pairs of feet. Eggs agglutinated, and forming a broad flat mass.

Sp. *Leposphilus Labrei.*

Colour varying from yellow to pale red. Length about 10 to 12 millims. Male unknown.

Inhabits the Green Wrasse, in the scales of which it hollows out a retreat.

XV.—*Observations on the Development and Position of the Hymenoptera, with Notes on the Morphology of Insects.* By A. S. Packard, Junr., M.D.*

The following notes form an abstract of a more extended memoir upon the changes of the insect after leaving the egg, not touching upon the evolution of the embryo.

After the larva has become full-fed, as it is about to enter upon the semipupa state, its body undergoes the following changes:—The thoracic rings and head become more elongated and fuller, so that whereas in the larva the underside of the anterior and posterior halves of the body are closely appressed to each other, now the two halves begin to recede, and the grub, as it lies in its cell, is but half doubled upon itself. With this important change of posture, the whole body becomes more cylindrical and rounded. Thus the sides (arthropleuræ) of the thoracic ring become absorbed, and do not project out from the walls of the body as in the larva; and later still, the corresponding area in the abdomen likewise almost wholly disappears.

The greatest activity, however, is observable about the cephalic portion of the body; for here the greatest differentiation of parts is to occur. The head of the pupa, already partially formed beneath the prothoracic ring, though as yet very small, by its presence still affects very sensibly the form of this region in the larva, the skin of which still remains unbroken, though very considerably distended. The whole length of the head (fig. 1 *a*) and prothorax (fig. 1 *b*) together is now equal to the united length of the head and thorax in the larva originally. To effect this, the larval head is greatly extended forwards, and the prothorax is three times as long as before, and much narrower, the sides converging towards the base of the head. The two posterior thoracic rings are also twice as long as in the larva. On the under (sternal) side the mouth-parts are also elongated; and

* Communicated by the author, from the 'Proceedings of the Boston Natural History Society,' Feb. 7, 1866.

the labium projects a little beyond the head, owing to the increased size of the mouth-parts over those of the larva.

At this period, the two pairs of wings are very equal in size, the posterior pair but little smaller than the anterior pair, and inserted much higher up the ring nearer the median tergal line of the body; and in the succeeding stage the posterior pair are seen to be scarcely smaller than the anterior pair, and exactly parallel in their insertions, their longitudinal diameter, and their tips. This change in the position of the posterior pair of wings, so important in a morphological point of view, is accompanied by a corresponding change in the proportions of the thorax. The metathorax has become mostly absorbed, so as to resemble more the same part in the pupa; while the mesothorax retains much of its original proportions, though becoming more compact and presenting less of the tergal area.

During this time the head has also greatly increased, especially in the size of the appendages; the eyes, antennæ, and mouth-parts begin to assume the size and shape of those of the pupa. Development here, as in the thorax, begins in the most important central parts, and proceeds outwards to the periphery.

In this stage (fig. 1), when the mouth-parts of the semipupa have become solid enough to enable the larval head to be stripped off without lacerating the extremities of the appendages, the head is seen to be divided into two portions. The basal region or body of the head, which is lodged under the prothorax of the larva, is orbicular when seen from the front; and its sides are continuous with the sides of the thorax, as is also the vertex, which is likewise of a continuous slope with that of the anterior tergal portion of the thorax. Seen from the side, there is no separation as yet between the head and thorax. The outline of the eyes is distinct, but they are not raised above the surface of the head. The antennæ, clypeus, and mouth-parts collectively form a second anterior portion separated by a curved line from the epicranium. It is this anterior portion which lies in the larval head in this stage. The great increase of size of the appendages of the semipupa have forced forward the hard crust of the larval head, which suggested to Ratzeburg the idea that the head of the pupa was originally composed of the first two rings (*i. e.* head and prothorax) of the body of the larva*. The antennæ are flattened down upon the surface, resting on each side of the small trapezoidal clypeus, over the front edge of which they again meet, when they are flexed upon themselves,

* "Ueber Entwicklung der fusslosen Hymenopteren-Larven, &c." (Nova Acta Natur. Curios. tom. xvi. 1832). Westwood has fully shown the fallacy of this idea (Trans. Ent. Soc. London, vol. ii. p. 121); and our own observations corroborate his statements and conclusions.

lying on each side of the labrum with its palpi and the maxillæ. These appendages do not as yet project much beyond the antennæ, being short and papilliform, preserving the general form of the same organs in the larvæ.

At this period the elements (*sterno-rhabdites,* Lacaze-Duthiers) composing the ovipositor lie in separate pairs, in two groups, exposed distinctly to view. The ovipositor thus consists of three pairs of slender non-articulated tubercles arising on each side of the mesial line of the body, in juxtaposition. The first two pairs arise from the eighth abdominal ring, and the third pair grow out from the anterior edge of the ninth ring. The ends of the first pair scarcely reach beyond the base of the third pair. With the growth of the semipupa the terminal or tenth ring decreases in size, the tip of the abdomen is gradually incurved towards the base (fig. 2), and the three pairs of rhabdites approach each other so closely that the two outer ones completely ensheath the inner, until a complete distensible tube is formed, which gradually is withdrawn entirely within the body (see fig. 4). The male genital organ is originally composed of three pairs of non-articulated tubercles, all arising from the *ninth* abdominal ring, being sternal outgrowths, and placed on each side of the mesial line of the body, two being anterior and very unequal in size, and the third pair nearer the base of the abdomen. Thus, in their position, the three pairs of tubercles destined to form the male intromittent organ cannot be said to be strictly homological with the female ovipositor; nor can the external genital organs be considered in any way homologous with the limbs, which are articulated outgrowths budding out between the sternal and pleural pieces of the *arthromere**. This view will apply to the genital armature of all insects, so far as I have been able to observe. It is so in the larva of *Agrion,* which completely repeats the structure of the ovipositor of *Bombus* in its essential features detailed above. Thus in *Agrion* the ovipositor consists of a pair of closely appressed ensiform processes which come out from under the posterior edge of the eighth abdominal ring, and are embraced between two pairs of thin lamelliform pieces of similar form and structure, arising from the sternite of the ninth ring. These sternal outgrowths do not homologize with the long, filiform, antenna-like, jointed appendages of the tenth ring, as seen in the Perlidæ and most Neuroptera and Orthoptera, which,

* This term is proposed as better defining the ideal ring or primary zoological element of an articulate animal than the terms *somite* or *zoönite,* which seem too vague; so also the term *arthroderm* for the outer crust or body-walls of Articulates, and *arthropleura* for the pleural or limb-bearing region of the body, being that portion of the arthromere comprised between the tergite and sternite.

arising as they do from the arthropleural or limb-bearing region of the body, *i. e.* between the sternum and episternum (or lower pleurite), are strictly homologous with the abdominal legs of the Myriapoda and the "false legs" of caterpillars; so that in these genito-sensory appendages we perceive faint traces of the idea of antero-posterior symmetry first observed in Vertebrates by Oken, and more recently by Professor Wyman and Dr. B. G. Wilder, involving a repetition of homologous appendages at the two opposite poles of the body. The broad leaf-like appendage to the tenth ring in *Agrion* seems homologous, both in function and structure, with the respiratory lamellæ of the swimming abdominal limbs of the lower decapodous Crustacea and the Tetradecapods, which perform the function of gills.

During this stage, the basal ring of the abdomen of *Bombus* (fig. 2 *c*) is plainly seen to be transferred from the abdomen to the thorax, with which it is intimately united in the Hymenoptera. This we deem the most essential zoological character separating the Hymenoptera from all other insects. This transfer of an entire arthromere from one region to that next in front, involving the remodelling of the entire form of the insect, though not uncommon in the Crustacea, is, in the class of Insects, peculiar to the higher families of the Hymenoptera, as in the lowest (the Tenthredinidæ) the transition is but partial, corresponding to the Lepidoptera in this respect. It is an instance of the principle of cephalization advanced by Professor Dana, so fully illustrated in the Crustacea, where in some groups changes occur in the primitive number of arthromeres, proved by the inconstant number of rings (arthromeres) forming the abdomen and cephalothorax respectively. This transfer of the zoological elements from the posterior end of an animal towards the head, involving in this act the entire reconstruction of the animal form, lies at the basis of all sound classification, and is a principle which must be followed by every student dealing with the classification of the larger divisions of the animal kingdom.

So intimately united with the thorax is this elemental ring, that, from its sculpturing, its coloration, and, in fine, its close mimicry of the normal thoracic segments, our best observers have united in calling it the metathorax, and homologizing it with that ring in the lower insects. Latreille and Audouin considered it as the basal ring of the abdomen, as did Newman, who termed it the *propodeum*. But our best hymenopterists of thirty years' standing consider it to be the metathorax, with the exception of Baron Osten Sacken, in his articles on the Cynipidæ*. During the autumn of 1863, when the observa-

* Proceedings of the Entomological Society of Philadelphia, vols. ii., iii.

tions here recorded were made, our attention was drawn* to this part. At this period the thorax is one-third smaller than in the pupa. The position of the three thoracic spiracles can be easily discerned. On the two posterior rings of the thorax they are seen situated in their respective "peritremes" (Audouin), which pieces lie at the base and just under the insertion of the wings, on the posterior half of the ring, while on the prothorax the peritreme lies contiguous to and partially under the posterior edge of the vascular tubercle, which in position is exactly homologous to that of the wings.

It is thus demonstrated that the wings grow forth, first as vascular sacs, through the arthroderm, just above the line of spiracles, and at the line of juncture of the lower edge of the tergite and upper edge of the upper pleurite or epimerum; while, on the other hand, the limbs grow out through the line of juncture of the sternite and the lower pleurite or episternum.

In what may be termed the third stage (fig. 3), though the distinction is a very arbitrary one, the change is accompanied by a moulting of the skin, and a great advance has been made towards the pupa form (fig. 4). There are seen to be two distinct regions to the body—the anterior, consisting of the head and thorax, which are placed close together, and the abdomen, which is separated from the rest of the body by a deep constriction. We cannot fail to be at least reminded of the biregional Crustacean—an analogy which Oken has called attention to, and which has been successfully used by that author in comparing the pupæ of Insects with Crustacea.

At this period the mode of sloughing of the larval skin is well shown. Instead of the violent rupture of the skin at one point on the tergum of the thorax, as in the majority of insects, accompanied with the great exhaustion consequent on the act, which makes the operation a perilous one to most Insects and Crustacea, in this species (and most probably all the Hymenoptera which at this stage have a soft tegument) the skin breaks away gradually, in shreds, from the tension due to the unequal growth of the different parts of the body. Thus, after the skin beneath has fully formed, shreds of the former skin remain about the mouth-parts, the spiracles, and anus. Upon pulling these, the lining of the alimentary tube and tracheæ can be drawn out, sometimes, in the former case, to the length of several lines. As all these internal systems of vessels are destined to change their form in the pupa, it may be laid down as a rule, in the moulting of Insects and Crustacea, that the lining

* Proceedings Essex Institute, vol. iv., "The Humble Bees of New England and their Parasites," &c., April 23, 1864, p. 3, note.

of the internal organs, which is simply a continuation of the outer tegument, or arthroderm, is, in the process of moulting, sloughed off with that outer tegument*.

Whereas before the head and thorax together were but little more than one-half as large as the abdomen, now they are conjointly nearly equal in size to the abdomen (fig. 3). The greatest changes have gone on in the two anterior regions of the body. They unitedly tend to assume a spherical form, while the elongated abdomen is shortened and very perceptibly altered in form, approaching near that of the pupa, and the whole body is flexed more upon itself.

The head is still closely appressed to the prothorax, but much less so than formerly, since the increasing size and different proportions of the prothorax have pushed it away. This act of separation has effected an important change in the position of the head as related to that of the rest of the body. It is now truly vertical. Before, its greater length was more continuous with the longitudinal axis of the body, that is, nearly horizontal, or rather inclined at a slight angle from the longer axis. The horizontal position is normal in the lowest insects, as the Neuroptera. In the Hymenoptera the longer axis of the head is most completely vertical.

The head in its size, and the development of the appendages, including the mouth-parts, now begins to resemble those parts in the pupa. The eyes are larger and more distinct than before; the maxillæ and antennæ, though still very short, are shaped more like those parts in the pupa. In the antennæ, the most marked change takes place in the three basal joints, or the "scape," of which the second joint now becomes the longest and somewhat contracted in the middle and round at the extremity; while the terminal joints are still doubled upon themselves, and rest folded upon the mouth-parts.

The thorax also resembles that of the pupa, though longer; and the basal ring of the abdomen (propodeum) is still exposed to view when seen from above. At this stage the præscutum of the mesothorax, before very distinct, is no longer seen, as in the pupa it is mostly absorbed and passes out of sight, though in the Tenthredinidæ it is a large and conspicuous portion of the mesonotum.

Most interesting changes have occurred in the hinder part of the thorax. Whereas in the previous stage the mesoscutellum was immersed in the ring to which it belongs, it is now elevated and becomes very prominent; the thorax posteriorly falls rapidly

* It remains yet to be proved whether the biliary tubes, salivary glands, and inner genital glands and cavities form exceptions to this rule.

away from it, at an angle of about 60°, and its hinder edge is much thickened and folded down on itself. The metathorax is entirely visible from above. The scutum is now entirely separated into the two lateral halves, being transversely narrow triangular pieces, the bases of which are square and closely adjoin the insertion of the hind wings, while their apices are much produced and extend under the mesoscutellum. The metascutellum is now distinctly seen to be a linear transverse piece reaching on each side to the middle of each half of the scutum. The basal ring of the abdomen (propodeum, fig. 3 *c*) is now undergoing the process of being transferred from the abdomen to the thorax. Whereas before it was a segment much narrower than those contiguous, it has now become still smaller, and its tergal portion, instead of being nearly horizontal, is now much inclined downwards posteriorly.

The abdomen, though still larger, approaches much nearer the form of the pupal abdomen than before, and the segments are flatter. The second ring has become much contracted, as it is destined to become the "pedicel" or "first abdominal segment" of descriptive entomology. There is now a differentiation of the elements of the ring. Thus the tergites (notum, fig. 3 *f*) are clearly distinguished from the pleurites (fig. 3 *e*, flanks) and *urites* (Lacaze-Duthiers, fig. 3 *d*, ventral side). The spiracles are situated on the upper edge of the pleurites, opening out just under the edge of the tergite. As we go back towards the tip of the abdomen, the tergites as well as the urites decrease in width, while the pleural region or pleurites increase in size. It is the pleural portion, however, which is afterwards to become absorbed, by which the dorsal and ventral portions of the abdomen approximate more intimately and overlap each other, thus making the tip acute, as in the pupa (fig. 4) and especially the perfect bee.

During this time the ovipositor, owing to the diminished size, by absorption, of the parts supporting it, has become gradually more and more retracted, while the entire tip of the abdomen is more acute and incurved.

The Pupa State.

In this stage (fig. 4) the whole body is shorter, and there is a decided transfer of the bulk of the body towards the head. The head has increased in size, the thorax is one-third larger, while the greatly shortened abdomen is a third shorter than in the preceding stage. At this period the longitudinal axis of the body is less curved than before. The mesoscutellum is now placed just in the middle of the body, when before it was situated at the anterior third. This change also carries the wings far back, to the middle of the body, from their previous situation very near the head and on the anterior third of the body. The limbs are greatly enlarged; the tarsi of the hind pair now reach near the tip of the abdomen, whereas before they were simply folded upon the thorax, not reaching to or resting upon the abdomen.

Great changes have occurred in the appendages of the head. The clypeus, labrum, and mandibles are now exposed to view. The antennæ have become straightened and greatly elongated, and a corresponding change has occurred in the maxillæ and labium with its palpi, which now reach to the middle of the abdomen, while the lingua extends as far as the seventh abdominal segment. This stage, therefore, is characterized by important modifications in the size and position of the extremities and appendages of the head, thorax, and abdomen. In the thorax the changes are not especially remarkable. The scutellum is now in contact with the base of the abdomen, as if the whole thorax had been carried backward, and the entire abdomen brought forwards and upwards, due to the absorption of the metathoracic ring and basal ring of the abdomen.

Thus each of the three regions of the body is a centre of development, the gradual perfection of the appendages belonging to each region proceeding from the centre towards the periphery, beginning at the insertion of the limbs to the trunk, and gradually perfecting their development towards the extremity. Hence the wings, the tarsi, or terminal joints of the limbs, and the abdominal appendages are the last to be developed and perfected. The anterior part of the thorax is perfected earlier than the posterior, while in the abdomen the development goes on from behind forwards. Prof. Dana has shown that in the Crustacea the cephalothorax and abdomen are each a distinct centre of development, in which progress reaches to a wider or narrower circumference in different species*. Researches on the embryology of the higher Annelids show that the development of worms proceeds from a single centre†.

At this stage, which may be properly called the pupa state, the eyes begin to turn dark, and a few hairs develope themselves upon the upperside of the abdomen; but the stage is so transitory, that in a long series of individuals it is impossible to select a single individual and denominate it a *pupa*, since there is no

* Introduction to the Crustacea of the U. S. Exploring Expedition, vol. i. p. 22.

† See S. Lovén, K. Vetenskaps-Acad. Handl. 1840 (Wiegmann's Archiv, 1842, part 1). M. Sars, Development of *Polynoë cirrata* (Wiegmann's Archiv, 1845, part 1). Milne-Edwards (Ann. Sc. Nat. 1845).

pause in the metamorphosis for a special biological design, such as obtains in the Lepidoptera and the majority of lower Insects. The terms larva, pupa, and imago are therefore not absolute terms.

Subimago State.

Certain individuals which would upon a casual glance be mistaken for "pupæ" differed so much from what we have called pupæ above, that they may be said to be analogous to the *subimago* state of Ephemeridæ. In this state the arthroderm, owing to the rapid deposition of chitine, is denser and harder; the wings are as large as in the perfect bee, and the joints of the legs are spiny, while the ovipositor has become wholly withdrawn within the walls of the abdomen.

In some specimens, remains of a thin pellicle were found upon the extremities; so that we are neither justified in calling this individual an *imago* nor, on the other hand, a *pupa*. The individuals had not left their cells. Their feet had not yet been used for purposes of locomotion, nor their jaws to assist in making their way out of their cells, while the hairs are nearly concolorous all over the body, though very faintly shaded with yellowish on the dorsal and lateral portion; so that the *species* can be distinguished, as some of the specific characters depending on ornamentation are at this time apparent. We have observed facts indicating three moultings of the skin during the so-called pupa state, in distinction from the *larval* and *imago* states; and it is highly probable that there are more. During the larval condition it would be safe to say that there are *four* distinct moultings, as there are five distinct sizes of larvæ. In some of the eggs the larval forms can be indistinctly seen through the thin walls, which we would homologize with the skin of the insect after birth; for the *fertilized* egg must be regarded as the insect in its inception, in a state equivalent to the larval, pupal, or perfect state of the insect. The genus *Bombus*, therefore, may be considered to undergo a series of at least ten moultings of the skin; and we are inclined to think further observations will tend to increase the number. Lubbock* has described twenty in *Ephemera*; and five have been noticed in several genera, such as *Meloë* and others.

The sexes of the larvæ can be easily distinguished, as the genital armature appears through the transparent skin.

The specific differences between the larvæ of the different species of *Bombus* are of the slightest possible amount, as they only differ in size, the rings of the body being smooth or rough,

* Trans. Linn. Soc. vol. xxiv. part 2 (1863).

and in having more or less clearly defined sutures between the pieces composing the head. The eggs of the different species compared presented no appreciable differences.

In the pupa state, the two sizes of male, female, and workers can be more readily appreciated than in the imago state, as the insects can be more easily measured and comparisons made. Corresponding cases of dimorphism in other insects will probably be studied to great advantage when the insects are observed at this period of life. Between the two sizes of the ♀ in the pupa of *Bombus fervidus* there was a difference of ·05 inch, and in the ♂ ·03 inch. In a number of the worker pupæ of *Bombus separatus* there was a difference of ·04 inch between the two broods of workers, the more advanced brood being smaller, and not only shorter but also narrower.

In this connexion we would present some views relative to a theory of the number of arthromeres composing the head of Insects (*Hexapoda*), and the number and sequence of their appendages, suggested by studies of the larval forms of Hymenoptera, and especially the lower Neuroptera, not omitting insects belonging to other suborders, and some forms of Crustacea. After Savigny had shown that the mouth-parts of Insects and Crustacea were jointed appendages like those attached to the thorax, and therefore repetitions of an ideal jointed limb or appendage, Audouin proved that in the ideal arthromere, of which the bodies of all Articulata are each a congeries arranged in a longitudinal series, the periphery should be distinguished into an upper (*tergite*, Duthiers), lower (*sternite*, Duthiers), and pleural part, and that in the thorax the legs were thrust out between the pleurite and sternite, and the wings grew out between the pleurite and tergite. The arthropleural region is therefore the limb-bearing region of the body, and the different parts of the ideal ring are developed in a degree subordinate to the uses of the limbs and wings. Thus in the walkers, such as the Carabidæ, the pleural and tergal regions are most developed; while in those insects, such as the Dragonflies, which are constantly on the wing, and rarely walk, the pleural region is enormously developed, and the tergites and sternites attain to their minimum development. The muscles used in flight are greatly increased in size over the atrophied muscles brought into requisition by the act of walking. In the Hymenoptera, however, which are both walkers and fliers, the three portions of the ring are most equally developed.

These parts of the arthromere are simplest in the abdomen, and become more differentiated in the thorax, where the numerous pieces composing them have been classified and named, mostly by Audouin, M'Leay, and Lacaze-Duthiers. Scarcely an attempt has been made to trace these parts in the rings of the head by those who have proposed theories of the number of arthromeres in the head of insects.

As we can understand the structure of the thorax better after studying the abdomen, so we can only homologize the different head-pieces after a careful study of the thorax of Insects and the cephalothorax of Crustacea, which thus afford us a standard of comparison.

Since the arthropleural is the limb-bearing region in the thorax, it must follow that this region is largely developed in the head, to the bulk of which the sensory and appended digestive organs bear so large a proportion; and as all the parts of the head are subordinated in their development to that of the appendages of which they form the support, it must follow logically that the larger portion of the body of the head is pleural, and that the tergal and, especially, the sternal parts are either very slightly developed or wholly obsolescent. Such we find to be the fact. As to the number of rings composing the head, it is evident that it is correlated with the number of appendages they are to support. Hence, as in the thorax there are three rings bearing three pairs of appendages or legs, it follows that in the head, where there are seven pairs of appendages, there must be seven rings. That there are seven such appendages, among which we would include the eyes, which, if not homologous with the limbs, or, more properly speaking, repetitions of the ideal appendage, are at least their equivalents, in that they are situated on a distinct ring, as are the ocelli, which are exact equivalents or repetitions of the eye, is evident.

The larvæ of *Ephemera* and *Libellula*, in the head of which these parts of the cephalic rings, by reason of the degradational character of the insects, appear in their simplest forms, afford us the best material for study. In the head of the larva of *Libellula* we have observed that the greatly elongated labium, masking, when at rest, the mandibles, is in reality composed of three *sternites*, immersed in and surrounded by three *pleurites*, all bearing appendages, the basal pair being the mandibles, the middle pair maxillæ, and thirdly, the pair of labial palpi, all of which are placed behind the mouth-opening. Beyond and in front of the mouth are successively placed the sensory organs, the antennæ, the pair of eyes, and what we must consider two pairs of ocelli, since the early forms of *Ephemera* and the early stages of *Bombus* show the three ocelli resting on three separate pieces, the two posterior pieces (*pleurites*) forming a pair, while the single ocellus in advance is placed on a triangular piece which we regard as two pleurites united on the median line of the body, as the ocellus has a double form, being broad, transversely ovate, and not round, as if resulting from the fusion of two originally distinct ocelli.

The antennæ*, by their form and position, naturally succeed the labial palpi. Considering how invariably in the Crustacea the eyes are situated in front of the gnathopods, we feel convinced that the same position must be allowed them in the head of insects. This will bring the ocelli most in advance of all the other appendages. The bulk of the head of insects must, then, be formed by the great expansion of the eye-pleurites, which, so to speak, are drawn back like a hood over the basal rings, while the rings bearing the maxillæ and labial palpi and the antennary ring are thrust out, telescope-like, through the large swollen eye-ring; as in Decapods, a single ring covers in the aborted ring composing the rest of the cephalothorax, as Edwards and Dana have shown, and our investigations have taught us. Thus the upper surface of the head is composed of expansions of the pleural pieces of the ideal arthromere, which never developes the sternal nor probably the tergal portions in front of the mouth. Thus each region of the insectean body is characterized by the relative development of the three elements of the arthromere. In the abdomen the upper (tergite) and under (sternite) surfaces are most equally developed, while the pleural line is reduced to a minimum. In the thorax the pleural region is much more developed, either quite as much as or often more than the upper or tergal portion, while the sternite is reduced to a minimum. In the head the pleurites form the main bulk of the region, the sternites are reduced to a minimum, and the tergites are almost entirely aborted, or may perhaps be identified in the centre of the "occiput," or what is probably the mandibular (or mandible-bearing) ring, and in the "clypeus."

In the abdomen the same abolescence of parts strikingly exemplifies what may be called the law of systolic growth, where certain parts of the zoological elements of a body are in the course of development either greatly enlarged over adjoining parts or become wholly obsolete, as stated by Audouin and St. Hilaire, who ascribed it to the principle of "arrest of development," which is now used by physiologists in a more limited sense. While, as we have shown above, the genital armature of insects is not homologous with the limbs, there are, however,

* Repeated observations have taught us that the idea advanced by Zaddach (Untersuchungen über die Entwickelung und den Bau der Gliederthiere) and adopted by Claparède (Recherches sur l'Évolution des Araignées), that the antennæ of the larvæ are not homologous with those of the perfect insects, is untenable. In the larvæ of all Hymenoptera and numerous families of Lepidoptera and Neuroptera they are identical in position in all stages of development.

true jointed appendages attached to the ninth or tenth abdominal rings or both, which are often antenniform, and serve as sensorio-genital organs in most Neuroptera and Orthoptera. The abdominal rings are confined, as a rule, to the two lower suborders of Insects, and are homologous with the "false legs" of the larvæ of Lepidoptera, the abdominal legs of Myriapoda, and, we believe, with the three pairs of abdominal appendages or spinnerets of the Arachnids. As in the most anterior rings of the head, so in the terminal abdominal rings, there only remain minute portions of the arthromere, which are tergal pieces, the other two elements of the ring being rarely present, or entirely aborted. The two opposite poles of the body are therefore fashioned according to the same laws, and are morphologically simply repetitions of each other.

In conclusion, we consider that twenty rings (arthromeres), as a rule, compose the bodies of insects, of which seven are contained in the head, three in the thorax, and ten in the abdomen, and that, as thus grouped, forming three distinct regions, the Insects differ from all other Articulates, standing as a class above the Crustacea and Worms. The Arachnids and Myriapods, as Mr. Scudder* has shown, agree with the Insects in possessing a distinct head separated from the thorax or "pseudocephalothorax;" so that the Myriapoda do not form a class by themselves equivalent to the Crustacea, or Worms, or Insects, but, with Leuckart, Agassiz, and Dana, we would prefer to rank them as an order of the class Insects†.

In a former communication‡ we proposed a classification of Insects into two series of suborders (not, however, agreeing with the Haustellata and Mandibulata of Clairville), of which the lower begins with the Neuroptera, and, through the Orthoptera and Hemiptera, culminate in the Coleoptera; while the second series ranks higher as a whole, beginning with the Diptera and ending with the Hymenoptera, which thus stand at the head of the Articulata. The Hymenoptera differ from all other insects in having the basal ring of the abdomen thrown forward upon

* Proc. Bost. Nat. Hist. Soc. vol. ix. p. 69, May 1862.

† The embryology of Arachnids, as worked out by Claparède, shows that the larva is strikingly worm-like, distinct rings ("protozoonites") appearing before the biregional Arachnid form is assumed. The embryos of two genera of mites, *Demodex* and *Acarus*, are at first hexapodous, as Newport has shown that of *Julus*, a Myriapod, to be. The close homologies of the Arachnids and Myriapods with the Insects (Hexapoda) convince us that the three groups, whether we call them orders or classes, are as a whole equivalent to the Crustacea or Worms.

‡ "Synthetic Types of Insects" (Bost. Journ. Nat. Hist. vii. 1863); "How to observe and collect Insects" (Second Annual Report of Maine State Survey, 1863).

the thorax; in having the three regions of the body more distinctly marked and more equally developed than in other insects. The mouth-parts are more equally developed, and at the same time more differentiated in structure and function; there are no abdominal jointed appendages present in the adult form, while the external generative organs are more symmetrically developed and more completely enclosed within the abdomen in the highest families than in any other suborder of Insects. They afford the highest types of Articulates, being more compact, less loosely put together, and thus presenting less of degradational features than any of the other suborders; but the most valuable *single* character is the transfer of the first abdominal ring forwards to the adjoining region, which involves an entire remodelling of the body, throwing *forwards* the prime elements of the organism, by which it becomes more cephalized, and thus the nervous power is rendered more centralized than in all other Articulates.

Selecting the Honey-bee as the type, being, in our view, the most perfectly organized of all insects, we find the head larger and the abdomen smaller in proportion than in other insects, accompanied with the most equable and compact development of the parts composing these regions. The brain-ganglia are largest and most developed, according to the studies of entomotomists. The larvæ, in their general form, are more unlike the adult insects than in any other suborder of Insects, while the pupæ most closely approximate to the imago. They are short, cylindrical, footless, worm-like grubs, which are helpless, and have to be fed by the prevision of the parents. In undergoing a more complete metamorphosis than any other insects, in the unusual differentiation of the sex into males and females and sterile females or workers, with a further dimorphism of these three sexual forms and a consequent subdivision of labour among them—in dwelling in large colonies, thus involving new and intricate relations between the individuals of the species and other insects—their wonderful instincts, their living on the sweets and pollen of flowers, and not being carnivorous in their habits as are the Neuroptera and a large proportion of the Orthoptera, Hemiptera, Coleoptera, and Diptera, and their relation to man as a domestic animal subservient to his wants,—the bees, and Hymenoptera in general, possess a combination of characters which are not found existing in any other suborder of Insects, and which we must believe rank them first and highest in the insect series.

Likewise the Hymenoptera are more purely terrestrial insects than all others. The Neuroptera are, as a whole, water-insects: their larvæ live in the water, and the perfect insects live near streams and pools. The Orthoptera are more terrestrial. Among the Hemiptera are numerous aquatic species, as there are in all the other suborders except the Hymenoptera, of which only two genera are found swimming, in the adult state, on the surface of pools; and they are the low minute Proctotrupids, *Prestwichia natans* and *Polynema natans*, Lubbock. As we have previously shown, the Hymenoptera do not imitate or mimic the forms of other insects, but, on the contrary, their forms are extensively copied, in the Lepidoptera and Diptera especially. There are synthetic types or mimetic forms which bind these suborders into a single series. As the Coleoptera, Hemiptera, Orthoptera, and Neuroptera are bound together by homomorphous or mimetic forms into a series by themselves, so the Hymenoptera, Lepidoptera, and Diptera possess their synthetic types linking them together.

Another and very accurate method of determining the relative rank of the larger groups in nature is by comparing the degradational forms occurring in each group. Among the Neuroptera the lowest wingless forms, such as *Lepisma* and allies, most strikingly resemble the Myriapods in the great equality in size of the arthromeres composing the body, and the slight distinctions preserved between the three regions into which the body is divided. The largest, most vegetative, monstrous, and bizarre forms of insects are found among the Neuroptera and Orthoptera. Among Hemiptera the parasitic wingless lice, and among Coleoptera the low *Meloë* and Stylopidæ, afford instances of a genuine complete parasitism such as obtains more fully among the low Crustacea and worms. While we find the degraded types of Insects belonging to the lower series of suborders present elongated, worm-like, myriapodous forms, in ascending to the second and higher series of suborders, the lowest wingless dipterous *Pulex* assumes a much compacter, more cephalized form; while in the wingless *Chionea*, which wonderfully mimics the higher Arachnids, there is a still greater concentration of the arthromeres. This concentration of the body progresses towards a higher type in the degradational forms of the Lepidoptera, such as the wingless females of *Orgyia*, *Anisopteryx*, and *Hybernia*. In ascending to the wingless Hymenoptera, such as *Pezomachus*, *Formica*, and *Mutilla*, there is a closer approximation to the winged normal form of the suborder. While in the lower Insects the loss of wings involves apparently a total change in the form of the body, in the Hymenoptera this change is remarkably less than in any other insects, and the tripartite form of the insectean body is more strongly adhered to.

Again, in the degradational winged forms of the Hymenoptera we find the antennæ rarely pectinated—a common occurrence in the lower suborders; also the wings of the minute Proctotrupidæ are rarely fissured, and when this occurs they somewhat resemble those of *Pterophorus,* the lowest Lepidoptera ; and in but a single hymenopterous genus, *Anthophorabia,* are the eyes in the male sex replaced by simple ocelli, like those in *Lepisma* and other degradational forms of the lower Insects.

What we know of the geological range of Insects proves that the Hymenoptera were among the last to appear upon the earth's surface. The researches of Messrs. Hartt and Scudder prove that the earliest known forms of insects found in the Devonian rocks of New Brunswick were gigantic, embryonic, and, in fine, degradational types of Neuropterous and Orthopterous insects. The Coleoptera appear in the Mesozoic rocks, where the lower Hymenoptera first appear in limited numbers, including representatives of the Formicidæ and lower families, and with them the Lepidoptera and Diptera.

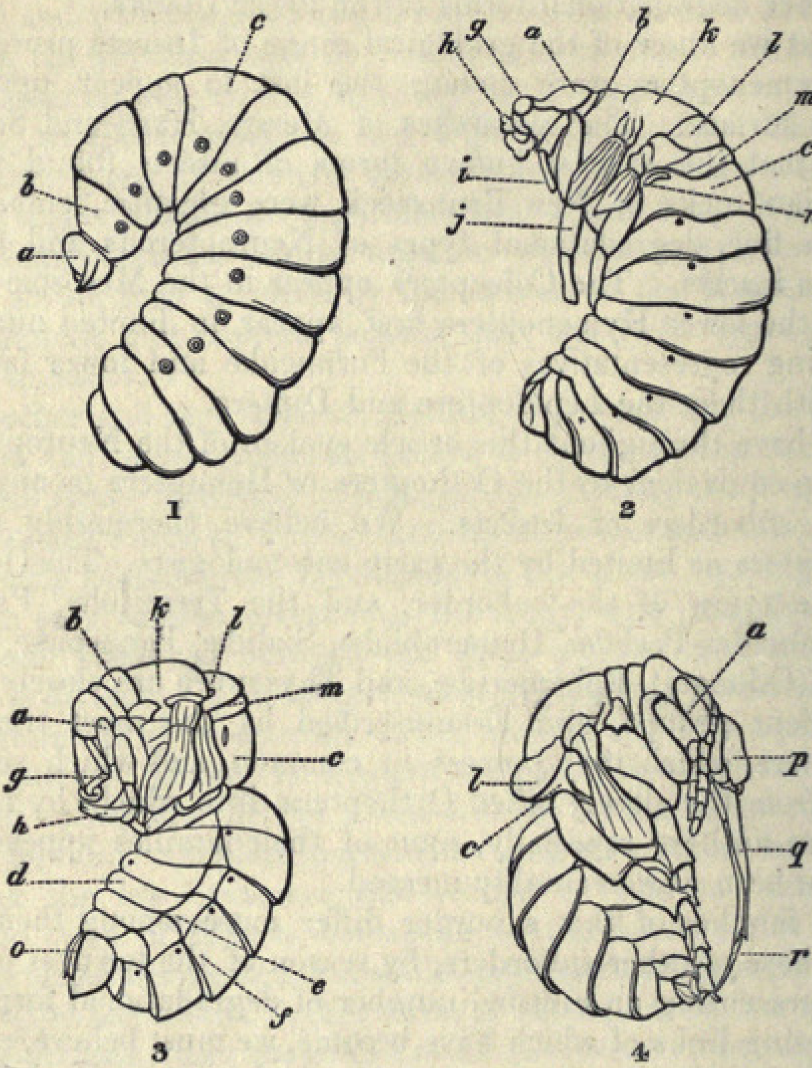
We have throughout this article spoken of the Neuroptera as a group equivalent to the Orthoptera or Hemiptera or any other of the suborders of Insects. We believe thoroughly in the Neuroptera as limited by the early entomologists. The Odonata are the types of the suborder, and the Termitidæ, Psocidæ, Phryganeidæ, Perlidæ, Hemerobiidæ, Sialidæ, Panorpidæ, Libellulidæ (Odonata), Ephemeridæ, and Thysanura are closely interdependent groups, and circumscribed by the most trenchant characters, which they possess in common, and which separate them from the closely allied Orthoptera, into which, by modern German authors especially, some of their families appear to us to have been unwarrantably merged.

The families of this suborder differ more among themselves than those of other suborders, by reason of the lowness of their type, presenting an unusual number of degradational forms, the connecting links of which have become, we must believe, extinct. The Neuroptera are moreover true synthetic types, combining, as do all decephalized embryonic forms, the structure of several equivalent groups, presenting features which remind us of characters more fully wrought out in higher and more compactly finished groups of Insects.

DESCRIPTIONS OF THE FIGURES.

Fig. 1. *Bombus fervidus.* The first stage of the semipupa, concealed by the larval skin. The semipupa head lies under the head (*a*) and and the prothoracic ring (*b*,. The basal ring of the abdomen (*c*), or fourth ring from the head, is unchanged in form. This figure also will suffice to represent the larva, though a little more produced anteriorly than in its natural form.

Fig. 2. *Bombus fervidus.* The second stage of the semipupa. The larval skin entirely sloughed off, the two pairs of wing-pads lying parallel, and very equal in size, like the wings of Neuroptera, the thoraco-abdominal ring, or propodeum (*c*), with its oblong spiracle (*n*), essentially differing from those on the abdomen. At this point the body contracts; but the head and thorax together are yet, as still more in the previous stage, much smaller



than in the pupa, and there is still a continuous curve from the tip of the abdomen to the head. *g*, antenna; *h*, lingua and maxillæ and palpi; *i*, fore legs; *j*, middle legs; *k*, mesoscutum; *l*, mesoscutellum; *m*, metascutellum; *n*, spiracle of the propodeum.

Fig. 3. *Bombus fervidus*. The third stage of the semipupa. The head and thorax together now nearly equal in size the abdomen; the propodeum (*c*) has become entirely transferred to the thorax. The head has become greatly enlarged; the wings are very unequal, the hinder pair are much smaller, and overlain by the anterior pair; the three terminal pairs of abdominal rings, so large in fig. 2, have been absorbed, and partially enclosed in the cavity of the abdomen; and there has been a further differentiation of the ring into the sternite (*d*), pleurite (*e*), and tergite (*f*). *a*, eye; *h*, lingua; *o*, ovipositor, two outer rhabdites exposed to view. The abdominal spiracles in figs. 2 and 3 are represented by a row of dots. In the pupa (fig. 4) they are concealed by the tergites.

Fig. 4. *Bombus fervidus.* The pupa state, where the body has become much shorter, the appendages of the head and thorax greatly differentiated, the external genital organs wholly retracted within the cavity of the abdomen, the head freer from the body, and the whole bulk of the head and thorax together, including the appendages, greater than that of the abdomen. *c*, the propodeum, nearly concealed in a side view; *p*, labrum; *q*, maxillæ, with the two-jointed palpi at the extremity; *r*, tip of the lingua.

XVI.—*On some Cetaceans.* By Hermann Burmeister.

(*From a Letter to Dr. J. E. Gray.*)

[Plate IX.]

The Museum has received another new species of Cetacea since my letter; it is a new *Orca*, which I name *O. magellanica*, and now send a figure of the skull with a description. The species is nearest to *O. capensis*, but more slender and different in many respects, as you will find by comparing my figure and description. The animal was found on the shore, near the mouth of the small river called "Arroyo de Cristiano muerto," in S. lat. 38° 50′, and was in a perfect state of preservation; but, by the negligence of the people who found it, the whole skeleton was lost, with the exception of the skull and two vertebræ (one dorsal, one caudal) which have come into my hands.

From your Catalogue I learn that you do not know the skull of the adult Sea-Lion or that of *Arctocephalus Falklandicus*. We have both in the Museum, these two species being the only ones which are found in the Atlantic, near the mouth of the Rio de la Plata. They were formerly very common on the small islands north of the mouth of the river, named from them "Islas de los lobos," *lobo marino* (sea-wolf) being the Spanish name for a Seal; and not unfrequently they come into the mouth of the river even as far as Buenos Ayres, where I have already twice seen full-grown living specimens of *Arctocephalus Falklandicus*. Both of these were, I believe, carried to France; but perhaps they died on the voyage. They were kept here for a long time in a large basin of fresh water; and I was one of the daily visitors to these very interesting animals*.

We have in the Museum a young half-grown specimen nearly 3 feet in length. From this I have taken the skull, of which I now send you a description and drawings (Pl. IX. fig. 1 from above, and fig. 2 from the side, one-half natural size; fig. 3, end of the palatine bones, natural size; and fig. 4, some teeth, seen from the inside, also natural size. The numbers indicate the

* I have no doubt it is one of these that is now alive in the Zoological Gardens in the Regent's Park.—J. E. G.

Packard, A. S. 1866. "XV.—Observations on the development and position of the Hymenoptera, with notes on the morphology of insects." *The Annals and magazine of natural history; zoology, botany, and geology* 18, 82–99.

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