METHODS OF STUDY

IN

NATURAL HISTORY.

BY L. AGASSIZ.

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PREFACE.

The series of papers collected in this volume may be considered as a complement or commentary to my "Essay on Classification," since I have endeavored to present here in a more popular form the views first expressed in that work. And although the direct intention of these pages has been, as their title indicates, to give some general hints to young students as to the methods by which scientific truth has been reached, including a general sketch of the history of science in past times, yet I have also wished to avail myself of this opportunity to enter my earnest protest against the transmutation theory, revived of late with so much ability, and so generally received. It is my belief that naturalists are chasing a phantom, in their search after some material gradation among created beings, by which the whole Animal Kingdom may have been derived by successive development from a
single germ, or from a few germs. It would seem, from the frequency with which this notion is revived, — ever returning upon us with hydra-headed tenacity of life, and presenting itself under a new form as soon as the preceding one has been exploded and set aside, — that it has a certain fascination for the human mind. This arises, perhaps, from the desire to explain the secret of our own existence; to have some simple and easy solution of the fact that we live.

I confess that there seems to me to be a repulsive poverty in this material explanation, that is contradicted by the intellectual grandeur of the universe; the resources of the Deity cannot be so meagre, that, in order to create a human being endowed with reason, he must change a monkey into a man. This is, however, merely a personal opinion, and has no weight as an argument; nor am I so uncandid as to assume that another may not hold an opinion diametrically opposed to mine in a spirit quite as reverential as my own. But I, nevertheless insist, that this theory is opposed to the processes of Nature, as far as we have been able to apprehend them; that it is contradicted by the facts of Embryology and Paleontology, the former showing us norms of development as distinct and persistent for each group as are the fossil types of each period revealed to us by the latter; and that the experiments upon domesticated animals and cultivated plants, on which its adherents base their views, are entirely foreign to the matter in hand, since the varieties thus brought about by the fostering care of man are of an entirely different character from those observed among wild species. And while their positive evidence is inapplicable, their negative evidence is equally unsatisfactory, since, however long and frequent the breaks in the geological series may be in which they would fain bury their transition types, there are many points in the succession where the connection is perfectly distinct and unbroken, and it is just at these points that new organic groups are introduced without any intermediate forms to link them with the preceding ones. In another series of papers, I shall endeavor to show the futility of the argument so far as it is founded upon the imperfection of the geological record.

I would add one word upon the way in which this volume has been prepared, since it has some features requiring explanation, if not apology. These chapters were first embodied in a course
of lectures delivered at the Lowell Institute in Boston, without any thought of their subsequent publication. Notes were, however, taken of them at the time, and I very willingly assented to the suggestion of some of my listeners, that they should be recorded in the form of articles for the Atlantic Monthly. They still retain something of the repetition which is needed in a public course of scientific lectures in order to keep the connection of the subjects clearly before the mind of a popular audience. An attempt to change this character would have amounted to writing the whole course anew,—a task for which I had neither time nor inclination. I have endeavored to avoid technicalities as far as possible in dealing with subjects many of which are quite unfamiliar to the general mind; and the closing chapter of the book, which has been incorporated in the volume, but did not appear in the Atlantic Monthly, is the only one especially addressed to the professional naturalist.

L. AGASSIZ

NAMANT, August 22, 1868.
CHAPTER I.

GENERAL SKETCH OF THE EARLY PROGRESS IN NATURAL HISTORY.

It is my intention, in this series of papers, to give the history of the progress in Natural History from the beginning,—to show how men first approached Nature,—how the facts of Natural History have been accumulated, and how these facts have been converted into science. In so doing, I shall present the methods followed in Natural History on a wider scale and with broader generalizations than if I limited myself to the study as it exists to-day. The history of humanity, in its efforts to understand the Creation, resembles the development of any individual mind engaged in the same direction. It has its infancy, with the first recognition of surrounding objects; and, indeed, the early observers seem to us like children in their first attempts to understand the world in which they
live. But these efforts, that appear childish to us now, were the first steps in that field of knowledge which is so extensive that all our progress seems only to show us how much is left to do.

Aristotle is the representative of the learning of antiquity in Natural Science. The great mind of Greece in his day, and a leader in all the intellectual culture of his time, he was especially a naturalist, and his work on Natural History is a record not only of his own investigations, but of all preceding study in this department. It is evident that even then much had been done, and, in allusion to certain peculiarities of the human frame, which he does not describe in full, he refers his readers to familiar works, say tr, that illustrations in point may be found in anatomical text-books.*

Strange that in Aristotle's day, two thousand years ago, such books should have been in general use, and that in our time we are still in want of elementary text-books of Natural History, having special reference to the animals of our own country, and adapted to the use of schools. One fact in Aristotle's "History of Animals" is very striking, and makes it difficult for us to understand much of its contents. It never occurs to him that a time may come when the Greek language—the language of all culture and science in his time—would not be the language of all cultivated men. He took, therefore, little pains to characterize the animals he alludes to, otherwise than by their current names; and of his descriptions of their habits and peculiarities, much is lost upon us from their local character and expression. There is also a total absence of systematic form, of any classification or framework to express the divisions of the animal kingdom into larger or lesser groups. His only divisions are genera and species; classes, orders, and families, as we understand them now, are quite foreign to the Greek conception of the animal kingdom. Fishes and birds, for instance, they considered as genera, and their different representatives as species. They grouped together quadrupeds also, in contradiction to animals with legs and wings, and they distinguished those that bring forth living young from those that lay eggs. But though a system of Nature was not familiar even to their great philosopher, and Aristotle had not arrived at the idea of a classification on general principles, he yet stimulated a search into the closer affinities among animals by the differences he pointed out. He divided the animal kingdom into two groups, which he called *Enaima* and *Anaima*, or animals with blood and animals without blood. We must remember,

* See Aristotle’s Zoology, Book I, Chapter XIV.
however, that by the word blood he designated only the red fluid circulating in the higher animals; whereas a fluid akin to blood exists in all animals, variously colored in some, but colorless in a large number of others.

After Aristotle, a long period elapsed without any addition to the information he left us. Rome and the Middle Ages gave us nothing, and even Pliny added hardly a fact to those that Aristotle recorded. And though the great naturalists of the sixteenth century gave a new impulse to this study, their investigations were chiefly directed towards a minute acquaintance with the animals they had an opportunity of observing, mingled with commentaries upon the ancients. Systematic Zoology was but little advanced by their efforts.

We must come down to the last century, to Linnaeus, before we find the history taken up where Aristotle had left it, and some of his suggestions carried out with new freshness and vigor. Aristotle had already distinguished between genera and species; Linnaeus took hold of this idea, and gave special names to other groups, of different weight and value. (Besides species and genera, he gives us orders and classes)—considering classes the most comprehensive, then orders, then genera, then species. He did not, however, represent these groups as distinguished by their nature, but only by their range; they were still to him, as genera and species had been to Aristotle, only larger or smaller groups, not founded upon and limited by different categories of structure. He divided the animal kingdom into six classes, which I give here, as we shall have occasion to compare them with other classifications:—Mammalia, Birds, Reptiles, Fishes, Insects, and Worms.

That this classification should have expressed all that was known, in the last century, of the most general relations among animals, only shows how difficult it is to generalize on such a subject; nor should we expect to find it an easy task, when we remember the vast number of species (about a quarter of a million) already noticed by naturalists. Linnaeus succeeded, however, in finding a common character on which to unite most of his classes; but his definition of the class of Mammalia, that group to which we ourselves belong, remained very imperfect. Indeed, in the earlier editions of his classification, he does not apply the name of Mammalia to this class, but calls the higher animals Quadrupedia, characterizing them as the animals with four legs and covered with fur or hair, that bring forth living young and nurse them with milk. In thus admitting external features as class characters, he excluded many animals which by their
mode of reproduction, as well as by their respiration and circulation, belong to this class as much as the Quadrupeds. — as, for instance, all the Cetaceans (Whales, Porpoises, and the like), which, though they have not legs, nor are their bodies covered with hair or fur, yet bring forth living young, nurse them with milk, are warm-blooded and air-breathing. As more was learned of these animals, there arose serious discussion and criticism among contemporary naturalists respecting the classification of Linnaeus, all of which led to a clearer insight into the true relations among animals. Linnaeus himself, in his last edition of the "Systema Naturae," shows us what important progress he had made since he first announced his views; for he there substitutes for the name of Quadrupedia that of Mammalia, including among them the Whales, which he characterizes as air-breathing, warm-blooded, and bringing forth living young which they nurse with milk. Thus the very deficiencies of his classification stimulated naturalists to new criticism and investigation into the true limits of classes, and led to the recognition of one most important principle — that such groups are founded, not on external appearance, but on internal structure, and that internal structure, therefore, is the thing to be studied. The group of Quadrupeds was not the only defective one.

In this classification of Linnaeus; his class of Worms, also, was most heterogeneous, for he included among them Shell-Fishes, Slugs, Star-Fishes, Sea-Urchins, Corals, and other animals that bear no relation whatever to the class of Worms as now defined.

But whatever its defects, the classification of Linnaeus was the first attempt at grouping animals together according to certain common structural characters. His followers and pupils engaged at once in a scrutiny of the differences and similarities among animals, which soon led to a great increase in the number of classes; instead of six, there were presently nine, twelve, and more. But till Cuvier's time there was no great principle of classification. Facts were accumulated and more or less systematized, but they were not yet arranged according to law; the principle was still wanting by which to generalize them and give meaning and vitality to the whole. It was Cuvier who found the key. He himself tells us how he first began, in his investigations upon the internal organization of animals, to use his dissections with reference to finding the true relations between animals, and how ever after his knowledge of anatomy assisted him in his classifications, while his classifications threw new light again on his anatomical investigations, — each science thus helping to fertilize the other.
He was not one of those superficial observers, who are in haste to announce every new fact that they chance to find, and his first paper* specially devoted to classification gave to the world the ripe fruit of years of study. This was followed by his great work, "Le Règne Animal." He said that animals were united in their most comprehensive groups, not on special characters, but on different plans of structure,—moulds, he called them, in which all animals had been cast. He tells us this in such admirable language, that I must, to do justice to his thought, give it in his own words:—

"Si l'on considère le règne animal d'après les principes que nous venons de poser en se débarrassant des préjugés établis sur les divisions anciennement admises, en n'ayant égard qu'à l'organisation et à la nature des animaux, et non pas à leur grandeur, à leur utilité, au plus ou moins de connaissance que nous en avons, ni à toutes les autres circonstances accessoires, on trouvera qu'il existe quatre formes principales, quatre plans généraux, si l'on peut s'exprimer ainsi, d'après lesquels tous les animaux semblent avoir été modelés, et dont les divisions ultérieures, de quelque titre que les naturalistes les aient décorées, ne sont que des modifications assez légères,

* "Sur un nouveau rapprochement à établir entre les Classes qui composent le Règne Animal."—Ann. Mus., Vol. XIX.

fondées sur le développement ou l'addition de quelques parties, qui ne changent rien à l'essence du plan."*

The value of this principle was soon tested by its application to facts already known, and it was found that animals whose affinities had been questionable before were now at once referred to their true relations with other animals by ascertaining whether they were built on one or another of these plans. Of such plans or structural conceptions Cuvier found in the whole animal kingdom only four, which he called Vertebrats, Mollusks, Articulates, and Radiates.

With this new principle as the basis of investigation, it was no longer enough for the naturalist to know a certain amount of features characteristic of a certain number of animals,—he must penetrate deep enough into their organization to

* If we consider the animal kingdom according to the principles advanced above,—freeing ourselves at the same time from prejudices founded on previously established divisions, and looking at animals only with reference to their nature and organization, excluding their size, their utility, our greater or less familiarity with them, and all other accessory circumstances,—we shall find that there exist four principal forms, four general plans, if we may so express it, in accordance with which all animals seem to have been modelled, and the ulterior divisions of which, by whatever title naturalists may have dignified them, are only comparatively light modifications, founded on the development or the addition of some parts not affecting the essential elements of the plan.
find the secret of their internal structure. Till he can do this, he is like the traveller in a strange city, who looks on the exterior of edifices entirely new to him, but knows nothing of the plan of their internal architecture. To be able to read in the finished structure the plan on which the whole is built is now essential to every naturalist.

Each of these plans may be stated in the most general terms. In the *Vertebrates* there is a vertebral column terminating in a prominent head; this column has an arch above and an arch below, forming a double internal cavity. The parts are symmetrically arranged on either side of the longitudinal axis of the body. In the *Mollusks*, also, the parts are arranged according to a bilateral symmetry on either side of the body, but the body has but one cavity, and is a soft, concentrated mass, without a distinct individualization of parts. In the *Articulates* there is but one cavity, and the parts are here again arranged on either side of the longitudinal axis, but in these animals the whole body is divided from end to end into transverse rings or joints movable upon each other. In the *Radiates* we lose sight of the bilateral symmetry so prevalent in the other three, except as a very subordinate element of structure; the plan of this lowest type is an organic sphere, in which all parts bear definite relations to a vertical axis.

It is not upon any special features, then, that these largest divisions of the animal kingdom are based, but simply upon the general structural idea. Striking as this statement was, it was coldly received at first by contemporary naturalists; they could hardly grasp Cuvier’s wide generalizations, and perhaps there was also some jealousy of the grandeur of his views. Whatever the cause, his principle of classification was not fully appreciated; but it opened a new road for study, and gave us the key-note to the natural affinities among animals. Lamarck, his contemporary, not recognizing the truth of this principle, distributed the animal kingdom into two great divisions, which he calls *Vertebrates* and *Invertebrates*. Ehrenberg also, at a later period, announced another division under two heads,—those with a continuous solid nervous centre, and those with merely scattered nervous swellings.* But there was no real progress in either of these latter classifications, so far as the primary divisions are concerned; for they correspond to the old division of Aristotle, under the head of animals with or without blood, the *Enatina* and *Anatina*.

This coincidence between systems based on

* For more details upon the systems of Zoölogy, see Agassiz’s Essay on Classification in his “Contributions to the Natural History of the United States,” Vol. I.; also printed separately.
different foundations may teach us that every structural combination includes certain inherent necessities which will bring animals together on whatever set of features we try to classify them; so that the division of Aristotle, founded on the circulating fluids, or that of Lamarck, founded on the absence or presence of a backbone, or that of Ehrenberg, founded on the differences of the nervous system, covers the same ground. Lamarck attempted also to make the faculties of animals a basis for division among them. But our knowledge of the psychology of animals is still too imperfect to justify any such use of it. His divisions into Apathetic, Sensitive, and Intelligent animals are entirely theoretical. He places, for instance, Fishes and Reptiles among the Intelligent animals, as distinguished from Crustacea and Insects, which he refers to the second division. But one would be puzzled to say how the former manifest more intelligence than the latter, or why the latter should be placed among the Sensitive animals. Again, some of the animals that he calls Apathetic have been proved by later investigators to show an affection and care for their young, seemingly quite inconsistent with the epithet he has applied to them. In fact, we know so little of the faculties of animals that any classification based upon our present information about them must be very imperfect.

Many modifications of Cuvier’s great divisions have been attempted; but though some improvements have been made in the details of his classification, all departures from its great fundamental principle are errors, and do but lead us away from the recognition of the true affinities among animals. Some naturalists, for instance, have divided off a part of the Radiates and Articulates, insisting upon some special features of structure, and mistaking these for the more important and general characteristics of their respective plans. Subsequent investigations have shown these would-be improvements to be retrograde movements, only proving more clearly that Cuvier detected in his four plans all the great structural ideas on which the vast variety of animals is founded. This result is of greater importance than may at first appear. Upon it depends the question, whether all such classifications represent merely individual impressions and opinions of men, or whether there is really something in Nature that presses upon us certain divisions among animals, certain affinities, certain limitations, founded upon essential principles of organization. Are our systems the inventions of naturalists, or only their reading of the Book of Nature? and can that book have more than one reading? If these classifications are not mere inventions, if they are
not an attempt to classify for our own convenience the objects we study, then they are thoughts which, whether we detect them or not, are expressed in Nature,—then Nature is the work of thought, the production of intelligence, carried out according to plan, therefore premeditated,—and in our study of natural objects we are approaching the thoughts of the Creator, reading his conceptions, interpreting a system that is his and not ours.

All the divergence from the simplicity and grandeur of the division of the animal kingdom first recognized by Cuvier arises from an inability to distinguish between the essential features of a plan and its various modes of execution. We allow the details to shut out the plan itself, which exists quite independent of special forms. I hope we shall find a meaning in all these plans that will prove them to be the parts of one great conception and the work of one Mind.