ZOOLOGY

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649195817

Zoology by Henry Edward Crampton

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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New York
THE COLUMBIA UNIVERSITY PRESS
1908

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A LECTURE DELIVERED AT COLUMBIA UNIVERSITY
IN THE SERIES ON SCIENCE, PHILOSOPHY AND ART
DECEMBER 11, 1907

bivouac can they come to realize how far-flung indeed are the battle-lines of the armies of science—how rich and diversified is the territory from which knowledge has driven ignorance and superstition. And they must realize also how impossible it is for them to conduct their operations at all times in entire independence. The results of physics and chemistry are indispensable weapons for the biologist; geology takes the field with paleontology for the study of fossil forms; while on the other hand the advance posts of zoology provide the students of many a human science with a secure base of operations.

I need not speak of the inter-relations of the several biological sciences, for these have been sufficiently explained in the earlier discourses. I shall pass directly to a description of the elements of the present science of zoology and of its history, so far as this is necessary for a clear understanding of the various divisions of the subject and of their connections; and finally I shall endeavor to show how through its human materials zoology articulates directly with other fields of knowledge.

ZOOLOGY is the science that deals with the structure, development and inter-relationships of animals, with the workings of their parts, their activities and their relations to their environment, and with the factors that determine their forms. We may recognize two great divisions of the subject, which are concerned respectively with static and with dynamic principles, though the materials of both divisions are the same—namely, all animals throughout the entire range from the highest to the lowest. It is of course clear that morphology—the science of structure—cannot be absolutely separated from physiology—the science of function in its widest sense—for we do not know of organic structures that play absolutely no part in an animal's

economy, even though this may be a relatively passive one; while on the other hand we do not know—in science at any rate—of a function that is devoid of a material basis. The division is made solely for the sake of analysis, and it depends entirely upon the point of view. Morphology treats adult animals, their different developmental stages, and, more naturally, the remains of extinct animals as though they were arrested in their living, but the dynamic aspects of organic life are so prominent and insistent that it is really impossible to ignore them even temporarily.

Besides dealing with the same materials, the many complicated problems of zoology are still further connected in that the central object of study for both the structural and physiological divisions is evolution. As we look back over the history of the subject from our modern vantage-ground, we can see how zoology began with ancient and mediaeval natural history, how from this parent stock arose the additional separate branches of anatomy, embryology, paleontology and distribution, how human physiology became comparative physiology which developed later into the broad and deep enquiry into all the activities of animals, their vital relations to one another, and their reactions to and upon the environment; and we can see how all these several branches were vitalized by the great principle of evolution. This whole history shows a steady progress through one phase after another toward the modern study of evolution, though the naturalists of the eighteenth and even of much of the nineteenth century were unconscious, in whole or in part, of the way their observations and views were contributing to the establishment of the doctrine of descent and to the partial description that can now be offered of the natural factors of evolution. As we shall see, the structural analysis of animals demonstrates the evolution of species as a universal process, while the broad study of the dynamic relations of

animals is concerned with the causes of this process, as what we may venture to call the physiology of evolution. In brief, then, the great questions of zoology are the *what* and the *how* of evolution.

In view of the earlier lectures, it is unnecessary to speak at length of classification or taxonomy—the first division of static or structural zoology. Aristotle, who gathered and studied some five hundred of the more common animals of the earth and shore and sea, and the mediaevalists Wotton and Ray, Gesner and Aldrovandi, were animated primarily by the instincts of the collector of interesting information. Linnaeus, the great figure of the eighteenth century, rendered an immortal service to zoology (and botany, too,) by introducing the present ordered system of naming and classifying organisms. But classification was to Linnaeus an end in itself, he could not see that it was but a means to the larger end of understanding and expressing evolutionary relationships,—that resemblance meant consanguinity. It remained for Erasmus Darwin, the elder St. Hiliare, Lamarck and others to appreciate this inner meaning which so vivifies the otherwise dead details of taxonomy.

The many connected details of animal structure and development and function constitute the threads, as it were, which are interwoven by comparative treatment to form the warp and woof of the fabric of zoology. Classification draws upon this fabric the pattern of genealogical connections, emphasizing those threads that run furthest, the so-called distinctive or diagnostic characters. And though the pattern must be altered here and there as knowledge increases, the zoologist feels that it has a real significance as a representation of evolutionary descent.

As more and more of the lower animals were brought by the microscope from the obscurity of their zoological underworld, as exploration revealed more of the creatures

of previously unknown lands, as investigation became more detailed and intensive, comparative anatomy arose as an independent branch of zoology with distinct purposes of its own; and it gained its specific form and character from the studies of the great zoologists of the early nineteenth century—Lamarck, Cuvier, Geoffroy St. Hiliare, Goethe, Owen, and Oken. These naturalists dissected and compared the various organic systems of animals, following them as widely as possible from group to group of the numerous vertebrate and invertebrate forms, and they and their followers have placed the doctrine of evolution upon the sure and broad foundation of comparative anatomy. The main principle of this department of zoology is that the varied forms of animals exhibit deep-seated likenesses that place them in groups related to one another not as the rungs of a ladder as Lamarck supposed, but rather as the branches of a tree or a bush; and such branches again like those of a tree bear smaller branches, and these reach to lesser or greater heights from the base level of primitive organization. Thus, anatomy holds that community of plan is an indication of genetic affinities, while modifications of a common plan exhibit the results of adaptation to different ends through evolution, The framework of the human arm is constructed out of the same elements with the same arrangement that we find in the leg of a cat, the flipper of a seal, the paddle of a whale, and even the wing of a bat, different though these structures are in function,—and in these resemblances comparative anatomy discerns evidence of a remote common ancestry of men and whales and bats.

Extended through the study of tissues, or histology, to the unitary elements of organic structure—the cells—comparative analysis has brought the whole realm of organic nature under the sway of a great principle—the cell-doctrine of the botanist Schleiden and the zoologist