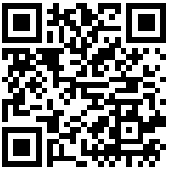

THE CLASSIFICATION OF ANIMALS BASED ON THE PRINCIPLE OF CEPHALIZATION.

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 *Ctenopters*, (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) *Ptero-prosthenics*, 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 these 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.

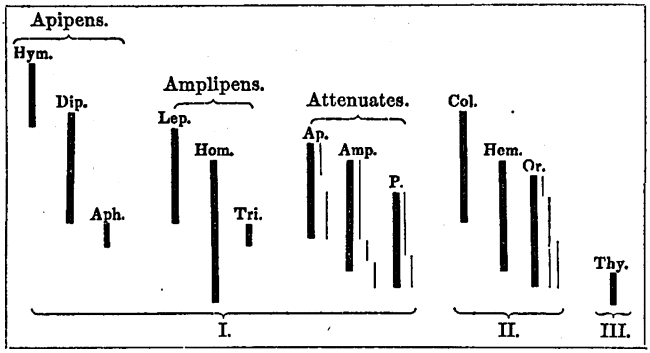
a. The lowest subdivisions of both the Pteroprosthenics and Pterometasthenics are long-amplificate; and in their subordinate subdivisions the same method is often illustrated.—Some Orthopters of the family of Phasmids have a length of a foot: there is here a diffusion of the systemic force through a 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.
2.	Dipters.	Homopters.	Amplipenniforms.	Hemipters.
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.

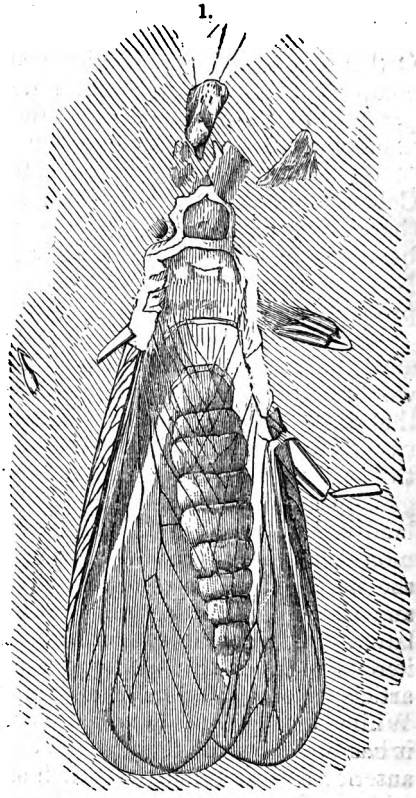


Figure 1 is twice the natural size lineally. In general form and the neuration of the wings the Insect is closely like the *Semblids* among the Neuropters, and especially, as I am informed by Dr. LeConte, the *Chauliodes*. In view of this resemblance, and also the fact that the outer wings are so thin 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.

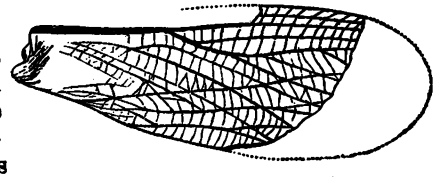
The number of abdominal segments is *ten*, or *one more than the typical number* in Insects—as is true also of many Neuropters, the Lepismæ, and some species of other tribes. The neuration of the wings and the form and relative sizes of the segments of the abdomen are well shown in the figure, and particular 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.