

ART. XXI.—*On Cephalization*; No. IV: *Explanations drawn out by the Statements of an Objector*; by JAMES D. DANA.¹

IN a paper published in the third volume of the Proceedings of the Entomological Society of Philadelphia, Mr. B. D. Walsh discusses the subject of the classification of Insects as based on the principle of cephalization, and criticises, not my views, but his own misconceptions of them.² As others may have fallen into similar errors, notwithstanding the long explanations which have been presented, I briefly notice here some of the points in his paper.

1. Our objector says (p. 238) that "as originally propounded by him [Mr. Dana] in Crustacea, cephalization consists in 'the transfer of the anterior members of the thorax to the cephalic series' (Sill. Jour., vol. xxxv, p. 66), or in other words in *legs* being converted into *head-organs*."

In the first place, our expositor, while claiming to cite what was "originally propounded" by me, had not seen my *original* memoir published in 1852³ in the Report on Crustacea, and in 1856 in this Journal, and refers to no paper earlier than that of 1863.

In the second place, he finds in the paper which he does cite what neither that paper, nor any other that I have written, contains. I have nowhere said that cephalization *consists* in such a

¹ For number I, of this series, see this Journal, xxxvi, 321, Nov. 1863; number II, xxxvii, 10, Jan. 1864; number III, xxxvii, 157, March, 1864.

² On certain Entomological speculations of the New England School of Naturalists, by B. D. WALSH, M.A., Proc. Entomolog. Soc., iii, 207. The writers of the "New England School" here particularly criticised are Prof. Agassiz and Prof. Dana; and, incidentally, A. S. Packard, Jr., some passages of a paper of his having been cited by the latter.

³ Not 1855, as stated in this Journal, xxxvi, 321.

transfer of members. The statement would be wholly at variance with the very idea of cephalization. What I have asserted is this: that variation in grade of cephalization is *manifested* in the structure by the transfer referred to, and by this as only *one among many methods*.

I have argued that since animals have a head as their grand characteristic feature, and a cephalic nervous mass as the fundamental element of the head and the prime center of force in the organism, exaltation and concentration anteriorly of the life-forces mark a high grade of cephalization; and relaxation or decentralization, and an enfeebling of the same, with a consequent spreading posteriorly or away from the cephalic extremity, indicate a low grade of cephalization. I have also said that these conditions of the life-forces of the individual, that is, of the organizing and working forces, should necessarily be apparent, and are in fact apparent, in the structure of the organism, the resultant of the forces. I have shown that concentration anteriorly, with exaltation of the cephalic extremity, is manifested not merely in the transfer of members to the cephalic series (thereby enlarging the sphere of the head), but also in the form and structure of the head,—in the form and condition of the organs of the senses—of the organs of the mouth—of the successive pairs of legs—of the abdomen—of the abdominal appendages; and in my later memoirs I have still more widely extended the list of characteristics that indicate grade of cephalization.

The laws of cephalization act conjointly with another principle in animal life:—that of the *oppositeness subsisting between the cephalic or anterior and the posterior extremities of the animal structure*, which is a kind of antero-posterior or fore-and-aft polarity. This oppositeness or polarity is *up-and-down* in the plant, and *fore-and-aft* in the animal. The fore-and-aft becomes strictly up-and-down *in position* in one animal alone—Man; and this by elevating heavenward the cephalic extremity, not by a change of the axis of symmetry to that of the plant. (See this Jour., xxxvi, 351.)

In view of the total misapprehension of this subject by our entomological critic, I may be excused for citing additional explanations from an article written for a popular magazine, even if they are essentially a repetition of what is contained in my former papers.

“As the head is the seat of power in an animal, it is natural that among species rank should be marked by means of variations in the structure of the head; and not only by variations in its structure, but also in the extent to which the rest of the body directly contributes, by its members, to the uses or purposes of the head. *Cephalization* is, then, simply domination of the head—cephalic domination—in an animal, as manifested in the structure; and any *degree* of it depends on the grade of power of the

cephalic center, and the degree of subordination to it in the structure. The following are some of the ways or methods in which it is manifested.

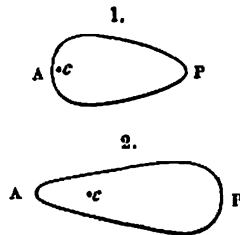
(1.) With *superior* cephalization, that is, as species rise in grade or rank, more and more of the anterior part of the body, or of its members, renders service to the head; with *inferior*, less and less.

(2.) With *superior* cephalization, the structure of the head, or of the anterior portion of the body, becomes more and more compacted, perfected, and condensed or abbreviated; with *inferior*, the same portion becomes more and more lax in its parts or loosely put together, and imperfect in the parts or members themselves; and, at the same time, the whole is more and more elongated, and spaced out or enlarged.

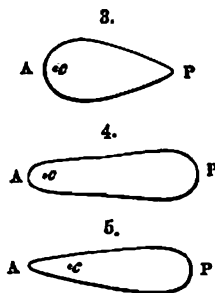
(3.) With *superior* cephalization, the posterior portion of the body becomes more and more compacted, or firmly put together and abbreviated; that is, as concentration goes on *anteriorly*, there is abbreviation *posteriorly*. Even the tail shows grade; for great length, or size, or functional importance is actually a mark of inferior grade, other things being equal.

(4.) With *inferior* cephalization, there is not only a less and less concentrated or compacted and perfected state of the whole structure, before and behind, but, in its lower stages, the degradation of the structure extends to an absence of essential parts, as *teeth, members, senses*; and often, also, to a gross enlargement of the body beyond the size which the system of life within can properly wield, and in this case the body is stupid and sluggish."

The question as to the condition of the life-forces thus passes from the sphere of speculation to one of direct observation. A *Lion*, for example, exhibits to the eye the high degree of cephalization of its structure by its strength anteriorly, or that of its head and fore-limbs, and the correlate form and structure of these and other parts of the body; and a *Whale* manifests its low degree by its degraded head and senses, its feeble limbs partly obsolete, and the immense size and strength of the tail; and this is so obvious, that the muscular or motorial force of the two might be sufficiently well represented by the annexed figures: figure 1 corresponding to that of the Lion, and 2, to that of the Right Whale, A being the anterior or cephalic extremity and P the posterior or caudal extremity. The figures give a faint idea of what is meant by *cephalization* and *decephalization*. If the sensorial forces of the Lion were taken into consideration, the contrast between the two would be still greater. c is the position of the prime systemic center; its remoteness from the front margin in the Right Whale, (figure 2) is one of the marks of the extreme decephalization of the structure. (See on Cephalization, No. III.) The arrangement of the muscular force in different Herbivores might be represented by figures intermediate between 1 and 2.



The following figures serve in a similar rude way to illustrate the condition of the force in the three subdivisions of Decapod Crustaceans; figure 3, in the Crab, which has the abdomen (the part so large in the lobster) almost wanting and very feeble, and the systemic center (c) very close to the front margin; fig. 4, in the Shrimp which has the body prolonged before and behind, but especially in the latter direction, the posterior portion or abdomen being of great size and powerful as an organ of motion; fig. 5, in certain species of the *Squilla* group, in which the cephalothorax is weak, its appendages feeble, the abdomen 2 or 3 times as long as the anterior part of the body and relatively to the cephalothorax far more powerful than in the Lobster or Shrimp. Other classes of animals afford similar illustrations.



There are probably no characters connected with the structure, growth and habits of an animal that have not something to reveal with reference to grade, under this principle of cephalization. To read the truth, especially among the lower subdivisions of a class, the families, genera, species, may often require profound study, and even a higher stage of science than the world has now attained to. But the necessity of profound study, when knowledge below the surface is sought for, is not peculiar to this department of nature.

I repeat, then—cephalization does not “consist in a transfer of members” one way or another, but is *manifested* by the whole animal structure within and without.

2. Our objector says that this character of cephalization “really appears to be of high systematic value in Crustacea”; but, as the neururation of the wings is a good characteristic in one group of Insects and not in another, so it is not necessarily good in other animals.

This comparison of the principle of cephalization, the origin of a host of characteristics, with the single superficial one *from the neururation of the wings*, is in accordance with the misquotation making cephalization to consist in a transfer of members, &c.

The laws of cephalization pertain to the elemental forces of the organism, or the fundamental nature of animal life, as much as the laws of attraction to the fundamental nature of a molecule; and, therefore, if true of one branch of the Animal Kingdom, they must be true of all. Yet the exhibition of these laws in the structure will be widely different, as the structures themselves are various in character. They cannot be precisely the same in footless Worms as in Crustaceans; or in Crustaceans as in In-

sects; or in Insects as in Mammals; although the grand fundamental principle at the basis of the organism is the same in each.

8. Our objector observes again, with like misconception of the subject, that as "the conversion of the front wings into elytra amounts to a decephalization," "instead of classing Hemiptera as inferior to Coleoptera and Orthoptera to Hemiptera, we ought to adopt exactly the opposite arrangement. For Coleoptera have the front wings entirely elytriform, Hemiptera (Heteroptera) only about one-half elytriform, and Orthoptera scarcely or but slightly elytriform. Those groups, therefore, according to Dana's own principle ought to stand, 1, Orthoptera, 2, Hemiptera, 3, Coleoptera, instead of the reverse."

Thus, Mr. Walsh sets up his man of straw, and combats it with great success.

"Dana's own principle," above announced and demolished, is not to be found in any of Dana's own writings. The fact of the fore-wings being coriaceous wholly, in part, or not at all, has no bearing whatever on the question; this is a mere external characteristic, of no dynamical value, like most of the characteristics appealed to by ordinary systematists. I expressly state that the true distinction depends on the *posterior* wings being the main flying-wings; I say, further, that the fore-wings may be used for flying, and still, if the hinder wings are the more powerful, the insects are *metasthenic*, and have the characteristic of the inferior or Coleopteroid division.

The segment of the body bearing the stronger flying organs in these *metasthenic* species (Coleoptera, Hemiptera, Orthoptera) is one *posterior* to the same in the higher *prosthentic* species (Hymenoptera, &c.); and the fact that the force is consequently, more posterior among the body segments, and among the nervous ganglions, is hence one of direct observation, and not a hypothetical inference. The terms *prosthentic* and *metasthenic* bear the profounder meaning of cephalization in their composition.

There being two *sthenic* characters of acknowledged value based on the limbs, one on the *wings*, and the other on the *legs*, it is asked, why the former should be made to have the precedence in classification. Simply because they have the precedence *in fact*. The species of the grand division of Coleoptera are *throughout metasthenic as regards the wings*; that is, the posterior wings are the only flying wings or, at least, the stronger, in all the species; and this is true also, of the Hemiptera and Orthoptera: while they are not all *metasthenic as regards the legs*; for under these groups there are subordinate divisions which include among the species both those that are *prosthentic* and those that are *metasthenic as regards the legs*. The latter distinction is, therefore, as a matter of fact, of limited importance or compre-

hensiveness compared with the former. But this point is sufficiently illustrated in my article on the classification of Insects and requires no additional explanation here.

4. Our objector says that the position of the wings in the Dipters is half a segment nearer the head than that of the anterior pair in the Hymenoptera, and that *therefore the Dipters ought to stand first in the system*. But he errs from failing to note that the wings in Dipters do not pertain to a *more anterior segment*, or nervous ganglion (center of force), than the fore-wings in Hymenoptera, but, on the contrary, to the very same; whence, there is no parallelism between this difference and that separating the Hymenoptera and Coleoptera. The difference of position alluded to has, consequently, little or no dynamical value, and little or no weight in a classification based on cephalization.

5. Our objector applies his mistaken definition of cephalization further, and argues as follows:

"If we apply the principle of Cephalization in its original signification to Insects, we shall find that there are certain families and genera, e. g. in Orthoptera *Mantidæ*, in Neuroptera *Mantispa*, in Heteroptera *Myodocha*, *Phymata*, *Macrocephalus*, *Syrilis*, *Reduviidæ* and *Nepidæ*, and in Diptera *Hemerodromia*, which have what are commonly known as raptorial front legs; in other words the front legs are used, not as *legs* but as *arms* to catch their prey with. In other species, e. g. the dipterous *Calobata antennæpes* Say, which takes its name from that peculiarity, and in many Nemocerous Diptera, the front legs are not used at all for locomotive purposes, but are elevated in the air and vibrated after the fashion of antennæ. Here therefore it is strictly true that "the anterior members of the thorax are transferred to the cephalic series;" and if, as Prof. Dana maintains, the cephalization of the anterior pair of limbs in Man, or in other words the conversion of his front limbs into arms, "places Man apart from the whole series of Mammals" (Sill. Journ., vol. xxxv, p. 68), then by parity of reasoning, if the principle of cephalization is universally applicable, all the above-mentioned families and genera of Insects ought to be placed in a group by themselves."

The prehensile or raptorial modification of the anterior limbs and the transfer of members to the cephalic series are here mixed up, although both characteristics are the subject of extended explanations in my paper; and hence our objector's remarkable result.

I have stated that there were but three examples of the *transfer of members to the cephalic series* in the whole animal kingdom—the Entomostracans or degradational Crustaceans excluded, in which the examples are not well-defined. One is that from Tetradecapods to Decapoda, the *four anterior* of the *fourteen* feet in the former being mouth-organs in the lat-

ter; the *second* is that from Spiders to Insects (or Octapods to Hexapods), the two anterior feet in the former being mouth-organs in the latter. One of these cases occurs between the two higher divisions of *aereal* Articulates or Insecteans; and the other two between the two higher divisions of the foot-bearing *aquatic* Articulates or *Crustaceans*.

The *third* case is that from Quadrupeds to Man, the *two* anterior feet in the former being in man taken completely out of the locomotive series and given up to the cephalic series, to which series, moreover, they *structurally* belong.

Now there are numerous Tetradeapods with *prehensile* fore-legs, but they are no less Tetradeapods in type of structure and all their relations. These prehensile legs aid in capturing food; but they are no more part of the cephalic series than are the prehensile fore-feet of a squirrel. There are Decapods with prehensile fore-legs, which are none the less Decapods; and there are also inferior macrural species (certain shrimp-like kinds) which have the four outer mouth-organs foot-like in size and function, so that they have as many feet as the Tetradeapods; and yet they are Decapods in type of structure, and show no true approximation to the Tetradeapod type.

Among Quadrupeds, the fore-feet of the Carnivores are prehensile, and those of the Squirrels and Monkeys quite perfectly so; and yet these limbs are part of the locomotive series. Man stands alone among Mammals in having the fore-limbs, not only prehensile, but out of the inferior series, the posterior pair being the sole locomotive organs.

The question of the exact parallelism of this last of the three cases with the preceding two admits of arguments on both sides. But whichever way decided, it does not affect in the slightest degree our deductions under the principle of cephalization. It touches only one single argument on the question whether Man constitutes by himself a separate Order among Mammals, and this, in our view, not seriously. All must admit, whatever his views of the question, that this ennobling of the fore-limbs is one mark of that preëminence of cephalization which belongs to Man.

6. The necessity of an exact balancing of all characteristics bearing on grade, in order to arrive at correct results, is too obvious for an argument. If the inferior criterion is in any case made the superior one, only absurdities are reached. Our objector affords examples of this kind of error. Observing that narrow limits of variation, and a less tendency to run into bizarre forms, are set down as generally characteristic of a superior group, and as part of the evidence of the superiority of

the Hymenoptera, he remarks that the Fleas are far more uniform in shape and size than the Hymenoptera, and therefore, according to the criterion mentioned, ought to be placed *first* among the Apipens; apparently unaware that in this bit of logic the criterion referred to is made *superior* to all others, or the most decisive of grade, and not perceiving, therefore, that the *reductio ad absurdum*, intended for the principle criticised, attaches to the critic himself. Again, by a similar misuse of the criterion connected with prehensile anterior limbs, and additional misunderstandings already alluded to, he arrives at other absurdities. In the same way he might assume that, because great length of antennæ is one of the marks of low grade,—the Macrurans (Lobsters, Shrimps, &c.,) showing by this character, as I have stated, their inferiority to Brachyurans (Crabs),—therefore Insects ought to be arranged according to length of antennæ; which would of course make very heterogeneous assemblages. Or he might next make abdomens or tails the grand criterion, (this characteristic being also set down as a mark of grade), with a like result. By thus assuming successively that each criterion is superior in value to the others, all may be run into the ground; a feat of no great prowess in logic or science.

While long antennæ and long abdomens are among the marks of that decentralization or decephalization which distinguishes the Macrurans from the Crabs, some of the higher Macrurans have, relatively to size of body, longer antennæ than the lower; and there are hundreds of Tetradeapods and Entomostracans, still inferior species, that have relatively to length of body, far shorter antennæ, and shorter abdomens too, than the Macrurans. There are, in all such cases, characters to be considered of higher value before we come down to that level where length of antennæ, or of abdomens, is decisive as a mark of grade.

7. As Nature is yet an unfathomed deep, our systems must have their imperfections and uncertainties, and we our difficulties in applying principles that have been ascertained. Examples of such difficulties from the subject of cephalization have been alluded to in the preceding remarks; and here is another.

Large size in species, as all know, is sometimes a mark of superior grade. The fact is pressed upon our attention by familiar facts, as well as by the general relations in mean size of high and low types among animals. Vertebrates are larger than Insects or Worms, Insects than Infusoria, Beasts than Birds, etc.

But, again, large size is sometimes, also, accordant with, and a mark of, inferior grade. Man is smaller than his inferior the Lion; the Lion is smaller than its inferior the Hippopotamus; the Hippopotamus than its inferior the Whale; the Crab than its inferior the Lobster; the Echinus than its inferior a large

Medusa; and so on. Now it may be urged, against the system of classification proposed, that size sometimes means one thing, and sometimes the reverse, and there is here manifest indefiniteness and a chance for indefinite assumptions. Or, the charge may be made with more point, and much less truth, as follows: "Because great size is correlated with superiority in *Crustacea*, you [Mr. Dana] infer that it is so correlated everywhere throughout the Animal Kingdom; and when, as nobody can fail soon to do, you meet with examples where facts contradict your theory, you get over the difficulty by assuming gratuitously that size is there due only to what you call 'vegetative enlargement.' As I cannot find that you have anywhere laid down any definite rules by which this vegetative enlargement is to be distinguished from the normal enlargement, the distinction appears to be an empirical one."

Now great size is not correlated with superiority in *Crustacea* any more than in the rest of the Animal Kingdom, and this I particularly illustrate in my first paper on the subject; for I there discuss at length the relations of rank to mean size, and of rank to size from overgrowth or vegetative enlargement. The facts in nature are always obscure of interpretation until thoroughly and properly studied; and if the relation of size to rank is among the things not understood, it is among the things to be investigated. I have endeavored to give some criteria for deciding on this point. Towards this end I have presented the consideration that where a structure is so large for the species that the animal is sluggish in its movements, or stupid in its senses, there is evidence in this that size is a mark of degradation. But I have shown, further, that where size is a mark of low grade, the low grade is also manifested in a multitude of other characters, so that we are not left to this one distinction alone. In fact, wherever size has been mentioned as one of the characteristics of an inferior group, I have rested mainly upon the others for proving the inferiority of the group.

Moreover, I have given illustrations explaining why size should be a mark of high grade, and also why in other cases a mark of low grade. I may add one or two comparisons in elucidation of this point. We all know that if a steam-engine of the size and strength for 100 horse-power has a working-force of 100 horse-power, it is an engine of respectable grade. But if, while thus large in its cylinder, beam, and other parts, it were furnished with the means of generating a force-system, as we may call it, of 1 horse-power, it would be a very feeble and worthless piece of machinery. Suppose, for closer parallelism with animal life, the engine to reach its size by a method of growth; and that

* From a recent letter of a critic.

its force-system attained thus a 1-horse capability when the engine had attained the size of a 100 horse-power, and poor construction with that. What would it be but a small thing vastly overgrown. In an animal there are the *sensorial* and *motorial* systems of force, which have their prime center in the cephalic nervous mass; and there is also the *vegetal*, or the power of growth or vegetative enlargement, which requires, as vegetation shows, no such nervous center, although in animals it is mostly under nervous control. If then this central control is weak, vegetative increase may make a vast structure, as unwieldy for the power within as the 100 horse-power engine with a 1-horse force-system; and it should in such a case manifest the feebleness of the force-system in an analogous manner, that is, by sluggish movements, or by stupid senses, and have corresponding structural deficiencies: as is true of a huge Medusa among Radiates, a Horse-shoe (*Limulus*) among Crustaceans; a Sloth and its kin among Mammals, etc., etc.

8. Mr. Walsh objects to the wide separation of the Hemipters (or Heteroptera) and Homoptera; and in this he is sustained by many facts and good authority. As respects this, and other like points in the classification, it is necessary to distinguish between direct inferences from the principle of cephalization, and conclusions from all the various considerations bearing on classification. By that principle, we prove that Hemiptera are inferior to Homoptera, since they are *metasthenic* in the wings, while the latter are *prosthentic*: but it does not also follow from it that the two groups should be so widely separated, for they may still be superior and inferior subdivisions of the same group. *Cephalization distinguishes grade among groups; but it is subordinate to type of structure in fixing the limits of natural groups.* Toward this latter object it affords aid through the many new criteria it brings to light, and through the evidence it supplies as to the relative value of such criteria; yet its distinctions are to be used in connection with all others that are available. And they have been thus used by the writer in his attempts to present the true system of arrangement among species.

I have been led to place the Homoptera near the Lepidoptera, and the Hemiptera near the Coleoptera, by the following considerations:—

a. The Homoptera, as most authors assert, have close structural relations to the Lepidoptera. The Hemiptera are much less near the Lepidoptera, and approximate, as some authors have admitted, to the Orthoptera and Coleoptera, especially the former. The fact that the anterior wings in Hemiptera, as in the Coleoptera and Orthoptera, are not flying wings, is an important point

of resemblance to the latter tribes, independently of any athenic value attached to this character.

b. The distinctions of (1) *prosthentic*, (2) *less prosthentic* or *metasthenic*, and (3) *degradational* correspond with the higher grand divisions in several orders and classes of animals. This fact, in connection with the comprehensiveness of the characteristics prosthentic and metasthenic among Insects, favors the conclusion that they are here of like importance.

c. It is common for a natural group to have affiliations in two or three directions; so that, if arranged in one division, it will have its representatives, or what might be almost regarded as its branchings, in another; and many of the fundamental relations of species can be exhibited only by systems of parallelisms with cross connections. I have observed that the Hemipters, among Metasthenic Insects, and the Homopters, among the Prosthentic, afford an example of this kind, and thus have recognized their intimate relations. Viewing the subdivisions of the classification in the lineal order in which they are presented on the printed page, the tribes of Hemipters and Homopters stand far apart, as if remote in the system of Insects. But making the Metasthenics and Prosthentics parallel divisions these two tribes stand side by side. And if the two tribes overlap through some species, it is not a solitary case of this kind in the system of animal life.

I would add here, with regard to the Trichopters, that their addition to the Lepidopteroid group, or the Amplipens, is not made as a direct inference from facts under the principle of cephalization, but on other considerations, and especially their relations to the Lepidoptera in structure. If the group were restored to the Neuropters, this would not affect at all the principles I advocate.

Passing by some other statements equally exceptionable with those which have been considered, we touch on one single point more.

9. Our objector enters his "protest, in the name of science," against "the arithmetical monomania, which is perpetually seeking to fetter the limbs of Nature in mathematical formula," alluding here to the approximate uniformity in the number of subdivisions through the system of classification proposed by me.

But Nature is throughout in a strait-jacket of mathematics. Chemical combinations, crystals, light, heat, electricity, all prove that there are simple numerical relations in the very constitution, and in all the movements, of matter; and even the multitudinous leaves of the forests are in mathematical order. It is not therefore *a priori* absurd that regular numbers should preside to some extent throughout the wide system of Nature's

living species; and if found, and not a device of the systematist, they may be recognized as a legitimate part of science, notwithstanding the above protest. Reasons for the frequent recurrence of *three*, as the number for the higher subdivisions in zoological classification, have been given in my former papers, and need not be here repeated. Protests like the above, while always exhibiting a large excess of self-confidence, might sound less presumptuous were there not *many facts in nature yet to be learned*.