacuo*. Dr. Burdon Sanderson, remarking on the results of these experiments, says, "I am content to have established—at all events to my own satisfaction—that by following Dr. Bastian's directions, infusions can be prepared which are not deprived, by an ebullition of from five to ten minutes, of the faculty of undergoing those chemical changes which are characterised by the presence of swarms of bacteria (minute vegetable organisms), and that the development of these organisms can proceed with the greatest activity in hermetically sealed glass vessels from which almost the whole of the air has been expelled by boiling."

It is worthy of notice that these remarks contain a plain statement of facts, without any indication as to their explanation, or regarding the conclusions which may be drawn from the results thus described. An impartial critic might in such a case be ready with the query, Has the vital limit of these lower organisms been ascertained; or, is it determined as a stable and unquestionable fact that exposure to the boiling point for five or ten minutes proves fatal to the lowest forms of life? Whilst it might also be asked whether the appearance of living things in the closed vessels might not be accounted for—in the absence of any definite information negativing the supposition—by presuming that the vitality and development of the organisms contained in the infusion had been simply suspended for a time by the process of boiling. After a period of repose, when we may presume their vital activities have recovered from the effects of exposure to a high temperature, the organisms appear to evince their wonted powers of development.

The naturalist would inform such a critic, in answer to

further inquiry, that the organisms which appear in infusions belong to the lowest grades of animal and plant life, and possess a vitality of very low and elastic kind. Even animals of tolerably high organisation,—such as the "wheel animalcules" of our ponds and ditches, which possess a nervous system and complex structure,—may be dried artificially, kept for months in a mummified and parched condition, and yet be revived on the application of moisture. If, therefore, animalcules of a very high grade may be desiccated and revived many times in succession without injury, it is only reasonable to believe that the lower forms occurring in infusions—forms which appear to hover, as it were, on the verge of vitality—may successfully withstand the rigorous conditions of the experimentalist. And if this be true of the adult forms of these lowly animalcules, the assertion must apply with still greater force to their mere germs, which must be regarded as possessing vitality of yet lower kind than the adult beings. It may therefore be reasonably urged that unless clear evidence be afforded that boiling, even of prolonged extent, absolutely kills bacteria, animalcules, and their germs, which may exist in fluids, the results obtained in such experiments do not weaken the theory of biogenesis. According to this theory negative results are explained by assuming that the conditions of the infusion have favoured the death by boiling of the contained life; whilst the affirmative results probably depend on the fact that the germs or organisms were favoured in some fashion in their struggle for existence, and survived their literal trial by fire. Dr. Bastian himself has duly recorded the significant fact—remarked by the Abbé Spallanzani—that the date of the appearance of life in infusions bears a distinct relation to the time the liquids have been boiled, and to the degree of heat to which they have been subjected. Long continuance of the ebullition usually delays, or may altogether prevent, the appearance of living organisms; and *vice versâ*, some infusions, owing to special peculiarities or conditions, present exceptions to

this rule. We have thus at the outset many circumstances presented to us, favouring the *à priori* consideration that we are dealing with conditions affecting rather the ordinary life and development of lower organisms, than the development of such beings in some mysterious and inexplicable fashion from non-living materials. Continental experimenters and investigators at home are perfectly agreed that organisms will appear in fluids treated and protected as already described; and some valuable additional information has been contributed regarding the effects which the specific or chemical nature of the solutions appears to produce on the development of life within them. Thus it has been ascertained that when infusions of hay—always a favourite substance with experimenters—are rendered acid, they exhibit a development of organisms less readily than when rendered alkaline or neutral.

The test-points to which experiments on spontaneous generation have led in the present day, appear to resolve themselves into a first query regarding the degree of heat capable of completely destroying not only the adult organisms which appear in infusions, but their germs also; and a second respecting the nature of the conditions within or without the infusions which may retard or favour the vitality of these lower organisms. An ingenious mode of determining the degree of heat necessary to kill the bacteria and other organisms found in fluids was devised by Dr. Bastian. A solution of some chemical salt, for example, is found, when protected from external influences, to show no disposition to generate living beings. But if such a solution be infected with a drop of fluid containing organisms, the latter will generate and multiply in the chemical solution as readily as within an ordinary infusion. By pursuing such a mode of experimentation, Dr. Bastian found that he could assure himself of the presence of bacteria in a pure fluid by actually conveying them into it, and that, having obtained these conditions to begin with, he could in the next instance experiment with some hope of arriving at a definite result

on the degree of heat necessary to kill these organisms. He accordingly found that when infected solutions were exposed to a temperature above 158° F.—the solutions being of varying nature—the contained organisms afterwards exhibited no vitality. If, on the contrary, the fluids were exposed to a lower degree of heat—say 130° F.—they invariably became cloudy and turbid on cooling, this turbidity being due to their rapid development and increase. Hence Bastian's present position rests on the supposition that he has determined the death-point, as it were, of lower organisms, and that—assuming these latter experiments to remain unchallenged—he is entitled to call upon the supporters of the germ theory to explain, in consistency with his facts, the occurrence of organisms in fluids from which all vitality has thus been, to all appearance, completely expelled. Possibly there may not be wanting biologists who may possess a faith in the vitality of these lowest organisms sufficient to enable them still to hold that the high temperature just mentioned, whilst usually ensuring the sterility of infusions, may nevertheless be counterbalanced by conditions arising within and operating on the infused substance itself. The disintegration and destruction of bacteria may be real in one case and only apparent in the next; and it is exactly these fine possibilities, which cannot be overlooked and which are difficult of determination, that render the whole question of the most complicated and of almost interminable nature.

It may be noted in connection with the present subject that a Commission was appointed by the French Academy of Sciences to adjudicate upon matters in dispute between M. Pasteur and Dr. Bastian; and the scientific world at large awaited with anxiety the decision of this tribunal on the evidence which Dr. Bastian was willing and prepared to submit in support of his allegations regarding the development of living organisms in hermetically protected solutions. After much discussion, however, the Commission came to naught. Anything more ridiculous or undignified than the

proceedings of the French Academicians, as reported in our scientific serials, cannot be imagined. It certainly reflects no credit upon the members of that Commission that they allowed petty squabbles of a personal kind to interfere with the discharge of their grave functions as judges in a most important controversy. The only excuse, indeed, which can be urged in palliation of the Academicians' conduct, is that they hardly appear to have appreciated the dignity or importance of the office to which they had been elected. One is tempted, after reading the correspondence which passed between Dr. Bastian and the Commission, to feel grateful with Professor Huxley that our own Royal Society has never had anything of an "academic constitution:" whilst the remembrance of the case of poor Jean André de Peysonnel, the accredited emissary of the Academy, and of the "shelving" of his reports on coral, does not serve to prejudice one in favour of that learned body's habits of fair dealing either with strangers or with its own kith and kin. The case before us may serve as a text for remark on the absence of any Scientific Court of Appeal or responsible tribunal to which questions in dispute might be referred. Is it too much to expect or believe that the verdict of a special jury or commission, given after hearing evidence, and regarded by the world at large as the most trustworthy of opinions, would be considered satisfactory and final in matters of scientific controversy? In any case, we apprehend, the solution of this, or of any other grave question, will not be sought for across the Channel, by English *savants* at least.

Professor Tyndall has recently published an important report detailing the results of a series of experiments on hay infusions, in which he has been for some time engaged; these experiments possessing an important bearing on the causes which favour or destroy the vitality of atmospheric germs. Tyndall remarks that infusions of hay "boiled for five minutes, and exposed to air purified spontaneously or freed from its floating matter by calcination or filtration, never showed the least competence to kindle into life."

Clear hay infusions allowed to stand for months could be inoculated with specks of liquid containing bacteria, and then were observed, as every one would have expected, to develop abundance of life. In the autumn of 1876 the experiments on hay began, curiously enough, to afford widely different results from those just detailed; the infusions being ultimately found to withstand boiling with impunity, as far as rendering them sterile was concerned, for fifteen minutes. Pursuing the inquiry, Professor Tyndall ascertained that the hay infusions which resisted sterilisation by boiling were made from *old* hay; solutions made from new hay being readily sterilised. Further experimentation on infusions of substances, such as fish and flesh, which formerly had been successfully and readily rendered barren by exposure to heat, showed that these latter materials also exhibited an unwonted resistance to high temperatures. So that the experimenter was led to conclude that "either the infusions of fish, flesh, and vegetable had become endowed in 1876 with an inherent generative energy which they did not possess in 1875, or some new contagium external to the infusions, and of a far more obstinate character than that of 1875, had been brought to bear upon them." These words are pregnant with meaning, and suggest forcibly that the moods and tenses of organic matters on the one hand, and of the atmosphere and its particles on the other, are probably of very varied character, and tend to complicate exceedingly the question of life-genesis.

Shifting his camp from London to Kew, Professor Tyndall found that the infusions which resisted sterilisation in the former place were sterilised with all their former readiness at Kew. And experiment carried on in a specially constructed chamber in London resulted in failures as far as sterilisation was concerned, until due precautions were taken to prevent infective influences being imported into the chamber. Highly interesting is it to find a feasible cause for the infection of the air of the London laboratory in the presence of fine dust arising from bundles of old and very

dry hay which had been allowed to lie on the floor; such dust being not only a fertile source of infection, but presenting matter which, as already remarked, resisted sterilisation by boiling in a very marked manner. But perhaps the most important hint thrown out by Tyndall in his remarks bears upon the relative vitality of germs; this being a point to which, as we have seen, Dr. Bastian has specially directed attention. The passage of a germ from a hard, dried, and indurated state, to a soft and plastic condition in which it is likely to become developed into an active living organism, is, as Tyndall remarks, probably performed "by different germs in different times. Some are more indurated than others, and require a longer immersion to soften and germinate." Hence we may explain in a clear manner the startling results obtained by Bastian and other experimenters, by assuming that cases of speedy sterilisation of infusions by heat depend for their success on the softened nature of their contained germs; whilst instances of delayed sterilisation, and of the appearance of life after prolonged boiling, may be reasonably explained on the supposition that the continued heat has gradually softened and awakened the vitality of "hard and resistant" germs.

Space would fail us were we to attempt to give further quotations from these interesting remarks, but sufficient has been said to show that the opponents of spontaneous generation are not behindhand in mustering their forces for the renewed discussion of this great question, and in detailing the results of investigations which would seem to carry with them the explanation of the knotty points offered for solution by the other side.

In a closing sentence it may not be out of place to note the plain refutation which careful microscopic work has given to certain statements made by the advocates of spontaneous generation regarding the alleged spontaneous development of lower organisms in protected infusions, and also respecting the transformation of lower into higher forms. Not content with assuming that lower

organisms are generated *de novo* from lifeless matter, the advocates of spontaneous generation have alleged that such low animalcules as the *Euglenæ* have been seen to become transformed into rotifiers, or "wheel animalcules,"—a transformation not more startling to the naturalist, as remarked by the Rev. W. H. Dallinger, than that whereby a humming-bird could be "hatched from a snake's egg," or the fact of "a gorilla being born from a kangaroo." The evidence of this microscopist, and of his fellow-labourers in the field of the minute, is highly interesting, as tending to show that the analogies of nature form, after all, a surer guide towards true conceptions of natural things, than the far-fetched suggestions of experimenters in new and undetermined lines of inquiry. A minute organism—one of the monads—measuring the $\frac{1}{1000}$th of an inch in long diameter, was thus found, after nine weeks, in an infusion of cress, which had been hermetically sealed during ebullition, and afterwards exposed to a temperature of 270°–275° F. for at least twenty minutes. The monad thus described and figured is now a well-known organism, its life-history and development having been carefully studied by the microscopicist just mentioned. These monads were found to be killed by an exposure to a temperature of 140° F., and the advocate of spontaneous generation therefore uses this latter fact in support of his contention that the animalcule must have originated spontaneously, seeing that the fluid in which it appeared had previously been heated up to 275° F. But the monads multiply by means of little spores or germs, and these spores resist a temperature of 300° F.; this fact endorsing the statement already made, that the germs of these lower organisms can bear an infinitely greater heat than the adults. Consequently, as Mr. Dallinger remarks, "by the logic of facts, the monads were not a result of 'spontaneous generation,' *but were the natural outcome of a genetic product* (namely, the heat-resisting germs) *contained in the infusion, and which the heat employed could not destroy.*"

The assertion that lower organisms could be seen giving

birth to higher forms of life, is refuted in a similar manner by microscopic evidence. Appearances are proverbially deceptive, and the naturalist requires evidence reaching beyond that furnished by mere appearances to justify a belief in transformations of so marvellous a nature as those described. The present attitude of science towards this subject is marked by a strong desire for the termination of the controversy, and for the institution of some crucial tests and experiments the results of which can be submitted for judgment to the world at large. There can, however, be little doubt of the overweighting influence which the theory of biogenesis possesses over spontaneous generation in the minds of the vast majority of thinking persons. For the support of the former doctrines, we are called upon to infringe no one law of nature. Spontaneous generation, as we have seen, begins by assuming the operation of a law which, as far as exact science at present shows, is unrepresented in the whole of nature's domain. The perfect harmony of biogenesis, and its clear analogies with the laws of natural development at large, constitute, as we have seen, strong points in its favour; and the matter may be fitly summed up in the words of one of the most able and critical of modern biologists, when he declares that "the present state of our knowledge furnishes us with no link between the living and the not-living."

The present subject links itself in an intimate manner with some of the highest interests of mankind. Aided by the methods of research practised in experiments on biogenesis, naturalists have successfully eradicated some grave diseases of the lower animals. Furnished with saving knowledge of a like kind, physicians are combating the diseases of humanity with new weapons, and with at least fair promise of effecting in due time the repression of the epidemic disorders which periodically decimate the populations of the globe. And our reflections on the means of physical salvation which science thus places at our disposal, should certainly be tempered with grateful memories of the older biologists who took the first steps in a line of research fraught with good to all succeeding generations.

PARASITES AND THEIR DEVELOPMENT.

If man is to be regarded as the favoured child of Nature, and if it be held as true that life at large is subservient to his sway and rule, it is no less true that he is liable to suffer severely from the attack of certain of his lower neighbours, and that he is despoiled in various fashions by some of the most insignificant of living beings. Insects of various kinds, insignificant as to size, but powerful beyond comprehension in virtue of their numbers, devastate the crops which exercise his mind and appliances in their cultivation. And after the crops have been duly stored and garnered, the labour of months and the full fruition of the farmer's hopes may be destroyed by the insidious attack of granary-pests. Plants of lowly grade,—minute fungi and like organisms,—personally known to the microscopist alone, blight at once the prospects of the agriculturist and of his cereals. A minute fungus, burrowing its way within the tissues of the potato-plant, has ere now brought destitution and famine on a nation, and still causes disease amongst our tubers to an extent which none but our potato-growers can fully realise. Nor is the farmer's sphere singular in respect of its liability to the attack of animal and plant foes. Parasites, the complexity of whose life-history almost defies belief, invade the stock of the breeder of cattle and sheep and decimate his flocks; whilst these same parasites may occasionally invade the human domain itself, and cause disease and death to

prevail to an alarming extent. Hidden enemies in the sea burrow into the sides of ships, or undermine man's piers and bulwarks. Poison-traps lie in wait for human footsteps; and claw and tooth are as ruthless when opposed to humanity as when prepared to attack lower life. Speaking generally, therefore, man may be readily shown to be by no means the undisputed "monarch of all he surveys" in the territory of either botanist or zoologist; and the province of mind and intellect may be invaded by foes against which man may find it impossible to contend. Much has been done, it is true, in the way of repressing many of our lower enemies, and the increase of scientific knowledge has had few triumphs of higher kind than are witnessed in those researches which have exposed the nature of our animal and plant enemies, and shown us the steps necessary to be taken for their annihilation. But the field of inquiry seems well-nigh boundless; and it should certainly form one of the most powerful arguments in favour of the study of natural science, that on the advance in our knowledge of economic botany and zoology the prosperity of our commerce and the conservation of our health may be shown largely to depend.

Perhaps one of the richest fields of research in the way of repression of our lower enemies, is offered by the life-history of some of the most common parasites which decimate our flocks and herds, and which, as already remarked, occasionally invade the human territory itself. Well does the shepherd know the symptoms of "rot" in his flock, and anxiously does he apply to the veterinarian for advice in his extremity. His sheep, in such a strait, present a dull and dejected appearance; they are "off their feed," he will tell the observer; and are in a thoroughly emaciated condition, despite the shepherd's kindly care and supervision. By-and-by deaths will begin to be of frequent occurrence, and when the dead subjects are carefully inspected the cause of the disorder is not hard to discover. The body of the affected sheep exhibits a state of thorough disorganisation, and when the liver is carefully inspected, hundreds of small flattened

bodies, each about three-quarters of an inch long, are found within the bile-ducts; whilst in the bile itself thousands of small particles are to be discovered by microscopic aid. The small flat bodies are "flukes" (Fig. 17), and the particles are the eggs of these animals. What, it may be asked, are these flukes, which, according to trustworthy evidence, carry off annually between one and two millions of sheep at the very lowest computation? The reply to this question is readily given. The "liver-fluke" is one of a group of internal parasites which has been known from comparatively early times. It was certainly known in 1547, and was lucidly described in 1552 by an author who was shrewd enough to attribute to its presence an epidemic which decimated the flocks of Dutch farmers in that year. Its "area of distribution," to use a scientific but expressive phrase, is not confined to sheep alone, but includes cattle, the horse, hares and rabbits, the spaniel, deer and antelopes, and even man himself. A little flat and somewhat oval body, with a tree-like arrangement of tubes for a digestive system, and possessing a couple of suckers for adhesive purposes,—such are the main features which a liver-fluke presents for examination. A more innocent-looking animal could hardly be found, and the cause of its injurious effects upon its animal hosts might remain a mystery, did our inquiries cease with the investigation, so to speak, of its *personnel.*

FIG. 17.—Liver-fluke, or *Fasciola*, magnified.

A highly important consideration, however, and one which extends beyond the restricted domain of our present subject, is that which recognises in *numbers* and *time* two important factors in elevating agencies of apparently unimportant kind into forces of vast or uncontrollable nature. The rain-drop is insignificant regarded merely as a particle of water, no doubt; but multiply your rain-drops indefinitely, and you obtain the agent which will wear the hardest rock, excavate the giant cavern, or form the foaming cataract with

strength to sweep away the greatest obstacles man or nature may oppose to its fury. Invest, further, the idea of the single raindrop with time, and the action which appears feeble, if viewed for a single moment, becomes of mighty extent when multiplied into years and centuries. And similarly with the case of the fluke and its neighbour-parasites. A single fluke is of itself an unimportant quantity, but when this quantity becomes multiplied by hundreds, the proverb that "union is strength" receives a new and very decided application. Existing in large numbers within the liver-ducts of the sheep, the flukes cause irritation, and a whole train of symptoms which end usually in starvation and death. Hence the extreme fertility of parasites might well afford a text whereon a sophist might inveigh against the wise regulation of the domain of living nature, were it not that in reality these animals are checked and controlled through the actual complexity of their own development. Strange as the statement may seem, it is nevertheless true that Nature appears to offer a premium against the development and increase of these and other parasites, through their having to undergo a series of very striking changes on the way to maturity. The parasite's path to adult life may truly be described as chequered in the highest degree. There are numerous pit-falls and snares laid for its reception, and for the extinction of its young life; and the "struggle for existence" in the present case is not only fierce, but, in the case of a very large majority of the combatants, utterly hopeless.

Let us briefly trace the life-history of a fluke by way of practical illustration of these latter remarks. From each individual fluke residing within the body of its sheep-host, hundreds of eggs are discharged. Each egg undergoes a preliminary process of development, and from the eggs which escape into water, little free-swimming bodies are liberated. These minute living particles are young or embryo flukes. Each resembles an inverted cone in shape, and swims rapidly through the water by aid of the microscopic filaments which fringe its body. It is clear that such

eggs as do not reach water, will not undergo development, and hence a first check to the increase of the flukes exists in the fact that many eggs must perish from the absence of appropriate surroundings. Sooner or later, the young fluke loses its power of swimming, and becomes of oval shape; crawling inelegantly, by contractions of its body, over the muddy bottom of its pool or river. Thereafter it appears to seek an entrance to the body of some co-tenant of its pool, such a creature being usually found in the shape of a water-snail. Buried within the tissues of this first "host," the young fluke becomes transformed into a sac or bag, within which other young may arise by a veritable process of budding. This rising generation appears in the form of small bodies, each provided with a vibratile tail. From the body of the snail, these "secondary young" soon make their escape; and whilst existing in the water, are readily conveyed into the stomach of the sheep in the act of drinking. Thence these young flukes penetrate to the liver of the animal, and become transferred into the mature and flattened adult.

FIG. 18.—Tapeworm (*Tænia echinococcus*) of dog, in its mature condition: *a*, head, with suckers; *b*, a full-grown joint; *c*, aperture by which the eggs escape.

The unexplained necessity for such a complicated series of changes in development, and for the varied circumstances which mark the career of the young fluke, present us with conditions which operate powerfully against the undue increase of the race. An exactly analogous series of changes is to be perceived in the development of many other parasites, and amongst others in that of the various groups of tapeworms (Figs. 18 and 19), which reside within the digestive system of man and other quadrupeds, and which are in reality "compound" animals, each joint being a semi-independent unit of the compound being. But for the

complexity of their development, and for the consequent limitation of their increase, these parasites would overrun and exterminate their hosts in a short period of time. A common tapeworm begins life as a minute body, set free from its coverings and investments, and provided with a special boring apparatus, consisting of six hooks. This little creature will perish unless it can gain access to the body of some warm-blooded quadruped, and the pig accordingly appears on the scene as the most convenient host for the reception of the little embryo. But within the body of the pig there is not the slightest possibility of the little embryo becoming a tapeworm. The pig has merely to perform the part of unconscious "nurse,' and to prepare its "guest" for a yet higher stage of existence. Being swallowed by the pig, the young parasite bores its way through the tissues from the digestive system to the muscles of the animal, and there develops around its body a kind of bag or sac. In this state it represents the "cystic worm" of old writers; and occasionally it may prefer the liver, brain, or even the eye of its first host to the muscles in which it usually resides. Here, however, it can attain no further development. If the pig dies a natural death, there can be no possibility of the tapeworm stage being evolved. But if, as is most likely, the pig suffers death at the butcher's hands, the little cystic worms may be bought by mankind at large along with the pork in which they are contained. Such persons as partake of this comestible in an imperfectly cooked condition,

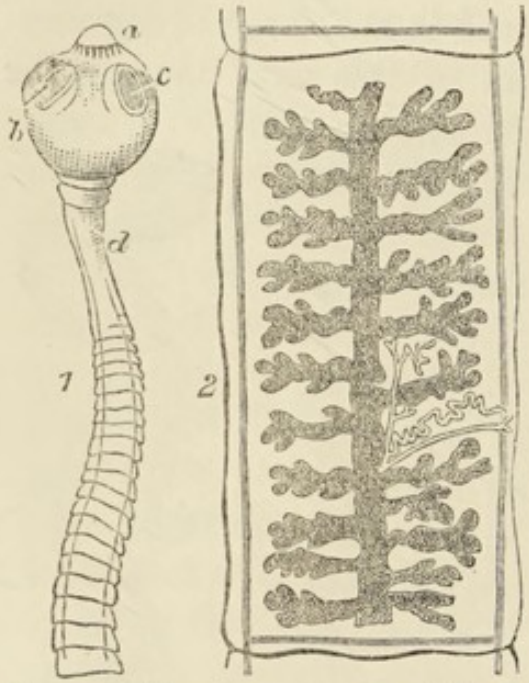


FIG. 19.—Common tapeworm (*Tænia solium*). 1. The head, magnified, showing hooks (*a*), and suckers (*b*, *c*); *d*, the neck, with immature joints. 2. A joint, largely magnified, showing the branching "ovary," in which the numerous eggs of each joint are matured.

thereby qualify themselves for becoming the "hosts" of tapeworms : since, when a cystic worm from the muscles of the pig is introduced into the human stomach, the little bladder or sac which the worm possesses drops off, and the minute head of the worm (Fig. 19, *a*) becomes attached to the lining membrane of the digestive system. Once fixed in this position, the circle of development may be said to be completed. A process of budding sets in, and joint after joint (Fig. 19, 2), is produced, until the adult tapeworm, measuring, it may be, many feet in length, is developed ; whilst each egg of this full-grown being, if surrounded by the requisite conditions, and if provided with a pig-host to begin with, will repeat the marvellous and complicated life-history of its parent.

The history of the tapeworms, like that of the flukes, therefore, exhibits a very complex series of conditions, and unless these conditions are fulfilled by the young parasite, development is either cut short or is altogether suspended. The fact of a double host having to be provided for the due development of tapeworms is not peculiar to the production of the species inhabiting man. All of these parasites pass through an essentially similar series of developments. The cystic worms, or immature tapeworms, which cause the "measles" in the pig, become, as we have seen, and when eaten by man, the common and adult species of human tapeworm (Fig. 19). The cystic worms man obtains from underdone beef, are developed within his economy into a tapeworm of another kind. The young parasites which reside in the liver of the rabbit, and which attain no higher development than that seen in the pig or ox, become, when swallowed by the dog or fox, the special tapeworm-tenant of these animals. The cystic worm of the mouse develops into the tapeworm of the cat ; so that the dog, fox, and cat do not enjoy an immunity from enemies, but actually acquire disease from the victims they so ruthlessly pursue. The chances of destruction which beset the young parasite on its way through the world are so multifarious when compared with its chances of favour-

able development, that, practically, the immense number of eggs produced by these animals are of small account. Of the thousands of eggs developed, the merest fraction attain development, and the presence of a complex life-history in parasites must be regarded as in reality forming a saving clause, as far as man is concerned, when we consider our comparative immunity from their attack.

Even more extraordinary than the phases of development which have just been detailed, are those undergone by a special form of tapeworm inhabiting the dog. The egg of this latter parasite gains admittance to the body of the dog-louse, and therein becomes the cystic worm, analogous to that formed within the muscles of the pig in the case of the human tapeworm. The dog, in the process of cleaning his skin, swallows the skin-parasite with its contained but immature tapeworm; and, once introduced to the dog's digestive system, the latter form liberates itself from the louse and becomes the mature and adult tapeworm. Anything more extraordinary than this peculiar circle of development can hardly be imagined in the life-histories of animals. Nor are the conditions which have determined, and which continue the development, rendered clear to us by the most careful study of the subject. Why it is that the tapeworm should not attain its full development within the pig, rabbit, mouse, or dog-louse, as its first host, we do not know; nor can it be rendered plain what conditions have so sharply divided the life of these parasites into two periods of such well-marked kind.

The whole question of parasitism, however, exhibits a striking illustration of the influence of habit and of surrounding conditions on the life of animals. No one may doubt that the habit of one animal attaching itself to another is an acquired one. The most ardent advocate of the doctrine of special creation would never dream of maintaining that parasites were created as we find them in relationship with their hosts. Even were this argument advanced as a mere matter of unsupported belief, the order and succession of life upon the globe would present facts which would at once

veto the belief. The lowest animals appeared first, and were succeeded by forms of gradually increasing complexity. Hence the parasites must have been developed before their hosts. Man appeared long after the tapeworms or their ancestors were produced; and the intricate relationship between man and his neighbour-animals and the parasites must have been acquired in a gradual fashion. Best of all, this opinion is supported by the information to be gained from a survey of parasitic life at large. We may begin such a survey by noting animals which attach themselves to other animals as mere "lodgers." Such are external parasites. Next may be traced parasites which depend for house-room upon other animals, but which do not require board and sustenance from their hosts. Such "messmates" are presented by the little fishes which live within the bodies of large sea-anemones and of other organisms, and which swim in and out at will, obtaining their food for the most part from the external world. A simple modification of habit in such animals would convert them into true parasites. Suppose that the guest found that it might readily obtain food

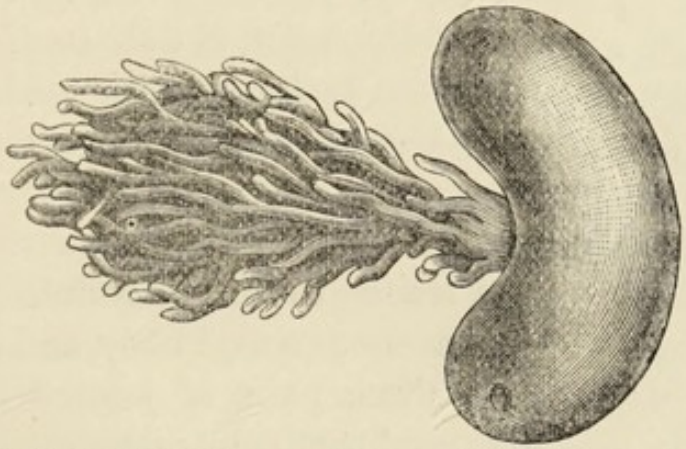


FIG. 20.—Sacculina purpurea, a crab-parasite, showing its "roots."

by living on the matters its host elaborated for its own use, and suppose, further, that the animal-guest gradually accommodated itself by successive modifications to its new mode of life,—we have thus the influence of habit brought into play and exercised upon the descendants of the first parasite in producing a literal race of such beings. Such a belief or

theory is neither contrary to facts as we find them, nor is it unsupported by direct evidence. Take, for example, the case of *Sacculina* (Fig. 20), a well-known parasite, which attaches itself to the bodies of hermit-crabs and their allies. In shape the sacculina resembles a simple sac or bag,—a kind of miniature sausage, in fact,—which sends into the body of its host a number of root-like processes. These roots entwine themselves amongst the organs of the crab's body, and serve to absorb from the tissues of the host a certain amount of nourishment. If we lay open this curious organism, we find that the sac-like body contains eggs. No traces of structure are discernible; and but for occasional movements of the body, destined to inhale water and to expel that fluid from its interior, one might regard the sacculina as some abnormal growth which had protruded from the body of the crab. The sacculina is a true parasite in every sense of the term. It is dependent, not merely for lodgment, but for nourishment also, upon its host; and, as we shall presently note, its thorough dependence upon the crab becomes the more curious when the past history of the sacculina, as revealed by its development, is duly studied.

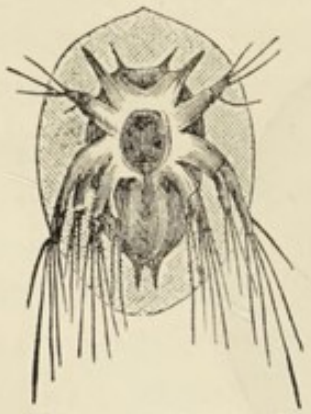


FIG. 21.—Young of sacculina.

From each egg of the sac-like parasite thus described, a little active creature (Fig. 21) is developed. Known to naturalists as a "nauplius," the young sacculina is seen to be utterly unlike its parent. It possesses an oval body, and is furnished with three pairs of jointed feet, which are used actively as swimming organs. By aid of the long bristles with which the feet are provided, the little sacculina swims merrily through the sea. Its body terminates behind in a kind of forked appendage of movable nature. After the lapse of a short period, changes ensue in the structure of the little body, but there appear as yet no indications of its parasitic origin, or of any tendency to imitate the fixed and attached existence of

its parent. The body of the young sacculina next becomes folded upon itself, so as to enclose the young animal in a more or less complete manner; and the two front limbs become developed beyond the other pairs, and form large organs wherewith the little creature may ultimately moor itself to some fixed object. From the extremities of these altered fore limbs two elongated processes or filaments are seen to sprout, and these processes are regarded as the beginnings of the root-like organs seen in the attached, parasitic, and full-grown sacculina. The other two pairs of feet are cast off, and in their place six pairs of short swimming feet of forked shape are developed. After this stage has been attained, the young animal seeks a crab-host; the root-like front feet attach themselves to the body of the crab and penetrate into its substance; the other feet are cast away as useless organs; and with the assumption of the sac-like body, the young sacculina becomes converted into the likeness of the parent-form.

Such is a brief sketch of the development of a true parasite, and we may now inquire what the life-history of this animal teaches us concerning its antecedents, and regarding its assumption of a parasitic life. The most reasonable view which can be taken of the development of an animal or plant is that of regarding the phases of its production as presenting us with a condensed or panoramic picture of the stages through which it has passed in the course of its origin or evolution from some pre-existing form. If we refuse to regard development in this light, the stages through which the living being passes in its progress towards maturity present themselves as a set of unmeaning and wholly inexplicable actions and conditions. Whilst, on the other hand, when we recognise that in the development of an animal we may trace its ancestry, much that is otherwise incomprehensible becomes plain and reasonable, and very discordant phases of life become harmoniously adjusted through such a consideration. And when we further discover that a large number of animals, widely differing from each other in their

adult structure, exactly resemble each other in their young state, the feasible nature of the statement that such a likeness implies a common origin, is readily demonstrated. On any other supposition, in short, the development of living beings presents us with phases of utterly unintelligible nature.

Now, the young sacculina is found to present a close resemblance to a large number of other animals belonging to the great class known as the *Crustacea*. To this group belong the barnacles, water-fleas, fish-lice, shrimps, crabs, lobsters, etc. Most of these animals leave the egg in the form of a "nauplius," and present the closest possible resemblance to young sacculinæ. The young of the fixed and rooted barnacles (Fig. 5), which attach themselves like pseudo-parasites to the sides of ships, so closely resemble young sacculinæ that it would be a difficult, if not absolutely an impossible, task to separate or distinguish the young from those of the sacculina in the earlier stages of growth. The young barnacle (Fig. 22), like the young sacculina, resembles a shrimp of peculiar kind on a roving commission, much more closely than it does the adult and attached form. And hence we discern in the common likeness of the young of these animals a proof of their common origin. At one time, therefore, we may believe that the sacculina existed as a free-swimming creature, of active habits, and possessing a tolerably high degree of organisation. Doubtless some less energetic member of the sacculina-family secured a temporary resting-place on the body of a crab, and found such a position to be of desirable kind from the rest and protection it afforded. The feelers or feet, which were at first used for mere attachment, may have come in time to penetrate the body of the crab-

FIG. 22.—Young barnacle.

host, and may thus have become transformed into organs of nourishment. By-and-by the sedentary life, with its advantages in the way of cheap living and easy existence for the sacculina, would become a fixed habit. The sacculinæ, which acquired this habit, together with their descendants, would flourish and increase in numbers owing to the advantage gained by them in that "struggle for existence" in which sacculinæ and their highest animal-neighbours are forced, one and all, to take part. And as the wholly free sacculinæ became transformed into higher forms of life, or became extinct, their rooted and parasitic brethren may be regarded as having gradually degenerated. A process of physiological backsliding invariably takes place in such cases. This retrogression would be manifested in the sacculinæ by the casting off of structures which were no longer of use to a fixed and rooted being,—the degeneration and disappearance of structures not required in the animal economy, taking place in virtue of the well-known law of the "use and disuse" of organs. The legs would thus become gradually diminished, and would finally disappear altogether. Internal organs, and parts useful to the free-swimming animal, would become useless as the creature became more and more dependent on its host. Finally the sac-like organism would be evolved as the result of its parasitic habits; and the degeneracy which marks the slavishly dependent mind in higher life is thus viewed as also destroying the independence and as warping and distorting the character which once marked the free and active creature of lower grade. Thus we may understand by the study of life-histories such as those of the sacculina and its comrades, how parasitism is induced, and how a change of life and habits of such sweeping character, converting an active being into a sedentary and degraded animal, becomes established through the slow but sure effects of habit, use, and wont, perpetuated through many generations.

Perhaps the most inveterate and dreaded enemy which man has to encounter in the ranks of parasites is the little *Trichina* (Fig. 23), which has, on more than one occasion,

caused a fatal epidemic, on the Continent especially, through its development in excessive numbers. This little worm-like parasite was first discovered in the dissecting-room of St. Bartholomew's Hospital. The circumstances of its discovery have been frequently repeated in anatomical rooms by the observation that very small hardened bodies are to be sometimes met with embedded amongst the muscular tissue of the human subject. When one of these little bodies is carefully examined, it is found to consist of a little sac or bag of oval shape (Fig. 23), containing within it a little worm coiled up in a spiral fashion. These sacs attain a length of about the $\frac{1}{70}$th of an inch or so, and if they have existed within the muscles for a lengthened period, they will be found to be somewhat limy in structure; the presence of this mineral implying degeneration of the sac and its tenant. When the first trichinæ were examined and named by Professor Owen, their life-history and importance, as regards the human economy, were unknown and undreamt of. But the occurrence on the Continent of certain mysterious cases of illness and the careful investigation of such cases by medical men, led to the recognition of the fact that this tiny worm, which, in its fully grown condition (Figs. 24 and 25), does not exceed a mere fraction of an inch, may nevertheless, through its development in large numbers, prove a source of fatal disease to man. In proof of this fact we may quote Dr.

FIG. 23.—Trichina imbedded in muscle, magnified.

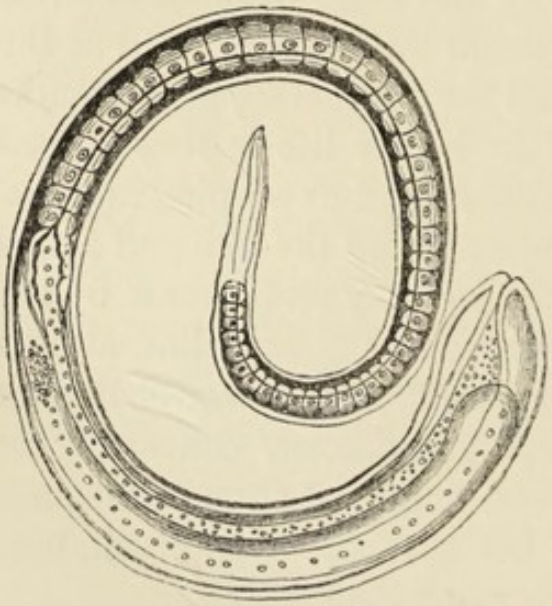


FIG. 24.—Trichina (female), magnified.

Cobbold's extract from the *Leipziger Zeitung* for December 8, 1863, in which it is stated that six persons were seized with all the symptoms of trichina disease, "after eating *raw* beef mixed with chopped pork." The *Neue Hannoversche*

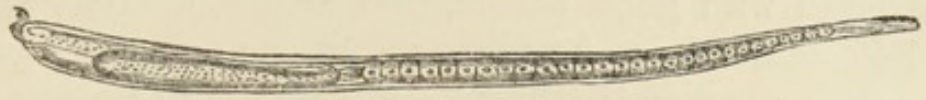


FIG. 25.—Trichina (male), magnified.

Zeitung for December 13 of the same year, chronicles the death of twenty-one persons in Hettstädt through eating the flesh of an English pig, the butcher himself perishing from the trichina disease. Eighty persons, according to the *Zeitung für Norddeutschland*, were affected in December, 1863, in Plauen, but only one died. In 1862, of thirty-eight persons attacked in Calhe, near Magdeburg, eight died; and in Hettstädt twenty died out of a total of 135 who were attacked.

The symptoms exhibited by the patients were those of an acute fever, accompanied by distressing pains in the muscles. The discovery of the trichina's fatal powers, as might be expected, caused no little consternation, but we are not aware that the affection of our Continental neighbours for raw meat declined in consequence. If one narrative, indeed, is to be trusted, there were not wanting, it seems, those who affected an entire disbelief in the trichina and in the fatal effects it was capable of inducing. One headstrong *savant* was thus said to have fallen a victim to his scepticism. Holding in his hand a piece of sausage, which he alleged had been declared to contain trichinæ, he avowed his entire disbelief in the fatal effects which were said to follow the introduction of those parasites within the human economy. He would, in fact, have no objection, for that matter, to eat the sausage. "Eat! eat!" was the cry which resounded through the hall, and in compliance with the request, the *savant* ate the sausage. Lamentable to relate, the trichinæ proved too much for even a scientific organisation, and the subject of the experiment was said to

have died from the trichina-disease induced by his own act. Nor may the fatality of the trichina disease be regarded as a mystery in the light of the facts as to the numbers of the parasites which one "host" may contain. Dr. Cobbold affirms, and with good reason, that 20,000,000 of trichinæ may be contained in one subject. In one ounce of muscle taken from a cat which had been experimented upon as a producer of trichinæ, Leuckart estimated that 325,000 of the parasites were contained. An average-sized man, weighing ten stones, will carry about four stones of muscle; and assuming that all the voluntary muscles of the body were affected, such a person might afford lodgment to 30,000,000 of these parasites. In this instance, therefore, numbers clearly mean power, and that, too, of a fatal kind.

The history of the trichina's development again brings before us a most singular series of phases, and once more presents us with the necessity for a "double-host," as in the case of the tapeworms. If we start with the trichina as they exist within the muscles of the pig, we find that the parasites are contained each within the little sac or cyst already mentioned. The pig, it may be remarked, is not the only host which affords lodgment to the trichina, since dogs and cats, rats and mice, rabbits and hares, oxen, horses, sheep, guinea-pigs, and other animals, are found to be subject to their attack. It must, however, be noted that, as found in the muscles of any animal, the trichinæ are not only perfectly harmless to that animal, but, further, exist in an undeveloped or immature condition. As seen enclosed in their little sac-like cradles (Fig. 23), the trichinæ are, in every sense of the term, "juvenile" parasites. They represent, in fact, a young and rising generation waiting for a favourable turn of Fortune's wheel to start them on the further stages of their life-history. This favourable turn arrives at the moment when the flesh containing the young and immature trichina-population is eaten by a warm-blooded animal. Suppose the "trichinaised" flesh of a pig to be eaten, without due culinary preparation, by man,

the result of the preliminary processes of digestion in the stomach is the dissolution of the little cysts, and the consequent liberation of the "juvenile" population. In two days thereafter, the precocious "juveniles," influenced by the change of life and situation, have become mature trichinæ; and, after the sixth day, enormous numbers of eggs are produced by these matured forms. After this stage has been attained, the parent parasites become of no further account in the history of the host, but the young form the subjects of grave concern. This new generation is found to be a restless and migratory body, and influenced by the habits of their ancestors, the young pass from the digestive organs, through the tissues of the body, to seek a lodgment in the muscles. Now comes the tug of war,—for the host at least. With thousands of these microscopic pests boring their way through his tissues, there is no lack of explanation of the excessive muscular pains felt by the trichinaised patient. But relief comes in due course when the restless brood has located itself in the muscles. There each young trichina developes around itself a cyst or capsule, and returns to the primitive form in which we first beheld it. There, also, it will rest permanently, and degenerate into a speck of calcareous matter—unless, indeed, an unlooked-for contingency arises. Were cannibalism a fashionable vice amongst us, the eaters would receive from the muscles of the eaten the young population of trichinæ, just as the original subject received the juvenile brood from the pig. Within the cannibal organisation, the young parasites would become fully developed, would produce young in large quantities, and would inflict upon the digester of human tissue, pains and grievances compared with which the proverbial troubles which afflict the just are as nothing.

Less to be dreaded than the trichina, but more extraordinary in its habits, is the "Guinea-worm," a well-known parasite, confined in its distribution to certain portions of Arabia, to the banks of the Ganges, and to Abyssinia and the Guinea coast. From the latter locality the organism

derives its name. The Guinea-worm troubles not the internal economy of man, but has, strange to say, a striking and persistent aptitude for locating itself under the skin of the legs and feet. The interest with which the Guinea-worm is regarded by naturalists and others is derived from the fact of its curious life-history and habits, and from the supposition that this parasite represents the "fiery serpents" which so exercised the minds and tortured the bodies of the ancient Israelites. This supposition is somewhat strengthened by the knowledge that Plutarch, in his "Symposiacon," quotes a remark to the effect that "the people taken ill on the Red Sea suffered from many strange and unknown attacks," and that, amongst other worms, "little snakes which came out upon them, gnawed away their legs and arms, and when touched, retracted, coiled themselves up in the muscles, and there gave rise to the most insupportable pains." Making allowance for a few exaggerations, such a description, especially in its latter portion, applies very closely to this curious enemy of man. In length, the Guinea-worm may vary from one to six feet, whilst specimens of twelve feet in length are not unknown. The body is cylindrical in shape, and attains a thickness of about one-tenth of an inch. Curiously enough, not a single male Guinea-worm has yet been met with, all the known specimens belonging to the opposite sex. The worm enters the skin as a minute organism which possesses a singular vitality, and which exists in its free condition in muddy pools, in wells, tanks, and in marshes. In all probability the young Guinea-worm gains access to the skin through the sweat-ducts. Once located within the skin, the animal grows rapidly, and in about a year attains the dimensions just given. Every traveller in the East knows the Guinea-worm by repute, and has witnessed the familiar operation performed for its extraction. Ancient works on medicine contain descriptions of this operation, and exhibit drawings of the worm and of the appearances produced by its tenancy in the skin. The sole aims of the operator are those of

extracting the parasite by gentle traction, and of avoiding the infliction of any injury to its body. This latter forms, in fact, the great *desideratum* of the operator; since, if the body of the parasite be broken, and a portion left still within the body of its host, additional and it may be serious irritation is thereby set up. The long and slender body of the worm is accordingly wound slowly and carefully around some object, and the negroes of the Guinea coast are said to be dexterous and skilful in the performance of this somewhat delicate operation.

Perhaps one of the most remarkable points in the history of parasites is that which refers to the geographical distribution of certain of their numbers. That parasites require to be provided with certain appropriate conditions for development is a fact already noted. Indeed, we may go much further and say that the conditions demanded for the successful development of many of these animals are infinitely complicated, and are in many cases of singularly curious nature. But it would also seem that in their "distribution" over the surface of the globe, and in their selection of certain countries or regions as especial spheres of development, some parasites evince remarkable traits of character. One of the best known instances of this fact is afforded by a species of tapeworm, to which the somewhat uncouth—to ears unscientific, at least—name of *Bothriocephalus* has been given. This latter is a species of "broad-headed" tapeworm, differing from its common neighbours in special points. It is unquestionably the largest or longest parasite which invades the human territory, and may attain a length of over twenty-five feet; its average breadth being about an inch or rather less. In a large "broad-head," as we may call it, upwards of four thousand joints or segments may exist, and as each joint—after the first six hundred—is capable of producing eggs and embryos, this foreign neighbour is seen to be fully as productive as its commoner relations. The most interesting fact regarding the "broad-head," however, relates to its geography and to its exact

range amongst the human populations of the earth. It is a tolerably well-ascertained fact, that our common tapeworms may affect inhabitants of any climate, but the "broad-headed" species affects a singularity in its distribution in that it has never been known to occur outside the European province,—that is, it has never been found in any other continent save in cases where it has been conveyed to other continents by European hosts. But the "broad-head" is moreover found to affect certain districts or regions within this European area, so that its distribution in Europe is itself of peculiar kind. Its head-quarters appear to be the cantons of Western Switzerland and the nearest French provinces. Its affects Poland, Russia, and Sweden in the north and north-western parts, and it also occurs, but less typically, in Holland and Belgium. In Eastern Prussia and Pomerania the "broad-head" has occasionally appeared; but the latter districts are probably to be regarded in the light of occasional habitats rather than of stated and permanent kind.

The reasons for the restriction of the parasite to such a limited field are by no means clear. We are not yet sufficiently acquainted with its development and life-history to make generalisations, but one significant fact remains to be noted, namely, that the "broad-head" flourishes in the regions in which the common tapeworm is an unknown or comparatively rare visitant. Now this observation is exactly paralleled by the peculiarities of the distribution of higher animals. In one country we may find what are termed "representative species" of the animals which occur in another and distant region. Thus the puma in the New World assumes the place of the lion of the Eastern hemisphere; the tapirs of the Eastern Archipelago are balanced in the opposite side of the world by the American species; and the llamas of South America represent their camel-neighbours of the Old World. There thus appears in such cases to be a balancing of animal life: the one species in one region or continent assuming the functions of the nearly

related but different species inhabiting another area of the world. Regarding the case of the parasites in this light, we may deduce a similar conclusion, namely, that the "broad-head" may discharge in its especial field of action the functions performed in other fields or areas by the common tapeworm. Nature, in any case, may certainly be credited with the general avoidance of any confusion of interests, and with the exclusion of rivalry from the domain and functions of like or nearly related creatures, wherever that domain may exist, and whatever these functions may be.

As a final example of a most singular and at the same time utterly harmless little intruder on the human domain, may be mentioned the minute mite known to naturalists as a species of *Demodex* (Fig. 26), and which, curiously enough, seems to take up its abode in the ducts or "follicles" of the skin at the sides of the nose. It is highly probable that this little creature is very frequently to be found in the situation just mentioned, its minute size and harmless character preventing our being made aware of its mere existence. Demodex measures a mere fraction of an inch in length, and may be said to present us with yet another instance of an organism whose selective powers in the choice of a habitation appear to be of the most singular description.

FIG. 26.—Demodex, magnified.

The lessons to be drawn from a consideration of the entire subject of the parasitic enemies of man bear very strongly on questions of common hygiene and sanitation. The extension of our knowledge of parasites and of their life-histories clearly points to the desirability for the exercise of great care in the choice and preparation of our common foods,—especially of animal kind. Uncooked animal food in any form should be unhesitatingly rejected on common sanitary grounds,—the prevailing and fashionable taste for "underdone" meat notwithstanding. The Mosaic abhorrence of the pig is fully justified by an appeal to zoological knowledge regarding the parasites to which that familiar and

not uninteresting quadruped plays the part of entertainer and host; but the due exercise of the culinary art should in large measure mitigate the severity of the sentence passed against pork as a common medium of parasitic infection. Unwashed vegetables, which may harbour or lodge, without developing, the embryos of parasites, are similarly to be regarded with suspicion. Indeed, it may be said that the chances of parasitic infection from this latter source are greater than those from badly cooked meat, the vegetable matter escaping even the chance of having its minute tenants destroyed. Unsavoury as the subject may at first sight appear, the whole question before us teems with an interest which should effectually appeal to every one in the light of saving knowledge. And it is not the least worthy remark which may be made regarding such a topic, that zoological science may be shown capable of extending its interests into the most intimate departments of the household, and even of encroaching on the sphere of that domestic autocrat, the cook.

THE LAW OF LIKENESS, AND ITS WORKING.

THAT the offspring should bear a close resemblance to the parent forms one of the most natural expectations of mankind, whilst the converse strikes us as being an infringement of some universal law that is not the less recognisable because of its unwritten or mysterious character. "The acorn," says a great authority on matters physiological, "tends to build itself up again into a woodland giant such as that from whose twig it fell; the spore of the humblest lichen reproduces the green or brown incrustation which gave it birth; and at the other end of the scale of life, the child that resembled neither the paternal nor the maternal side of the house would be regarded as a kind of monster." Thus true is it of the humblest as of the highest being, that the law of likeness or "heredity," as it has been termed, operates powerfully in moulding the young into the form and resemblance of the parent. But the law that is thus admitted to be so universal in its operation exhibits, at the same time, very diverse readings and phases. The likeness of the parent may be attained in some cases, it is true, in the most direct manner, as, for example, in the higher animals and plants, where the egg or germ, embryo and seed, become transformed through a readily traced process of development into the similitude of the being which gave it birth. So accustomed are we to trace this direct resemblance between the parent and the young in the higher animals and amongst ourselves, that any infringement of the

law of likeness is accounted a phenomenon of unusual kind. Even extending to the domain of mind as well as of body, we unconsciously expect the child to exhibit the traits of character and disposition which are visible in its parents, and to grow up "the child of its father and mother," as the expression runs, in every phase of its bodily and mental life.

A wider view of the relations and harmonies existing in nature, however, shows us that this direct development of the young into the similitude of its ancestors is by no means of universal occurrence. Many forms attain the resemblance to their progenitors only after passing through a series of changes or disguises, often of very complicated nature. And a very slight acquaintance with the facts of physiology would serve to show that the law of likeness, like most other laws regulating the world of life, has its grave exceptions, and that it exhibits certain phases of singular interest in what may be termed its abnormal operation. The young of an animal or plant may, and frequently do, exhibit very remarkable variations from the parent in all the characteristics which are associated with the special nature of the being. The circle of repeated and perpetuated likeness may thus be broken in upon at any point, and the normal law of heredity may be regarded as occasionally superseded in its working by the operation of another law,—that of variation and divergence. Forms unlike the parents are thus known to be frequently produced, and these errant members of the family circle may be shown to possess no inconsiderable influence on the nature and constitution of the world of life at large. Family likeness, as every one knows, lies at the root at once of the differences between, and relationships of, living beings. The offspring must resemble their parents and their own kind more closely than they resemble other groups, else our knowledge of the relationship of one form to another must be regarded as possessing no sound basis whatever. But admit that the young may not resemble the parent, and a veritable apple of discord is at once projected into the apparent harmonies

of nature, and dire confusion becomes the order of the day. As will be hereafter shown, however, whilst the law of variation does undoubtedly operate, and that to a very great extent, amongst living beings, other and compensating conditions are brought to light by the careful study of development at large; and the old law of like producing like may be seen, after all, to constitute the guiding principle of nature at large. As a study of high interest, and one the elements of which are afforded by our observation of the everyday world, the investigation of the law of likeness may be safely commended to the seeking mind. And in the brief study of this law and its operations we may firstly glance at some instances of development by way of illustration, and thereafter try to discern the meaning and causes of similitude or heredity. "*Rassemblons des faits pour nous donner des idées*," says Buffon, and the advice is eminently appropriate to those who purpose to enter upon a popular study of an important natural law.

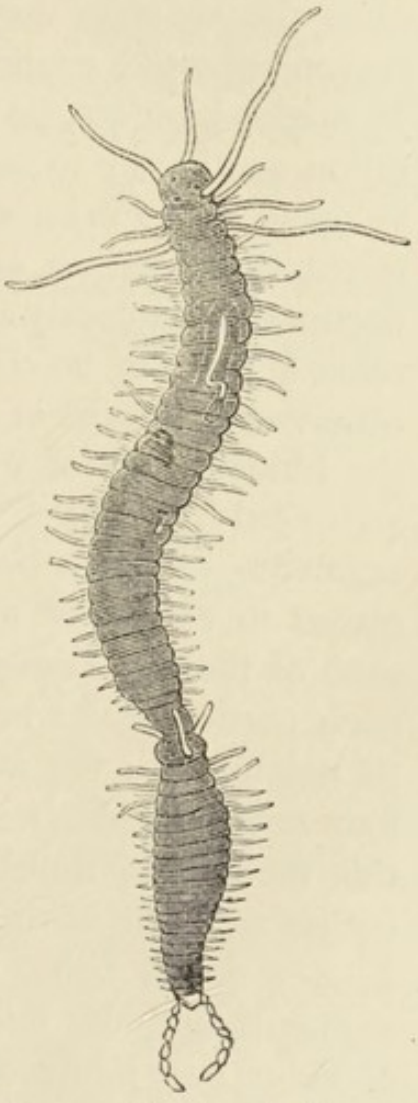


FIG. 27.—A naïs, or fresh-water worm, producing a new individual by budding.

One of the simplest instances of development, in which the young are not only transformed directly into the likeness of the parent, but represent in themselves essential parts of the parent-body, is illustrated by the case of the little worms known to the naturalist as *Naïdides*, and familiar to all as inhabitants of our ditches, and as occurring in damp mud and similar situations. If a naïs (Fig. 27) be chopped into a number of small pieces, each piece will in time develop a head and tail and become a perfect worm, differing in no respect, save in that of size,

from the original form. A naïs cut into forty pieces was transformed through the operation into as many small worms of its own kind. Here the law of likeness or heredity operates in the plainest and most direct fashion. The young are like the parent-stock, because they consist in reality of detached portions of the parent's personality. The experiments of naturalists carried out on animals of lower organisation than these worms, such as the little fresh-water polype or hydra,* show a power of artificial reproduction which is of literally marvellous extent; and all such animals evince at once the simplest mode of development and the plainest reasons why the young should exactly resemble the parent. It might, however, be alleged that such artificial experimentation was hardly to be accepted as illustrative of natural development; but in answer to such an observation the naturalist might show that an exactly similar method of reproduction occurs spontaneously and naturally in the naïs and in certain other animals of its class. A single naïs (Fig. 27) has been observed to consist of four connected but distinct portions, the hinder three of which had become almost completely separated from the original body,—represented by the front segment. A new head, eyes, and appendages could be traced in course of formation upon the front extremity of each of the new segments; and as development terminated, each portion could be seen to gradually detach itself from its neighbours; the original worm thus resolving itself into four new individuals. The most curious feature regarding this method of development consists in the fact that the bodies of these worms and of nearly related animals grow by new joints being added between the originally formed segments and the tail. If, therefore, we suppose that one of these new joints occasionally develops into a head, we can form an idea of the manner in which a process, originally intended to increase the growth of one and a single worm, becomes competent to evolve new individuals, each of which essentially resembles the parent in all particulars.

* See page 62.

The great Harvey, whose researches on animal development may be regarded as having laid the foundation of modern ideas regarding that process, adopted as his physiological motto the expression, *Omne animal ex ovo.* Whilst it is undoubtedly true that the egg, or ovum, must be regarded as the essential beginning and type of development in animals, we note that, as in naïs, the production of new beings is not solely dependent on the presence of that structure. Just as plants are propagated by slips and cuttings, so animals may be developed from shoots or specially detached portions of the parent-body. And it is in the development of the egg, or in the course of what may be regarded as the most regular and defined stages of that process, that the exceptions to the law of likeness are most frequently met with.

One of the most remarkable deviations from the normal law of development is seen in the case of the little *Aphides*

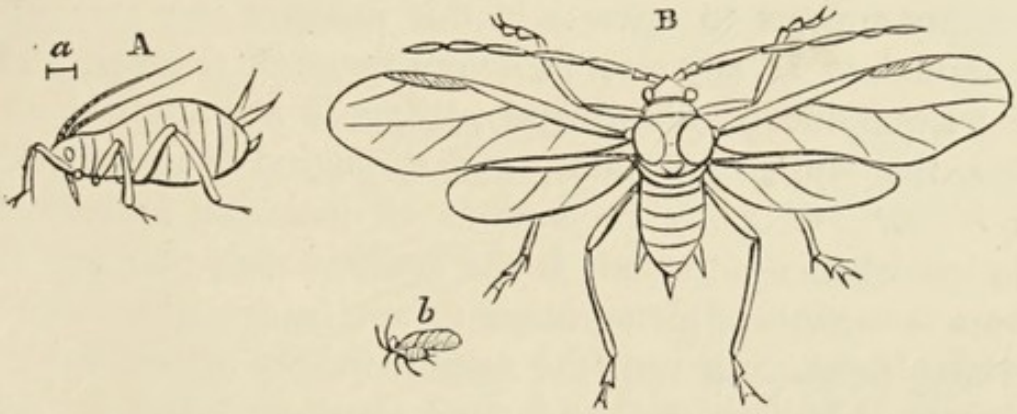


FIG. 28.—Plant-lice, natural size (*a*, *b*) and magnified : A, wingless, and B, winged form

(Fig. 28) or plant-lice, the insects so familiar to all as the pests of the gardener. At the close of the autumn season, winged males and females of these insects appear amongst their neighbour-aphides, and these produce eggs, which, however, lie dormant throughout the winter. Waking into life and development with the returning spring, these eggs give birth each to a wingless female; no insect of the sterner sex being found amongst the developed progeny of these insects. The presence of both sexes is

throughout the animal world regarded as necessary for the production of eggs capable of developing into offspring. Strangely enough, however, these wingless females not only produce eggs, hatching them within their bodies, but the eggs develop into beings exactly resembling themselves; not a single male aphis being represented within the limits of this Amazonian population. Seven, eight, nine, or even eleven generations of these wingless females may be produced in this manner, and the swarms of plant-lice which infest our vegetation attest the fertility of the race. But in the last brood of these insects, produced towards the close of autumn, winged males appear in addition to the females, which latter also possess wings. The members of this last brood produce eggs of ordinary nature, which lie dormant during the winter, but which in the succeeding spring will inaugurate the same strange life-history through which their progenitors passed. The case of the plant-lice may for the present be dismissed with the observation that the law of heredity appears to operate in this instance in a somewhat abnormal, or at any rate in a very unusual, manner. The true similitude of the winged parents is not attained until after the lapse of months, and through the interference, as it were, of many generations of dissimilar individuals. No less worthy of remark is the circumstance that one sex alone is capable of giving origin to new beings, which sooner or later produce in turn the natural duality of sex, forming the rule of both animal and plant creation. And the case of the plant-lice is rendered the more remarkable by the consideration that of 58,000 eggs laid by female silk-moths which were separated from the opposite sex, only twenty-nine developed into perfect caterpillars,—the female plant-lice possessing a fertility under like circumstances which would be amazing even if taking place under the normal laws and conditions of development.

Cases of the unusual development of animals, which serve as parallel instances to the case of the plant-lice, are by no means rare. Thus in the case of the star-fishes, sea-

urchins, and their neighbours, the egg gives origin to a free-swimming, active body, which develops a structure of its own, and appears in a fair way to become, as might be expected, the future star-fish. But within the body of this first embryo another formation is seen to take place; and sooner or later this secondary development comes to assume priority, and appears as the true and veritable representative of the young star-fish,—the primitive body or embryo which produced it, being either absorbed into its substance or cast off on development being fully attained and completed. The production of the second star-fish, as it were, out of a first-formed embryo, is paralleled by the curious case of a certain kind of gall-flies (*Cecidomyia*), within the larvæ or caterpillars of which other young or larvæ are produced. The latter case partakes thus of the nature of a striking exception to the ordinary laws of development, seeing that a young and immature form possesses the power of producing other beings, immature like itself, no doubt, but capable of ultimate development into true flies. In other words, heredity, or the power of like producing like, which ordinary observation demonstrates to occur usually in the mature and adult being, is here witnessed occurring in the young and imperfect form.

Certain very typical, but more complicated, cases of animal development than the preceding instances are witnessed in the reproduction of those curious animal colonies collectively named "zoophytes." Any common zoophyte, such as we may find cast up on our coasts or growing attached to the fronds of tangle, is found to consist of a plant-like organism (Fig. 29), which, however, instead of leaves or flowers, bears numerous little animals of similar kind, connected together so as to form a veritable colony. Each of the little members of this colony possesses a mouth, surrounded by arms or tentacles, and a little body-cavity in which food is digested; and it may be noted that each member of the colony contributes to form the store of nourishment on which all the members, including itself, in

turn depend for sustenance. Such a veritable animal tree, growing rooted and fixed to some object, increases by a veritable process of "budding." As the animal buds die and fall off, new buds are thrown out and developed to supply the place of the lost members; the zoophyte, like the tree, renewing its parts according to the strict law of likeness, and each new member of the colony bearing as close a likeness to the existing members as that borne by

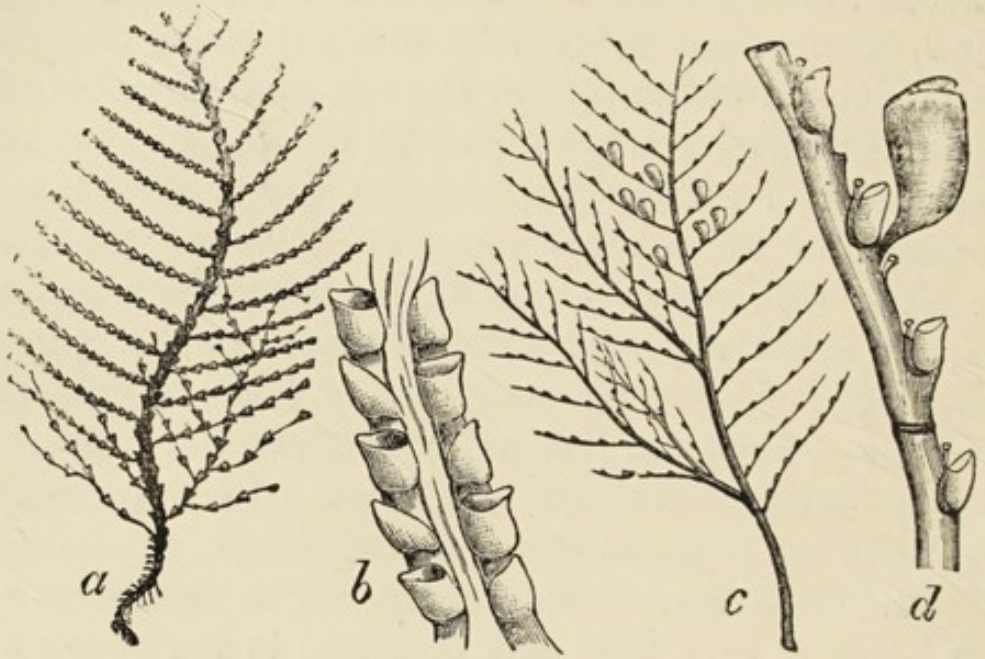


FIG. 29.—Zoophytes: *b* and *d*, showing the cells in which the animals live, are magnified portions of *a* and *c* respectively.

the one leaf of a tree to its neighbouring leaves. But, as the tree sooner or later produces flowers which are destined to furnish the seeds from which new trees may spring, so the zoophyte in due time produces animal buds of a kind differing widely from the ordinary units which enter into its composition. These varying buds in very many cases appear in the likeness of bell-shaped organisms, and when they detach themselves from the zoophyte tree and swim freely in the surrounding water, we recognise in each wandering bud a strange likeness to the familiar medusæ or jelly-fishes which swarm in the summer seas around our coasts. Living thus apart from the zoophyte-parent, these medusa buds may pass weeks or months in an independent existence. Ulti-

mately, however, they develop eggs, and with the production of the eggs the clear, elegant, glassy bodies undergo dissolution, and vanish away amid the waters, to which, in the delicacy of their structure, they presented so close a resemblance. From each egg of the jelly-fish bud there is gradually developed, not a medusa, but a zoophyte. The egg, in in fact, develops a single bud of the zoophyte, and this primitive bud, by a process of continuous budding, at last produces the connected tree-like form with which the life-history began. Thus the zoophyte is seen to give origin to a jelly-fish, and the jelly-fish in turn reproduces the form of the zoophyte,—one generation of animals, as the older naturalists believed, "alternating" in this way with another.

The law of likeness would at first sight seem to be ill adapted, in virtue of its essential nature, to explain the cause of an animal, such as the zoophyte, producing an entirely different being, represented in the present instance by the jelly-fish bud; and it might appear to be equally inexplicable that the progeny of the jelly-fish should revert to the zoophyte-stock and likeness. The case of those curious oceanic organisms, allied to the "sea-squirts," and known as salpæ, presented to the zoologist of former years phenomena of an equally abstruse kind. The salpæ are met with floating on the surface of the ocean in two distinct forms. One form exists in the shape of a long connected "chain" (Fig. 30) of

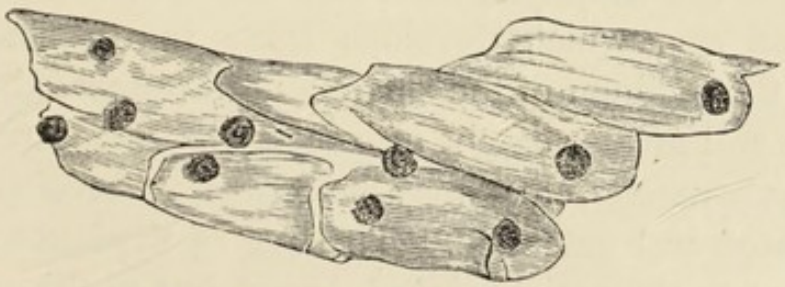


FIG. 30.—Part of a chain of salpæ.

individuals, whilst the other form is represented by single salpæ (Fig. 31). It was, however, ascertained that these two varieties were linked together in a singularly intimate manner by their development. The chain-salpæ were found to

produce each a single egg, which developed into a single salpa; and the latter, conversely, produced each a long "chain" of individuals,—the one variety, in fact, reproducing the other. The apparently mutual development of the zoophyte and the jelly-fish, and of the chain and single salpa is, however, explicable, as far as its exact nature goes, on other grounds than those on which the naturalists of former years accounted for the phenomena. The jelly-fish is not a distinct animal from the zoophyte, but merely one of its modified

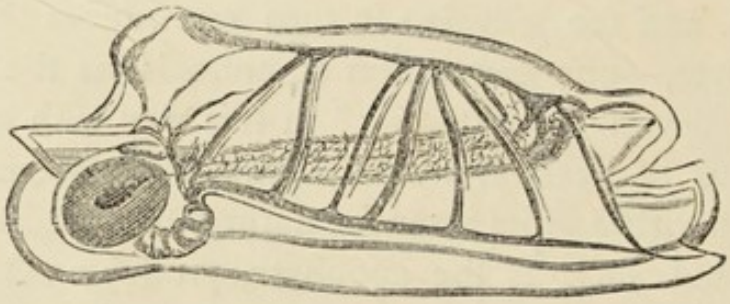


FIG. 31.—Single salpa.

buds, produced, like the other parts of the animal tree, by a process of budding, and destined for a special end,—that of the development of eggs. The latter illustrate the law of heredity because they are to be regarded as having been essentially and truly produced by the zoophyte, into the form of which each egg directly develops. And similarly with the salpæ. The chain-salpa may be regarded as corresponding to the zoophyte, each individual of the chain producing an egg, which develops again into a chain-salpa, through the medium of the single and unconnected form.

To a still greater extent in insects and some crustaceans —such as barnacles, etc.—may the process of development be complicated and extended. The egg of the butterfly gives origin, not to the aerial winged insect, but to the mundane caterpillar (Fig. 32), which, after passing an existence devoted solely to the work of nourishing its body, envelops that body in a cocoon and becomes the chrysalis; finally appearing from this latter investment as the winged and mature form. In the case of all insects which, like the butterfly, pass

through a *metamorphosis*, as the series of changes is named, the law of likeness appears to be protracted, and its terms somewhat evaded or extended. The egg, in other words, develops into the mature form only after passing through an extended development, and evolves the similitude of the parent-form through certain intermediate stages of well-marked kind. And so also with the well-known barnacles which attach themselves to the sides of ships and to floating timber. The young barnacle (see Fig. 22) appears as an active little creature, possessing limbs adapted for swim-

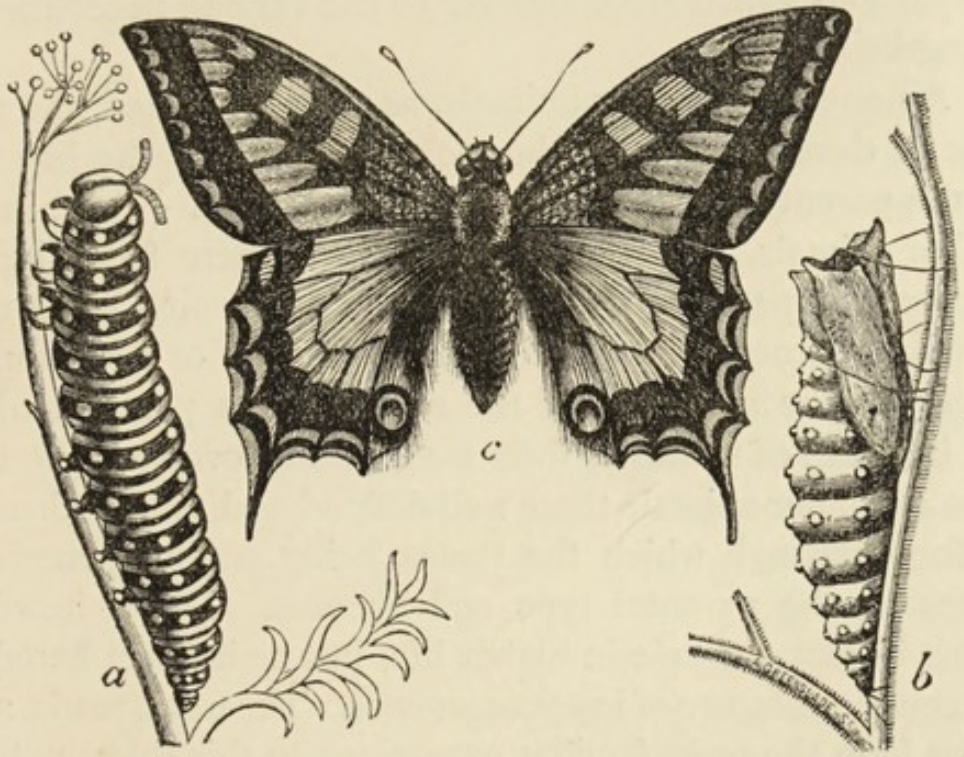


FIG. 32.—Metamorphosis of swallow-tailed butterfly; *a*, larva; *b*, chrysalis; *c*, perfect insect or imago.

ming, along with feelers, eyes, and other appendages. Ultimately, the embryo-barnacle forms its shell, loses its limbs and eyes, attaches itself by its feelers to some fixed object, develops its flexible stalk, and passes the remainder of its existence in a fixed and rooted condition. The development in this latter case, although in due time producing the likeness of the parent, clearly leads to a state of life of much lower character, and to a structure of humbler grade, compared with the life and organisation of the young barnacle.

The invariable law of heredity in the various examples detailed is thus seen to operate sometimes in clear and definite manner, converting the offspring into the likeness of the parent directly, and with but little change, save that involved in the process of growth into the parent-form. In other cases, the operation of the law is carried out through an extended and often complicated process of development; and the observation of the manifold variations which the working of the law exhibits, adds but another to the many proofs of the inherent plasticity of nature, and the singular adaptations which are exhibited to the varying necessities of living beings.

Amongst the higher animals, as we have noted, the process of development for the most part evolves the likeness of the parent in a simple and direct manner. True, in all higher animals, as in lower animals, the mere formation of organs and parts of the body of the developing being constitutes a process in which, from dissimilar or from simple materials, the similarity of the animal to its parent and to the intricacy of the adult form are gradually evolved. But we miss in higher animals these well-defined and visible changes of form through which the young being gradually approximates to the parental type and likeness. Direct heredity forms, in fact, the rule in higher life, just as indirect heredity is a common feature of lower organisms. The frogs, toads, and newts form the most familiar exceptions to this rule amongst higher animals; the young of these beings, as is well known, appearing in the form of "tadpoles" (Fig. 8), and attaining the likeness of the adult through a very gradual series of changes and developments. But in no cases can the existence of hereditary influences be more clearly perceived or traced than in cases of the development of higher animals, in which traits of character, physical peculiarities, and even diseases, are seen to be unerringly and exactly reproduced through the operation of the law of likeness; whilst in certain unusual phases of development the influence of the law can be shown not less clearly than in its common and normal action.

The case of the "Ancon" or "Otter" sheep serves as an apt illustration not only of the transmission of characters to the offspring, but likewise of the sudden appearance and development of characters not accounted for by heredity. In the year 1791 a ewe belonging to a Massachusetts farmer produced a lamb differing materially from its neighbours in that its legs were disproportionately short, whilst its body was disproportionately long. This departure from the ordinary type of the sheep could not be accounted for in any way; the variation being, as far as could be ascertained, perfectly spontaneous. The single short-legged sheep became the progenitor of others, and in due time a race of ancons was produced; the variety, however, falling into neglect, and ultimately disappearing, on account of the introduction of the merino sheep, and of the attention paid to the development of the latter breed. The law of likeness in the case of the ancon sheep proved normal in its working after the introduction of the first ancon. The offspring of two ancons was thus invariably a pure otter sheep; the progeny of an ancon and an ordinary sheep being also pure either in the direction of the sheep or the ancon; no blending or mixture of the two races ever taking place. The law of likeness thus holds good in its ordinary operation, but takes no account and gives no explanation of the abstruse and unknown causes arising from the law of variation, and on which the development of the first ancon sheep depended.

The heredity and transmission of mere influences, which have been simply impressed upon either parent, and which form no part of the parent's original constitution, presents some of the most marvellous, as well as some of the most inexplicable, features of animal and plant development. Thus an Italian naturalist, taking the pollen or fertilising matter from the stamens of the lemon, fertilised the flowers of the orange. The result was that one of the oranges, subsequently produced, exhibited a portion of its substance which was not only coloured like the lemon, but preserved the distinct flavour of the latter fruit. Changes of similar

nature have been produced in the fruit of one species of melon by fertilising the flowers with pollen of a different species, and thus producing, through the operation of the law of likeness, a blending of the character of the two species. Equally certain as regards their effects on the young forms of animals, are the effects of the transmission of influences or qualities impressed on the parents. The birth of a hybrid foal, half quagga, half horse, from a mare, has been a sufficient influence to transmit to the subsequent and pure progeny of the mother the banded stripes or markings of the quagga; the influence of the first male parent and offspring extending, as it were, to the unconnected and succeeding progeny.

The case of the human subject presents no exceptions to the laws of heredity and of hereditary influences, since the common experience of everyday life familiarises us with the transmission of the constitution of body and mind from parent to child; whilst the careful investigation of the family history of noted artists, sculptors, poets, musicians, and men of science clearly proves that the qualities for which they are or were distinguished have, in most cases, been transmitted to them as a natural legacy and inheritance,—so fully does science corroborate the popular saying, that qualities of body and mind "run in the blood."

A notable case of the operation of the law of likeness in perpetuating a singular condition of body is afforded by the history of the Lambert family. Edward Lambert was exhibited in 1731, at the age of fourteen, before the Royal Society of London, on account of the peculiar condition of his skin, which was covered with horny scales; these appendages, in their most typical development, according to one account, "looking and rustling like the bristles or quills of a hedgehog shorn off within an inch of the skin." In 1757 the "porcupine man," as Lambert was called, again exhibited himself in London. He had in the interim suffered from small-pox; the disease having had the effect of temporarily destroying the roughened skin, which, however, reappeared

during his convalescence. Lambert's children presented the same peculiar skin-development, and the correlation between parent and offspring in this case was most marked, even in the date of the first appearance of the abnormality, since the skin developed its scales in each of his children, as in himself, about nine weeks after birth. In Lambert's grandchildren this peculiarity was also well marked; two brothers, grandsons of Lambert, being exhibited in Germany on account of their peculiar body-covering.

The history of the Kelleias, a Maltese family, is no less instructive than that of Lambert, as tending to prove the distinct and specific operations of the laws of heredity. Gratio Kelleia,—whose history is given by Réaumur in his "Art de faire éclore les Poulets," as a kind of lesson in the rearing of poultry,—was a Maltese, who possessed six fingers on each hand and six toes on each foot. His parents possessed the ordinary number of digits, and hence the law of variation may be regarded as operating in the case of the human subject, as in the ancon sheep and in lower animals still, in producing sudden and spontaneous deviations from the normal type of a species or race. Kelleia's family consisted of four children, the mother exhibiting no abnormality of hands or feet. The eldest son, Salvator, exactly resembled his father. George, the second son, had five fingers and five toes, but his hands and feet were deformed. André, the third son, exhibited no abnormality; and Marie, the daughter, had deformed thumbs. The operation of the law of heredity was not especially marked in this first generation, but its effects were of very striking character in the second. To begin with the family of André, none of his children exhibited any divergence from the normal type. Of Marie's family, only one, a boy, had six toes; his fingers being normal. Of George's four children, one boy possessed hands and feet of ordinary type; one girl had six fingers on each hand, but, curiously enough, six toes on the right foot only; whilst the remaining two girls had each six fingers and six toes on each hand

and foot. Salvator's family likewise consisted of four children, three of whom possessed the six fingers and six toes of their father and grandparent; the fourth and youngest possessing the ordinary number of digits. The four mothers of the second generation of Kelleias exhibited no abnormality in respect of hands or feet, and hence the hereditary influence of the female parent doubtless made itself felt in the development of a proportion of normal hands and feet,—although, as far as the genealogy of the family is traced, the proportion of six-fingered and six-toed members clearly tends to exceed that of those possessing the nomal number of fingers and toes.

Having thus selected and marshalled some of the chief facts relating to the occurrence of heredity or the likeness between parent and offspring, it may be fairly urged that these facts seem to establish the existence of some well-defined law, in virtue of which the bodily structure, the mental characteristics, or even the peculiarities induced by disease, are transmitted from one generation to another. And it also becomes an important study to determine the causes which operate in producing such variations in the law of inheritance as we have endeavoured to illustrate in the case of certain groups of lower animals. Can we, in other words, account for the similarities and resemblances, and for the diversities and variations, which living beings present, apparently as a natural sequence of their life, and of the operation of the laws which regulate that existence? The answer to some such question as the preceding closely engaged the attention of physiologists in former years, the result of their considerations being the framing of various theories whereby the facts of heredity could be correlated and explained. It is evident that any explanation of heredity must partake of the nature of a mere speculation, from our sheer inability to penetrate deeper into the investigation of its laws than the observation of phenomena can lead us. But when rightly employed, generalisations and theories serve as leading-strings to the truth; and,

moreover, aid in the most valuable manner in connecting facts which otherwise would present a most confusing and straggling array. We may, in truth, sketch in the outlines of the subject in theory, and leave these outlines to be deleted or intensified by the subsequent progress of knowledge.

Buffon speculated, about the middle of last century, on the causes of heredity, and viewed the subject from a very comprehensive stand-point. He assumed that the ultimate parts of living beings existed in the form of certain atoms, which he named "organic molecules," and maintained that these molecules were received into the body in the shape of food, and became stored up in the various tissues and organs, receiving from each part a corresponding "impression." The molecules in each living body were, in fact, regarded by Buffon as plastic masses, which not only received the imprint, in miniature, of the organ in which they had lodged, but were also fitted to reproduce that organ or part. Potentially, therefore, each molecule might be said to carry within it some special portion of the body of which, for a time, it had formed part. It was organic and, moreover, indestructible. For after itself and its neighbours had been freed from corporeal trammels by the death of the organism in which it had existed, they were regarded as being capable of entering into new combinations, and of thus building up afresh the forms of living animals or plants similar to, or widely different from, those in which they had previously been contained. Buffon's theory had special reference to the explanation of cases of the "spontaneous generation" of animalcules in closed vessels, but it also served to explain the cause of heredity. The molecules, each charged with the form of the organ or part in which it existed, were believed ultimately to pass, in the case of the animal, to the egg-producing organs, or, in the plant, to the seed; the egg and the seed being thus formed, as it were, from materials contributed by the entire body. The germ was to the body at large, as a microcosm is to the greater "cosmos."

A second authority who framed an explanation of the causes of likeness was Bonnet, who maintained that lost parts were reproduced by germs contained in the nearest portions of the injured body; whilst by his theory of *emboîtement* it was held that each germ was in itself the repository of countless other germs, these bodies being stored up in a quantity sufficient for the reproductive needs of countless generations. Professor Owen's explanation depends upon the recognition of the fact that certain of the cells of the germ from which the living being springs pass into its body, and there remain to transmit to its successors the material characters which it has acquired; whilst, also, the repair of injuries, and the propagation of new beings by budding and like processes, are explained on the supposition that these germ-cells may grow, increase, and operate within the organism which they are ultimately destined to propagate. Lastly, Mr. Darwin has come to the solution of heredity with his theory of *Pangenesis*, which may be said to avail itself of all that is reasonable and probable in the explanations just discussed, and also to include several new and important ideas of which the older theorists took no account.

As paving the way for an understanding of this and other explanations of the law of likeness, we may briefly glance at some of the chief facts with reference to the structure and intimate composition of living beings, with which microscopic study has made us acquainted. When the anatomist or physiologist seeks to unravel the complications of human structure, or when, indeed, he scrutinises the bodies of all animals, save the very lowest, he finds that each organ or tissue of the body is composed of certain minute vesicles or spheres, to which he gives the name of *cells* (Fig. 33). Cells, in fact, are the units of which the bodily whole is composed. Nerves thus resolve themselves under the microscope into fibres, and the fibres, in turn, are seen to originate from cells. Muscles similarly originate from muscle-cells. Each tissue, however compact it may

appear, is capable of ultimate reduction to cells of characteristic kind. Nor is this all. The cells themselves are in turn composed of smaller particles, and these smaller particles—of infinitesimally minute size—may be regarded as consisting in turn of the essential material of life—the *bioplasm* or *protoplasm*—with the name of which every one must be more or less familiar from the part it has played in more than one grave biological controversy. But the body of every living thing is in no case stable, viewed either in its chemical or in its more purely physical aspects. It is continually, as the inevitable result of living and

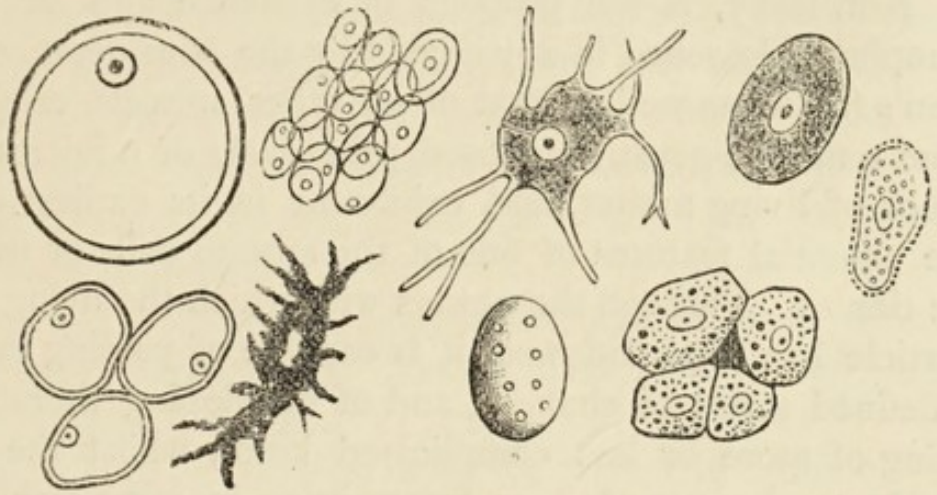


FIG. 33.—Various cells, magnified.

being, undergoing change and alteration. Chemical action is wasting its substance and dissipating its energy with prodigal hand on the one side, and rebuilding and reconstructing its parts on the other. Its material particles are continually being wasted and excreted, whilst new particles are as incessantly being added to its frame. A never-ending action of waste and repair is maintained within every living being; and it is not the least striking thought which may ensue from the study of such a subject, that, notwithstanding the constant renewal of our frames, we continue to preserve the same recognisable form and features. The development of new particles in place of the old appears to follow the same course as that whereby the first-formed particles were guided to their place in the developing young. Germs,

or "nuclei"—"germinal centres," as the physiologist terms them—are abundantly to be descried within most of the tissues. Imbedded amongst the fibres of muscles, for example, are to be seen the germs from which new muscular fibres will be developed; and in the brain itself, such reproductive bodies are to be observed. Thus the growth and continuance of our mental existence may be shown to be dependent on the presence of these new particles, which are destined to renew in a material sense those powers which, of all others in man's nature, most nearly approach the immaterial and spiritual.

Nor, lastly, is the problem of existence and structural complexity lessened in any degree by the consideration that man's frame, as well as that of all other animals, originates from a minute germ, composed primitively of a microscopic speck of living matter, and exhibiting in its earliest stages the essential features of one of the minute cells or units of his tissues. Through the powers with which the living germ-particle has been endowed, it is capable of passing through a defined series of changes, and of developing therefrom a being of more or less complicated kind; whilst the germ itself must be regarded as transmitting in some fashion or other, and in a material form, the likenesses which link parent and offspring together in so close and intimate a union.

Applying the reasoning of the theory of pangenesis to the explanation of heredity and likeness in the light of the physiological evidence thus briefly detailed, we are required to bear in mind that, as an established fact, the cells of which a living being is composed increase and multiply to form tissues and organs; the new cells retaining the form and essential characters of the parent-cells. The cell, in short, is formed, is nourished, grows, and reproduces its like, as does the body of which it forms part. And botanists and zoologists would inform us that lowly plants and animals, each consisting of but a single cell, not only exist, but carry on the functions of life as perfectly, when regarded in relation to the wants of their existence, as do the highest animals or

most highly organised plants. Each cell, possessed thus of vital powers, may further be regarded as correlating itself with the life of the body at large, in that it is capable of throwing off minute particles of its substance. These particles, named gemmules, may be supposed to circulate freely through the system, and when duly nourished are regarded as being capable of developing into cells resembling those from which they were derived. These gemmules are further supposed to be thrown off from cells at every stage of the development and growth of a living being. More especially do they aggregate together to form the germ, or the materials from which the germ is formed. Transmitted thus from parent to offspring, the latter may be regarded as potentially composed of the gemmules derived from its parent,—which, like the organic molecules of Buffon, are charged with reproducing, in the young form, the characters they have acquired from the parent.

Regarded from a physiological stand-point, this explanation of the transmission of likeness from parent to offspring appears, it must be owned, to present no difficulties of very formidable kind. Scientific evidence regarding the functions and properties of cells is thoroughly in agreement with the theory, as far as the behaviour of these bodily units is concerned. The exercise of scientific faith and the weighing of probabilities commence with the assumption of the development of the gemmules from the cells; and it may be asked if the belief that these gemmules are capable of transmission and aggregation as held by this theory, is one inconsistent with the tenets and discoveries of biological science at large. If we inquire regarding the feasibility of the mere existence of such minute gemmules, we shall find that physical science opposes no barrier to the favourable reception of such an idea. The inconceivably minute size of the particles given off from a grain of musk, for example, which scents a room for years without losing so much of its substance as can be determined by the most acute physical tests, lies beyond the furthest limit even of the scientific

imagination to conceive. The particles of vaccine lymph diffused through the body by the lancet of the vaccinator, are much more minute than the smallest cells; yet, judged by the standard of development and by the effects of their multiplication in our frames, their existence must be regarded as anything but problematical. Then, as regards numbers, the eggs of some animals exist in quantities, of which, at the best, we can only form a dim and approximate idea. A small parasitic worm, the *Ascaris*, is known to produce 64,000,000 eggs, and some of the orchids will produce as many seeds; whilst the fertility of some fishes is almost inconceivable. It has been objected, it is true, to this conception of the manner through which the law of likeness operates, that it is difficult to believe in the complicated powers and tendencies of the gemmules to select and carry the special qualities of the cells from which they originate; and that, in short, the conception credits the gemmules with powers of too mysterious and occult a kind for ordinary acceptance and belief. But in answer to this objection it may be urged that the powers with which the gemmules are credited are not a whit more extraordinary than those possessed by cells; or than those which nerve-cells and nerve-fibres possess, for example, in forming and transmitting the undetermined, mysterious nerve-force which under certain conditions becomes resolved into thought and mind. The mere *conditions* of heredity which the theory explains, constitute in fact a greater draft upon scientific credulity than is demanded by any conditions or ideas included in the explanation itself.

Moreover, there is hardly a condition, illustrated by the examples of heredity and animal development already given, which is insusceptible of explanation through the aid of this theory. The cases of fission illustrated by the fresh-water worms (Fig. 27), and the process of budding exemplified by the zoophyte, become intelligible on the idea that a determination of the gemmules to the parts concerned in these processes takes place, and that by their aggregation they form

parts resembling those from which they were derived. The curious phases of reproduction in the plant-lice, in which, it will be remembered, female insects were seen to be capable of producing generation after generation of beings resembling themselves without the intervention of the opposite sex, is likewise explained by the supposition that gemmules aggregate in quantities in the egg-producing organs of the insects. These gemmules are further regarded as being charged with the power of perpetuating the likeness of the stock from which they were originally derived, and are simply transmitted from one generation to another, until, through some more special modification, the periodical production of fertilised eggs in autumn is once more illustrated. The exact nature of "alternate generations" of the zoophytes and salpæ becomes clear to us if we presume that the gemmules of the producing form, such as the zoophyte, are multiplied and specially developed to form the jelly-fish bud, which finally, as we have seen, is launched abroad charged with the task of reproducing the zoophyte. Each egg of the jelly-fish contains thus the gemmules inherited from, and which convey the likeness and form of, the zoophyte; the special development of new beings seen in this case presenting a contrast to the ordinary increase of the single zoophyte by budding. The metamorphoses or changes which animals undergo in passing from the egg to the adult state—well illustrated by the insect class—can similarly be explained by the deductions of pangenesis, if we suppose that the gemmules which tend to form the perfect being undergo a progressive development, and a gradual elaboration in the earlier stages of the process. And we can the more readily apply this reasoning to the explanation of the manner in which the winged butterfly, for example, is evolved from the caterpillar, when we find that within the chrysalis-case or cocoon the body of the larvæ is literally broken down and resolved into atomic parts, whilst, by a wondrous process of reconstruction and rearrangement of these atoms, the perfect insect is in due time formed. Metamorphosis, in this

respect, may truly be described as a process of the readjustment and rearrangement of the atoms and gemmules of the insect's frame. The variations of living beings may in their turn be explained by assuming an irregularity to exist in the arrangement of the gemmules which unite to form the germ of the varying form. Modified cells will give out modified gemmules, and these last will produce variations in the new being. Any cause producing alterations in the gemmules, either in the direction of over-fertility or in that of deficiency, will tell with corresponding effect on the germ which they tend to form. Whilst in cases in which bodily structures, mental qualities, or even diseases lie dormant in one generation, and become developed in the succeeding race, the gemmules may be regarded as having been transmitted in a latent condition in the former race, and as having been awakened and redeveloped in the latter. The transmission of active disease to a particular generation through an intervening and latent stage represented by the preceding generation, is explicable, if we suppose that the dormant condition acts on the gemmules as rest acts on wearied muscles in serving to restore their pristine strength. Some diseases are known to gain strength and virulence after the lapse of a generation, in which they have lain dormant and inactive. And the reappearance of the diseased condition becomes connected by the explanation just given, to use Mr. Darwin's words, with "the wonderful fact that the child may depart from the type of both its parents, and resemble its grand-parents or ancestors removed by many generations."

Not less interesting is it, however, to trace the transmission of mental qualities, powers, and traits of disposition from one generation to another. The mere fact of such transmission would seem to imply the importance of the physical side of mental acts, and the closer dependence of mind on physical textures and nerve-tissues than is generally admitted. The transmitted quality can only be regarded, in fact, as having been materially and physically transmitted,

—just as, in short, our entire bodies represent so much physical matter, which appears as the outcome of a previous age, and, indeed, as the cumulative products—physical and mental—of many antecedent generations. The study of the law of likeness, as applied to peculiarities of mind, has materially benefited from the advances in the means of physical research which recent years have brought. Indeed, to the merely casual observer there can appear little doubt that the domain of mental science is being invaded on more than one side by the sciences which deal more especially with the material world and with the physical universe around us. When physiologists discovered that the force or impulse which travels along a nerve, which originates in the brain, and which represents the transformation of thought into action, is nearly allied to the electrical force,—now one of man's most useful and obedient ministers,—one avenue to the domain of mind was opened up. And when physiologists, through the aid of delicate apparatus, were actually enabled to measure the rate at which this nerve-force travels along the nerve-fibres, it may again be said that physical science was encroaching on the domain of mind, being in a certain sense thus enabled to measure the rapidity of thought.

A study, exemplifying in a more than ordinary degree the application of the methods of physical science to the explanation of states of mind, and to the results of the operation of the law of likeness, was brought under the notice of the members of the British Association at the meeting of that body for 1877. In the department of Anthropology, —the science investigating the physical and mental constitution of the races of man,—Mr. Francis Galton, as president of this section, devoted his address to the exposition of the classification or arrangement of groups of men, according to their habits of mind, and their physiognomy.

Of the curious and absorbing nature of such a study, and of its connection with heredity, little need be said. Lavater's method of pursuing the study of character through

the investigation of the features of the human face has long been known. But Lavater's system is on the whole much too loose and elementary to be regarded as satisfactory by modern scientists, whose repudiation of phrenology as a system capable of explaining the exact disposition of the brain functions, has unquestionably affected Lavater's method also. Mr. Galton refers at the outset of his address to the fact we have already alluded to, namely that physiologists have determined the rate at which nerve-force, representing a sensation or impulse of thought and action, travels along the nerves. The common phrase "as quick as thought" is found to be by no means so applicable as is generally supposed, especially when it is discovered that thought or nervous-impulse, as compared with light or electricity, appears a veritable laggard. For whilst light travels at the rate of many thousands of miles—about 186,000 miles, according to the latest researches—in a second of time, nerve-force in man passes along his nerves at a rate varying from 110 or 120 to 200 feet per second. Or, to use Mr. Galton's words, nerve-force is "far from instantaneous" in its action, and has "indeed no higher velocity than that of a railway express train."

As we could naturally suppose from a consideration of this fact, small animals presenting us with a limited distance for nerve-force to travel, will avoid rapid blows and shift for themselves in the struggle for existence at a much quicker rate than large animals. Take two extreme cases in illustration of this fact. A mouse hears a suspicious or threatening sound, and at once, so to speak, accommodates its actions and movements to its protection. The ear of the mouse, as one of its "gateways of knowledge," is situated so close to the brain that the interval which elapses between the reception of the sound by the ear, or between its transmission as an impulse to the brain and the issue of a command or second impulse from the brain to the muscles of the body for the purpose of movement, is too short to be perfectly appreciated by the observer. In a whale, on the

contrary, which may attain a length of eighty feet, a much longer interval will elapse before action of body follows on nervous impulse, seeing that the nerve-impulse has a longer distance to travel. Assuming that in such animals as the whale the nerve-action travels at the rate of seventy or eighty feet per second, it follows that in a large whale which has been struck near the tail by a harpoon, a second or so will elapse before the impulse is transmitted to the brain, whilst another second will pass before the second impulse is sent from the brain to put the muscles of the tail in action for the purpose of retaliating upon the harpooner. In such a case it is assumed that the brain of the animal will be the nervous centre or station at which information is received, and from which instructions are in turn telegraphed to the various organs and parts of the body. In the actual details of the case, however, it is probable that the spinal marrow of the animal or some part of it would act as the "head-office" for receiving and issuing commands. We know that a headless frog will wipe off with one foot a drop of vinegar that has been placed on the other, and in the absence of the brain, we thus assume that the spinal cord may act as a nerve-centre.

Doubtless the spinal marrow discharges this function naturally; and in view of this latter supposition, the interval between the reception of a blow and the muscular actions of an animal would be of less duration than in the case we have just supposed, where the brain is regarded as the central station of the nervous system. As Professor Tyndall has remarked, "the interval required for the kindling of consciousness would probably more than suffice for the destruction of the brain by lightning, or even by a rifle-bullet. Before the organ (that is, the brain) can arrange itself, it may therefore be destroyed, and in such a case we we may safely conclude that death is painless."

But confining ourselves to the domain of human thought, it seems perfectly clear that the differences between persons of different temperament are in reality referable in great

part to the varying rates at which nervous impulses are transmitted through the nerves, and to or from the brain, and the variations in the rate of nerve-impulse are of course referable to inherited peculiarities, and to ancestral and transmitted qualities of mind. The difference between a person of phlegmatic disposition and a person of sanguine temperament, may thus be properly enough referred to the varying rates with which sensations and feelings are appreciated and acted upon. Disposition or temperament thus becomes referred, secondarily, to the manner in which and aptitude with which nerves receive and transmit impressions. Primarily, of course, we must refer the exact causes of the quicker or slower transmission of impulses to the constitution of the individual who exhibits them.

Mr. Galton gives a very interesting example of the differences to be observed between various individuals in the respects just noted, by a reference to a practice common amongst astronomers. He says: "It is a well-known fact that different observers make different estimates of the exact moment of the occurrence of any event. There is," he continues, "a common astronomical observation in which the moment has to be recorded at which a star that is travelling athwart the field of view of a fixed telescope, crosses the fine vertical wire by which that field of view is intersected. In making this observation it is found that some observers are over-sanguine and anticipate the event, whilst others are sluggish, and allow the event to pass by before they succeed in noting it." This tendency of each individual is clearly not the result either of inexperience or carelessness, since, as astronomers well know, "it is a persistent characteristic of each individual, however practised in the art of making observations or however attentive he may be." And so accustomed, indeed, are astronomers to these differences in observers, that a definite and standing phrase—that of the "personal equation"—is used in that science to express the difference between the time of a man's noting the event and that of its actual occurrence. Every assistant in an observa-

tory has his "personal equation" duly ascertained, and has this correction applied to each of his observations. This most interesting fact relates exact or mathematical science in the most curious manner to the mental character of an individual. Mr. Galton, however, does not rest merely with the announcement of this latter result. He goes much further in his theoretical inquiry, and suggests that peculiarities in the respect just noted might be found to be related to special points in the conformation of the body. Thus could the "personal equations" of astronomers be related to the height of body, age, colour of hair and eyes, weight and temperament, some valuable facts might be deduced regarding the union of definite characters to form a special constitution.

Some other methods may be cited of estimating the differences between various temperaments in appreciating sensations and in acting upon them. If a person is prepared to give an instantaneous opinion as to the colour of a certain signal—black or white—but is unaware of the particular colour which is to be exhibited, and if he is further instructed to press a stop with his right hand for the one colour and a left-hand stop for the other, the act of judgment necessary to determine the particular stop in each instance is found to occupy an appreciable interval. This is particularly the case if a single signal has been previously shown, and the observer's quickness of sight has been tested and calculated by his pressing a single stop whenever he saw the object. The comparison between the interval elapsing between the mere sensation of sight and the act of pressing the stop in the latter case, and the interval which elapses when the observer has to make up his mind as to the difference between two signals, is seen to be very marked.

Setting thus before his mind a certain number of tests of individual temperament and character such as have been illustrated, the observer may next proceed to the task of discovering whether persons who exhibit similar qualities of mind in these experiments can be proved to be related to

each other in other particulars of their physical or mental disposition. Mr. Galton has ingeniously suggested that by an arrangement of mirrors, four views of a person's head might be taken at once, and would thus afford an ordinary photographic portrait, a portrait of a three-quarter face, a profile view, and a figure of the top of the head respectively. Such a series of views would present all the aspects required for a comparison of the general as well as special contour of the head of the individual with the heads of others photographed in like manner.

Our author, whose researches on the heredity of men of genius and the transmission from one generation to another of qualities belonging to the highest development of man's estate, are well known, turned his attention to the opposite phase of human life and character, and investigated in an avowedly casual, but still important manner, the likenesses and differences between members of the criminal classes of England. The social and practical importance of a study such as the present may be readily estimated. There are few persons who have not considered the bearings and influence of criminal antecedents upon the offenders of the present day. Although to a certain extent our temperaments and dispositions are of our own making, and are susceptible of the favouring influences of education and moral training, there can be no doubt of the truth of the converse remark, that to a very great extent the traits of character we inherit from our parents exercise an undeniable influence over us for weal or for woe. If, therefore, through research in the direction we have indicated, it can be shown that criminality runs in types, our notions of criminal responsibility, and our ideas regarding the punishment, deterrent and otherwise, of the criminal classes, must be affected and ameliorated thereby.

That criminality, like moral greatness, "runs in the blood," there can be no doubt. It would, in fact, be a most unwonted violation of heredity and of the commonest law of nature, were we to find the children of criminals free from the moral

taints of their parents. As physical disease is transmissible, and as the conditions regulating its descent are now tolerably well ascertained, so moral infirmities pass from one generation to another, and the "law of likeness" is thus seen to hold true of mind as well as of body. Numerous instances might be cited of the transmission of criminal traits of character, often of very marked and special kind. Dr. Despine, a Continental writer, gives one very remarkable case illustrating the transmission from one generation to another of an extraordinary tendency to thieve and steal. The subjects of the memoir in question were a family named Chrétien, of which the common ancestor, so to speak, Jean Chrétien by name, had three sons, Pierre, Thomas, and Jean-Baptiste. Pierre in his turn had one son, who was sentenced to penal servitude for life for robbery and murder. Thomas had two sons, one of whom was condemned to a like sentence for murder; the other being sentenced to death for a like crime. Of the children of Jean-Baptiste, one son (Jean-François) married one Marie Tauré, who came of a family noted for their tendency to the crime of incendiarism. Seven children were born to this couple with avowedly criminal antecedents on both sides. Of these, one son, Jean-François, named after his father, died in prison after undergoing various sentences for robberies. Another son, Benoist, was killed by falling off a house-roof which he had scaled in the act of theft; and a third son, "Clain" by nickname, after being convicted of several robberies, died at the age of twenty-five. Victor, a fourth son, was also a criminal; Marie-Reine, a daughter, died in prison, as also did her sister Marie-Rose—whither both had been sent for theft. The remaining daughter Victorine, married a man named Lemarre, the son of this couple being sentenced to death for robbery and murder.

This hideous and sad record of whole generations being impelled, as it were, hereditarily to crime, is paralleled by the case of the notorious Jukes family, whose doings are still matters of comment amongst the legal and police authorities

of New York. A long and carefully compiled pedigree of this family shows the sad but striking fact that in the course of seven generations no fewer than 540 individuals of Jukes blood were included amongst the criminal and pauper classes. The account appears in the thirty-first annual report of the Prison Association of New York (1876); and the results of an investigation into the history of the fifth generation alone may be shortly referred to in the present instance as presenting us with a companion case to that of the somewhat inaptly named Chrétien family. This fifth generation of the Jukes tribe sprang from the eldest of the five daughters of the common ancestor of the race. One hundred and three individuals are included in this generation, thirty-eight of these coming through an illegitimate granddaughter, and eighty-five through legitimate grandchildren. The great majority of the females consorted with criminals; sixteen of the thirty-eight have been convicted—one nine times—some of heinous crimes; eleven are paupers and led dissolute or criminal lives; four were inveterate drunkards; the history of three is unknown; and a small minority of four are known to have lived respectable and honest lives. Of the eighty-five legitimate descendants, only five were incorrigible criminals, and only some thirteen were paupers or dissolute. Jukes himself, the founder of this prolific criminal community, was born about 1730, and is described as a curious unsteady man of gipsy descent, but apparently without deliberately bad or intently vicious instincts. Through unfavourable marriages, the undecided character of the father ripened into the criminal traits of his descendants. The moral surroundings being of the worst description, the beginnings of criminality became intensified, and hence arose naturally, and as time passed, the graver symptoms of diseased morality and criminal disposition.

The data upon which a true classification of criminals may be founded are as yet few and imperfect, but Mr. Galton mentions it as a hopeful fact that physiognomy and

the general contour of the head can be shown to afford valuable means for grouping of criminals into classes, and also for estimating, as far as circumstances will permit, the influence of heredity and its working. This method of investigation, however, it must be noted, is by no means a return to the old standing of phrenology, which, as all readers know, boasts its ability to mark out the surface of the brain itself into a large number of different faculties. The most that anthropologists would contend for, according to the data laid down, is, that certain general types of head and face are peculiar to certain types of criminals. Physical conformation of a general kind becomes thus in a general manner related to the mental type, and the intercalation between brain and mind is thus demonstrated anew.

The practical outcome of such a subject may be readily found in the ultimate attention which morality, education, and the State itself, may give to the reclaiming of youthful criminals and to the fostering, from an early period in their history, of those tendencies of good which even the most degraded may be shown to possess. Thus it is clear that, contrary to the deep-rooted belief of many, we do not come into the world like clean slates, upon which the world may write what it pleases; nor are we born with utterly fixed and immovable characters, but with a natural heritage of good and evil, upon which circumstances may operate either for woe or for weal. It is thus true that we are largely the products of past time, and that our physical and mental constitutions are in great measure woven for us and independently of us. But it is none the less a stable fact that there exists a margin of free will, which, however limited in extent, may perchance be made in the criminal and debased, and under proper trainining and encouragement, the foundation of a new and better life.

The relativity of our knowledge, however, forms a subject which may well be suggested as a closing thought. Whether pangenesis or any other explanation of heredity be ultimately proved to be true or not, the consideration must

be ever with us that we are likely to remain ignorant of the primary causes which determine and regulate the more apparent laws of likeness. We may thus scarcely hope to reach that "law within the law" which operates through the medium of secondary laws and ascertainable conditions. But it should form at the same time no mean consolation, that we have been able to approach, theoretically at least, towards an understanding of one of the commonest, but at the same time most abstruse, parts of the puzzle of life.

SOME MOOT POINTS IN NATURAL HISTORY.

One of the most remarkable features included in the study of living beings, is the marvellous plasticity, if one may so term it, of form and function which is everywhere exhibited in the domain of living nature. The variety of form presented by the animal and plant worlds is a matter of commonplace remark, and the fertility of contrivance wherewith the aims and ends of life of every grade are subserved and carried out, forms a subject of equally plain and obvious kind. So diverse, indeed, are the aspects of natural-science study, as distinguished from those presented by the exact or mathematical sciences, that the methods of the latter are almost wholly inapplicable to the investigation of living beings. Nowhere is the plasticity of living nature better seen than when the naturalist attempts to frame an exact definition of a group of animals or plants. Let his terms be ever so plain, exact, and apparently applicable, it will invariably be found that one or more of the beings included in the proposed group will exhibit characters which to a greater or less extent fall without the bounds of the definition. Hence arise the difficulties which beset the merest tyro in zoology or botany who attempts to understand the various systems of classification which from time to time have represented the desire of scientists to place their belongings in satisfactory order and arrangement. And hence also have originated the numerous subordinate groups and

divisions of the animal and plant world, the mere existence of which in the pages of scientific works constitute the veritable eyesores of the naturalist. This fertility of form and novelty of structure and function in which living nature seems to delight, causes the multiplication of new orders and classes for the reception of those beings which, whilst presenting certain resemblances to well-established groups, nevertheless also exhibit differences of such material kind that the naturalist is compelled to construct for their especial behoof new divisions in which, it may be, only a single abnormal animal or plant may come to be contained. There exists, for example, a singular creature known to naturalists as *Sagitta* (Fig. 34), which attains a length of about an inch, and presents itself as a clear, transparent little body, bearing a faint resemblance to an arrow in outward form,—this resemblance giving origin to its scientific name. Sagitta swims on the surface of the ocean, and possesses a hinder fin, representing the feather of the arrow, the head being fringed, as it were, with a series of bristles. Now this curious little animal exemplifies, in an exceedingly interesting manner, those difficulties of the naturalist which arise from the apparent caprice of nature in the production of beings whose nearest relations, as determined by science, are so far removed from them as to necessitate the construction of special divisions of the animal world for their reception. Sagitta was at first regarded as an abnormal crustacean, and as a distant relative of the crab and lobster class. Then it was regarded as an errant shell-fish, and it has, in the course of its scientific travels, found a temporary home even amongst the vertebrate animals. Ultimately, it has settled down within a division of the animal world specially constructed

FIG. 34.—Sagitta and its structure: *a*, head; *b*, termination of digestive system; *c*, *d*, reproductive organs.

for its reception, and in modern manuals of zoology appears as a far-off friend of the worms.

No less remarkable in respect of their singular divergence from their nearest allies, are those singular little beings known as *Appendicularians*. These latter undoubtedly possess very close relations with the "sea-squirts," those rooted sac-like animals found attached to rocks and stones on the sea-beach at low-water mark; but they differ from the common sea-squirts in that they possess a tail and swim freely about in the sea, presenting no small resemblance to miniature tadpoles. Appendicularia also exists in the light of a most singular being, since it illustrates what zoologists call a "permanent larval form." All sea-squirts begin life as tadpole-like beings (Fig. 35), but sooner or later lose

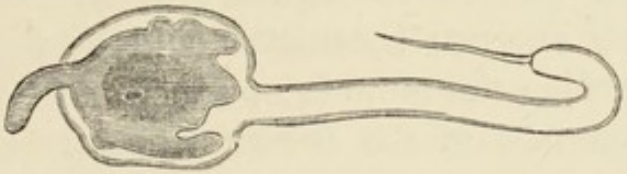


FIG. 35.—Young sea-squirt, or ascidian.

their tails, and settle down into the fixed and rooted state that characterises their wonted and usual existence. The little appendicularia, however, retains its tail throughout life, and in that it permanently retains its young features, illustrates as great an anomaly of sea-squirt existence as would be constituted by the possession by humanity of the frame of the child, associated with the age and belongings of mature years. In this latter case also, naturalists have had to construct a figurative dwelling-place for appendicularia in the shape of a special division of the sea-squirt class, and thus again the plasticity of living forms entails a speculative hardship to the student of natural history.

Occasionally it happens that a whole division of the animal world, with its many included forms, may illustrate the case of a house literally divided against itself. Such a division is that containing as its tenants animals of such ill-assorted

kind as the star-fishes and their neighbours, and such beings as parasitic worms, flukes, wheel-animalcules, and the like. Edward Forbes long ago spoke of this division as a kind of "refuge for the destitute," in respect of the exceedingly diverse forms which had become aggregated within its limits, and which presented to the eye of a zoologist, the scene of incongruity beheld in the casual ward of a work-house. And to this day the group remains with its ill-assorted inhabitants, as a testimony against zoology at large; many naturalists, on the principle that it is one thing to object to an arrangement and quite another thing to better it, preferring to retain the division until a new and better classification is proposed for their acceptance. The botanist fares no better, in respect of confusion amongst groups of plants, and with regard to the development of strange and unusual forms, than his zoological brother. It is doubtful, for example, if any two botanists could be found to agree perfectly regarding the number of species of brambles or of willows represented in the British Islands. One observer will inform us that of a certain number of either plants all are perfectly good and distinct species. The next authority we consult will maintain that the distinct "species" of his friend are mere varieties, and not true species at all; whilst a third botanist would find cause to disagree with both opinions, and would entertain very decided views as to the specific nature of some of the plants regarded by others as varieties, and respecting the varietal character of some specimens which others would account as true species. The present state of natural-history science, in short, exhibits all the characteristics of a transition-period in literature, or of a time of revolution in the arena of political life. Old ideas of the rigidity of species are fast disappearing. In some quarters all traces of opinions regarding the fixity of living forms, formerly held as articles of scientific faith, have long been obliterated. But with enlargement of wisdom there has come increase of sorrow, in a scientific sense; and one of the greatest difficulties which the naturalist of to-day has

to face, consists in the impossibility of drawing strict lines of separation between groups of animals and of plants, the identity of which, in former years, was regarded as being of the most distinct and well-marked kind.

The march of progress in natural science, moreover, has not left untouched those grander distinctions which, as ordinary observers, we are accustomed to regard as plainly impressed on the face of living nature, and by means of which we are enabled to separate the animal from the plant. If there is one feature in the common-sense knowledge of everyday life upon the verity of which we are accustomed to pride ourselves, it is assuredly on that whereby we deem ourselves competent to distinguish between the one great group of living beings and the other. The child, in his first lessons regarding the outer world, obtains a certain definite knowledge of the objects which he sees around him, and divides the objects into animals, plants, and minerals. In each succeeding year of life, the classification of these early days is placed on a firmer basis through the collective teachings of experience, and the information acquired in childhood is taken throughout life as the guarantee of our ability to distinguish perfectly, and as far as the exigencies of everyday existence demand, between the animal and plant creation. It might be thought, therefore, that distinctions of ordinary life, apparently so plain and well-founded as those just alluded to, would possess an equal rank and value in the estimation of the man of science. For what likelihood is there, it might be asked, of any one confusing the bird with the tree amidst the foliage of which it builds its nest, or the ox with the grass that it eats? What parallelism or similarity can be drawn or shown to exist between the flower that decks the person of the beauty, and the highest type of life which that fair one may be said to personate? At first sight, indeed, the differences between these contrasted living forms are so marked, and the points of resemblance so few and insignificant, that, as might well be urged, the mere fact of both sets of organisms being

endowed with a common life, constitutes the only phase of their nature in which any comparison whatever is permissible.

But if we reflect, even in the most casual manner, on the extent of the knowledge of nature which ordinary life requires and demands, we at once perceive that our powers of comparing animals and plants possess no very extensive range. Our observation is of necessity limited to the higher animals and plants, the differences between which are certainly of the most pronounced kind; and we are conversely unable, without the assistance of science, to determine if these distinctions hold good universally, and if we are able invariably, from the appearance of lower forms of life, to indicate their exact nature. An appeal to the naturalist respecting the latter point would result in our being informed that, so far from the separation of animals from plants being an easy matter, the construction of a plain, thorough definition of either the animal or plant form is simply an impossibility in the present state of science. Whilst the accumulated evidence of past years clearly points to the recognition of a certain territory in the world of life, belonging to neither the animal nor plant world alone, but formed apparently of beings which, in a strange and confusing fashion, unite the characters of the one great group of living beings with those of the neighbouring creation. That there actually exists in living nature a veritable "no man's land,"—a portion of territory in which the lower roots of the great trees of animal and plant life may be said to merge in a confusing identity of substance, form, and function, —is a notable fact. And it is equally true, that, regarding the vast majority of the organisms included in this territory, science is unable at the present time even to suggest the means whereby the dissolution of this intermediate kingdom may be effected. Some authorities, indeed, struck with the apparent hopelessness of separating the animal from the plant world, have proposed to recognise the stable and permanent nature of the "no man's land" of the naturalist; and the name *Regnum Protisticum* has been duly proposed

as the scientific appellation of this ill-defined border-land of modern natural history. But, as has well been remarked, the recognition of this intermediate ground simply "doubles the difficulty which before was single." In other words, the task of taking the scientific census of "no man's land" would prove a difficulty of no ordinary kind, in addition to that already imposed upon the naturalist of attempting to simply distinguish the members of the animal series, and to determine the definite characteristics of the plant.

One or two examples, however, will illustrate more effectually than many precepts, the nature and extent of the difficulties which meet the biologist in his researches into the life-history of lower organisms. If we take a handful of chopped hay, pour boiling water thereupon, and, in short, infuse the hay after the fashion of the "cup that cheers," and microscopically examine such an infusion some days thereafter, when the mixture exhibits signs of turbidity and of commencing decomposition, we find therein a large number of minute living organisms, amongst which the active little specks, known generally under the name of *Monads*, form prominent objects. The monads consist each of a microscopic particle of living matter, which exhibits little or no traces of the structures we are accustomed to associate with animal or plant life in its higher phases of development. As regards size, these members of the teeming population of our hay-infusion do not exceed the $\frac{1}{3000}$th part of an inch in length. The body in the common species is pear-shaped, and to the slender extremity of the body one or more exceedingly delicate filaments, named *cilia*, are seen to be attached. By the aid of these organs the little monads propel themselves through the miniature sea in which they live, and very swiftly indeed do these living specks contrive to move about; the spectacle, familiar to every microscopist, forcibly reminding the observer of the jostling crowds and traffic in the thoroughfares of a great city. A careful study of the monads reveals the interesting, but in one sense painful, fact, that we are utterly unable to say what they are.

They *may* be animals, it is true; but on the other hand they *may*, with equal propriety, and with as little fear of scientific contradiction, be termed plants. The ordinary modes which the botanist and zoologist possess, of recognising each his own and special foster-children, are perfectly useless in assisting us to settle the identity and nature of the monads, which present a singular combination of the properties and actions of both groups of living beings, along with a most mysterious absence of definite characters or of a disposition to lean to either side of living nature. In their mode of feeding the monads might well be animals, but in their manner of multiplication they might equally well be plants, and the puzzle is not rendered in the least degree less inexplicable, when we find that the monads bear a very close resemblance in many points of their structure and life to some avowed animals, whilst on the other hand they closely resemble certain well-known lower plants in other aspects. Thus, whatever increase of knowledge the future may bring, the nature of the monads certainly forms a moot point in present-day science.

Another case of equally complicated nature with that of the monads is afforded by the consideration of certain peculiar living bodies which in certain features of their existence might well be deemed plants, but which in other, and quite as marked characteristics, exhibit tendencies of animal nature and kind. As will presently be pointed out, the nature of the food has been very justly relied on as a distinctive point between the animal and plant series. The power of plants to subsist on inorganic or lifeless matter derived from the soil and the air, and the necessity, for the support of animal life, of a bill-of-fare in which the chief items are culled from the organic or living side of nature, are facts well known to the great majority of readers. Plants, in other words, feed on water, gases, mineral matters, and the like; whilst animals, as a rule, can subsist only on living matter afforded by the substance of other animals or by plants. This broad distinction is, however, virtually set at

naught when we consider the case of a fungoid growth—the *Æthalium* of the botanist—which grows upon putrefying plants, and which is frequently found in tan-pits. This fungus—if fungus it be—when undergoing certain developmental changes, actually becomes endowed with powers of movement; feeds after the fashion of its kind on living matter, that is, on animals or other plants; and has, moreover, been well ascertained to be capable, like an animal, of taking in solid food,—plants, as every one knows, possessing no mouths, but subsisting on liquid or gaseous nutriment. Æthalium and its neighbours form in reality a collective *bête noire* of the modern biologist, and at present, therefore, we are positively unable to return any answer whatever to the question, "Is æthalium an animal or a plant?"

Such examples might be multiplied almost indefinitely from the *index expurgatorius* of the botanist and zoologist, but enough has been said to show that the mere surroundings of the subject of animal and plant nature are anything but plain and well-defined. No less clear is the fact that whilst the higher groups of animals and plants are readily separable, the lowest members of the two great groups of living beings merge together in a union of form and functions which modern science is at present totally unable to dissolve. The ordinary idea, that the separation of animals from plants, so clearly effected in the higher life of either side, may be carried out in the domain of lower existence, is thus seen to be entirely erroneous. And when the demand of science for a philosophical definition of an animal or a plant,—which shall apply, as such a definition should, to all animals and to all plants alike,—is submitted to the naturalist, he is forced to own that at present he is unable to say definitely what are the essential characters of the one kingdom or of the other.

The subject before us presents some exceedingly interesting features, if examined somewhat in detail and from the popular point of view, which attaches to the details of form, power of motion, and the like, a high importance in

distinguishing between the most highly organised animals, and plants of equal rank. Take, for example, the very obvious characteristics which appear to be presented by the form of animals and plants respectively,—bearing in mind, of course, that our object is that of constructing a definition of an animal or plant which shall hold good alike of the highest and lowest members of each series. If the outward appearance of animals and plants, which forms so satisfactory a guide to distinction in the case of the higher forms of each group, be relied upon as a means of separation in lower life, we speedily find ourselves involved in confusion and perplexity. For very many true animals are found to present the closest possible resemblance to plants, and many undoubted plants of lower kind mimic in a marvellous manner the likeness of their animal neighbours. The green fresh-water sponge, common in our canals and rivers, closely resembles a plant-organism in colour, appearance, and mode of growth, although it is at the same time worthy of remark that there are a few naturalists, who, in opposition to the well-founded opinions of their brethren, still advocate the ancient idea that sponges should be relegated to the care of the botanist.

More remarkable, however, in respect of their close resemblance to plants, are those curious colonies of undoubted animals to which the names of zoophytes and polyzoa have been given. The oyster-dredger is very familiar with the zoophytes or "sea-flowers" (Fig. 36), as he terms them, which grow in rich clusters attached to oyster-shells, to stones, and to other objects obtained from the depths of the sea. Each zoophyte grows rooted and fixed like a plant, possesses usually a well-defined stem and branches, and closely imitates in other respects the life and form of a plant. The writer has before him at present a specimen of a beautiful genus of zoophytes named *Plumularia*, which raises its various stems in beautiful clusters from the shell to which it is attached, and which, as preserved for the museum, presents the most accurate reproduction of a plant

form which can well be conceived. When this, or any other zoophyte is examined, it is seen to grow from a well-defined root, and to bear on its branches numerous little animals, which represent the leaves, as it were, of this strange animal tree. The hundreds of animals which enter into the formation of a single zoophyte form in reality a connected colony of beings, whose interests are of identical kind, and which co-operate in the most perfect manner to ensure the growth and sustenance of the colony at large. Nor does the likeness to the plant cease with the mere details of outward

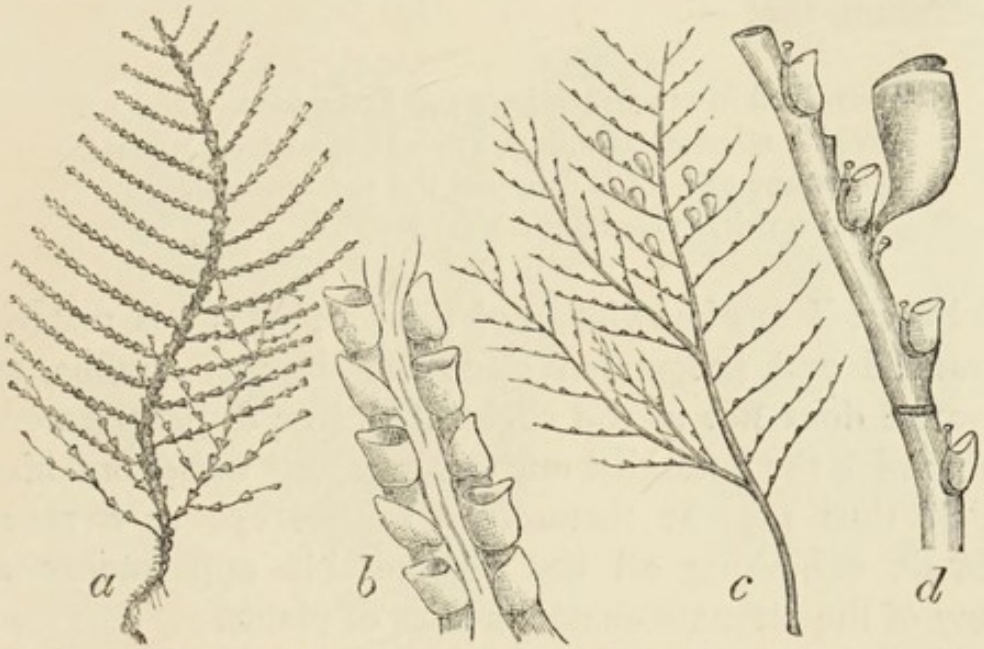


FIG. 36.—Zoophytes. *b* and *d* are magnified portions of *a* and *c* respectively.

form. If we watch the progress of events in zoophyte-history, we shall find the resemblance to include deeper and more intricate phases. Thus, as the leaves of the tree wither and fall, and are duly replaced by new leaves, which the tree as a whole has the power of producing, so in the zoophyte there is continual loss of substance and death of its component parts. The little animals of the colony are constantly dying off; but the process of budding, which produced the compound colony at first, is also competent to repair the losses which the mere act of living appears to entail in the zoophyte as in every other living organism.

New buds are constantly being developed, and these grow into new animals; and as the plant in due season produces flowers, and as seeds and new plants are therefrom developed, so the zoophyte will sooner or later produce its reproductive bodies, and from these latter true eggs will spring. Each egg, after passing through a defined series of changes, will ultimately develop into a single little animal form; and this primitive member will root itself to some fixed object, and by a veritable process of budding will produce in time the zoophyte-colony with which development began. Crabbe wrote of the zoophytes, in a past generation, that—

> "Involved in sea-wrack here you find a race
> Which science, doubting, knows not where to place;
> On stone or rock is dropped the embryo-seed,
> And quickly vegetates a vital breed."

And even if our knowledge of the zoophytes has materially advanced and progressed since the days of Crabbe, such advance does not in the slightest degree dispel the wonder with which the naturalist must ever regard these organisms, which thus present themselves to the eye as a race of animals exhibiting all the recognisable appearances and many of the intimate characteristics of plants.

From amongst our pond and water weeds, and from the sea, we may obtain specimens of other animals, which, like the zoophytes, are so plant-like, that the unscientific observer could not by any chance hesitate to pronounce them as objects for the investigation of the botanist. Such are those animals named polyzoa, beings by no means of the lowest grade of animal organisation, but related in all essential points of their structure to the true shell-fish or molluscs. It forms the best possible proof of the success of nature's mimicry, in causing such animals to grow in the likeness of plants, that sea-side visitors of botanical tastes almost invariably gather those common polyzoa, the "sea-mats" or *Flustræ*, in mistake for sea-weeds. The sea-

mats, as cast up on our coasts, present us with perfect imitations of pieces of pale-brown sea-weed (Fig. 37); and in this mistaken light they are duly gathered, and frequently figure as undetermined species of marine plants in the herbaria of collectors. The microscopic investigation of a sea-mat, or even the close inspection of the larger species by the unassisted sight, at once reveals the fact that the supposed sea-weed represents in reality the remains of a colony of animals. The dried organism is made up of hundreds of little oval cells (*b*), packed as thickly as they can lie on each side of the structure. Could we observe

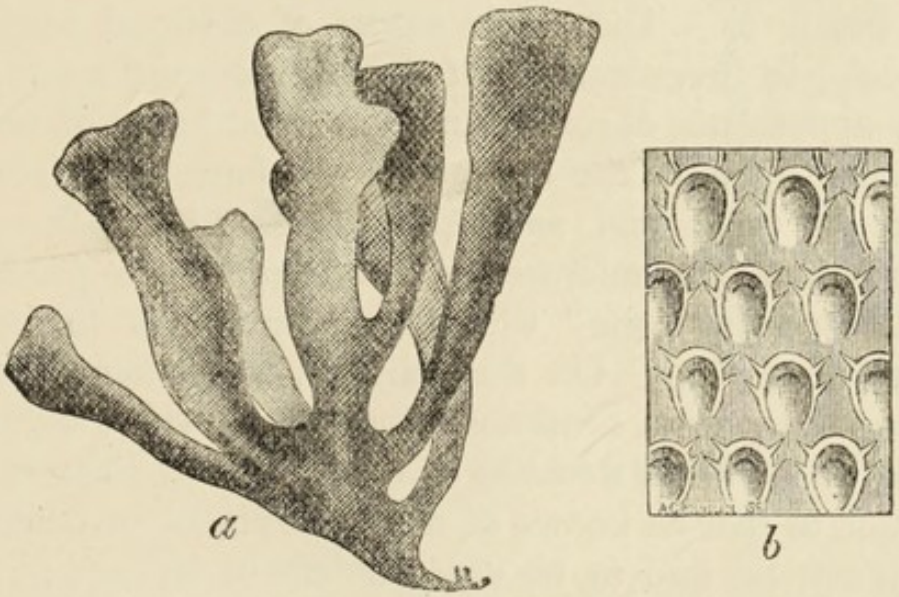


FIG. 37.—*a*, *Flustra*, or sea-mat, natural size; *b*, a small portion magnified, showing the cells.

the colony in life, we should find each cell to be occupied by a little animal, provided with a beautiful crown of delicate tentacles, which are continually being protruded from and withdrawn into the little abode; thus accomplishing the important actions of obtaining not only food, but also oxygen for breathing from the water around. Once again, we thus meet with a colony of animals growing rooted and fixed like a true plant, and enlarging its existence by a process of budding, strictly comparable with the similar process on which the increase of plants depends.

Little need be said in addition to these examples to

prove that form and appearance are most deceptive and utterly unreliable aids in the task of distinguishing between the animal and plant creations. Even animals of a high grade are seen to present a striking resemblance to plants; and when we ascertain that the truly animal nature of the well-known coral-polypes was first ascertained only some hundred and fifty years ago, we can readily appreciate the fact that the separation of the two great groups of living beings was a task which proved of somewhat trying nature, even for the scientific acumen of a tolerably advanced age.

A very natural appeal might be made to the chemist and microscopist for aid from their respective sciences in the task before us. The subtle nature of chemical tests, and the delicate investigations of the microscopist, might, with every appearance of reason and with great hopes of success, be relied upon in the endeavour to find the distinctive marks of plant and animal character. But neither the chemist nor the microscopic investigator can produce a "philosopher's stone" which shall enable us to separate animal from plant. On the contrary, both sciences contribute to the general confusion of substance which apparently exists in the lower domains of living nature. The chemist will tell us that he knows of no one element or compound which can be said to be characteristic of either amimal or plant series; whilst he is forced to admit that if he had to judge certain well-known animals by a purely chemical standard, he would be forced to conclude that they were true plants. For example, the old ideas that the element nitrogen was characteristic of animals, and that carbon was a substance belonging exclusively to plants, have been long disbanded, in the light of the certain knowledge that these elements unquestionably enter into the composition of both groups of living beings. Nor is this latter the only point which the advance of chemistry has corrected. Certain substances long thought to be absolutely peculiar to animals in the one case, or to plants in the other, have been discovered entering into the intimate and apparently natural composi-

tion of the bodies of the opposite organisms in either case. If there exists one substance which might be thought to be the exclusive property of plants, it is certainly the matter which imparts the green colour to their tissues, and which is so widely diffused through nature's domain. Yet this identical substance, or *chlorophyll*, as it is named, is found entering in the most intimate manner into the composition of many true animals, and is thus duly manufactured or secreted by animal tissues. The common fresh-water polype or hydra (Fig. 38), and many animalcules, are thus coloured

FIG. 38.—Hydræ, or fresh-water polypes, showing young budding from the mature forms.

green with the identical substance which we behold in the leaves of plants. Starches and sugars, long regarded as the exclusive products of plant life, are now well ascertained to be manufactured by even the highest animals. And a starchy substance known as *cellulose*, found entering in the most intimate manner into the composition of plant-cells and plant-tissues generally, has been noted to occur in large proportions in the outer layer or covering of those sac-like animals the sea-squirts, already alluded to. It would seem, in fact, as if the animal form, like a dishonest manufacturer, had infringed the patent rights of the plant, and had thus produced substances which in bygone days were esteemed the sole and exclusive products of the plant-economy.

It may be urged, however, that the common and well-

known reactions which take place between animals and plants and the atmosphere, should serve as guides of some value in distinguishing between the two groups. As every school-boy knows, animals, from the lowest to the highest, demand oxygen, as the gas necessary for breathing, that is, for the purification of the blood, whilst they emit carbonic acid gas, as the part-result of their vital wear and tear. Plants, on the contrary, absorb this carbonic acid, and by a subtle chemical process, which really forms one of the marvels of plant life, decompose this gas into its constituents, carbon and oxygen, and after retaining the carbon in the light of food, restore the oxygen to the atmosphere for the use of animals. This elementary knowledge undoubtedly founds a distinction of a certain value in separating animals from plants by differences in their breathing processes, but the value is found to be of no very great extent when we reflect upon the singular alteration in the functions of plants which changes of strictly natural kind induce. Thus, to begin with, plants can only inhale carbonic acid gas when two conditions are supplied them, these conditions being green colouring-matter and sunlight. Of these two conditions, the latter appears to be, if anything, the most important, since, when a plant is placed in the dark it not only ceases to absorb carbonic acid and to emit oxygen, but actually reverses its mode of life, and becomes, as far as its breathing is concerned, a true animal, since it inhales oxygen and emits carbonic acid. And, as if to depreciate the value of the distinction in still further measure, we find that plants which want green colour, are by habit and repute animals, not only as regards their breathing, but in respect of their dietary also. A fungus of any kind, not only inhales oxygen and emits carbonic acid like an animal, but feeds on the living matter afforded by the tissues of other plants or of animals. The fungi which cause skin-diseases in man and in his animal-neighbours, or those which infest other plant-tissues, may truly be said to resemble animals in respect of their mode of subsistence ; since they demand living or

already elaborated matter for their support, and are not content, as it were, with the inorganic matters, such as the water, mineral matters, etc., upon which the highest plants subsist. Distinctions which chemical science might be regarded as having founded, and means of separating between animals and plants which at the commencement of the present century and even at a later date were regarded as of stable kind, are seen to break down like weak evidence, when subjected to the strict cross-examination of modern investigation.

Turning next to the microscopist in search of definite information respecting the boundary-lines between the two kingdoms of living beings, we find that histology, or the science which investigates the minute structure of bodies, frankly owns its inability to solve the mystery of animal or

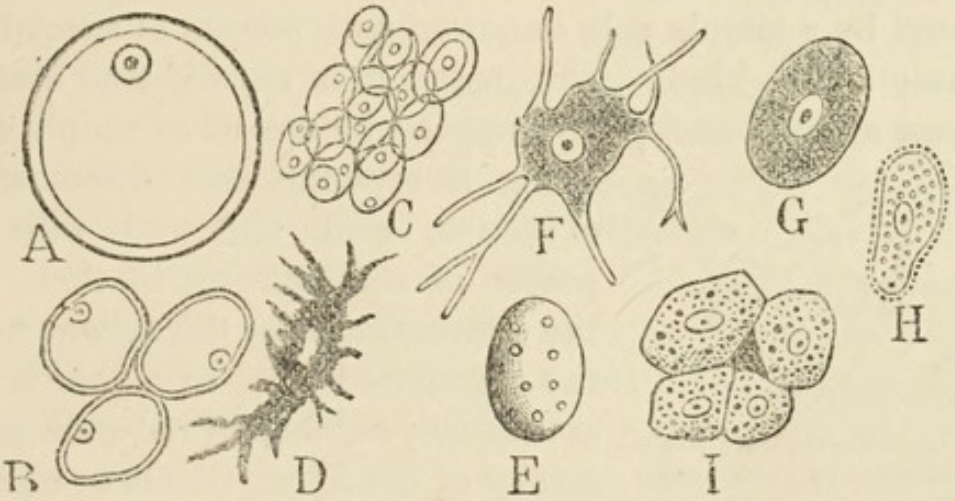


FIG. 39.—Various cells, all highly magnified; A, a typical cell; B, cells from cartilage; C, from fat; D, colour cell from frog's skin; E, a plant-cell; F and G, nerve-cells; H, a cartilage cell; I, liver cells.

plant-individuality. Thus, varied and different as the forms of animals and plants appear to be, they present a striking uniformity of structure and composition when resolved under the scrutiny of the microscope into their constituent elements. In the years 1837-38, the ideas which had previously been growing upon microscopic observers regarding the composition of living bodies, took definite shape and appeared in the form of the "cell-theory." This theory, supported in the most direct manner by the accumulated observations of

many investigators, held that all the tissues and membranes of the bodies of animals and plants originated from minute rounded structures named "cells" (Fig. 39), which were readily demonstrated by microscopic investigation to occur in every part of living tissues. When animals and plants grow they may indeed be said to grow through the increase of their constituent parts—the cells,—and these latter are regarded by modern physiologists as representing not merely the actual units of the living body, but as containing in themselves the powers and qualities which characterise the being of which they form part. Nor does the cell-theory of organisation rest with the assertion that the animal or plant-body is a collection of cells. The germ of the plant or animal, through the development of which the most complicated body is in time produced, can be shown to be represented by a simple cell, endowed with powers of special and characteristic kind. Nay, more, it is equally true that the lowest animals and plants appear before us as simple cells, living a separate and disconnected existence, and endowed with the power of representing in their lives the concentration of the actions which the aggregated cells of higher beings collectively exhibit. A red-snow-plant, or any of the lowest plants or *algæ*, or a yeast-plant (Fig. 40), exhibits all the characters of a simple isolated cell, which in the latter case may be seen to grow, to nourish itself, and to reproduce its like in the most perfect manner, and to cause by its mere act of living the curious series of phenomena to which the term "fermentation" has been applied.

FIG. 40.—Yeast-plants, each represented by single cell.

Structurally regarded, then, by aid of the microscope, animal and plant bodies are seen to present a most singular identity of composition, in respect of the fact that both bodies are primatively cellular, and that the lowest members of each group exist as simple isolated cells. But the facts revealed in 1837–38 merely formed the introduction to new

facts and ideas regarding the constitution of the living body. The progress of microscopic and chemical science, so far from resting at the discovery of cells and of their qualities, served to open up a vista of large extent, along which the lines of scientific thought were already beginning to travel, in the direction of demonstrating a still closer unity of form and composition between animals and plants. Gradually the idea that cells represented a stage in which a certain work of formation had already been begun and completed, grew upon the minds of physiologists. "What preceded the cell?" and "From what was the cell itself formed?" were questions which naturally suggested themselves to observers. After the excitement which had ensued on the physiological contest,—which might well be named "the battle of the cells,—had subsided, and after the various theories regarding the paramount importance of one or other part of the cell had been duly ventilated, physiologists were led to see that a certain substance which had been greatly overlooked in their discussions, held a place of high importance in the life and structure, not only of cells, but of the bodies of animals and plants at large. This substance was found to enter into the composition of cells of every kind. It appeared to form the active and essential element in these bodies, and constituted a substance upon which the increase of cells, and—through the cells—the growth of the living body at large, depended. This matter is that now of world-wide celebrity, and known under the name of "Protoplasm;" and it may fairly be said that whatever be the views held by physiologists as to its connection with the life it exhibits, this substance may most appropriately be named the "physical basis of life." Life, as far as the furthest research has shown, does not exist apart from this protoplasm. A mere speck of this matter, destitute of definite structure or parts, constitutes a living being, able, as exemplified by the yeast-plant, or by the structureless proteus animalcule or amœba (Fig. 41), to carry on all the functions of life, as perfectly, regarded with reference to the

results of its living, as the highest animal or plant. Whilst it must not be forgotten that the bodies of all living beings, without exception, originate from germs which consist of this protoplasm. So that it may be said, without fear of contradiction, that the bodies of man and of the monad, of the highest plant and of the lowest plant, are essentially alike in respect of the primitive matter of which each is composed. Development and inherited powers simply shape

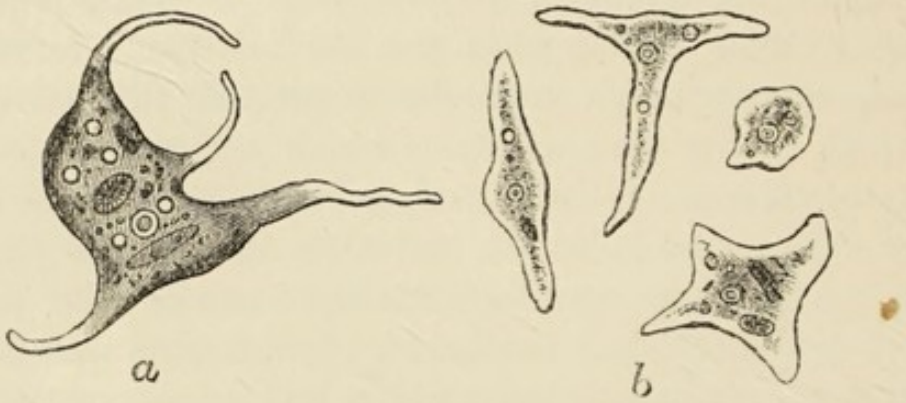


FIG. 41.—Amœbæ, or "proteus animalcules:" *a*, *Amœba radiosa*, showing the protrusions of its body-substance; *b*, *Amœba diffluens*. The figures represent the same animalcule in different stages of contraction.

and fashion the primitive and uniform matter of the germ into a higher or lower form of life; but the end and result of this development does not in the slightest degree invalidate the assertion that in their earlier stages all organisms are alike. Thus, neither chemical science nor the microscope has as yet been able to show any difference between the primitive protoplasm of the animal, and that of the plant. The further back the history of the animal or plant is traced by the keen gaze of the microscopist or by the subtle art of the chemist, the more realistic does the identity and similarity of the two natures become. Whilst not the least remarkable thought engendered by the failure of the microscope and of chemistry in this respect, is that which suggests and owns that the furthest research is incompetent to distinguish between the germ which in the one case may ultimately advance in little or in nothing beyond its primitive state, and that which,

in its subsequent history, may evolve the form of the highest being, with all the attributes of intellect and mind.

A thoroughly popular mode of distinguishing between animals and plants is that which credits the former with the exclusive possession of locomotive powers, and which assumes plants to present the ordinary aspect of stable and rooted existence. But that animals are by no means universally endowed with powers of voluntary movement, is proved by the consideration that very many of them exist in a permanently fixed condition. The coral-polypes, zoophytes, sea-mats, and sea-squirts, already mentioned, exemplify true animals which present exceptions to the ordinary rule of animal life, in respect of their rooted state, and to

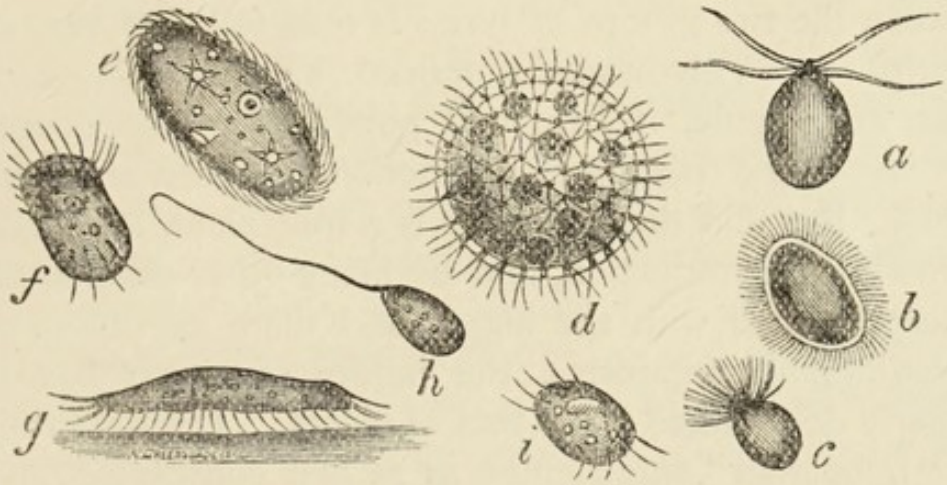


FIG. 42.—A group of lower animals and plants, all highly magnified, showing free-swimming habits in both. Figs. *a* to *d* inclusive represent lower forms of plant life; *e* to *i* represent forms belonging to the infusorian animalcules.

this list the sponges and other animals might be added. Neither, on the other hand, is it true that plants are invariably fixed. The slightest acquaintance with the habits of lower plants will show, indeed, that fixation is the exception, and absolute freedom the rule; very many of the lower plants or algæ (Fig. 42, *a* to *d*) swimming freely about in their native waters during their entire existence. The spores or germs of sea-weeds (*a*, *b*, *c*) present the closest resemblance to animalcules, and propel themselves through the water by means of the delicate filaments with which they

are provided. And, perhaps, the most convincing proof of the impossibility of distinguishing the animal from the plant, not only as regards the possession of motor powers by the latter, but also in respect of similarity in appearance, is afforded by the case of the volvox, or "globe animalcule," as it is termed, an organism familiar to every microscopist, and met with in stagnant waters. A volvox (*d*) presents the appearance of a hollow sphere, the edge of which is formed of numerous little green bodies, each provided with two long vibrating "tails." By means of the movements of the latter organs, this living sphere rolls over and over upon itself, and paddles its way amongst its neighbours. When such beings are beheld, surrounded by a crowd of true animalcules (*e* to *i*), the resemblance between the two groups of forms is seen to be of very close description. Volvox might, indeed, be very well classified as an animalcule, if form and power of motion count for anything in the framing of distinctions between animals and plants. But that this organism is a true plant, is proved by its mode of reproduction, and by many other traits of direct correspondence with the algæ; and there are many other free-swimming organisms, the nature of which has been similarly determined to be that of plants. The old group of the "infusorian" animalcules, as at first constituted, and in which volvox and its neighbours were contained, was a most motley assemblage of beings of many different ranks and grades, drawn from both animal and plant worlds; the advance of microscopic inquiry resulting in the re-arrangement of this heterogeneous group, and in its being literally weeded out and its contents distributed far and wide in the realms of living nature.

Along with the distinctions derived from the power of motion now no longer relied upon, but which the older naturalists regarded as of stable kind, another means of separating animals from plants was believed to exist in the possession by animals of an internal sac or cavity, represented in its fullest development by the digestive system of

higher animals, in which food was received and digested. Associated with this nutritive system was another set of organs, namely, that devoted to the circulation of the nutritive fluid or blood, which had been prepared by the action of the digestive apparatus. Now, whilst it is true that animals, as a rule, possess such an internal cavity or stomach, and in the case of higher animals a circulatory system likewise, it is equally clear that no distinction between animals and plants can be founded upon this observation. Many animals, of by no means the lowest grade, for example, want a mouth and digestive system. As a rule, all parasitic animals obtain their food by imbibing the fluids of their hosts, and, like plants, can subsist on fluid or gaseous matter only. The need for distinct and independent organs of digestion is superseded by the parasite's habits of dependence on its host; and thus parasitism in lower, as in higher life, is seen invariably to produce degradation and retrogression in the dependent being. But it is also a curious and notable fact that whilst in the lowest animalcules, represented as already remarked by mere specks of protoplasm (Fig. 41), no digestive or indeed any other organs are to be descried. Certain animals of tolerably high organisation may present exceptions to the rule of organisation even in their own species, by exhibiting no traces of a digestive system. Thus, whilst the female rotifers or "wheel animalcules" possess a complicated organisation, including a digestive system, sense-organs, and other vital apparatus, the male animalcules possess no digestive organs, and exist probably by the imbibition of fluid matters. Hence, if the presence of an internal cavity or digestive sac is to be regarded, as it was by Cuvier in 1828, as a distinctive character of animals, we have no alternative but to exclude the male rotifers and most parasites from the lists of zoologists; the latter procedure involving an idea which of course cannot for a moment be entertained, especially when distinctions of apparently greater weight have gone by the board before the levelling assaults and tests of recent research.

Thus, as far as our investigations have extended, the ordinary distinctions on which stress has naturally been laid with the view of separating animals from plants, have one by one been proved either to be wholly untenable, or at least to present so many glaring exceptions that their value has become considerably deteriorated in the eyes of modern scientists. There yet remains one point for consideration, however, upon which considerable stress may very naturally be laid, as a distinctive characteristic of one of the great groups of living beings. Driven back into the very citadel of former beliefs by the assault of advancing research, many may assert that the presence of a nervous system in animals, and the exhibition of those phenomena we collectively term "sensation" and "feeling," are definite characteristics of animals alone. Let us briefly inquire whether this last assertion has reserved for it a better fate than that which has befallen our other points of separation.

The simplest acts of life in higher animals and even in animals of low grade, are regulated by the nervous system, which, in whatever form it is represented, may be defined as that by which the animal is brought into relation with the world in which it lives. The differences, in fact, between the nervous acts of the highly organised animal and those of the lower form, as will be discussed in another place, are rather those of degree than of kind; and there is every reason to believe that even those complicated phenomena to which we apply the collective term "mind" represent in large measure the high or extreme development of the instincts and nervous acts seen in animals of lowly grade. Unquestionably the beginnings of a nervous system, as exemplified in the animal series, consist of means whereby the being is enabled to exercise a low degree of sensitiveness to outward impressions. The lower we proceed in the scale of animal life, the fainter does this sensitiveness appear to become. And although it can hardly be said that any animal form absolutely wants the means for

exercising sensation, or for acquiring a certain knowledge of its surroundings, in the lowest grades the nervous power is but ill-defined, and partakes rather of the character of a low and diffused sensitiveness than of definite perceptions. An animalcule such as the amœba, whose body consists of a speck of structureless protoplasm (Fig. 41), will push out its soft substance to encompass the particle of nutriment against which it has stumbled, as it were; and although the primitive simplicity of its body forbids us to expect that we should descry definite nerve-structures or any of the other organs which belong to higher states of existence, we may not doubt that the being still possesses diffuse sensitiveness of a low kind. Whilst the fact that a particle of food is seized and engulfed amid its substance, argues strongly in favour of the idea that this endowment of sensitiveness is intended to serve a well-defined end, namely, that of aiding in the nourishment of the organism. Recognising then, the general presence of sensation in animals, and that this sensitiveness serves as a means for acquainting the animal with its surroundings, and for guiding the acts of its life, we may next inquire if sensation is unrepresented in any of its aspects in the world of plant life?

The answer to this question may be fitly prefaced by the brief recital of some of the more typical cases of so-called sensitiveness or irritability of plants. With the common wood-sorrel (*Oxalis acetosella*) almost every one is well acquainted. The leaves of this plant exhibit a three-fold or ternate arrangement, each leaf bearing three leaflets at the extremity of the elongated leaf-stalk. If the leaflets be observed at any period before midday, they are seen to lie flat and horizontally, the edges being in contact. But if during the heat of the day the leaf-stalk be tapped smartly, each leaflet may be seen to gradually fold upon itself, and the leaves ultimately come to depend in a loose fashion from the stem. When also, the sunlight has ceased to play upon the plant, the same act of closing its leaves is to be observed. Of a much better defined character, is the

irritability displayed by the compound leaves of the *Mimosæ* or sensitive-plants (Fig. 43), the praises of which Shelley has so well sung in his flowing and melodious rhythm. The main leaf-stalk in mimosa gives off four divisions, each of these latter bearing a double row of little leaflets. The leaflets are expanded when the plant is exposed to light, but when darkness comes on, or, more curious still, if the leaf be touched, the leaflets become huddled together on each leaf-stalk, as if in terror and alarm; and the main leaf-stalk also droops and becomes closely applied to the side of

FIG. 43.—*Mimosa pudica*, the sensitive-plant.

the stem,—the entire action reminding one of the cowering aspect of an animal under the influence of strong fear. After all sense of irritation may be presumed to have passed away, or, in the plant's normal state of existence, when the morning light breaks, the leaflets or leaf-stalks once more expand, and present themselves in their normal and undisturbed condition. But the mimosa is sensitive to stimuli of a kind which affect the animal organisation and animal

sensitiveness in a very defined manner; whilst the plant may, like the animal, become accustomed to stimulation, and cease to show the amount of irritability it at first exhibited. The contact of chemical substances with the leaflets produces the same effect as touch or darkness. The mimosa exhibits irritation, like its animal-neighbours, on being at first exposed to the fumes of chloroform; but after a continued exposure to the vapour the plant loses its sensitiveness, and remains with expanded leaflets, perfectly insensible to stimulus of any kind. A sensitive-plant was carried on one occasion by Desfontaines in a coach. The jolting of the vehicle at first produced rapid contraction of its leaves; but

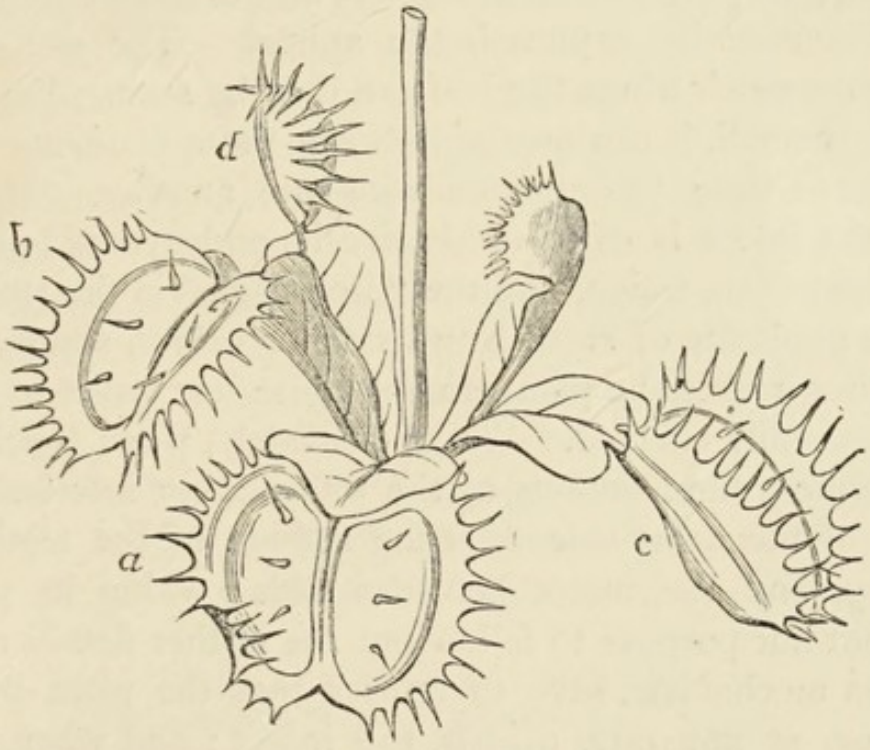


FIG. 44.—Leaves of Venus's-flytrap: *a*, *b*, leaves expanded; *c*, leaf closing; *d*, leaf closed.

as the journey advanced, the plant, despite the shaking, spread its leaflets as if it had become accustomed to the movement, and as if it had lost all sense of alarm.

More curious even than the acts of the sensitive-plant, are the phenomena of sensitiveness exhibited by the Venus's-flytrap (*Dionæa muscipula*, Fig. 44), a native of American marshes. This well-known plant possesses leaves which

have very broad stalks, and which exhibit broad blades capable of being folded in two as along a hinge-line. The margins of the leaves are deeply cut, so as to provide the blade of the leaf with a set of very prominent filaments. When the leaf is expanded, three hairs, or filaments may be seen to project from each half; and when any one of these hairs is touched or irritated, the halves of the leaf become folded together. The purpose of this is clearly associated with the capture of insects. When an insect unwittingly walks over the broad leaf-surface which lies spread so temptingly before it, and comes in contact with the sensitive hairs, the leaf folds upon it, and the plant may thus be said to have laid a trap for, and to have deliberately and intentionally captured, the animal. The use of the filaments which fringe the leaf can then be seen. For if the insect is small, it can escape between these filaments before they have time to interlace with one another. If, however, the insect is of tolerable size, its endeavours to escape from its prison, which, like the "iron cage" in the story, becomes gradually of smaller and smaller extent, simply serve to further irritate the plant, and to cause its closure to be the more speedily effected. Whilst ultimately, when the leaf is fully closed, the filaments of the one margin interlock with those of the other side, after the fashion of the teeth of a rat-trap, and the insect becomes stifled within its prison. It is not our purpose to follow out the further details of this curious mechanism, save to remark that the plant literally eats, or, at any rate, digests, the insect; and when, some weeks afterwards, the leaf uncloses, no traces of the hapless animal are to be found. Thus the Venus's-flytrap presents a singular exception to the rule of plant life, in that it not only exhibits sensitiveness of a very marked order, but also in that it appears to subsist partly on an animal dietary.

A wider view of the functions of plants only serves to confirm the idea which the consideration of the preceding cases impresses on the mind, namely, that plants certainly exhibit sensitiveness. The familiar daisies—the "floures

white and rede" of Chaucer—which close their florets on the approach of evening's chill; the marigold, which similarly guards its effulgence from the cold of twilight and darkness; and the sun-flowers, influenced in their mode of growth by the kindly rays of the sun,—nay, even the fact that plants grow and flourish best where they can most readily obtain the genial influences of heat and moisture; strongly impress the mind with the belief that sensitiveness exists throughout the whole plant creation, varying, no doubt, in degree, but still represented, and serving to connect the organism with its surroundings. Thus, although the flower which we pull to pieces gives no sign of pain, and although the idea of "pain," as we of higher grade understand that word, cannot be said to apply in any sense to plants or to the lowest animals, the thought must nevertheless be present in the mind of the physiologist that the plant is "feeling" the separation of its parts in a low and unspecialised fashion. To this low sensation of common plants the better-defined irritability of a sensitive-plant may be said to bear much the same relation as the start and alarm of the higher animal exhibits, when compared with the low sensitiveness of the animalcule.

Thus the botanist, indulging in no wild dream, but expressing a belief warranted by scientific induction, may not inaptly adopt the language of Wordsworth, when he says—

> "And 'tis my faith that every flower
> Enjoys the air it breathes."

The development of active movements in plants, these movements being excited by outward impressions and by stimuli of various kinds, necessarily suggests the further inquiry whether such phenomena in plant life result from the presence of nerves or equivalent structures. The irritability of a sensitive-plant or of a Venus's-flytrap, judged by all the signs we are accustomed to note as evinced by the nervousness of animals, would appear to present a singular coincidence and analogy to nervous acts. But, as Mr. Darwin

remarks, "Analogy may be a deceitful guide;" and the observation of similarity or resemblance in results, does not necessarily carry with it the assumption that the cause of action or *modus operandi* is the same. In the present case, however, dealing as it does with the means whereby living beings of one grade or another are brought into relation with the outward circumstances of their life, there exists a strong and natural presumption that the sensitiveness of the plant and that of the animal depend on similar causes. The contrary supposition, in fact, is one which receives no support whatever from physiology at large, there being nothing to warrant the belief that sensation in the one group of living beings should be subserved by different means from those which prevail in the other group. The uniformity and harmonies of nature, in fact, point directly in the opposite direction; and the consideration of one or two

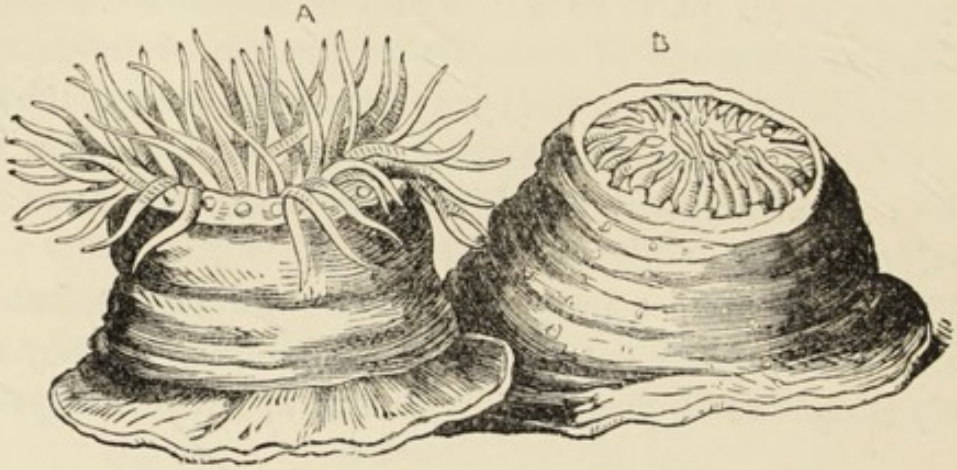


FIG. 45.—Sea-anemones: A, expanded; B, contracted.

instances of animal sensitiveness will pave the way for a clearer understanding of "how plants feel."

When the tentacles of a sea-anemone (Fig. 45) are touched, the animal, as every sea-side visitor knows, withdraws these organs, and contracts its body into a conical mass, exhibiting no trace of the graceful flower-like appearance which characterises the placid and undisturbed state of anemone existence. When the margin of the body of a jelly-fish is brought in contact with rays of light, active movements take place in the body; and when the sensitive

margin of the body is cut off, the amputated portion, as will hereafter be described, will continue to move for days in its independent state. That sea-anemones are sensitive to impressions of much more delicate nature than touch, is proved by the fact familiar to all aquarium-keepers, that the sudden obstruction of the light which has been playing on the tentacles will cause their retraction and withdrawal. The sensitiveness of these and like animals is very naturally referred to the presence of nerves; but it is a most noteworthy fact that but few traces of nerves have been discovered in sea-anemones after the most careful research; and if nerve-filaments exist in the still lower jelly-fishes, they must be present in a condition of the most primitive and rudimentary nature. Whilst in the equally sensitive hydræ (Fig. 38) and other polypes, no traces whatever of a nervous system can be perceived.

Hence we find that veritable animals, of which the anemones and their lower neighbours are examples, exhibit a delicate sensitiveness, notwithstanding the absence of demonstrable nerve-fibres. After the recital of this fact it can hardly be maintained with reason that the absence of nerves in plants affords any reasonable grounds for the opinion that sensation in the vegetable world is something different from the sensitiveness of animals. The consideration of facts like the preceding, forces us thus to the conclusion that animals and plants are endowed with a common sensibility of very varying degrees of perfection; and that, judging from analogy, the apparatus whereby this sensitiveness is exercised in the one group of living beings does not materially differ from that excercising this quality in the other. Whilst the subject also shows us the impossibility of distinguishing between animals and plants in respect of sensation and its results, and also tends to strengthen the belief that the primitive form of a nerve is simply that of a specially modified line or tract in the bodies of lower animals and plants connecting two points of the body, and capable of inducing, through such communication, changes of a more

or less definite kind in these two regions. Strange is it to think that the nervous apparatus of the lowest forms of life are thus bound in a connected series with that of the highest forms, and that there is such a veritable link between the power which guides the actions of the lowliest organism and that which evolves the qualities and properties of mind itself.

The animal and plant worlds are thus shown to be bound together by ties and characters of a very close and intimate kind. The entire fabric of life might very aptly be compared to a great tree, the branches of which diverge most widely in their highest levels; whilst the root-portion serves, nevertheless, to link and unite the diversities of the branches in a common bond. And if this parallelism of the common origin of animal and plant life should prove to be something more real than a convenient form of expressing the fact that science is unable to separate out the one great group of living beings from the other, the consideration of the unity of life and the probablity of the common origin of living beings, will certainly not lessen the wonder and interest with which we must regard the forces and powers, which, out of a community of material, have produced the infinite variety of living forms and which have made the universe of life the wondrous thing it is.

THE ORIGIN OF NERVES.

One of the most characteristic features of the present age, regarded from a scientific stand-point, is the marked desire to account for the origin and causes of natural phenomena. The hackneyed quotation from Virgil—

"Felix qui potuit rerum cognoscere causas,"

in respect of its fitness, might well be adopted as a motto by the scientific thought of our day and generation. Not content with investigating facts, we look beyond the facts to their causes, and endeavour to show how and why these causes have brought about the familiar results, and how one cause becomes related to another in the great sequence of nature. Unquestionably, the improvement of the means of research must be credited with the chief merit of inspiring the search after the "causes of things." So long as we are unable to peer very far beneath the surface of nature, we are not likely to possess much incentive to discover the hidden source of Nature's actions. But when the eye is unsatisfied with its own limited power of seeing, and calls to its aid the microscope or telescope; when the laboratory of the physiologist becomes furnished with instruments capable of measuring the rate at which the subtle thought-force travels along nerves; when the chemist and physicist boast of their ability to analyse by aid of the spectroscope the far distant orbs of heaven, or to make far-off sound audible;—then we have reached an era when it becomes impossible for mankind to rest content with the declaration

that such things are, and when the spirit of "das rastlose Ursachenthier" moves abroad in search of the well-springs of knowledge. The cause-seeking tendency of these latter days has been well illustrated in physical science in two ways. Of these, the first is exemplified by the endeavours of scientists to account for the origin of the varied species of living beings, and for the causes in virtue of which the existing order of living nature has been fashioned and evolved. Then, again, the question of the origin of matter and of the universe itself has largely engaged the attention of physicists and geologists. Although the origin of living beings and of the world they inhabit was long ago decided according to the Mosaic interpretation, the spirit of scientific inquiry has found abundant cause to reject the idea of "special creation" and also that of the "six days" theory when applied to the foundation and building of the universe. The higher knowledge of to-day has issued its fiat against the pure assumption and dogmatic assertion of yesterday; and now, taking nothing for granted, we "step forth into the light of things," and accept Nature as our great teacher: seeking, in the search after causes, not what is likely, not what is probable, but only what is true.

Amongst the multifarious phases and aspects which are included in the general question of the manner in which living beings have been produced, no study has received a greater impulse than that of "embryology." This department of science is that which traces the stages through which the young animal passes in development, from its earliest appearance in the germ or egg until it has attained the features of its parent, and until it has assumed the form or likeness of the adult. No branch of study presents a greater fascination to the scientist; for in its pursuit he seems to peer further into the causation of living nature than when engaged in any other department of inquiry. It can be well understood how absorbing must be the interest with which Nature's wondrous process of building the frame of a living being is watched, and how large a view one may

obtain of the powers and contrivance of the forces of life, as displayed in the fashioning of a complicated body from apparently the very simplest of materials. Some such thought, doubtless, stirred the great Harvey, one of the first to study the development of animals, when he maintained in his "Exercitations" that "in the generation of the chicken out of the egg, all things are set up and formed with a most singular providence, divine wisdom, and an admirable and incomprehensible artifice."

The importance of the study of development has, however, been greatly increased of late years, through the growing force of the idea that in the development of animals and plants we may obtain a clue to their origin and manner of descent. Starting with the idea—supported by well-nigh every consideration which natural science can offer—that the living beings around us have been evolved from pre-existing forms of life, it is held that in their development we may see illustrated the various stages through which their ancestors have passed, and through which their modern and existing forms and structures have been produced. The development of a living being is thus regarded as teaching us *how* living nature has been evolved; the "*why*" is a subject upon which the fullest research sheds no light, and regarding which even the boldness of speculation has as yet pronounced no opinion. To use the words of Mr. Darwin himself, "Community in embryonic structure reveals community of descent;" and again, "Embryology rises greatly in interest, when we look at the embryo as a picture, more or less obscured, of the progenitor, either in its adult or larval state, of all the members of the same great class."

Applying the principle that in development we find a clue to the origin of the structures and organs of living beings, we purpose to investigate briefly the history and origin of that part of the animal frame which is concerned with the maintenance of relations between the organism and the outer world,—the nervous system. We may endeavour, in other words, to apply the foregoing principle to explain

the origin of nerves, and to set before us some reasonable ideas concerning the conditions in living beings which have favoured, inaugurated, and perfected the most complex part of our physical belongings. In such a study we may perchance touch upon several issues which lie very near to some weighty matters connected with mind and brain; whilst in any case the subject itself is one of the most attractive which can be presented to the thinking mind.

A few words concerning the functions of a nervous system, wherever found, and in whatever degree of perfection it may exist, may form a suitable introduction to the topic which awaits our study. Shortly expressed, the function of nerves is that of bringing their possessor into relationship with the outer world. This result is attained through the especial property of nerves, termed "irritability" by the physiologist, —a term which, in unconscious sarcasm, might be, and is, applied to indicate an excess of nerve-action in humanity itself. Through the property of irritability, and of responding to impressions made upon them by the outer world, nerves affect the parts in which they are distributed; whilst through their action on these parts, they may in turn affect the entire body of their possessor. But the simple observation of any common action in man and lower animals will serve to show that there exists a wonderful sameness of working, so to speak, in the nervous acts of high and low forms of animal life. When a blow is aimed at the face, or when the hand of a bystander is passed rapidly before our eyes, the result of these actions in ourselves respectively consists in the withdrawal of the head and in the closure of the eyes. If we endeavour to rightly comprehend what is implied in these actions, we shall have laid a sure basis for the further understanding of how nerves act in well-nigh every detail of life.

The blow or threat which comes from the bystander, represents an "impression" of the outer world made upon a special portion of our nervous system,—the sense and organ of sight. It is the function of these organs to receive

but one kind of impulse or impression,—the impression in the present case resulting from that disturbance of the ether and light-rays which gives origin to the sense of sight,—just as disturbance of another kind, producing sonorous vibrations, results in the production of sound, and in its appreciation by sense-organs, the ears, specially adapted to receive such an impression. Received by the organ of sight, the impression is conveyed to the nearest "nerve-centre," represented in this case by a part of the brain. Only when the impression has reached the brain do we "see," in the true sense of the term. For the sense of sight, involving a knowledge and appreciation of what is seen, is resident not in the eye, but in the brain, as representing that part of the nervous system where the act of "knowing" is performed. Thus we note that an impulse is conveyed inwards to the brain; and we may call this a "sensory" impression, since it has been received by a "sense"-organ, and has moreover given rise to a "sensation,"—that of sight.

But the actions which follow the impression made upon the organ of seeing do not end thus. Active exertion—the withdrawal of the head and the closure of the eyelids—follows the sensation. How, then, is this action related to the appreciation by eye and brain of the threatened danger? Because, we may reply, the brain transmits another and a different impulse or command to the muscles of the head and neck and to those of the eyelids, sets these muscles in action, and thus produces movements destined to save the body from the act of our assailant. There is thus illustrated the great principle of *reflex action*, with the discovery and enunciation of which the name of Marshall Hall is so worthily associated. We note that an impression which we have named "sensory" passed inwards (Fig. 46) through a "gateway of knowledge," the eye (E), to the brain (B); and, conversely, we note that a second impulse is sent outwards from the brain to the muscles of the neck and eyelids (S), directing the movement of the former and the closure of the

latter. This second impulse,—which may simply consist of the first or sensory one directed or "reflected" into a new channel and modified by the brain,—we term a "motor" impulse, because, as we have seen, its office is that of producing motion in muscles. If, now, we take a wide survey of the field of animal life, we shall find that "reflex" nerve-action forms the apparently universal rule wherever bodily action follows upon the outward stimulation of the world. It is immaterial whether the original impulse comes from the nervous system or from the world; in any case it is "reflected" from the great nerve-centre to muscles, to a sense-organ, or to some other part or tissue of the body. When we "will" to perform any bodily action, such as that

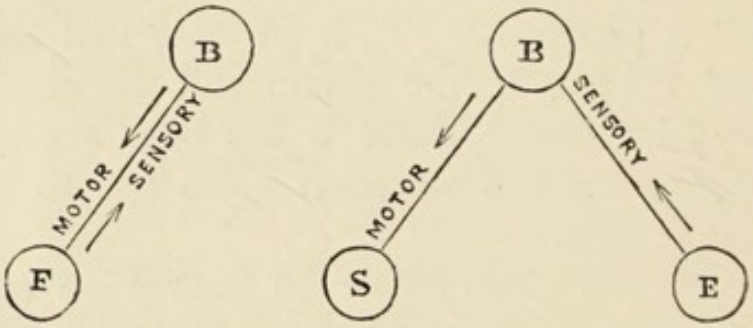


FIG. 46.—Diagrams of nerve-action.

of touching a table, the thought or idea generated in the brain (B) passes outwards on its "motor" journey, and puts the muscles of the finger (F) in movement or in action; and we are made aware that the act has been accomplished only through a second or "sensory" impression which has been transmitted or reflected to the brain. Similarly when the "mouth waters,"—that is, when saliva is secreted rapidly and enters the mouth,—at the sight of some "dainty dish," the sensory impulse flashes from the eye (E) to the brain (B), and is thence "reflected" as a motor or "secretory" impulse to the salivary glands (S), with the effect of producing the familiar result. When we touch the tip of a snail's tentacle or feeler, the feeler itself is rapidly withdrawn, and the animal itself retreats within its shell.. Reflex nerve-action evidently holds sway here, just as in man. For the sensory

impulse was transmitted in the snail to the nearest nerve-centre (B) in the animal's head, and thence "reflected" to the muscles (F) of the body as a "motor" impulse, with the result of the animal's withdrawal into private life for a longer or shorter period. No matter where or how we glance at the acts of living beings, the same actions are to be witnessed. The presence of "consciousness" in higher animals or its absence in lower forms, does not in the least affect the community of method whereby each and all act in response to the stimuli of the outer world.

Entering the domain of the botanist, we may find feeling and sensation not merely to be represented in the plant world, but, in some cases, to approach very nearly indeed, if not to actually eclipse in definiteness, the acts of many animals. When a sensitive-plant (see Fig. 43) droops its leaf-stalks and huddles its leaflets together, on being touched, in what respect, it may be asked, do its actions differ from those of many lower animals, such as sea-anemones and the like, which evince, in their daily life, acts but little elevated above the quiet vegetative existence of the plant? Or when the Venus's-flytrap (see Fig. 44) closes its treacherous leaf on an insect which has touched one of its six sensitive hairs, wherein shall it be said that the act of the plant differs from that of the sea-anemone which seizes, by aid of its tentacles, the unwary crab which has tumbled into a living pitfall in its meanderings? To these queries comparative physiology can return no reply, save one, which admits that the actions of plant and animal are alike "reflex" in nature; and which affirms that, despite the absence of demonstrable nerves in plants and lowest animals—for both are nerveless—the acts of the lower forms of life are bound up in a strange sequence with those which regulate the existence of humanity itself.

Primarily, then, it may be asserted that there is a striking community and sameness of detail in the common nervous acts of animals and plants. For between the essential nature of the irritability witnessed in the two groups of living beings there can be no just distinction drawn; and the con-

clusion that sensation, in some degree or other, is an unvarying concomitant of life, is one which the consideration of the phenomena of animal and plant existence fully endorses. But this community of sensation may be more plainly demonstrated if we take a comprehensive glance at the phenomena of sensation and nerve-action as illustrated in an ascending scale, and as we pass from lower to higher confines in each kingdom. One of the most useful animals for purposes of zoological instruction is the *Amœba* or "proteus animalcule" (Fig. 47), a creature belonging to

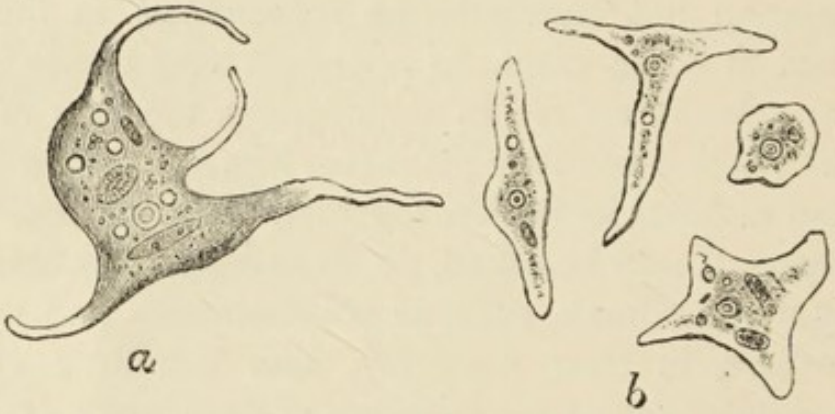


FIG. 47.—Amœbæ or "proteus animalcules:" *a*, *Amœba radiosa*, showing the protrusions of its body-substance; *b*, *Amœba diffluens*. The figures represent the same animalcule in different stages of contraction.

the lowest grade of organisation, and whose body may be accurately described as consisting of a microscopic speck of jelly-like matter—the *protoplasm* of the biologist. To watch an amœba moving across the field of vision presented by the microscope, by slow contraction of its jelly-like body, and to see it literally flowing from one shape into another (*b*), is to behold one of the most common and yet most perplexing sights which may meet the biologist's eye. Locked up within this minute speck of protoplasm, in which none of the structures or organs belonging to animal life at large can be discerned, are powers and properties which specially and distinctively characterise the living animal, and which elevate our amœba, simple as it is, far above all forms of inorganic or lifeless matter. Our animal-

cule literally eats and digests without possessing a digestive apparatus; and, as we may note, "feels," in the absence of the faintest traces of a nervous system. Watch a particle of food approach the amœba, for instance, and you may observe that when the article impinges against the soft body of the animal, the protoplasm will be extended so as to engulf the morsel, and the amœba may thus be seen to receive food simply by surrounding the food particles with its soft elastic frame. Thus we may learn from a simple observation that the protoplasm of which the amœba's body is composed is pre-eminently a contractile substance, and that it is moreover highly sensitive. In these two conditions the art of feeling may be said to begin. The sensitiveness of the body is the primary condition; and the power of acting upon the impressions received by the sensitive medium is the second essential in the process. Here also, in reality, we have the beginnings of truly nervous acts. For there can be no doubt that the animalcule "feels" the contact of the food-particle, and that the result of the impression made upon its body is to produce contraction—depending on molecular movement of the protoplasm,—and to stimulate this contractile protoplasm to engulf the morsel. The action of the amœba thus appears essentially of the nature of "reflex action" after all, and claims kindred with the simpler acts of higher existence.

If, now, we investigate the conditions of life in lower plant organisms, we shall find the great difference between most of these forms of life and their lower animal-neighbours to consist in the development of a definite wall or envelope to their bodies, or rather to the "cells" or minute structures of which the lower plants are composed. That the protoplasm of which the lower plants are composed is essentially similar in its physical characters to that seen in the lower animals, is a chemically demonstrable fact. And when we look through the microscope at the cells of a low plant, such as *Chara,* we note the protoplasm or living matter of the cells to be in a state of constant movement. Any one who

has beheld, through the botanist's microscope, the movements of the protoplasm in the cells (Fig. 48), of which the hairs of *Tradescantia* are composed, will not readily forget the sight of the streams of protoplasm which hurry hither and thither, laden with granules or solid particles, and which keep up a continual bustle within the miniature world encompassed by the cell-wall. The cells of the stinging hairs of the nettle afford an example of the same wondrous spectacle. "The protoplasmic layer of the nettle hair," says Huxley, "is seen to be in a condition of unceasing activity. Local contractions of the whole thickness of its substance pass slowly and gradually from point to point, and give rise to the appearance of progressive waves, just as the bending of successive stalks of corn by a breeze produces the apparent billows of a corn-field." Thus the protoplasm of the plant-cell is eminently active and contractile, and appears to be the seat of energy as potent as that which animates and directs the acts of an amœba.

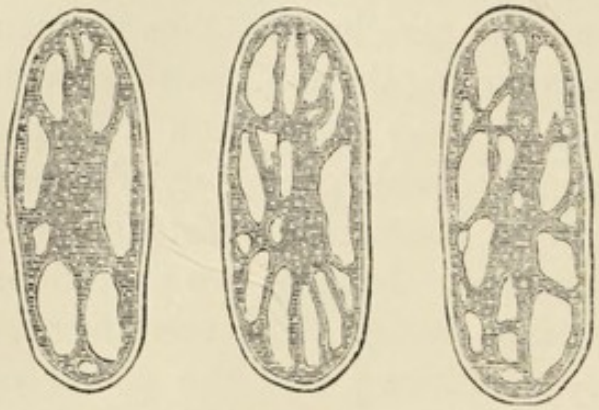


FIG. 48.—Cell of *Tradescantia*. The illustration represents the same cell drawn at successive intervals of two minutes, and showing alterations in the contained protoplasm.

But why, it may be asked, considering the presence of sensitive protoplasm in plant-cells, do not we obtain the same active responses from the plant when stimulated, that we behold when the animal protoplasm is irritated? The answer is clear and apparent. Because the protoplasm of the plant is not continuous. It is broken up into detached portions separated by cell-walls, which present great, or it may be insuperable, barriers to the transmission of impulses through the plant-tissues. Each plant-cell, as regards its irritability, is in fact an isolated unit; and even in those cases in which the plant becomes highly sensitive,—as in

the case of the Venus's-flytrap, or in the hairs of the sundew leaves—the cell-walls appear to influence the rate of transmission of the impulse which brings the irritability of the plants into action. Darwin's researches on "Insectivorous Plants" contain much suggestive matter bearing on the present point. The stimulus applied to the leaf-hair of a sensitive-plant can be seen to pass through the cells of the hair, its passage being indicated by the successive movements and contractions of the protoplasm of the cells; and Darwin remarks that, in the case of the sundew's hairs, the cell-walls appear to present obstacles to the quick passage of the stimulus. This conclusion is fully supported by the fact that a stimulus passes more rapidly in a longitudinal than in a transverse direction in the leaf of the sundew; and this for the reason that in the longitudinal pathway through the leaf there are fewer cell-walls than in the other direction. Summing up the question of plant-nervousness, therefore, we may hold that the sensibility of plants is limited chiefly by the fact that their protoplasm is even in the lowest plant organisms enclosed within cells; and that the cell-walls appear to present partitions, which, in the great majority of cases, act as effectual barriers to the quick transmission of impulses. Certain plants, as we have seen, have surmounted the difficulty in a very decided fashion; but even in their case the sensitiveness is inferior to that of the animal, and their impulses are of slower kind than those of their neighbours in the "*règne animal.*"

But if the special constitution and structure of the plant militates against the development of nerves within the confines of the vegetable world, the conditions of animal life present favourable conditions, on the other hand, for the higher exercise of sensation. There are no obstacles to the free passage of an impulse through the amœba's body, and special tracts and pathways, named nerves, are developed for the transmission of impulses in animals of by no means a very advanced grade. Hence, the main question at issue is that of accounting for the progressive development of distinct

nerves and definite nervous acts from the simple exhibitions of sensitiveness we see in the amœba and its kindred. The problem of the acquirement of sensitiveness by some plants, and even of the power,—as exhibited by the Venus's-flytrap (see Fig. 44),—of a selective discretion and choice of food, is one which it is difficult even theoretically to investigate. We may, therefore, more profitably devote our consideration to the origin of nerves and nerve-actions as exhibited in the animal kingdom: the theoretical pathway by which nerve-development has been reached in animal life, if not clearly defined throughout its entire extent, being yet sufficiently plainly marked to give promise of intellectual gain from even a cursory pilgrimage made therein.

The amœba's life may be said, as regards its irritability, to be concerned with the reception of external impressions of a simple character, and with responding to these impressions by contractions and movements of the protoplasm of its body. How the protoplasm contracts or moves in obedience to the stimuli which play upon its outer parts we do not know, any more than we can describe what takes place in the nerve of a higher animal when an impulse travels through or along its fibres. But there is every reason to believe that molecular movements and activities of like kind which prevail amongst the tissues of living beings at large, are concerned in some special phase of their action with the production and transmission of nerve-force in man. And there similarly exist no grounds for the belief that the molecular actions and forces which affect the protoplasm of nerve-cells and nerve-fibres in man, are in any sense different from those which affect the protoplasm of an amœba and produce movement in the animalcule's frame. The difference, if it exist at all, is one not of kind, but merely in degree.

If now, we direct our attention to the observation of animals of higher grade than the amœba, and compare their acts with those of the animalcule, we may possibly be enabled to explain more definitely the acts of the latter, and at the same time to understand how an advance in the

development of the nervous system is made possible through very simple means. Recent experiments conducted by Mr. G. J. Romanes on the *Medusidæ* or jelly-fishes, have in a large measure aided our comprehension of the stage in the development of nerves which follows close upon the primitive condition of the amœba, and have supplemented by demonstration the hypothetical influences regarding the origin of nerves which we owe to Mr. Herbert Spencer.

With the jelly-fishes or *Medusidæ*, few readers can be un-

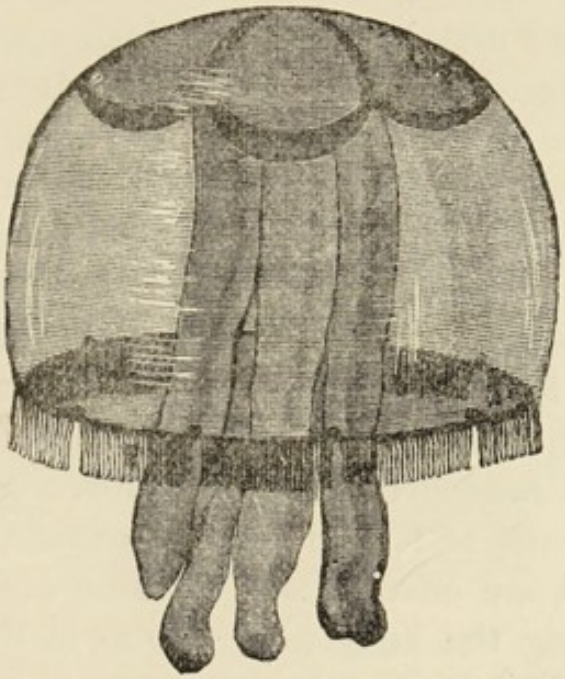


FIG. 49.—*Aurelia aurita*, a common jelly-fish.

acquainted. They form some of the most familiar as well as most interesting tenants of the sea around our coasts in the summer months. By the aid of a tow-net we may capture the smaller species in hundreds; many of the so-called medusæ, however, being merely the free-swimming and detached reproductive bodies of rooted and fixed zoophytes. The larger species are equally well known to sea-side visitors, in the form of the graceful swimming-bells (Fig. 49) of clear gelatinous matter which pulsate through the calm sea of summer—the type of all that is fragile and ethereal in nature. From the middle of the clear azure bell hangs a stalked body, corresponding to the "clapper" or "tongue," and

to which we may, in zoological language, apply the term "polypite." This polypite is the most characteristic part of the medusa in the eyes of systematic naturalists. At its free extremity the mouth is found, and this aperture leads into a hollow body-cavity, which is in its turn continued into the "canals" that radiate through the body of the jelly-fish and that are united by a circular vessel which runs round the margin of the bell. Around the margin of the body we also find tentacles or organs of touch, many or few, as the case may be. In addition, we may observe certain structures known as "marginal bodies," which appear in the form of spots of pigment named *ocelli*, these being rudimentary eyes. And we also find at the rim of the bell certain little sacs or bags containing limy particles suspended in a clear fluid,—these latter representing the rudiments and beginnings of organs of hearing. Thus the jelly-fish may be found to possess a higher degree of organisation than might at first sight be supposed. A closer examination of the swimming-bell, which constitutes the bulk of the body, will reveal the mechanism of its movements. The "polypite" or stalked mouth, and the inner or concave surface of the swimming-bell, are covered with a tissue which differs from that comprising the body as a whole, in that it is highly contractile. This contractile tissue may in fact be regarded as representing the beginnings of muscle in the animal world; and through its agency the medusa is able to move gracefully through the yielding waters. When the layer of tissue just mentioned contracts, the walls of the bell are pulled together. The water contained within the cavity of the bell is thus forcibly expelled, and by its reaction on the surrounding fluid propels the jelly-fish onwards. The subsequent relaxation and distension of the contractile layer and swimming-bell permit a fresh inflow of water, preparatory to the next contraction and succeeding expulsion of fluid. One observation regarding the sensitiveness of the medusa is worthy of remark, and that is, the special localisation of its irritability and the regulation of its move-

ments in the margin of the bell. If we cut off the rim of the bell with its tentacles and "marginal bodies," the animal becomes completely paralysed; whilst the detached and separated rim will continue, under favourable circumstances, to move and contract even for days after its severance from the body of which it once formed part.

That the nervous acts of a medusa are infinitely superior in respect of their definite manner of working to those of the amœba may be demonstrated by one or two very simple experiments. If, in certain species of medusæ, such as *Tiaropsis* (Fig. 50), we irritate any part of the swimming-

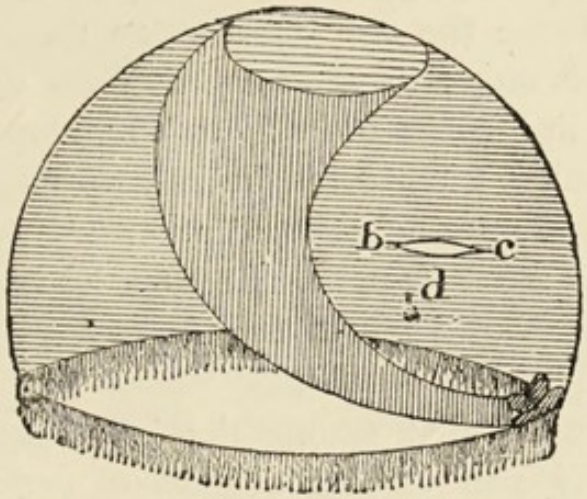


FIG. 50.—*Tiaropsis indicans.*

bell the central mouth or polypite will move over towards the irritated point, and indicate accurately the exact seat of the irritation. Now, such an observation seems to prove, without any reasonable shadow of doubt, that the impressions made upon the body of the animal have been conveyed to the central polypite; not irregularly or indefinitely, but in definite lines or tracts, which, to use Spencer's term, we may name "lines of discharge." And that these lines communicatewith other lines or tracts, just as nerves interlace in higher animals, appears to be equally clearly proved by the results which follow the formation of a transverse or cross cut in the body of the jelly-fish. If such an incision (*b*, *c*) be made, and if thereafter the

body be irritated *below* the cut, as at *d*, the polypite, instead of moving at once to indicate as before the irritated portion, will move in an erratic and undetermined fashion. We have, in plain language, cut the direct connection or line of discharge between the irritated point and the polypite, so that our stimulus has to travel by a nervous loop-line and reaches the polypite after all, it is true, but without affording to that structure direct and definite information concerning the irritated point. The result of the foregoing experiment also serves to impress the idea that habit and use favour the development of special lines of discharge in the jelly-fishes. *Tiaropsis* is thus able accurately to indicate the seat of irritation through certain of its nervous lines only: these being the lines ordinarily used by the animal in the acts of its life. The loop-lines through which the impulses travel after the infliction of our cross-cut fail to convey accurate information regarding the impression, simply because the new nervous routes have not been exercised to the same extent as the interrupted lines of discharge.

It also appears that among the jelly-fishes themselves there are many and varying degrees of perfection in the definiteness of their sensations, and in their aptitude to respond to impressions made upon them. In a common genus (*Aurelia*, see Fig. 49) of jelly-fishes, the irritability is not nearly so distinctly localised nor so definitely transmitted as in the last-mentioned case of *Tiaropsis*. In the latter instance, the object of the polypite being able to move so as accurately to indicate the irritated point is that of stinging its prey, by means of an offensive apparatus placed at the extremity of the mouth. So that the definite acts of the animal have arisen in clear connection with a purposive end,—that of killing and seizing prey. But in other species (*e.g. Aurelia*) the impulses travel in less definite fashion, if we may judge from the results which follow stimulation. A portion of the body of *Aurelia*, a very common species of jelly-fish, when cut, as in one of Mr. Romanes' experi-

ments, so as to form a mere elongated strip (Fig. 51), which in its turn was intersected or divided by numerous slits and notches, was still shown to transmit impressions, thus proving that there was little selective choice by the impressions of special lines or tracts along which to travel. Mr. Romanes says of this experiment, that although the swimming-bell of *Aurelia* had "been cut into the form of a continuous parallelogram of tissue, and then subjected to the tremendously severe form of section" (depicted in Fig. 51), "yet on very gently stimulating any point in this ex-

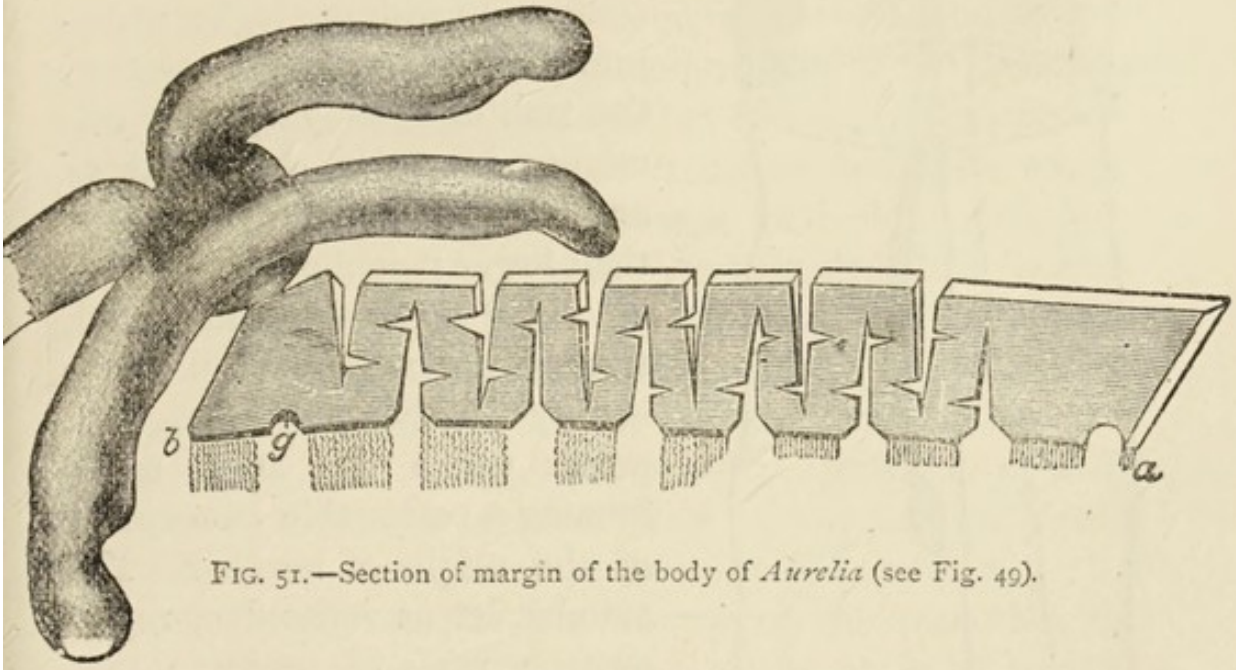


FIG. 51.—Section of margin of the body of *Aurelia* (see Fig. 49).

panse of tissue, as at the end *a*, a tentacular wave would course all the way along the margin to *b*, thus showing that the wave of stimulation must have passed round and round the ends of all the intervening cuts." But in *Tiaropsis* we see evidence of a higher development of sensitiveness and nerve-action in the accurate response of the central mouth to impressions made upon the swimming-bell. Here the reception of impulses may be regarded as having become specialised, and the influence of use and habit may be credited with converting the at first ill-defined lines of discharge into definite and accustomed tracts, along which impulses would regularly and normally pass. In other

medusæ, again, the lines of discharge may be traced as having become definite nerve-tracts; actual nerve-elements having been demonstrated to occur in *Aurelia*. When these higher jelly-fishes,—such as the *Sarsiæ*, one of which is represented in Fig. 52,—are stimulated, their actions are seen to be still more purposive and direct, and more quickly manifested, than in forms in which the nerve-impulses travel along less definite pathways. And in conformity with the higher structure of their nervous system, the task of destroying their irritability is easier than that of annihilating the sensitiveness of their lower neighbours.

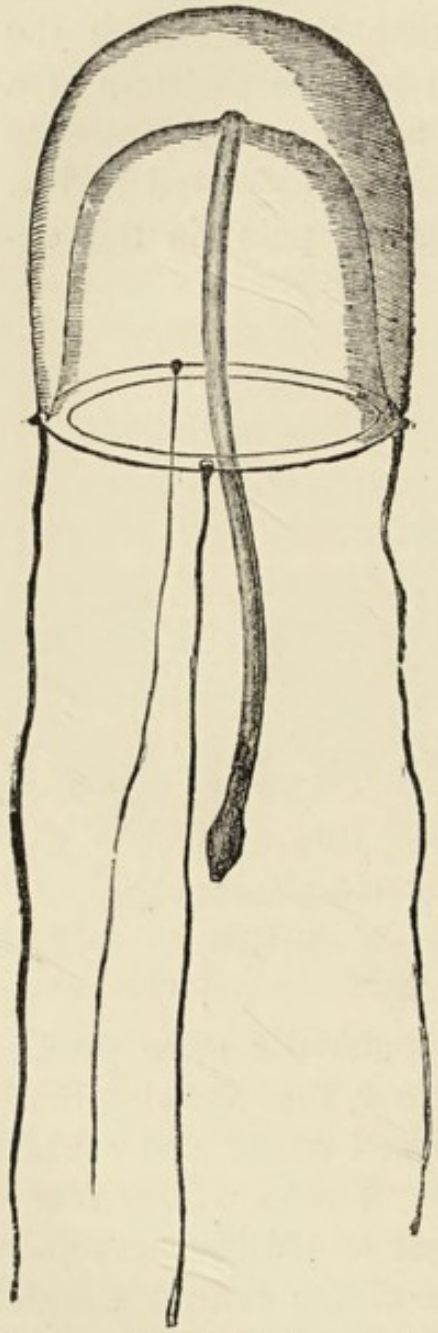


FIG. 52.—*Sarsia tubulosa*, showing the central polypite and the tentacles.

Have we, then, elucidated, through the consideration of the history of the jelly-fishes, any points which will assist us in framing a reasonable conception of the origin of nerves? The amœba, let us remember, represents a mass of sensitive protoplasm, through which impulses pass in an indefinite manner, with the result of producing irregular contractions of the animalcule's body. The nerve-power has its beginning here, but nothing more; and any or every part of the body may in turn be brought into contact with the outer world. With a less changeable and more definite shape of body, some parts of an animal of necessity become more exposed than other parts to the outer world

and to impressions derived therefrom. And the influence of use and habit can be well understood and appreciated, when it is alleged that these exposed parts of the body will become more sensitive than the non-exposed portions, and impressions will thus come to select, or to be directed in, certain lines or paths in preference to others. These stimulated parts will become the seat of constantly recurring molecular changes and movements inducing the formation of definite contractile tissues or muscles; whilst the lines along which the impulses have passed will ultimately represent the primitive nerve-tracts or nerve-fibres,—such, indeed, as are seen in varying degrees of perfection in the jelly-fishes. Mr. Spencer's own comparison of the development of nerve-tracts to the formation of water-channels is a perfectly just simile. Constantly recurring molecular waves define the primitive lines of discharge in living tissues, just as continuous currents of water deepen the shallow and ill-defined channel along which the first waters of the river ran. Once established, nerve-actions and impulses will continue to flow and to become better defined; and with the necessity and demand for sensory apparatus of still higher kind, the same inevitable law of use and habit will supply an increased and more perfect nervous system.

Such, briefly told, is the history of the evolution of nerves. If we pass a little higher in the scale of animal life from the jelly-fishes, we find that nerve-fibres and nerve-cells—the elements found in the highest nervous systems—become distinctly developed; although, indeed, the beginnings of these elements are to be discerned in these graceful organisms themselves. The arrangement of nerve-systems in animals follows the inevitable law of necessity, in that their nerve-fibres and cells are placed so as most perfectly to control and correlate bodily actions with the impressions which are received from the outer world. Organs of sense,—specialised parts of the nervous system, adapted to receive one kind of impression alone,—may be regarded as having arisen in obedience to the same law of

use and habit, and through impressions or stimuli of special kind having been made upon particular parts of the body. There is little need to pursue this idea further, since the theory of nerve-origin lies literally in a nutshell, and derives its feasibility from the reasonableness of its assertions. Given an animalcule with a sensitive body-substance; admit that its body becomes stable so as to present certain parts to the outer world; and that, through use and want, impulses come to travel in particular lines from these parts, and so to produce changes and contractions in its internal structure—and we have outlined the essential details of the only scientific and consistent theory which can account for the genesis of muscle and nerve in living beings.

The development of nerves in the animal world at large, however, bears a very distinct relation to the development of nerve-centres and sensory-organs in the highest of animals. Can the development of the nervous system in higher animals be said to throw any light upon the manner in which nerves and sense-organs have originally arisen,—namely, through the contact of impulses with certain outward parts of a living being, and through the subsequent relationship which became established between these outward portions and the inner structures of the organism? We have already assigned to the study of development a paramount place, as showing us the manner of origin of the organs and parts of living beings. Let us inquire if the development of the highest animals throws any light on the source and beginnings of their nerves?

The egg or germ of a vertebrate animal exists as a small, or it may be microscopic, mass of protoplasm, known as the "ovum," or "egg," exhibiting all the features of a "cell." Man himself springs from such a body, which in his case attains a diameter not exceeding the one hundred and twentieth part of an inch. When the ovum exhibits the process of development which results in the production of a new being, its substance divides and subdivides (Fig. 53, A, B, C, D) in a regular fashion into a mass of cells; the egg being said, in

physiological language, to undergo the process of "segmentation." At length the division of the germ ceases, and the "blastoderm," or "germinal membrane," is formed. From

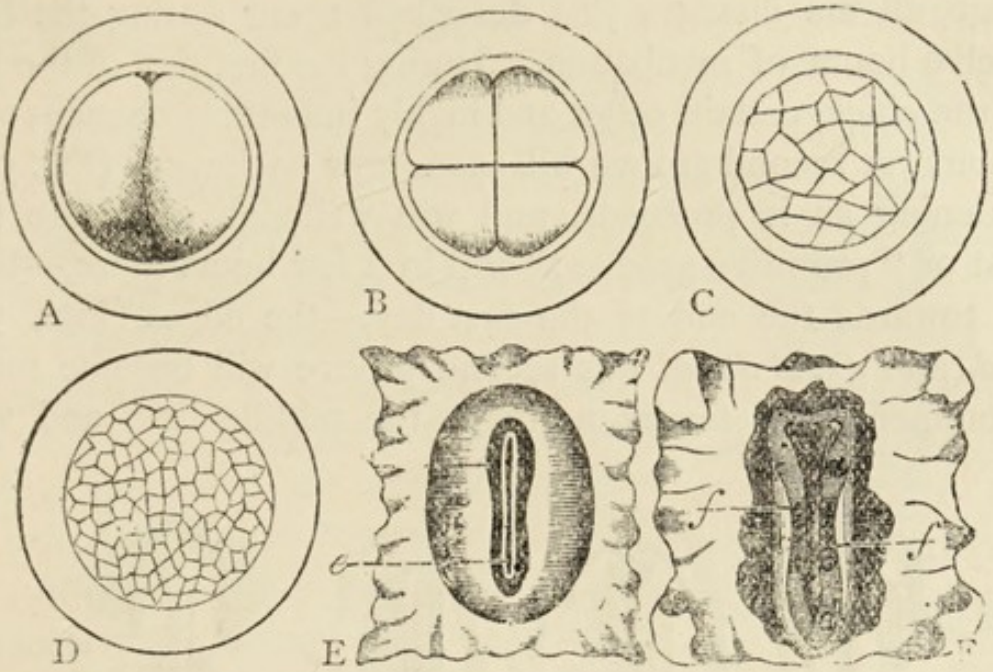


FIG. 53.—First stages in the development of a vertebrate animal. Figs. A, B, C, and D exhibit the process known as "segmentation," or division of the ovum. At E, the germ is seen in a more advanced stage, the primitive groove (*c*) being represented; whilst in F, the development has advanced still further, *d* being the primitive groove; *e*, the primitive brain; and *f*, the first traces of vertebræ.

this latter structure all the parts of the young animal are formed, and the blastoderm itself divides into three layers (Fig. 54), respectively named—in the order in which they occur from without inwards—the "epiblast" (E), "meso-

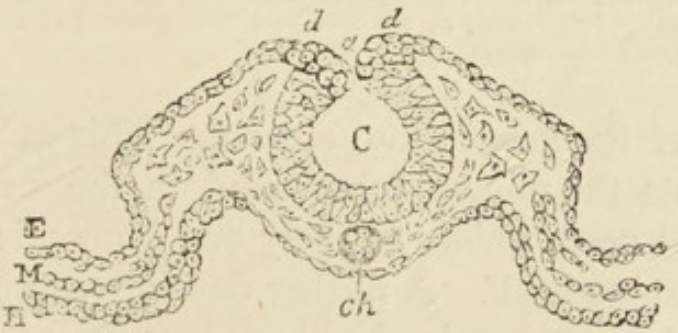


FIG. 54.—Development of chick. Magnified cross-section, showing epiblast (E), mesoblast (M), and hypoblast (H); *a*, primitive groove, closing at *d d*; and C, spinal canal; *ch*, the notochord, or early representative of the spine.

blast" (M), and "hypoblast" (H). Now appears the first trace of the future animal, in the shape of a furrow known as the "primitive groove" (Figs. 53, E, *c*, and 55, *c*), and which

consists of a longitudinal streak or depression formed in the epiblast or outer of the three layers already mentioned. When the development of the chick is studied stage by stage, all the changes just described occur during the first twelve hours of incubation. During the first day of the life of the chick, certain other and highly important changes will occur. A second groove will soon grow backwards (Fig. 55), widening as it proceeds, and will well-nigh obliterate the first or "primitive groove;" and in a few hours more,—that is, towards the end of the first day,—the edges (Figs. 54, *d d*, and 55, *d d*), of this second groove will become more prominent, will finally unite in the middle line, and will

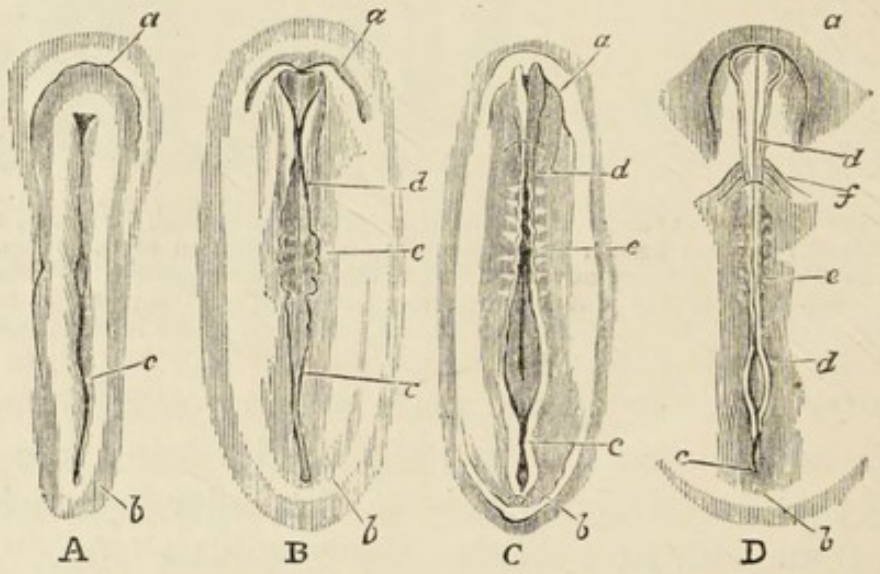


FIG. 55.—Development of chick in various stages, A, B, C, D: *a*, head; *b*, tail-extremity; *c*, primitive groove; *d*, sides of primitive groove; *e*, first traces of the vertebræ; *f*, primitive veins.

thus convert the groove into a canal. This canal (Fig. 54, c) represents the minute tube found in the centre of the future spinal cord, which, as every one knows, is contained within the spine itself. A further development of the front portion of the young animal will produce the head-folds and skull, with its contained brain (Fig. 56, *fb*, etc.), and the growth downwards of other parts of the embryo will similarly produce the great bulk of the body (Figs. 55, 56) with its contained organs. In Fig. 55 the gradual formation of the primitive groove (*c*) may be studied as represented in

the development of the chick; the sides of the groove (*d d*) being seen gradually to close, and so to form the cerebro-spinal canal; whilst the first traces of vertebræ (*e e*) are also observed. In D also, the first appearance of the brain is also shown.

The further development of the chick is shown in Fig. 56, where the preceding stages are seen to have produced the three dilatations of the brain (*fb*, *mb*, *hb*), and the beginnings of the eye and ear are shown at *op v* and *au p* respectively. The vertebræ, or joints of the spine (*pv*) have become well developed, and the remains of the "primitive groove" are shown at *pr*.

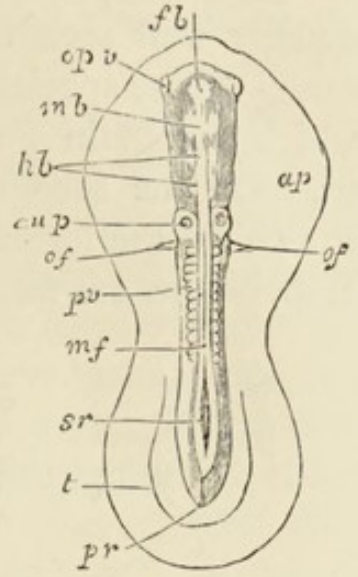


FIG. 56.—Further development of chick.

Such is a brief sketch of the processes which occur in the early life-history of every vertebrate animal, man included. Let us now glance for a moment at the part which each of the three layers of the young animal plays in the formation of the various systems of the body; since thereby we may understand how the nervous system is formed. From the "hypoblast" or undermost layer (Fig. 54, H) the general lining membrane of the internal parts of the body, such as the digestive system, is developed. The middle layer or "mesoblast" (M) gives origin to the tissues and organs of the body generally, except the brain and spinal cord and the outer skin of the body, which are formed from one and the same layer—the "epiblast" (E). Thus we arrive at the startling fact *that the great nervous centres of man and the higher animals are formed from the same layer of the young being which gives origin to the skin or outer layer of the body.* In other words, our nervous centres are formed from an infolded portion of what in the early condition was the outer layer of our frame. This infolded part ultimately obtains, through the development of connecting nerves, a communication with

the outer world, and thus comes as the nervous system to regulate and control the entire organism.

But the process of formation of the nervous system from an infolded layer of the original outer surface of the body, is equally well seen in the development of the eye, ear, or nose,—those specialised parts of the nervous system through which we obtain a defined knowledge of the world around us. On the second and third day in the development of the chick, the formation of the eye and ear proceeds apace. Both organs are formed by an infolding of the outer or skin-

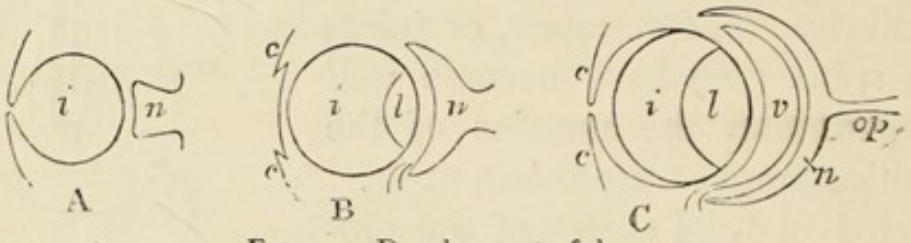


FIG. 57.—Development of the eye.

layer, the epiblast; this fold growing inwards to meet and to unite with an outgrowth from the brain. In the accompanying figures (Figs. 57 and 58) the formation of the ear and eye

FIG. 58.—Development of the ear.

is illustrated. At *n*, in the illustration of the development of the eye, the outgrowth from the brain is figured, and at *i* the ingrowth of the skin-layer, which becomes the lens (*l*), with the aqueous humour (B, *i*) in front. The brain-outgrowth (*n*) ultimately forms the retina (C, *n*), and is connected to the brain by the optic nerve (*op*). The "vitreous humour" of the eye is shown at *v*, as growing in between the lens and the brain-outgrowth. The eyelids are formed by two skin-folds (*c c*). The ear is developed from a sac or folded-in portion of the skin-layer (*i*), which itself forms what is

named the "membranous labyrinth" of the ear. The lower part (*c*) of this sac becomes the "cochlea" of the ear, the other part forming the "semicircular canals" (*l*). The "auditory nerve" (*n*), or that of hearing, appears to be formed on the inner side of the labyrinth (*l*), and thus places the ear in communication with the brain.

It may thus be said that the ear-structures are more largely indebted for formation to the skin-layer than are those of the eye; since no outgrowth from the brain comparable to that seen in the case of the eye takes place in the development of the ear. Be this as it may, however, there remains the fact that the most important of our sensory organs,—eye, ear, and nose,—with the intricate structural relationships they evince in the adult animal, are not originally formed within the body, but are developed from the outermost or skin-tissues of the young animal, and are placed thereafter in connection with the brain, which itself, as we have seen, was developed from the same outward layer so distinctly to be discerned in the earliest stages of life. What, then, are the inferences concerning the origin of nerves which may be reasonably drawn from the story which development not merely tells, but substantiates by the plainest of evidence? Simply, that our nervous centres and sense-organs, by means of which we not merely feel, see, and hear, but through which we exercise the highest powers of will, reason, and intelligence, are formed from a layer which originally, and in antecedent states of existence, met the rough and direct contact of the outer world. Through the scientific use of the imagination we note that as time passed, and as development advanced, with its wondrous work of evolving and fashioning new forms out of the old, the nervous system gradually rose in complexity. From the condition of a soft contractile body, typified by the amœba, and subject at each and every part of its surface to receive impulses, we reach a stage wherein a stable shape of body presented certain points for the reception of sensations in preference to other portions. Then, as in the medusa, a defined communication between

the exterior and interior was at last established, and nerve-force flowed in established pathways, which in their turn represented the nerves of the future. Finally, as organisation advanced, and with the necessity for the establishment of a clearer relationship with the world around, the external layer of the body, which itself originally received the rude shocks of the outer universe, and which was thus by habit impressed with a facility for such reception, became infolded, and the nerve-pathways were brought into relationship with the nerve-centres thus formed. Then, also, special parts accustomed to receive impressions of peculiar kind participated in the new era of development, and became infolded, as the sense-organs, so as to communicate with the great nerve-centres within. Purpose and design, as regulated by necessity and use, were thus illustrated to the full; and as the relationship between the living being and the outer world became fully established, we may then conceive of the dawn of intelligence, and of the powers which successively mark the higher animal and the man.

Thus development teaches us through its marvellous story, first, that the formation of man's nerve-centres is affected through the same stages and by the same means as those of all the members of the great division of the animal world to which he belongs; and secondly, that the genesis of nerves is due primarily to the contact of the world with sensitive parts of living beings, and to the effects of habit and use in the further development of these parts to form nerves. It is not given to science to trace the exact stages or processes through which the powers of mind have become evolved. But once determining that there is the closest of relationships between the structure and formation of the human nervous system and that of lower forms of life,—cells and fibres of the same nature entering universally into the structure of nervous systems,—we must logically assume that man's mental powers are as strictly dependent on the physical characters and qualities of his nervous system as the acts of the medusa are upon the perfection of

the primitive lines of discharge we are able to trace in its frame. Physical change, produced by disease, for example, makes sad havoc in the mental estate of man, and may obliterate entirely the intellectual existence of our species. Is it any the less a reasonable theory to assume that on changes of like,—that is, of physical,—kind, depend our thoughts and ideas; or that from habit and use, and their effects on the brain-substance, new powers of mind and new intellectual features may have arisen in the past, and are now being continually evolved in the history of our race?

These declarations may possibly sound a little materialistic in some ears; but there is certainly less materialism involved in the supposition that we are the creatures of habit and circumstance acting upon our nervous centres, than in theories of human life which begin their explanation of man's mental and moral nature by assuming the inherited and exceeding badness of the race. Whatever powers we attribute to man must be shown to depend on the character of his nerve-centres, and on the powers of these parts as modified by ignorance, superstition, or animalism, or as perfected, on the other hand, by the process which in one word may be termed "education." The theory of an originally depraved nature, which leaves no room for possible good in man's mental constitution, in this view, has no logical standing whatever; since it begins by postulating the grossly materialistic view that all human qualities and mental acts are vile. Bad and depraved by nature,—sodden with "original," that is, "natural sin,"—we may hopelessly inquire, "Why fight against nature, and why try to alter the fiat of the inevitable?" More cheering, because more true, is the doctrine which the genesis of nerves impresses upon us,—namely, that from our ancestors we receive a natural heritage in which good and evil certainly commingle; but which is also susceptible, through the effects of new habits and proper training, of repressing the baser parts of our nature, and of evolving in our lives the "outward and visible sign of an inward and spiritual grace."

ANIMALS AND THEIR ENVIRONMENTS.

THERE are few studies in natural history of greater interest and of more captivating nature than that of investigating the relations which exist between living beings and their surroundings. How are animals and plants affected by their environments? in what degree and in what fashion do external influences modify habits? and how do varying surroundings alter the structure of living beings?—such are the questions which the biologist of to-day proposes, and such are a few of the problems to the solution of which the energies of the modern naturalist are directed. A backward glance of by no means very extended kind at the natural history of the past, will suffice to show the wide and sweeping changes in opinion which the lapse of a few years has wrought regarding the relation between animals and plants and the world they live in. Of old, naturalists paid little heed to such a relationship, and to the effect which a change in climate, food, or habitat induced in living organisms. The living being, able no doubt in virtue of its vital powers to override many of the outward and physical forces which operate so powerfully on the non-living part of the universe, was apt to be regarded as almost wholly independent of external conditions. "In the world, but not of it," is an expression which may be said to summarise the tendency of biological thought in the past with reference to the relationship existing between animals and plants, and the outward

conditions of their life. Nor need we look far afield to discover the reasons which induced naturalists to credit the living part of Nature with a fixity which nowhere held sway in the inorganic world. The tendency of biological opinion in the past was to regard the forms of animal and plant life as fixed quantities, which varied now and then, no doubt, but which on the whole preserved, as far as observation could detect, a perfect and stable uniformity of form and function. With the extreme prevalence of the idea of the fixity of animal and plant species, the doctrine of "special creation" had unquestionably much to do. A glance at a natural history text-book of some twenty years back or so, will serve to show clearly and unmistakably that the former idea of a "species" of animals or plants was based on the continued and unvarying likeness of a number of living beings to each other. Buffon's definition of a "species," for example, shows that he regarded it as "a constant sucession of individuals similar to and capable of reproducing each other." And another authority, Müller, defines species to be "a living form, represented by individual beings, which re-appears in the product of generation with certain invariable characters, and is constantly reproduced by the generative act of similar individuals." Thus the various species of animals and plants were regarded as essentially immutable in their nature, and as continuing permanently in the likeness which they had inherited from the creative fiat in the beginning of this world's order.

But meanwhile, ideas of a widely different nature regarding the nature of living beings had been slowly asserting themselves, and had their part outcome in the work of Lamarck, who clearly recognised the effects of use and disuse and of habit on the frames of animals, in producing modifications of their form and structure. Similar or analogous thoughts were beginning to influence the sister science of geology. The writings of geologists who, like Hutton, Playfair, and Lyell, advocated the doctrine of Uniformity in opposition to that of an ill-defined Catastrophism, had a

powerful effect in suggesting that the order of Nature, both in its living and non-living aspects, might be different from the old ideas founded on the stability and unalterable nature of the universe,—ideas these, which, like many other thoughts even of modern kind, had come to be regarded with respect from the fact of their venerable age, if from no other or more satisfactory cause. From Goethe himself, as from a master mind, came abundant suggestions tending to enforce the opinion that living beings were to a large extent amenable to outward causes, and influenced by external agencies. In his "Metamorphosis of Animals," the poet-philosopher, with that imaginative force so characteristic of his whole nature, thus enunciates the opinion that the outer world, the animal constitution and the manner of its life, together influence in a most decided fashion the whole existence of the living being:—

"All members develop themselves according to eternal laws,
And the rarest form mysteriously preserves the primitive type.
Form, therefore, determines the animal's way of life,
And in turn the way of life powerfully reacts upon all form.
Thus the orderly growth of form is seen to hold,
Whilst yielding to change from externally acting causes."

Elsewhere, Goethe says of this subject, that while "an inner original community forms the foundation of all organisation, the variety of forms, on the other hand, arises from the necessary relations to the outer world; and we may therefore justly assume an original difference of conditions, together with an uninterruptedly progressive transformation, in order to be able to comprehend the constancy as well as the variations of the phenomena of form."

Thus are clearly expressed Goethe's views that the living form was a mobile quantity, influenced and altered to a greater or less degree by outward causes, acting in concert with the internal life-forces and inherited constitution of the being. In other words, with regard to the form of animals, and to borrow Shakspeare's phrase, we might say—

"In them Nature's copy's not eterne."

Later years brought to biology the enriching knowledge of Darwin; and generalisations regarding the origin of living beings, startling and revolutionising in their nature, were submitted to the scrutiny of the scientific world. But after the first feelings of surprise had passed away, and as the clearness of Darwin's views and their exceeding harmony with the facts of life were observed, biologists gladly hailed his generalisations as affording the basis of a reasonable conception of nature at large. Facts in animal life, hitherto regarded as simply inexplicable, and which were accepted as primary mysteries of biological faith, received at the hands of Darwin new and rational explanations; and to the eminently plain and consistent nature of the ideas involved in his system of thought, may be ascribed the great success and ready acceptation which evolution has met in the world of thought at large. Amongst other features which this method of thought exhibits in characteristic fashion, is that of assigning a paramount place to the influence of habit and use, and of outward circumstances upon the form and "way of life" of living beings. A few illustrations of the changes which both common and unwonted circumstances of existence may effect in the history of animals, together with a brief chronicle of the influence of such changes on the development of life at large, form the subjects we propose for treatment in the present paper. The inquiry, it may be added, is one full of promise, especially if regarded as an incentive to a fuller and more complete study of the relations of living beings to the world in which they live.

No fishes are better known to ordinary readers than the so-called "flat-fishes"—the *Pleuronectidæ* of the zoologist. Under this designation we include the soles, flounders, halibut, turbot, brill, plaice (Figs. 59 and 60), and other less familiar forms. As these fishes are observed on the fishmonger's slab, or better still, when they are seen swimming with a beautiful undulating motion of their bodies in our great aquaria, the epithet "flat," as applied to their form, would be regarded as of most appropriate kind. If an un-

scientific observer were asked which surfaces were flattened in these fishes, he would be very apt to reply that the one

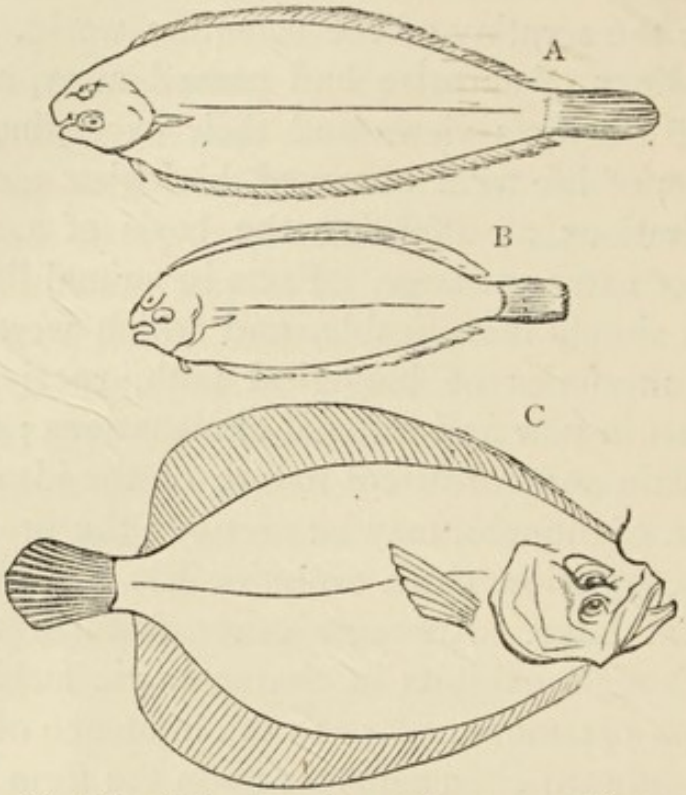


FIG. 59.—Flat-fishes (after Gosse): A, sole; B, monochirus; C, turbot.

flat surface was the back, and the other the belly of the animal. In proof of the correctness of his assertion, he

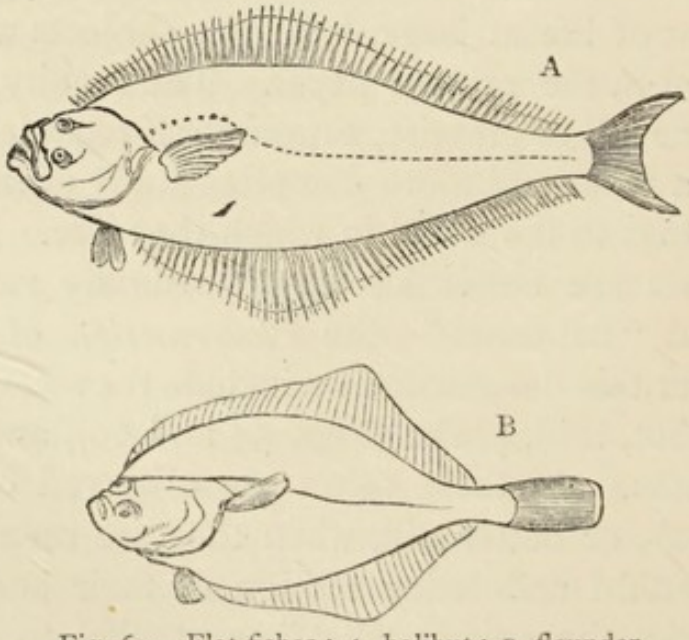


Fig. 60.—Flat-fishes: A, halibut; B, flounder.

might point to the well-known fact that one surface—the so-

called "back"—is dark-coloured, whilst the opposite and presumed under surface is white. Again, the idea that the darker surface is the back, would be strengthened by the observation that it bears the eyes, and further that the fish swims with this surface uppermost. Notwithstanding these apparently well-founded observations, however, the zoologist finds ample reason for a complete denial of their validity and correctness. He would firstly direct attention to the fact that, in the middle of each flat surface of the fish, and in the breast region, a certain short fin (Figs. 59 and 60) is to be discerned. These fins form a pair, possessed by all save the very lowest fishes; they are named "pectoral" or "breast fins," and correspond, as may be proved by an examination of their skeleton, with the fore limbs of other vertebrate animals. In the flat-fishes, it usually happens that one pectoral fin is of smaller size than the other. Moreover, there are other two fins, also paired, to be discerned in these fishes, placed below the breast fins, one on each flat surface of the body, but exhibiting a somewhat rudimentary structure and only a slight development as compared with their representatives in other fishes. These latter are the two "ventral" fins of the zoologist, and an examination of their skeleton and nature shows that in reality they represent the hind limbs of the fish, just as the breast fins correspond to the fore members.

A very cursory examination of other fishes in which both sets of fins exist, would satisfy us that the paired fins are invariably borne on the sides of these animals. This rule of fish-structure accords with the position of the limbs in all other vertebrate animals. These appendages are always paired, and are invariably lateral in their position and attachments. We are therefore forced to conclude that, unless the flat-fishes present extraordinary exceptions to the laws of limb-development and situation represented in all other vertebrate animals, they must, like other fishes, carry their paired fins or limbs on the sides of their bodies. Otherwise, we must assume that they bear the limbs on their backs and on the lower surfaces of their

bodies respectively; a supposition, the mere mention of which is sufficient to show its absurd and erroneous nature. It may thus be clearly shown that the flat surfaces of the soles and their neighbours, judged by the fact that they bear the paired fins, must represent the sides of their bodies. And an examination of the other series of fins found in these fishes would show the latter statement to be correct. The second set of fins possessed by fishes includes the so-called "unpaired" fins, which are invariably situated in the middle line of the body. With the "back" fins, and "tail fin," as examples of these latter appendages, every one is acquainted, and when we look for these fins in the flat-fishes we find them developed in a very typical fashion. There is a long "back" fin, for instance, fringing the body above, and defining the back for us; a second or "anal" fin of equal extent, borders the body below; and the tail fin is equally well developed. An examination of the tail fin alone would in fact show us the true relationship of the various surfaces of these fishes; since in all fishes this fin is set vertically, and not crosswise, as in the whales. Placing the tail fin in its proper position, that is, setting our flat-fish with the back fin uppermost, we then note that the flat surfaces of the tail will correspond with the flattened surfaces of the fish, and that the latter must therefore be the sides of the animal.

But there still remain for comment and explanation the remarkably placed eyes, which, according to our observations, are now seen to be situated on one side of the body, and not on the back, as is commonly supposed. The side on which the eyes are placed is usually the left side; but in several species they are situated on the opposite surface; the eyed side being, as we have seen, the dark-coloured surface. To this latter side, also, the mouth is to a large extent drawn, this aperture thus becoming unsymmetrically developed. Occasionally, also, it may happen that in species of flat-fishes in which the eyes are habitually situated on the left side, these organs may be placed on the right, and *vice*

versâ. The occurrence of this reversion of the eyes throws some little light on the somewhat mechanical causes and chance nature of the conditions which determine the peculiar features and form of these fishes. How have the eyes of these fishes come to be developed on one side of the body, and is this condition original or acquired? are questions which the mere consideration of their peculiar structure must suggest to the most casual observer. It may be said that but two explanations are open for acceptation in this, as in all other cases relating to the development of life at large. Either we may believe that the animals were originally and specially created with these peculiarities and abnormal features fully developed; or that these features are the result of secondary laws and outward forces acting upon the form; and through the form, determining the "way of life" of the being, to use Goethe's expressive phrase. The first hypothesis admits of no enlargement or discussion. If accepted, it must be treated as a matter of unquestioning faith around which the mind may not attempt to travel. But it is exactly this unquestioning belief in a theory which the scientist will not recognise; and more especially if from the other view of the matter, he gleans a large measure of aid in the attempt to understand how the modifications before us have been produced. Having due regard to the alterations and changes of form and structure that are so characteristic of living beings, and recognising the plasticity of life in all its aspects, the zoologist will no more believe that the peculiarities of the flat-fishes present us with originally created features, than that the deformities in man which follow the accidents of human existence, and which may be transmitted like diseases from one generation to another, are the products of a creative force of special kind.

That the case of the flat-fishes has long formed a text for grave biological discussion is evident from the attention it has received at the hands of Mr. Spencer, Mr. St. George Mivart, and other naturalists. Mr. Spencer, in dealing with the modification of animal forms by the influence of external

conditions and environments, explains the want of symmetry in the flat-fishes by assuming that the two surfaces of the body have been exposed to different conditions. Respecting Mr. Spencer's views, Mr. Mivart has remarked, that "Abundant instances are brought forward by him of admirable adaptations of structure to circumstances, but in the immense majority of these instances it is very difficult, if not impossible, to see *how* external conditions can have produced or even have tended to produce them. For example," he continues, "we may take the migration of an eye of the sole from one side of the head to the other. What is there here either in the darkness, or the friction, or in any other conceivable external cause, to have produced the first beginning of such an unprecedented displacement of the eye? Mr. Spencer has beautifully illustrated that correlation which all must admit to exist between the forms of organisms and their surrounding external conditions, but by no means proved that the latter are the *cause* of the former. Some internal conditions," concludes the author, "(or in ordinary language some internal power and force) must be conceded to living organisms, otherwise incident forces must act upon them and upon non-living aggregations of matter in the same way and with similar effects." These quotations will serve to show that zoological authority has recognised, in the case of the flat-fishes, an important subject of remark. With reference to the latter portion of Mr. Mivart's observations regarding the power and presence of internal forces in animals, it may be said that no naturalist may for a moment doubt the influence of those forces—summed up in the words "life" and "vital action"—nor does Mr. Spencer, so far as I can learn, ignore their existence. It is the life and internal forces of the living being which present us with the primary conditions of existence. What we do contend for, however, is that outward circumstances powerfully influence these internal forces, and through such influence produce modifications both of form and structure in living beings. In support of this latter opinion, no animals furnish more satisfactory evidence than the flat-fishes.

The first point in their history to which attention may be directed is that in their early life and when the young fish emerges from the egg, the eyes are situated where we should naturally expect to find these organs—one on each side of the head. Moreover, in the days of its youth, the flat-fish is thoroughly symmetrical in all other respects, even to the coloration of its body, the two sides being tinted of the same light hue. Soon, however, a change of structure and conformation begins to be apparent, especially in the head-region. The eye of the lower side on which the fish is destined to rest begins literally to travel round to the upper side of the body; this process taking place merely through a curious malformation and twisting of the bones of the head, and not by means of the eye passing through the skull, as was formerly supposed. Then also the colour of the upper side of the body gradually deepens and acquires the tint of adult life; a hue admirably in harmony with the surrounding sand, and rendering the detection of these fishes as they rest on the sandy sea-bed a matter of extreme difficulty, as any one who has "speared" flounders knows. The causes of the development of colour on the upper surface may doubtless, as Darwin remarks, be attributed to the action of light; but it is notable that in some flat-fishes there exists a chameleon-like power of altering the tint of their bodies so as to bring them into harmony with the particular colour of their surroundings. The acquirement of this latter condition becomes allied to that termed "Mimicry;" but to explain the development of the power of changing colour, we must call to aid conditions other than that of the action of light, and which affect and influence the more intricate and hidden forces of living beings. Thus are gradually acquired the peculiar features which mark the adult existence of these fishes. The chronicle of their early life and history impresses one fact primarily on our minds, namely, that if their development is to be held as furnishing a clue to the origin of their modifications, the knowledge that at first the flat-fishes possess symmetrical bodies demonstrates that origin-

ally they exhibited, as adults, no modification or deformity such as they now possess. Assume with Darwin—and the assumption is both reasonable and warranted—that the "embryonal (or young) state of each species reproduces more or less completely the form and structure of its less modified progenitors," and we may be taught by the development of the flat-fishes that they have sprung from ancestors which possessed symmetrical bodies, and that the conditions they present to our notice have certainly been of acquired nature.

But the question, "How have these abnormal conditions and modifications of structure been acquired?" still remains for consideration. It is on this point that Mr. Mivat challenges the adequacy of external conditions and outward influences to produce the characteristic deformities before us. On another occasion this author remarks, "If this condition had appeared at once, if in the hypothetically common ancestor of these fishes, an eye had suddenly become transferred, then the perpetuation of such a transformation by the action of 'Natural Selection' is conceivable enough. Sudden changes, however, are not those favoured by the Darwinian theory, and indeed the accidental occurrence of such a spontaneous transformation is far from probable. But if this is not so, if the transit was gradual, then how such transit of one eye a minute fraction of the journey towards the other side of the head could benefit the individual is indeed far from clear. It seems, even," concludes Mr. Mivart, "that such an incipient transformation must rather have been injurious." So far as these remarks regarding the rarity of sudden variations are concerned, they are perfectly appropriate; although it must at the same time be borne in mind that occasionally startling modifications have appeared in a species of animals in one generation, and without the slightest warning or indication that a sudden alteration was to be produced. A well-known instance of this kind was the sudden appearance of the ancon or otter sheep of Massachusetts,—a sheep possessing a long body and short legs,

which was produced as the offspring of an ordinary ewe and ram. This sheep in its turn became the progenitor of a whole race of ancons; and many other examples of sudden variations from the type of a species might be illustrated in both animal and plant worlds. But apart from the fact that alterations of structure, as great as those seen in the flat-fishes, have been suddenly developed in animals, Mr. Mivart is correct enough in laying stress on the fact that, to satisfy Mr. Darwin's ideas, it must be proved to be likely that the variations in the flat-fishes arose gradually, and were as gradually intensified and transmitted as distinct characters to their descendants. Whilst, if Mr. Darwin's theory is tenable, it must also be shown that the propagation of such deviations from the ordinary structure of the fishes, was an advantage to the animal concerned. In this last thought, indeed, lies the essence and strength of Darwinism. Nature selects such variations for transmission to posterity as will favour the existence of the species. Unfavourable variations will, in the "struggle for existence," tend to die out. Hence Mr. Mivart most appropriately calls upon the supporters of the theory of evolution by "natural selection" to show cause that the variation in the flat-fishes was beneficial and not injurious to the individuals exhibiting it. Such are the issues of the question before us. Let us try to discover how the evolutionist, viewing the question from the Darwinian standpoint, will answer the demands laid upon him by opposing tenets and theories.

It may be observed in the first place that the flat-fishes are, to an appreciable and in a readily understood sense, gainers from their ground-inhabiting tendencies. Their bodies, as already remarked, closely approach the colour of the sand and other surroundings, and they not only find protection from their enemies in this fashion, but readily obtain food from the sand on which they rest. As far as the advantages gained from their habits are concerned, the case seems clear enough if regarded in this light. This observation, however, throws no light on the question of the

manner in which the modifications of body which so perfectly adapt them for a ground life, have been gained; and to attain the desired information on this latter point, we must once again study the early history of these fishes. When young and possessing symmetrical bodies, and when the eyes are placed in the natural situation, they may be observed to swim through the water in a vertical position, like other fishes; their flattened surfaces appearing as their sides, and the long dorsal and anal fins bordering the upper and lower margins of the body respectively, whilst the tail fin is set vertically. Soon, however, it is observed that they retain their vertical position in the water with difficulty, owing to the great relative depth of their bodies. Like crank ships, in fact, they have a tendency to become overbalanced; and there can be little doubt that the small size of the pectoral and ventral fins, together with the absence of a "swimming bladder" or "sound," materially aid in producing this result. Thus unable to swim erect for any length of time, the young flat-fish comes to a natural enough position of rest *on its side*. Malm's observations now appear to aid our comprehension of the case in a very remarkable degree. This observer tells us that the young fish, as it lies on its side, twists the lower eye upwards as if in the effort to see above; or, in plain language, tries to look round the corner of its own head. So strenuous are these efforts of the young animal, that the eye is pressed with a great degree of force against the upper part of the orbit or eye-cavity, with the result, as Malm testifies, of contracting, in a marked fashion, the forehead or space between the eyes. This observer, indeed, mentions that he has witnessed a young flat-fish elevate and depress the lower eye through a distance corresponding to an angle of seventy degrees. The effect of this frequent muscular exertion on the soft cartilaginous and flexible tissues of the skull of the young fish may readily be imagined. In time, the temporary displacement of the tissues caused by the movements of the lower eye comes to exercise a permanent influence in producing a decided deformity, and induces the twisting of the

bones of the head. So that in response to the frequent efforts of the young fish, the lower eye is gradually transposed to the side of the body which will hereafter be the uppermost surface, and which will meanwhile have been acquiring its characteristic coloration. Such is the explanation given by competent observers of the manner in which the flat-fishes have acquired their strange modifications of structure. The flat-fishes of to-day acquire this modification in virtue of inherited tendencies and of the effect of habit transmitted through many antecedent generations. But the observation of the stages through which the young animals pass in the seas of to-day, reveals a truthful and unerring history of the fashion in which their far-back progenitors inaugurated the first phases in their singular transformations.

So far as the explanation of the curious features presented by the flat-fishes goes, it is fully supported by facts as they stand. Additional evidence of weighty kind, however, is obtainable from various sources in favour of Goethe's assertion that form of body "determines the animal's way of life," and that "in turn the way of life powerfully reacts upon all form." The evidence that the deformity in question has been acquired through the material contact of surroundings with the bodies of the first flat-fishes is derived from a two-fold source,—firstly, from a view of the various members included in the group of the flat-fishes; and secondly, from our knowledge of the development of abnormal features in other fishes and in other groups of animals. It would certainly afford some ground for Mr. Mivart's remark, that by "natural selection" we might require to postulate the sudden transference of the lower eye to the upper side of the head, if the flat-fishes were found to present a thorough uniformity and similarity in their deformity. If the whole race or family of these fishes, without a single exception, presented the malformations in a typical degree, then the idea of sudden and sharp modification might be rendered probable enough. But the systematic naturalist would inform us that these fishes are not uniformly modified. On

the contrary, they present us with a varied array of forms, at the one extremity of which we meet with symmetrical flat-fishes, having eyes entirely unaltered in position, possessing equal-sized fins, and retaining their young or embryonic characters; whilst at the other extremity of the group we observe fishes in which the deformities obtain their highest development. Thus there is a genus of flat-fishes known as *Hippoglossus* (see Fig. 60), and which includes the various species of halibut. Some species of this group—such as *Hippoglossus pinguis*—retain throughout life the characters, form, and symmetry they present on leaving the egg. From this unaltered and undeformed species of flat-fishes we may pass by easy and gradual transitions to such fishes as the soles, in which the distortion reaches a very typical development. In this fact of the varying degrees of abnormality exhibited by these fishes, we may find a counterproof of the acquirement of these peculiar features. A creative act or a sudden modification would have affected the entire race. A graduated series of forms, exhibiting every degree and stage of abnormal development, shows that the distorted conditions have been not merely acquired, but that they have been favoured in some species to the neglect or escape of others. In the hippoglossi we may see representatives of the original type from which the modern flat-fishes have been evolved; and we may conceive of this evolution having taken place through the laws of ordinary development acting upon bodies, which, from a mechanical cause—that of overbalancing themselves—and from thus being placed in a false position, as it were, have gradually adapted themselves, through a curious modification of form, to a new "way of life."

A second series of facts corroborative of the view that the flat-fishes have thus evolved their peculiar features by adaptation to the outward circumstances of their existence, is furnished by a knowledge of the distortions which follow upon unusual modes of life or accident in other animals. Mr. Darwin mentions the curious fact of human history, authenticated by surgical experience, that "in young persons

whose heads from disease have become fixed either sideways or backways, one of the eyes has changed its position and the bones of the skull have become modified." So also, if one ear of a lop-eared rabbit tends to fall downwards and forwards, its mere weight is found to affect the development and growth of all the bones of the skull, and to cause a forward protrusion of the head on that particular side. Mechanical causes, and the mere action of weight or strain, may thus produce changes of surprising extent in structures of greater firmness than the soft skulls of fishes. The evidence in support of the evolutionist's theory of flat-fish modification, however, is also strengthened by certain cases of distortion which follow upon the habit evinced by the young of certain well-known and symmetrical fishes of resting on one side. Young trout, salmon, and perch have been found to acquire unsymmetrical skulls from this habit; and they have also been seen to strain their lower eyes in the endeavour to look upward, after the fashion of the young flat-fish. One authority, indeed, declares that it is possible that the young of the most modified flat-fishes are in reality unsymmetrically

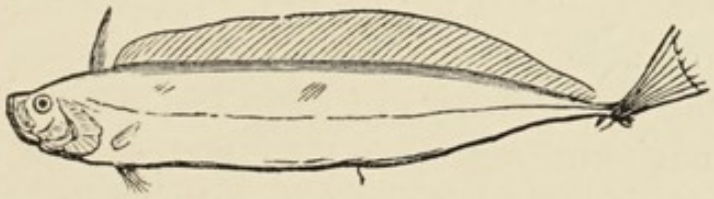


FIG. 61.—*Trachypterus*, or vaagmär, one of the "deal-fishes."

developed even within the egg. This condition, if actually present, must necessarily be viewed as the inherited result of the typical development of the unsymmetrical state in ancestral forms; and its occurrence would render easy of explanation the cause of the young fish losing its balance so soon after its escape from the egg. In some fishes, which are widely removed in their systematic position from the flat-fishes, there is a want of symmetry which compels them to rest on one side. Such are the curious "deal-fishes" (*Trachypterus arcturus*), or vaagmärs (Fig. 61), which derive

their popular name from their exceeding thinness of body, and which are allied to the familar tape or ribbon-fishes. The deal-fish rests on its left side, and, like the flat-fishes, is a bottom-living species. Moreover, it swims diagonally through the water from its want of symmetry, and evinces a disparity in development between the two sides of the head. The occurrence of allied conditions in the heads of higher animals and in other and distinct groups of fishes, would seem to argue clearly and forcibly in favour of like conditions producing like results to those seen in the flat-fishes. Nor must we lose sight of the fact that disuse of the fins of the lower side in the flat-fishes will account for their lesser size, as compared with those of the upper surface; and that the jawbones are stronger and teeth more numerous on the lower side of the head. This latter result accrues naturally from the more constant use of the jaws on the lower side of the head than on the eyed side in the act of feeding on the ground,—a fact pointed out by Dr. Traquair, and which serves to illustrate the influence of "use" in developing structures, as opposed to the effects of "disuse" in rendering organs useless and abortive. From every consideration, we are forced to conclude that the flat-fishes present us with typical examples of animals which owe their peculiar form and habits to the circumstances of their life, associated with the action of environments upon their frame. We learn from the consideration of such features of living beings, not only how perfectly adaptation to circumstances is correlated with structure and life at large, but also how plastic and mobile under the sway of outward forces the living organism may prove. Whilst no less powerfully does the consideration of the flat-fishes and their modifications support the ideas that the existing order of nature is largely due to secondary causes and to mechanical forces which acquire dominance and power over living beings through the effects of perpetuated habit, and of use or disuse continued through long periods of time.

Within the confines of the group of vertebrate animals

ranking next in order to that of the fishes, we may find examples of the relationship between living beings and their surroundings, if anything, of more typical and distinct nature than those presented by the flat-fishes. This group of animals is known as that of the amphibia, and is represented by the frogs, toads, newts, and allied animals, which, in popular phraseology, would be termed "reptiles," although zoologically they form a perfectly distinct group from the latter creatures. It may facilitate the comprehension of the

FIG. 62.—Metamorphosis of the frog.

illustrations about to be brought forward, if we firstly glance at certain of the chief characters by which the class of amphibians is distinguished.

The newts, frogs, toads, and their allies, without exception, pass through a series of changes in form (or *metamorphosis*) in their young condition, and possess breathing

organs in the form of external gills in early life;—facts well known to any one who has seen a young frog in its tadpole stage, and who has had the curiosity to watch the transformation of the tadpole (Fig. 62) into the adult frog. All amphibians further possess lungs in their fully grown condition, whether the gills of early life persist or not. Thus the curious lizard-like proteus, found in the caves of Adelsberg, and the still more curious axolotl of Mexico, exemplify newt-like creatures which retain the gills of early life, and breathe by these organs as well as by the lungs with which they are provided in their adult shape. The common newts of our ponds and ditches, the land-newts of other countries, and the frogs and toads breathe, on the contrary, by lungs alone in their perfect condition; the gills of early life being discarded when these creatures assume terrestrial habits. Thus the newts, although living essentially in water, breathe like the frogs by lungs alone in their adult state; and, like the aquatic and lung-bearing whales, have to ascend periodically to the surface for a supply of atmospheric air.

Bearing these characters of this group of animals in

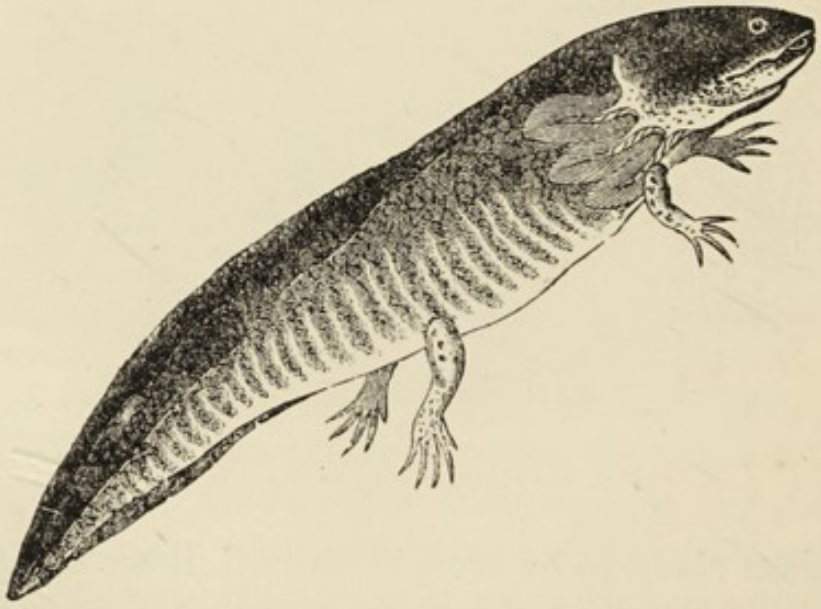


FIG. 63.—The axolotl *(Siredon pisciforme)*, showing the external gills.

mind, the curious nature of the changes through which certain of its members pass may be fully realised. The axolotl (*Siredon pisciforme*, Fig. 63) is a creature inhabiting

the fresh waters of Mexico, and despite its somewhat uninviting appearance, is used in its native regions for food. It is a lizard-like animal; possesses a fin-like flattened tail, which forms an efficient swimming organ; and as a further adaptation to an aquatic existence, possesses three well-developed and fringe-like gills on each side of its neck. Lungs also exist in the axolotl, which is thus a most typical amphibian, in so far as the possession of a double set of respiratory organs is concerned. Its length is about ten or twelve inches, and its colour a dark brown spotted with black. The axolotl has been long known to science as an interesting amphibian; but the possibility that it was only an immature or larval form of some other amphibian, formed perhaps the most noteworthy point in its history. Cuvier appears to have had doubts of its identity; and Mr. Baird, writing of the axolotl, thus says: "It so much resembles the larva of *Amblystoma punctata* (a North American newt), in both external form and internal structure, that I cannot but believe it to be the larva of some gigantic species of the genus." Nothing very definite, however, could be urged in support of the idea that the axoltol was a creature still in the days of its youth; and there existed, moreover, one feature which strongly militated against such a supposition,—namely, that these animals were capable of perfectly reproducing their species, since they were known to produce young freely, both in a state of nature and captivity. Of all physiological tests of an animal's maturity, this latter may be said to be that of the most general application. The law that the perpetuation of the species is a function of adult life only, is, in fact, one of the most universal application. But in 1857, Dumeril laid before the French Academy of Sciences a communication in which he noted the instructive fact that some thirty axolotls had mysteriously emigrated from the water in which they lived peacefully with hundreds of their neighbours, had shed their gills, cast off their skin, and had assumed the colour and appearance of the genus amblystoma (Fig. 64), a well-known group of American land-

newts, which, like other amphibia, possess gills in early life, but breathe when adults by lungs alone. This transformation of the axolotl into a completely different animal, with which it was not known to possess any relationship whatever, excited, as might be supposed, no small amount of interest, especially when the presumably adult nature of the axolotls was kept in view. Professor Marsh, of New Haven, U.S., has placed on record the fact, that a species of axolotl

FIG. 64.—Amblystoma, a North American newt.

(*Siredon lichenoides*) common in the western parts of the United States, also loses its gills and fins when kept in confinement, and exhibits other changes of structural nature. This species further assumes the likeness of a species of amblystoma (*A. mavortium*); and Professor Marsh has also remarked that the changes just described occur when these axolotls are brought from their native lakes—situated in the Rocky Mountains at an altitude of 4500 to 7000 feet—to the sea-level.

The exact causes of these curious changes have only recently, and through the perseverance and ingenuity of a lady experimenter, Fräulein Marie von Chauvin, been brought to light. This lady's experiments confirm in a very striking manner the ideas biologists have been led to form

regarding the influence of surrounding conditions, not merely on living beings in the present but in their past history as well. Dumeril, thinking that excision of the gills might induce the change of form, cut off these organs in the axolotls, but without obtaining a successful result; the animals simply producing new gills in virtue of the power of replacing lost parts so common in their class. But Fräulein von Chauvin, by dint of care and patience, succeeded in enticing five specimens from their native waters by gradually inuring them to a terrestrial existence. The animals were highly refractory as far as their feeding was concerned; but their objections to diet when under experimentation were overcome by the ingenious method of thrusting a live worm into the mouth; whilst by pinching the tail of the worm, it was made to wriggle so far down the amphibian's throat, that the animal was compelled to swallow the morsel. Of the five subjects on which the patience of Fräulein von Chauvin was exercised, three died, after a life of nearly fifty days on land. At the period of their death, however, their gills and tail fins were much reduced as compared with the normal state of these organs. The two surviving axolotls, however, behaved in the most satisfactory manner. Gills and tail fins grew "small by degrees and beautifully less," and apparently by an actual process of drying and shrivelling through contact with the outer air, as opposed to any internal or absorptive action. The animals moulted or shed their skins several times, and finally, as time passed, the gills and tail fin wholly disappeared; the gill-openings became closed; the flattened tail of the axolotls was replaced by a rounded appendage; the eyes became large; and ultimately, with the devolopment of a beautiful brownish-black hue and gloss on the skin, varied with yellow spots on the under parts, the axolotls assumed the garb and guise of the land-amblystomas. It was thus clearly proved that a change of surroundings—represented by the removal of the axolotls from the water, and by their being gradually inured to a terrestrial existence, —has the effect of metamorphosing them into not merely

a new species, but apparently an entirely different genus of animals.

The bearings of this case will be more fully noted hereafter, but we may, as a last example of the influence of surroundings on animal existence, mention Fräulein von Chauvin's experiments on the black Alpine salamander (*Salamandra atra*), a species of land-newt, living on the Alpine range, at heights of about 1000 feet above the sea-level, and in comparatively dry places. As in all other amphibians, the young possess gills, but the possession of gills by immature creatures in dry and stony places would appear to place the animals at a singular disadvantage. How, then, has Nature surmounted the difficulty, and adapted the young animals to their surroundings? Simply by causing the young to undergo their metamorphosis within the body of the parent—these animals being *ovo-viviparous*, that is, retaining the eggs within their bodies until the young are hatched. Thus the young of the Alpine salamander pass their "gilled" condition within the parental body, instead of in water, as do the young of our common newts. But it might be asked, did the young of the Alpine salamander at any previous period in the history of the species, ever live in water; in other words, is their present an acquired condition or not? Fräulein von Chauvin's experiments supply a clear reply to this question.

Of two young salamanders possessing external gills, which were taken from the body of the parent and which were placed in water, one died; the survivor casting off its first set of gills four days afterwards, and actually developing a second and larger set of unusual form, but probably resembling those with which these animals in their original water-habitation were provided. A tail fin was also developed, and for fifteen weeks this young salamander, at a time when it should have been living a terrestrial existence, enjoyed its life in water. At the expiry of that period, however, the gills were cast off, and the animal appeared in the likeness of its land-living parent. Succeeding experiments of Fräulein von Chauvin on the development of the Alpine salamander served

to reveal other interesting details, supplementing in a remarkable manner that lady's previous observations. Two larvæ, the survivors of a set of twenty-three, were placed in water; one of these young salamanders being somewhat more advanced in development than the other. The younger possessed six red gills of branched form, and of such a size that they appeared to impede its movements in swimming. Soon after being placed in the water, these gills began to shrivel, and were finally rubbed off by the movements of the animal against the sides of the aquarium so that it appeared to be entirely destitute of breathing organs. It lay quiescent in the bottom of the vessel for three days, three new gills of different structure from the first organs being then developed on each side of the head; whilst the new breathing organs were much shorter than the discarded gills, and did not interfere with its movements in swimming. A new tail fin had also been developed in place of the first with which it was provided, the second appendage being the larger of the two. After fourteen weeks of aquatic life, the gills began to decrease in size, and the tail to become rounded, and in a few days more the young animal cast its skin, quitted the water, and assumed the form, colour, and entire aspect of the adult. The second specimen, which, as already remarked, was more advanced in development than the first, assumed the likeness of the adult after a much shorter existence in the water. The young appeared to be perfectly at home in the water, and fed greedily when they entered it; this fact being somewhat remarkable in view of the present life and modern development of the species.

That the present course of development in the Alpine salamander is an acquired condition, and one altered from its original state, there can be no doubt. Its mere relationship to its amphibian kith and kin proves this assertion to be true; whilst the fact that the young will live for an extended period in water, and the mere presence of gills in the young state, place the altered nature of these animals beyond a doubt. The development of useless gills in the

young salamander cannot be explained by any such phrases as "adherence to type," "unity of type," "natural symmetry," and the like,—unless, indeed, we may suppose that Nature imitates humanity in its anxiety for symmetry, and supplies the young salamander with gills which never were used, and which never were meant to be used, on the principle of an architect who places blank windows and painted imitation blinds on a house under the idea of securing uniformity. Such a practice, admittedly far from æsthetic in architecture, is positively degrading when applied to the explanation of Nature's ways and works. It is an idea, besides, which is founded on pure and baseless assumption, and as such demands no further notice. The opposing view, which regards the gills of the young Alpine salamander as the representatives of organs which, at a former period in the history of the species, were used for breathing in its water-living stages of development, is, on the other hand, not only reasonable and consistent, but also demonstrates how great an alteration in the nature of a living organism a change of surrounding conditions may induce. As Mr. G. H. Lewes remarks, "this aquatic organisation has no reference to the future life of the animal, nor has it any adaptation to its embryonic condition; it has solely reference to ancestral adaptations, it repeats a phase in the development of its progenitors." That the change in the Alpine salamander's mode of development has, in reality, been one entirely dependent upon external causes, is a suggestion which, as made by Fräulein von Chauvin, carries weight with it in support of the idea of the close relationship between living beings and their environments. Want of food would thus be a condition which could scarcely be conceived as having driven the Alpine newt to its high habitat, since the dietary would become scarcer and more difficult to obtain the higher the altitude it reached. More probable is the idea that slow elevation of the land surface was the cause of the change in habits and development. A slow rise of land would imply an equally gradual alteration

of habits, as water-pools became less numerous. The young, at first born alive and gilled, would be produced at less frequent intervals and in fewer numbers, whilst they would also be retained for longer periods within the parent-body. This view accords with the actual detail of the animal's life. For only two young are produced at a birth by these animals; the other eggs serving as food for the developing minority. This latter remarkable feature of the sustenance of the young by their immature brethren can, of course, be regarded only in the light of an acquired condition, and as one which has arisen out of the needs and necessities of the species.

The conclusions to which the earnest and unbiassed student of Nature may arrive regarding any points involved in his studies may very frequently be found to be greatly at variance with the notions of natural law and order that prevail in the world at large. But as Tyndall has well remarked, "in the choice of probabilities the thoughtful mind is forced to take a side;" and the attitude of the seeking mind towards natural phenomena and their explanation must ever be that of estimating causes by the likelihood and value of the evidence brought to light. Judged by the standard of once-popular faith, that the living things of the world were created as we find them, the cases of the flat-fishes and amphibians do not seem very promising, it must be confessed. But the choice of a side admits of no hesitancy here. The evidence that outward and mechanical agencies, operating upon living bodies and correlating themselves with the forces and ways of life, are the causes of the peculiarities we have noted, is too forcible to be for a moment doubted. A peculiar form or shape of body, a rise of land, and the influence of the "law of likeness" in perpetuating the variations thereby produced,—such are the causes and means through which the greater portion of the world of life has been and is still being moulded. How much in any case may be due to the influence of outward causes, and what amount of power we are to ascribe to the

internal forces and constitution of living beings, no one may dogmatically assert. But our ignorance of the exact relations of these causes to outward conditions, will not militate in any way against the recognition of the power of the latter to effect change and alteration in living nature. In the axolotl, the external influences of a land life are seen to cause gills and tail fin to shrivel and ultimately to disappear. In the young salamander, on the contrary, the vital process of absorption must apparently be credited with the chief share of the work of modification, and of causing gills and other larval structures to become abortive. In the flat-fishes a mechanical cause, namely, a tendency to lopsidedness, presents us with the primary reason for the peculiar development and position of the eyes. And we thus see in the case of the axolotl, the mechanical beginnings of actions, which in the flat-fishes and Alpine salamander have been operating through long periods of time, and which, through the agency of the law of likeness and heredity, have become well-defined characters of the species. Admitting that variations may begin from without, that they are transmitted to posterity, and that as time passes they may come, as we have seen, to represent the "way of life," we are thus placed in possession of rational ideas regarding the manner in which cause and effect in one phase of nature are related. And if it be urged that great are the mysteries which yet beset the "ways of life," the knowledge we have obtained of even a small part of the order of Nature may still be shown to lead towards a fuller and wider comprehension of the universe and its laws. We are now only studying the alphabet of Nature. A little patience—and we may be able to say with Shakspeare's soothsayer :—

"In Nature's infinite book of secrecy
A little I can read."

WHAT I SAW IN AN ANT'S NEST.

Amongst those spectacles and incidents in human existence which remain fixed on the memory of the spectator from their sad or unwonted nature, that of a panic-stricken crowd, gathered by the report of some national disaster, stands pre-eminent. Still more terrible in its details is the history of some catastrophe which has laid a city in ruins and wrought death and desolation to thousands of the inhabitants. A deadly epidemic, or fatal plague, searing a nation with its dread, mysterious power, is a calamity appalling enough; but the spectacle of a city overthrown at one fell swoop by the earthquake shock, may perhaps rank foremost amongst the untoward incidents which environ the sphere of man. A certain event, occurring during a recent holiday by the sea, tended forcibly to impress upon the mind that the great catastrophes of life are not limited to humanity's special sphere, and that in lower life panic and alarm seem to exercise no small influence, as in man's estate; whilst the incident referred to also afforded food for reflection on topics not far removed from some weighty matters in the history of man's own nature and constitution. In this latter view, it is especially hoped the observations of a brief period of leisure-time may not be without their due meed of interest.

The chance removal, from its secure site, of a large stone placed in close proximity to the sea-beach, where the bliss of idleness was being fully exemplified by a small party of holiday-makers, proved, on close examination, to be the cause of a literal revolution in lower life. Imagine a city to

be totally unroofed; try to conceive of the sudden downfall of houses and buildings, and the consequent panic of the inhabitants, and you may obtain an idea of the disturbance our simple procedure effected in the peaceable, well-ordered colony of ants which had located themselves securely beneath the friendly shelter of the stone. The scene presented to view was one of the most curious and interesting which could engage the attention of an observer in any field of inquiry, and the occurrence certainly banished the idle mood of the time, and lent a zest to the subsequent hours of our holiday. Running hither and thither in wild confusion were the denizens of this underground colony; their six little legs carrying their curious globular bodies backwards and forwards over the disturbed area from which the stone had been removed. At first the movements of the ants were extremely erratic and purposeless. Panic and alarm appeared to be the order of the day during the few minutes which elapsed after the removal of the stone. But soon the eye could discern movements of purposive kind on the part of the alarmed residents. There was "racing and chasing" in all directions; but the ants which had at first radiated from the centre of disturbance, as if on some definite quest, soon returned thereto, and continued to advance and retire from the field of action with tolerable regularity. Not less than sixty or seventy ants appeared to be engaged in this labour of scouring the country around. The object of their repeated journeys in all directions was soon discovered. They were the self-appointed scouts, engaged in the work of reconnoitring. Such at least is a fair interpretation of the acts of the ants, and such also is the conclusion, borne out by the subsequent course of events. For, after the scouts had spent a considerable time in their rapid journeys to the environments of the nest, a new set of ants appeared upon the scene, destined to perform a highly important series of labours.

The scouts continued their journeyings, and gave one the idea of a set of fussy individuals who were superintend-

ing, or even bullying, their new neighbours, who appeared from amongst the ruins and *débris* of the ant city, carrying in their mouths certain oval bodies of a dirty-white colour, and measuring each about one-third of an inch in length. Each of these bodies closely resembled a grain of corn in shape, size, and appearance. The spectacle of these small insects carrying off these bodies in their powerful jaws impressed one forcibly with the idea that, relatively to its size, an ant is an herculean insect.

Occasionally there might be seen certain rather ludicrous incidents connected with the removal of the objects in question. One ant might be witnessed in the endeavour to hoist the oval body it was carrying in its mouth over some obstacle lying in the path, and the staggering gait of the insect seemed very accurately to mimic the similar disposition of a human porter struggling under a burdensome load. Another ant, carrying the oval body before it, would arrive at a steep incline formed of loose sand, and presenting a treacherous surface even to the light feet of the insect. The efforts of the ant to carry the body upwards being found to be fruitless, the insect might be seen to whirl about with great rapidity of action, and to ascend the hill backwards, pulling the body after it, instead of pushing it as before.

Another instance might be witnessed in which an ant which had literally come to grief with its burden would be assisted by a kindly neighbour; but it was no uncommon sight to behold in the excessive eagerness of the insects an actual means of defeating the object they had in view, since two ants would in same cases seize the same burden, and then came the tug of war. One pulled one way whilst the other tugged in the opposite direction; and the observer could almost have supposed that the burden itself might have been parted in twain by the treatment to which it was subjected,—the incident affording a new application of the remark that a surfeit of zeal is destructive of the best intentions. The nature of the bodies which the ants seemed so excessively anxious to preserve from injury was readily determined.

The oval bodies, resembling grains of corn, were the *pupæ* or *chrysalides* of the ants,—the sleeping babies and young hopefuls, on whom the hopes of the colony were, and, I may say, are, founded. It is noteworthy, however, that upon some mistaken notion regarding the nature of these bodies many of the ideas concerning the frugal care of these insects were founded. Solomon's advice that the sluggard should "go to the ant," with the view of considering her ways and of gaining wisdom as a result of the study, was in days of old thought to be approved by the observation that the ants husbanded their stores of food in the shape of the grains of corn they had gained from the autumnal store. There can be little doubt that some species of ants do store food; but their praiseworthy actions in this direction have been greatly exaggerated, and there appears, indeed, to be some danger of idle persons being prepared with the retort to the wise man, that the ant is by no means the model creature he thought her to be. If, however, the supposed corn-grains turn out to be the rising generation of ants in their chrysalis-state, it may be said that what the ants may have lost in the way of fame in this direction has been amply compensated for by the discovery of more wonderful traits of character than Solomon could possibly have dreamt of.

The work of removing the developing population thus appeared in our ant's nest to absorb the entire energies of the alarmed denizens. Pupa after pupa was carried out from amongst the *débris* and taken for a considerable distance—certainly fifteen inches—to a place of security, beneath a small sloping stone of flat shape, which roofed over a hollow in the ground. So far as I could observe, the scouts must have discovered this place of refuge, and have communicated the intelligence to their neighbours. The regularity with which the slumbering innocents were conveyed to the same spot would appear to point to concerted work and to a definite idea, if one may so term it, having animated the labourers. I was careful to ascertain at an early stage of the proceedings that the place of refuge had no communication

with the nest. It was, in point of fact, an entirely new habitation, and, as far as human judgment might venture upon an opinion, the new residence appeared to give promise of being a safe and convenient domicile. Now and then an ant would emerge from the ruins of the nest carrying a younger, hopeful in the larva or caterpillar stage. This latter was a little white grub, which corresponds in its development to the grub or caterpillar of the butterfly or fly; the ants thus exemplifying insects which undergo a complete "metamorphosis." It was rather a difficult matter to ascertain clearly if the ants were actually excavating the chrysalides from amongst the *débris*. Bearing in mind what Sir John Lubbock has told us concerning the apparent inability of ants to discover the whereabouts of companions buried under earth, I rather lean to the belief that my ants simply conveyed to a place of safety those chrysalides which were at hand and readily obtainable. The latter fact I could not ascertain, since I feared to disturb the ants at their interesting labours; but a simple experiment served to show the feasibility of the idea that the chrysalides were probably within easy reach of the ants.

Taking possession of one chrysalis which was being conveyed to the new domicile, I buried it about half an inch deep in the sand, directly in the track over which the ants were journeying to their new residence, and a second chrysalis I placed at a little distance from this track, but in a spot over which numerous ants were running apparently without any definite aim. The second pupa-ant was not buried in any sense, and was covered merely with a sprinkling of sand. The result in both cases was negative. No attempt was made to disinter the chrysalis from the beaten track, although numberless ants walked directly over it; and I extricated the chrysalis five hours after its interment, and when the busy scene of the morning had been replaced by a dull prospect, over which only a single ant now and then hurried in a rapid fashion. The other chrysalis was also unnoticed, despite its proximity to the surface

of the sand. Whether or not ants want a sense of smell or other means of guiding them to the whereabouts of their neighbours or children, is a subject difficult of determination either towards a positive or negative result. And I am the more inclined to wonder at the incapacity of the insects to discover their buried companions, since they appear to be perfectly capable of detecting them at a considerable distance above ground. When a chrysalis was placed in a spot remote from the nest, and an ant placed within a foot or so of the chrysalis, the insect would occasionlly seem to be attracted to the neighbourhood of the object. I frequently observed that if an ant happened to crawl within two or three inches of the chrysalis as it lay on the ground, it appeared to become conscious of the object, although at the same time it seemed ignorant of its precise locality. In such a case the insect would proceed hither and thither in an erratic fashion, but would continue to hover or rotate around the chrysalis until it seized the object and bore it off in triumph in its jaws. Relatively to the size of the ant, we must consider this latter incident by no means a slight tribute to its acuteness.

The busy scene resulting from the disturbance of the nest proceeded actively during at least two hours. The nest appeared to be by no means a large one. At the end of two hours, however, the ants were still rushing hither and thither, bent on errands unknown to their observers, although the work of conveying the chrysalides had at the lapse of the period just mentioned entirely ceased. Five and a half hours after the nest had been alarmed, not an ant was visible over the disturbed area, and our next task was that of investigating the manner in which the insects had dispersed themselves and their belongings in their new habitation by carefully removing the flat sloping stone already mentioned as that beneath which the main stream of the ants had disappeared. Not an insect was to be seen after this operation was performed, and it was only after the removal of several small stones which lay below the flat

stone that the colony in its new sphere was brought into view. Our investigation once again excited the restless beings. Then ensued, for the second time, the seizure of the chrysalides, which, however, were to be seen packed together in a secure position and already partly covered with particles of earth and sand. To have reached the position in which we found them, the insects must have descended at least three inches after entering below the stone, and the labour of the continual ascent in search of fresh chrysalides must therefore have been of no light kind. We saw enough to convince us that the ants had already settled down in a new organisation, which, with an undisturbed history, might repeat the peaceful state of their former life; and we also had the thought presented, that in the exercise of their duties under the pressure of an unwonted exigency, the insects behaved and acted with no small degree of intelligence, and apparently in harmonious concert to the desired end.

But the thoughts suggested by the brief observation of the disturbed ant's nest hardly end thus. We may very naturally proceed to inquire into the regular organisation and constitution of the ant colony, and also, as far as fact and theory may together lead, into the analogies—if analogies there be—which exist between the social instincts of ants and the ways of the higher animals, man included.

The common ants and their neighbours belong to the order of insects known as the *Hymenoptera*, a group represented by other insects of "social" habits, such as bees, wasps, and hornets. The termites, or white ants of the tropics, are the only "ants" foreign to this order of insects, the white ants being near relations of the dragon-flies, May-flies, etc. The family history of the latter, as told by Mr. Bates, may serve to introduce us agreeably to ant society at large. The nests of the termites may attain a height of five feet, and present the appearance of conical hillocks, formed of earth particles "worked," says Mr. Bates, "with a material as hard as stone." In the neighbourhood of the nests, nar-

row covered galleries or underground ways are everywhere to be seen, these latter being the passages along which the materials used for building the nests are conveyed. The termites are small soft-bodied animals of a pale colour, but resemble the common or true ants in that they live in colonies, composed, like those of bees, of three chief grades of individuals. These grades are known as males, females, and blind "neuters," the latter forming at once the largest bulk of the population, and including in their numbers the true

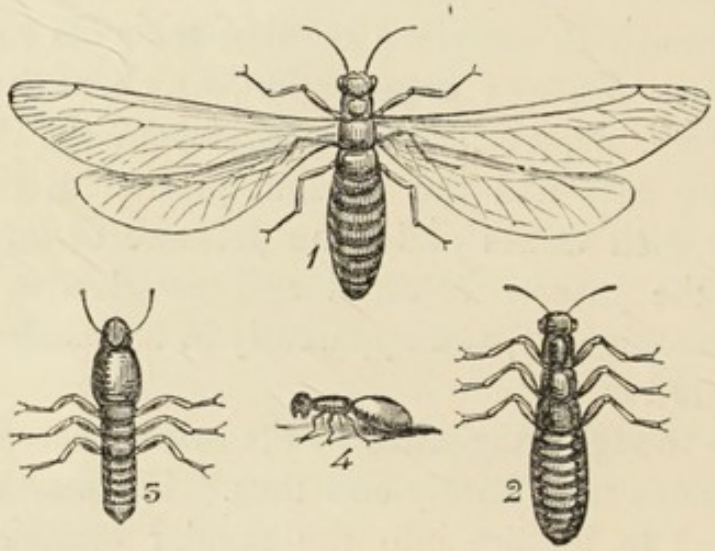


FIG. 65.—1, winged termite; 2, wingless termite; 3, soldier; 4, worker.

"working classes" of this curious community. In the common ants, the "neuters" are regarded as being undeveloped female insects. These neuters exhibit in the termites a further division into ordinary "workers," (Fig. 65, 4) which perform the multifarious duties connected with the ordinary life of the colony, and "soldiers" (3), which perfectly exemplify the laws of military organisation in higher life, in that they have no part in the common labour, but devote themselves entirely to the defence of the colony and to the—

"Pride, pomp, and circumstance of glorious war."

The workers appear to perform a never-ending round of duties. They build the nests, make the roads, attend to the wants of the young, train up the latter in the ways of ant existence, wait on the sovereigns of the nest, and, like

diplomatic courtiers, duly arrange for the royal marriages of the future. As Mr. Bates remarks, "The wonderful part in the history of the termites is, that not only is there a rigid division of labour, but nature has given to each class a structure of body adapting it to the kind of labour it has to perform. The males and females form a class apart; they do no kind of work, but in the course of growth acquire wings to enable them to issue forth and disseminate their kind. The workers and soldiers are wingless, and differ solely in the shape and armature of the head. This member in the labourers is smooth and rounded, the mouth being adapted for the working of the materials in building the hive. In the soldiers the head is of very large size, and is provided in almost every kind with special organs of offence and defence in the form of horny processes resembling pikes, tridents, and so forth. . . . The course of human events in our day seems, unhappily, to make it more than ever necessary for the citizens of civilised and industrious communities to set apart a numerous armed class for the protection of the rest; in this, nations only do what nature has of old done for the termites. The soldier termes, however, has not only the fighting instinct and function; he is constructed as a soldier, and carries his weapons not in his hand but growing out of his body." When a colony of termites is disturbed, the ordinary citizens disappear and the military are called out. The soldiers mounted the breach, says Mr. Bates, "to cover the retreat of the workers," when a hole was made in the archway of one of their covered roads, and with military precision the rear-men fall into the vacant places in the front ranks as the latter are emptied by the misfortune of war.

In a termite colony there is but one king and queen, the royal couple being the true parents of the colony. The state-apartments are situated in the centre of the hive, and are strictly guarded by workers. Both king and queen are wingless, and are of larger size than their subjects. The queen engages in a continual round of maternal duties, the

eggs deposited by the sovereign-mother being at once seized by the workers and conveyed to special or "nursery cells," where the young are duly tended and brought up. Once a year, at the beginning of the rainy season, winged termites appear in the hive as developments of certain of the eggs laid by the queen-termite. These latter are winged males and females (Fig. 65, 1), the two sexes being present in equal numbers. Some of these, after shedding their wings, become the founders—kings and queens—of new communities, the privilege of sex being thus associated with the important and self-denying work of perpetuating the species or race in time. Sooner or later—a termite family takes about a year to grow—a veritable exodus of the young winged termites takes place; and just before this emigration movement occurs, a hive may be seen to be stocked with "termites" of all castes and in all stages of development. The workers never exhibit a change of form during their growth; the soldiers begin to differ from the workers in the possession of larger heads and jaws; whilst the young which are destined to become the winged males and females are distinguished by the early possession of the germs of wings which become larger as the skin is successively moulted. Amongst the bees, blind Huber supposed that an ordinary or neuter egg develops into a queen bee if the larva is fed upon a special kind of food—"royal food," as it is called. Although some entomological authorities differ from Huber with regard to the exact means by which the queen bee is reared and specialised from other larvæ, yet the opinion thus expressed possesses a large amount of probability. Whatever may be the exact method or causes through or by which the queen bee is developed, Mr. Bates strongly asserts that the differences between the soldiers and worker termites are distinctly marked from the egg. This latter observer maintains that the difference is not due to variations in food or treatment during their early existence, but is fixed and apparent from the beginning of development. This fact is worthy of note; for it argues in favour of the view that if,

as is most likely, the differences between the grades of termites may have originally been produced by natural selection or other causes, these differences have now become part and parcel of the constitution of these insects, and are propagated by the ordinary law of heredity. Thus acquired conditions have become in time the natural "way of life" of these animals.

Mr. Bates has also placed on record the noteworthy fact that a species of termites exists in which the members of the soldier class did not differ at all from the workers "except in the fighting instinct." This observation, if it may be used at all in elucidation of the origin of the curious family life of these insects, points not to sudden creation, but to gradual acquirement and modification as having been the method of development of the specialised classes and castes in termite society. Firstly, we may thus regard the beginnings of the further development of a colony to appear in a nest in which workers and soldiers are alike, as stated by Mr. Bates. Then, through the practice of the fighting instinct, we may conceive that natural selection would be competent to adapt the soldiers more perfectly for their duties militant, by developing the head and jaws as offensive weapons. Possibly, were our knowledge of the termites at all complete, we should meet with all stages in the development and specialisation of the various grades of society amongst these insects,—at least the present state of our knowledge would seem to lead to such a conclusion as being much more feasible than the theory of special or sudden creation of the peculiarities of the race. It is admitted that the termites are in many respects inferior in structure to the bees and wasps, whilst the white ants themselves, are the superiors of their own order—that of the *Neuroptera.* That the termites preceded the bees and their neighbours, the common ants, in the order of development of social instincts is a conclusion supported by the fact that the *Neuroptera* form the first group of insects which are preserved to us in the "records of the rocks." Fossil *Neuroptera* occur in the Devonian rocks of North America; the first traces of

insects allied to the bees and wasps being geologically more recent, and appearing in the oolitic strata. The occurrence of high social instincts in an ancient group of insects renders the repetition of these instincts in a later and higher group the less remarkable. The observation, however, does not of necessity carry with it any actual or implied connection between the termites and their higher neighbours, although, indeed, the likenesses between the social life of the two orders of insects might warrant such a supposition.

The common ants (Fig. 66), the study of which in their native haunts is a matter of no great difficulty, and one which will fully reward the seeking mind, like the termites, possess three grades of individuals. In a single ant's nest more than one female may be found, the ants differing from the bees in this respect; and in the nests of some species of ants there are apparently "soldiers" resembling the military termites in the possession of large heads and well-developed jaws. Very amazing differences are to be perceived amongst

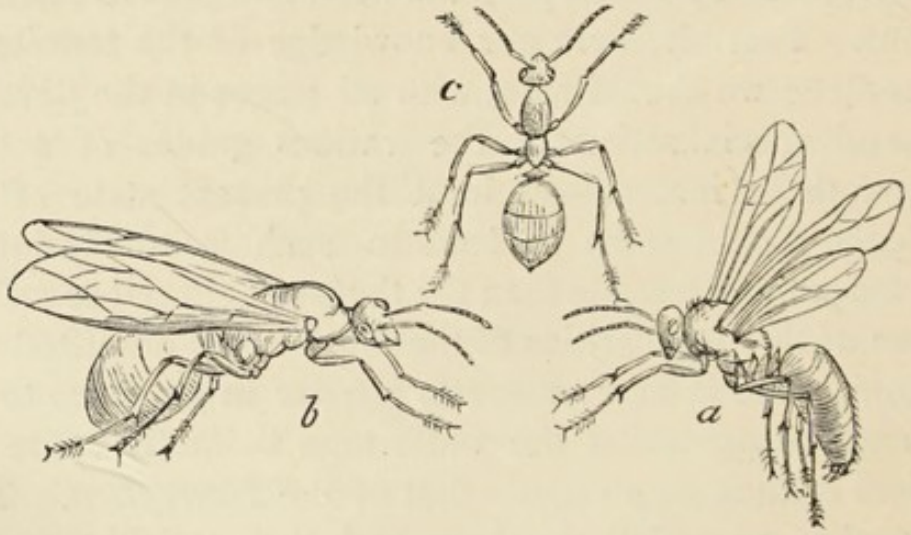


FIG. 66.—Red, or horse-ant (*Formica rufa*): *a*, male; *b*, female, winged; *c*, worker.

the various species of ants. Differences in size are of common occurrence, but naturalists have actually succeeded in classifying ants in a general way, by differences in manner and disposition. We know, for example, that the horse-ant

(*Formica rufa*, Fig. 66), has little *individual* intelligence, but is extremely socialistic, and moves and acts *en masse* with precision and tact. Another species (*F. fusca*) is timid and retiring. *F. pratensis* is a revengeful creature, since it "worries" its fallen foes; *F. cinerea* is bold and audacious; others are termed "thieves" and "cowards;" some are phlegmatic; and to complete the list of failings and traits which are human enough in character, one species is said to present an invariable greediness as its prevailing characteristic. The common ants resemble the termites in the general details of their life. We see in an ant's nest the same restless activity of the workers, the same earnest attention paid to the young and pupæ, the same instinct in shielding the young from danger, and much the same general routine of development. Certain rather special, and it may be said extraordinary, habits of ants may, however, demand notice before

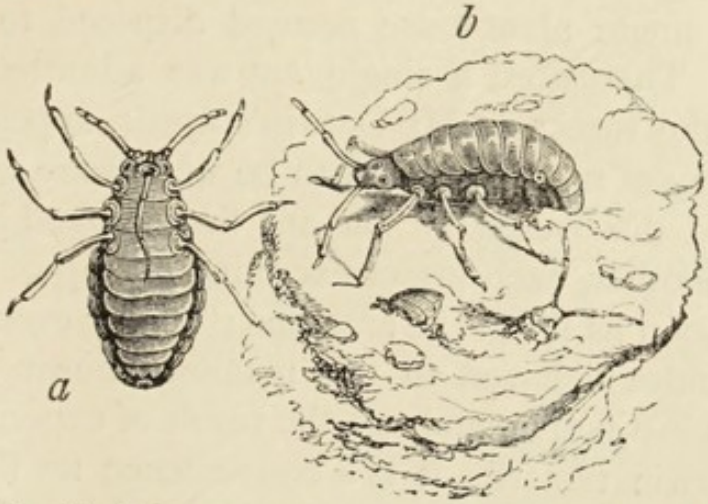


FIG. 67.—Apple aphis (*Eriosoma mali*): *a*, wingless insect, magnified; *b*, wingless insect in excrescence of the tree, magnified.

we attempt a brief survey of their instincts at large. Few readers are unacquainted with the *Aphides*, or plant-lice, those little wingless insects which infest our plants and herbs in myriads in summer. It is a fact now well known to naturalists, and first placed on record by Huber, that between the ants and plant-lice, relations of a very friendly and, as far as the ants are concerned, advantageous character have become established. Ants have been observed to stroke the tips of

the bodies of the plant-lice with their antennæ, this act causing the plant-lice to exude drops of a clear sweet fluid, of which the ants are extremely enamoured. The ants would thus appear to habitually "milk" their insect-neighbours, and, as far as observation goes, some ants seem not merely to keep the plant-lice in their nests so as to form a veritable dairy-establishment, but also to make provision in the future by securing the eggs of the aphides, and bringing up the young as we rear calves.

That the relations between the ants and plant-lice are of very stable kind is proved by the interesting remarks of Mr. Darwin, who "removed all the ants from a group of about a dozen aphides on a dock-plant, and prevented their attendance during several hours." Careful watching showed that the plant-lice after this interval did not excrete the sweet fluid. Mr. Darwin then stroked the plant-lice with a hair, endeavouring thus to imitate the action of the ant's feelers, but not a single plant-louse seemed disposed to emit the secretion. Thereafter, a single ant was admitted to their company, the insect, in Mr Darwin's words, appearing, "by its eager way of running about, to be well aware what a rich flock it had discovered." The ant first stroked one aphis, and then another, each insect excreting a drop of the sweet juice "as soon as it felt the antennæ;" and "even the quite young aphides behaved in this manner, showing that the action was instinctive, and not the result of experience." If, as Mr. Darwin remarks, it is a convenience for the aphides to have the sweet secretion removed, and that "they do not excrete solely for the food of the ants," the observation does not in any degree lessen the curious nature of the relationship which has become established between the ants and their neighbours, or the interesting features in ant life which have inaugurated and perpetuated the habit.

Not less remarkable are the "slave-making" instincts of certain species of ants. It may be safely maintained that the slave-making habit forms a subject of more than ordinary interest not merely to naturalists but to metaphysicians

given to speculate on the origin and acquirement of the practices of human existence. Pierre Huber, son of the famous entomologist, was the first to describe the slave-making instinct in a species (*Polyergus rufescens*) noted for its predaceous instincts, and subsequent observations have shown that other species participate in these habits. *Polyergus* is thoroughly dependent on its slaves. Without these bondsmen it is difficult to see how the ants could exist. Huber tells us that the workers of this species perform no work save that of capturing slaves. Use and wont, and the habit of depending entirely on their servitors, have produced such changes in the structure of these ants, that they are unable to help themselves. The jaws of these ants are not adapted for work; they are carried by their slaves from an old nest to a new one; and, more extraordinary still, they require to be fed by their slaves, even with plenty of food close at hand. Out of thirty of these ants placed by Huber in a box, with some of their larvæ and pupæ, and a store of honey, fifteen died in less than two days of hunger, and of sheer inability to help themselves. When, however, one of their slaves was introduced, the willing servitor "established order, formed a chamber in the earth, gathered together the larvæ, extricated several young ants that were ready to quit the condition of pupæ, and preserved the life of the remaining Amazons." It must be noted, that there are very varying degrees in the dependence of the ant-masters on their slaves. In the recognition of this graduated scale of relationship and dependence, indeed, will be found the clue to the acquirement of this instinct. The horse-ant (*Formica rufa*) will carry off the larvæ and pupæ of other ants *for food*, and it sometimes happens that some of these captives, spared by their cannibal neighbours, will grow up in the nest of their captors. A well-known ant, the *Formica sanguinea*, found in the South of England, is, however, a true slave-making species, but exhibits no such utter dependence on its servitors as does *Polyergus*. The slave-making habit is not only typically developed in the *Sanguineas*, but

the bearing of the captives to their masters indicates a degree of relationship and organisation such as could hardly be conceived to exist outside human experience. The *Sanguineas* make periodical excursions, and, like a powerful predatory clan, carry off the pupæ or chrysalides of a neighbouring species, *F. fusca*. Thus the children of the latter race are born within the nests of their captors in an enslaved condition. As slaves "born and bred," so to speak, they fall at once into the routine of their duties, assist their masters in the work of the nest, and tend and nurse the young of the family. The slaves, curiously enough in this instance, are black in colour, whilst the masters are twice the size of the servitors, and are red in colour, and that the slaves are true importations is proved by the fact that males and females of the slave species are never developed within the nest of the masters, but only within those of their own colonies. The slaves in this instance rarely leave the nest, the masters foraging for food, and employing their captives in household work, as it were; whilst, when the work of emigration occurs, the masters carry the slaves in their mouths like household goods and chattels, instead of being carried by them, as in the case of *Polyergus*.

Mr. Darwin gives an interesting account of the different attitudes exhibited by the *Sanguineas* towards species of ants other than the black race from which their slaves are usually drawn. A few pupæ of the yellow ant (*F. flava*), a courageous and pugnacious little species, were placed within reach of the slave-making *Sanguineas*. A like chance presented with the pupæ of their slave race was eagerly seized, and the chrysalides carried off. The pupæ of the yellow ants, however, were not merely left untouched, but the slave-makers exhibited every symptom of terror and alarm at the sight of the chrysalides of their yellow neighbours. Such an instance demonstrates the existence not merely of perception but also of the memory of past experience, probably of not over-agreeable kind, of encounters with the yellow ants. When, on the contrary, a

nest of the slaves is attacked, the *Sanguineas* are both bold and wary. Mr. Darwin traced a long file of *Sanguineas* for forty yards backwards to a clump of heath, whence he perceived the last of the invaders marching homewards with a slave pupa in its mouth. Two or three individuals of the attacked and desolate nest were rushing about in wild despair, and "one," adds Mr. Darwin, "was perched motionless, with its own pupa in its mouth, on the top of a spray of heath, an image of despair over its ravaged home." The picture thus drawn is not the less eloquent because its subject is drawn from lower existence; although the pains and sorrows of ant life may not legitimately be judged by the standard of human woe.

The explanation of the slave-making instinct in ants begins with the recognition of the fact that many ants, not slave-makers, store up pupæ of other species for food. If we suppose that some of the pupæ, originally acquired through a cannibal-like instinct, came to maturity within the nest of their captors, and in virtue of their own inherited instincts engaged in the work of the hive, we may conceive of a rational beginning of the slave-making instinct. If, further, the captors learned to appreciate the labours of their captives, as lightening their own work, the habit of collecting pupæ as slaves might succeed and supersede that of collecting them for food. In any case, we should require to postulate on the part of the slave-makers a degree of instinct altogether unusual in insects, or, indeed, in higher animals; but that such instinct is developed in ants other than slave-makers admits of no dispute. The strengthening, through repetition, of a habit useful to the species, may thus be credited with the beginning of the practice of slavery amongst ants; whilst special circumstances—such as the number of slaves as compared with the number of masters—would tend to develop a greater or less degree of dependence of the captors or their servitors.

Huber, for instance, informs us that the *Fusca*-slaves of the *Sanguineas* of Switzerland, work with their masters in

building the nest; they close and open the doors of the hive; but their chief office appears to be that of hunting for plant-lice. In England, on the contrary, the slaves are strictly household servants, rarely venturing out of doors. Such differences depend most probably on the fact that a greater number of slaves occur in Swiss than in English nests, and they may therefore be employed in a wider range of duties on the Continent than at home. A fewer number of slaves, a greater aptitude on the part of the slaves for their duties, the inability of the masters to perform the duties of the slaves,—each or all of these causes combined would serve to increase the value of the servitors, and at the same time to reduce the independence of the masters.

This increase of the value of the slaves as active factors in the ant community, might at length proceed to such extremes as we see exemplified in the *Polyergus*, already referred to,—a race which has become literally unable to feed itself, and to discharge the simplest duties of ant existence, and whose actual life is entirely spent in marauding expeditions on the nests of its neighbours.

The subject of the general intelligence of ants, and of their ability to adapt themselves to awkward and unusual circumstances, may be briefly touched upon by way of conclusion.

Between the reason and intelligence of higher animals and the "instinct" of ants there is unquestionably a great gulf fixed. I make this statement unhesitatingly, notwithstanding that I should no more willingly attempt to define "instinct" than to give an exact definition of "insanity." In the latter case one may make the definition so limited, as practically to exclude all save one class of cases, or so wide as to include even the judge on the bench. In the case of instinct, the rigid definition of one authority might cause us to regard it as the exclusive property of lower forms and as having no relationship whatever with the mental powers of higher beings; or, on the other hand, as being but a modified form of, or in some respects identical with, these very powers. We know too little respecting the so-called "auto-

matic" powers and ways, even of higher animals, to dogmatise regarding the acts of lower animals, but we may safely assume that one apparent ground of distinction between instinct and reason may be found in the common incompetence of instinct to move out of the beaten track of existence, and in the adaptation of reason, through the teachings of experience, to new and unwonted circumstances. Let Dr. Carpenter, quoted in a previous paper, speak as an authority on such a subject. "The whole nervous system of invertebrated animals, then, may be regarded as ministering entirely to *automatic* action; and its highest development, as in the class of insects, is coincident with the highest manifestations of the 'instinctive' powers, which, when carefully examined, are found to consist entirely in movements of the excito-motor, and sensori-motor kinds. (The terms '*excito-motor*' and '*sensori-motor*' are applied to nervous actions resulting in movements of varying kinds, and produced by impressions made on nervous centres, but without any necessary emotion, reason, or consciousness.) When we attentively consider the habits of these animals, we find that their actions, though evidently adapted to the attainment of certain ends, are very far from evincing a *designed* adaptation on the part of the beings that perform them. . . . For, in the first place, these actions are invariably performed in the same manner by all the individuals of a species, when the conditions are the same; and thus are obviously to be attributed rather to a uniform impulse than to a free choice, the most remarkable example of this being furnished by the economy of bees, wasps, and other 'social' insects, in which every individual of the community performs its appropriated part with the exactitude and method of a perfect machine. The very perfection of the adaptation, again, is often of itself a sufficient evidence of the unreasoning character of the beings which perform the work; for, if we attribute it to their own intelligence, we must admit that this intelligence frequently equals, if it does not surpass, that of the most accomplished Human Reasoner."

Appealing to the most recent observations on ants, we may find evidence of the truth of Dr. Carpenter's statements, whilst at the same time we may also detect instances of the development of higher powers which are hardly to be classed as "automatic," and which, in certain species (as in the *Ecitons*, charmingly described by Mr. Belt in "The Naturalist in Nicaragua"), may be said to be elevated above the common instincts of the race. Dr. Henry Maudsley has also well summed up the relationship of the acts of these insects to the acts of higher forms, and to new adaptations when he says: "I do not say that the ant and the bee are entirely destitute of any power of adaptation to new experiences in their lives,—that they are, in fact, purely organised machines, acting always with unvarying regularity; it would appear, indeed, from close observation, that these creatures do sometimes discover in their actions traces of a sensibility to strange experiences, and of corresponding adaptation of movements. We cannot, moreover, conceive how the remarkable instincts which they manifest can have been acquired originally, except by virtue of some such power. But the power in them now is evidently of a rudimentary kind, and must remain so while they have not those higher nerve-centres in which the sensations are combined into ideas, and perceptions of the relations of things are acquired. Granting, however, that the bee or ant has these traces of adaptive action, it must be allowed that they are truly rudiments of functions, which in the supreme nerve-centres we designate as reason and volition. Such a confession might be a trouble to a metaphysical physiologist who would thereupon find it necessary to place a meta physical entity behind the so-called instincts of the bee; but can be no trouble to the inductive physiologist,—he simply recognises an illustration of a physiological diffusion of properties, and of the physical conditions of primitive volition, and traces in the evolution of mind and its organs, as in the evolution of other functions and their organs, a progressive specialisation and increasing complexity."

The recently published experiments of Sir John Lubbock show that ants under certain circumstances are both stupid and devoid of any intelligent comprehension in the way of surmounting difficulties; but this distinguished observer has also shown that as regards communication between ants, and in the regulation of the ordinary circumstances of their lives, these insects evince a high degree of intelligence, and exhibit instincts of a very highly developed kind. Still, making every allowance for the development of extraordinary mental powers in some species of ants, there can be little doubt of the purely automatic beginnings and nature of most, if not all, of the acts of ordinary ant existence. The young ant, wasp, or bee, will begin its labours and discharge them as perfectly at the beginning of its existence as a perfect insect, as at the close of life. Here there is no experience, no tuition, no consciousness, no reason, and no powers save such as have been transferred to the insect as a mere matter of heredity and derivation from its ancestors, who lived by an unconscious rule of thumb, so to speak. It is very hard at first to convince one's self, when watching an ant's nest, that intelligence and consciousness play little or no part in the apparently intelligent operations of these insects. But to assume the contrary would be to maintain that the insect stands on an equal footing to man himself, and for such a supposition there is neither lawful ground nor sympathy. The marvellous instinct of lower life stands on a platform of its own, has its own phases of development, and probably its own unconscious way of progress. The higher reason and intellect of humanity similarly possesses its own peculiar standard, rate, and method of culture. And man may seek and find in the ways of lower existence not merely a lesson in the ordering of his existence, but some comfort also in the thought that the progress of lower nature is not unknown in the domain of human hopes and aspirations.

A SUMMER'S DAY.

THE morning has been oppressively warm. One could have foretold a very hot day by the morning mist which rose off the meadows and floated heavenwards into the blue ether; affording, as friends skilled in natural philosophy tell us, an illustration of the perpetual change and unaltering quantity of matter; in virtue of which properties, this morning mist may be held to represent evaporated water caught up to the clouds, whence it will descend again to spoil my holiday as the rain-shower, and to refresh thirsty plant-life as the evening dew. To-day, one feels restless indoors, grateful as the shade may be. In such a summer-time the restlessness of indolence reigns paramount. Too lazy for physical exertion, the sybaritic side of one's nature longs for some employment and pleasant recreation which shall amuse without fatiguing. To concentrate attention on books of philosophical type is simply impossible; and the opposite extreme of literature, represented by the last yellow-boarded volume which captured our florin at the railway bookstall as we left town, also appeals in vain. Emphatically the day predisposes to *ennui*, and the choice between somnolence and the alternative of "do-nothingness," for a moment appals us by the magnitude of the issues involved. The day is too bright for snoozing, but too warm for even a botanical ramble. It must be sweltering in the wheat-field yonder, where the reapers are busy at work; and as the waggons roll to and from the farm-yard, groaning beneath their golden weight, one regards the boy-drivers with feelings

of admiration and envy as they toil and moil with their willing quadrupeds. But Hodge finds comfort in beer, in the thought of big wages for piecework, and possibly, in the idea of a carouse at harvest home. Alas! in none of these thoughts can one find consolation *in extremis*, as represented by our condition on a warm day of summer with nothing to do.

Is there, after all, anything which powerfully draws us towards the running water which gurgles past our windows, and which sings a never-ending lullaby as it streams lazily beneath the mill, and drips over the water-gate close by? Or are we attracted to the river because it presents us with the antithesis of our indoor estate, and promises coolness by the margin of its waters? Let us believe in the utilitarian rather than in the transcendental, if you will, and sally forth into the sunlight and regard the fair prospect before us. Yonder, in the landward direction, stretch the flat lands dear to minds agriculturally-wise inclined, and which terminate some ten miles off at the slope of the low ridge of hills which, in the eyes of dwellers in these parts, are mountains in verity. You spent your last summer holiday mayhap in Skye, and you revelled in hill and mountain until you understood William Black better, and until you half owned that the Skye hills were preferable to the Alps, and the west coast of Scotland more picturesque than Helvetia itself. And now you are vegetating in the flat lands of Oxon, it may be, with the Thames within a mile of you, and with Babylon the modern lying only some sixty miles or so to the south-east. Your holiday seasons are in striking contrast, and you look with disdain on flat land and hill after Skye. But there is poetry enough around you, if you will but read it, and even if the mood of the flat river-land is different from the rhythm of the brae-side and glen.

We see the orchard just before us standing on an island formed by the division of the river, which has been utilised as a mill-stream, and which is hurrying onwards with a sleepy monotonous grumble to Father Isis. We will cross

this primitive plank-bridge, built over the trunk of an oak which fell years ago handily across the stream; and now we are in the orchard, amidst a forest of apple trees, whose branches hang heavily laden with pomes of divers varieties. Here is a quiet nook, a grassy *embouchure*, close by the river-bank, which invites us to rest a while and study nature at large,—or ourselves, if we are so minded. Here we may exercise the *dulce cum utile* spirit, and enjoy a siesta under conditions the most agreeable and pleasant.

That is the "mill" you see before you as you gaze up stream. The outjutting ledge of the river-bank, with its leafy canopy, hides everything but the mill and a portion of the green meadow beyond from view. The water-meadows, despite the hotness of the season, are deep green, and the artist who has pitched his umbrella and easel beside the mill will have hard work to counterfeit the pure tint of the grass before him. For the greenness of the water-meadows, like the whiteness of snow, is a colour *sui generis;* and as the old mill stands out before you to-day, from a background of green foliage and a side-setting of willows, you can realise why artists are never weary of reproducing its features, and why in many a gallery next winter you will meet the old familiar spot so frequently. The river beside us appears a quiet, innocent-looking stream, as we see it now at its summer level. But natives of these parts will tell you wonderful stories of its extent in the winter season, and of the punting expeditions they have to make across the fields that are now being reaped and shorn, but which become huge water areas for weeks together. At a time when you may be complaining of fogs and gutters full of mud in town, the inhabitants of these coasts will have to pick their way through floods of water, and the spot where we are now resting will be overwhelmed and unapproachable in those winter days. The bank before us bears evidence of the action of these winter floods. You notice how the swirling currents have cut a deep groove along its upper margin, and have thereby left an overhanging and treacherous ledge, that will surely fall

beneath the weight of an unguarded heifer, which may thus find itself in an awkward predicament, and which will have to be rescued amidst much shouting and bawling of Hodges, old and young, who have been summoned to its assistance. Thus do the greater streams of our world wear and erode the land year by year; and you have here illustrated to you, in the river-bank, a great geological truth,—that of the erosion of the land by rivers, and of the transportation of the matter of our earth to the sea by the streams. The matter torn from yonder bank, long ere this, may have made the circuit of the sea-bed, and particles of mud torn from the spot whereon we sit, and swept to the Thames, and thence to the sea, may have mingled with countless other samples of soil gathered from every land and deposited in the ocean-bed to form the foundations of the worlds to come. No wonder, then, that the meadows around us are so green, since our stream so bountifully laves them in winter, and even in summer loads them with favours of very beneficial kind.

Peer we into the depths of the stream, and try to discern if life in any shape be represented therein. Fresh from the "Life of Thoreau," * the man who in Walden Wood made friends with squirrels and racoons and snakes, and who, like St. Francis d'Assisi, even made friends with the fishes, one can realise, sitting in the calm of retirement, something of that "nature-instinct" which so largely imbued Thoreau's whole nature, and enabled him to carry into practical life the Wordsworthian idea of

> "——the man
> Who, in this spirit, communes with the forms
> Of Nature."

A quiet day in a forest, by a river, or by the sea, spent in conclave with the nature-voices around, is no bad medicine for a wearied mind or saddened heart and brain. We are spoken to in such places by a something "not ourselves," and this something draws out of us the best and purest part

* "Thoreau: his Life and Aims. A Study." By H. A. Page. Chatto and Windus.

of our nature in reply. The present is such a time as favours largely the development of the nature-instinct within us.

There is little sign of active life to be perceived around us at first sight; but the "mind's eye" will look deeper for its harvest than is customary with the gaze of an everyday intellectual existence. That dragon-fly that hums by you, for instance, is a subject you cannot afford to neglect in your nature-studies and reflections here. What a stir he causes to prevail amidst the group of gnats and May-flies, which a moment ago were disporting themselves in the air! *Libellula*—as friends skilled in the nomenclature of the insect-world term the dragon-fly—is now the petty tyrant of the insect-domain, and, like most petty tyrants, is destitute of even greatness of origin. Not so long ago he was crawling about in the bed of the river, in the form of a big grub, provided with six legs, and with an apparatus reminding one of a hydraulic engine, whereby he was enabled to propel himself forward by means of *jets d'eau*. Then, also, he was provided with a pair of large jaws, supported on a movable stalk, so that when folded upon his face he might look the most innocent of beings. But with these same jaws he snapped up such unwary insects as came in his way, and thus exhibited in his earlier days a foreshadowing of his later rapacity. Then the grub-like body attached itself to the stem of some water plant; next it split open along the back, and there emerged therefrom the perfect dragon-fly, whose limbs were at first weakly, and whose wings were flaccid and soft. After a period of rest, *Libellula* spread its wings to the light, and careered heavenwards in its maiden flight and first evolutions in the air. And now, like a wise insect, he is making the best of his time, and slaying and devouring his brethren without mercy.

Signs of activity now and then evince themselves from the direction of the waters. Now you may see a trout leap up to catch a gnat just by the spot where the upper branches of the fallen poplar, whose root lies near us, dip in the stream. The minnows are busy, as usual, darting hither and

thither in shoals, innocent of fear and of *Esox lucius*, otherwise pike, and a dread enemy of such small fry. And a lazy perch and one or two trout swim idly past us, as if, like ourselves, feeling the present to be a day of *ennui* in the water. I can discern a big jack floating in the water within the aqueous arbour formed by the roots of the poplar which has fallen close by, undermined by the winter floods of the river. The fish is perfectly still, save for an occasional whisk of his tail and a lazy, deprecating movement of his breast fins. The sight of the jack arouses within one instincts of piscatorial kind, and suggests thoughts of line and hook, and of other appliances familiar to disciples of ancient Izaak. I think of certain friends of mine who would regard my present chance of Waltonian distinction with feelings of envy. But I ask myself, *Cui bono?* I am content, and so I presume is my piscine friend below; and I am hardly in a mood to analyse the argument which would prompt the enticement of the jack from his hiding-place. I find consolation, moreover, in the fact that the jack is no child, but a rather aged member of his race; and that in all probability, having been often tempted by juvenile and other anglers, who swarm in these parts, he is likely to be a wary individual, who would successfully manœuvre my bait off the hook, and afterwards swim off in triumph with a supercilious wave of his tail at the non-success of my unskilled venture. So philosophy prevails, and I continue to be edified by the sight of his complacent bearing in his watery arbour, whilst mankind above him suffers from mundane conditions at large and from the heat in particular.

Thinking of friends piscatorial has set one's thoughts off at a tangent. What an inveterate gossip old Izaak was after all, and how lovingly he doats upon favourite points and foibles in the study of his science! I begin to wonder what certain other friends of anti-vivisectionist tendencies would say to Izaak's description of the treatment to which I might, in the exercise of piscatorial art, subject the frog I see sitting

on his haunches close by, surveying me with a placid stare of content, and swallowing air with a motion which seems to suggest that even cold-blooded and thin-skinned amphibian creatures are feeling the heat of the day to be oppressive. Shall I quote to the frog (who is evidently listening intently) what Izaak recommends should be done, by way of showing esteem at once for fish and frog? "In Part I. Chapter viii. of the 'Complete Angler,' you will find the following remarks, my amphibious friend—'Thus use your frog: put your hook, I mean the arming-wire, through his mouth and out at his gills' (where are your gills, you lung-breathing creature?), 'and then, with a fine needle and silk sew the upper part of his leg, with only one stitch, to the arming-wire of your hook, or tie the frog's leg above the upper joint to the armed wire; and' (mark this, my reptile) 'in so doing use him as though you loved him.' There is a mark of the esteem in which one member of the human species held you—one who thought angling the most 'calm, quiet, innocent recreation' that God ever made, and who regarded the term angler as a synonym for a very honest man,—since he tells us, in Part I. Chapter xxi. of the classic volume from which I have already quoted, that 'this dish' (referring to a special titbit) 'of meat is too good for any but anglers, or very honest men.'" The frog winks as I conclude my oration, and I know thereby he has heard and understood. To me, personally, the frog is a most delightful animal. He afforded me delight in youth when I read of his marvellous powers of supporting life enclosed in a solid rock, and of his lively habits when liberated from durance vile, like the genii in the "Arabian Nights," whom the fisherman allowed to escape from the marvellous jar he had fished up. But when I left childish things behind, I began to esteem the frog still more highly; for, although I learned that the story of the solid rock episode was incorrect, I found out that the amphibian had a most curious life-history, and began life as a tadpole, which Mr. Darwin might say represented an ancient ancestor of my own. Latterly I found that a headless frog taught me something

concerning my own brain and my nervous acts; and if I still refuse to regard myself as a "conscious automaton," I will not forget some truths which the acts of the frog, minus the head, were the means of conveying.

What a glorious harvest of wild-flower life blossoms around our nook! Look at the duckweed leaves which float placidly on the surface of the stream, and which wave gently up and down with the rippling movement of the water. Each leaf is a haven of rest for wearied insects, and represents the beauteous symmetry of living nature, in which no hard and fast straight line is to be found. Whoever maintained that the "line of beauty's curved," must have drawn inspiration from the living part of nature. It is typically in animals and plants that we see forms bounded by curved lines. You will not find a single straight line in the duckweed leaf, nor will you discover any of its surfaces to be absolutely plane. And so with the outline of the fish, or with the symmetry of any group of living things you may observe. Each outline is made up of curves, each surface bulges out or curves inwards, but is never rigidly flattened as in the domain of the dead and lifeless.

Plenty of waterweeds grow by the margin of the stream. Look at the water-crowfoot, which tints with golden patches the river-bank; or at "ragged-robin," which variegates the scene with its pink hues. Yonder is a little patch of brook-lime, radiant in its blue colour; and the forget-me-nots are lending their turquoise in return for the grateful shade and for the moisture of the stream. The butterwort gleams purple and pink from the banks, and the white umbels of the water-parsnips, despite their commonness, harmonise with the brighter tints around. There is the sweet sedge, with its sweet-smelling spadix or cluster of flowers which protrudes horn-like from its leaves, fringing the margin of the river; and we should sadly miss the purple comfrey, with its purple hue and its drooping flowers. "The harvest of a quiet eye," in truth, may be gathered in all the fulness of colour and beauty here; and methinks that the very dis-

order which reigns paramount in the vegetation around, adds but a new sense to its loveliness. Nor may we miss enumerating the tall poplars which grow around the mill, or the dark green of the osiers which fringe its sides; and the pollard willows near, stirred by the gentlest of summer breezes, show the gleaming silver white of their leaves for a moment, and then relapse into their dark green once more. The tiles of the mill-roof have become coated with lovely mosses and lichens, which vary pleasantly the dull red to which the lapse of time and the beating of the weather has turned the originally bright hue of the roof. What would the artist do without the lower forms of plant life? Where, then, would be the effects of green and grey and neutral tints he loves to show on ruined tower, on stone fence, and on mill-roof and wall? And how deep should be one's sense of gratitude to these lowest forms of life, in that they enhance that mysterious sense of the beautiful which cynics never tire of mocking, but which, despite cold criticism, asserts its dominant sway in the better part of our lives!

The great mill-wheel is silent to-day, and for many days to come. As I passed the wheel-house this morning, I saw the little stream of water which had escaped below the water-gate playing in and out between the paddles of the wheel, and I can hear the re-echo of this water-music from our resting-place by the river, so still and quiet is the air. Close by the wheel-house exists the overflow-passage for the water, down which most of the river is at present rushing; its bulk being swelled by a minor stream, which finds its way below the mill into a pond serving the farm for varied purposes. In this overflow-passage exists an iron grating, and from its side a trough is led into a deep tank close by. The whole arrangement was suggestive of one thing or subject only, that subject being eels. I can discern a very small member of that serpentine race of fishes making its way against the stream, and one's thoughts immediately rush forward to winter, when our river rolls along, swelled many times over its present bulk, and containing, amidst its other treasures,

delights of piscatorial and culinary nature in the shape of huge eels. After thunderstorms, and when the night is dark,—for your eel is a fastidious fish in the matter of moonlight,—the eels will leave their retirement, and will be swept down the stream through the open flood-gates upon the grating, and will thence wriggle into the eel-tank, placed so conveniently for their reception. Thence will they be transferred to the presiding genius of the kitchen, who will serve them up in fashions various and diverse, simple and complicated, so as to suit the tastes of participators in the feast. But even now, if your taste should desire it, you may obtain a dish of eels. You may fish for eels in the mill-pond, provided you have a tangled mass of worms writhing together on the end of a string, and below a small bunch of worsted. The fishes, as every one knows, are rapacious, and as a juvenile friend sits on the stone ledge close by the mill, you may see him now and then pull up his finny prey, entangled by the mouth and gills in the worsted of his line. Eel-sniggling is another favourite pastime with our young friend. Then you may see him pushing his needle and lobworm into the mud, probing for eels, and when the bait has been swallowed and the line drawn back, the needle comes to lie athwart the mouth or throat of the fish, which is thus dragged ashore. Further down the river you will see other juveniles setting their lines for these "greedy fishes"—it was old Izaak that named them thus—and further on in the season, and in flat estuary lands near the sea, they will spear these dainty fishes, and impale them by hundreds, to whet the palates of the dwellers in towns.

The sun has reached his height some hours ago, and now we feel the coolness of approaching evening stealing around. The intense heat has passed away, but still leaves its traces behind in the grateful warmth that will soon be dispersed by the chill of the night. You say you are not wearied of our river. Very good: come, then, and punt with me for a mile or two down-stream to the Thames, down a water-avenue, which winds so frequently that the really near

Isis is placed afar off,—the devious course of our stream giving us cause for the exercise of skill and care in guiding our ship along the narrows. "Happy thought," you say. Well, so be it. Jump into the punt, which lies moored to the orchard-bank within some ten feet of us; and, pole in hand, let us guide our craft down the water-way, which curves to the right within the next twenty yards or so. A strong push, and our prowless barge leaves the bank and shoots out into the stream. Pole in hand, we dexterously shift our course as the bend of the river before us is reached, and as the punt sweeps round in obedience to the impetus, we may see for a short distance a straight prospect. Your punt is a stubborn machine, albeit that it draws its water by the inch, and can be made to accommodate itself in wondrous fashion—to inexperienced eyes, at least—to all the windings and other untoward exigiences of a river. Going with the stream is easy work practically and in a punt, as is the task of drifting with other currents in life less tangible, perhaps, but quite as unstable and shifting as those of the water-ways before us. For the stream carries you onwards, and with a few touches of the pole, which may be administered even by the inexperienced hand, progress is a sure thing; and the navigation of the reeds and shallows is pleasant, even if somewhat slow. But *revocare gradum* is to punt very hard against the stream; and this latter is no easy task, if it be remembered that your craft is, so to speak, all stern, and that your efforts with the pole are at the best but partial and onesided. Now you swing round into position and give the punt a forward movement. But the practical study of combined dynamics and hydraulics becomes painful; for ere you may counteract the effect of your first stroke, the prowless boat has swung round with the force of the stream, and you simply describe a circle instead of progressing. But we will walk home through the meadows, and we need not trouble ourselves regarding the toils of punting at present.

The plant life on the banks is even more lovely than that of the upper reach we have left. Pass we now through serried

ranks of rushes, which grow tall and stately even to the middle of the river, and which are crowned each by a tuft of purplish blossom. There are golden asphodels and corn-flags brilliant above the dark waters, overshadowed by the wooded banks between which we pass. Beautiful leaves, shaped like arrows and spears, and fit for the weapons of wood-nymphs or water-babies, grow around; and the pink and purple flowers of the orchis grow in plenty from the water-sodden soil of the bank-margins. Now and then the beautiful water-lilies, yellow and white, will give us a kindly greeting as we pass them, and will dip their flowers amid the swell caused by the passing of our labouring craft; whilst the guelder-roses on the bank above are sweet, as the water-plantains below are pretty in their lilac dress.

A bend in the river brings us nigh to a quaint old village, with a venerable church—the mere remnant of a cathedral-like edifice—whose square tower forms a familiar county landmark. The river winds past "God's Acre," where sleep the "rude forefathers" of Hodge and his neighbours, whose merry laugh reaches us from the harvest-fields on either side. The church is left far behind by this time, however, and still our river journey has not yet terminated. Still we wind in and out, but the absence of wood and the uniformity of the flat land around us, together with the widening of the stream, show that we are approaching its estuary. Life is still active in these lower reaches, despite the evening cool, which makes itself felt as the time passes. Gnats circle around us in plenty, and weather-wise people will tell us that to-morrow may bring showers, because the swallows and swifts are flying low after their insect prey. How graceful the flight of these birds, and with what elegant curves, reminding one of the movements of a ship riding on the surface of a heavy swell, do they dip and ascend! A wild duck has been alarmed by our too near approach, and flutters in alarm and dismay before us, disappearing within a reed-fringed haven, from which at the same time a frightened moor-hen emerges, and makes its unsteady way along the low

bank. A water-rat or two glide in and out of their holes, or splash into the water and swim rapidly across the stream at a safe distance beyond. Still the stream widens, and at length we arrive at its estuary, where its waters mingle with those of the broad Thames, and lose themselves beyond recall in the larger river. The fiery evening sun is still strong, and throws a bright light on the bosom of the Thames, whose easy-flowing current gives no sign here of the busy traffic and bustle which mark its lower limits. We take boat here, and paddle out into the glare of the evening sun, which falls behind us as we paddle down stream and London-wards. The trout and other finny tenants of the waters are rising everywhere around, and snapping up the unwary flies and gnats which hover in swarms on the surface of the river; but we are beginning to miss the signs of activity in nature which were so evident in the earlier part of the day. Floating with the stream, we appreciate the true pleasure of the *dolce far niente* phase of existence,—a pleasure which the smoothness of our present mode of transit serves but to enhance.

Now we may put about, and pull homewards. The sun is still strong, but the fierceness of the rays has given place to the evening effect, with its warmer light, and its display of colour in the heavens around. The sense of evening stillness is increasing, and becomes almost oppressive in its character. The plash of our oars, unnoticed before, now sounds loud and distinct amid the silence which is creeping alike over river and field; and the merry laugh which resounds from the camp-fire and tent of a boating party on the bank, who have come to rest for the night, sounds right welcome as we row along. These are probably University men who are doing the Isis in the pleasantest of fashions, and who are tasting for a time the pleasures of a nomadic existence. The memory of such a boating party may linger in the mind of its members during their whole after-life; and the associations which brought them thus together may form chains of thought which will unite them, it may be, when scattered widely over the earth.

The sun has set, and has left a gorgeous halo of crimson-red and purple with gold-tinted clouds to mark its apotheosis. When you stroll through next year's Academy, or visit the studios of your brethren of the brush, you will have learned from the sunset yonder to be not overwise or over-critical in looking at evening effects, or boastful of your ability to distinguish what is natural from what is unreal. Yonder clouds, if painted in all their gorgeous and fast-fading reality, might seem unreal and impossible; and the critic might then set himself above nature and artist alike, and maintain the absurdity of effects he has never seen. Therefore let the sunset teach you a canon of fair criticism and a lesson in guarding against undue assumption of what nature may do or can do.

We have reached by this time the estuary of our stream, and we disembark, and, standing on the river's bank, survey the fair prospect around. Once again, the morning stillness repeats itself; but the sense of evening quiet carries with it a difference from the stillness of the day,—a difference we may feel, but can hardly express. Deeper grow the shadows; and presently, as we stroll homewards, the moon rises and makes a silver pathway of the broad river we have left, the silver sheen succeeding the golden lustre along which we previously passed. As evening comes on apace, field and river are bathed in the pale light and the rippling water sparkles beneath the gleam. The stillness is broken only by the tinkling of sheep bells from the folds close by; but as we pass homewards, drinking in the beauty of the scene, the church bells ring out an evening peal, the melody of which resounds around us, and seems to float down the river in varying cadences and strains. The bells cease their chiming at last; and as the notes die away and re-echo over hill and dale, river and field, nature at large seems to sink into a rest, and to be hushed with a peace so still and sweet, that it is hard to realise that the morrow will awake us with its stern call to the duties of a new day.

SCIENCE AND POETRY.

A Valedictory Address to a Literary Society.

WHEN the request that I should deliver the usual valedictory address to your society was submitted to me, I could not avoid the thought that there had not been exercised that strict law of "natural selection" which might be thought to regulate the choice of your lecturer this evening. It is, doubtless, a time-honoured custom that your annual closing address should be delivered. But I apprehend the custom has been hitherto exercised in the direction of asking one of your literary leaders to say some words by way of farewell for the session that is about to be closed, and to give some counsel by way of encouragement and guidance in the work that lies hidden and beyond. Why your present choice should have fallen upon a representative of the scientific rather than of the literary order remains a mystery, into which it might be neither wise nor profitable for me to enter. The thoughts, modelled on the wise saying, *Ne sutor ultra crepidam*, which may have entered into my mind ere I consented to address you, need not now be particularised. Suffice it to say that I fully endorse the practical wisdom of the proverb, and deem it to be thoroughly applicable to all persons ambitious of seeking "pastures new," and whether they be cobblers or no.

Having consented to occupy your time and attention, the selection of a theme formed an all-important matter for decision. In plain deference to the aims and objects of your society, I could not well address you on a topic purely

scientific in its nature, nor did I feel myself warranted, on the other hand, in selecting for treatment a purely literary theme. The *via media* was of course open to choice, but the middle path between science and literature is hard to enter and difficult to tread. Frequently, in the grave concerns of life, a veritable atom may decide our fate, and waft our schemes to full fruition or to ruin and dismay. So was it in my dilemma regarding a subject which I mean not to designate as a "weighty matter," save, indeed, in so far as my ability to interest you was concerned. A chance perusal of Principal Shairp's charming volume, "On Poetic Interpretation of Nature," afforded a clue towards the selection of a subject which might fall somewhat within the special bent of your studies, whilst it might be said also to reach somewhat within the range of mine. I shall, therefore, ask your attention to a brief survey of some of the relations of poetry to science, in the hope that such a study may perchance lead to our cultivating a wider sympathy and a better understanding between the two chief modes of interpreting nature which exist at the beck and call of civilised man.

The learned and genial tone which characterises the entire work of the Oxford professor of poetry renders the volume a delightful companion under any circumstances, or in almost any of the moods which constitute in their totality the existence of man. Doubtless many, as I myself discovered, will find in the work opinions with which they must profess themselves at variance; but there can be but one deliverance concerning the candour and fairness with which Principal Shairp states his own convictions and criticises the opinions of others. At the very outset, we learn from our author certain facts which are pertinent to our present inquiry; for it need hardly be said that I purpose to deal with but a single aspect of poetry,—that in which it relates itself conformably or the reverse to science. "Poetry," says Principal Shairp, "has three objects, which in varying degrees enter into it,—Man, Nature, and God." In this work, the author deals with the second of those aspects alone,

and in my turn I propose to deal with but one special phase of the relations of poetry to nature,—that phase being the exact explanation of nature and natural phenomena we ordinarily and collectively name "Science."

Once again, let us turn to the volume under discussion for a succinct summary of the differences which are usually held to separate the poetic from the scientific interpretation of nature. "The same external Nature," says Principal Shairp, "which poetry works on supplies the staple or raw material with which all the Physical Sciences deal, and which they endeavour to reduce to exact knowledge, subduing apparent confusion and multiplicity into unity, law, and order. Each of the Physical Sciences attempts to explain the outward world in one of its aspects, to interpret it from one point of view. And the whole circle of the Physical Sciences, or Physical Science in its widest extent, confines itself to explaining the appearances of the material world by the properties of matter, and to reducing what is complex and manifold to the operation of a few simple but all-pervading laws. But besides those aspects of Nature which Physical Science explains, over and above those laws which the Sciences discover, there are other sides or aspects of Nature which come to us through other than scientific avenues, and which, when they do reach us, bring home to us new truth, and raise us to noble contemplations. This ordered array of material appearances, these marshalled lines of Nature's sequences, wonderful and beautiful though they be, are not in themselves all. No reasonable being can rest in them. Inevitably he is carried out of and beyond these, to other inquiries which no Physics can answer: How stand these phenomena to the thinking mind and feeling heart which contemplates them? how came they to be as they are? are they there of themselves, or is there a Higher Centre from which they proceed? what is their origin? what the goal toward which they travel? Inquiries such as these, which are the genuine product of Reason, lead us for their answer not to the Physics of the

Universe, but to another order of thought,—to Poetry, to Philosophy, and to Theology. And," concludes Principal Shairp, "the light thrown from these regions on this marvellous outward framework, while it contradicts nothing in the body of truth which Science has made good, permeates the whole with a higher meaning, and transfigures it with a splendour which is Divine."

Now the simple meaning, as I take it to be, of the expressions thus eloquently conveyed to us, is that poetry allies itself to philosophy and theology in seeking to connect the phenomena of the universe with a cause and origin. With Principal Shairp, we may say that the mind which contemplates earnestly the face of nature is, sooner or later, bound to inquire concerning the origin and beginnings of the things of the universe and of the universe itself. But it seems to me at the same time, that the queries which Professor Shairp puts as those of such an inquiring mind, may be fully answered by philosophy alone, or by philosophy and theology, if you will, but in either case without the aid of poetry at all. The "poetic interpretation of nature," in its simplest, in its most typical phase, reveals itself to us as a particular way of looking at things, as a special means of reading what nature is saying to us, and less as an explanation of nature in any sense. To make my meaning clear, let us select the rainbow as a common phenomenon of nature, and try to discover if the poetic aspects of the subject account for its causation or not.

In Milton's "Comus," for instance, occurs the passage :—

> "I took it for a faery vision
> Of some gay creatures of the element,
> That in the colours of the rainbow live
> And play i' th' plighted clouds."

Here there is an admiration of the hues of the bow, and the suggestion of exceeding brilliance in the "gay creatures of the element" is implied by the comparison of their colours with those of the bow. This, so far as I can judge, is a legitimate enough example of a poetic thought, of a

particular way of expressing the brilliance and lustre of the rainbow hues, but it leads to no idea of causation whatever. Byron has even a finer simile, when in "The Bride of Abydos," he says :—

> "Be thou the rainbow to the storms of life !
> The evening beam that smiles the clouds away,
> And tints to-morrow with prophetic ray !"

Here the metaphor is plain, elegant, appropriate. No critic would deny, I apprehend, that this is a good example of the deftest touch of the poet, or that it is fairly to be esteemed a form of the truly poetic interpretation of nature. Yet withal you must rest content with the poetic thought. There is no attempt to go further, to relate the rainbow to any other phenomena of nature, or even to its own causation. There is, moreover, in my humble opinion, no need whatever for the expression of any such relationship ; for you receive and recognise the poetry of Byron's thought. You see that his metaphorical interpretation of the rainbow as an augur of hope and peace is true and applicable, and you demand nothing further. The thought pleases and charms, and you are content. You do not expect that the poet's expression should lead you directly or indirectly into the midst of physical science in general, or into the study of colour, light, and heat in particular. Whether or not you may know that Newton showed a rainbow "to be due to the unequal refrangibility of elementary rays," is nothing to the purpose. Not that I maintain for one moment that, provided you knew the exact physical explanation of the rainbow, you would on that account enjoy either the sight of the bow or the poet's allusion to it, one whit the less. I shall strive, on the contrary, to show you presently that such scientific knowledge, so far from destroying the poetic feeling, may, when rightly used, encourage and supplement the poetic interpretation of nature in its best and truest aspects. When we know that the rainbow is not "based on ocean" and does not "span the sky," as Byron tells us, we do not on that account enjoy

the poet's imagery the less. He places before us, as a poet, and in the vein and mood of fancy, the appearance of the bow; and our poetic sense, apart from all ideas of causation, responds to the well-chosen thought. Nor may we for the same reason undervalue the imagery of the Preacher, because he maintains that "it compasseth the heaven about with a glorious circle, and the hands of the Most High have bended it." Because the rainbow is not

"Made up of tears and light,"

there is nevertheless no questioning the aptitude and beauty of Coleridge's simile; and even if one be heterodox enough to deny the Deluge, he need not dispute the beauty of the idea which gave to the ancients a promise and surety of future safety from terror by water.

In such instances—capable of being multiplied to an indefinite extent—we clearly see that the poet's thoughts about nature gratify us independently of any attempt at explaining the cause and origin of the phenomena described. Indeed, were such causation a matter for poetic settlement, the varied, not to say impossible, causes assigned by poets to the phenomena of nature would present a choice and variation hardly to be excelled in any other department of human thought. The origin of things, then, may be safely left to science and philosophy; poetry has no place whatever as an explanatory aid to the universe. You may dress the explanation in poetic guise, it is true, but poetry in such a case is the mere drapery and not the figure or entity itself. Principal Shairp's definition of physical science, which I have read to you, fully brings before you the part played by science as the true expounder of causes and relationships. Poetry looks at the world with a view of its own. It in no sense originates the idea of cause and effect, but at the most only tints the explanation with a fervid glow, or strengthens the imagery wherewith the ideas of causation are brought home to the human mind.

If it be objected, however, to this idea of the entirely

negative aspect or place held by poetry in the exact interpretation of nature, as being of too narrow a phase, I reply that I am simply judging the claims of poetry on their own merits, and as set forth by no mean advocate of their power. But poetry, according to Principal Shairp, deals immediately with a certain "truth of the External World." This, put "in the simplest way," says our author, "is Beauty," and "the Poet is the man to whom is given the eye that sees this more instinctively, the heart that feels it more intensely, than other men do; and who has power to express it, and bring it home to his fellow-men." Principal Shairp is here speaking in the truest of terms, and appeals directly to our own innate experiences, when the moods of nature, as reflected from the pages of the poet, or directly from the fair face of wood and sky, hill and dale, river or sea, have reached us and touched our hearts. The question "What is beauty?" is one which Professor Shairp answers shortly in the phrase, that certain qualities and combinations of objects and laws of the outer world, transformed by the æsthetic and imaginative faculties, give rise to the sense or perception of beauty,—very much, indeed, as vibrations of the air, received by the tympanum of the ear, and modified by the inner ear, and transmitted to the brain, give rise to the perception of sound. Beauty, in this view, which has all the merits of a sensible explanation, is simply the modification by special powers of mind, of particular sense-impressions, derived from the outer world. The justice of this view, also, is well seen when we find that it makes due allowance for the relative nature of the beauty-sense. Why does the same view of nature present the brightest aspect to one man, and the dullest prospect to another? Why does the greenness of trees or the fairness of the seascape charm one and fail to impress another? I reply, because the beauty-sense, and the special nervous mechanism implied in its possession, is actively developed in the former and absent in the latter. To the former, nature is appealing as to a poet; by the latter the appeal is met with an unheeding obtuseness to

the stimulus of outward beauty. We pass to but another phase of beauty when we enter the domain of poetry. The "beauty" of the poet possesses, however, a range so wide and diverse, that the phrase is incompatible to express the mere subjects of his treatment, although the manner and mode of his treatment present us with a perennial feast of fair, true, and chaste thoughts.

But the idea I have just mooted of the relative nature of our sense of beauty in nature, and of the fact that the scene which evokes the warmest response of joy and admiration in one may fail even to arrest the eye of another, carries with it, as a corollary, a further and special interpretation of the poetic instinct. That is to say, it is difficult to see or discover any special standard of beauty, or for the correct and poetic interpretation of nature. Nature appears to each man and woman simply as the mind and senses allow. The higher the culture of the beauty-spirit and nature-sense, the more feelingly will nature appeal to us. And the varying moods of the poet-observer, like those of other persons, can in any case stand only for a special and single interpretation of the phenomena he sees and delights in. Is it surprising, then, to find that the term "poetic interpretation of nature" is simply synonymous with the particular reading of nature which each poet's senses, disposition, and culture have permitted him to construct? We may safely maintain that a colour-blind poet might write a charming poem on outward nature, though to him the grass appeared red, and the luxuriant foliage of spring appeared any colour but green. His imagery might be subtle, his metaphor keen, and his rhythm exquisite,—his poetry, in a word, might be of its particular phase the finest, and yet his interpretation of nature would be in any case singular, and as to colour, at any rate, absolutely incorrect. The exaggerated case of colour-blindness is but a parody on the real state and manner of our poetic interpretation of nature. Each individual poet interprets nature as nature appears to him; and according as the poet thinks of himself and others, so

will he fancy nature stands related to himself and to the world at large. The poets have, in fact, taken

> "——the earth whole for their toy.
> They played with it in every mood;
> A cell for prayer, a hall for joy;
> They treated nature as they would."

Were any further proof,—I mean other than this plain explanation of how and why different poets see nature with different eyes,—required, I might ask you to read the same lesson in the varying interpretations of similar aspects of nature, which various poets have left us as their contribution to the imagery and beauty-culture of their day. In how many different aspects have poets sung of the sea, for instance; and even of one mood of the ocean, how many varying poetic phases have been created! To one poet it is the emblem of security, to another of temptation and dispeace; to one it is the image of serenity, to another it is merciless and austere; one terms it "a parent;" another calls it "a thief." Or inquire, briefly, in how many varying aspects have the stars appeared to the poetic fancy, and you will find that the incongruities are to be explained not by mere differences in what was seen, but by the varying moods of the poet-chroniclers themselves. The Hebrew poet invests them with bellicose propensities when he declares that "the stars in their courses fought against Sisera." Sir Henry Wotton calls them—

> "Meaner beauties of the night,
> That poorly satisfie our eies;"

whilst Young termed them the "eyes" of Heaven. According to Heine they are "Golden lies in deep blue nothingness;" and to Byron they were "unutterably bright." Contradictory moods seem, in fact, the order of the day regarding every phase of nature poets have described. And amidst the shower of inconsistencies which meet us in our research there is but one comfort, one explanatory consolation,

namely, that poetry is thoroughly relative to its expounder and votary; and that the inconsistencies fade away in the charm of variety, and in the still greater utility of suiting the varying moods of the men and women who find in poetic literature, amusement, instruction, and interest, or perhaps comfort and consolation in many a dark hour and weary day of life's pilgrimage.

I have purposely devoted a considerable portion of my remarks to the examination of the nature of poetry and of the results and moods of poetic interpretation, in order that I might the more clearly set before you the relations which exist between poetry and that exact method of interpreting the world and its phenomena we denominate Science. We have seen that poetry cannot pretend to be an expounder of causation. It can at the most serve only as a medium for the conveyance of the thoughts which science suggests. We have also noted that the poetry-sense is emphatically a beauty-sense, whatever else may be included within the limits of the poetic sentiments and practice; and we have lastly insisted on the due recognition of the fact that poetic interpretation, as dependent on the moods of the poet, must be a matter relative to his particular disposition and mental character. There still remains for consideration the questions: How is poetry related to science? Does science necessarily destroy poetry? And of what character are the relations which may be shown to exist between science and poetry?—provided it can be demonstrated that any relationship whatever exists.

That poetry must possess some relationship or other with science, is an inference which rests on the plain fact that, both claiming to interpret or construe nature, they must possess some features in common. Science is one way of looking at nature, poetry is another. Science, however, looks at nature for the purpose of discovering the true meaning of nature's phenomena, and of accounting for these phenomena by the discovery of the laws which regulate them. Poetry, as we have seen, rests content with the dis-

covery of a new aspect or imaginative rendering of the phenomena, without heeding their cause or relations. The scientist "interprets" nature in the true sense of that word, by showing us what nature means, and how her ways and works are regulated, formed, and construed. The poet "interprets" nature only in the limited sense of showing us how the outward aspect of matters strikes him. Whenever he ventures upon the explanation of the why and wherefore, he becomes either the scientist, the metaphysician, or the theologian, and is merely clothing ideas of causation obtained from these sources in poetic garb. Poetry, in short, at its best, is a medium for the conveyance of ideas; and as the excellence of the colour is largely due to the correct choice of a medium, so the beauty and worth of the poet's labours must bear a distinct relation to his individual capacity and soul.

But Principal Shairp, in addressing himself to the relationship of poetry and science, wisely reminds us that the subject is as old as Plato, who "banished poets as false teachers from his well-ordered State,"—an action which possibly might have met with the theoretical approval of those who, with Mr. Froude, declare that "the greatness of the poet depends on his being true to nature." Proceeding to deal, in an admittedly cursory manner, with the relation of poetry to science, Principal Shairp remarks that the "simpler aspect of the question" concerns "the action of imagination on the external world." "When the eye," says Dr. Shairp, "rests on the ranging landscape, and the heart responds to the beauty of it, the emotion which is evoked is as true and as rational as is the action of any law of nature. This kindling of heart in the presence of nature, may be said to be 'another aspect of reason.' It is not confined to any one order of men or stage of civilisation, but belongs alike to the child, the peasant, and the philosopher, if only the heart be natural and unspoiled." *Quis negavit?* we reply. So far good and true. Next in order we are reminded of the "Yarrow Shepherd," who, going forth at dawn of day, re-

joices in the rising sun, and in the glorious effulgence which soon floods hill and vale, and who exhibits thus a feeling containing "the first stirrings of that which, when the poet fashions it into fitting words, becomes an immortal song." Then comes the scientific contrast. Imagine, argues Principal Shairp, that the shepherd youth described by Wordsworth had been "college-bred, and crammed with all the *'ologies* which Physical Science now teaches, would he still have had the same elevated joy in presence of that spectacle?" There is just the slightest *soupçon* of contempt, if I may so put it, in the question. It is as if our author had said, "Surely you cannot imagine for a moment that a knowledge of the 'ologies' would increase the poetic aspiration or the feeling of joy that rises within the breast of the watcher of the rising sun!" Suppose him to have been a geologist, argues Dr. Shairp, and to have known something about the structure of his native hills and valleys, —"in the presence of such scientific thoughts as these," asks our author, "what would become of the boy's imaginative and devout ecstacy?" True, there is a qualification in the succeeding page of Dr. Shairp's volume, where he admits that a physicist "of large soul" may "rejoice at the great things of Nature which he sees, as genuinely as the unreflecting child, the thoughtful peasant, or the most spontaneous poet." But withal, Principal Shairp is no believer in the advantages of scientific knowledge as an aid to poetic sentiment. It is, on the contrary, if not an absolute hindrance to poetic thought, at least a disqualification, in Dr. Shairp's eyes. For your scientist may wonder, may reverence, may admire, but his analytical habits, his inductive tendencies, and his deductive speculations are liable to "scare away poetry" from his world "for ever." Even with the admission that to the "sovereign minds of science" poetry may be a living reality, Dr. Shairp clearly contends for the antithetical nature of science as regards the poetic instinct. The early "poetic glow of wonder and emotion," which according to Principal Shairp exists "before Science

begins its work," may and does express itself in poetry; but of the development of that "larger, deeper, more instructed wonder," which succeeds the early "poetic glow," he is by no means sanguine, as an element in the scientific mind.

In all of these opinions, it seems to me there is a misapprehension of the exact attitude of the scientific mind to the sense of beauty and poetry which may be presumed to exist in mankind at large. The question in which the gist of the matter lies may be shortly stated as that which inquires—Whether an exact knowledge of the laws and constitution of nature necessarily unfits the mind for the appreciation or exercise of the poetic faculty and instinct? Let me try to frame a brief reply to this important query.

I will not do more at the outset than point out that to fully realise the effect of a scientific training on the poetic instinct, individual peculiarities of mind must necessarily count for much. Once again we must face the problem of relativity. In one case, Dr. Shairp's remarks regarding the effect of science on the "small-souled" amongst the physicists will hold good; in another case, the scientific habits might leave unaffected the whole poetic bent of the man's nature,—admitting always that the scientific and poetic faculties are capable of simultaneous cultivation. But dealing with generalities as the only quantities of value in the case before us, can it be rationally maintained that a knowledge of causation necessarily destroys the faculty of appreciating the beauty and harmony of the universe as revealed by the imagery and diction of the poet? To such a question I would fain return a very strong and negative reply. Nay, I will go further, and maintain that a knowledge of science, so far from serving to chill and blight the aspirations of the poetic mind, may, on the contrary, serve not only to foster but to extend and enlarge the range of poetic sympathy and vision.

Does the knowledge of the fact that oxygen has been discovered in the sun tend to diminish by one iota the feeling of joy, the inexpressible sense of delight and wonder,

with which we see the red rays rising aslant over the Righi, and finally bursting into a glorious effulgence as peak after peak is tinged with the morning glow? Or when we walk abroad in the full glow of the mid-day, does the idea of the immensity of Heaven's great orb, the knowledge of its distance from us, or the information which details the extent of time occupied in the transit of its light-rays earthwards, interfere in any sense with our delight in the poetry which has selected astronomy as its theme. Does such knowledge repress what Dr. Shairp would call "the momentary elevation of heart," for which its subject "has no words"? The eye rests on the grateful green of nature which everywhere meets our gaze, and drinks in the sense of beauty and of this earth's sweet fairness. Shall I the less be filled with joy because I know that the green is the botanist's "chlorophyll," and that but for the verdant hues of plants, our world would become a great stagnant pond of foul air? We stroll through a garden, and the sensuous colour and perfume of the flowers appeal to our sense of the beautiful, and make us glad. Shall this sense be thwarted and annulled because we know that colour and scent are but snares for insects, and that the flower-plot is as a garden of temptation to each little winged messenger bent on nature's errand of flower-fertilization? Because I know something of the theory of dew, shall my sense of pleasure or of poetry, aroused by the contemplation of the "infant diamonds" which bespangle every blade of grass, and add an inexpressible charm and freshness to the morning air, be annihilated and suppressed? The hues of the shell which is tossed up at our feet by the restless waves enchant us, again, through the colour-sense, and beauty of form and shape appeals eloquently to us as part of the poetry of nature. Shall you say that the colour is less bright when you find that it is due to the refraction of the light, or that the form of the shell is more mundane because you can tell how it was made? That tiny blossom which waves in all its

luxuriance has ere now inspired a poet's song. Because you know how many sepals, petals, and stamens it possesses, will its beauty fade away into commonplace colour, and the sympathies it called forth in the poet and in yourself be dispersed because you know its natural order and genus? Or turn shortly to consider other forms and methods wherein the beautiful in nature appeals to us, and causes our hearts to burst forth into song. You hear the entrancing strains of music, and listen to the poetry of sound; your beauty-sense is inspired through the ear, and imagination peoples the very air around you with the creations of the "divine art." Will you tell me that your poetry-sense of the beautiful in music is destroyed at the moment you acquire a knowledge of musical principles, or when you understand the mysteries of construction of the "cornet, flute, harp, sackbut, psaltery, dulcimer, and all kinds of music" of modern times? The notes of glorious song ring through the vaulted cathedral church, and lift our souls heavenwards; or the impassioned strains of a Norma touch within us the chords of truest sympathy. Do you maintain seriously that, because you happen to know the physiology of the larynx and the mechanism of the vocal chords, the sweetest notes touch you with no effect, and that the beauty and poetry of song have fled from you for ever? To all such queries there is but one reply. There is nothing, absolutely nothing, in the nature of scientific study which, to a mind naturally poetic, can chill or destroy the sense of beauty and the faculty of poesy in which it originally rejoiced. Mr. Ruskin, to my mind, does not deal with the question in the wide, and I will add fair, sense in which it demands to be treated, when he says, "This is the difference between the mere botanist's knowledge of plants and the great poet's or painter's knowledge of them. The one notes their distinctions for the sake of swelling his herbarium, the other that he may render them vehicles of expression and emotion. The one counts the stamens, affixes a name, and is content; the other observes every

character of the plant's colour and form, considering each of its attributes as an element of expression, he seizes on its lines of grace or energy, rigidity or repose, notes the feebleness or the vigour, the serenity or tremulousness of its hues. . . . Thenceforward the flower is to him a living creature, with histories written on its leaves and passions breathing in its motion. Its occurrence in his picture is no mere point of colour, no meaningless spark of light. It is a voice rising from the earth, a new chord of the mind's music, a necessary note in the harmony of his picture, contributing alike to its tenderness and its dignity, nor less to its loveliness and its truth."

Here Mr. Ruskin, in so far as he is detailing the happy effects of association with nature, and of a study of natural objects on the poet's and painter's mind, is both eloquent and impressive. But to his assertion that the sole end and aim of the botanist's study is merely that of finding a new species, or of affixing a name, I for one must oppose a strong denial. That "strain" of assuming the necessary opposition and antagonism of science and poetry, appears to have "a dying fall," and but a weakly support in facts. It seems to me that unless you maintain the absurd doctrine that complete ignorance of natural objects is the best form of poetic nurture, unless poetry and ignorance of nature have met together and have kissed each other, you must own that a knowledge of nature should rather aid the poetic faculty, by extending your range of vision, by revealing new and hitherto unknown harmonies of nature, and by teaching you to read the inner voices of nature, which are all unknown to the mere surface observer. Peter Bell and his primrose appears exactly to parallel Mr. Ruskin's painter and the flower. I do not deny that there are beauties of form, and delicacies of colour, which these observers might appreciate, and through which the poetic sentiment might be aroused. But I fail to see that the mere surface-consideration of the flower is better fitted to evoke "expression and emotion" than a knowledge of the

wondrous harmony of its parts, of the association of organs to special ends, and of the many contrivances whereby nature works out her manifold intentions in the world of life. Hear Dr. Henry Maudsley on this point, as a candid apologist for scientific culture as related to the poetic sense. "To a right-thinking and right-feeling mind," says this author, "the beauty, the grandeur, the mystery of Nature are augmented, not lessened, by each new glimpse into the secret recesses of her operations. The sun going forth from its chamber in the east to run its course, is not less glorious in majesty because we have discovered the law of gravitation, and are able by spectral analysis to detect the metals which enter into its composition,—because it is no longer Helios driving his golden chariot through the pathless spaces of the heavens. The mountains are not less imposing in their grandeur because the Oreads have deserted them, nor the groves less attractive, the streams more desolate, because Science has banished the Dryads and the Naiads. No, Science has not destroyed Poetry, nor expelled the Divine from Nature, but has furnished the materials and given the presages, of a higher poetry and a mightier philosophy than the world has yet seen. The grave of each superstition which it slays, is the womb of a better birth. And if it comes to pass in its onward march, —as it may well be it will come to pass,—that other superstitions shall be dethroned as the sun-god has been dethroned, we may rest assured that this also will be a step in human progress, and in the beneficent evolution of the Power which ruleth alike the courses of the stars and the ways of men."

I do not thus think well, or indeed anything, of the doctrine that a poetry nursed in utter ignorance of the scientific aspects of nature presents us with an essentially typical development of the poetic faculty. No one can deny that in the absence of all scientific knowledge, that faculty may be developed to sing in loftiest strains and fullest measure. But I enter a strong protest against the misrepresentation that the scientific faculty destroys the

poetic; or that of necessity, an exact method of looking at things should utterly annul the sense wherewith we discover their external beauty or the wondrous and subtle rhythm and measure that pervades the universe at large.

If, therefore, in answer to the query, "Does science necessarily destroy poetry?" I find ample reason to return a negative reply, there yet remains for consideration the question of the true relations of poetry to the scientific interpretation of nature. The age we live in has been blamed, perhaps not unjustly, for its over-practical tendencies, and its utilitarian demands. I shall not deny that the spirit of "use and no use" is too much employed as the criterion of intellectual studies, and tends of itself to destroy the finer emotions, from the very heart of which the sense of poetry alone can spring.

Whilst the fuller scientific knowledge of nature does not necessarily destroy these emotions, but is calculated, as I have tried to show, to foster and enlarge their range of expression, there is an aspect of science in which it may certainly modify the results and exercise of the poetic faculty. Provided you accept Mr. Froude's dictum, that the greatness of poetry lies in its "being true to nature," you may readily see that science may and does act as a censor of ideas of nature which are founded on imperfect conceptions and rude or even absurd ideas of natural objects, or of the world as a whole. You are familiar with the stories—related even now as matter-of-fact observations—in some popular manuals of natural history, regarding the little cuttle-fish known as the paper nautilus or argonaut, and its wondrous powers of sailing on the surface of the sea. You remember Pope's lines:—

> "Learn of the little nautilus to sail,
> Spread the thin oar and catch the driving gale."

You know Byron's description also:—

> "The tender nautilus, who steers his prow,
> The sea-born sailor of his shell canoe,
> The ocean mab, the fairy of the sea."

And you are doubtless familiar with Montgomery's eulogy of the animal in his "Pelican Island":—

> "Light as a flake of foam upon the wind,
> Keel upward from the deep, emerged a shell
> Shaped like the moon ere half her horn is filled;
> Fraught with young life, it righted as it rose,
> And moved at will along the yielding water.
> The native pilot of this little bark
> Put out a tier of oars on either side,
> Spread to the wafting breeze a twofold sail,
> And mounted up and glided down the billow
> In happy freedom, pleased to feel the air,
> And wander in the luxury of light."

I question if you can find more elegant metaphor or more poetic description of a natural object in the English language than are contained in these quotations. The poetry is excellent, the ideas are clear and terse, and the imagery is delicate. But what shall we say of the poetry when we discover that the facts are utterly erroneous? The argonaut does not sail on the surface of the sea. Did it hoist its two broadened arms, as Montgomery describes, in sail-like fashion, its voyage would come to a premature end, since its shell-boat would drop away from its body into the depths of the sea. It does not use its other six arms as tiers of oars, but propels itself backwards in the water by a kind of hydraulic engine, which it possesses in common with all other cuttles, or crawls head downwards over the floor of the sea, in mundane fashion, by aid of the arms and their ample provision of suckers.

Now this, I imagine, is a crucial instance of the effects of science in modifying poetry. You read the poem in happy ignorance of the zoology of the cuttle-fishes, and you are more than satisfied with the poet's work. But "light" if not "sweetness," dawns at length, and you learn that the poetic faculty has been lavishing its tenderness and grace on a myth. What are the natural thoughts which arise in the mind in such a case? I answer that unless there be any

special tendency in the morals of poetry to prefer a pleasant delusion to the truth, you will accept the light and correction of science, even if you may still admire the poetry,—mythical as it may be. The poetry is modified as to its exactitude, but I would fain believe the imagery and grace remain untouched. You may think of the poet's descriptions as those of ethereal fancy, and as the delicate imaginings of what the argonaut might be—not what it really is. The poetry may not be true to nature, still you can value and appreciate it for itself. Beyond the scientific modification there remains the essence of the poesy, and it is this latter which pleases our æsthetic sense, and forms the charm and the sweetness of the poet's song.

If I might quote another, and a recent instance of the modification which poetry must undergo at the hand of science, I should cite a passage from Mr. Browning's "Prince Hohenstiel Schwangau," wherein, speaking of the descent of man, he says :—

> "That mass man sprang from was a jelly lump
> Once on a time ; he kept an after course
> Through fish and insect, reptile, bird, and beast,
> Till he attained to be an ape at last,
> Or last but one."

Now, as explanatory of Mr. Darwin's theory of the "Descent of Man," Mr. Browning's words are absolutely incorrect. In that theory, despite the popular notions, Mr. Darwin certainly does not hold that the insect, fish, reptile, bird, and beast are so many connected links in one continuous and connected chain of descent ; and he does not maintain that man is the direct descendant of an ape. Once again, the poetry is subtle, but the inferences are wrong ; and even as a matter of theory, the more exact knowledge of what Mr. Darwin teaches or holds, is shown to act as a corrective to the substance of the poetry, although the form retains all its grace and charm. Thus it would appear that the mere mood of poetry is untouched by science, and that a poem utterly at variance with nature

may subserve the functions of poetry as poetry. But I would as strongly maintain that the criterion of perfect poetry is not elegance but truth; and that in proportion as the poet's knowledge of nature is true, so will his work represent the thoughts which have power to charm, instruct, and better mankind through all time. I know of no better example of the complete reconcilement of poesy and an accurate knowledge of nature than is contained in Tennyson's "Two Voices." Let any one watch the birth of a dragon-fly, and say whether or not the poet has written sweetly and well—and all the more sweetly, because his words are true:—

> "To day I saw the dragon-fly
> Come from the wells where he did lie.
>
> "An inner impulse rent the veil
> Of his old husk: from head to tail
> Came out clear plates of sapphire mail.
>
> "He dried his wings: like gauze they grew:
> Through crofts and pastures wet with dew
> A living flash of light he flew."

In a closing sentence, permit me to point out what I conceive to be the true place and function of poetry as related to other modes of modern thought. That poetry must ever assert a powerful influence on man's estate, no reasonable being may doubt. It is too closely bound up with the personal history of man in all stages of civilisation, too nearly related to his inmost mind, as the expression of his deepest emotions, to fall into decay even when it lights upon a grossly utilitarian time. The song of victory, the pæan of joy, the "Io triumphe" of the conqueror, or the coronach and lament for the dead,—are expressions wherein the true poetry of our nature bursts forth in spite of ourselves; whilst developing from these more rugged and primitive sources, as a softened stream passes sidewards from a mountain torrent, we find the cultured soul of the

poet communing with nature, and teaching us new and better feelings, and the glory of a higher life.

It is not saying too much, then, to predict that the true mission of poetry is that of leading us to see fairer aspects of things, to cultivate the beauty-sense, and to lead us to see nature in her thousand moods, even if the thoughts it evokes are ofttimes "too deep for tears." Poetry thus becomes the handmaid of culture, and still more of religion. Science, it may never attempt to supersede; although there is and must be a poetry of knowledge, and the æsthetic celebration of every new fact and history which research adds to our stores of thought. Theologies may grow apace, and in turn wax old and decay,—dying out because unfitted to represent the newer aspects of life and the nobler thoughts of God which the progress of the ages reveals. But poetry, as the expression of the deepest emotions of the human soul, can never fade. In her records lie embalmed, as in a treasure-house, the thoughts of the far-back past, and the noblest sentiments which humanity may express. Such are the functions of true poesy, and such the mission of those

> "Who on earth have made us heirs
> Of truth and pure delight by heavenly lays!"

THE END.

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