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THE CLASSIFICATION OF ANIMALS BASED ON THE PRINCIPLE OF CEPHALIZATION.

ON FOSSIL INSECTS FROM THE CARBONIFEROUS FORMATION IN ILLINOIS.

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The Classification of Animals based on the principle of Cephalization.—No. II. *Classification of Insects.*[1]

THE principles which have been presented in my former article on the classification of animals may be further exemplified by a discussion of the natural system of classification in a few subdivisions of the animal kingdom; and at the present time I take up for this purpose the order of Insects.

The subject may be appropriately introduced by a recapitulation, arranged so as to be convenient for reference, of those of the characteristics bearing on grade which are of most prominent importance. In connection with the mention below of these characteristics, the number of the page is added on which they are explained and illustrated in the preceding volume of this Journal. Other characteristics not here enumerated will be found on the pages referred to.

Under each head the characteristic to be looked for in a *superior* group is first mentioned; and then those of related kinds in *inferior* groups.

I. In a *superior* group, (A) a *prosthenic* condition. In an *inferior* group (B) a *metasthenic* condition of different grades or kinds; or in a still lower group (C) a *urosthenic* condition. (P. 323.)

These conditions come under the *transferent* method of cephalization, which is exhibited in a transfer of force and function towards the head (preferent) with ascending grade, or in the reverse direction (retroferent) with descending.

This transfer is similar in nature to that which results in *amplificate* forms and the reverse; in one direction, the descending, it is *outward* or

[1] For Article I, see last volume of this Journal, p. 321.

circumferential diffusion, and may be designated *apocentric;* in the other, the ascending, it is *cephalic concentration* or *epicentric*—the systemic centre here referred to corresponding in position to the cephalic nervous mass or brain (p. 322).

The degrees of concentration do not generally shade indefinitely into one another. There is a range of variations under a given type or specific condition of the systemic force; and then a drop-down or *saltus* to another typical grade, or condition. Such conditions, in all probability, have specific mathematical relations, like other conditions of force in nature, (as in chemistry,) although science may never succeed in giving them a written expression.

II. In a *superior* group, (A) compactness, regularity and perfection of structure, with normal proportions and narrow limits of variation.

In an *inferior* group, (B) a condition of inferiority in general structure, attended with a wide diversity of form and size, and sometimes bizarre shapes; (C) an *amplificate* condition, manifested either in a widening of the structure (broad-amplificate), or in a lengthening of body anteriorly and posteriorly (mostly the latter), or a lengthening or attenuation of limbs (long-amplificate), or in a general enlargement (large-amplificate, gross-amplificate); (D) a *multiplicate* condition, or an indefinite multiplication of segments or members, as in Myriapods and Worms, and opposed to a *limitate* condition like that of Insects, Spiders, and Crustaceans; (E) an *analyzed* or *elementalized* condition, being a more or less complete resolution into elemental segments or parts, each more or less nearly of normal equality; (F) an *elliptic* condition exhibited in either a diminution of size of parts or members, or of number of segments, organs or parts, through abnormal weakness of the life-system, and manifested especially in inferior or degradational species. (Pages 324–328, 337, 440.)

III. *Sup.*, (A) a highly *differentiated* condition of structure corresponding to highly specialized or subdivided functions.—*Inf.*, (B) a *simplified* condition, or one less specialized in functions and therefore less differentiated in structure. (P. 327.)

IV. *Sup.*, (A) a *perfunctionate* condition of any organ or part, that is, one in which an organ is characterized by its highest normal functions. *Inf.*, (B) a perverted condition of an organ, or a prostitution of it to other than the normal function; (C) a more or less completely *defunctionated* condition of any organs or members. (P. 324.)

V. *Sup.*, (A) a *terrestrial* mode of life in all stages.—*Inf.*, (B) an *aquatic* mode of life, (*a*) in the adult stage, but not connected with aquatic respiration; (*b*) in the larval stage only; (*c*) in all stages, with aquatic respiration throughout each. A terrestrial mode of life in all stages may be distinguished as *perterrestrial;* and an aquatic mode of life in all stages with aquatic

respiration, *peraquatic*. The latter has been observed on page 330, (Art. I.) to have a *dilutive* effect on the materials and powers of growth; and the effect is similar, though less extreme, or *semidilutive*, when only the young stage is *aquatic*. (P. 330.)

VI. *Sup.*, (A) *permaturative* in development: of which there are two grades in Insects—the higher (*a*) when the larve is imperfect in its mouth-organs and nearly or quite foot-less; the lower (*b*) when it has large mouth-organs and is locomotive and active. Condition *b* distinguishes the lower subdivision of Hymenopters, and *a* the other species. Condition *a* may occur in inferior grades, as among Coleopters, apparently through degradation.—*Inf.*, (B) *prematurative*, or passing through no period of rest in the young state, as in Insects undergoing no complete metamorphosis. (P. 328.)

VII. *Sup.*, (A) *holozoic*, or strictly and wholly animal in type, being neither radiate externally or internally, nor attached, nor having the power of budding.—*Inf.*, (B) *hemiphytoid*, either in (*a*) having the faculty of budding, or (*b*) in being attached, or (*c*) in being radiate externally but not internally; (C) *phytoid*, being radiate internally—either (*a*) this alone, or (*b*) this in addition to the budding function, or (*c*) in addition to being attached. (P. 327.)

VIII. Besides the above there are cases among the higher groups which exhibit in the transition to the group next below a strongly marked *general lowering of grade of structure and potentiality*, but not the prominent characteristics of any one or two of the special methods of decephalization. Sometimes it is accompanied by a fundamental change in plan of structure, but not in accordance with any of the methods enumerated, it being of a more profound character.

The distinction between Megasthenes and Microsthenes under Mammals is of this kind (p. 338); also that of Mammals and Birds; also that of Insecteans and Crustaceans among Articulates. In the last, there is not only a change from terrestrial to aquatic life, and a marked amplification of the structure, but also a profound change of type, in which, contrary to the transferent method, the Crustacean or inferior type takes into the cephalothorax *five* more of the body-segments than belong to this part in Insects; while, at the same time, the body is made normally larger by three segments. Moreover, in the highest Crustaceans, the Crabs, the head includes three more body-segments than in Insects. The differences also between Hymenopters and Dipters (see p. 17), Lepidopters and Homopters, Coleopters and Hemipters, exemplify a *general lowering of the grade of structure*, not referable to any special one or two of the methods of cephalization. The general term *potential* is applied to cases like the above on page 322 of Art. I, as a convenient term, though really applicable to all methods of cephalization.

Internal characteristics, as those of the digestive, reproductive

or nervous system, have not been referred to among the above characteristics, because (1) they often undergo very wide variations under a given type, and especially in its inferior or degradational subdivision; further, (2) when any internal condition is distinctive of a natural group of species, there is always some type or plan of general structure corresponding to it in limits; and (3) the type or plan of structure is the surest criterion as to whether a group is natural or not. As an example of this last, it may be observed that the *Radiate* or *phytoid* plan or type of structure overrides vast diversities, as to the nervous, digestive and reproductive systems; and so it is, though to a less degree, with subordinate types or plans of structure. Herbivores and Carnivores, regarding only the characteristic of food, blend as completely as any Lamarckian could desire; for there are omnivorous species of both tribes. And again, looking to the characteristics of the *placenta*, a point seemingly of great importance because connected with the process of development,—a *decidua* is developed, according to Huxley, in the *Herbivorous* Elephant and Hyrax, as well as in the Carnivores and higher Mammals, Bats, Insectivores and Rodents, but not in the Horse, Hogs, or Ruminants. And still Carnivores and Herbivores are in structure distinct natural groups. Besides other decisive distinctions, the former have without exception prehensile fore-feet, while in the latter, these organs are defunctionated of this power of prehension, and are simply locomotive organs.

Classification of Insects.

The three grander subdivisions of Insects have been indicated in Article I, on page 344—namely (1) *Prosthenics* or *Clenopters*, (2) *Metasthenics* or *Elytropters*, (3) *Thysanures* or *Apters*.

The transition from the Prosthenics to the Metasthenics has been shown to depend on a transfer of force and function away from the systemic centre; and this by an abrupt transition, producing an abrupt downward step in grade.

This *retroferent* transfer is exhibited prominently in the wings, the *anterior* wings in the Metasthenics having little or no use in flying. These organs have been stated to have eminent importance in the order of Insects because the type is *aërial*. There is additional reason for this importance in the fact that the *dorsal* side of an animal is the *superior*, and the *ventral*, the *inferior*; or, the former is the more *central* in the life-system, and the latter the more *circumferential*.

As the series of legs, as well as wings, may present cases of transfer of locomotive functions, the terms *Prosthenics* and *Metasthenics* become more precise if reference to the wings is included. They will thus be (πτερον being the Greek for wing) (1) *Pteroprosthenics*, and (2) *Ptero-metasthenics*. The two-winged species

under the former (the Dipters) have the *posterior* wings obsolescent, and those under the latter (Strepsipters) the *anterior*.[2]

Insects of the first of these grand divisions are eminently *pterosthenic* or *strong in the wing*—Hymenopters, Dipters, Lepidopters and Neuropters being relatively good flyers. Those of the second are as decidedly *podosthenic*—Coleopters, Hemipters and Orthopters being relatively poor flyers, and strong in the leg. Consequently the terms *Pterosthenics* and *Podosthenics* might be employed for the two grander divisions of Insects, as well as for those of Birds (Art. I, p. 343). Yet their use in the two cases would be different; for in Birds the wings and legs are relatively *anterior* and *posterior* members, and not *dorsal* and *ventral* as in Insects. But since the dorsal and ventral parts have a similar opposite relation to the systemic centre as the anterior and posterior, as just now remarked, the difference is one of degree rather than of kind.

As there are *pteroprosthenic* and *pterometasthenic* Insects, so there are *podo*prosthenic, or those in which the *anterior* legs are stronger than the posterior, and *podo*metasthenic, or those in which the *posterior* are the main organs of locomotion. Fleas and Grasshoppers, as they use their hind-legs for leaping, are examples of the latter. This sthenic difference in the feet, though of less weight as a mark of grade than that in the wings, is of real value among inferior subdivisions.

The *Thysanures* or *Apters*, which constitute the third grand division, are *urosthenic*, most of the species having even the power of leaping by means of the caudal extremity.

After these observations on the grander subdivisions of Insects, I present a synopsis of the general system of classification arrived at by the aid of the principles explained; and following this, some of the characteristics of the groups, especially those which are marks of grade on the basis of these principles. To the names in the synopsis are added only the two characteristics of (1) *perterrestrial* (terrestrial in both larval and adult life) or *semiaquatic* (aquatic in larval life), and (2) *permaturative* or *prematurative*.

I. Ptero-prosthenics, or Ctenopters.

1. APIPENS (from *Apis bee* and *penna wing*, the wings being approximately like those of the Bee).

a. Hymenopters.—Perterrestrial. Permaturative.
b. Dipters.—Mostly perterrestrial. Permaturative.
c. Aphanipters (Fleas).—Perterrestrial. Permaturative.

[2] As the anterior pair (or that which is obsolescent in the Strepsipters) is of little functional value in the *Pterometasthenics*, the distinction of two-winged or four-winged among them is of much less importance than among the Pteroprosthenics. Moreover, there is a line of gradation from ordinary Coleopters to the Strepsipters through the Rhipiphoridæ.

2. AMPLIPENS (from *amplus large* and *penna*).
   - *a. Lepidopters.*—Perterrestrial. Permaturative.
   - *b. Homopters.*—Perterrestrial. Prematurative.
   - *c. Trichopters.*—Semiaquatic. Permaturative.

3. ATTENUATES, or NEUROPTERS.
   - *a. Apipenniforms.*—Perterrestrial. Permaturative, or prematurative.
   - *b. Amplipenniforms.*—Perterrestrial, or semiaquatic. Permaturative, or prematurative.
   - *c. Perattenuates*, or *Typical Neuropters.*—Semiaquatic. Prematurative.

II. Ptero-metasthenics, or Elytropters.

- *a. Coleopters.*—Mostly terrestrial. Permaturative.
- *b. Hemipters.*—Mostly terrestrial. Prematurative.
- *c. Orthopters.*—Terrestrial. Prematurative.
  - *α. Cursors.*
  - *β. Ambulators.*
  - *γ. Saltators*, or *Typical Orthopters.*

III. Thysanures, or Apters.

Lepismians and *Podurians.*

I. PTERO-PROSTHENICS, or CTENOPTERS.

1. Apipens.—The structures among Apipens are compact, comparatively uniform in proportions, and with rather narrow limits as to size, much narrower than in the Amplipens, Coleopters or Orthopters. The species are strongly pteroprosthenic, the anterior wings being much the larger. The wings are essentially of one type of form and texture, and are well described by the term *apiform;* they are free from scales and other defunctionating appendages or impediments, and are rapid in motion; in the second subdivision the posterior pair is wanting, and in the third, both pairs. The species are almost all perterrestrial. All are permaturative, and, with a few exceptions, they are so in the highest degree (Char. VI, A, *a*, p. 12).

a. Hymenopters.—The Hymenopters are the most uniform in shape or size of Apipens. The integuments are firm, the parts neatly adjusted and all well-proportioned. Among them, there are no imitations of the forms in other tribes, while they are extensively copied after—a characteristic peculiar to a type of the very highest grade.[3] The mouth has a suctorial lip for feeding;

[3] This point is well presented in a recent paper on "*Synthetic Types in Insects*," by A. S. Packard, Jr., (*Jour. Boston, Soc. Nat. Hist.*, 1863, pp. 590–603). The author observes, on page 591, "the clear-winged *Sesia* [Lepidopter] imitates the humble-bee in its form and flight; the different species of Ægerians [Lepidopters] simulate members of nearly every hymenopterous family, as we can see when recalling such names as *apiformis, vespiformis, philanthiformis, tiphiæformis, scoliæformis, spheciformis, chrysidiformis, cynipidiformis, formiciformis, ichneumoniformis, uroceriformis*, and *tenthrediformis*. So also other Ægerians resemble different family forms of Diptera, as seen in the names of *culiciformis, tipuliformis, bibio-*

but, besides this, well-developed mandibles, and these serve in many species for the high purposes of making nests, taking prey, transporting young and food: the jaws are therefore *perfunctionate* in th se species to a degree comparable with that of the jaws of a Carnivore among Mammals. The higher kinds also supply the young with food, either by storing it or by direct feeding—a quality approximating to that of the Altrices (Nursers) or highest subdvision of Birds. The food is either vegetable or articulate-animal, not vertebrate-animal; the animal food being thus the same in kind with the material to be made of it, just as, among *Mammals*, the highest of Carnivorous species live on the flesh of Mammals, and only the lower on fish and insects. Individuals of many of the higher species live in communities for mutual work and with sometimes a special division of the work among them. The wings are fitted eminently for the legitimate purpose of flying, and are typical in size, texture and power. The species are all perterrestrial.[4]

The above characteristics show that the tribe of Hymenopters takes the lead among Insects, and therefore stands at the head in the subkingdom of Articulates.

Note on Size under the Insect-type.—If, then, Hymenopters stand *first* among Insects, we may learn from the higher of the species the *normal size* of the Insect-type under its best condition as to structure, form and functions. This *archetypic* size is between 8 and 12 lines (or twelfths of an inch) in length and 2½ and 3 in breadth:—taking the Wasps as the superior type, 11 lines by 2½ to 3; taking the Hive-bee, 8 by 2½. Such being the size connected with the most highly cephalized condition of Insect-life, (1) any larger size of structure among inferior tribes of Insects is an exhibition of *amplification*, that is, of a more diffused condition of the systemic force—which force never exceeds that of the archetype, and may be less to any degree; (2) the more inferior the group in which large forms occur, the greater the amount of

formis, anthraciformis, muscæformis, &c. In the Diptera we find *Bombylius*, resembling, as its name implies, *Bombus;* and also *Laphria*, which so closely apes the humble-bee in its form, coloration, size and flight, even to the buzz, which is, if anything, still louder. Also there is the strongest resemblance in some *Syrphi* to *Vespa*, and especially to different species of *Crabro*. But while the Lepidoptera and Diptera resemble the Hymenoptera, we cannot say that Hymenoptera ever *assume* the form of any flies and moths. They seem isolated; and resemble only themselves. In the case of the *Laphria*, the plump, bee-like form, and the dense yellow and black hirsuties, which cause them to be mistaken for humble-bees by persons unacquainted with their structural differences, are just those features that are exceptional in the Diptera, and are normal in the Hymenoptera. The fly to get them has to pass over one sub-order to obtain a bizarre form which is a prevalent and common family attribute of the Apidæ."

Addition to Note, while in the press.—These, and other observations beyond, for which I am indebted to Mr. Packard, are so apposite to my subject as to appear as if prepared for the use here made of them. In fact, however, my paper with its notes was written without any acquaintance with the author beyond what I had derived from his valuable paper, and also without his knowledge.

[4] Some Hymenopters can swim with their wings or legs; but none are *semiaquatic*.

amplification for any given size; and (3) structures below the archetypic size in inferior groups may be amplificate upon smaller life-systems. Thus the gigantic size of some beetles is *evidence* of their inferiority to the Hymenopters, however it may be among Coleopters themselves; the great size of some Longicorn Coleopters is unquestionably a mark of inferiority among Coleopters, as they belong to an inferior subdivision of the tribe of Coleopters; the extravagant size of some Orthopters is a mark of much lower inferiority, as this type is one of the lowest in rank; and the moderate size among Hemipters, which does not exceed the mean size of Coleopters, is amplificate, since the Hemipter-type is much inferior to the Coleopter-type.

b. Dipters.—The Dipters vary widely as to general form of body, and considerably in size, though never attaining the magnitude of some Coleopters; but in their wings and legs there is a general uniformity. The integuments are less firm than in Hymenopters. The mouth is simply suctorial, and self-feeding is the only function. Individuals never live in communities. The food is various, either vegetable, articulate-animal, or vertebrate-animal, and either living, freshly dead, or decaying. The species are mostly perterrestrial,—one group among the attenuate, and therefore inferior, kinds being semiaquatic.

The rudimentary condition of the posterior wings in Dipters is attended with (1) an enlargement of the mesothorax (the segment supporting the anterior pair) at the expense of the metathorax (or posterior segment of the thorax), and (2) an increased size in the wings, making their surface nearly equal to that of both pairs in Hymenopters. It is hence an example of *forward transfer* of function, such as attends higher cephalization, and not of ellipsis through degradation. But while this characteristic proves cephalic concentration, others of this type show that the *degree* of force thus concentrated is far less than that of the Hymenopter-type. For the Dipters evince in all points their inferiority:—for example, in the structure or functions of the mouth, in their vastly wider limits of variation as to shape and size, in their many imitations of Hymenopters, in the semiaquatic life of some species, their less strength as compared with size, their habits, &c. It is stated on page 12 that the transition from Hymenopters to Dipters is an example of a *general lowering of grade* not referable to the particular methods of cephalization enumerated; that is, it is a case of profound *potential* difference registered in the general structure rather than in any one structural characteristic.

The foot note on the preceding page states some of the relations between Dipters and Hymenopters. On this point Westwood says: "It seems to be admitted on all hands that the Insects which are the real analogues of the Hymenopters exist in

the Dipterous order, almost every Hymenopterous genus having its representative in the latter." The analogies as well as affinities are so many and close that there can be no question as to the union of the Hymenopters and Dipters in the one group of Apipens.

c. Aphanipters.—Fleas have a suctorial or haustellate mouth like Dipters, and firm shining integuments like Hymenopters; and, as with the higher species of both tribes, they are permaturative in the highest degree, and perterrestrial. But while thus related to the Hymenopters and Dipters, they differ from both, not only in the less important fact of having no wings, but in being metapodosthenic, for the hind-legs are not merely the longest pair, but the main reliance in leaping. They show that they are an independent type, also, in the structure of the haustellate mouth, which is different from that of the Dipters; and also in their strength and agility. Defrance asserts that the female places with the eggs some bits of dried blood; and if so, there is a degree of nursing among Fleas which is an additional relation to the Hymenopters. The body is amplificate behind. The absence of wings is to be attributed to ellipsis through decephalization.

2. Amplipens.—The Amplipens are amplificate species, being eminently broad- or long-amplificate in their wings, and usually either long- or gross-amplificate, or both, in body; and among them there is a very wide diversity in shape and size, in which respect they are quite in contrast with the Hymenopters. The wings in the more typical species are slow in motion and are covered with scales and variously colored, often seeming like a wide spread of canvas for the display of pretty colors. The mouth in the adult is rostrate (except in a hypotypic group of species that eat nothing in the adult state) and has no function besides that of feeding. The species are all perterrestrial, except in the hypotypic group referred to. Those of the highest subdivision are permaturative, and the rest are prematurative; and when permaturative they are so only in the second degree (Char. VI, A. *b.*), the larves being very active, and furnished with strong jaws and feet.

a. Lepidopters.—The wings of Lepidopters are typically very broad-amplificate, scale-covered and variously colored, with the anterior pair the larger; in inferior species the wings are comparatively narrow, but through degradation of type. The amplificate character of the tribe is also apparent in the fact that the *smallest* species are far larger than the smallest of Apipens and of most other tribes of Insects. The mouth is haustellate, with the mandibles atrophied or nearly so.[5] The species are all

[5] It has been argued that since the larves of Lepidopters have mandibles, while the butterflies have these organs only in a rudimentary state, the latter condi-

perterrestrial and permaturative. Some caterpillars are in a sense social, but not for mutual work, and adults are never social.

b. Homopters.—In Homopters, the wings, though large, are less broad than in the typical Lepidopters. They are submembranous or a little thickened in the larger species, but not scale-covered, and are thin-membranous in the smaller; they are sometimes colored (in *Fulgora*, *Cercopis*, &c.), as in Lepidopters; the posterior are often equal to the anterior, and sometimes larger; in many species they are deflexed in position, roof-like. The mouth is simply haustellate and suctorial; though having mandibles, they are enclosed within the rostrum. The species are perterrestrial, as in the preceding group, but are prematurative.

Prof. Agassiz, in his memoir on the Classification of Insects, (see note below,) places the Hemipters (including under this term the Homopters as well as Hemipters) next to the Lepidopters, on the ground of the structure of the mouth and their development. While this cannot be sustained with regard to the proper Hemipters since these are *pterometasthenic*, it is true of the Homopters which have sometimes a striking resemblance to Butterflies in their large-amplificate, colored wings, besides being *pteroprosthenic* and otherwise approaching the Lepidopters.

c. Trichopters.—The Trichopters, while permaturative like the Lepidopters, are *semiaquatic*, and hence are inferior to both Lepidopters and Homopters. The wings are pilose, and are veined like those of a Lepidopter instead of being reticulate like those of a Neuropter; in position they are deflexed, roof-like, as in many Homopters and Lepidopters. The mouth-organs are almost completely atrophied, and the adult takes no food, so that the Phryganea has little use for its head, being almost solely a procreator. The larve spins silk-like fibres from

tion is evidence of superiority of rank *among Insects in general*. (See Agassiz on the Classification of Insects from Embryological data.) But as Lepidopters are on various grounds inferior to Hymenopters, this is manifestly one of the many cases in which the embryological law with regard to grade does not hold good. Others are alluded to in the remarks on the *elliptic* method of decephalization, on page 440 of the last volume of this Journal. An additional example is afforded by the Cirripeds. The *attached* amplificate and defunctionate Barnacle or Anatifa is not superior to the free Cypris or Ostracoid Crustacean, although it is the *adult* stage following an earlier Cypris-like condition of the animal. So in the case of any *attached* species, the moment of becoming attached is the commencement of vegetative increase, partial or complete defunctionation of the organs of sense, and general decline in grade. The progress thence is backward, toward a plant-like condition; it is a degradation of the type, as much as when the digestive system of certain Nematoid Worms becomes atrophied with growth.

Exceptions like these do not set aside the embryogenic law of grade: they only show that this law must sometimes, at least, be tested by the profounder law of cephalization, before it can be safely followed in determining the grade of species. For, as the writer has observed elsewhere (*this Jour.*, [2], xxv, 213, 1858), the steps in embryogenic development are, in a general way, steps in the cephalization of individual growth. The former affords aid toward understanding the latter; and the latter principle, once recognized, more than reciprocates.

the extremity of the abdomen, or the lip, or both, and by this means unites bits of sticks, pebbles, etc., into a portable case or sheath for itself.

All entomological writers acknowledge that the Trichopters resemble Lepidopters. They have so much the aspect of some Phalænids, that they were called *Mouches papillonacées* by Reaumur; and the larves, according to De Geer, are closely like caterpillars in internal organization. Other Lepidopteroid characteristics mentioned by different authors are observed in the rudimentary condition of the mandibles, the structure of the legs, the faculty of spinning fibres possessed by the larve, the portable larval sheath closely imitating those of the larves of many Tineids and the Psychids. One genus of Phryganeans is named Hydropsyche in allusion to the resemblance, and Newman transferred the genus Psyche from the Lepidopters to the Trichopters. The species naturally constitute a hypotypic group to the Amplipens. The hypotypic division of a terrestrial group often consists of aquatic or semiaquatic species. Although the Trichopters are generally united to the Neuropters, they are always placed to one side in a group by themselves, on account of their wide divergence from that type. The parallelism between the subdivisions of Amplipens and those of the Amplipenniforms on page 22, further sustains our arrangement.

3. Attenuates, or Neuropters.—The Neuropters are mostly long-amplificate, being generally slender in body, wings and legs; they are also widely diverse in shape and size. The wings are membranous, but are sometimes partly colored; they are often equal; the posterior are sometimes even the larger, but sometimes also much the smaller, and occasionally obsolete. In a few species both pairs are wanting. The mouth, unlike that of the Lepidopters and Homopters, but like that of most of their *larves*, is not suctorial but mandibulate. Among the species there are perterrestrial and semiaquatic kinds, and also permaturative and prematurative.

Two of the subdivisions of Neuropters appear to be representatives severally of those of Apipens and Amplipens, and may accordingly be named the *Apipenniforms* and *Amplipenniforms*. The third includes the *typical* Neuropters, the species which stand most widely apart from the other tribes of Insects.

a. Apipenniforms.—The Apipenniforms show their relation to the Apipens, both in their structure and habits, the higher species being related to the Hymenopters, through the Ants, and the lower to Dipters, through the Tipulids. Like Apipens, also they are all perterrestrial, although not all permaturative. The two subdivisions are (1) the *Termitideans* (White-Ant group) or Hymenopteroid species whose Ant-like habits are well-known; and (2) the *Panorpideans* or Dipteroid species, having the mouth

rostrate, the wings narrow, and the legs and body slender, as in the Tipulæ.[6]

b. Amplipenniforms.—The Amplipenniform Neuropters are related to the Amplipens in having the wings amplificate; but, as follows naturally from the fact of the inferior grade of Neuropters, these wings resemble rather the narrower forms of the inferior Lepidopters, or those of the Homopters and Trichopters, than the wide forms of the typical species—they being long-amplificate and at the same time only sparingly broad-amplificate. In some species they are partly colored, another Lepidopteroid character. They diverge most widely from those of the Lepidoptera in being reticulate, which is a special *Neuropterous* characteristic, although not without exceptions. The posterior pair is sometimes a little broader than the anterior. The species are either perterrestrial or semiaquatic, and either permaturative or prematurative.

[6] A. S. Packard, Jr., in his memoir already mentioned remarks as follows on the Termites, and the Panorpids.

"The *Formicidæ* among Hymenoptera have in the Neuroptera their well-known analogues, the *Termites* or White Ants. Like the true ants, these interesting insects rear nests of sand or clay, or the colonies are concealed beneath various objects, or in decayed trees and roots. There are also a differentiation of the individual, a partition of labor, and wonderful instincts, as in ants. Those characters which place the *Termitidæ* the highest in their suborder are just those which make them so much like Hymenoptera. Thus, in the small occiput, the large epicranium which occupies the largest part of the head, and in the general arrangement of the small mouth-parts, this family differs widely from other Neuroptera. Though the prothorax is large, yet the middle region of the body is massed together more than usual. Like the ants, the costal nervures of the wings are well-developed, while those occupying the hinder portions of the wings are obsolete. Indeed, both the true and white ants do not fly much, and that for the most part when swarming."—p. 601.

"The family *Panorpidæ* assumes dipterous shapes. *Bittacus* has its analogue in the fly *Bittacomorpha*. The resemblance of the female *Panorpa* to *Tipula* is very striking. In both the mouth parts are greatly elongated, and the head much produced in that direction, leaving a very short vertex; and the antennæ are much the same in size and shape. Panorpa is remarkable for the short, ovate, compressed thorax, owing to the reduced size of the prothorax, and the compactly massed notal and side pieces, wherein it simulates Tipula; but the resemblance is still greater in the elongated episterna and coxæ, and the long slender legs. If we go more carefully into a comparison of the notum of both insects, we shall find the large mesoscutum, the short scutellum, and the longer-than-broad horse-shoe-shaped scutum of the metathorax of Panorpa closely resembling those pieces in Tipula. There is the same form of the first pair of wings. In both the straight costa bends gradually around at the apex, as the inner edge curves up just as rapidly to meet the costa at the apex which is situated in the middle line of the wing. Also in the disposition of the main nervures, their relative distances apart, and their termination, even to the formation of the pterostigma and the branches that lead to and from it, the analogy is still maintained. At the base of the wing, and towards the outer margin of Tipula, there are a few cross recurrent nervules, and irregularities in the branching of the principal nervures that remind us of the system of net-veins that cross the wings of Panorpa. The abdomen in the two genera is dilated at its base and appressed to the thorax; and in its long cylindrical form it bears a similar proportion to the head and thorax, while the swelled extremity and genital pieces in the females of both genera are strictly analogous. Both genera agree, according to the representations of authors, in supporting themselves on their long legs, while introducing their slender and pointed abdomen into the earth, when about to deposit their eggs." pp. 594, 595.

They include: (1) the *Planipennians*, (Myrmeleontids, Hemerobiids, Nymphids, Mantispids and Semblids) which are Lepidopteroid in being *permaturative*, as well as in the other character already mentioned, and which, excepting the Semblids, are all *perterrestrial*.—(2) The *Psocideans*, which are Homopteroid in being *prematurative* and perterrestrial, and which, as observed by Packard, approach in form and in the roof-like position of the wings the Homopterous group of Aphides.[7] The little book-lice belong to this group, and thus represent the plant-lice among the Homopters.—(3) The *Perlideans*, semiaquatic and prematurative species, which are Trichopteroid (or like the Phryganeans) in the form of the wings, in the larve being not only aquatic but also *living in a sheath*, and in the adult eating little or nothing.

Thus each subdivision of the Amplipens, the Lepidopterous, Homopterous and Trichopterous, appears to be represented in the subdivisions of the Amplipenniforms.

The subdivisions of Attenuates or Neuropters deduced are the following:

1. Apipenniforms.
    1. *Termitideans*, or Hymenopteroid group.
    2. *Panorpideans*, or Dipteroid group.
    3. *Aphanipteroid*. Group unknown.

2. Amplipenniforms.
    1. *Plannipennians*, or Lepidopteroid group.
    2. *Psocideans*, or Homopteroid group.
    3. *Perlideans*, or Trichopteroid group.

3. Perattenuates or Typical Neuropters.
    1. *Libellulideans*.
    2. *Ephemerideans*.

As the higher Apipenniforms, the *Termitideans*, are *prematurative*, while the Dipteroid *Panorpideans* and the higher Ampli-

[7] Mr. Packard observes with regard to the Psocideans:—

"The *Psocidæ* find their analogues in the Hemiptera [Homoptera]. The species of Psocus are so much like the Aphidæ that when flying they are often mistaken for each other. And, indeed, in the short broad body and broad head and long antennæ, in the very unequal wings, which are folded roof-like over the short abdomen, in their simple neuration, in the short legs and feeble tarsi, and in their mode of flight and their appearing winged towards the close of summer, these small insects are remarkably like the winged plant-lice."

He also illustrates at some length the relations of some of the Planipennians to the Lepidopters, in the course of which he remarks, that among the Myrmeleontids "*Ascalaphus* was described by Scopoli as a Papilio, and has been said by Kirby to resemble Heliconia." The form of the antennæ is strikingly Lepidopteroid in its club-like shape, and its rather broad wings are colored. We add that the species of *Drepanopteryx*, a genus of the Hemerobiids, closely resembles some of the small Butterflies, and is called *D. phalænoides*.

penniforms or Plannipennians are *permaturative*, it might be questioned whether the latter groups should not rank before the Termitideans, among Neuropters. If so, then the groups considered as Dipteroid and Lepidopteroid would stand above the Hymenopteroid. But since Hymenopters are the highest of Apipens (and the highest therefore of Insects), and consequently occupy a level far above that of the Dipters (the second subdivision of Apipens), or that of the Lepidopters (the first of Amplipens), it is natural that the descent required to bring the Hymenopterous type down to a Neuropterous level should be much the greatest; and hence comes apparently this sinking to the *pre*maturative characteristic,—the *Hymenopteroid* division *prematurative*, being not below the Dipteroid or Lepidopteroid *permaturative.*

c. Perattenuates or *Typical Attenuates.*—The body and wings in these species are narrow or long-amplificate, the posterior wings sometimes small or wanting. The species are *semiaquatic* and *prematurative.*

They include: (1) the *Libellulideans*, which have the wings nearly equal, and the mandibles stout; and (2) the *Ephemerideans*, which have the posterior wings smallest and sometimes obsolete, and the mouth organs in the adult atrophied. The latter show their inferiority in being short-lived and in eating nothing or but little in the adult state; the functions of the adult are almost solely those of the *posterior* portion of the body.

II. PTERO-METASTHENICS, OR ELYTROPTERS.

a. Coleopters.—Coleopters, in their compact structures consisting of well-adjusted parts, their comparatively limited diversity of form, and their being imitated by many species of other tribes while never themselves imitators,[8] exhibit the characteristics of a type of the highest grade in its subdivision. At the same time they show inferiority to the Hymenopters in their

[8] A. S. Packard brings out this fact, in his pamphlet, in connection with the corresponding one with regard to Hymenopters already cited. He says "There is a similar parallelism of analogous forms between the Coleoptera, Hemiptera, Orthoptera and Neuroptera, which seem bound together by affinities such as those that unite by themselves the Bees, Moths, and Flies." "The suborders below reach up and connect themselves by these remarkable analogies with the Coleoptera, which do not in turn assume any of their forms. Some Orthoptera are very Coleopterous-like, and some Hemiptera are very Coleopterous-like. The reverse cannot be said."

Mr. Packard, adopting, yet it would seem from his words provisionally, the two grand divisions of Insects of *Mandibulates* and *Haustellates*, remarks that they *culminate* in the Coleopters and Hymenopters, respectively. As the Hemipters are *haustellate*, the facts respecting their relations above mentioned go against this old division of Insects and sustain fully the new arrangement proposed in which the Hemipters follow the Coleopters although the latter are mandibulate,—the distinction of mandibulate and haustellate, as the system shows, being one of minor importance.

stouter or grosser forms, and their greater diversity as to size and shape; in the jaws of the highest species being perfunctionate to a less degree; and, very decidedly in their metasthenic nature as regards the wings, the anterior pair being only wing-covers or elytra. The mouth is mandibulate, and often rodent as well as feeding. In some species there is a degree of care for the young that approaches somewhat that in the Hymenopters. They never live in communities for mutual work. The food, like that of Dipters, is various, being either vegetable, articulate-animal or vertebrate-animal, the last either living, freshly dead or decaying. The species are mostly perterrestrial. They are all permaturative.

b. Hemipters.—Among Hemipters the structures are rather laxly put together compared with those of Coleopters, the body thinner and softer, the wings usually more or less overlapping; and their strength for the same size very much less. There are some of the same differences between Hemipters and Coleopters as between Dipters and Hymenopters. Though never very large, they appear to be amplificate species,—sometimes broad-amplificate, being thin for their breadth, and sometimes long-amplificate. The elytra are coriaceous only in the basal half; and this thinning of the wing-covers comports with their being systemically weaker animals than Coleopters. All the wings are sometimes obsolete, as in the Pediculi. The mouth is suctorial, and simply gnawing and feeding in function. The species are mostly perterrestrial, and all are prematurative.

c. Orthopters.—The Orthopters also have a lax structure and rather soft bodies. They are either broad- or long-amplificate, and sometimes extravagantly so, and by their occasional great size, as well as the non-occurrence of very small species, they exhibit the low inferiority of unconcentration: they are low *because* large. The elytra are semicoriaceous. Both pairs of wings are sometimes obsolete. The mouth is mandibulate, and simply gnawing and feeding in function. The species are mostly perterrestrial, never semiaquatic; all are prematurative.

The Orthopters include three grand subdivisions,—the *first* and *second* representatives respectively of Coleopters and Hemipters, and the *third* typical.

(1) The *Cursors* or *Coleopteroid* species consist of the Blatta and Forficula groups, which, though elongate, are still comparatively short in body, and much like Coleopters; the wings in the Blattids are rather lax, and the bodies soft for the size.

(2) The *Ambulators* or *Hemipteroid* species, that is, the Mantids and Phasmids. The species are often thin and broad, and simulate leaves, bark and sticks in color and markings; and in this respect this group and the Hemipters show an approximation. There is also some approach between these groups in the

texture of the wings as well as the rather slow habit of body in many kinds. The Orthopterous Nirmids or Bird-lice represent the Hemipterous Pediculi or common lice, and so nearly that they are often arranged together in one tribe. The resemblance of these Orthopters to the Hemipters is less close than that of the preceding subdivision to the Coleopters. It is to be considered, however, that the Hemipters, although amplificate, are much more restricted in size, and therefore do not run off into those extravagances which give to Orthopters their most obvious features.

(*c*) The *Saltators*, or *Typical* Orthopters, (Grasshoppers, Crickets, &c.,) differ from the preceding in being strongly *podometasthenic*, a mark of low inferiority. The species show that they are the typical Orthopters by their trim and well-made forms, their great leaping powers, and the absence of any close likeness to other groups.

III. THYSANURES, or APTERS.

The Lepismians and Podurians are the only apterous Insects here included.

The *Lepismians* are larve-shaped with the distinctions of head, thorax and abdomen imperfect; the abdomen is long and 9 or 10 jointed; the body is usually covered with scales as in Lepidopters: the extremity of the abdomen bears setæ as in some Neuropters and Orthopters. The mouth is mandibulate. They are quick in movement, having a worm-like motion, and some of them leap by means of the caudal extremity.

The *Podurians* are rather short in body, the abdomen short, 4 to 6 jointed; the body sometimes scaly; the extremity, or the under surface near the extremity, furnished with a seta for leaping except in one genus *Anura;* the mouth mandibulate except in the Anuræ, in which it is suctorial.

The Lepismians have been often said to be related to both Lepidopters and Neuropters, and some authors regard them as apterous species of the latter group. Erichson referred them to the Orthopters.

The reasons for making the Thysanures a third grand division of Insects, and for not including in the same other apterous groups, are as follow:

1. The agility of movement of these species show that they are not degraded forms pertaining to the inferior limits of another higher type, but constitute an independent type, or, are typical in the grand division to which they belong.

2. While the Lepismians may be regarded as related to Lepidopters and Neuropters, such caudal setæ are found in no Lepidopter and the scales on no Neuropter. They stand in distant relation to both.

3. The forms among the Lepismians are related to those of Myriapods, as has been observed by different writers, and so also are their movements. Thus they occupy a position between Insects and an inferior order of Insecteans.

4. The third or degradational group of Insects, if such there be, should contain, according to analogy, elongated larve-like forms, such as make an elementalized exhibition of the Insect-type. As the longicaudate Birds, or Erpetoids, constitute the third or degradational division of Birds (aërial Vertebrates), so the longicaudate Thysanures may well represent the degradational division of Insects (aërial Articulates). The shorter Podurians are elliptic forms.

5. While Insects of the *first* grand division are *prosthenic*, and those of the *second* are *metasthenic*, those of the *third* are, on the scheme proposed, *urosthenic*, even those few which are not saltatorial using the caudal extremity in locomotion. It accords with the relations in many other departments of the animal kingdom that these three sthenic grades should mark off the three grand divisions.

6. With regard to the exclusion of other apterous Insects, we offer the following remarks. The apterous Pediculi, as Nitzsch long since observed, have no characteristics that would separate them from Hemipters, and the Nirmids none that would remove them from Orthopters. They are simply inferior wingless species of those types, as much as the Coccids are of Homopters; and they have nothing of the agility of the Lepismids. There are no points of structure indicating an affinity to any two or more of the higher subdivisions of Insects, or to the inferior Myriapods; they are not *urosthenic*, being in no way essentially different, as regards their legs, from the types to which they are referred.

Fleas are permaturative, like all Apipens, and in this and other ways show that they have no relations to the Lepismians. The reasons for regarding them as an independent type under the Apipens have been presented on page 18.

The Lepismians and Podurians appear therefore to be rightly made the *third* grand group of Insects. Like the Erpetoid birds, and degradational or intermediate types in other cases, the group may have been well-represented in species in past geological ages. At the present time we know of only the two above-mentioned families under this type, and both are supposed to have closer relations to the Pteroprosthenics than to the Pterometasthenics. If any group ever existed related as closely to the Pterometasthenics, as the above mentioned are to the Pteroprosthenics, and if, besides, there has existed a third *typical* group, the species are yet to be discovered, either fossil or living.

Parallelism between Pteroprosthenics and Pterometasthenics.

(1.) *Between the subdivisions of the Pterometasthenics and those of Apipens, or the higher Pteroprosthenics.*—The two *first* subdivisions, *Coleopters* and *Hymenopters*, are much alike in having compact well-made forms and comparatively small limits of variation, and freedom from imitation of other species while imitated by many—characteristics which belong to the highest typical subdivision of a group. They are approximately alike in having the mouth mandibulate, although unlike in that the latter (or highest species) are also suctorial; alike also in being with few exceptions terrestrial, and also in being permaturative.

Hemipters and Dipters, or the two *second* subdivisions, are alike in having the mouth suctorial, and feeble species for their size as compared with those of the first subdivisions.

The *typical Orthopters* and the *Aphanipters*, or the types under the two *third* subdivisions, consist alike of saltatorial and *podometasthenic* species.

(2.) *Between the three subdivisions of the Pterometasthenics and the three of the Pteroprosthenics.*—The more prominent of the relations between *Coleopters* and *Apipens* have just been mentioned. Those of *Hemipters* and *Amplipens* are still closer; Hemipters being so near to Homopters in structure, and especially in the composition of the rostrate mouth, that they have been placed together in the same tribe by most entomologists.

The *Orthopters* and *Neuropters*, or the *third* subdivisions of each, show a degree of approximation in the close resemblance in form between the Neuropterous Mantispids and the Orthopterous Mantids, indicating a tendency to run off into the same style of amplificate structure, and also in the Cricket-like form of the Neuropterous Borei; more profoundly in the resemblance in structure of mouth and the nature of the metamorphosis between the Neuropterous Perlæ and the Orthopterous Phasmids, as remarked upon by Westwood.

Thus the grand divisions of the Pterometasthenics constitute a parallel series to those of the Pteroprosthenics.

The further parallelisms, under both the Pteroprosthenics and Pterometasthenics, between the *third* of the grand divisions of each and the *first* and *second* have been explained on pages 20 to 22, and 24.

The affinities and analogies of species and groups appear hence to be fully exhibited in the system of classification presented, far more so than in any arrangement of osculant circles.

(3.) *Between the several groups as to the number of subdivisions, and the grades of types constituting them.*—The number of subdivisions in the groups, both the higher and lower, is *three*, as in most of the classes and orders that came under consideration in Article I.

Of these three subdivisions both among the Pteroprosthenics and Pterometasthenics—the first and second grand divisions of Insects—the *two* higher are *typical*, of different grades, and the *third* is *hypotypic*. The same is true of the three subdivisions of each the Apipens and Amplipens, or the first and second grand divisions of the Pteroprosthenics. This is exhibited in the following table, in which the grades are expressed by the same terms as in Article I.

	Pteroprosthenics.	Pterometasthenics.	Apipens.	Amplipens.
Betatypic,	Apipens.	Coleopters.	Hymenopters.	Lepidopters.
Gammatypic,	Amplipens.	Hemipters.	Dipters.	Homopters.
Hypotypic,	Attenuates.	Orthopters.	Aphanipters.	Trichopters.

In the *third* or *hypotypic* division of both the Pteroprosthenics and Pterometasthenics, on the contrary, the first and second of the three subdivisions appear to be *hypertypic* groups, while the *third* is *typical;* and the hypertypic groups are more or less closely representatives respectively of the first and second grand divisions, as follows:

	Attenuates, or Neuropters.	Orthopters.
A-Hypertypic,	Apipenniforms.	Coleopteroids, or Cursors.
B-Hypertypic,	Amplipenniforms.	Hemipteroids, or Ambulators.
Typical,	Perattenuates.	Saltators.

In the fact that these hypotypic divisions include *two hypertypic* subdivsions and *one*, the inferior, *typical*, there is a parallelism with the subdivisions of Fishes, (Art. I, p. 343,) and those of many other hypotypic groups of animals.

Methods of cephalization, or decephalization, at the basis of the successive grades of subdivisions.

A. In the subkingdom of Articulates, as shown by the writer (last volume, p. 7) and long held by Agassiz, the classes or highest subdivisions are *Insecteans*, *Crustaceans*, and *Worms*.

In passing from *Insecteans* to *Crustaceans*, the principal methods of decephalization illustrated are the *amplificative*, there being a great enlargement through apocentric or circumferential extension; the *dilutive*, or a change from perterrestrial to aquatic life and respiration (See Char. V, p. 12,); and, over and above these, a fundamental change of type not expressed in any of the special methods of decephalization laid down, (page 12).

In passing from *Crustaceans* to *Worms*, the methods illustrated are the *analytic*, in the resolution of the body mostly into its normal annuli; the *multiplicative*, in the indefinite number of segments; the *elliptic*, in the absence of antennæ, feet, &c.

B. The grand subdivisions of Insecteans are *Insects*, *Spiders*, and *Myriapods*.

In passing from *Insects* to *Spiders*, the methods of decephalization illustrated are the *retroferent*, case *a*, in the transfer of one pair of mouth organs to the locomotive series; and a shade of the *analytic*, in the loss of the independent definition of the head and thorax.

In passing from *Spiders* to *Myriapods*, the methods illustrated are the *analytic*, in the loss of independent definition of thorax and abdomen, and the reduction of the body to nearly equal rings all with nearly similar members; and the *multiplicative*.

C. The grand subdivisions of Insects are *Pteroprosthenics*, *Pterometasthenics*, and *Thysanures* or *Apters*.

In passing from the first to the second, the principal method illustrated is the *retroferent*, case *b*, as shown in the transfer backward of the flying function, and also in the locomotive function being transferred in a considerable degree from the wings to the feet.

In passing from the *second* to the *third*, the methods exemplified are the *analytic*, shown in the equal annuli and partial loss of distinction of thorax and abdomen; the *retroferent*, case *b*, in the transfer backward to the caudal extremity of a part of the locomotive function; *elliptic*, in the absence of wings; *prematurative*, in there being no metamorphosis.

D. The grand subdivisions of the Pteroprosthenics are the *Apipens*, *Amplipens*, and *Neuropters* or *Attenuates*.

In passing from the *first* to the *second*, the principal method illustrated is the *amplificate*, especially the broad-amplificate, as exhibited largely in the wings. In passing from the *first* and *second* to the *third*, the *amplificate*, especially the long-amplificate, accompanied by a general diminution and inferiority of life-system, the species being mostly rather small and slender.

The methods are in general the same for the subdivisions of the *Pterometasthenics*.

E. The grand subdivisions of the Apipens are the *Hymenopters*, *Dipters* and *Aphanipters*.

In passing from the *first* to the *second*, there is a *general lowering of grade of structure* (p. 12,) as exhibited in inferior integuments and strength, and partly defunctionated mouth.

In passing from the *second* to the *third*, the methods exemplified are the *elliptic*, in loss of wings; the *retroferent*, in the locomotive function being transferred largely to the hind-legs, these being the strongest and longest; the *amplificate*, in enlargement behind and in length of legs.

F. The grand divisions of the Amplipens are *Lepidopters*, *Homopters* and *Trichopters*.

In passing from the *first* to the *second*, the methods exemplified

are mainly the same as in passing from the first to the second under the Apipens. In passing to the *third*, there are the *semidilutive*, the larves being aquatic; and the *defunctionative*, the mouth in the adult failing mostly of the organs and function of feeding.

The same *potential* method, which distinguishes *Hymenopters* from *Dipters*, or the two highest subdivisions of Apipens, also distinguishes the two highest of Amplipens, or *Lepidopters* and *Homopters*, and the two highest of Pterometasthenics, or *Coleopters* and *Hemipters*.

It is not necessary to continue these illustrations further.

From the above review of the relations of the successive stages of groups, it is seen that the distinctions between them are throughout strictly *ordinal*, taking the word in its primary sense; that is, all, from the highest to the lowest, are distinctions *in rank*.

Two other points are to be observed in this connection.

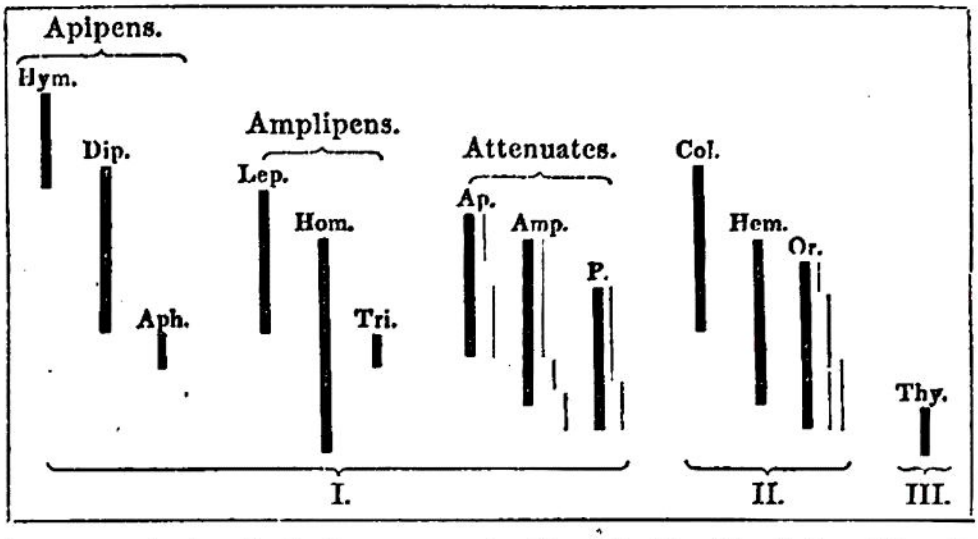
a. The lowest subdivisions of both the Pteroprosthenics and Pterometasthenics are long-amplificate; and in their subordinate subdivisions the same method is often illustrated.—Some Orthopters of the family of Phasmids have a length of a foot: there is here a diffusion of the systemic force through a radius *twelve times as great* as in a typical Hymenopter. Besides this, the force thus diffused is much less, for the tribe is among the lowest in the order of Insects. The *long-amplificate* method is frequently that of the inferior subdivision in groups of various grades.

b. The degradational species under a high type are often far inferior to the typical species of a very low type.—Thus species of Aphis and Coccus under the Homopters, the former leading almost a stationary life and reproducing by budding, the latter budding also and completely stationary as regards the female, are very inferior in the attributes of life to the active Lepismæ. As the author has illustrated in his paper on Crustaceans, a type of structure requires a certain amount of force to be worked to advantage; and if this force is diminished beyond the proper limit, the animal loses activity and becomes low and stupid in every function except often the vegetative of growth and reproduction. An active animal under this amount of force can be had only by a change of type to an inferior grade adapted to the force.

These two principles are of great importance in classification. The first affords an indication of inferiority not to be overlooked; the second accounts for the association in one group of very high and very low species.

The following diagram appears to the writer to represent approximately the relative grades of the ranges of species under the several subdivisions of Insects in the proposed classification. Along side of the vertical lines standing for the groups of Attenuates and Orthopters, there are other finer vertical lines for

their subdivisions (pp. 22, 24). The line for the Homopters is made to run lowest on account of the Aphids and Coccids,



which seem to be inferior even to the Pediculi of the Hemipters and Nirmids of the Orthopters.

Designations of the successive grades of groups.

The parallelism between the grander subdivisions of the Pterometasthenics (Coleopters, Hemipters and Orthopters) and those of the Apipens, (Hymenopters, Dipters and Aphanipters,) and Amplipens, (Lepidopters, Homopters and Trichopters,) teaches that these subdivisions are *coördinates*, or of one grade.

This is further indicated by other points of parallelism, namely, that the first subdivision of the Pterometasthenics and Apipens, the Hymenopters and Coleopters, have eminently the features each of a high type; and the last, the Aphanipters and *typical* Orthopters, are alike metapodosthenic or saltatorial species. So also under the Amplipens, the 2nd subdivision, or that of Homopters, is closely related to the second of Pterometasthenics, or that of Hemipters (page 27).

Hence, if the grander subdivisions of Apipens and of Amplipens are called tribes, those of the Pterometasthenics should also be so designated.

Under the *subkingdom* of Articulates, there are the *classes* of Insecteans, Crustaceans and Worms; and under Insecteans, the *orders* Insects, Spiders and Myriapods.

If then the term *tribe* be used for the familiar groups, Hymenopters, Dipters, &c., as just suggested, the question comes up as to the designations of the two intermediate grades of groups between *orders* and *tribes*.

The distinctions on which they are based are so obviously ordinal that they may be well called orders of subordinate grades; and I propose for the first of the two the designation *suborders*, and for the second *ordinules*, a diminutive of *orders*. The stages will then be as follows.

Orders: Insects, Spiders, and Myriapods.

Under *Insects*—

Suborders: 1 Pteroprosthenics, 2 Pterometasthenics, 3 Thysanures.

Ordinules (confined to the Pteroprosthenics): 1 Apipens, 2 Amplipens, 3 Attenuates or Neuropters.

	Apipens.	Amplipens.	Attenuates.	Pterometasthenics.
Tribes, 1.	Hymenopters.	Lepidopters.	Apipenniforms.	Coleopters.
Tribes, 2.	Dipters.	Homopters.	Amplipenniforms.	Hemipters.
Tribes, 3.	Aphanipters.	Trichopters.	Perattenuates.	Orthopters.

The subdivisions of the three tribes under the Attenuates or Neuropters, (p. 22,) and those of the tribes of Orthopters, (p. 24,) may be all designated *subtribes;* there is in the two higher of each a like reference to the *higher* tribes of Insects.

This subject will come up again for further discussion. But, for comparison, I allude here to one other department of animal life—that of Mammals.

The *orders* of the *class* of Mammals, as explained in former papers, are (1) Man, (2) Megasthenes, (3) Microsthenes, (4) Oötocoids; and in the distinctions between the highest of these orders, there is an example of the *retroferent method*, case *a*, as in the distinctions between the *highest* of the orders of Insecteans. Hence there is reason for concluding that the orders of Mammals and those so-called of Insecteans are actually all *orders*, or are groups of coördinate value. See further on this point, page 350, Art. I.

Under these orders of Mammals, (a class few in species), there are no *suborders* or *ordinules;* the next grade of groups is that of *tribes*, namely, as explained on page 341, of Art. I:—I. Under *Megasthenes*, (1) Quadrumanes, (2) Carnivores, (3) Herbivores, (4) Mutilates; II. Under *Microsthenes*, (1) Chiropters, (2) Insectivores, (3) Rodents, (4) Edentates. There appears to be no occasion for doubting that these subdivisions are coördinates with the *tribes* of Insects. As groups they stand out before the eye and mind of the zoologist with similar prominence and distinctiveness in their respective subkingdoms.

Geological History.—The memoir of A. S. Packard, Jr., which has afforded so many convenient illustrations of our subject, aims especially to show that Neuropters are remarkable among Insects for their many relations to the other tribes, or for the number of "synthetic" types which they embrace. The classification explained throws into their natural relations these affiliating groups, and shows that the many interlinkings are dependent on the position of this tribe as the lowest or hypotypic group of Pteroprosthenics, and its correspondence in grade with the Orthopters or the hypotypic group of Pterometasthenics.

But there is further reason for the many analogies, in that the Neuropters and Orthopters, while at the base of their respective

grand divisions, lead off apparently in geological time the Insects of the globe—the Neuropters the pteroprosthenic, and the Orthopters the pterometasthenic, Insects.

In view of this fact, we should naturally expect to find among the early representatives of these tribes foreshadowings of the higher tribes of Insects, that is, comprehensive (or synthetic) types embracing some of the characteristics of those higher tribes. Now two of the subdivisions of both Neuropters and Orthopters, in the classification proposed, consist mainly of such comprehensive types, and these were the forms which were apparently most characteristic of the Carboniferous Insect-fauna: namely, Termitideans or the Hymenopteroids and Planipennians or the Lepidopteroids, among Neuropters; and Cursors or the Coleopteroids and Ambulators, among Orthopters. With these there were also the typical Orthopters or Saltators, (Crickets being among Carboniferous species,) and possibly also Coleopters. Nothing is yet known of ancient Thysanures, although it is probable they were in existence at the same time.

We should expect also from the association of the Neuropters and Orthopters in the same Carboniferous fauna that there would be examples of intermediate types between these tribes, that is, those which, while related fundamentally to one of the two tribes, presents some characteristics of the other; for in this way the striking harmony in the flora or fauna of an age in geological history was often produced,—as, for example, in the land-vegetation of the Carboniferous era, which embraced common Acrogens (Ferns) and Gymnosperms; and besides these, the intermediate or comprehensive types of the Lepidodendra and Calamites of the former, and that of the Sigillariæ of the latter. And thus it was in fact. The Insect from the Carboniferous rocks of Illinois, figured and described in the following article, is one example of a comprehensive type of this kind. While Neuropterous in wings, closely approaching the *Semblids*, it has broad costate femurs, and even a large spinous joint to the anterior legs, peculiarities which seem to be almost inconsistent with the Neuropterous type, although in part characterizing the *Mantispids*, and which are in complete harmony with the Orthopterous type.[9]

We here see that the interlinkings between Orthopters and Neuropters began in the Paleozoic. It is probable that such comprehensive or intermediate forms were more numerous in the past than they now are.

[9] The Orthopterous features among Neuropters appear to be modifications of form under the types in this group which have been already mentioned, especially the Lepidopteroid, and not indications of a distinct type of *Orthopteroid* Neuropters. The fossil species referred to, and also the modern Mantispids, are true *Planipennians* in their wings and in their other characteristics of special importance. They properly constitute an Orthopteroid group in this subtribe.

On Fossil Insects from the Carboniferous formation in Illinois.

The remains of Insects, represented in the following figures, were discovered by Mr. John G. Bronson in the Carboniferous beds at Morris, Illinois. They occur in the flattened iron-stone concretions of the beds. Other concretions of the locality contain various coal plants, and also the remains of two or three species of *Amphipod* Crustaceans. The plants have been investigated by Mr. Lesquereux and descriptions of them, we understand, will appear in the Report on the Geology of the State by Mr. Worthen. Among them, according to Mr. Lesquereux, the following are common species: *Neuropteris hirsuta* Brgt., *N. rarinervis* Brgt., *Pecopteris Miltoni* Brgt., *P. unita* Brgt., *P. æqualis* Brgt., *Annularia longifolia* Brgt. The description of the Crustaceans we reserve for another time.

1.

Figure 1 is twice the natural size lineally. In general form and the neuration of the wings the Insect is closely like the *Semblids* among the Neuropters, and especially, as I am informed by Dr. LeConte, the *Chauliodes*. In view of this resemblance, and also the fact that the outer wings are so thin as not to obscure at all the outlines of the abdominal segments, and hardly the inferior wings, there is no reason to doubt that the species was *pteroprosthenic*, and that therefore it must have been a *Neuropter*, and not an Orthopter. Yet in the broad costate femurs of the second pair of legs, and the form of the prothorax, it approaches the Orthopters of the Phyllium family, and is very unlike any known Neuropters. The anterior legs are peculiar in having a large and broad femur armed above with very slender spines as long as the joint, three

of which, though mutilated, are seen in the specimen. But something of this kind is observed under Neuropters in the *Mantispids.* It is quite probable that these anterior legs were prehensile, as in *Mantispa:* and the fact that the tibia and tarsus are not in sight in the specimen favors this conclusion. Only the left leg in the specimen has the large joint tolerably perfect; in the right, however, it is sufficiently distinct to show that it had the same large size and was also spiculigerous. The coxal joints of this leg, are faintly indicated between this large joint and the anterior part of the somewhat prolonged prothorax.

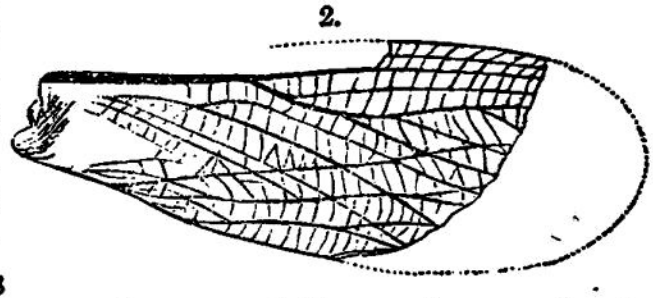
The number of abdominal segments is *ten*, or *one more than the typical number* in Insects—as is true also of many Neuropters, the Lepismæ, and some species of other tribes. The neuration of the wings and the form and relative sizes of the segments of the abdomen are well shown in the figure, and particular description is therefore unnecessary. There appears to have been a pair of short obtuse appendages at the extremity of the abdomen, much as in *Phyllium.* The head is mostly obliterated.

The length of the specimen, from the anterior margin of the large joint of the anterior legs to the posterior margin of the wings, is 1 inch 10 lines; and the breadth, from the medial line of the abdomen to the left margin of the left wing, 5 lines.

By request of the discoverer, I name the new genus here indicated, *Miamia*, after the Miami University, his "alma mater." In view of the important results of his explorations, the species may be designated the *Miamia Bronsoni.*

Figure 2 represents, natural size, a mutilated anterior wing of another Neuropter. The neuration approximates to that in the genus *Hemerobius.* The dotted line shows the probable length and outline of the wing—these organs in the Planipennians being 3 to 4 times as long as their breadth. The areolets are obliterated towards the base of the wing.

2.



There appears to be sufficient reason in the character of the neuration for the institution of a new genus, and I propose for it the name *Hemeristia* (from ἡμερα *day*, one of the roots of Hemerobius), designating the species *Hemeristia occidentalis.*

The feebleness of the life-system in most Neuropters is shown in the numerous nervures of the wings; and this is very marked in this ancient species. The great multiplication of these nervures and their irregularity appears to be owing to a want of directive force in the system, or to a low grade of cephalization or systemic control in the animal.

[From the Am. Journal of Science and Arts, Vol. XXXVII, March, 1864.]

I. THE CLASSIFICATION OF ANIMALS BASED ON THE PRINCIPLE OF CEPHALIZATION.—No. III. CLASSIFICATION OF HERBIVORES.

II. NOTE ON THE POSITION OF AMPHIBIANS AMONG THE CLASSES OF VERTEBRATES.

By JAMES D. DANA.

Art. I.—*The Classification of Animals based on the principle of Cephalization.*—No. III. *Classification of Herbivores.*[1]

The principle of cephalization and its applications rest on the following simple facts:

(1.) An animal is embodied or concentred force, which force manifests polarity in the results of its action in development, that is, in the oppositeness of the anterior and posterior extremities of the structures evolved and also in the dorso-ventral relations of these structures.

(2.) The *primary* potential centre is in the head, or more precisely, in the cephalic nervous mass—an animal being fundamentally a cephalized organism. But, besides this, there may be one or more *secondary* centres.

(3.) Species differ (*a*) in the amount of force concentred; (*b*) in the degree of control of the systemic force over vegetative growth and development; (*c*) in the distribution of the force along the principal (or fore-and-aft) axis—that is, in its being concentrated mainly anteriorly, or diffused, to a greater or less degree, from the cephalic extremity posteriorly toward the caudal extremity or pole.

(4.) The differences just mentioned are expressed in the structure of the organism; and all such expressions are necessarily expressions of grade.

(5.) Each of these kinds of differences must have expression, or, be apparent, (*a*) through the various circumstances attending

[1] For Article I, see the last volume of this Journal (vol. xxxvi), pp. 315, 440; and for Article II, this volume, p. 10.

development or growth, and (*b*) through all the steps in the progress of growth, as well as (*c*) in the resulting structures.

The above general facts are at the foundation of all the methods of cephalization, or decephalization, pointed out in Article I. They receive further illustration in the pages beyond, and special explanations on pages 175 to 182.

This subject of cephalization throws new light, as has been shown, on the limits and gradal distinctions of groups. The characteristics which it affords, like all others appealed to in classification, cannot overrule affinities based on obvious resemblances in type of structure. Their object or use, on the contrary, is rather to exhibit the affiliations and distinctions of types by presenting new views of their relations and making manifest the true basis of all affinities. Between different types of structure there is generally a difference of grade, which is evinced in characters that indicate different degrees of cephalization.

It follows from the nature of the principle that both high and low cephalization, although *opposites*, should often lead to *similar* results; as, for example, to abbreviations anteriorly and posteriorly in animals generally—to memberless abdomens in Crustaceans—to small wings in Insects, etc. (Art. I, pp. 337, 440). This evolving of approximately like results from the opposite extremes of cephalization is one source of the difficulties in the subject of classification. But the law cannot, on account of the trouble it may give, be condemned; for, as I have before remarked, it is in accordance with universal truth that smallness, or circumferential contraction, should proceed both from concentration, and from lack of quantity, although these are opposite conditions. The difficulties in the way of a right use of the principle of cephalization are, therefore, in nature, and must be met by the only legitimate means—thorough study.

Many errors in the attempts to present to view the system of nature have arisen from confounding cases that, as above explained, are widely diverse. The writer would not claim to be always right in his own interpretations; for he is well aware that far profounder knowledge is requisite for unfailing accuracy. But he believes that the principle appealed to is right and fundamental; and if he ventures to present new classifications of departments in zoology in which adepts in these departments have made trials with different results, it is only to offer such illustrations of the principle in view as will serve to exhibit the methods of its application and its various bearings.

In the first article on this subject, after explanations of the general subject of cephalization, the higher subdivisions of the animal kingdom were considered. In the second, one of the *Orders* was reviewed and an arrangement given of its subdivisions, down to the grade of Tribes. In the present, the classification of a *Tribe* is followed out, down to the grade of Families.

Classification of Herbivores.

Under the order of Megasthenes,[2] the tribe of Quadrumanes, as stated on p. 334, Art. I, is properly *hypertypic*, that of Carnivores *superior typical*, that of Herbivores *inferior typical*, and that of Mutilates (or Cetaceans) *hypotypic*.

1. *Distinctions between Herbivores and the tribes next superior and inferior.*

A. Herbivores show their inferiority to Carnivores, or the superior typical group of megasthenic Mammals, on the basis of the principle of cephalization, in the following ways:

(1.) In the fore-limbs being defunctionated of the power of prehension and reduced to simple locomotive organs.

(2.) In the fore-limbs being not as much superior to the hind-limbs in strength as in the Carnivores, and even inferior to the hind-limbs in some species,—Herbivores, being less strongly *prosthenic* than Carnivores, and the species of the larger and most characteristic group being *metasthenic*.

(3.) In the structure being strongly amplificate.—Taking the Lion as the standard of size for the highest grade of life among typical Megasthenes, the Elephant—certainly inferior in type, and, therefore, also in degree or quality of systemic force—exhibits inferiority likewise in its great bulk; it is a marked example of a *gross-amplificate* structure. Hogs and the related species are no less gross-amplificate, but on a feebler life-system. Again, the Horse and also all Ruminants are *long-amplificate*, as appears strikingly in their lengthened limbs, especially the extremities of the limbs, and, also, in the neck and body.

(4.) In the head being prolonged or amplificate.—Even the Elephant is here no exception; for the great tusks and trunk correspond to an elongation of the head extremity, their development being at the expense of the jaws and of part of the teeth. In the Horse, the facial part of the skull is four times as long as the cranial portion. (See p. 165.)

[2] In order that the position of Herbivores, as recognized by the writer, may be clearly understood by the reader, I repeat here the arrangement of the higher divisions of Mammals proposed in the number of this Journal for January, 1863, (vol. xxxv, p. 65), presenting the tribes of Megasthenes and Microsthenes, as before, in parallel columns in order to exhibit their parallel relations.

Order I. Man.

Order II. Megasthenes.	Order III. Microsthenes.
1. Quadrumanes.	1. Chiropters or Bats.
2. Carnivores.	2. Insectivores.
3. Herbivores.	3. Rodents.
4. Mutilates.	4. Edentates.

Order IV. Oörocoids.

Marsupials and Monotremes.

(7.) In the extremely wide variations as to size and shape under the type, and the occurrence of bizarre features.—As, for example, (1) in the existence of horns on the forehead or nose; (2) in the nose being prolonged into a proboscis; (3) in the teeth being sometimes elongated into tusks which have the size and function of horns, and might be called *jaw-horns;* (4) in the limbs and neck having sometimes extravagant length; (5) in abnormal growths on the body, as in the hump of the Camel and the Brahmin Ox, the dewlaps of Oxen, etc.

(8.) In the forehead, in very many species, being perverted to serve for defense or attack; and the nose sometimes for prehension, digging, etc., as well as defense.

(9.) In the typical species being elliptic as regards one or more of the four types of teeth in one jaw or both, this deficiency in the dental series being a characteristic of the type; also in a void interval in the series of teeth between the molars and canines in the same typical species.

(10.) In being prematurative in development, the young animal having the power of sight and locomotion almost as soon as born.

The abnormal outgrowths from the body or skeleton of Herbivores—as of horns on the forehead or nose, of a proboscis by an elongation of the nose, of tusks, horn-like in function, by an elongation of teeth, of humps of fat as in the Camel—serve to show, and even, if possible, more strikingly than the tendency to amplificate structures, that the vegetative force in Herbivores is far less under systemic control than in Carnivores. The Carnivores may be styled a *tight* type, the Herbivores remarkably a *loose* one. Stepping over the line from Carnivores to Herbivores is passing from a group of marked regularity to one full of abnormities.

B.—The superiority of the urosthenic aquatic Herbivores (Sirenians) to the Mutilates (Cetaceans) is exhibited in their—

(1.) Having the nostrils never defunctionated, nor perverted to blowholes, these organs being essentially like those of terrestrial Mammals.

(2.) Never being multiplicate as to the number of phalanges, or joints, of the digits.

(3.) Never being multiplicate as to the teeth.

(4.) Never being so elementalized as to the teeth that the distinction into the different types (molars, etc.) is lost (Mutilates, like Reptiles, having the teeth all of a kind).

(5.) Having the *primary* potential centre (p. 157) never abnormally remote from the anterior extremity.

Some species of Cetaceans (Balænæ and Physeters) have, like the Limulus among Crustaceans, one-third to one-half of the length of the body anterior to the base of the jaws, so that

the primary centre (or that of the brain) is very remote from the anterior extremity—thus approximating to the position it has in the Radiates, and showing a low grade of decephalization. See on this point, Art. I, p. 328, and beyond, p. 179.

Mutilates consequently differ from aquatic Herbivores fundamentally in (*a*) being *multiplicate* structures, as manifested in their limbs and teeth, as well as in the less important fact of great length of body behind; and also (*b*) in being more *elementalized* structures, as shown in the reptile-like teeth. The type is eminently, therefore, a multiplicate and elementalized type, and thus stands apart from that of the Sirenians.[3]

2. *Prosthenic, metasthenic and urosthenic distinctions among Herbivores.*—The distinctions, *prosthenic, metasthenic* and *urosthenic* appear to be an important basis of subdivisions under the Herbivorous type.

The *urosthenic* species (or those using the caudal extremity for locomotion) are the *Sirenians*, as the Dugong and Manatus.

The distinction of *prosthenic* and *metasthenic* is manifested among the other Herbivores in two ways: (1) a higher or *primary*, in the general structure; and (2) an inferior or *secondary*, in the extremities of the limbs.

(1.) *In the general structure.*—Under this method, the *prosthenic* species are those in which the fore-limbs are the stronger pair, and the *metasthenic*, those in which the hind-limbs are the stronger. The *former* include the Proboscideans, Rhinoceroses, Tapirs, Hogs and Hippopotamids. The Hog is particularly strong in the neck and fore-quarters. It is well known that a fatted hog often loses the use of its hind-limbs from overgrowth, and not of the fore-limbs, although the fore-limbs carry not only their share of a body nearly equally divided between the limbs, but also the heavily weighted head.

The *metasthenic* species are the Solipeds and the Ruminants, in which the hind-limbs are well known to be the strong pair. The Horse and Camelopard use their hind-limbs for self-defense, and so do also, to some extent, many of the Ruminants. Among the large Mammals, strength in the posterior limbs is an essential requisite for a draught-animal; and not less so for a mountain-climber, especially when the fore-limbs are not prehensile; and, consequently, nearly all the larger mountain-climbing animals, frequenting precipitous heights, are species of Ruminants.[4]

[3] This definition excludes not only the Sirenians but also the Zeuglodonts, which have been shown to be Carnivores, with normal teeth and nostrils, although very elongate in body and *urosthenic*.

[4] For a draught-animal something more is needed than mere strength of hind-limbs, and consequently all of these metasthenic species are not good for this kind of service. There may be too great length of limb,—too little real strength for the long and steady pull which it requires, and which is very different from the mere

Such species, strong in the hind-limbs, are well named *Sthenomeres* (from the Greek σθενος *strong* and μηρος *thigh*).

(2.) *In the extremities of the limbs.*—The sthenic distinction referred to under this head is the inferior of the two because it appears only in the *extremities* of those organs which in their general relations exhibit the former. The manifestation of it is confined to the hand and foot.

As the inner side of the hand or foot is the more central side in the system and the outer the more circumferential—a fact which any one will become aware of on looking at his open hand as it lies on a table—the higher species should have the principal strength in the inner fingers rather than the outer. The transfer of force from the innermost to the outer, with descending grade of species, is well exemplified among Herbivores and the higher Mammals.

In Man the *inner* toe is the strongest, and the order of strength is that of the toes, or 1, 2, 3, 4, 5. It is the same also in the hand. In the Gorilla it is the same for the foot, and for the hand there is only this difference that 1 and 2 are about equal. In the inferior Quadrumanes and the superior Carnivores the *third* is the strongest as well as largest digit, and in many Carnivores the first in the hinder pair is obsolescent. In the inferior Carnivores, as the Plantigrades, the *third* and *fourth* digits are often about equal, and the *fifth* as strong as the *second:* thus in *Ursus Americanus* (as figured in Blainville's *Osteologie*) 4=3, and 5=2; in *U. arctos* (*ferox*) 2, 3, 4, 5 are very nearly equal; in *U. labiatus* 4 and 5 are *the longest*, exceeding 3; in species of *Nasua* 4=3 and 5=2; in the *Cercoleptes* or kinkajou, one of the lowest of Carnivores, 4 *is a little longer than* 3 and 5 *than* 2; in *Gulo luscus* 4=3; in the Mustelids, *Lutra vulgaris* and *Mustela Foina*, 4=3, or 3 is scarcely the longer; in the Viverrids 3 is generally slightly longer than 4, but in the inferior aberrant species *Eupleres Goudotii* and *Bassaris astula* 4=3 and 5=2. These species are therefore essentially *paridigitate*, except that the first digit is present. Thus there is an outward diffusion of force in descending from Man to the lower Carnivores.

Under Herbivores, the higher species have the *third* toe the longest—or, they are *imparidigitate*, as these kinds are usually styled. Thus it is with the Proboscideans, Rhinoceroses and Tapirs, and it is so *whether the number of toes be three or four*, that is whether *even or odd in number*.

In the inferior Herbivores the force is still more circumferentially diffused; for the *fourth* digit is equal to, and sometimes

movement of the legs demanded of a beast of burden,—too little superiority in the posterior to the anterior limbs, or an ill-adjustment of muscles and lungs, etc., for the purpose. The Camel, one of the hypotypic or degradational Ruminants, is a case here included.

even stronger than, the *third;* and, at the same time, the *fifth* is as strong as, or stronger than, the *second*, if both are not altogether wanting; while the *first* is obsolete. The examples include all the so-called *paradigitate* species, as the Hog, Stag, Ox, etc., in which the toes are equal (or approximately so) in pairs, the larger pair consisting of the *third* and *fourth* toes, and the other, of the *second* and *fifth*. In the common Ox, the *fourth* toe appears to exceed slightly the *third* in size, and so also, the rudimentary *fifth* the *second*. In the Hog, also, the *fourth* toe is sometimes a little the largest.

This sthenic distinction partially fails among degradational forms, such as the Seals, Sirenians and Cetaceans, in which the structure is so far degenerated that this delicate mark of grade has not its full normal exhibition.

3. *Distinction depending on the existence, or not, of a power-organ to aid in feeding, additional to those of the jaws.*—Carnivores have, as one of their characteristics, organs apart from the teeth to aid in seizing or gathering their food. Among Herbivores, the Elephant has an organ of prehension of great power and perfection in the trunk or elongated nose. The Tapirs and Hogs have also an elongated nose, which, although incapable of prehension, except to a slight degree in the former, is a power-organ essential to the animal for the collection of its food. The Rhinoceros has a nose-horn serving in the same way. The nose is thus in all these groups, from the Elephant to the lowest of the Suids or Hog-group, not merely a nose, but an organ of special power and use for obtaining the food of the animal; and the species might be described in a word as *Sthenorhines* (from the Greek *σθενος strong* and *ῥις nose*).

The Horses and the Ruminants feed themselves by grazing, using their lips, teeth and tongue for the purpose, but having no aid from the nose.

4. *Distinction of gross-amplificate and long-amplificate.*—*Gross-amplification* consists in a general enlargement of the structure beyond the type-size for a given amount of systemic force, and does not necessarily imply a change in the relative sizes of the parts, or in their proportions. It may be manifested both in the skeleton and in its fleshy covering; and when in the latter it is often apparent in the production of an abnormal amount of fat over the body. This fatty overgrowth is the lowest grade of gross-amplification.

Long-amplification is exhibited in an increased proportional length of the body and its limbs or members, involving in Vertebrates an elongation of the bony structure.

The *gross-amplificate* terrestrial Herbivores are those of the Elephant, Tapir and Hog groups, in which there is little difference in the proportions of the body from those of the Carnivores.

The *humerus*, for example, bears approximately the same proportion in length to the *radius* and to the whole limb, and also to the neck, in the Elephant, Rhinoceros, Hog and Hippopotamus as it does in the Carnivore. The length of head is increased in each of these groups by an amplificate snout—as remarked on the preceding page; but this is in part a *fleshy* elongation; and it is sometimes increased also by means of a horn, but only an *epidermic* horn. The bony-structure of the head has an elongation beyond that characteristic of the lower Carnivores; but it is independent of any in the limbs.

The Bovine species are examples of gross-amplification on a *long-amplificate* structure.

The *long-amplificate* species include all the Ruminants, together with the Solipeds or species of the Horse-family among the Non-ruminants.

This long-amplification is exhibited prominently in the *limbs*, *neck* and *head*.

(1.) *In the limbs.*—As in other cases, it is manifested most strikingly toward the circumferential limits of the system. The humerus shows no elongation, and is often even shorter, as compared with the size of the body, in these amplificate species than in more typical kinds. Below the humerus, amplification is apparent in the fact that the radius exceeds in length the humerus; it is still more manifest in the great elongation of the bones below, especially the metacarpals and phalanges, the former alone being sometimes as long as the radius. The same general facts are true of the hind-limb. Owing to this extension of the extremities, the joint which seems like the knee in the leg of a Horse, Deer, Ox, etc. is really the commencement of the foot. In the fore-limb of a Horse, the humerus is hardly *one-fourth* the whole length of the limb; the radius is nearly *a fourth* longer than the humerus; and the cannon-bone is *two-thirds* as long as the radius. In the Camel the proportions are not very different; the radius is relatively a little longer, and the cannon-bone as much shorter. In the Camelopard the humerus is but a little more than *one-fifth* of the whole limb (measured, as in the Horse, from the commencement of the humerus to the extremity of the digits); the radius is *one-half* longer than the humerus; and the cannon-bone, or metacarpal, is *as long as* the radius. The facts strongly contrast with those among the Elephant, Tapir and Hog groups, the humerus in these species being between *one-third* and *four-ninths* of the length of the whole limb, and longer than the radius.

It would seem, therefore, that *the length of the humerus in the long-amplificate species may be taken as an approximate indication of the true type-size, or as a standard from which to measure the degree of amplification of the structure.* Still, I see no positive

proof that the humerus is not here shortened in compensation for the lengthening below.

(2.) *In the neck.*—No one will question the fact of a long-amplification of the neck and head in these species. It is however difficult to find a proper standard of length for definite comparisons. There is some special interest in the relations to the length of the humerus, and I therefore mention these relations, as has been done in the comparisons between the parts of the limbs.

In the species of Felis, the neck is not longer than the humerus; in the gross-amplificate Herbivores, as the Rhinoceros, and Hippopotamus, the same is true; but in the long-amplificate species, a very different relation exists. In the Horse the neck is *twice* the length of the humerus; in the Camel nearly *three times;* in the Camelopard over *three times.*

(3.) *In the head.*—The outer or more circumferential portion of the jaws, corresponding to the incisors and canines, pushes out, under this amplification, far away from the more basal or molar portion, making the void space between quite wide, much wider than in the Rhinoceros and Tapir. Referring to the humerus as a standard of length, as above, the cranium in the genus Felis, measured from the extremity of the jaws to the occiput, is from *four-fifths* to *once* this unit; in the Rhinoceros, *one and one-fourth*, to *one and one-third;* in the Horse, nearly *twice;* in the Camel, *one and one-third;* in the Camelopard, *one and a half.* The ratio for the Camelopard and Camel does not exhibit the true condition, because both species are cephalically vastly inferior animals to the horse and therefore have unusually small heads for the size of the animal. The Camelopard shows the long-amplification of its head in the narrow proportion of the skull, and the long void space in the jaws. This aberrant Ruminant is built, not only in its long legs and neck but also in its little elongate head, on the type of a Grallatorial or Wading bird.

This amplification or circumferential extension of the head appears in many species to be concurrent with that in the limbs, as if the two were of like dynamical origin, or had a dependent genetic relation in the structure.

Long-amplification in the head is still further exhibited in the typical Ruminants through an outgrowth of horns on the forehead. This is a frontal elongation, bony in its nature (or having a bony core at least), and peculiar to these *long-amplificate* species. In other words, those species in which the bones of the limbs grow long have generally long growths of horn from the forehead.

5. *Subdivisions in the classification of Herbivores.*—The distinctions which have been mentioned on the preceding pages point to the same general arrangement of the terrestrial Herbivores.

Two grand divisions are indicated.

I. The *Elephant*, *Tapir* and *Hog* groups are alike in being—

(1.) Prosthenic in general structure.

(2.) Gross-amplificate; rarely long-amplificate in the limbs.

(3.) Not amplificate in the forehead through an outgrowth of bony horns—the only horns being nasal, and these epidermic.

(4.) Amplificate in the snout, there being, in addition to the anterior elongation of the cranium, a fleshy elongation, or sometimes an epidermic horn.

(5.) STHENORHINES, the elongate snout being a power-organ for aid in feeding, etc.

II. The *Solipeds* and *Ruminants*, on the contrary, are—

(1.) Metasthenic in general structure, and, therefore, STHENOMERES.

(2.) Long-amplificate in the limbs, neck and head, and sometimes, *in addition*, gross-amplificate.

(3.) Long-amplificate in the forehead through an outgrowth of horns, except in the superior group of Solipeds and the inferior or hypotypic species.

(4.) Not amplificate in the fleshy part of the snout.

(5.) Not Sthenorhines—having no use for the nose but the legitimate one.

The two groups are then—

I. The Prosthenics, or STHENORHINES, including the Elephant, Tapir and Hog groups.

II. The Metasthenics, or STHENOMERES, including the Solipeds and Ruminants.

The species of the Hog-group and Tapir-group are closely related, in general form; in their short limbs; in the long and powerful and, thereby, *working* snout; in their teeth approximating to those of the Carnivores; and in the omnivorous character or tendency of some species. And the relation of the Tapirs to the Elephant-group is no less striking. These affiliations have been generally admitted by zoologists. The species of the Tapir and Hog groups, especially the latter, are the most Carnivore-like of Herbivores.

So, among the Sthenomeres, the living Ruminants have by all been associated in classification. The Solipeds alone have been arranged in most systems with the Pachyderms. But these are metasthenic like the Ruminants, being the strongest of Sthenomeres and the most valuable of draught-animals; they are grazing animals, like the Ruminants, and have no rooting nose; they have the same great length to the void interval on the jaw between the molar and the other teeth; and they have similar long-amplificate limbs. While, then, the Horse has undeniable

relations to the Pachyderms, it has close affinities also to the Ruminants. It is a *Sthenomere* and not a Sthenorhine; but it stands in the group of Sthenomeres, between the Ruminants and the Sthenorhines,[5] representing a Pachydermatoid division in the group.

The prosthenic species, it appears, are the *gross-amplificate*, and the metasthenic are the *long-amplificate*. But this distinction in amplification is not of that fundamental nature which would lead to its being an exclusive feature of either type; and yet the exceptions to its being so are remarkably few. In the *gross-amplificate* group, or that of the *Sthenorhines*, the *Macrauchenia*, if a Tapiridean (see p. 172), is one exception—the species having, according to Owen, a long neck, nearly as in the Llamas. The extinct *Paleotheres* are other exceptions; for in these Eocene associates of the Anoplotheres the metacarpals and metatarsals have about the elongation of those of the *Anoplotheres*. All the long-amplificate Sthenorhines are *extinct species* (p. 183).

The distinction of prosthenic and metasthenic observed in the *extremities* of the limbs, or the digits, which has given rise to the subdivision into *Imparidigitates* and *Paridigitates*, affords an indication of grade *under* the above two grand divisions—the paridigitate species being the inferior. Thus the Hog-group (paridigitate) stands below the Tapir-group (imparidigitate), and is, hence, at the foot of the *Sthenorhines;* and the Horse-group (imparidigitate) is at the head of the *Sthenomeres*. As this distinction is inferior in sthenic value to that of prosthenic and metasthenic manifested in the general structure (pp. 161, 162), it cannot properly be made the basis of the *principal* grand divisions of Herbivores, as proposed by Owen, unless all such sthenic characters are overruled by fundamental resemblances in type, which is here not the case; the type-resemblances bear the other way, and not to a separation of the Hogs and Tapirs, nor to a union in one group of the Hogs and Ruminants.

The existence in Paridigitates of two horns, one either side of the front, is mentioned by Owen as an example of *pairs* in these species, additional to that in the toes; and the occurrence in the Imparidigitates of a horn (or horns) only on the medial line of the front as an additional case in these Herbivores of an *odd* organ. This *odd* horn occurs only in the Rhinoceroses among the Imparidigitates, and on a *medial* organ, the nose; and with so small a range of facts to sustain the deduction, we may reasonably doubt the alleged connection between the odd or

[5] It may also be here repeated that the Horse is related to the Ruminants in not having a *decidua* developed,—a *decidua*, as stated by Huxley, characterizing the higher Megasthenes, from Man through the Quadrumanes and Carnivores to the higher Herbivores (the Elephant and Hyrax, at least); but not the species of the Hog-group, the lowest of Sthenorhines, nor any of the Sthenomeres. (See Art. II, p. 13).

even in horns and the odd or even in the toes. The true distinction with regard to the horns appears to be that already mentioned:—that the Sthenorhines have only the *nose*—not the forehead—elongated or amplificated through a growth of horns, and this is an epidermic amplification, while among the Sthenomeres, an inferior group, the bony structure of the *forehead* is long-amplificate.

If it be sustained that the Camelopard has a central horn on the front of the head, as has been claimed and recently reaffirmed, a case of an odd or medial horn occurs among the *Paridigitates;* but it is a forehead-horn.

We should therefore make the statement thus:

The Sthenorhines, *gross*-amplificate species, may have one or two *nasal epidermic* horns, or *horns proceeding from the exoskeleton.*

The Sthenomeres, *long*-amplificate species, may have two or more *frontal bony* horns, or *horns proceeding from the endoskeleton.* In addition, the exoskeleton, under this inferior type, sometimes contributes large epidermic additions in the shape of sheaths to the horns, as well as hoofs to the feet.

III. The *third* group of Herbivores includes only the *Sirenians*—aquatic species that fail of hind-limbs, like Whales, but bear various marks of superiority to the Mutilates, as already briefly indicated.

The grand divisions of the tribe of Herbivores, which have been pointed out and elucidated in the preceding pages, are indicated in the following Synopsis, together with the subdivisions to which we appear to be led by the further application of the principle of cephalization. In connection, one or two of the more prominent distinctions of the higher groups are mentioned.

Synopsis of the proposed classification of Herbivores.

I. Sthenorhines.

Prosthenic. Snout serving as a power-organ, usually elongated. Gross-amplificate, rarely long-amplificate in extinct species. Horns, when any, proceeding from the exoskeleton alone, nasal.

1. PROBOSCIDEANS.—Snout an organ of digital as well as brachial prehension. Imparidigitate.

(1.) Elephantids.
(2.) Dinotherids. (?)

2. TAPIRIDEANS.—Snout imperfectly, or not at all, prehensile, there never being prehension at the extremity (or digital prehension). Imparidigitate.

(1.) Rhinocerotids.—Having a nasal horn.

(2.) Tapiroids.—Without a nasal horn. Snout elongate, often imperfectly prehensile.

a. Tapirids.
b. Paleotherids.

(3.) Hyracids.—Without a nasal horn. Snout not elongated.

3. SUIDEANS.—Snout elongate, but not at all prehensile. Paridigitate.

(1.) Suids.
(2.) Hippopotamids.

II. Sthenomeres.

Metasthenic. Long-amplificate, even when gross-amplificate. Snout not a power-organ. Horns, when any, proceeding from the endoskeleton, frontal.

1. SOLIPEDS.—Without horns. Imparidigitate.

(1.) Equids.
(2.) Macrauchenids. (?)

2. RUMINANTS.—Having horns in the typical group, except often in females. Paridigitate.

(1.) Cornigers.—Having horns. Frontiferient.

a. Cervids.
b. Antilopids.
c. Camelopardalids.

(2.) Nudifronts.—Without horns. Not frontiferient, feeble in self-defense.

a. Camelids.
b. Moschids.
c. Anoplotherids.

3. ————— ?

III. Sirenians.

Urosthenic, natatorial. Having a large caudal fin for swimming. Posterior limbs wanting.

Manatus, Halicore or Dugong, Rytina, etc.

In the following enumeration of the distinctions of the several subdivisions, I confine myself almost entirely to those characteristics which are obviously based on the principle of cephalization, omitting the many anatomical details to be found in zoological treatises.

A. *Subdivisions of the Sthenorhines.*

(1.) The *Proboscideans* are distinguished by the high characteristic of having in the proboscis a prehensile organ of great

power and perfection—one that combines the qualities both of a prehensile hand and a grasping arm, and which, therefore, is more serviceable for prehension than the fore-limb of a Carnivore. Although this is a perverted use of a nose, it is not supposed to be attended with any degeneration of the normal sense below that of other Herbivores. The elliptic condition of the jaws in the species is connected, as already explained (Art. I, p. 400), with the enormous development of the tusks. The forelimb is proportionally as short as in the Lion, and the hand-portion even shorter, its length being only *one-half* that of the humerus.

The Dinothere appears to show in its skull that it was a true Proboscidean, that is, an animal with an Elephant-like proboscis. If so, it was, in all probability, a terrestrial animal, like an Elephant, or not more aquatic than a Hippopotamus. The fact that prehension is a characteristic of Carnivores and the higher Mammals, and, among terrestrial Herbivores, only of the superior species, indicates that it is a mark of high grade, and, therefore, one that is not likely to be associated in such perfection as that of the Elephant with the structure of an aquatic natatorial Herbivore.

(2.) The *Tapirideans* are related to the Proboscideans in the snout, and to the Suideans in this and many other characteristics. Unlike the latter, they are imparidigitate, the third finger being the longest. The cranium is considerably elongated, being from one-half to two-thirds longer than the humerus, and thus diverges widely from the same in the Carnivores.

The family of the Rhinocerotids is distinguished by the greatly thickened nasal bones and the nasal horn, and by the snout not being at all prehensile. The joints of the fore-limb in the *Rhinoceros Javanus* have very nearly the same proportional length as in the higher Carnivores; but the cranium as compared with the length of the humerus is one-third longer.

The Tapiroids have the snout prolonged, and often, if not always, somewhat prehensile, the prehension being brachial in kind and not digital; and the fore-limbs have the outer or *fifth* toe well developed, while the inner or *first* is wanting, thus showing inferiority (according to the principle stated on page 162) both to the Rhinoceros (3-toed) and Elephant (5-toed), in each of which the toes are nearly balanced either side of the *third*. In one division of the Rhinoceros group, including the extinct species made into the genus Acerotherium by Kaup, the toes of the fore-limbs are four in number, as in the Tapir, and besides this the horn is absent; and if, as suggested by Blainville, the so-called Acerotheres are only females, there is no question that this extra outside toe without a first is, among the imparidigitate Herbivores, a mark of inferiority, as argued on page 162. The same conclusion might be drawn, though less safely, from the fact that these

Acerotheres (whether females or not) are among the earliest geological representatives of the Rhinoceros group.

The Hyracids are degradational forms, having the snout not prolonged and not horned, yet having it terminate in a flat naked space with the nostrils on either side, also having the tail reduced to a mere tubercle, and having the small size, as well as some of the habits, of a Rodent of the Hare family. It is good at digging. This abbreviation before and behind in the Hyrax may be an example under the *elliptic* method of decephalization, evincing feebleness in a life-system which is of extreme smallness for the Herbivore-type. The animals of the little Syrian species were long since described as "a feeble folk." (Prov. 30 : 26).

3. The *Suideans* are generally acknowledged to be far more closely related to the Tapiroids than to the other Paridigitates (or Ruminants). Yet they bear many evidences of inferiority to that group. Besides being paridigitate, they have the jaws more amplificate than in the Tapirs, as appears in the fact that the extremity, bearing the incisors and canines, is more remote from the molar portions, and still more strikingly, in many species, in the canines being elongated into tusks, and the incisors also being sometimes large and spaced out. This amplificate condition reaches its extreme in the Hippopotamus. There is also a great tendency to gross-amplification through the development of fat—the lowest kind of amplification. Another hypotypic feature is the graceless and bizarre forms of many species. Still another is the abnormal reverted growth of the upper canines, which, in one species, the Babyroussa, pass out through the facial part of the skull, becoming long curving nasal horns. Still another evidence of inferiority is the very small size of the brain compared with that of the head.

The Hippopotamids are extreme examples among Pachyderms of gross-amplificate structures, and are evidently hypotypic species in this hypotypic group. They manifest this in their size, grossness of head and body, aspect of deformity in every part, soldered radius and ulna, and in their being the most aquatic of the group. Their unusually short legs and spread toes, also, are evidently marks of inferiority; for in a system so low in structure throughout, these peculiarities cannot be a consequence of high cephalization. It is a step toward the Mutilates.

B. *Subdivisions of the Sthenomeres.*

1. The *Solipeds* rank the Ruminants, not only because imparidigitate, but also, because of their higher grade of digestive system, and the bare forehead; for in these species absence of horns appears to be a mark of elevation. That they are the highest of Sthenomeres is also evident from the elegance of form,

grace of motion, fleetness and strength which characterize one or more species of the group, and which combination of qualities is presented in equal perfection in no other Herbivore. The type, therefore, may rightly claim the first place in its grand division, and not a subordinate one, either between Tapirs and Rhinoceroses or Hogs, or below Goats and Oxen.

The Macrauchenia, according to Owen, was much like a Ruminant in its *legs*, although *imparidigitate*, and near the Camel in its *neck*, while it had *probably* (the head is yet unknown) no Tapir-like proboscis. The radius and ulna were united, and so also the tibia and fibula. Its place in the system may be, therefore, along side of the Equids, or the imparidigitate Sthenomeres. If, however, the animal had a proboscis, the species would fall among the Tapirideans and represent an inferior long-amplificate subdivision. The term *Solipeds* or *Solidungulates*, might well be replaced by *Equideans*, as the existence of a *solitary* hoofed toe is not an essential characteristic of the group.

2. The *Ruminants* are naturally divided into two groups.—

(1.) The *Cornigers* or typical species.—These are (*a*) furnished with horns (whence the name applied to them) at least in the males. They are (*b*) *frontiferient*, that is, strike with the forehead in attack. (*c.*) The foot has great compactness, the two principal toes (normally the *third* and *fourth*) being so large, and so well hoofed, that the animal walks upon them; the hoofs are flat on the inner side and fit well together, so as to look and act much like one cloven hoof. (*d.*) The two posterior toes (*second* and *fifth*) are too short to touch the ground, and are sometimes altogether wanting. (*e.*) Two metacarpals, and also two metatarsals, are, with a rare exception, coalesced into a single "cannon-bone"; also, the scaphoid and cuboid bones, at the base of the cannon-bone, are united. These particular characters are here enumerated in order to exhibit the contrast between this type and that of the Nudifronts.

The two families of Cervids and Antilopids, mentioned in the Synopsis, page 169, are the same in limits as those usually so named, except that the Camelopard is excluded. The Camelopardalid is the special long-amplificate, or Heron-like group, under the Corniger type. The horns are persistent, as in the Antilopids; but instead of a corneous sheath, they have for a covering only the hairy skin. In this respect and, further, in their extreme long-amplification, in the young animal's having horns at birth, and in their using the hind-legs in kicking as the principal means of defense, like the Horse, (and not merely as the occasional, like many Ruminants,) they diverge from the other Cornigers and rightly constitute a separate family, and one *hypotypic* in grade. It is stated that the males sometimes make use of their horns in attack; and one female at the Zoological Gardens, London, is said to have driven her horns through an

inch board. As the head of a Camelopard is raised seventeen or eighteen feet above the ground, the systemic force in this inferior Herbivore is diffused through a sphere whose radius is nearly twice that of the Lion, and six to eight times that of its superior among Herbivores, a common Stag or Goat—a condition betokening very low grade. Its inferiority among Cornigers is also apparent in the small head and brains for so large a body, its singularly awkward use of its long limbs when running, and its being a *mute* animal.

(2.) The *Nudifronts*.—The Nudifronts manifest their inferiority to the preceding in different ways.—

(*a*.) In a comparatively relaxed condition of the extremities.

In the *Camelids*, the toes spread forward so that the animal walks on a pad or pads beneath the foot and toes; the hoofs are small, of symmetrical shape instead of being fitted to one another, and cover only the extremities of the toes; the scaphoid and cuboid bones of the tarsus are disjunct; and the cannon-bone, though single, is divided at its lower extremity to a higher point than in the Cornigers.

In the *Moschids*, the toes are lax, as in the Camelids, and similarly covered with short hoofs, so that there is not the appearance of a single cloven hoof; moreover the two posterior toes are elongated so as to touch the ground in walking; and, in one species, not only are the scaphoid and cuboid bones disjunct, but also the metacarpals and metatarsals which make up the cannon-bone of the Cornigers and Solipeds. In others, also, the metacarpals are not completely coalesced.

The *Anoplotherids* are like the Moschids in the lax condition of the two large toes; and, as in the *Moschus aquaticus*, the scaphoid and cuboid bones are disjunct and also the metacarpals and the metatarsals.

(*b*.) In the forehead not being a power-organ, and not furnished with horns.—

This condition in an animal may be a mark either of a highly cephalized, or of an enfeebled, life-system. In the Horse it appears to be the former. But in the Nudifronts, it is so associated with other proofs of inferiority that it is unquestionably additional evidence of this inferiority. Absence of horns characterizes the *females* of many Cornigers, which shows that it might naturally be a feature of related inferior species.

The Camel and Musk-deer have feeble heads, both as respects mechanical and psychical power. The Musk-deer not only has no trace of horns but the forehead is not used in defense or attack, being apparently unfitted for this purpose.

(*c*.) In their feeble means of defence and bizarre shapes.—

The Camel sometimes bites—an almost universal propensity among animals, there being a consciousness of power in the

jaws when none elsewhere. The male Musk-deer is aided by long canines; yet it is a very timid animal, and although it takes extraordinary bounds when fleeing from a pursuer, it is said to become very soon exhausted, and thus is a little after the Grasshopper-style among hypotypic Insects. The Llamas spit.

The Camel has a body out of proportion to its legs, and exhibits awkwardness in features and gait; its hump is an abnormal growth of fatty and cellular tissue, having no functional value beyond that of serving as fuel for the craft when out on the desert; and its formation evinces large vegetative powers with consequently feeble systemic control.

(*d.*) In the presence of canines in most of the species; and in the Anoplotherids the set of teeth, besides being complete, having the canines short and not projecting, as in Man.—

The variation from the Ruminant type in the teeth shows a tendency to return to normal regularity and simplicity, as is common in *inferior* species (Art. I, pp. 326, 440), and is not a mark of elevation toward the Pachyderms.

Owen observes that an Anoplotherid resembles, in its absence of horns, its divided metatarsals and metacarpals, its lax toes, and its even and normal number of teeth, "the embryo Ruminant," these characteristics of the embryo being retained in them through adult life. He speaks of it, again, as exhibiting the features of the more generalized (or less specialized) Mammalian type, and remarks upon the same as also shown, though less strikingly, in the Camel. This relation, so correctly presented, accords with the view we hold, that these species are low in grade of cephalization; for a condition analogous to that of an animal in an unfinished or young state is one of comparative feebleness. The embryological resemblance, on this view, extends not only to *form* but also to *force*.

The *Pachydermatoid* qualities in the Moschids, and some among those so regarded in the Camelids, correspond therefore to a *degradation* of the Ruminant-type.

On page 165, the long-amplificate jaws and limbs of Solipeds and typical Ruminants are shown to be mutually dependent on that condition of the systemic force which is essential in order to bring out the Ruminant type-structure. It here appears that the *relaxed* or enfeebled condition of that force which leads to a lax state of the digits or extremities of the limbs is attended by modifications of the teeth—the dental series losing its type-character by the development of some or all of the missing teeth, and so returning toward elemental regularity. The two extremes of the body, the jaws and the limbs, thus vary together with the enfeebling or relaxation of the systemic force.

It is apparent, from this survey, that the Nudifronts are distinct from the higher Sthenomeres in several important characteristics,

indicative, each, of inferiority of grade. They are feeble in the head, and have no use for the forehead in attack or defense; they are weak as to means of defense of any kind; they have a lax condition of the extremities; they have a more complete and regular series of teeth, but as a result of a more diffused state of the systemic force, or less systemic control.

C. *Sirenians.*

The distinctions of the Sirenians have already been sufficiently indicated (p. 169).

In conclusion, the writer may here state that he does not look upon the classification which has been presented, as in all points that to which *beyond question* the right application of the principle of cephalization leads; but only as that which, as far as he now understands the facts and the principle, appears to him to be correct to nature.

D. *Dynamical considerations.*

1. *Amplification.*—On page 165 it is shown that in the skeleton of the long-amplificate Herbivores, the head and limbs are both elongated, although unequally; and that the elongation is little or none in the basal portion of these parts, while large in the rest, and especially toward the extremities of both the jaws and limbs.

On page 174, it is likewise shown that a relaxation of the parts in the extremities of the limbs is concurrent with a relaxing also of the elements of the jaws.

Thus the head and the limbs, parts alike circumferential, undergo analogous changes under similar conditions—the amplification in the *head* increasing from the basal portion of the skull toward the extremity of the jaws; and that in the *limbs* increasing from the body toward the extremities of these limbs.

Now it is to be noted that, while the head and the limbs diminish in amplification toward their basal portions, they are separated in the same species by a *long-amplificate neck.* It seems to follow, therefore, that the head is one centre of amplification, and the body another; or, in other words, that there are two distinct centres of amplification, a *cephalic* and a *thoracic*, the former the *primary.*

The question may be asked, whether the neck, in its amplification, should be considered as subordinate to the cephalic, or to the thoracic, centre, or to both equally. In reply, it is to be observed that the amplification in the case of the neck accords in amount much more nearly with that in the limbs than with that in the head. Moreover, short limbs and a short neck go together (as in the natatorial Herbivores and Mutilates), even

when the head is excessively elongated; and when the limbs are reduced to fins, as in Fishes, the neck is essentially wanting. Again, the longer cervical vertebræ are those most remote from the body, and the stoutest those nearest it; and, in the Camelopard, an animal in which the part of the limbs remote from the body is very much elongated, these cervical vertebræ remote from the body are likewise much elongated. It would hence appear that the amplification in the neck in these species is subordinate mainly to the thoracic or secondary centre.

But although this argument in favor of a connection at times between amplification in the neck and limbs may appear direct, we deem it only a doubtful suggestion. In any case, the fact of two systemic centres in Mammals seems to be established—one, the *cephalic* or *superior*, quite small in radius and with narrow limits of amplification; the other, the *thoracic* or *inferior*, very large in radius, and admitting of a wide range of amplification.

In Crustaceans the head and thorax make one single division of the body, the cephalothorax; and the cephalic nervous mass is often quite near the first thoracic, the two in some inferior species being on opposite sides of the esophagus. The cephalothorax here corresponds, therefore, to one single primary centre; and this centre is situated near the anterior margin of the mouth-aperture, or between the mandibular and 2nd-antennary segments, where it is placed by the writer in his former articles on this subject. There is an inferior or *secondary* centre in Crustaceans, but this is abdominal, as remarked in Art. I, p. 322. In Insects, as the body consists of three parts, a head, thorax and abdomen, there appear to be, besides the cephalic, two secondary centres, a thoracic and an abdominal; and in the Mantids and like species we have an example of a large anterior amplification of the thoracic. At page 328 of Art. I, a fact is mentioned bearing on the existence of two centres in Worms.

While amplification, then, depends on the degree of systemic control over vegetative growth and development, it may take place about the structure as a systemic unit, or about its primary and secondary systemic centres; and each centre may be more or less independent of the others in the amplification subordinate to it.

When, in an organism, the systemic force controls in the highest possible degree, under the type, the tendency to vegetative increase, or the mere powers of growth (the centrifugal tendency), there is the highest concentration and greatest circumferential contraction; and when in any less degree, there is amplification or circumferential extension.

When the systemic control is still so great as to keep the parts essentially within typical proportions as to relative lengths of parts, the amplification, if any, is simply gross-amplification—gross-amplification of the whole bony structure in superior spe-

cies, and of fatty, cellular and dermal tissues mainly, in species of a feebler life-system. But when the control is less complete, the parts of the bony structure increase *in length* by amplification, especially the more circumferential portions of them—*this amplificating tendency increasing in amount with the distance from the systemic centre or centres*—and the structure is long-amplificate. With a feebler life-system, not able to keep the structure evolved to type-perfection, the limbs may have lax or imperfect extremities, that is, lax as compared with their condition in the typical species under the type.[8]

2. *Definiteness of the distinction of gross-amplificate and long-amplificate.*—It has been observed that the two higher groups of terrestrial Herbivores are distinguished, the first, by being very generally gross-amplificate in the structures included, and the second by being long-amplificate, and that the two groups are thus quite well separated, there being but few cases of long-amplification in the former, and the gross-amplification in the latter taking place upon long-amplificate structures. It is a general fact throughout the animal kingdom that the long-amplificate groups under a type stand apart from, instead of blending insensibly in this respect with, the typical or gross-amplificate groups. Thus there is a Tipulid group among Dipters; a Grallatorial group among Birds of the tribe of Præcoces; a Heron group among the Altrices; a Serpentarius family among the Accipiters, etc.

The reason for this definiteness of limit between gross-amplificate or typical forms and long-amplificate is apparent from the preceding discussion. To produce the former, there is the systemic control which determines typical proportions and admits only of narrow limits of variation. For the latter, there is a diminished degree of that control, leaving vegetative growth to elongate the structure; and this diminution is not one of gradual stages, but an abrupt step down to the new condition. The limits of typical proportions once fairly overstepped, the structures pass suddenly to amplificate forms of very varied proportions. This capability of elongating the bony skeleton in Sthenomeres is very different from that of mere general enlargement which characterizes the Sthenorhines; and without an abruptness of transition between the two conditions the two types would not stand as far apart as they do in style of amplification.

3. *Axial distribution of force.—The retroferent method of decephalization.*—There is another law with regard to the systemic force, to which the above, relating to amplification, is actually subordi-

[8] The separateness of these two powers is also illustrated by the arrest of development in the brain, in many cases, as shown by fewer gyri and a greater simplicity of folds, while there is an increase of size up to normal dimensions. See W. C. Minor's translation of articles by Dr. Wagner, in this Journal [2], xxxiv, 188, and, in particular, the remark of Dr. Minor on this pofnt, on p. 199.

nate—which is, that *the force may vary in cephalic concentration, and thereby in its distribution along the principal body-axis.*

It has been shown in this and the former articles that there is often, with descending grade of species, a transfer of force and function backward in the structure—a method of decephalization termed the *retroferent*, and including under it, the *prosthenic*, *metasthenic* and *urosthenic* conditions of structure. These have been illustrated from all departments of the animal kingdom; and with examples from Herbivores in the preceding pages. We refer again to the facts among Crustaceans in this Journal (vol. xxii, 14, 1856, and the chapter in the author's Expl. Exped. Report, p. 1412,) as especially clear and conclusive, and as having peculiar interest because historically the source in the writer's mind of the principles here explained.

Moreover, this backward transfer of force and function manifests itself also in the posterior elongation of the structure and also in some anterior dilation. Conversely, elevation of grade is manifested in the abbreviation of the structure behind, and to some extent also anteriorly, and in the transfer of force and function forward, or toward the cephalic extremity.

This connection of grade with a transfer of force along the body-axis—through a weakening or strengthening of the cephalic concentration—is dependent on the polar or cephalic nature of an animal—a condition remarked upon in Art I, at page 321, and referred to at p. 157 of this paper. The higher the grade of a species under a type, the greater the extent to which the force of the system is gathered in, or toward, the cephalic extremity or pole; and the lower the grade, the more complete its diffusion toward the posterior extremity.[9]

In the forward transfer attending cephalic concentration, the anterior limbs, as the species rise in prosthenic character, increase in muscular force, so that, as in Carnivores, this force is far greater in the fore-limbs than in the hind-limbs. When the transfer of force toward and about the anterior or cephalic extremity is at its maximum under any type, the structure is *prosthenic* in the highest degree possible for that type. But if the anterior extremity of the body-axis is not in this maximum state, owing to a diffusion of the force posteriorly, the condition is one less prosthenic; by a further loss and diffusion posteriorly, there may be another step down (for such transitions, as we have before found, appear to be by a *saltus*) perhaps to a lower grade of prosthenic, or else, still lower, to a *metasthenic* condition, and attending this, there is often an increasing length of body; by a further loss or diffusion posteriorly, there may be the pro-

[9] In my last article (Art. II. p. 10) I have referred the amplificate and retroferent methods of decephalization alike to *apocentric* distribution of force—or diffusion away from the principal or cephalic systemic centre. This, although true, is but an imperfect expression of the fact.

founder descent to a *urosthenic* condition, with great length behind and a large part of the force of the structure thrown into the caudal extremity.

But, besides the increase of muscular force attending cephalic concentration, there is also increase of cephalic force—the sensorial and higher cephalic—an increase which is not so easily measured or compared. Man is probably prosthenic looking only to his limbs, the arms being stronger than the legs. Yet this is but a small fraction of the force which makes him the prosthenic being he is. The force is so largely purely cephalic, that he may be styled, with special appropriateness, *cephalosthenic.* In such a species the increase of force along the body-axis from behind forward would be represented by a very rapid divergence of lines; in a Carnivore, by a divergence much less rapid; in a Whale by lines diverging but little from parallelism.

When the supremacy of the cephalic extremity in an organism is of high order, the cephalic centre is near the front margin of the head. Thus in Man, the being eminently of onward head-power, the jaws project but slightly beyond the anterior margin of the brain; moreover this cephalic concentration and contraction is connected with a reduction of the number of teeth from 44 to 32, one pair of incisors and two of premolars being wanting in either jaw out of the full number that belongs to the Mammal type. There is a great contrast between this abbreviated form of head and the elongated cranium of the 44-toothed Anoplothere, one of the lowest of Herbivores.

When the cephalic supremacy is so feeble that the force approximates to equality along all parts of the body-axis, the animal is the next thing in grade of life to a plant; the cephalic centre in such a case often has a position remote from the anterior extremity, the head portion becoming greatly dilated, as in the Whale as mentioned on page 160. If, in addition, the systemic force is feeble, the body may be contracted both before and behind, about the *nearly central* cephalic pole, as in Radiates.

With decreasing cephalic concentration, there may be not only increasing length throughout the structure, and especially circumferentially, but also an increasing relaxation of the parts of the structure, and a tendency toward a resolution into its normal elements, or an elementalizing of it; and also a tendency toward an equality in the series of parts or elements. This is decephalization by the *analytic* method explained in Art. I, p. 326.

The same kind of relaxation, favors not only ordinary vegetative increase, and an analytic resolution of structure, but often, also, that extraordinary multiplication of parts included under the *multiplicative* method of decephalization (Art. I, p. 325), and that multiplication of ova or young at a birth, included under the *genetic* method (Art. I, p. 330). In the higher animal species,

the forces and material of the being can develop at one time but one or a few ova; in others inferior, the amount required for each is so small; or, is so small a part of the whole energies of the individual, that the number produced is almost indefinitely large.

4. *Relation of the law of amplification to the law of axial distribution of force.*—The condition as to the distribution of force along the body-axis under a type, determines, as has been shown, the form or general nature of the structure, in any case, and the structure thus established is that which undergoes amplification. Thus the law of amplification is secondary to the law of axial distribution. Gross-amplification in a Whale is amplification of a *urosthenic* structure, or one in which the forces are so distributed along the axis that the anterior pole is not very highly superior to the posterior—a structure which is of great length and size behind *because* urosthenic, or feeble in cephalic polarity, while, at the same time, powerful in life-system.

5. *Diminution of cephalic concentration or polarity not necessarily a diminution of the total amount of force in an organism.*—As a Whale has more locomotive force than any other animal, it is evident that the transfer of force posteriorly, or the loss of cephalic concentration, does not necessarily involve a great diminution of strength of body: in a transfer of force, there is not necessarily a lessening of force. In fact, it might be inferred from the case of the Whale, and also from examples among the higher Mammals, that sensorial and other higher cephalic force becomes converted, in the transfer posteriorly, into muscular force; so that a Whale is a representative of the force of a typical megasthene,—a Lion, for example—in the condition almost exclusively of *muscular* force. The last part of this statement may be quite true; for the Whale may not differ from a Lion so much in amount of systemic force as in the proportions of that force divided between the several kinds of muscular, sensorial, and psychical. But this commutation of kinds of force cannot properly be admitted. It is more correct to say that the systemic developments in one case produce almost solely muscular force; in the other, less of this with a larger proportion of sensorial, or sensorial and psychical; and that these proportions are determined by the cephalic polarity of the life-energy characterizing the organism under development. The brain is the last part of an animal that is perfected. It becomes complete in its powers only after the rest of the structure has so far reached its limits of growth that the whole system may combine its nutrient energies and material on the one great feature of the being. In this way the cephalized structure attains its most highly cephalized condition.

The views here set forth rest on the ground that in a living organism there are not only molecular forces everywhere individually at work, carrying on all changes and growth, but also

that there is centralized control over all molecular forces, determining the limits, nature and condition of the organism.[10]

I would not be understood as including Man's higher nature among the attributes that can be developed out of simple matter and cephalized life. For Man evinces in his power to comprehend Nature's laws and use them for his physical, intellectual and moral progress, that he is *above* Nature. He shows in his thoughts of the infinite—in his recognition of an omnipotent Creator, (or, as well, in his efforts to reason himself out of this recognition, or into the substitution of an infinite Nature)—in his sense of obligation to moral law, and law as emanating from an infinite God—in his aspirations towards the infinite—in his hopes reaching into the indefinite future—and in his capability of indefinite development, that he has within him an element of the infinite, a spiritual element, which places him above nature, constitutes his likeness to his Creator, and assures him of a future of spiritual existence apart from matter and its inferior developments.

6. *Distinction of Megasthenes and Microsthenes.*—The fact stated with regard to the powerful life-system of the Whale affords aid towards a definite understanding of the distinction between the great groups of Megasthenes and Microsthenes. The subdivisions of these groups are mentioned in a note to page 159, and in a manner to exhibit their parallelism:—the Quadrumanes and Chiropters being in one line, since they have long been regarded as correlates in many of their characters; so Carnivores and Insectivores in the second; Herbivores and Rodents in the third; and Mutilates and Edentates in the fourth. Carnivores and Insectivores are both carnivorous and both prosthenic tribes. Herbivores and Rodents are both herbivorous, and the larger and most characteristic part of the former and all of the latter are metasthenic. Mutilates and Edentates are both degradational types; the latter, like the former, sometimes multiplicate and elementalized in their teeth, sometimes wholly elliptical as to teeth, sometimes vast in amplification; and bearing, through all their structure, evidence of great inferiority among the placental Mammals. The mean sizes of the Megasthenes and Microsthenes have been shown to be about as 1 : 4.

Now the Whales, by their enormous muscular power, make it manifest, as has been explained, that they are true Megasthenes, or that the life-system is really large, not very much smaller perhaps than that of the higher Herbivores. Although degradational species, they still retain this peculiar feature of the Megasthenic type.

[10] This idea is illustrated by reference to the nature of coral polyps in the writer's Report on Zoophytes, 4to, 1846.

The Edentates are also large beasts, and the first impulse, under the influence of the sense of sight, is to declare them likewise Megasthenes, because they are big enough to be so. But these animals, large and small, while degradational like the Mutilates, are in striking contrast with the latter as regards muscular force and all other powers. They are cephalically feeble, below other Mammals; and they are of extreme muscular debility as compared with a Whale or any Megasthene. There is no increase of muscular power *because* of the degradation of the sensorial and psychical elements, as in the Whale, but a general degradation of every function and part. Thus they are literally microsthenic in life-system. Compared even with a quick-moving Rodent, the slow Sloth is muscularly feeble; for relative strength is to be measured, not by the single blow that may be given, but by the product of the strength of a single blow into the number of times this blow may be repeated in a given time, as for instance, in twenty-four hours.

The Edentates appear therefore to be as truly degradational *Microsthenes*, as the Mutilates are degradational Megasthenes. They show their feebleness according to the elliptic method, in their head and jaws to an extent not manifested even among Mutilates.

The Edentate type exhibits its inferiority to that of all other placental Mammals also in admitting more or less of a commingling of Reptilian characteristics with the Mammalian, as appears in the scale-made or shield-like armor of many species, the feeble sensibility of all, and several peculiarities in the skeleton: —showing thus that the type holds a position in some respects between those of Mammals and Reptiles, or at the extreme lower end of the placental series.

D. *Additional Observations.*

1. *Grade among groups.*—The groups under the several subdivisions in the proposed classification show a gradation in rank corresponding with their position. Moreover, the third group, as in the higher subdivisions of the animal kingdom, and in those presented in the article on Insects, is literally a *hypotypic* group. The hypotypic features are connected either with a more or less aquatic mode of life, and gross-amplification, or with long-amplification.

It may be here observed that were we to make the Imparidigitates and Paridigitates the two grander divisions of Herbivores, and so unite the Solipeds to the Proboscideans and Tapirideans, and the Suideans to the Ruminants, the Solipeds would have to go, because *metasthenic*, at the foot of the higher division, when they have the characteristics of a *superior* typical group, and not those of a hypotypic; and the Suideans would

take their place at the head of the lower, before the Ruminants, because *prosthenic*, although decidedly hypotypic in shape, structure and stupidity.

2. *Designations of the grades of subdivisions in the tribe of Herbivores.*—Under the tribe of Herbivores, the subdivisions of the first grade, that is, those of Sthenorhines, Sthenomeres, and Sirenians, may be conveniently named *subtribes*. The subdivisions of the second grade, or those of Proboscideans, Tapirideans, etc., may be called *tribules*, this word being diminutive of *tribe*.

The subdivisions of the third grade are, with three exceptions, *families*. The three exceptions are that of the Tapiroids among Sthenorhines, and those of Cornigers and Nudifronts among Sthenomeres, for each of which the term *stirps*, one already somewhat in use in classification, might be employed. The name of the group of *Rhinocerotids* might be written Rhinocerotoids, so as to make it coördinate with that of Tapiroids; but it would still contain only the single family of *Rhinocerotids*, and the change would be adding words to the system without sufficient reason.

3. *Geological History.*—The earliest of Herbivores in geological history, or those of the opening Tertiary period, were mostly species of Tapiroids and Nudifronts—*Lophiodon* (Tapirid) of the earliest Eocene, being one of the genera of the former, and *Dichobune* (Anoplotherid) of the same epoch, of the latter. The Lophiodonts led off, therefore, the Sthenorhines, and the Dichobunes, the Sthenomeres. Later in the Eocene, if not cotemporaneously, there existed the Paleotheres and the true Anoplotheres, as other representatives, respectively, of these two grand divisions; and with these there were species of Suideans of the Chœropotamid type. The Sirenians were also among the first of Herbivores; and the earliest Eocene genus of these *urosthenic* species, Halitherium, was related to the Halicorids.

It is to these Eocene species, according to all analogy, that we should look for the closest approximation of the two grand divisions of terrestrial Herbivores. And so in actual fact, the Anoplotherids, as long since observed by Cuvier, have near relations in structure to the Tapirids and Suids among the Sthenorhines, as well as to the Camelids among Sthenomeres. This accords in general relation with the facts among Insects mentioned at page 33 in Art. II.

In the Paleotheres, among the earliest of Sthenorhines, moreover, there was, besides an approximation to the Sthenomeres in general structure, an approximation also in long-amplification (p. 168), a feature which is typical for the Sthenomeres, but which disappeared almost entirely from among the Sthenorhines in the later exhibitions of the type.

ART. II.—*Note on the position of Amphibians among the classes of Vertebrates.*

IN a recent article by the writer on the *Parallel relations of the classes of Vertebrates*,[1] Amphibians are made the inferior division of the class of Reptiles. The usual arguments against this view were not alluded to because they were believed to be familiar to all interested in the subject, and their discussion at the time seemed not to be required. A few words with regard to them are here added in order to set forth more distinctly the special value of the analogies appealed to in that paper.

The evidence in favor of separating the Amphibians from Reptiles as an independent *class* is undeniably of great weight. Their approximation to Fishes in embryological development and the corresponding divergence from ordinary Reptiles have the appearance of being decisive proof that they are as closely related to Fishes as to Reptiles, and, therefore, that they occupy an intermediate position between the two in classification.

The chemical researches on the composition of eggs by Fremy, made a few years since,[2] claiming to show among their results "the curious physiological fact that Amphibians, besides passing through an early condition of existence like that of Fishes, lay eggs which have the greatest affinity in chemical composition to those of Fishes," seemed to the writer, when they were first published, to carry the evidence to the most fundamental point in the nature of the species, even below that of embryological development. If the fundamental elements thus differ, should not the superstructures also, and far more widely?

But the question recurred whether in the subdivision of the subkingdoms of animal life into classes, it is not, after all, the more correct method to take note primarily of species in their finished or adult state; that is, whether adults do not express the true idea and nature of species, or the objects to be classified, rather than the special series of changes through which the adult characteristics are reached.

In favor of an affirmative reply to this question, the fact stands out prominently that, as regards the subkingdoms in animal life, embryology in the hands of the best embryologists has only sustained what Cuvier had derived from the study of the adult animals themselves; and in the hands of other embryological investigators, and some of the latest, even these great natural groups have not been left without mutilation. And as to the subordinate divisions under the subkingdoms there is not only great diversity in the different embryological systems, but violations of natural affinities in all. Professor Agassiz, in his Essay

[1] This Journal, [2], xxxvi, 315, November, 1863.
[2] This Journal, [2], xix, 38, 238, xx, 65, 1855, from the *Journ. de Pharmacie*, 1854.

on Classification,[3] criticizes the systems of Van Beneden, Kölliker and Vogt, on account of their violating the structural affinities of groups, implying that embryological conclusions have to be tested by a reference to the natural types of structure. In nature a specific type is often expressed in a long series of species running through a very wide range of grade; and structures so diverse in grade as those of the higher and lower extreme groups are diverse in the nature of the changes which take place in the course of embryological development. Not appreciating this fact, embryological systemists have cut the series, and made bold demarcations between parts that are essentially one in type. Thus has resulted the separation of the class of Worms from Articulates by both Van Beneden and Vogt, and of the order of Cephalopods from Mollusks by the latter, etc.; and such errors will continue to attend upon the decisions of pure embryology until the precise value of its characteristics in classification is understood.

If, then, the structural relations of the developed animals are an authority to which embryology must appeal, the adult Amphibians may claim to be considered, on a question of their relations to ordinary Reptiles, even before their eggs and young. Embryology proves that Amphibians and ordinary Reptiles are *distinct groups*, as is proved also by structural considerations; but, in the present state of the science, it can hardly be said to demonstrate that these groups are *classes*, coördinate with those of Birds and Mammals;—and I venture to say, as regards the separation of groups, that, in no state, will it prove what the adult structures will not sustain.

But, further, if it were proposed to make a Reptilian whose early life should be aquatic, could it be accomplished by means of eggs having the same chemical constitution as those of ordinary or terrestrial Reptiles? The development, at each step, involves, and depends upon, chemical changes; and it is hence

[3] See the first volume of his Contributions to the Natural History of the United States (pages 220 to 232). Even von Baer, as here quoted, in subdividing the placental Mammals, places in one group the *Carnivores*, *Insectivores* and *Rodents*, and in another *Man*, *Monkeys*, *Ruminants*, *Pachyderms* and *Cetaceans*. Van Beneden divides the Invertebrates into two groups, the *first*, including Insects, Myriapods, Spiders and Crustaceans, the *second*, the subkingdom of Mollusks, *the inferior part of the subkingdom of Articulates*, that is, *Worms*, together with the Radiates, Rhizopods and Infusoria; and his division of Polyps, among the Radiates, in his latest amendments of his system, *includes both Polyps and Acalephs*. Vogt makes three grand groups of animals: the *first*, including Vertebrates, and all Articulates *excepting Worms;* the *second*, Mollusks, Worms and Radiates; the *third*, Infusoria, and Rhizopods; and his division of Mollusks *does not embrace the Cephalopods*, while it does include a tribe of Acalephs. Recently, Prof. Huxley, in lectures before the Royal College of Surgeons, of which a report is given in the Medical Times and Gazette, for May, 1863, says, (page 555,) after discussing the importance of the placenta in Mammals as a basis of classification, that, in his view, there is no difficulty in the way of a classification which unites the Proboscideans with the Rodents rather than with Paridigitate and Imparidigitate Herbivores.

reasonable to infer that the egg which was to be developed when bathed in *water* should thus differ somewhat from one that was to be developed in the *air;* and also that such *aquatic* eggs should approach in constitution those of the true *aquatic* Vertebrates, or Fishes. We may safely conclude, further, that the method of development for eggs thus different in constitution, and at the same time of inferior grade, would necessarily differ from those of ordinary Reptiles, and differ by approximating to those of Fishes. Accordingly, in Amphibians there may be only that divergence from the method of making a Reptile that was required in order that a division of inferior Reptiles should exist characterized by a fish-like life in the young state.

The fact is that the *superstructures* (p. 184) do *not* widely differ. In the adult state the species are Reptiles in all essential structural characters:—they are air-breathing; they have imperfect circulation and, consequently, are cold-blooded; and outside or inside there are no fundamental differences in type that would require a separation from the Reptilian class. The divergence is small compared with that between typical Amphibians and Fishes.

Such considerations are sufficient to authorize the assertion that the evidence in favor of regarding Amphibians as Reptiles at least balances that on the other side, if it does not outweigh it.

Now add to the above the analogy drawn from other classes of Vertebrates, as presented in the paper referred to in the opening paragraph of this article:—that the class of Mammals has its *inferior* subdivision—the Oötocoids, or *semioviparous* species—intermediate between ordinary Mammals and the *oviparous* classes below; that the class of Birds, according to recent discoveries, has its *inferior* subdivision—the Erpetoids, or *Reptilian* species—between ordinary Birds and *Reptiles;* and that between ordinary Reptiles and the class below, or that of *Fishes*, there are the Amphibians, or *fish-like* Reptiles; also, that the grand distinction between semioviparous and ordinary Mammals is manifested in *their embryological development*, or their young state, as well as that between Amphibians and ordinary Reptiles; and the evidence becomes strong that if Oötocoids constitute a hypotypic subdivision of Mammals, so Amphibians constitute a hypotypic subdivision of Reptiles. It is not necessary to repeat at length the argument on this point, as the reader can easily refer to the former paper on the subject. This point is illustrated also in the following article in the same volume (Article I, On the Classification of animals based on the principle of Cephalization) by a wider range of analogies, showing that similar hypotypic groups constitute the lower subdivision in several departments of the animal kingdom.

From the Author.
James D. Dana

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

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.—No. I.

By JAMES D. DANA.

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:[2]

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.

[2] 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.

II. *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

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.

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

To be substituted for section 9, on p. 227. 3

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

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 a d 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 term 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 *urothenic*, 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 Author.

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ON CEPHALIZATION.

No. IV.

EXPLANATIONS DRAWN OUT BY THE STATEMENTS OF AN OBJECTOR.

BY JAMES D. DANA.[1]

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

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

In the first place, our expositor, while claiming to cite what was "originally propounded" by me, had not seen my *original* memoir published in 1852[3] in the Report on Crustacea, and in 1856 in this Journal, and refers to no paper earlier than that of 1863.

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

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

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

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

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

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

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

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

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

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

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

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

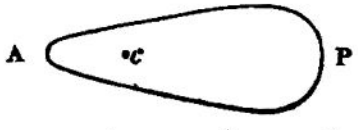
(3.) With *superior* cephalization, the posterior portion of the body becomes more and more compacted, or firmly put together and abbreviated; that is, as concentration goes on *anteriorly*, there is abbreviation *posteriorly*. Even the tail shows grade; for great length, or size, or functional importance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

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

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

1.

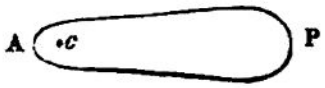
2.



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

3.

4.



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Medusa; and so on. Now it may be urged, against the system of classification proposed, that size sometimes means one thing, and sometimes the reverse, and there is here manifest indefiniteness and a chance for indefinite assumptions. Or, the charge may be made with more point, and much less truth, as follows: "Because great size is correlated with superiority in *Crustacea*, you [Mr. Dana] infer that it is so correlated everywhere throughout the Animal Kingdom; and when, as nobody can fail soon to do, you meet with examples where facts contradict your theory, you get over the difficulty by assuming gratuitously that size is there due only to what you call 'vegetative enlargement.' As I cannot find that you have anywhere laid down any definite rules by which this vegetative enlargement is to be distinguished from the normal enlargement, the distinction appears to be an empirical one."[4]

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

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

[4] From a recent letter of a critic.

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

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

I have been led to place the Homopters near the Lepidopters, and the Hemipters near the Coleopters, by the following considerations:—

a. The Homopters, as most authors assert, have close structural relations to the Lepidopters. The Hemipters are much less near the Lepidopters, and approximate, as some authors have admitted, to the Orthopters and Coleopters, especially the former. The fact that the anterior wings in Hemipters, as in the Coleopters and Orthopters, are not flying wings, is an important point

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

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

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

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

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

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

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

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