DANA (J. D.)

On Cephalization. xxx

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ART. XXX.—*On Cephalization;* by JAMES D. DANA. Part V.

Cephalization a fundamental principle in the Development of the System of Animal Life.

THE principle of cephalization has been explained at length in memoirs in former volumes of this Journal,* and to them I would refer for detailed illustrations of the subject. Among these illustrations the attention of the reader is especially called to those from the department of Crustacea, the study of which—occupying more than half of my time between the years 1837 and 1855—brought before me the facts on which it rests. It cannot fail to be perceived, in the review, that, with elevation in grade among the Decapods, for example—passing upward along the line of Macrural forms to the Brachyural (or from the lowest of shrimp-like species to crabs)—there is in general, with the rising grade, an abbreviation relatively of the abdomen, an abbreviation also of the cephalothorax and of the antennæ and other cephalic organs, and a compacting of the structure before and behind; a change in the abdomen from

* For former papers on Cephalization, see this Journal, II. xxii, 14, 1856; xxxv, 65, xxxvi, 1, 159, 321, 440, 1863; xxxvii, 10, 157, 1864; xli, 163, 1866.

One point made in these papers, I would withdraw, viz: that the transfer of the anterior pair of members in Man from the locomotive to the cephalic series is analogous to the transfer which takes place in Crustaceans in passing from the Tetradecapod to the Decapod type, or from the Arachnoid to the Insect type. The latter is plainly a structural transfer, the two anterior pairs of limbs in the Crustacean, or the one in the Insectean class, becoming, by the transfer, strictly cephalic organs (pertaining to the mouth series), and existing thus in a large tribe of species. But in man it is properly only a functional transfer, analogous to cases among spiders and Tetradecapods, where the anterior legs become adapted to serve functionally the mouth or head, without that structural transfer which would place them of itself in the higher order.

an organ of great size and power and chief reliance in locomotion, to one of diminutive size, and no locomotive power; and a change as to the particular pair of legs which is the strongest, from one of the more posterior to the anterior in the series; in other words, that, as grade rises, there is abbreviation behind and before, and thus a concentration of the structure, and a more forward or anterior position in the stronger of the organs of locomotion and prehension. The shrimp and crab are so widely unlike in form that the common eye hardly suspects that they are made up of the same parts or organs arranged in precisely the same order: that the latter is only a shrimp contracted in length, dwindled to almost nothing in its abdomen, and compacted in its mouth organs so that the outer pair makes a well fitting operculum over the others, and shortened in its very long multiarticulate antennæ to a few articulations giving them a length often not a tenth of that of the cephalothorax.

I would refer also to the case among mammals, for an illustration of the same principle—that the lowest forms are those having their locomotive functions located in the posterior parts of the body;* and that in the higher, the forces, or force-organs, are more and more forward in the structure. For example, in the whale—the tail is the propelling organ and is of enormous power and magnitude, and the brain is very small and is situated far from the head extremity in a great mass of flesh and bone furnished with poor organs of sense; a grade up, in the horse or ox, the tail or posterior extremity is no longer an organ of locomotion, and is little more than a caudal whip-lash, and locomotion is performed by organs situated more anteriorly, the legs, and a well-formed head carries a brain which is a vastly higher organ of intelligence than that of the whale—but the legs are simply organs of locomotion, and the hinder are the more powerful; and higher up, in the tiger or cat, the fore-legs—not the hind-legs—are the organs of chief muscular force, and these have higher functions than that of simple locomotion, and, further, the body is proportionally shortened, and the head is shortened anteriorly or in the jaws and approximates thus toward the condition in man. The existence or not

* The fact that fishes have, with few exceptions, the tail as the chief or only locomotive organ, corresponds with their inferior position among Vertebrates. At the same time, it makes the application of the principle of cephalization in determining grade among them quite difficult. In most classes or groups the force-organs constitute a series along the body, and the position of the strongest, and the transfer forward with the rise in grade, is openly manifested. But in nearly all fishes, the tail remains the locomotive organ, with no transfer of its locomotive function to more anterior members, and, therefore, other less obvious and much less certain modes of determining any forward transfer of force are all that remain. And, further, as the conclusions we may arrive at hold good, among all classes of animals, only in case *other conditions in the structure are essentially equal*, the inferences from such evidence can ordinarily extend only to the grade in the family or smaller group to which the species belong.

of a switch-like tail, as in ordinary quadrupeds, has little bearing on the question of degree of cephalization, since the organ is not an organ of locomotion, or one indicating a large posterior development of muscular force. But, approaching man in the system of life, even this seems to have significance.

In accordance with the principle and method illustrated, animals of a given type differ widely as to the conditions and arrangements for action—muscular, sensorial and psychical—in the animal structure. In the low,* there is, usually, large size and strength behind, an elongation of the whole structure, and a low degree of compactness in the parts before and behind; in the high, there is a relatively shorter and more compacted structure, a more forward distribution of the muscular forces or arrangements, and a better head; and the progress in grade, under a type, is progress along lines from the former condition toward the latter, that is, progress in the strength, perfection and dominance of the anterior or cephalic extremity; in a word, it is progress in cephalization.

The principle of cephalization is thus fundamental because, first, the chief center of nervous power or energy in an animal is at the cephalic extremity; and, secondly, because form in nature's species is, with some limitations, an expression of force.*

Again, I have exemplified, in my memoirs, the corresponding fact that progress in cephalization generally attends progress in embryonic development; referring, for illustration, to the loss of the locomotive tail in the frog and many other Amphibians at the time of the passage to the adult stage, and the concurrent development anteriorly of limbs, with the perfecting of the head in structure and senses; to a similar abbreviation posteriorly in the development of modern gars; to the fact that the higher insects rise from a state that is worm-like in form, having no distinction of thorax and abdomen and sometimes furnished with abdominal locomotive appendages, to an adult stage in which the abdomen is greatly dwindled in size, the thorax and abdomen are distinct segments and the former alone has locomotive members and these of perfected structure, and the well-defined head has highly developed sense-organs and exalted senses; and to other examples, all illustrating the view that through the developments going forward in the progress of embryonic development, there may in general be distinguished a cephalization, or forward improvement, of the structure.

It has also been illustrated that the geological progress in the life of the world has been progress in accordance with the principle of cephalization, this being manifested in the succession of forms under the various types, and also in the correspondence

* For a consideration of the inferior species of some groups, related to half-developed embryonic forms in structure, I would refer to my former papers.

so often exhibited in a general way—as announced by Agassiz—between the biological succession and embryonic development. I need not dwell on the facts in this place, as they are well understood.

Professor Marsh has recently brought forward facts which exemplify fully the view that the succession in the animal life of the globe has been more or less connected with brain-progress, facts which sustain strongly the doctrine, which I have elsewhere urged, that this progress involved changes in structures in obedience to the principle of cephalization.*

Professor Marsh states† that in the Eocene Dinoceras, from the Rocky Mountain region, the brain was not more than one-eighth the bulk of that of the modern Rhinoceros—its nearest recent ally; in the Miocene Brontotherium it was much larger, about equalling that of the Indian Rhinoceros; and in a Pliocene Mastodon, the brain was larger than in Brontotherium, but not equal to that of living Proboscidians. In a paper on the Eocene Coryphodon of the same region,‡ the brain was even lower than in Dinoceras. Again, after a further study of the subject,§ and a comparison of an extensive series of ancient and modern crania, he gives as his conclusions—in advance of a full and illustrated memoir on the subject: "*First*, all Tertiary Mammals had small brains; *second*, there was a gradual increase in the size of the brain during the age; *third*, this increase was mainly confined to the cerebral hemispheres, or higher portions of the brain: *fourth*, in some groups the convolutions of the brain have become more complicated; *fifth*, in some, the cerebellum and olfactory lobes have even diminished in size;" and, further, "there is some evidence that the same general law of brain-growth holds good for birds and reptiles from the Cretaceous to the present time."

A growth of eight fold in bulk since the early Tertiary is enormous, vastly exceeding in amount the growth in other organs; in fact, the species related to the Rhinoceros have not increased in bulk with the progress of time, but diminished. And the same is true of other species; there is in general higher grade *with smaller bulk*. Moreover, concurrently with the change in the brain, there has been in succeeding species a relative shortening of the head and especially of the jaws, besides other modifications, such as mark a rising grade of cephalization.¶

* Author's Manual of Geology, 1874, p. 596.

† This Journal, III, viii, 66, 1874, and xi, 163, with figures of the Dinoceras brain; xi, 335, with figures of the brain in Brontotherium; and xi, 425, with figures of the brain in the Eocene Coryphodon.

‡ Ibid., xi, 425, 1876. § Ibid., xii, 61, July, 1876.

¶ The jaws are in some mammals relatively short through the incisor portion being imperfectly developed, and this condition is a mark of inferior grade. The shortening referred to above is not of this degradational kind, but that presented in a diminished distance between the normal incisor-extremity and the normal position of the posterior molar—an abbreviation which reaches its extreme limit in man.

But have other peculiarities of the later species any connection with this growth and change of brain? We can hardly doubt, that, inasmuch as there has been no corresponding change in the animal's bulk, there must have been concordant changes somewhere, and change of equal magnitude and importance; and the supposition that they included the structural modifications which mark the line of species from the early Tertiary onward, does not appear to be extravagant.

Such growth or progress in the brain and nervous system—the seat of power in the animal—is accordant with, and consequent upon, the great fact that this is the part of the structure which comes into actual contact with outside and inside nature. It is the means in an animal by which communication is had with the outer world and also with its own inner workings and appetites; that which takes impressions, which feels whatever inspires energy, prompts to action, exhilarates, or exalts; the part, therefore, which must grow whenever circumstances favor progress, and, at the same time, fail to grow or dwindle under unfavorable circumstances; which communicates whatever it receives to the being to which it belongs, and, in each case, to the part or parts responding to its condition; which reaches every part of the system and dominates in all action and growth, and hence must cause an expression of its own condition in some way on the structure; which, moreover, must ordinarily produce correlate changes in correlated parts, if any, because in its own nature and distribution the system of correlation has a full expression. Energetic use gives increasing strength to muscle; and that wonderful strengthening growth in the brain since Eocene times may also have come from use.

It would hence appear that a prominent means of change in species is the action of influences on the brain; that the brain grows and changes and sends its changing forces through the animal; and that this gives progress, or degradation; and hence it is that progress is exhibited in cephalization, and degradation in decephalization. The brain could not grow to the adult stage in the frog without the change in the structure that cotemporaneously takes place; and no more could the brain of a species like a shrimp grow into a brain of the higher grade of a crab without its determining in some sense a concordant higher grade of structure in the animal, involving the loss of locomotion in the abdomen and also other changes.

We recognize, as evidence of upward progress in Man, an increasing height, width and erectness of the forehead, and a shortening of his jaws, and see therein evidence of improved intellect; which means higher grade of cephalization. But, more than this, the erect form of Man, the shortened arms, the naked skin, as well as the large, smooth-surfaced cranium, may

also be as directly and necessarily connected with, and dependant upon, his superior degree of cephalization in the system of animal life; while the hairy skin, the long arms, the crested skull, the inclined posture of the man-ape, may be all involved in the ape's inferior degree of cephalization. If so, the development of the brain in Man and of all the highest structural perfections of the Vertebrate type which he exhibits is inconsistent with the existense of the hairy covering and some other circumferential as well as interior characteristics of the brute.

We may therefore believe that in all progress in grade, upward or downward, there was involved some changes in the animal structure of the kind expressing degree of cephalization. Brain-progress could not have taken place without structural progress: and with the brain eminently the growing organ, the brain-progress would have had a determining relation to the latter. More than this, many peculiarities of form or structure in animals which are not evidently marks of grade in cephalization, or have little or nothing to do with it, may have had the same source. The type of structure characteristic of a group of species is beyond doubt connected with some peculiarity of chemical composition, or rather of chemical compounds present, in the great center of activity; and this chemical condition once established, the progress afterward, connected with brain growth or change, might well be a development in that line of type structure, displaying the type under new forms.

I do not mean to imply, in the above, that the method of progress pointed out accounts for the existence of the various types of structure in the animal kingdom, or for all the developments under them: but only that, whatever the types of structure in course of development, there was also a general subordination in the changes to the principle of cephalization; because the nervous system by its growth and domination must necessarily have determined such subordination; and, further, that, through the same agency, the development of other peculiarities of structure and form, not obviously marks of grade, may have been occasioned. The origin of the grander types of structure must be connected with the profoundest of molecular laws; and how connected, man may never know.

These views may hold whatever be the true method of evolution. The method by repeated creations through communications of Divine power to nature should be subordinated, as much as any other, to molecular law and all laws of growth; for molecular law is the profoundest expression of the Divine will, the very essence of nature; and no department of nature is without its appointed law of development. But the present state of science favors the view of "progress through the derivation of species from species, with few occasions for Divine

intervention."* If then there has been derivation of species from species, we may believe that all actual struggles and rivalries among animals, leading to a "survival of the fittest," must tend, as in Man, to progress in cephalization, and dependent structural changes. In fact, mere living, the surmounting of the daily obstacles in getting food and shelter and satisfying ordinary desires, may have given growth to the brains and structures of the Eocene mammals, aiding, but perhaps exceeding, all other influences from environments.

The source of variation here pointed out is not at all at variance with Darwinism. Darwin, in fact, does not aim to explain the origin of variation among species, but chiefly the workings of natural selection—variations being in progress by some means—in leading to the "survival of the fittest" of the varieties. Variation he refers to environments, and especially to action on the genital system. The genital system may have this prominence in plants; but for animals I would give the *nervous* system the higher place, inasmuch as upon it environments make their first and most powerful impress.

One reason why plants present but few simple types of structure compared with animals, and why marine plants are almost the same for all geological time, and thus strongly contrast with the immense diversity and complexity of types and kinds among marine animals, may be found in the fact that plants possess not that feeling, knowing, outreaching and inworking thing, a nervous system. This, however, is not all: for the presence of so large a proportion of nitrogen in the animal structure, in addition to other elements, gives an opportunity for a vastly wider range of chemical combinations.

ART. XXXI.—*On an Electro-magnetic Machine constructed at the Cornell University Workshop;* by WM. A. ANTHONY, Professor of Physics at the Cornell University.

THIS machine is essentially the same as the "Gramme" electro-magnetic machine, and its construction was undertaken on account of the difficulty that seemed to exist in the way of procuring the "Gramme" machine from the European manufacturers.

The soft iron core of the revolving armature consists of a coil 24 cm. external diameter, 20 cm. internal diameter, and 15 cm.

* This sentence is cited from my Manual of Geology, 1874, p. 603. After it come these words:—"For the development of Man, gifted with high reason and will, and thus made a power above Nature, there was required, as Wallace has urged, the special act of a Being above Nature, whose supreme will is not only the source of natural law, but the working force of Nature herself," and this I still hold.