
I. ON PARALLEL RELATIONS OF THE CLASSES OF VERTEBRATES, AND ON SOME CHARACTERISTICS OF THE REPTILIAN BIRDS.

II. THE CLASSIFICATION OF ANIMALS BASED ON THE PRINCIPLE OF CEPHALIZATION.

By JAMES D. DANA.

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II. THE CLASSIFICATION OF ANIMALS, BASED ON THE PRINCIPLE OF CEPHALIZATION. No I pp. 321,

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I. *On certain parallel relations between the classes of Vertebrates, and on the bearing of these relations on the question of the distinctive features of the Reptilian Birds.*

At the close of an article by Prof. Hitchcock, in this volume (p. 57), a portion of a letter of the writer is quoted, in which a parallelism is drawn between the Oötocoid or semi-oviparous Mammals (*Marsupials* and *Monotremes*), the Ichthyoid Reptiles (*Amphibians* of DeBlainville, *Batrachians* of many authors), and the Reptilian Birds. The general fact of this parallelism throws light on (1) the classification of Mammals, (2) the distinctive features of the Reptilian birds, and (3) the geological progress of life.

1. *Classification.*—The Amphibians are made by many zoologists an independent class of Vertebrates, on the ground of the fish-like characteristics of their young. The same systematists, however, leave the Marsupials in the class of Mammals, notwithstanding their divergencies from that type. The number of classes of Vertebrates, usually regarded as four, thus becomes *five*, namely, Mammals, Birds, Reptiles, Amphibians and Fishes. There are some indications that this number will soon be further increased by some zoologists, through the making of another class out of the *Reptilian Birds*.[1]

[1] Professor Agassiz, in vol. i of his *Contributions to the Natural History of the United States*, page 187, subdivides Fishes into four *classes*, namely, 1, Myzonts; 2, Fishes proper, or Teliosts (Ctenoids and Cycloids); 3, Ganoids; 4, Selachians; which would make the total number of classes of Vertebrates *nine*.

The discovery of the Reptilian Birds has brought the general law to view, that, among the four classes of Vertebrates, ordinarily received, each, excepting the lowest, consists of, *first* a grand *typical* division, embracing the majority of its species, and *secondly*, an inferior or *hemitypic* division, intermediate between the typical and the clsss or classes below.

Before proceeding with our illustrations of this point, a word may be added in behalf of these four classes. In order to appreciate their true value, it is necessary to have in view the *type-idea* which is the basis of the fundamental characteristics of each, and which is connected with the existence of *three* distinct habitats for life—the water, the air, and the land: that in Fishes, this idea is that of *swimming aquatic* life; in Reptiles, that of *creeping terrestrial* life; in Birds, that of *flying aerial* life; in Mammals, that of *terrestrial* life, again, but in connection with a higher grade of structure, the Mammalian. The type-idea is expressed in the adults both of the typical and hemitypic groups; and any attempt to elevate the hemitypic into a separate class tends to obscure these ideal relations of the groups in the natural system of Vertebrates.

The following are the illustrations of the law above mentioned.

(1.) In the classification of Vertebrates, Mammals, the first class, are followed by Birds, as the second; and while the former are viviparous, the latter are, without exception, *oviparous*. The species of the inferior or hemitypic group of Mammals, partake, therefore, in some degree, of an *oviparous* nature, as the term *semi-oviparous* or *Oötocoid* implies.

In fact, all Vertebrates excepting Mammals are typically oviparous, although some cases of viviparous birth occur among both Reptiles and Fishes. In the viviparous Mammals, the embryo during its development derives nutriment directly from the body of the parent until birth, and also for a time after birth; while in the viviparous Fish, the Selachians excepted, there is simply a development of the egg internally, in the same manner, essentially, as when it takes place externally. Applying then the term oviparous to all cases in which the embryo is shut off from any kind of placental nutrition, Reptiles and Fishes, with the exception mentioned, are as essentially oviparous as Birds. Hence, the Oötocoids or non-typical Mammals are actully intermediate in this respect, and in others also, between the typical Mammals, on one side, and the inferior oviparous Vertebrates collectively, on the other.

(2.) Again, the class next below Birds is that of Reptiles. And, correspondingly, the inferior or hemitypic group of Birds is *Reptilian* in some points of structure.

(3.) Again, the class next below Reptiles is that of Fishes; and therefore the inferior or hemitypic group of Reptiles is the

intermediate or *Ichthyoid* one of Amphibians—the young of frogs and salamanders and other included species having gills like fishes, besides some additional fish-like peculiarities.

The parallelism between the three classes, Mammals, Birds and Reptiles, is thus complete.

(4.) Fishes have no class of Vertebrates below them, so that an *inferior* hemitypic division is not to be looked for. It might be suspected that the intermediate group in this case would be one between Fishes and the lower subkingdoms either of Mollusks or of Articulates; but none such exists. The lowest fish, an Amphioxus, is as distinctly a Vertebrate as the highest, and no Mollusk or Articulate exhibits any transition towards a vertebrate structure.

There are, however, *hemitypic* Fishes; but their place is towards the *top* of the class instead of at its bottom. Ganoids constitute one group of this kind, between Fishes and Reptiles, as long since pointed out by Agassiz. Again, Selachians (or Sharks and Rays) constitute another, between Fishes and the higher classes of Vertebrates. This last idea also has, we believe, been suggested by Agassiz (although we cannot refer to the place where published), this author regarding the species as intermediate in character between Fishes and the allantoidian Vertebrates. Moreover, Müller long ago observed the relation of the Sharks to the Mammals in having a vitelline placenta, by which the embryo draws nutriment from the parent, as does the mammalian fetus by means of its allantoidian placenta.

Ganoids and Selachians are, thus, two *hemitypic* groups in the class of Fishes.

The scheme of grand divisions is then as follows:[3]

I.
A. Typical Mammals,
B. Hemitypic Mammals.
or Oötocoids.

II.
A. Typical Birds,
B. Hemitypic Birds.
or Erpetoids.

III.
A. Typical or true Reptiles.
B. Hemitypic Reptiles,
or Amphibians.

IV.
A. Hemitypic Fishes, or Selachians.
B. Hemitypic Fishes, or Ganoids.
C. Typical Fishes, or Teliosts.

One of the groups of hemitypic Fishes looks directly towards Reptiles, and the other towards the three higher classes of Vertebrates collectively, but especially Mammals and Birds.

[3] It is here seen that the term *Oötocoid*, applied to Marsupials and Monotremes, has great significance; and so likewise, *Erpetoids*, and *Amphibians*. *Oötocoid* is simply the Greek form of the term *semi-oviparous*.

It is plain from the preceding that the subkingdom of Vertebrates, instead of tailing off into the Invertebrates, has well-pronounced limits below, and is complete within itself.

2. *Distinctive features of the Reptilian division of Birds.*—The skeleton of the fossil Bird, discovered at Solenhofen, has some decided Reptilian peculiarities, as pointed out by Wagner, Owen, and others. But even if perfect, it could not indicate all the Reptilian features present in the *living* animal. It is, therefore, a question of interest, whether the relations of the hemitypic to the typical species in the two classes, Mammals and Reptiles—one superior to that of Birds, and the other inferior—afford any basis for conclusions with regard to characteristics of the hemitypic Birds undiscoverable by direct observation. The following considerations, suggested by analogies from the classes just mentioned, may be regarded as leading to unsatisfactory results; and yet they deserve attention.

A. *Mammals.*—(1.) It is a fact to be observed that the hemitypic Mammals are as truly and thoroughly *Mammalian*, as regards the fundamental characteristic of the type—the suckling of their young—as the typical species.

(2.) The departure from the typical Mammals is small in the *adult* individuals, especially the adult males. But it is profoundly marked in their *young*, they thus approximating in period of birth and some other respects to oviparous Vertebrates.

B. *Reptiles.*—(1.) The *adult* Amphibians, or hemitypic Reptiles, depart but little from the typical Reptiles, either in structure or habits.

But (2.) the *young*, in their successive stages, from the egg upward, partake strikingly of characters of the inferior class of Fishes.

The law seems, then, to be that the species of the hemitypic group have their principal or most fundamental resemblance to those of the class or classes below in the *young* state. We should hence conclude that the *young* of the Reptilian Birds or Erpetoids possessed more decided Reptilian peculiarities than the adults.—What these unknown peculiarities, if real, were we can infer only doubtingly from the analogies of the known cases already considered.

The characteristic of the intermediate type, on which the intermediate character depends, is, in the case of both Mammals and Reptiles, that particular one which is the special distinction of the inferior type. The types inferior to Mammals are *oviparous*, and hence the hemitypic Mammals are semi-oviparous. The type inferior to Reptiles, or that of Fishes, is distinctively *aquatic* and breathes consequently by means of *gills* instead of lungs, and hence the hemitypic Reptiles have gills in the young state.

What then are the characteristics of Reptiles that may have been presented by the inferior or hemitypic Birds? The more prominent distinctions of Reptiles are the following:

(1.) A covering of scales, or else a naked skin, instead of a covering of feathers.

(2.) A terrestrial creeping mode of life instead of an aerial or flying mode.

(3.) Incomplete circulation, and hence, to some degree, cold-blooded, instead of complete, and warm-blooded.

Now, as to the young of the Reptilian Birds, it may be inferred that—

(1.) They were unquestionably unfledged. For this is universal among birds, for a while after leaving the egg. It is quite probable that they were more completely unfledged, or for a longer time, than is common for the young of ordinary birds; for even the adult bird, judging from the Solenhofen specimen, was less completely feathered than usual.

(2.) They were unquestionably *walking* chicks. For Birds in the lower division of the class (*Præcoces* of Bonaparte) have the use of their legs immediately after leaving the egg, and seek their own food. A brood of Reptilian bird-chicks, with long tails and nearly naked bodies, creeping over the ground, would have looked exceedingly like young Reptiles—very much, indeed, as if the eggs of a Reptile had been hatched by mistake. Moreover, these Reptilian Birds were probably not only walking birds when young, but as much so as hens and turkeys are, if not more exclusively so, even when adults; for, in the inferior division of ordinary birds, the species are far inferior as flying animals to those of the superior division, and in some, as is well known, the wings only aid in running.

(3.) But the characteristics which have been mentioned under (1) and (2) are not of fundamental value, like that of the existence of gills in the young of hemitypic Reptiles, or that of the semi-oviparous method of reproduction in Oötocoid Mammals; and it would seem that there must have been some more profound Reptilian characteristic. It is therefore probable that the third distinction of Reptiles stated belonged also to the young Reptilian Bird; that is, it had incomplete circulation, and, hence, an approximation to the cold-blooded condition of Reptiles. The heart may have had its *four* cavities complete, as in Birds, and in Crocodiles among Reptiles; but, in addition, there may have been a passage permitting a partial admixture of the venous and arterial blood, such as exists not only in Crocodiles but also in the young Bird during an early stage in its development. This peculiarity in the vascular system of the young Bird of the present day ceases with the beginning of respiration. But in the Reptilian birds it may have continued

on through the early part, at least, of the life of the chick, or until it was fledged.

This conclusion is made to appear still more reasonable by the following comparison of the three obvious methods of subdividing Vertebrates, and the connection therewith of the characteristics of the hemitypic groups. These three methods are—

1. Into *viviparous* and *oviparous;* which places the dividing line between Mammals, and the inferior Vertebrates.

2. Into *warm-blooded* and *cold-blooded*, or those having perfect, and those having imperfect, circulation; which places the line between Mammals and Birds, on one side, and Reptiles and Fishes, on the other.

3. Into *pulmonate* and *branchial*, or those with lungs, and those with gills; which places the line between Mammals, Birds and Reptiles, on one side, and Fishes, on the other.

Now the characteristic of the *first* of these methods of subdivision is that on which the hemitypic group of the first class, or that of Mammals, is based. The characteristic of the *third* is that on which the hemitypic group of the third class, or the Reptilian, is based. Hence, the characteristic of the *second* should be, if the analogy holds, that on which the hemitypic group of the second class, or that of Birds, rests for its most fundamental distinction.

3. *Geological history.*—It has been observed, on page 318, that the Vertebrate subkingdom has well-drawn limits below, instead of tapering downward into Mollusks or Articulates. This feature of the subkingdom is further evident from the fact in geological history that the earliest species of Fishes were not of the *lower* group, that of Teliosts, but of the two higher, or those of Ganoids and Selachians. The Vertebrate type did not originate therefore in the subkingdom of Mollusks, or of Articulates; neither did it start from what might be considered as its base, that is, the lower limit of the class of Fishes; but in intermediate types, occupying a point between typical Fishes and the classes above.

Moreover, the inferior group did not come into existence until the Cretaceous period, in the latter part of geological history, when the Reptilian age was commencing its decline.

In the Devonian age, or closing Silurian, appeared the first Ganoids and Selachians. In the Carboniferous, Reptiles were introduced,—first the inferior Amphibians, and then typical species. Afterward, in the early part of the Reptilian age, as Reptilian life was in course of expansion, there were the first of the Reptilian Birds and the first of the Marsupials or hemitypic Mammals (with probably some typical species of each of these classes). Thus the Vertebrate type, commencing at the point

of approximation of Reptiles and Fishes, expanded until each of its higher classes had representative species, before the inferior division of true or typical fishes—Teliosts—came into existence. Afterwards, in the Cenozoic, the true or typical Birds and Mammals had their full expansion.

The Vertebrate type, therefore, not only was not evolved along lines leading up from the lower subkingdoms, but was not, as regards its own species, brought out in lineal order from the lowest upward. The subkingdom has, therefore, most evidently a separateness and a roundness below, so to speak, or an entireness in its inferior limits, which belongs only to an independent system.

We find in the facts no support for the Darwinian hypothesis with regard to the origin of the system of life.

The Classification of Animals based on the principle of Cephalization.

Number I.

As the principle of cephalization is involved in the very foundation of the diverse forms that make up the animal kingdom, we may look to it for authoritative guidance with reference to the system that prevails among those forms. Some of its bearings on zoological classification have already been pointed out.[1] I propose to take up the subject more comprehensively; and, in the present article, to bring the light of the principle to bear on the relations of the subkingdoms, classes, orders, and some of the tribes of animal life.

It is essential, first, that the methods or laws of cephalization be systematically set forth, that they may be conveniently studied and compared. The following statement of them is an extension of what has already been presented.

As an animal is a *cephalized* organism, (or one terminating anteriorly in a head,) the anterior and posterior extremities have opposite relations. The subdivision of the structure into *anterior* and *posterior* portions has therefore a special importance in this connection. As these terms are used beyond, the *anterior* portion properly includes the head, which is the seat of the senses and mouth, with whatever organs are tributary to its purposes, anterior in position to the normal locomotive organs; the *posterior* portion is the rest of the structure. The anterior is eminently the cephalic portion. The digestive viscera from the stomach backward, and the reproductive viscera, belong as characteristically to the posterior portion.

[1] Expl. Exp. Report on Crustacea, p. 1412, 1855; this Journal, [2], xxii, 14, 1856; xxxv, 67, xxxvi, 1, 1863.

It follows, further, from the cephalized nature of an animal, that its *primary centre of force*, or the point from which concentration and the reverse are to be measured, anteriorly and posteriorly, is in the head, near the anterior extremity of the structure. In an Insect or Crustacean, its position is between the mouth and the organs of the senses—over which part the cephalic mass is located. This is sustained by embryogeny; and also by the fact, that, as the two most fundamental characteristics of an animal are its being sense-bearing and mouth-feeding, the mouth, on descending to the simplest of animals, is the last part to become obsolescent. Only in the inferior Invertebrates is the position of the mouth approximately *central* in the structure, as explained on page 328.[2]

1. *Methods of Cephalization.*

The methods, according to which the grades of cephalization are exhibited, may be arranged under the following heads:

A. *Size (force-measured) of life-system:* each type, between Man at one extreme and Protozoans at the other, having its special range of variation in this respect.

B. *Functional:* or variations as to the distribution of the functions *anteriorly* and *posteriorly*, and as to their condition.

C. *Incremental:* or variations as to vegetative increment, that is, as to amplitude, and multiplicative development.

D. *Structural:* or variations in the conditions of the structure, —whether (1) compacted, or, on the other hand, resolved into normal elements; (2) simple, or complex by specialization; (3) defective, or perfect; (4) animal-like, or plant-like.

E. *Postural:* or variations as to posture. (Only in Vertebrates.)

F. *Embryological:* or variations connected with the development of the young.

G. *Geographical distribution.*

For greater convenience and uniformity, the methods under these heads are mentioned beyond as they appear when viewed along the *descending* line of grade, instead of the ascending. This is, in fact, the more natural way, since the typical form in a group—the fixed point for reference—holds a position towards the top of the group. The methods, as given, are therefore more strictly methods of *decephalization* than of cephalization; but the former are simply the reverse of the latter.

A. SIZE (OR FORCE) OF LIFE-SYSTEM.

1. *Potential.*—Exhibited in less and less force and size of life-system with decline of grade (and the reverse, with rise of

[2] There may also be one or more *secondary* centres of force; but they are, as regards the subject before us, of compartively small importance. The independent development of the abdomen and cephalothorax in Crustaceans is a case of the kind, as explained elsewhere by the writer. See paper on the Classification of Crustaceans referred to.

grade); as that in passing from the type of Megasthenes (Quadrumanes, Carnivores, Herbivores and Mutilates) to that of Microsthenes (Chiropters, Insectivores, Rodents, and Edentates); or from that of Decapods to that of Tetradecapods among Crustaceans—in which latter case, unlike the former, there is also *retroferent* decephalization; and so, generally, in passing from a higher to a lower type, it being equivalent to passing to a type of smaller and weaker life-system. See further, this volume, pp. 8 and 338.

B. FUNCTIONAL.

2. *Retroferent.*—A transfer of functions backward that belong anteriorly in the higher cognate type.

Under this method, there are the following cases:

a. A transfer of members from the cephalic to the locomotive series; as the transfer of the fore-limbs to the locomotive series in passing from Man to brute Mammals; that of a pair of maxillipeds or posterior mouth-organs to the locomotive series in passing from Insects to Spiders; that of two pairs of maxillipeds to the locomotive series in passing from Decapod to Tetradecapod Crustaceans.

b. A transfer of locomotive or prehensile power and function, more or less completely, from the anterior locomotive organs to the posterior.

c. A transfer of the locomotive function, more or less completely, from the limbs (these often becoming obsolete) to the body, and mainly to the caudal extremity.

Under *b* and *c*, the condition may be described as—

(*a*) *Prosthenic*, (from the Greek προ, *before*, and σθενος, *strong*,) if the anterior locomotive organs have their normal superiority.

(*b*) *Metasthenic* (from μετα *after*, etc.), if a posterior pair is the more important and the anterior are weak or obsolete.

(*c*) *Urosthenic* (from ουρα *tail*, etc.), if the posterior part of the body, or the caudal extremity, is the main organ of locomotion.

Ordinary flying Birds are *prosthenic*, while the *Præcoces* (Gallinaceous Birds, Ostriches, &c.), being poor at flying, or incapable of it, are *metasthenic*, and they thus exhibit their inferiority of grade. Hymenopters, Dipters, Lepidopters, &c., among Insects, are *prosthenic*, while Coleopters, Orthopters, Strepsipters, etc., in which the fore-wings (the *elytra*) do not aid in flight, or but little, are *metasthenic*. Fleas, which are degradational species, related to Dipters, have the third or *posterior* pair of legs much the longest and strongest. Among Macrural Crustaceans, the strongest legs are, in the higher species, the *first* pair; in others inferior, the *second;* in others still inferior (the Penæids) the *third* pair.

(See further, for examples, this Journal, [2], xxii, 14, and xxxvi, 1.)

Viewed on the ascending grade, this method is the *preferent.*

3. *Pervertive.*—A subjection of an organ to any abnormal function inferior to that normal to it;—as in the adaptation of the nose of the Elephant to prehension; of the antennæ of many inferior Crustaceans to prehension or locomotion; of the maxillipeds of inferior Macrurans to locomotion; of the forehead in many Herbivores to purposes of defense.

The perverted nose of the Proboscideans is one of the indications of their inferiority to the Carnivores; but it is not necessarily a mark of inferiority among Herbivores themselves, as the faculty of prehension is one of those especially characterizing Carnivores and other higher Mammals, and nearly all Herbivores fail of it.

Viewed on the ascending grade, this method and the following may be included under the term, *perfunctionative.*

4. *Defunctionative.*—Exhibited in the defectiveness or absence of the normal function of an organ;—as in the absence of the function of prehension from the fore-limbs of Herbivores (this prehension in the fore-limbs belonging to the Mammalian type); and that of locomotion mostly from all the limbs in the Mutilates; that of locomotion from the female Bopyrus; that of locomotion from Cirripeds and other attached animals; that of the sense connected with the *second* pair of antennæ (and probably also the *first*, these organs being obsolete) in the Lernæas and Cirripeds, these antennæ being simply prehensile organs in a Lernæa, and constituting the base of the peduncle in an Anatifa.[3]

This degradation and loss of functions is connected often with the *elliptic* and *amplificative* methods of decephalization (see beyond). It is connected with the latter in the Bopyrus, and also in Cirripeds and other attached species.

C. INCREMENTAL.

5. *Amplificative.*—Exhibited in an elongation or general enlargement of the segments or members, and an increased laxness of the parts. Includes the cases—

a. Lengthening, widening, or laxness in the *anterior* portion of the body; the same in the *posterior* portion.

b. An abnormal enlargement of the general structure.

The elongation or enlargement which takes place with decline of grade is mainly *posterior*, it being small anteriorly, and sometimes none at all. In passing from the Brachyural to the Macrural type of Crustaceans, the change anteriorly is princi-

[3] See *Expl. Exp. Report on Crustacea*, p. 1393, and plate 96, where it is shown that the antennæ of the young Anatifa have a sucker-like organ for attachment, and become, in the metamorphosis, the bottom of the peduncle by which the adult Anatifa is attached.

pally in an increased laxness and lengthening of the parts, with little increase in the dimensions of the body anterior to the mouth; while the abdomen (or *posterior* extremity) is enlarged 10 to 50 times beyond the bulk it has in the Crab. Descending from a snail to an oyster, there is diminution anteriorly and great enlargement posteriorly, and the animal is little more than a visceral sac.

In less marked cases of the *amplificative* method, there is only an attenuation or lengthening of the body and limbs, as in many Neuropters, Orthopters, Homopters, wading Birds, etc. The Lepidopters, also, in their very great expanse of wing, exemplify this method. In species that are attached, as the Cirripeds, the young are usually free; and it is only when they begin to outgrow, amplificately, the minute life-system (Entomostracan in the Cirripeds) that they become fixed. As attached animals, they often attain great size.

Viewed on the ascending grade, this method is the *concentrative;* and it is exhibited in the increased abbreviation and condensation of the anterior and posterior members and segments, or of the whole structure.—For examples, see further volume xxii and the present, as already referred to.

6. *Multiplicative.*—Exhibited in an abnormal multiplication of segments or members; as in Myriapods, Worms, Phyllopods, Trilobites, etc. There may be—

a. Simple multiplicative; as in the superior Myriapods, the Chilopods, in which the body-segments, thus multiplied, have each its single or normal pair of members.

b. Compound multiplicative; as in the Myriapods of the Iulus division, or Diplopods (Chilognaths), in which there is a duplication of the pair of legs of a body segment. The name *Diplopod,* adopted by Gervais and some other authors, has the advantage of having thus a dynamical value.

The multiplicative method is, in general, a degradational one. When it affects only subordinate parts of the structure, as the length of the tail of Mammals, or of Reptiles, etc., the forms are not necessarily degradational. But when it affects the general structure, and the types are indefinite in segments, like the Myriapods, Worms, and Snakes (see page 4 of this volume), the forms are degradational. In Mammals, the tail may be said to have indefiniteness of limit; but, since this part is only an appendage to the body and has little functional importance, its elongation cannot properly be regarded as a mark of degradation, although one of inferiority. When, however, the posterior extremity is, in magnitude and importance, a part of the main body structure itself, as in Snakes and Fishes, the case is properly an example of multiplicative degradation.

The abnormal number of segments under the multiplicative

method may arise from a self-subdivision of enlarging normal segments, or from additions beyond the range of the normal number. The many joints of the antennæ in Crustaceans of the Cyclops group, the writer has shown to result through the former method, and the multiple segments of Phyllopods may be of the same origin: but there are no facts yet ascertained that would refer the multiplication of segments in Myriapods and Worms to this method.

Viewed on the ascending grade, this method is the *limitative*.

D. STRUCTURAL.

7. *Analytic.*—Exhibited in a resolving of the body-structure, or of an organ, more or less completely, into its equal normal elements, or in a tendency to such a resolution.

A relaxed state of the cephalic power leads to a relaxed and elementally-constituted structure. When this method characterizes strongly the general structure, the form is usually degradational; as in Myriapods, Worms, larves of Insects,—these structures consisting of a series of nearly similar rings, (the normal elements of an Articulate,) without a subdivision into head, thorax and abdomen. Fishes, of the Vertebrate type, are, as nearly as may be, in this elementalized condition. An approximation towards analysis or resolution of the body appears in the absence of the constriction between the head and thorax in Spiders and Crustaceans; and still further, in the absence of the constriction between the thorax and abdomen in the lowest of Spiders, the Acaroids.

Under this method, there is, in no case, among adults or larves, a complete analysis or resolution of the head into normal segments; the closest approximation to it, in Insecteans and Crustaceans, occurs in the Gastrurans (Squilla group) as explained in a note to page 6 of this volume. But here the mandibular and one, two, or more maxillary segments are still united. In an Insect, the head, as stated on page 234 of this volume, contains six normal segments, and the thorax three; and yet the thorax has 3 to 5 times the bulk of the head;—showing a condensation in the head-part equal to 6 to 10 times that of the thorax. Concentration in an animal structure is therefore eminently cephalic concentration, or, in a word, *cephalization*,—the head being the part most condensed, and least liable to occur resolved into its elements.

The analytic method, viewed on the ascending grade, is the *synthetic*.

8. *Simplificative.*—Exhibited in increased simplicity of structure, and in an equality of parts that are normally identical. The cases are—

a. Simplicity from diminished number of internal or external organs for carrying on the processes of life; as in the absence of

distinct respiratory organs, or of different parts in the digestive system, etc.; or the union of the sexes in one individual, etc.; —a simplification which reaches its extreme limit among Radiates in the Hydra, and among animals, in the Protozoans.

b. Simplicity from equality in parts normally alike; as, equality in the height of the teeth of some of the earliest of Tertiary Mammals; in the annuli of Worms. This case is related to the analytic.

Viewed on the ascending grade, this method is the *differentiative*, the facts exhibiting which are embraced under the well known law of differentiation or specialization, which is fundamental in all development.

Differentiation internally, as it multiplies and perfects the means of elaborating the structure, is attended with an increasingly higher grade of chemical change, more perfect nutrition, and more complete decarbonization of the blood; and implies, therefore, improvement in all tissues, a more sensitive nervous system, and greater cephalic power and activity. And from the reverse comes the reverse effect.

9. *Elliptic.*—Exhibited in the defectiveness, or absence, of segments or members normally pertaining to the type of the *order* or *class* containing the species. The cases are—

a. Incomplete, or deficient, segments or members, in either the *anterior*, or the *posterior* portion of the body; as with certain teeth in the Herbivores, toes in the foot of the horse, one or two pairs of antennæ in some inferior Crustaceans.

b. Defective, or deficient, senses.

When the deficient parts are only those that are normally deficient in the type of the *order* or *class*, the examples may come under the *simplificative* above. It differs from the *defunctionative* in implying a deficiency not of function only, but of organ or member. The foot of the horse is elliptic, whether viewed with reference to the Animal-type, or the Megasthenic-type. The Fish is elliptic as regards limbs, if considered with reference to the Vertebrate-type, but not so with reference to the Fish-type, unless the fins corresponding to the Vertebrate limbs are wanting.

Viewed on the ascending grade, this method is the *completive.*

10. *Phytozoic.*—Exhibited in a departure from the Animal-type through a participation in structural features of the Plant-type, that is, through a plant-like arrangement of the organs.—The cases are—

a. A radiate arrangement of external organs; as in the Bryozoans and inferior Tunicates.

b. A radiate arrangement of internal as well as external organs; as in Radiates.

c. Perfect, or nearly perfect, symmetry in the radiation, instead

of eccentric or irregular forms. Perfect symmetry is most general where the number of rays is based on the numbers 4 or 6 (which, it is to be noted, are multiples of 2 and 3), 4 being the number for the class of Medusæ, and both 4 and 6 occurring in that of Polyps. But if the number of rays is 5, as in the highest of Radiates, the Echinoderms, while examples of perfect symmetry occur, there are many cases of unsymmetrical forms (as in the Spatangi) in which the Radiate type seems to tend to emerge from phytoid towards true animal-like forms. In the regularly radiate, the mouth is central or very nearly so, while in the Spatangi, there is something of the fore-and-aft form of the animal.

Among species under the true animal-type, there are forms showing an approximation to the central position which the mouth has in Radiates. In a Limulus, for example, the mouth-aperture is only one-half less remote from the anterior margin of the body than from the posterior (base of caudal spine). The Limuli are extreme in *amplificative* decephalization and in lowness of grade. Under the *multiplicative* method also, there is something similar in Worms and Myriapods. The head is here strictly at the anterior extremity; but the cephalic force has so feeble control, that joints multiply behind; and in the lowest of Worms, each separate segment is nearly equal in all functions to the cephalic segment. Moreover, in the embryological development of an Annelid, the first segment (with its pair of appendages) that is formed after the appearance of the head is not the anterior one close to the head, but the *eighth* (or one near this); and from this point the rings form in succession posteriorly, and also towards it from the head; as if, in these *multiplicate* species, there was a *secondary centre of force* distant from the front which preponderates over the *primary* one.

This method viewed on the ascending grade is the *holozoic*, (from ὅλος all, and ζωον animal); it is exhibited in a rise from the plant-like type to the true animal-like type.

E. Postural.

11. *Postural.*—Exhibited in an increasing proneness in the position of the nervous system—the extremes being *verticality* in Man, and *horizontality* in the Fish.

F. Embryological.

12. *Prematurative.*—Exhibited in precocity of young or larves.

Thus, the chicken, as soon as born, runs about and seeks its own food, while the young of those Birds which belong to the superior group,—the true flying Birds—remain helpless until able to fly; a fact recognized in Bonaparte's classification of Birds. So the young colt or calf (Herbivorous) is on its legs almost as soon as born; but the young kitten (Carnivorous, and higher in type) is for a considerable time helpless.

Prematurity has often been recognized as evidence of low development and low rank; and the following is the explanation of it.

When an animal has reached the condition required for locomotion and for the care of itself, it has already the essential faculties of an adult; and although these faculties of locomotion and self-feeding are of comparatively low grade, the animal possessing them is approximately mature in its cephalic forces, and afterwards rises but little with growth. Prematurity hence involves inferiority. The pupa-state of an Insect is a means of higher development the more perfect its inactivity. For this complete rest allows all the forces of the individual to be concentrated on the internal processes, and favors, therefore, that cephalic growth which makes a special demand on these forces; while in an *active* pupa (or rather the larve that passes through no pupa-state), activity, whether that of locomotion, or of digestion, constantly exhausts force; and only the balance, not thus run away with, goes towards the maturing process. With such an open outlet of force, the animal may mature physically, that is, grow and perfect its outer structure; but cephalically, or, in all those points of structure, as well as psychical powers, that are connected with superior cephalic development, it makes little advance.

Hence, (*a*) those insects whose larves are essentially like the adults and undergo no metamorphosis are inferior in type,—as generally so recognized.

Again, (*b*) those Insects (as most Hymenopterous) whose larves are footless grubs are superior in type to those (as the Lepidopterous) whose larves are most highly developed and active.

Viewed on the ascending grade, this method is the *permaturative.*

13. *Gemmative.*—Exhibited in multiplication by buds. Budding may produce—

a. Perfect individuals, capable of egg-production.

b. Individuals capable only of budding, and giving origin to a perfect egg-producing individual as the last of a series of buddings.

c. Caducous, or persistent buds; the *latter* leading to compound forms, either branching, lamellar, or massive.

This power of reproduction by buds occurs in many Worms, both superior and inferior; in Bryozoan and many Ascidian Mollusks; in Polyps and many other Radiates. The production of persistent buds is the lowest grade, and is common in the budding Mollusks and Radiates, but not the Articulates. Among budding Articulates, case *b* appears to be of lower grade than case *a.*

This method is allied to the *multiplicative,* p. 325. It is also *phytozoic* (p. 327), or a plant-like feature in animal life.

14. *Genetic.—Number of young or eggs.*—As is well known, there is a mark of grade in the number of eggs or young produced at a single period or in a given time—the number, other things equal, being inversely as the rank or grade of the species.

15. *Thermotic.—Temperature required for embryonic development.*—Another mark of grade is afforded by the temperature required for egg-development:—for, in general, the higher the temperature, the higher the grade. Thus, the eggs of Birds require heat above ordinary summer heat, while those of Reptiles do not. The embryos of Mammals require still higher and more uniformly continued heat until their maturity, the Oötocoids alone excepted, in which birth is premature. The eggs of some Hymenopterous Insects mature inside of the larves of other Insects, where they are never exposed to a temperature of 32° F.; while those of ordinary Lepidopters and many other species mature in the summer heat, and may stand a temperature below 0° F.

The necessity of a higher temperature indicates, ordinarily, that the chemical processes in the vital economy are of a higher or more delicate character, or those required for a higher grade of cephalization.

G. Geographical Distribution.

16. *Habitational.*—(1.) *Terrestrial species higher than aquatic.*—This law, announced by Agassiz, is also directly dependent on the conditions determining the grade of cephalization.

a. In the case of *aquatic* species, the ova, as well as the adult animals, are bathed in a liquid that penetrates to the interior, and dilutes, to some degree, the nutrient or developing fluids; and, under such circumstances, the grade of chemical or vital evolution cannot be as high as in the atmosphere. The germ must therefore be one of an inferior kind. Aquatic animals are, in an important sense, *diluted* animals.

b. Again, *terrestrial* species whose ova are hatched in water, or whose young are aquatic, are for the same reason inferior, as a general rule, to those whose ova are hatched on the land.

Aquatic development or life is one of the most important marks of low grade. Among embryological characteristics, it has often a profounder value than prematurity. The *inferior division* of a *class*, *order*, *tribe*, and even *subordinate group*, is often one consisting either of *aquatic* species, or those that are *semiaquatic* (aquatic in habit though not strictly so in mode of life, or aquatic in the young state when not in the adult).

(2.) *Living* (a) *in impure waters, or those abnormal in condition; or* (b) *in deficient light, as in shaded places, or the ocean's depths, a mark of inferiority.*—Muddy waters, or salt waters excessively saline as in some inland lakes, or waters only brackish, are here included.

But *oceanic waters*, although saline, are not properly impure. Of the subkingdoms and the classes containing aquatic animals, the *highest* groups are those of *marine* waters. Thus, the highest of Mollusks, the Cephalopods, are marine; the highest of Radiates, the Echinoderms; the highest of Fishes, the Selachians; of Crustaceans, or the Maioid or Triangular Crabs; of Worms, the Dorsibranchs; of Acalephs, all but the Hydroids are marine; while *all* species of Echinoderms and Polyps are marine. Among the subordinate groups there are some fitted particularly for fresh water. Types that belong to fresh water sometimes have inferior species in brackish or salt water; and those that belong to salt water sometimes have inferior species in brackish or fresh water.

(3.) *Species of cold climates inferior to those of warm.*—According to the 15th canon, the highest oviparous animals should be tropical species; but not necessarily so the viviparous Mammals, since, with them, the requisite temperature for embryonic development is obtained within the parent.

An exception to this, as regards oviparous species, is afforded by Crustaceans; for, as shown by the writer, the highest kinds, the Maioid or Triangular Crabs, have their fullest development in the cooler temperate zone.

(4.) *Having a wide range with regard to any of the earth's physical conditions, as* (a) *climate,* (b) *height,* (c) *oceanic temperature,* (d) *oceanic depth,* (e) *hygrometric conditions, etc., commonly a mark of inferiority.*—For, if the development of a high order of cephalized life requires rest for a while in the young, as, for example, the nursing time in the higher Mammals and Birds and the Pupa-state in Insects, and also an absence from diluting or impure waters and the presence of the full light of the sun, it should also equally demand precise or narrowly restricted limits in all physical conditions, these being essential to the more refined or delicate chemical or vital processes. Man is the chief exception to this law,—and for the reason that he is not simply in and of nature, but also above nature, and has the will and power to bring her forces under subjection, overcoming the rigors of climate and subjugating other inimical agencies by his art. Protophytes and Man are the only species that have the range of the world—the one because so low, the other, so high. The Dog accompanies Man in his wide wanderings: but only through the virtue which is in Man, who provides the artificial heat, protection and food his brute attendant needs. Even the human race dwindles in extremes of climate, either hot or cold.

Recapitulation.—The following are the names of the several methods of cephalization pointed out, both those based on the descending and ascending lines of grade.

	Descending.	*Ascending.*
A. Size of Life-system, -	1. Potential.	1. Potential.
B. Functional, - - - -	2. Retroferent.	2. Preferent.
" - - - -	3. Pervertive.	3. } Perfunctionative.
" - - - -	4. Defunctionative.	4. }
C. Incremental, - - -	5. Amplificative.	5. Concentrative.
" - - - -	6. Multiplicative.	6. Limitative.
D. Structural, - - - -	7. Analytic.	7. Synthetic.
" - - - -	8. Simplificative.	8. Differentiative.
" - - - -	9. Elliptic.	9. Completive.
" - - - -	10. Phytozoic.	10. Holozoic.
E. Postural, - - - - -	11. Postural.	11. Postural.
F. Embryological, - - -	12. Prematurative.	12. Permaturative.

The remaining terms fall into both columns.

With *ascending* grade, the changes are mostly *concentrative;* with *descending*, they are *diffusive* or *decentrative.*

2. *Additional Observations.*

1. *Typical, Degradational and Hemitypic forms.*—Typical species are those within type-limits, and *degradational* those outside of the same.[4] But, as groups of all grades have each their own type and type-limits, species may be typical in one relation, and degradational in another; as Fishes, for example, while degradational Vertebrates, have still their own type and type-limits, the Teliosts being the typical Fishes, or those within these limits.

The characteristics of a type, in any case, are those fundamentally distinctive of the group. As to that of the animal kingdom at large,—we observe that an animal is (1) a fore-and-aft, (2) cephalized, (3) forward-moving organism. The type-idea is hence expressed in a structure having (1) fore-and-aft and dorso-ventral polarity; (2) a head at the forward extremity containing the seats or organs of the senses, as well as the mouth and mouth organs; and (3) the power of locomotion, if not also limbs for the purpose. Consequently Radiates, as they fail in the first criterion, are not within type-limits; neither are any *attached* species of animal, and only in a partial degree species without limbs for locomotion.

Again, the Vertebrate-type, in addition to having the characteristics of the animal type and the vertebrate structure, is essentially terrestrial, and, therefore, the requisite limbs and structure for terrestrial life are in the type-idea. Fishes are therefore outside of type-limits, or are degradational species.

The Mammal-type, the highest under Vertebrates, in addition to the characteristics of the Vertebrate type, has that of being viviparous in its births, embracing under this quality, that of sustaining the embryo by placental nutrition until its maturity

[4] The term *degradational* has no reference to any method of origin by degradation: it implies only that the forms so called represent or correspond to a degraded condition of the type.

(as is not true of the oviparous); and with this there is also that of sustaining the young for a while after birth, by suckling. Hence, the Oötocoids, in which there is only imperfect placental nutrition and birth is premature, and there is an approximation thus to oviparous species, constitute a degradational type.

The Megasthene-type, under Mammals, has its degradational group in the Cetaceans or Mutilates, which fail mostly of limbs and are aquatic species; and the Carnivore its degradational group in the Seal and related Pinnipeds. The latter have the type-structure of the Carnivores; while the Mutilates have the type-structure of neither Carnivores nor Herbivores, and are therefore an independent type under the division of Megasthenes.

Again, the Bird-type, in addition to the characteristics of the Vertebrate-type, embraces features adapting the animal to flying, as feathers and wings; perfect circulation; and also a vertebral column which is posteriorly limitate, instead of one admitting of a caudal elongation,—somewhat as Insects and Spiders are *closed* types behind, in contrast with the *multiplicate* Myriapods. Hence the Reptilian Birds, having *indefinite* posterior elongation, and some other Reptilian characteristics, are outside of type-limits. So, again, under the subdivisions of Birds, species that have the wings unfledged or but half-fledged, and which, therefore, cannot lead an *aerial* life, are degradational; and species that have the feet imperfectly digitate by their being web-footed, and which therefore lead a *semiaquatic* life, are semi-degradational in the group to which they may belong.

These examples are sufficient to illustrate the uses of the words typical and degradational.

It is of the highest importance, for the correct classification of species, that in all cases it should be rightly determined whether a degradational genus is degradational to the *family* to which it belongs, or to the *tribe*, or *order*, or to a still higher division. Although Seals and Whales are similarly adapted to the water, it is plain, to one familiar with the species, that the former are degradational Carnivores, and the latter degradational Megasthenes, as stated above. But like cases come up in every part of the animal kingdom, and close study is necessary for a true decision. The first preliminary towards such a decision is a clear idea of the class-type, order-type, tribe-type or subordinate type under which the genus or group falls.

The term *hemitypic* has been shown in the preceding paper to imply, in general, a grade of the degradational. But, in some groups, as in the class of Fishes among Vertebrates, it is applicable to cases which are not typical because of their being intermediate between the type of the group and a *superior* type or types (p. 317).

Typical groups, or, more properly, the groups above the degradational, may be of several grades. Thus, under Vertebrates, the classes of Mammals, Birds and Reptiles, represent different grades of Vertebrate types, and the grades may be designated, in order, *Alphatypic*, *Betatypic*, *Gammatypic* (from the first three Greek letters α, β, γ). Under Mammals, also, there are three grades, those of Man, Megasthenes, and Microsthenes; then, below these, the hemitypic or degradational Oötocoids. Under tribes, families and genera, the number of grades may be large.

Degradational subdivisions are strictly *hypotypic*, or *below* the typical range.

Typical subdivisions, or those above the degradational, are not, in all cases, *true* typical, as well exemplified by the orders of Fishes; the Teliosts alone being true typical, and the Ganoids and Selachians, called *hemitypic* above, being properly *hypertypic*, or *above* the typical range. Another example of this is afforded by the subdivisions of Megasthenes. Carnivores and Herbivores are different grades of the *true typical*, the former the more perfect, or *eutypic;* while the Quadrumanes or Monkeys are *hypertypic*, being an *intermediate* type between the typical Megasthenes and Man; and the Mutilates (Cetaceans, etc.) are *hypotypic*. Among the Microsthenes, the Chiropters or Bats are *hypertypic*, the Insectivores and Rodents *true typical* of two grades, and the Edentates *hypotypic*.

Among the subdivisions of Mammals there are *three* grades of true typical; and, of them, Man is *archetypic*, as he has been styled, being the *one perfect* type.

Degradational forms may be classed under three heads, as follows:

1. *Degenerative;* in which the forms are thoroughly animal in type. The methods of decephalization which lead most commonly to degenerative forms are the analytic, multiplicative, elliptic and defunctionative.

2. *Hemiphytoid;* when, without an *internal* radiate structure, the species are (*a*) attached to a support, like plants (see *defunctionative* method, p. 324); *b*, budding (*gemmative*, p. 329); *c*, radiate externally (*phytozoic*, case *a*, p. 327).

The externally radiate structure is a lower grade of hemiphytoid degradation than either being attached, or gemmate.

3. *Phytoid* (from φυτον, *a plant*); when the structural arrangements are *internally*, as well as externally, radiate (Phytozoic, case *b*).

As Radiates have no limbs and but imperfect senses, the higher grades among them are manifested most prominently in the conditions of the nutritive system. Some of them (the Echinoderms) are superior, as animals, to the lower *hemiphytoid* species such as the Bryozoans.

2. *Further exemplifications of the preceding methods of cephalization.*—In order to give greater clearness to the explanations which have been made on the preceding pages, the application of the terms expressing the methods of cephalization to grades of species may here be further illustrated.

In the class of Crustaceans, the distinction between the 1st and 2nd orders, or Decapods and Tetradecapods, depends on case *a* under the *retroferent* method—a transfer of members from the cephalic to the locomotive series. In connection with it, there is also an exhibition, to some extent, of the *analytic* method, more of the segments of the body in the latter being free, and all, more regular or normal in form.

Under Decapods, the difference between the 1st and 2nd tribes, the Brachyural and Macrural, depends mainly on the *amplificative* method—there being in the latter, by an abrupt transition, greater length and laxness before and behind. Under the *analytic*, also, the lengthened abdomen in the Macruran has its normal number of segments and members.

Among the subdivisions of *Macrurans*, the *retroferent* method appears prominently in the transfer of force from the *first* pair of legs to the *second* and, among the lower genera, to the *third* pair (see p. 323); the *amplificative*, in the length of antennæ in some families, and in the length of abdomen as compared with that of the cephalothorax in others; the *elliptic*, in the absence of posterior cephalothoracic members, and also the obsolescence of the abdominal members in many Schizopods or degradational Macrurans; the *pervertive*, in the outer maxillipeds taking the form and functions of feet, as in many inferior Macrurans.

Under *Tetradecapods*, the difference between the 1st and 2nd tribes, or Isopods and Amphipods, depends on the very same methods as that between the 1st and 2nd under the Decapods: that is, on the *amplificative*, as shown in the greater length of cephalothorax and the elongated abdomen, and on the *analytic*, the lengthened abdomen having its normal segments and approximately normal members.

Under the Amphipods, the *amplificative* method is variously illustrated; the *elliptic* in the obsolescent abdomen of the Caprellids, as well as in the absence or obsolescence in many species of two pairs of thoracic legs.

Again, in the class of Insecteans, the distinction between the 1st and 2nd orders, or Insects and Spiders, depends on *case a* under the *retroferent* method (see this vol., p. 3); and, in connection, there is an exhibition of an incipient stage of the *analytic*, the head and thorax in Spiders constituting a single mass (p. 326).

Under Insects, the difference between the two highest divisions, *Prosthenics* and *Metasthenics*, depends on *case b* under the *retroferent* method, or a transfer of the flying function mainly or wholly

to the posterior pair of wings. And the third is a degradational group, in which, by the *amplificative*, *analytic* and *elliptic* methods, the species (Lepismæ, etc.) are wingless and larve-like.

Among Herbivores, the Elephant shows superiority (1) in having, as in Carnivores, the teeth (its tusks) for defensive weapons; (2) in having, as in Carnivores, the power of prehension, a quality, however, transferred from the teeth to one of the organs of sense, the nose; this organ of prehension also aids in defense; (3) in having the normal number of toes; (4) in having pectoral mammæ, as in the highest Megasthenes or Quadrumanes, the highest Microsthenes or Bats, and also in Man. The great size is not a mark of overgrowth and inferiority, for the animal is neither stupid nor sluggish. The Ruminants are inferior to the Elephant in having, not an *inferior* organ of sense, but the forehead, or typically the most important part of the head, perverted to use for self-defense; and also in other ways. Among Ruminants, the Stag or Elk-type shows superiority to the Ox-type, in (1) its more compact and smaller head; (2) its less magnitude *posteriorly*; (3) its limbs adapted to fleet motion; (4) its fore-limbs adapted for climbing and clinging, giving them a special *prosthenic* character and great superiority to those of the Ox. The Horse-type shows inferiority to the Elephant-type, in (1) its long head and neck (amplificate); (2) its one-hoofed foot; (3) its being *metasthenic*, the hind legs serving as the principal organs of defense; and also in the characters mentioned above.

The discussion of the subject of classification beyond, will be found to be a continued exemplification of the laws of cephalization, and we refer forward for additional elucidation.

3. *The forms, resulting from the expression of the same law of cephalization in diverse groups, often similar; and hence come some of the analogies between groups, or their osculations.*—It is apparent that the grades of cephalization may have expression in *any* division of the animal kingdom, and that hence may come *parallel* results as to form. For example, there may be cases of *amplificative* decephalization—or of long-bodied or long-legged species—in the different orders or tribes of Insects; and, when so, the species, in these different groups thus characterized, will be, in a sense, representatives of one another, and the groups will "osculate" at such points. One example is that of Orthopters and Neuropters through the Mantids in the former and the Mantispids in the latter; also, that of Dipters and Neuropters, through the slender Tipulids of the former. The same may be exemplified among the orders of Birds. The degradational feature, for example, of webbed feet, or that of defective wings may characterize the inferior species of different subdivisions, and so produce

osculant groups; so may the *amplificative* feature of great length of limb and neck, the Herons among the Altrices, thus representing the Grallatores among the Præcoces.

The osculations or close approximations of classes, orders, tribes, etc., are thus often connected with like expressions of the methods of cephalization.

4. *Forms resulting from high and low cephalization sometimes similar.*—High and low cephalization often lead to similar forms, the former through cephalic *concentration*, the latter through cephalic and general feebleness; just as a thing may be small, when the material is condensed or concentrated, and equally small when dilute and there is little of it. Thus the Crab has a very small memberless abdomen, from a contracting of the sphere of growth through concentrative cephalization; on the other hand, the Schizopod has a memberless abdomen, through a limitation of the sphere of growth resulting from mere feebleness in the life-system. The abbreviated memberless abdomen of the Caprellid and the obsolescent spine-like abdomen of the Limulus are other examples among Crustaceans of this *elliptic* decephalization. See also page 6 of this volume for a comparison of a Limulus and an Insect. The Butterflies have very large wings through the amplificative method; but some inferior nocturnal species have the wings narrow through inferiority of grade, on the above principle, and not properly through concentration and elevation.

There is, in general, no danger of confounding the two cases, because the accompaniments in the structure of the superior species, as well as those of the inferior, commonly indicate their true relations, at once, to the mind that is well versed in the department of zoology to which the species belong. But there are many cases in which it is not safe to make a hasty decision.

5. *Uniformity of shape and size in any group greater among the higher typical species than among the lower typical or degradational species.*—On the higher typical level in any class, order, tribe, &c., the type is represented generally in its greatest number of species, and always under the least extravagance of form and size. Thus, Insects, the higher typical division of Insecteans, are vastly more numerous in species, and less diversified in size, form and structure, than Crustaceans or Worms. And, under Insects, the Hymenopters have little variety of form of body, and form or size of wings, compared with the Neuropters, Lepidopters, Homopters and even the Coleopters; and the Coleopters, little compared with the Orthopters. The fantastic shapes, in all cases, occur in the inferior typical or the degradational groups. In these, cephalization is of low grade, and as a consequence of this relaxing of the system, or its inferior concentration, the forms run off into varied extravagances.

6. *Classification hereby placed on a dynamical or sthenic basis.*— The laws of cephalization, as is apparent from the explanations which have been made, are based upon the idea that an animal is centralized force; and that the degree of concentration of this force may be exhibited in the structure; that, consequently, the various grades of species or groups become apparent, to some extent, through size and form, and their determination is thus, in part, a matter of simple measurement. Dimensions or spatial conditions have a relation to force in the animal kingdom as well as in that of the celestial spheres.

Rank or grade are thus brought to the rule and plummet, and classification, thereby, has a dynamical basis. The distinctions between groups have a dynamical or sthenic character, and all subdivisions in classification, when thoroughly understood, will have recognized sthenic relations.

It must, however, be kept in mind that the element of *size*, when used in the application of the principle, or as a mark of superiority, is not *absolute* size. For it is one of the laws of life that vegetative growth may enlarge a weak life-system to gigantic dimensions. Thus, the life-system of an Entomostracan takes great magnitude in a Limulus; of a Tetradecapod, in a female Bopyrus; of an Edentate, in a Megathere; of a Mutilate, in a Whale. The body of a Crab has 50 times the dimensions of that of an Insect; and its head probably 100 times that of the head of an Insect, although an Insect is the superior species.

Neither is mere muscular strength an indication of grade; for there is force used in sustaining the structure which is greater the higher the organism, and, superior to this, there is sensorial and other cephalic force. Were we to base our comparison between the grade of life-system in a Crab and that of a Bee on the ground of muscular strength, we should go far astray; and still wider from the mark, were we to rely on the relative sizes of the cephalic nervous masses; for this nervous mass in a common Crab (*Maia squinado* of European seas) has 25 to 30 times the bulk of that in a Bee. Man yields in size and muscular strength not only to the higher Megasthenes, but to the Whales or lowest; and the brain in the Elephant and the Whale outweighs his. The Megathere, although much more powerful than a Rodent, has not, on this account, as his structure and habits show, any claims to a place above the lowest of Microsthenes.

The terms *Megasthenes* and *Microsthenes* are not to be understood as signifying large Mammals and small Mammals, but Mammals of *strong life-system* and *weak life-system*. Comparing the typical species of Megasthenes[5] with those of Microsthenes,

[5] These orders of Mammals, (see last volume of this Journal, page 70, and page 342, beyond), make parallel series—the Chiropters or Bats of the Microsthenes representing the Quadrumanes of the Megasthenes, the Insectivores representing the Carnivores, the Rodents the Herbivores, and the Edentates the Mutilates.

there is some correspondence between average size of structure and strength of life-system. But a comparison of the typical of the former with the degradational of the latter leads to very false results.

An approximation to the right ratio is obtained from a comparison of the degradational species of each; but this is of no importance in its bearing on the question, since vegetative growth is apt to give the greatest proportional enlargement to the *lowest* species.

These facts teach that relative size of body, or of brain, is no necessary test of relative rank. The ratio, in *bulk*, of 1 : 3 between the brain of an average Man and that of a gorilla tells nothing of the actual difference of life-system, or of brain-power. At page 70, in the last volume of this Journal, the relative *lineal* dimensions of Microsthenes and Megasthenes is estimated at 1 : 4, which gives, for the relative *bulk*, 1 : 64. If this be the typical ratio between the life-systems of the highest Microsthenes and highest Megasthenes, surely that between the highest Megasthenes and normal Man—he constituting a *distinct order* (see p. 341)—must be at least as great.

The same ratio of 1 : 4, as shown by the writer, is that for the mean size, lineally, of Tetradecapods and Decapods, under Crustaceans. In two cases, then, consecutive orders differ by a like ratio, or approximately so, in dimensions. As has been remarked, deductions from mere size may be very erroneous; yet there is no reason, in either of the above cases, to suppose the ratio of life-systems less than that thus indicated. May not, therefore, some similar ratio exist between other analogous consecutive orders, where size does not manifest it,—as, for example, between Spiders and Insects? And is not the ratio a much greater one between the highest of Insecteans and highest of Crustaceans, since these subdivisions of Articulates are not orders but *classes?* Important results may flow from following out the idea here touched upon.

After the preceding explanations, I proceed to exhibit some of the relations of the higher groups in zoological classification, as they appear in the light of this subject of cephalization.

3. *Classification of Animals.*

1. *Subkingdoms.*—Of the four subkingdoms, first recognized by Cuvier and since by most zoologists, the Vertebrate, Articulate and Molluscan are typical, or of the true *animal-type*, and the Radiate is degradational, being *plant-like* in type. Using the terms alphatypic, betatypic and gammatypic *simply as a numbering of the grades* of types (see p. 334), their relations are as follows:

Alphatypic,	1. Vertebrates.
Betatypic,	2. Articulates.
Gammatypic,	3. Mollusks.
Degradational,	4. Radiates.

An important dynamical distinction between Mollusks and Articulates has been suggested on page 10 of this volume.

2. *Classes of Vertebrates, Articulates, Mollusks and Radiates.*—(1.) The classes of *Vertebrates* are four (see page 319), namely, Mammals, Birds, Reptiles and Fishes,—three of which are typical, of different grades, parallel with the above.

(2.) The classes of *Articulates* are but three, Insecteans, Crustaceans and Worms. This is illustrated at length at page 3 of this volume, where it is shown that the three divisions of Insecteans, namely Insects, Spiders and Myriapods, are distinguished by characteristics analogous to those which separate the divisions of Crustaceans,—Decapods, Tetradecapods and Entomostracans. The facts on this point are briefly presented on page 335. Insects and Spiders do not, in fact, differ more widely in external form or in structure than Decapods and Tetradecapods.

Insecteans and Birds express in different ways the same type-idea,—that of aerial life, Birds being flying Vertebrates and Insects flying Articulates; and, in accordance, they are of the same grade of type, both being *betatypic*. This follows, further, from the fact that there are but two grand divisions of Insecteans above the degradational division, that of Worms.

(3.) Among *Mollusks*, there are two well-characterized classes, the *first* including the *ordinary* Mollusks; the *second*, the *Ascidioids*, or the Brachiopods and Ascidians, which are mostly attached species and thus hemiphytoid. Besides these, there are the Bryozoans, which either make a third division under the Ascidioids (Edwards having long since pointed out their relations to the Ascidians); or they constitute a *third* class of Mollusks, characterized by being polyp-like both in external appearance and in being attached, and hence doubly hemiphytoid.

(4.) The *Radiates* are all degradational in their relations to the animal-type. But under the *Radiate-type*, the species of the first two classes are within type-limits, while those of the third are degradational, since almost all are attached and very inferior in type of structure, being the most phytoid of phytoid animals. The grades of structure as marked in the digestive system are as follows: (1) having approximately normal viscera, as in Echinoderms; (2) having, for the digestive system, only a stomach cavity, with vessels, imbedded in the tissues, radiating from it, as in Acalephs; (3) having, for the same, no system of viscera or radiating vessels; but only a central stomach surrounded by a cavity more or less divided at its sides by partitions, as in Polyps.

The following table presents the relations and the parallelisms of these classes, and of each to the subkingdoms.

	Subkingdoms.	Vertebrates.	Articulates.	Mollusks.	Radiates.
α.	Vertebrates.	Mammals.	———	———	———
β.	Articulates.	Birds.	Insecteans.	Ordinary.	Echinoderms.
γ.	Mollusks.	Reptiles.	Crustaceans.	Ascidioids.	Acalephs.
D.	Radiates.	Fishes.	Worms.	Bryozoans?	Polyps.

Arranging the divisions according to the relations of the groups to the *animal-type*, instead of the special type of each class, the table takes the following form:

	Subkingdoms.	Vertebrates.	Articulates.	Mollusks.	Radiates.
α.	Vertebrates.	Mammals.	———	———	———
β.	Articulates.	Birds.	Insecteans.	———	———
γ.	Mollusks.	Reptiles.	Crustaceans.	Ordinary.	———
α. D.	———	Fishes.	Worms.	Ascidioids.	———
b. "	———	———	———	Bryozoans.	———
c. "	Radiates.	———	———	———	Echinoderms.
d. "	———	———	———	———	Acalephs.
e. "	———	———	———	———	Polyps.

The letters *c*, *d*, *e*, stand for different grades of phytoid degradational, *b*, hemiphytoid, and *a*, degenerative. The blank interval between Mollusks and Radiates is filled up by the inferior divisions of the higher subkingdoms.

We may now consider the subdivisions under some of the classes; and first, those of Vertebrates.

3. *Higher subdivisions of the class of Mammals.*—The higher subdivisions of the class of Mammals are four in number: Man, Megasthenes, Microsthenes, and Oötocoids, as explained in the preceding volume of this Journal, p. 70 Man is shown to stand apart from the Megasthenes on precisely the same characteristic that separates the two highest orders under the classes severally of Insecteans and Crustaceans; for, in passing from Man to the brute Mammals, there is a transfer of the forelimbs from the cephalic to the locomotive series.

Moreover, a study of the Vertebrate skeleton has shown that the forelimbs in the Vertebrate-type, as well explained by Professor Owen, are *cephalic appendages*, being normally appendages to the posterior or occipital division of the head. In the Fish, these forelimbs (the pectoral fins) have at any rate an actual *cephalic position* (back of which position they are thrown, by displacement, in other Vertebrates). Now, in Man, they are not only cephalic in normal structural relations, but *cephalic* also in *use*. The transfer of these cephalic organs to the locomotive series, by which the brute structure is made, is a manifest degradation of the type. Man is thus the only Vertebrate in which the Vertebrate-type is expressed in its perfection, and therefore occupies *alone* the sublime summit of the system of life.

Three of the orders of Mammals, namely, Man, Megasthenes, and Microsthenes, are typical, of different grades, and one, Oötocoids, as explained on pages 316 and 332, is semidegradational.

For remarks on the *subdivisions* of Megasthenes and Microsthenes, see the articles above referred to, and also p. 338, preceding.

The Oötocoids may be divided into three groups—a *megasthenic*, a *microsthenic* and a *degradational;* the *first* to include the genera Phalangista, Dasyurus, Macropus, Diprotodon, etc.; the *second*, Perameles, Didelphys, Phascolomys, Echidna, etc., or Marsupial Insectivores, Rodents and Edentates; the *third*, Ornithorhynchus.

The following table presents to view the subdivisions of Mammals and its orders. Under Oötocoids, the relations of the two higher groups are indicated by the above adjectives, without giving them special names.

	Mammals.	Megasthenes.	Microsthenes.	Oötocoids.
α.	Man.	Quadrumanes.	Chiropters.	———
β.	Megasthenes.	Carnivores.	Insectivores.	Megasthenic.
γ.	Microsthenes.	Herbivores.	Rodents.	Microsthenic.
D.	Oötocoids.	Mutilates.	Edentates.	Ornithorhynchs.

4. *Higher subdivisions of the classes of Birds, Reptiles and Fishes.* —(1.) In the class of *Birds*, there are three grand divisions: the first two, as recognized by Bonaparte, are the *Altrices* (Rapacious birds, Perchers, &c., and other birds that feed their young until they can fly), and the *Præcoces* (or the Gallinæ, Anseres, Ostriches, etc., which feed themselves as soon as hatched). The third includes the Reptilian Birds or Erpetoids (p. 317). The terms *Pterosthenics* and *Podosthenics* apply equally well with *Altrices* and *Præcoces* to the two higher divisions of Birds, as explained on page 323, and have an advantage in their direct dynamical signification.

The type of ordinary Birds (or Pterosthenics and Podosthenics) is stated on page 333 to be essentially *limitate*, like that of Insects, while the type of Erpetoids is *multiplicate*, like that of Myriapods or of ordinary Reptiles; so that the relation of Erpetoids to the higher division of Birds is in an important respect analogous to that of Myriapods to the higher division of Insecteans.

(2.) In the classification of *Reptiles* there are three prominent types of structure recognized by Erpetologists; (1) that of the Chelonians; (2) that of the Lacertoids (including Saurians, Lizards, Snakes); and (3) the degradational or hemitypic one of Amphibians. It is now well known that Snakes and Lizards are alike in type of structure, the two groups graduating almost insensibly into one another, some species ranked as Lizards being

footless like the Snakes. The Snakes constitute the degradational group under the Lacertoids. The Amphibians, constituting the third order, are on the same level with the Erpetoid Birds and the Oötocoid Mammals, as presented in the following table.

The three orders of Reptiles—Chelonians, Lacertoids and Amphibians—make a parallel series with the three lower classes of Vertebrates; the Chelonians representing the Birds, to which they approximate in some points, besides being betatypic like them; the Amphibians representing the Fishes, with a still closer approximation between the two; while the Lacertoids are the typical Reptiles. The Chelonians might be viewed as *hemitypic* Reptiles; not *hypotypic* like the Amphibians, but *hypertypic*, like the Selachians and Ganoids among Fishes.

(3.) *Fishes* are all degradational species in their relations to the animal-type. The two higher groups, or those of Selachians and Ganoids as already explained (p. 334), are *hypertypic*. The third, including Teliosts, is *typical* if viewed with reference to the Fish-type. Below these, the Dermopters or Myzonts, (including Amphioxus, Myxine, etc.) constitute an inferior *hypotypic* or degradational group,—that is degradational in its relations to typical Fishes (p. 332). Thus *typical* Fishes are gammatypic in their relations to other Vertebrates, while the alphatypic and betatypic groups are *hypertypic* orders.

The following table exhibits the relations of the orders in the classes of Birds, Reptiles and Fishes; and, for comparison, those of Mammals are added.

	Mammals.	Birds.	Reptiles.	Fishes.
Alphatypic,	Man.	———	———	Selachians.
Betatypic,	Megasthenes.	Altrices, or Pterosthenics.	Chelonians.	Ganoids.
Gammatypic,	Microsthenes.	Præcoces, or Podosthenics.	Lacertoids.	Teliosts.
Hemitypic, or Degradational,	Oötocoids.	Erpetoids.	Amphibians.	Dermopters.

We pass now to Articulates.

5. *Subdivisions of the classes, Insecteans, Crustaceans and Worms into Orders.*—(1.) The higher subdivisions in each of the classes, *Insecteans* and *Crustaceans*, are three in number, none existing above the betatypic grade, which is that of Articulates among the subkingdoms, and of Insecteans among Articulates. (See page 7.)

(2.) *Worms* are of four types of structure. First, *Annelids*, or *typical* Worms, including the Branchiates, Abranchiates, and Nematoids—the last the degradational group, and showing this in the obsolete body-articulations and some internal characters.—Second, *Bdelloids*, or *Molluscoid* Worms, including the Hirudines or Leeches, Planarians and Trematodes; characterized by obso-

lescent or obsolete body-articulations, and by often wanting the nervous ganglia excepting the anterior; by usually a Gasteropod-like breadth and aspect, an *amplificate* feature; by being in general *urosthenic*, even the highest having a caudal disk for attachment; and in an up-and-down movement of the body in locomotion, *Mollusk-like*, instead of the worm-like lateral movement of the Annelids. The fact of this mode of movement has been recently made known to the writer by Dr. Wm. C. Minor, as a distinctive feature of the Bdelloids. Quatrefages remarks that the Planarians and Trematodes may well be regarded degraded forms of the Hirudines, and the three tribes are arranged in one group by Burmeister.—Third, *Gephyreans* (of de Quatrefages), or *Holothurioid* (*Radiate*-like) Worms, including the genera, Echiurus, Sipuncula, etc.[7]—Fourth, *Cestideans*, or *Protozoic* Worms, including the Cestoids, in which there is no normal digestive system, and the segments are independently self-nutrient.[8]

The orders of these classes of Articulates are the following:

	Insecteans.	Crustaceans.	Worms.
Alphatypic,			
Betatypic,	Insects.	Decapods.	Annelids.
Gammatypic,	Spiders.	Tetradecapods.	Bdelloids.
a. Degradational,	Myriapods.	Entomostracans.	Gephyreans.
b. "			Cestideans.

6. *Subdivisions of the orders of Insecteans and Crustaceans into tribes.*—(1.) The orders of *Insecteans* have each three divisions, excepting that of Myriapods in which but two have been recognized. The three of Insects are indicated on pages 323, 335. The fact that Insects are, in type-idea, *flying* Articulates gives special importance to the wings in classification. The *first* order includes the *Prosthenics*, in which the anterior wings are flying wings, as the Hymenopters, Dipters, Neuropters, Lepidopters and Homopters. The *second* consists of the *Metasthenics* or *Elytropters*, in which the anterior wings are not used in flying, or but little so, as the Coleopters, Strepsipters, Orthopters and Hemipters. The Hemipters and Homopters, united in one tribe by most entomologists, are hence profoundly distinct. The *third* tribe, or *Apters*, embraces the Lepismids and Podurellids; the remaining Apterous insects being distributed among the other

[7] The Holothurioid characteristics are well exhibited by de Quatrefages in Part ii, p. 248 and beyond, of *Recherches Anatomiques et Zoologiques faites pendant un voyage sur les Côtes de la Sicile, etc.*, in 3 vols. or parts, the second by de Quatrefages. Paris.

[8] The *Acanthocephali*, according to van Beneden and Blanchard, are Nematoids, (with which they agree in form and general structure) although without a digestive system. Blanchard states that there is reason for believing that the digestive system becomes atrophied with the growth of the animal, and mentions that cases of like atrophy occur even in species of *Gordius* and *Nemertes*.

groups, as suggested by different entomologists. The Lepismæ show their degradational character in their larval forms and in other approximations to the Myriapods, and the Podurellids appear to be still inferior in having the abdomen elliptic in some segments.

(2.) The orders of *Spiders* suggested by the principles of cephalization are in precise parallelism with those of the Decapod and Tetradecapod Crustaceans. They are, first, *Araneoids*, including all the *Pulmonates*, except the Pedipalps; second, *Scorpionoids*, or the Pedipalps from among the Pulmonates, and the Chelifer group from among the Trachearians; third, *Acaroids*.

The Araneoids are *Brachyural* Spiders; the Scorpionoids, *Macrural;* while the Acaroids are *degradational*. The last show their degradational character in having no division between the abdomen and cephalothorax; so that, while Insects have the body in *three* parts, head, thorax, and abdomen, and ordinary Spiders in *two*, cephalothorax, and abdomen, the Acaroids have it *undivided* (page 326). Thus, one of the most prominent characteristics marking the descent from Insects to Spiders becomes the characteristic of a further descent among Spiders themselves—illustrating a common principle with regard to such subdivisions. (See p. 350 beyond.) The propriety of making the Acaroids a distinct group appears therefore to be well sustained.

The usual subdivision of Spiders into Pulmonates and Trachearians depends on *internal* characters, which is not the fact with any other subdivisions in the table beyond. Moreover, these names, though *seeming* to mean much, are not based on any *functional* difference between the groups. Spiders have many relations to Crustaceans; and it is natural that the subdivisions in both should depend on the same methods of cephalization, the amplificative and analytic (p. 335).

(3.) The two orders of *Myriapods* are examples, one of case *a*, the other of case *b*, under multiplicative decephalization (p. 325).

The close relations between Isopods and the higher Myriapods, suggest that they are of like grade under their respective types, that is, betatypic.

(4.) *a.* Under *Decapod Crustaceans*, the subdivisions are *three*, as remarked upon by the author, at page 326 of this volume.[9]

The Anomurans are only degradational Brachyurans, and do not represent an independent type of structure. The Schizopods, similarly, are degradational Macrurans, with which they should be united. The *third* type is that of the *Gastrurans*, which are peculiar, among Decapods, in having the viscera extend into the abdomen, one of the marked degradational features of the type. They are the Stomapods of Latreille; but this author, in his last edition, made the group, in connection with the Schizopods,

[9] See also vol. xxv, [2], pp. 337, 338.

coördinate with that of Decapods. Being coördinate with Brachyurans and Macrurans, the change of name is necessary.

b. The *Tetradecapods* include two divisions precisely parallel with the first two of the Decapods, the first literally *brachyural*, the second *macrural*. (See p. 335 of this volume.) The *Anisopods*, of the writer, are degradational Isopods, just as the Anomurans are degradational Brachyurans. The Lemodipods (Caprellids, etc.) are only degradational Amphipods, the structure of the two being essentially the same in type. Hence, neither the Lemodipods nor the Anisopods are an independent type corresponding to a *third* subdivision.

The *third* subdivision probably is made up of *Trilobites*, although these are generally regarded as Entomostracans. One of the most prominent marks distinguishing Entomostracans from Tetradecapods is the absence of a series of abdominal appendages. It is highly improbable that the large abdominal (or caudal) plate of an Asaphus, or the many-jointed abdomen of a Paradoxides, Calymene, etc., should have been without foliaceous appendages below; and if these appendages were present, the species were essentially Tetradecapods, although degradational in the excessive number of body-segments.

c. Entomostracans (or Colopods, as they are more appropriately styled) embrace four orders. First, *Carcinoids* (as named by Latreille) consisting of the Cyclops group (Copepods of Edwards), whose species have a strong Macrural or shrimp-like habit; to which should be added the Caligoids, (Cormostomes of the writer, Siphonostomes of others,) since they are essentially identical in type of structure with the Cyclopoids, as may be seen on comparing *Sapphirina* of the latter with *Caligus*.—Second, *Ostracoids* (or the Daphnia, Cypris and Limnadia groups), which have, besides a bivalve carapax more or less complete, a much more elliptic abdomen than the Carcinoids, it being short, incurved, and without a lamellar terminal joint or terminal appendages.—Third, *Limuloids*, which have the abdomen still more elliptic, it being reduced to a mere spine, or nearly obsolete, and which have the mouth-organs all perfect feet and the only locomotive organs. (The joint across the carapax of the Limulus corresponds in position to a suture or imperfect articulation in the carapax of the Caligi, etc.)—Fourth, the *Rotifers*, a low Protozoic grade of degradation, in which all members are wanting, and locomotion is performed by cilia. The Phyllopods are distributed between the first two divisions.

The Rotifers are sometimes arranged under Worms. If they are degradational species of a limitate type, they are Crustaceans; and if of a multiplicate, they are Worms. The very small number of segments present, when any are distinct, the character of the dentate mandibles (for mandibles are *not* found

in the inferior subdivisions of Worms), and the resemblance in the form of some species to Daphniæ and other Entomostracans, sustain the view that they are Crustacean.

The Cirripeds appear to be only attached, amplificate Ostracoids. (See pages 324, 325.)

The subdivisions of the orders of Insecteans and Crustaceans are then the following:

	Insects.	Spiders.	Myriapods.	Decapods.	Tetradecap's.	Entomostr.
α.						
β.	Prosthenics or Ctenopters.	Araneoids.	Chilopods.	Brachyurans.	Isopods.	Carcinoids.
γ	Metasthenics or Elytropters.	Scorpionoids.	Diplopods.	Macrurans.	Amphipods	Ostracoids.
a. D.	Apters.	Acaroids.	?	Gastrurans.	Trilobites.?	Limuloids.
b. D.						Rotifers.

7. *Subdivisions of the orders of the class of Worms.*—On the true method of grouping the typical (Branchiate and Abranchiate) Annelids, I here make no suggestions. The tribes of the other orders are probably those indicated on page 343, and which need not be here repeated. The Cystics are there included with the Cestoids. If any of the *simple* Cystics are really adults, they may possibly make a second subdivision of the Cestideans.

8. *Subdivisions of the classes of Mollusks.*—The Ordinary Mollusks include three orders, as usually given: (1) *Cephalopods*, (2) *Cephalates* and (3) *Acephals;* of which, the first two correspond to different grades of typical Mollusks, and the last is degradational in its relations to the type, the species being imperfect in the senses and means of locomotion.

The Ascidioid Mollusks comprise (1) *Brachiopods* and (2) *Ascidians*, with perhaps the *Bryozoans* as the *third* order. If the last, however, be made a third *class*, as suggested (though with hesitation) on page 340, there is no third order, unless the inferior of the compound Ascidians, having water-apertures to a *group* of individuals instead of to each one, and the mouth-opening of each usually *radiated* (the number of rays *six*), be regarded as the third. This would make the orders, (1) *Brachiopods;* (2) *Ascidians;* (3) *Incrustates;* the first two typical, the last degradational and strikingly hemiphytoid.

4. *Conclusions.*

The preceding review of zoological classification appears to sustain the following general conclusions.

1. *Number and typical relations of the subdivisions of groups.*

I. The number of subkingdoms, classes, orders, and tribes in the system of animal life is either *four* or *three*, that is, the division in each case is either *quaternate* or *ternate*.

II. The lowest of the subdivisions in each group is a degradational or semidegradational subdivision, or *hypotypic*.

III. The quaternate division is confind to *six* cases (excepting two or three among inferior types in which there are *two* degradational subdivisions): 1, the number of subkingdoms; 2, the number of classes under Vertebrates, the highest of the subkingdoms; 3, 4, the number of orders under Mammals and Fishes, the highest and lowest classes of Vertebrates; 5, 6, the numbers of tribes under two of the orders of Mammals.

IV. In *three* only of the six cases of *quaternate* division are the three higher subdivisions all *true typical*, namely; 1, in the division of the animal kingdom into subkingdoms; 2, of the Vertebrates into classes; 3, of Mammals into orders. In the last we reach Man. As man alone is archetypic in the class of Mammals (p. 334), so the Mammal-type is archetypic among Vertebrates, and the Vertebrate-type among the subkingdoms.

b. Below this archetypic level, in the orders of Mammals, the number of *true typical* subdivisions is but *two*—and these are the *betatypic* and *gammatypic;* for the first or alphatypic subdivision in both Megasthenes and Microsthenes, as explained on page 334, is *hypertypic*, and not true typical.

c. Again, of the *four* orders of Fishes only *one* is typical, the *two highest* being *hypertypic* (p. 334).

V. In the rest of the animal kingdom, the number of *true typical* groups, in the classes, orders and tribes that have been reviewed, is either *two*, the *betatypic* and *gammatypic*, or *one*, the *gammatypic* alone.

2. *Lines of gradation.*—Lines of gradation between groups are lines of convergence or approximation through intermediate species. Before mentioning under this head the deductions from the preceding classification (or VIII, and IX beyond), two general principles (VI and VII), having an important bearing upon them, are here introduced.

VI. The approximations between two groups usually take place, as has been frequently observed, through their *lower limits*, or most inferior species, that is, between the degradational subdivision of the inferior as well as of the superior group.—For example, plants and animals approximate only in their simplest species, the Protozoans and Protophytes; Birds and Quadrupeds most nearly in the Ornithorhynchus or Duckbill—which, at the same time that it is the lowest of Mammals, is related to a very inferior type of Birds, the Ducks; Quadrumanes and inferior Mammals through the Lemurs of the former and the Bats and Insectivores of the Microsthenes, and not through the higher Carnivores or even any of the Megasthenes.

The classes of Reptiles and Fishes may appear to be an exception. But the *Perennibranchs* (or the species with permanent gills) among Amphibians, if referred to the type of Fishes, and

especially to the Ganoid type, would rank low, as is obvious from their exsert and loosely-hung gills without gill-covers, the absence of scales, and the general inferiority in all structural arrangements. The Ganocephs, known only as fossils and generally regarded as Perennibranch Amphibians, have, it is true, a higher grade of organization, both as regards gills and scales, being allied, in these respects, to the highest of Ganoids. And this fact, in view of the above canon, sustains the opinion of Agassiz that the Ganocephs (or Archegosaurs) are actually Ganoids,—having a Reptilian feature in the partial elongation of the limbs, but in little that is fundamental in the structure beyond what belongs essentially to the Ganoid-type.

VII. The lines of gradation between classes, orders and tribes, are only approximating, not connecting, lines, there being often wide blanks of the most fundamental character. The Ornithorhynchus, although Duck-like in some points, leaves still a very wide unfilled gap between the Mammal and Bird, and the Marsupials a still wider. The species are fundamentally Mammalian, and Bird-like only in points of secondary importance. In a similar manner, there are long blanks between the Oötocoids and higher Mammals; between Myriapods and either Insects or Spiders; between Reptiles and Mammals. The intermediate groups belong decidedly to one or the other of the two approximating groups, and are never strictly intermediate.

VIII. Under any *class*, *order* or *tribe*, the lines of gradation run in most cases between the *degradational* subdivision and severally the *gammatypic* and *betatypic* subdivisions, and far less clearly, or not at all, between the gammatypic and betatypic themselves; that is, between D and γ, and D and β, rather than β and γ. For example, in the class of Mammals, the lines run between Oötocoids and either Megasthenes or Microsthenes, and not distinctly between Megasthenes and Microsthenes; in Insecteans, between Myriapods and either Insects or Spiders, and not distinctly between Insects and Spiders; in Crustaceans, between Entomostracans and either Decapods or Tetradecapods, and not distinctly between Decapods and Tetradecapods; etc. There are exceptions to the canon; and still it is a general truth.

IX. Under any *class* or *order* the line of gradation between the *degradational* and the *betatypic* subdivision (or D and β) is often more distinct than that between the *degradational* and *gammatypic*, (or D and γ), although the gammatypic is nearer in grade to the degradational.—Thus, the line between Myriapods and Insects is more distinct than that between Myriapods and Spiders; or that between Entomostracans and Decapods, than than that betweeen Entomostracans and Tetradecapods.

There is an exception in the class of Mammals: the Oötocoids seem to graduate towards both Microsthenes and Megasthenes with nearly equal distinctness.

3. *Coördinate grades and distinctions in Classification.*

X. The coördinate value of subdivisions in the system of classification is brought out to view in the parallel columns of the preceding tables, and evidence is thence afforded as to what groups are rightly designated, classes, orders, etc.

a. We thus learn that the subdivisions of the class of Mammals—Man, Megasthenes, Microsthenes,—are properly *orders*, if we so call the subdivisions Decapods and Tetradecapods under Crustaceans, or Insects and Spiders under Insecteans.

b. Again, we have a solution of the question whether in each of the classes, Mammals, Birds, and Reptiles, the *hemitypic* division, as so-called on page 316, is a *subclass* coördinate with the *typical* division of the same, *or* whether it is an *order* coördinate with the three higher subdivisions of the class. The question appears to be decided, (contrary to former views of the writer,) that it is correctly made an *order*. These hemitypic divisions actually correspond severally to the degradational division in other columns of the different tables; and, therefore, if in the case of other classes, as those of Crustaceans, Insecteans, &c., they are *orders*, so are they in the three classes of Vertebrates mentioned. They have also a relation to the *hemitypic* divisions among Fishes, which are the first and second *orders* of the class.

XI. In an *inferior* or *degradational* group, the distinctions of the subdivisions included are generally much more strongly and obviously exhibited in the structure than among *typical* groups. Thus, the orders of Fishes are based on characters that have nearly a class-value among the higher Vertebrates. In the same manner, Amphibians, or hemitypic Reptiles, differ from true Reptiles more obviously than Oötocoids, or hemitypic Mammals, differ from other Mammals. So, the distinctions among the groups of Crustaceans are very wide compared with those among Insects; and those among degradational Crustaceans far wider than those among the typical subdivisions. The relative force of the life-systems is, in all probability, as great between Oötocoids and typical Mammals as between Amphibians and typical Reptiles, although so unequally expressed in the structure of the high or concentrated groups and the low or lax groups of species. Overlooking this principle has often led authors to allow too great importance to the structural differences among inferior or degradational groups.

XII. Under any class, order, tribe, the *typical* groups are often represented more or less clearly among the subdivisions of the *degradational*. Hence characteristics which separate the typical groups frequently separate only subordinate divisions under an inferior or degradational group. Examples occur in the class of Fishes under Vertebrates, in whose subdivisions the other classes of Vertebrates are partly represented; in the order

of Oötocoids under Mammals, which has its megasthenic and microsthenic subdivisions; under Worms, etc.

4. *Distinction between Animals and Plants.*

XIII. This subject well illustrates a fundamental distinction between animals and plants.

a. An animal, as has been stated on page 332, has *fore-and-aft*, or antero-posterior, polarity; that is, it has a fore-extremity and a hind-extremity which have that degree of oppositeness that characterizes polarity.

b. With this fore-and-aft polarity there is also *dorso-ventral* polarity.

c. The dorso-ventral and antero-posterior axes are at *right angles* to one another. In Invertebrates and a large part of Vertebrates the antero-posterior axis is horizontal and the dorso-ventral vertical; and only in Man, the prince of Mammals, is the former vertical and the latter horizontal.

d. An animal, again, has not only oppositeness between the fore-extremity and hind-extremity, but also a *head*, the seat of the senses and mouth, situated at the fore-extremity and constituting this extremity.

e. In addition, the typical animal is *forward moving.*

But in animals of the inferior type of *Radiates,* while there is an anterior and a posterior side, and also, in most species, forward motion, the mouth-aperture—which indicates the *primary centre* in an animal (p. 322)—is not placed at one extremity, but is more or less nearly *central*; and almost precisely central in the symmetrical (and therefore inferior) Radiates. The mouth-extremity and the opposite are at *the poles of the dorso-ventral axis*, and not at those of the antero-posterior; that is, they are at the extremity of the axis which in the inferior animals is normally *vertical.* This is true even in a Holothuria, the mouth of which is not at the *anterior* extremity, but is central, or nearly so, as in an Echinus. A Limulus has been referred to on page 328 as showing an approximation, under the true animal type, to this same central position of the mouth.

We pass now to *Plants.* The plant, in contrast with the fore-and-aft animal, is an *up-and-down* structure, having up-and-down polarity. The axis is *vertical* like the dorso-ventral in the lower animals, to which it is strictly analogous, as is shown from a comparison with Radiates,—Radiates and Plants being alike in type of structure. The primary centre of force is central, in the same sense, in the regular flower and the symmetrical Radiate.

Thus, the structures under the animal-type and plant-type are based on two distinct axial directions, one at right angles to the other: in the *animal-type* the antero-posterior axis being the dominant one, while the two coexist; and in the *plant-type* the axis at right angles to this being the only one.

In the above way, (as well as in its non-percipient nature,) the plant exhibits complete decephalization—a condition to which the Radiate only approximates, as it has generally, if not always, an anterior and posterior side, besides other animal characteristics.

Note to page 327.—The term elliptic, as used on page 327, implies defectiveness or deficiency of parts *through abnormal weakness* in an organ or the general system. The foot of the horse, one of the examples mentioned, is therefore hardly elliptic, since it has its full normal strength in the one toe, this being enlarged at the expense of the others. Paragraph *a* and the second under *b* hence require correction accordingly. In the fifteenth line from the foot of the page, Animal-type should be Mammal-type.

[From the American Journal of Science and Arts, Vol. XXXVI, pp. 440, 441, Nov., 1863.]

To be substituted for section 9, on p. 227.

Classification of animals based on the principle of Cephalization; by J. D. Dana.—A modification of the brief section on the elliptic method of decephalization, at page 227, is suggested in a note on page 352. The subject admits of much fuller elucidation, and the following is here presented as a substitute for the section referred to.

9. *Elliptic.*—Exhibited in the defectiveness or absence of segments or members normally pertaining to the type of the order or class containing the species, and arising from *abnormal weakness* in the general system, or in an organ. It is exhibited especially in the degradational or inferior types. The cases are—

Incomplete or deficient (1) segments, or (2) members, in either (*a*) the *anterior*, or (*b*) the *posterior* portion of the body; as in the absence of some, or all, of the teeth in Edentates; of the posterior limbs in Whales; of the abnormal appendages and posterior thoracic segments in some Schizopods or degradational Macrurans; of the antennæ, either one or both pairs, in many inferior Entomostracans; of wings in the Flea, etc.

This method of decephalization differs from the defunctionative in implying a deficiency not only of function but also of organ or member.

The incompleteness or deficiency of normal parts referred to above will be better appreciated if contrasted with deficiencies from other causes. The principal other causes are the following:

(1.) A *high degree* of cephalization or cephalic concentration in the system.—Thus in the Crab, the highest of Crustaceans, the abdomen is very small, and *elliptic* both in segments and members, because of the *high degree* of cephalic concentration; while in the Schizopods referred to above, and in the Limulus and many other inferior Crustaceans, the same deficiency comes from *weakness* of life-system or decephalization.

(2.) High development of one part of an organ, at the expense of other adjoining parts.—This principle may be said to include the preceding, since, in that, there is a high development of the anterior or cephalic portion of the structure at the expense of the posterior or circumferential. But here, there is reference to special organs rather than to the structure as a whole. Thus, in the foot of a Horse, there is an enlargement of one toe, normally the third, at the expense of the others, and this enlarged toe has the full normal strength that belongs to the foot under the Herbivore-type.

It is apparent from the facts in paragraphs (1) and (2), that there may be an *elliptic* method of *cephalization* as well as of *decephalization*. The Crab-type is a striking example of the former. The foot of the Horse, considering separately the *Horse-type*, is a case under the former rather than the latter; for, in any related species, a lessening of the disparity of the toes would be evidence of weakness and inferiority *under that type*. Yet, as compared with the higher Carnivore-type, in which the life-system has the strength to develop all the toes in their completeness and fulness of vigor, with great strength of foot, the foot of the horse is *elliptic*, and a mark of inferior cephalization. In the typical Ruminants, the complete

series of teeth is indicated in an embryonic state before birth; but part of them fail of development, while the others—those specially characteristic of the type—go forward to great size and perfection. As in the foot of the Horse, there is here an enlargement of one portion at the expense of the others. And this, under the Ruminant-type, is progress toward the highest condition of the type, or *cephalization* by an elliptic method. A Ruminant in which the teeth should be all equally developed would be one of too great feebleness of system to carry the structure to its typical perfection; and such is the Eocene Anoplothere.[1] If, however, the Ruminants were referred to the Megasthene-type as represented in the Carnivores, the *deficiency* of teeth would be an example of *decephalization* by the elliptic method; for such a deficiency under the higher type of the Carnivores would be evidence of abnormal weakness.

The same principle is exemplified in Carnivores; for the size and number of the molar teeth are less the larger the canines. The Machærodus with its huge tusks and but *three* molars to either side of a jaw is a remarkable example. Again, in the Elephant, two incisors are developed into the great tusks of the upper jaw at the expense of the other incisors and canines; and jaws that look as if bearing profoundly the mark of degradation or decephalization, are hence compatible with high *cephalization* under the Herbivore-type.

It is not to be inferred that the enlargement of one part of an organ at the expense of others, is *necessarily* an indication of *general* elevation of grade. Even in the case of the foot of the Horse, the elevation implied is elevation only under the Horse-type or among Solidungulates, and not elevation above all other Herbivores.

These examples are sufficient to illustrate the contrast between the elliptic method of cephalization and of decephalization; and also the fact, that a case of the former in one relation may be one of the latter in a higher, that is, if referred to a higher group as the standard type. The cases that would come under the elliptic method of *cephalization* (as that of the Crab) have been already referred by the writer to the *concentrative*, they being a result of concentration in the life-system.

(3.) That simplicity of structure which is opposed to the specialized or differentiated condition of superiority of type.—It is evident that the examples of elliptic decephalization, taking this term in its most comprehensive sense, may include the various simplifications which mark unspecialized structures of inferior types. Yet we propose to restrict the term to those examples of deficiencies which are obviously connected with degradational or hypotypic conditions under any type.

[1] "Amongst the varied forms of existing Herbivora we find certain teeth disproportionately developed, sometimes to a monstrous size; whilst other teeth are reduced to rudimental minuteness, or are wanting altogether: but the number of teeth never exceeds, in any hoofed quadruped, that displayed in the dental formula of the Anoplotherium. It is likewise most interesting to find that those species with a comparatively defective dentition, as the horned Ruminants for example, manifest transitorily, in the embryo-state, the germs of upper incisors and canines, which disappear before birth, but which were retained and functionally developed in the cloven-footed Anoplothere."—*Goodsir, British Assoc. Rep.*, 1838. *Owen's Brit. Mamm.*, 1846, 433.