SECTION II.

ZOÖLOGY.

A MONOGRAPH OF THE PHYLLOPOD CRUSTACEA OF NORTH AMERICA, WITH REMARKS ON THE ORDER PHYLLOCARIDA.

BY A. S. PACKARD, JR.

PLATES I—XXXVIII.

CONTENTS.

The Phyllopods constitute a division or suborder of the *Branchiopoda*, an order of Neocaridous Crustacea, intermediate between the *Entomostraca* (represented by the Copepoda and parasitic forms or fish-lice) and the Malacostracous Crustacea (Tetradecapoda and Decapoda). They inhabit fresh water alone, in a few cases brackish water or strong brine, but none dwell in the sea.

The Phyllopod Crustacea are especially characteristic of the western plains of our Territories, where the most striking and typical forms abound, one entire family (*Apodidæ*) not occurring east of the western edge of the Mississippi Valley, while the most bizarre member of the entire group, the Thamnocephalus, lives in pools on the plains of Kansas.

These Crustacea are of singular beauty and interest in themselves. The outlines of the *Branchipodidæ* are interesting, and their movements while swimming on their backs are singularly graceful. Moreover, when we consider the habits of all the Phyllopods; their singular means of adaptation to great changes in their environment; the great vitality of the species; when we take into account their weak and delicate individual organization, and when we note their interesting metamorphoses and many points in their structure, we are forced to conclude that the Phyllopods are the most interesting of all the Crustacea.

The materials for this monographic account of a most interesting group of Crustacea have been accumulating for over ten years.

My collection has consisted of specimens obtained by the various government surveys and sent to the Smithsonian Institution, and received from the late Dr. Stimpson, secretary of the Chicago Academy of Science, shortly before the fire which destroyed the museum of the academy. A large and very valuable collection was made for me by Dr. L. Watson, of Ellis, Kans., while a very valuable collection from Fort Wallace, Kansas, has been kindly loaned me by Prof. Joshua Lindahl, of Augustana College, Rock Island, Ill. I am also indebted to the Peabody Academy of Science, Salem; the Museum of Comparative Zoology at Cambridge, for the loan of specimens, as well as to the Museum of Yale College; and to Dr. C. F. Gissler, Mr. W. P. Seal, Mr. S. A. Forbes, Prof. A. E. Verrill, Mr. Edward Burgess, Dr. E. Coues; acknowledgments of whose valuable aid are made in their appropriate places.

In the following pages I have touched upon some points in the internal anatomy of these interesting Crustacea, and only regret that want of time has prevented me from entering more into detail. For a number of microscopic slides of Branchipus, Thamnocephalus, Estheria, &c., I am much indebted to the friendly aid and skill of Norman N. Mason, esq., of Providence, R. I.

I desire also to express my thanks to Prof. F. V. Hayden, for the kind interest which he has taken in this work, and for the liberal number of plates with which the essay has been illustrated.

The chapter on the development of the young of *Apus lucasanus* and *Streptocephalus texanus* has been contributed by Dr. C. F. Gissler, of Brooklyn, N. Y., who made the drawings which illustrate the text, and also those composing Plates XXXIV and XXXV. A number of the drawings of the entire animal of the species of Apus and Lepidurus, &c., were made by Mr. J. H. Emerton; some anatomical drawings in the plates were prepared by Mr. J. S. Kingley, while I am under obligations to Mr. Edward Burgess for the masterly manner in which he has executed the difficult sketches of the animals of *Limnetis brevifrons*, Estheria of several species, Eulimnadia, and *Branchipus vernalis*.

I. CLASSIFICATION OF THE LIVING PHYLLOPODA.

HISTORY OF THE SUBORDER PHYLLOPODA.

The history of this group is an interesting one. Originally mentioned in 1785, by O. F. Müller, in his "*Entomostraca seu Insecta testacea*," the Entomostraca were first defined in 1806, by Latreille, in his *Genera Crustaceorum*, &c. Under *Legio prima*, *Entomostraca*, the *Phyllopoda* constituted the third order, the sole representative of this order being *Apus*, while the genus *Branchiopoda* (Branchipus of Schoeffer) forms part of a sixth order, *Cephalota*. The other genera of Phyllopods were not then known.

In 1820, Brongniart proposed the genus *Limnadia* for Hermann's *Daphnia gigas* (1804).

Meanwhile in 1817, in the first edition of Cuvier's Règne Animal, the order *Branchiopoda* was proposed by Latreille, while the classification of this order was further amended and improved in the second edition of this work (1829). In this edition the *Phyllopoda* constitute the second suborder of the *Branchiopoda*, and now the Phyllopods comprise the genera *Limnadia*, *Branchipus*, *Artemia*, and *Apus*.

In 1837, Straus-Durckheim described the genus *Estheria*, of which *Cyzicus* of Audouin (1837) and *Isaura* Joly (1842) are synonyms. The genus *Limnetis* was described by Lovén in 1845.

In 1840, Milne-Edwards, in his Histoire Naturelle des Crustaces, established the Legion Branchiopodes, equivalent to the Entomostraces. Under the Branchiopoda he regards the *Phyllopoda* as forming an order, and they are succeeded by the *Cladocera*, while the Legion of *Entomostraca* comprises the *Ostracoda* and *Copepoda*.

In 1853, Prof. J. D. Dana, in the Crustacea of the United States Exploring Expedition, regarded the *Phyllopoda* as constituting the second Legion of his first order (*Gnathostomata*) of Entomostraca.

In 1863, Gerstaecker regarded the *Phyllopoda* as forming a family of the order *Branchiopoda*, the *Trilobita*, *Cladocera*, and *Ostracoda*, forming the remaining families. Claus, in 1868 (Grundzüge der Zoologie), divided his order *Phyllopoda* into two suborders, *Cladocera* and *Branchiopoda*. Gerstaecker in Bronn's Classen und Ordnungen Arthropoden, 1866–'79, adopts the order *Branchiopoda*, and divides it into three suborders, *Ostracodea*, *Branchiopoda genuina*, comprising the *Cladocera*, *Phyllopoda* of other authors, and the *Branchiura* (Argulus, &c.).

In 1879 the writer, in his "Zoology for Colleges," adopted the order *Branchiopoda*, with three suborders, viz, *Ostracoda*, *Cladocera*, and *Phyllopoda*.

Suborder PHYLLOPODA.

In this group the body is usually (the *Branchipodidæ* excepted) in part covered by a large carapace (the mandibular segment greatly developed tergally), which is in the lower forms (*Limnadiacea*) bent down, forming two valves, connected by a true hinge, and opening and shutting by an adductor muscle, so that the shell resembles that of a bivalve mollusc, such as the fresh-water *Cyclas* and *Pisidium*. They have two pairs of antennæ, a pair of mandibles, and two pairs of maxillæ, and in *Apodidæ* a pair of maxillipedes. The name of the group, *Phyllopoda*, is applied to them on account of the feet, which are broad and leaf-like, with a series of six primary inner lobes or endites and two exites, the latter forming a gill and accessory gill or flabellum. The abdomen is not clearly differentiated from the thorax, and the abdominal feet are not different in shape from the thoracic appendages. The number of body-segments varies more than in any other group of genuine Crustacea, there being seventeen in Limnetis and sixty-nine in Apus, or over three times as many as in the lobster or Decapods in general; the segments are thus often irrelatively repeated, a sign of inferiority. The eyes are either sessile and united into a single mass, or, in the highest family (*Branchipodidæ*), they become stalked, thus anticipating the stalked eyes of the Decapoda. The telson is usually large and spiny, bearing in all the genera a pair of caudal appendages probably homologous with the limbs.

All the members of the suborder hatch from the egg in the *Nauplius* form, like that of the Copepod Crustacea, with some differences, all having three pairs of appendages corresponding to the two pairs of antennæ and mandibles of the adult.

The species for the most part live in pools of fresh water liable to dry up in summer; those of Artemia live in brine pools and lakes. The eggs, after being fertilized and borne about for a time under the shell or in egg-sacs, are finally suffered to drop to the bottom of the pond; here they lie after the water of the pond has evaporated, the eggs remaining in the dry mud until, the ponds having been refilled by the autumn rains, the young hatch out and the cycle of life begins anew.

Family I. LIMNADIADÆ Baird.

Limnadiadæ Baird, Proc. Zool. Soc. London, XVII, 86, 1849; Ann. & Mag. Nat. Hist. 2d Ser. XIV, 229, 1854.

Estheriadæ Packard, Hayden's U. S. Geol. Surv. Ter., for 1873, 618. 1874.

Body inclosed in a bivalved shell; head usually with a large rostrum; eyes compressed, small, sessile, closely contiguous or united. 1st antennæ minute, 3-jointed or multiarticulate, the segments not being well marked; 2d antennæ large, with two flagella, each consisting of from 9 to 20 joints. A pair of mandibles; one or two pairs of maxillæ; 10 to 27 pairs of swimming phyllopod feet, each with six lobular endites, and a gill and flabellum divided into two divisions, the upper in the female keeping the eggs in place. 1st (Limnetis), or usually the 1st and 2d, pair of feet in the male provided with a hand; the 4th, 5th, and 6th endites modified to form a claw, finger, and thumb-like clasping organs. Posterior segments each bearing a pair of spines; the telson large, compressed, often spined, and bearing a pair of caudal appendages. Larvæ nauplius-shaped.

Subfamily LIMNETINÆ Packard.

Shell nearly spherical, with no lines of growth; rostrum very large and broad at the end, mucronate in the females, broad and truncate in the males; 10–12 pairs of feet; in the males only the 1st pair provided with a hand; terminal segments of the body not spined; telson undeveloped.

But a single genus, *Limnetis.*

Genus LIMNETIS Lovén.

Limnetis Lovén, Kongl. Vet. Akad. Handlingar, Tab. IV, 203, 1845; Ofversigt Vet. Akad. Förhandl. 57, 1846; Wiegmann's Archiv, II, 203, 1847.

Hedessa Lievin, Neueste Schrift. der naturf. Gesellsch. in Danzig, IV, Heft II, 4. Tab., I, II.

Hedessa Siebold, Neueste Preuss. Provincialbl. VII (XLI), Heft 3, 198, 1849.

Carapace bivalved, nearly spherical, oval, smooth; polished fine puncture-like marks in the parenchyma of the shell, giving it the appearance of being finely punctured; no beaks or umbones. Head large, the front bearing the eyes enormous, and produced into a very large rostrum, either truncated in ♀ and either mucronated or truncated in ♂ in front. Eyes small, sometimes separate. First antennæ minute, slightly elbowed, with indications of three joints; second antennæ with scape or base rather short; the flagella rather short, composed of from 15 to 21 joints, with remarkably long setæ. From 11 to 12 pairs of feet; in the males the anterior pair converted into a complicated hand; the end of the abdomen blunt, simple, with no spines.

The species of this genus are readily recognized by the spherical small, smooth shell, with no lines of growth, entirely inclosing the animal; by the enormous head, the large broad rostrum; the few feet, there being but one pair of hands in the males, instead of two, as in *Estheria*, and by the simple unarmed telson. The antennæ are shorter and thicker than in *Estheria.* They are sometimes mistaken by shell collectors for specimens of Cyclas or Pisidium. They swim on their backs, with the shell a little open, in a graceful but not very rapid manner compared with the Ostracoda.

Synopsis of the species.

Shell subspherical, small, front of head of male narrow; second antennæ 16-jointed; flabellum very large...... *L. gouldii.*

Shell large, suboval; front of male broad and square; second antennæ 14 and 17-jointed; flabellum remarkably narrow .... *L. mucronatus.*

Shell large, suboval; front broader than in any other species except *gracilicornis;* antennæ 20-jointed; gill very large, flabellum short and broad..................... *L. brevifrons.*

Shell small, subspherical; front very broad; antennæ long, 20-jointed .... *L. gracilicornis.*

LIMNETIS GOULDII Baird.

Plates II, Figs. 1–6; XXIX, Fig. 9.

Limnetis gouldii Baird, Annals and Mag. Nat. Hist., 3d ser., vol. x, 393, 1862.

Shell smooth, spherical, quite round, not often oval as in the two succeeding species, and of a uniformly smaller size. 1st antennæ very slender, not so broad at the end as in *L. brevifrons*. 2d antennæ with the stem longer and slenderer than in the two following species; the upper flagellum 16, the lower 16-jointed, with longer setæ than in the other species. First leg of female with a very large, long, and broad flabellum (*br′*), the posterior division (*br″*) very long and slender, closely resembling the 6th endite, but considerably longer; the gill rather small. The coxal lobe (1st endite) rather broad and not so long as in the two other species; the hand is much slenderer, and the claw (6th endite) is longer and slenderer than in *L. mucronatus*; in the male the coxal lobe is considerably smaller and more triangular and acute than in the two other species; the comb, or 4th endite (l^4) is armed on the edge with an inner row of small and a marginal row of much larger digitate setiferous processes; the finger (l^5) is of moderate size, and the claw-like 6th endite is long and slender; the flabellum (*br*) is about twice the size of the gill; and its posterior process (*br″*) is long, narrow, extending only a little beyond the base of the 6th endite. The front in the male (Fig. 3 *d*, in text) is truncated, but contracts below the eyes more than in the other species; while the carina on the front of the head is unusually high. In the female the rostrum ends in a sharp point, with lateral acute angles much as in sharply mucronate specimens of *L. mucronatus*.

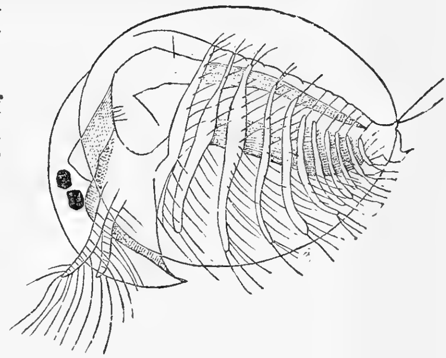

FIG. 1.—*Limnetis gouldii*, enlarged. Burgess del. 1st antennæ not drawn.

Length of the shell, 3mm; breadth, $2\frac{3}{5}$mm.

The species was first discovered in "fresh water at St. Ann's, twenty miles from Montreal, Canada." Collected by Charles Gould, esq., June, 1857 (Brit. Mus., W. Baird). The young received from Hanover, N. H. Near Boston, Mass. (Edward Burgess); near Providence, R. I., in great abundance in a pond which dried up in midsummer, occurring during May, and for at least a month after *Branchipus vernalis* had disappeared from the pond (A. S. Packard, jr., and H. C. Bumpus); abundant in a pond at Glendale, Long Island, in March and April (Dr. C. F. Gissler); Normal, Ill. (S. A. Forbes); Rock Island, Ill. (W. H. Pratt, Davenport Academy).

This is our most abundant species, and appears to range over New England, Canada, westward to the Mississippi River at Rock Island, Ill. It is distinguished from the two other species by the more spherical shell, its smaller size, the rather narrow, contracted front of the male, and by the differences in the antennæ and legs indicated in Plate II.

We have kept these beautiful little phyllopods in confinement from early in May until the middle of July, with few changes of water;

they appear to be very hardy compared with the Branchipodidæ. The animals are pale flesh-colored, with black eyes, and are tolerably rapid in their movements, swimming often on their backs and rapidly gathering the vegetation at the surface with their antennæ and either their coxal lobes or jaws. The eggs are carried upon the back under the shell, and are found in the spring.

We have received numbers of the cast shells of the larva or nauplius from a correspondent at Hanover, N. H. The carapace bears a close resemblance to that of the nauplius of the European *L. brachyura*, having the lateral front spines and two small caudal spines.

LIMNETIS MUCRONATUS Packard.

Plate I, figs. 1–6. (In fig. 1 the 1st antennæ are not represented by the artist.)

Limnetis mucronatus Pack., American Naturalist, ix, 312, 1875.
Bulletin Hayden's U. S. Geological and Geog. Survey, iii, No. 1, 172, 1877.

Male.—Carapace much flattened, oval-triangular, the dorsal edge of the valve but slightly curved, the posterior end well rounded, while the front end is but slightly curved. Head in front truncate, much as in the males of *L. gouldii* and *gracilicornis*, the end being broad and square. Hand large, a little longer than broad, with the claw large, and as long as the hand is broad; the lower edge of the hand (or 4th endite) armed much as in *L. gouldii.* There are twelve pairs of limbs, the twelfth ending in a pair of large, strong, recurved hooks. The end of the terminal segment on its ventral side is rather more produced, and with a more conspicuous spine than in the female. Two males occurred among forty-four females.

The length of carapace, 4^{mm}; breadth, 3.2^{mm}.

Female.—Carapace scarcely distinguishable from that of *L. gracilicornis* in outline, though it varies slightly in form, some being quite round and regular, others slightly ovate, and some quite flat and triangular. Muscular impression as in *L. gracilicornis*, but the muscular impression is much broader and proportionately shorter than in *L. gracilicornis*, where the front of the head is suddenly truncate, and wider at the extremity than behind in *gouldii;* while in *gracilicornis* it is also truncate, but does not contract so much in front of the eyes, the narrowest point being between the eyes and the end of the front. In the present species, however, the front is very much produced into a long, acute, mucronate point, with two teeth on each side, the middle tooth varying much in length. The carina is very high and sharp (see *a* in Fig. 3 in text). 2d antennæ with the second joint half as long as the basal; the four succeeding joints very close, and together not as long as the succeeding seventh joint, from which arises the flagellum, the upper branch of which is 14–15-jointed, the lower one 17-jointed, with ciliated hairs about as long as in *L. mucronatus*, the longest ones as long as the entire antenna. Twelve pairs of feet.

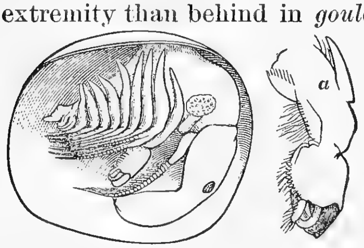

FIG. 2.—*Lymnetis mucronatus*, male; *a*, claw; both enlarged. 1st antennæ not drawn. Emerton del.

The feet have a very long and slender flabellum, the gill being either in the first pair short and rounded at the end, or in the second and succeeding ones long and pyriform, being about the same shape and size as in *L. gouldii;* the filiform lower end (Pl. I, Fig. 4, *br.*) is much shorter than in *L. gouldii*, and endites 4–6 are also much shorter; while the coxal lobe is large and very long.

End of the body blunt, squarely docked, the point blunter than in *L. gouldii*, and ending in a slender spine. Two dorsal terminal filaments, much as in *L. gouldii.*

Length of carapace, or shell, 4^{mm}; breadth, 3^{mm}. Forty-four females, nearly all with eggs, occurred with *Lepidurus couesii*, in pools on the west bank of Frenchman's River, Montana, 49° N. (Dr. Coues.) It also occurred in large numbers associated with *Limnetis brevifrons* in pools at Ellis, Kans., collected by Dr. L. Watson June 29, 1874. The specimens were females with eggs, and as a rule were triangular in outline, compressed, only one or two of the Montana examples being so much compressed. The species is easily recognized by the mucronate, tridentate front, the short, thick hand and claw, by the number of antennal joints, and the long, narrow flabellum, the short endites 4–6, and by the long, stout, jaw-like coxal lobes.

LIMNETIS BREVIFRONS Packard.

Plate XXVII, figs. 1–3.

Limnetis brevifrons Packard. Bulletin of Hayden's U. S. Geol. and Geogr. Surv., iii, No. 1, 172, April 9, 1877.

Many females. Carapace decidedly triangular in outline, more so than in *L. gouldii*, while it differs very decidedly in this respect from *gracilicornis*, and is considerably larger than *gracilicornis* or *mucronatus*, and is flatter than both. Front shorter and broader than usual; less contracted in width at the base of the antennæ than usual. The frontal carina is high, especially a little in front of the eyes. Compared with that of *Lymnetis gracilicornis* (Fig. 3, *b*, in text) it is much broader, shorter, the keel reaching to the end, which is squarely docked, the end being a flattened triangle; the end of the front reaches to the middle of the antennæ, while in *L. gracilicornis* the end reaches two-thirds of their length. It differs from *L. gouldii* (Fig.

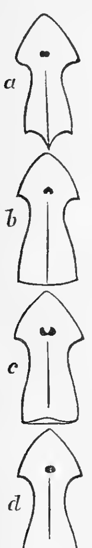

FIG. 3.—Front of head of *Lymnetis* spp.—*a*, *L. mucronatus;* *b*, *L. gracilicornis;* *c*, *L. brevifrons;* *d*, ♂ *L. gouldii.*

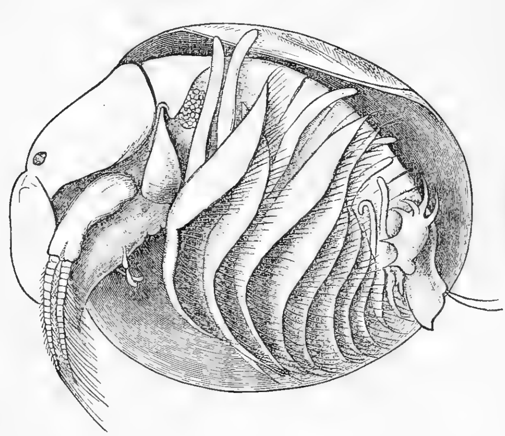

FIG. 4.—*Limnetis brevifrons*, female, much enlarged. Burgess del.

3, *d*) in the front being thicker, the truncated end forming, seen from the end, a much less flattened triangle.

First antennæ much stouter than in *L. gouldii*. Second antennæ considerably longer than in *L. gouldii*, the terminal joint extending well beyond the end of the front, while in *L. gouldii* it does not extend beyond the front; the upper branch of the flagellum has 20 joints; the lower, 20. (In *L. gouldii* there are 14 joints in the upper and 12 in the lower branch of the antennæ.) In form the antennæ resemble those of *L. gouldii*, but the setæ are much shorter than in any of the other species. There are 12 pairs of feet. The male has a much smaller hand than in *L. gouldii* or *L. mucronatus*, the claw (Plate XXVII, fig. 3, en^6) is shorter, but the finger (en^2 should be en^5) is much larger than in the foregoing species. The jaw-like coxal lobe is larger than in *L. gouldii* or *L. mucronatus*. The gill is enormous, as is also the flabellum (br^1), the two being of the same size and half as long as the entire limb, while the lower division of the flabellum, that next to the hand, is rather broader and larger than in *L. gouldii*. In the female the upper division of the flabellum (br^1) is short and broad; the gill is very long; the lower division of the flabellum (Plate XXVII, fig. 2 *a*) is as in *L. mucronatus*; the 4th endite is long and narrow, while the 5th is longer than the 6th. Terminal segment less prominent than in *L. mucronatus*, while the dorsal edge is less excurved.

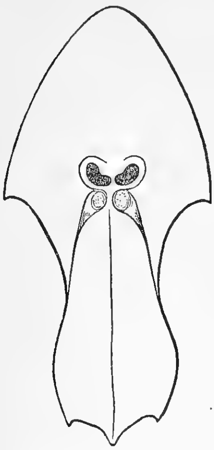

FIG. 5.—*Limnetis brevifrons*, front of female, greatly enlarged. Lindahl del.

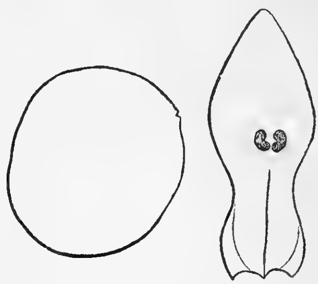

FIG. 6.—*Limnetis brevifrons*, *a*, outline of shell; *b*, front of head of female. Lindahl del.

Average size of most of the specimens: Length, 4^{mm}; breadth, $3\frac{1}{2}^{mm}$. Several larger examples were 6^{mm} long and 5^{mm} broad.

Ellis, Kans., June 28 and 29, Dr. L. Watson, in pools, associated with several other species of Phyllopods. A few eggs were contained in most of them. This is the largest species known, and is as a rule flatter and more triangular than any other species, while the truncate front of the head of the male is shorter and broader than in any other American species yet known.

LIMNETIS GRACILICORNIS Packard.

Limnetis gracilicornis Packard. Amer. Jour. Sc., 3d ser., vol. ii, Aug., 1871.

This species differs from *L. gouldii* in the longer and slenderer 2d antennæ, the flagella of which are 20-jointed; the keel on the front of the head does not reach to the front edge, while in *L. gouldii* it does. (Fig. 3, *b*.) Shell of the same form, but much larger than in *L. gouldii*.

Length of shell, 4.2^{mm}; breadth, 4^{mm}.

Waco, Tex., with *Eulimnadia texana* and *Streptocephalus texanus* (G. W. Belfrage). I have unfortunately been unable within late years to obtain any specimens for dissection and study.

Subfamily ESTHERIANÆ Packard.

Carapace or shell oblong, more or less flattened or oval, sometimes subglobose, with distinct lines of growth. From 18 to 27 or 28 pairs of feet; in the males the two anterior pairs of feet with hands; the end of the abdomen with dorsal spines and two pairs of very long, large, curved, terminal spines.

Synopsis of the genera.

Shell oval, more or less globose, with 18–22 lines of growth, amber-colored; flagella of 2d antennæ 11–17 jointed; 24 to 27 or 28 pairs of feet .... *Estheria.*

Shell large, broad oval, much flattened, subtriangular, with about 18 lines of growth, a haft-organ present. Flagella of 2d antennæ 12–13 jointed; 18–22 pairs of feet...... *Limnadia.*

Shell narrow-ovate, rather prominent behind the umbones, with 4–5 lines of growth. A haft-organ present. Flagella of 2d antennæ 9–10 jointed; 18 pairs of feet.... *Eulimnadia.*

Genus ESTHERIA Rüppell.

Plates III, IV, V, XXIV, XXV, XXVI, figs. 1, 2, XXVII.

Estheria Rüppell, Museum Senckenbergianum. Bd. II, Heft. 2. Ueber *Estheria dahalacensis* Ruppell, von H. Strauss-Durckheim. 1857.
Cyzicus Audouin, Annales Soc. Ent. France, vi, 9, 1837.
Isaura Joly, Annales des Scienc. Nat., ser. 2, XVII, 293, 1842.

Carapace valves or shell oval, more or less globose, with a prominent hinged back, Cyclas-like, with numerous lines of growth; amber colored. Body with 25–27 segments. Head with no "haft-organ;" as a whole the head is very large, being more like that of *Limnetis* than *Limnadia*, having a long narrow rostrum forming a large proportion of the head; first antennæ large and long, reaching nearly to the middle of the flagella of the second pair; the latter with a stout multiarticulate scape, the flagella extending well beyond the edge of the shell, and usually composed of about 15–20 joints. Usually about 20 pairs of feet; in the female the coxal or maxilliform lobe is recurved, triangular, acute; the second and fourth endites are small lobes of nearly equal size, while the fifth is a long, slender, narrow process, the sixth being like it, but either wider and pointed at the end, or shorter than the fifth and scalloped along the lower edge. Of the three exites, the gill is elongate, pear-shaped, while the upper division of the flabellum is very long and almost filamental at the end, nearly reaching the upper side of the body, the lower division being narrow, either pointed or rounded at the end, and scalloped along the upper edge, closely resembling in form the sixth endite. In the males the two anterior pairs are provided with hands, differing from those of the single first pair in *Limnetis* in the tubercle-like fourth endite, armed with stiff, sharp spines, forming the comb, while the finger-like fifth endite is somewhat bulbous at the end.

The species of this genus may be recognized by the globose amber-colored shell with numerous lines of growth. It differs from *Limnadia* in the large head, and long, large, acute beak, and in the lack of a haft-organ, while it differs from *Limnetis* in the shell having lines of growth, a distinct beak and hinge, while the rostrum is narrow and pointed, and the number of body segments and legs is much greater, and the two anterior pairs of feet in the male are provided with hands. Moreover, the first antennæ are much larger, with indications of numerous joints.

Synopsis of the species.

Shell large, flat; beaks close to anterior end and very small; second antennæ 13- and 15-jointed .... *E. californica.*
Like *californica*, but with more prominent beaks, dorsal edge sloping directly down to the posterior end .... *E. newcombii*
Shell long and narrow; beaks small, situated very near anterior end; telson armed with small fine teeth; hands of male short and thick; flagella 15- and 14-jointed .... *E. complexímanus*
Shell more swollen; beaks larger, and farther from anterior end; dorsal edge short, suddenly sloping to posterior end; flagella 17- and 16-jointed; telson with larger teeth interpolated in the smaller ones .... *E. mexicana*
Shell still more globose than in *E. mexicana*; beaks more prominent in anterior third of shell; flagella 17- and 16-jointed .... *E. morsei*
Shell globose; beaks large and prominent, more central than in preceding species; flagella 14- and 15-jointed .... *E. belfragei*
Shell very large, thick, globose, swollen; beaks larger and fuller, central; with more numerous lines of growth than any preceding species; flagella 17- and 16-jointed .... *E. jonesii*

ESTHERIA CALIFORNICA Packard.

Plate IV, figs. 1–5.

Estheria californica Packard, Sixth Rep. Peab. Acad. Sc., Salem, 55, 1874. Hayden's U. S. Geol. Surv. Terr. for 1873, 618, 1874. Lenz, Estheria californica, &c., Lübeck, Aug. 5, 1876.

Shell remarkably thin, so that at first sight it might be mistaken for a *Limnadia*; in outline subtriangular; the umbones unusually small, very oblique, flattened, and situated much nearer than usual to the anterior edge; dorsal edge convex, curving gradually to the rounded posterior end. Eighteen to thirty-five lines of growth. Shell very smooth, shining, with very fine granulations too numerous to be counted with a two-thirds-of-an-inch trip, let; when more highly magnified they appear as in Plate XXIV, fig. 5. First antennæ rather slender, the papillæ, however, not very well marked. Second antennæ with the upper flagellum 13-jointed, and much shorter than the lower, which is 15-jointed. Twenty-two pairs of feet. The gill is rather small and short; the upper division of the flabellum very long and slender, reaching to the back of the animal; the lower one acutely trianglar; the sixth endite is a little longer than the lower flabellum, and is broader in the third than in the first pair of limbs; the fifth endites are slender, long, and narrow, finger-shaped. The telson is armed above with numerous fine

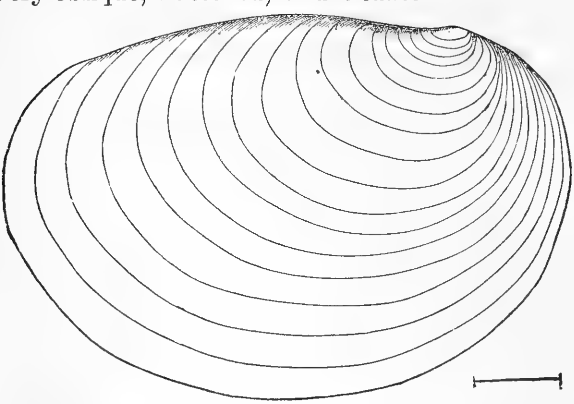

FIG. 7.—Estheria californica.

teeth, and about 8 much larger than the others, while the long acute caudal appendages are peculiar from having but about 4 long spines on the base of upper edge, with no fine teeth.

The hands of the males show no specific characters of decided importance.

Length of shell, 16 mm; breadth, 10 mm; thickness, 4 mm;

California (Rowell) Mus. Chicago Acad. Sc. 4 specimens; Alameda County, Cal. (James Behrens), Santa Cruz, Cal., collected by Laura F. Hicox, received through Mr. J. S. Kingsley.

It is closely allied in form to *E. ticinensis* of Lombardy, Italy, and may be said to represent that species in the Californian fauna. A detailed account of the external anatomy of this interesting species is given in "Estheria Californica Pack. Inaugural dissertation," &c., by H. Lenz, wherein the mouth-parts and appendages, &c., are figured. Of 25 specimens Lenz received from Mr. Behrens 11 were males and 14 were females.

From the next species, *E. newcombii*, it appears to differ in the less prominent beaks, in the fact that the dorsal edge of the carapace does not slope *directly* down to the posterior extremity, which is *not* "nearly as broad as anterior extremity"; and there are 18 lines of growth, instead of "about sixteen," as in Baird's species, and the punctations of the shell are separate. Still it may be found that our species is synonymous with Baird's *newcombii*. I have been unable to see the plates, as in the copy of the Proceedings of the Zool. Soc. at hand the plates are wanting.

ESTHERIA NEWCOMBII Baird.

Estheria newcombii Baird. Proc. Zool. Soc., London, 122, Pl. XII, fig. 2, 1866.

"Carapace oval in shape. Beaks prominent, placed near anterior extremity. The dorsal margin slopes directly down to the posterior extremity, which is nearly as broad as anterior extremity. Ribs of carapace, about sixteen in number, narrower at the beaks, and becoming broader as they descend towards the ventral margin. The intervals of the ribs are dotted with punctations, which are small and very numerous, and run into each other so as to produce a sort of running pattern."

"Length nearly ½ inch; breadth about ¼ inch."

"*Hab.*—California (W. Newcombe, esq., Mus. Brit.)."

ESTHERIA COMPLEXIMANUS, n. sp.

Plates V, figs. 1–7; XXIV, figs. 8, 10; XXV, fig. 6.

Eulimnadia compleximanus Pack., Bull. U. S. Geol. Survey III, No. 1, 174, April 9, 1877, Zoology for Colleges and High Schools, 1st and 2d editions (no description) fig. on p. 302, 1879, 1880.

Shell very long, oblong, not very thick compared with the following species; the beaks very small, situated at the anterior sixth or seventh of the dorsal edge of the shell, this edge being remarkably long and straight, more so than in any of the other species. The posterior end of the shell is narrow, not full and rounded, neither is the anterior end as full as in *E. californica*. About 15 lines of growth. Head with the rostrum rather long, approaching *E. mexicana* in this respect. Edge of shell with small short spines, and between the lines of growth confluent spaces arranged in oblique parallel lines. 1st antennæ long and slender, reaching beyond the lower edge of the shell, the sense papillæ very distinct and acute. 2d antennæ moderately slender, the scape not so thick as in *E. californica*; the upper flagellum 15-, the lower 14-jointed; the joints longer and slenderer than in *E. mexicana*. The legs of the female, especially one of the anterior pairs, have larger gills than in *E. Mexicana*. (Compare Plate XXIV, figs. 9 and 10.) The adjacent upper flabellum is moderately long, filamental in the upper half, but not reaching to the back of the animal; the lower division of the flabellum (fig. 7 br'') forms a long lobe scalloped on the upper edge, and closely resembling in form and size the 6th endite. The 5th endite is long, finger shaped, and reaches beyond the 6th. In the male the first pair of feet have short, broad hands, with a broad 4th endite, but the finger-like 5th endite is slenderer than that of the second pair, in which the hand is much longer and slenderer. Both pair of hands, particularly the first, are much stouter than those of *E. mexicana*. The telson is armed along the upper edge with very numerous even teeth, no larger ones being interpolated among smaller ones, and the caudal appendages are finely serrated from base to tip.

Length of shell, 11^{mm}; breadth, 6^{mm}; diameter or thickness, 2.5^{mm}.

Ellis, Kansas, in pools, June 24-29, 1874 (Dr. L. Watson).

Fort Wallace, Kansas, abundant, associated with *E. mexicana*, *Streptocephalus texanus*, &c. (Prof. Joshua Lindahl.)

This species may be readily recognized by the long, narrow shell, and

FIG. 8.—*a*. Hand of male *Estheria compleximanus*, much enlarged; *b*, telson. Emerton del.

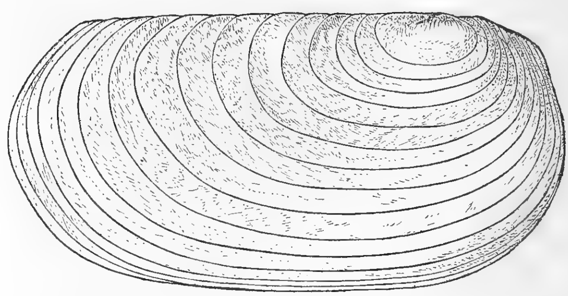

FIG. 9. Estheria compleximanus Pack, magnified. Lindahl del.

the small beaks situated very near the anterior end of the dorsal edge; by the finely serrated edge of the telson and caudal appendages, the large gills, the short, thick hands of the male, and by the sculpturing of the shell.

By an unfortunate mistake it was referred to the genus Eulimnadia, for which it was hastily mistaken on account of its oblong-oval smooth shell.

ESTHERIA MEXICANA Claus.

Plates XXIV, figs. 3, 6, 9; XXV, figs. 1-5; XXVIII, figs. 1-5.

Estheria mexicana Claus, Beiträge, zur Kennt. d Entomostraken, Marburg, Taf. III, IV, figs. 33-54, 1860.

Estheria dunkeri Baird, Proc. Zool. Soc., London. 147. Pl. XV, figs. 6, 6*a*, 6*b*, 1862. Annals Mag. Nat. Hist., 3d ser., 391, 1862.

Estheria caldwelli Baird, Proc. Zool. Soc., London, 148. Pl. XV., figs. 4, 4*a*, 4*b*, 1862. Ann. Mag. Nat. Hist., 3d ser., x, 393, 1862.

Estheria clarkii Packard, Sixth Report Peabody Acad. Science, Salem, 55, June, 1874. Hayden's U. S. Geol. Surv. Terr., 1873, 619, Pl. III, fig. 7, 1874.

Shell or carapace valves thin, amber-colored, oblong oval, thin, about two-thirds as broad as long, with the umbones or beak rather prominent, oblique, situated on the anterior fourth of the shell, which is fuller, more globose than in the foregoing species; dorsal edge straight behind the beak, and a little beyond the posterior third of the entire shell rather suddenly sloping down, though the end is full and rounded. Shell (Fig. 10, in text) narrower than usual in the transverse diameter; about sixteen to twenty lines of growth, with fine setæ along the lines; unusually fine microscopic punctures between the lines, too numerous to be counted with a triplet. Under a higher power the dark spots in the soft tissue of the shell are seen to be either separate (Plate XXIV, fig. 3) or confluent (Plate XXIV, fig. 6), forming parallel markings, which disappear before reaching the line above. (The series of oval clear spaces in the drawing are the attachment of the setæ, which are long and slender, see Plate XXIV, fig. 3.) In Baird's fig. 4*a* and 6*b of E. dunkeri* the punctures are separate, and probably there is a variation in this respect. Male shell narrower, and with rather more prominent beaks than in that of the female. Head, with the rostrum, long and pointed; first antennæ rather thick, and moderately long; second antennæ with rather short joints, 17 in the upper and 16 in the lower flagellum; the upper sides of all the joints with 4–5 slender setæ; legs of the female, with the gill, rather long and large, the lower division of the flabellum quite broad; the upper or *oviger* (Plate XXIV, fig. 9) quite long and slender, but shorter than in *E. compleximanus.* First and second pair of legs of the male with rather slender hands, and both divisions of the flabellum are rather short and broad; the claw (sixth endite) is shorter than in *E. compleximanus*, as is the thumb, or fourth endite; the fifth endite is much as in *E. compleximanus.* The telson is shorter and higher than in *E. compleximanus*, with about twenty pairs of unequal spinules, the first, third, sixth, ninth, twelfth, fifteenth, seventeenth, and nineteenth much larger than in the others, while in *E. compleximanus* they are of uniform size; each spine is minutely spinulated; the terminal superior spine one-half as large as the inferior, but finely spinulated; the caudal appendages with fine, hair-like setæ on the upper edge.

The males have stouter spines on the telson than in the other sex. Length of shell, 10–12^{mm}; height, 7^{mm}; transverse diameter, 4^{mm}. This species differs from *E. compleximanus* in the more globose shell, the much shorter dorsal edge, which suddenly bends down, the fuller ends, the shorter hands of the male, and the unequal spines on the telson. From *E. morsei* it differs in the flatter, more oblong shell, and in the beak being much smaller, more oblique, and much nearer the anterior end of the dorsal edge, while the hands of the males are much slenderer than in *E. morsei.*

This is apparently the most abundant and widely diffused species on the continent, as will be seen by the following notes:

Lake Winnepeg, North America (W. Caldwell, esq.); (Mus. Brit.) (Baird.)

Several hundred young (figures on Plate XXVIII, figs. 1–6) about one-half full size, collected by the late Prof. H. James Clark from a puddle in Lexington, Ky., May 21.

Cincinnati (Mus. Chicago Academy Science), Hamilton County, Ohio, in a cart rut, "so numerous that a dip of the hand would take up a dozen" (V. T. Chambers).

Ellis, Kans., "in an upland pool supplied by a spring" (Dr. L. Watson), Fort Wallace, Kansas, in company with *Estheria compleximanus* and *Streptocephalus texanus.* (Prof. J. Lindahl.)

Common at the pueblo of Santa Ilsafonso, New Mexico, August;

collected by Dr. Yarrow, Lieutenant Wheeler's Survey west of the 100th Meridian.

Zimapan, Mexico, (Prof. W. Dunker coll.), Claus.

This species is exposed to considerable variation, so that I was misled by the rather indifferent figure of Baird in considering it as distinct from *E. caldwelli* from Lake Winnepeg; and described it as *E. clarkii.* The specimens from New Mexico are large and well developed, little and a larger than in the majority of the Kansas specimens. They agree well with Claus's figure of the shell, and the appendages are much as he figures them, so that as the species is abundant in New Mexico, I do not doubt but that it extends to Zimapan, Mexico, and thus the name for our most common and widely spread Estheria should be *mexicana* of Claus. This species is allied to the European *E. dahalacensis*, but the beak is fuller.

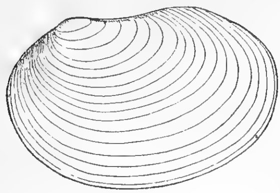

Fig. 10.—Estheria mexicana, enlarged four times.

I have ventured to place *E. dunkeri* from Zimapan, Mexico, as a synonym of this species. Baird's description is almost identical with that of his *E. caldwelli;* but my New Mexican specimens have the same outline, the same number of lines of growth, and only differ in having less full and prominent beaks; but the artist may have exaggerated this feature in his drawing, though it is referred to in Baird's description, yet some smaller Kansas specimens have fuller beaks than the New Mexican ones, but, as the locality (Zimapan) and collector (Dunker) are the same as Claus's *E. mexicana*, there is little doubt but that taking into account the tendency to variation in this species our synonymy is correct.

ESTHERIA MORSEI Packard.

Plate XXIV, fig. 7; XXVI, figs. 1, 2.

Estheria morsei Packard, Amer. Journ. Sc., II, Aug. 1871.
Sixth Report Peab. Acad. Sc. Salem, 56, June, 1874.
Hayden's U. S. Geol. Surv. Terr. for 1873, 619, 1874.
Morse's First Book of Zoology, 149, fig. 138, D. (No name.)

Shell much fuller, more globose than in any of the preceding species, with fuller, more prominent, less oblique, and centrally situated beaks; shell oblong oval, of a pale horn or amber color. Dorsal edge shorter than in *E. mexicana*, and in front of the beaks, instead of being straight and suddenly curved downward, is regularly rounder, much as in *E. belfragei;* posteriorly the dorsal edge slopes rapidly downward, without the well marked angle of *E. mexicana*. Coarse punctures between the lines of growth, rather coarser than in *E. mexicana*, there being on an average 5–10 of these marking between the ribs in the center of the valve. Plate XXIV, fig. 7, also represents the markings at the edge of the shell.

Second antennæ, with a larger scape than in *E. belfragei*, 17 joints in the upper, 16 in the lower, flagellum. Legs of the male with a smaller lower division of the flagellum, and a smaller gill than in *E. belfragei*, while the upper division or oviger is much shorter and broader than in any of the foregoing species, being no longer than the gill. The hand is apparently a little thicker than in *E. belfragei*.

Telson much as in *E. mexicana*, with about 20 pairs of teeth, coarser than in *E. belfragei*, about 5 pairs of which are much larger than the others.

Length, 12.2^{mm}; height, 8.2^{mm}; thickness, 6^{mm}.

Six specimens from Dubuque, Iowa, collected by Rev. A. B. Kendig.

Six specimens from "Grindstone Creek, half way from Fort Pierre to the Bad Lands, Dakota," collected by Dr. F. V. Hayden, and received from the Chicago Academy of Science through Dr. Stimpson.

The smallest specimen from Dakota agrees exactly with the Iowa examples in being long, ovate; the others are considerably larger and with age seem to grow broader, more wedge-shaped. The following are the dimensions of the most wedge-shaped examples; length, 14^{mm}; height, 10.5^{mm}.

Differs from any of the preceding species by the full globose higher shell, with more prominent and central beaks, and the shorter oviger.

ESTHERIA BELFRAGEI Packard.

Plate III, figs. 1, 2, 4, 6; XXIV, fig. 1.

Estheria belfragei Packard, Amer. Journ. Sc., II, Aug., 1871.
Hayden's U. S. Geol. Surv. Terr. for 1873, 619, Pl. III, fig. 8, 1874.

Shell (Fig. 11 in text) or carapace valves with the beak situated between the anterior third and the middle of the shell; dorsal edge straight for a very short distance behind the beak, slightly serrate, bent rather suddenly downward at two-thirds of the distance from the beak to the posterior end, the end being very full and rounded; the anterior dorsal edge slopes down rapidly from the beak, and the anterior end is full and convex. Beak very full and prominent, more so than in any other species except *E. jonesii*, but they are not oblique. About twenty-four lines of growth, between which the shell is coarsely punctate; from 5–8 dots (when placed in a straight line) between the lines of growth in central part of the shell; these punctures are reduced to a single row on the edge. In a piece taken from the edge of the shell and highly magnified (Plate XXIV, fig. 1) there are seen to be two rows of setæ, one very short and thickset, the row of larger ones very long and slender arising at some distance from the edge of the shell. The punctiform markings are seen to be large with scattered masses of denser tissue than that inclosing them. Second antennæ with 14 joints in the upper, and 15 joints in the lower ramus of the flagellum. In the two anterior pairs of legs of the male, the lower division of the flabellum is rather broad and short, while the gill is moderaten in size and rather short; the hands are rather small, of the general shape of *E. mexicana*, but the claw is a little shorter. There are along the back seventeen pairs of dorsal spines exclusive of those on the telson, which are fifteen in number (in *E. mexicana* they are much more numerous), and the middle one is much larger than those near it. Caudal appendages longer and slenderer than in *E. mexicana*, and the terminal spine is longer and slenderer.

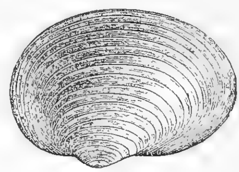

FIG. 11.—Estheria belfragei, enlarged about four times. Emerton del.

Length of shell, 7.5^{mm}; height, 6^{mm}; transverse diameter, $\pm$ 3.8^{mm}.

Six specimens, Waco, Tex., April (G. W. Belfrage).

This fine species differs from *E. morsei*, its nearest ally, in having a much shorter and higher shell with the larger beaks nearer the anterior end.

ESTHERIA JONESII Baird.

Plates III, figs. 3, 5, 7; XXIV, fig. 2; XXVIII, fig. 7.

Estheria jonesi Baird, Proc. Zool. Soc. London, 147, Pl. XV, figs. 1, 1*a*, 1*b*, 1*c*, 1*d*, 1862. Packard, Hayden's U. S. Geol. Surv. Terr. for 1873, 619, 1874.

Shell very large, full, globose, nearly twice as thick as any of the preceding species; the beaks very large, full, and high, situated between the middle and the anterior third of the shell; dorsal edge short; shell donaciform or wedge-shaped. It also differs from all the other species in the very numerous crowded lines of growth, with a bead-like rim of coarse punctures just above each line; along the lower edge of the shell a rim of short stiff coarse setæ. (Plate XXIV, fig. 2.) Seen from either end the shell is broad, heart-shaped.

Second antennæ stout, upper flagellum 18- the lower 17-jointed. In the first pair of legs of the male the gill is smaller than usual; the flabellum next to it is short and nearly twice as broad as in any of the other species, and the entire limb is short, and the hand also is short and stout, the claw being unusually short and thick.

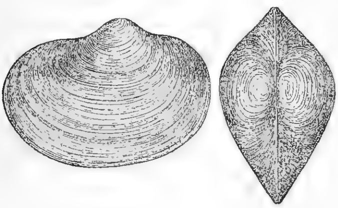

FIG. 12.—*Estheria jonesii*, magnified twice. After Baird.

The telson is very short and high; the upper edge with 13 pairs of coarse teeth of nearly uniform size; while a few hairs are on the basal half of the upper side of the caudal appendages.

Length of shell, 14^{mm}; height, 11^{mm}; thickness, 8^{mm}.

Cuba (Dunker).—I am indebted for specimens to Dr. E. Von Martens, of the Berlin Museum. A number of specimens, which do not differ from the Cuban examples, were loaned me by Dr. Stimpson, curator of the Chicago Academy, and are marked "Locality lost." As no other specimens from the West Indies occur in the collection received from Dr. Stimpson, it indicates that *E. jonesii* may possibly occur in the Southern States, or Central America; the only habitat as yet known being Cuba, where it is said by Baird to inhabit brackish water.

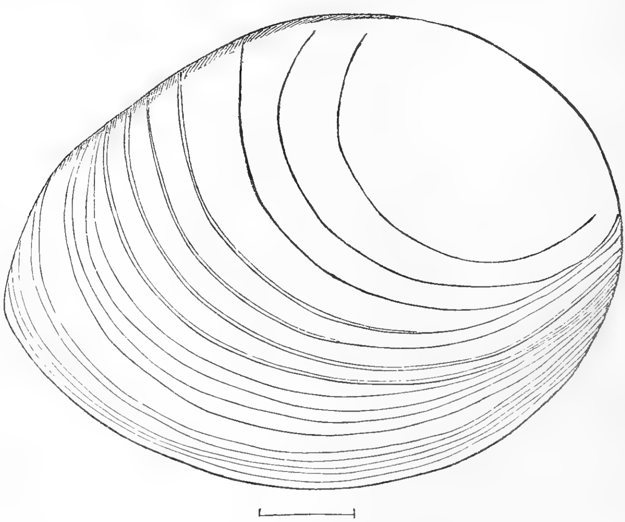

FIG. 13.—*Limnadia americana*, Packard.

Genus LIMNADIA Brongniart.

Limnadia Brongniart, Mémoires du Muséum d'Hist. Nat. VI, Pl. 13, 1820.
Milne-Edwards, Hist. Nat. des Crustacés III, 561, 1840.

Shell broad, flat, with about 18 lines of growth, disappearing near the very flat nearly obsolete beaks; 22 pairs of feet.

LIMNADIA AMERICANA Morse.

Limnadia americana Morse, Proc. Bost. Soc. Nat. Hist. XI. First Book of Zoology. Fig. 138, L., 1875.

Shell (Fig. 13 in text) large, broad, ovate, much flattened, with 18 lines of growth; smooth and shining; allied to *L. gigas* of Europe.

Length of shell, 12.5^{mm}; breadth, 9^{mm}.

Museum of Peabody Academy, collected by Mr. Tufts, at Lynn, Mass.

Genus EULIMNADIA Packard.

Eulimnadia Packard, Sixth Report Peab. Acad. Sc. Salem., 55, June, 1874.
Hayden's U. S. Geol. and Geogr. Surv. Rep. for 1873; 618, 1874.

Shell narrow, oblong, oval, not nearly as wide as in *Limnadia*, with only 4 or 5 lines of growth; the dorsal edge straighter, less curved than in *Limnadia*; 18 pairs of feet. The head and antennæ do not differ essentially, but the gills are much larger than in *Limnadia*; while the upper or dorsal lobe of the flabellum is much smaller than in *Limnadia*.

The Australian *Limnadia stanleyana* King and *L. antillarum* Baird are congeneric with our *E. agassizii* and *texana*.

Synopsis of the Species.

Shell narrow-ovate, with 4 lines of growth .... *E. agassizii*.
Shell narrower than in preceding, more oblong, with 5 lines of growth; 2d antennæ longer, more spiney and hairy than in foregoing species .... *E. texana*.

EULIMNADIA AGASSIZII Packard.

Plate VII, figs. 5, 6.

Eulimnadia agassizii Packard, Sixth Rep. Peab. Acad. Sc., 54, 1874.
Hayden's U. S. Geol. and Geogr. Surv. for 1873. 618, 1874.

Carapace valves whitish, very transparent, quite regularly oval, narrower than usual, somewhat truncate at the end, widest slightly in front of the middle, with four lines of growth, valves much more con vex than in *Limnadia americana*.

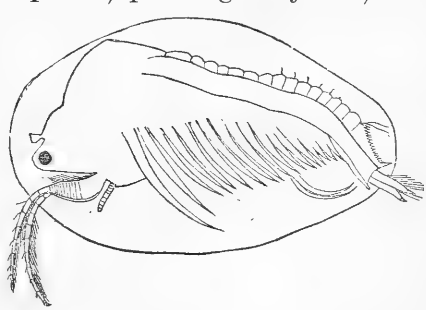

FIG. 14.—*Eulimnadia agassizii* Packard, enlarged about 6 times.

Head with the "haft-organ" larger than in *E. texana*. First antennæ much shorter, smaller and less distinctly segmented than in *E. texana*, not reaching beyond the middle of the stem or scape of the 2d antennæ, while in *E. texana* they reach to the basal joint of the flagella. Second antennæ with 9 joints to each flagellum. In the upper flagellum but a single seta at the end of each joint, while there are four or five in *E. texana*; the setæ on the under side are much shorter and stouter than in *E. texana;* the stem is shorter and stouter than that of *E. texana.*

Eighteen pairs of feet.

Telson rather broad; along the dorsal edge are twelve pairs of acute spinules with the usual long forked filament between the first and second pair of spines; the large terminal spines of the telson fringed with long hair-like setæ instead of spines, as in the European *Limnadia gigas*, but the tip is armed with minute short spines. A stout conspicuous spine on the lower angle of the telson under the terminal spines. A pair of long abdominal cirri. The eggs are yellowish and roughly granulated.

Length of shell, 6.2^{mm}; breadth, 3.8^{mm}.

About one hundred females, mostly with eggs, occurred in a small pool of fresh water on Penikese Island, Buzzard's Bay, August 27, 1873, collected by Mr. Walter Faxon. Upon examining the pool the following July or August (1874), the young, about a line in length were found, but the pond subsequently dried up. The eggs are yellowish and with the chorion roughly granulated.

The species was dedicated to Prof. L. Agassiz.

Compared with *L. americana* Morse, which closely resembles *L. gigas* (received from Sweden through the kindness of Prof. W. Lilljeborg), it differs very decidedly in the much narrower shell and fewer lines of growth. It belongs to a different genus from the two above-named species, agreeing in the structure of the animal and the bivalved carapace with *L. antillarum* Baird, Proc. Zool. Soc., 1852, 30, from St. Domingo (Fig. 15), and *L. texana* Pack. From *L. antillarum* it differs in being more regularly oval and much more prominent behind the umbones. It also agrees with Baird's description of *L. antillarum* in its two large terminal caudal spines being hairy, it having eighteen feet and nine-jointed flagella. It differs from *L. texana* in the stouter haft-organ, being less triangular in outline; in the broader telson, on the upper edge of which the teeth are less numerous; in the smaller first antennæ, and the less spiny second pair; the shell differs in being more broadly ovate than in *E. texana*, which is oblong, less concave along the dorsal edge, and it differs from that of *E. texana* in having four instead of five lines of growth, as in *L. texana*.

EULIMNADIA TEXANA Packard.

Plates VI, VII, figs. 1–4.

Eulimnadia texana Packard, Amer. Jour. Sc., vol. ii, Aug. 1871.

Carapace valves rounded, oval, whitish, with 5 concentric lines of growth; shell very minutely punctured; these markings being coarser at the posterior end of the shell, where they are arranged in lines parallel to the edge of the shell; eyes double, but with the inner edges contiguous. Twenty body-segments behind the head, including the telson; 18 pairs of feet; first antennæ extending to the first joint of the flagella of second pair; the latter each 9-jointed, each joint above with 4 or 5 stout setæ, and beneath with long spinulose setæ. First pair of legs of male with a slender hand; the claw moderately large, the fifth endite very long and slender.

Telson with sixteen fine teeth above, not including the terminal acute spine; caudal appendages long and slender, knife-shaped, the under edge fringed with long hairs; the upper edge straight, the end blunt, with the lower edge slightly curved. The eggs are yellowish and pentagonal in outline.

Length of shell, 7^{mm}; breadth, 4^{mm}.

"Quite common in many places in Western Texas in the early spring"

(G. W. Belfrage). Very common at Ellis, Kans., collected by Dr. L. Watson, and at Fort Wallace, collected by Prof. J. Lindahl. It is associated with *Streptocephalus texanus*, *Thamnocephalus brachyurus*, *Estheria compleximanus* and *mexicana*.

The shell compared with Baird's figure of *Limnadia antillarum*, which belongs to this genus, and is closely allied to the present species; is more rounded oval at each end, the shell being somewhat truncated in the St. Domingo species.

Species not recognizable.

Limnadia coriacea Haldeman. Proc. Acad. Nat. Sc., Phil. I, 184, 1842.

"Body lengthened; swimming branchiæ extending along three-fourths of the inferior surface, from the neck to the extremity of the tail; tail crested above with a row of large conical obtuse tubercles; apex of the shell elevated, and about one-fourth of the length from the anterior extremity; color, light brown; length, 5 millim.; height, 3; diam., 1½.

"*Hab.*—Ditches along the Susquehanna, in quiet water."

It is difficult to say whether this is a *Limnadia* or *Estheria*, as the description is too brief and inexact to enable us to determine the genus or species. It cannot be a *Limnadia*, and seems to approximate more closely to *Estheria*; though it cannot belong to that genus, as the antennæ are said to be 12–13 jointed. Until some one collects in the localities visited by Mr. Kite, we shall be in doubt as to what this form may be.

Limnadella, novum genus.

Charles Girard: On a new entomostracan of the family Limnadidæ, inhabiting the Western waters. Proceed. Academy Nat. Sciences of Philadelphia, vol. vii, 1854, 1855, page 3.

"*Gen. character.*—Eye, one. Antennæ subequal, provided upon their inferior side with long and plumose setæ, whilst on the upper side there are short, slender, and simple spines. Two elongated, tape-shaped jaws. Feet in twenty-four pairs, provided upon their extremities and sides with slender and plumose setæ or hairs. A series of spiny processes along the posterior half of the dorsal line. Post-abdominal plate very large. Nutritive system phlebenteric.

"*Observations.*—This genus differs from *Limnadia* in being provided with one eye only instead of two. Also by its antennæ, the two pairs of which are similar in structure, whilst in *Limnadia* one pair is smaller than the other. The post-abdominal plate and number of feet will afford other distinguishing characters between *Limnadella* and *Limnadia*. From *Cyzicus* or *Estheria* it differs, first by the structure of the shell, which in *Estheria* resembles that of an *Arca*, whilst in *Limnadella* it is altogether cyproid in its general aspect. There is a marked difference between these two types in the structure of the antennæ, the joints of which are provided on their upper part with numerous spines in *Limnadella*, whilst in *Cyzicus* there is but one single spine at the anterior edge. The structure of the feet is likewise dissimilar, being furnished with plumose setæ in *Limnadella*."

Limnadella Kitei, n. spec.

"*Specif. character.*—Shell: elongated, subelliptical, thickest anteriorly; twice as long as deep; anterior, inferior, and posterior margins regularly continuous; upper outline somewhat irregular on account of the beaks being rather prominent. Valves uniformly convex. Greatest depth, one-eighth of an inch; greatest length, one-quarter of an inch. Specimens may occasionally attain to a larger size. Color, deep or light brown, mottled with black. Animal: antennæ composed each of twelve or thirteen subequal joints. Twenty-four pairs of feet, the six posterior ones diminishing gradually away so as to render the last three rudimentary. The last of all is inserted upon the last caudal segment but one. There is a broad subtriangular plate, terminated by two pairs of very large spines, curved upwards; the inferior pair being longer and slenderer than the upper one. The concave margin of that plate is furnished with a series of quite small spines. On the uppermost part of the post-abdominal plate is inserted a pair of very delicate sword-shaped appendages, very difficult to be observed even with a good microscope. Along the posterior half of the back there exists a series of sixteen processes, provided upon their upper and posterior sides with about five or six minute-curved spines, the tip of which is bent backwards. The anterior two of these processes are but rudimentary; the most developed occupy the middle of the series; the posterior ones again diminish gradually as they approximate the post-abdominal plate.

"Specimens collected at Cincinnati were sent to the Smithsonian Institution by Thomas Kite, of that city."

Afterward Professor Haldeman makes the following statement, in Proc. Acad. Nat. Sc., Phil., vii, 34, 1854:

"I find that the *Limnadella* described by Mr. Girard, Proceed. Acad., vol. vii, page 3, is my *Limnadia coriacea*, *ib.*, 1, 184, for June, 1842. At that time I doubted the propriety of placing it in *Limnadia*, chiefly on account of the dorsal tubercles mentioned in my description, but I had no means of making the necessary comparisons. It was discovered in great abundance in a road-side puddle subject to dessication, and although I removed a number of them to a small pond, I have never met with them since."

EULIMNADIA ANTILLARUM (Baird).

Limnadia antillarum Baird. Proc. Zool. Soc. London, xx, p. 30. Plate XXIII, figs. 1, 1*a*, 1*b*, 1*c*. 1852.

"Carapace valves of a rounded oval shape, and of a transparent whitish color; prominent on dorsal margin where the muscular attachment of the body takes place, sloping from thence rather suddenly towards anterior extremity, where it forms a somewhat blunt point, and more gradually to posterior extremity, which, as well as ventral margin, is rounded. Antennules bluntly serrated or crenulated on their upper edge, rather shorter than peduncles of large antennæ, which are stout and not half the length of the body. They consist of nine articulations, each having one or two long plumose setæ springing from the under edge, and one short stout spine at each joint on the upper edge. Caudal lamellæ of considerable length, and beset on under edge with long plumose setæ to within a short distance of the tip, which is somewhat curved, sharp-pointed, and slightly serrated on upper edge. Feet, 18 pairs.

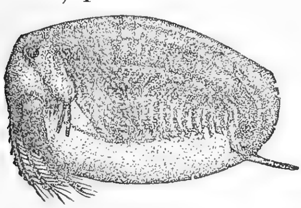

FIG. 15.—*Eulimnadia antillarum.* Enlarged 6 diams. After Baird.

"The structure of the carapace is the same as in Limnadia Hermanni, the surface being covered with minute dots or punctuations.

"This species differs from the two others in the shape of the carapace and in having the setæ of antennæ and tail plumose.

"*Hab.*—St. Domingo, West Indies; M. Sallé, Mus. Brit." (Baird.)

Family APODIDÆ Burmeister.

Head and body in front broad and flat, shovel-shaped; carapace broad and flat; the body cylindrical, few or numerous segments extending beyond the carapace; antennæ small, 2d pair minute, sometimes wanting; labrum large, broad, flat; feet numerous, usually 63 pairs; with a large coxal, maxilla-like basal lobe forming gnathites; beyond five subjointed endites; the 2–4th endites in 1st pair of feet very long and slender, especially the 5th; gill pear-shaped or bottle-shaped; flabellum triangular, simple; the 5th endite of the 1st pair of legs is sometimes nearly as long as the body, the 11th pair bearing egg-sacs, and in the male having the genital outlet. Behind the 11th pair two of the abdominal segments bear each six pairs of appendages, there being many more appendages than segments to the abdomen, while a variable number at the end are without appendages. Telson cylindrical, either short or ending (in *Lepidurus*) in a long paddle-like outgrowth. A pair of long filiform jointed caudal appendages. Larva a nauplius.

Synopsis of the genera.

Telson ending in a long paddle-shaped outgrowth............*Lepidurus*
Telson short, cylindrical, simple..................................*Apus*

Genus LEPIDURUS Leach.

Plates XV, figs. 2, 2*a*, 3; XVI, figs. 1, 1*a*, 1*b*; XVII, XXI, figs. 1–6, 9, 11.

Lepidurus Leach. Dict. des Sc. Nat. I, 259. 1816.

Body rather deeper, more rounded than in *Apus*; the carapace longer in proportion to the body than in *Apus*. Frontal doublure much as in *Apus*, but with a rather prominent tubercle at the base of the hypostoma, while the latter is much larger than in *Apus*. Eyes as in *Apus*, but the tubercle behind the eyes is oblong-oval, instead of round, as in all the species of *Apus* I have seen. Antennæ much as in *Apus*. Mandibles as in *Apus*, with the same number of teeth; but the dorsal mandibular transverse tubercle on the carapace is larger; the maxillæ also as in *Apus*. The endites of the 1st pair of legs are very short, the outer ones in some species scarcely projecting beyond the edge of the carapace; there are about twelve subjoints in the 5th or longest endite, and the ends are usually (not always) rather blunt. The flabellum is very small compared with that of *Apus*, being narrow, triangular, the distal end acutely pointed, the gill or gill-sac itself much as in *Apus*. In the succeeding pair of legs there are no good generic differences between *Apus* and *Lepidurus*, though endites 2–5 are inclined to be rather the longer in *Lepidurus*. Gnathobases or coxal lobes much alike in the two genera.

In comparing the 10th pair of feet of *Apus* and *Lepidurus* no generic differences are to be observed, while the 11th pair, bearing the ovisacs, do not essentially differ in the two genera, but afford excellent specific characters; however, the ovisacs in *Lepidurus* are considerably larger and deeper than in *Apus*.

The telson is produced behind, with a long, broad, often spatulate plate or expansion, in *A. glacialis*, twice as long as the body of the telson itself; the end subacute, or broad and rounded, or bilobed; the edge smooth or spiny. The telson itself less spiny than in *Apus*. The caudal stylets, or cercopoda, about as in *Apus*.

The principal generic differences are in the long produced telson, the shorter endites, the usually larger carapace, being larger in proportion to the body than in *Apus* (though not so in *L. bilobatus*), and with usually only from 5 to 12 abdominal segments, besides the telson, projecting beyond the hinder edge of the carapace.

Geographical distribution.—Western North America appears to be richer than Europe-Asia in the species of this genus, one (*L. productus*) occurring in the Eastern Hemisphere, ranging from Central Europe to Scandinavia and England, while two species occur in the central zoological province of the United States, and one in Greenland and Arctic America. No species of the genus have as yet occurred in the Mississippi Valley or on the Atlantic coast, and none on the Pacific coast.

Synopsis of the species.

A. Endites 2–5 very short, not projecting beyond the carapace. Carapace large; telson short, pointed, spiny on edge ..... *L. glacialis.*
B. Endites 2–5 rather long and slender, projecting well beyond the carapace. Carapace large, leaving only 5 abdominal segments and telson uncovered; telson long, spatulate .... *L. couesii.*
Carapace very short; telson long, bilobed................. *L. bilobatus.*

LEPIDURUS GLACIALIS Kroyer.

Plates XVI, figs. 1 (enlarged nearly 3 times), 1*a*, 1*b*; XVII, figs. 1, 5; XXI, figs. 1, 2.

L. glacialis Kroyer. Naturhistorisk Tidskrift, 2d ser. vol. ii, 431. 1847.

Carapace very large, narrowing somewhat toward the eyes, being more regularly ovate than in *L. couesii*, which is more elliptical ovate. The twelve terminal abdominal segments are left uncovered by the carapace; the telson broad at the base and extended into a blunt prolongation armed with coarse teeth on the edges, and as long as the telson is broad at base; three sharp median teeth and a finely-denticulated tubercle on each side, at the base; the telson and its extension are smooth beneath. The cercopoda or caudal stylets are nearly as long as the body, slender and very hairy, rather than spiny.

The appendages differ decidedly from the other American species in the 2d to 5th endites being very short and broad and more equal in size; the 5th endite is much shorter than in the other species; the third and fourth of nearly the same size and length, and one-half as long as in the two other species; the second is about twice as large in proportion as in the two other species. The scale of the sixth endite is very long and slender, the tip much attenuated, with very long, hair-like setæ; the gill itself narrow, pear-shaped.

In the second pair of feet the second endite is twice as large as in the two other American species; the third and fourth of about the same size as in the other species, while the fifth is about one half as long, the scale (6th endite) very large and ensiform, with the tip curved and ending in a spine, the inner edge with sharp spinules, the outer edge with numerous long hairs. The accessory gill is inequilaterally triangular, the proximal edge straight, not produced backwards, as in the other two species; the fringe of hairs is very long; the gill itself is narrower than in *L. couesii* or *bilobatus*. In the tenth pair of limbs the third and fourth endites are much longer and narrower than in *L. couesii*, the gill and flabellum very different from the other two species, the gill being small, pyriform, with a constriction near the end, while the flabellum is nearly as broad as long, rounded anteriorly, and with the posterior edge straight.

In the eleventh pair of limbs, bearing the ovisacs, the endites are also longer and narrower than in *L. couesii*.

Length of body, 14^{mm}; of carapace, 10^{mm}; breadth of carapace, 9^{mm}.

Length of cercopoda, 6^{mm}; of telson, $1\frac{1}{2}^{mm}$.

Locality.—Received from Southern Greenland, through Dr. C. F. Lütken; Jacobshavn, North Greenland (Gerstaecker, 1064); Cape Krusenstern, Arctic America (Richardson).

Lepidurus couesii Packard.

Plates XV, figs. 2, 2*a*; XVII, figs. 2, 3, 7; XXI, figs. 4, 5, 6, 9, 11.

Lepidurus couesii Pack. American Naturalist, ix, 311, 1875. Bull. U. S. Geol. and Geogr. Survey, F. V. Hayden, in charge, iii, No. 1, 177, fig. 16. April 9, 1877.

Compared with *Lepidurus productus* Bosc of Europe, the carapace is of the same proportions, being large, broad, and leaving above five entire terminal abdominal segments exposed, including the telson. The denticulations on the hinder edge of the carapace are finer than in the European species, and show a tendency to become obsolete on the lower part of the incision. The eyes are slightly fuller, more prominent than in *L. productus*, and the interocular tubercle is smaller. The mandibular area of the carapace is the same as in *L. productus*. Labrum a little smaller than in *L. productus*. The feet are the same as in *L. productus*. The mandibles in this species (Pl. XXI, fig. 11) have, on the cutting edge, six well-marked teeth, which are rather blunter, less attenuated at the end than in *Apus lucasanus* (fig. 12). The maxilla (Pl. XXI, fig. 9) has a three-toothed lobe externally, and the inner larger lobe is setose throughout. There are usually from ten to twelve spines on the penultimate segment, as in *L. productus*. The chief distinction lies in the very long spatulate telson, which is about twice as long in proportion as that of *L. productus*, and is long and narrow, varying somewhat in width, and in size. The median ridge and edge are finely spinulose, the tip is well rounded; caudal stylets nearly as long as in *L. productus*.

The eggs of this species, Pl. XXI, are somewhat larger than those of *Apus lucasanus* (Pl. XVIII, fig. 5; the figures of the ovisacs containing them having been drawn to the same scale by the camera lucida).

From *L. glacialis* Kroyer, of Greenland, it differs in the longer, larger carapace, eleven terminal segments being uncovered in *L. glacialis*. The spines on the excavation are much smaller; telson twice as long, and not subtriangular, and excavated at tip, as in *L. glacialis;* eyes larger; interocular tubercle decidedly smaller; labrum smaller. The first pair of legs are much longer than in *L. glacialis*, in which the endites are very short.

Length of an average specimen from head to end of telson, 20.2^{mm}; telson, 5^{mm}; stylets, $15–19^{mm}$.

This species was collected by Dr. Elliott Coues, naturalist of the United States Northern Boundary Commission. He writes me that they "occurred in myriads in several small prairie pools, from a hundred yards to a half mile or so wide, exactly on the boundary-line, 49° N., just on the west bank of Frenchman's River, Montana. You will not find this stream on the map, perhaps, by this name.

"It is one of the first of the whole series of similar streams flowing south into Milk River. The species was not observed elsewhere. The ponds were extensive shallow sheets of sweet water, of a comfortable wading-depth, generally with a little open space in the deepest part, but mostly choked with luxuriant vegetation (*Gramineæ*, *Utricularia*, &c.). Date of collection, first week in July, 1874." Thirty-two males and thirty-one females were obtained by Dr. Coues: this equality in the number of the sexes is noteworthy.

Several females with eggs were also obtained by C. Carrington, of Hayden's U. S. Geological Survey, at Smithfield, Cache Valley, Utah. The specimens are in the Museum of the Academy of Natural Sciences, Philadelphia, to the curator of which I am indebted for the opportunity of examining the specimens.

LEPIDURUS BILOBATUS Packard.

Plates XV, fig. 3; XVII, figs. 4, 6; XXI, fig. 3.

Lepidurus bilobatus Pack., Bull. U. S. Geol. & Geogr. Survey, F. V. Hayden, in charge, iii, No. 1, 178, Fig. 17, April 9, 1877.

10 ♂, 3 ♀.—*Male.*—Carapace broad and short; as broad as long, measured along the median line. The eyes as in *L. couesii*. The excavation in the front edge of the carapace is much larger and broader than in *L. couesii*, and the teeth are more numerous, but very unequal in size, there being a few large teeth, with a number of smaller ones between them. The abdomen is longer than usual, with six (and part of another) segments beyond the last pair of feet, while in *L. couesii* there are only five. The spines on the edges of the abdominal segments are larger than in *L. couesii*, including the five teeth on the edge of the segments as well as the spines. There are about sixteen segments beyond the posterior edge of the carapace; in *L. couesii*, eight. On the dorsal side of the abdominal segments there are eight spines on the hinder edge, while there are nine in *L. couesii*. The species differs from any others in the remarkably short telson, which is short and broad, nearly one-half as long in proportion as in *L. couesii*. The segment is broader at base and the telson is broader than in any other species; it is truncate at the end, and divided by a slight incision into two well-marked lobes, with about seven more or less well marked median spines on the blade of the telson; this segment, including the telson, is as long as the preceding segments collectively. In the carapace, seen from beneath, the distance from the anterior edge of the hypostoma to the anterior edge of the carapace is much less than in *L. couesii*, while the hypostoma itself is much more convex. The 1st pair of legs are much longer and broader than in *L. couesii*, and the succeeding pair are rather broader than in that species.

Length of body, including caudal stylets, 48^{mm}; length of carapace (measured along median line), 18^{mm}; breadth, 18^{mm}; caudal appendages, $17\frac{1}{2}^{mm}$; 1st pair of feet, 15^{mm}.

Female.—Differs from the male in the much shorter body and shorter first pair of feet. There are five segments beyond the last pair of feet, and twelve segments beyond the edge of the carapace. It is easily distinguishable by the shorter abdomen and 1st pair of feet, but otherwise it does not differ, the telson and caudal filaments being of the same proportion. The egg-sacs were empty; they are situated on the tenth pair of feet. Length of body, 35^{mm}; length of carapace (measured along median line), 15^{mm}; breadth, 17^{mm}; length of caudal appendages, 14^{mm}; antennæ, 10^{mm}.

Po Cañon, Vermillion River, Colorado; collected by Dr. C. A. White, of Major Powell's Survey. Described from specimens kindly loaned by Prof. H. A. Ward, of Rochester, N. Y.

This exceedingly interesting species differs from any other known to me in the large, broad, bilobed telson, that of *L. glacialis* being small, subtriangular, while in *L. productus* and *L. couesii* it is long and spatulate. It differs from the two latter species in the longer, broader, 1st pair of feet, the longer body, and shorter carapace.

The differences in the appendages in *L. bilobatus* and *couesii* are very slight; in the 2d pair of feet the accessory gill of *L. bilobatus* is longer, less rectangularly triangular than in *L. couesii*, while the pear-shaped gill is of nearly the same shape in both species. In both species the four endites are long and slender, those of *L. bilobatus* being rather wider than in *L. couesii*. The scale (6th endite) is blunt, knife-shaped, and finely denticulate on the outside in *L. bilobatus*, while in *L. couesii* it is acute, shorter, and triangular. In the 2d pair of feet the scale in *L. bilobatus* is very large, stout, knife-shaped, and finely denticulated on the inner edge, with fine setæ externally; that of *L. couesii* is one-third smaller and acutely triangular; the four endites are much broader in *L. bilobatus* than in *L. couesii*. The accessory gill is larger and much the broader in *L. bilobatus*, the posterior end being very much produced in *L. couesii*. In the 10th pair of limbs the endites are longer and narrower in *L. bilobatus* than in *couesii*, and the scale is narrower.

The following exotic species may be referred to here:

Lepidurus viridis Baird, Proc. Zool. Soc., London, 1850. Van Diemen's Land.

Lepidurus angusii Baird, Proc. Zool. Soc., London, 122, 1866. Rain pools on the Gawler Plains, north of Adelaide, South Australia.

APUS Schaeffer.

Plates XV, figs. 1, 1*a*, 1*b*; XVI, figs. 2–5*a*; XVIII, XXXII, XXXV.

Apus Schaeffer, Der krebsartige Kiefenfuss, 1756. Bosc, Hist. des Crust. ii, 244, Pl. XVI, fig. 7. Latreille, Hist. des Crust. Ins. iv, 195. Milne-Edwards, Hist. Nat. Crust. iii, 356, 1840.

As in Lepidurus, but the carapace is shorter, the abdomen being longer and extending much farther beyond the hinder edge of the carapace; the 2d–5th endites of the 1st pair of legs are much longer than in Lepidurus, the 5th when stretched back sometimes reaching near the telson; the latter is short, cylindrical, without any paddle-like extension.

Synopsis of the species.

Carapace longer than in the other species; telson short, with 4 large central spines above .... *A. æqualis*.
Carapace shorter than in *æqualis*, but the telson longer ... *A. newberryi*.
Carapace shorter than in foregoing species; telson with only 3 central spines .... *A. lucasanus*.
Carapace much as in *A. lucasanus;* telson very short, with 5 central spines .... *A. longicaudatus*.

APUS ÆQUALIS Packard.

Plates XV, figs. 1, 1*a*, 1*b*; XVIII, fig. 1; XIX, fig. 2; XX, fig. 2.

Apus æqualis Packard, Amer. Journ. Sc. Aug. 1871.

Two males.—This species differs from the following species in the carapace being as long as the abdominal portion beyond it. The doublure is shorter than usual; while the hypostoma is rather larger, being as long as the doublure; the front of the head beneath resembling that of *A. longicaudatus*. There are 17 teeth on each side of the sinus of the carapace. Eyes considerably larger than in *A. longicaudatus;* the post-ocular tubercle much smaller than in the species just named. In the first pair of feet the fifth endite is rather longer than in *A. newberryi*, the fourth longer and slenderer, and the second also long and slender. In the second pair of feet the four endites are rather short and broad, especially the first; the "scale" (or sixth endite) is much shorter than the fifth endite, the latter being long and slender, and in one specimen reaching to the base of the telson. The fourth endite in one specimen is two-thirds as long as the fifth, in another scarcely half as long. The flabellum is smaller, but of nearly the same form as in *A. newberryi*, while the gill is smaller and more regular in form. In the tenth pair of feet the four endites are rather longer and narrower than in *A. newberryi;* the tips of the fifth endite and its scale are of equal length, the end of the latter terminating in a curved spine; the flabellum is much rounded, with a long fringe of hair-like setæ, but is not much larger than the gill itself; telson about as long as in *A. longicaudatus*, unusually smooth, with five median spines, three arranged in a triangle near the edge, with two moderately prominent lateral ones at the base of the caudal appendages, the latter moderately spiny, the spines being fine and numerous; beneath the telson is quite smooth, with fine spines in the middle and on the sides. Number of segments beyond hind edge of carapace, 23; beyond last pair of appendages, 11. Total length of the body, 29^{mm}; length of carapace, 14^{mm}; breadth, 12.5^{mm}; length of carina of carapace, 9^{mm}; distance from front end of keel to front edge of head, 5.2^{mm}; length of caudal appendages, 19^{mm}.

Thirteen females.—Carapace with 20 spines on each side of the hinder edge or sinus. The fifth endite of the first pair of feet reaches in all the Matamoras specimens but one to the base of the telson, in the others midway between the hind angle of the carapace and the base of the telson. Number of segments beyond the hind edge of shield, 25; number beyond last pair of appendages, 9. Total length of the body, 29^{mm}; of carapace, 14^{mm}; breadth, 11.5^{mm}; length of keel, 8.5^{mm}; length from end of carina to front edge of head, 5.8^{mm}; length of abdomen behind the carapace, 14^{mm}; length of caudal appendages, 19^{mm}. "Matamoras, Mexico, General Couch," "Kansas, No. 5," Mus. Chicago Acad. Sc., "Plains of Rocky Mountains, No. 390," Museum of Yale College. Having been favored by Professor Baird with the opportunity of examining a colored painting by Dugés, September, 1877, of an Apus collected at Guanajuato, Mexico, I am inclined to refer it to *A. æqualis*, though in comparing the drawing with the specimens from Matamoras the antennæ are represented as much too short, and the body behind the carapace too thick; but it fairly represents the proportions of the carapace.

I have received small specimens of this species from Bosque County, Texas, through Mr. Belfrage. One of them was a young one, whose total length was 29^{mm}, the carapace along the median line measuring

11.5^{mm}, the abdomen beyond the middle fold of the carapace being 5^{mm} long; the carapace was longer and the abdomen much shorter than in the adult, but in the number and arrangement of the spines on the telson and in the caudal stylets, as well as the eyes and adjacent parts, the Texan ones are the same as the type specimens from Kansas and Matamoras.

This species may at once easily be distinguished from the other American species by the greater length of the carapace, which equals that of the abdomen, also by the smooth telson with its five spines and the rather smooth, slightly spined caudal appendages. The young, one-half an inch in length, have the same proportions of the carapace and abdomen as in the largest specimens.

APUS NEWBERRYI Packard.

Plates XVI, fig. 3, *3a*, *3b*; XVIII, figs. 2, 7; XIX, fig. 3; XX, fig. 1.

Apus newberryi Pack., Amer. Journ. Sc. Aug. 1871.

Carapace rather longer than in *A. longicaudatus* and *lucasanus*, though leaving about the same number of appendages in view when seen from above. The dorsal keel of the carapace is about one-third longer than the distance between its anterior end and the front edge of the carapace. The eyes are rather larger than in *A. longicaudatus*, and the post-ocular tubercle is of the same form, though, owing to the larger eyes, not quite so prominent as in *A. longicaudatus*. The transverse muscular eminence is not so long (antero-posteriorly) as in *A. longicaudatus* where it is much produced posteriorly. There are 14 spines on each side of the sinus of the female carapace, the posterior angle of which is a little more obtuse than in *A. longicaudatus*. Doublure and hypostoma as in *A. longicaudatus*, the tubercle at the base of the hypostoma not so strongly marked however. The fifth endite of the first pair of feet reaches only a little beyond the cephalic shield, and only as far as the basal third of the abdomen (that part not covered by the carapace), while in *A. longicaudatus* it reaches as far as the middle of the abdomen.

The second endite unusually small and slender; third and fourth moderately short, shorter than in *A. lucasanus*; the flabellum is considerably prolonged and attenuated backwards, much more so than in *A. lucasanus*; the gill itself is rather large and twice as wide as in *A. lucasanus*; in the female there are no marginal filaments. In the second pair of feet the endites are slightly longer than in *A. lucasanus*, especially the first one, and they are more deeply incised or denticulated. The scale (sixth endite) is large and long, reaching to the tip of the 5th endite; it is finely spinulose, with a curved terminal spine. The flabellum is large, as is the gill itself, which is nearly twice as broad as in *A. lucasanus*, and without any marginal filaments. In the tenth pair of appendages the endites are very broad, triangular; the scale longer than the 5th endite, and with a stout terminal spine; hairy externally and spiny on the inner edge. The flabellum and gill are unusually large. The endites of the eleventh or ovigerous pair are broader than in *A. lucasanus*.

The under side of the abdominal segments are a little more spiny than in *A. longicaudatus* and *A. lucasanus* owing to the secondary small spines developed on the base of each segment; above there is one less spine on each ring than in *A. longicaudatus*, but the same number as in *A. lucasanus*.

The telson is longer than either in *A. longicaudatus* or *A. lucasanus*;

the lateral spines are minute; along the middle line are five spines; the lateral group near the base are arranged more in a line than in *A. longicaudatus*, where they form a more irregular group. The under surface is nearly smooth compared with *A. longicaudatus* or *A. lucasanus*. The caudal appendages are two-thirds as long as the body, and gradually taper towards the tips instead of being suddenly thicker at base, as in *A. longicaudatus*, and are much less spiny. In *A. longicaudatus* there are four or five large stout, broad teeth on one side, while in the present species there are a number of minute spinules around the basal as well as the terminal segments. Number of abdominal segments beyond hind edge of carapace, 29; number of segments behind the last pair of appendages, 11.

Total length of carapace, 25^{mm}; length along the middle, $19\frac{1}{2}^{mm}$; breadth, 21^{mm}.

Length of dorsal keel of carapace, $12\frac{1}{2}^{mm}$; from front end of keel to front edge of head, $7\frac{1}{2}^{mm}$.

Length of abdomen behind the carapace, 25^{mm}.

Length of caudal appendages, 26^{mm}.

This species differs from *A. longicaudatus* and *A. lucasanus*, to which it is nearly allied in form and in geographical range, in the longer carapace, and shorter abdomen with its longer telson. It need not be confounded with *A. æqualis*, in which the carapace is much larger and longer and the telson much shorter, while the latter species is restricted to the eastern border of the Rocky Mountain plateau and to Texas and Mexico. It differs chiefly from *A. longicaudatus* and *A. lucasanus* in the shorter endites and much longer, smoother telson, and the smooth, almost hairy, instead of spiny caudal appendages, and in the entirely different arrangement of the spines on the telson.

Locality.—"Utah, J. S. Newberry, No. 1." Two females, Mus. Chicago Acad. Sc. Ogden, Utah, collected by Mr. Henshaw, Wheeler's Survey, one female. In this individual there is one less spine on the middle of the telson than in the two others, and there are only eight instead of nine segments between the telson and the last pair of appendages. The carapace does not differ, nor do the appendages.

APUS LUCASANUS Packard.

Plates XVI, figs. 2, 2*a*, 2*b*; XVIII, figs. 3, 5; XIX, figs. 1, 5; XXI, figs. 7, 8, 10, 12, 13.

Apus lucasanus Pack., Amer. Journ. Sc. Aug., 1871. Bull. U. S. Geol. and Geogr. Survey, iii, No. i, 171, 179, April 9, 1877.

Males.—This is the more aberrant of the two sexes. It is very near *A. longicaudatus*. The eyes and post-ocular tubercle as in *A. longicaudatus;* the muscular eminence is not so much produced behind as in *A. longicaudatus*. Carapace a little longer than wide, with 14 teeth on each side of the posterior sinus. Doublure rather longer than in *A. longicaudatus* and the hypostoma a little smaller. Antennæ as in *A. longicaudatus*. The 5th endite of 1st pair of feet are shorter than usual, often not reaching to the hind edge of the carapace, being much shorter than in any of the other American species. (It is represented as rather too long in fig. 2, Pl. XVI.) The first pair of feet and succeeding appendages are shorter and rather smaller than in *A. longicaudatus*. In the 1st pair of feet of male the 2d endite is much larger than in *A. longicaudatus*, the three other endites being much as in the male of *A. longicaudatus;* the gill is narrow, regularly oval, and fringed with sparse, thick filaments, while the flabellum or accessory gill is full, evenly rounded in front and acute behind. In the 2d pair of feet the 2d endite is larger and much stouter than in *A. longicaudatus;* the scale of the 4th pair is large, broad, acutely ovate, the edges smooth, the end only reaching to the outer third of the 5th endite; the flabellum is large, rounded, oval, while the gill is much as in the first pair. In the 10th pair of appendages the endites are much as in *A. longicaudatus*, but slightly broader, and the scale has the same relations to the 5th endite as in *A. longicaudatus.* As regards the flabella, the two species, though so much alike externally, differ decidedly in form, those of *A. lucasanus* being larger and more rounded externally, while the gills are narrower, and provided with scattered thick filaments on the edges, which are wanting in *A. longicaudatus.* The under side of the telson, which is longer, is also less spiny than in *A. longicaudatus*, and on the upper side there are three spines in the middle instead of five, as in *A. longicaudatus*, with two large spines on each side. Caudal appendages less spiny than in *A. longicaudatus;* their spines are blunt, and their arrangement into rows differs from that in *A. longicaudatus*, where the rows are arranged in twos, a row of small spines being just behind a row of large ones on the edge of the joint. Number of segments exposed behind the carapace is 33; number of abdominal segments beyond the last pair of appendages, 13.

Length of body, excluding the caudal appendages, 27^{mm}.

Length of carapace, 12^{mm}; breadth of the same, 10^{mm}; length along the middle, 9^{mm}.

Length of the keel, 6^{mm}; distance from front end of keel to front end of carapace, 4^{mm}.

Length of caudal appendages, 14^{mm}.

Female.—The carapace is longer and the abdomen shorter than in the male. There are 17 spines on each side of the sinus of the carapace. Telson as in the male, while the caudal appendages have smaller spines; beneath not spined, being smooth, with a row of fine teeth on the edge. The exites of the 11th ovigerous feet are decidedly shorter and broader than in *A. longicaudatus.* Number of segments beyond the hinder end of carapace, 29; number of segments behind the last pair of appendages, 11. The eggs are of the same size as in LeConte's species; they are spherical, orange-yellow; the chorion thin, transparent; the yolk granules rather large.

Total length of body, 20^{mm}; length of carapace in the middle, 10^{mm}.

Length of keel, 6^{mm}; distance from front end of keel to front edge of carapace, 4^{mm}.

Length of abdomen behind the hind edge of the carapace, 14 inches.

Several males from Museum of Chicago Academy of Sciences labeled "Cape St. Lucas, J. Xanthus, 4."

Six male specimens in a bottle received from Dr. Stimpson, and marked "Kansas ? 5"; in the same bottle were 13 females of *A. æqualis.* These could not be distinguished from Cape Saint Lucas specimens.

This species occurred in great abundance at Ellis, Kans., associated with the other Phyllopods from this locality. It was collected in June by Dr. L. Watson. The specimens are not distinguishable from my types of *A. lucasanus* from Cape Saint Lucas, Lower California.

Numerous specimens have also been received from Fort Wallace, Kansas, through Prof. Joshua Lindahl.

The occurrence of this species so abundant locally in Kansas, at Cape Saint Lucas, is interesting. Fearing that some mistake had been made, I have repeatedly compared the Cape Saint Lucas specimens with numerous ones from Kansas, and have observed no differences; in comparing every part of the 1st and 2d pairs of feet of individuals from Cape Saint Lucas and Kansas no differences can be found.

As the species has proved to be the most abundant and accessible of all the species in this country, the specific name is not altogether appropriate, still it will serve to remind one of the interesting features in its geographical distribution.

The food of this species appears to be Crustacea, as in dissecting the mouth-parts of one of this species the legs of an Asellus-like Crustacean were found partly swallowed. Hence they are quite predaceous in their habits.

APUS LONGICAUDATUS Leconte.

Plates XVI figs. 4, 4*a;* XVIII, figs. 4, 6; XIX, fig. 4; XX, figs. 3, 4.

Apus longicaudatus Lec., Annals N. Y. Lyceum, iv, 155, Pl. IX, 1846.
Apus obtusus James, Long's Expedition, ii, 336. Packard, Hayden's U. S. Geol. Survey, Terr. Report for 1873, 620, 1874.

Carapace about as long as wide, being shorter than in any other known American species. This species, besides the characters given by Leconte, has the following: The frontal doublure is about one-half as long in proportion as in *A. cancriformis*, being shorter than the hypostoma; the latter is rather shorter and broader than in *A. cancriformis*, and with a swollen area or eminence at the base, not present in *A. cancriformis.* The antennæ are two-jointed, the 2d joint slenderer, more chitinous than in *A. cancriformis*, and reaching to within a distance from the edge of the shield equal to one-fourth of their length. The 1st pair of feet are alike in both sexes. The endites are long and slender, differing only slightly from those of *A. lucasanus;* the specific differences are, however, best marked in the exites of all the limbs, the gills being small, rather narrow, but still wider than in *A. lucasanus*, but without the fringe of coarse filaments of the latter species; the flabellum is shorter, more triangular, the anterior edge being less full and rounded. In the 2d pair of feet the endites are much as in *A. lucasanus*, but the scale is long, knife-shaped, acute, and extends nearly to the tip of the 5th endite. The gill is regularly rounded, ovate, and the flabellum is subtriangular.

In the 10th pair of limbs, while the endites are much as in *A. lucasanus* they are a little narrower, and while the flabellum is of nearly the same shape and size, the gill itself is much shorter and broader, being nearly round.

In the 11th pair of female limbs bearing the ovisacs, the short flabella are longer and narrower than in *A. æqualis.*

Seen from above, 32 segments may be counted in the males (in the female, 28) beyond the edge of the carapace; and seen from beneath, there are 14 segments beyond the last pair of appendages (in the female, 10).

The abdomen is unusually spiny, as also the caudal stylets, the segments of the latter being well marked by the spinules, which project unusually far out. The telson is shorter and more spiny than in *A. lucasanus;* on the upper side is a median group of three spines arranged in a triangle, with a pair lower down, with three stout lateral spines, and a group of five or six spines just within the outer edge, and near the base of the telson; the under side is more heavily spined laterally than in *A. lucasanus*, and there are more numerous, finer spines on the under side of the segment next in front of the telson.

Total length of carapace, 19^{mm}; width of the same, 17^{mm}.

Length of keel on the carapace, $8\frac{1}{4}^{mm}$; from anterior end of keel to front edge of carapace, 6^{mm}.

Length of abdomen beyond the carapace, $21\frac{3}{4}^{mm}$.

Length of caudal appendages, 20^{mm}.

Diameter of the ovisacs, $2\frac{1}{2}^{mm}$.

Our female differs from the males in the carapace being longer, with 28 segments, uncovered, beyond the carapace; and 10 segments beyond that bearing the last pair of appendages, while the under side of the telson is much smoother than in the males, but the upper side as in the males; the caudal appendages less spiny than in the males.

The ovisacs contained a few eggs, which were of the same size as in *A. lucasanus* and otherwise the same, except that the germ had commenced to develop; they were arranged in the cavity of the ovisac side by side in two rows, the lower or inner row the larger.

I have had the opportunity of examining Professor Dana's original type of Leconte's, contained in the museum of Yale College. It was, when received, broken and dried up, but with the carapace preserved, while the caudal appendages were wanting. The specimen was labeled "Rocky Mountains, near Long's Peak." This would place it within the present limits of Colorado.

Four specimens from the museum of the Chicago Academy of Sciences, received through the late Dr. William Simpson, were labeled "Texas, J. H. Clark No. 3." They only differ from Dana's type specimen in the dorsal carina of the carapace being considerably shorter than in the type, being twice as long as the distance from the front margin of the carapace to the anterior end of the keel.

In the other specimen this distance is one-third or one-fourth as great as the length of the keel. The specimens vary somewhat in the relative length of the keel, in the length of the abdomen, and the size and number of spines on the under surface of the telson, while the endites of the 1st pair of feet vary slightly in length. The size and form of the telson, and the number and arrangement of the spines afford good specific characters in this genus.

Three specimens labeled "Pools near Yellowstone River, Dr. Hayden, 6," were also received through Dr. Stimpson, of the Chicago Academy. The range of the species would seem to be from the Yellowstone River along the eastern flank of the Rocky Mountains to Texas, probably the upper part of the State.

James, in Long's "Expedition to the Rocky Mountains," says of this species: "Rain-water puddles on the Platte River, near the Rocky Mountains. . . . In rain-water puddles we remarked a new species of Branchipoda belonging to the genus *Apus*; small crustaceous animals, which exhibit a miniature resemblance to the King or Horse-shoe Crab (*Limulus polyphemus*) of our own sea coast, but which are furnished with about 60 pairs of feet, and swim upon their back. The basins of water which contained them had been very much diminished by evaporation and infiltration, and were now crowded to excess, principally with the *Apus*, great numbers of which were dying upon the surrounding mud, whence the water had receded. This species is distinguished from the *productus* of Bosc and *montagui* of Leach, by not having the dorsal carina prolonged in a point behind; and from *cancriformis* by the greater proportional width of the thorax, and more obtuse emargination behind. The length of the thorax along the middle is three-tenths of an inch, and its greatest breadth somewhat more. It may be named Apus obtusus."—Note 7, p. 336.

We should regard *A. longicaudatus* as standing at the head of the genus, and the European species, *A. cancriformis*, lowest, the former species being on the whole more specialized, since the carapace is in *A. longicaudatus* smaller, not reaching to the middle of the whole body, while that of *A. cancriformis* is more as in the larval stages, since it reaches nearly to the telson, nearly concealing from above the limbs. The frontal doublure is also much smaller than in the European species, while in the latter species the caudal appendages are considerably longer than the body, in *A. longicaudatus* being barely one-half as long as the whole body. On the whole, therefore, *A. longicaudatus* seems nearer allied to *Branchipodidæ*, while *A. cancriformis*, by its large shield covering nearly the whole body, shows some slight approximation to the *Limnadiadæ*.

APUS DOMINGENSIS Baird.

"*Apus Domingensis* Baird, Proc. Zool. Soc. London, Part xx, 5 (Tab. 22, fig. 1), 1852.

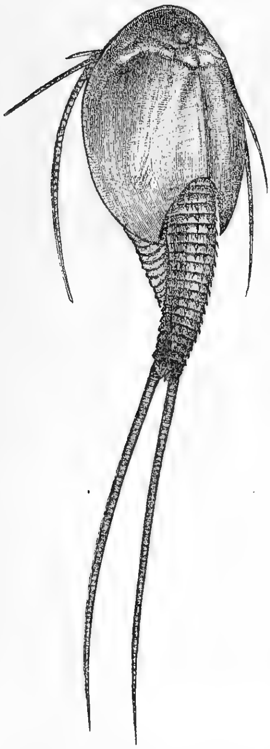

FIG. 16.—*Apus domingensis*, enlarged. After Baird.

"Clypeo corporis dimidiam partem tegente, rotundo, tenui, corneo; ramo externo pedum primi paris corpus æquante. Long. toti corporis 1 poll; lat. clypei ¾ poll.

"*Hab.*—In Insula St. Domingo, India Occidentali. Collegit M. Sallé. Museum Britannicum.

"Though a native of the West Indies, this species may be easily distinguished from *A. Guildingii* by its round-shaped carapace of a horny colour, covering half the body of the animal, and its external branch of the first pair of feet only the length of the body, while in *A. Guildingii* it exceeds the whole body and caudal filament included. The carina down the center of the carapace, and the fork which it takes at the anterior extremity where the division into cephalic and thoracic portions takes place, are marked throughout their length with a deep brown color, as are also the short stout spines on the abdominal portion of the body. These are straight, not hooked, as in some of the other species. The caudal filaments are nearly the length of the body, and are covered with very numerous, extremely short setæ. The oviparous feet are present in all the specimens I have examined, but none contain any ova."

This species (Fig. 16) is very closely allied to *A. æqualis*, and represents that species in the West Indian fauna.

APUS GUILDINGII Thompson.

Apus Guildingii Thompson, Zool. Researches, Fasc., v. 108, t. 6, fig. 3; Milne-Edwards, Hist. Nat. Crust. iii, 561. Baird, Monog. Family Apodidæ, Proc. Zool. Soc. London, Pt. XX, 3, 1852. Clypeo corporis vix dimidiam partem tegente, quadrato, membranaceo, nigrescente; ramo externo pedum primi paris longissimo, totum corpus, filamentis caudalibus inclusis, excedente.

Hab.—In Insula "St. Vincents," India Occidentali; Rev. Lansdowne Guilding.

Mr. Thompson, in his Zoological Researches, remarks: "I received this species of Apus together with the Artemia Guildingii from the West Indies, and having as yet no details must leave its history in the hands of its distinguished discoverer. It is of a light blackish color, the clypeus translucent, almost membranous, and shorter in proportion than in any of the known species, with the extreme branch of the anterior member extremely long." Unfortunately we have no further history of this species from its discoverer, the Rev. Lansdowne Guilding, but the short square-shaped carapace and the extreme length of the external branch of the first pair of feet sufficiently distinguish it.

We add the following description of an Asiatic species, briefly described by us in 1871.

APUS HIMALAYANUS Packard.

Plate XVI, figs. 5, 5*a*.

Apus himalayanus Pack. Amer. Journ. Sc. 1871.

Several females.—Carapace two-thirds as long as the body, with from 14 to 16 teeth on each side of the sinus on the hind edge, the last tooth on the extreme end of the shield being more prominent than usual. Eyes and post-ocular tubercle small, as in *A. cancriformis;* mandibular muscular eminence behind also as in *A. cancriformis;* frontal doublure, hypostoma, and appendages as in *A. cancriformis.* The 1st pair of feet closely resemble those of *A. newberryi* in the form of the long knife-like scale, as well as in the form of the gill and accessory gill (flabellum); the length of the 5th endite of the first pair of feet is 19^{mm}., and it is composed of from 72 to 80 subjoints, while *A. cancriformis* has about 50, and *A. æqualis* 42. Diameter of the ovisac is nearly 4^{mm} (.15 inch). There are the same number of spines on the abdominal segments as in *A. cancriformis*, and the spines on the telson have the same arrangement, there being on the upper side four spines at the insertion of the stylets, the 4th being minute; a single spine on the hind edge projecting over the sinus in the middle of the hind edge, which is deeper and narrower than in *A. cancriformis;* there is also a minute spine on each side of the sinus as in *A. cancriformis*, and two minute spines at the bottom of the sinus. Near the base of the telson, on each side, is an oval depression, with the posterior side raised and bearing three teeth, just as in *A. cancriformis.* The telson, however, is considerably longer than in *A. cancriformis*, being two-thirds as long as wide, while in the latter it is only one-half as long. On the under side of the telson the hind edge is rather more deeply incised than in *A. cancriformis*, and the edge is much more spiny, there being about 7 spines on each side.

The cercopoda or caudal spines are finely spinulated, almost hairy, as in *A. cancriformis*, in this respect differing from all the American species.

Total length of body, 25^{mm}.

Greatest length of carapace, 16^{mm}.

Of the keel, 11^{mm}.

Distance from anterior end of the keel to the front edge of the head, $5\frac{1}{2}^{mm}$.

Length of abdomen beyond the hind edge of carapace, 9^{mm}.

Length of caudal appendages, 28^{mm}.

Number of segments beyond the hind edge of the carapace, 19 (in *A. cancriformis*, 14).

Number of segments behind the last pair of limbs, 7 (in *A. cancriformis*, 6).

This species belongs to the third division of the genus, of which the European *cancriformis* is a type, having the small eyes, and small post-ocular tubercle, while the telson is marked in the same manner, and the caudal appendages are finely spinulose, or hairy, as in no American species. The 2d pair of feet are, however, very much like those of *A. newberryi*, in the form of the long cultriform scale, or 6th endite, and in the form of the gill and its flabellum, as well as the size of the carapace.

"Collected from a stagnant pool in a jungle, four days after a shower of rain had fallen. For five months previous to this rain there had been no rain upon the earth. Himalaya Mountains, North India, near where the Sutlege River debouches into the plains. April, 1870." Museum of Comparative Zoology, Cambridge. This is, evidently, a high-plateau species, and a member of the Central Asiatic rather than Oriental fauna.

Apus dukianus Day (Proc. Zool. Soc. London, p. 392, 1880) differs from *A. himalayanus* in the shorter carapace and much longer abdomen, which has 24 segments beyond the hinder end of the carapace, while in himalayanus there are 17. In the Himalayan species, also, the 5th and 6th endites of the 1st pair of legs are much longer and the caudal appendages are much longer. *A. dukianus* was discovered by Dr. Duke in Afghanistan, in a pond near Kelat, in April, 1877.

Family BRANCHIPODIDÆ Baird.

Branchipoda Leach, Dict. des Sc. Nat. xiv. 1816.
Branchipiens Milne-Edwards, Hist. Nat. des Crust. iii, 364, 1840.
Branchipusidæ Baird. Trans. Berwick Nat. Club, 1845.
Branchipodidæ Fischer. Middendorf's Reise, ii, 149, 1851.
Branchipodidæ Baird, Proc. Zoöl. Soc. London, 1852. Ann. and Mag. Nat. Hist. XIV, 216, 1854.
Branchipidæ Burmeister, Organiz. of Trilobites, Roy. Soc. edit. 34.
Branchipidæ Verrill, Proc. Amer. Assoc. Ad. Sc. July, 1870.
Branchipodidæ Packard, Report of Hayden's U. S. Geol. Surv. Terr. for 1873, 620. 1874.
Gerstaecker, Bronn's Class. u Ord. Thierreichs, V, 1034. 1866–'79.

Body soft, delicate, without a carapace; head small; the eyes stalked; a distinct median ocellus; 1st antennæ filiform; 2d antennæ stout in the males, forming clasping organs; frontal appendages often present; 11 pairs of feet (19 in Polyartemia), which are without a gnathobase or coxal lobe; the other lobes (endites), especially the 5th and 6th, broad and foliaceous, with a gill and simple rounded flabellum. First and 2d uromeres with a penis in the male or an ovisac in the female. A specialized abdomen, with 8 to 9 segments not bearing appendages. Terminal segment bearing a pair of filamental not-jointed setose appendages. Larva a nauplius.

Subfamily 1. BRANCHIPODINÆ Packard.

Eleven pairs (in *Polyartemia* 19) of feet, with the outer endites moderately broad. Abdomen slender, cylindrical; terminal abdominal segment with two filamental setose caudal appendages.

Synopsis of the genera.

a. No frontal appendages.
Abdomen with eight segments; male claspers with 2d joint flat, triangular; ovisac short .... *Artemia*

Abdomen with nine segments; male claspers simple, cylindrical; ovisac long, slender .... *Branchinecta*

b. Frontal appendages present.

Frontal appendages ribbon-like, or broad triangular; 2d joint of male claspers chitinous, simple, bent at tip .... *Branchipus*

Second joint of male claspers long, tortuous, and forked irregularly; ovisac long and slender................................ *Streptocephalus*

Frontal appendages long and variously lobed or spinulose; ovisac short and broad .... *Chirocephalus*

Genus ARTEMIA Leach.

Plates VIII, XXII, XXIII.

Cancer Linnæus, Systema Nat. ed. 12, i, pars. 2, 1056.
Apus Schaeffer, Monogr. fig. 1, 12, 1754.
Branchiopoda Lamarck, System. des Anim. sans vert. 161. 1801.
Branchiopoda Latreille, Gen. Crust. et Insect, i, 22, 1806.
Eulimine Latreille (pre-occupied),* 1817.
Artemia Leach, Dict. des Sc. Nat. xiv; 1819.

Body very slender, with eleven pairs of feet; the head rather smaller in proportion than in the other genera of the family; the male claspers (2d antennæ) very large, thin, and broad; 2-jointed, the 2d joint bent at nearly right angles upon the 1st, the latter thick, about twice as long as thick, a deep rounded sinus between the bases of the claspers exactly fitted so as during connection with the female to enclose her back. Near the middle, on the inner side of the 1st joint, a knob-like projection. The 2d joint simple, broad, flat, acutely triangular, from ½ to ⅔ as broad as long. The legs beyond the 5th endite rather slenderer and more pointed than in the other genera. The gill is moderately large, about half as wide as long; the flabellum broad and rounded, the edge serrate and setose as usual. The 1st endite divided into two lobes, the 2d of which is about ⅓ as long as the 1st; endites 2–4 are minute, conical; the 5th is moderately large and rounded on the outer angle, with large, coarse setæ, the distal edge oblique and somewhat full and rounded; the 6th is narrow, long, and more produced and acutely pointed than usual, much more so than in *Branchinecta* or any other genus of the family, while the setæ are much longer than in *Branchinecta*.

Abdomen eight-jointed, very slender, ending in a pair of unusually short, small cercopods (caudal appendages) not more than twice as long as broad, being less than half as long as in *Branchinecta*, and less than half as long as the terminal segment. The male genital deeply cleft, each half long and slender, more so than in *Branchipus*, but somewhat as in *Branchinecta*, though shorter and less curved. Ovisac of the female rudely bottle-shaped, shorter and broader than in any of the other genera, with a short, broad "neck" or opening.

Remarks.—This genus is in some respects simpler than *Branchinecta*, or any other genus of the family, and differs decidedly from any other genus, not only in the small size of the body, but also in the broad, flat, triangular 2d joint of the male claspers, as well as in the much smaller, shorter caudal appendages, and the long, narrow, acute distal or 6th endites, which render the legs rather long and slender. The ovisac is also shorter and broader than usual.

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*According to Dr. Baird (Monograph of the Family Branchipodidæ, etc., in Annals and Mag. Nat. History, xiv, 216, 1854) the genus *Eulimine* Latreille, 1817, was based on specimens of *A. salina*, which were badly preserved and erroneously described. That name was, however, pre-occupied among Acalephs, see Verrill, Observations, etc.

Compared with the other genera, this upon the whole stands at the base of the family, though the male claspers are a little more complicated than in *Branchinecta*. Considering the fresh-water forms by themselves, *Branchinecta* is, without much doubt, the lowest or simplest in structure. As seems most probable from the experiments of Schmankevitch, *Artemia* is a modification of *Branchinecta*, and is a depauperated form, smaller in size, with less developed caudal appendages, due to perhaps less favorable means of obtaining food in its brine than the fresh-water forms. Hereafter, then, in diagnosing the other genera we will take *Branchinecta* as the simpler form, affording us a truer standard of comparison than the less normal *Artemia*.

The Siberian fresh-water genus *Polyartemia* of Dr. S. Fischer* is remarkable for possessing 19 pairs of feet; the tail is short, the ovisac quite voluminous; the male claspers are broad, flat, and consist of two branches, one covering the other; the front of the head is prolonged into a broad, very thin tentacle-like organ; in other respects it agrees with the genus *Branchipus*. *Polyartemia forcipata* Fischer was found by Middendorf in pools on the Tundra, near the rivers Taimyr and Boganida, and also in Lapland, near the Tri-Ostrowa.

ARTEMIA GRACILIS Verrill.

Plates VIII, XXII, figs. 1, 2, 2*a*, 2*b*; XXIII.

Artemia gracilis Verrill, Amer. Journ. Sc. 2d Ser. xlviii, 248, Sept. 1869. Proc. Amer. Assoc. Adv. Sc. July, 1870.
Artemia monica Verrill, Amer. Journ. Sc. 2d Ser. xlviii, 249, Sept. 1869. Proc. Amer. Assoc. Adv. Sc. July, 1870.
Artemia fertilis Verrill, Amer. Journ. Sc. xlviii, p. 430, Nov. 1869. Proc. Amer. Assoc. Adv. Sc. July, 1870.
Artemia utahensis Lockington,† Month. Micr. Journ. 137, March, 1876.

This species is characterized by the slender body, its small head and small eye-stalks and eyes. The male claspers are rather slender, the 2d joint varying with age and in different individuals from the same locality; it is unusually broadly triangular and from one-half to two-thirds as wide as long; at the outer angle is a large angular projection, while the apex is acutely pointed and slightly excurved (Pl. VIII, fig. 1). The frontal knobs on the inside of the 1st or basal joint are small, rounded, button-like. The ocellus is black, trilobate. The legs are long and slender; the 6th endite narrow, long, and acutely triangular; the 5th endites full and rounded. The abdomen is slender, and the cercopoda very short, usually scarcely as long as one-half the width of the terminal segment of the abdomen.

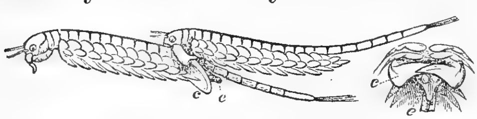

FIG. 17. *Artemia gracilis*, from Great Salt Lake. A pair swimming, the male clasping its mate with the claspers (*c*), in front of the ovisac (*e*); enlarged about 3 times. Also a view from beneath of the male claspers (*c*) and the ovisac (*e*) still more enlarged. Emerton del.

In color either whitish, flesh-colored, often deep red, sometimes greenish, with black eyes.

Length of male, 8–10mm; female, 10–12mm.

For the reasons stated beyond I am disposed to unite Verrill's *A. monica* and *A. fertilis* with his first described form, *A. gracilis*, as I do not regard the difference he points out as more than individual; probably

*Middendorf's Sibirische Reise, Bd. II, Thl. 1, 154, 1851.
†From Great Salt Lake, with a brief description.

they are not varietal. It appears, then, that we have but one North American species of *Artemia* so far as yet known.

Upon comparing our species with the European it is difficult to find good differential characters, as the portions of the body where specific differences would be expected to occur are liable to considerable variation. Upon comparing a number of females from Great Salt Lake with a number of females of the maleless generation from Trieste, Austria, received from Professor Siebold, there are really no differences of importance; our *A. gracilis* (Verrill's *fertilis*) is slighter, with a smaller head, and perhaps the 2d antennæ are a little slighter in build; I see no essential difference in the form of the ovisac, while the shape of the legs, especially the 6th endites, is essentially the same. The length of females (as well as males) is the same in both species.

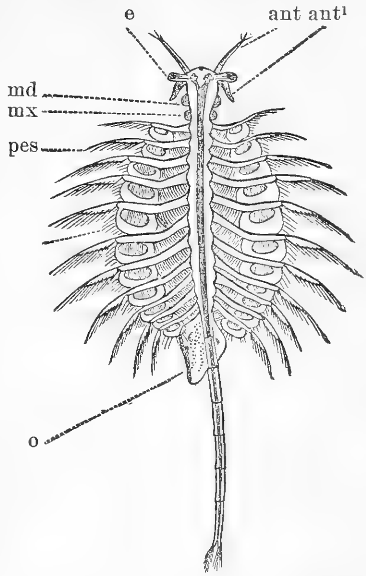

FIG. 18.—*Artemia gracilis*, from New Haven, seen from beneath, much enlarged. After Verrill. *e*, eye; *ant*, 1st antennæ; *ant*[1], 2d antennæ; *md*, mandibles; *mx*, maxillæ; *pes*, foot; *o*, ovisac.

Upon comparing a good many males from Great Salt Lake with several, both stained with carmine and unstained, received from Cagliari, Sardinia, through Prof. J. McLeod, of Ghent, the European *A. salina* is seen to be considerably stouter, the head wider, the eye-stalks longer and larger, and the eyes larger; the frontal button-like processes of the first joint of the claspers are nearly twice as large as in the American species, and a little more pointed, while the claspers themselves are larger and stouter. The legs and sixth endites are of about the same form. The most apparent difference is in the caudal appendages or cercopods, which in *A. salina* are several times larger than in *A. gracilis*, being in the Sardinian specimens nearly three times as long and much larger than in our species. In this respect the genus shows a close affinity to *Branchinecta*. However, in a lot of *A. salina* ♀ from Trieste, the cercopods are very much shorter than in the Sardinian females, and only a little longer than in our American specimens. These appendages do not differ in the two sexes.

As regards the genus in Europe, several nominal species have been described, but it seems probable that but one occurs there. As stated by Verrill in his "Observations on Phyllopod Crustacea," in a foot-note, owing to differences in the development of the caudal lobes and setæ, "several nominal European species, established mainly on differences in the caudal lobes and setæ, are probably only the young of others, or all perhaps of *A. salina*, especially since those with small, caudal lobes and few or no setæ, are described as small; as for example *A. milhausenii*, *A. arietina*, and *A. köppeniana* (Fischer species)."

Verrill's types of *A. monica* I have not examined, but have certainly found specimens at Great Salt Lake which agree with his description, and especially his figures of the head and male claspers.

Variations in Artemia fertilis from Salt Lake.—With specimens of the sexually mature males from Great Salt Lake the description of Verrill agrees well, the claspers being very broad, the second joint being as wide as two-thirds its length. The outer angle or elbow varies greatly, in some individuals not being noticeably produced, and with the outer edge nearly straight, while in others the angle is remarkably produced and the outer edge is much excavated. In one specimen, 7^{mm} in length, the claspers are one-half as wide as in another, but with the elbow still produced. In another male, 7^{mm} in length, selected from fifty more or less normal individuals, the elbow is enormously produced, and the claspers are small, long, narrow, and acute. In sixty other males the elbow is a good deal produced, while the claspers are broad and triangular. These specimens were collected at Lake Point from the wharf, July 26, 1875, the temperature of the water under the wharf in the shade being 73° F. The females bore about 23–24 eggs in their ovisacs.

Sixty red-colored males from a hot, shallow brine pool at Farmington, late in July, the temperature of the water probably not less than 80° Fahr., were examined. Of these, one male, 5.5^{mm} in length, had claspers which were even smaller and narrower than in a smaller individual, 4.5^{mm} in length, showing an unequal degree of growth, being perhaps an example of retarded development of a secondary sexual character. A stronger example is seen in two individuals of the same length (5.5^{mm}); one was very immature, the head being smaller than in the other, the claspers unusually small and narrow, the genital appendages smaller, and the caudal appendages one-half as long as in the other; in the second example the head is large and the claspers fully three times as broad as those of the first individual, being three-quarters as broad as the space between the eyes, while the caudal appendages were twice as long as thick, longer than those of *A. gracilis*, as figured by Verrill. This difference in two specimens so nearly of a size shows that the sexual characters are suddenly acquired. No young were observed less than 3^{mm} long.

Identity of A. fertilis, A. gracilis, and A. monica.—On comparing 30 males of *A. gracilis* from New Haven the claspers in small specimens look like Verrill's figure of those of *A. gracilis;* in large specimens like that of his figure of *A. monica*, the claspers increase in width with age. In two specimens of the same size and probably age, one has very narrow claspers, as in Verrill's figure of *gracilis*, in another the claspers are broader than in his figure of *A. fertilis*. In half-grown males the claspers are narrow, as in Verrill's figure of *A. gracilis*. The forms of the caudal appendages vary with age.

On comparing a few days after, to be sure that I had made no mistake, 200 males of *A. fertilis* with males of *A. gracilis*, I could find absolutely no essential specific or varietal differences between these so-called species.

On examining 45 females of *A. gracilis* from New Haven, and comparing them with a number of Salt Lake females, no differences could be observed. Comparing with care a large female from Utah (Great Salt Lake) with one from New Haven of the same size, there was also the same proportion of parts. The eyes were of the same size, the eye stalks of the same length; the first and second, the latter especially, had the same proportion. The feet and endites were the same, and the length of abdomen the same, though this region varies, as it irregularly contracts in alcohol. The egg-sacs in the New Haven example are a little longer and with a more acute lateral angle than in Utah examples, but this depends on age, and these differences disappear in those which are of the same size and degree of sexual maturity, and in which the eggs are similarly developed. The caudal appendages in the Salt Lake example (which was 12.5^{mm} in length) are nearly but not quite so long as in New Haven ones, but there are not even *varietal* differences in the two examples. From these comparisons it may be inferred that the two species should be united.

On comparing a number of Salt Lake females with individuals of the same sex of the European *Artemia salina*, our species was found to be undoubtedly specifically distinct; the Utah specimens are slenderer, smaller, and the sixth endite of all the feet considerably slenderer and longer in proportion than in *A. salina.* The ovisacs were of the same proportion but slenderer, and the head is slighter and smaller in our American species.

Habits of Artemia fertilis at Great Salt Lake, Utah.—The food of the *Artemia* appears to be the smaller fragments of brownish algæ which abound in the water, especially *Polycistis Packardii* of Farlow.* The cells of this alga are filled with molecules of protoplasm. The contents of the alimentary canal of alcoholic specimens of *Artemia* is a darkish mass, which, on being examined under a $\frac{1}{5}$ Tolles objective, shows the same granulated protoplasmic mass as that to be found in the lobules of the alga, leaving little doubt in my mind that the partly digested substance in the digestive canal of the *Artemia* is the alga.

At Farmington, on the shores of the lake, where there are old brine pools, filled with strong brine, the shallow water was crowded with *Artemiæ.* The water was very warm, and the *Artemiæ* were deep red in color, though some red ones were collected in the lake itself. They were afterwards observed at Lake Point July 26, 1875. The temperature of the water in the shade at the end of the wharf was 73° F. at the surface, and also at the bottom at a depth of eight feet; the temperature of the air was 80° F. at 11 a. m.

Out of a large number observed, from 500 to 800 individuals, but very few were half grown, some being from $\frac{1}{5}$ to $\frac{1}{4}$ inch long. Few solitary males were seen, as the large majority were attached by their claspers to the females in the attitude shown in fig. 17. The females far outnumbered the males, as certainly over half of them had no males attached.

The egg-sacs and eggs were in different stages of development. I could see no attempts at copulation, unless in one instance, where a male violently jerked his body; but that was perhaps simply to obtain a stronger hold with his claspers around the body of the female, the claspers being placed just in front of the ovisac.

The eggs are light, floating on the surface of the water. They are dull, dirty, yellowish white.

The nauplius (Pl. XXII, fig. 1) is blood-red, with a single sapphire-red eye, and it is very active.

Four sets of *Artemiæ* were observed:

A. Some, both males and females, entirely green.

B. Most of the females were red in front of the abdomen, the red being caused by scattered pigment cells. The males attached to them were greenish.

C. Some red males attached to green females.

D. The largest females entirely deep blood-red, with distended ovisacs, but containing no eggs.

There must be numerous sterile or parthenogenous females. There is a great disproportion in the numbers of the sexes. The males are stronger swimmers than the females, darting at certain individuals and then leaving them to go after others, as if exercising some choice.

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* American Naturalist, Nov., 1879, p. 702.

Some males were attached to females much larger than themselves. I was told that the *Artemia* appears in the spring, from the middle of April to May 1, and disappears during very cold weather in autumn.

ARTEMIA GUILDINGII Thompson.

Artemia Guildingii Thompson. Species haec, reperta in India Occidentali, delineata est a Domino Thompson in 'Zoological researches' sed non descripta, necnon satis accurata delineata est.
Artemi Guildingi, Thompson Zool. Research, Fasc, 5, t. p. 11.

Hab.—In insula "St. Vincents," in India Occidentali; Rev. L. Guilding.

"This species is figured by Mr. Thompson, but not sufficiently described to enable me to give a good diagnosis of it. It was found at St. Vincents, in the West Indies, by the Rev. Lansdowne Guilding, by whom its natural history was intended to have been more fully detailed. The body seems to be thick and the abdomen shorter than the body and stout; the caudal segment does not appear to be lobed nor setigerous. The cephalic segment is conical in shape, and the superior antennæ, according to Mr. Thompson's figure, consist each of four joints. The ovarian sac consists, according to the same authority, of two articulations." (Baird's Monograph of the Family *Branchipodidæ*. Annals and Mag. Nat. Hist. 2d ser. xiv, 1854, p. 226).

Genus BRANCHINECTA Verrill.

Plates IX, X.

Branchipus Milne-Edwards, etc. (in part).
Branchinecta Verrill, Amer. Journ. Sci. 2d ser. xlviii, 250. Sept. 1869.
Proc. Amer. Assoc. Adv. Sc. July, 1870.

Body rather long and slender, but stouter than in *Artemia;* head rather small, but larger than in *Artemia;* 2d antennæ of male (claspers) with a knob on the basal joint as in *Artemia;* the claspers simple, quite persistent in form in the different species, not elbowed, 2-jointed, with joints cylindrical; 1st joint slightly bent; the 2d joint not bent on the first, round, and about one-half as thick as the basal joint. The 2d antennæ of the female are rather long and slender. Labrum large and long, extended beyond the closed mandibles; the end is square, with a nipple-like projection in the middle. Eleven pairs of legs, which are shorter and broader than in *Artemia.* The gills are usually larger, the flabella moderately large, and quite regularly oval externally; the 1st endite and the three following are much as in *Artemia*, but the first is not so distinctly divided distally into a secondary lobe. The 5th is decidedly rectangular in outline, the distal edge being straight, sometimes hollowed out, with rather shorter setæ than in *Artemia;* the 6th endite in all the legs is much shorter than in *Artemia*, being short and broad and well rounded at the end, with rather short setæ.

The abdomen has nine segments, and is as long or a little longer than the head and thorax together; the cercopoda are much longer than in *Artemia*, and equal in length to the terminal segment, which is much shorter than in *Artemia;* compared with *Branchipus* and succeeding genera they are small, short, and conical. The penis is deeply divided into two long slender curved branches. The ovisac is cylindrical and remarkably long and slender; in *B. coloradensis* nearly half as long as the abdomen, and deeply cleft at the end.

This genus stands in simplicity of structure next above *Artemia*, being related to it by its short cercopoda or caudal appendages, and the simple male claspers, with the knob-like projection at the base of each. It is less complicated than in *Branchipus*, and in his valuable paper on this group I hardly understand why Professor Verrill should have interposed *Branchipus*, his *Eubranchipus*, *Streptocephalus*, and *Chirocephalus* between *Artemia* and the present genus, as the genera in the order we place them in this essay present successive degrees of complexity from *Artemia* to *Chirocephalus* and *Thamnocephalus*. The Southern European *Branchipus spinosus* Nordman, from a salt lake at Odessa, appears to us, on examination of a number of specimens received from Professor Siebold, to belong to this genus, contrary to Verrill's opinion, who referred it to his genus *Eubranchipus*. In this species the knob-like processes of the male claspers are present; the male claspers also are much as in *B. coloradensis*, but much slenderer; the caudal appendages are short and small, as in our American species of *Branchinecta*, but the ovisacs are rather shorter than in any American and Arctic species, though still longer than in *Branchipus*. The genus is certainly a good one, and easily distinguishable. It is especially interesting to indicate the close affinities of this genus to *Artemia*, for it is *Branchinecta ferox* (Fischer sp.) which Schmankevitch found to transform by artificial means into Artemia, and the characters ot Branchinecta are such as we might believe a well-fed Artemia subjected also to water of suitable temperature and freshness might suddenly acquire. The fact, however, that the two genera may be artificially produced does not militate against the naturalness of the two genera, Artemia and Branchinectes, since we can point to three American and Arctic species of Branchinecta which preserve their generic identity.

As suggested by Verrill, Milne-Edwards' *Branchipus ferox* (Edwards' Crustaces, iii, 369), from fresh water near Odessa, most probably belongs to this genus. Milne-Edwards thus characterizes it: "Cornes cephaliques sans appendice près du côte interne de leur base, pointues au bout et sans dent sur le bord externe. Abdomen lisse, nageoires caudales longues et étroites." It has been rediscovered in 1872 in salt pools near Odessa by Schmankevitch. Verrill also states that *Branchipus middendorffiana* Fischer, of Siberia and Lapland, may be a *Branchinecta*, and, judging by Fischer's figures of the male clasper, the ovisac, and the cercopoda, it is without much doubt a genuine *Branchinecta*. By Grube and Dybowski it is regarded as a synonym of *B. paludosa*. It inhabits Siberia, having been collected by Middendorf near the rivers Taimyr and Boganida, as also in Lapland near Tri-Ostrowa, while it was also collected by the Ural Expedition. Hence the species of the genus *Branchinecta* range from the Arctic regions to Southern Russia in Europe, and to the higher portions of the Rocky Mountain plateau of Colorado in North America, as well as the plains of Kansas, the genus, with the exception of the two species living at Odessa, and *B. lindahli*, of Kansas, being inhabitants of Arctic and Alpine regions.

Synopsis of the species.

Male claspers pointed, not turned in, serrated inside of 2d joint; no knob .... *B. paludosa.*
Male claspers large, end broad and bent in, with no teeth; knob present.. *B. coloradensis.*
Male claspers short; caudal appendages very long......... *B. lindahli.*

BRANCHINECTA PALUDOSA (Müller).

Plate IX, figs. 1–6; Pl. X, figs. 1–5.

Cancer stagnalis O. Fabr., Fauna Groen. (non Linn. et Müll. Prodr.), 247, 1780.
Cancer paludosus Herbst, Naturgeschichte der Krabben. Bd. II, p. 118.
Branchipus paludosus, Müller, Zool. Danica, ii, 10, Pl. 48, figs. 1–8, 1788–1806.
Branchipus paludosus Reinhardt, Bidrag til en Beskrivelse af Groenland, 1857; Packard, Glacial Phenomena of Maine and Labrador, etc. Memoirs Boston Soc. Nat. Hist. i, 295, 1867.
Branchipus (*Branchinecta*) *groenlandicus* Verrill, Amer. Jour. Sc. 2d ser. xlviii, 253, Sept. 1869.
Branchinecta groenlandica Verrill, Proc. Amer. Assoc. Adv. Sc., July, 1870.
Branchinecta paludosus Verrill in part (*B. arctica* regarded as distinct).
Branchipus middendorfianus Fischer,* Middendorff's Sibirische Reisen. Bd. II, p. 153.

Body moderately large. Male claspers much shorter and slighter than in *B. coloradensis*, not reaching far beyond the middle of the thorax, basal joint more bent than in the other species, but of the same proportionate length, though without any knobs (also absent in immature males of *B. coloradensis*); the distal half of the inner edge with a row of fine teeth, the points ending in fine setæ. 2d joint very slender, narrowing gradually to the tip, which is one-half as wide and not bent in or slightly expanded as in *B. coloradensis*; 2d antennæ of the female narrow and slight, at the tip suddenly contracting and ending in a mucronate tip.

The feet are short and broad; the 5th endites, straight on the outer edge, with the outer angle rectangular, while the 6th endites are short and broad; the setæ, especially at the distal angle, are rather coarser and shorter than in *B. coloradensis*.

Caudal appendages small, narrow, scarcely longer than the terminal joint. The ovisac is oval-cylindrical, rather long, the lobes pointed at the end; only one-half as long as the abdomen.

Length of body of male, 15^{mm}; length of clasper, 4^{mm}; 2d joint, 1.5; cercopoda, 1^{mm}.

Length of body of female, 12^{mm}; of ovisac, 4^{mm}.

The foregoing description was drawn up from an individual selected from a collection of about 80 made by Dr. Emil Bessels, at Polaris Bay, Northern Greenland, August 1, 1872.*

On carefully re-examining, after the lapse of over fifteen years, a portion of the material originally collected at Labrador, and comparing a male and three females (labeled *Br. arctica* by Verrill) with the abundant material collected by Dr. Bessels, in Northern Greenland, I am unable to find any specific differences between them. The Greenland examples are smaller and less mature than the Labrador ones. I find that they possess the same characters as those which separate the species from *B. coloradensis*, and which occur in the Greenland *B. paludosus*. There are the same proportions in the male claspers, the knob-like processes on the basal joints are also wanting, the row of teeth on the distal half of the joint are of the same size. Owing to the greater size of the specimens the male claspers are a little larger, but the 2d joint has the same proportions, being narrow, not widening at the tips, which also is not incurved. The ovisac is of the same length and form. The penis is of the same form, and with a similar prong-like process projecting

*Considered by Grube and also Dybowski as a synonym of B. paludosus. See Archiv für Naturgeschichte, XXVI, i, p. 201.

*I have been kindly permitted by Dr. Bessels to use this material in this connection, and also the excellent drawings by Mr. Emerton, which were made originally for a report on the Natural History of the Polaris Expedition.

inward near the base of each branch or fork. The caudal stylets are a little longer than in the Greenland examples, but this is probably due to the more mature development of the specimens.

Length of male, 19^{mm}; length of claspers, 5^{mm}; length of 2d joint, 2^{mm}.

Length of cercopoda or caudal appendages, 1.5^{mm}.

Length of female, 18^{mm}; length of ovisac, 5^{mm}.

Although predisposed to think that Professor Verrill* had found good reasons for separating the Labrador from the Greenland individuals under a distinct specific name, though I originally had examples of the Greenland *B. paludosus* from Dr. Lütken, of the Copenhagen Museum, for comparison, I have carefully re-examined them for any specific characters that I might have overlooked. I see no differences in the appendages, the 5th and 6th endites especially not differing in any essential point, as will be seen by the numerous figures on Plates IX and X, the apparent discrepancies in the drawings being due to different stages of preservation. There is a slight difference in the tips of the male claspers, which are a little blunter in the Labrador than in the Greenland examples, but this may be on account of the smaller size and less degree of maturity of the Greenland examples. I have not at hand the larger Greenland examples originally received from Greenland through Mr. Lütken. The Labrador examples were taken August 7, 1864, in a small pool of water in a depression in the rocks on a point of land projecting into the water at "Indian Tickle," on the north side of Hamilton or Invuctoke Inlet, Northern Greenland; and others were seen at Tub Island, on the south side of the entrance of the bay, August 10.

We add the following account by Baird of what seems to be without much doubt *B. paludosus*, and which shows that it inhabits Arctic America in latitude 68° 15′ N., longitude 113° 50′, of Greenwich:

"Some fragments of a species of Branchipoda were brought by Sir John Richardson from Cape Krusenstern, in North America, collected there by Mr. John Rae in August, 1849, along with the *Apus glacialis*. They consist of portions of two males and two females. The male antennæ are two-jointed; the basal joint is thick, and has at its lower part, near its junction with the second, a row of small teeth; the second joint is cylindrical and pointed. The female horns or antennæ are flat, apparently, and have a short hooked spine at the extremity. The caudal fins are rather long, and fringed with long cilia. In some respects this species resembles the figure of the *Cancer paludosus* of Müller, but the fragments are too much decayed in the spirits to enable me further to describe it. It does not appear to have either antenniform appendages or any apparatus attached to the antennæ of the male.

Should these three species prove to be distinct they may form another genus of this family, characterized by the want of these appendages and the toothed or serrated basal joint of the male cephalic horns."

Under the name of *Branchipus* (*Branchinecta*) *arcticus*, Mr. E. J. Miers notices this species in the Annals and Mag. Nat. Hist., ser. 4, vol. xx, p. 105, Pl. IV, fig. 1. His figure is a very indifferent one, and he erroneously represents the ovisac as double. Discovery Bay is in latitude 81° 41′ N., longitude 64° 45′ W. We reproduce his description and remarks:

"Coll. Hart: Discovery Bay, in a small fresh-water lake and in a stream under ice. Several specimens were collected, including males and females, of a species of Phyllopoda, which I refer to the *B. arcticus* of Verrill. Of these species I have only seen the descriptions in the journals above quoted, not having been able to meet with Verrill's full re-

* Prof. Verrill writes me that he has since (Amer. Jour. Sc.) decided that his *B. groenlandica* is identical with *B. paludosa*.

port on the American Phyllopoda in the volume for 1869 of the American Association for the Advancement of Sciences and Arts. These specimens possess the elongated claspers, with serrated basal joints, and elongated egg pouches of the species of Branchinecta, and are distinguished from the *Branchipus paludosus* of Müller, also from Greenland, (if his figure in the Zoöl. Danicá, Pl. 48, be correct) by the much shorter lanceolate caudal appendages. In *B. paludosa* these are represented as very slender, acuminate, and half as long as the abdomen.

"These specimens differ slightly from the descriptions of *B. arcticus* and *groenlandicus*, as will appear from the following description. If distinct (which may be possible, although I think it more probable that the three forms are varieties of one and the same species), the species may be designated *B. Verrilli*. The antennæ are slender, linear, and nearly as long as the basal joint of the claspers. The large prehensile antennæ, or 'claspers,' as they are called by Verrill, are nearly half as long as the body, two-jointed, the basal joint as long as the second, nearly straight, and of the same thickness throughout, with a not very prominent rounded lobe at the distal extremity on the inner side. This, and the distal half of the inner margin, armed with a series of ten or a dozen small teeth or spines. The second joint is smooth, slightly tapering to its distal extremity and concave on its inner surface. The branchial feet are eleven in number, and the lobes on the inner margin are beautifully fringed with long, close, flexible hairs; the fifth and sixth pairs are the longest, and the others decrease regularly in size. The vesicular body is narrow, oblong-oval; the terminal lobe of the second joint is regularly oval in shape. The caudal appendages lanceolate, small; margins with slender setæ, which become longer as they approach the distal extremity. The specimens are smaller than that collected by Dr. Packard, averaging only 12 millimeters in length.

"Verrill's specimens of this species were from Labrador, and if, as is thought possible both by Packard and Verrill, this species be not distinct from the *B. groenlandicus* and *B. coloradensis*, it must have a very extended geographical range. Specimens of *B. groenlandicus* are mentioned by Packard as having been obtained during the late American expedition of the Polaris at Polaris Bay, between latitudes 81° 20′ and 81° 50′."

BRANCHINECTA COLORADENSIS Packard.

Plate X, figs. 6, 7.

Branchinecta coloradensis Packard, U. S. Geographical and Geol. Survey, Report for 1873, 621, fig. 12. 1874.

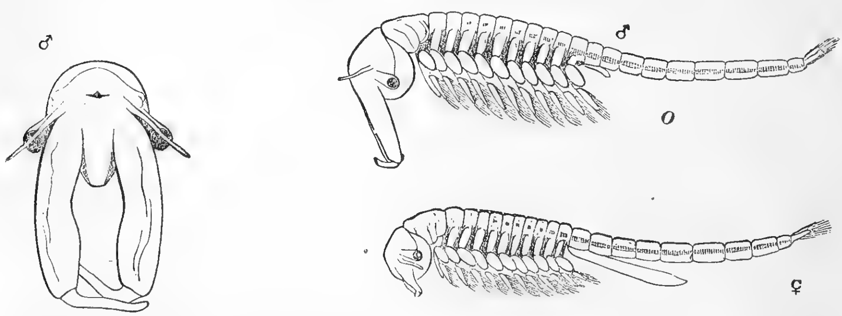

FIG. 19.—*Branchinecta coloradensis*, male and female, with a view of front of the head of the male, showing the claspers; all enlarged. Emerton del.

Body considerably larger than in *B. paludosa;* moderately stout; head rather large; ocellus larger than in *B. paludosa*, and the eyes also rather larger. The claspers of the male are large, thick, and long, extending to the base of the last pair of feet. The basal joint is provided with stout prominent tubercles at the base; the joint itself is nearly one-fourth longer than the distance between the outstretched eyes. The second joint is one-half as thick as the first, and as long as the first beyond the basal internal knobs; it is slightly bent near the base, the tips broad, rounded, and suddenly bent inwards a little. The forks of the penis are long, slender, suddenly curving outwards, and nearly meeting at the tips over the median line of the body. The caudal appendages are rather long and slender, nearly twice as long as the terminal segment, though shorter than in *B. paludosa*, and not slightly contracting near the base as in *B. paludosa.* Female larger and stouter than in *B. paludosa;* the ovisac very long and slender, reaching to a point beyond the middle of the penultimate abdominal segment, and with the lobes acutely pointed. The 2d antennæ are much broader than in *B. paludosa*, being more triangular and coming more gradually to a mucronate point than in *B. paludosa.* In life this species is of different shades, from deep salmon or flesh color to pale whitish.

Length of body of male, 18^{mm}; length of male claspers, 7^{mm}; of 2d joint, 3^{mm}; of caudal appendages, 1^{mm}.

Length of female, 17^{mm}; length of ovisac, 8^{mm}.

Described from several hundred specimens collected by myself from a small pond or pool forming the head of a brook above timber line and near the snow line, about 12,000 feet elevation, near the trail leading to the summit of Gray's Peak; it is doubtful if this pond ever dries up, as I have seen it full in the summers (August) of 1875 and 1878. They were observed in great abundance August 21, associated with a species of Daphnia, and swam as usual on their backs; a number were seen copulating. They thus live under almost exactly the same meteorological conditions as *B. paludosa* in Northern Labrador and Greenland, the temperature near the snow line in Colorado in August being about the same as that of Northern Labrador and Greenland in August.

My first published brief description was drawn up from a female specimen from a "pond on a mountain near Twin Lake Creek, Colorado, elevation 12,500 feet" (Hayden's Survey of Colorado, 1873, collected by Lieut. W. L. Carpenter, U. S. A.); also from about 100 males and females with eggs, Colorado, Dr. Viele (Museum Comp. Zoology, Cambridge, no date).

From Mr. V. T. Chambers we have received the following note regarding the occurrence of this form in Colorado:

Beauchinecta Coloradensis occurs in countless thousands in a pond fed by melted snow on top of Weston's Pass, altitude 11,676 feet elevation (Hayden), and a Caddis larva feeds voraciously upon it.

BRANCHINECTA LINDAHLI n. sp.

Plate XI, figs. 1, 7.

One male.—Body robust; 2d antennæ or claspers short and stout; 1st joint of the usual thickness and much as in *B. coloradensis*, but much shorter, at least a third; 2d joint as long as the basal, curved, distinctly triquetal, with the angles prominent; much thicker than in *B. coloradensis*, rather blunter at the end than in *B. coloradensis*, and with the inner side of the tips larger and more turned in than in *B. coloradensis*, giving an entirely different appearance to the joint. Male genital organs much as in the Colorado species, but the caudal appendages somewhat longer, otherwise of the same form.

Twelve females.—Eyes rather large; 2d antennæ slightly shorter, less blunt than in *B. coloradensis.* Oviduct with the lower lip acutely produced. The caudal appendages are nearly twice as long as in *B. coloradensis*. The eggs are more numerous (about 50 contained in the ovisac) and much smaller than those of *B. coloradensis*, being about one-half as large. The feet are well developed; the 5th endite square and hollowed out a little on the outer edge; the 6th is long and more pointed than in the other species of Branchinecta; the gill is large, as is also the oval broad flabellum.

Male, length of body, 8^{mm}; 2d antennæ, 3^{mm}; length of 2d joint, $1\frac{1}{2}^{mm}$; caudal appendages, 1^{mm}.

Female, length of body, 15^{mm}; ovisac, 4–5^{mm}; caudal appendages, 2^{mm}.

This species differs remarkably, especially in the long caudal appendages, and in the large pointed 6th endites of the feet. It may at once be distinguished from *Branchinecta coloradensis* by the shorter 2d antennæ, the basal joint being one half shorter, and the 2d joint very short, while the inner projection or spur is much larger and more pointed than in *B. coloradensis*, and the caudal appendages are much larger, while the ovisac is much shorter than in that species. The eggs are of the same size as those of *B. paludosus*.

The specimens occurred in a pool at Wallace, Kansas, in company with the other Phyllopods from that place.

This species is named in honor of Prof. Joshua Lindahl, of Augustana College, Rock Island, Ill., who collected the specimens examined, with many other Phyllopods which he kindly lent me for study.

Genus BRANCHIPUS Schaeffer (in part).

Branchipus Schaeffer (in part), Elementa Entomologica, 1766 (type *B. pisciformis* = ? *B. stagnalis* Ex. Verrill). Latreille, Règne Animal; Leach. Milne-Edwards, Crustacés, iii, 364 (in part), 1840.
Chirocephalus Dana (in part), non Bénédict-Prévost, 1803; Jurine, Thompson, Baird.
Branchipus Verrill, Amer. Journ. Science, xlviii, 250, Sept. 1869.
Branchipus (and *Eubranchipus*) Verrill (in part), Proc. Amer. Assoc. Adv. Sc., July, 1870.

Body large and very stout; head large; male claspers elbowed, large and thick, complex, varying much in form; 1st joint very stout and thick, nearly straight, with a stout inward-pointing spine at base; 2d joint varying in form, usually simple and straight, chitinous, bent a little at the tip. Head of male with a pair of frontal appendages hanging down between the male claspers and varying much in form, being long, slender, filiform, and simple (in *B. stagnalis*), forming two broad, flat triangular lobes with crenulated edges (in *B. vernalis*), or very large and deeply and finely lobulated (*B. grubei*). The 11 pairs of feet are much as in *Branchinecta*, but usually the 5th endites are larger and the edge less square than in *Branchinecta*, and the 6th endites are larger and more pointed. The penis is large and broad, in *B. stagnalis* quite deeply cleft, or (*B. vernalis*) only slightly so, the cirrus long and slender. Caudal appendages long and slender, nearly twice as long as is usually the case in *Branchinecta* (*B. lindahli* excepted).

Female with the body long, the head large, caudal appendages as in the male, the ovisac broad and short, bottle-shaped, the opening transverse, at the end of a short neck.

The type of this genus is *Branchipus stagnalis* (Linn.) of Europe, and in this country it is represented by *B. vernalis*.

As limited by Milne-Edwards, the genus was too comprehensive, being composed of three generic forms, since he included in it *B. spinosus* and *B. ferox*, which, as we have previously explained, are true *Branchinectæ*, and also *Chirocephalus diaphanus*. In 1870 Verrill eliminated his *Branchipus vernalis*, described in 1869 under the name *Eubranchipus vernalis*, and also remarked that "this genus appears to include *Branchipus spinosus* Edwards, from a salt lake near Odessa, but the latter appears to have no tooth at the base of the second joint of the claspers." Had Professor Verrill had specimens for examination he would undoubtedly have seen that this species was a *Branchinecta*.

I do not see good reasons for separating our common American species generically from the common European *B. stagnalis* and the less known more recently described species *B. grubei*. Comparing *B. vernalis* with *B. stagnalis*, the frontal lobes of stagnalis are in position homologous with the much more complicated ones of *B. vernalis* and the lobulated, highly complicated ones of *B. grubei*. In both species the 2d joint of the claspers is thick, in section triangular, but much slenderer than the very thick 1st or basal joint.*

The ovisac and penis, as well as the caudal appendages and the general form of the body, are the same. *B. grubei* Dybowsky, which I have received from Breslau through Professor Siebold, is a genuine Branchipus; the large, deeply lobulated frontal appendages, a sexual character peculiar to the males, are only exaggerations of those of *B. vernalis*. It has similar stout claspers; the ovisac of the female differs from the two other species examined, in being a little longer and slender, but still it retains the short, broad, bottle-shaped form so characteristic of the genus, while the caudal stylets are the same.

To this genus also undoubtedly belongs Fischer's *Branchipus birostratus* (see Middendorf's Reise, p. 152, Pl. VII, figs. 12–16, from Charkow, Russia). As regards the frontal appendages, this species is intermediate between *B. vernalis* and *B. grubei*, as those organs are short, triangular, but little longer than in *B. vernalis*, but deeply, acutely lobed at the end.

The frontal appendages in this genus and in Chirocephalus are possibly the homologues of the knob-like projections near the base of the 2d antennæ of Artemia and Branchinecta, but the frontal appendages are situated nearer the base of the 1st joint, and are more dorsal. On the outer side of each appendage there are transverse lines reaching to the edge between the tubercles, giving a segmented appearance to the outer half of the appendage. Under a Tolles' $\frac{1}{5}$ B eyepiece the tubercles are seen to be filled with nucleated oval cells like those scattered through the meshes of the fine muscles which ramify throughout the middle region of the appendage. The cells are not nerve-cells, and I do not regard these organs as sensory, but probably auxiliary to the claspers, and possibly of use in holding the female.

Synopsis of the species.

Frontal appendages short, finely lobed; 2d joint long and pointed..*B. vernalis*.
Frontal appendages very long, with six long finger-like processes on each side; 2d joint of male clasper half as long as in *B. vernalis*, and square at tip..*B. serratus*.

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* Gerstaecker makes a singular blunder in copying Dybowski's figure in Bronn's Classen und Ordnungen der Thierreich, Bd. v, abd. 1, Taf. xxix, figs. 2, 4, from Dybowski in Archiv. für Naturgeschichte xxvi, 1. The male and magnified head of the male of *Branchinecta paludosa* from Greenland, correctly figured by Dybowski as such, are by Gerstaecker in his explanation of Taf. xxix called the female of *Branchipus grubei*.

Branchipus vernalis Verrill.

Plates XI, figs. 2–6; XXII, figs. 3–6.

Branchipus stagnalis Gould, Invertebrata of Massachusetts, 339, 1841.
Branchipus vernalis Verrill, Amer. Journ. Sc., XLVIII, 251, Sept., 1869.
Eubranchipus vernalis Verrill, Proc. Amer. Assoc. Adv. Sc., July, 1870.

Body stout, pale flesh-colored with reddish tints, head large; claspers with the basal joint very stout, slightly curved, nearly one-half as thick as long; retractile, drawing in with it the base of the 2d joint; 2d joint chitinous, rigid, with a long obtuse spur on the inner side at the base, which is directed inwards at right angles; beyond this spur the joint in transverse section triangular, the edges very prominent; the inner edge of the joint is hollowed out at the base, while the extremity is bent outward somewhat like the foot of a sock before it is worn. The inter-antennal or frontal appendages are broad, triangular, flat (from above downward), nearly twice as long as broad, acutely pointed; with the edge finely serrated, the teeth, when highly magnified, being separate at base, and bottle-shaped, with one, and sometimes two, rarely three, "necks" or "points" (Pl. XXII, fig. 5, 5*a*). The external organ of reproduction (penis) is stout, massive, not deeply cleft in the middle, while the cirrus (Pl. XXII, fig. 3, *c*) is minute, long, and filiform.

The body of the female is as stout and of the same size as in the male; the ovisac is not so long as broad, pink, with a prominent, full "neck," with a transverse narrow opening for the exit of the eggs; the lower lip of the opening is smaller than the upper lip.

Male.—Total length of body, 23^{mm}; of 2d antennæ, 8^{mm}; 2d joint of same, 4.5^{mm}; of penis, 3.5^{mm}; caudal appendages, 4^{mm}.

Female.—Total length, 23^{mm}; length of ovisac, $3–4^{mm}$; of caudal appendages, 4^{mm}.

This species ranges from Salem, Mass., through Rhode Island to New Haven, and southward to Philadelphia (March 27, Mr. W. P. Seal) and westward to Southern Ohio (Wapakoneta, Ohio, Wm. Kayser), and Indiana, (received from Irvington, Ind., Mr. O. P. Hay, Amer. Nat. 1882, 242). In Southern New England it is found from the last of November until the first week in May, but has not yet been found during the summer from the middle of May until the middle of November, as will be seen by the following record of localities and dates of capture: Salem, Mass., April 19, 1859 (R. H. Wheatland, Essex Institute); April 12, 1876, a few half-grown ones (Packard); Danvers, Mass., Nov. 25, 1878, December and Jan. 10 (John Sears); Brookline, Mass., March 30, 1878 (M. T. Henshaw); Pawtucket, R. I., March 18, 1880 (H. H. Davison); Newport, R. I., Feb 15, 1877 (Mr. Powell, Mus. Comp. Zool.); New Haven (Dana, Eaton & Verrill); At Seekonk, Mass., they occurred abundantly May 2, in a large pond which completely dried up in summer (*H. C. Bumpus*); when I visited the pond in company with Mr. Bumpus, May 13, none were to be found. It seems from this quite evident that the animal probably dies off at the approach of warm weather and does not reappear until after cool weather sets in late in the autumn, being represented in the summer by the eggs alone; and thus the appearance and disappearance of this Phyllopod is apparently determined mainly by the temperature.

In life the body is of a pale flesh color, the tips of the penis deep reddish-brown, from thence a narrow line widening to the posterior half of the abdomen. The white setæ on the caudal appendages and the white tips of the endites contrast with the deep reddish-brown of the rest of the posterior half of the abdomen. The tips of the 5th endites are edged with reddish. Observed in very large specimens, from Dorchester, Mass. Jan. 4 to 9, 1882.*

BRANCHIPUS SERRATUS (Forbes).

Eubranchipus serratus Forbes, Bull. Illinois Mus. Nat. Hist. I. 13, Dec. 1876.

This interesting species is of the size and general appearance of *B. vernalis*, but the frontal appendages are twice as large and long, reaching to the end of the first joint of the male claspers. They are broad and flat; on the middle of the inner and outer edge is an expansion from which arise six digitiform processes, those on the inner edge being shorter and smaller; the appendages each end in a rolled-up slender tip. Male claspers with the 1st joint short and thick; the 2d joint much shorter and thicker than in *B. vernalis*, being one-half as long, thicker in proportion, with the end squarely cut off, and triquetal seen from the end. At the base of the joint is a broad-based stout spur which points inwards. The caudal appendages are a little shorter and less coarsely setose along the edge than in *B. vernalis*. The genitals are as in *B. vernalis;* the ovisac of the female is similar, the opening being the same, while the eggs are of the same size as in that species.

Total length of male, 15–20^{mm}; length of claspers, 4^{mm}; length of 2d joint, 2^{mm}; of caudal appendages in both sexes, 2.5–3^{mm}; total length of female, 20^{mm}.

"Collected in temporary pools of water at Normal, Illinois, in April, 1876; about a fortnight afterwards it entirely disappeared." "Another species [specimen] has been sent me by Professor Bundy, by whom it was taken in Wisconsin." I am indebted to Prof. S. A. Forbes for a pair of type specimens of this interesting species, which bears a close resemblance to, and thus represents in the United States, *Branchipus grubei* of Europe; it differs, however, from that species in the rather smaller frontal appendages, which are not so continuously and deeply fringed

*The following observations by Dr. Gissler, made on the appearance of *Branchipus vernalis* and *Chirocephalus holmani* may prove of interest:

BROOKLYN, *November* 14, 1881.

I recorded the following in my memorandum *last* year: Ponds near Maspeth dried up in October, 1880, until October 30, filled up; heavy rain again November 5; heavy rain again and 68°F. on November 11; November 18, a thin coat of ice formed in the evening; November 19, little rain in afternoon, again cold in evening; November 20, cold; November 21, freezing; ditto November 22, 23, and 24, a little snow at 9 p. m.; 25th, snow, cold; 26th, very cold, and 27th and 28th, thawing after 10 a. m.; same day rain from 10 a. m. till 11 p. m.; 29th, clear and mild; 30th, frozen; December 1, rain; 2d, mild and clear; 3d, cool and clear; 4th, mild; 5th and 6th, warm; 7th, cold; 8th, 9th, 10th, and 11th, very cold; 12th, mild; 13th warmer, and 14th, ditto with rain; December 15, 16, and 17, all ponds solidly frozen; 18th, thawed; 19th, frozen; ditto 20 and 21, with snow; frozen, 22, 23, and 24; thawing on 25th; frozen, 26, 27, 28, and 29; December 30, 5° below zero; 31st, cold, frozen; ditto January 1, 2, 3, 4, and 5, 1881; milder and muddy on 6th, 7th, and 8th; colder on 9th, rain in the evening; ditto all day on 10th; 11th, went to Maspeth, ice 1 inch thick on isolated pond, water running into it from neighboring elevated fields, nothing found; 12th and 13th cold; warm rain in A. M. of 14th, cold after 3 p. m., went to Maspeth and obtained one larva, the smallest I ever saw, from pale race; 15th, 17°F. at 9 a. m.; cold 16th, obtained 3 red *Eubranchipus* larvæ a few days old; 16th, cold; 17th mild; ditto 18, 19, and 20, eight inches ice at Maspeth; 21st, warm rain; 22d, snowed over night, cold; 23d, cool; 24th, 25th, and 26th, cold; 27th, 28th, 29th, 30th, and 31st, very cold; a larger larva was found February 10, age about 5 days; heavy rains February 18 and 19; March 3, obtained from Maspeth 4 larvæ 3½^{mm} long, red *Eubranchipus*, ice 3 inches; March 6, obtained 17 larvæ of the red *Eubranchipus* between 3–5^{mm} long, no pale ones seen; March 11, obtained 40 or 42 half-grown red *Eubranchipus*; March 23, a great number of adult *Chirocephalus* found near Glendale.

C. F. GISSLER.

with the digitate processes as in the European form. Its occurrence, however, in this country and its being an intermediate form between *B. vernalis* and *B. grubei* shows that the genus *Eubranchipus* is not sufficiently distinct to be regarded as a valid genus. As our description is brief and gives only the salient points observed in alcoholic specimens, we reproduce Mr. Forbes's original descriptions, drawn up from living examples:

"An important character, constant in the large number of both sexes which I have examined, is found in the *abdominal segments*, which are narrowed in front, with rounded anterior angles, while the posterior angles are produced backward, giving a decidedly serrate appearance to the abdominal margin. The last two abdominal segments are closely united and broader than the preceding.

"The *antennæ* extend a little beyond the eyes, and terminate in a cluster of about five slender olfactory clubs. The *frontal appendages* of the male are considerably longer than the claspers, to the front inner base of which they are attached, the line of attachment being parallel to the length of the basal joint. Their form is irregularly oval, the inner edge being regularly convex on its distal three-fourths, and the outer sinuate-convex on basal two-thirds, and slightly concave on terminal third. Both margins are pectinate, except near base, with thick blunt teeth, which are longest on the basal half of the outer margin, where they are as long as the undivided part of the appendage is wide. At the middle of this margin the teeth become suddenly shorter. On the inner margin they are longest near the middle, regularly lessening towards each end. The under (posterior) surface of the appendage, as well as the teeth, is set with short spines, each springing from an inflated base. The *claspers* of the male are shorter and stouter than in *E. vernalis*. The basal joint is soft and inflated and bears a corneous rounded tubercle at its inner base (wanting in *vernalis*). The second joint is stout and regularly incurved, strongly angulated at its base in front where it is received into the first joint. A long strong tooth, about half as long as the joint, extends backward and a little inward from near its base. The rounded tip of this tooth is thickly set with minute, low, circular elevations, each with a central depression, within which is a disk-like elevation, the whole having the appearance of a minute sucking disk. The tip of the clasper is expanded and flattened within so that the inner (anterior) part has a spatulate form, while the opposite surface rises into a thick prominent ridge, giving to a transverse section of the tip the form of the letter T. The *anal appendages* are linear-lanceolate, as long as the last four segments of the abdomen, and plumosely haired to the base. The ovisac of the female is as broad as long, three lobed behind, with the middle lobe the largest.

"Length of a full grown male, including anal stylets, 20^{mm}; width, 6^{mm}; across eyes, 4^{mm}; clasper, 4.5^{mm}; frontal appendage, 5^{mm} by 3^{mm}. The largest females were a little more slender than the males."

Genus STREPTOCEPHALUS Baird.

Plate XII; figs. 1–7.

Streptocephalus Baird, Annals and Mag. Nat. Hist. 2d Ser. XIV, 219. 1854.
Heterobranchipus Verrill, Amer. Journ. Sc. xlviii, p. 250. 1869.
Streptocephalus Verrill, Proc. Amer. Assoc. Adv. Sc. July, 1870.

Body rather slender, much more so than in *Branchipus*. 2d antennæ of male 3-jointed, remarkably long and large, tortuous and twisted, the basal joint stout, armed externally at the end with a very long, slender spur, about as long as the joint itself; the 2d joint thick, very long and bent upward and inward; near the end on the inside is a row of small papillæ; at the extremity it enlarges into a short, thick hand-like portion, the 3d joint, which divides into two long unequally forked chitinous appendages. 2d antennæ of the female as usual, broad and suddenly mucronate at tip. Eleven pairs of feet; much as in *Branchinecta* and *Branchipus*: the first endite as usual, but the fringe is rather long, as also that of the other endites; the 5th endite square, the outer edge hollowed out, the spines on the lower edge few and unusually blunt; the 6th endites more acute than in *Branchipus;* the flabellum large and rounded, fuller than in *Branchipus;* the gills rather large. The penis consists of two separate very long curved filiform processes. Ovisac of the female long and slender, much as in *Branchinecta.* Caudal appendages longer and broader than in *Branchipus.*

This genus differs from Branchipus in the want of frontal appendages, and may be easily identified by the long 3-jointed twisted and elbowed claspers, and by the two long slender filamental processes forming the male genital armature. Judging by the form of the 2d antennæ, particularly the 1st joint, and by the absence of any frontal appendages, and especially the form of the ovisac, *Streptocephalus* appears to be a modified *Branchinecta*, and to have been differentiated from that genus rather than from *Branchipus;* in fact we may, I think, regard *Branchinecta* as the more generalized, ancestral type of the family.

Synopsis of the species.

Male claspers larger and slenderer at tip than in *S. similis* ... *S. texanus.*
Male claspers shorter than in *S. texanus* .... *S. sealii.*
Male claspers shorter and broader at base than in *S. texanus* .... *S. floridanus.*

STREPTOCEPHALUS TEXANUS Packard.

Plate XII, figs. 1-7.

Streptocephalus texanus Pack., Amer. Journ. Sc. August, 1871.
Streptocephalus watsonii Packard, Hayden's Annual Report of the U. S. Geol. & Geogr. Survey of the Territories for 1873, p. 622. Pl. IV, fig. 13.

Male.—Front of the head with a small median lobe which projects downward between the bases of the second antennæ, and is flattened,

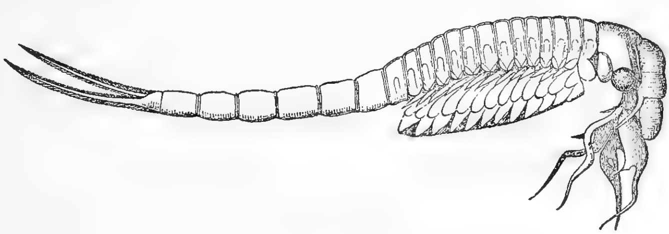


FIG. 20. Streptocephalus texanus, enlarged.

broad at the end, but not lobed, there being but a very faint median sinus. The subconical upper surface of the head bearing the oblong ocellus near the front edge is truncated-conical, being a little longer than broad. 1st antennæ long and slender, twice as long as the eyestalk, 2-jointed, 2d joint about two-thirds longer than the 1st, tapering towards the end; basal joint curved a little at the base. 2d antennæ or claspers large and tortuous; the basal joint extends outward and downward; the 2d joint extends backward parallel to the body, and is bent at right angles to itself, and the 2d is directed forwards and inwards, the ends nearly meeting over the median line of the body; 3d joint short, swollen, and subdividing into three branches, the longest of which reaches in its natural position to the 8th segment behind the 1st antennary segment. An antenniform appendage springs from the end of the basal joint and reaches to the end of the 5th ring behind the eyes; it is slender, flattened, and much as described in *S. similis* Baird. At the end on the outside of the 2d joint is an acute, short, flat, conical appendage. Of the two terminal large appendages, the longer and slenderer one is sinuate and sends off a slender spur from the base, reaching nearly to the bend in the appendage, where there is a slight projection, beyond which it is long and slender, flattened, cylindrical. The other appendage is irregularly flattened, very sinuate, and about two-thirds as long as the other. Near the base on the outer edge are two flat lamellate teeth, the inner much the smaller and slenderer; the outer broad and suddenly ending in a finger-like point, the appendage ending abruptly in an acute point. For want of material it is difficult to draw up a good comparative description of the appendages of this species as compared with *A. floridanus* and *A. sealii*.

By reference to the figures on Plate XII a good idea of the form of the appendages and their endites and exites can be obtained; but which characters are generic and which specific would be difficult to say. The 1st endite is broad and large, with long, fine, hair-like setæ; in the 8th pair the base of the edge of the 5th endite has six stout, truncated, short spines (see Pl. XII, fig. 5 l^5). The gills are oval, lanceolate in form; the flabellum rather broad and well rounded on the outer edge, which is serrate, the teeth giving rise to small, fine setæ.

The male reproductive organs arise from the 8th segment counting forward from the telson, or the 15th from the head, and are slender, simple, unarmed, cylindrical, of the same thickness throughout, with the end blunt, and are curved around so as to touch at their origin.

Telson very short; caudal appendages but slightly separated at base, long and rather stout, gradually tapering to the end and well fringed on both edges.

Length of the whole animal, 16.2^{mm}; length of longer appendage of 2d antennæ, 4.2^{mm}; length of caudal stylets, 3.2^{mm}; length of penis, 3.2^{mm}.

Female.—Differs from the male in the 2d antennæ, which scarcely reach beyond the 1st antennæ, and which are flat, conical, ending in a finger-shaped point. Ovisac attached to the 13th and 14th segments behind the head; it reaches backwards to the segment in front of the telson, forming a long cylindrical sac ending in two valves, the upper one triangular, hollowed beneath, the under one short, forming the end of the ovisac. The external opening of the oviducts are situated on the basal segment of the abdomen. The eggs are a little the larger at the end of the ovisac. The caudal appendages are rather shorter and considerably stouter than in the male.

Total length, 14^{mm}; of caudal appendages, 3^{mm}; of ovisac, 5^{mm}.

This description is mainly based on the few examples received from Waco, Tex., through Mr. G. W. Belfrage, who found it in 1871, and again February 17, 1872, with Limnetis and Estheria. Afterwards a large number, mostly immature, were received from Dr. Watson, at Ellis, Kans., and these were supposed to represent a different species and described in the Bulletin of Hayden's U. S. Geological Survey of the Territories in 1877. Since then I have received a number of specimens from Wallace, Kans., through Professor Lindahl, some of which were of the same size and state of preservation as the Texan specimens, and which showed no specific differences, and finally, on carefully examining and drawing the feet of specimens from the two States, I found that they could not be separated specifically.

I append the description of the Kansas specimens from Hayden's Bulletin, which may show how the individuals vary, especially in the male claspers:

"*Male.*—The claspers (2d antennæ) are much longer than in *S. texanus*, reaching, when extended, to the middle of the body, while in *S. texanus* they only reach a third of the length of the body. The median lobe of the head, which is very large and long in *S. texanus*, reaching nearly as far as the insertion of the basal filamentary appendage of the third joint of the claspers, is, in *S. watsoni*, not half as large. The two basal joints of the claspers are twice as long and much slenderer than in *S. texanus;* the third joint is nearly as long, while the branches and spines of the 4th joint, though of the same number, are much longer and slenderer. Of the longer branch the supplementary spine is much longer, and without the small inner spine, while the main branch beyond is bent at right angles, the elbow being much bent, the inside, however, regularly curved. At the base of the broader and shorter branch are four unequal teeth; one attached to the third joint, the other to the fourth, the two terminal ones very unequal, and the fourth square and three times as large as the third, while the corresponding tooth in *S. texanus* is long and narrow, and smaller than the one behind it. The genital appendages are long and slender, much as in *S. texanus*, being as long as the three segments following the one to which they are inserted. The caudal appendages are much shorter and broader than in *S. texanus*, each blade being broader, and tapering regularly from base to tip, not contracted in the middle, nor curved, as in the male of *S. texanus;* on the other hand, they are of much the same form as in those of the female *S. texanus.*

"*Female.*—Very closely allied to the female *S. texanus*, though as a rule somewhat smaller, the eyes being decidedly smaller. The second antennæ are a little, sometimes much, longer in proportion, and are mucronate, as in the other species. The ovisacs are as in *S. texanus*, but the eggs are much smaller in proportion. The caudal appendages do not differ materially from those of the males, nor from those of the females of *S. texanus.*

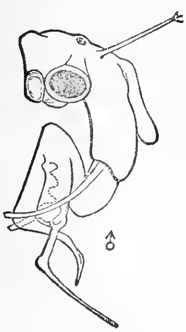
"Length of males, 16^{mm}; females, $12–18^{mm}$. About fifty of each sex examined, although several hundred were casually looked over, without finding any that approached *S. texanus* any nearer than has been indicated.

"Ellis, Kans., in pools on the prairie, June 28, 29, September 27, and October 10–22, Dr. L. Watson. A large number of half-grown males and females occurred in June. The largest females, those measuring 18 millimeters in length, occurred October 22, the ovisacs filled with eggs in some cases; in others, partially or entirely empty. The body was soft and in such a state of preservation as to indicate that they were at the point of dissolution. They were found associated with *Thamnocephalus*, *Limnetis*, *Estheria*, *Eulimnadia*, and *Apus lucasanus.* The tails were red, says Dr. Watson, and in some the bodies were blue. This refers to those which were collected in June and early in July. 'Those found in October and early in November (the 6th) were pure white, and the appendages to the tail seemed to me to be more divaricate than those of summer, in which those appendages were of a red color.' While the males are easily distinguishable from those of *S. texanus* by the much greater length and different style of branching of the second antennæ, as well as in the smaller frontal tubercle and the slenderer caudal appendages, the females differ but slightly, but may still be distinguished by the smaller eyes and longer second antennæ. This species is dedicated to Dr. L. Watson, who has been indefatigable in securing me specimens for examination of this and other Phyllopods. The male differs from *S. similis* Baird from St. Domingo in the second antennæ or claspers being much longer and slenderer at tip of the longer branch, while the shorter branch is much narrower. In the female the ovisac reaches to the penultimate segment of the abdomen, while, according to Baird's figure, in *S. similis* it scarcely reaches to the end of the fourth segment from the end, and the second antennæ are represented as being much larger than in our species. The figures do not exactly correspond with Baird's description, for it is nearly impossible to make a characteristic drawing of the members of this family, and particularly of this genus."

STREPTOCEPHALUS SEALII Ryder.

Streptocephalus sealii Ryder, Proc. Acad. Nat. Sc. Phil., p. 200, 1879.

"In form and size this species resembles *S. torvicornis* Waga, but the third joint of the second antennæ differs from that species in the details of its structure, and the ovigerous sacs of the female are not blue, as in Waga's animal. The inner branch of the terminal joint of the male claspers is the shortest instead of the longest, as in *S. torvicornis;* at the interno-anterior margin of the short branch there are two unequal lobes extending forwards and lying flat against the laminar posterior border of the anterior branch; at the lower posterior angle of this lamina, or blade of the forward branch, there is a well-marked, somewhat falcate process, which fits between the lower lobular process of the posterior branch and its scythe-shaped lower extremity. The anterior branch crosses the posterior at nearly right angles, and for about a third of its length maintains a pretty uniform thickness, and is straight, when it suddenly swells and bends forwards, and as suddenly contracts and tapers for its remaining two-thirds, ending in a slender, slightly-curved, pointed extremity. The first joint is long and robust, and from its apex externally the cylindrical, curved, antenniform organ arises, which is about as long as the filiform first antennæ. The second joint is very tortuous, and is strongly bent and twisted upon itself. The third joint, which bears the complex terminal appendages, is wide; the appendages close against each other like the blades of scissors, whilst the processes of their opposing margins interlock as has been already described, and as can be fully understood by reference to the accompanying cut of the head of the male. The front of the head is prolonged into a straight beak, which hangs down nearly vertically between the first joints of the claspers, and is flattened antero-posteriorly, and emarginate at its tip. The antenniform appendage is much longer than in *S. texanus* Packard, whilst the terminal branches of the claspers are widely different from those of that species in their shape and relative proportions. The male



21.—Head of *Streptocephalus sealii*, enlarged; after Ryder organs are very feebly armed with a few short spines and are nearly straight. The cephalic horns of the female are twisted upon themselves, slightly bent and flattened at their extremities, which are fringed with short hairs. The large lateral, ovoid, pedunculate, apparently glandular organs behind the eyes are the same in size and shape in both sexes. The ovigerous sacs are large, nearly half as long as the abdomen, conical in form, and contain a great number of ochraceous eggs, more numerous and much smaller than those of *Chirocephalus holmanii* from the same locality. The male is of a beautiful green, deeper about the head, as though saturated with acetate of copper; the female, on the other hand, is yellow, with a tinge of green, verging to brownish in parts, and is very nearly of the same size as the male, if not a little larger. This similarity in the size of the sexes, with a tendency in the females to be largest, is observed only in *S. torvicornis*, as far as I am aware. The two rather long, plumose, tapering branches of the tail are red in both sexes, but of a much brighter red in the female; more slender in the male. Length, 27^{mm}" (Ryder).

The main difference between *S. sealii* and *texanus* is that in the former the claspers are considerably shorter, the 2d joint being much shorter and the 3d joint at base much broader, while the 2d spine on the shorter fork is nearly three times as large as in *S. texanus*, and the longer fork is much slenderer. There are no differences in the feet, as I find after careful microscopic examination. *C. sealii* also appears to be rather larger.

Regarding the mode of occurrence of this species we quote from a letter of Mr. W. P. Seals, dated Woodbury, N. J., November 7, 1879:

"I have delayed answering your letter until I could assure myself positively as to the present existence of *Streptocephalus sealii.* Unfortunately I did not save any specimens, and the swales in which I found them are now dry with one exception, and in that I cannot find a single specimen. Perhaps the following notes which I have made will interest you. I find them in two places separated by about a mile. One of these is never dry. In this one they disappeared about the beginning of June, and have not yet reappeared. In the other swale they disappeared about June 6th by reason of its drying up. In about two weeks after the heavy rains in the latter part of August they had again made their appearance. By October 20th they had again disappeared by reason of the drying up of the swale. *Chirocephalus holmanii* also exists in this swale, but has not made its appearance since disappearing last June."

We have also received numerous specimens from Dr. C. F. Gissler, who sends us the following notes:

"I send you now a bottle with Chirocephalus of both sexes. A few specimens of *Eubranchipus vernalis* might have slipped in also, as they occur together in a very large and deep pond (no fishes seen so far) near Glendale, L. I. With one Eubranchipus about twenty *Chirocephalus holmani* occur. The males are in average about $1\frac{1}{2}^{mm}$ shorter than the females. Color yellowish or reddish or greenish, last 3 abdominal segments with red pigment, the latter confluent, not granular. The ♀ has the same second inner lobe as Ryder figures it. Ovary (observed in many ♀) extends upward to the 4th pair of branchipods from the end; no anastomosis in the post-abdomen. The water of the pond is perfectly clear, colorless, numberous Entomostraca occurring in it. I have seen them in copulation many a time, and can assure you that the tentacles do not come into use as an auxilliary."

On March 23, 1881, Dr. Gissler visit d the same pond at Glendale and found *C. holmani* in great abundance, getting two or three dozen at every dip of the net.

STREPTOCEPHALUS FLORIDANUS Packard.

Streptocephalus floridanus Packard, American Naturalist, p. 53, Jan. 1880.

The two basal filaments are as in *S. texanus;* of the forceps at the end of the claspers, the filaments are much shorter and smaller than in *S. texanus*, so much so that there is no need of confounding the two species, and, besides, in the Floridian species the processes are less broad and flat, and the inner of the two blades of the forceps have but one instead of two teeth. It approaches *S. texanus* in the robustness of the body, in the form and size of the caudal appendages, which equal, in length, the three last abdominal segments. It seems to approach *S. similis* Baird, which inhabits St. Domingo, but that species is not described with sufficient exactness to enable us to compare it properly, and indeed without good specimens for comparison it is difficult to say whether this species is different or not from *S. sealii* Ryder.

Total length of male, 10^{mm}; length of 2d antennæ when stretched out, $5–6^{mm}$; length of caudal appendage, 2^{mm}; total length of female, 10^{mm}.

A pair, ♂ and ♀, found in the Saint John's River, Florida, May 23, 1879, by Alex. P. Fries; received from Dr. Carl F. Gissler. It appears to differ from *S. similis* in the shorter filiform appendage of 3d joint of 2d antennæ, which is also very much shorter than in *S. texanus*.

STREPTOCEPHALUS SIMILIS Baird.

Streptocephalus similis Baird, Annals and Mag. Nat. Hist. 2d ser. xiv, 220, 1854.

"This species, which was found by M. Sallé in the island of St. Domingo in the West Indies, is of a slender and cylindrical form. The male is about five-eighths of an inch in length, and the female half an inch. The inferior antennæ or cephalic horns in the male are large and tortuous; they are composed of three joints; the first or basal joint is the largest, is cylindrical, and extends for some distance straight forwards; the second, smaller than the basal, is also cylindrical, curves slightly at first, then bends suddenly backwards upon itself; the third or terminal joint bends as suddenly forwards and terminates in a club-shaped extremity, which divides into two branches, one longer than the other, terminating in a long filiform process; the other flatter, shorter, and dividing into two shorter filiform processes of unequal length. The antenniform appendage is long and cylindrical, rather stout, and springs from close to the extremity of basal joint. The basal joint is destitute of the lanceolate-toothed appendage on internal edge, which we see in the preceding species (*S. cafer* Lovén). The superior antennæ are long and slender, and consist of two joints, the basal one much shorter than the 2d. The male organs are rather long, cylindrical, and of a horny texture. The front of the head is prolonged into a beak, which is flat, rather broad and slightly lobed at the extremity. Feet short. Abdomen slender. Caudal appendages of moderate length, and beset on each side with numerous short and plumose setæ.

"The cephalic horns in the female are short, thick, and terminate in a short spine at the extremity. The ovarian bag is conical, acute, and the ova are of an ochreous color.

"The chief differences between this species and *S. cafer* consist, in the male, in the shape of the front of the head, the organs of generation, and in the inferior antennæ having no lamina with teeth on the basal joint; in the female, in the shape of the external ovary."

Genus CHIROCEPHALUS Prevost.

Plate XIII.

Chirocephalus Prevost, Journal de Physique, lvii, 37, 1803; Thompson, Zoological Researches, 1834.
Branchipus, Milne-Edwards, Fischer, Latreille, Desmarest, Guerin, Lamarck.
Chirocephalus Baird (in part), British Entomostraca, 38, 1850; Annals and Mag. Nat. Hist. 2d ser. xiv, 221, 1854; Verrill, Proc. Amer. Assoc. Adv. Sc., July, 1870.

Body slender, head of moderate size, 2d antennæ or male claspers with the basal joint very large and thick and somewhat curved; 2d joint very long and slender, curved inward, with a basal sharp spur. Two remarkably long and large frontal appendages arising between the base of the 2d antennæ, about twice as long as the 2d antennæ, much twisted and coiled and variously lobed and spinulated. Eleven pairs of swimming feet; the basal lobe or endite long and with the edge regularly curved, the 2d with an outer subdivision about $\frac{1}{4}$ as broad as the 1st; each paler, with rather long fringe of delicate hair-like setæ; the 2–4th endites, as in the foregoing genera, small, each with three or four long minutely spinulated setæ. The 5th endite of the usual size, but rather square, much as in *Branchipus*, but with a tendency in the lower outer angle to be somewhat produced so as to be subtriangular in outline. (Pl. XIII, fig. 1.) The 6th endite is unusually long and narrow, almost lanceolate, and with long setæ in the 3d pair of feet, or small, narrow, and abruptly rounded in the 1st pair; in the 10th pair they are narrow and rounded at tip. Flabellum and gills much as in *Branchipus*.

Male genital apparatus short and small, deeply cleft, forming two slender curved portions, each with its cirrus. Caudal appendages long and broad, much more so than in *Branchipus*.

In the female the 2d antennæ have the mucronate spur or tip larger and longer than usual. Ovisac short and broad, with the end produced like the neck of a bottle, much as in *Branchipus*. The eggs are few in number (about a dozen), and the eggs are larger than in *Streptocephalus* and *Branchipus*.

This genus differs from Branchipus in the slenderer body, the very long, coiled, twisted, lobulated, and spinulose frontal appendages, and in the differences in the endites already noted. In the form of the external male organs and of the ovisac the genus approximates closely to *Branchipus*, and in the frontal appendages, as seen in the European *C. diaphanus*, is only an exaggeration of those of Branchipus. It seems reasonable to infer that Chirocephalus is a more recent group than Branchipus, and has probably originated from that genus, as *Streptocephalus* has in all probability arisen from individuals. The singular frontal appendages are supplied with two large muscles, and as no nerves have as yet been detected in them it is probable that the organs are simply prehensile and perhaps of use during the union of the sexes.

CHIROCEPHALUS HOLMANI Ryder.

Plate XIII, figs. 1–5.

Chirocephalus holmani Ryder, Proc. Acad. Nat. Sc., Philadelphia, 148, 1879.

Body rather slender; 2d antennæ or claspers of the male with the the 2d joint considerably shorter than the 1st; it is forked, spur large and pointed; the longer branch slender (its tip crossing that of its fellow of the opposite side when in repose). The two frontal appendages (Pl. XIII, figs. 4, 5) very long, coiled, and twisted, with the appearance of being jointed, and gradually diminishing to a long, curved point, which is minutely spinulated, the spinules short, stout at base, and acute at tip; variously and finely lobed with about seven finger-like spinulated processes, best marked in old males (Fig. 22); near the middle a group of four or five setæ. These organs, when stretched out, are about three times as long as the male claspers. As a rule the 6th endites of all the feet are narrow and obtuse at the end, much as in *Branchipus*, the gill varying much in size. The head of the female is simple, without any frontal appendages; the ovisac is short and small, containing about a dozen very large eggs, showing that the number of individuals in this species is far less than in the other species of the family except, perhaps, *Artemia*.

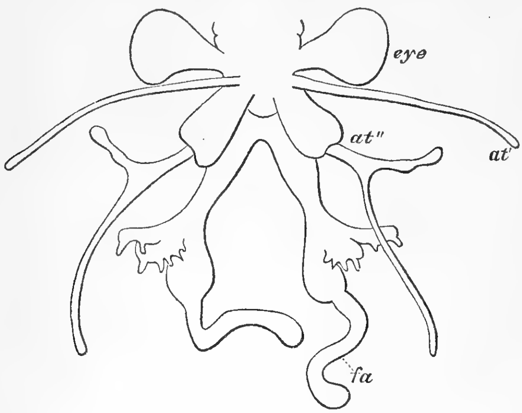


FIG. 22.—Chirocephalus holmani; male. Front view of head of male, much enlarged, the frontal appendages somewhat retracted; *at'*, first antenna; *at''*, second antenna or male clasper, with the spur and filiform 2d joint; *fa*, frontal appendage. Gissler del.

Total length of body of male, 15mm; of 2d antennæ, 3mm; of frontal appendages when outstretched, 5–6mm; of genital organs, 2mm; caudal appendages, 2–2, 3mm.

Total length of female, 16mm; of ovisac, 2mm.

I have received the ♂ and ♀ from Mr. Ryder, the types of his description, and also a number of both sexes, the females with eggs, from Woodbury, N. J., near Philadelphia, collected in company with *Branchipus vernalis*, March 27, by Mr. William P. Seal; also from Glendale, Long Island, from Dr. C. F. Gissler, who kindly sent me a drawing of the head of an old male, although the sketches of the head of the male by Mr. Ryder in the Proceedings of the Philadelphia Academy of Sciences are truthful to nature.

This Branchipod is certainly, only excepting the next genus, the most interesting and bizarre of all our fresh-water Phyllopods. The sketches in Plate XIII will convey a better idea of the form of the feet than any verbal description.

Subfamily THAMNOCEPHALINÆ Packard.

Body large, very stout and thick; eleven pairs of feet; 2d male antennæ with the 2d joint simple, curved; nine abdominal segments; abdomen broad and flat, ending in a single broad, spatulate, fin-like lobe; endites of feet much broader and more rounded than in *Branchipodinæ;* frontal appendage of male tree-like; of female, long and clavate, simple.

THAMNOCEPHALUS* Packard.

Thamnocephalus Pack., Bull. Hayden's U. S. Geol. and Geogr. Survey Territories, iii, 175. April 9, 1877.

Male.—Claspers (second antennæ) with the basal joint short, the upper

* θάμνοζ, shrubby, bushy; κεφαλς, head.

lobe forming a long, up-curved, chitinous, slender appendage, extending, when outstretched, to the first third of the body; the lower lobe fleshy and short, straight. A distinguishing and remarkable character is the frontal, interantennal, shrub-like, branched, biramous appendage extending out in front, the brush more than half the length of the body, and sending off branches anteriorly, which are provided with minute spinules. The male genitals united at base as usual; they are small and deeply cleft.

Female.—The frontal shrub is replaced by a pair of long, slender appendages, acute, lanceolate-ovate at the end, and contracted somewhat in the middle. Labrum rather long and large. The second antennæ are remarkably long and broad, oar-like, acute at the tip. The egg-sac is long, subconical, rather thick and broad at the base, which is concealed by the leaf-like feet; it ends in two valves.

In both sexes the body is unusually short and thick, though the head is of the usual size. There are 11 pairs of feet, with the lobes broad and short, much more orbicular than usual. The gill is larger and broader than usual, the flabellum being somewhat ovate in outline (the relation of the gill to the rest of the appendage is best seen in the transverse view of the body, Plate XIV, fig. 4 *br.*). The 1st endite or lobe is much shorter than in the other genera, and with coarser, hair-like setæ; the 2d endite is large, being from one-third to one-half the size of the 1st endite; the setæ are rather coarse; the 3d and 4th endites small as usual, each with three or four setulose setæ; the 5th endite is broad and large, bluntly and quite regularly pointed, not so rectangularly bent as in most of the other genera of the family. The 6th endite is usually short and broad, quite different from the long subacute-ovate form prevailing in the other genera of the family. The abdomen consists of nine segments, dilates into a remarkably large, broad, fin-like expansion, beginning at the sixth segment from the end, and expanding at the last segment until it becomes wider than the body, and extending a little way beyond the last segment. It is fringed with delicate hair like setæ, and canals from the body ramify in it; at the end it is deeply notched, forming two broad, rounded lobes.

This remarkable genus differs from any other known to me by the short and broad, spatulate, fin-like expansion of the abdomen, while the male claspers are curved and simple. In both sexes the body is stout, broad, and the egg-sac of the female is subconical, spreading out at the base. It is quite unlike any European genus, and in the frontal appendage, the end of the abdomen, and the broad, short gills and endites stands alone in the family.

THAMNOCEPHALUS PLATYURUS Packard.

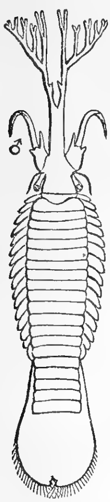
Plate XIV, figs. 1–7.

Thamnocephalus platyurus Packard, Bull. U. S. Geol. and Geogr. Survey Territories, iii, No. 1, 175. April 9, 1879.

Male.—Frontal shrub over half as long as the body, the two branches subdividing into about seven subbranches, all directed forward. First antennæ long and slender, extending to the end of the basal joint of the second or male claspers. The latter with the basal joint rather short, the claspers long, slender, and recurved, simple, saber-like, chitinous, the lower lobe soft, acute, subconical. Genital appendages in the usual position, short, not so long as the segment to which they are attached, and bilobed, there being two short terminal tubes, with distinct, large openings, directed downward.

Female.—Second antennæ large and long, extending back a little beyond the base of the ovisac, oar-like, expanding broadly on the outer two-thirds, especially on the upper edge. The ovisac is subconical, the base broad and concealed by the limbs; it terminates at the posterior edge of the fourth segment from the end, ending in two unequal flaps, the upper four times larger than the under flap, and triangular in outline.

Length of male, 23mm; female, 26 5mm. Ellis, Kans., Dr. L. Watson, collected June 26, 28, and 29, and again September 27, October 1, 10, and 22, 1874, in pools of water on the plains, in company with Estheria and Limnetis. A fully-grown male occurred September 27th. October 1–22 females of full size were collected, in company with *Apus lucasanus*, *Estheria compleximanus*, and *Estheria mexicana*.* The ovisacs still contained eggs, though empty at the ends.



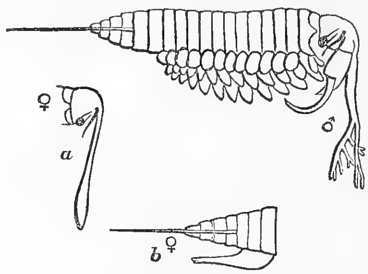


FIG. 23.—*Thamnocephalus platyurus* PACK., male, natural size, dorsal and side view; *a* head, and *b* end of body of female, showing ovisac.

No striking variation was observed among several hundred specimens of different ages. Dr. Watson writes that the general color is pinkish, the edge of the tail red, and the genitals light blue.

The sexual characters are very distinct when the animal is one-third grown, the oviducts being red with eggs, and the males with the frontal bush-like appendage well developed.

The following account of the occurrence in Kansas of this interesting genus, and of Apus lucasanus, Streptocephalus texanus, Estheria mexicana, and Limnetis I extract from a letter of Dr. Watson, dated Ellis, Kans., October 12, 1874:

The Apus moves about on the bottom of the pools, rarely rising enough to allow the slipping of the net under him, and is not easily captured unless in close quarters. The Estheria and Limnetis swim about, going to the bottom and coming to the surface, and are easily captured by slipping a net under them when up. The Thamnocephalus are always *in medio*, and by gentle action are easily taken. The forked-tail ones (Streptocephalus) at the edge of the pool, and the larger emarginated-tailed ones always in the middle, or in circumscribed clear places having 6 or 12 inches of water. The heavy rain of June 14 washed out the ravines by torrents. The dates I have before given for former collections indicate the development of those specimens after that date. Those now sent (October 14) have developed, certainly since September 2; probably since September 8; possibly since September 13.

"In relation to the localities where I have found the Crustaceans:

"There are "divides" upon these plains, between streams; just here,

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* From Mr. R. P. Whitfield we have received specimens of *Estheria mexicana* collected by Dr. C. A. White, on the Vermilion River, Colorado, in company with *Lepidurus bilobatus* Pack. See *American Naturalist*, xiv, 53, 1880, where this species is referred to under the name of *Estheria watsoni* Pack. (no description), which is synonymous with *E. mexicana*.

three hundred miles west of the Missouri River, the Smoky Hill River is twelve miles south. The 'divide' between it and Big Creek, one of its tributaries (upon which Ellis is situated), is about one-third of the distance, or four miles. Six miles north is a tributary of the Saline River, with a "divide" about midway between it and Big Creek. From these "divides," at varied intervals, are ravines, those upon the north side often deep enough to be called cañons, and in some of which are small springs, sufficient to maintain pools containing fishes (and Amphipods). The ravines from the south of these 'divides' are more gentle or less abrupt, and though, upon heavy rains, torrents of 8, 10, or more feet of depth, rush down them, they are ordinarily dry pools of water remaining only two or three weeks at the angles where are bluff banks, or in other excavated places. In such pools, well up the ravines beyond where fishes from the creek run up during the flood, these Crustaceans are found. They are not found in 'buffalo wallows,' or in any upland pools. Under the circumstances of this year or last only three or four weeks of life can they have. Millions of them perish by the drying up of the pools in July. A less number hatch out after the fall rains, and they can have hardly more than a month to live.'

II.—THE GEOLOGICAL SUCCESSION OF THE PHYLLOPODA.

FOSSIL FORMS.

Up to this date but four species of fossil Phyllopoda are known from North America; these are:

Estheria pulex Clarke;* from the base of the Hamilton shale in New York.

Estheria ovata T. R. Jones; from the Triassic beds of North Carolina, Virginia, and Pennsylvania.

Estheria dawsoni Packard; from the Quaternary Clays of Canada.

Leaia leidyi, T. R. Jones; from the Lower Carboniferous of Pennsylvania.

We reproduce the descriptions of the forms described by Prof. T. R. Jones from his monograph of the fossil Estheriæ. London Palæontological Society, 1862.

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* *Estheria pulex* Clarke, Amer. Journ. Sc. June, 1882, 476.

"In examining some fragments of soft, olive-colored shale from near the base of the Hamilton proper, in Miles' Gully, Hopewell, Ontario County [N. Y.], I have detected the above representative of this extremely interesting genus. The little carapaces are never more than $\frac{3}{5}^{mm}$ in width and $\frac{1}{2}^{mm}$ in length, and may be described as having the ventral margin nearly semi-circular, the beak central or very slightly anterior, hinge line sloping laterally. The surface is marked by six, or in the largest seven, concentric ridges, which are very broad, with narrow intervening furrows. There appears to be no more elaborate sculpturing of the carapaces than Jones has figured for his species, *E. membranacea*, which is the simplest of any as yet noticed.

"It is interesting to notice that this *Estheria*, the first ever found below the Trias in America, and nowhere at so low a horizon as this, resembles in its subcentral beak, its outline and surface markings, this species just referred to, *E. membranacea* Jones, from the Old Red of Caithness, while all others figured by that author (Mon. Esth. Palæontogr. Society, vol. xviii) all from higher horizons, have the beak anterior and the outline of the carapace more nearly subtrigonal."

This is a very remarkable species of *Estheria*, and may yet be found to represent an undescribed genus. It differs from any species of the genus figured by Jones, including *E. membranacea*, in wanting a straight hinge-margin. Its small size, few lines of growth, and lack of a hinge-margin, indicate that it is very young, and for that reason may yet prove to be a true *Estheria*.

ESTHERIA OVATA Jones.

Posidonomya minuta (Bronn.) W. B. Rogers, Proc. Acad. Nat. Sci. Philad., 1843, vol. 1, p. 249; *Posidonia*, sp.? Proc. Boston Soc. Nat. Hist., 1854, vol. 5, p. 14. ? Lyell, Quart. Journ. Geol. Soc., 1847, vol. iii, p. 274, fig. 6.

Posidonia ovata Lea, Proc. Acad. Nat. Sc. Philad., 1856, vol. 8, p. 77.
parva, Lea, ibid.

P. ovalis Emmons Geol. Rep. North Carolina, 1856, p. 323, fig. W, 1 and 2; Amer. Geol., part 9, 1857, p. 40, fig. 12; Manual Geol., 2d edit., 1860, p. 191, 166, 3.

P. multicostata Emmons, Geol. Rep. N Carolina, 1856, p. 337, fig. X; Amer. Geol., part 6, 1857, p. 134, fig. 103; Manual of Geol., 2d edit., 1860, p. 191, fig. 166, 4.

P. triangularis, Emmons, Geol. Rep. N. Carolina, p. 338, fig. 5; Amer. Geol. part 6, p. 134, fig. 104.

	Inch.	Inch.	Inch.	Inch	Inch.
Height	$\frac{\frac{3}{4}}{12}$	$\frac{1}{12}$	Less than $\frac{3}{12}$	More than $\frac{2}{12}$	More than $\frac{2\frac{1}{2}}{12}$
Length	$\frac{1}{12}$	$\frac{1\frac{1}{2}}{12}$	$\frac{4}{12}$	Less than $\frac{3}{12}$	Less than $\frac{4}{12}$
Proportion	$1:1\frac{1}{4}$	$1:1\frac{1}{2}$	$1:1\frac{3}{4}+$	$1:1\frac{1}{3}+$	$1:1\frac{1}{2}-$

"Carapace valves broadly subovate, almost semicircular; the straight dorsal line reaches across the valve, the extremities curving suddenly downwards; the postero-dorsal angle being the sharper of the two. The front and posterior margins are nearly equally rounded, but the valve is usually deepest at the anterior third, in a line with the umbo; the well-curved ventral border being rather more oblique posteriorly than anteriorly. The concentric ridges are about fifteen in fig. 26, about twenty-eight in fig. 27, and much more numerous in fig. 28. In fig. 27 we see the gradual crowding of minor concentric ridges towards the ventral border in an adult specimen, and in fig. 28 we have an individual in which, owing to some peculiarity of growth, the ridges are too numerous to be very distinct, and are unaccompanied with any ornament of the interspaces (figs. 29, 30). In other specimens we find, besides blank surfaces (fig. 37), modifications of a reticulate ornament on the interspaces (figs. 32, 36), with occasionally a barred or transversely wrinkled pattern (figs. 37, 38). Fig. 31 is a set of narrow interspaces, smooth and without ornament. Fig. 32 shows how a smooth surface may mask the reticulate structure. Figs. 33, 34, 35, and 36 are reticulate interspaces, the meshes being of various sizes and arranged either longitudinally, diagonally, or vertically. In the first case the walls of the meshes would strengthen if not give rise to minor concentric striæ; in the last case they may give rise to the bar-ornament, such as is seen in fig. 37. The obliquity of the meshes in fig. 35 may be due to pressure. Fig. 38 seems to show narrow interspaces bonneted by thick ridges and crossed by short thick bars.

"For most of these illustrations we have had recourse to specimens from Pennsylvania, Richmond, and Dan River (from Prof. W. B. Rogers' collection), which evidently belong to the species. These specimens are—

1. From Pennsylvania. Black shale. Estheriæ excessively crowded in horizontal layers.

2. From Prince Edward, near Richmond, Va. Black shale, with conchoidal fracture, fine-grained. Estheriæ tolerably well preserved, but crumpled.

3. From Dan River, North Carolina. Black, laminated shale, obliquely crushed. Estheriæ very thin."

LEAIA, gen. nov.

"I have proposed the above name as a generic denomination for certain peculiar, quadrate, bivalved carapaces, occurring in the Coal-measures of Britain and the lower Carboniferous red sandstone of Pennsylvania. I know nothing of their nature, except that they are small, thin, horny, brown, stiffly quadrate, symmetrical bodies, unlike Molluscan shells, but possibly Crustacean and Phyllopodous.

"I have some specimens from the upper Coal-measures of Ardwick, near Manchester (collected by Professor Williamson, F. R. S., several years since), and some from the lower coal-measures of Fifeshire, collected by Mr. Salter, F. G. S., of the geological survey. Dr. Isaac Lea described and figured, a few years ago, a similar fossil from the red sandstone of Pennsylvania, and named it *Cypricardia leidyi*. All these three are very much alike; but, on account of the obscurity of their relationship, and the distant places, geological and topographical, of their occurrence, and making the most of their slight differences of contour, I propose to keep them nominally distinct as *Leaia leidyi* (Plate 5, figs. 11, 12), *L. leidyi*, var. *williamsoniana* (Plate 1, figs. 19, 20), and *L. leidyi* var. *salteriana* (Plate 1, fig. 21) Dr. I. Lea, of Philadelphia, being the first to notice and figure a specimen of this proposed genus, I have distinguished it by a name commemorative of that well-known conchologist. The carapace-valves are oblong; truncate behind, with a slight curvature of outline; boldly rounded in front; either straight or somewhat curved on the ventral border; straight on the dorsal edge; a slight umbo takes the place of the antero-dorsal angle, from whence two conspicuous ridges (hollow within) pass along the surface of the valve; one directly across the valve to the antero-ventral angle; the other, and longer one, passes diagonally to the postero-ventral angle; these ridges divide the convexity of the valves into three, unequal, triangular, smooth, sloping areas; the anterior space is the smallest, and nearly semicircular; the middle one has its apex at the umbo, and its base along the ventral margin; and the posterior space is based on the hinder margin, and reaches along the dorsal region to the umbo. The surface of the valve is marked with 10–13 (?) delicate ridges (hollow within), concentric, beginning at the umbo, conformable to the outline of the valve, and sharply bent at the divergent ridges; they are curved and closely set on the anterior area; more open, horizontal, and straight, or nearly so, on the middle area, and vertically straight or slightly curved, and wider apart, on the posterior part of the valve. These symmetrical markings of concentric angular lines and transverse divergent ridges give this fossil, at first sight, a striking likeness to some fish-scales, when the two valves lie open, in contact by their dorsal edges (as in Plate 1, fig. 19), and produce a bilaterally symmetrical, subquadrate, concentrically lined figure, with triangular sloping areas. Dr. Lea points out some Cypricardiæ and other shells of Palæozoic age to which this little fossil has some resemblance in shape; and some Orthonotæ have a general resemblance to it; but some of the small Astartes of the Chalk and Oolite, small as the *A. Roemeri*, Müller's Petref. Aachen, Kreideform, Plate 6, fig. 12, and *A. interlineata*, Morris and Lycett, Mollusca of the great Oolite (Palæontog. Soc. Monograph), Plate 9, figs. 14, 15, have even a greater resemblance in size and shape, without being at all allied to the form before us.

The horny tissue of Leaia—its long dorsal edge destitute of hinge—its stiff and simple style of ornament—and its two diagonal, raised hollow ridges or folds, remove it from the Mollusca. It has been suggested (by Phillips and Williamson) that these fossils may be Trigonellites (of Goniatites?); but there is little or nothing to support the hypothesis.

LEAIA LEIDYI T. R. Jones.

Cypricardia leidyi Lea, sp. Proceed. Acad. Nat. Sc. Philadelphia, 1855, 7, p. 341, pl. 4.

Height of valve, nearly $\frac{3}{24}$ inch.
Length of valve, nearly $\frac{5}{24}$ inch. } Proportion 7 to 12, or 1: $1\frac{3}{4}$—.

In the "Proceedings Acad. Nat. Science of Philadelphia," May, 1855, vol. 7, p. 341, Dr. I. Lea has described a small fossil found by Dr. Leidy in red sandstone at Tumbling Run Dam, about a mile southeast of Pottsville, in Pennsylvania. The specimen consists of the impression of the outside of the two valves. It is figured carefully, of natural size, and enlarged, in plate 4 (op. cit.[1]), and is named *Cypricardia Leidyi* by Dr. Lea, who thus describes it:

"Shell oblong, round before and truncate behind, very inequilateral, striate; dorsal and basal margins parallel; umbonal slope shortly carinate; anterior slope with an elevated line from the back to the basal margin; striæ about twelve, very regular, and nearly equidistant (bent at an angle of 90° at the umbonal slope). Length, two-twentieths, breadth, nearly four-twentieths, of an inch." "The shell is accompanied on the specimen with some obscure impressed linear marks of a dlant.

The figures are reproduced here (Plate 5, figs. 11, 12). The sandstone is referred to the formation called No. 11 by Prof. H. D. Rogers in the State Geological Survey of Pennsylvania, and referred by him to the base of the Carboniferous system, but regarded by some geologists as the uppermost part of the Devonian or Old Red Sandstone. In this formation of sandstone (which, with its associated shales, is 3,000 feet thick), foot-tracks of reptiles, rain-prints, wave marks, and trails of annelids or molluscs are not uncommon at two or more horizons.

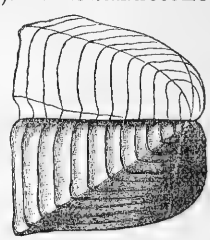


Fig. 24.—*Leaia leidyi* enlarged. After Lea.

Jones then describes as varieties of the foregoing, *Leaia williamsoniana*, from the uppermost coal-measures of Lancashire, England, and *L. salteriana*, from the lower Carboniferous rocks of Fifeshire, Scotland.

ESTHERIA DAWSONI Packard.

(Plate XXIV, figs. 4, 4 a, 4 b.)

Estheria dawsoni Packard, American Naturalist, xv, June, 1881, p. 496.

We have received through the kindness of Principal J. W. Dawson, LL. D., of Montreal, a valve, in partial preservation, of an Estheria quite unlike any existing American form. The following account of its discovery is from Principal Dawson:

"It was found at Green's Creek, on the Ottawa River, in nodules in the Post-pliocene clay, holding skeletons of *Mallotus villosus* and other northern fishes, and shells of *Leda* (*Portlandia*) *arctica*, *Saxicava rugosa*, &c.; also leaves of Populus, Potamogeton, &c. The deposit is of the age of the Leda clay of the Saint Lawrence (middle glacial) and belongs to a period of submergence where, in the bay or estuary then representing the Ottawa River, northern marine animals were embedded in deposits into which was also washed the *débris* of neighboring land, and of fresh-water streams. The climate at the time was colder than at present, and the area of land less, so that, if this Estheria still lives, it is most likely to be found in the vicinity of the Arctic coast."

This Estheria is entirely unlike any northern American or European species, differing decidedly from *Estheria morsei* or *Estheria mexicana*. It rather approaches *E. jonesii* from Cuba in the form of the shell and style of marking of the valves. It does not resemble closely any of the fossil forms figured in Jones' Monograph of fossil Estheriæ. The markings, however, present some resemblances to *E. middendorfii* Jones, but differs in the want of anastomosing cross-wrinkles between the ridges.

One valve and portions of others were preserved; but none of them show the breaks (umbones), though the form of the remainder of the shell indicates that they were situated nearer the middle of the valve than usual, *i. e.*, between the middle and the anterior third of the shell. The shell is deep, probably more so than in *E. jonesii*, though the valves have evidently been flattened and somewhat distorted by pressure, but apparently the head-end was more truncated than in *E. jonesii*, as the edge of the shell and the parallel lines (or ridges) of growth along the head-end are below bent at right angles to the lower edge of the shell. The raised lines of growth are very numerous and near together; they are of nearly the same distance apart above near the beaks as on the lower edge. The very numerous lines of growth are thrown up into high sharp ridges, the edges of which are often rough, finely granulated, and often the valleys between are rugose on the surface. In one or two places a row of papillæ for the insertion of spinules may be seen where the shell has been well preserved, and between many of the lines of growth there are irregular superficial ridges. Length 10^{mm}; depth 7.5^{mm}.

The valve is evidently that of an Estheria, much truncated anteriorly, and with the lines of growth much thicker, higher, and closer together than in any North American species known to us, and may prove, when better specimens are found, to be allied to the Tertiary Siberian *E. middendorfii*.

The species is named in honor of the discoverer, J. W. Dawson, LL. D., who has so persistently and ably investigated the Leda clays of Canada.

It should be observed that fig. 4 is not a particularly good representation of the fossil.

A point of a good deal of interest in connection with this Quaternary species is that at present no species of Estheria is known to be peculiar to the Atlantic province. *Estheria mexicana*, however, ranges as far east as Ohio, but this is not at all related to *E. dawsoni*. The question arises where did the latter Quaternary species come from. It is not an Arctic form, for no species of the genus is known to inhabit the circumpolar region. It would seem as if it had been a Quaternary survivor through the glacial period of a southern or Tertiary species.

Geological Succession.—The following table gives a view of the geological succession of the fossil Phyllopoda; it is compiled from the works of T. R. Jones and Gerstaecker, with the additions made, (1878–'81,) since the publication of those works.

Quaternary	*Estheria dawsoni* Packard	Leda clay, Canada.
Tertiary?	*Estheria middendorfii* Jones	Siberia.
Eocene Tertiary	*Branchipus*	Fresh-water limestone, Isle of Wight.*
Mesozoic?	*Estheria forbesii* Jones	South America.
Wealden	*Estheria elliptica* Dunker	Germany.
	Estheria elliptica var. *subquadrata*	Sussex, England.
Oolite	*Estheria concentrica* (Bean)	Yorkshire, England.
	Estheria murchisoniæ Jones	Skye, Scotland.

*Proceedings Geological Society of London, 1878. Abstract in Annals and Mag. Nat. Hist., 5th ser., i, p. 99, 1878.

Triassic	*Estheria ovata* (Lea) *Estheria mangaliensis* Jones	United States, Pennsylvania, Virginia, North Carolina. India.
Rhætic	*Estheria minuta* (Alberti) var. *brodieana*	England.
Rhætic or Jurassic	*Estheria kotahensis* Jones	India.
Keuper	*Estheria minuta* (Alberti)	Hanover, Germany, England.
Keuper Lettenkohle Bunter	*Estheria minuta* and "*Apus*"	France, Germany.
Permian	*Estheria exigua* Eichwald *Estheria portlockii* Jones *Estheria tenella* Jordan	Russia. Ireland. Saxony.
Upper Carboniferous Middle Carboniferous Lower Carboniferous	*Leaia leidyi* (Lea) var. *williamsoniana* Jones *Estheria tenella* (Jordan) *Estheria beinertiana* Jones *Estheria striata* (Münster) *Estheria striata* (Münster) var. *tateana* *Estheria striata* var. *beinertiana* *Estheria striata* var. *binneyana* *Leaia leidyi* *Leaia leidyi* var. *salteriana*	England. France, England, Germany. England. Bavaria, Belgium. England. Silesia, England, Scotland. England. Pennsylvania. Scotland.
Devonian	*Estheria membranacea* Pacht	Livonia and Scotland.

It appears from the foregoing table that the oldest Phyllopod crustacean is a genuine Estheria,* judging, of course, from the carapace valves alone; the more or less problematical form, *Leaia*, being carboniferous. Thus Estheria dates from the Devonian.

As to the ancestral forms of Phyllopods in general, they may have been derived from forms like the Cladocera. *Limnetis* indicates in its resemblance to Daphnia, that from this Branchiopod with its cladocerous allies the Phyllopods may have sprung. Next below the Branchiopods stand the Copepoda from which all the other Neocarida have sprung; the Copepoda all originating from a nauplius ancestor. The Ostracoda, the lowest suborder of Branchiopoda, flourished in the Lower Silurian seas, hence the Branchiopoda must have originated in the Laurentian period and the Phyllopod suborder at least as early as the Upper Silurian period.

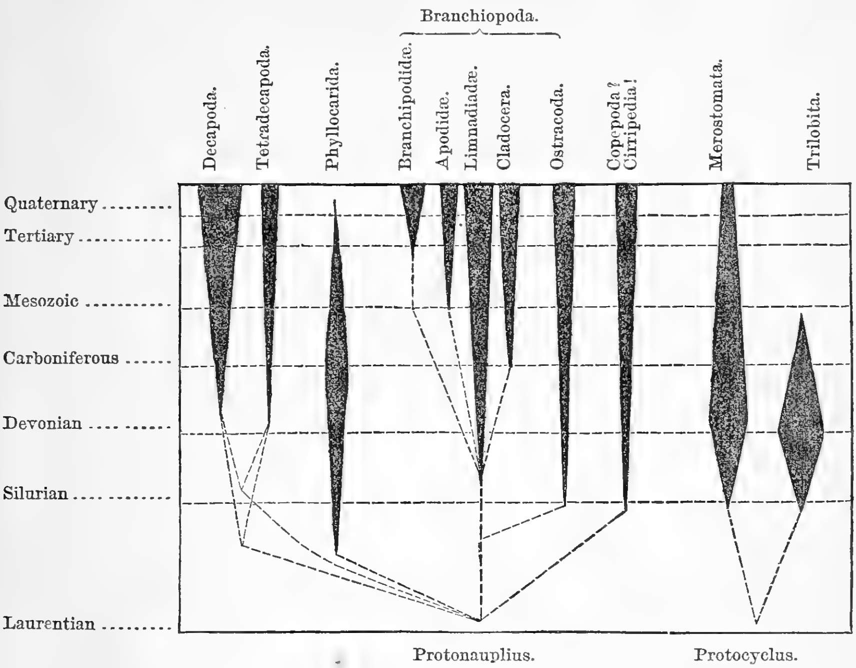
The accompanying table may serve to give a rude idea of the relations of the principal groups of the Crustacea, and their appearance in geological history, so far as the extremely scanty data we possess will allow, while the diagram may also serve as a genealogical tree, showing the probable origin of the main divisions of the Crustacea.

As is well known, the Trilobites are met with in comparative abundance in the lowest fossiliferous beds of the Silurian period, and they are the most ancient of Crustaceans, so far as their remains give evidence. The genera Conocephalites, Dicellocephalus, Paradoxides, and Agnostus, besides other forms, appear in the Potsdam sandstone or equivalent primordial rocks of this and other countries. The type disappeared during the Carboniferous period, the genera Phillipsia (one

*As there exists some doubts in my mind as to the Estherian nature of *E. palex* Clark, I have left this out of present consideration.

species is Permian), Griffithides, and Brachymetopus being the sole representatives of the type which prevailed so extensively during the Silurian.

Geological succession of the Crustacea.



Simultaneously with the appearance of the larva-like Agnostus, and the more highly organized Paradoxides, &c., we find in the Lingula flags the remains of a species of *Phyllocarida*, the *Hymenocaris vermicauda*. Mr. J. W. Salter, who was the first author to draw attention to the close relation of the fossil-genera Hymenocaris, Ceratiocaris, Peltocaris, Dictyocaris, &c., to Nebalia, has given us a series of sketches showing graphically the geological succession of this group and the Estheriadæ. Hymenocaris, which Salter regards as "the more generalized" type, lived during the primordial period; Peltocaris and Discinocaris (Woodward) characterize the Lower Silurian period; Ceratiocaris the upper; Dyctyocaris the Upper Silurian and lowest Devonian; Dithyrocaris and Argus the Carboniferous. No Mesozoic member of the family has yet been discovered, but as there are several species of Nebalia now living in our seas, it is reasonable to suppose that the type has existed in an unbroken succession from primordial times until now. The Palæozoic species were gigantic in size, some being about a foot or more (the carapace of *Dithyrocaris pholadomya* Salter being seven inches long) in length, while our recent Nebalia is less than an inch in length.

The Potsdam sandstone also contains the remains of a third grand division of Entomostraca, the Ostracoda; remains of Leperditia having been found in Canada, as well as the Lower Silurian of Europe.

No fossil Copepoda have yet been discovered, but we should scarcely wonder at this, owing to their soft bodies. Gerstaecker (Bronn's

"Classen und Ordnungen der Thierreichs") suggests that the Lernæans might have infested Palæozoic fish, and on general grounds we should think that they probably extended as far back as the primordial zone, inasmuch as highly developed Trilobites and Ostracodes appear there. Another argument is the interesting discovery made in 1865, by Mr. Woodward, of the Cirripede *Turrilepas Wrightii* from the Wenlock limestone and Dudley shale of the Upper Silurian formation. Previous to this, according to Woodward, "the oldest known Cirripede was the *Pollicipes rhœticus* from the Rhœtic beds of Somersetshire"; while the type is not uncommon in the Cretaceous, and has flourished from that period to the present.

Of the Merostomata the oldest group is the Eurypterida, the Xiphosura not dating beyond the Lower Carboniferous. The Eurypterids have not been found below the Upper Silurian (Lower Helderberg in America), and the aberrant forms Hemiaspis, Bunoödes, Pseudoniscus, and Exapinurus are Upper Silurian forms. Among the Xiphosura, Cyclus, the lowest form, is found in the Carboniferous, and ranges, according to Woodward, as far up as the Permian. In the same period occur Bellinurus, Prestwichia, and Euproöps, being in this country found in the lower part of the true Coal-measures, and associated in the same beds with Ceratiocaris, Eurypterus (Anthraconectes and certain Isopoda and Macrurous Decapoda (Anthrapalæmon). The genus Limulus first appears in the Jurassic, and the species differ but slightly from those now living.

The more typical Phyllopoda made their appearance during the Triassic period. The lowest group, however, the Estheriadæ, appeared during the Devonian, a species referred to Estheria being found in that formation in Europe. The Cladocera are not known to have existed previous to the Tertiary period, and it was not until recently (1862) that Von Hayden discovered the ephippium of a Daphnia in the Rheinish brown coal (Gerstaecker, in Bronn's Klassen und Ordnungen, &c.), said by Lyell to be of Eocene age. It should be noticed, however, that the fossil belongs next to Sida, the most highly organized genus of the group, and as it is not unlikely that such pelagic forms as Evadne may have existed in the Mesozoic seas, if not earlier, I have ventured to run the point of the wedge into the Carboniferous period.

The Apodidæ date back to the early part of the Mesozoic, a Triassic species of Apus having been found in Europe, according to Mr. Salter.

III.—GEOGRAPHICAL DISTRIBUTION.

(With a map.)

The materials for the thorough study of the geographical distribution of the Phyllopod Crustacea of North America, as indeed of any other of the continents, perhaps not excepting Europeo-Asia, are quite scanty. The exceptional habits of the members of this suborder, their usual rarity or periodical occurrence, and their very local distribution, have caused them to escape the observation of most collectors, and to be found more by accident than as the result of well-matured plans of search.

The salient points in the distribution over the globe of the Phyllopods are as follows; although the conclusions here presented are, of course, provisional, and much yet remains to be discovered as to the distribution of these interesting forms.

It will be seen by reference to the lists presented in the following pages that a large proportion of our North America Phyllopoda, including nearly all the species of *Estheria*, are restricted to the elevated dry central zoögeographical province of the United States, and adjacent portions of Arctic America, and of Northern Mexico, a region exposed to great summer heats, winter cold, to long droughts, sudden rainbursts, and other meteorological extremes. And it is interesting to notice that the larger proportion of the Old-world forms are likewise restricted to Eastern and Southern Europe, to the Mediterranean region, and to Central and Northern Asia, *i. e*, to Mr. Sclater's "Palæ-arctic Region." The Western European species are few in number, as in the Eastern United States. In Africa the Phyllopods are restricted to the northern portions of the continent, which are more or less elevated, dry, and arid, as Algeria, Egypt, and Abyssinia, or to the Cape of Good Hope (Capeland), while but a few, and those species of *Estheria*, have been brought from the "Oriental Region" in Asia, and few from the Æthiopian Region" in Africa. *Apus himalayanus*, described by us from the Himalaya Mountains, is evidently a member of the Central Asiatic or Manchurian province, and not of the Indian region, while *A. dukianus* is reported from Afghanistan.

Of purely tropical forms there are two species of *Apus*, one living in St. Domingo, another in the island of St. Vincent, while a species of *Eulimnadia* exists in St. Domingo, and a species of *Estheria* flourishes in Cuba. The Mexican forms are plateau species, while none have yet been described from Central America. Two species of *Estheria* have been described from South America.

The map accompanying this memoirl represents the principal faunal divisions of North America, with the isothermal lines of 32°, 40°, 60°, and 72°. The American continent is divided into—

1. The Arctic Realm and its Alpine outliers.
2. Boreal province and its Alleghanian outliers.
3. The Atlantic or Eastern province.
4. The Central province.
5. The Western or Californian province.
6. The Antillean region.

There are no species from the Central American province.

THE AMERICAN ARCTIC PROVINCE.

This is a more or less natural subdivision of the Arctic or Circumpolar Realm, which includes the coast of Labrador, the northern shores of Hudson's Bay, and the Arctic coast of North America, north of the sothermal of 32° around to Bering's Strait and Greenland. We reject the term "Nearctic" proposed by Mr. P. L. Sclater, and adopted by Mr. A. R. Wallace, for America north of Central America, for the reason that it seems to us an unnatural and artificial term. The fauna is essentially American north temperate, while the Arctic regions of America and Europe-Asia form a realm by itself, of much less importance, it is true, than the north temperate realm (American and Europæo-Asiatic regions), when we consider the land plants and animals, but of nearly as much importance as regards marine life. To apply the term *Nearctic* to so vast a region as the American involves the idea that the region covers an area essentially arctic in its features. It is to be hoped that the term will not be adopted by American writers, as it is not by German and French writers, and we heartily indorse Mr. J. A. Allen's protest against the use of the term by American writers on this subject. The circumpolar or Arctic realm is a realm by itself, limited by the low degree of temperature and mainly bounded by the isothermal of 32°, and the adoption of this term will conduce, it appears to us, to clearer and more concise ideas of the geographical distribution of life on our continent.*

The following two species of Phyllopods characterize this realm: *Lepidurus glacialis*, Arctic America, Lapland, Nova Zembla, Spitzbergen, Beeren Island; and *Branchinecta paludosa*. Neither of these are confined to the American continent (being found at Cape Krusenstein) and Greenland, as they occur in Arctic Europe and Asia. These two species occur not only in Greenland and Arctic America, but also in Swedish Lapland at an elevation of 2,000 feet; *Branchinecta paludosa* occurs in Finmark near the North Cape and in Russian Lapland, and Middendorf found it (var. *middendorfianus*) in Asiatic Siberia.

THE ATLANTIC OR EASTERN PROVINCE.

This region includes the area bounded on the north by the isothermal of 40°, including the northern shore of the Saint Lawrence west of Quebec, the Great Lake region, except the northern shores of Lake Superior, and the United States east of the ninety-seventh meridian.

The following species inhabit this province:

Limnetis gouldii.
(*Limnadella coriacea.*)
Limnadia americana.
Streptocephalus sealii.
floridanus.
Estheria mexicana.
Eulimnadia agassizii.
Branchipus vernalis.
serratus.
Chirocephalus holmani.

THE CENTRAL PROVINCE.

This province lies between the Atlantic and the Californian, extending northward into British America to the limits of trees near latitude 55°; and southward along the Mexican plateau as indicated on the map. The Rocky Mountains oppose no continuous barrier to the distribution of the species; and it includes the southern extremity of the Californian peninsula. We reproduce from the *American Naturalist* for August, 1878, the leading characteristics of this Central province.

The first attempt to divide the United States as a whole into zoölogical provinces was in 1859, by Dr. Le Conte, in his "Coleoptera of Kansas and Eastern New Mexico (Smithsonian Contributions, 1859)." He divided the Coleopterous fauna of the United States into three great zoölogical districts, distinguished each by numerous peculiar genera and species, which, with but few exceptions, do not extend into the contiguous districts. He named them the Eastern, Central, and Western divisions;

*In our "Observations on the Glacial Phenomena of Labrador and Maine," etc., Mem. Bost. Soc. Nat. Hist., 1866, p. 254, we thus referred to this fauna, speaking especially of the marine animals:

"The arctic or circumpolar fauna is restricted to a district north of the yearly isothermal line of 32°, which thus includes the Arctic American archipelago, Northern Greenland, Spitzbergen, Nova Zembla, and the coast of Siberia. This is a true *circumpolar* fauna, and can scarcely be said to be Asiatic, European, or American, though members of the group extend in diminished numbers and size down on the Asiatic coast to Japan, as we are informed by Dr. W. Stimpson, and by P. P. Carpenter in the Report of the British Association for 1856; on the European coast as far as the Mediterranean Sea, and on the eastern American coast as far as New Jersey, where the polar currents give, at great depths, the necessary amount of cold for their existence."

Compare also our monograph of Geometrid Moths, or Phalænidæ, of the United States, pp. 567, 586, 1876. Our classification of the American fauna is adopted with slight modifications from Mr. J. A. Allen's writings on the Mammals and Winter Birds of Florida, etc., Bull. Mus. Comp. Zoöl. ii, 3, 1871, Bull. Hayden's U. S. Geol. Survey, 1878, p. 529.

so that to him is due the credit of first distinguishing the Central province.

In 1866, Professor Baird,[1] from a study of the avifauna of the United States, concluded that "the ornithological provinces of North America consist of two great divisions of nearly equal size in the United States, meeting in the vicinity of the one hundredth meridian, the western half divisible again into two, more closely related to each other than to the eastern, though each has special characters. These three sections form three great provinces to be known as the western, middle, and eastern; or those of the Pacific slope; of the great basin, the Rocky Mountains and the adjacent plains; and of the fertile plains and region generally, east of the Missouri."

In 1871, Mr. J. A. Allen[2] divided the avifauna of the United States into two provinces, the eastern and western, the latter embracing the Pacific coast. Mr. Allen afterwards adopted Professor Baird's division into three provinces. (The geographical distribution of the mammalia, etc. Bulletin of Hayden's U. S. Geographical and Geological Survey of the Territories, May 3, 1878.)

In 1873,[3] Mr. W. G. Binney published a map of the distribution of our land shells, dividing the molluscan fauna into the Eastern, Central, and Pacific provinces.

In 1875, Prof. E. D. Cope, in his check-list of North American Batrachia and Reptilia,[4] divided the Nearctic realm of Sclater into the Austroriparian, Eastern, Central, Pacific, Sonoran, and Lower Californian regions. He remarks that "the Pacific region is nearly related to the Central, and, as it consists of only the narrow district west of the Sierra Nevada, might be regarded as a subdivision of it. It, however, lacks the mammalian genera *Bos* and *Antilocapra*, and possesses certain peculiar genera of birds, as *Geococcyx*, *Chamæa*, and *Oreortyx*. . . . There are some genera of reptiles, *e. g. Charina*, related to the Boas, *Lodia*, *Aniella*, *Gerrhonotus*, and *Xantusia*, which do not occur in the central subregion. There are three characteristic genera of Batrachia, all Salamanders, viz: *Anaides*, *Batrachoseps*, and *Dicamptodon;* while the eastern genera *Plethodon* and *Diemyctylus* reappear after skipping the entire central district." Cope adds that "the fresh-water fish fauna is much like that of the central district in being poor in types." Cope's Sonoran region is evidently a northward extension of the Central American fauna, which sends its outliers into Southern Arizona, Utah, and New Mexico, and is not to be taken into account in discussing the faunal provinces of the United States alone.

In 1876, Wallace, in his "Geographical Distribution of Animals," divided the Nearctic region into four subregions, viz: the Californian, Central or Rocky Mountain, Alleghanian, and Canadian. His Central subregion extended to lat. 25° N.

It will be seen from this review that by general consent the fauna of the Pacific slope is on the whole regarded as belonging to a separate province from that of the Rocky Mountain plateau, whether we regard the mammals, birds, reptiles, amphibians, Coleoptera, or land shells.

Botanically, as observed by those who have traveled across the plains to California, the flora of the great plains is quite different from that of the Eastern States, and the Pacific flora is as distinct from the central flora. This has been clearly shown by Sir J. D. Hooker and Prof. Asa

[1] American Journal of Science and Arts, January and March, 1866.
[2] Bulletin of the Museum of Comp. Zoology, April, 1871.
[3] Catalogue of the Terrestrial Molluscs of North America. Bull. Mus. Comp. Zool., 1873.
[4] Bulletin U. S. Nat. Mus., Washington, 1875.

Gray in their preliminary notices of the results of their botanical researches in connection with Dr. Hayden's U. S. Geological Survey of the Territories.

In traveling in the summer of 1877, in pursuance of the work of the United States Entomological Commission, I passed rapidly over a large area of the Central province lying north of the fortieth parallel, including Colorado, Wyoming, Northern Utah, Western Idaho, Central and Northern Montana, and was thus enabled to observe in a superficial way the general features of the flora and fauna nearly up to the British line. I was impressed with the resemblance of Central and Northern Montana to Northern Utah, the insect-fauna being apparently nearly identical. Doubtless this insect-fauna extends northwards into the Upper Saskatchewan valley as far as the southern limit of trees, there being much less intermixture with Canadian forms than might be expected. Then crossing the Sierra Nevada, and going overland to Oregon, I was able to trace the gradual passage of the Californian insect-fauna into the Oregonian, with some Canadian forms; and by passing up the Columbia River to Wallula, here as well as at Reno in Nevada, to perceive the great differences between the fauna of the Pacific slope and that of the plains and deserts of the Central province.

In briefly reviewing the different orders of insects, other than Coleoptera, which have been so fully elaborated by Dr. Le Conte, and certain groups of Crustacea, we will begin with the *Hymenoptera*, and point out a few characteristics distinguishing the Central from the Pacific provinces. In 1865 and 1866 a large number of Coloradian fossorial Hymenoptera passed under the writer's hands, Mr. Cresson having previously described from this material a large number of Coloradian Hymenoptera of all families. The richness of the hymenopterous fauna of Colorado struck me, and I was impressed with its distinctness from that of the Eastern States. I have seen few of these from California. Among the family of ants (*Formicidæ*), there was one form characteristic of the plains which does not occur on the Pacific slope. This is the *Pogonomyrmex occidentalis* (Cress.). I have seen its large hills at Brookville, Kans., and observed them in Colorado and Utah, and in Reno, at the base of the Sierra Nevada, but not west of that point. It ranges, according to Mayer, south into New Mexico, and San Luis Valley, Colorado. Its nest, forming large elevations in cleared spaces sometimes six or eight feet in diameter, is one of the characteristic sights on the plains.

Among the *Lepidoptera*, family *Bombycidæ*, there are several forms peculiar to the central district, notably the genus *Dirphia* (Coloradia), *Euleucophæus*, *Gloveria* (*Mesistesoma*), *Hemileuca*, *Juno*, and *Hera*, and *Platysamia gloverii*. The family is feebly represented in the Central province, but richly so by numerous species on the Pacific slope, which do not appear east of the Sierra Nevada.

The *Phalænidæ*, or geometric moths, are richly developed in the Pacific province, and but poorly in the Central province, owing to the absence of deciduous trees; of those found in the latter some occur west of the Sierra Nevada, and some are peculiar to the plains and Rocky Mountains.

Of the *Orthoptera* there is a large number of species peculiar to the plains which I did not observe in the Pacific States; of these, *Caloptenus spretus* is thoroughly characteristic of the Central province. It does not occur in the Pacific and only breeds temporarily in the Eastern province, and its natural limits define well those of the province itself. It ranges up to latitude 53° N. on the North Saskatchewan and south to Southern Utah and Colorado. The exact limits of its distribution are given in the First Annual Report of the United States Entomological Commission.

While we are still quite ignorant of the distribution of insect life between the hundredth meridian and the Pacific Ocean, there seems good reason, from what little we do know, and from the great differences in the flora, and the soil and climate, especially the rainfall east and west of the Sierra Nevada, to regard this lofty range as the general point of separation defining two grand zoological provinces. Many groups of insects abounding west of the mountains do not occur east, except in isolated cases. Of a number of Myriopods found on the Pacific coast none occur east, and so of the Arachnida so far as known, and Dr. Thorell, who has worked up some of the spiders of Colorado, was struck by the general similarity of some forms to those occurring in the plateau of Northeastern Asia. Among the insects there are a few Pacific forms which closely resemble European species, and which are not represented east of the Sierra Nevada. It should be borne in mind, however, that the Sierra Nevada does not present an absolute barrier, as a considerable number of species occur on each side of it, and it is well known that the Rocky Mountains are but a slight barrier to the distribution of the animals on either side, the fauna of Colorado, Northern Utah, Wyoming, Montana, and Idaho being quite homogeneous, and the fauna of these Territories the same on each side of the high mountain ranges traversing them.

Among the fresh-water Crustacea the *Astaci* of the Pacific slope, as is well known, belong to the European genus *Astacus*, those east of the Sierra Nevada to the genus *Cambarus*, which is so richly developed in the eastern provinces, especially in the Mississippi Valley.

The distribution of the fresh-water *Phyllopoda* is of peculiar interest. The family *Apodidæ* is restricted to the Central province; none are found in the Mississippi Valley, and none in California. Of the four species of *Apus* all inhabit the Central province; *Apus æqualis* lives on the plains of the Rocky Mountains, and also at Matamoras, in Mexico. It is a curious fact that *Apus lucasanus* Pack. not only occurs at Cape Saint Lucas, Lower California, but is also an abundant species at Ellis, Kansas. This is a parallel case to the presence of certain birds at Cape Saint Lucas which, as observed by Professor Baird, belong to the Central rather than to the Pacific province. Of the genus *Lepidurus* there are two forms (*L. couesii* and *L. bilobatus*) characterizing the plains. *L. couesii* occurs in Northern Montana and in Utah, and is allied to the recently described *Lepidurus macrourus* from Archangel, Russia, according to Lilljeborg.

The eastern limits of the Central province extend to near the 97th meridian in Kansas and Nebraska, according to the writer's observations. The following species inhabit this province:

Limnetis mucronata.
brevifrons.
gracilicornis.
Estheria complex imanus
mexicana.
belfragei.
morsei.
Eulimnadia texana.
Lepidurus couesii.
Lepidurus bilobatus.
Apus newberryi.
æqualis.
lucasanus.
longicaudatus.
Branchinecta coloradensis.
lindahli.
Streptocephalus texanus.
Thamnocephalus platyurus.

THE CALIFORNIAN OR PACIFIC PROVINCE.

But one species, *Estheria californica*, (unless *E. newcombii* be regarded as distinct) inhabits this area, which is separated by the Cascade Mountains and the Sierra Nevada from the Central province, and extends from 52° north southward to San Diego.

No species is as yet known from Central America; and the two Mexican forms occur in elevated regions in Northern Mexico, and are not peculiar to Mexico, being characteristic of the Central province of the United States.

THE ANTILLEAN PROVINCE.

The species inhabiting the West Indies are comprised in the following brief list:

Estheria jonesii.
Eulimnadia antillarum.
Apus domingensis.
Apus guildingii.
Artemia guildingii.
Streptocephalus similis.

SPECIES COMMON TO THE ATLANTIC AND CENTRAL PROVINCES.

Estheria mexicana ranges from Ohio to Lake Winnepeg, northward, and westward to Western Colorado, and into Northern Mexico.

Artemia gracilis ranges from Salem, Mass., to Mono Lake, in California, but the life-conditions of this brine-inhabiting genus are so exceptional that we have not mentioned it in the foregoing lists. Our only truly Alpine form is *Branchinecta coloradensis*, found at an elevation of 12,000 feet in Colorado.

SPECIES INHABITING SOUTH AMERICA (*Brazilian Region*).

Estheria brasiliensis Baird. Brazil.
Estheria dallasii Baird? Brazil.

SPECIES INHABITING THE EUROPÆO-ASIATIC REGION.

a.—The European Province.

1. Western Europe.

Limnetis brachyurus. Germany.
Estheria cycladoides. Toulouse.
Limnadia hermanni. France and Germany.
gigas. Central and Northern Europe.
tetracera. Germany.
*Branchipus stagnalis.** England and Central Europe.
grubei. Central Europe.
Artemia salina. England and Europe.
Chirocephalus diaphanus. England, France, Switzerland.
Lepidurus productus. England and Central Europe.
Apus cancriformis. Central Europe.
grubei. Germany.
lubbockii. Germany.

* *Branchipus lacunæ* Guérin, Baird, Grube; and *B. braueri* Frauenfeld, are regarded by Lilljeborg (Nov. Acta Upsala (3), ix, A, p. 3) as synonyms of *B. stagnalis.*

2. Eastern Europe (Russia, &c.).

Limnetis brachyura.
Limnadia tetracera. Charkow.
Esthèria pestensis. Pesth.
Branchinecta ferox. Odessa.
claviger Nordmann. Odessa.
Branchipus birostratus. Charkow.
braueri Frauenfeld. Parndorper Heide.
Chirocephalus carnuntanus Brauer. " "
Streptocephalus torvicornis. Warsaw.
Artemia salina, vars. *mülhausenii.*
arietina.
köppeniana.

b. The Mediterranean Province (including Northern Africa).

Estheria dahalacensis. Abyssinia.
donaciformis. Korkofan.
gubernator. Cairo.
hierosolymitana. Jerusalem.
gihoni. Jerusalem.
lofti. Bagdad.
♀ *cycladoides.* Algeria.
melitensis Baird.
ticinensis. Italy (Lombardy).
Apus numidicus. Algeria.
cancriformis. Italy, Algeria, and Constantinople.
Branchipus eximius. Jerusalem.
Chirocephalus recticornis Brauer. Tunis.
rubricaudatus Kosseir.
oudneyi. Fezzan.
Branchinecta ferus Brauer. Jerusalem.
Artemia sp. Egypt.
Chirocephalus bairdii Brauer. Jerusalem.

c. Siberian.

Limnetis brachyura. Archangel.
Polyartemia forcipata. Northern Sweden, Lapland, Taimyr, and Siberia.
Branchinecta paludosa (*Middendorfianus*). Siberia and Lapland.
Chirocephalus claviger (Fischer). Taimyr, Siberia.
Lepidurus macrourus Lilljeborg. Archangel.

d. Manchurian.

Apus dukii Day. Afghanistan.
Apus himalayanus. (North India.)
Apus numidicus Dauria. Baikal Sea.
Apus sp.*

* *Apus* sp. in Tibetan Salt Lakes. Schlagintweit, Reisen in Hochasien ii, 218, 1872.

SPECIES INHABITING THE INDO-AFRICAN REALM.

a. African Region. (Central Africa, White Nile; South Africa, Cape of Good Hope.)

Limnetis wahlbergi. Port Natal.
Limnadia africana Brauer. White Nile.
Estheria rubidgei. Cape of Good Hope.
macgillivrayi. Cape of Good Hope.
australis. Caffer-land.
Apus dispar Brauer. White Nile.
sudanicus Brauer. Chartum.
Branchipus abiadi Brauer. White Nile.
Streptocephalus cafer. Port Natal.
vitreus Brauer. White Nile.
proboscidens Frauenfeld. Chartum.

b. Indian Region.

Estheria compressa. India.
hislopi. India.
polita. India.
boysii. India.
similis. India.
Branchipus dichotomus. India.
Apus granarius. Peking.

SPECIES INHABITING THE AUSTRALIAN REALM.

Limnetis maclayana. Australia.
Limnadia stanleyana. Australia.
Apus viridis. Tasmania.
angasii. Australia.
Apus sp. New Zealand.
Lepidurus kirki Thompson. New Zealand.
compressus Thompson. New Zealand.

From these data it appears that but a single genus is peculiar to North America, *i. e.*, *Thamnocephalus*; while *Polyartemia* is peculiar to the Europæo-Asiatic Region; all the other genera occur in nearly all of the continental masses of the globe, though no *Branchipodidæ* occur in Australia, and no *Limnadia* has yet been found in Asia. This cosmopolitan distribution of the Phyllopoda (the *Branchipodidæ*, the highest family, being excepted) points towards the high antiquity of this group of fresh-water crustacea. The distribution through zones across continents, noticed by Gerstaecker, appears not to be exceptional to that of other classes. We have noticed it in Geometrid moths, and also in mammals, the central portion of Asia repeating the characteristics of Central North America.

IV.—MORPHOLOGY AND ANATOMY.

A transverse section of the anterior part of the body of any genus of Phyllopods will convey an excellent idea of the leading features in their organization, especially those by which they differ from the members of other Crustacean orders. The leading topographical features in the body, particularly of Arthropods, are the form of the elemental segments with their appendages, and the relations of the principal anatomical systems to the body walls.

General relations of the systems of organs to the body-walls.—We will first look at sections of representatives of the three families of Phyllopods; *i. e.*, an *Estheria* (Plate XXIV, figs. 9, 10), *Apus*, Plate XXXII, fig. 2 (see also fig. 25 in text), and a Branchiopod, such as *Thamnocephalus* (Plate

XIV, fig. 4). The body-walls are rather thick and the muscles are well developed, particularly the dorsal extensor muscles, and the motor or extensor muscles of the limbs, which arise in part from the dorsal region, and in part from the sides and sternal region. The body cavity is rather small. The heart is large, either cylindrical as in Estheria, or flattened as in *Thamnocephalus*. The digestive tract is large, capacious, and the cavity of the head is mainly filled with the two liver masses; the brain being remarkably small, while the nervous cord, especially the brain and succeeding ganglia, are remarkably small and weak, compared with other Crustacea, either the malacostracous or the entomostracous orders; this peculiarity is well brought out in the transverse sections, where the diminutive size of the thoracic ganglia, particularly in *Estheria* (Plate XXIV, figs. 9 *n*, 9), is noteworthy. The apparent bulk of the body is largely due to the large size and nature of the leaf-like or foliaceous appendages, with their broad attachments; the latter peculiarity is characteristic of the Branchiopods in general and the Phyllopods especially, and is quite different from the definite, small coxal articulations of the legs of Malacostraca or Copepoda. The ovaries or testes, according to the sex, form a large lobulated mass extending along each side of the digestive canal, as far forward as the base of the head. Their relations in *Apus* are seen in Plate XXXII, fig. 2, and in *Thamnocephalus* in Plate XIV, fig. 4.

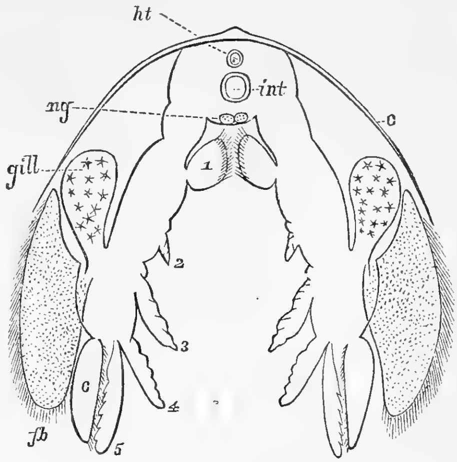


FIG. 25.—Section of Apus. *ht*, heart; *int*, intestine; *ng*, ganglion; *c*, carapace; 1–6, the six exites, 1 being the gnathobase; *gill* and *fb*, flabellum, representing the exites.

Nomenclature of the body-regions and appendages.—As the terms "head," "thorax," and "abdomen" are more or less inexact when used for Arthropoda as compared with the worms and molluscs, as well as vertebrates, there should be suitable designations for these regions.

In 1869, in our Guide to the Study of Insects, we proposed the term *arthromere* for the segment or ring forming the primary element in the composition of the body of any jointed or articulated animal. The terms "zoönule," "zoönite," "zonite," and "somite," have been used by various authors, but these terms have been used rather indiscriminately, and we therefore suggested the term *arthromere* for the body segments of articulated animals (worms and arthropoda). While the term "somite" or "zonite" may be properly applied to the rings of worms and other animals as the Chitons, we would suggest that the term *arthromere* be restricted to the segments, or body-elements of *Arthropoda*.

For the three primary regions of the head the only scientific terms as yet in use are those proposed by Prof. J. O. Westwood in Bate and Westwood's History of British Sessile-eyed Crustacea (vol. 1, p. 3). These are *cephalon* for the head, *pereion* for the thorax, and *pleon* for the abdomen; while the thoracic feet are termed *pereiopoda* and the abdominal legs *pleopoda;* the three terminal pairs being called *uropoda*.

As the names applied to the thorax and abdomen have no especial morphological significance, the Greek περαιον, simply meaning ulterior, and πλεον, more, we would suggest that the head of Arthropoda be termed the *Cephalosome*, the cephalic segments *cephalomeres*, and the cephalic appendages in general *protopoda*, the term "cephalopoda" being otherwise in use. The thorax of insects and of most of the crustacea might be designated the *Bænosome* (βαινο, to walk, locomotion), and the thoracic appendages *Bænopoda*, the segments being called *bænomeres;* while *Urosome* might be applied to the *abdomen*, the abdominal segments being called *uromeres.* Westwood's term *uropoda* might be extended so as to include all the abdominal appendages. The term *gonopoda* we have suggested for the external organs of the Decapods concerned in reproduction, which are simply modified *uropoda.* The long, slender, antenna-like anal appendages of the cockroach, mantis, &c., corresponding to the anal cerci of Acrydii, may be designated as *cercopoda*, and this term might be applied to the terminal pair of uropoda of the Phyllopods, *i. e.*, the jointed, slender, spinulose appendages of *Apodidæ*, or the unjointed appendages of the *Branchipodidæ.*

The segments of the body.—The Phyllopoda are exceptional to other Crustacea in having an indefinite number of segments composing the body, and in having in one family (*Apodidæ*) more than one pair of appendages to an arthromere. While the normal number in the Decapoda is 20, in the Phyllopods it varies from 14 in Limnetis to 47 in Apus. The following table shows the number in different genera of American species:

	Antennal segments.	Mandibles.	Maxillæ.	Maxillipedes.	Limb-segments.	Abdominal segments.	Telson.	Total.
Limnetis	2	1	1	......	12 (-14)	0	1	17-19
Estheria	2	1	2	......	23-27	0	1	29-33
Limnadia	2	1	2	......	1 22	0	1	28
Apus	*2	1	1	†1	27 (60 pairs limbs).	32 (14)	1	47
Artemia	2	1	2	0	11	8	1	25
Branchinecta	2	1	2	0	11	9	1	26
Branchipus	2	1	2	0	11	9	1	26

* Second antennæ sometimes wanting. † The endite wanting in the American species of *Apus.*

In an *Apus lucasanus* 42 millimeters in length there are 60 pairs of legs behind the maxillipedes. There are 42 segments behind the maxillipedal segment, including the telson, and 27 limb-bearing segments, or 60 pairs of legs to 27 segments, the average being $2\frac{6}{27}$ appendages to each leg-bearing segment. On the first eleven leg-bearing arthromeres, or the 10 thoracic (bænomeres) together with the first abdominal arthromere there is but a single pair of appendages to a segment, so that there are 49 pairs of abdominal appendages to 16 arthromeres, or $3\frac{1}{16}$ pairs of limbs on the average to each abdominal arthromere. The fourteenth, fifteenth, and sixteenth pairs are situated on two arthromeres, and so on with the succeeding until the limbs become more numerous. On the two arthromeres before the last leg-bearing one there are 12 pairs of appendages, or 6 to each arthromere.

This irrelative repetition of arthromeres is only paralleled in one other Branchiate group, the *Trilobita.* In this group the new segments are interpolated between the head and abdomen at successive moults, as shown by Barrande.

The grouping of the body segments into a cephalothorax and abdomen, comparable with those two regions in the Decapoda is but slightly, if at all, indicated in the Phyllopoda. In *Limnetis* there is no such distinction of regions, in Apus the cephalothorax merges insensibly into the abdomen, and it is not until we ascend to the Branchipodidæ that we meet with a well-marked abdomen separated by tolerably clear indications from the thorax.

THE APPENDAGES IN GENERAL.

The appendages of Crustacea may be divided into four groups: First, the sensory appendages, or antennæ, which are in the adult preoral; second, the organs of prehension of food and of mastication, *i. e.*, the mandibles and accessory jaws, or maxillæ and maxillipeds, which are postoral; third, organs of locomotion, whether natatorial or ambulatory, which are appended to the thoracic portion of the body; and, fourth, the appendages of the abdomen, which are both natatorial and concerned in reproduction; of the latter are the two pairs of gonopoda* in the Decapoda, while the eleventh pair of appendages in Apus may be regarded as gonopods.

Spangenberg has described the mode of origin of the intromittent organs, and has shown that they arise as two independent outgrowths from the under side of the twelfth and thirteenth segments in *Branchipus stagnalis*, but from his drawings they appear essentially to arise from the twelfth. Each process or finger-shaped lobe contains a cirrus or intromittent organ. These two appendages appear from Spangenberg's illustrations to be three-jointed. If so, we do not see why they should not be properly regarded as homologous with the eleventh pair of legs of male Apodidæ, in which, as stated by Gerstaecker, were found the male openings for the passage of the semen. We hence regard these organs as in general homologous with the gonopods of Decapoda, although the latter are solid and do not act as direct intromittent organs.

It is perhaps as probable, however, that the gonopods or double intromittent organ of the *Branchipodidæ* is homologous with the male organ of the Copepoda, which is a double eminence, on each of which is a genital pore. The female genital outlet is in the Copepoda also situated on the first segment of the abdomen, according to Claus.

Lankester has suggested, and it seems to us with good reason, that in order to arrive at true conclusions with regard to the homologies of the limbs of the Arthropoda we should "abandon altogether the use of such terms as 'antenna,' 'mandible,' and 'maxillipede' as homological categories, and to apply them merely as descriptive terms proper to the particular case under examination. In the consideration of homologies, the appendages should be regarded simply as first, second, third, and so forth, without the introduction of terms calculated by their reference to function to prejudice the argument as to homology. The first appendage of an Arthropod, A, may be homologous with (or homogenous with) the first appendage, or with the second or third of another Arthropod, B, and so on; but ambiguity is inevitably introduced if we attempt to indicate this homology by the use of such terms as antennule and antenna, to be applied in both cases alike, for in such cases as the parasitic Copepoda, the various Arachnida, and the living and fossil branchiate scorpions (*Merostomata*), these descriptive terms, and others like them, are found to be absolutely contrary to fact in their implications, and involve also debatable assumptions in reference to ancestral primitive forms."

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*I have (*American Naturalist*, xv, p. 881, 1881) applied the term *gonopoda* (Gr. γονή, generation; πους, ποδος, foot) to the first and second abdominal limbs of the Decapoda, which are, as is well known, modified into accessory generative organs. The term is suggested as a convenient one to use in descriptive carcinology when speaking of either or both pairs of the basal abdominal limbs of the male Decapod. In the female they are not modified.

With this view, with some restrictions, we would agree, and while believing that the use of the terms antenna, mandible, maxilla or maxillipede would be authorized within the limits of the same subclass, as the normal, neocaridan crustacea, or the *Merostomata* (which we certainly would not consider as branchiate scorpions), with the *Trilobita* (*Palæocarida*), or either of the three subclasses Tracheata or Insecta, *i. e.*, *Hexapoda*, *Arachnida*, and *Myriopoda;* the different pairs of appendages must receive different names in different subclasses. The following table will give our idea as to the nomenclature of the appendages in the three subclasses of Tracheata and the two subclasses of Branchiate Arthropods.

TABLE A.

Number of segments.	Hexapoda.	Arachnida.	Myriopoda.	Crustacea (neocarida decapoda).	Merostomata. (Limulus.)
1	Antennæ	Mandible	Antennæ	First antennæ	First (preoral) leg.
2	Mandibles	Maxilla (chela)	"Maxilla"	Second antennæ	Second (post-oral) leg.
3	First maxillæ	First thoracic leg.	"Mandible"	Mandibles	Third pair legs.
4	Second maxillæ (labium).	Second thoracic leg.	"Labium"	First maxillæ	Fourth pair legs.
5	First thoracic legs (bænopods).	Third thoracic leg.	First pair of legs	Second maxillæ	Fifth pair legs.
6	Second thoracic legs (bænopods).	Fourth thoracic leg.	Second pair of legs.	First maxillipedes	Sixth pair legs.
7	Third thoracic legs (bænopods).	Embryonic, deciduous.	Third pair of legs.	Second maxillipedes.	First abdominal legs.
8	First embryonic deciduous legs.*	....do	Fourth pair of legs	Third maxillipedes	Second abdominal legs.
9	Second embryonic deciduous legs.	....do	Fifth pair of legs	First pair of legs (bænopods).	Third abdominal legs.
10	Third embryonic deciduous legs.	....do	Sixth pair of legs	Second pair of legs (bænopods).	Fourth abdominal legs.
11	Fourth embryonic deciduous legs.	First pair spinnerets.	Seventh pair of legs.	Third pair of legs (bænopods).	Fifth abdominal legs.
12	Fifth embryonic deciduous legs.	Second pair spinnerets.	Eighth pair of legs	Fourth pair of legs (bænopods).	Sixth pair abdominal legs.
13	Sixth embryonic deciduous legs.	Third pair spinnerets.	Ninth pair of legs	Fifth pair of legs (bænopods).	
14	First pair of rhabdites.†	Telson of scorpion.	Tenth pair of legs.	First abdominal legs (uropods).	
15	Second pair of rhabdites.	....	Eleventh pair of legs.	Second abdominal legs (uropods).	Telson (spine).
16	Third pair of rhabdites.	....	Twelfth pair of legs.	Third abdominal legs (uropods).	
17	Cercopoda of some Orthoptera and Neuroptera, and anal legs of caterpillars.	....	Thirteenth pair of legs.	Fourth abdominal legs (uropods).	
18	Eleventh abdominal segment in some Orthoptera and Pseudoneuroptera.	....	Fourteenth	Fifth abdominal legs (uropods).	
19	....	....	Fifteenth	Sixth abdominal legs (uropods).	
20	....	....	Sixteenth; 200th in Geophilus.‡	Telson	

* See Kowalevsky, Embry., Studien an Würmern und Arthropoden, 1871, Plate XII, fig. 10. Embryo of *Sphinx populi*, in which the first ten abdominal segments have temporary rudimentary appendages, some of which persist in the caterpillar, serving as prop-legs.

† The ovipositor of insects, as we originally pointed out in 1868 (Proc. Boston Soc. Nat. Hist., xi, 393), is primarily composed of three pairs of appendages (called by Lacaze-Duthiers "rhabdites"), which arise in the same way as the legs; this view has been confirmed by Ganin, Kraepelin, and Dewitz.

‡ The number of movable segments in the Geophilidæ, according to Newport, varies from about 35 to more than 200.

This view as to the homologies of the limbs is directly opposed to what we have previously held, and to the views of Claparède* and Zenker; but progress in the embryology of Arthropods and of worms has now given us a basis for better grounded views as to the homology of the limbs of the leading groups of Arthropods. It now appears that in the higher worms the mouth is, as a rule, situated in the first segment, the invagination of the ectoderm forming the stomodæum or primitive gullet. This is seen in the Nematelminthes (*Cucullanus*)[1] in *Nephelis*[2] and in *Lumbricus*, and is probably common to all worms; and in the Annelida the mouth does not shift; it is a fixed point, and the first pair of tentacles arise from the first segment. So also is the vent or anus (proctodæum), which is the result of an invagination of a portion of what becomes the terminal segment of the body. In Arthropods the anus remains invariably, in all proctuchous forms, a fixed point. On the other hand the mouth shifts from a position originally in the embryo in front of all the appendages in the head to a point posterior to the antennæ of both pairs, when two pairs are present, as in the Crustacea; *i. e.*, to a position in adult life between the mandibles. So far as we are aware we were the first to call attention to this fact of the change from an anterior to a posterior position of the mouth in relation to the antennæ in our account of the embryology of *Limulus polyphemus*,[3] where the mouth at the time of the appearance of the limbs is anterior to the first pair of appendages. This was probably the case with all the extinct Merostomata and Trilobita. In the normal Crustacea Bobretsky[4] has shown that in Oniscus the mouth-opening is at the extreme end of the body, in the antennal segment, the middle of the procephalic lobes or antennal segment forming the front wall or roof of the stomodæum. In the nauplian stage *in embryo* of Astacus, Reichenbach[5] has shown that the mouth is placed directly between the first antennæ; and in the active freshly-hatched nauplius of the Copepoda, as well as of all the Phyllopoda, the mouth opens between the first pair of limbs, which become finally the first pair of antennæ of the adult. In Peripatus Moseley has shown that the mouth opens in the antennal segment, which really forms the procephalic lobes. In the Arachnida, according to Claparède, all the appendages are in the embryo postoral.

In the Hexapodous insects Kowalevsky has clearly shown that the mouth is at first situated between the antennæ, which arise from the procephalic lobes; before hatching it retires to an intermandibular position.

The embryology of all the Arthropodan subclasses (the Myriopods probably not excepted, this point not being shown in Metschnikoff's plates) shows, then, that the mouth is not a permanent fixed point, since in the embryo it is pre-appendicular, while towards or at adult life it assumes a position behind the antennæ, when functional antennæ are present, or in Arachnida and in Merostomata behind the first pair of appendages.

An examination of the structure and homologies of the Arthropodan brain or supra-œsophageal ganglia shows that in the Phyllopods the

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* Claparède, Recherches sur l'Evolution des Araignées, 1862, pp. 77–87.

[1] Bütschli. "Entwicklungsgeschichte der Cucullanus elegans," Zeit. f. wiss. Zool. xxvi, 1876.

[2] C. O. Whitman, Embryology of Clepsine, Quart. Journ. Micros. Sc. xviii, 1878.

[3] The Development of Limulus polyphemus. Mem. Bost. Soc. Nat. Hist. i, March, 1872.

[4] N. Bobretsky. Zur Embryologie des *Oniscus murarius*. Zeit. für wissen. Zoologie xxiv, 1874. See Taf. xxii, figs. 20, 23.

[5] S. H. Reichenbach. Die Embryoanlage und erste Entwicklung der Fluskrebses. Zeit. für wissen. Zoologie, xxix, 1877. See Taf. x, fig. 8.

brain only innervates the ocelli and eyes, the two pairs of antennæ arising in Apus from the commissures connecting the supra and infra œsophageal ganglia. In Limulus, the living representative of the Merostomata, the first pair of limbs are innervated from the ganglionic subœsophageal ring, and not the brain; while in most other Crustacea the brain supplies the antennæ of both pairs, as well as the eyes. Thus, apparently, the only sure basis for exact comparison is to begin with the first pair of appendages and to regard them, whatever name be applied, as homologous throughout the Arthropodan series, the parasitic Isopods and Copepods perhaps being counted out by reason of the degradational changes, which render it difficult to determine in adult life the exact homologies of their appendages.

The general relations of the segments of the bodies of Arthropods being similar to what exists in Annelids is to our mind a strong argument for the derivation of Tracheate and Branchiate Arthropods, each independently, from the worms, the first pair of appendages of the Arthropods being perhaps homologous with the first pair of tentacles of Annelids.

Homologies of the labrum.—This brings us to consider in passing the probable origin and homologies of the labrum* of Arthropods. We are inclined to regard the labrum as possibly the homologue of the median frontal tentacle of certain larval Annelids, for instance. If the reader will compare Metschnikoff's figure of the temporary long, large, slender, tentacle-like labrum of Chelifer, the general resemblance to the frontal unpaired tentacle of certain Annelids is suggested. We have always regarded the clypeus and labrum as a median development, merely forming the front wall of the mouth; embryology certainly bears out that view. In the embryos of most insects the clypeus and labrum project out remarkably, and may then, perhaps, be compared to the unpaired, median tentacle of certain young Annelids.

The history of this organ is interesting. While in the larval *Estheria* and *Limnadia* the labrum is enormous, and nearly as long as the body, thus resembling the larval Cirripedia; in the adult it becomes a small fleshy process under the base of the second antennæ, and partly resting on the base of the mandibles. In *Limnetis* (Plate XXXI, fig. 6, *lab.*) it is rather large. In the *Apodidæ* it forms a comparatively large, square, horizontal plate (Plate XXXI, fig. 1) on the under side of the head, behind the frontal doublure. In the *Branchipodidæ* it is again reduced to a small fleshy inconspicuous lobe.

The carapace.—This is greatly developed in the *Limnadiaceæ*, where it forms two large valves, usually with definite "lines of growth," and connected over the region of the mandibles by a definite specialized hinge, and completely encloses the body, only the second pair of antennæ and perhaps the telson projecting beyond the edges while the animal is swimming. Plate XXIV, fig. 9, shows the relation of the bivalvedcarapace in *Estheria* to the body and its appendages. The hinge has a large central median tooth projecting inwards, each valve having a sharp denticle which strikes against the central much larger tooth. (See also Pl. XXXIII, fig. 1.

The histology of the carapace has been described briefly by Grube in 1865, but his figure (Taf. X, fig. 11) does not express satisfactorily the nature of the soft cellular portion or layer. The cuticular layer is structureless but laminated, and it has been claimed by Prof. E. S. Morse that the carapace valves in *Estheria* are due to the fact that the shell, instead of being cast free from the body when molted, remains attached

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* Hypostoma of Limulus and Trilobites.

to the new shell underneath, and thus the "lines of growth" correspond to the successive molts of the animal. In his First Book of Zoology, p. 149, he remarks: "The concentric lines on the shell appear like lines of growth, and such they really are; but they are not made like the lines of growth on the mussel. When the creature molts the delicate skin covering the antennæ and swimming legs is discarded. The molting process also takes place with the bivalve shell; but, instead of its being discarded, the molt is held or cemented to the new shell, which forms underneath. Molt after molt of the shell is thus retained, the increasing size of each molt showing as separate concentric lines of growth. If the shell is cut into and the cut edge is examined with a microscope, the successive molts will be seen resting one upon the other, like the leaves of a book." This view would seem, at first sight, to be borne out by the relation of the marginal row of spinules, which are present in most species of *Estheria*, as seen in our figures of the edge of the carapace of *Estheria jonesii* (Plate XXIV, fig. 2), where there are four marginal rows of round sockets, which must originally have borne spinules like the marginal ones. But our sections of the shells of *Estheria mexicana* show that Morse's view is not tenable, as the shell, if anything, is thicker at the edge than near the hinge, and there are no overlapping lines of growth.* An inspection of the broken shell of *E. jonesii* (Plate XXIV, fig. 2) shows that the ridges or so-called lines of growth are superficial, and, like the rows of beads and tubercles on the shells of the other species, together with the spines themselves, are merely external ornamentation; for when the shell is broken and split, as in our fig. 2 of this plate, they are seen not to extend through the shell, there being irregular, not parallel, structural, lines in the substance of the shell. That the entire shell is molted with the integument or cuticula of the head and appendages is also shown by the fact that the carapace-valves of *Limnetis* show no such lines of growth, nor the carapace of *Apus*. So that, in respect to the casting of the carapace, the process in the Limnaniadæ is not an exception to that in other crustacea where the cuticula of the entire body-wall is cast at once. Hence it would appear that the so-called "lines of growth" may be simply a superficial ornamentation, the ridges differing in different species.

That the shell of *Estheria mexicana* is cast at each molt is shown by a number of sections where the new chitinous shell is seen lying next to the hypodermis and the shell about to be cast is split off; also near the hinge, and especially over it, the shell is absorbed, so that the hinge margin is not cast. The old shell was also in our sections divided into three layers. Claus also states that *Estheria mexicana* casts its shell.

It is probable that each species of Estheria has a row of spinules along the edge of the carapace-valves; we have found these spinules very long and slender in *Estheria belfragei* and *E. mexicana*, very short in *E. jonesii* and *E. lindahli*. We have not observed any in *E. californica*, nor has Lenz.

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*According to Joly and Klunzinger in *Estheria* and *Limnadia* during the moulting as seen in repeated precise periods, only the delicate layer lining the inside of the shell is cast off with the skin of the telson, the hardened lamellated outer layer not only remains, but forms each time a new marginal zone. Since the inner layer is a direct continuation of the delicate body-skin, so is a periodical renovation of the same through a process of formation arising from the underlying matrix evidently found at each moulting of the telson; at the same time, however, this matrix, while it adds to the extent of the surface, also externally produces a new layer which, on the other hand, lies under that last formed and projects from the edge. In this way with the general growth of the shell, not only the lamellæ overlying one another, but also the concentric lines, each one of which corresponds to a line of growth, find their simple explanation, and hence the view of Claus, who considered that the whole shell was cast at each moulting and was newly formed, cannot be the true one.

The structure of the hypodermis is seen in fig. 7, Plate XXXIII. The sets of curved fibers (*f*) are arranged in upright bundles, with some transverse fibers, the ends of the former radiating at the surface and forming the stellated appearance so characteristic of the surface of the integument in these Phyllopods. The spaces between the bundles are not hollow, as represented by Grube; but in the specimens we examined besides numerous smaller cells there is a very large central cell (*l. c.*), which is perhaps actively concerned in secreting the shell.

The shell-gland (Plate XXIV, fig. 9, *shg*) is seen to be a specialized portion of the cellular layer of the carapace; the cells glandular in their nature and secreting the material for the shell or cuticle, which is distributed by the three primary ducts represented by the six openings seen in the drawing. The structure of the shell-gland in the Phyllopoda has been fully described by authors, particularly by Leydig, Claus, etc.

While the carapace is well developed in the *Limnadiadæ*, with the *Apodidæ* it is very much smaller, covering only the cephalothoracic portions, leaving the abdomen exposed, so far as cephalothorax and abdomen may be said to exist in the Phyllopoda. The carapace is largest in the lower species and smaller in what we regard the higher species in the genera Lepidurus and Apus, respectively. In this family, therefore, its small size in adult life is a sign of superiority; as when it is large and covers most of the abdomen, it approaches nearly the larval condition of the species, and also the Limnadiad nature of the carapace, and in this respect, as well as in regard to the head, the *Apodidæ* are but one step removed from the *Limnadiadæ*.

It also appears that the carapace is, as in Decapods, due to the hypertrophy of the tergum of the mandibular segment, the adductor muscle being situated immediately over the mandibular adductor muscles.

In the adult Branchipodidæ the carapace is entirely wanting. In adult life the shell-glands persist (Pl. XXIII, figs. 1, 2, *gl.*). Thus the *Branchipodidæ* are the extreme in the Phyllopod series, and stand at the head of the suborder, and hence as regards the carapace the development of the individual Branchiopod is in a degree an epitome of that of the suborder; and we have already seen that this succession or relative standing of the three families of Phyllopods accords with the geological succession of the genera *Estheria*, *Apus*, and *Branchipus*.

Morphology of the head.—The relative size and form of the head varies greatly in the three families of the Phyllopoda. In Limnetis the head is enormous in size and about equals in bulk the rest of the body; this is due to the great development of the sternal side, but especially of the tergal portion in front of the eyes. In respect to the great bulk of the head the Limnadiadæ, and especially Limnetis, are connecting links between the Cladocera and Phyllopoda. In the Cladocerous genera *Daphnia*, and especially *Acroderus* as figured by Leydig, the head and particularly the frontal region is greatly developed, though much less specialized than in the *Limnadiadæ*. For example, the front is produced into a large, broad, solid preocular subregion, forming the rostrum, which is acutely mucronate at the tip in the females, broad and truncate in the males; behind this is a broad, solid region in which the eyes are situated. The head, in fact, may be divided into a distinct, specialized preoral antenniferous and oculiferous, or sensory; and into a postoral region; the preoral region in *Limnetis* and *Estheria* may be subdivided into two, namely, a preocular and an ocular subregion. In *Limnetis* the preoral region is separated from the rest of the head by a deep suture, and in *Estheria* there is a deep dorsal incision, allowing a considerable play of this region upon the postoral region. In Limnadia the whole preocular subregion is wanting, the head under the eyes rapidly retreating backward and downward. This great development of the preocular region is probably connected with the burrowing habits of these crustacea, which take refuge in the soft mud at the bottom of ponds.

In *Apus* and *Lepidurus* (*Apodidæ*) the head is shovel-shaped, being also adapted for burrowing like a Limulus in soft mud; in this family the preoral region is very large, but instead of being compressed, it is flattened vertically, or shovel-shaped.

In the more highly differentiated *Branchipodidæ* the head is small in proportion to the rest of the body, and more completely differentiated or separate from the thoracic portion of the trunk, and the bulk of the head is composed of the preoral region; the postoral, as seen in fig. 2, Plate XI, carrying the mandibles and the nearly obsolete maxillæ, and forming what appears as a single segment, a little smaller than the first limb-bearing segment next behind it. In this family the preocular region of *Limnetis* and *Estheria* is reduced to a minimum and is represented by the small triangular frontal, inter-antennal lobe, which in *Branchipus* and *Chirocephalus* is subdivided into two appendages of various complicated shapes. There is, thus, as we ascend from *Limnetis* to *Branchipus* a more or less gradual differentiation and condensation of the head; and the head of *Apus* approximates in form the Estherian type.

The postoral region bears the mandibles and maxillæ, and maxillipedes when present, and merges insensibly into the limb-bearing or thoracic region (bænosome), so that there is in the Phyllopoda only a slightly marked cephalothoracic region, the urosome also being but slightly differentiated from the bænosome.

The urosome or abdomen.—This region, so well marked in the *Decapoda*, is in the lower Phyllopods not differentiated from the cephalothoracic, no arthromeres being in the *Limnadiadæ* interposed between the last limb-bearing or appendigerous arthromere and the telson. The external genital organs, which may serve to roughly indicate the limits between the cephalothorax and the abdomen are wanting in the *Limnadiadæ*.

In *Apus* and *Lepidurus* the eleventh pair of feet (first pair of uropods) are modified to form ovisacs, but there are numerous pairs of uropoda beyond, and there is no regional distinction of even the slightest description between the limb-bearing segments and the telson. In the *Branchipodidæ*, however, a differentiation into a head, thorax, and abdomen is tolerably marked. As may be seen by reference to figs. 1 and 2 of Plate IX, and Plate XXII, fig. 3, the last pair of limbs are, in the male, modified to form a penis-like organ, which is double at base and is developed from a single segment. In the female *Apodidæ* the oviducts open externally into the same segment as that which bears the ovisac, and we are disposed to regard the ovisac as an extreme modification of the gonopods; as in *Branchipus* and *Artemia*, Plate XXII, fig. 2, this organ is at base bilaterally symmetrical. The abdomen, then, of Branchinecta and Branchipus, for example, consists of nine segments, including the last, which corresponds to the telson of the lower Phyllopods.

In the *Decapoda* the first pair of gonopods (there being two pairs corresponding to the first and second abdominal feet of the females) is situated on the first abdominal segment, and thus the Branchipodidæ somewhat approach the Decapods in this respect. It will also be remembered that in *Limulus* the genital outlets of both sexes are in the first abdominal segments. Whether, however, the eleventh pair of feet in *Apus* should be regarded as the first abdominal pair or not must, it seems to us, remain an open question; there seems, however, to be no other line of demarkation in the family which this genus represents.

The telson.—This portion of the abdomen, sometimes called "post-abdomen," is large and well differentiated in the two lower families, especially in *Estheria*—where it is compressed, high, armed above with numerous spines, and bearing below a pair of modified caudal appendages which we shall consider under the head of the appendages.

We will rapidly recall the salient points in the form of the telson in the three families of Phyllopods. In Limnetis the telson is much as in some *Cladocera*, being small, without teeth along the upper edge, though still bearing the pair of dorsal filaments (see fig. 4, in text, and Plate I, fig. 6). These are also present in certain Cladocera, *Daphnia*, *Bosmina*, &c., and in several genera allied to *Daphnia*, *Alona*, *Pleuroxus*, &c., the upper edge is dentate or spined; this with other features in *Limnetis* shows that the Phyllopods have probably descended from Cladocera-like ancestors. In *Estheria* and *Limnadia* the telson is large and densely spined along the upper edge. The large spiny telson is probably of use to aid the animal in pushing itself through submerged dense vegetation, for all that portion of the body which can be thrust out between the valves is armed with stout spines, whereas in *Limnetis*, only the telson can project beyond the edge of the carapace valves.

In *Apus* the telson is nearly cylindrical, short and small, and flattened from above downwards, and is without much functional value, though the cercopods are of use in swimming; but in *Lepidurus* it is produced into a long spatulate portion like a beaver's tail, and which must give it an advantage over *Apus* in extricating itself from muddy places.

In the *Branchipodidæ* the telson assumes the form of a simple segment, cylindrical, soft, unarmed, but in *Thamnocephalus* becoming very broad and flattened into a lateral fin-like expansion and without any caudal appendages, which are always present in the other genera of the family.

What we call the telson, and which is simply the last abdominal segment, is called by Gerstaecker, and we suppose earlier authors, the "post-abdomen." Some authors, the most recent, Gerstaecker in Bronn's Classen und Ordnungen, &c., speak of the "abdomen" and "postabdomen" in the *Branchipodidæ*, but they do not state where the abdomen begins. The term "postabdomen" is applied to the last eight (*Artemia*) or nine (*Branchipus*, &c.) segments of the body (*uromeres*), but we see no good reason for not regarding these segments as forming a true abdomen (urosome), the first segment, or ninth from the end, in *Branchipus* bearing the external reproductive organs. We really see no need of employing the term "postabdomen" in speaking of any Branchipod, nor in fact, so far as we are aware, does it have any special significance in other groups. We here consider the so-called "postabdomen" of the *Limnadiadæ* and *Apodidæ* as the telson, and the homologue of the telson in the macrurous *Decapoda*.

The eyes.—There are in the lower Phyllopoda but a single pair of compound or facetted eyes, but in the *Branchipodidæ* the simple, unpaired eye of the larva is retained. In the *Limnadiadæ* these are sessile; in the *Branchipodidæ* they are stalked. The structure of the eye of *Apus cancriformis* and *Branchipus* (species not named) has been described and in part figured by Grenacher in his great work "Untersuchungen über das Sehorgan der Arthropoden" (1879). The eye of *Branchipus stagnalis* has previously been investigated by Leydig in 1851; and that of *Estheria californica* by Lenz in 1876. The eye of *Limnetis* has apparently not been investigated, and our own observations on it are but fragmentary and superficial. The eyes are closely approximate, appearing as a single eye. Unlike that of *Estheria* the number of lenses is small. Plate II, fig. 6, represents the eye of *Limnetis gouldii*, a circle of crystalline lenses surrounding the central pigment mass or retina. The lenses are contiguous, the pigment not extending between them as in *Artemia*, Plate XXIII, fig. 6. Plate II, fig. 5, represents the two optic nerves and optic ganglia, the cornea with the crystalline lenses and pigment layer having been torn off with the needle. The optic nerves are very thick, and instead of, as usual, being composed solely of nerve fibers, appear to be largely made up of nerve cells; fig. 5 *a* represents an enlarged view from near the middle of the optic nerve, which is made up almost wholly of strings of nerve cells. Toward the distal ends of each optic nerve converge delicate fibers which connect the cells of the optic ganglion with the optic nerves. An enlarged view of the optic ganglion is seen in Plate XXIX, fig. 9. The ganglion cells are not very numerous nor crowded; they are nucleated and nucleolated, and a nerve-fiber broad, triangular next to the cell, rapidly diminishes in size towards the middle of the fiber. It is interesting to notice the intercommunication in the median line of the head between the two eyes; a small number of cells on the opposing edges of each eye are seen to send transverse nerve-fibers (fig. 9, *tr. n.*) across to the opposite optic ganglion; though externally the system of crystalline lenses do not quite touch each other. We have not examined the crystalline lenses of *Limnetis*.

The eye of *Estheria* is nearly on the same general plan as in *Limnetis*. Lenz has discovered that the lenses are composed of five segments, instead of two, the usual number in Crustacea, particularly *Apus* and *Branchipus*.

The inner structure of the eye of *Artemia* was studied on the living specimens, Plate XXIII, figs. 1 and 6. Fig. 1 shows the general relation of the sessile square simple eye and of the stalked compound eyes to the head and also to the brain. Fig. 6 represents the relations of the eye and its optic lobe to the eye-stalk of the living animal. The optic nerve is in the center; the large rectus muscle of the eye is situated on the hinder or outer side of the stalk, arising near the brain and being inserted on the cornea at the base of the eye near the first crystalline lens; the exact mode of insertion was not observed. The blood circulates freely, flowing from the head along the anterior side of the outstretched eye, the corpuscles, of different sizes and not very numerous, passing between the optic nervules (*op. n.*) and returning, as the arrows indicate, along each side of the rectus muscle back to the head.

The general structure of the eye of *Artemia gracilis* is much as represented by Leydig in *Branchipus stagnalis;* the *ganglion opticum*, however, is in our specimen of *Artemia* composed of but a single mass, not of two distinct masses connected by coarse nerve-fibers. From the ganglion opticum about a dozen optic nervules penetrate the retina, which is larger in proportion to the eye than represented in Leydig's figure; the superficial circle of crystalline lenses or cones showing very plainly.

The question as to whether the eyes of Crustacea, particularly the stalked eyes, are homologous with the other appendages, and thus represent distinct segments of the head, and which is still held by some naturalists, may, it seems to us, be set at rest by examining the eyes of Phyllopod Crustacea. In the *Limnadiadæ* and *Apodidæ*, where the eyes are sessile, it is easy to see, particularly in *Limnetis* and *Limnadia*, that the eyes are modified epidermal cells covering the ends of the optic nerves. They are situated on the front or upper walls or tergum of the first antennal segment; and, as it is a general law that but a single pair of appendages are borne by a single segment, we should not expect to find the law broken in this case, at least as regards the cephalic segments.

When we come to the *Branchipodidæ*, where the eye is mounted on a long moveable stalk, they are still plainly tergal outgrowths of an antennal segment. The embryological history of the eyes would also prove that the eyes in all stalked Crustacea first begin as a specialized group of epidermal cells, developing on the anterior segment of the head; even in the zoëa of Decapods, the eyes remain sessile until just before the hatching of the larva; the growth of the stalk is one of the latest changes in embryonic life. If the eye-stalk were homologous in its history and structure with the limbs, then why should not the stalk in the stalk-eyed species bud out from an independent primitive segment, as do the appendages of the cephalothorax and abdomen? Instead of that, the stalks on which the eyes are situated are developed very late in embryonic life, and are evidently not derived from ancestral forms; while in all stalk-eyed forms, whether Phyllopoda, Phyllocarida, or Decapoda, the stalk is preeminently an adaptive feature of the head, and is developed on the first antennal segment.

The first antennæ.—The Phyllopoda have, with the exception of individual Apodidæ, invariably two pairs of antennæ. They are, however, very unequally developed, the first pair being minute and smaller than the second pair, except in *Apodidæ*, where the second pair are minute and sometimes wanting. In *Limnetis* they are minute and difficult to find. Their position and size in relation to the first pair are well shown by Mr. Burgess in Fig. 4 (in text). They are there seen to be inserted quite in advance of the second pair, and to be slender and two-jointed. Those of *L. gouldii* are much slenderer than in *L. brevifrons*.

In *Estheria* and *Limnadia* they are much larger and longer, multiarticulate, the joints, however, not well defined on the inner edge; they appear to be inserted behind the second pair, but careful examination shows that they originate anteriorly. In the *Apodidæ* the first antennæ are much larger than the second pair, but small as they are, and apparently almost functionless, they are yet invariably present. The relative size and form of the two pairs are shown on Plate XXXII, figs. 2*a*, 2*b*. The first pair are inserted on the vertical inner wall of the frontal doublure. They are slender, two-jointed, and by their position and diminutive size must be nearly useless to the animal, and only the survival of larval organs. In the *Branchipodidæ* the first antennæ resume somewhat of their normal size and importance, being rather long, slender, filamental appendages, but not jointed. The histology of the first antennæ in Limnetis has not been previously noticed. Under a high power, those of *Limnetis gouldii* (Plate XXVI. figs. 4, 4*a**) are seen to be provided along the outer edge with long, slender sense-filaments, rather more closely crowded and better developed at the end than along the side. The substance of the joint is rich in cells which are not closely crowded, and are arranged in series ending at the base of the sense-filaments, where the cells become more closely crowded. These cells occur at the base of the sense-filaments, but elsewhere in the filament there are only minute scattered corpuscles of the size of the nuclei of the sense-cell. In *L. brevifrons* (figs. 5, 5*a*) the histological structure is nearly the same, but the

* In Fig. 4, which represents the second joint of the antenna, the left side has been omitted by the artist. The line which should have been drawn here has wrongly been added to the right side of fig. 4*a*.

sense-filaments, or what we may call the olfactory filaments, are smaller and less numerous than in *L. gouldii.*

In *Estheria mexicana*, Plate XXIX, fig. 1, 1*a*, 1*b*, the segments on the anterior side are produced into what may be called the olfactory tubercles, which give a bluntly serrate outline to this side of the antenna in contrast to the even opposite or inner side. In fig. 1, the antennal nerve (*at. n.*), where the sense cells and tubercles do not occur, is seen passing through the middle of the antenna, and the ends of the fibers disappear among the nerve cells, which crowd the olfactory tubercles (fig. 1*b*, *ol.*). In this species no olfactory filaments were observed to be present. In *Estheria compleximanus* however, Plate V, figs. 3, 4, they are well developed, two or three, and sometimes more, short filaments arising from the tubercles, which are more acute than in *E. mexicana* (from Kansas). The structure of the olfactory papillæ (*ol. pap.*) is nearly identical with those of *Limnetis.* The ultimate fibers of the olfactory nerves are here plainly seen to enter the mass of nerve cells.

In *Limnadia texana*, Plate XXVI, fig. 3, the joints of the antennæ are more richly charged with nerve cells, which are rather smaller than in *Estheria compleximanus*, though those of the latter species are larger than in *E. mexicana.* The histological structure of the first antennæ in the present family is quite unlike that of the same appendages in the *Apodidæ* and *Branchipodidæ*; and reasoning by exclusion, and taking into account the fact that this pair of antennæ do not project much beyond the edges of the valves, and that they are placed very near the jaws and mouth-opening, and also bearing in mind the great abundance of the sense-cells, we are inclined to believe them to be either olfactory or gustatory in function, and that in this family at least the first antennæ are mainly organs of smell or taste. We have often observed *Limnetis gouldii*, swimming quite rapidly on its back at the surface of the water, apparently feeding upon the vegetable matter floating on the surface; during its movements it would stop and feed upon some object, as if arrested by its smell. The sense lodged in these organs are therefore restricted either to the sense of smell or taste, probably the former.

The finer structure of the antennæ of *Apus* has not been examined, and it is probable in an indifferent state. That of the first antennæ of *Branchipodidæ* is quite simple. Plate XXIX, fig. 6, represents the first antenna of *Branchipus vernalis* greatly enlarged. It is simpler in structure than in the European *B. stagnalis* as figured by Leydig (Sieb. u. Köll. Zeits. Wiss. Zool., iii, Pl. VIII, fig. 8), since it lacks the series of seven sense filaments ending in knobs of the European species, though the three terminal setæ are much longer. In our species the antennæ are seen to be unjointed throughout its whole length. Two nerves, one on each side (fig. 6*n*), and composed of several fibers with here and there a ganglion cell, approach each other in the middle of the appendage, where they are reinforced by a ganglion cell or two. At *n'* two nerves are seen passing along the center of the appendage; at *g c* are situated several ganglion cells in the nerves, which finally lose themselves in a terminal mass of small compact ganglion cells, situated at the base of the three setæ. Leydig only figures five cells, where in *B. vernalis* they are smaller and much more numerous. It seems obvious that in this family the first antennæ only possess the sense of touch.

On Plate XXXIV, fig. 4, Dr. Gissler has figured the first antenna of the larva of *Streptocephalus texanus*, from Kansas, and it will be seen that the histological structure is rather different from that of the adult *Branchipus.* The ganglion cells are more abundant at the base of the antennæ; the nerve passes along the center, is reinforced by a few large spindle-shaped ganglion-cells before terminating in the spherical ganglion-cells at the insertion of the three setæ. The same general arrangement of the nerve-fibers and cells is seen in the same organs earlier in life at fig. 3.

In *Chirocephalus holmani*, according to Dr. Gissler's figure, the first antennæ each bear not only three terminal setæ, but also a series of about five sense-setæ like a ten-pin (Fig. 8). These are apparently homologous with the olfactory cylinders of Leydig* on the smaller antennæ of *Asellus aquaticus*.

The second antennæ.—These are not apparently organs of any special sense. In the *Limnadiadæ* they are evidently derived from the "ruderarme" of the Cladocera, being large, long, biramous appendages of constant use as oars in swimming, the long setæ assisting in the oar-like movements. The form is very persistent in this family, the use of the appendages being the same in each genus.

In the *Branchipodidæ*, the second antennæ of the males are modified in a striking way, which afford apparently good specific characters useful in such a difficult genus as *Streptocephalus*. As clasping organs their use is seen in the engraving of *Artemia* (fig. 17 in text). The rounded sinus between their bases just fit over so as to inclose the back of the female, and the two knob-like processes further seem to hold her fast; in *Branchinecta* the structure of the base of the claspers is the same, while the simple unarmed second joint is not particularly well fitted for prehension. In *Branchipus* each second joint has a stout spine pointing inward which acts as a prehensile apparatus, as has *Streptocephalus*, in which also the second joint is variously divided into prehensile parts.

In *Chirocephalus* and *Thamnocephalus* the second joint is incurved, and thus rendered sufficiently prehensile.

It appears, then, that the highly specialized male second antennæ have lost perhaps altogether their sensory functions, or their use as swimming organs, like those of the *Limnadiadæ*, and are simply of use as clasping organs and minister solely to the reproductive function.

In the *Apodidæ*, as stated by Lankester (Quart. Jour. Micr. Sc., April 1881, p. 346), the existence of the second pair of antennæ has recently been denied. "Zaddach states that they were generally absent in *A. cancriformis*, but were found by him in two cases; Huxley states that he was unable to find them in *Apus glacialis* examined by him, whilst Claus, whose statements have the very greatest weight, both on account of his extended investigation of the morphology of the Crustacea and of his special observations on the development of Apus and Branchipus, brings forward the total absence of the second pair of præoral appendages in Apus, as a special characteristic of the family Apusidæ." Gerstaecker simply, in reference to this point, quotes Zaddach's statement. Lankester adds "In the adult *Apus cancriformis* and *Apus dukii*, from Affghanistan (? *A. himalayanus*), this second pair of præoral appendages, although reduced to a rudimentary condition, is always present,

* Leydig, F. Ueber Geruchs- und Gehörorgan der Krebse und Insecten. Reichert u. du Bois-Raymond's Archiv. 1860, Tab. 7, fig. 4.

Spangenberg (on *Limnadia hermanni*, Zeits. für W. Zoologie Suppl. 1878) thus describes the taste-organs. On the 1st antennæ "they are situated—usually six in number—as small, clear points on the hinder much-swollen surface of the base of the antennæ, and may be traced back, as all these taste-filaments, to the spines on the nauplius-antennæ. The structures on the base of the known pale taste-cylinder, described by Claus as 'highly characteristic shaped nerve-pins,' are the young taste-cylinders reaching out in the succeeding moult, and are not of a nervous nature, but cuticular early growths."

so far as my observations go. I have found them always present in full-grown specimens of *Apus cancriformis* from Munich, from Prag, and from Padua."

In specimens of *Apus cancriformis* kindly sent us by Professor Siebold, of Munich, we have found the second antennæ to be inserted on the inner declivity of the frontal doublure forming the front of the head, and inserted behind the first antennæ, and farther out from the labrum than the first antennæ. They are in form as described and figured by Lankester. I also found them in my examples of *Apus himalayanus*, and, as in *A. cancriformis*, they are larger and more easily found than in the American species.

On looking for the second antennæ in our American species I was at first unable to find them, they were so minute and so closely appressed to the body. In specimens of *Lepidurus couesii* which were well preserved the antennæ were found, but none in *L. bilobatus*, of which I had but two indifferently preserved specimens. Figs. 2*b*, 2*c*, of Plate XXXII, show their relative size in *Apus lucasanus*, both being drawn to the same scale. In order to find them the mandibles have to be forcibly moved backward. They were also found in *Apus newberryi*, *A. æqualis*, and in *A. longicaudatus*, but in all these American species they are much smaller and more difficult to find than in the European and Asiatic species; a point of some interest, which coupled with the greater obsolescence of the maxillipedes and the smaller carapace shows that the American species have reached a stage farther removed from the larval condition than the Old World forms.

Histology.—The histological structure of the 2d antennæ of the *Limnadiadæ* is shown at fig. 2, Plate XXIX, which represents the three terminal joints of one of the flagella of the second antennæ of *Estheria*. The joints are seen to be crowded with nerves of special sense, and the antennal nerve is seen to terminate in fibers, one of which passes into each seta; so that these organs must be highly sensitive, perhaps only tactile, however, while they are also rowing or swimming organs.

The mandibles.—All Phyllopoda have well-developed mandibles, except in the highest or most specialized family, the *Branchipodidæ*, in which they are weak and feeble in function, though with primarily the form common to the group.

In the *Limnadiadæ* (according to Lilljeborg), in *Limnadia gigas*, and as we have observed in the *Apodidæ*, the mandibles are without a palpus in the adult, and are solid chitinous appendages with the biting edge either smooth, as in *Limnadiadæ*, or provided with strong acute teeth as in *Lepidurus* and *Apus*. (Plate XXI, figs. 11, 12.)

When we look at the larval mandibles of *Apus*, which are represented by Dr. Gissler (Plate XXXV, fig. 1, *md*), it is not only plain that they are the third and last pair of the limbs of the Nauplius, but it is also plain that the mandible originally consists of two portions, the basal joint with its masticating edge and the two-jointed palpus; this palpiform appendage becomes absorbed or at any rate disappears in the two families under consideration, and it is easy to see that the mandible proper represents or is the homologue of the basal joint of the axis of the limb, together with the first endite, coxal lobe, or gnathobase of the adult Limnadiad or Apodid leg (*e. g.*, Plate V, figs. 5 l^1, 7*a*; Plate XXI, fig. 4 *cl*).

In the Apodidæ the cutting edge of the mandible is provided with eight or nine teeth, which are naturally less blunt in the adult than in the larva (see Plate XXXV, fig. 4, 4*a* palpus).

In the *Branchipodidæ* the mandibles, as shown by Spangenberg (suppl.

Taf. I, Fig. 6, *md*), retain the palpus, which is represented by a single setose bristle, the remnants of the large part of the Nauplian third leg. The teeth on the cutting edge in *Branchipus stagnalis* are finer and more numerous than in the two other families.

The first maxillæ.—Succeeding the mandibles are two pairs of maxillæ in the *Limnadiadæ* and *Branchipodidæ*, while in the *Apodidæ* there appears to be but a single pair of maxillæ, which are succeeded by a rudimentary gill-bearing appendage, the maxillipede. The first pair of maxillæ in *Limnadia gigas* are described and figured by Lilljeborg; those of *Estheria mexicana* by Claus. According to Lilljeborg the first maxilla of Limnadia consists of but a single lobe with very numerous uniformly dense, fine, slender, and very long setose setæ.

In the *Apodidæ* the first maxillæ consist of two parts, the basal (Plate XXI, figs. 9, 10), which consists of a single large chitinous piece, with the free cutting edge provided with two kinds of teeth, an inner submarginal row of stout, acutely triangular teeth, while there is a marginal row of hair-like setæ. In *Lepidurus* the external portion of the cutting edge is somewhat differentiated, there being here, as seen in Plate XXI, fig. 9, a specialized portion with three stout teeth; this becomes obliterated in *Apus lucasanus*, but in the larva of the same species, as Dr. Gissler's drawing (Plate XXXV, fig. 5) shows, this portion is at first separate from the rest of the cutting edge, and in *Lepidurus* this feature is retained in adult life. Situated close behind the large chitinous portion and loosely connected with it at base is what I should regard as the palpus (Plate XXI, figs. 7, 8, 13); that this should be regarded as a portion of the first maxilla is, I think, proved by reference to the condition of the maxilla in the larva. By reference to Dr. Gissler's figure of the maxilla of the larval *Apus lucasanus* this palpus-like portion is clearly seen to be a large flat bilobed portion lying behind but next to the outer part of the cutting edge of the maxilla.

The maxilla proper, *i. e.*, the cutting or main portion of the appendage, is with good reason homologized by Lankester with the first endite or coxal lobe (his *gnathobase*) of the feet of Apus. The piece which we regard as the palpus, Lankester is apparently disposed to regard as a part of the maxilla, and not, as Zaddach thought, the second maxilla.

In the *Branchipodidæ* the first maxillæ have been best described and figured by Spangenberg (Taf. I, fig. 5). It consists of a broad, flat maxilla, the inner edge, *i. e.*, that corresponding to the cutting toothed edge of the maxilla of *Apus*, but which is smooth, with fine, delicate, hair-like setæ; while appended to it on the hinder side is a large palpus with long, slender, stiff setæ. The same parts are represented by Dr. Gissler in the first maxilla of the larval *Streptocephalus texanus* (Plate XXXIV, fig. 6), where the maxilla without setæ and its stout palpus with two sets of setæ are represented. When the larva is 5 millimetres in length a considerable change has taken place in the palpus; one of the outer set of bristles has become barbed; while the inner set, originally composed of three setose bristles, is now composed of eleven setæ.

The second maxillæ.—In *Limnadia gigas*, according to Lilljeborg, the second pair of maxillæ are very much smaller than the first pair, and are rounded on the free edge, which is provided with long setiferous bristles and short stout ones.

In the advanced larva of *Estheria* according to Claus's "Untersuchungen," etc, Taf. xix, fig. 1, the second maxillæ are very small, slender, two-jointed appendages, consisting of two portions, apparently the maxilla proper and an outer, slender palpus.

In the *Apodidæ* no traces have yet been discovered of the second maxillæ.

In the *Branchipodidæ* they are present. Spangenberg figures them in *Branchipus stagnalis* as a pair of single elongated oval appendages, very minute, and ending in a long setose bristle, with a group of smaller setæ on the inside near the middle, next to the first maxillæ.

Gissler has figured them in *Streptocephalus texanus* (Plate XXXIV, fig. $6m^2$), where they are represented as oval bodies, with two setæ, having nearly the same form as in the adult *Branchipus stagnalis*, but less setose.

The maxillipedes.—These organs, which are here called maxillipedes because they bear a gill, are characteristic of the *Apodidæ* alone. No such appendages have been found in the *Limnadiadæ* or *Branchipodidæ*, and thus those of the *Apodidæ* may yet be proved to be homologues of the second maxillæ of those two families, true second maxillæ not existing in the *Apodidæ*, though it should be borne in mind that they constitute in the *Apodidæ* the second pair of appendages behind the mandibles, and thus occupy the place of the second maxillæ of the two other Phyllopodous families.

The maxillipedes of *Apus cancriformis* have been described and well figured by Lankester; we have found them as he describes in our specimens of this species, and also in *Apus himalayanus*.

We have also found them in *Lepidurus couesii* and *L. bilobatus*, the spiny inner appendage or first endite corresponding to the maxilliform coxal lobe (gnathobase of Lankester) of the succeeding feet.

Lankester says of this endital portion of the appendage, after speaking of the gill, or what he calls the "bract," "The other process is an oval chitinous plate, with long marginal setæ (*en'*); it may possibly represent the flabellum, but more probably one of the endites, perhaps endite 1 (the gnathobase). There is no means of deciding this point, for Claus gives but a very slight allusion to the early condition of this appendage in his account of the development of Apus."

On carefully examining our four American species of *Apus*, none were found to have the endite of the maxillipedes present, only the gill or exite being developed. It thus appears that in the absence of the endite of the maxillipedes, and in the nearly obsolete second antennæ, the American species of *Apus* have advanced, so to speak, a step farther than the Old World species of the genus, which have retained the *Lepidurus* condition; and in this respect as well as in the smaller carapace and the longer abdomen, the genus *Apus* stands above *Lepidurus*. The history of the maxillipede in the development of the early stages needs special research, as it will be most interesting to learn the date of its appearance, its structural changes during the metamorphosis of the individual, and the final disappearance of the endite in the American species.

The thoracic feet or bænopods.—Although the differences between the first eleven pairs of feet and those succeeding in the *Apodidæ*, or the thoracic feet and so-called abdominal feet in the *Limnadiadæ*, are but very slight, and they mainly differ as regards the abdominal members, in having genital openings situated upon one (the anterior) pair, so that on the whole the distinction seems artificial, yet when we ascend to the *Branchipodidæ*, where the abdomen is differentiated from the thorax, and has but a single pair of appendages (the gonopoda), it is easy to see that all the members in front of the external reproductive appendages may be properly designated as thoracic (bænosomal). We will, then, in this paper consider the external opening of the oviduct in the female, and the genital pore of the male *Limnadiadæ* and the *Apodidæ*, together with the gonopoda of the male *Branchipodidæ*, as indicating the line dividing the thorax (bænosome) from the abdomen (urosome).

In the *Limnadiadæ* the female bænopods are remarkably uniform in appearance; in the males, however, the first pair (*Limnetis*) and in *Estheria* and *Limnadia* the first two pairs have the fourth to sixth endites transformed into a grasping or hand-like extremity, whose structure is very interesting.

We will first describe the thoracic foot of the female, as it is simpler in structure than in the male. As seen on Plate I, figs. 3 and 4, Plate II, fig. 1, in *Limnetis* the axis or trunk of the limb is quite indefinite in outline, and is entirely subordinate in size and differentiation to the lobular outgrowths, the endites and exites.* In this respect the Limnadiad leg closely resembles the Cladocerous appendage, and in this characteristic the appendages seem clearly enough a direct bequest of the lower Branchiopods (*Cladocera* and *Ostracoda*). Considering first the inner or sternal series of lobes, *i. e.*, the *endites*, we can easily make out six endites, the normal number for all Phyllopoda. (See fig. 26 in text.) The first endite (fig. 1 *l′*, in other figures *cl*) we have called the coxal lobe (*cl*); it is the "*maxillarfortsatz*" of Grube, and corresponds, or is homologous with, the first *foot-lobe* of *Apus* of Gerstaecker, or the *gnathobase* of Lankester (Q. J. M. S., p. 348, 1881). It would be difficult, and a straining of homologies, to compare this with the coxopodite of a Decapod, as these endites are characteristic of the Branchiopoda, and do not exist in a completely jointed appendage, such as those of the Malacostracous or Copepodous Crustacea.

The gnathobase is large, long, and well developed in *Limnetis;* its long, sharp, stout spines nearly meeting those of its fellow opposite, over the sternal groove of the under side of the body, and serving admirably as maxilla-like organs for the retention of the food, and for passing it forwards to be crushed between the mandibular teeth guarding the mouth.

The second and third endites are broad, short, unequal lobes, the second the longer, and provided with long, delicate setulose setæ. The fourth endite assimilates in form to the fifth and sixth, being long and slender, though the setiferous edge is as extended as in the second endite. The fifth and sixth endites (l^5, l^6) are each very long and slender, and semi-jointed, a seta arising from each pseudo-joint.

The exite in this family is much more differentiated than in the *Apodidæ* or the *Branchipodidæ*, and the flabellum performs a variety of work besides respiration. In *Limnetis* the exite is divided into three portions; the gill, which is oval, pear-shaped, and moderately large, while the flabellum is differentiated into a dorsal or upper very large and broad (Plate II, fig. 1; Plate XXVII, fig. 3), or rather narrow (*L. mucronatus*) portion (*br′*), and a lower slender part (*br″*) which assimilates in form, and probably in function to the fifth and sixth endites of the same appendage.

In *Estheria* and also in *Eulimnadia* the relations of the dorsal division of the flabellum (which is narrow and slender) to the gill is seen in Plate V, fig. 1, and also in Plate XXIV, figs. 9 and 10. Some of those at the middle of the body serve to hold the eggs in place, for which function they are well qualified by reason of their great length, since they nearly meet over the back of the animal, and their long setæ seem to hold the

* The terms *endite* and *exite* were first proposed by Professor Lankester in his memoir on Apus, Q. J. M. S., 1881. We have extended the term to the outer lobes of the feet of Phyllopods in general.

eggs in place in the different genera of the family. On account of its holding or keeping the eggs in place, this portion of the flabellum may be called the *oviger*. These *ovigers* are best developed functionally near the end of the body, the eggs being grouped near the end of the dorsal edge of the shell.

In *Estheria* the gnathobase (Plate V, figs. 6, 7 cl^1, 7*a*) of the anterior bænopods is rather more complicated than in *Limnetis*. Fig. 7*a* represents one highly magnified. The inner edge is beset with rather stiff simple setæ, while those on the outer edge are thick at base, beyond slender and setulose. Similar hairs are seen on the gills (flabella) of the *Ostracoda* (*Cypris*, &c.) and in the endopodal as well as the exopodal portion of the feet of the *Cladocera* (*Daphnia*, &c.).

In *Estheria* the second, third, and fourth endites are equal in size, while the fifth is long and narrow, and the sixth shorter and broader, scalloped on the inner edge; the gill is large, the oviger long and narrow, while the lower lobe of the flabellum (br'') exactly repeats in form the sixth endite.

In *Eulimnadia* (Plate VI) the female endites 2–5 are quite equal in size and appearance while the sixth is finger-shaped in outline, like the end of the flabellum, and the gill (*br*) is very large. The hand of the male differs from that of *Estheria* in lacking the thumb-like growth on the fourth endite (en^4); while the diminutive flabellum (br'') does not reach to the base of the fourth endite, and the dorsal end of the flabellum is rudimentary.

Turning now to the first male bænopod of *Limnetis*, while the exite and their basal endites have undergone no modification, the three outer endites are curiously changed into a hand-like organ. The fourth endite is a long and broad lobe, with two rows of short, basally stout setæ. This lobe we call the comb or *pecten* (Plate II, fig. 2; Plate I, fig. 5). From the distal end arises a thumb-like moveable process provided externally with setæ. The fifth endite is modified into a curved fore-finger-like process with a few terminal setæ opposing the thumb; while the sixth endite forms a still longer and much larger finger, which is bent upon the entire hand and is not setose. These lobes arise from a distal chitinous specialized portion, which may be called the hand or manus, with its two "fingers" opposing the "thumb."

The second pair of bænopods are in *Estheria* and *Eulimnadia* modified in the same manner (Plate V, fig. 6); the chief difference being the narrower fourth endite, whose setæ are broad, stout, lancet-like (Plate XXV, fig. 3*b*). In the second pair of feet of *Estheria* the fifth endite differs from that of the first pair, and also the single pair of *Limnetis*, in being two-jointed (Plate XXV, fig. 3*a*, l^5); the end of the distal joint being slightly bulbous.

Claus represents the sixth endite or "claw" of *Limnadia stanleyana* from Australia as bearing a sucking disc; a similar disc occupies the same position in *Limnadia africana* Brauer and *L.mauritiana* Guerin. It thus seems to occur in certain species of *Limnadia*, but not in the American genus *Eulimnadia*.

Turning now to the appendages of the *Apodidæ*, we find it comparatively easy to homologize the different parts with those of the *Limnadiadæ*, though, as a whole, the apodid foot is the most peculiar, *sui generis*, of any phyllopods. The limbs of the European *Apus* have been studied with care by Professor Lankester in his paper on the appendages and on the nervous system of *Apus cancriformis;* and he has briefly compared them with the published drawings of other phyllopods, as well as of the Decapods. He regards the axial portion of the limb of

Apus as the *axis* or corm; and finds that the first and second pairs only are divided into joints—the first pair into four joints, and the second into two joints; the remaining pairs not being jointed. The figures in our Plates XVII–XX were drawn chiefly to exhibit the zoological differences of the appendages in our American *Apodidæ* without reference to the morphology of the axis, but since reading Professor Lankester's suggestive paper we have re-examined the appendages; and our observations teach us that, as he states, only the first and second pair of feet show traces of joints, and even these are such as to be easily overlooked, and should rather be styled pseudo-joints (or *pseudarthra*). Plate XXXI, fig. 4, shows the pseudo-segmentation of the axis of the first pair of feet in *Apus lucasanus*.

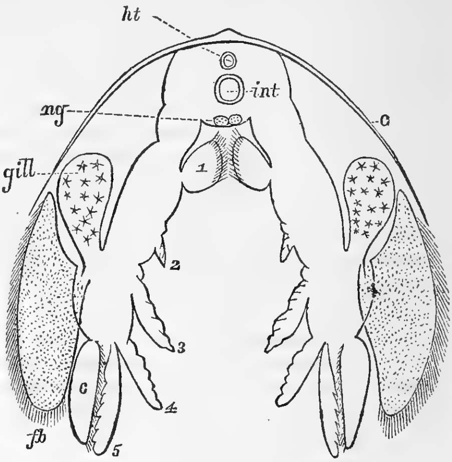

FIG. 26.—Section of Apus. *ht.* heart; *int*, intestine; *ng*, ganglion; *c.* carapace; 1–6, the six exites, 1 being the gnathobase; *gill* and *fb.* flabellum, representing the exites. Partly diagramatic.

As our figure indicates, the basal pseudo-joint (ax^1) bears the first endite or gnathobase; the second pseudo-joint (ax^2) is in our species reduced to a minimum, but the second endite rises from it; this joint is represented by Lankester as being much larger in the European species. The third joint is tolerably well marked, but its basal limits are not differentiated well from the outer part of the first joint. The third endite is thrown off by the third joint (ax^3) plainly enough. The fourth joint (ax^4) is a definite segment, and from it originate the fourth, fifth, and sixth endites. In *A. lucasanus*, however, the gill and flagellum plainly arise from the fourth joint; but according to Lankester's drawing of the same limb in *A. cancriformis*, these exites arise from the third joint. Taking into account, then, the incomplete nature of the two basal joints, and the fact that the succeeding pairs of feet are not jointed, we see that they share the nature of the feet in other Phyllopods, and that it is one of the characteristics of the Branchiopods in general, including the *Phyllopoda*, not to have truly jointed feet comparable with those of Copepods on the one hand or Malacostracous Crustacea on the other hand. On this account, while it may be safe to regard the basal joint of the anterior foot of *Apus* as perhaps the homologue of the coxopodite of Decapoda, we should not venture to go farther and homologize the succeeding more or less perfected joints with those of the adult Decapodous foot.*

But the jointed nature of the first foot of *Apus* and *Lepidurus* is valuable from a morphological point of view, as indicating that the endites are processes from the subjoints, as we may call the imperfectly differentiated joints, and do not in any Phyllopod form the joints themselves.

*Huxley's (Manual of the Anatomy of Invertebrated Animals, 1877) account of the nature and homologies of the foot of *Lepidurus glacialis* is somewhat inaccurate and misleading. He has torn away the feet represented in his fig. 63 E, F, from the body, leaving the gnathobase attached to the body; and this important and easily recognized part is not drawn; he figures five endites but counts them backwards, beginning with the sixth one. The gnathobase he briefly describes under the name of coxopodite. "Each appendage," he says, "consists of three divisions—an endopodite, exo-

The axis of the second pair of bænopods is composed of two joints, but we should not agree with Lankester's notation of the joints; the joint marked 1 includes what corresponds to ax^1 and ax^2 of the first leg; and his joint 2 (ax^2) corresponds to ax^3 and ax^4 of the first leg; in other words, of the two divisions of the axis of the second leg the first represents the two basal joints of the first leg and the second the third and fourth. So it seems to us the "joints" are more or less arbitrary subdivisions of the axis, and are not, properly speaking, true joints, hence we would call them pseudo-joints or subjoints.

Beginning with the endites, the first is transformed into a large, broad, thick, squarish lobe, whose inner edge is beset with dense fine, stiff setæ. This is the *gnathobase* of Lankester, and what we have called the coxal lobe (Plate XIX, fig. 3, elsewhere *cl*, or l^1). The gnathobase of each limb is diverted outward and backward, and thus, with those of the other limbs, forms a long series bordering the median sternal line of the body behind the mouth-parts, and which, as in the *Limnadiadæ*, serves to retain the food and to push it toward the mouth and jaws.

. We should not, as Professor Lankester appears to do, say that "a similar feature is characteristic of Limulus." The set of stiff spines in the Merostomata are developed directly upon the coxopodite or basal joint of the limb, which is directly homologous with the coxopodite of a crab, the resemblance to that of Apus is one only of analogy, though a very interesting one; the function, of course, being the same in each.

The succeeding five endites of the first pair of limbs are similar in form, being subjointed, the joints not, however, being complete and not movable upon each other, the sutures marking them only extending part way towards the middle of the process. The third, fourth, and fifth endites, particularly the fifth, are remarkably long and antenniform. The sixth forms a minute pointed scale, whose base is confluent with that of the fifth.

The gill in the *Apodidæ* is rather small and pyriform; while the flabellum is very simple in form compared with the *Limnadiadæ*, but still well provided with muscles, and, as in the latter family, forming the principal swimming as well as respiratory organs. They are triangular, the outer end rounded, the inner pointed and somewhat produced, but there is no such interesting differentiation in form and function as occurs in the Limnadiad flabellum.

Both exites and endites are remarkably persistent in form in the different species and are not of much use in taxonomy.

In the larva, $2\frac{1}{2}^{mm}$ long, of *Apus lucasanus*, as drawn by Gissler (Plate XXXV, fig. 7), which corresponds well with Claus's drawing of the same stage in *Apus cancriformis* I have added the references to the pseudo-joints (ax^1-ax^4). The gnathobase has two series of spines, the inner short; the sixth endopodite is seen to be very long and slender, while it is minute, short, and broad in the adult. The two spines at the end are noticeable, as there are four small ones in Claus's drawing. The flabellum is very much smaller than in the adult, while the gill is but little larger.

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podite, and epipodite, supported on a protopodite or basal division (fig. 63 D, E, F). The latter consists of three joints—a coxopodite produced internally into a strongly setose prominence (not represented in the figures), a basipodite, and an ischiopodite, the latter elongated internally into a lanceolate process, and bearing on its outer side two appendages, of which the proximal—the epipodite or branchia is pyriform and vesicular in specimens preserved in spirits. The distal appendage which appears to represent the exopodite (6) is a large flat plate, provided with long setæ on its margin." Huxley did not find the maxillipedes and second antennæ in *Lepidurus glacialis*.

In the second and succeeding thoracic pair of limbs the second to fifth endites are short and nearly equal in size, while the sixth is much larger than in the first pair, being nearly as long as the fifth endite and varying somewhat in the different species. In *Lepidurus glacialis* it is noticeably slender, as are the exites.

In the male of *Apus dispar* from the White Nile, the second pair of feet are curiously modified to serve as grasping organs, the notches along the edge of endites 2–5 being much enlarged so as to aid the animal in retaining its hold of the female.

A more generalized form of the leg is seen in the tenth and several succeeding pairs (Plate XVIII, figs. 1–4; XXI, figs. 1, 3, 4, 5), there being no difference in form between the last thoracic (tenth) and first abdominal (eleventh) legs; except the female eleventh pair and the fact that the eleventh male foot has the genital pore.

The tenth leg of *Apus lucasanus*, for example (Plate XVIII, fig. 3), or of *Lepidurus glacialis* (Plate XXI, fig. 1), has a portion or lobe of the axis, which Lankester calls the subapical lobe, which does not even exist in a rudimentary state in the first pair of limbs in *A. lucasanus*; nor does it exist in *A. cancriformis*, and is not to be seen in the larval limbs of *A. lucasanus* figured by Gissler, nor is it figured by Claus. Lankester regards this lobe as present in the second pair of thoracic feet of *A. cancriformis* and figures it, but states that it "is relatively small." We have not noticed it in the second pair of feet of any species of *Apus*, but have seen it in the second feet of *Lepidurus bilobatus* (Plate XVII, fig. 6), where it forms a lobe at the base of the exites.

In the tenth pair of feet of the different species of *Apus* this lobe becomes a large and prominent expansion situated between the base of the sixth endite and the flabellum. (Plate XVIII, figs. 2, 3, 4, *x*, and Plate XXI, figs. 1, 4, 5, no lettering.) The importance of this exital lobe becomes apparent when we examine the modified legs of the eleventh pair of the female. The history of this lobe in *Apus cancriformis* has been well related by Professor Lankester, and an examination of our American species shows that it is developed in all our species of *Apus* and of *Lepidurus*, much as he describes in the European *Apus*.

In the posterior feet this lobe finally becomes obsolete.

Under the rather ponderous name *oostegopod*, Professor Lankester describes the singular ovisacs or brooding-legs of the female and their mode of origin, with which our own observations on the American *Apodidæ* agree. On Plate XVIII, figs. 5, 6, 7; XXI, figs. 2, 6, are shown the forms of the eleventh pair of legs in the female of *Apus* and *Lepidurus*. The ovisac as originally shown by Zaddach, and more recently by Lankester, is formed by the great development of the subapical lobe, over which, as Lankester says, "the flabellum fits as a lid." Our lettering on Plate XVIII, fig. 7, was put on two years ago when making the drawings for the plate, and from hasty examination and overlooking the minute gill, which, however, is figured in this drawing, we supposed, with Gerstaecker, that the sac was formed by the flabellum and gill; but since the plate was figured Lankester's description has been published, and upon re-examination we have found the mouth of the egg-sac* (Plate XXXI, fig. 5, *os*).

*Brauer, in 1872, in his Beitrage zur Kenntniss der Phyllopoden, gives an account of the mode of copulation in Apus. "In the spring of 1871, a male was discovered among twenty ♀. The male swimming towards a ♀ turned under the ♀, placed itself firmly on the dorsal shield of the same, so that the whole body assumed a curved, almost humpbacked, position, and made repeated convulsive contractions. It then attempted, by feeling around with the end of its body over the hinder edge of the carapace of the ♀, to reach to it, and then threw several times and very rapidly the

Except the diminished size of the gill, the only other important modification in the foot is the large triangular sixth endite, which shares in part the enlargement of the subapical lobe.

In the *Branchipodidæ*, where the head, thorax, and abdomen are clearly differentiated, all the legs are thoracic, there being no abdominal appendages except the gonopoda and the cercopoda. The legs also differ much more from the two lower Phyllopodous families than those of the members of these two families from each other. The axial relations of the Branchipod limb are much as in the *Limnadiadæ*, the axis being not only entirely without any traces of joints, but not differentiated in any such way as in the *Apodidæ* from the endites or exites; in this respect the limb corresponds to those of the *Limnadiadæ*. The chief difference, however, from the two lower families is the absence of a functional gnathobase. The basal or first endite, as seen in the figures on Plates VIII–XIV, forms a very short and broad uniformly curved lobe with no armature at the base, the edge being uniformly fringed with very long, delicately setulose setæ; the lobe is weak and only adapted for swimming. By reference to Plate XIV, fig. 4, it will be seen, as in the genus *Thamnocephalus*, that the sternal groove along the under side of the body is broad, that the endites on either side are quite remote from each other, so as to be of little use in retaining the food or prey. This figure also shows the relations of the endites to the leg or axis, and of the leg as a whole to the body. The second endite is in general about one-third as wide as the first, while the third and fourth are minute, more or less pointed, and provided with three or four long setulose or ciliated setæ.

The great size and breadth of the fifth and sixth endites constitute a characteristic and diagnostic feature of the family. The fifth is very large and squarish or rounded, and armed on the edge with short remote spines. The sixth is more or less paddle-shaped, subtriangular, and provided with a fringe of very long and rather stiff setæ, being well adapted for use in swimming; this lobe, with the fifth, is mainly concerned in locomotion. The two exites, the flabellum and gill, are in this family much more alike than in the other two groups. The gill (*br*) in *Artemia*, *Branchinecta*, *Branchipus* is small, oval in outline, and much as in the *Apodidæ*, but in *Chirocephalus*, and especially in *Streptocephalus*, it becomes much larger, while in *Thamnocephalus* it is much like the flabellum (*br′*) in size and form as well as in structure.

It is interesting to observe, from the drawings of Claus and of Gissler, that in the development of the legs in the early larval stages the endites are the first to be developed, the exites not appearing until some time after the six inner lobes are indicated.

The abdomen and the abdominal legs (Uropoda).—These are not present in the *Branchipodidæ*, and in the *Limnadiadæ* and *Apodidæ* they do not

whole of the abdomen not covered by the shield over the edge of the carapace of the female to her ventral side. These motions were wholly similar to those made by the male Branchipus with its body during sexual congress, so that I have no doubt that the smaller individual was the male, and that the whole performance was none other than the fertilization of the gill-foot. The male repeated this act upon all the other females present through a period of several days. Then a pause ensued, whereupon the exhibition began anew.

During the act of copulation the egg-sac of the ♀ came in contact with the 11th feet of the ♂; but the whole occurrence was so short, the animals going under and turning themselves several times, that it was difficult to give a clear idea of the relation of the body parts to one another.

Through a later anatomical examination of the male I found my view completely confirmed. It was filled abundantly with testes-tubes, finger-shaped, the branches filled with seminal cells, as were described by Kozubowski. He then quotes Kozubowski's similar observations on the mode of copulation, from which Brauer's observations differ somewhat.

differ in any important respect from the thoracic limbs, since the abdomen in these families is not differentiated from the anterior part of the body. Indeed, if an abdominal leg were exhibited to us separately and placed side by side with a thoracic leg, it would be mere guess-work to distinguish them. The only distinction between the two regions, or the so-called abdominal and thoracic legs, is the fact that in the *Apodidæ* the eleventh pair contains the end of the oviduct of the female or *vas deferens* of the male. In the *Apodidæ* the gonopods or ovisac-bearing legs have been described.

Kozubowski has discovered and described the male outlet for the seminal fluid on the eleventh pair of feet of *Apus cancriformis.* The short *vas deferens* ends in a minute cup-shaped opening on the gnathobase or coxal lobe of the eleventh pair of feet. (Gerstaecker's Arthropoden.)

The abdominal legs succeeding the eleventh pair lose somewhat of their characteristic features, until the terminal pairs assume a generalized form; the endites, including the gnathobase, being equal in size and appearance except the last (sixth), which differs mainly only in being larger; the gill is small, while the flabellum is in proportion large and orbicular with a few large setulose setæ, instead of the fringe of fine, short, cilia-like setæ edging the exite.

As to *Limnetis*, Grube states that the narrow opening covered by a rather long lamella in the last three limb-bearing segments of the body may prove to be the male *porus genitalis.* The eggs are held in place by the ovigers of the last three segments in the female. The upper lobe of the flabellum of the last pair of feet appears, as seen in fig. 4 (in text), to be enlarged and modified to hold the eggs, and I have found the freshly extruded eggs held by the ovigers of the last three pairs of appendages, so that we may conclude that in *Limnetis* the last three segments of the body form what we may regard as corresponding to the abdomen, although the distinction is a somewhat arbitrary one.

In reference to the male opening in *Estheria* nothing is known, as Grube states. He thinks he found the opening of the oviduct of the female at the base of the ninth and tenth pairs of feet. Should the hole he discovered be proved to be the genital pore, then the part posterior to the eighth pair of legs should be regarded as abdominal; and thus, in this respect, the abdomen in its general relations would compare with the abdomen of the *Apodidæ.*

Spangenberg has discovered the genital opening in Limnadia. "The position of the [oviger] on the 11th pair of feet, as well as the general agreement in the structure of the Phyllopods, have enabled me to discover the hitherto hopelessly-sought-for sexual opening. It lies, certainly as in Apus, on the basal joint of the 11th pair of feet; but it is very difficult to find if the oviduct is not very full of the shell-forming secretion. Except the lengthening of its gill-appendages (oviger), which it shares with the two feet in front, the 11th foot undergoes no change with the reproductive function."

The last joint of the abdomen (urosome), viz, the *telson*, is only in one genus produced into a median spine-like process. This is seen in Lepidurus. This spine-like process is seen in the fossil *Phyllocarida*, and in common in the Malacostracan Crustacea.

The telson itself, particularly the tergal or spinous portion, in Lepidurus, as in Decapods (shrimps, lobsters, etc.), forms the roof or upper wall of the rectum, and may thus be functionally compared with the labrum of the head, which, like the spinous portion of the telson, is a median unpaired process. The cercopoda, on the other hand, may be homologized with the antennæ, being true appendages. This is especially seen in the cockroach and in *Mantis tessellata* (Guide to Study of Insects, p. 17, fig. 23).

The cercopoda.—We would suggest the name *cercopoda** for the caudal appendages of the Phyllopoda, which are outgrowths from the telson. There seems to be no such appendages of the telson or anal arthromere in the Malacostracous Crustacea, as the uropoda are developed on the segments anterior to the telson. But when we turn to the Entomostraca, we see that they occur, as a rule, in all Copepoda, where, in some genera (*Pontellina, Zaus, Thalestris*), they are two-jointed. These appendages then, in *Copepoda*, are true jointed appendages, arising from the end of the terminal segment of the urosome, and thus forming the last pair of abdominal appendages. In the order *Branchiopoda* the cercopods of the *Copepoda* are represented by the moveable, curved, slender, terminal claw of the telson; and this form persists in the higher *Limnadiadæ* (Plate III, fig. 7; *Estheria*, Plate XXV, figs. 5, 6), being absent in *Limnetis*. The long, jointed, style-like caudal appendages of *Apus* are also the homologues of the Copepodous cercopoda, as well as of the Limnadiad claw-like appendage. In the larva, as seen by Dr. Gissler's drawings, fig. 8, Plate XXXV, they are short and broad, and their cavity is continuous with the body-cavity. Late in larval life, as seen in fig. 9 of the same plate, a joint appears, and later on in adult life the cercopoda of the *Apodidæ*, as seen in Plate XVI, are nearly perfectly jointed, with short, stout setæ arising from the edge of each joint.

In the cercopoda of the Branchiopods we have reproduced quite exactly those of the *Copepoda*. So it appears that these appendages are restricted to the Entomostracous Crustacea, although they are also a characteristic feature of the *Phyllocarida*.

Histology of the postoral appendages.—The male hands of the first pair in *Estheria* and *Limnadia* present some peculiarities of interest. The finger-like two-jointed fifth endite of *Estheria mexicana* (Plate XXV, fig. 3*a*, l^5) is traversed by a thick nerve, which appears to originate from a multitude of nerve-cells, almost completely filling the distal joint. The latter when magnified by a Tolles $\frac{1}{5}$ A eye-piece (fig. 3*c*) is seen to be filled with rather large nerve-cells (*g c*), which are arranged serially. Between the rows of cells are apparently fine nerve-fibers, which have not been so distinctly indicated by the artist as in my original drawing. These fine fibers appear to arise near the terminal cells (*g c*) and probably originate in the seven setæ at the end of the joint. It is plain that this endite is the sensitive portion of the hand, though whether it is of any special sense and other than tactile may seem doubtful.

In *Estheria compleximanus* (Plate XXIX, fig. 5) and in the same joint of the fifth endite of the first pair of hands, when magnified by the same power ($\frac{1}{5}$ Tolles A), the main nerve is seen to traverse the joint, passing through a great number of very large nerve or ganglion cells (*gc*), which are not, however, arranged serially as in *E. mexicana*. The nerve appears to break up into a number of fibers which probably innervate the numerous fine cilia-like setæ at the end of the finger-like appendage.

In the first pair of legs of *Estheria compleximanus* (Plate V, fig. 7) the sixth endite is provided with nerve-cells and nerves which supply the setæ, as seen in Plate XXIX, fig. 3. Here the ganglion-cells are contained

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* We should also apply this name to the jointed anal stylets of insects such as the cockroach, Mantis, and other Orthoptera and Pseudoneuroptera, as well as the dipterous Chrysopila, and numerous other forms.

in the nerves, *i. e.*, forming ganglionic enlargements, while there is a marginal fine nerve which connects the ends of the setal nerves. The structure and arrangement of the nerves in the sixth endite of *Estheria* appears to be nearly the same as in the *Branchipodidæ*, described farther on, and the ganglion-cells are seen to be of the same size, the parts being magnified with $\frac{1}{5}$ Tolles A eye-piece. Plate XXIX, fig. 4, represents the end of the oviger of the same leg as fig. 7, Plate V. A ganglion and setal nerve supply each seta, while the main nerve passes through the middle, at *tn*, being reinforced by ganglion-cells; while at the end are several cells from which a nerve passes into each seta.

In *Eulimnadia texana* (Plate VII, fig. 2, 2*a*, 2*b*) where the fifth endite of the first leg of the male is provided with a minute palpus-like process, which was not observed in *Estheria*, the histological structure of the second joint is the same, though the nerve-fibers were not so distinct in the specimen examined; *Eulimnadia* differs, however, in the terminal setæ being coarser and much more numerous.

In the *Apodidæ*, from the nature of the dense opaque integument of the appendages, it is probable that no special sense-apparatus is present.

In the delicate swimming thoracic appendages of the *Branchipodidæ* some interesting histological features were observed, especially in legs stained with carmine.

In *Branchipus vernalis* the edges of the endites are provided with clusters of two or three ganglion-cells which are situated in the margin near the insertion of the setæ. These are noticeable in the fifth endites, but especially so in the paddle-like sixth endite. (Plate XXX, fig. 1.) This figure is drawn with the camera lucida and shows the relation of the muscles supplying it, and also of the peculiar system of ganglionic nerve-cells and nerves supplying the marginal tactile setæ. The striated muscular fibers are situated in the central portion of the foot (*muscle*); they suddenly terminate in the manner indicated in the figure, and originate from a median muscle passing out of the axis of the limb; associated with them are irregular groups of ganglion-cells.

The marginal ganglion-cells are arranged in two series: a submarginal set (nc^1) and a marginal set (nc^2). Whether the masses of parenchymatous matter filling the spaces between the two sets is truly nervous matter, or undifferentiated protoplasm, I cannot say, but, judging by fig. 3, it is probably nervous. At the base of the anterior margin of the endite where the setæ are reduced in size the submarginal series of cells disappear. Toward the posterior margin the setal nerves are seen to enter the setæ from a group of submarginal ganglion-cells. The connection of the submarginal and marginal series of cells and nerves with a main axial nerve of the leg was not observed, though several specimens were examined and search made for it, and hence I am inclined to think that the system of setal nerves and their cells is independent of the central nerve system.

In fig. 2 of the same plate is represented the sixth endite of one of the anterior legs of *Streptocephalus texanus*, in which there is nearly the same relation of parts as in *Branchipus*. The axial branches of the two muscles (*mus*) are seen to be in one case connected with the series of striated muscles in the central area of the endite. No main endital nerve was detected, and here, as in *Branchipus*, we see the same system of submarginal and marginal nerve-cells, and of setal nerves. The cells, however, are less numerous as seen in fig. 3, which represents the end of a bundle of striated muscular fibers; also their mode of termination, the space between the ends of the muscular fibers, and the submarginal nerve-cells (*nc*[1]). There is in each set but a single submarginal and a marginal nerve-cell (*nc*[2]). The two cells are connected by a broad nervous tract, and beyond the marginal cell the setal nerve continues into the base of the setæ.

In the sixth endite of the first pair of feet of *Thamnocephalus platyurus* the arrangement of the ganglion-cells differs somewhat from the other Branchipods described. As seen in Plate XXIX, fig. 8, there seems to be no marginal ganglion-cells, but a much larger number of submarginal cells, which are arranged serially, the outer row of the separate nerves forming a quite regular series parallel to the edge of the endite. The tactile nerves (*tn*) containing these ganglion cells pass into the setæ. There is also to be seen a submarginal row of minute setæ. The same histological nervous structure is seen in one of the smaller endital lobes, *i. e.*, the fourth (Plate XXIX, fig. 7). A nerve here evidently leads from the axis of the leg, and enlarges before reaching the large mass of ganglion-cells (*gc*) from which the setal nerves arise. It will be seen that the ganglion-cells are of the same size and appearance as in the end of the finger of the male of *Estheria compleximanus* (fig. 5).

The base of the flabellum of *Thamnocephalus*, as of all the genera in the family, are filled with large cells, rich in fat granules, as seen in Plate XXIX, fig. 8 *b*; while the polygonal cuticular cells of the flabellum are represented at fig. 8 *a*.

NOTES ON THE INTERNAL ANATOMY OF THE PHYLLOPODA.

It was not the author's design to make a special investigation of the internal anatomy of the Phyllopods, and the following notes on American species should only be regarded as supplementing what has been already published by Zaddach, Grube, and Spangenberg, which we have consulted and of which a *résumé* will be found in Gerstaecker's Arthropoden.

The general anatomy of Limnetis observed in *L. gouldii* while alive does not differ in any important respect from that of *Limnetis brachyura*, well figured by Grube, whose figure I have reproduced on Plate XXXI, figs. 6–8. The form and topographical relations of the digestive canal with the liver, and of the heart are the same in our species as Grube represents.

Our fig. 6 on Plate XXVI represents the structure of an ovarian lobe of *Limnetis gouldii*. The mass is filled with ovarian nucleated cells.

The digestive system.—An undeviating characteristic of the Phyllopods is the relation of the liver to the stomach and the peculiar way in which it is packed away in the head-cavity, enveloping the brain and filling the frontal cavity of the *Limnadiadæ* and of *Apodidæ*. The only other Crustacean except the Branchipods which have this characteristic is *Limulus*, and in this respect this animal closely resembles the Phyllopods.

In *Limnetis* the mouth (Plate XXXI, figs. 6, 8) is situated between the mandibles, as seen in our copy of Grube's figure, and the duct of the liver (Fig. 8, *liv.*) is seen to enter the digestive tract very near the short œsophagus.

In *Estheria mexicana* Plate XXXIII, fig. 2, shows the relation of the lobes of the liver to the common duct, and the connection of the latter with the rather large stomach. The cavity of the head is capacious, and filled with the convoluted lobules of the liver, of which transverse and longitudinal sections are shown in the figure. Fig. 2*a* is a still more enlarged view of one of the lobules, there being a single layer of secreting nucleated cells.

The relations and cellular structure of the œsophagus of the same species are seen in figs. 1, 4, *oes*, and 4 *a*. A section of the œsophagus where the microtome passes through the brain and larval ocellus shows that the walls of the œsophagus are formed above of two layers of epithelium and beneath of three or four, the serial arrangement of the cells below not being so marked as above.

In Fig. 1 we see that the razor passed through the œsophagus and the intestine, the section being oblique, and the digestive canal curving considerably in the front part of the body, so that it is cut through twice. The comparative size and general relations of the intestine to the other viscera are seen in figs. 9 and 10 of Plate XXIV.

In the *Apodidæ*, as seen in Plate XXXII, figs. 1 and 2, the mouth is situated between the mandibles. The œsophagus is narrow and very oblique, while the rest of the digestive canal is large and of quite uniform thickness. The cavity in fig. 1 is the body-cavity, after the digestive canal has been removed; but that its body-cavity is completely filled by the digestive canal is seen in fig. 2 *int*. The intestine gradually contracts towards the narrow rectum, the anus (*an*) being small and situated rather dorsally than ventrally, as in most, if not all, Anthropoda, and opening between the bases of the cercopods.

In living examples of *Artemia gracilis* (Plate XXIII, figs. 1, 2), the œsophagus is very short, while the stomach is situated in the head. The stomach is apparently divided by a medio-longitudinal constriction into two large sacks or pouches, these being the ducts to the liver, which has a few short lobules, the liver being much less voluminous in the *Branchipodidæ* than in the two lower families.

The intestine we regard as that portion lying behind the liver. It is divided into two portions, one in the head and thorax (bænosome), and the other in the urosome. The anterior or cephalothoracic portion is a large, straight tube with thin walls, and is of nearly the same thickness throughout its length (fig. 2 *int*). It contracts at the base of the urosome and forms a slender tube one-half the diameter of the anterior portion (fig. 3, *int*), ending in a well marked rectum (*rec*), which is provided with constricting circular muscles, and held in place by three sets of slight muscular threads (*m*). It does not contract at the vent.

The ovaries.—The relation of the genital glands, particularly the ovaries, are seen in Plate XXXI, fig. 7 (*Limnetis* after Grube); those of *Estheria mexicana* in Plate XXXIII, figs. 1 and 6. The ovary in *Limnadiadæ* forms a rather large mass, situated in the body behind the head. Fig. 6, Plate XXXIII, represents a portion of the ovary of *Estheria mexicana*, showing the epithelial or ovarian cells (*ep*) and the developing egg. It forms a compact mass, situated on each side and below the intestine. The ovary in *Apus lucasanus* (Plate XXXII, fig. 1 *ov* and 2 *ov*) forms a loose mass, extending from the region over the mouth to the last pair of uropoda. Its general appearance and histology is well shown in the figures of Siebold in his work on parthenogenesis in Arthropoda (Taf. II).

When we ascend to the more specialized *Branchipodidæ* we see that the genital glands are restricted to a special sac, which grows from the under side of the basal uromere. We have nothing new to add to the descriptions already given by European authors. Plate XXII, figs. 2, 2*a*, 2*b*, 3, 4, 4*a*, from drawings by Dr. Gissler and myself, give the general relations of parts in *Artemia gracilis* and *Branchipus vernalis*, and for particulars regarding certain points the reader is referred to Dr. Gissler's remarks further on, and to the explanation of the plate. In fig. 2 (*Artemia*, drawn from living specimens) the ovaries are without any ovarian eggs, the cells representing simply the epithelium. The ovary sends two slender attachments into the last bænomere, and two larger tubular prolongations into the second and third uromere. The oviducts (*e*) are just large enough to contain a single egg (Fig. 2*b*, *egg*) at one time. The glandular cells secreting the chorion are represented at 2*a* and 2*b*, *ec*. They are about $\frac{1}{5}$–$\frac{1}{6}$ the diameter of the mature egg, and have a very distinct nucleus.

The heart.—In the *Limnadiadæ* the heart of *Limnetis* is a short, thick tube, as represented by Grube (see our Plate XXXI, fig. 6, *ht*), and does not extend far back in the body. In the section of *Estheria mexicana* (Plate XXIV, fig. 9), which passes through the antennæ, the heart is seen to be present, but in *E. compleximanus*, fig. 10, it does not appear to reach far behind the anterior pairs of bænopods.

In *Apus* the heart has been figured and described by Zaddach, our fig. 6, Plate XXXII, being copied from his work, and in our fig. 1 the heart is represented diagrammatically, the drawing not being strictly accurate in some respects. The size of the heart of *Apus lucasanus* in relation to that of the intestine is seen in fig. 2, which is a camera drawing. The walls are thick and muscular.

In the *Branchipodidæ* the heart is much larger than in the *Apodidæ*, as seen in Plate XXIII, figs. 2, 3, 3*a*, and 4, drawn with the camera from living specimens of *Artemia gracilis*. The heart extends from a point just below the mandibles, and extends as a long, slender tube to the middle of the terminal uromere. In fig. 2 the anterior end of the heart is represented conjecturally, as we could not see the exact mode of termination or the origin of the arteries;* but the valve at the posterior end was readily made out as at 3, *ht*, and 3*a*, where a treble valvular arrangement allows the blood to enter, and is closed at the time of contraction of the heart. Two lateral arteries are sent off to the shell-gland, and there is a median notch or ostium in front. The lateral valvular openings are more numerous in front than at the end, as the last pair of valvular openings is situated a long distance from the end of the heart, as seen in fig. 3. As seen in fig. 4, the heart is loosely held in place by slight muscular bands (*m*), and along the outer walls of the heart are scattered rounded epithelial cells (*ep. c*). The valvular openings, indicated in the figures by the arrows, are arranged alternately. The size of the blood-corpuscles, which are colorless, is shown in the figure. The blood flows into the heart through the valvular openings, and is pumped out of the anterior end and passes into the head by two currents, while a current on each side passes backward, thus indicating the existence of two anterior arteries and a pair extending downward and backward. The circulation in the eye is readily observed, and is indicated by the blood-corpuscles and arrows in fig. 6. The mode of circulation in one of the feet is illustrated by the blood-corpuscles and arrows in fig. 7 (Pl. XXIII). The blood flows directly toward the end of the sixth endite, while a portion passes around the edge of the gill; the circulation is more active in the gill proper than in the flabellum. The blood passing into the sixth endite along the upper side, returns by the lower edge; a current, entering the fifth endite, passes along the upper and returns by the lower edge; a current also enters the basal endites. Each

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* The anterior end of the heart in the young *Apus* is well shown by Claus in fig. 6, Taf. VIII, of his elaborate memoir.

endite has its distinct blood passage, and thus respiration takes place all through the appendage.

The nervous system.—The nervous system is quite uniform in the Phyllopods, and that of *Limnetis* has been described by Grube, that of *Limnadia* by Klunzinger,* and more lately by Spangenberg, and that of *Apus* by Zaddach, while the brain and nervous cord of the young *Branchipus stagnalis* has been figured and described by Claus.

Our Plate XXXI, fig. 8, copied from Grube's drawings, illustrates the nature of the brain and nervous cord of the European *Limnetis brachyura.* The brain is very small, forming a single flattened mass from which the large optic nerves arise. The first antennal nerves arise from the beginning of the commissure, which forms an œsophageal ring, and the second antennal nerve arises opposite the transverse commissure, which com pletes the œsophageal ring behind. Then succeed the peculiar ladder-like ganglionated ventral cord; from the two anterior ganglia arise respectively the mandibular and maxillary nerves, the third pair of ganglia supplying the first bænopods.

The anatomy of the nervous system of *Limnadia hermanni* has been fully described by Spangenberg,† but unfortunately he has given no illustrations. The following account is translated from his paper:

"The nervous system of *Limnadia* shows the greatest agreement with that of *Apus.* It has a primitive, embryonal character, as that of *Apus.* This is seen in the ganglions of the second antennæ. These are in most Crustacea united in a common mass with the brain. In *Limnadia* not only the ganglion-swelling, but also the two transverse commissures uniting them preserve their original form, and the ganglion pair of the second segment differ here in no important point from that of the other segments, except in the lip-commissure springing from it. There also remain the ganglia of the ventral cord in the last body segment, both longitudinally and transversely well separated from each other, while in *Branchipus* and *Artemia* they are not more perfected, but in *Apus* suffer a widespread consolidation.

"The central nervous system of *Limnadia* consists, as that of all Phyllopods, of a two-lobed supraœsophageal ganglion before the œsophagus—scarcely properly called a brain—and right behind the œsophagus, between the digestive canal and floor of the body a ladder-like ventral chain of 26 ganglia, the tail segment being without a ganglion.

"*Brain.*—The supraœsophageal ganglion consists of two spindle-shaped lateral lobes and one unpaired median section. All these possess their own centers and send out the nerves originating from them. Such centers are five in all, four arranged in pairs in the lateral lobes, the fifth unpaired in the middle lobe.

"Of the two paired centers the foremost is by far the largest; it serves as the central organ for the optic nerve, the eye-muscle nerves, and furnishes the nervous tract reaching to the so-called larval eye. The smaller, situated somewhat farther behind, lying under and external, sends fibers to the first antennal nerve. What significance the *bean-shaped central body* of the middle lobe, met with in all Phyllopods, has is not clear to me. It lies perpendicular to the longer axis of the animal in the hinder third of the middle lobe between the commissural threads passing from one lateral lobe to the other. From all sides pass curved nerve-fibers into it, which are variously covered and intertangled with one another. It consists quite unlike the paired centers of large ganglion-cells, but solely of the so-called Leydig's *punctsubstanz*, a confused mass of the finest fibers variously matted together. Whether,

* See his figure in Sieb. u. Köll. Zeits. w. Zool. XIV, Taf, XIX, fig. 26.
† Zeitschrift für wissensch. Zoologie. Supp. 1878.

however, nucleus-like bodies occur on the points of intersection, I have not yet been able to discover. In the profile view of the animal the central body appears exactly as in the *Daphnidæ*, in the form of a clear round vesicle in the feeble (*matten*) brain-substance, and can thus give ready opportunity for illusion. An independent vesicle, such as Claus describes in *Daphnia magna*, I have not seen here.

"From the lateral lobes of the supraœsophageal ganglion arise the following 5 nerve-pairs:

"1. The large optic nerve.

"2. Several nerve-twigs to the eye-muscles.

"3. A slender fiber on each side to the frontal organ.

"4. First antennal nerve.

"5. The 'hirnschenkel.'

"From the middle division arise only 3 paired and an unpaired nerve, viz:

"6. An at least externally unpaired nerve, and

"7. A paired nerve-stem, both to the so-called larval eye.

"8. An outermost fine fiber on each side, which arises laterally from the seventh pair, and goes above and outside of it.

"9. A slender pair of nerves to the œsophageal musculature.

"Of these nerves Zaddach (*Apus*) knew only those mentioned under 1, 4, 5, 7, and 9, but as they occur also in *Branchipus* as well as in several *Cladocera* investigated by me, there can be no doubt that they are present also in *Apus*, and were overlooked by him."

Spangenberg then describes the *ganglion opticum* and eye.

Ventral ganglion chain.—The second cephalic or first ventral pair of ganglia, which lie on the side of the œsophagus, are the second antennal ganglia. This ganglion, and the 2d antennal nerve which arises from it, is figured by Klunzinger.

Then follows the mandibular and then the maxillary ganglia. These are succeeded by 22 pairs of ganglia.

There is probably no essential difference between the nervous system of *Estheria* and *Limnadia*. From a number of sections of *Estheria mexicana* kindly made for us by Mr. N. N. Mason, we have drawn figures 1, 2, 4, and 5, Pl. XXXIII, which partly illustrate some points in the structure of the nervous system. Fig. 2 represents a section which evidently passed through the brain (*br*). It is seen to be a double ganglion, with the hemispheres more distinctly marked than in Grube's representation of that of *Limnetis*. Fig. 1 and the enlarged view, Fig. 4, passes through a ganglion, which we take to be the brain. The section must have been very oblique, as the œsophagus is seen to appear as if situated above the brain. The section passes through the larval ocellus, whose cones and pigment mass have still survived, though sunk out of sight under the integument.

Fig. 5 represents a ganglion posterior to the maxillary ganglion, and probably supplying the nerves to the first pair of feet, and situated directly under the intestine, the epithelium of which is shown in the figure. The histological structure is seen to be very simple. The ganglion consists of scattered ganglion-cells and fine granules, which may be the ends of fibers, but no distinct fibrous structure was to be detected. The brain, fig. 4 *br*, and fig. 2 *br*, is apparently no more complex in its histological structure than the ventral ganglia.

A good deal of time was given to attempts to work out the nature of the brain, but though Mr. Mason very kindly made sections of a number of specimens of *Estheria*, *Apus*, and different fresh *Branchipodidæ*, yet owing to the inherent difficulties in the nature of the investigation very poor success attended our efforts. The brain lies, as seen in fig. 2, in the midst of the liver, and in the process of cutting through the head the brain slips aside from or crumbles before the edge of the razor. Of course the only proper way is to remove the brain from the living animal and properly prepare it for the microtome; but this is next to impossible owing to its small size. Indeed, the difficulties in the way of making a good dissection of the brain of these creatures, particularly *Apus*, are very great. After working for some time at the brain of well-preserved *Apus lucasanus*, we were able to satisfy ourself that the drawings and descriptions of Zaddach in his classical work on *Apus cancriformis* are correct, although his drawing of the entire ventral chain (his Tab. III, fig. 1) might be improved; his representations of the brain are undoubtedly correct enough for all practical purposes, and we have copied in Plate XXXII three of his excellent figures. The figure of the entire nervous system of *Apus lucasanus* (Plate XXXII, fig. 1) was drawn by Mr. Kingsley, and adopted with some important corrections in the position and form of the brain. The sketch is necessarily in part diagrammatic, and no nerves to the appendages are represented. As seen in the copies of Zaddach's figures the brain is small, situated right under the compound eyes, and it innervates only the simple eye or ocellus and the compound eyes. The nerves to the two pairs of antennæ, fig. 5 (ant^1, ant^2), arise from the commissures, and not from the supraœsophageal ganglion. The rest of the nervous cord is ladder-like.

In the *Branchipodidæ* the nervous system shares with the other systems of organs in a general advance to a higher plane of organization. According to Claus excellent figures of the brain, especially of the very young *Branchipus stagnalis*, the nerves to the first and second antennæ arise from groups of ganglion-cells situated on the outside of the commissures, the ocellus and two stalked eyes being innervated from the brain as in all other Phyllopods, and it will probably be found that in the early stages the commissures are provided with ganglionic enlargements from which the appendages of the head are innervated; thus there may be a slight resemblance in this respect to the ganglionic œsophageal ring of Limulus.

We have, then, in the subœsophageal ganglion of all the Phyllopods a simple, small ganglion, no more differentiated than those forming a part of the ventral cord. Plate XXIII, fig. 1, gives a vertical view of the brain of the adult *Artemia*, which is nearly continuous with the optic ganglion. On Plate XXXIII, fig. 8, is represented a section of the small brain of *Branchipus vernalis*. It is very simple in structure, the ganglion cells small, scattered, and indistinct. Fig. 8*a* shows the ganglion cells enlarged. No fibers appear, though more careful observations than I was able to make are needed before we can have a complete knowledge of the brain of the supraœsophageal ganglion in the Phyllopods.

For the structure of the abdominal portion of the nervous cord the reader is referred to Leydig's account and his figure in Tafeln zur Verg. Anatomie, Taf. V, fig. 5.

It is apparent, however, that in the Phyllopoda the brain is a very simple affair, and not much higher in complication of structure than the brain of worms, and when we compare it with the brain of the Decapods, or at least that of the crayfish and lobster, these alone having been studied, we are comparing two very different organs. The brain of the Decapoda is an aggregate of at least two pairs of ganglia besides the primitive pair innervating the eyes. The extreme degree of cephalization, by which the head becomes more compact and homogeneous, has had its resultant effect upon the primitive brain and the ganglia behind it, and thus the brain of the shrimp or crab represents the brain of the Phyllopod *plus* the œsophageal ring of the latter. We have seen that in the larval Branchipus the two pairs of antennal nerves actually do arise from masses of ganglion cells. These two masses may form the two pairs of antennal lobes in the Decapodous brain, which is therefore probably an aggregate of three pairs of ganglia.

The brain of the Phyllopods is more primitive than in the Cladocera. Claus'* figures of the brain of *Daphnia magna* show that the first antennal nerves arise from the brain, while the second antennal nerves arise some distance back from the succeeding pair of ganglia.

In the *Calanidæ* there is a distinct brain from which arises the first antennal nerves, while in the *Corycæidæ* the ventral cord is fused with the brain.

It will thus be seen that the Phyllopods possess the simplest, most primitive form of brain, characterized by the lack of antennal nerves. If we were to confine ourselves simply to the *Apodidæ* and *Branchipodidæ*, in which the body is much elongated, we should attribute the want of concentration of the brain peculiar to the Phyllopods as due to the elongation of the body and to the exceptional number of arthromeres composing the body, but we see the same structure and form of the brain in *Limnetis*, the most generalized form in the suborder, where the body in lack of differentiation approaches the Cladocera. Hence the nervous system of the Phyllopods does not seem to have been borrowed from the Crustacea standing below them.

The brain of the *Apodidæ* is called by Lankester, in his paper on Apus, an *archicerebrum*, while the composite brain of "all Crustacea, excepting Apus, and possibly some other Phyllopods," he denominates a *syncerebrum*. As to the nature of the brain of Limulus, Professor Lankester states that "the only other case amongst adult Arthropods, in which it appears with certainty that the so-called cerebral ganglion is a pure archi-cerebrum, is that of Limulus," although he adds (p. 375), "I should wish, however, to guard against the inference that I consider any close affinity to obtain between Apus and Limulus."

We are disposed to agree with the view that the brain of Limulus is a genuine archi-cerebrum, comparable with that of the Phyllopods, and regard this as corroborative proof that Limulus is a Crustacean rather than an Arachnidan, no true archi-cerebrum being known to exist in adult Arachnida. Furthermore, in the œsophageal ring of Limulus, which is fundamentally made up of ganglia with cross-commissures, it appears to us that we have a parallel to the ladder-like arrangement of the postoral head-ganglia of the Phyllopods.

The histological structure of the archi-cerebrum of *Limulus* is more complicated than in that of the Phyllopods, which, so far as we have been able to see, is slightly more complicated than the brain of the Chætopods, judging by Leydig's excellent figures (Taf. IV).

The following provisional grouping of Crustacean brains appears to be justified by known facts, although, except the brain of Decapoda and Limulus, no special histological work has been accomplished:

Syncerebrum:
- Decapoda.
- Tetradecapoda.
- Phyllocarida.
- Cladocera.
- Entomostraca.
- Cirripedia.

*Zur Kenntniss der Organization und des feinern Baues der Daphniden und verwandter Cladoceren. Von C. Claus. Zeit. wissen. Zool. XXVII, 1876, 362, Taf. XXVI, figs. 8–10.

Archicerebrum { Phyllopoda.
Merostomata (Limulus).

The syncerebrum of the Tetradecapoda (Amphipoda and Isopoda), judging by Leydig's figures[1] and our own observations (from dissections made by Mr. J. S. Kingsley) on that of Idotæa and Serolis[2], is built on a different plan from that of the Decapoda. The syncerebrum of the Phyllocarida is somewhat like that of the Cladocera and Copepoda (Calanidæ); being essentially different from that of the majority of the Malacostracous Crustacea.

The Copepodous syncerebrum is an unstable, highly variable organ, but on the whole belongs to a different category from the syncerebrum of other Neocarida.

We have then, probably, three types of syncerebra and two types of archicerebra among existing Crustacea.

HOMOLOGIES OF THE CRUSTACEAN LIMB.

Comparison with limbs of Cladocera.—We should naturally first compare the appendages of the Phyllopods with the members of their own

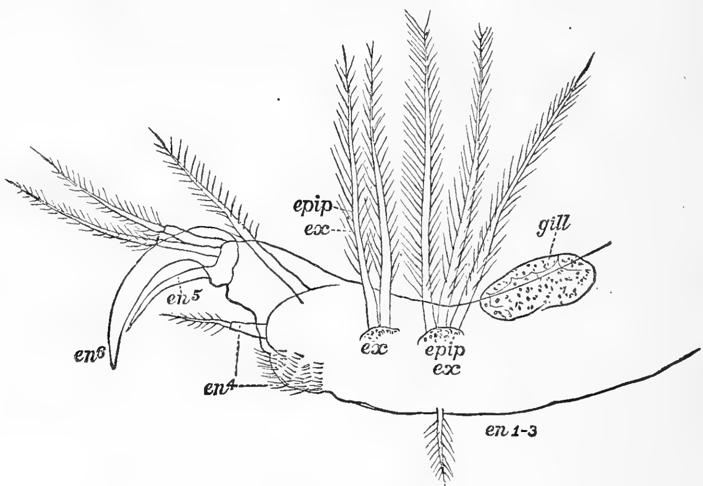

FIG. 27.—First leg of male of Moina (for comparison with that of male Limnetis): *ex*, exite; *epip*, epipodal portion of limb; *en*4–*en*6, endites 4-6, to compare with the endites forming the hand of the male Limnetis. The base of the endopodal region (*en* 1–3) not differentiated as in the Phyllopod limb.

order, and especially the *Cladocera;* and here, whether we consider the carapace-valves, the eyes single and compound, the two pairs of antennæ, or the telson, we find a very close connection in form between *Limnetis* and *Daphnia* or *Moina*. In the accompanying figure from Grube's and Weismann's excellent paper on the Daphnidæ[3] (which we have slightly modified, introducing dots in the branchial portion) may be seen how nearly the first leg of the male of *Moina rectirostris* agrees with that of the male *Limnetis*, as seen in the sixth endite forming a claw like that of *Limnetis*, although the flabellum is not clearly dif-

[1] Tafeln zur Vergleichenden Anatomie. Von F. Leydig. Tübingen, 1864.
[2] Zoology for High Schools and Colleges, figs. 255, 256.
[3] Ueber einiger neue oder unvollkommen gekannte Daphniden. 1877.

ferentiated from the endopodal portion of the limb. But when we look at the third pair of limbs of the female of the same Cladoceran (fig. 28), we find an epipodal portion (flabellum [*ex.*] and gill) differentiated from the endopodal portion of the limbs. The endopodal

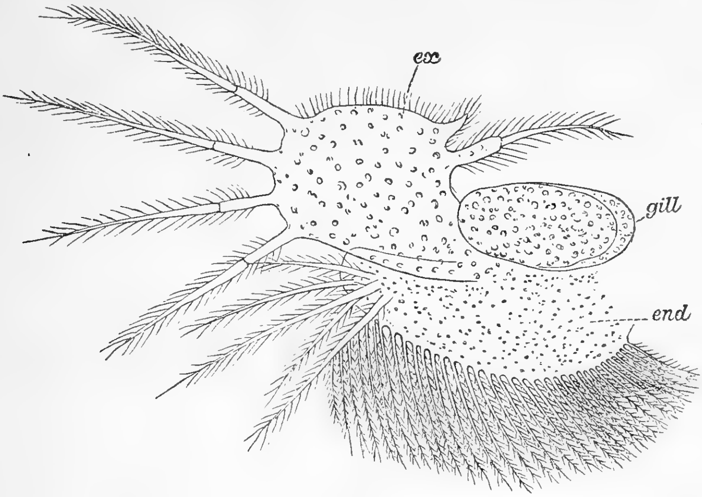

FIG. 28.—One of the third pair of limbs of Moina: *end*, the endopodal portion; *ex*, the exopodal (epipodal) portion of the limb.

portion in the *Cladocera* is not differentiated, not forming a number of well-marked lobes or endites, as in the Phyllopoda, this differentiation into six endopodal lobes being peculiar to the *Phyllopoda.*

The Cladocerous limb is intermediate in form and complication between the Phyllopodous and Ostracodous limbs, and the latter are evidently derived from the Copepods, so that there is a continuous ascending series from the Copepoda through the Ostracoda to the Cladocera, and thence to the Phyllopoda. Hence, as the young of the Copepoda are all Nauplii, and also those of the Phyllopoda, it follows that the ancestral form of all the Entomostracous Crustacea, as originally insisted on by Fritz Müller (Für Darwin), was a nauplius-like animal.

Comparison with the Decapodous limbs *—Having studied the homologies of the Phyllopodous limbs among themselves, and also compared them with those of the Cladocera and Ostracodes, it remains now to compare the thoracic appendages of the Phyllopods with those of the adult *Decapoda.* At the outset, however, it seems nearly impossible to compare the swimming legs of the Phyllopods with the abdominal and thoracic appendages of Decapods. The thoracic Decapodous legs are axially jointed, consisting of an axis or protopodite, which is wanting in the Phyllopoda and all lower Crustacea, with no endital lobes as in Phyllopods, though the gill and flabellum of the Phyllopods are homologous with the gills and flabellum of the Decapod. There is no such relation or close resemblance as to lead us to infer that as regards the nature of the thoracic and abdominal feet the Decapods have descended from the Phyllopods. The Decapods have probably come down to us by a different branch of the Crustacean ancestral tree, and have arisen entirely independently of the Phyllopodous branch, by a line leading

* In comparison with those of the Nebalia, the reader is referred to the last chapter on *Phyllocarida.*

back directly to the ancestral Nauplius, the common ancestor of all the *Neocarida*.

Nor does it seem to us that this statement or hypothesis is weakened when we consider the resemblances between the thoracic feet of the Phyllopods and the maxillæ and maxillipedes of the Decapoda. When we compare the leg of a Phyllopod with the second maxillæ* of the lobster or cray-fish, we can detect a close homology, the chief difference being in the fact that the lobes of the endopodite are less numerous in the Decapod than in the Phyllopod. This close resemblance is based on the fact, which appears to have been overlooked by Claus and Lankester, *i. e.*, that, as in the Phyllopodous limb, the maxillæ of the Decapods have no jointed axis, the limb consisting of epipodal and endopodal portions alone, the stem or axis being wanting. In the maxillipedes, where part of the endopodal region of the limbs becomes, as Lankester claims, two multiarticulate endites, the fifth and sixth; or, as in the thoracic leg, becomes a single seven-jointed endite, the homologies cannot with certainty be traced. The lobster's thoracic leg consists of the jointed axis which is the homologue of perhaps the fifth endite of the Phyllopodous foot, and the complicated gills and gill-fan (scaphognathite) correspond to the gill and flabellum of the Phyllopodous leg or flabellum.

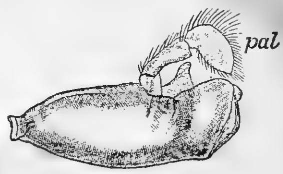

FIG. 29.—Mandible of the lobster, *Homarus americanus*: *pal*, palpus.

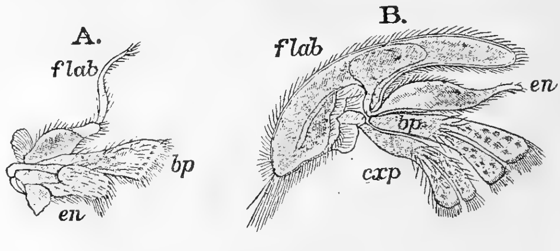

FIG. 30.—A, first maxilla of lobster; *en*, endopodite; *bp*, basipodite; *flab*, flabellum. B, second maxilla of lobster; *bp*, basipodite (epignathus); *cxp*, coxopodite. (This appendage, with its five endopodal lobes, approximates nearest to the Phyllopod limb.)

In brief the maxillæ of the Decapoda most closely resemble the leg of Phyllopods. The maxillipedes, for example those of the third pair, are much more differentiated than the limbs of the Phyllocarida or Phyllopoda. In the Decapoda the gill and flabellum are homologous with those of the groups just enumerated;

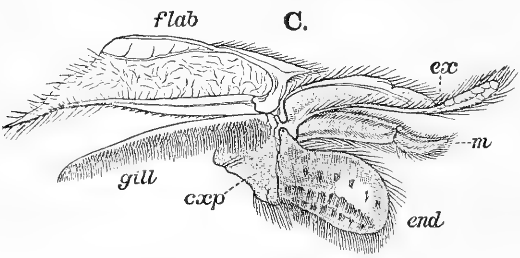

FIG. 31.—C, first maxillipede of lobster.

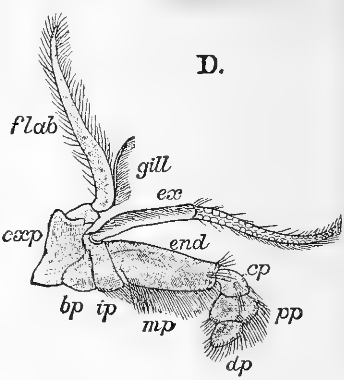

FIG. 32.—D, second maxillipede; *ex*, exopodite; *end*, endopodite; *flab*, epipodite or flabellum, or scaptogathnite.

* The resemblance to the second maxillæ of the young lobster in its first stage when freshly hatched is still more striking. See Smith's Early Stages of the American Lobster, Pl. XVI, fig. 4.

while the endopodite and exopodite of the Decapoda represent the endopodal portion of the limb of the lower groups. There is in the Phyllopoda no division into a coxopodite and basipodite or stalk, from which two axially jointed divisions branch off, homologous with the exopodite and endopodite of the Decapoda. In the latter the max-

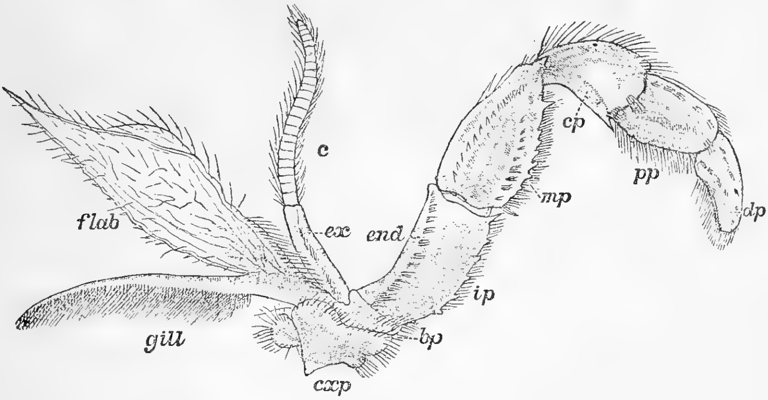

FIG. 33.—B, third maxillipede; *cxp*, coxopodite; *bp*, basipodite; *ip*, ischiopodite; *mp*, meropodite; *cp*, carpopodite; *pp*, propodite; *dp*, dactylopodite; *c*, multiarticulate extremity of exopodite or palpus; *flab*, epipodite.

NOTE.—The maxillæ and maxillipedes of the lobster are drawn in their natural position; so far as possible the exopodal portion (gill and flabellum) dorsal, and the endopodal portion ventral to compare with the Phyllopod limbs. (Compare Plates xxiv and xxxii and Fig. 34. Apus.)

illipede is highly differentiated; in the thoracic limbs of the Phyllocarida and Merostomata it is uniaxial and jointed, but in the Phyllopoda not truly jointed. In the simplest Decapod limb, that of the abdomen, we have a stem succeeded by two divisions, the exopodite and endopodite; in the thoracic feet we have but one of these branches, the endopodite, while in the maxillipedes, the most differentiated, we again have a stem and two branches (endopodite and exopodite), together with the gill and flabellum. Thus the entire leg of the Phyllopod (without the gill and flabellum) is homologous with the endopodite of the Decapod maxillipede, and the gill and flabellum with those of the Decapoda.

Comparison with the thoracic limbs of Nebalia (Phyllocarida).—Not to enter into detail, by a glance at the accompanying figure (36) and the figures in Plate XXXVII, as well as the wood-cuts in section VII, it will be seen that the thoracic appendages of *Nebalia* consist of an inner axial, jointed portion (the endopodite), which may perhaps be regarded as homologous with the endopodite of the Decapod maxillipede, and also with the thoracic legs of the lobster. This also corresponds to the endopodal unjointed portion of the Phyllopod thoracic limb. In the exopodal or respiratory portion (*ex*) the upper part corresponds to the Phyllopod gill, and the double lower portion to the flabellum.

Comparison with the feet of Limulus (Merostomata).—The resemblance between the abdominal legs of Limulus and the thoracic ones of Nebalia is apparent on inspection of figs. 36 and 37 (p. 409). In Limulus the shell flares out widely and the appendages are united in the middle, although separate in embryonic life, so that this is a feature of secondary importance. The point of special interest is that the abdominal feet of Limulus may, as in the thoracic appendages of the *Phyllopoda* and of the *Phyllocarida*, or the maxillæ, maxillipedes, and thoracic feet of the Decapoda, be divided into an inner endopodal portion (whether ambulatory or natatory), and an outer or respiratory portion, as in *Nebalia* and Decapoda. The endopodite of Limulus (*en*) is axially jointed, there being three well-marked joints to this part of the limb. The branchiate portion of the limb (*ex*) is homologous with that of Nebalia, and the epipodital or branchiate portion of the Decapod thoracic limb. At the same time that of Limulus presents some remarkable peculiarities, *i. e.*, the exopodal (or epipodital) portion is jointed; and the gill, instead of being a simple fan-like extension, as in the Phyllopoda and Phyllocarida, is replaced by a number of flat, thin gill-plates, arranged parallel to each other, in an antero-posterior sense. When, however, we compare the gill, or rather the epipodital portion of the leg of Limulus, with that of the lobster we have the various fundamental elements, *i. e.*, an artery and a vein passing into the foot and in connection with a number of gill-plates. In the lobster we have along the base of the gill (fig. 33) collective veins and an artery into which the blood passes after being aerated in a large number of cylindrical gill-filaments. Morphologically there is a fundamental resemblance between the two types of branchiæ; in Limulus there are gill-plates, in Decapods gill-filaments, each presenting in the aggregate a large respiratory surface. The gills of the Isopoda are in some degree intermediate between the Decapods and the Merostomata.

When we compare the anterior or cephalic appendages with the thoracic appendages of the lobster, there is a close resemblance in the axially-jointed endopodite (fig. 38, *end*) of Limulus with its large terminal claw to the foot of the Decapod. The absence of the gill or branchiate (epipodital) portion in Limulus is correlated with the ambulatory nature of its anterior or cephalic appendages.

In the trilobites, however, as may be seen by Mr. Walcott's able restoration (fig. 40), we have attached to the thoracic ambulatory feet a respiratory epipodital portion. In some respects, then, in the trilobites we have a style of structure intermediate between the Merostomata and the Decapoda.

In the trilobite we apparently have, besides a true-jointed locomotive endopodite (fig. 40, *en*), an inner jointed appendage (*en'*), which may be homologized with the exopodite of the Decapod maxillipede (fig. 33). From near its base arises the two singular spiral gills, which are unique. It is to be observed that the two jointed appendages and the stem of the gills arise from what appears to be a true coxopodite, and that this coxopodite is apparently homologous with that of Limulus (fig. 38). It thus appears that a study of the general internal anatomy and of the appendages of the normal, recent Crustacea (*Neocarida*) throws light upon the structure of the archaic Crustacea (*Palæocarides*), and that the most archaic Neocarida, the Phyllocarida (Nebalia), as regards their thoracic limbs, do not remotely resemble the abdominal limbs of Limulus. In this connection we would draw attention to fig. 39, which is designed to show the possible relations between Limulus and Calymene or the Merostomata and the Trilobita. The essential difference is in the nature of the limbs; the thoracic limbs of the trilobite, while having a jointed endopodite as in Limulus, also having an exopodite and a forked spiral gill. Now, if we append to the coxopodite of Limulus an exopodite, and instead of having the gills arranged anteroposteriorly, like the leaves of a book, have them arranged on one side (the outer) of a more or less cylindrical epipodite, as we have drawn them in fig. 39, we shall hardly be doing greater violence to nature than we see to occur in any Decapod, where, as may be seen in fig. 35 of the lobster, the maxillæ have no specialized exopodite, such

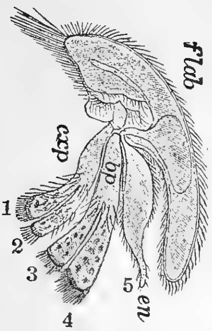

FIG. 35.—Maxilla of lobster, with its five lobes (1–5) corresponding to the endites of the Phyllopod thoracic limb.

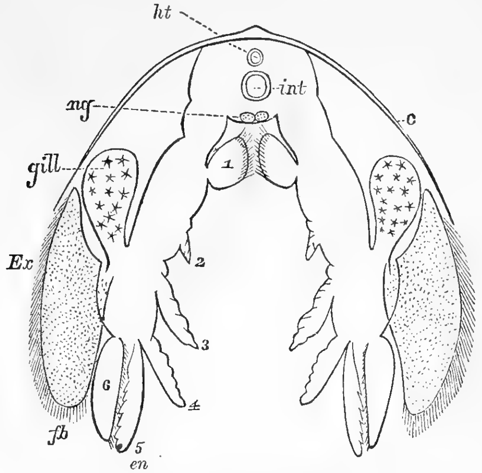

FIG. 34.—Section through the thorax of Apus: *en*, 1-6, the six endites; *ex*, exopodal or respiratory portion of the limb; *c*, carapace.

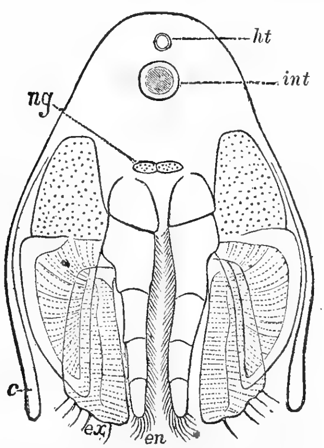

FIG. 36.—Partly diagrammatic section through the thorax of Nebalia: *en*, the axial-jointed endopodite; *ex*, exital portion or gill (above irregularly dotted) and flabellum below with rows of dots; *c*, carapace.

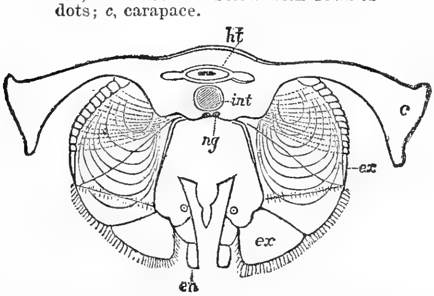

FIG. 37.—Actual section through the abdomen of Limulus: *c*, carapace; *ht*, heart; *int*. intestine; *ng*, ganglia (lettering being the same as in Fig. 36); *en*, axial, jointed endopodite; *ex*, exital or respiratory portion bearing the gill-lamellæ; the outer division (*ex*) homologous with the exopodal portion of the Phyllopod and Phyllocaridan appendage.

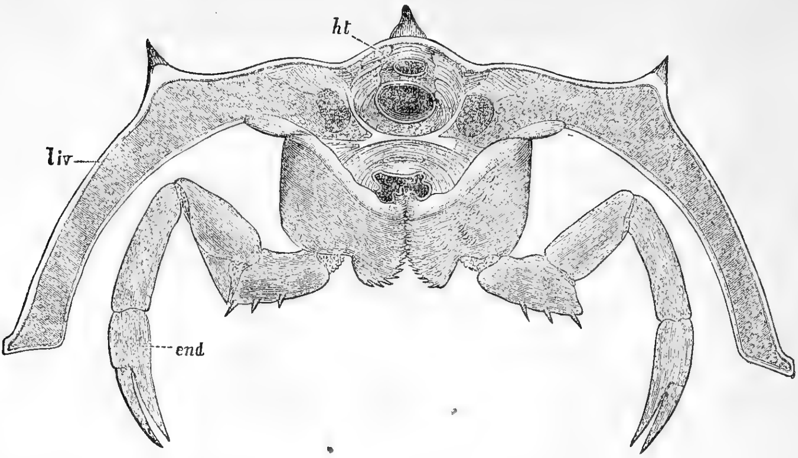

FIG. 38.—Actual section through the head of Limulus, showing the second pair of appendages and their relations to the shell or carapace: *ht*, heart; *liv*, liver; *end*, appendage homologous with the endopodite of Decapoda.

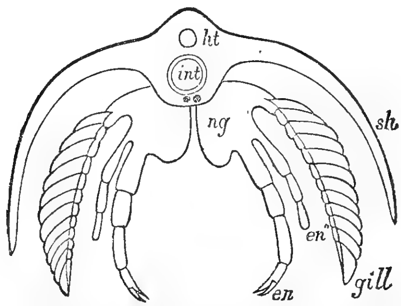

FIG. 39.—Diagrammatic section through body of a hypothetical form to show the possible homologies between the appendages of Limulus and a trilobite; the lettering as in Fig. 40.

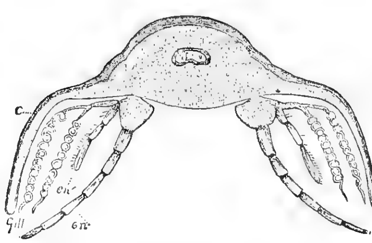

FIG. 40.—Restored section of the thorax of a trilobite (Calymene) after Walcott: *c*, carapace; *en*, endopodite; *en′*, exopodite, with the gills on the exopodal or respiratory part of the appendage.

as is so well marked in the maxillipedes, and the thoracic legs possess not even the rudiments. Change of function and radical changes of structure are most extreme in the Malacostracous Crustacea, from the Brachyura to the Isopoda and Amphipoda. If so startling in these comparatively recent forms, it is not to be wondered at that still greater and more fundamental modifications of the Crustacean type obtain in the archaic forms, the Palæocarides, of which Limulus is the sole survivor. To those who insist on the Arachnidan affinities of the Merostomata, we would suggest that the same shifting and change of function and structure is to be observed among the Tracheate Arthropoda, and that Limulus is not less a genuine Branchiate Arthropod for presenting some features analogous to the Arachnida.

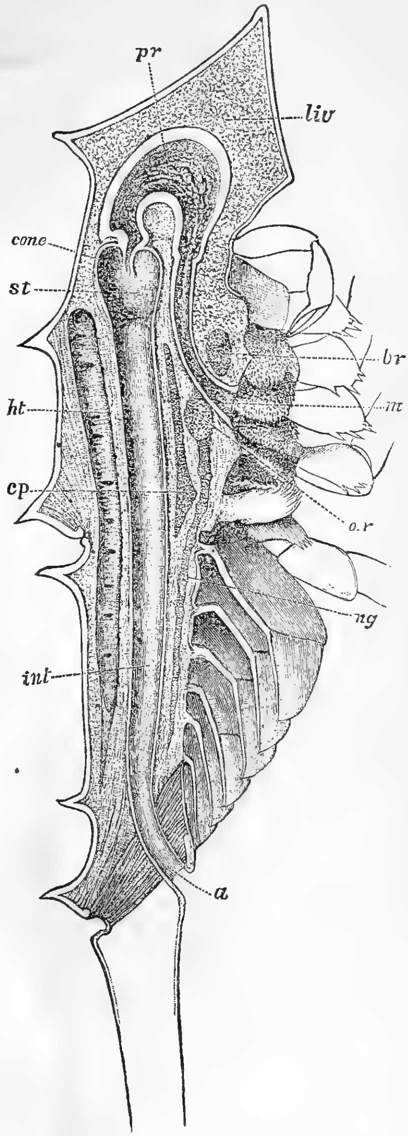

FIG. 41.—Section through a small Limulus polyphemus (much enlarged), to compare with a neocaridous Crustacean such as Apus: *liv*, liver; *pr*, proventriculus; *st*, stomach; *ht*, heart; *cp*, cartilaginous plate over the nervous system; *int*, intestine; *a*, anus; *br*, brain; *m*, mouth; *or*, œsophageal ring; *ng*, abdominal ganglia.

A study of the Phyllopoda and Phyllocarida must tend to confirm the view we have expressed as to the synthetic, or generalized nature of Limulus, while we have in another place endeavored to show in the light of A. Milne-Edwards' anatomical studies on Limulus, that it is an abnormal Crustacean and far removed from the Branchiopoda; there are nevertheless some points in which it comes in contact with the Phyllopoda, and which have been noticed ever since the time when O. F. Muller comprised Apus in his genus "*Limulus*." If the reader will compare the accompanying longitudinal section of Limulus with our section of Apus in Pl. XXXVII, some striking resemblances will be seen; externally the front edge of the carapace, *i. e.*, the frontal doublure, so well adapted for burrowing in the mud; the relations of the hypostoma or labrum, and the retention of the ocelli, as well as the mode of moulting the shell, are external points of resemblance, while internally the front part of the head filled with the lobules of the liver, the oblique, long, narrow, œsophagus, the position of the stomach under the eyes so far in front in the head, the simple archi-cerebrum, the general form of the heart, and the gnathobases near the mouth are additional points of resemblance.

In his little tract on Worms and Crustacea,[1] Professor Hyatt refers to the simple eyes of Limulus, as if they were the primitive eyes, retained from larval life. The structure of the two simple eyes of Limulus appears to be in some important respects quite different from that of Apus, Estheria, and other Phyllopods, in which there is a circle of cones, while in Limulus there is a single large corneal lens on the same plan as the facets of the composed eye of the same animal. If, however, these simple eyes, be regarded as survivors of the primitive larval eye, it would suggest that Limulus and all Merostomata which have similar eyes, have like the Neocarida, descended from a Nauplius ancestor; although the development of *Limulus polyphemus* has been shown to be an abbreviated one, the young hatching in the form of the adult. The presence of the single eyes would of course be an argument for its Crustacean affinities; while on the other hand the possession of compound eyes is a still more important Crustacean character.

Another point of interest is the mode of moulting in Limulus as compared with Apus. From our childhood we have found the cast shells of Limulus, with the carapace split around the edge of the doablure, and we have a partially moulted specimen in alcohol. We have not seen a cast skin of Apus, but on asking Dr. Gissler, who has raised the young Apus from the egg, as to the mode of exuviation in this Crustacean, he writes me as follows: "I am certain that the larvæ of Apus (from skins examined) split across or just in front of the eyes, and with two or three jerks the animal rids itself of the underlying skin." It would appear then that Apus, which is shaped in front so much like Limulus moults in a nearly similar manner.

In a general way we accept the homologies pointed out by Professor Lankester between the Phyllopodous leg and the maxillæ and maxillipedes of the cray-fish, but think that he, in common with Professor Huxley, pushes the homologies too far when he proceeds (on p. 365) to compare minutely the first leg of Apus with the third maxillipedes of Astacus. We do not, as we have stated on p. 391, regard the axis of Apus as truly jointed, and he stretches his homologies entirely too far when he attempts to homologize the first and second endites of Apus with the coxopodite of Astacus; and the third and fourth exites of Apus with the basipodite of Astacus. We would suggest that here, as among the orders of *Arachnida*, or *Hexapoda*, or *Myriopoda*, if we do not stop at a certain point, we are led into erroneous and misleading attempts at too close homologies. We should, it seems to us, bear in mind the fact that there are ordinal and class homologies; or, in other words, there are different degrees of blood relationship, *i. e.*, different and more or less parallel branches of the Crustacean genealogical tree.

The Decapods did not descend directly from the Phyllopods, but by a longer line, independent on the one hand from the Phyllocaridous ancestral line, and on the other from the Branchiopodous stem or branch. But a comparison between the Phyllopodous leg and Decapod maxillæ and maxillipedes shows that the Decapod exopodite is but a modified endopodital lobe, and is not homologous with the exites of the Phyllopods, the latter corresponding to the epipodite (or gills and flabellum, of the Decapods. We have seen that in all Phyllopods the gill and flabellum are differentiated parts of the epipodal portion of the leg (epipodite). Huxley's view, that the base of the corm or "protopodite" of the first thoracic foot is the endopodite, and the endites are merely second-

[1] Boston Society of Natural History. Guides for Science Teaching, No. VII, Worms and Crustacea. By Alpheus Hyatt, Boston, 1882.

ary processes, is apparently not correct. We regard the Phyllopodous limb as not differentiated into an axially-jointed portion, but that it is divided into a dorsal and ventral portion, the outer side of the limb being epipodal and the inner side endopodal, the endites of Lankester being processes of the endopodal portion.

Returning now to the general homologies of the Crustacean limb, in the light of Professor Lankester's suggestions as to the nomenclature of the limbs of Apus, and from our knowledge of the limbs of Crustacea from the Copepoda and Ostracoda upward, and more especially the *Cladocera*, *Phyllopoda*, and *Phyllocarida* compared with the Decapoda (the Tetradecapoda being considered as a side branch of the Malacostraca and not affecting the general homologies here given), we would suggest the following views:

Looking at the generalized legs of the Cladocera as exemplified in Moina (fig. 28, third pair), we see that there is no specialized axis or stem, and that the limb may be divided into an outer, partly dorsal or respiratory *epipodal* moiety (the dotted portion in the figures), and an inner, ventral locomotive moiety, which may be called the endopodal portion of the limb.

Now, if we look at the figures in the plates we shall see that the larger part of the epipodal or respiratory portion of the limb is thrown up over the back, as seen in the side view of *Limnetis*, *Estheria*, *Limnadia* (Plates I, III–V), or in the sections of *Estheria* (Plate XXIV), *Apus* (Plate XXXII, fig 2), or *Thamnocephalus* (Plate XIV, fig. 4). This relation is also seen in the lobster or cray-fish upon removing the side of the carapace; the branchiæ and flabellum are thrown up dorsally, while the locomotive portions of the limb hang down or are usually directed forward. The importance of the epipodal or branchial portions of the limb has been underestimated by writers on the homologies of the Crustacea, because they have viewed the subject from the standpoint of the Decapodous structure, where the epipodites are comparatively unimportant. But in the order *Branchiopoda* these parts are often quite as well developed as the endopodal, and are not only respiratory, but, as in the large flabellum of the Phyllopods, are largely locomotive, while in the *Limnadiadæ* and *Apodidæ* they are variously modified to carry the eggs.

The epipodal portion is differentiated into the flabellum and branchia or gill, the simple gill of the Phyllopods being the homologue of the highly differentiated complex decapod gill; and the fan-like flabellum of Apus, for example, is the homologue of the scaptognathite of the Decapoda. The gill and flabellum might be properly called *branchites*, but we have adopted Lankester's term, *exites*, for these parts.

The *endopodal* or locomotive portion of the limb of the Phyllopod is differentiated into six lobes or *endites* (Lankester); there being no parts corresponding to the stem or protopodite (the coxopodite and basipodite together) of *Decapods*. These are to be found only in the *Decapoda*. In *Apus* there is a slight approach to the Decapodous protopodite, but we differ from Huxley or Lankester in regarding the base of the apodid leg as truly axial and jointed, as the supposed joints are shifting and with incomplete articulations. Lankester considers "that the endopodite of the *Astacus* maxillipede is the homologue of the endite 5 of the *Apus* limb; its exopodite is homologous with endite 6 of the *Apus* limb, and its epipodite is homologous with the flabellum of the *Apus* limb." (Quart. Jour. Micr. Sc., 1881, p. 365.)

The nomenclature and synonymy of the parts of the Crustacean limb in general may, then, be tabulated as follows:

Epipodal portion of limb ..
- Epipodite, flabellum, scaphognathite, gill-scraper, gill-fan. (In Limnadia upper or dorsal (*br*) part (oviger) and lower (*br*[1]).
- Branchia, gill.

Endopodal portion of limb, with—
- 6 endites in Phyllopod thoracic legs.
- 5 endites in 2d maxilla of Astacus and Sergestes.
- 4 endites in 1st maxillipede of Astacus and Sergestes.
- 2 endites (5th and 6th endopodite and exopodite) in 3d maxillipede of Astacus and Homarus.
- 1 endite ? (=5thPhyllopod endite ?) in thoracic leg of Homarus and Astacus arising from a 2-jointed axis or protopodite (consisting of coxopodite and basipodite), to which are appended
  - (*a*) epipodite and branchia.
  - (*b*) (endopodite) the leg in Decapoda with 5 joints.
    - 5 dactylopodite.
    - 4 propodite.
    - 3 carpopodite.
    - 2 meropodite.
    - 1 ischiopodite.

The carapace.—This is seen, when we study the development of the *Phyllopods*, to originate in the Nauplius as the undifferentiated covering or tergal portions of the first and second and mandibular segments of the Nauplius, which become enlarged during the successive moults of the animal until, as in *Estheria* or *Limnadia*[1], it may cover the entire body. In adult life it becomes bivalvular and is attached to the body by the adductor muscle, which is situated in the mandibular segment, the præ-oral part of the head in the *Limnadiadæ* and *Apodidæ* being more or less differentiated from the carapace proper.

As long ago pointed out by Professor Dana, the carapace of the Decapoda (the lobster for example) is a development of the tergal portion of the second antennal and mandibular segments. The development of *Penæus* and *Euphausia* from the nauplius to the adult confirms the view that the carapace is originally the antennal and mandibular tergites which form a single carapace and finally covers the cephalothorax of Decapoda. That no part of the carapace represents the thorax is seen in the zoëal carapace which covers the front part of the body before the thoracic segments are developed.

HOMOLOGY OF THE EYES.

When we consider the nature of the compound eye of the Cladocera and Phyllopoda and study the mode of development of the cornea from epidermal cells, we see that the eye-stalk of the Branchipod eye is simply an unjointed protuberance of the first antennal segment, and can in no way be regarded as the homologue of a jointed appendage. Moreover, the embryology of these Crustacea shows that the compound eyes are developed upon the tergal part of the first segment of the head, and that there are no traces of a præ-antennal segment.

In the Decapoda our unpublished observations on various zoeæ (*Lupa*, *Palæmon* and *Tozeuma carolinensis*), as well as the data given by those who have written on the embryology and metamorphosis of Decapods, all show that the faceted stalked eyes of Decapods should not be regarded as homologues of the legs, although eminent authorities, such as Huxley, Claus and others, regard them as being the morphological equivalent of the succeeding jointed members. In Tetradecapods the compound eyes are invariably sessile. In the Merostomata, Limulus, as

[1] In Limnadia, as shown by Lereboullet (see Fig. 43), and in Estheria, as stated by Claus, the carapace valves apparently arise from a post-mandibular segment, but this is exceptional among the Phyllopods.

well as its fossil allies, and the Eurypterida, the compound eyes are sessile and situated on the third segment of the head, and, as we have endeavored to show in our essay on the development of *Limulus polyphemus*,[1] the stalked eyes of Decapods do not represent a pair of appendages.

V.—THE DEVELOPMENT, METAMORPHOSES, AND GENEALOGY OF PHYLLOPODS.

I.—THE NAUPLIUS FORM IN THE PHYLLOPODS.

As introductory to the notes furnished by Dr. Gissler on the development of *Apus* and *Streptocephalus*, we will preface his remarks with some account of the early phases of different Phyllopods, beginning with *Limnetis*, as worked out by Grube.[2]

The young of this genus is a Nauplius of peculiar form, with three pairs of appendages, a very large carapace which covers the entire body, and the edges of which are serrated. The carapace is larger than in any other Phyllopod larva known, and there are two large lateral hornlike projections from each side of the head in front of the first pair of appendages. The labrum is not especially developed, while in the other genera it forms a characteristic feature of Phyllopod nauplii.

Limnetis gouldii has a nauplius of the same general shape as the European species, as we have received specimens of a similar carapace from Hanover, N. H.

A quite full account of the development of *Limnadia hermanni* has been given by Lereboullet. Fig. 42 represents the freshly-hatched Nauplius, which is of very primitive form. The first pair of antennæ are in the Nauplius wanting, not budding out until near adult life.

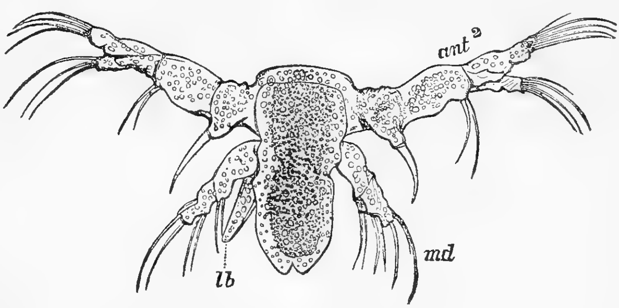

FIG. 42.—Nauplius of *Limnadia hermanni*. *ant*2, second antenna; *md*, mandible; *lb*, labrum. Much enlarged. After Lereboullet.

The labrum (*lb*) is enormous and very long. The carapace arises in this genus, as also in Estheria, from a point in the head just behind the mandibular segment. Fig. 43 represents the larva before the first antennæ have begun to grow out. The ocellus is still large and performs its functions, while the abdomen ends in a pair of uropoda. The development of *Estheria*, as given in a fragmentary way by Joly, shows that the Nauplius differs mainly from that of Limnadia in the labrum being three-toothed at the end.

Fig. 44 represents the freshly hatched larva of *Apus cancriformis;* the usual three pairs of nauplius-appendages representing the first and second antennæ, and the mandibles of the adult are present; while the ovate body is segmented behind the mandibular segment.

The first larval stage of *Lepidurus*, as worked out by Brauer (Figs. 45, 46), is rather different from that of *Apus*. The limbs are slenderer, and a rudimentary carapace arises on the antennal segments, while the body behind is not segmented.

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[1] Memoirs Boston Soc. Nat. Hist., 1872, Vol. I, pp. 174, 175.
[2] Bemerkungen über die Phyllopoden.

Plate XXII, fig. 1, provisionally represents the freshly hatched larva of *Artemia gracilis*, which we observed at Great Salt Lake, Utah, the drawing having been made from an alcoholic specimen. On comparing it with Claus' figure of the freshly hatched larva or Nauplius of the European *Branchipus stagnalis* (Fig. 47) the first antennæ are seen to be much shorter; the second pair with much shorter and smaller setæ; while the mandibles are nearly destitute of setæ. Moreover the body is segmented behind the mandibles.

Our Salt Lake Artemia differs from the figures of the European *Artemia salina* in the shorter first antennæ; in the shorter and smaller setæ of the second antennæ. But a single larva was, however, observed, and our figure is, though a camera drawing, subject to future correction.

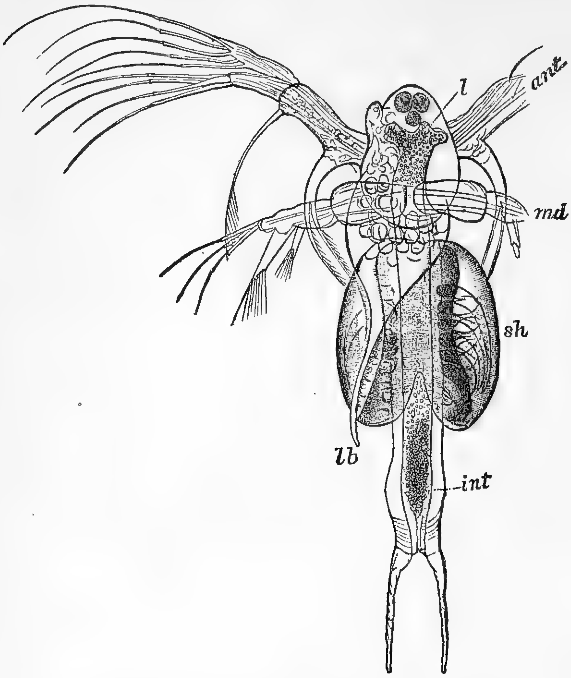

FIG. 43.—Advanced larva of *Limnadia hermanni*, lettering as in fig. 42. *sh*, carapace valves; *int*, intestine; *l*, liver, much enlarged. After Lereboullet.

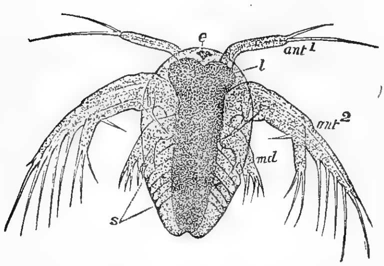

FIG. 44.—Nauplius freshly hatched, of *Apus cancriformis*. *s*, segments behind the mandibular segment; *l*, liver; *e*, simple eye. After Claus.

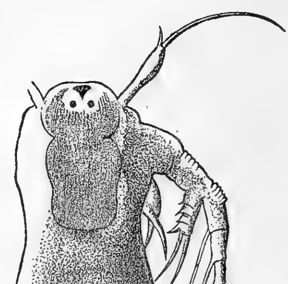

Fig. 45.—Nauplius of Lepidurus much enlarged. After Brauer.

THE GENEALOGY OF THE PHYLLOPODA.

In considering the question of the genealogy of the Phyllopods, we have two sets of considerations to guide us. First the embryology, anatomy, affinities, and systematic position of the group, and second their palæontological history, the latter being an important check upon any errors arising in the former.

It has seemed to us the more natural view that the systematic position and relations of the Phyllopods, as compared with the Cladocera, is that the Phyllopods are simply a highly developed and extremely specialized branch of a Cladocerous stem; that the Cladocera are a step higher than the *Ostracoda*, which connect the *Branchiopoda* with the *Copepoda*. There is a tolerably complete ascending series of forms, beginning with the Copepoda and culminating in the Phyllopods. Here we should stop, and in endeavoring to account for the origin of the Decapoda, we do not see what facts there are to sustain the view that the highly specialized Decapoda, much less the Tetradecapoda, originated from the Phyllopods or forms like them. The more natural view is that the Malacostraca originated by a direct line of ancestral forms, resembling the zoëa, protozoëa, &c., beginning with a Nauplius condition; the development of *Penæus* and *Leucifer* giving us data for such a hypothesis.

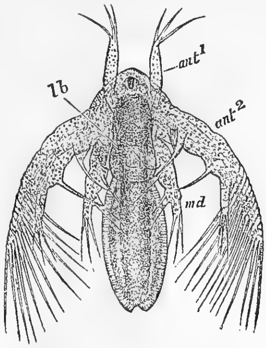

FIG. 47.—Nauplius of *Branchipus stagnalis*. After Claus.

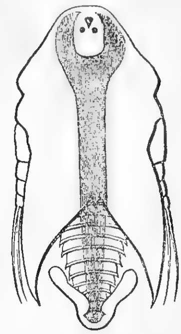
Fig. 46.—Advanced larva of Lepidurus enlarged. After Brauer.

Hence the Phyllopods and Decapods, for example, for a time probably followed the same developmental path or rather parallel paths. The Phyllopods, culminating in the highly specialized peculiar type of *Apodidæ* and especially the *Branchipodidæ*, were the flowering out or consumation of, so to speak, the Branchipodous branch of the Neocaridan crustacean tree. On the other hand the Decapods, beginning with the Nauplius form, perhaps more rapidly and by an accelerated course of development comparatively late in palæontological history, assumed the primitive Decapodous characteristics perhaps before the Phyllopodous type had been perfected, but in the Tertiary Period culminated in a great profusion and luxuriance of forms, remarkable for the number of species and variety of shapes of macrourous and especially brachyurous types.

The palæontological history of the Neocarida, as we have endeavored to show by the diagram on p. 361, shows that the shrimps existed during the Devonian,[1] that the crabs were already in existence during the Carboniferous Period, before the *Apodidæ* and *Branchipodidæ* had, judging by their fossil remains, appeared; while the *Limnadiadæ*, genuine Phyllopods, appeared before any Decapods in the Devonian, the Ostracodes being abundant in the Lower Silurian strata. It seems to us therefore most probable from a geological standpoint that the Decapods could not have originated from the Phyllopods, as the two types were developed during the Palæozoic era.

That the Phyllocarida were developed independently either of the Phyllopods or of the Decapods seems probable from the fact that the Phyllocaridan type became established as early as the Lower Silurian. We shall see that the *Phyllocarida* are not related to the zoëa of Decapods, and that the Decapods probably did not originate from them.

[1] *Palæopalæmon newberryii* has been described by Whitfield from the Devonian of Ohio.

Hence the three orders of *Branchiopoda*, the *Phyllocarida*, and the *Decapoda* (with the *Tetradecapoda*) must, it appears to us, have independently of each other originated from some Laurentian Nauplius-like form.

The views of Claus and some important criticisms upon them are given at length by Mr. Balfour in his valuable Comparative Embryology, while we would observe that neither Claus, Dohrn, nor Balfour appear to refer to the palæontological history of the Crustacea.

Professor Claus, in his suggestive work on the genealogy of Crustacea, according to Balfour, claims that the later Nauplius stages of the different Entomostracan groups and the Malacostraca (*Penœus* larva) exhibit undoubted Phyllopod affinities. He therefore postulates the earlier existence of a Protophyllopod form, from which he believes all the Crustacean groups to have diverged. This ancestral form, Balfour thinks, had three anterior pairs of appendages similar to those of existing Nauplii. It may have had a segmented body behind the third pair of appendages provided with simple biramous appendages. A heart and cephalothoracic shield may also have been present, though the existence of the latter is perhaps doubtful. There was no doubt a median simple eye, but, adds Balfour, it is difficult to decide whether or no paired compound eyes were also present. The tail ended in a fork, between the prongs of which the anus opened, and the mouth was protected by a large upper lip. "In fact, it may very probably turn out that the most primitive Crustacea more resembled an Apus larva at the moult immediately before the appendages lose their Nauplius characters (fig. 208 B), or a Cyclops larva just before the Cyclops stage (fig. 229), than the earliest Nauplius of either of these forms" (Balfour, p. 418).

That the Decapods and Phyllopods may have originated from such a form as Balfour thus depicts seems to us to be quite probable.

Mr. Balfour, on page 380, states that "the *Branchiopoda*, comprising under that term the *Phyllopoda* and *Cladocera*, contain the Crustacea with the maximum number of segments and the least differentiation of the separate appendages. This and other considerations render it probable that they are to be regarded as the most central group of the Crustaceans, and as in many respects least modified from the ancestral type from which all the groups have originated."

Against this view may be, however, offered two criticisms. The excessive number of segments in the *Apodidæ* is paralleled among the *Tracheata* by the Chilopods, in which the numerous segments appear to have each two pairs of feet, and these *Myriopoda* are probably not the more ancestral, generalized Myriopodous forms, the Pauropus and Eurypauropus being much more so, these forms having few segments, each with no more than one pair of feet. The excessive number of segments in *Apus* and the irrelative repetition of abdominal feet appear to us to be signs of a vegetative repetition of parts in a type which has culminated, and is subject to decline and extinction.

Again, in *Polyartemia*, with its 19 pair of feet, where *Artemia* has the normal number of eleven (within its family limits) appears to us like *Apus* to be a highly specialized and extreme form; *Artemia* being the more generalized, though, as compared with *Branchipus*, a degradational form.

The view that the Phyllopods "are members of a group which was previously much larger and the most central of all the Crustacean groups," is not fully sustained by zoögeography or palæontology. At present all Phyllopods are fresh-water forms, and they are exceptionally rare forms, occurring only locally, though every continent has its quota of these Crustacea. There are no marine allies of the Phyllopods. Moreover all the fossil forms appear to have been fresh-water forms, their remains occuring in fresh-water strata. No fossil Phyllopods have occurred as yet previous to the Devonian Period.

The difficulty is (and this is a point apparently overlooked by Fritz Müller, Dohrn, Claus, and Balfour) to account for the origination of the Phyllopods at all from any marine forms. The only explanation we can suggest is that the Phyllopods have arisen through *Limnetis* directly from some originally marine Cladocerous type like the marine forms now existing, such as *Evadne.* We imagine that when a permanent body of fresh water became established, as, for example, in perhaps early Silurian times, the marine forms carried into it in the egg-condition, possibly by birds or by high winds, hatched young, which, under favorable conditions, changed into Sida, Moina, and Daphnia-like forms. The *Cladocera* are, then, probably the more generalized forms, from which the Phyllopods, at this time and probably ever since Devonian times, *par excellence* a fresh-water assemblage of forms, took their origin. This view, it seems to us, accords with the well known facts in the biology and palæontology of these forms.

The view which we believe Dohrn entertains, and to which Mr. Balfour gives some support (though Claus opposes it), that the *Ostracoda* may have decended from ancestors with a larger number of appendages than they have at present, appears to us to be negatived by the fact that their valves are so abundant in the lowest palæozoic rocks. The type appears to have persisted and to have remained unchanged from the Potsdam Period to the present day, and is more marine than fresh water. So close do the lower Cladocera approximate to Cypris that the transformation of an Ostracode[1] into a Cladoceran, and a Cladoceran into a Phyllopod, is much more easily imaginable than a hypothetical Protophyllopod ancestor for the Phyllopods.

All this clears the way for the view that the Malacostraca had an independent origin from some Nauplius, through, we will admit, some ancestral Protophyllopod form which was succeeded by a protozoëa, and finally a zoëa, the ancestor of the existing Decapods as a whole; and it also leaves open a field for the independent evolution of the Phyllocaridan type, composed of gigantic Nebalia-like Silurian forms, which also have originated at a much earlier date than the Decapods, and have held somewhat the same relations to the Decapods as the Eurypterida did to the *Limuli.*

In conclusion, therefore, we consider the Phyllopods as a whole, especially the *Apodidæ* and *Branchipodidæ*, to be a comparatively recent, highly specialized group, which were developed under exceptional biological conditions in bodies of fresh water, and which, as in Apus, show that this branch of the Crustacean genealogical tree has culminated. The irrelative repetition of the segments and appendages (in Apus) gives evidence that the type, so far from being ancestral, is one comparatively modern, specialized, and fully worked out.

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[1] Balfour remarks that "the independent origin of the Ostracoda from the main Crustacean stem seems probable." Page 424.

VI. MISCELLANEOUS NOTES ON THE REPRODUCTIVL HABITS OF BRANCHIOPODIDÆ.[1]

By Carl F. Gissler, Ph. D.

I. EUBRANCHIPUS VERNALIS Verrill.[2]

Among the very large individuals gathered during the past winter (1879–'80), I found a male and female, each with but one right clasper. Several experiments on Eubranchipus showed that the least artificially applied lesion of the claspers proved to be fatal to them, and so I am inclined to see in the above mentioned two specimens simply a malformation acquired through some unknown cause at an early larval stage. Where the other claspers ought to be the integument is perfectly smooth and rounded. During eleven days I could never see the malformed male in copulation, although I always noticed him pursuing the females. He was frequently seen to be touched by other normal males, especially when they approached his left side from behind, on account of the missing left clasper, and also probably on account of the excessively swollen genital segment, taking it for a female bag. This singular individual presented altogether much oddity in its behavior. Unlike the others, it often swam suddenly through the aquarium in a bee-line, frequently resting on its back at the bottom of the jar for 10 or 12 minutes, slowly moving its branchipeds. Perfect sammersaults and other curious motions were often noticed.

The malformed female did not present any odd movements; I kept it for several days alive and could see no other anomaly about it. The largest females usually preferred the bottom of the aquarium as a protection against the ever-attacking males. In old females I often noticed a laceration of the furca[3] (sometimes entirely gnawed off), caused by insect-larvæ crawling about the bottom. They bear a lacerated furca well for a long time, as the furca merely consists of chitin and bristled integument.

The larger ponds were found already in January to swarm with *Lymnetis gouldii* Baird, a great number of a species of Daphnia, many Cypridinæ, Cyclopidæ, and Calanidæ.

If the months of November and December are mild, as has been the case during the past three years, there occur in January adults 1½ inches long, as well as larvæ of only a few millimeters in length. Three years ago they disappeared in the beginning of May, year before last in April, last year in March, and this year (1881) in the middle of April. A sudden change in temperature, warm or cold, will cause them to disappear for two or three days, when, after another change, they suddenly reappear diminished in number and in company with another young generation.

The female sexual organs of the red *Eubranchipus vernalis* are less complicated than those of its pale races, and I have occasionally alluded to them in describing those of the latter.

Copulation in the red Eubranchipus lasts but a moment, and on this account I was unable to closely observe the same.

SEXUAL ORGANS. (Plate XXII.)

(1.) *Male organs.*—The posterior (lower) tapering end of the testicle is fastened by a very fine hyaline thread to the wall near the eighth post-

[1] This is in part a continuation of a paper entitled "Evidences of the effect of chemico-physical influences in the evolution of Branchiopod Crustaceans," read before the 29th meeting of the Amer. Assoc. Adv. Sc. held at Boston, Aug. 1880.

[2] Observations on Phyllopod Crustacea, etc., by Prof. A. E. Verrill, 1869.

[3] The red Eubranchipus has a white furca, the pale races have a red furca.

abdominal segment; it broadens rather suddenly, and reaches up in the form of a whitish tape to near the middle of the united genital segments, where it expands and suddenly contracts again into a more cylindrical, narrow string, the vas deferens, for but a short distance, after which follows a second larger expansion, representing the seminal vesicle, bending knee-shaped down and outward, and after again narrowing to a tubular duct, the ductus ejaculatorius, is interrupted several times with what I take to be accessory glands, just before entering the terminal extensile portion, the complicated muscular apparatus. The cirri are non-perforated, and supplied with minute hooklets (as in *Branchipus grubei* and *B. stagnalis*). At its base several powerful muscles insert themselves, the musculi retrahentes.

The anterior (upper) end of the testicle is in younger individuals of the red Eubranchipus and pale race A an obliquely cut-off tip, as Spangenberg[1] figures it in *Branchipus stagnalis*, but in set B no trace of this prolongation, either in younger or older individuals, can be seen, thus resembling Dr. F. Leydig's figure.[2]

The complicated muscle-apparatus, described and figured by Dr. H. Nietsche[3] (*Branch. grubei*), occurs also in *Eubranchipus* and its pale races, the cirrus being likewise non-perforated and hooked. Chitinou papilli (*Branchipus grubei*) and spines (*Branchipus stagnalis*) I could not observe.

(2.) *Female organs* (pale).—The spirally-wound ovary extends in set B (and A?) not only with its posterior end into the penultimate post-abdominal segment (as in red Eubranchipus, *Branchipus grubei* and *B. stagnalis*), but also with the anterior (upper) end up to the limit of the fourth last pair of branchipeds.[4]

I have often observed in living specimens from 5 to 6 plasmatic eggs of a turbid white color in the upper ovarial string, but then the post-abdominal section on the same side was empty, or the reverse. I also occasionally observed both sections, the anterior and posterior, full of plasmatic eggs, and at the moment of entering the oviduct by jerks from the posterior section, the anterior portion of the ovary remained filled for some time until also emptied into the oviduct. The emptying of the anterior section usually took place also on putting live specimens into alcohol, and in this instance the posterior portion remained filled. The eggs of the anterior section have the same form and appearance as those of the posterior.

Another notable fact is a very short, transverse, tubular anastomosis within the sixth and near the seventh post-abdominal segment. This I have not seen to occur in the females of red *Eubranchipus*, neither have I found it in all females of the pale races. The anastomosis[5] passes *under* (ventrally) the intestinal tract, and is sometimes filled with 2 or 3 plasmatic eggs. It is about $1,^{1mm}$ long, narrower than the lateral ovaries; its skin apparently muscular, since the eggs are squeezed sideways out into the lateral strings when live specimens are placed in alcohol, or when, by a jerk, the eggs enter the oviduct.

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[1] Zur Kenntniss von Branchipus stagnalis von Dr. Friedrich Spangenberg, mit Tafel I–III. Zeitsch. f. wiss. Zoologie, xxv; Supplementheft, 1875, Fig. 28, t.

[2] Dr. Franz Leydig, "Ueber Artemia salina und Branchipus stagnalis." Zeit. f. wiss. Zool. iii, 1851, Taf. VIII.

[3] Dr. Heinrich Nitsche, "Ueber die Geischlechtsorgane von Branch. Grubei von Dybowsky" in Zeit. f. wiss. Zool., xxv, page 281, Taf. XXII.

[4] Schmankewitsch doubts whether or not some of the branchiped-bearing body-segments belong to the post-abdomen. The peculiar arrangement of the ovary here seems to give support to this assumption. See Zeit. f. wiss. Zool. 1875, pages 114 and 115; also Spangenberg, in op. cit. pages 8 and 9; and Nietsche in op. cit.

[5] This anastomosis indicates a sexual relationship with certain Schizopod and Copepoda.

A little above the middle of the genital segment the two ovaries are rather loosely attached to a yellowish and somewhat trilobed body,[1] the median (unpaired) funnel of the two oviducts. I said "loosely," because on macerating a female in dilute acetic acid this funnel as well as the two ovarial strings separate, the funnel usually remaining loosely—apparently only attached by connective tissue—to one of the strings, and sometimes it is entirely separated. The two oviducts resemble inflated pig-bladders; their skin is very muscular and elastic. The lower (outer) terminus of each oviduct appears to be closed by a sort of a sphincter, since the eggs contained therein (often crammed together) will be retained until the chorion is formed. The time occupied is very variable, but I have neglected to record the same. After copulation the eggs are emptied from the oviducts into the outer "uterine" bag, where they appear in the shape of a small cluster at each outer side of the two oviducts, where they undergo the process of segmentation. This outer bag consists of a very thin but tough chitinous skin inclosing the two oviducts and the cement-glands, and is fastened with a broad base to the upper (anterior) part of the external genital bag. Its exit is a very short tip in the median line and connects with the outer valve. The eggs are now still plasmatic, not quite spherical in shape, and remain in their present place, surrounded by the brown cement-glands, during continual rhythmic motions produced by a ramified muscle-net,[2] for from 14 to 20 hours. At the end of this time they are perfectly spherical, having received by the liquid brown secretion of the gland (the gland-lobules are now perfectly colorless, the brown secretion surrounding the eggs), a chitinous, light-brown, finely granulated egg-shell.

The cement-gland consists of three nearly equal, long, parallel, and longitudinal sections; there are two lateral and a median section. The median section (between the two oviducts) has now acquired a dark-blue hue. The newly-formed ovarial eggs have meanwhile also entered the oviduct, and, after copulation, are again emptied from the oviduct into the outer "uterine" bag, simultaneously expelling the already present light-brown eggs around the oviducts toward the median line, where they cluster in the median dark-blue cement gland. After two hours the blue glands become colorless, and again, after some three or four hours, they turn from a slight pink into brown. There the eggs remain until they become dark brown and very hard, afterwards to be deposited through the median apex of the inner uterine bag and thence through the valvule into the water, where they sink down.

Remarks.—In a paper read before the American Association Adv. Science, 1881, I have referred the evolutionary changes seen in the pale races to direct chemico-physical influences;[3] morphological differences were explained through Wagner's migration theory,[4] as well as through Darwin's selection theory.[5]

Morphological changes, such as seen in set B, C, and (?) D, may be regarded as a sort of Hypertelie,[6] (specimens, not showing similarity in form without purpose, originate after certain laws, slumbering in them until the phenomenon, Hypertelie, is animated by external influences.)

[1] Probably what Spangenberg (page 46, op. cit.) took for a receptaculum seminis.

[2] See R. Buchholz, "Ueber Branchipus Grubei" in Schriften der phys.-œcon. Gesell. zu Königsberg, v, page 100, Taf. III, and also F. Leydig in op. cit.

[3] See Schmankewitsch, loc. cit., and same author in Zeit. f. wiss. Zool. 1877, XXIX: "Ueber den Einfluss äusserer Lebensbedingungen auf die Organisation der Thiere."

[4] "Die Darwin'sche Theorie und das Migrationsgesetz der Organismen" von Dr. Moritz Wagner, 1868. See, also, "Kosmos," iv, April, 1880; "Ueber die Entstehung der Arten durch Absonderung" von Dr. M. Wagner.

[5] "On the origin of species by means of natural selection," 1859.

[6] "Ueber Hypertelie in der Natur" in Verhandlungen der k. k. zool.-bot. Gesellsch. zu Wien, 1873, xxiii, page 133.

The indirect factor of the red color[1] (or green, of others) of Eubranchipus I assume to be microscopic organisms contained in the soil of the ponds, primarily and gradually acted upon by quercitannic acid or tannates and humus.

I have grave doubts whether to regard the pale races, set B, as partially starved individuals, since their nourishment consists of organic matter contained in the mud. The latter is taken up in precisely the same manner as known in the European *Branchipus stagnalis*, *i. e.*, by striking with the occipital part of the head against the mud, thus filling through the agitated mud the ventral median canal between the branchipeds, and thence by gradual paddling, the mud will pass therefrom toward the head and mouth. The contents of the alimentary system, as examined, also correspond with this manner of feeding. They will never partake of any kind of food thrown into the water. (The pale races had not reached sexual maturity had they not had food enough.) Sesquichloride of iron did not indicate even a perceptible trace of quercitannic acid in the clay-water of the isolated pool, but such was the case with the brownish clear water of the surrounding ponds inhabited by the normal large and red Eubranchipus.

The slightly milky water of the isolated pool owes its color to finely suspended clay-particles, and, I should judge, although I have neglected to microscopically examine the same, contains comparatively more organic matter, adhering to the inorganic particles, than the clear water of the other pools. This is contrary to the assumption that the pale races were partly starved individuals.

I rather draw the inference, that we here have both, a difference in quantity, and quality of nourishment, the former preponderating, the latter indifferent as to color. The contents of the alimentary system of Branchiopods are for the greater part a fine soft magma of mud intermixed with oil-globules, the latter being the secretion of the wall-glands of the canal.

Very likely specimens living in water with finely dispersed mud or clay, have less trouble in getting their food, the nourishment being more uniform and already so fine that it needs not to be masticated or separated from coarser particles.[2]

Remarks on the cephalic scute or Kopfschild.—Is not the larval cephalic scute[3] (in our form ♂ of set B, preserved in the adult) a rudiment of the two valves of the Estheridæ? In that family two or three thoracic segments serve for the insertion of the bivalvular duplicature.[3]

Mode of copulation of pale race of Eubranchipus vernalis.—The copulation between males of set B with females exhibiting the two forms of claspers illustrated by figures 61, A, B, lasts from 3 to 4 minutes, but many unsuccessful attempts to accomplish the same are usually made, often ending with the escape of the females, owing to the check caused by the crossed claspers. In both the red and white race the attempts were never made

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[1] An interesting note on chlorophyll and protection of colorless cells as an absorbent of certain light-rays is to be found in Amer. Nat. March, 1880.

[2] Mr. E. P. Austin—Amer. Nat. X (Aug. 8, 1876), page 508—mentions that in March he obtained 28 different species of Dytiscidæ from a small clay-pit which had been filled with water. Some of the species occurred in immense numbers.

Hermaphroditism, Amer. Nat. March, 1880, page 200.—Hermaphroditism seems to be a thraldom necessary at the outset, but from which all living things are seeking to escape. (Sexual differentiation in Epigæa repens, by Lester F. Ward, A. M.)

[3] Spangenberg, loc. cit., page 14, Taf. I, Fig. 1, and also Dr. Carl Claus, "Zur Kenntniss des Baues und der Entwicklung von Branchipus stagnalis und Apus cancriformis." Göttingen, 1873, Taf. II, Fig. 5, D. P.; also same author in "Beiträge zur Kenntniss der Entomostraken." Marburg, 1860, I. Heft; also Dr. A. S. Packard in "Phyllopod Crustacea," and same author in "Cave Fauna of Utah and descr. of new spec. of Crust."

on already copulated females, with filled uterine bags, which fact agrees with what has been observed in *Branchipus stagnalis*. (In the latter the claspers do not cross.) Slipping off of the female after having once been clasped by the male, I could never observe in the normal red Eubranchipus. Therefore comparatively more muscular power is required to open the crossed claspers, and owing to this fact only has the copulation a longer duration in the pale races; the same difficulty was noticed on releasing the copulated female. Immediately after the clasping the post-abdomen turns around to the ventral side of the female, the two normally crossed cirri-points enter the valvule simultaneously, spreading open the same.

The protruding trifold muscular apparatus, first observed and figured by Dr. Heinrich Nitsche, in *Branchipus Grubei* von Dybowsky (op. cit.), is closely brought to the valvule, emptying through it (apparatus) and not through the two cirri, the spermatic fluid evidently into the inner uterine bag, where it meets with the revolving eggs. The claspers of the male tightly pressing upon the anterior (upper) portion of the female sack thus produce a gaping of the valvule. All this taking place in an instant, the entering of the two cirri, however, is repeated several times during the three or four minutes. A few jerks of the male post-abdomen, apparently coincident with strained jerks of the male claspers (and following right after) are necessary to free the two sexes. The male slowly sinks to the bottom for several seconds, lays curved on its back and repeats the post-abdominal jerks with protruded cirri and apparatus. In this condition, and more so in clay-water, the seminal fluid can be observed with an ordinary magnifying glass to ooze out of the extensile apparatus and slowly flow over the sides of the curved abdomen.

II.—Larval stages of Chirocephalus holmani Ryder.

The single specimen of *Chirocephalus* found in January, 1880, proved to be *Chir. holmani* Ryder, being considerably larger, but agreeing in general with the latter. On March 22, 1881, I found a very large and deep pond between Glendale and Ridgwood, L. I., about three miles from Maspeth, populated with *Chirocephalus holmani*. So abundant were they that with every dip I brought up some 30 to 50 specimens of both sexes. They were of a greenish transparent hue with their furca reddish pigmented. The pigment of the furca was confluent and not granular.

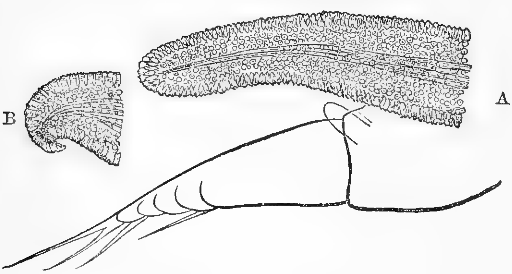


Fig. 48.—A, male frontal tentacle of *Ch. holmani*
B, the same in male of *Eubranchipus vernalis*.

The males averaged 20^{mm} in length and the females about 18^{mm}. The stalked eyes were of a beautiful dark-red color. *Eubranchipus* occurred sparingly together with them, and now (in May, 1881), also a great number of a variety of *Diaptomus sanguineus* Forbes[1] and *Lymnetis Gouldii* Baird.

Having observed them often in copulation in the aquarium, I can state that the latter is of very brief duration, and details relate to those of the normal red Eubranchipus, and principally the frontal tentacles do *not* come into play as auxiliary organs.

The internal genital organs of the male are the same as those figured

[1] Bulletin of Illinois State Laboratory of Natural History No. 1.

and described by Dr. R. Buchholz, in his "Branchipus Grubii von Dybowsky," Tafel III, fig. 6, with the exception that the blind appendage of the descending testis is missing.

The smallest larval stage I obtained from the Glendale pond measured 3^{mm} in length, but when mounted in glycerine jelly I could not tell whether it was a Chirocephalus or an Eubranchipus larva, as the frontal tentacles were not exposed. The same thing occurred in three other larger larvæ. One larva of $4\frac{1}{2}^{mm}$ in length showed the appendage as illustrated by Fig. 48. The inner basal clasper-hook just budded, is turned downward, the anterior, upper surface of the second antennæ and the frontal tentacle is seen. Another larva scarcely larger, second antennæ in about the same stage of development, exhibits the frontal tentacle as illustrated by fig. 49. It appears, and I judge from twenty-six mounted heads (in glycerine jelly) that the growth of the frontal tentacles of our *Chirocephalus* is very rapid, its entire length being probably attained between two exuviations.

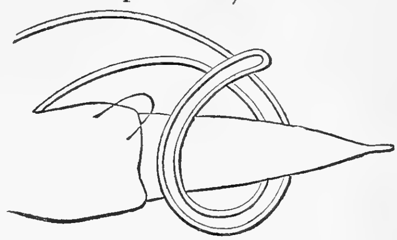


FIG. 49.—C. holmani, second antenna with frontal tentacle, from above.

II.—LARVAL STAGES OF APUS LUCASANUS Packard ESTHERIA COMPLEXIMANUS Pack. AND STREPTOCEPHALUS TEXANUS Packard (Plates XXXIV, XXXV).

From dry mud received from Dr. L. Watson, of Ellis, Kans., I hatched numerous specimens of larvæ of both *Streptocephalus texanus* Pack. and *Estheria compleximanus* Pack. but only three specimens of *Apus lucasanus* Pack. The mixture of mud and fresh water was kept at a temperature of about 75° to 80° F. during the summer months, and in nearly every instance, after the third or fourth day, I could, with the naked eye, observe some small larvæ actively swimming about in the aquarium. The larvæ of *Streptocephalus*, as well as those of *E. compleximanus*, look at first like little white birds, and Prevost, in Jurine's "Histoire des Monocles," in 1820, has compared the larvæ of *Chirocephalus* in a similar manner.

I have often obtained from one and the same lump of mud both the very small Nauplii of *Estheria compleximanus* and the *Streptocephalus texanus* but, strange as it appears, when the larvæ of the two genera were thus together, only those of the former (Estheria) survived, but those of the latter rapidly died off. In the single instance, when three Apus larvæ of several millimeters length were found at the bottom, they were also the only occupants of the jar. F. Spangenberg has drawn attention to this fact on page 61 of his paper on *Branchipus stagnalis*. He says that a single larva of *Apus cancriformis* kills in a few days a number of Branchipus larvæ. How one kills the other I could not observe, but have either raised Streptocephalus alone or Estheria or Apus alone. It is very likely that the secretion of the antennal gland, which is present in all members of this family, whose outlet is under the base of the second antennæ, is antagonistic to other species. The principal function of the gland is believed to be for lubrication, to assist the constantly-moving second antennæ. Its early appearance in the larva, its comparatively large development, together with its distinct orifice, may give support to my opinion.

F. Brauer, C. Claus, and F. Spangenberg agree that the new-born Apus sinks to the bottom, and gradually, with sluggish motions, rises again. I did not observe this, but found that older larvæ keep constantly creeping over the mud, and do not so actively swim about as other *Branchipodidæ* do.

I received about a pound and a half of dried clay-mud of a greyish color from Kansas, of which from five to ten grammes were used at the time for each experiment.

Plate XXXV (except figs. 3 and 4*a*) refers to *Apus lucasanus*, of which I obtained but three advanced stages. A very high and uniform temperature appears to be necessary to keep them alive.

Estheria compleximanus (Plate XXXV, figs. 3 and 4*a*) was frequently hatched, even at a temperature of 45° to 50° F., but I have unfortunately neglected to follow up its stages of development. It is a limnicolous, ostracod-like crustacean. The older larvæ, as well as the adult, like to dig and make furrows in the clay. I have seen them also swimming *in copula* for several seconds. The *Nauplius* is extremely minute, and has on either side two long, broad, juxtaposed spines (one a little higher up than the other) at the posterior side of its carapace. In the adult the shell-duplicature is of an elliptic form and of milk-white color. It is frequently cast off, but no notes were taken as to the number or manner of castings. They seem to take up their food while making furrows in the clay; the carapace protects the branchipeds which paddle continuously while the animal feeds.

With every moult a new addition of limbs is effected, an advanced specialized structure attained, until after the sixth or seventh moult of Streptocephalus, when of about 3^{mm} in length, the inner genital glands make their appearance, followed by the outer, and shortly afterwards a change of the second pair of antennæ is noticed, simultaneously with the full development of the eleven pair of feet. To avoid repetitions as to the gradual development of the latter, as well as of the inner and outer genital organs and the furca, I must refer to C. Claus and F. Spangenberg's papers.

I presume that the chorion proper in all Branchiopodidæ, situated between the exochorion or outer shell and the amnion or inner egg-membrane, has the same structure as that of *Argulus* and is similarly acted upon by water (under conditions peculiar to each species), described and figured by C. Claus.

The egg of *Streptocephalus texanus* is rather small, when dry, partly transparent, brownish, and measures three-tenths of a millimeter in diameter. It is of spherical shape and finely granulated.

The egg of *Apus lucasanus* is larger, brown, and measures one-half millimeter. Its exochorion is of the same structure as that of *Apus cancriformis*, showing large, thick-walled polygonal markings.

The Nauplius-stage of *Streptocephalus texanus* does not in the least differ from that of *Branchipus stagnalis* of Europe, perhaps the whitish instead of yellow color excepting. The first acinaciform or saber-shaped hook-bristle is on the inner side of the first or basal segment of the second antennæ. It is naked and becomes beset with two rows of fine ciliæ after the first moult, and after another moult it is split into two unequal flat termini, which are also ciliated. The second segment also bears a long flat and bent-inward hook-bristle, which is first naked and ciliate after the first moult. The second antenna terminates likewise with two branches, the shorter inner one bearing three long bristles, the outer longer having five long bristles arising from four segments. The second antennæ are the principal parts of locomotion, and give the larvæ the appearance of little white pigeons. The second antennæ remain in their previously described shape until a time when sexual differentiation takes place.

The further growth of the larva brings about an elongation and segmentation of the body. The latter begins from the base of the body, finally extending to its tip.

A nearly perfect circular disc is seen on the anterior part of its dorsal side; this is the cephalic scute (carapace).

With the subsequent gradual development this scute retreats, confining itself in the adult to the occipital part of the head. In the base of the second pair of antennæ a rather large meandering gland is seen whose outlet is right below the first saber-shaped flat bristle. This is the so-called antennal gland, whose presence has been ascertained in most members of this family of Crustaceans.

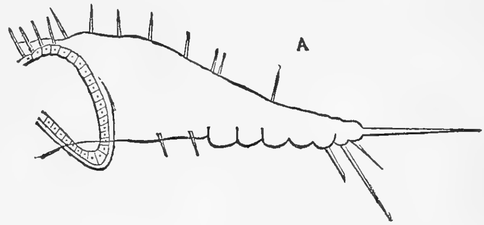


Fig. 50—Streptocephalus texanus. Left clasper of male larva with main branch budding; the greater part of bristles dropped, the remainder are shortened.

Below the middle of the front of the larval head hangs down a short broad fleshy lobe, which in live specimens under the microscope is seen occasionally to lift and lower again. This is the labrum, which we also find in the adult in a somewhat reduced state. The median pigmented eye on the front of the larva is sessile, very simple, having but one pair of "corpora vitrea" placed laterally. The Nauplius can distinguish light from dark, but cannot discern the exact outlines of objects with it.

The mandibular basal process of the third larval leg is transformed into a mandible with a curry-comb-like dentation, and makes its appearance at the time when the fourth or fifth pair of branchipeds begin to bud.

A ♀ of *Streptocephalus texanus* had 22 flat acinaciform, long maxillary teeth, and a very minute curved spine at the lower end. The first of the teeth at the upper end has 14 spines, all the rest have 8 or 9; the uppermost of them in each case being about twice as long and much stouter.

Transverse segmentation of the body always preceeds the lateral budding of the branchipeds.

The furca or terminal fork of the abdomen very early begins to bud in the shape of two latero-terminal protuberances with two short minute spines, and a little later another smaller lateral spine is formed. In larvæ of about 3.5^{mm} in length, five such spines have made their appearance on each of the two protuberances. The number of spines, with the middle one the longest, gradually after each moult, multiplies until the typical furca of the adult is attained. Between the first pair of branchipeds and the mandibulary palpus at an early age the two pair of maxillæ are formed, the first pair of which has in the adult Streptocephalus the characteristic form as illustrated by Plate XXXIV, fig. 7. In none of the numerous specimens examined by me could I ever find a mandibulary palpus in the adult.

When of about 3 or 4^{mm} in length, the second pair of antennæ are replaced by another form, the old one gradually degenerating. First the posterior, together with the two curved basal hooks, then the middle, and finally also the terminal long bristles and inner branch drop off from the inner side of the second antennæ. In the interior of the second antenna, near its base, an exuberant growth of cells takes place at this time (Fig. 50). On the outer side, near the base, three protuberances are seen, from each of which groups of hyaline, rather stout and short spine-like bristles arise. Their bases can be seen to originate from the deeper underlying cells, in fact they are prolongations of the latter. This change takes place in our Streptocephalus at a time when the eleventh pair of branchipeds has made its appearance and the stalked eyes which laterally bud out of the head are already contracted behind and provided with

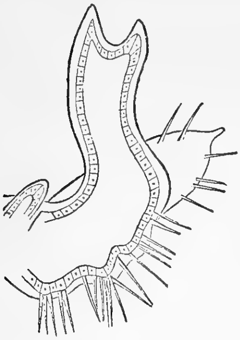


Fig. 51.—Streptocephalus texanus—right clasper ♂ larva 4mm in length.

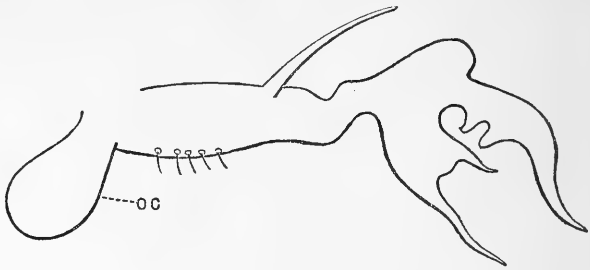


Fig. 52.—Right clasper ♂ *Streptocephalus texanus* Pack. *oc.* eye.

a stalk, while in *Branchipus stagnalis* the change in the second antennæ takes place earlier.

The three protuberances do not appear before the accumulated cell-masses have pushed out on the inner side of the antennæ in a downward direction part of the main branch of the male forked clasper. At the time when the latter just begins to fork at its tip a second inner branch is budding near its inner base (Fig. 51).

The remainder of the former second antennæ grows out into the outer long flat branch of the clasper, but, as in the aquarium the full grown form is seldom reached, I could not closely follow the development of this outer branch in detail. The new clasper shows in its entire length polygonal cells in the integument, which, after another moult, have partly disappeared, being then permanently confined to but a few spots on the inner rounded corrugate sides of the same.

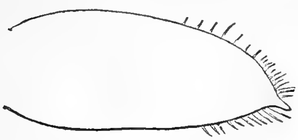


Fig. 53.—♀ Streptocephalus texanus, right clasper.

Fig. 54.—Cast-off skin of subimago-stage Streptocephalus texanus left male clasper from above.

III.—Larval stages of Eubranchipus vernalis Verrill.

During the whole summer of 1880 I experimented with dry mud from ponds inhabited by either the normal or pale race of this Branchiopod, but all in vain. Neither jars kept on ice in a large refrigerator, nor frozen, dampened mud, gradually or suddenly thawed, developed any larvæ. The mycelium of a fungus, a few Daphnidæ, and microscopic organisms were the usual result.

However, I obtained a few early stages of the pale race and many specimens of the later stages of the normal form from the ponds themselves. The latter are reddish and already pigmented when but 4mm in length, while those of the pale race were dull white.

Eubranchipus larvæ are comparatively much stouter and larger in their first stages than their allies. Larvæ of 0.8mm in length with the first three branchipeds budded out and (osmic acid prep.) nine more segments indicated show a diameter of 0.55^{mm} on the broadest part of the body, at the first pair of branchipeds.

Streptocephalus texanus in the same stage of development (in an aquarium) of branchipeds and segments measures 0.8^{mm} in length and 0.43^{mm} in width. The first and second pairs of antennæ, of course, are also proportionally stouter in *Eubranchipus.*

The anterior antennæ have (in the above stage) three hyaline flagellate bristles of 0.75^{mm}! in length, which, after the third moult, are reduced considerably.

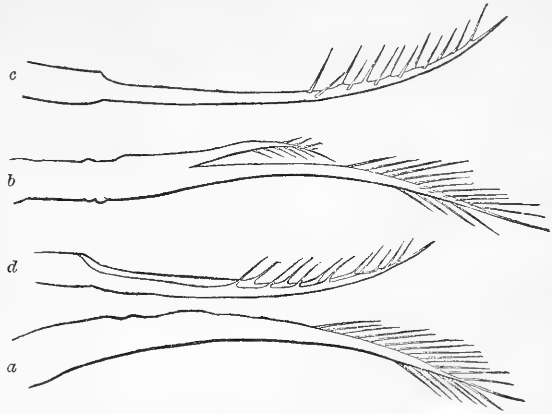


FIG. 55.—*Eubranchipus.* *a* First bristle-hook of 2d antenna of larva, $1\frac{1}{2}^{mm}$ long; *b* the same when older; *d* 2d bristle-hook of 2d antenna of larva; *c* one of the two middle bristles of mandibulary palpus. Pale var.

Shortly before the time when the second antennæ drop their long bristles the first four *olfactory bacilli* make their appearance at the side of the tip of the anterior antennæ.

The *second pair of antennæ* agree in general with those of *Branchipus* or *Streptocephalus.* There is a basal hook bristle, first plain then ciliate (Fig. 55 *a*) and then split. Second bristle-hook appears (Fig. 55 *d*) to be triangular or rounded exteriorly, and two-edged and ciliate interiorly. The terminal outer branch of the second antenna has fifteen long bristles and a terminal shorter one; the inner or posterior branch has three long and one short bristle. This branch is three-jointed; terminal branch is subjointed.

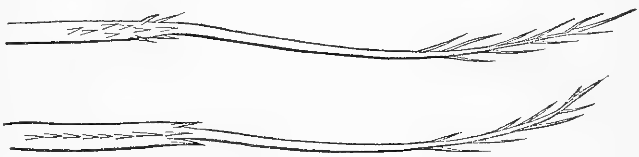


FIG. 56.—Setæ of first maxilla of Eubranchipus.

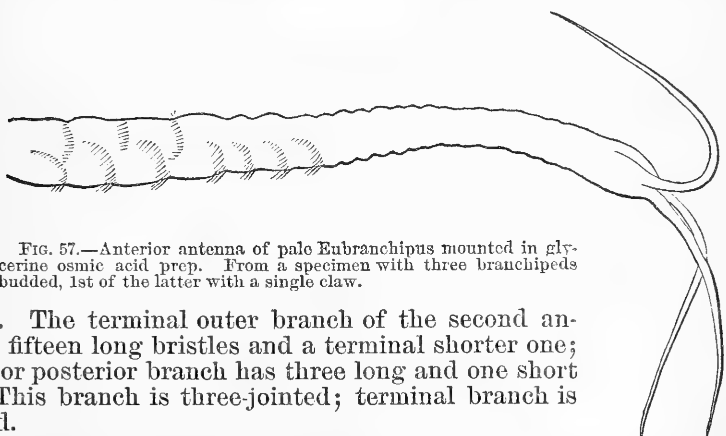


FIG. 57.—Anterior antenna of pale Eubranchipus mounted in glycerine osmic acid prep. From a specimen with three branchipeds budded, 1st of the latter with a single claw.

First maxilla of *adult Eubranchipus* is plain, and has thirty-one long, flat, acinaciform bristles or teeth, equally long (Fig. 56.)

The *second maxilla* is composed of a narrow, small, basal piece, with two strong, thick spines, each finely ciliate.

Mandibulary palpus is four-jointed, bearing seven ciliate bristles, the two basal and the three terminal ones being nearly straight (more so the former); the two middle bristles have a stout base, and are curved inwardly (Fig. 55 *c*).

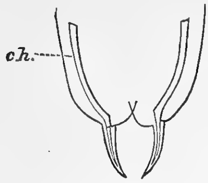


FIG. 58.—*a*. Same larva (with 3 branchipeds budded, 1st of the latter with a single claw): Lower part of abdomen with a chitinous bacillus, *ch.*, entering the furca. Plasmatic matter and remainder of yolk retreated through the effect of osmic acid.

The first (anterior) (Fig. 57) and second antennæ have their basal half, in very young forms, at least, peculiarly ciliate. This is mentioned also by F. Spangenberg, but not figured.

Second antennæ.—At the time of sexual differentiation the greater part of the bristles and the inner branch drop, the basal piece sprouts a few single ciliæ (not in groups), and from the under side at its base the future first clasper-hook begins to bud, which then becomes corrugate at its tip. An exuberant cell—complex in the basal piece, formation of transverse and longitudinal muscles, subdivision of the terminal piece of the antenna near its base, and budding of a small roundish protuberance at the inner side of the middle piece takes place, and the male clasper is nearly developed. If a female specimen, the entire antenna remains but with muscular differentiation; and at its inner base, on a broad frontal protuberance, a number of hyaline ciliæ appear. Somewhat later the form of the female clasper slightly changes into one peculiar to this genus (Fig. 61), which is very variable in form.

Fig. 59.—Seta of first maxilla of Streptocephalus texanus.

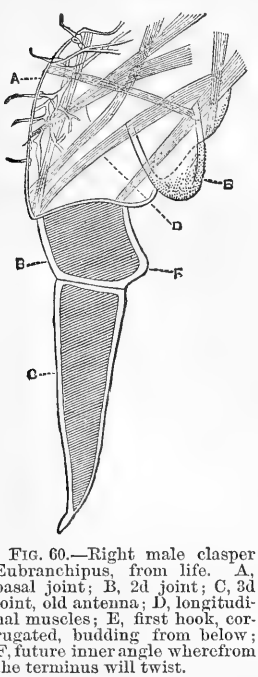
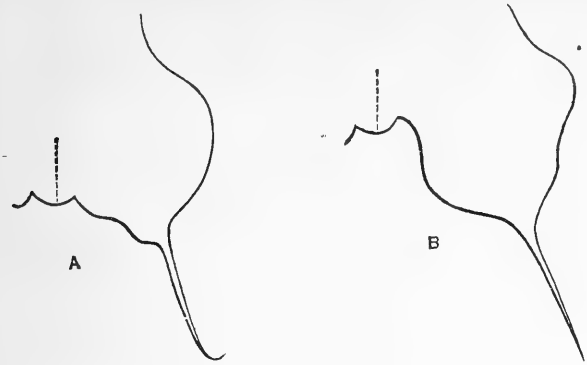


FIG. 60.—Right male clasper Eubranchipus, from life. A, basal joint; B, 2d joint; C, 3d joint, old antenna; D, longitudinal muscles; E, first hook, corrugated, budding from below; F, future inner angle wherefrom the terminus will twist.

At the time when in the male clasper the first hook is budding, the frontal tentacles are already present, but owing to their tendency to coil ventrally and their small size I did not succeed in closely following their mode of origin (Fig. 60 B). In its early stage the margin is entire, with a continuous row of large marginal cells; plasmatic contents in general intermingled with oil globules, and longitudinal muscles transversely striate. I think at a later time the latter will branch laterally, since the developed tentacle shows also transverse muscles. The peculiar mammiform excrescences along the margin are attained after several moults.

Larvæ with three branchipeds budded, the first of which, with a single claw, show the development of the post-abdominal *furca*, as illustrated by Fig. 58. I am of the opinion that the narrow piece running along the end of the body is a support for the embryonic *furca*, and is not a muscle, but a chitinous stick or bacillus, which, after one or more moults (Fig. 63) is pushed out, and its integument becomes ciliated. But the latter, after more moults, does not become the permanent *furca*, as we should expect, for it is cast off with the other integument, and the typical development of the *furca* begins (Fig. 62).

No internal chitinous support is found until in the adult state, when we again meet with a flat chitinous plate, confined to the *furca* alone. It is



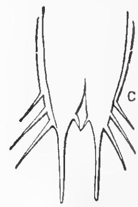


Fig. 62.

Fig. 61.—Female claspers; *b* more peculiar to the pale race.

an interesting phenomenon to see that the red normal *Eubranchipus* has a white and the ale prace a red *furca*. The transparent, greenish, *Chirocephalus holmani* and the whitish *Streptocephalus texanus* have also a red *furca*. The red *Eubranchipus* occurs in brownish, clear water, the others in turbid, milky water. It may be an assistance in copulation, *i. e.*, to make the individuals more visible, or conspicuous. Spangenberg (in op. cit. page 10) makes it more than plausible that the first (anterior) antennæ

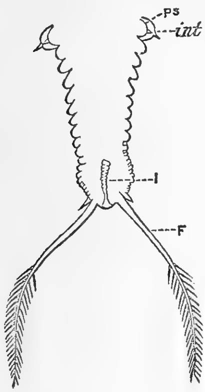


Fig. 63.—Last few segments of an Eubranchipus larva of $1\frac{1}{2}$mm length. Camera-lucida drawing from a mounted osmic acid preparation. P^5, fifth pair of branchipeds; *int*, cast-off integument (by the osmic acid); I, intestine; F, furca, ciliate. Gissler del.

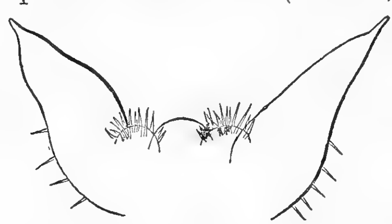


Fig. 64.—*Eubranchipus*, red ♀ larva, 13mm long; sides of head fimbriate above. From life. Gissler del.

of Branchipus are homologues of the leg, and I venture to compare the frontal tentacles in a similar manner. The following points support this theory: First, they are *lateral* appendages; second, their marginal appendages, more developed exteriorly, closely agree with the embryonic development of the branchipeds, from a single mammiform process up to two and three of the latter. The frontal appendages are different in nearly every species of branchiopod crustaceans; they are sometimes on the basal portions of the claspers in the adult, or they are reduced to minute papillæ. Dybowsky[1] calls them basal appendages, referring to the base of claspers, while Grube calls them more properly frontal appendages; Fischer calls them cephalic tentacles (Middendorf's Reisen nach Sibirien, Band II); Verrill calls them lanceolate, ligulate, fleshy processes.

[1] Archiv. für Naturgeschichte, 1860, Vols. 1 and 2, 26th Jahrgang: Beitrag zur Phyllopoden. Fauna der Umgebung Berlins nebst Kurzen Bemerkungen über Cancer paludosus Müller von B. von Dybowsky, M. D., page 195, Taf. X.

VII.—The order Phyllocarida and its systematic position.

Having studied the Phyllopoda, we may now discuss the relationships of Nebalia and the group which it represents.

History of the Phyllocarida.—The genus *Nebalia* was first established by Leach[1] in his Zoological Miscellany, vol. 1, p. 99, 1814. *Nebalia geoffroyi* Edwards, was described and the external appendages figured by Milne-Edwards in the Annales des Sciences Naturelles, tome 13, p. 297, 1828, and in the 2d series, tome 3, p. 309. Our *Nebalia bipes* was originally described under the name of *Cancer bipes* by Otho Fabricius in his Fauna Groenlandica, 1780.

In his Histoire naturelle des Crustacés (1840) Milne-Edwards places Nebalia in the family Apusidæ among the Phyllopoda; at the same time he remarks: "Les Nébalies sont de petits crustacés très-curieux qui, à raison de leurs yeux pédonculés et de leur carapace, se rapprochent des Podophthalmes, mais qui ne possèdent par de branchées proprement dites, et respirent à l'aide des membres thoraciques devenus membraneux et foliacés. Elles semblent, à plusieurs égards, établir le passage entre les Mysis et les Apus."

In 1850 Baird, in his British Entomostraca, founded the family *Nebaliadæ*, regarding Nebalia as a Phyllopod.

In 1853, in his great work on Crustacea, Prof. J. D. Dana gave the name *Nebaliadæ* to the family, with a diagnosis. He placed the group in his tribe *Artemioidea* in the Legio *Phyllopoda.*

Nebalia remained, by the general consent of carcinologists, in the *Phyllopoda* until Metschnikoff, in 1865, published an abstract of his essay on the development of *Nebalia geoffroyi*, which appeared in full in 1868. Unfortunately, his work was published in Russian, but Fritz Müller, in his "Für Darwin," quotes as follows from Metschnikoff, "that *Nebalia*, during its embryonal life, passes through the Nauplius and zoea stages, which in the Decapoda occur partly (in *Penëus*) in the free state." "Therefore, I regard *Nebalia* as a Phyllopodiform Decapod."

In 1872, Claus gave an account, with excellent figures, of the external anatomy of *Nebalia geoffroyi;* and in 1876, in his valuable work on the genealogy of Crustacea, he described the internal anatomy of the same species.

In 1875, in his "Atlantic Crustacea from the Challenger Expedition," Willemoes-Suhm placed the *Nebaliadæ* among the *Schizopoda.* While, however, the thoracic appendages of his *Nebalia longipes* have very narrow respiratory lobes (exites), yet they can be directly homologized with those of the other species of Nebalia, and in all other characters *N. longipes* does not differ essentially from the other species of the genus.

In 1879, in the *American Naturalist* for February, 1879, and in our "Zoology" (1879) we proposed the name *Phyllocarida* for Nebalia and

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[1] "Dr. Leach, in his 'Naturalist's Miscellany,' vol. 1, p. 99, published in 1814, describes it [*Nebalia bipes*] more fully than Montagu, and says the species he describes is not uncommon on the southwestern and western coasts of England. As he saw that it constituted a very distinct genus from any previously given by modern writers, he formed the genus Nebalia to receive it, and adds, 'in a systematic work this genus would hold a very conspicuous and important place, as it is not referable to any family hitherto established.' In a paper published soon afterwards by him, in vol. xi of the Linnean Transactions, on the Arrangement of the Crustacea, he assigns its place amongst the Malacostraca, in the order Macroura; in which he is followed by Lamarck, Bosc, and Desmarest, Latreille, Olivier, and Risso; the three latter authors, however, referring the species described to the genus Mysis." Baird's British Entomostraca, p. 32. 1850.

its fossil allies (see Bibliography), and gave a description of the order and mentioned the types composing it.

Nearly a year later, in 1880, Claus, in the last edition of his Zoology, according to Carus' Yahresbericht, 1880, also suggested that Nebalia represented a distinct order, which he calls *Leptostraca*. We have not seen the last (fourth) edition of Claus' Zoology (1882), in which the order is noticed.

Habits.—The species of Nebalia inhabit the sea at moderate depths. We have dredged *N. bipes* on the coast of Labrador in from four to eight fathoms, and on the coast of Puget Sound we collected a similar species, just below low-water mark, among fucoids. The following is taken from Baird's British Entomostraca: "Otho Fabricius tells us that it carries its eggs under the thorax during the whole winter; that they *begin to hatch* in the month of April, and that the young are *born* in May. They are very lively, he adds, and adhere to the mother, who appears then to be half dead. The adult swims in a prone state, using its hinder feet to propel it through the water. They are not very active. Montagu informs us that when moving in the water the superior antennæ are in constant motion as well as the abdominal feet, but that the inferior antennæ are usually motionless and brought under the body. They are found, according to Leach, on the south-western and western coasts of England, under stones that lie in the mud, amongst the hollows of the rocks; and Mr. McAndrew dredged it from a considerable depth amongst the Shetland Isles."

1.—The anatomy and development of Nebalia.

The first published description of the present species was by Kröyer, in his Naturhistorisk Tidskrift (Ser. 2, Bd. 2). It is written in Danish, and not accompanied by any figures.

In *Nebalia bipes* the body is rather slender and somewhat compressed, the anterior half protected by a carapace, beyond the lower edge of which the broad thin phyllopodiform feet do not project.

The carapace.—The head and anterior half of the body, including the thorax and four anterior abdominal segments, are covered by the carapace, which on the lower edge extends below the ends of the thoracic feet, covers the basal joints of the antennæ, and entirely covers the mouth parts. The sides are compressed, and are drawn together over the body by a large but rather weak adductor muscle (Pl. XXXVII, fig. 6), situated a little in front of the middle of the thorax. There is no large highly specialized adductor muscle connecting the two sides of the carapace, nor any well-marked round muscular impression in the carapace, such as is characteristic in the *Estheriadæ;* nor is there any hinge, a still more characteristic feature in the bivalved Phyllopods. On the contrary, as seen in Pl. XXXVI, fig. 3, representing the carapace removed from the body and flattened out, there are no signs of a median hinge-joint.

The nature of the rostrum is one of the diagnostic features of this order. In *Nebalia*, the rostrum is long and narrow, oval, seen from above, terminating in an obtuse point quite far in advance of the head. It is loosely attached to the sinus in the front of the carapace, and thus forms a long, narrow, tongue-like flap, with a free movement up and down. It is thus seen to be rather a movable appendage of the carapace than a solid, immovable continuation of it, as in the *Decapoda*. Upon removing the carapace and flattening it out, it is seen to be readily comparable with the carapace of *Ceratiocaris*.

The eyes.—The eyes are mounted upon a stalk, and thus *Nebalia* may be said to be essentially stalk-eyed. In this respect it is similar to the eye of the *Branchipodidæ* on the one hand, or to the eye of the *Decapoda* on the other. They are inserted just above and slightly in front of the 1st pair of antennæ. The cornea is considerably less in extent than the end of the eyestalk itself, and in this respect differs from the eye of Decapods.

The antennæ.—The two pairs of antennæ are large, well developed, and of nearly equal size in the female, but in the male the second pair extend backward beyond the bases of the caudal appendages. In the 1st pair the stem (scape or protopodite) is seen to be composed of fine joints, the 1st, 2d, and 4th the longest, the 3d and 5th short. From the scape arises the flagellum or endopodite, which has 16 well-marked joints, each joint provided externally with numerous setæ; and besides, there arises from the 5th joint of the scape or stem a scale-like unjointed appendage, which may be regarded as an exopodite; if so, then the 1st instead of the 2d antennæ in the *Phyllocarida* bear a scale-like exopodite; the 2d antennæ in *Decapoda* bearing the exopodite. The outer edge of this exopodite is thickly fringed with numerous long, delicate setæ. It thus appears that what corresponds to the setæ or protopodite of the 1st antennæ of Decapods consists of 5 instead of 3 joints.

The 1st antenna of *Nebalia* may be compared with that of the first stage of the larval lobster (Smith, Pl. XV, fig. 8) at the period when the exopodite is short, scale-like, and single-jointed.

The 2d antennæ have a 2-jointed stem or scape (protopodite), and a single long many-jointed flagellum or endopodite, the basal joint a large one; no exopodite being present, even in a rudimentary form.

The 1st and 2d antennæ are thus seen to be quite unlike those of the Malacostraca, and to resemble the Copepods, in that the anterior pair are rather the stouter of the two; but in those Copepods with very long antennæ it should be remembered that they are the 1st and not the 2d pair, as in the male *Nebalia*. It will thus be seen that while the antennæ of the *Phyllocarida* are entirely unlike those of the *Phyllopoda*, they are neither closely homologous with those of the *Decapoda* (*Mysis* or *Cuma*) or the *Copepoda*.

The 2d antennæ of the male is said by Claus to be very long, and to resemble those of male *Cumaceæ*, but upon a comparison the stem of the antenna is in *Cuma* quite different in the relative length of the three joints. So also, while, as Claus observes, they are like the antennæ of the *Amphipoda*, this resemblance is quite general; on the whole, however, the antennæ of both pair bear a general resemblance to the Malacostracous type; also, on the other hand, they may also be compared with the more primitive Copepodous type.

The mandibles (Pl. XXXVI, fig. 4; fig. 2, *md*).—These are remarkable from the small size and weak development of the biting edge or mandible itself compared with the palpus. The oval or biting end of the protopodite is small, and armed with comparatively few and weak setæ, which shows that the *Phyllocarida* probably feed on decaying animal and vegetable food, which is easily brushed into the mouth by their slight stiff bristles. The palpus, however, is enormously developed, extending out quite to, if not a little beyond, the edge of the carapace (Fig. 1). It is 3-jointed; the 2d a little longer than the basal, and swollen at the base, while the 3d is somewhat longer but slenderer, and edged with a fringe of close-set, rather stiff setæ. Though so immensely developed as to the palpus, and entirely unlike the mandible of the Phyllopoda, in which only the protopodite is developed, it may be compared with the mandibles of the Decapoda, especially of Mysis and other Schizopods,[1] in which a very long three-jointed palpus is developed. But the very long and large mandibular palpus and very weak protopodite may be set down as a diagnostic feature of the *Phyllocarida*.

The 1*st maxillæ* (Pl. XXXVI, fig. 2, mx^1; fig. 5, mx^1; 5 *a*).—These are likewise singular and diagnostic features of this order, as represented by their structure in the *Nebaliadæ*. They consist of a small lobe (Fig. 5 *a*, cx^1) with about 8 stout setæ, and a larger lobe (cx^2) with the outer edge fringed with long coarse setæ, one of which is a large ciliated seta; from this arises, after bending on itself at its base an extremely long and slender multiarticulate process (or endopodite?) which, in the female, is directed upward and backward (Fig. 5 *a*, *en*), reaching to the tergum of the basal abdominal segment, and ending in two very long slender setæ, while a few other similar setæ arise, one from each joint.[2] In the male of *N. geoffroyi*, according to Claus, the long setose process is directed forwards and downwards.

The 2*d maxillæ* (Pl. XXXVI, figs. 2, 5, mx^2).—These are entirely unlike those of the first pair, and unlike the Decapodous or Phyllopod type. They consist of a basal portion composed of four thin, delicate, unequal lobes (Fig. 5, ^{1,2,3,4}), edged with long setæ, with two setæ twice as long as the others arising from the 4th lobe; from this 4-lobed basal joint or coxopodite arise two appendages, the anterior (exopodite, *ex*), small, 1-jointed; the posterior (endopodite, *en*), 2-jointed, the end of the second joint carrying above 5 long, spreading, stout, slender setæ. This two-jointed appendage Claus considers as representing the stock of a palpus.

This pair of maxillæ are quite unlike those of Decapods (*Mysis*, etc.), as well as those of the Phyllopods, and appear to be another diagnostic feature of the order.

The absence of any maxillipedes, or of any rudiments of them, either in the adult or in the embryo, is a negative character of a good deal of importance when we regard the affinities of the group to the Decapods, or the zoëa-form of the same order, where two (*Macrura*) and three (*Brachyura*) pairs of maxillipedes are present, there being three pairs in the adult Decapod.

The eight pairs of Phyllopodiform thoracic feet (Plate XXXVII, fig. 3).—The maxillæ are directly succeeded by eight pairs of leaf-like thoracic feet, the maxillipedes not being present. The feet all repeat each other in form, and a description of the 3d or 4th pair will answer for the 1st as well as the last. The leg (Fig. 3, 3d or 4th pair) consists of a broad, thin, six-jointed appendage, the endopodite (*en*), which is fringed with very long delicate setæ, those arising from the terminal joint being ciliated; while a second series of fine stiff setæ arise obliquely from the edge. To the second joint of the endopodite are appended a distal or lower very broad thin gill, not quite twice as long as broad, and which reaches to the end of the endopodite, while situated more externally is a double broad large lobe which corresponds to the exite or flabellum of the Phyllopod foot, this flabellum being as long as the entire endopodite, but not quite so broad as the gill. The distal portion of the flabellum is more pointed than the proximal, and, as will be seen by referring to the figure, is more actively engaged in the process of respiration. The figure shows by the dotted lines of parenchymatous matter

[1] Compare G. O. Sars. Monographi over Mysider, 1870; Pl. I, fig. 8. Claus states that the large palpus is very similar to that of many Amphipoda, but apparently overlooks the still closer resemblance to that of Mysis.

[2] Claus draws attention to the position of this foot as compared with the 2d maxillæ (putzfuss) of the *Ostracoda*.

the course taken by the blood in passing through the gill and accessory gill or flabellum, and that it must also be partly aerated by the jointed endopodite; the entire appendage, therefore, as in those of the *Branchipodidæ*, is concerned in respiration. It will thus be seen that the limb is lamellated, but differs essentially from the Phyllopodous limb in that the endopodite is simple, the axis multiarticulate, but sending off no endopodal lobes from the axites, such as form the characteristic feature of the Phyllopodous foot. From overlooking this important and radical difference from the Phyllopodous foot the earlier observers were led to place Nebalia among the Phyllopods.

In comparing the thin, lamellar thoracic foot of Nebalia with the thoracic foot of any Decapod from *Cuma* to *Mysis*, and up through the *Macrura* to the crabs, it will be found impossible to homologize the parts closely, though a general homology is indicated, the endopodite of the Nebalia and the gills corresponding in a general sense to those of the Decapods, and it is this lack of close homology more than any other which forbids us from regarding the *Nebalidæ* as entitled to take rank under the order of *Decapoda*, or with any of the Malacostraca. But when we compare the thoracic legs of the adult Nebalia with the maxillipedes of the zoëa of the Decapods, then we can detect a slight and interesting resemblance, but the resemblance and homology is not so close as between the thoracic legs of the Phyllopods and the maxillæ of the early zoëa.

On comparing the broad lamellate thoracic feet of the adult Nebalia with the rudimentary thoracic feet of the later stages of the zoëa the resemblance is but slight. Just before the zoëa passes into the adult condition the five pairs of thoracic feet of the adult bend out as two-lobed processes; but the resemblance to the leaf-like foot of Nebalia is too remote to be of any taxonomic value; and this remote resemblance shows that Nebalia does not belong to the Decapod type.

The six pairs of abdominal feet (Plate XXXVII, figs. 4, 5).—Turning to the abdominal feet, we find that they are simple, without gills, and entirely different from the leaf-like thoracic appendages, and we have in this differentiation of true abdominal from the thoracic feet a Malacostracan character, one quite unlike the differentiation or blending of the two regions in the Phyllopods.

The abdomen is nine-jointed, the segments cylindrical and edged with obtuse spines (Pl. XXXVI, fig. 8.) much as in Copepoda.

The segment succeeding the 8th thoracic is much larger and extends farther down sternally than the 8th thoracic, and bears a large, stout pair of feet, to which the three following pairs are closely related in form. For example, the 2d pair (Pl. XXXVII, fig. 4) consists of a large, thick, long stem (protopodite) which sends off three appendages, an outer (exopodal) stout, blunt appendage, (*ex*); edged with stout setæ externally and more densely on the inner edge with ciliated, delicate setæ the middle two-jointed appendage (endopodite, *en*) is longer and slenderer than the outer, and edged externally with finer setæ; a third minute bract-like appendage, Claus says, acts as a retinaculum (Fig. 4, *ret.*) to connect the two legs of the same pair while the creature is in the act of swimming. In their general form the abdominal legs appear to resemble the simple biramous legs of the *Copepoda*, but still more closely those of the *Amphipoda*, in which, as Claus observes, there is a similar retinaculum. (See also Milne-Edwards's Crustaces, Pl. 30, fig. 3^a.)

The 5th and 6th segments of the abdomen bear much smaller, more rudimentary legs. The first pair (Pl. XXXVII, fig. 5) are seen to be two-jointed, the 2d joint long and slender, bearing near the end stout raptorial setæ, and on the inner edge slender setæ. The 6th pair are still more rudimentary, one-jointed, and with but few setæ, which are stiff and coarse. These resemble the simple, unbranched 5th and last pair of abdominal feet in Copepoda (*Calanus* ♀).

The long, slender terminal segment bears two very long, narrow cercopods (Pl. XXXVI, fig. 7) ending in one large and several small setæ, but there is no telson; the cercopods are simple, the integument entirely smooth, with no striæ or any other markings, and they are edged externally with short and internally with long ciliated setæ. In the absence of a telson Nebalia differs from Cuma or any other Decapod, and in this respect, and the simple cercopods, shows a close resemblance to the terminal segment with its two setiferous cercopods of the *Copepoda*. According to Claus the males differ from the female in *N. geoffroyi* in the rather narrower carapace and slighter body, but chiefly in the very long 2d antennæ, the flagellum of which reaches nearly to the end of the caudal appendages. The male sexual glands open on the last of the eight thoracic segments, which fact Claus regards as a proof of the agreement of Nebalia with the Malacostracous type.

Internal anatomy.—Claus remarks in his "Untersuchungen zur Erforschung der genealogischen Grundlage des Crustaceen-Systems" (1876) that in all the internal systems of organs Nebalia is considerably removed from the *Phyllopoda*, and shows an immediate relationship to the Malacostraca, sometimes approaching near the *Amphipoda*, sometimes near the *Mysidæ*. The nervous system consists of a large two-lobed brain and of a ventral cord extending through all the limb-bearing segments, there being, as shown in Metschnikoff's Fig. 25 of the embryo, 17 ganglia, corresponding to the 17 limb-bearing segments of the body behind the head. A transverse section of a ventral ganglion of *N. bipes* (Pl. XXXVI, fig. 9, or Fig. 66, in text, *ng*) shows a form of ganglion quite unlike that of the *Estheria* and other Phyllopods (Pl. XXIV, fig. 9, *ng*; XXXI, fig. 8, G^3, G^4; XXXII, fig. 2, *ng*; XIV, fig. 4, *ng*; XXXIII, fig. 5, *gang.*), in which the ganglia are separate, connected by rather long transverse commissures, whereas in Nebalia the pair of ganglion are consolidated and of the form of the Decapod ganglion, as also pointed out by Claus, who says that there is a very close resemblance in the form of the nervous centers to the ventral ganglionic chain of the *Mysidæ*.

We have endeavored to obtain good sections of the brain of *Nebalia bipes*, and Fig. 65 (in the text) will serve to illustrate tolerably well the form and intimate structure of the supra-œsophageal ganglion. The brain is very small, and the section represented was the third from the front of the head. The ovaries (*ov*) pass into the head, the end of each ovary overlying the brain. The brain itself is composed of two lobes closely united, and seen in section the brain is as deep as broad, with a constriction passing around the outside in the middle. The histological structure is very simple, with nothing approaching the complex nature of the Decapodous brain. Each division or ganglion of the brain is composed of nucleated ganglion-cells, the nuclei large and distinct, as seen in Fig. 66 *a*, and imbedded in a fine granular substance (*puntzsubstance*). At the lower part of each ganglion the fibers forming the commissures are quite distinct. Whether the 1st antennæ or both pairs are innervated from the brain Claus does not state, and we have been unable to observe. It is probable, however, that at last the 1st antennal nerves arise from the brain, judging from Metschnikoff's Fig. 25, wherein he shows a nerve descending from the under side of the ganglion, while the œsophageal commissures are directed backward; and we feel uncertain whether the descending nerves in our figure are the 1st antennal nerves or the œsophageal commissure. Claus also likens the stalked eyes to those of *Mysidæ*. In Nebalia no ears have been found.

In the digestive canal, says Claus, we have a quite specific peculiarity, together with approximations sometimes to the *Amphipoda* and *Isopoda*, and sometimes to the *Mysidæ* and *Podophthalmata*. The short up-curved œsophagus leads into a stomach with a complicated chitinous armature, in which an anterior and a posterior division can be distinguished. While in form and relative size of both parts there is a resemblance to the stomach of *Amphipoda*, so we may also observe in the position and number of the chitinous plates of the apparatus for triturating the food a true resemblance to the Isopoda, but also to the pyloric division of the stomach of the Mysidæ, whose capacious and sack-like expanded cardiac division seems to correspond to the differently-formed œsophageal portion of Nebalia. The slender intestinal canal along its whole course is surrounded with a uniform layer of circular muscles, and on the inner side of the *tunica propria* is surrounded with a thick, fatty layer of epithelium; it reaches to the beginning of the last segment, which is nearly filled by the muscular rectum (*afterdarm*). At the origin of the intestine (chylusdarm) arise two anteriorly and four (two larger than the others) posteriorly-directed liver-tubes; these four latter-named tubes or cœca are attached by a richly-developed fatty tissue of the serous membrane to the intestinal walls, and reach far into the abdomen. The two anteriorly-directed cœca reach to the antennal segment, and are frequently wholly enveloped by the fat corpuscles of their serous coat. (Compare our figure of *N. bipes*, Pl. XXXVII, fig. 6.)

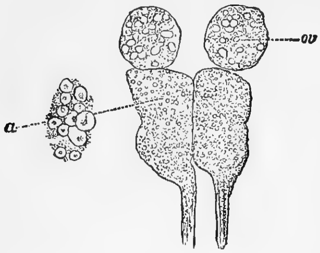


FIG. 65.—1. Section of brain of *Nebalia bipes*: *ov*, ovary; *a*, portion of brain still more enlarged to show the ganglion cells. Author del.

"The two anterior biliary cœca manifestly correspond to those which we so often, though not always, meet with in Podophthalmatous larvæ (Phyllosoma, Sergestes-larvæ, &c.), but which, however, exist only in a rudimentary state in many Edriophthalma. The histological structure of the liver-tubes agrees closely with that of the intestine; the circular muscles still remain, though scattered and absent at intervals. The epithelium consists of smaller and larger cells filled mostly with large, fat cells, whose secretions, like a fluid tinged yellowish, fills the often widely distended cavity of the canals. Now, arising in a remarkable way on the under (or lower, *unterer*) side of the intestine are two long ascending appendicular tubes, for the most part embedded in the fat body, which is enveloped by fat cells. The hinder intestinal appendages of Nebalia, in which we could not detect the colored secretion of the liver-tubes, remind one of the so-called malpighian tubes of the Gammaridæ, which arise at the beginning of the much longer rectum which passes through the three terminal segments of the abdomen. In Nebalia the relatively short rectum, by means of the numerous muscular bands suspending it from the intestine, performs the movements so generally observed in Phyllopods, by which the water is drawn in in an almost rythmical manner and then expelled. The anus, concealed by two triangular chitinous plates of the terminal segment, opens between two small lateral flaps, which closely resemble those in the inner side of the furcal appendages of the Protozoëa larva of Penæus.

"Of the pair of tubular glands which serve in the body of Phyllopod larvæ as antennal and shell glands, but which in the Malacostraca undergo a substantial reduction, we find in Nebalia the anterior pair as slender glandular tubes in the basal joint of the 2d antennæ. This relation of this gland, which is absorbed in the course of the metamorphosis, but in the Malacostraca, however, is generally present as a simple or winding glandular passage, affirms further the near affinity of Nebalia to the Malacostraca stem. Of the complicated shell-gland no remains survive in the Malacostraca. What we are accustomed to regard in the Decapoda as shell-glands is nothing more than the anterior gland which belongs to the maxillary region, but opens externally on the basal joint of the 2d antennæ. But we can surely prove, after careful researches on living Malacostracan larvæ, that the rudiments or survivors of this gland are situated on the sides of the maxillæ (kiefer). In the Stomapod larvæ I think I have found such a survival in the shape of a simple, somewhat curved glandular tube; and also in this place the residuum of the shell-muscles are preserved. The shell or adductor muscles of Nebalia appear to be well developed, quite as in the shelled Phyllopods. On each side of the shell we observe, under the mandibles, somewhat dorsally, a large round impression with an upper and under somewhat curved row of muscle-facets. On the upper end of the group of muscles, however, on the inner side of the shell, is to be found a small glandular tube, which with a contracted neck extends to the region of the maxillæ, and is surely nothing else than the survivor of the true shell-gland of the Entomostraca."

Our sections of the body of *Nebalia bipes* show that in their general features the digestive canal and appendages are much as Claus describes for the Mediterranean species. We were unable to get good sections of the proventriculus or *kaumagen*. Plate XXXVII, fig. 6, evidently passes through the stomach in front of the heart, which is much

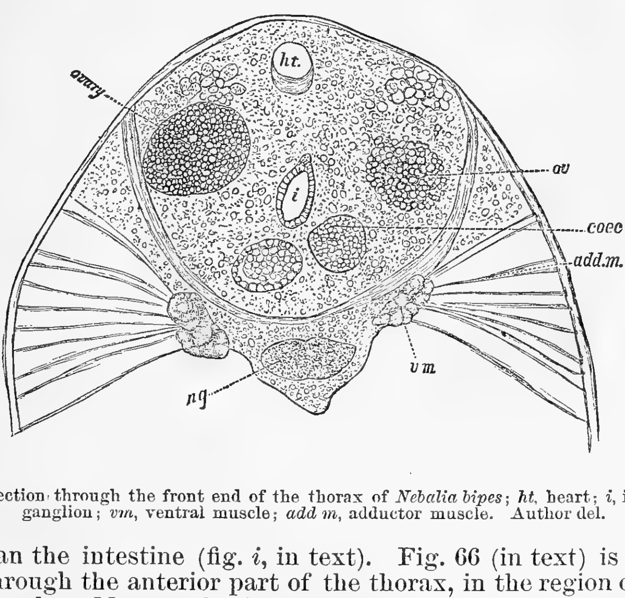


FIG. 66.—Section through the front end of the thorax of *Nebalia bipes*; *ht*, heart; *i*, intestine; *ng*, ganglion; *vm*, ventral muscle; *add m*, adductor muscle. Author del.

larger than the intestine (fig. *i*, in text). Fig. 66 (in text) is a section (No. 9) through the anterior part of the thorax, in the region of the adductor muscle (*add. m.*); the heart (*ht*) is quite remote from the small intestine, which is smaller than the two anterior cœca. In Fig. 67 (in text) of section 14, through the same specimen at the end of the thorax, the heart (*ht*) is of its maximum size, and now we see sections of six cœcal tubes, the series of four lower ones being the four posterior tubes described by Claus as passing back into the abdomen. In this section the dorsal muscles (*dm*) of the posterior part of the body appear, and the ventral muscles (*vm*) are larger than in section 9, while the ovarian tubes (*ov*) are smaller.

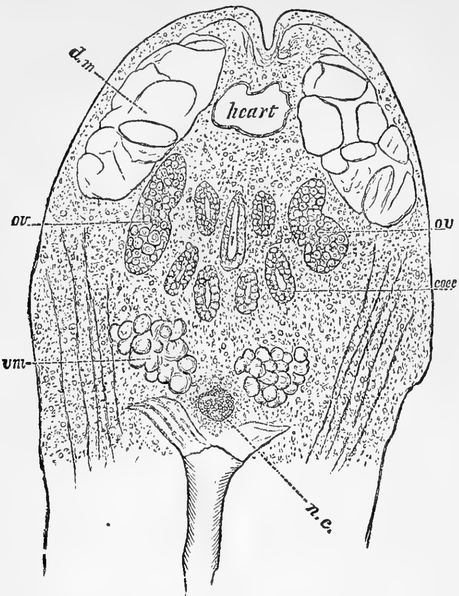


FIG. 67.—Section through the end of thorax of *Nebalia bipes*, showing the six cœca (*cœc*), the heart (*ht*), the ovaries (*ov*), and the sets of muscles; *dm*, dorsal muscles; *vm*, ventral muscles; *nc*, nervous cord; *ov*, ovary; *i*, intestine. Author del.

Without translating in full Claus' description of the heart and circulation we will only give his conclusions. The heart of Nebalia is a long straight tube a little thicker just in front of the middle, beginning over the maxillæ just in front of the 1st thoracic segment (tergite) and extending to the middle of the 4th abdominal segment. It has two pairs of lateral large ostia for the entrance of the venous blood, and four pairs of dorsal arterial openings in the anterior part of the heart. Says Claus: "The heart combines the characters of Phyllopods and Malacostraca, while the tubular dorsal vessel passing through twelve segments, in its form and in the greater number of ostia resembles the many-chambered dorsal vessel of the Phyllopods, so on the other hand the relation of the two ends with the head and abdominal aortæ, together with the hinder pair of arteries, reminds us of the swift, regular, and in general complicated and vascular circulation of the Malacostraca. Of especial interest is the similarity of the shell, or carapace-circulation of the Stomapods and Mysidæ with Nebalia."

Of especial interest, says Claus, is the sexual apparatus, which combines in a surprising way in structure and form the peculiarities of Phyllopods and Malacostraca (Amphipoda), and also in position and topography retains the primitive relation of the ovaries and testes. Both are slender, long tubes, which lie right and left on the dorsal side of the intestine from the sixth abdominal segment to the region of the stomach (kaumagen), and by means of a short cross passage open out on the thorax. In the male sex this efferent duct opens in the basal segment of the 8th pair of thoracic limbs, namely, in the same place as in the Malacostraca.

Claus includes Nebalia among the Malacostraca, but when we consider the composite nature of the internal organs as described by him, we wonder that he failed to appreciate the independent, synthetic nature of the Phyllocaridan type, which, when we take into account the external as well as internal organization, forbids our regarding Nebalia as a true Malacostracan, though the type of a group standing outside of, but nearer to the Malacostraca than are the Phyllopods.

The development of Nebalia.—Our knowledge of the development of Nebalia is due to the distinguished Russian embryologist, who in 1868 published an elaborate account of the developmental history of *Nebalia* *geoffroyi*. Unfortunately the pamphlet is in Russian, and only brief abstracts of it have appeared in German. But as ample and well-drawn figures illustrate the work we can state the salient points in the ontogeny of this interesting Crustacean. The yolk does not undergo total division, but by the subdivision of a large polar cell the yolk becomes surrounded by a layer of blastodermic cells. Soon after the rudiments of the two pairs of antennæ and of the mandibles bud out, the abdomen also being differentiated from the rest of the body (Pl. XXXVIII, fig. 1). This is regarded as representing the free nauplius condition of other Crustacea. At a succeeding stage (Fig. 2) the two pairs of maxillæ and two pairs of thoracic feet bud out; and in a stage immediately succeeding (Fig. 3) the palpus of the mandibles elongates, the maxillæ are two-branched, and seven (or eight) pairs of thoracic feet are indicated. In a succeeding stage (Fig. 4) Nebalian characters assert themselves; such are the carapace and large rostrum, the biramous anterior pair of antennæ, the unbranched 2d pair, the long mandibular palpus, the absence of any rudiments of maxillipedes, and the eight pairs of thoracic feet (bænopoda) and three pairs of abdominal feet (uropoda), all of which are now well developed. At this stage it may be seen that, as in spiders, the 1st pair of thoracic feet may represent the 2d maxillæ of insects transferred from the head to the thorax; so in Nebalia, the three first of the eight pairs of thoracic feet may correspond to the three pairs of maxillipedes of Decapods, which in early life, before the thorax is differentiated from the head, may have remained afterwards as a part of the thorax. An intermediate step is the retention in the *Mysidæ* of the last pair of maxillipedes or the 1st pair of thoracic feet, so that these Crustacea have six pairs of feet. Moreover Nebalia at this time, in the absence of differentiation of thorax from the abdomen, and of thoracic and abdominal feet, the two sets being similar in form and development to each other, may also represent the Phyllopod stage. In the next stage, at the the time Nebalia leaves the brood sac of the mother, it is but one step removed, so to speak, from the adult form.

Metschnikoff's observations were made on *Nebalia geoffroyi* of the Mediterranean Sea. We have in the sections of *Nebalia bipes* observed stages of development in the young similar to the stages represented by Metschnikoff's figure 13 or 14, and have found in the bottom of the vial in which the specimens were sent several young which had fallen out of the brood sac of the parent. Upon comparing these with Metschnikoff's Fig. 19, or Fig. 68, in text, they are of the same form; the rostrum being large, the procephalic lobes large, the eyes small, the stalks not yet developed, while the maxillary palpus stretches back to the 1st abdominal feet; the thoracic feet are covered by the large carapace; and a 4th pair of abdominal feet have developed, while the caudal appendages are as in the adult. In all these features we see only a general resemblance to the Schizopods of any value, the similar earliest phases of development proving of no special importance.

Comparison between the early stages of Nebalia and the Decapod (*Schizopod*) *Mysis.*—It would appear that if Nebalia were a Decapod that in its larval stage it should present a close homology with the Schizopods at a similar stage of existence. In Euphausia the young leaves the egg and becomes a free swimming nauplius, and then a protozoëa, and at length a zoëa larva before assuming the adult condition. It is evident that since Nebalia passes its early stages in the incubatory pouch of the mother, that it should be rather compared with the young, when about ready to leave the mother, of some Mysis-like form.

Happily Prof. G. O. Sars has afforded us the material for such a comparison. The early stages of Mysis, as worked out by Van Beneden and Claparède, and of Nebalia, are much alike; the formation of the blastoderm is much the same. The nauplius stage in the egg is nearly identical in both, but beyond this the parallelism ceases to be an exact one; Nebalia turns off and follows quite a different developmental path from Mysis or any Decapod. If we compare the young of Nebalia, taken from the brood-sac, with that of Mysis, as figured by Claparède (Plate XVII,

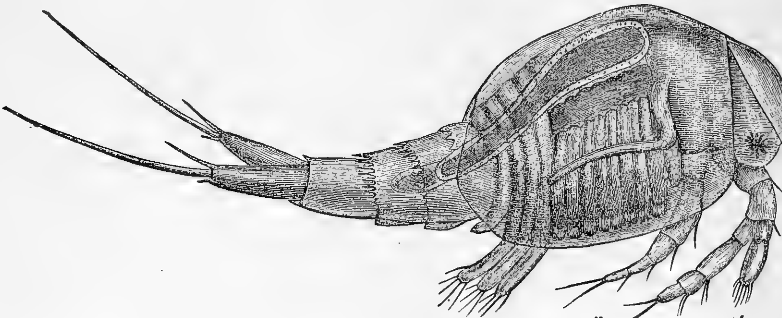


Fig. 68.—Embryo of Nebalia ready to hatch, enlarged; *ant'*, 1st antennæ; *ant''*, 2d antennæ; *ab.f.*, abdominal feet or uropoda. The first maxilla crosses the thoracic feet. After Metschnikoff.

fig. 6), or a more advanced stage, particularly that of *Pseudomma roseum*, as figured by Sars,[1] we shall find that many of the differential characters which, in the adult, separate the *Phyllocarida* from the *Decapoda*, are to be found in the young. In Mysis and allies at the same stage as Metschnikoff's, fig. 18 of Nebalia, (our Plate XXXIII, fig. 4,) the 2d antennæ are simple instead of being bifid as in Nebalia; there are no maxillipedes, and the maxillæ are, as in the adult, immediately succeeded by the eight pairs of thoracic feet; moreover there are no abdominal feet in *Mysis* or *Pseudomma*, while three pairs are present in the young Nebalia. But with the exception of the lack of abdominal feet in the *Mysidæ* at this stage, it may be thought upon the whole, as has already been stated by Balfour, that "the development of Nebalia is abbreviated, but from Metschnikoff's figures may be seen to resemble closely that of Mysis. . . . There is in the egg a nauplius stage with three [pairs of] appendages, and subsequently a stage with the zoëa appendages." It seems to us that the comparison[2] here made is, as regards any resemblance to a zoëa, loose and inexact, whether applied to the *Mysidæ* or to the *Phyllocarida*. The stage of the *Mysidæ* succeeding the nauplius is characterized by the presence of the rudiments of eight pairs of appendages, the two pairs of maxillæ, and the six pairs of thoracic feet of the Schizopodous type, while the zoëa has no thoracic feet at all, so that it would appear that the Schizopods do not pass through a genuine zoëa state like that of the higher Decapods. Nor on the other hand is the Nebalia stage represented by Metschnikoff's fig. 18 (our fig. 4), a zoëa stage, for the embryo has the rudiments of eight pairs of thoracic feet, and besides those of three pairs of abdominal feet, while there is a well-marked carapace and rostrum, as well

[1] G. O. Sars, Monog. over Mysider, Heft 1. Taf. IV, fig. 23.

[2] Claus (Genealog. Gundlage des Crust. Systems, p. 31), as we find since writing the above, does not accept Metschnikoff's comparison of the young Nebalia with the zoëa, although he does not give the reasons for his dissent.

as procephalic lobes with eyes, all these parts not being developed in the embryo Mysidæ.

But whatever may be said of the resemblances between Nebalia and the *Mysidæ* at an early period after the nauplius stage has been discarded, when we compare the later stage represented by Metschnikoff's fig. 19 (our fig. 68, in text) with the latest larval stage of Pseudomma (see Sars's figure, our Plate XXXVIII, fig. 5), then we see that the diagnostic ordinal characters of the *Phyllocarida* have declared themselves. There are to be seen in Nebalia the large movable rostrum, the compressed pseudobivalvular carapace, the lack of maxillipedes, the eight pseudophyllopod thoracic feet, four pairs of abdominal feet, out of the six of the adult. On the other hand, in Mysis of the same stage, the two pairs of maxillipedes are well developed, and the six pairs of remarkably long thoracic feet (the first pair modified maxillipedes) are present. There is little to indicate that the Schizopods have descended from a Nebalia-like form, but rather from some accelerated zoëa form; while, as we attempt in this essay to show, the Phyllocarida have had no Decapod blood in them, so to speak, but have descended by a separate line from Copepod-like ancestors, and culminated and even began to disappear before any Malacostraca, at least in any number, appeared.

II.—The Paleozoic Allies of Nebalia.

Having studied the anatomy and development of Nebalia we are prepared to compare it with a group of fossil forms which are scattered through the older Paleozoic rocks from the lowest Silurian to the Carboniferous. In a brief article[1] Mr. Salter, nearly twenty years since, sketched out the characters and showed the relationship of *Ceratiocaris* and a number of allied forms to *Nebalia* in the following paragraph:

"Before the structure of *Ceratiocaris* was known, of which genus a reduced figure is here given, the rostral portion of *Peltocaris* could not have been understood. But a reference to the accompanying series of wood-cuts will show that a tolerably broad rostrum, placed in the same relative position, occurs in *Ceratiocaris*. In the recent *Nebalia* it is fixed, and in *Dithyrocaris* and other genera it is perhaps yet to be discovered. Again, *Ceratiocaris*, together with its movable rostrum, has a bivalved shell, yet habitually keeps its valves half closed, as I learn from perfect specimens."

Salter then enumerates the characteristics of the fossil genera, beginning with *Hymenocaris*, which he considers the more generalized type, and in the wood-cuts which we partly here produce shows the geological succession of these genera, which also serves as a genealogical table. He regards them as Phyllopods, associating Estheria and Apus, regarding the latter as "the most complete and decided form, and it is one of the latest of the group, as it commences in the Trias." He also says: "The links between these coal-measure forms and those of recent times are many of them wanting; but in *Nebalia* we have a good representative of the compact, shield-shaped form of *Ceratiocaris*, the two valves soldered into one, and the rostrum attached, the eyes being still beneath the carapace." It is evident from this that Mr. Salter regarded the fossil genera he enumerates as allied to and as the ancestors of Nebalia, and as representatives of it in Palæozoic times. He evidently adopted the views of Milne-Edwards and others as to the Phyllopodous nature of Nebalia.

[1] On *Peltocaris*, a new genus of Silurian Crustacea, by J. W. Salter, Quarterly Journal of the Geological Society of London, vol. xix, 1863, p. 87.

Discarding the Phyllopod forms, we here reproduce Salter's figures and geological succession, which has been confirmed by the discoveries of Barrande and H. Woodward. Salter's figure of Nebalia is, however, replaced by an original one.

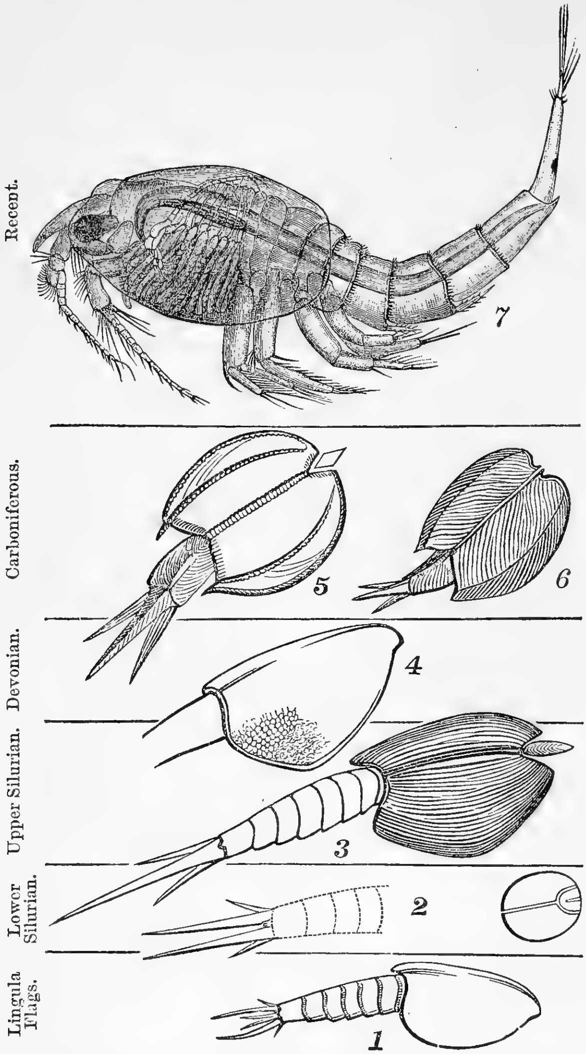


Fig. 69.—1. Hymenocaris (Lingula Flags); 2. Peltocaris (Lower Silurian); 3. Ceratiocaris (Upper Silurian); 4. Dictyocaris (Devonian); 5. Dithyrocaris (Carboniferous); (6. Argus); 7. Nebalia (Recent).

In his article on the structure and systematic position of Nebalia,[1] Claus thus refers to the paleozoic forms:

"It is generally considered that the oldest paleozoic crustacean remains whose shells and form of the body partly resemble Apus, and partly show a great similarity to Nebalia, for this reason are considered to be Phyllopods, though we are without any information as to the nature of the limbs. But now the instructive error, to which the consideration of Nebalia gave occasion, will lead us to exercise greater caution in the interpretation of such incomplete and imperfectly known remains.

"In *Ceratiocaris* Salter we have a great Nebalia-like carapace by which a series of free segments were covered, and moreover a long well-separated lancet-formed rostrum. On the other hand, the form of the abdomen, with the powerfully developed telson beset with lateral spines, indicates a different form, which also finds expression in the appendages of *C. papilio* Salt. figured as antennæ or thoracic limbs. If these representations indicate true limbs, then they remind us most of the larval limbs of Decapods. So also the position of *Dictyocaris* Salt. and *Dithyrocaris* of Scouler to the other Silurian fossils regarded as Phyllopods (Hymenocaris, Peltocaris) will remain problematical until

[1] Siebold u. Kölliker's Zeitschrift. xxii, 1872, p. 329.

we have obtained more precise explanations as to the nature of their limbs.

"It is in the highest degree probable, however, that all these forms are not true Phyllopods, but have belonged to a type of Crustacea, of which now there are no living representatives, but which, taking their origin from forms allied to the lower types of Entomostraca, have prepared the way for the Malacostracan type. Such a connecting link, which has served to the present day, we evidently find in the genus *Nebalia*."

In 1879,[1] without knowing the views of Claus, just quoted, we published the following brief notice of the leading characteristics of the group, and proposed that the paleozoic fossil forms, Ceratiocaris, etc., be united with the Nebaliadæ to form a separate order of Crustacea under the name of *Phyllocarida*.

"The *Nebaliadæ*, represented by the existing genus *Nebalia*, have generally been considered to form a family of Phyllopod Crustacea. Metschnikoff, who studied the embryology of *Nebalia*, considered it to be a 'Phyllopodiform Decapod.' Besides the resemblance to the Decapods, there is also a combination of Copepod and Phyllopod characteristics. The type is an instance of a generalized one, and is of high antiquity, having been ushered in during the earliest Silurian Period, when there were, when we regard the relative size of most Crustacea, and especially of living *Nebaliæ*, gigantic forms. Such was *Dithyrocaris*, which must have been over a foot long, the carapace being 7 inches long. The modern *Nebalia* is small, about half an inch in length, with the body compressed, the carapace bivalved as in Limnadia, one of the genuine Phyllopods. There is a large rostrum overhanging the head; stalked eyes; and, besides two pairs of antennæ and mouth parts, eight pairs of leaf-like, short, respiratory feet, which are succeeded by swimming feet. There is no metamorphosis, development being direct.

"Of the fossil forms, *Hymenocaris* was regarded by Salter as 'the more generalized type.' The genera *Peltocaris* and *Discinocaris* characterize the Lower Silurian Period, *Ceratiocaris* the Upper, *Dictyocaris* the Upper Silurian and the lowest Devonian strata, *Dithyrocaris* and *Argus* the Carboniferous Period. Our existing northeastern species is *Nebalia bipes* (Fabricius), which occurs from Maine to Greenland.

"The Nebaliads were the forerunners of the Decapoda, and form, we believe, the type of a distinct order of Crustacea, for which the name *Phyllocarida* is proposed."

A slightly fuller account of the order was also published in the writer's Zoology,[2] and the order Phyllocarida was placed (pp. 325, 326) below Tetradecapods and Decapods, the scheme then presented being on the following page:

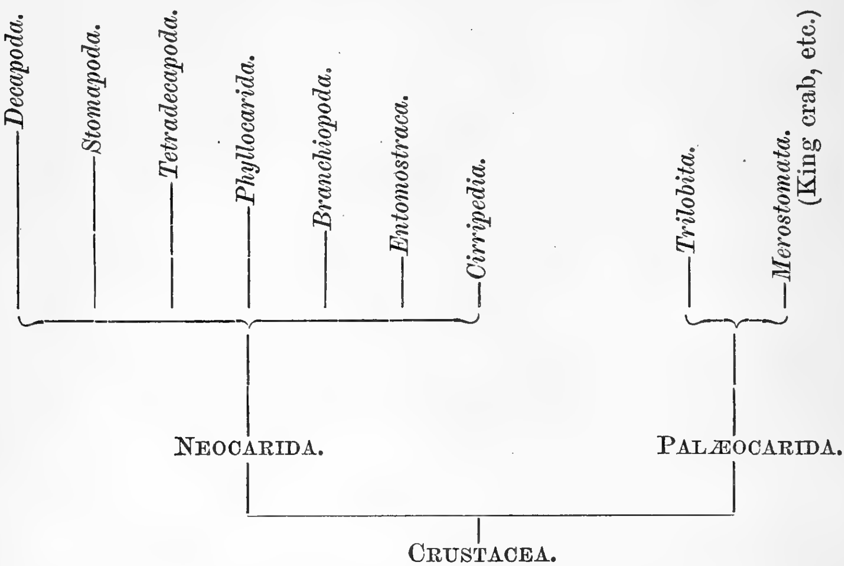
On examining the figures of Salter and of Barrande, for we have been unable to study any of the fossils themselves owing to their extreme rarity, the relationship to Nebalia is very marked, as seen in the form of the carapace, the nearly free or detached rostrum, unless the separation took place after the death of the animal, and also of the rather long, slender abdomen. Upon examining the appendages at the end of the abdomen there is to be seen an important distinction from Nebalia; a long, slender telson is usually present, with a single pair of large caudal stylets, or cercopoda, in form like those of Nebalia. But in *Hymenocaris* and *Peltocaris* the telson appears to be represented by a pair of small

[1] The Nebaliad Crustacea as types of a new order. By A. S. Packard, jr. American Naturalist, February, 1879, vol. XIII, p. 128.

[2] American Science Series. Zoology for High Schools and Colleges, 1st edition, 1879. 12°. H. Holt & Co., New York.

(in *Peltocaris* minute) spines. In the presence of the telson in the typical fossil genus *Ceratiocaris* we certainly have an important character separating the type with its allies from Nebalia, and allying them to the Decapods; and thus in the provisional synopsis of the order presented farther on, we have placed the fossil forms in a separate suborder from the *Nebaliadæ*.

CLASSIFICATION OF THE SUBCLASSES AND ORDERS OF CRUSTACEA.



While the posterior edges of the abdominal segments in *Hymenocaris* appear to be spined as in Nebalia, there are some characteristics of importance in the fossil forms which deserve mention; these are the sculptured carapace, especially of Dictyocaris, in which the surface is reticulated.[1] Moreover the size of these genera was enormous, but if we, as we seem to be warranted in doing, regard Nebalia as a survivor and decrepit or old-age type of the order, which has lost the ornamentation of the integument, the size, and the telson even, being dwarfed, smooth-skinned, and in general very simple compared with the forms which existed at the time when the type culminated and before it began to die out, we may have an explanation of the greater simplicity of the carapace and abdomen of Nebalia, as compared with its paleozoic ancestors.

From our total lack of any knowledge of the nature of the limbs of

[1] It should here be remarked that while the carapace of Nebalia is smooth, upon making a section of it a reticulated structure is plainly seen in the parenchyma or soft parts of the shell, but it is entirely too minute to be perceptible in the shell even under high powers. This structure may be comparable with that of Dictyocaris, especially as Salter remarks (Ann. and Mag. Nat. Hist., 1866, p. 161): "The entire surface of the carapace is marked with hexagonal reticulations one-thirtieth of a line in diameter, of which the areæ are convex and the bounding lines sunk on the exterior aspect. This would, I think, indicate the ornament to be connected with the structure of the carapace rather than to be a mere external sculpturing. As no films can be obtained thick enough to furnish a section for microscopic examination, the point cannot be ascertained."

the fossil Phyllocarida, we have to be guided solely by analogy, often an uncertain and delusive guide. But, in the absence of any evidence to the contrary,[1] there is every reason to suppose that the appendages of the head, thorax, and abdomen were on the type of Nebalia, since there is such a close correspondence in the form of the carapace, rostrum, and abdomen.

But whatever may be the differences between the fossil forms represented by *Ceratiocaris*, etc., they certainly seem to approach *Nebalia* much nearer than any other known type of Crustacea; they do not belong to the Decapods; they present a vague and general resemblance to the zoëa or larva of the Decapods, but no zoëa has a telson, though one is developed in a postzoëal stage; they do not belong to any other Malacostracous type, nor do they belong to any existing Entomostracous type, using those terms in the old sense. No naturalist or paleontologist has referred them with certainty to the Decapods, or to any Crustacean type than the Phyllopods. To this type (in the opinion of Metschnikoff and Claus, who have studied them most closely) they certainly do not belong; and thus, reasoning by exclusion, they either belong to the group of which *Nebalia* is a type, or they are members of a lost, extinct group. The natural conclusion, in the light of our present knowledge, is that they are members of the group represented by the existing Nebalia.

In order, then, to summarize our present knowledge of the living *Nebalia* and its fossil allies, we will give what we regard as the characters of the group and subdivisions, which may be regarded as provisional, though perhaps of some present use.

Order PHYLLOCARIDA Packard.

External diagnostic characters of the order.—Body compressed; consisting of 21 segments, 5 cephalic, 8 thoracic, and 8 abdominal. Carapace compressed, with no regular hinge, loosely attached to the body by an adductor muscle; with a movable rostrum inserted in a depression in the front edge, the carapace covering the basal joints of the abdomen. One pair of stalked eyes; no simple eyes. Two pairs of well-developed, many-jointed, long, large antennæ, the first pair biramous, the 2d pair with a very long flagellum in the male. Mandibles weak, with a remarkably long 3-jointed palpus. Two pairs of maxillæ; the first with a remarkably long, slender multiarticulate exopodite; 2d pair well developed, biramous; no maxillipedes; 8 pairs of biramous, broad, thin, respiratory, thoracic feet, not adapted for walking; the exopodites divided into a gill and flabellum; 4 pairs of large and 2 pairs of small abdominal swimming feet; no appendages on the 7th segment, the terminal one bearing two long caudal appendages (cercopoda). No telson present in the living species; well developed in the *Ceratiocaridæ*. Young developed in a brood sac; development direct; no marked metamorphosis; the young but slightly differing from the adult.

Remarks.—By the sum of the foregoing characters the Phyllocaridæ appear to be excluded from any other group of Neocaridan Crustacea.

[1] Close scrutiny of specimens in existence may yet show indications as to the nature of the limbs; for example, Salter figures, in the Annals and Magazine of Natural History, 3d series, vol. 5, 1860, p. 154, fig. 3*e*, what he calls the jaws of *Ceratiocaris papilio*, but the figure appears to us rather to represent a 4-jointed piece of an antenna. In fig. 2 there are represented the tergal portion of seven segments lying under the carapace. If fresh attention were directed to the discovery of the nature of the limbs success might result.

The differential characters separating them from the Decapods or any other Malacostracous type are:

1. The loosely-attached carapace, the two halves connected by an adductor muscle.
2. The movable rostrum, loosely attached to the carapace.
3. The very long and large mandibular palpus; the long, slender appendage of the first maxillæ, and the very long biramous maxillæ.
4. The absence of any maxillipedes.
5. The 8 pairs of pseudophyllopod thoracic feet, not adapted for walking; the animal swimming on its back.
7. No zoëa-formed larva.

The differential characters from the Phyllopods are the following:

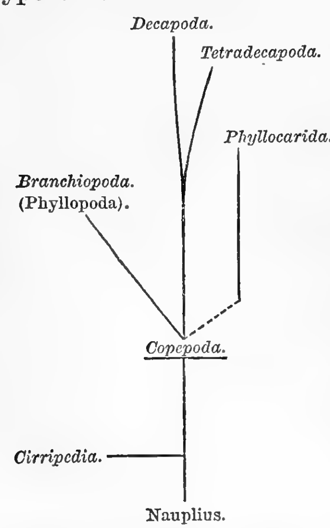
1. Carapace not hinged; a rostrum present.
2. Two pairs of well-developed long and large multiarticulate antennæ; the hinder pair in the male longer than the 1st pair.
3. The thorax and its appendages clearly differentiated from an abdomen.

Internal organs—no functional shell gland; no highly developed liver tubes like those of all Phyllopods; stomach and cœcal appendages (liver) entirely unlike those of Phyllopods.

The nervous system is entirely unlike the Phyllopod type, and approaches more the Decapod and Tetradecapod type.

The resemblance to the Copepoda is in some points quite striking; this is seen in the equal size of the two pairs of antennæ, in the form of the abdomen, and the two caudal appendages, as well as the spines on the hind edge of the segment, in the well-developed palpus of the mandibles, in the absence of maxillipedes, as well as the simple reproductive glands.

In short, we regard the *Phyllocarida* as an accelerated, prematurative type of Crustacea which became well established in the lowest Primordial Period, flourishing at a time when there was no Malacostracous forms, and which culminated in the Upper Silurian Period, and became nearly extinct at the close of the Carboniferous. Judging the group by the structure of Nebalia alone, whether we consider the external or the internal structure, it is a highly composite or synthetic type, combining Copepod, Phyllopod, and Decapod-like features with more fundamental characteristic ones of its own. The group existed at a time when, save in the Carboniferous Period, no Malacostraca, or at least very few, existed, and they thus anticipated the incoming of the more specialized Decapods. Like many other synthetic types, the fossil representatives were of colossal size compared with the living survivors.



The accompanying diagram will express our views as to the relation of the Phyllocarida to other Neocaridan Crustacea.

Family NEBALIADÆ Baird, 1850.

With the characters of the order; the telson wanting.

Genus NEBALIA Leach, 1815.

With the characters of the family. *Paranebalia* has narrow gills.

Nebalia bipes Kroyer, Grönlands Amfipoder, 91; Kroyer's Naturh. Tidskrift. 436, 1847.
Cancer bipes O. Fabricius, Fauna Groenlandica, 246, fig. 2, 1870.
Nebalia bipes Baird, Brit. Entomost. 1850.
Monoculus rostratus Montagu, Linn. Trans. 1807.
N. herbstii Leach, Zool. Misc. i, 100, Pl. 44, 1814.
N. glabra Lamarck, An. S. Vert. v, 345, Bosc.
N. ciliata Lamarck.
N. montagui Thompson.
Nebalia geoffroyi Edwards, Ann. Sc. Nat. 1828. (*N. strausii* Risso.)
Nebalia longipes Willemœs-Suhm, Trans. Linn. Soc. London, 2d ser. vol. 1, 1875. Bermuda.
Paranebalia longipes Claus. (See Carus' Yahresbericht, 1880).
Nebalia longicornis Thompson, Ann. & Mag. Nat. Hist., 1879, 418. New Zealand.

We found in August, 1877, what is probably a fifth species, closely allied to *N. bipes*, between tide-marks at Victoria, Vancouver's Island, Brit. Columbia. The specimen was unfortunately lost.

Family CERATIOCARIDÆ Salter, 1860.

Often gigantic forms, like Nebalia, but with a long, spine-like telson, which is sometimes represented by a pair of spines.

It is possible that the Nebaliadæ and Ceratiocaridæ should rather stand as suborders; and that under the Ceratiocaridæ there are two families, one represented by Ceratiocaris and allies, and the other by Peltocaris.

Salter states that the carapace of *Dictyocaris slimoni* from the upper and lower Ludlow Rock "frequently measured from 9 inches to a foot in length!" If so, then the entire length of the animal must have approximated 2 feet; and he says the length of the largest Ceratiocaris yet known could not have been less than 15 inches.

The following imperfect synopsis of the fossil genera is taken, with some modifications, mainly from Salter; it begins with *Hymenocaris*, which Salter regarded as the oldest as well as most generalized type. (Compare Barrande's account, Syst. Sil. vol. 1, 1872, p. 436.)

Genus HYMENOCARIS.

The shield neither flat nor bivalved, but simply bent; and without any rostrum. A median number (6–7) of free abdominal segments; the body ending in 3 pairs of spines. Lingula flags or Primordial zone.

Genus PELTOCARIS Salter, 1863.

Only the carapace known, which is orbicular, with a median suture, and a deep, rounded rostrum? or piece whose front edge is continuous with the rounded front edge of the carapace.

P. harknessi Salter, Journ. Geol. Soc. 1863. Llandeilo flags.
P. aptychoides Salter, l. c. p. 87.

Genus CERATIOCARIS McCoy, 1850.

Leptocheles McCoy, 1850.

Carapace bivalved, united by a hinge-like suture, the valves ovate, semiovate, or subquadrate, with a long, narrow rostrum. Head (or thorax?) with jointed appendages. Body many (fourteen or more) jointed, of which 5 or 6 segments extend beyond the carapace; the last one longest, and supporting a strong, bulbous telson and two shorter appendages. Surface generally lineate, often finely so.

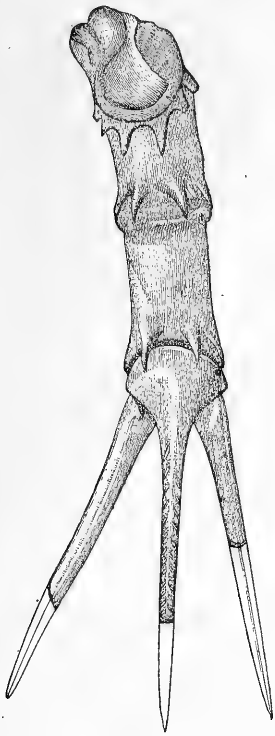


Fig. 70.—*Echinocaris punctatus*; abdomen, dorsal view, natural size. From Hall.

C. papilio Salter, Siluria, 262, figs. 1, 2, vol. 5. Great Britain.
C. stygius Salter, Ann. Mag. Nat. Hist. 1860; Quart. Am. 1860, 156. Great Britain.
C. inornatus McCoy, l. c. 156. Great Britain.
C. murchisoni McCoy, l. c. 157. Great Britain.
C. leptodactylus McCoy, l. c. 157. Great Britain.
C. robustus Salter, l. c. 157. Great Britain.
C. decorus Phillips, Mem. Geol. Surv. ii, Pl. 30, fig. 5. Great Britain.
C.? ensis Salter, l. c. 159. Great Britain.
C. vesica Salter, l. c. 159. Great Britain.
C. cassia Salter, l. c. 159. Great Britain
C. aptychoides Salter, Quart. Geol. Journ. viii, Pl. 21, fig. 10. Great Britain.
C. ludensis Woodw., Geol. Mag. viii, 3, 1871. (Over two feet in length.)
C. oretonensis Woodw., l c.
C. truncatus Woodw., l. c.
C.? brevicauda Salter; Bigsby, J. J. Thesaurus silur. 73, 1868.
C.? gigas Salter; Bigsby, J. J. Thesaurus silur. 73, 1868.
C.? legumen Salter; Bigsby. J. J. Thesaurus silur. 73, 1868.
C.? pernonatus Salter; Bigsby, J. J. Thesaurus silur. 73, 1868.
C. bohemicus Barrande, Syst. Sil. 447, Pl. 19. Bohemia.
C. debilis Barr., l. c. Pls. 18, 19, 26, 31. Bohemia.
C. decipiens Barr., l. c. Pl. 21. Bohemia.
C. docens Barr., l. c. Pl. 21. Bohemia.
C. inæqualis Barr., l. c. Pl. 19, var. *decurtata*. Bohemia.
C. primulus Barr., l. c. Pl. 18. Bohemia.
C. scharyi Barr., l. c. Pl. 32. Bohemia.
C. tardus Barr., l. c. Pl. 18. Bohemia.
C. longicaudus Hall, 16th Rep. State Cab. N. York, Pl. 1, figs. 4–7, 1863. Genesee.
C. (Onchus) dewii Hall,[1] Pal. N. York, ii, 320, Pl. 71, 1852. New York.
C. maccoyanus Hall, Pal. N. York, iii, 420, 1859. New York State. Devonian. New York.
C. acuminatus Hall, l. c. 1859. New York.
C. aculeatus Hall, l. c. 1859. New York.

Genus ECHINOCARIS Whitfield, 1880.

Carapace bivalve, valves subovate. Abdomen composed of several segments, each bearing spines on the posterior margin. Type, *E. sublevis* Whitfield.

E. sublevis Whitfield, Amer. Journ. Sc. 36, 1880.
E. punctatus (Hall), 16th Rep. State Cab. N. Y. 74, Pl. 8, fig. 1.

[1] The following species are of doubtful position (see, also, Whitfield, l. c.):
Ceratiocaris (Colpocaris) bradleyi Meek, Ohio Geol. Surv. Palæontology, Pl. 18, figs. 6*a*–*e*, 318, 1875.
Ceratiocaris (Colpocaris) elytroides Meek, l. c. Pl. 18, figs. 5*a*, *b*, *c*, 319.
Ceratiocaris (Solenocaris) striata Meek, l. c. Pl. 18, figs. 4*a*, *b*, *c*, 321.

E. armatus (Hall) = *E. punctatus* (Hall), Hamilton group, Devonian, New York.
E. pustulosus Whitfield, l. c. 38, Erie shales, Devonian. Ohio.
E. multinodosus Whitfield, l. c. 38, Erie shales, Devonian. Ohio.

Genus DISCINOCARIS Woodward, 1866.

Like the upper valve of a Discina, but with a wedge-shaped opening which cuts the disk nearly to its center.

D. browniana Woodward, Proc. Geol. Soc. 502, 1866.

Genus SPATHIOCARIS Clarke, 1882.

Differs from *Discinocaris* in the presence of the "rostrum" or plate acting as another valve to cover the cleft, and also in its more nearly circular outline (Clarke).

S. emersonii Clarke, Amer. Jour. Sc. xxiii, 477, June, 1882.

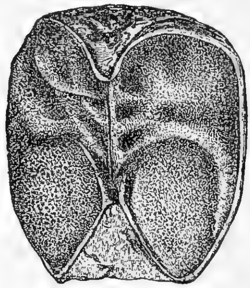


Fig. 71 A.—*Echinocaris multinodosus.* After Whitfield.

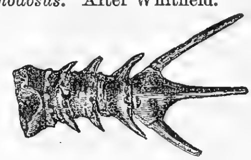


Fig. 71 B.—*Echinocaris sublevis.* After Whitfield.

Genus LISGOCARIS Clarke.

Carapace in one piece, without evidence of dorsal suture. Periphery subpentagonal, lateral edges parallel, making sharp angles with the two anterior edges, which are re-entrantly curved, and meet in the axis of the carapace. As in *Spathiocaris*, there is a cleft beginning centrally at the highest point of the carapace.

L. lutheri Clarke, l. c. 478, 1882.

APTYCHOPSIS Barrande, 1872.

Differs from *Peltocaris* in the rostrum being triangular instead of parabolical; and from *Discinocaris* in having no suture indicating the separation of the two principal valves.

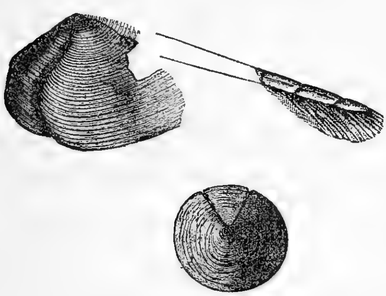


Fig. 72.—*Discinocaris browniana*, natural size, side view and disk, with the wedge-shaped rostrum in situ. After Woodward.

A. *primus* Barr. l. c. 457, Pl. 33, 1872. Bohemia.

Genus DICTYOCARIS Salter (1860).

Carapace ample, bent along the dorsal line, but not two-valved, largely reticulate, the area of the reticulations being convex. The shape of the carapace is rudely triangular, pointed or rounded in front, truncate and produced behind, and margined along the hinder and ventral edges by a strong furrow.

D. slimoni Salter, Ann. Mag. Nat. Hist. vol. 5, 1860, 162.
D. ramsayi Salter, l. c. 162.

Genus DITHYROCARIS Scouler.

Carapace large, apparently covering all but the last abdominal segment; "the rostrum minute or possibly (but not probably) absent" (Salter).

Lower Carboniferous Rocks. The genus Argus seems to be the same as Dithyrocaris, although Salter does not express that opinion. Fig. 69[6] represents *Argus testudineus;* the surface of the body is striated. *Dithyrocaris pholadomyia* Salter had a carapace 7 inches long. The genus *Argus* of Scouler is apparently the same as *Dithyrocaris.*

D. tenuistriatus McCoy, Woodward, Geol. Mag. viii. Great Britain.
D. belli Woodw. l. c. Devonian, Gaspé, Canada.
D. Neptuni Hall (Fig. 73), 16th Ann. Rep. State Cabinet, N. York. 75, Pl. I, fig. 9, 1863. Hamilton group, Devonian of New York.

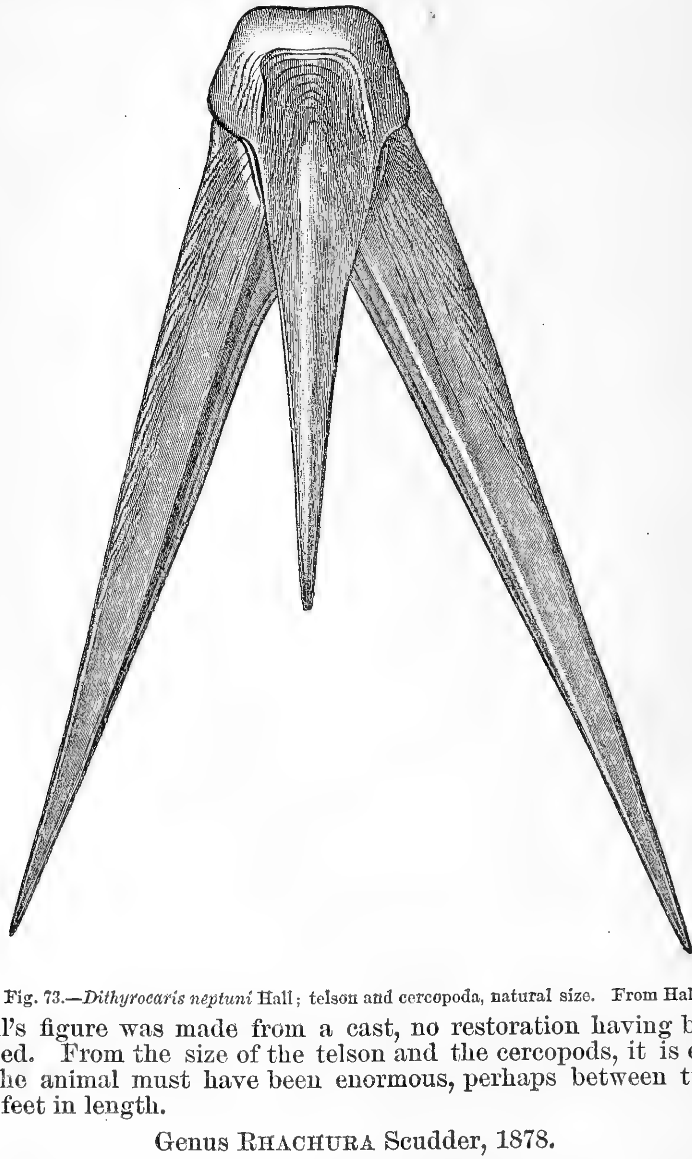


Fig. 73.—*Dithyrocaris neptuni* Hall; telson and cercopoda, natural size. From Hall.

Hall's figure was made from a cast, no restoration having been attempted. From the size of the telson and the cercopods, it is evident that the animal must have been enormous, perhaps between two and three feet in length.

Genus RHACHURA Scudder, 1878.

R. venosa Scudd., Proc. Bost. Soc. Nat. Hist. XIX, 296. Pl. 9, fig. 3, 3*a*. March, 1878. Coal measures, Danville, Ohio.

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APPENDIX.

A.—ON ARTEMIA FERTILIS VERRILL, FROM GREAT SALT LAKE, UTAH TERRITORY.[1]

By Prof. C. Th. von Siebold, of Munich.

[Translated by Dr. Phil. Carl F. Gissler, of Providence, R. I.]

Having positively convinced myself several years ago that *Artemia salina*, which is known to inhabit in countless numbers shallow brackish water ponds along the shores of Europe, in those localities propagates parthenogenetically without males,[2] I put to myself the question whether this was also the case with other species of the genus Artemia. To solve this problem I conceived the idea of procuring live specimens of the brine-shrimp from the Great Salt Lake of Utah, which I knew to occur there in both sexes and in great numbers. The middle of March this year (1876) I obtained, through the kindness of Dr. Hermann A. Hagen, of Cambridge, Mass., a considerable quantity of dried mud from the Great Salt Lake, with which I experimented in the following manner: Toward the end of March, of the same year, I divided some of the dried mud into several shallow glass jars, pouring over it on the 6th of April artificially prepared sea-water, using common hydrant-water and Reichenhaller brine. On the 8th day of April already the water in one of these jars swarmed with Nauplii, the hatching of which I eagerly watched, as I observed many brown Artemia eggs on stirring up the mud infusions. The brood prospered excellently, the mud being evidently impregnated with organic matter, the latter serving as food during their different moults and stages of development; and already on April 16, about eleven days after hatching, indications of sexual characters could be perceived, in the male sex perceptible by a stouter swelling of the claspers. This sexual character, after which the differentiation of the organs of reproduction appear, refers to the organs of copulation only, and not to the true fructification organs, and was for my experiments of great importance. This early differentiation of the male and female individuals of *Artemia fertilis* gave me occasion to distinguish the males from the females, and to keep them separate already at a time before the internal sexual organs, the testicles of the males and the ovaries of the females, began to develop. The second pair of legs of the six-footed Nauplius is, after the first moult, promi-

[1] Ueber die in München gezüchtete *Artemia fertilis* aus dem grossen Salzsee von Utah. Von Prof. C. v. Siebold in München. Separatabdruck aus den Verhandlungen der 59ten Jahresversammlung der Schweiz. naturf. Gesellschaft in Basel, 1876. Basel, 1877. 8°. pp. 16.

So much that is of great interest in connection with the doctrine of evolution and of parthenogenesis has been published regarding the Phyllopods, that we avail ourself of the kind permission to insert, as an appendix, the most important papers which have appeared. I am indebted to Dr. C. F. Gissler for this and the following translations and abtracts.

[2] See my lecture on "Parthenogenesis of Artemia salina," in the Sitzungsberichte der mathematisch-physikalischen Classe der K. Akademie der Wissenschaften, of June 7, 1873, p. 168.

nently developed, serving as a rudder organ; after the subsequent moults this organ becomes gradually shorter, less movable, bent down, loses its bristled margin, and in the females is transformed into two small, scarcely movable, tongue-like bent processes, while in the males the same develops itself into disproportionately large claspers with broad lobes, functionating as a catching and clasping apparatus. These robust claspers, bent downwards and backwards, betray the male sex, as above stated, in the earlier stages by an incipient swelling of the said rudder organs, while the same, after their hystolytic degeneration, remain small in the females. In this way it was easy for me early to distinguish the males from the females and, significant for my experiments, to keep them apart.

The growth and prosperity of the carefully-separated sexes proceeded well in various jars with artificial sea water, and pains were also taken to add only boiled Utah mud to prevent any Artemia eggs from hatching. Without this precaution I would eventually have received younger broods of different sexes together with the older ones, already kept apart, which would have interfered with my experiments, in which latter the utmost certainty was required to prevent the meeting of the two sexes before the setting in of concupiscense. Having raised a large number of carefully-watched virgin individuals in the above mentioned manner, I waited the period of concupiscence in one-half of their number without giving them occasion to come in contact with any males, while the other half of virgins I placed together with a number of matured male individuals for the purpose of getting fertilized by them. I succeeded in this, since the males very early, as already stated, betrayed their future sex and were vigorously grown up, and gave repeated indications of sexual desires. They manifested the latter in their pugnacious behavior, embracing themselves with their powerful claspers in such a manner as if they would perform copulation; many of them clasped other males, no matter how they struggled against it, and with such a violent fervor that they, as may be assumed, applied the claspers on almost every part of their body. Such couples remained entangled for several days, swimming around in the most unnatural positions.

The testicles, filled with whitish zoösperms, presented themselves to the naked eye through the translucent body. I selected the most vigorous individuals, placing them in a jar together with boiled-up Utah mud and a number of virgin Artemiæ, and had then very soon the pleasure to see that they did not refuse the ardent embraces of the males, the females making no efforts to free themselves of their burden. The male with its claspers embraces the postabdomen of the female from the back, which region appears swollen by the ovisac. In this way both individuals, bearing their abdomens parallel above each other, swim about as if animated with but one will. From time to time such a couple swims along the surface of the mud, turns around its longitudinal axis, dorsal side up, thus whirling up the loose mud for the purpose of obtaining food. Occasionally the male, utilizing the embrace of the female, bends its postabdomen around for the purpose of inserting its two protrusile cylindrical copulative organs into the female genital orifice, whereby the closest contact with the female, as well as an afflux of spermatic particles, was effected.

The actual process of copulation, as closely observed by me, was interrupted after shorter or longer intervals, but in incessantly long-continued embraces it was often repeated. One of these couples hung together for three days. After copulation ensued, I transferred those females which were abandoned by their males and which females I regarded as fecundated into a new jar, into which they could eventually deposit their eggs. But to be sure that no new brood of Artemia was developed out of the Utah mud added as food, I again took the precaution to use only well-boiled mud in which any possible eggs would then be destroyed. The fecundated Artemia females, however, continued to prosper in their new jar, and I soon perceived the activity of their inner generative organs. This activity manifested itself very soon in the two blind ovarial strings situated in their postabdomens; in the interior of those strings white, uniseriately-placed ovarial germs came into view, which latter grew more and more, their places of contact becoming flattened. All these eggs in their complete form possessed neither a germinal vesicle nor a yolk-skin. The latter is not formed until the uncovered eggs have entered the upper bent-inward-and-backward end of the ovarial strings, and then it represents a very tender translucent and homogeneous egg-membrane. I should call these bent terminal portions of the ovarial tubes oviducts, since they enter after a short course a capacious cavity, the latter certainly functionating as an uterus.

The uterus possesses in its walls a very complicated muscular apparatus, which, through its active contractions, moves the contents of the uterus in various ways. One can now also observe six cell complexes in three pair of groups on the right and left behind each other, divided and fastened to the uterus walls, which in their organization and meaning fully correspond with the egg-shell glands, as observed and described[1] by me in *Artemia salina*, only with the difference that in *Artemia fertilis* three pairs, in *A. salina* only two pairs of such shell-glands occur. These glands at first appear perfectly colorless, becoming gradually amber-yellow, finally assuming a rust-brown color, with which coloration the secreting function of these glands begins. It was now interesting and striking to me in these investigations that the first lot of eggs that entered the uterus through the oviduct, which eggs were surrounded by but a delicate yolk-membrane, did not yet receive any hard egg-shells, although they were incessantly moved to and fro by the muscular walls of the uterus. They remained without shells, because the shell-glands had not yet discharged their contents into the uterine cavity. On the other hand, to my greatest astonishment, a perfect segmentation process was going on in the uncovered eggs, which could be closely followed through the tender and transparent yolk-skin. Finally, I perceived the red eye-dot of the now developed Nauplius through the yolk-skin, soon afterwards the entire brood of Nauplii escaping and rowing about in the water. Curiously enough, this parturitive act did not repeat itself in all those females of Artemia which gave birth once, although their uterus was repeatedly filled with tender-skinned eggs; in short, all fertilized females of *Artemia fertilis* became, after first giving birth to live young ones, from this time oviparous.[2] Whether now all females of *Artemia fertilis* show the peculiarity of always producing live young ones at the first process of propagation and then become oviparous, I can give no decisive answer. The observation seems to me important, which I here, though already mentioned, again repeat, that in raising Nauplii from the "Dauer-

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[1] Opus citatum, p. 191.

[2] I had already occasion to make similar observations on *A. salina*, and refer to p. 190 of *op. citat.*, and there I attempted to express presumptions as to the causes which induce the females of Artemia at one time to be viviparous and at other times oviparous; the correctness of those conjectures I cannot warrant, since I have not yet acquired the necessary amount of experience on these striking phenomena.

eggs"[1] contained in dried Utah mud, male as well as female Artemiæ, and both in about the same number were obtained. To these observations I have to annex the following, which, as regards the questions what sex issues in the different manners of propagation in the Nauplii, in future will turn out to be important. Namely, I refer to the fact that also those Nauplii, which the fecundated, primiparous females of *Artemia fertilis*, raised from "Dauer-eggs," yielded in exactly the same manner, like those Nauplii hatched from "Dauer-eggs" contained in Utah mud, male and female individuals of *Artemia fertilis*.

Concerning the manner of propagation going on after (*einmalig*) viviparturition and oviposition of the fecundated females, I have to say that this process of oviposition occurs in the same manner and with the same repetition as observed by me in non-fertilized females, and which I shall describe later. As the second part of my report on the domestication (*Zeuchtung*) of *Artemia fertilis* I have to mention experiments through which I tried to force this Branchiopod to produce parthenogenetic generations. In how far I did or did not succeed in these experiments I cannot yet call to account, since I till now could realize only preparations and introductions for the same. I only want to state how I succeeded in obtaining the material with which I could convince myself whether *Artemia fertilis*, like *A. salina*, possesses the peculiarity under certain circumstances to propagate parthenogenetically. It was easy for me to procure the necessary material, since I kept separate, as already stated, a jar with Artemiæ, which showed in their earlier developing stages indications of yielding female individuals. From this jar I selected such females in which the first traces of concupiscence were noticed, and those I raised separately in a jar with brine water and boiled Utah mud, watching them carefully to prevent any access of males, and to let them, as genuine virgins, become concupiscent.[2] At the time when in these isolated virgins the generative organs attained maturity, which showed itself in the ovaries distended with germs, my particular attention was directed to the jar containing them. There I noticed that in these virgins the eggs entered from the ovaries into the oviduct, whence they accumulated in the uterine cavity, during which time the six above-mentioned shell-glands assumed a brown color. Later on the amber-colored secretion of the glands discharged into the uterus, flowing around the tender-skinned unfecundated eggs, which latter, kept in rhythmic motion by the contractions of the muscular walls

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[1] Above I make use of the word "Dauer-eggs" (or permanent eggs) avoiding the hitherto customary specification "winter-eggs" as not quite proper. Of course (allerdings) most Phyllopods deposit two different kinds of eggs, one kind of which develops soon after being deposited, while the other kind hatches after a very long time, and in our climate, in most cases, after hibernation. But those latter eggs can also endure two or more winters under casual external conditions, if the necessary impulse from outside for the hatching of the eggs continues; I mean to say when the suitable moisture, giving action and completion for the development of those Phyllopods, does not come into effect. In this way it is accounted for that in such pools serving as a habitation for Phyllopods, but which remain dry for several years and which afterwards again become filled with water, the long disappeared Phyllopods suddenly reappear, as the there buried winter eggs (or better) "Dauer-eggs," under the influence of the water become animated to live activity out of the latent condition.

[2] To demonstrate during my lecture I prepared three jars with mud and salt water, into which I divided three different objects concerning Artemia in the following manner: One jar contained several full-grown males, the second jar contained fertilized egg-bearing females, together with two entangled copulating couples, while the third jar, contained virgin females, bearing non-fertilized eggs. These Artemiæ arrived in goode condition, after being conveyed in their jars from München to Basel, and there could be exhibited alive during the lecture.

of the uterus, became darker and darker and surrounded with a hard brown shell, so that the non-fecundated, differed neither in form nor color or structure from the fecundated ones. The virgin Artemiæ deposited their eggs some time afterwards, dropping them into the mud at the bottom of the jar. The uterus of such unfertilized females appeared to be empty after the eggs were dropped; their shell-glands were pale, but their ovaries again contained new germs, which gradually developed, while the pale shell-glands, after some time, again assumed their brown color, and I surmised that they prepared themselves once more for ovipositing non-fecundated eggs. The same process reoccurred several times in virgins, the latter not differing therefore in this respect from fecundated ones. In this manner I succeeded in accumulating a large number of non-fecundated eggs in the mud of the jar prepared for the concupiscent, non-fertilized females. I must now draw your attention to the fact that such oviparous virgins were never viviparous before depositing eggs. For the success of my experiment on parthenogenesis this was a bad omen. It is evident, however, that the primiparturition of live young ones is not realized in virgin females of *Artemia fertilis;* but it is, nevertheless, possible that the "Dauer-eggs" dropped by the virgins possess the peculiarity of developing themselves without fertilization, and do yield females, and therein we would have again a contribution to our knowledge on the distribution of parthenogenesis. I shall preserve during the coming winter (1876–'77) the different kinds of dried mud which are partly impregnated with fertilized, partly with non-fertilized "Dauer-eggs" of *Artemia fertilis*, for the purpose of examining next spring whether the mud with fertilized eggs alone, or besides it, also the mud with non-fertilized eggs, will yield Nauplii, when it will be of importance to learn from what set the parthenogenetic Nauplii develop themselves.

B.—PROF. CARL THEODOR VON SIEBOLD ON PARTHENOGENESIS IN ARTEMIA SALINA.[1]

ABSTRACT.

By Dr. C. F. Gissler.

Owing to the remarks expressed two years ago in my paper "Beiträge zur Parthenogenesis der Arthropoden" (Leipzig, 1871, p. 197), I am indebted to Prof. Carl Vogt, of Geneva (Switzerland), for a lot of live individuals of *Artemia salina*, which arrived at München August 27, 1872. I was very pleased to have received seventy live and five dead specimens, together with a number of larvæ, in a jar of salt water. All the full-grown individuals were females, which was also the case with a number of Artemiæ Dr. Vogt received from Professor Martins at Cette. I observed that in all the seventy specimens thus obtained the egg-sac was filled with embryos. The various behavior of this brood attracted my special attention. Having dissected the egg-sac of a dead individual, I noticed several live embryos escaping from the same, together with a few pear-shaped bodies of orange color sinking to the bottom. The latter proved to be also embryos inclosed in a homogeneous thin egg skin. The outlines of the inclosed embryos could be distinctly seen through the egg skin, as well as the motions of the embryo. Such viviparous

[1] "Sitzungsberichte der mathematisch-physicalischen Classe zu München, 1873, Heft. II."

Artemiæ I also observed amongst the other live specimens. After the escape of the brood the egg skins remained in the egg-sacs. But many Artemiæ proved to be also oviparous. The egg-sac in such oviparous specimens then contained brownish spherical, hard-shelled eggs. In breaking this brittle shell between two glass slides the homogeneous inner egg skin could be noticed. Joly, who also observed this mode of multiplication, supposed the season of the year had something to do with it. Vogt noticed that they became oviparous when kept in a more capacious vessel, and viviparous when kept in small jars. I, myself, did not succeed in raising more than two generations. Not a single male individual was obtained from the young Artemiæ received as viviparous generation; only 35 females attained sexual maturity. Of these 35 females, on the 20th of October the largest ones had soft, white eggs in the egg-sac, which became gradually brown in a few days; some had their eggs deposited on November 5, involving at the same time a certain mortality among my specimens, all having died by November 21, 1872. The deposited egg did not hatch.

After this unsuccessful attempt I concluded to get some more fresh material, which was forwarded to me through the kind intermediation of Duke Carl Theodor of Bavaria, of whose active interest in natural science I was aware. On the 3d of December I received two bottles with 50 live Artemiæ, which were collected near Capodistria by Dr. Syrski, of Triest, also a large bottle of marine mud and fresh sea water. The Artemiæ were, though dead, still of a fresh appearance. They were all females, and their egg-sacs were crammed with brown eggs. After removing the eggs I placed them in a shallow vessel with marine mud and sea water. Already four days afterwards I observed new-born embryos swimming about, and many more toward evening. I divided them on December 12 in two jars, marked with *a* and *b*. Owing to the marine mud containing much organic matter (which was probably not the case in the former experiment) they prospered well, shed their skins often, and developed into *females*. The jar destined for the specimens originally received from Capodistria I marked with *e*. The embryos hatched therein from the eggs of the killed original specimens and those embryos I divided into the two jars *a* and *b*.

That the embryos thus hatched did not all come from the eggs taken from the egg-sacs of the original dead but still fresh specimens is quite obvious, as the marine mud very likely also contained eggs of Artemia, which were thus brought to development. Finally I got fully convinced of this view, as in the larger jars *a* and *b* gradually an immense number of young Artemiæ grew up, whose number by far exceeded the sums of those embryos which I took from jar *e*, and which I placed into the jars *a* and *b*. In no case could this superfluous brood have originated from the older, fully-raised embryos, as the latter were not yet sexually mature when I noticed the bulky throng of continually forthcoming embryos. On examining a quantity of the remaining mud from Triest I found many Artemia eggs. The hatching of embryos in jar *e* kept on from December 7, 1872, till March 23, 1873.

Some marine mud I placed also into jars *a* and *b*, and care was taken to replace the evaporated salt water, a water of 1° Beaumé having been used for this purpose. On January 12, 1873, I counted 31 full grown and 136 younger individuals, not counting the very youngest ones. In the ovaries of seven adult females I noticed on January 19 the first traces of egg-formation; on the 24th I saw the yellowish eggs in the ovaries in 18 adult ones; 4 of them had yellowish eggs in the egg-sacs, and 3 had brown ones; on January 26th 3 more had also brown eggs in the egg-sacs.

To verify whether those eggs were really *unfertilized*, I arranged another large jar with artificial sea water and marked it with *f*. Into this jar I placed some Triest marine mud which had been previously boiled to destroy any eggs possibly contained therein. The adult females placed in this jar prospered well. The number of adult females in jars *a* and *b* continually increased, counting, on February 1, 24 females, all with brown eggs in their egg-sacs. Six of these females dropped their eggs on February 5, their ovaries again showing activity. I again arranged another jar, bearing the letter *h*, placing previously boiled mud into it and those 6 females, whose egg-sacs, on February 16, contained for the second time brown eggs, and again the same day I placed 8 more specimens into it, taken from jar *f*, which afterwards prepared themselves for a third oviposition, so that I was urged to take for those 14 females another moderately large jar, bearing the letter *i*, to allow them to deposit for a third time. On March 2 this jar *i* was arranged with the 14 females, the latter depositing their eggs during March; on April 15 a jar marked *m* was prepared with boiled mud, placing 2 females into it from jar *i*, which were about to deposit for the fourth time. On May 4 one of the two deposited for the fourth time, and although a fifth series began to form, I did not prepare another jar; the specimen showed great weakness, and died subsequently.

As a matter of course the females taken from jars *a* and *b* multiplied in the jars *f*, *h*, *i*, *m*. In jar *f*, out of which I took, up to February 28, 14 females and placed them into jar *h*, I counted, on April 6, 39 females. It would be too tiresome to put down here all the notes as I wrote them down *seriatim* in reference to further development of Artemia, and I shall here briefly state the result of my experiments. The eggs were for the greater part on the surface of the muddy bottom. On March 16, being the 40th day after my first raised virgin Artemiæ deposited their eggs, I noticed two embryos of the Nauplius-stage, as figured by Joly. For the sake of maintaining stricter control ot the embryos, of whose parthenogenetic origin I had to be fully convinced, I placed these, as well as all those later hatched in jar *f*, into a smaller jar, *g*, with some previously boiled Triest mud. On March 24 I had eight such embryos in jar *g*; counting on March 30, 22; and up to May 10 I had transferred 71 embryos from jar *f* into jar *g*. Henceforth the development in jar *f* increased rapidly (May 11, hatched 25, and May 12, 49 embryos), so that up to May 23 I obtained from jar *f* 402 embryos. In this manner I verified *that from eggs deposited by virgin females of Artemia salina, which were not fertilized by any male sperm, a brood can develope.* The empty egg-shells were found to be partly floating on the surface or hidden in the mud at the bottom. The fresh unhatched egg never swam on the surface, and the empty egg-shells on the bottom all showed a crack.

Seventeen embryos were removed from jar *g* and placed in a jar marked *k*, with a quantity of prepared (boiled) Triest mud. This was done for better observing the sexual development. Of these 17 individuals 5 were nearly full grown on April 30, with no indication of ovaries, though with beginning egg-sac formation; two other individuals of those 17 Artemiæ did not yet show, though full grown, any sexual differentiation.

On May 10 I transferred from jar *k* those specimens which approached sexual maturity into a jar marked *o*, together with some unprepared fresh-water clay-mud. These 14, in jar *o* transferred Artemiæ developing into egg-bearing females, prospered well in the salt water of the new jar, and filled, as usual, their intestine with mud as if they had had marine mud. I had to take fresh-water mud because the marine mud began to show signs of decomposition.

On May 22 the four oldest individuals in jar *o* had brown eggs; also all the others attained maturity by May 29, so that I was sure that these 15 females would soon deposit for the first time their eggs.

How many successive generations of *Artemia salina* retain the faculty to reproduce parthenogenetically without males remains to be examined. Joly made his observations with Artemiæ from Southern France in 1840, and supposed that these Artemiæ must be either hermaphroditic, or, if really males existed, that a single fertilization was sufficient for many generations.

It would be of interest to re-examine the specimens of Artemiæ of the localities cited in literature of the years 1840, 1755 (Schlosser), 1830 (Thompson), 1851 (Leydig). Very likely the result would be that parthenogenesis in Artemia often occurs.

The examination of the ovaries and the occurrence of viviparous and oviparous individuals led me to the conclusion that oviposition appears in Artemia only when the egg-shell glands have so fully developed that the necessary quantity of congealing matter can be recreated, as only by this can the eggs obtain a solid, durable shell. Surrounded with such a shell the eggs obtain the power, hidden away in mud or even perfectly dried up, to endure the most unfavorable external conditions and preserve the faculty of development after long periods of time. But if the development of the egg-shell glands has not been fully attained the conditions for the formation of a solid and durable shell are wanting. The eggs of such Artemiæ then only receive a very thin egg skin, in consequence of which the favorable influences for the development of the embryo will act upon the egg contents from outside, thus accelerating the embryo formation.

C.—ON THE RELATION OF ARTEMIA SALINA MILNE-EDWARDS TO ARTEMIA MUEHLHAUSENII MILNE-EDWARDS AND TO THE GENUS BRANCHIPUS SCHÆFFER.

By W. J. SCHMANKEWITSCH.[1]

[Translated by Dr. C. F. Gissler. With Plate XXXIX.]

In the session of the Neorussian Society of Naturalists at Odessa, held September 20, 1874, I made an addition concerning this matter to the observations made in former years, and now I have again to communicate the following later results. I shall here briefly state that *Artemia salina* M. Edw., Joly (*Branchipus arietinus* Grube var. Schmankewitsch, *Artemia arietina* Fischer var. Schm.), a very variable form, yields not only by domestication but also in a state of nature even at a gradually increased concentration of the water, a form similar to *Artemia muehlhausenii* Milne-Edw., Fischer, which I had occasion to observe in the closed Kajalniker Salt Lake (Andreewsky-Liman) near Odessa during the years 1871 to 1874, inclusive.

In 1871, on the occasion of a great spring flood, the embankment which separated the lesser saline water of the upper portion of the Kujalniker Lake from the more saline portion of the lower part of the same lake broke, whereby the water of the latter became diluted to 8° Beaumé. At the same time *Artemia salina* appeared in great numbers, probably

[1] Zeitschrift für wissensch. Zoologie, xxv, 1tes Supplementheft, 1875.

brought along with the flood from the upper portion as well as from the surrounding brine ditches near the same.

After restoration of the embankment the density of the water of the lower part rapidly increased, showing already in the summer of 1872 14°, in 1873 18°, at the beginning of August 1874, 23.5°, and after a continued drought in September of the same year 25° of Beaumé's areometer, at the latter time the lower part of the lake beginning to deposit salt.

Simultaneously *Artemia salina* gradually degraded from generation to generation, so that toward the end of the summer of 1874 the majority of individuals were without furcal lobes, showing then all the specific characters of *Artemia muehlhausenii* (Fig. 6). In 1871 *Artemia salina*, or better, one of its varieties, had moderately large furcal lobes, and on each of them eight to ten, seldom 15, setæ, distributed over both sides and the tips (Fig. 1).

In the successive generations in the beginning of the summer of 1872, these furcal lobes were already smaller, with but 3 to 5 or 3 to 4 setæ, the salt water then showing 14° Beaumé (Plate XXXIX, Figs. 2 and 3).

In the same season of 1873 and at 18° B. the furcal lobes were still smaller, representing short conical knobs with but one, two, seldom three, setæ (Fig. 4). Toward the end of the summer of 1874, many individuals still possessed conical knobs or protuberances instead of furcal lobes, without or with but one seta on tip, but the majority of them were entirely destitute of furcal lobes and setæ, as is the case in *Artemia muehlhausenii* with which these degraded examples were identical in their smaller size as well as in other characters (Figs. 5 and 6).

I also obtained the same results by domesticating *Artemia salina* in salt water of gradually increased density or concentration, the examples obtained being identical with those from the Kujalinker Lake at the end of the summer of 1874 (*Artemia muehlhausenii*), yielding also the same transitory forms.

By a reverse treatment, *i. e.*, by gradually diluting the salt water, I succeeded with *Artemia muehlhausenii* in producing already, after several weeks, a furca in the form of conical knobs, with one terminal bristle, by which treatment also the development of other parts of the body assumed a direction toward the higher specialized varieties of *Artemia salina*, this being at variance with the retrograde development taking place in condensing the salt water.

It is remarkable that the gills of these animals enlarge in proportion or in ratio with the density of the water, so that in the form without furcal knobs (*Artemia muehlhausenii*) the surface of the gills is much larger in proportion to the size of the body than in *Artemia salina*. The gills of the former especially enlarge in width. I draw the inference that as the water of higher density contains less oxygen these Crustaceans adapt themselves by gradually enlarging the surface of the breathing apparatus.

Concerning the gills, I have to state that they are elongate in *Artemia salina* and oval in *A. muehlhausenii* (Figs. 7 and 8). The width of the gills in *A. salina* average scarcely half of their length, in *A. muehlhausenii* two-thirds of their length.

As regards the length of the body, I may mention the following measurements, showing the proportionate sizes of the gills; In *Artemia salina* the average length of the gills at a density of 10° B. is the one-twenty-first part of the body length, the width being the one-thirty-ninth part of the same. In *Artemia muehlhausenii* the average length of the gills at a density of 24° B. is one-eighteenth part; their width is the one-twenty-eighth part of the body length.

In measuring the *Artemia salina* the furcal lobes were not counted in, which would have made the difference still greater, considering the larger bulk of the body of *Artemia salina* compared with *A. muehlhausenii.*

It appears that the species (Arten) of the genus *Artemia* are liable to undergo, also, progressive developments at a gradually lessened density of the salt water. The nature of those salt-water pools yields the conditions necessary for their progressive growth, which pools, after a number of years by continued washing of the briny soil, may turn into fresh-water pools. Indeed, *Artemia salina* inhabits, also, such salt-water pools in the neighborhood of the lake in which occurs, at a low density of the water, also *Branchipus spinosus* Grube; at a still lower density, *Branchipus ferox* Grube, and another species of *Branchipus* with hook-like bent furcal lobes, which latter species I described as *Branchipus medius* in the "Schriften der dritten Versammlung russischer Naturforscher."

In artificially domesticating *Artemia salina* in gradually diluted salt water I obtained a form with the characters of the genus *Branchipus*, (*B. Schaefferi*) which might be regarded as a new species of Branchipus.

I had already occasion to discuss this point in the "Schriften" of the Russian Naturalists, third session, and in the "Schriften" of the Neo-russian Society of Naturalists (Vol. II, part 2), and again have to state as follows:

The only two characters separating the genus *Branchipus* from the genus *Artemia* are the following: Firstly, that *Artemia*, inclusive of the genital segment (two segments together), possesses *eight apodous postabdominal segments*, with the last of these eight segments nearly twice as long as the penultimate (Fig. 9*c*), while *Branchipus* has *nine* such segments, of which the neighboring segments, by twos, show but a small difference in length; and, secondly, the existence of a physiological difference, parthenogenesis occurring in *Artemia*, which phenomenon has not yet been observed in *Branchipus*. This is a negative and ill-defined character.

The first mark of distinction seems to be more important, but undergoes changes in *Artemia* under the influences of the surroundings, where the character of the genus *Branchipus* appears especially, than when several generations of *Artemia* are domesticated in gradually diluted salt water.

I have convinced myself, that *the last long eighth segment of the post-abdomen of Artemia is homologous with the two last segments of the post-abdomen in Branchipus, namely the eighth and ninth.*

In the progressive growth of several generations of *Artemia* in gradually diluted salt water the last apodous eighth postabdominal segment of *Artemia* subdivides itself into two segments, whereby nine apodous segments are formed (Figs. 10*c* and *d*), as in *Branchipus*. *Branchipus*, however, in its youth and towards the end of its last larval state, has but *eight* abdominal segments, of which the last is also as long as in *Artemia*. Also without artificial domestication we can convince ourselves of the homology of the last eighth apodous segment of *Artemia* with the same two last apodous segments of *Branchipus*.

In the species of *Branchipus* occurring in this region we find fine bristles distributed around the posterior end of each postabdominal segment, except in the last ninth segment. Every bristle arises from the middle of a complex of small tooth-like spines which are of extraordinary size in the male of *Branchipus spinosus.* Such bristles we also find in *Artemia* in the same places and similarly distributed (Fig. 9*d*), only that they do not arise out of a complex of dentate spines, but out of the middle of a complex of cuticular cells, which can scarcely be distinguished from the surrounding tissue (Fig. 11).

It is of some importance that in *Artemia* not only near the end of each segment do we find such circularly placed bristles, but also *in or a little above the middle* of the last long eighth postabdominal segment, *i. e.*, on that spot where the articulation ought to be, and where it is actually found in *Branchipus*, between the eighth and ninth segment, and where in *Artemia* this articulation after domestication of several generations in salt water of successive lower density, *i. e.*, under such conditions, is formed, which may be serviceable to progressive development.[1]

Under the same conditions the complexes of cuticular cells just mentioned transform; out of their midst bristles develop by degrees in both sexes of the domesticated Artemiæ, into complexes of denticular spines, as they are found in both sexes of *Branchipus.* (Fig. 12.)

These denticular spines are small and of equal size in both sexes of *Branchipus ferox;* in the female of *B. spinosus* they are also small, but in the males of extraordinary size; in *Branchipus medius* (described elsewhere) they are large in both sexes, somewhat larger however in females than in males.

At the same time, in domesticating *Artemia*, all other characters change progressively toward *Branchipus;* as, for instance, the length of the furcal lobes, the number of their bristles, and so forth.

After such results we unwillingly arrive at the conclusion that the Artemia usually occurring in salt water of great density is nothing else than a degraded form of *Branchipus* under the influence of its surroundings, which latter form usually inhabits fresh water or salt water of low density.

On the other hand we have in *Branchipus* a higher developed form of *Artemia*, which has transformed in a progressive direction.

The cause of this may not only be the different concentration of the water, but also its temperature. In nature *Artemiæ* mostly inhabiting salt lakes represent the summer forms, while *Branchipus*, often populating dried-up pools, represents the spring or fall form.

In domesticating, I observed that a high density of the water retains the growth and the development of specific characters of these animals, while a simultaneous higher temperature evokes sexual maturity earlier than the complete development of limbs; higher temperature together with higher density of the salt water also contribute to retrogradation of forms and their degeneration.

Of course, as I convinced myself, a gradually increased density of the salt water, even at a lower temperature, tends to degradation of forms; for such a water, besides its mechanical influences upon the organism, contains less oxygen than less saline water and much less than fresh water, which plainly shows itself in artificially domesticating these animals, and which point I have already referred to.

The following are the principal results of my investigations:

1. In artificial domestication of several successive generations of *Artemia salina* Milne Edw. in salt water of gradually increased density we obtain a form identical with *Artemia muehlhausenii* M. Edw.

2. *Artemia salina* M. Edw. is also apt in a state of nature after a

[1] See Plate II of the "Schriften" of the third meeting of Russian Naturalists, Zoological Part.

small number of years, and a comparatively short series of generations, in a salt lake with increased density to transform itself into a form identical with *Artemia muehlhausenii* M. Edw., whereby this form is enabled to *remain constant, as long* as the surroundings are not changed.

3. *Artemia* is apt, in artificially domesticating several generations in salt water of gradually decreased density, to progressively develop towards the genus *Branchipus*, obtaining thereby its generic characters, *nine apodous segments.*

4. In a state of nature salt-water ditches of different density, inhabited also by the higher specialized forms of *Artemia*, yield the conditions for progressive development of *Artemia* into *Branchipus.*

5. The size of the furcal lobes in *Artemia*, the number of bristles and their distribution on the tips and sides of the lobes, are, together with the other generic characters, dependent on the concentration of the salt water inhabited by *Artemia.*

6. At a lower density of the salt water occur also in certain brine ditches *Artemiæ* with pretty long furcal lobes, with a considerable number of bristles (up to 22 distributed over each lobe), similar to *Branchipus.*

7. The only characteristic features distinguishing the genus *Branchipus* from the genus *Artemia* are:

Firstly, the presence of eight apodous postabdominal segments, whereby the last eighth segment is nearly twice as long as the preceding, while in Branchipus there are nine such apodous segments, of which neighboring segments, by twos, show but a trifling longitudinal difference.

Secondly, parthenogenesis occurs in Artemia, while in Branchipus it is not yet known to occur.

8. The last long eighth postabdominal segment of *Artemiæ* is homologous with the last two postabdominal segments of *Branchipus.*

I have now to append a few words on the parthenogenetic propagation of our *Artemia.*

I had already observed parthenogenesis in *Artemia* in 1871, while artificially domesticating several isolated generations. It being something new to me at that time, I devoted more attention to investigations on the influence of surroundings on *Artemia* relative to morphology.

Of three isolated generations of ♀ *Artemia salina* I obtained, while artificially domesticating them, by parthenogenetical propagation, in every density of the salt water that sustained their life, *only females.* . . . I mentioned in the "Schriften" of the third meeting of Russian naturalists at Kiew, . . . that the males appear in the lake in great numbers at a moderate density of the salt water.

For such moderate density I took the density of the Hadschibei Lake in the summer of 1870, it having been literally filled with *Artemiæ*, whence they were thrown on the shores in piles by the waves, where they decayed.

However, I committed a mistake, overlooking an error in the protocol of the third meeting at Kiew, having said in my printed report that only at a mean (moderate?) density of the water, similar to the density of the preceding year (1870), by domestication as well as during the summer in the lake *males* appear, instead of having said, only at a moderate density of the water, similar to that of the preceding year, by domestication as well as during the summer in the lake the males *ought to appear.* As I noticed at the time, that the males of *Artemia* appear in the lake at a certain density of the water, I assumed, after I could not obtain them either at a higher or lower density, that they still ought to make their appearance at the density for which I took the salt water in the summer of 1870, then not yet being aware that, according to Professor Siebold's investigations, no males could be developed.[1] The same error crept into an extract of the protocol, sessions of the zoological part of the third meeting of Russian naturalists at Kiew contained in this journal (Zeitsch. f. w. Zoologie), and this gave Professor von Siebold occasion for a timely remark.[2] Taking advantage of the present occasion to correct the mistake, observing that it was not printed in my paper, although the latter, together with the report, was prepared in the same session, I have yet to add that *Artemia salina* becomes accustomed to gradual changes in the concentration of salt water in the lake, as well as in domesticating them, and then becomes fitted to stand a very high or very low density of the water, so that either of them form a suitable environment. In rapidly changing the concentration of the salt water the same is rendered unfit to sustain life, changing the manner of obtaining food, and produces, at the same time, in a state of nature, the appearance of males in forms to which parthenogenesis is peculiar.

I had already observed this in *Artemia* in the lake, but saw this especially in *Daphnia* with artificial domestication of non-isolated females, that the males of the domesticated species first appear on the most extreme life-sustainable limits of the surrounding elements, *i. e.*, as well at a too low as at a too high temperature.

If we domesticate the fresh-water species, *Daphnia magna* Leydig, in weak salt water, which they stand well, there appear, at this comparatively rapid heightening of density of the salt water, males and fertilized eggs at such a moderate temperature, at which ordinarily the same species in fresh water propagates parthenogenetically.

In the Hadschibei Lake occurs *Daphnia rectirostris* Leydig, at a density of the salt water of 5° to 8° B., especially in spring and fall; the same disappearing in summer at a higher density of the salt lake, while before the females often in the middle of the summer cease to propagate parthenogenetically, bearing as in fall fecundated eggs in ephippia.

Altogether I produced during the artificial domestication of Daphnia the appearance of males and fecundated eggs through rapid augmentation of the density of the salt water as well as through rapid increase of temperature. However it is difficult to say which will be the mean of concentration for a known species of Artemia, because a slightly lessened density, though favorable for the growth of the individual, weakens its power of propagation, while a heightened density augments (or supports) propagation, on the other hand this being a hindrance for the development of the individuals. The undiscovered mean of density, it seems to me, must be between these two points, the most extreme limits of the favorable condition of the surrounding elements being then outside of those two points.

On these limits we must find a density at which the males appear in the lake in great multitudes, as several observations and analogous investigations on Daphnia have demonstrated.

I therefore recede from my opinion that the males of *Artemia* appear at a mean density of the salt water, if the mean density is determined between that of favoring the development and that of assisting the propagation.

Until now I have found the greatest number of males of *Artemia salina* in the Hadschibei Lake in the middle of the summer of 1870, at a

[1] C. von Siebold, Beiträge zur Parthenogenesis der Arthropoden. 1871, p. 224.

[2] C. von Siebold, Ueber Parthenogenesis der Art. salina. Extract of the sessions of the Royal Academy of Sciences at München, 1873, p. 190.

strong evaporation after continued drought, the salt water then rapidly reaching a high concentration.

I have yet to add a few words on the geographical position of the lake and the salt-water ditches inhabited by *Artemia salina*.

Two great salt lakes, the Hadschibei and the Kujalnitzky, are situated about 7 or 9 versts from Odessa towards Nikolajeff. These two lakes (Russian, limane) were formerly two broad river entrances and ocean bays, into which two rivers formerly poured.

At present these two small draining rivers no more deserve their names. The "limanes" were subsequently cut off from the sea by broad stretches of sand, the Peresippe, and were transformed into salt lakes.

Only in the lower part of the Kujalniker-Limane, separated by an artificial embankment from the upper part for the purpose of obtaining salt, is the salt deposited.

The Hadschibei-Limane showed with my areometer 5° B. as the lowest and 12° B. as the highest concentration.

The salt-water ditches are distributed over the saline soil in the neighborhood of the lake, situated between the lakes and the seashore along the Peresippe to near the city of Odessa.

In the various ditches occurs salt water of various densities from nearly fresh water up to water of 5° Beaumé.

Only the more salty ditches of 4° to 5° B. are inhabited by a (ziemlich ausgebildet) developed form of *Artemia salina*, often associated with *Branchipus spinosus*. In less saline ditches occurs *Branchipus ferox* and *Branchipus medius*.

Similar results, as regards the evolution of the form, I have also obtained from Daphnia, Cyclops, and Canthocamptus, and I promise to soon publish these investigations.

REMARKS.—1. I have especially endeavored in the above writings to draw attention to the fact that in domesticating *Artemia salina* in gradually diluted salt water, after several generations and at a progressive development, I obtained a form presenting the most important *morphological* characters of the genus *Branchipus*, so that such a form was at one time regarded by me as a new species of Branchipus.

The principal generic characters of Branchipus I regard as the nine apodous postabdominal segments.

Although we obtain in progressively domesticating *Artemiæ* the characters of the genus *Branchipus*, and although, also, the other characters change in the direction toward *Branchipus*, such an artificially domesticated *Artemia*, for many reasons and marks of distinction, can only be considered as a lower form of a *Branchipus*, representing, consequently, a transitory form from *Artemia* toward *Branchipus*, and an intermediate form between these two genera. Such a form can also be looked at as a prototype or radical type of these two genera.

2. An important circumstance is that in those *Branchipus* observed by me, a few bristles are distributed in a circle around each postabdominal segment just before the articulation, and that in *Artemia* such bristles occur also in a circle at a little above the middle of the last postabdominal segment. I mentioned above that in *Branchipus* each such bristle arises out of the middle of a complex of dentate spines, which are of very large size in the male of *Branchipus spinosus*.

I find it necessary to add that I found such dentate spines in both sexes of the species of *Branchipus* examined by me only on the *ventral* side of the postabdominal segment just before the articulation, at which location they could be plainly seen. It is well known that in the male of *Branchipus spinosus* groups of dentate spines occur only on the *ventral* side of the postabdomen just before the articulation.

In the same places fine bristles arise out of groups of circulatory cells in *Artemiæ* living in salt water of high density, which cells, by domestication of several generations of Artemia in gradually diluted salt water, transform into groups of small dentate spines.

3. Under the name of postabdomen I mean the last nine segments of the posterior section of the body, or all apodous segments which are frequently called postabdomen. *Artemia* has eight such segments.

After all, it seems to me that not all apodous segments deserve either the term abdomen or postabdomen, since the first two segments, bearing the external genital organs, are more sharply defined or insected from the following segments, being also somewhat shorter and broader than the latter, having therefore more resemblance with the preceding limb-bearing segments.

It appears to be more proper to add the two connate genital segments to the præabdomen, calling postabdomen all the other apodous segments; this view concurring also with the developmental history. According to the latter view we have seven apodous segments in *Branchipus* and six in *Artemia*.

D.—CONTRIBUTION TO A KNOWLEDGE OF THE INFLUENCE OF EXTERNAL CONDITIONS OF LIFE UPON THE ORGANIZATION OF ANIMALS.

By WLADIMIR SCHMANKEWITSCH.[1]

[Translated by Dr. C. F. Gissler.]

I published in 1875 in the Russian language, in the Transactions of the Neo-Russian Society of Naturalists (Vol. III, 2d part), a paper under the title "Some Crustaceans of the salt and fresh waters, and their relation to the surrounding elements."[2]

After the further elaboration of the material, I shall publish the entire contents of my labors, at present submitting only the part which I regard as the more complete.

I.—*Some instances illustrating the influence of salt-lake surroundings upon the life and development of several crustaceans.*

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[1] Zeitschrift für Wissenschaftliche Zoologie, XXIX, 429–494, 1877.

[2] The contents of the paper are the following: Chapter I. The genus Cyclops (*C. bicuspidatus* Cls. and *C. odessanus* n. sp., *C. brevicaudatus* Cls., *C. brevicornis* Cls., *C. serrulatus* Fischer. *C. tenuiformis* Cls., *C. minutus* Cls.). Enumeration of the species and races of this genus from the neighborhood of Odessa. Diagnosis of the undescribed forms of Cyclops. The indication of forms necessary to compare the characters of the known species of this genus. General remarks on *Cyclops brevicornis* and *C. brevicaudatus*. Effect of the surrounding element upon the forms of Cyclops under artificial domestication. Chapter II. *Cletocamptus* genus novum (family of Harpactidæ), *Cl. strömii* and *Cl. retrogressus*, and domestication of the latter in changed surroundings. Chapter III. *Transfuga* gen. novum (fam. Harpactidæ), *Tr. salinus* n. sp., and *Tr. lacustris* n. sp. Chapter IV. The relations between marine forms and fresh-water forms in the family of Harpactidæ. Chapter V. The genus Daphnia. *D. magna* Leyd. varietas, *D. rectirostris* Leydig (*Moina rectirostris* Baird) of salt and fresh waters. *Daphnia degenerata* n. sp. and *D. rudis* n. sp., both marine forms. Chapter VI. The genera *Artemia* and *Branchipus*. *Artemia salina* Milne-Edwards. The generations of *Artemia salina* receiving the characters of *Art. Milhausenii*. *Branchipus ferox* Chyzer varietas. *Branchipus spinosus* Milne-Edw. *Branchipus medius* mihi. The characters of the genera Artemia and Branchipus. The transformations of the branchial sacs and posterior gill-lobes in Artemia and Branchipus under the influence of the surroundings.

For the purpose of illustrating this, I have chosen *Daphnia rectirostris* Leydig (*Moina rectirostris Baird*) and *Branchipus ferox* Chyzer.

Daphnia rectirostris occurs here in large numbers in fresh-water basins, brine ditches, and also in the Chadschibaisky Salt Lake. In the latter they occurred at a concentration of from five to eight degrees of Beaumé's areometer. Two characters are seen in the *Daphnia rectirostris* living in so diversified elements, the former depending on the latter. It appears *firstly*, that in salt water, and especially in the more saline Chadschibai Lake the middle temperature is lower, *i. e.*. the temperature more favorable for the life of *Daphnia rectirostris* than the temperature favoring the life of the same Daphnia in fresh water, so that the Daphnia, being in reality a summer form of the fresh waters, changes in salt water into a fall form, occurring till the beginning of winter in the salt lake at a concentration of 7° to 8° Beaumé in immense quantities, even remaining viviparous at a temperature at which the individuals of the fresh-water generations of the same species could live no longer. *Secondly*, the individuals of the salt-lake generations of *Daphnia rectirostris* represent a degraded or retrograde form of the fresh-water generations of the same species, differing from the latter the more the higher the concentration of the salt-water basins in which they occur increases, so that the individuals of the salt lake differ more from the fresh-water forms than the individuals living in salt ditches.

So much do the forms of *Daphnia rectirostris* from the salt lake differ from those of the fresh waters that they could be regarded as a separate variety of *Daphnia rectirostris*, although it is but a transformed generation retarded in its development, and changed under the influence of the surroundings of *Daphnia rectirostris* inhabiting the fresh waters. On account of various observations and experiments, I presume that the peculiarities of the salt-lake form of *Daphnia rectirostris* are entirely dependent on the properties of the salt water which they inhabit.

Daphnia rectirostris cannot stand in summer a density of the water of the salt lake of 6° B., while it lives in great quantities in the same salt lake at a density of 8° B. in the fall, toward the end of October and in November, being than viviparous, that is, at such a season in which the fresh-water form of our Daphnia has already ceased to live. This is not an extraordinary phenomenon, considering that a certain aeration of the water is unconditionally necessary to sustain the life of *Daphnia rectirostris*, and that it is unimportant by which means the aeration of the water is regulated. Agreeing with the physical law the less the aeration of the salt water, the higher its density becomes, which results that fresh water must contain more air than any salt water of the same temperature. It consequently follows that also in a salt water of certain concentration at a corresponding lower temperature the same quantity of air as in fresh water could be contained. It is obvious that the quantity of air in the water of the Chadschibai Lake toward the end of October and at a density of 8° B. could approximately be the same as that in fresh water during the summer, and therefore the processes of nutrition in the organism of *Daphnia rectirostris* could in reality be as favorable in both the fresh and salt water. Though analogous in general, they differ singly from each other, as, for instance, by the higher pressure of the more dense water, which density again depends on the quantity of salt and the lower temperature of the water. Dependant on such differences between salt and fresh water are also partly some differences in the organization of the salt and fresh water forms of *Daphnia rectirostris*.

In the females of the Chadschibai Lake, the penicilli or fascicles of knobbed setæ (Tast-borsten) are but little developed, being scarcely fifty times shorter than the antennæ themselves, while in the females of the fresh water the same sensitive penicilli are moderately long, and only six times shorter than the entire antenna. In the males, the sensitive bacilli are also shorter than in those males inhabiting fresh water. The small hooks situated near the sensitive bacilli on the tips of the male antennæ of fresh water are strongly curved with pointed tips, while in the males of the Chadschibai Lake those hooks are shorter, less curved, and with blunt tips. Of the two pointed pale sensory threads situated on geniculated protuberances of the first posterior third section of the male antennæ, the posterior one is a little shorter than the anterior thread, the latter coming out a little more in front. These threads are in the males of *Daphnia rectirostris* of the Chadschibai Lake, not in a straight, but in a screw-like line. The distance between one thread and the other is considerable, which character in the fresh-water males is much less prominent. *The fresh-water individuals of this species have in their earlier stages a period during which they resemble in this, as well as in other respects, the mature forms of the salt lake.*

Besides the differences observed in the antennæ of the salt-water generations of *Daphnia rectirostris*, our attention is called to the number of slender "gefiederten," or, better, finely toothed spines, which occur on the lateral surface of the postabdomen of *Daphnia rectirostris*, running laterally seriatim and nearly parallel with the direction of the rectum. Leydig[1] called them finely feathered spines, which I would have called triangular, laterally finely dentate plates. However this may be, we observe in our fresh-water forms of *D. rectirostris* on each side 11 to 13 of these spines or plates, only 7 to 9 in the salt-lake form, meaning here, as a matter of course, mature individuals only. In younger specimens there are less spines than in the adults of the same surroundings, and *therefore the young fresh-water forms have the same number of spines at a certain age* as the adult forms of the Chadschibai Lake, which demonstrates the retarded development of the latter. Furthermore, our fresh-water Daphniæ (*D. rectirostris*) are nearly colorless, or of a slight yellowish color, while the same species in the salt lake are of a reddish color. The so-called winter eggs of the former have an ochreous or orange-colored yolk. Those of the latter are red throughout. The bristles in general are less numerous in the salt-lake form of the Daphnia than in the fresh-water form, and the average size of body in the latter is also less than in the former, although the difference is but slight.

The generations of *D. rectirostris* inhabiting our salt ditches represent in every respect a transitory form between the fresh-water form and the salt-lake form, which lake has a higher density of the salt water than the water in the salt ditches, where it fluctuates between 1° and 5° Beaumé.

In domesticating *Daphnia rectirostris* I also convinced myself that the salt-lake form can also live at a lower concentration of the salt water, only requiring herein a higher temperature, than that fit for them in the very saline lake; that is, it wants a summer but no fall temperature. In this less concentrated salt water the degradation of individuals is considerably diminished with the generations, so that they finally resemble the individuals of this species from salt ditches, *i. e.*, they approximate the fresh-water form. In so domesticating,

[1] Naturgeschichte der Daphniden, Leipzig, 1860, p. 175, Tab. X, 76.

during a rather brief duration the sensory threads on the tips of the antennæ become nearly three times longer than before the beginning of domestication.

We now find in comparing the fresh-water generations with the salt-water generations of *Daphnia rectirostris* that the latter generations not only changed in consequence of the immediate effect of the surrounding elements, but also in consequence of retarded development under their influence; and, furthermore, that the sexual maturity shows itself earlier in the salt-water generations than the complete typical development of the body parts. The termination of the sensory antennæ, the color of the body, the lesser pinnulation of the bristles in the salt-water generations are principally dependent upon the immediate effect of the surrounding elements. The smaller number of the above-mentioned spines on the postabdomen principally depends upon the retarded development under the influence of changed surroundings. In the latter case the individuals commence, without awaiting the development of their body parts, to augment, and are in that state a complete animal form.

Branchipus ferox affords a still more characteristic example of the influence of the salt-lake element. Milne-Edwards,[1] whose words Grube[2] repeated in his diagnosis of this species, gives a brief description of *Branchipus ferox* from the neighborhood of Odessa. Chyzer[3] completed his description from Hungarian specimens. The diagnosis by Chyzer of this species differs so much from that of Milne-Edwards that both authors could not possibly have had one and the same form of Branchipus, as we shall see later on. It is difficult to understand why Milne-Edwards does not mention the two so important characters of this species, which ought to rank with the principal characters which Chyzer enumerates. This is the conspicuous length of the egg-sac, and especially the fact that the abdominal appendages or furcal lobes are bristled only on their inner edge. To this latter peculiarity Chyzer especially points out the characteristics of *Branchipus ferox*. It is evident that Milne-Edwards had a very closely allied form to that of Chyzer's, since in the neighborhood of Odessa, wherefrom Milne-Edwards's form came, generations of this species occur in salt, brackish, and fresh water, which, owing to their dependence of the density of the water basins, considerably differ in their characters. The generations inhabiting salt-water ditches of about 5° Beaumé differ as much from the individuals inhabiting fresh water, especially the Hungarian forms described by Chyzer, as any species will differ from another one. Had I not found all possible transitory forms between fresh-water and salt-ditch forms, had I not convinced myself of the variability by domestication of this form, I should have regarded the salt-lake specimens as a new form. For some time I really took them for a variety of *Branchipus ferox* Chyzer. At present, and after so many convincing results, I can only conditionally regard this form as a variety.

To demonstrate how much the salt-lake generations of *Branchipus ferox* (from the salt-water ditches) differ from the Hungarian fresh-water specimens, compare the following characters: The egg-sac of the salt-lake *Branchipus ferox* reaches in its length only to the beginning, or to the middle, of the fifth apodous segments, but as the following sixth, seventh and eighth segments are longer than the anterior segments, the egg-sac reaches scarcely to the middle of the postabdomen,

[1] Histoire naturelle des Crustacées, III p. 369.

[2] Bemerkungen über die Phyllopoden, Archiv f. Naturg p. 142, 1853.

[3] Fauna Ungarns Crustaceen. Verhandl. der zoologisch-botanischen Gesellschaft in Wien, 1858, p. 516.

counting in all apodous segments, while in the Hungarian forms the length of the egg-sac equals the whole postabdomen, excluding the abdominal appendages. Besides, in *Branchipus ferox* of the salt-water ditches the egg-sac is not spindle-shaped, only elongate, often entirely oval, *i. e.*, not only shorter, but also broader, as in the form diagnosed by Chyzer. In our salt-water ditch forms the furcal lobes average in length the eighth part of the body length, inclusive of the furcal lobes; in Chyzer's Hungarian form, as shown by the measurements, the furcal lobes average the fourth and a half part of the whole body length including them, that is, they are much longer in the Hungarian form. The most important difference consists in that while in *Branchipus ferox* of our salt ditches the furcal lobes *have both edges bristled*, in the form described by Chyzer only the inner edges of the lobes are bristled. Lastly, our salt-water ditch form measures, inclusive of the abdominal lobes, seventeen to twenty-two millimeters, the Hungarian form twenty-nine to thirty-four millimeters. Our salt-water form approaches in all other respects the diagnosis of Chyzer, and does not disagree with the determinations of Milne-Edwards and Grube.

Besides the difference between the specimens of our salt-lake-water and the Hungarian fresh-water forms of *Branchipus ferox*, we find, after strict examination of the matter, that the bristles of the furcal lobes in our salt-water-ditch forms, only in young animals shortly before becoming sexually mature, commence at the base of the lobes in one height, and that on getting older the number of bristles is lessened along the exterior edge, and that in the adult, and especially in old individuals, the bristles on the exterior edge of the furcal lobes will be seen to commence more than twice lower than on the inner edge of the same. At a length of the furcal lobes of 2.5^{mm}, in the adult form, the bristles begin on the inner edge at a distance of 0.24^{mm} from the base of each lobe, but on the exterior edge they begin at a distance of 0.52^{mm} from the base of each lobe. The bristles on the exterior edge of the lobes are in adults of this form more than twice shorter than those on the opposite inner edge, especially on the first half of the furcal lobes. *The younger the individuals are the more trifling is the difference between the bristles of the inner and outer edge of the lobes.* Furthermore, in the salt-water ditches of low density such generations of *Branchipus ferox* live, whose individuals have an average size of about 22^{mm}. In these larger specimens the exterior edge of this or that abdominal appendage in the adult state has no bristles from base to the middle of the lobes. The bristles of the exterior edge are also shorter and more sparsely distributed than in the preceding form. Their egg-sac usually reaches down to the middle of the fifth apodous segment, and is a little longer than the egg-sac of the preceding form. The ditches with nearly fresh, scarcely saline-tasting, water harbor also still larger specimens of *Branchipus ferox*, measuring some 25^{mm} in average length. In these large individuals in mature age the exterior edge of either furcal lobe is without bristles from base down to over the middle of each lobe. The remaining bristles are again still more sparsely placed, and also shorter than in the preceding form; the egg-sac is also a little longer.

Specimens of *Branchipus ferox*, collected by me in ditches on Taman Island, in the neighborhood of the city of Kertsch, represent another link in the series of transitory forms between the extreme generations of the salt-lake and Hungarian fresh-water specimens. In the Taman specimens, which have a length of 30^{mm}, the egg-sac reaches to the middle or to the end of the fifth apodous segment of the abdomen, the furcal lobes having nearly the same length as those of the Hungarian specimens; but in the adult state, on their exterior terminus of the lobes, remain more or less short, sparsely placed bristles, the less the older the specimens are. As the smallest number of bristles, I found seven; so that at 6.9^{mm} length of a lobe its exterior margin was bristled only up to a distance of 1.5^{mm}. As the highest number of bristles in mature specimens, I counted fifteen; so that at 6.8^{mm} length of a lobe its exterior margin was bristled up to a distance of 3.4^{mm} from the tip of the lobe.

To explain the formation of such a remarkable character as the missing of bristles on the exterior margin of the furcal lobes in generations of *Branchipus ferox* inhabiting fresh-water ditches, we need only be reminded that these lobes are the longer the less dense the water is in which they live, and that in the real fresh-water generations of this species the furcal lobes are the largest. I have also observed that these lobes distend at a wide angle in swimming; the wider they distend the longer they are. In addition, the exterior margin of these lobes continually cut the water, being therefore in a higher degree, subject to the mechanical influence of the water. Even if the pressure of the salt-water be higher then are the furcal lobes of the salt-water forms of this species much shorter, and, besides, we may say that the salt-lake generations do not fully grow up; therefore, remaining provided with the principal characters of the *young* fresh-water forms. The fresh-water generations of *Branchipus ferox* have, amongst all European species of Branchipus, the longest furcal lobes.

The domestication of several generations of this species in salt water of various concentration verifies also the effect of the surroundings.

I therefore can see no necessity of admitting here an influence of natural selection and to add new unknown factors to solve this problem.

One of the most remarkable phenomena is the fact that in our shallow marine district so rich in salt-water basins (closed lakes and salt-water ditches), even in pure fresh water the typical fresh-water form of *Branchipus ferox* Chyzer does not occur, but only a form approximating in a certain degree those of the lowest generations of this species, inhabiting our salt-water ditches, connecting it with the Artemia; above all with the extreme race of *Artemia salina* (varietas *a*), which also lives in our salt-water ditches. This is not the only example of such an abberration of form. In the fresh waters of the neighborhood of Odessa we do not find the real *Daphnia magna* Leydig; however, one of its races occurs, representing an abberration toward *Daphnia pulex* Leydig[1] of a lower grade. The generations of our fresh-water *Daphnia magna* variety, distribute themselves also in a few salt ditches, where they form a still greater deviation from the typical form. In more saline ditches (of about 3° Beaumé) occur such forms of Daphnia, bearing the characters of another, simultaneously reminding one of *Daphnia magna* varietas, *D. pulex*, and partly also of *Daphnia reticulata* and *D. quadrangulata* Leydig. I described this form under the name of *Daphnia degenerata*[2]

Regarding it as a degraded form of those ancestors, which gave origin to the existence of *Daphnia magna* and *D. pulex*, I actually convinced myself in examining generations of *Daphnia degenerata* at different seasons of the year and at various densities of the salt water, and also, by domesticating them, that it is a changed and degraded form of our

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[1] See my reports in the "Schriften" of the Neorussian Society of Naturalists, Vol. III, Part 2, pp. 196–216.

[2] Opus citatum, pp. 228–232. I have to add the following: The sensory antenna of the female of *D. degenerata* is provided on its upper surface with the same bristle as occurs in *D. magna*.

variety of *Daphnia magna*, the latter variety being itself again an inter mediate form between the typical *Daphnia magna* and *D. pulex*. If we would restore the middle radical form, which gave origin to *Daphnia magna* and *D. pulex*, we would receive a form most similar to our *Daphnia magna* varietas, in the production of a still farther allied, a prototype for the largest number of Daphniæ, we would arrive at a form most similar to *Daphnia degenerata* from the salt-water ditches. Such examples show *that, owing to the neighborhood of salt waters* in which the generations of the fresh-water species distribute themselves and in which they change under retardation of development, *the species themselves in fresh waters of such districts deviate to a certain degree from the typical form*, *i. e.*, they change toward the direction of the next lowest species of their genus. In consequence of the existence of such an element in these districts the area of distribution of the species changes; but as the center of this area will be found somewhere between the fresh-water and the salt-lake element, the aberration of the fresh-water generations in the neighborhood of salt-lake waters, in which the generations of the fresh-waters pecies already considerably changed themselves and become retarded in their development, is easily understood.

The salt ditches, which distribute themselves on saline soil near Odessa between the sea and the two salt lakes, the Chadschibaisky and the Kujalnitzky, become fresh-water ditches after gradual elevation, and simultaneously begin to become populated with fresh-water generations, whereby these generations form, to a certain degree, changeable transitions toward the more changed salt-lake forms. Some of the ditches six years ago containing salt water of about 3° to 4° Beaumé, and inhabited by the salt-water species, *Branchipus spinosus* Milne Edw., now contain nearly fresh water, and are populated this year (1876) with the fresh-water forms *Daphnia magna* Leydig varietas and *Cyclops brevicaudatus* Claus, slightly changed in the direction toward the lower forms. In relation to the latter, a transitory form of *Cyclops brevicaudatus* varietas *b*[1] and *Cyclops brevicaudatus* Claus, was to me of great interest. In the real fresh-water *Cyclops brevicaudatus* the extreme inner one of the four furcal bristles is twice as long as the extreme outer, or actually the twenty-fifth part shorter than the double length of the last outer bristle; in generations inhabiting less saline ditches the extreme inner bristle is, on an average, the sixth part shorter than the double length of the extreme outer. In *Cyclops brevicaudatus* varietas *b.* the extreme inner furcal bristle is but little (one-quarter) longer than the extreme outer. *The adult forms of the changed generations of Cyclops brevicaudatus in the less salty ditches exhibit nearly the same relation of body parts, as seen in the young, immature, pure fresh-water forms of the same species; but the mature individuals of said variety correspond in this point with the younger individuals of the species.*

To this I have to refer also the interesting influence of the surroundings upon the development of specimens of *Artemia*. The growth of the specimens of *Artemia salina* in salt water of high density and at the same temperature proceeds at least twice as slow as the growth of specimens of *Branchipus ferox* in less saline water. Abstractedly from the fact that the growth of specimens of *Artemia salina* requires much time, sexual maturity appears much earlier *in proportion to the full development of body-parts*, than in Branchipus. At a high concentration

[1]Consult my paper in the "Schriften" of the Neoruss. Soc. of Naturalists, vol. iii. part 2, pp. 32 to 36, and 74 to 77. Also on the domestication of Cyclopidæ, *ibidem*, pp. 84 to 95.

of the salt water, only inhabitable by *Artemia*, and especially at sufficient warmth, the mature sexual products show themselves already at a time when the provisional parts of the second, lower antennæ were scarcely dropped, *i. e.*, when they have not yet left the last larval stage. *Artemia lives a much longer time in the larval state than Branchipus*, indeed the longer, the higher the concentration of the water for Artemia and the lower for Branchipus. Between the fresh-water *Branchipidæ* and those *Artemiæ* which can still live in a salt-lake self-depositing salt, there is a relative great difference. Accordingly we must allow that we can produce, by corresponding domestication of generations of *Artemiæ*, already in their larval stage, but in any case in the last period of the latter, before the second antennæ have dropped their provisional parts, sexual maturity. Carl Vogt's observations have shown that the eyes appear much later in Artemia than in Branchipus,[1] and I presume that this is applicable to those Artemiæ which are in relation to Branchipides, degraded forms of the latter.

I have to mention the circumstance that the concentration of the salt water vigorously stimulates the multiplication of Artemia. The highest increase of a given species of Artemia is brought about by a density of the salt water which is a little higher than that generally assumed as the mean for this species; therefore under such conditions which hinder, to a certain degree, the growth of the individuals and the development of their body-parts. On the other hand the most rapid growth and the progressive development of body-parts happen to appear at such a concentration of the salt water, which is a little below the mean for a given species, and at which density the propagation of the individuals decreases. In *Artemia salina* I observed the highest multiplication in a state of nature at a density of the salt water of 10° to 12° Beaumé's areometer and with summer temperature; the highest developments of body-parts I noted at 5° to 7° Beaumé, and at the same temperature. Between these limits must be the mean density of the salt water for our *Artemia salina;* I have also to remark, that the density of the salt water, together with the temperature, and independently of the same, influences the growth and the propagation of these animals. It appears that the parthenogenetic reproduction in Artemia does not only depend upon the temperature, as in Daphnia, but also upon the density of the salt water. I observed at least viviparous reproduction in *Artemia salina* in stronger saline water at such a low temperature at which viviparturition in the same species does not occur in less saline water, although it does not hinder viviparturition at a comparatively higher temperature. In all such cases the quantity of air contained in the water and dependent upon temperature, as well as upon concentration of the salt water, plays an important rôle, regulating many of the functions of life. Perhaps the variability of the concentration of the salt water yields, in Artemia, one of the main causes of parthenogenesis, the latter not being yet known to occur in *Branchipodidæ*, inhabiting principally fresh water. Density and temperature of the salt water in their influence upon Artemia are combined in such a manner that, when the existence of an Artemia-like form in fresh water is possible, the same can only exist at a nearly summer and possibly high temperature. The lower the density of the salt water the higher a temperature is required, if Artemia shall preserve its form at least in its principal characters. In this sense, *Branchipus stagnalis*, which, according to the

[1] "Revue scientifique de la France et de l'étrang.," 2. series, 1873, No. 27, pp. 632 to 633. Also in "Meeting of Swiss Naturalists" in Freiburg i. s., 1872.

statements of the authors (Leydig, Claus, Spangenberg) has eight apodous segments of the abdomen, represents in its principal characters an Artemia-like form; however, it remains to be determined whether this species is peculiar to summer temperature, of which we have a few intimations. It seems that the dependence of the quantity of air in the salt water upon its density, beside the mechanical effect of such a water, forms one of the main factors of the sexual and specific characters of Artemia, whose forms are distributed according to the various densities of the salt water, as the species of a known genus are dispersed according to geographical latitudes, or also after their appearance at different seasons (annual species). Moreover, a certain concentration of the salt water is, probably again in consequence of a certain quantity of air, in accordance with the physiological processes in Artemia. I here omit the respiration and the changing of the gill-sacs of Artemia with the changing of the concentration of the salt water, simply mentioning the circumstance, that we most rarely find males with those lowest degraded forms of our Artemia, bearing the characters of *Artemia Milhausenii*, living at the highest density for Artemia, and that, as we will see, the males of that race of *Artemia salina* (varietas *b.*) in salt ditches occur, which are most progressively developed and which live, in comparison with our other forms, at the lowest density of the salt water, as will be explained later on.

II.—On the Gill-sacs and the Posterior Branchial Lobes in Artemia and Branchipus.

I shall speak in this section of the relation of these appendages in Artemia and Branchipus to their external life conditions. First we have to agree as to the determination of these parts. The gill-sac in these forms is called by C. Claus (in his paper on *Branchipus stagnalis* and *Apus cancriformis*) "Kiemensäckchen"[1] (gill-sacklet).

Grube calls it "unterer Branchialanhang"[2] (lower branchial appendage).

S. Fischer called it "unterer Branchialsack"[3] (lower branchial sac).

The posterior branchial lobes are called by Claus (*ibidem*) "hinteres Branchialblatt" (posterior branchial leaf); by Grube, "oberer Branchialanhang" (upper branchial appendage); by S. Fischer, "oberer Branchialsack" (upper branchial sac).

The first which demands our attention is that the gill-sacs and posterior branchial lobes in Artemia and the salt-lake Branchipus enlarge in length and more so in width during the domestication of specimens, or still more of generations of these forms in salt water of increased density.

Specimens of *Artemia salina* taken from the Chadschibai Lake, showing a density of 9° Beaumé, I divided into two equal vessels, gradually diluting the salt water in one of them, but increasing the density of the salt water in the other. I kept the water in both vessels at equal height. In both vessels were old and young growing specimens. Both jars stood near to each other and were, with the exception of differently-concentrated water, as regards temperature and all other influences, under the same circumstances. The experiment lasted for four weeks, during which time I daily measured the length and width of the gill-

[1] "Abhandlungen der königlichen Gesellschaft der Wissenschaften zu Göttingen," vol. xviii, 1873.

[2] "Bemerkungen über die Phyllopoden" in "Archiv für Naturgeschichte," 1853, p. 141.

[3] Middendorf's Sibirische Reise, St. Petersburg, 1851, vol. ii, part 1, p. 151.

sacs and the posterior branchial lobes of the domesticated mature specimens of both vessels, measuring also the length of the body, finding also the ratio between the length and width of these appendages to the length of the body, inclusive of the furca. The resulting figures gradually increased with the strength of concentration of the salt water in one or the other vessel in two different directions, the animals showing in the fourth week of domestication a very considerable difference, which plainly illustrated the increase of the length, and more so of the width, of said appendages at a heightened density of the salt water, and also the decrease of those parts at a reduction of density of the water. Toward the end of the fourth week the salt water in both jars attained a difference of 10° Beaumé, the gradually-diluted salt water showing then 3° Beaumé; the salt water of gradually-increased density indicated 13° Beaumé. To compare the size of the gill-sacs and posterior branchial lobes of *Artemia salina* at decreasing and increasing density of the salt water, in measuring I searched for figures which indicated which part of the body-length the length and width of these or those appendages in these or those specimens formed. During the fourth week of the above-mentioned period of domestication I obtained the following figures as *average results* in two diverging directions:

At a *decreased* density		At an *increased* density
	of the salt water	
	the *gill-sacs* yielded	
in length the 24, 3,		in length the 22, 4,
in width the 46, 5		in width the 40, 6
	part of the entire body-length;	
	the *posterior branchial lobes* yielded	
in length the 17, 6,		in length the 16, 8,
in width the 38, 9		in width the 34, 9
	part of the entire body-length.	

I have to remark that toward the end of the period of domestication the resulting figures in the measurements showed considerable oscillations. The cause of it is that in salt water of extremely decreased or extremely increased density the animals soon became so short-lived that the older individuals, as well as the younger just before or soon after becoming sexually mature, died. The relation of the body-parts in such young, though sexually mature individuals, resembles in some degree the relation of the body-parts in young immature individuals in another surrounding element, then normal for the species; for we observe also a slight retardation of growth in a suddenly produced extreme decrease of the density of the salt water the same as in the increase of the density of the salt water. In insufficiently gradually diluting the salt water the individuals of *Artemia salina* die, as it were, of debility, which cause lies probably in the heightened oxidation in the organism dependent on the increased quantity of air in diluted salt water. The highest development of the furca and the greatest number of its bristles are not incongruous with the lowest density of the salt water which this species can endure for a longer or shorter time, but it is congruous with a concentration not much lower than that peculiar to the species. The more gradual the concentration of the salt water in the domestication of successive generations of *Artemia salina* is changed the more deviates the mean (for this species) favorable concentration from that concentration which is the mean for it in free nature.

In comparing *Artemia salina* with those degraded forms and genera of this species exhibiting the characters of *Artemia milhausenii*, living at a very great density of the salt water, approaching the natural deposition of salt, or having attained the latter already, we find a great difference in the size of the gill-sacs and the posterior branchial lobes, since the appendages mentioned are considerably larger in the latter than in *Artemia salina.* To see this, we compare specimens of *Artemia salina* from the Chadschibai Lake at 9° Beaumé in the first half of September with the degraded genera of this species[1] taken from the Kujalnetzki salt lake at 24° Beaumé, also in the first half of September of the same year, that is, at very different density of the salt water and at nearly the same temperature. Hereby we receive in middle average, and omitting fractions, the following figures:

In *Artemia salina* in September at 9° Beaumé—		In degraded specimens of *Artemia salina* with the character of *Art. milhausenii* at 24° Beaumé—
	the gill-sacs yielded	
in length the 23,		in length the 18,
in width the 44		in width the 28
	part of their body-length;	
	the posterior branchial lobes yielded	
in length the 17,		in length the 15,
in width the 36,		in width the 24
	part of their body-length.	

The length of the body of *Artemia salina* was here taken together *with the furcal lobes*, exclusive of their terminal bristles, in the same manner as in the above stated experiment; the body-length of the specimens with the characters of *A. milhausenii* to the end of the abdomen, as they have no abdominal furca. Since the furcal lobes form a part of the body of *Artemia salina* and partake of the nutrition like the other body-parts, I have not excluded them in my calculations, although, too, the relations without this furca, which is of inconsiderable length, in comparing the specimens of this or that species, scarcely vary. I also add that I took here, as well as in the above stated experiment, the gill-sacs and posterior branchial lobes of the *eighth pair* of legs, though they are not the largest in this leg. These appendages in mature specimens increase in size from the first to the sixth pair of legs, on the following legs becoming somewhat smaller, without, however, there being much difference between the sixth and eighth pair of legs. The comparison in any case loses nothing, as the specimens have been compared after one and the same pair of legs. I took these appendages from the eighth pair of legs, coming nearer the mean figure, which would express their size in all pairs of legs.

Not less different is also *the form* of the gill-sacs in the degraded generations with the character of *Artemia milhausenii* and in *Artemia salina.* For comparison it is better to take the gill-sacs from the middle pair of legs, as they are of smaller size on the first two or three pairs of legs, and as if not fully developed, having a somewhat deviating form in the last pair of legs, gradually broadening towards the end, becoming in *Artemia salina*, as well as in specimens with the characters of *A. milhausenii*, nearly uniformly rounded. In comparing the gill-sacs of the middle pairs of legs of *Artemia salina* and *Art. milhausenii* we see that these sacs in *Artemia salina* are of an elongated form and that

[1] Compare my report in the Zeitschrift f. wiss. Zoologie, 1875, vol. xxv, 1st supplemental part.

the width of the sac nearly amounts to the half of its length, while they have an oval form in *Art. milhausenii*, the width of the bag nearly amounting to two-thirds of its length.[1] In long continued domestication in salt water of gradually increased density I obtained, after several successive generations of *Artemia salina*, specimens in which the gill-sacs and posterior branchial lobes had the same form and size as those of the specimens with the characters of *A. milhausenii*, out of the Kujalniker Lake at 24° Beaumé, and in which still other characters appeared peculiar to them in free nature.

It is important that in young individuals of *A. salina* in a certain age the gill-sacs and posterior branchial lobes have nearly the same size and form *as in the mature individuals*, with the characters of *Artemia milhausenii*, with the difference that in young individuals directly after quitting their larval state, and even, also, until they liberate themselves from the provisional parts of the second antennæ, the largest of these appendages are not on the sixth pair of legs as in the mature forms, but on the fourth pair. Under the same circumstances under which in mature specimens of *Artemia salina* the gill-sacs *on the fourth pair* of legs amount in their length to the twenty-eighth and in their width the fifty-sixth part of the whole body-length, the gill-sacs in the young specimens (in the above-mentioned age) of the same pair of legs measure the seventeenth part of the body-length in length and the twenty-seventh part in their width; but at the time at which in mature specimens (at low temperature) of *A. salina* each gill-sac measured, *on the sixth pair* of legs, in its length the twenty-fourth, in its width the forty-eighth part of the body-length, in young specimens of the above-mentioned age each gill-sac of the same pair of legs measured in its length the nineteenth and in its width the thirtieth part of the entire body-length. In *young individuals* of *Artemia salina* of this age the gill-sacs of the *eighth pair* of legs corresponded, together with the posterior branchial lobes, in form and size with the same appendages of the same pair of legs in the *mature individuals*, which have the characters of *A. milhausenii*, inhabiting most saline water (about 24° Beaumé). In any case, on the whole, these appendages are, in the young specimens of *A. salina* of the stated age, considerably larger than in mature specimens of the same species, being, also, as it must be in the course of development, larger on the anterior pair of legs to the sixth than on the following pairs. In the young individuals of the age stated the gill-sacs measure on the third, fourth, and sixth pairs of legs in their mean length together the eighteenth and in their middle width the twenty-ninth part of the whole body-length, but in mature specimens of this species and under the same conditions the gill-sacs of the third, fourth, and sixth pairs of legs measure in their middle length together only the twenty-eighth and in their middle width the fifty-sixth part of the body-length.

From the fact that the gill-sacs and posterior branchial lobes of the young individuals of *Artemia salina* of the stated age correspond in form and size with the same appendages in the mature individuals bearing the characters of *A. milhausenii*, we can infer that the latter is a generation of *A. salina* retarded in its development in consequence of the appearance of sexual maturity before the full development of the parts of the body. However, such an inference would be but partially true. The individuals with the characters of *A. milhausenii* not only exhibit retarded development under the influence of their surroundings, but they are also the result of the demand of the same element—the result

[1] Consult my report in Zeitschrift f. w. Zoologie, 1875, vol. xxv, 1st suppl. part, Tab. VI, figs. 7 and 8.

of the influence of the organism upon the surrounding element. The hightening of the density of the salt water is naturally accompanied by a decrease of aeration in such a water, but this decrease again must produce in Artemia an enlargement of the breathing surface, *i. e.*, the surface of the gill-sacs. Concerning the posterior branchial lobes, they (partly also the gill-sacs) have to enlarge themselves in water of high density as auxilliary organs of locomotion, perhaps they also serve as auxilliary organs in respiration, especially in Artemia, wherein the posterior branchial lobes are marked out for their greater tenderness, than generally in Branchipus, in which they often are margined with tooth-like spines or little-developed bristles, being, as it were, the beginning of bristles and spines developed on the other branchipeds.

According to Leydig's view the gill-sacs of Artemia and Branchipus do not serve as special respiration organs; but the investigation of Claus[1] and Spangenberg[2] make it in the highest degree probable that the inference that the gill-sacs, but not the posterior branchial lobes, are not special respiration organs, is a proper one. Such a conclusion will also be made by the consideration of these appendages in their relation to the surrounding element, under which latter I not only mean the density of the salt water, but also the temperature; toward the latter the gill-sacs are especially sensitive in a high degree, as we shall see further on.

From such a great sensibility of these appendages toward the surrounding element, we must assume that they have a considerable size in specimens with the characters of *Artemia milhausenii*, not only owing to retained growth of *A. salina*, whose younger specimens have larger appendages, but also in consequence of *their accession*, owing to *augmentation of their mass*, due to the surrounding element, owing to the high density of the salt water. The fact serves as a proof that, in comparing young individuals of *Art. milhausenii* with individuals of *Art. salina* of the same age, we find the appendages in the former of considerably larger size. Only a much earlier state of growth of *Art. salina* relatively agrees with the later state of age of those individuals, bearing the characters of *Art. milhausenii*, inhabiting salt water of much higher density than *Artemia salina.* Beside the interesting changes occurring during the course of development of generations influenced in a known manner by the surrounding element, we here observe an accession and, as it were, an accumulation of mass in the known parts reacting upon the element and developing according to the demands of this element. I call this a direct influence of the surrounding element, and moreover such an influence, toward which the organism keeps active, and I distinguish it from another likewise direct influence of the same element, toward which the organism, so to speak, passively submits. As an example of this latter influence, I mention the retrograde development of the abdominal furca of *Art. salina* in salt water of high density, whereby the furca becomes as if atrophied, and, indeed, independently of the sexual maturity in specimens, appearing earlier than the full development of the body-parts. That influence of the element upon which depends the change of form, owing to the changed point of appearance of sexual maturity, I call the immediate influence of the surrounding element upon the organism. In Artemia, and also to some degree in

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[1] "Zur Kenntniss des Baues und der Entwicklung von Branchipus stagnalis und Apus cancriformis." In the "Abhandlungen K. Ges. der Wissensch. zu Göttingen." Vol. XVIII, 1873, p. 19.

[2] "Zur Kenntniss von Branchipus stagnalis." Zeitschrift f. w. Z., vol. xxv, 1st supplemental part, pp. 23 and 37.

other species of crustaceans examined by me, we can observe all these modifications of the influence of the surroundings upon the organism.

The formation and full development of the gill-sacs and posterior branchial lobes depend in Artemia and Branchipus not only on the salt-quantity of the water, but also on its *temperature;* since *by a lowering of temperature the size of the gill-sacs decreases*, by a heightening of the temperature they enlarge. I do not possess sufficient measurements concerning the *posterior branchial lobes* by which I could attest with correct figures the change of these appendages by temperature, although I obtained unmistakeable results, according to which they, contrary to the gill-sacs, but in a less degree, *enlarge by lowering the temperature.* Putting temporarily the posterior branchial lobes aside, I shall treat of the gill-sacs only.

In measuring the gill-sacs in specimens of *Artemia salina*, gathered in the first half of September out of the Chadschibai Lake, I was surprised at the figures obtained by the relation of their size to the length of the body, deviating far from the figures received in measuring the summer-forms, although the density of the salt water in the lake was but little lessened. Later in the fall, the specimens of *Art. salina* collected out of the Kujalniker Lake, at a density of the salt water of 13° Beaumé, had even a little smaller gill-sacs than the specimens collected in summer at 9° Beaumé, from the Chadschibai Lake. Subsequently, I divided the young and old specimens taken from the Kujalniker Lake at a density of 13° Beaumué into two sections and domesticated one section at an average temperature of 14° [Réaumur?] the other section at an average of temperature of 7°+ Réaumur. A considerable difference showed itself after two weeks, those individuals living at a lower temperature, but kept by me at a uniform concentration in both jars, had their gill-sacs, especially in width, considerably smaller. In individuals living in higher temperature, each gill-sac on the eighth pair of legs on the average amounted to the twenty-second part in length and the forty-second part in width of the whole body-length; in individuals living at a lower temperature the gill-sac of the same pair of legs gave the twenty-fifth in length and the fiftieth part in width of the body-length.

It seems that temperature has upon the gill-sacs a more vigorous effect than the concentration of the salt water; on the other hand, the density of the salt water has a stronger influence on the posterior branchial lobes. The circumstance is hereby illustrated, that in the first, red variety of *A. salina* (varietas *a*, description farther on), the gill-sacs are smaller, but the posterior branchial lobes are larger than in *A. salina.* Not to mention so many figures, I point to the width of these appendages, since in these forms they differ in length little from each other. In measuring the specimens of *A. salina* at a density of 13° Beaumé, and the specimens of the first, red variety at a density of 16° Beaumé, at one and the same (moderately low) temperature, I found that the width of the *gill-sacs* of the eighth pair of legs in *A. salina* was the thirteenth, but in the stated variety it was the forty-ninth part of the body-length, and that in *A. salina* the width of the posterior branchial lobes was the thirty-fifth, but in the red variety it amounted to the thirty-second part of the whole body-length. In this manner, besides the fact that the specimens of this variety were collected at a higher density of salt water than the specimens of *A. salina*, their gill-sacs are nevertheless smaller than in the latter; but the posterior branchial lobes are larger in the variety than in its species, this corresponding already with the larger quantity of salt contained in the water. Such a phenomenon is only explicable by the fact, that in a state of nature, on the average, *a lower temperature* is, together with *a higher density of the salt water* than with *A. salina*, peculiar to the first variety of *A. salina* (varietas *a*). The gill-sacs, as special organs of respiration, must become smaller by a lower temperature, whilst the posterior branchial lobes, as the auxiliary organs of locomotion, must enlarge by the greater density of the water dependant on the lower temperature and the higher concentration. But since the density of the salt water depends more on its concentration than on temperature, it is obvious why, by domestication of Artemia, we observe more changes in the posterior branchial lobes by the concentration of the salt water than by temperature.

The first of these varieties of *A. salina* (varietas *a.*) corresponds amongst our forms of Branchipus mostly with the species *Branchipus spinosus* Milne-Edw., according to the relation of the gill-sac and posterior branchial lobes and some other characters, together with the element which it inhabits. *Branchipus spinosus* is characterized among our forms of Branchipus in a similar manner as the first variety of *A. salina*, and *A. salina* by small gill-sacs and large posterior branchial lobes, only here in *Branchipus spinosus* is the difference in size of these appendages considerably larger. Such a phenomenon also fully corresponds with that element which *Branchipus spinosus* among our salt-water forms of Branchipus principally inhabits. It lives, in comparison with our other Branchipus forms, in a lower temperature, but at a higher concentration of the water. Especially in younger age and at a certain time the gill-sacs and posterior branchial lobes much resemble the appendages of the mature specimens of the stated variety of *A. salina* (varietas *a.*), and altogether in younger age of the specimens of Branchipus there is a certain period when their leg-appendages in measurements more approach the appendages of the mature forms of Artemia than the appendages of mature forms of the same species of Branchipus. For comparison we take mature individuals of *Branchipus spinosus* and young individuals of this species, some time after they quitted their larval state, when the section between the eighth and ninth apodous segments of the abdomen has scarcely just been formed, and the furca is still two or two and a half times shorter than the section consisting of the two last segments of the abdomen, and which is homologous with the last (eighth apodous) segment of the abdomen in Artemia. In the mature *Branchipus spinosus* the furca equals the section consisting of the last two apodous segments. We obtain the following proportions:

In the old specimens of *Branch. spinosus*—		In the young specimens of *Branch. spinosus*—
	the gill-sacs amounted	
in length the 40, in width the 118		in length the 24, in width the 61st
	part of the whole body-length;	
	the posterior branchial lobes amounted	
in length the 19, in width the 37		in length the 16, in width the 28th
	part of the whole body-length.	

The first variety of *A. salina* (varietas *a.*) is in relation to this, especially concerning the gill-sacs, between the species *A. salina* and the young specimens of *Branchipus spinosus*. I only kept the figure of the measurement of varietas *a.* of *A. salina* at such a salt capacity of the water, at which it (the variety *a.*) forms the transition to the corresponding variety of *A. milhausenii*, that is, at 15°, 16°, and 18° concentration after Beaumé's instrument. In concluding, it results that at such a concentration of the salt water, at which the above stated measurements of *A. salina* showed themselves, *i. e.*, at 9° Beaumé, and the temperature of the month of September, we must obtain the following figures for this race:

The gill-sacs		The posterior branchial lobes
	must amount in their length	
the 25th,		the 16, 5th,
	in their width	
the 52d		the 34th
	part of the whole body-length.	

The variety *Branchipus ferox*, hereabouts living in salt water ditches, and to which is peculiar a lesser concentration of the salt water, however at a higher temperature than that peculiar to the species *Branchipus spinosus*, yields the following figures, in relation to the gill-sacs and posterior branchial lobes:

The gill-sacs		The posterior branchial lobes
	amount in length to	
the 24th,		the 20th,
	in width	
the 56th		the 43d
	part of the whole body-length.	

The variety *Branchipus ferox* (from salt-water ditches) is, in its leg-appendages and according to the element which it inhabits, in proportion to *Artemia salina* as *Branchipus spinosus* is to varietas *a.* of *A. salina*. Especially those generations of *A. salina* which live in salt-water ditches of about 4° Beaumé, or the generations of the second variety of *A. salina* (varietas *b.*) are in relation to gill-sacs and posterior branchial lobes and some other characters, also in the element in which they live nearer the salt-lake generations (from salt-water ditches) of *Branchipus ferox* (varietas). I must add here that the legs themselves are longer in *Branchipus ferox* var. and in *A. salina* than in *Branchipus spinosus* and in *A. salina* varietas *a.*, and that only on this account the posterior branchial lobes of the forms of the one or the other category relative to length have no great differences. But the length of the legs corresponds with that temperature and with that concentration of the salt water which is peculiar to each of these forms.[1]

Concerning *Branchipus medius* mihi, we can nevertheless recognize abstractedly from the point that it forms a too isolated species in its characters and in the relation-figures of its gill-sacs and posterior branchial lobes, the result of the effect of the element in which it is distributed, as I have mentioned in the description of this species.[2]

The knowledge of the effect of the surrounding element upon the gill-sacs and the posterior branchial lobes in these animals is important because the differences of size between these appendages, according to authors (Milne-Edwards, S. Fischer, Grube), represent no important species-characters.

It is here the place to add a few remarks which show how far the life of *A. salina* depends on the air-capacity (actually the oxygen of the

[1] Consult any paper in the "Schriften der Neurussischen Gesellschaft der Naturforscher," 1875, vol. iii, 2d part, pp. 297 to 300.

[2] *Ibidem*, pp. 305 to 313

air) of the salt water. By changing the air-capacity of the salt water by a changed concentration of the water, we can at least explain a number of interesting phenomena in the life of Artemia.

1. If we in certain limits dilute the salt water too much in domesticating Artemia, then the animals become, by the too much reduced concentration of the salt water, transparent, attenuated, their intestinal canal empties and becomes translucent, the gill-sacs often blacken, and the animals will die at the bottom of the jar, as it were, of debility. But if we in time notice at the excessive dilution of the salt water the sickness of the animals, and if we, instead of augmenting the concentration of the salt water, heighten its temperature a few degrees, the diseased animals will become animated, the intestinal canal fills itself, the motions become more rapid, the animals leave the bottom of the jar, doing well in such diluted salt water at a corresponding higher temperature. It seems to me that such a temperature supplants the superfluous air of the diluted salt water, which in the organism of the animals produced a too great oxidation, leading to weakness, during which the nutritive substances could not replace the consumption. If by too strongly diluting the salt water the Artemia is consumptive, on account of want of nourishment, owing to the dying off of those microscopic organisms on which Artemia lives, these animals would not have revived so soon after a corresponding increase of temperature. Moreover, microscopic organisms appear in the diluted salt water in great number, even Infusoria, while Joly[1] observed that Artemiæ are omnivorous, and that they principally live on the lowest organisms of the vegetable kingdom peculiar to the salt lakes, such as various forms of Chlamidomonas, zoospores of Cladophora, &c.

2. If we, in domesticating Artemia, excessively increase the concentration of the salt water and not sufficiently gradually, its alimentary canal becomes solidly constipated, the animals keep nearer the surface of the water and die there, especially during exuviation, which is hereby just as difficult to overcome as in too much diluted salt water. However, if we in time in this case lower the temperature, instead of diluting the salt water, the animals, even at a too high concentration of the salt water, revive, doing well in such a water with, to a certain degree, lowered temperature. It seems to me that in this case such a combination of high concentration and temperature is formed, bearing to the equilibrium of aëration in the water, *i. e.*, the quantity of air in the salt water is lessened by the increase of its concentration for just so much, as it is, according to physical laws, heightened by lowering the temperature. A want of nourishment in very saline water is here out of question, since such a water is inhabited by immense numbers of simple organisms, and even at a concentration, allowing self-deposit of salt, great quantities of a red Monad occur, which is known under the name of *Monas dunalii* Joly (*Diselmis dunalii* Dujardin = *Chlamidomonas dunalii* Rabenhorst).

3. If we gather out of a salt lake the adult Artemiæ, together with their larvæ, and dilute the salt water to excess, then the larvæ will soon expire, while the adult individuals long after resist the dilution of the salt water. It appears that the larvæ of Artemia die faster in too strongly diluted salt water, because the small stock of material in the organism is not sufficient toward the intense oxydation in consequence of an excess of oxygen in such a water.

4. In a broad jar and at a low surface of water these animals also

[1] Joly, Sur l'Artemia salina. Annales des sciences naturelles, vol. xiii, Zoologie, pp. 246 and 255.

prosper in such non-diluted salt water, which was taken from the salt lake at a middle concentration peculiar for this species (*Artemia salina*), but they do not prosper so well in a narrower jar with higher water-surface, as they soon die in such a water. In the same narrow vessel and at the same high water-level these animals will still prosper if the salt water is proportionally diluted. In this latter case the animals are so circumstanced, as in more saline water in the broader jar with lower water-level. The diluted water contains more air, it being more penetrable and better adapted for gas exchanges.

5. Accepting the fact that the water in a salt lake at a given time shows 10° Beaumé, and that it is populated with crustaceans of the genus Artemia, if we now take two equal vessels, placing in one of them water of this salt lake and a certain number of specimens of one genus of these crustaceans, and placing in the other jar specimens of the same animals out of the same salt lake, diluting the salt water to 7° or 6° Beaumé, a large number of animals will die in the first vessel under the same conditions, while keeping up the initial concentration of the water, but in the second vessel the majority of the animals will remain alive. In the second case, that quantity of air is as if restored, which is wanting in the first, apparently by the influence of the vessel itself, as the water in the vessel is under different conditions from that in the salt lake. This is all the more so the case with a summer-like temperature.

6. The animals prosper also in a non-diluted salt water better at a temperature lowered to a certain degree than at a higher temperature, yet they do much better in diluted salt water, when the concentration of the salt water has not been reduced above a certain degree.

7. Finally, the enlargement of the surface of the gill-sacs in Artemia with the increase of concentration of the salt water proves, as mentioned already above, apparently the dependence of Artemia in this relation principally on the reduction of air-capacity of such a water, even if the gill-sacs, according to their location and formation, as it were, in these animals represent modified organs of locomotion. It remains for the physicists to determine how considerable is the solubility (the coefficient of assumption or of capacity) of the oxygen of the air in salt water when the variation of its concentration varies. In relation to this I can find no accurate data.

III.—The genera Artemia and Branchipus, and the relation of some of their species to the surrounding elements.

In the whole order of Phyllopoda the species of the genera Artemia and Branchipus are apparently those which are most sensitive to the influence of the surrounding element, in such a sense that a modification of the surrounding element is capable of producing in their generations in a pretty short time visible mutations in their forms. A change of the surrounding element can even in one and the same generation produce such a variation of some parts of the body that it is difficult, in a state of nature, to immediately distinguish those forms which are most closely allied to each other. The species of these genera have been found by me mostly in salt lakes and salt ditches (Artemia exclusively), whereby they distribute themselves in such a manner that each species is peculiar to a certain concentration, and the change of this concentration in artificially domesticating their generations produces a change of form in the direction towards the next species or race which lives in another concentration of salt water, toward which side the change of concentration in the artificial domestication yielded. The temperature hereby co-operates with the concentration of the water. Relating to this, the forms of the genus Artemia deserve special attention.

1.—*Artemia salina Milne-Edwards.*

This species occurs here in the closed Chadschibai and Kujalnitzki Lake and in the salt-water ditches. It sustains a fluctuation easily noted in the variation of body-parts, and in its growth at a fluctuation of the concentration of the salt water from 5° to 12° Beaumé, in which limits it was found by me in the water basins. At a concentration of the salt water which is higher than 12° (and still more than 15°) Beaumé, our *Artemia salina* commences in its generations to exhibit transitory forms towards *Artemia milhausenii* Milne-Edw., the latter living by a far greater concentration of the salt water than *Artemia salina*, that is, at self-deposition of salt or not far from it, *i. e.*, at 24° and 25° Beaumé,

To the description of *Artemia salina* given by the authors we have to say, that the representation of characters of this species, as altogether of the whole genus Artemia in the present time, is very inexact and vague. Firstly, we find mentioned that Artemia possesses but six terminal segments, while there are eight, since we have to count also these two first apodous segments of the posterior part of the body, on which, in the species of Artemia-genera, the external genitals occur. Grube,[1] in making of Artemia a section or a sub-genus of the genus Branchipus, repeats the mistake of his predecessors, saying, in the diagnosis of the group Artemia "*segmentis apodibus sex.*" Only in *Artemia milhausenii*, which lives at a very high concentration of the salt water, are the articulations between the segments, especially between the more posterior ones, some what less distinct; but we can nevertheless, at least in specimens bearing the characters of this species from our districts (also from the Krimea), always distinguish them, especially in fresh material which has not been preserved in weak alcohol for a long time. In the latter case, even in *Artemia salina*, only with difficulty can we see the articulations of the abdomen. If in any region *Artemia milhausenii* occurs with connate, apodous segments, be it in some or all specimens, then it is very likely that we, even in such an Artemia, cannot count six apodous segments. Secondly, it has been considered hitherto as the principal characters of the genus Artemia, that in the species of this genus the abdomen ends with a short furca, whose branches are bristles only on the end, and such a diagnosis of the genus Artemia we discover even in the very latest zoological hand-book. Grube[2] repeats in the diagnosis of his group Artemia in the genus Branchipus the characteristics of the genus Artemia of his predecessors, in saying: Appendicibus caudalibus brevibus, *apice tantum setosis aut nullis.* Our Artemia and two of its varieties, which I shall mention later on, have the bristles not only on the end but also on the sides of the furcal lobes, just as in the species of Branchipus, which usually only have more bristles. Besides the *Artemia salina* from the district of Odessa I have the same distribution of bristles on the furca in specimens of this species brought from the neighborhood of Astrachan and the Krimea. We have here dry years with a hot summer where the concentration of the salt water in the Chadschibai Lake is too high for *Artemia salina.* Then many specimens of this species have, especially in summer, bristles only on the end of the

[1] "Bemerkungen über die Phyllopoden" in "Archiv für Naturgeschichte," 1853, p. 139.

[2] *Opus citatum, ibidem.*

furca, the furca being at the same time shorter and less bristled, as under opposite physical conditions. If we compare the descriptions and illustrations of *Artemia salina* of the various authors, we find that they agree less among themselves than they do compiled from specimens of *Artemia salina*, or taken from the descriptions of specimens gathered under various physical conditions, that is, at various concentrations in combination with temperature. Milne-Edwards[1] says: That on each furcal lobe in *Artemia salina* occur three or four bristles, while Grube[2] states, in his diagnosis, that 5 to 8 bristles occur on each furcal lobe. We find in *Artemia salina* from our district, under various behavior of the surroundings, on each lobe of the furca 4 to 12 bristles, seldom more. In the third form, living in salt ditches in the neighborhood of Odessa and the Krimea, we find 12 to 22 bristles on each lobe of the pretty-well developed furca. I take the latter form to be another variety or race of *Artemia salina*, though it obviously originated from generations of this species with progressive development under the influence of salt-water ditches, having a lower saline capacity than the salt lakes, populated with *Artemia salina*. In those cases, where in our Artemia are more than five or six bristles on each lobe of the furca, the bristles are distributed not only near the end but also on the sides of the furcal lobes. The specimens of Artemia from the very saline Kujalnitzki Lake, having but three, two, one bristles on the end of the furcal lobes, or lacking them altogether, in the latter case having a very slightly developed furca, with the other parts modified; those I take to be transitory forms between *Art. milhausenii* and *Art. salina;* altogether the distribution of bristles on the furca, the number of bristles, and the shortness of the furca itself can not serve as an important distinctive character between the genera Artemia and Branchipus, and much less so as a point of distinction between the species of Artemiæ.

In *Artemia salina*, as one of the most constant points of distinction, we observe the termination of the superior antennæ or antennæ of the first pair. The upper antenna here terminates with two protuberances or papillæ of the form of a truncated cone, one of which is somewhat stouter than the other. At the terminus of the stouter, broader cone, we notice three moderately short spines, only one of which can be seen on the terminus of the thinner cone. Each spine is a little curved, having at its base a quadrate, yellowish, light-refracting body. These four spines are the olfactory bristles of these animals. Immediately under the terminus of the upper antenna, near the end of its upper surface, arise three moderately long and usually curved bristles.

Beside the mentioned terminations of the upper antennæ we have to complete the description of *Artemia salina* by the following characters. In Artemia the posterior part of the body consists of eight apodous segments, the first two of which bear the external genital organs, but the last eighth segment is twice as long as the preceding, being homologous to the two last apodous segments of the Branchipodes. The furca in *Artemia salina* is of very variable length. In our Odessa *A. salina* the furca is on the average six times shorter than the prolonged last abdominal segment. The bristles of the furca are also of very variable number. We notice in our *Artemia salina* on each lobe of the furca from four to twelve bristles, which are not only near the end of the lobes, but for the greater part distributed along their sides, at least if there are more than four or six bristles on each lobe. Toward autumn at a lowering of temperature and dilution of the salt water of the Chad-

[1] Histoire naturelle des crustacées, Vol. III, p. 370.

[2] "Bemerkunken über die Phyllopoden," Arch. f. Nat. 1853, p. 144.

schibai Lake by rain, the furca becomes in the late generations longer and the number of bristles greater, since under these conditions the growth of *Artemia salina* is less retained and the sexual maturity appears not so early, that is, not earlier than the complete development of the body-parts, which, however, is not so well defined in this species, being, as it were, but a relative matter. Also the termination of the upper antennæ, being the most constant character of this species, modifies to a certain degree. For instance, I found in the autumn of one year, at low temperature and diluted salt water of the Chadschibai Lake, in many individuals of *A. salina* near the end of the upper antennæ five olfactory bristles, instead of the normal number of four. In domesticated generations of this species in gradually diluted salt water we perceive also five olfactory bristles on the upper antennæ. With the distinctive characters of *A. salina* we have also to include the form of the gill-sacs. They are in *A. salina* of an elongate form, their width being on the average twice less than their length. This character distinguishes *A. salina* from *A. milhausenii*, in which the gill-sacs are of oval or more rounded form, being on the average two-thirds as wide as long.

As another important point of distinction of *A. salina* from the nearest allied races, I mention the proportional size of the posterior part of the body constituting the apodous segments; the anterior part from the beginning of the head to the end of the last leg-bearing segment, *i. e.*, to the beginning of the first apodous segment and the posterior part of the body, from the beginning of the first apodous segment to the end of the last segment before the beginning of the furca. The furca does not come into account, as its length is variable, being for instance in *A. milhausenii*, with which the other forms must relatively also be compared, entirely missing. We find that in *A. salina* the anterior part of the body is somewhat shorter than the posterior; proportionate to it as five to six or as five to seven. This relation of the parts also depends upon the concentration of the salt water in which these generations live. In reduced concentration the posterior part has an inferior size than in the higher concentration. Altogether the postabdomen of *A. salina* becomes longer and more slender with increased concentration. In many of our specimens with the character of *A. milhausenii*, which live at self-deposition of salt or nearly so, the anterior part of the body is twice shorter then the posterior part.

To the most variable characters of *A. salina* we must reckon that reddish layer which lines the anterior part of the alimentary canal in the shape of a tube, which layer Joly[1] calls the liver, and Leydig[2] the stomach, as he separates it from the following part, the alimentary canal to the anal orifice. For better distinction I shall call the anterior part the *stomach part* of the tract, the second, the *posterior part*.[3] The stomach part of the tract terminates in Artemia about in the middle of the seventh apodous segment, but the length of this part depends upon the concentration of the salt water inhabited by the generations of this species, and partly also from the growth (age) of the specimens. At high salt capacity of the water this part of the tract does not reach to the end of the sixth apodous segment of the abdomen; at lower salt

[1] "Sur l'Artemia sâlina" in Annales des Sciences nat. 1840, pp. 238 to 239.

[2] F. Leydig, "Ueber Artemia salina und Branchipus stagnalis," Zeitschrift f. w. Z. 1851, pp. 283 to 264.

[3] The first part of the tract Claus calls "Magendarm," the second part, the "End-Darm" in his "Zur Kenntniss des Baues und der Entwicklung von Branchipus stagnalis und Apus cancriformis," l. c., as above.

capacity of the water, but especially in autumn, it exceeds by far the beginning of the eighth abdominal segment. Likewise this part is *longer* in *old* individuals than in *young*, otherwise sexually mature specimens. If we examine, relative to this, specimens on the extreme concentration-limits of the salt water, we find a great difference amongst them. In *A. milhausenii* the stomach part of the tract scarcely reaches to the beginning of the sixth apodous segment, but in our species of Branchipus this part terminates not far from the anal orifice.

Finally, we must mention as a character of our *A. salina* the following: The claspers, or the lower antennæ in the males, are much broadened on their second joint, having such a form as the male claspers of *A. arietina*, according to a drawing of S. Fischer.[1]

On the anterior part of the male claspers, between the head and the protuberances, serving to clasp the female with, near the bent-down margin, there are two groups of ten-pin-shaped teeth or spines, in one group on each side. It appears that these denticulate groups correspond as rudiments of the well-known appendages, occurring on the claspers of many species of Branchipus, as for instance in *Branchipus spinosus*. Such bundles of teeth or spines occur also in that form of Artemia examined by Ulianin from Sebastopolis, and which was regarded by him as a race of *Branchipus arietinus* Grube (= variety of *Art. arietina* Fischer).

Artemia salina Milne-Edw. varietas a.—This form, called by me *Artemia salina* var. *a.*, approaches the species *Artemia salina* so much that, beside its larger size, no other distinct characters exist by which we, with the general variability of so many characteristic points of the Artemiæ of this species, could distinguish the same. However, if we have specimens before our eyes of this or that form, we must confess that we have to do with forms differing so much that we even could regard them as different species of the genus Artemia.

A view of profound truth has been expressed already in 1871, by Professor C. Th. von Siebold, on the comparison of descriptions of *Artemia salina* of various authors. Siebold says:[2] "In comparing the various descriptions and illustrations given of *Artemia salina*, we become convinced that probably with this species-name entirely different species or races were marked out, and therefore a revision of the species of the genus Artemia by carcinologists would be recommendable, though this, however, would necessitate a comparison of vast material, especially as the hitherto insufficient diagnoses of the species of Artemiæ, without reference to the characteristic formation of the male heads, have been compiled." Further on Professor Siebold, in perusing the descriptions of the second antennæ of the males in *Artemia salina* and that of the postabdomen of this species, foresaw what is now actually corroborated. I find two principal races of *Artemia salina*, one of which is of smaller size, the *Artemia salina*, but the other is *Artemia salina* varietas a., and there are, besides, still other changes of its generations depending on various concentrations of the salt water, including also those degraded and modified generations of the *two races* of *Artemia salina*, which are, as I suppose, recorded in zoological literature under the name of the species of *Artemia milhausenii*.

The main distinctions of the variety *a.* of the species *Art. salina* forms another mean length of it. Accepting as the mean length of *Artemia salina* six lines, we must accept eight lines of French foot for

[1] Middendorf's sibirische Reise. St. Petersburg, 1851, Vol. II, 1st part. Table VII, fig. 32.

[2] "Beiträge zur Parthenogenesis der Arthropoden." Leipzig, 1871, p. 203.

the mean length of *Artemia salina* var. *a.* As a rule the specimens of this variety are two lines or nearly so larger than the specimens of the species.[1]

With the mean size as a point of distinction, the fact may serve to show that the posterior part of the body in this variety from the beginning of the first apodous segment to the end is somewhat longer than in the normal species. The anterior part of the body in *Artemia salina* is in proportion to the posterior part in most cases as 5 to 6 (or 5 to 7 in higher concentration of the water), but in this variety usually as 5 to 8, slightly fluctuating to this or that side in different salt capacity of the water. The postabdomen in this variety is not only longer, but also slenderer than in the normal species.

The furca is longer in the variety than in the species, and the number of bristles on the furca is also greater in the variety. If the furca in the species is six times shorter than the last prolonged segment of the abdomen, then it is but four times shorter than that segment in the race. But we also meet with specimens of the species with such a proportion of the furca to the last segment, as in this variety, and again we see furcal lobes in specimens of the variety with the same proportion to the last segment as in the normal species. In *Artemia salina* occur from 4 to 12 bristles on each lobe of the furca, rarely more; in the variety *a.* of *Artemia salina* there are from 8 to 15, but seldom more. In this race, as well as in the species, we find however also less than four bristles on each furcal lobe; there occur three, two, and one bristle on each lobe, especially in more concentrated water; but such specimens and generations must, by modifications of other structures, be regarded as transitory forms between *Art. salina* and *A. milhausenii.*

The claspers or second antennæ of the males of the variety are *less broad* than in the males of the normal species. The groups of spines or teeth on the anterior part of the claspers, near their base, are somewhat better developed in the males of the variety than in the males of the species *A. salina.* The second antennæ of the females of this race are a little smaller and narrower than in the normal species, just as the male claspers are narrower than in the species.

The specimens of the variety *a.* of *Artemia salina* are of a far darker red color than the specimens of the species, although there occur also specimens with the same color amongst the latter. The variety *a.* of *A. salina* is usually of a red color, and is found here in the Kujalnitzki salt lake, but *Art. salina* is usually of a grayish or reddish-gray color, occurring principally in the Chadschibai salt lake, in which occur also specimens of red color,[2] which represent, as it were, the points of aberration of the species toward its race (var. *a.*).

In the variety *a.* of *Artemia salina* the gill-sacs are a little smaller; the posterior branchial lobes, on the other hand, a little larger than in the normal species. According to the other structures, it does not differ from the species *Artemia salina;* and all that was said relative to the influence of the surrounding element about the species refers also to the variety *a.* of *A. salina.*

All the characters of this variety correspond with the circumstance that specimens of them, in comparison with the specimens of the species, prosper better at a higher concentration of salt water, but at a lower temperature.

[1] The specimens of the species are about 14^{mm} length, the specimens of this variety 17 or 18^{mm}. The summer generations are in one, as well as in the other form, a little smaller than the fall generations.

[2] The Kujalnitzki Lake has more saline water than the Chadschibai Lake.

Important for my purposes is the following remark of Dr. Nitsche concerning *Branchipus Grubii* (von Dybowski) from the neighborhood of Leipzig: "Further on it exhibited the remarkable circumstance that two races of this species occurred: a larger one about 20 to 22mm long, and a smaller one about 15mm long. These lived in various ditches, and those inhabited by the larger race contained far less specimens than those inhabited by the smaller race."[1] The existence of two races of different sizes of *Branchipus Grubii* and the circumstance that the specimens of these races lived in different ditches is of importance. It would be interesting to learn[2] whether this "ratio quantitatis" between two races occurs at any time of the year (which I do not accept). Information about this latter point would especially be of value, whether the specimens of these two races occurred together in one and the same ditch.

Artemia salina Milne-Edw. varietas b., like variety *a.*, in reference to the species, represents, so to speak, another branch of the middle radical form, from which it, together with the normal species, originated in the distribution of generations in a modified element; this second variety (var. *b.*) represents in its distribution in an element of lesser concentration of the salt water the progressively developed generations of the species itself.

Variety *b.* occurs in salt ditches near Odessa and Sebastopolis. In salt ditches near Odessa I found it at a concentration of 4° Beaumé, while at the same time in the other salt ditches of higher concentration specimens of *A. salina* occurred.

The length of the specimens of variety *b.* scarcely differs from the length of specimens of the normal species; its postabdomen, however, is shorter and stouter than in the species; the furca is by far longer and more bristled than in the normal species. The postabdomen (exclusive of the furca) is in this race also a little shorter than the anterior part of the body, at least in the young, though sexually mature specimens, while the same somewhat elongates with age. As the posterior part of the body elongates with the growth of the specimens to mature and old age, and likewise in heightening the concentration of the salt water, we can presume that it is in *A. salina* var. *b.* either shorter than the anterior part, or equals it, or is scarcely longer than the same, while in the species *A. salina* the posterior part of the body is considerably longer than the anterior.[3] Only in the young specimens of the species itself, some time before becoming sexually mature, the posterior part of the body is still shorter than the anterior. In any case, such a character cannot sharply demarcate this variety from the normal species. There are other characters by which we can distinguish them. The furca of the variety *b.* does not show any simple conical protuberances at the end of the abdomen like two prolongations of the same, but real—even if not segmented from the end of the abdomen, but only by a transverse, easily noticed ring, separated at the sides from its base—divided furcal lobes. They are rather large and more developed than in other forms of Artemiæ. They have the shape of lancet-like plates, tapering

[1] H. Nitsche: "Ueber die Geschlechtsorgane von Branchipus Grubii (von Dyb.)." Zeitschrift, f. w. Z., vol. xxv, p. 281.

[2] From Dr. Nitsche we cannot expect to hear all the singularities referred to the race of *Branchipus Grubei*. Especially inquiring into the structures of the *sexual organs* of *Branch. Grubii*, which formed the topic of his dissertation, Nitsche sufficiently pointed out the existence of two races of *Br. Grubii*, calling it a remarkable circumstance.

[3] The postabdomen is on the average longer and slenderer in the species of Artemia than in those of Branchipus.

toward the tip, with sides and ends bristled, whose number fluctuates on each lobe between 12 and 22. The furcal lobes are in length only two and a half times shorter than the last abdominal segment.

This last (eighth apodous) prolonged segment of the abdomen differs here in the important peculiarity that it possesses, a little above its middle, often a more or less distinct transverse ring, like an articulation, as existing between the eighth and ninth apodous segments of the abdomen in the species of Branchipus, in which the furcal lobes are in the majority strongly developed, as it were, on account of the ninth apodous segment, which is rather short with them. This transverse ring is just below the last sensitive bristles, occurring in *A. salina* a little above the middle of the eighth apodous segment of the abdomen,[1] as also at the end of each of the anterior apodous segments just before the segmentations. If this transverse ring on the eighth prolonged apodous segment was more conspicuous in variety *b.* of *A. salina*, and if it was of constant occurrence, then we would have a form with nine apodous abdominal segments, which is one of the principal characters of the genus Branchipus. But since there is no actual segmentation on the eighth apodous abdominal segment of variety *b.* of *A. salina*, this race forms, remaining with the genus Artemia, a transitory link between this genus and the genus Branchipus. With the latter genus the examined race possesses by far more harmony than the other hitherto known forms of Artemiæ. The prolonged, laterally and terminally, bristled furcal lobes, the transverse ring between these lobes and the abdominal end, the shortness of the postabdomen, the lesser length in proportion to these parts in other Artemia forms, the greater thickness of the segments of the postabdomen, the more or less distinct traces of segmentation on the last (eighth) apodous, homologous with the two last (eighth and ninth apodous) segments of Branchipus, likewise also yet other less conspicuous characters of *Artemia salina* varietas *b.*, demonstrate this.

Amongst the characters in which the examined Artemia-form incline to the genus Branchipus I will note two more. One of them consists in the presence of *groups of spines* on the ventral and lateral surface of the postabdomen, on the end of the third, fourth, fifth, sixth, and seventh apodous segments, anteriorly of each segmentation, and a little before the middle of the eighth apodous segment before the more or less noticeable transverse ring on this segment. On some segments occur two aggregations, one on each side, but on others occur four aggregations arranged circularly around the segment. From the middle of each aggregation arises a sensory bristle, which, together with the groups of spines situated near their base, can easily be seen under a magnifying power of 350. In *A. salina* and its variety *a.* occur, instead of groups of spines, on the same spot groups of cuticular cells, which do not rise above the surface of the integument (from which they are somewhat differentiated), and which give rise to one bristle arising from their midst. These complexes of cuticular cells in *A. salina* and in its variety *a.* are homologous with the mentioned complexes of spines in race *b.* of *A. salina* and the species of Branchipus. In domesticating several successive generations of the species *A. salina* in gradually diluted salt water, I obtained, together with the other corresponding characters on the post-

[1] On this spot of the last segment of the abdomen we obtain the segmentation in the species *A. salina* by domesticating several of its generations in gradaually diluted salt water. Compare my paper in the "Schriften" of the third meeting of Russian naturalists at Kiew, Zoological section, pp. 71 and 87; also, my paper in Z. f. w. Z., xxv, 1871.

abdomen, the development of groups of spines from the above-mentioned groups of cuticular cells. However, these cuticular cells also commence in free nature in fall generations of the species *A. salina* to point themselves on their tips and to elevate themselves above the integument. To be sure under such external conditions the enlargment of the furca and the number of their bristles testify in these specimens to a lesser retention of growth than in summer at higher salt capacity of the water and at higher temperature. These cuticular groups of cells, or, in known cases, these denticular groups of spines occurring near the base of the sensory bristle on the abdomen of *A. salina* and its varieties, are homologous with the minute denticular spines occurring near the base of the sensory bristles on the lateral surface of the postabdomen in both sexes of *Branchipus ferox* and *B. spinosus*. Concerning the large spines on the ventral surface of many apodous segments (from the third to the eighth) of the abdomen of the males of *B. spinosus*, they apparently represent a phenomenon independent of the sensory bristles and their basal denticular groups of spines, or both structures are so connected with each other that the substituted sexual characters can be connected with the sensory organs, for which we have to take the large ventral spines of certain abdominal segments of the male *B. spinosus*. Beside these large spines, occur, exteriorly of them, at the side of the segments, in the males as well as in the females of this species, groups of minute denticular spines, each with a sensory bristle.

The last of such conspicuous characters of the variety *b.* of *A. salina*, approximating this form to the genus Branchipus, consists in the fact that the male claspers on the anterior ventrally-directed side near the margin between the rugose protuberances and the middle have not only at the sides a complex of teeth, but also that they have on these spots several protuberances or integumental duplicatures. It seems to me that those teeth occur on that spot where certain appendages on the male claspers of many species of Branchipus occur. The claspers themselves are considerably smaller in the males of this race than in the species *A. salina*.

Still further on a circumstance in the biology of *A. salina* var. *b.* points to the inclination of this form towards the species Branchipus. It is that the males of this variety evidently occur comparatively more frequently than in the other forms of Artemia. Of sixteen specimens brought to me indiscriminately from the Krimea, six of them proved to be males.[1] Such a percentage of males I never met with in other species of Artemia, among which the males are generally rare. Near Odessa I had succeeded hitherto in finding but one female of this variety, together with *B. spinosus* in a salt-water ditch of 4° Beaumé, none of the other forms of Artemia occurring there. Variety *b.* of *A. salina*, however, lives among all forms of Artemia known to me at the lowest concentration of salt water in salt ditches, in which live also several species of Branchipus, some at higher, others at lower concentration of the salt water. This circumstance is of importance, inasmuch as in species of Branchipus, which do not indicate such a difference in figures as the species of Artemia, parthenogenesis is unknown, while it without doubt exists in Artemia, and in this number probably also in variety *b.* of *A. salina*, being yet solely on the limits of the genus Artemia. Very rarely

[1] In the summer of 1876 I found in the neighborhood of Sebastopolis, in several salt-water ditches and smaller salt lakes of lesser salt capacity of the water, progressively developed generations of *A. salina;* nearly half of their number were males.

do we find males in the degraded generations of *A. salina* already bearing the characters of *Artemia milhausenii*, and which live in the most saline water. However, we can plainly notice that in the salt ditches and in very small salt lakes drying up in summer, that the males of Artemia appear in immense numbers at a certain time of the year, and at a certain concentration of the salt water, as I observed it at a comparatively rapid evaporation of the water of the salt-water basins at the time of continued drought. Here we have to give ourselves the solution of the question about the change of this physiological function in consequence of the distribution of generations of a species in another element, together with a certain variation of other functions, and of the animal organism. Referring to this I mention but one of the sides, to which variety *b.* of *A. salina* inclines to the genus Branchipus.

This variety has with the species the other structures in common, with the exception of those less noticable aberrations depending upon the element, *i. e.*, principally from the lower concentration of the salt water, together with their own organization. So, for instance, are the gill-sacs in the variety a little smaller, but especially narrower than in the species; likewise in the body more of a gray than a reddish color, and more transparent. This form most closely approaches the variety of *Branchipus ferox* of our salt ditches, but perhaps it is the radical form of *B. ferox* and *B. spinosus*.

Consequently we have, therefore, here three closely allied forms of Artemia: *A. salina*, *A. salina* var. *a.*, and *A. salina* var. *b.* The species *A. salina* must justly be regarded as a double form, consisting of *A. salina* and its first variety (var. *a.*), as these two forms in long past times must have originated by division and formation of races of their generations from one for both middle forms. Regarding the second variety (var. *b.*), it represents a form originated from *A. salina*, and became distributed in salt ditches of lesser salt capacity, and it is likely that also a similar offspring of the second variety exists.

These three forms, however, have so many different characters that they in any case can be recognized as varieties amongst themselves. We find such cases also in other widely-distributed species of Crustaceans,[1] for instance, in *Cyclops bicuspidatus* Claus, and especially in *Cyclops odessanus* n. sp., where two (*Cyclops bicuspidatus*) or still more (*C. odessanus*) near, but still differing forms under certain external conditions, each living in either its peculiar pond in one and the same, or also in different water basins, and where each under certain external conditions or at another season of the year obtains preponderance at least in the number of specimens. But the forms of Artemiæ have the preference before other Crustaceans, inasmuch as the surrounding element includes less complicated conditions, which by the observer can be kept under better control.

Among the forms of Artemiæ we may regard *A. milhausenii* as one of the most retrogressively developed ones; but as one of the most progressively developed forms we have that which I provisionally call variety *b.* of *A. salina*. Parallel to this *A. milhausenii* lives in very saline water, near the self-deposition of salt, or near the same (about 23° to 25° Beaumé), but variety *b.* of *A. salina* lives in comparatively less saline water (4° B.).

Our *A. salina* does not fully agree with that examined by Joly,[2]

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1 Consult my paper in the "Schriften" of the neorussian Society of Nat. 1875, vol. III, 2d part.

2 Joly, Sur l'Artemia salina, Annales des Sc. Nat. 1840.

occurring in the south of France. Our *A. salina* is rather a middle form between *A. salina* Joly and our large race of *A. salina* (var. *a.*). The considerably prolonged furca and the rather thin female claspers (males were unknown to Joly) of *A. salina* Joly recall these parts in the mentioned variety, but the body-length and the proportional length of the abdomen agree with the same characters of our *A. salina.* The mean concentration of the salt water Joly mentioned for his species corresponds better with the mean concentration for our variety *a.* of *A. salina.* Besides, according to the drawing of Joly, in his *Artemia salina* the sixth apodous (Joly's fourth) segment of the abdomen is a little longer than the seventh, but in our *A. salina* the sixth apodous abdominal segment is usually a little shorter than the seventh; still it becomes longer only at too high concentration of the salt water and also in younger stages of the specimens. In mature specimens of our *A. salina* is the sixth segment especially longer when the concentration of the salt water does not change from year to year, but in a shorter time, as, for instance, from spring toward summer. The relative length of the sixth and seventh apodous abdominal segments in our *A. salina* may also serve as a measure for determining the age of already mature specimens at a given concentration of the salt water, since the seventh apodous abdominal segment prolongs with the age, and when this segment in heightened concentration of the salt water, also in mature specimens, remains equal with the sixth or shorter, it indicates that sexual maturity appears under such conditions a little *earlier* than the *full development* of the body-parts. In variety *a.* of our *A. salina* is the sixth apodous abdominal segment generally somewhat longer than the seventh, which corresponds with the illustration of Joly and the usually *not sexually mature* specimens of our *A. salina.*

The male claspers of our *A. salina* are, as alluded to above, of the same form as figured by S. Fischer for his *A. arietina* (Middendorf's sibir. Reise, vol. II, part i, Pl. VII, fig. 32), but the termination of the upper antennæ separates, according to the description and illustration of S. Fischer, this form from *Artemia salina.*

Concerning the diagnosis of *A. salina* Grube (*Branchipus salinus* Grb.) it remains unknown wherefrom Grube took the statement, that in this species there are eleven bristles on the edges of the terminal plates (lobus tarsalis Grb.) of the legs. The lobus tarsalis Grb. is the palette of Joly, as expressed by Grube, but Joly points out 30 to 38 bristles on each such plate. I believe that this is a mistake in Grube's diagnosis, and that Grube counted eleven bristles from Joly's illustration on another foot-plate of *Art. salina*, that is, on one of those plates which Grube[1] calls himself *lobi tibiales.* This mistake in Grube's diagnosis can be sufficiently cleared up by the comparison of the description and illustration of Joly with Grube's diagnosis and synonyms, which Grube mentions for the terminology of these lobes in these animals after various authors.

I wonder that I have not hitherto succeeded in finding that species which S. Fischer described from the neighborhood of Odessa[2] under the name of *Artemia arietina.* The principal and very great difference of *A. arietina* consists, according to Fischer, in that the terminations of the first pair of antennæ in this species are divided into two branches, whereby the end of one branch bears two olfactory bristles, but the end of the other bears two prolonged bristles, while in all Artemiæ collected

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[1] "Bemerkungen über die Phyllopoden," Archiv f. Nat. 1853, p. 141.

[2] Middendorf's Sib. Reise, Vol. II, part i, pp. 156 to 157.

by me here and in the Krimea an entirely different type of structure of the first antennæ predominates, there being on the scarcely biramous end of the antennæ of the first pair four olfactory bristles and three rather long bristles. Also at my visiting the Krimea last year (1876) I found the same Artemiæ as near Odessa. It is the same *Artemia salina* with its two forms (a smaller, the *Artemia salina*, and a larger, the variety *a.* of *A. salina*), and moreover with its different variations, as they depend upon the different concentrations of the water in a known salt lake (the specimens with the characters of variety *b.* of *A. salina* and those with the characters of *A. milhausenii*). Beside the lake near Eupatoria I also visited five other small lakes near Sebastopolis. Out of one of these lakes, the second on the Chersonesis and at the same season of the year, *Ulanin*[1] obtained Artemiæ and, as communicated to me by the author himself, alcoholic preparations already rather injured, which he described as a variety of *A. arietina* Fischer (*Br. arietinus* Grb.). S. Fischer described his *A. arietina* also from alcoholic specimens, but we ought from all Crustaceans, Artemidæ the least, not to describe them after alcoholic specimens, as in them especially the number and the relation of the postabdominal segments remain concealed from any observer who does not succeed in obtaining live material. Unhappily also the systematic description of the Artemiæ and Branchipus has hitherto remained still the same, as founded in literature by descriptions from alcoholic specimens. Such misrepresentations arise from this, that, for instance, in one species, *Artemia salina*, the second antennæ of the male, while in another species, *Artemia milhausenii*, under the same name, the second antennæ of the female have been described (cornes céphaliques, Milne Edw. Hist. nat. des crustacées), as the males of this species were not yet known,[2] about which I shall speak further below. For those uninitiated in Artemia and the singularities of its literature, such diagnosis may form a source of many errors, which I have elsewhere endeavored to clear up.[3]

2.—*Generations of Artemia salina Milne Edw. receiving the characters of Artemia Milhausenii Milne Edw.*

Artemia milhausenii has been described by authors under various names (*Branchipus milhausenii* Fischer von Waldheim, *Art. salina* Rathke, *Art. milhausenii* S. Fischer) from alcoholic specimens, and therefore we find various contradictions and inaccurate accounts in the descriptions of this species. Other authors (Milne Edw., Grube) borrowed accounts from the former for the diagnosis of this species. If the forms occurring in nature and those obtained by a certain domestication from *A. salina* and its first variety (varietas *a.*) agree with those which have been described by the authors under the name of *A. milhausenii* and synonyms, or, better expressed, if there is in a state of nature no other *A. milhausenii* than the degraded and modified form of *A. salina*, which receives with the generations after a certain time and by heightening the salt capacity of the salt lake the characters of *A. milhausenii*, then *A. milhausenii*, owing to the manner of its origin and the

[1] "Schriften der kaiserlichen Ges. der Liebhaber der Nat. Anthrop. und Völkerbeschr. Moskau. Vol. V, part i, page 96.

[2] C. von Siebold, Beiträge zur Parthenogenesis der Arthropoden, 1871, p. 209.

[3] Consult my paper: Explications relatives aux différences qui existent entre l'Artemia salina et l'Art. milhausenii et entre les genres Artemia et Branchipus. Biblioth. Universelle et Revue Suisse. "Archive des sciences phys. et natur. Genève." Vol. 57, No. 224, 1876, pp .358 to 365.

infirmity of its characters, in which, however, it differs from the nearest forms, *as one species differs from another species*, does not represent an independent or original species. At constant high or little changed concentration of the salt water, this form is able to produce entire series of generations with the characters of *A. milhausenii*, like an original species. Even if the generations of our form with the characters of *A. milhausenii* are qualified at a certain behavior of the surrounding element to preserve their distinctive specific characters, then these generations only represent a degraded and modified form of *A. salina*, or, indeed, two closely allied forms of *A. salina*, of which one represents the changed generations of *A. salina*, the other the changed generation, of the first variety (varietas *a.*) of this species.

In a short treatise in Zeitschrift f. w. Zoologie, Vol. XXV, first supplementary part, I have spoken of the changes of the generations of *A. salina* produced by heightening the salt-capacity of the water in nature and by artificial domestication, whereby they received the species characters of *A. milhausenii.* Without repeating the same, I will only point out that, together with the modifications of the postabdomen of *A. salina*, the other parts also gradually changed in the direction toward *Artemia milhausenii*, *i. e.*, the postabdomen became more slender and longer, the female claspers narrower; the leg-parts also changed themselves, whereby the number of bristles and fimbriate spines of the leg-lobes lessened, and the gill-sacs (Claus) changed from elongate to oval, thus comparatively increasing their size. We obtained finally all the peculiar characters of *A. milhausenii*, as they were described by the authors.

The specimens with the characters of *A. milhausenii* in the Kujalnitzki salt lake justly represent a degraded and changed form of *A. salina* and its first large variety (*a.*), for that we also distinguish two different forms of individuals with the characters of *A. milhausenii.* Some correspond with the specimens of the species, others with the mentioned variety of *A. salina.* Even if the characters of the species and this variety of *A. salina*, through degradation of their individuals, become somewhat obliterated, it is nevertheless still possible to distinguish individuals originating from this or from that form. Those corresponding with *A. salina* have about 10^{mm} length, those of the mentioned variety are about 12^{mm} in length. In the former the postabdomen is a little shorter, and the posterior or apodous segments is shorter than the double length of the anterior part of the body, and is in proportion to it on the average as 8 to 5, but in the latter the posterior part of the body is equal to twice the length of the anterior part, or a little shorter, in the proportion in the latter case of 9 to 5. In both species this relation moreover depends upon the age of the already sexually mature individuals, since in already older ones the posterior part of the body is longer. Moreover, the former have a less dark red color, and their rounded abdominal end is somewhat broadened and as if flattened in the direction from above downward, but the latter have a more dark red color and the abdominal end is less broadened, only rounded. In this way the specimens of *A. milhausenii* have two forms, but the difference of their characters is scarcely sufficient to regard one of them as a true race in relation to the other, and the less so, as the deviation of the individuals of the one or the other category on one or the other side, according to age, even at the time of sexual maturity, allows some transitory stages to be recognized between them. It is only apparent that some represent a degraded form of *A. salina*, but that others represent a degraded form of variety *a.* of *A. salina.* It is necessary to remark, that the former already at 20° Beaumé represent a just as far degraded or retrograded form as do the latter at 23° or 24° Beaumé, and that the former occur principally in one, but the latter in another, now cut-off part of the Kujalnitzki salt lake. For better distinction I shall call the former the smaller, the latter the larger form with the characters of *A. milhausenii.*

Did this Artemia, with the characters of *A. milhausenii*, one form of *A. salina*, change by the influence of the surroundings, or one by the influence of the same in the development-retarded form? To this question the characters themselves, and the course of postembryonal development of this *modified* and also *in development retarded form*, answer. Not only characters show themselves in this form peculiar to the younger age of *A. salina*, and originated from retarded development, but also newly acquired to the surrounding adapted characters. The young individuals of *A. salina* and its variety have, as is known, in the beginning no furca, but it develops much later. This circumstance testifies that in adults with the characters of *A. milhausenii* no furca has been formed, owing to retarded growth. But we must consider that in those transitory forms between *A. salina* and *A. milh.*, which in mature and old age have a little-developed furca, with a very small number of bristles, have, in still young age, just before the appearance of sexual maturity, and shortly after the same, a still more developed furca, with a larger number of bristles preserved, *than in old age, during which this part at one and the same salt capacity of the water more degrades.* This phenomenon can still be better noticed in the domestication of successive generations of *A. salina* in salt water of gradually increased concentration, wherein that period, during which the furca mostly develops, shortens with each following generation, the development of the furca becoming a weaker one, *appearing in shorter time-spaces.* It is important that this period includes the space of time immediately before and partly also after the appearance of sexual maturity, in the beginning of mature age; also in those specimens in nature in which in later, mature, and old age altogether no furca exists, a little developed appears in said period, partly with bristles, or only in later generations, by the influence of the surroundings in the same direction, *this phenomenon of characters of higher original form is more and more obliterated.* All these phenomena prove that the absence of the furca in the forms with the characters of *A. milhausenii* depends upon retarded development of the organization of the generations, not only from the appearance of sexual maturity still before the full development of the body parts, but also from the immediate influence of the salt water of higher concentration, at which the appendages just beginning to develop became as if atrophied. There are many similar examples of retrograde development of the form and of the individual.

The greater length and slenderness of the postabdomen in the specimens with the characters of *A. milhausenii* compared with the part in mature and still more in younger *A. salina*, proves with certainty that the organization of such specimens in this relation depends almost entirely upon the immediate influence of the element, but not upon an indirect influence, *i. e.*, from the mechanical pressure of the salt water, and the later appearance of sexual maturity, and not from the retained growth and the appearance of sexual maturity *before the complete development of the body-parts.* Had the postabdomen of the specimens with the characters of *A. milhausenii* formed as a consequence of retarded growth and in comparison to *A. salina* earlier and before the full development of the body-parts ensuing appearance of sexual maturity, this postabdomen would have remained comparatively short and stout in the conduct of these parts in the young *A. salina*, in which the furca is not yet developed, or it would be in any case shorter and stouter than in the mature *A. salina*. I admit that in further degradation of the generations with the characteristics of *A. milhausenii* the postabdomen could have become even, if not shorter, yet less shorter, than in the mature *A. salina*, but I only speak of what has really been the case in these specimens. The circumstance that at a higher salt capacity of the water, the growth of the degraded specimens of *A. salina* is going on slow, and the sexual maturity appears in time late, gives its postabdomen the chance, as if in contrast with the degrading influence of the element to prolong, and the latter perhaps also retains the prolongation of the abdomen, especially in combination with the heightened temperature, which also, according to the time, awakens the sexual maturity earlier. In *A. milhausenii*, described by Rathke[1] under the name of *A. salina*, is the posterior part of the body, consisting of apodous segments, also shorter than the anterior part, although the description, illustration, and figures of this author stand in great contradiction to each other. From the description of this author it follows that this Artemia in summer lives in a concentration of the salt lake reaching self-deposition. Even if the postabdomen in our specimens with the characters of *A. milhausenii* is larger than in *A. salina*, there is nevertheless in transitory forms, in which the degradation did not yet reach the extreme limits, a postabdomen somewhat longer than in the specimens which in the further generations live at a higher concentration, lacking the furca already, as is especially noticed in the *summer generations*. The length and slenderness of the postabdomen prove in any case, especially in our specimens with the characters of *A. milh.*, the dependence of the organization of these specimens upon the immediate influence of the surrounding, dependent upon the retarded development and sexual maturity appears earlier than the full development of body-parts, since on the whole the postabdomen of these forms is longer and slenderer than in the young, and also even in the mature forms of *Art. salina*.

Contrarily the gill-sacs also prove the retarded development of *A. milhausenii* if they are also in their development simultaneously adapted to the demands of the surroundings. That is, in young specimens of *A. salina* exists a period in which their gill-sacs have nearly the same form as in the mature individuals with the characters of *A. milhausenii*. Likewise the gill-sacs are in the mature individuals with the characters of *Art. milh.* larger than in mature individuals of *A. salina*, especially in relation to width and in the comparison with the length of the body in these or those individuals.

But the young individuals of *A. salina* now have larger gill-sacs than the full-grown ones, there being a period in their development in which the gill-sacs are in length and width so in proportion, as is the case in mature specimens with the characters of *A. milhausenii*. This apparently points to the exclusive dependence of the gill-sacs upon retarded development of the form in the latter specimens, but this only seems to be so. If we domesticate generations of *A. salina* in gradually diluted salt water this period appears, during which the gill-sacs of the young Artemia have the measure of the gill-sacs of the mature specimens with the characters of *A. milhausenii*, *always earlier*, *i. e.*, it approaches the beginning of development; in the domestication of these generations in an opposite direction, this period always appears later; *i. e.*, it ap-

[1] H. Rathke, Beiträg. zur Fauna der Krim. pp. 395 to 401.

proaches the end of the development, so that the young specimens of one and the same age, but, from a different element, do not correspond in this relation, and the younger age of the former concurs with the later age of the latter. Since the whole development of these or those specimens proceeds similarly, so must the development itself depend upon the immediate influence of the surroundings, after which the organism of these or those forms develops, whereby that in the generations sums up what the external conditions in them produces; and what they as a consequence of the influence of the surroundings acquire. Here we must imagine the transfer of the course of development of a single individual upon the course of development of particular animal forms. From all this it results that the gill-sacs of the *young* individuals of *A. salina* are in a certain age *similar* to the gill-sacs of the *mature* individuals of *A. milhausenii*, but the gill-sacs of the young individuals of *this latter species* are at the same period *still larger*, and obviously represent an *addition* in the organization of this form in comparison with *A. salina*, and a result of the influence of some force. This force was the surrounding element of a certain composition, that is, the large salt capacity of the water alone, or in combination with heightened temperature. Hence, we see that the gill-sacs in *A. milhausenii*, together with some other parts of the body, testify to the retrograde development of this form under the influence of the surroundings as well as of the immediate influence of this element. It is worthy of remark that the fact that the adaptation to the element is accompanied by a retarded development of the generations, as in other cases the adaptation to the element in these animals is accompanied by a progressive development of the generations; in another element by the, as regards this species, typical development of the body parts and sexual maturity. In the one and the other case the element effectuates a change of form in a direct and indirect manner. Of course, nature effects this in a great measure, not so much by the change of the element as by distributing generations of a species in a highly varied element.

Touching now the question, whether the specimens with the characters of *A. milhausenii*, which in the course of several years and a comparatively small number of generations issued from *A. salina* in the Kujalnitzki Lake, at a gradual heightening of the salt capacity, do represent a species, or at least a variety, I must answer in the negative. If it turns out that the actual *Artemia milhausenii* of the authors, according to its structure and origin, is equal to the degraded specimens of *A. salina*, then it has no right to be regarded as a species proper, yea, not even to be a variety of *A. salina*, or of any other species, since the manner of its origin under the mentioned conditions contradicts the prevailing conception of species and race. Species and race possess a comparatively great endurance of characters, and must originate in consequence of more or less widely spread distribution of generations of their preceding or contemporary forms in a differentiated element (without natural selection or with it), but not owing to the modification of the surrounding element in a given locality, and moreover in a brief space of time, in the course of perhaps four years.[1]

Even if the change of the element at a certain rate of slowness can favor the change of form, the main cause of their origin must, neverthe-

[1] The lowest organisms appear, by certain changes of the surroundings, in an inconsiderable space of time to represent definite series of forms, which we are accustomed to hold as species. The beginning of my papers in this direction relative to the lowest organisms, forms my article in the "Schriften" of the Neorussian Society of Naturalists, 1876, vol. iv.

less, lie in the disposition of the generations to distribute themselves in much varied elements, that is, to distribute themselves beyond the limits of that element, at which, in the generations, the typical characters of the species preserve, regardless as to the causation of such distribution, by increased augmentation of the individuals, or of such external influences, like modification of the element in a given locality. Our individuals with the characters of *A. milhausenii* actually represent the *degraded and modified generations* of *A. salina*, by the itself rapidly changing element which also influences the Artemiæ living in it. Similarly, like certain annual species, which with their generations are much distributed, according to the seasons of the year, represent rather great differences in spring and summer forms. As the most extreme generations of the seasonably distributed species deviate from their species-type toward the nearest allied forms, as is seen, for instance, in *Cyclops brevicaudatus* Claus, and *Daphnia magna*, Leydig, var.,[1] so likewise deviates *Artemia salina* with its generations at the most extreme limits of endurable concentration of the salt water toward the forms allied to them. But there is a great difference between these phenomena. *Artemia salina* changes during the course of several years in the direction toward *A. milhausenii*, passing through a comparatively large series of generations, and whereby we, in comparison, finally obtain a far greater modification than any hitherto known deviation in the generations distributed seasonally. If there actually exists in nature a self-sustaining species, *A. milhausenii*, like an *A. koeppeniana* Fischer, besides the degraded generations of *A. salina* and similar forms, then such degraded generations of the highest species of Artemiæ represent transitory forms toward the lower species of this genus, and indicate the element under whose influence the latter originated. This element must be a salt water of great concentration, together with heightened temperature. It is possible that in long-continued duration of the salt-lake element peculiar to the lowest Artemiæ, the degraded generations of the higher species of this genus still more degenerate, rendering their characters more permanent, but the forms themselves more independent, even if the *principal condition* of the origin of independent forms consists in the distribution of generations of these forms producing species in a heterogeneous element, but not (or less) in the modifications of the element of a known district or of a certain water-basin. It seems to me that, with a very gradual increase of the concentration of the salt lake, the species populating it will rather die off in this location, than producing a *new self, sustaining* itself with the element modifying species.

In view of such phenomena a strict scrutiny of such lowest Artemiæ as *A. milhausenii* is unconditionally necessary; all the more, since these species were described by the authors for the greater part from alcoholic specimens, and moreover at a time in which the modifying effect of the salt water upon the Artemiæ was yet entirely unknown.

To solve the question, whether *A. milhausenii* exists as a self-sustaining species, I visited during the middle of July, 1876, the Krimea and examined specimens of Artemiæ from that salt lake, which is located near the Tatare village Sakki on the way between Eupatoria (Koslov) and Simpherpolis, from which the authors (Fisher von Waldheim, H. Rathke, S. Fischer), who described the *Artemia milhausenii* obtained their Artemiæ. I saw that in this lake occurred already at the self-deposition of salt specimens fully answering the descriptions of *Artemia*

[1] Consult my paper in the "Schriften" of the Neoruss. Soc. of Naturalists. 1875. Vol. iii., Pp. 18 to 44 and 206 to 214.

milhausenii of the authors (exclusive of their mistakes), and likewise occurred in it at the same time specimens of the transitory form toward *A. salina* Milne-Edw., whose specimens here were in various degrees of degeneration in the direction of *Artemia milhausenii.* They were all such specimens as those found by me at the end of summer, 1873, and middle of summer, 1874, in the Kujalnitzki Lake, near Odessa, that is to say, partly complete, partly not fully changed, specimens in form, known under the name of *Artemia milhausenii.* The circumstance that in the very saline Sakki Lake, there still occurred also in the middle of July many specimens of the transitional form between *A. salina* and *A. milhausenii,* is explained by the fact that the preceding winter in the Krimea was very snowy, that the water in the salt lake in spring became very diluted, and that the specimens and generations of *Artemia salina* had to change rapidly in one summer, therefore many specimens did not succeed in fully transforming in this one summer. (Only at very gradual increase of the concentration of the salt water have the following generations of *Artemia salina* in all their specimens the form of *Artemia milhausenii,* as observed by me in the course of several years in the Kujalnitzki salt lake near Odessa.) After several days of great drought and increase in the amount of the deposited salt in the Sakki Lake, I could not find a single individual of Artemia. I have to state that the specimens of Artemia in this lake belong to those two races of *Artemia salina,* which live in the neighborhood of Odessa in the Kujalnitzki salt lake. The smaller individuals of this much distributed species answer to *Artemia salina,* changed in the known manner, but the larger individuals answer to variety *a.* of *Artemia salina* changed in the same direction.

It would here be important to know what is really wanting in the degraded generations of *Artemia salina,* in order to possess all the characters of *Artemia milhausenii* Autorum.

Contrary to the diagnosis of this species (*A. milhausenii* of Milne-Edwards), we in our generations notice but the one difference, that on the female claspers of our individuals toward the middle is found a small protuberance or broadening, Milne-Edwards not mentioning this (of course in the females, as the males were yet unknown at that time). These words of Milne-Edwards do not correspond with Rathke's statements, who described this species under the name of his *Artemia salina.* We see from Rathke's drawing and description that the second antennæ of the female of this species has two broadenings divided by a transverse ring, which the author regards as the two first joints, whereby a broadening occurs near the base, another one in the middle of the antenna, which answers the same as similar broadenings in our female specimens with the characters of this species. In comparing *Artemia milhausenii* with *A. salina* we must observe that in Milne-Edwards's diagnoses (Histoire naturelle des crustacées, Vol. III) the second antennæ of the *males* of *A. salina,* and the second antennæ of the *females* of *A. milhausenii,* of which latter the males were yet unknown, have been described, as already stated above. For these determinations in both diagnoses (cornes céphaliques) Milne-Edwards omitted to give the necessary explanation.

Opposed to this the description of Rathke gives the following difference: He says that in this species the upper antennæ are four-jointed, which is very doubtful, since in the forms of this genus and in Branchipus the upper antennæ are not jointed, but we only observe after a number of subsections similar to faint transverse rings, which should not be

[1] Midderdorf's Sibirische Reise, Vol. II, part i, pp. 155 to 156.

taken for articulations. Furthermore, according to Rathke, this species has, besides the upper lip, no other oral parts, while S. Fischer,[1] in completing the description of this species, describes beside the upper lips, also other oral parts (upper and lower jaws), which differ in nothing from the same parts in other Artemiæ. In our specimens with the characters of *A. milhausenii*, these parts fully correspond with the description given by S. Fischer. Such a great contradiction between the authors awakes a doubt whether they had to do with the same forms, thus rendering the determination of this species difficult. Likewise Rathke does not mention in this species the existence of the posterior branchial lobes, while he dwells at length upon the gill-sacs, as if the former were not existing at all. But in reality Rathke probably did not see them at all on account of their transparency. These branchial lobes exist in our specimens (and those from the Krimea) with the characters of *Artemia milhausenii*, and S. Fischer gives an illustration of them with his description of *Artemia köppeniana*. On the contrary, in Rathke's description there is yet a difference in the length of the abdomen. In our individuals with the characters of *Artemia milhausenii*, the posterior part of the body, consisting of apodous segments, is longer than the whole anterior part, being to it in proportion at least as eight to five; but in the specimen described by Rathke the posterior part of the body is shorter than the anterior. However, we can with certainty say of Rathke's description, what length the posterior part of the body had in the specimens described by him. From his words it is to be assumed that Rathke calls the whole posterior part of these animals (without the first two apodous segments of the abdomen?) a tail. The comparative length of this tail he compares with the tail (postabdomen) of the scorpions, and shows by the illustration that the posterior part of the body is nearly $\frac{1}{7}$ shorter than the anterior part, while in the stated measurements he has such figures as surprise me by their disproportion, and according to which the tail would be two and a half times shorter than the anterior part of the body. The latter can only be called a misprint; it remains unknown, however, how the omission of oral parts (excepting the upper lips) and the posterior branchial lobes can be explained in Rathke's descriptions. If the degradation of this form had proceeded so far, that with them these parts were not developed at all, it would have been different from the form examined and more completely described by S. Fischer. S. Fischer, however, calls the tail of the form examined by him, long, which expression[1] H. Rathke does not use, but the termination of the postabdomen, according to Fischer's drawings, differs from the termination of this part in Rathke's drawing, not showing any broadening. It is possible that Rathke and Fischer had different forms in possession, whereby Rathke's form is identical with the very degraded generations of *Artemia salina*, or corresponds with them, while Fischer's form is a degraded form of the larger variety *a.* of *Artemia salina.*

Finally, on the other hand, Grube's[2] diagnosis of this species differs from our generations with the characters of *Artemia milhausenii*, in having on the terminal lobe (lobus tarsalis Grb.) not about 17, but about 25, marginal bristles; it is possible that here Grube borrowed the number of bristles from Rathke's drawing, who drew on his small illustration about such a number of bristles, only saying in the description

[1] Milne-Edwards calls in his diagnosis the postabdomen of *Artemia milhausenii* also long, but does not take this expression in his diagnosis of *Artemia salina*.

[2] "Bemerkungen über die Phyllopoden" in Archiv für Naturgesch. 1853, p. 145. He correctly remarks, amongst other things, that Rathke could not have observed the very tender and transparent posterior branchial lobes in so old alcoholic specimens.

that there were many bristles. On Rathke's drawing are 18 such bristles, and even if there had not been more this makes no great difference, especially in view of the fact that the specimens obtained by Rathke, from a salt lake in comparison with ours, could have been more degraded. I must here add that in our *Artemia salina* there are some thirty bristles on the terminal lobe of the leg (?); in variety *a.* of *Artemia salina* there are some thirty-three marginal bristles. Had we not had in the Kujalniker Lake in 1874 a second inundation, the generations with the characters of *Art. milhausenii* would certainly have proved more degraded in relation to this, as there stronger concentrated salt water would have remained in the lake.

I therefore cannot, without excluding the possibilty of the existence of a self-sustaining species of *Artemia milhausenii*, regard the degraded generations of *Artemia salina* obtained as a species proper, and even not then, if such degraded generations exhibited all the characters of *Artemia milhausenii:* the characters of *A. milh.* at a certain modification of the element in the course of several years or also by domestication of several successive generations of *Artemia salina* in a correspondingly changed element.

After all I hope nobody will think that I endeavor, with the aid of modifying the element in the domestication of animals, to produce from one species one or more new species. Everywhere I have sought to obtain the intermediate transitional forms between the nearest-allied species, and I approached myself in a moderate degree the characters of the actual species, but we cannot regard such forms as independent ones which have by domestication received characters of unknown constancy (in nature), and which we obtain by changing the element during domestication of several generations. It is possible that in earlier times and even also at present in different other localities, as species and ancestors of our present species such middle transitional forms among the closest allied forms live; nevertheless these forms, resulting from domestication, will neither represent independent species nor varieties, as incipient species, but they only show *the way* in which the characters of a given species combined and which way man, with his zoological experiments, especially with the present means of science, cannot fully follow. Should we succeed in producing, with the aid of domestication, a form possessing all the characters of a species existing in a state of nature, then this form will differ from the real in nearly the same way as the best picture will differ from the original. This would be like making concessions to the present conception of species. Owing to the stated facts it seems to me that our present species can be artifically produced by man, only this does not happen with the aid of artificial domestication, but by adaptation of physico-chemical factors. We should never forget that in nature the characters of a species have a relative stability.

3.—*The characters of the genera Artemia and Branchipus.*

The characteristics of the genera *Artemia* and *Branchipus* are demonstrated by many authors, owing to an insufficient knowledge of the characters of the genus Artemia, in a confused and even wrong manner. Already in 1853 had Grube made[1] his protest against the stability of the genus Artemia, seeing that Artemia differs only from Branchipus by quasi-negative characters; he also saw the necessity of forming

[1] Grube, Bemerk. über die Phyllopoden in Arch. f. Nat. 1853, pp. 132 to 134.

from Artemia a proper group or a subgenus of the genus Branchipus, like Branchipus proper and Polyartemia. Dr. Grube, nevertheless, gave in reference to the then known facts of Artemia a mistaken characteristic of his subgenus *Artemia*, saying, amongst other things, that it possessed six apodous segments and that the short furca was only bristled at the ends (appendicibus caudalibus brevibus, *apice tantum setosis* . . . .). Relative to the number of apodous segments of the abdomen, Grube repeated the statement of those authors (Joly) who in Artemia did not take into consideration the first two apodous segments of the abdomen, bearing the external sexual parts. Without these two first apodous segments of the abdomen Artemia has really six apodous abdominal segments, but since the external sexual organs answer morphologically to modified limbs, we only in this sense can count in Artemia six segments of the abdomen; like Branchipus in this case it would have but seven and not nine segments. But Grube in this sense does not count six apodous segments in Artemia, as he demonstrates nine apodous segments for his subgenus Branchipus, and we can see from the general diagnosis of the genus Branchipus (l. c., p. 136), that those segments, bearing the external genitals, were taken in with the apodous segments of the abdomen of *his* genus *Branchipus*, *i. e.*, inclusive of *Artemia* and *Polyartemia*. But, in fact (as mentioned above in the completed description of *Artemia salina*) the species of *Artemia* have eight apodous abdominal segments, the first two of which bearing the external genitals, and of which the last is nearly twice as long as the preceding and is homologous with the two last apodous segments of the species *Branchipus*, but the *Branchipodæ* have nine apodous abdominal segments, of which the first two also bear the genitals, and of which the last, located before the furca, is not longer, but usually shorter than the preceding.[1]

In regard to the position of the furcal bristles in *Artemiæ* I have already stated above that in our forms of *Artemia* the bristles are not only at the end but also often on the margins of the furca, and that these bristles often occur also in great numbers, the furca assuming, as in variety *b.* of *Artemia salina*, a plate form.

If we ask now whether all species of Branchipus really possess nine apodous segments, of which the two last ones are homologous with the prolonged last segment of *Artemia*, then it seems indeed to be the case. Only *Branchipus stagnalis* could form an exception. At least from the statements of the authors[2] the number of apodous abdominal segments (whether eight or nine) cannot be inferred with certainty, and I myself had not hitherto occasion to examine *Branchipus stagnalis*.

Concerning the question whether all the species of the genus Artemia have eight apodous abdominal segments, and whether in all the last segment is prolonged and homologous with the last two abdominal

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[1] In my paper in Zeitschrift f. w. Zool., vol. xxv, supplement part, appearing under the title "Ueber das Verhältniss der Artemia salina M. Edw. zu Art. milhausenii M. Edw. und dem genus Branchipus," I must add a correction relative to the proportional length of the last abdominal segments in Branchipus. There it says: "Branchipus has nine last apodous segments, of which the two neighboring segments show only a small difference in length among themselves" (l. cit., pp. 106 and 110). I ought to have said: "Branchipus has nine apodous abdominal segments, of which the last, situated before the furca, is not longer but usually shorter than the preceding segment."

[2] Leidig, "Ueber Art. salina und Branch. stagnalis." Zeit. für w. Zool. 1851, p. 281. Spangenberg, "Zur Kenntniss von Branch. stagnalis" in Zeit. f. wiss. Zool. 1876, pp. 8 to 9. Supplement part. Claus, "Zur Kenntniss des Baues und der Entwicklung von Branch. stagnalis und Apus cancrif." Göettingen, 1873, p. 14, Tab. V, fig. 10.

segments of Branchipus; of this no indications occur in literature. That *Artemia salina* observed by Joly has eight apodous abdominal segments with a very prolonged last segment can be seen from Joly's illustrations, and also from this, that he counts six apodous abdominal segments without including the two first apodous abdominal segments which bear the external sexual organs. According to Rathke, who observed alcoholic specimens of *Artemia milhausenii* (*Art. salina* Rathke), the postabdomen is indistinctly divided into segments; he did not indicate how many segments there are. Our degraded generations of *Artemia salina* with the character of *Artemia milhausenii* have just as many apodous abdominal segments as *Artemia salina*, only the articulation is more distinct. In the description of *Artemia arietina* S. Fischer and *Artemia köppeniana* S. Fischer nothing was said about the number of apodous abdominal segments. Grube very incorrectly states the number of apodous segments in Artemia as being six, incorrect, for because right after in another diagnosis he correctly mentions in *his* subgenus Branchipus nine apodous segments, thus showing which segments of the abdomen he considers as apodous. Joly gave occasion for this conclusion in omitting the two first apodous segments of the abdomen, which in *Artemia*, as well as in *Branchipus*, bear the external sexual organs. In the other mostly examined alcoholic specimens of *Artemia*, the articulation is not very plain to see. In this regard *Branchipus oudneyi* Lievin (*Artemia oudneyi* Baird's) deserves attention, under which name an Artemia from a salt lake in Africa was described by Dr. Lievin.[1] This African form has in the illustrations eight apodous abdominal segments, of which the first only bears the external genitals, the last being short, at least shorter than the preceding. Although this form, as in *Artemia*, has eight apodous abdominal segments, it can nevertheless *in this proportion* be included neither with the genus *Artemia* nor with the genus *Branchipus*. But the illustration now does not correspond at all with the description of the posterior part of the body of this Artemia. It is said in the description[2] that the specimens examined had laid a long time in alcohol, and that therefore the number of abdominal segments could not exactly be determined; that the abdomen of some specimens answered as if to one segment only, while in others four could be distinguished, again, in others five segments; but from the fifth in the others they could not be distinctly seen. Dr. Lievin considers the presence of eight abdominal segments as probable. Here the author understands as abdomen only the whole of the apodous abdominal segments. Accordingly, the number of apodous abdominal segments of this Artemia-form, and also their proportion to each other, is considered as unknown.

It appears to me that with the absence of certain characters in *Artemia* for distinction from *Branchipus*, we must assume eight apodous abdominal segments. Of these the first two bear the external genitals, but the last, terminating with a furca, is nearly twice as long as the preceding, and is homologous with the two last apodous abdominal segments in *Branchipus*. The latter possess at the end of the abdomen, besides these segments, also abdominal appendages, mostly separated from the last segment by an articulation. In *Artemia* the last abdominal segment is only somewhat shorter than the double length of the penultimate segment, sometimes even a little longer. Here I have to remark that in young, though fully developed specimens, the relative length of this segment is more considerable than in old ones, as the

[1] Lievin, "Branchipus oudneyi, the Tezzanworm," in "Feneste Schriften der Naturforschanden Geselesch. zu Danzig." Vol. V.

[2] Loc. cit., pp. 8 to 9.

preceding segments in old specimens are more prolonged than in young ones. With the furca is the last abdominal segment usually a little longer than the double length of the penultimate segment, however sometimes also a little shorter, which probably depends upon the age as well as upon the surroundings. I have yet to add that the longer the abdominal furca in the form *Artemia* is, the shorter appears the last abdominal segment; it is as if the furca develops on account of this segment, especially on account of the second half behind the sensory bristles (which are nearly in the middle of its length). This answers the circumstance, that in the species *Branchipus*, with usually great length of the abdominal appendages, the last abdominal segment is considerably shortened, as the abdominal segment, which corresponds to that part of the last abdominal segment in *Artemia*, which part is behind the last sensory bristles, *i. e.*, behind that part where *Artemia* lacks the articulation, which exists in *Branchipus* (excepting *Branchipus stagnalis?*).

Regarding the circumstance that the last apodous abdominal segment of *Artemia* is homologous with the two last, *i. e.*, the 8th and 9th apodous segments of *Branchipus*, we must firstly realize the disposition of the sensory bristles on the abdomen of the species *Artemia* and *Branchipus*, and secondly the origin of the articulation in the middle of the last prolonged segment of *Artemia*, immediately behind the sensory bristles, in the domestication of the entire generations of these animals in continually diluted salt water. On each apodous abdominal segment of the *Branchipidæ* the sensory bristles are at the end of the segment before the articulation; the last segment makes an exception, which has no sensory bristles before the abdominal appendages. The *Artemiæ* show an equal disposition of sensory bristles on the postabdomen, with the sole exception that such bristles are also on the last (eighth apodous) prolonged segment, about in the middle or above it. As into the sensory bristles, located about in the middle of the last prolonged (eighth apodous) segment in *Artemia*, enter likewise nerve-branches, as is the case with those at the end of the preceding segments, and the sensory bristles at the end of the segment in *Branchipus* (therefore also into those at the end of the penultimate segment), it follows that *the first half of the last segment* (eighth apodous) *in Artemia corresponds with the whole penultimate* (eighth apodus) *segment of Branchipus*, while the second half of this segment (eighth apodous) in *Artemia* is homologous with the last (ninth apodous) segment in *Branchipus*. As I do not write a monograph of a species, and as for me only the disposition of the sensory bristles was of importance, I cannot give the number of bristles on each apodous abdominal segment. Sometimes I found only two bristles on the segments, sometimes four, circularly distributed around the segment). I only know that these sensory bristles also exist at the end of the two first apodous segments opposite the external sexual organs, and also at the end of the last limb-bearing segment, likewise also on the other segments of this body-part. Spangenberg found in *Branchipus stagnalis*[1] sensory bristles by twos on the abdominal segments, and only on the eighteenth, being the seventh apodous segment, he found four bristles. It is without doubt, that in *Branchipus stagnalis*, in case it has only eight apodous segments, the sensory bristles are not at the end of the eighth apodous segment, but before the faint articulation of this segment, which is figured by Claus,[2] or if *Branchipus stagnalis* should, like the other species possess nine segments on the end of the eighth segment.

[1] Zeitschr. f. wiss. Zool., vol. xxv, supplem. p. 28.
[2] Loc. cit., Plate V, fig. 16.

This location corresponds to that, where in *Artemia* on the long segment an articulation is formed, if we domesticate entire generations in gradually diluted salt water (especially at not too high temperature), and also to that location where in the *Branchipidæ* this articulation exists between the eighth and ninth apodous segment. It would look too forced, on account of a single character, to include the one assemblage in the genus *Artemia*, the other in the genus *Branchipus*. By this rather unnatural systematic treatment *Branchipus stagnalis* would come into the genus *Artemia*, though this species according to its characters, with the exception of the eighth apodous segment, belongs to the genus *Branchipus*. I note that in regard to apodous segments *Branch. stagnalis* has not the full characters of *Artemia*, as with it the last (eighth) apodous segment is not so long as compared with the preceding, as in *Artemia*. There are other structures, according to which the species of *Branchipus* can be distinguished from *Artemia*. Such a character is that in the males of *Artemia* the claspers toward the end, that is, in the second half (last joint) become broader, so that the second half is tabulate, which does not occur in *Branchipus*, since their male claspers are not tabulate; moreover, their first half is broader and thicker than the second.[1]

The circumstance that there are often certain appendages on the claspers or on the front of various *Branchipidæ*, and that the furca generally is tabulate and better developed, can be but partly regarded as a character of *Branchipus*. On the male claspers of *Artemia*, we see also certain appendages in the shape of little tuberosities for holding the female; we even see whole groups of denticular spines, while in certain species of *Branchipus* (*Branchipus ferox* Grb. and *B. medius* mihi) no appendages at all occur on the claspers of the males. Although the branches of the furca in *Artemia* have mostly the shape of a stylet, or are conical in shape, there are, nevertheless, also *Artemiæ* with tabuliform branches of the abdominal furca, like the second variety of *Artemia salina* (var. *b.*), *Artemia salina* itself has even often a large development of the furca under the influence of certain external conditions. Otherwise, the furca of the above-mentioned *Branchipus medius* resembles this part in *Artemia*, only it is somewhat obliquely cut off or shoe-sole-shaped, curved.[2] Concerning the statement that the furca in *Artemia* was only terminally bristled, this is incorrect, as even in one and the same species the furca can be more or less developed, being bristled either terminally, or both terminally and laterally, according to conditions in life. But there is a physiological feature, which can be added to the characters distinguishing the species of *Artemia* from those of *Branchipus;* in the genus *Artemia* the phenomenon *parthenogenesis* is known to occur, which is unknown with *Branchipus*. After all this is a negative character for *Branchipus*, but is important together with other structures in *Artemia*. Consequently, according to my view, the distinguishing characters of the genera *Artemia* and *Branchipus* are the following:

Genus Artemia.

Eight apodous abdominal segments, of which the first two bear the external sexual organs, but the last about twice as long as the preceding, being homologous to the last two abdominal segments, the apodous eighth and ninth, in Branchipus. The segments of the abdomen have a considerable

[1] In some species of *Branchipus*, like *B. rubricaudatus Klunzinger*, the male claspers are divided at the end into several branches.

[2] Consult my paper in the "Schriften" of the third meeting of Russ. Naturalists at Kiow, 1871, Zoological section, Plate III, figs. 1 to 3 and 5.

greater length than width. The antennæ of the second pair (claspers) are more or less broadened in the males, and have principally on their second interiorly directed part a flattened form. These antennæ are either without appendages, or only with a few little developed appendages, in the form of rounded or knob-like protuberances on the interior margin of their anterior, outwardly directed, or finally with small appendages in the shape of denticular spines near their base. For the most represents the little developed, terminally and often laterally, bristled abdominal furca, a simple prolongation of the last segment of the abdomen; the furcal branches are conical or stylet-shaped, seldom tabulate. Parthenogenesis is known to occur in this genus.

Genus BRANCHIPUS.

Nine apodous abdominal segments (Branch. stagnalis excluded?), of which the first two bear the external sexual organs, the last segment located before the furca being not larger, but mostly smaller than its preceding. The antennæ of the second pair (claspers) in the males have their first joint stout, often with much developed appendages on their sides or at their base, in the shape of digitate processes or denticular tuberosities, the second part being more slender and narrower than the first; in the opposite case the antenna is terminally divided into several branches. The generally much developed, laterally and terminally, bristled furca has its branches nearly always of a tabulate form, which are separated from the last segment by an articulation. *Parthenogenesis* is unknown in this genus.

Eleven pair of legs are the common character for these two genera, distinguishing them from the genus *Polyartemia* Fischer, which has nineteen pair of legs and a lesser number of apodous segments of the abdomen.

ODESSA, *May* 5, 1877.

EXPLANATION OF PLATE I.

LIMNETIS MUCRONATUS Packard.

FIG. 1. The male, enlarged; the first antennæ unfortunately omitted by the artist.

FIG. 2. Second antenna of female, × ½ Tolles objective A eye-piece.

FIG. 3. Either the first or second foot of female; l^1, first endite or gnathobase; l^2–l^6, second to sixth endites; *br*, gill (gill-sack; *br′*, upper, *br″*, lower end of flabellum, × ½ A.

FIG. 4. One of the anterior feet of female, × ½ A.

FIG. 5. Hand or fourth endite of the first foot of male; *p*, palpiform appendage of the fourth endite; l^5, the fifth exopodite, and l^6, the sixth, modified to form a curved, finger-like, grasping spine; *comb*, the comb-like inner edge of fourth endite of the hand.

FIG. 5*a*. Branchia (*br*) of the same leg.

Fig. 6. Telson or end of the body of the female.

Fig. 1 drawn by J. H. Emerton; Figs. 2 to 6 drawn, and details filled in with camera lucida, by the author.

A. S. Packard and J. H. Emerton, del. T. Sinclair & Son, Lith.

EXPLANATION OF PLATE II.

Details of LIMNETIS GOULDII Baird. (For figure of the entire animal, female, see Fig. 1 in text.)

FIG. 1. First leg of female, × ½ A. Lettering as in Plate I. The lower branchial lobe (*br''*) very slender, and subjointed, as in the fifth and sixth endites (l^5, l^6).
FIG. 2. First leg of male.
FIG. 3. Second antenna, × ½ A.
FIG. 4. First antenna, from the same specimen as Fig. 3.
FIG. 5. Eyes (double), with the optic nerves; the cornea and retina removed.
FIG. 5*a*. A portion of the optic nerve situated half-way between the brain and eye, magnified ⅙ B Tolles, to show the ganglion cells, constituting the greater portion of the optic nerves.
FIG. 6. Cornea, with the peripheral circle of crystalline cones, and the retina in the middle of one of the double compound eyes.

Drawn, with the details filled in with the camera lucida, by the author.

A. S. Packard del

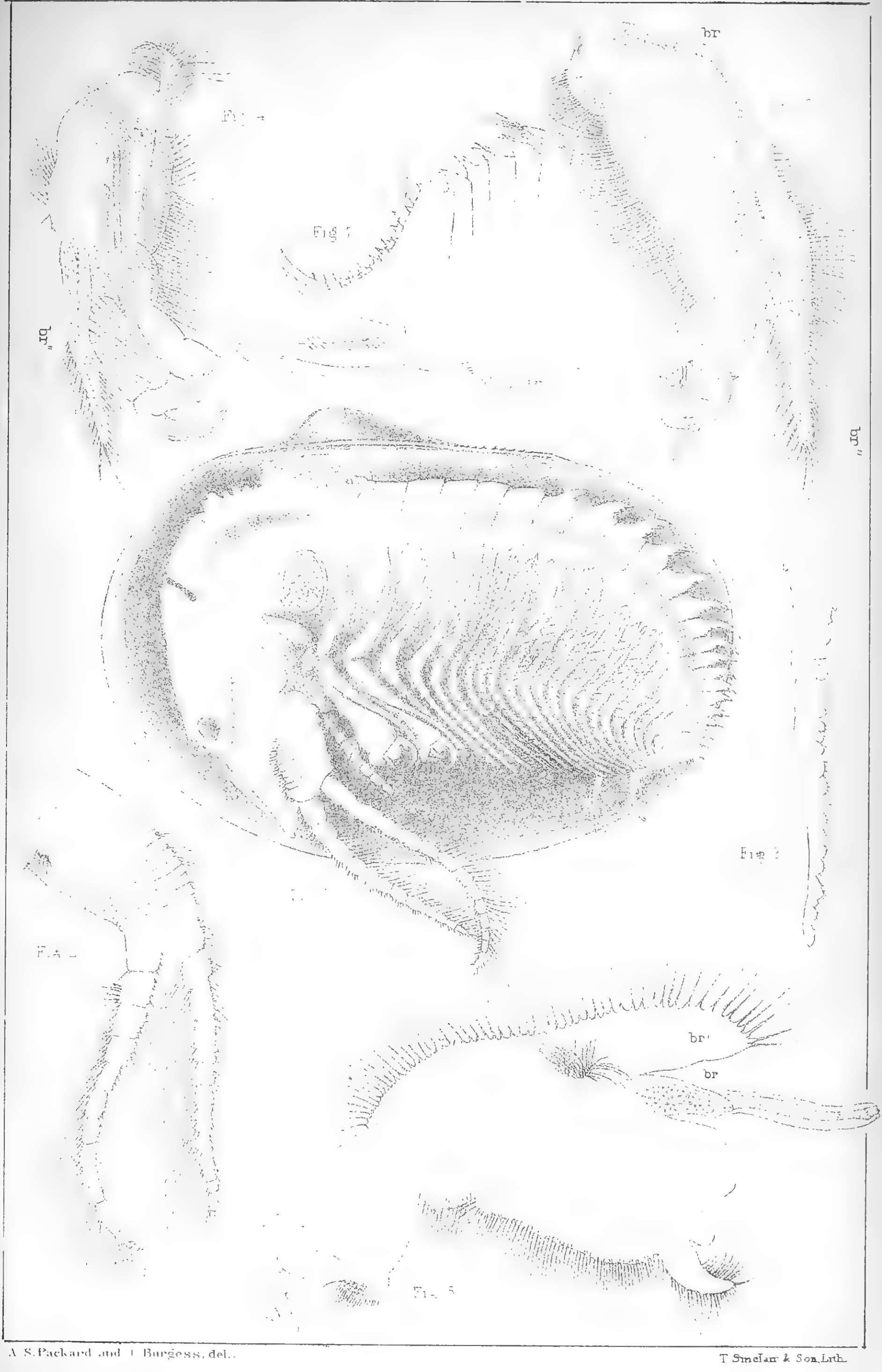
T. Sinclair & Son Lith.

EXPLANATION OF PLATE III.

ESTHERIA BELFRAGEI Packard, and details, with details of E. JONESII Baird.

FIG. 1. The male of *E. belfragei*, much enlarged, in its shell.
FIG. 2. Second antenna of male of *E. belfragei*.
FIG. 3. First antenna of *Estheria jonesii*.
FIG. 4. First leg of male *E. belfragei*.
FIG. 5. First leg of male of *E. jonesii*. The process extending beyond the gill is probably a muscle.
FIG. 6. Second leg of male of *E. belfragei*.
FIG. 7. End of body, with telson, of *E. jonesii*.

Fig. 1 drawn by Mr. E. Burgess; details drawn, and filled in with the camera lucida, by the author.



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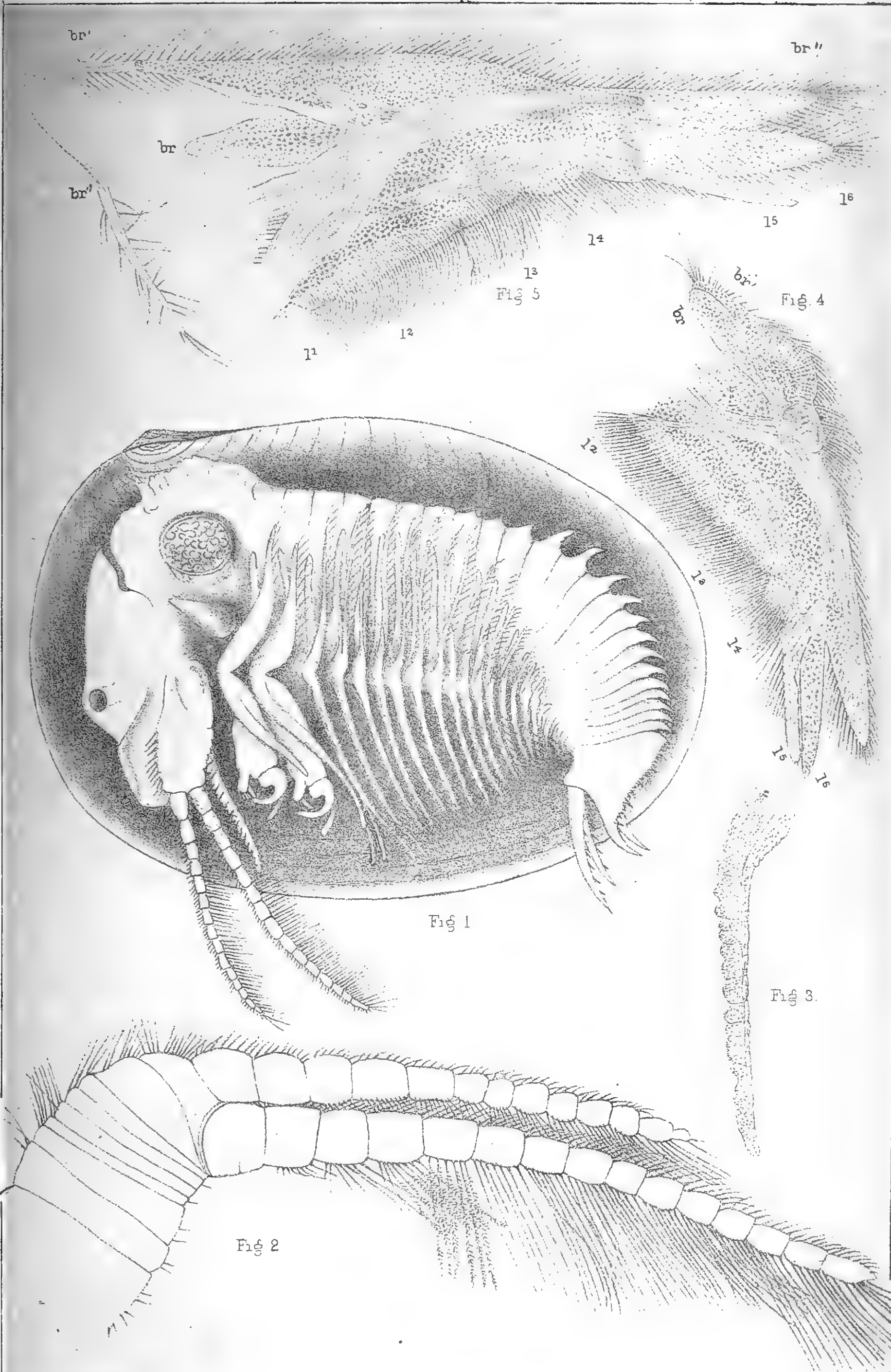
EXPLANATION OF PLATE IV.

ESTHERIA CALIFORNICA Packard, and details.

FIG. 1. The male, much enlarged.
FIG. 2. Second antenna of female, × about 30 diameters.
FIG. 3. First antenna of female, × about 30 diameters.
FIG. 4. First leg of female, × about 30 diameters.
FIG. 5. Leg of third pair of female; *br′*, the extremely long and slender upper branchial lobe forming the *oviger*.

Fig. 1 drawn by Mr. E. Burgess, the details by the author, with the camera lucida.



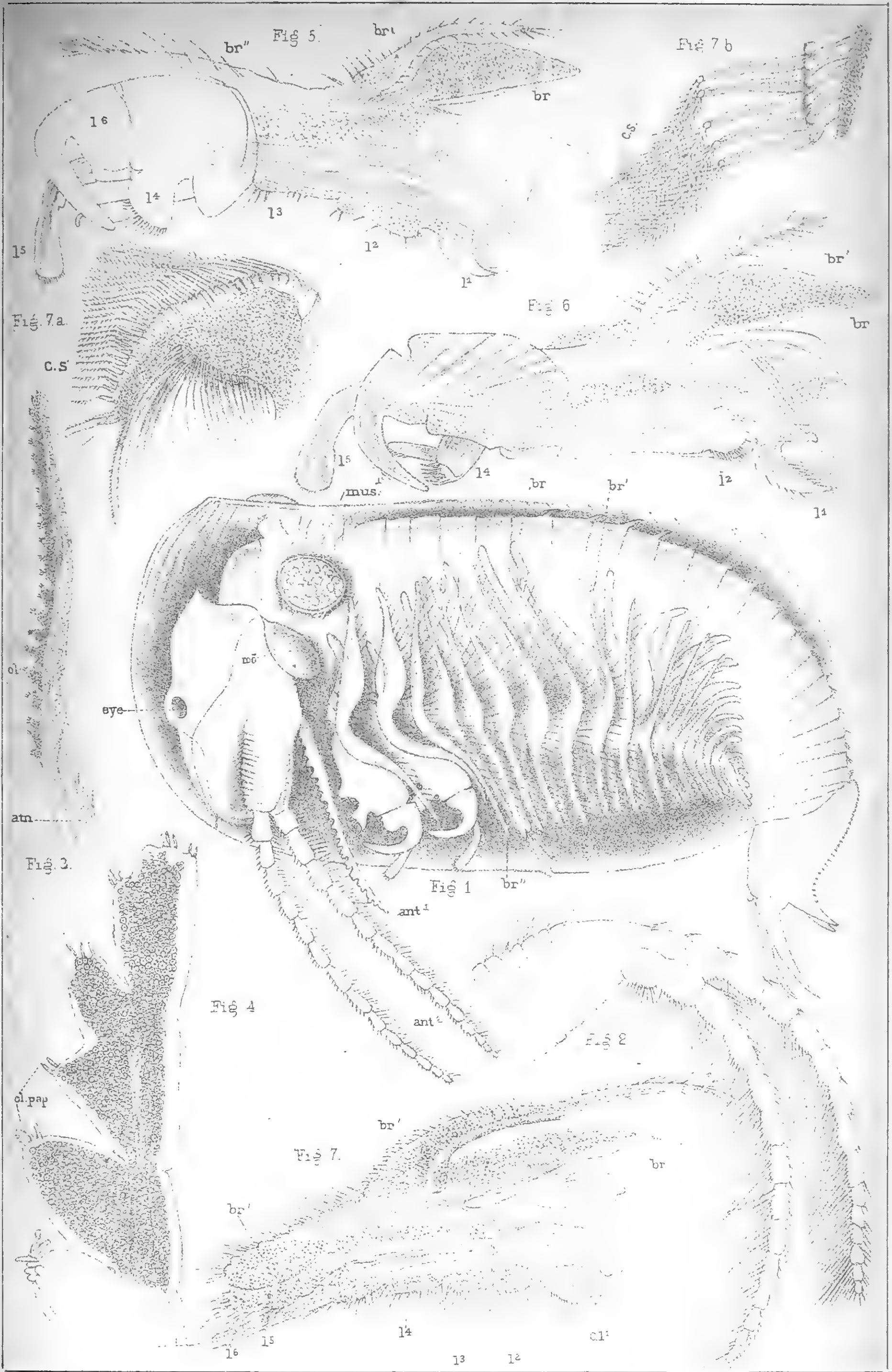
A. S. Packard and E. Burgess del. T. Sinclair & Son, Lith.

EXPLANATION OF PLATE V.

ESTHERIA COMPLEXIMANUS Pack., and details.

FIG. 1. Male; much enlarged, *ant*[1], 1st antennæ; *ant*[2], second antennæ; *md*, mandible; *mus*, adductor muscle; *br*, gill; *br'*, upper, and *br''*, lower end of flabellum.
FIG. 2. Second antenna of male.
FIG. 3. First antenna of male; *atn*, antennal nerve; *ol*, olfactory process.
FIG. 4. Five terminal joints of 1st male antenna, showing the terminal fibers of the antennal nerve imbedded in the sense-cells; *ol. pap*, olfactory papillæ.
FIG. 5. First leg of male.
FIG. 6. Second leg of male.
FIG. 7. One of the foremost legs of the female; br'', broad, flat lower end of flabellum, closely resembling in form the sixth endite (l^6).
FIG. 7*a*. First endite, or gnathobase of Fig. 7, forming the maxilla-like lobe situated on each side of the median ventral line of the body, just behind the mouth; *c s*, setæ, $\times \frac{1}{2}$ A.
FIG. 7*b*. Five setæ of the gnathobase still further enlarged, to show the muscular tissue (not nerves) entering base of the jointed setæ; the outer joint fringed.

Fig. 1 drawn by Mr. E. Burgess; the others by the author, with the camera lucida.



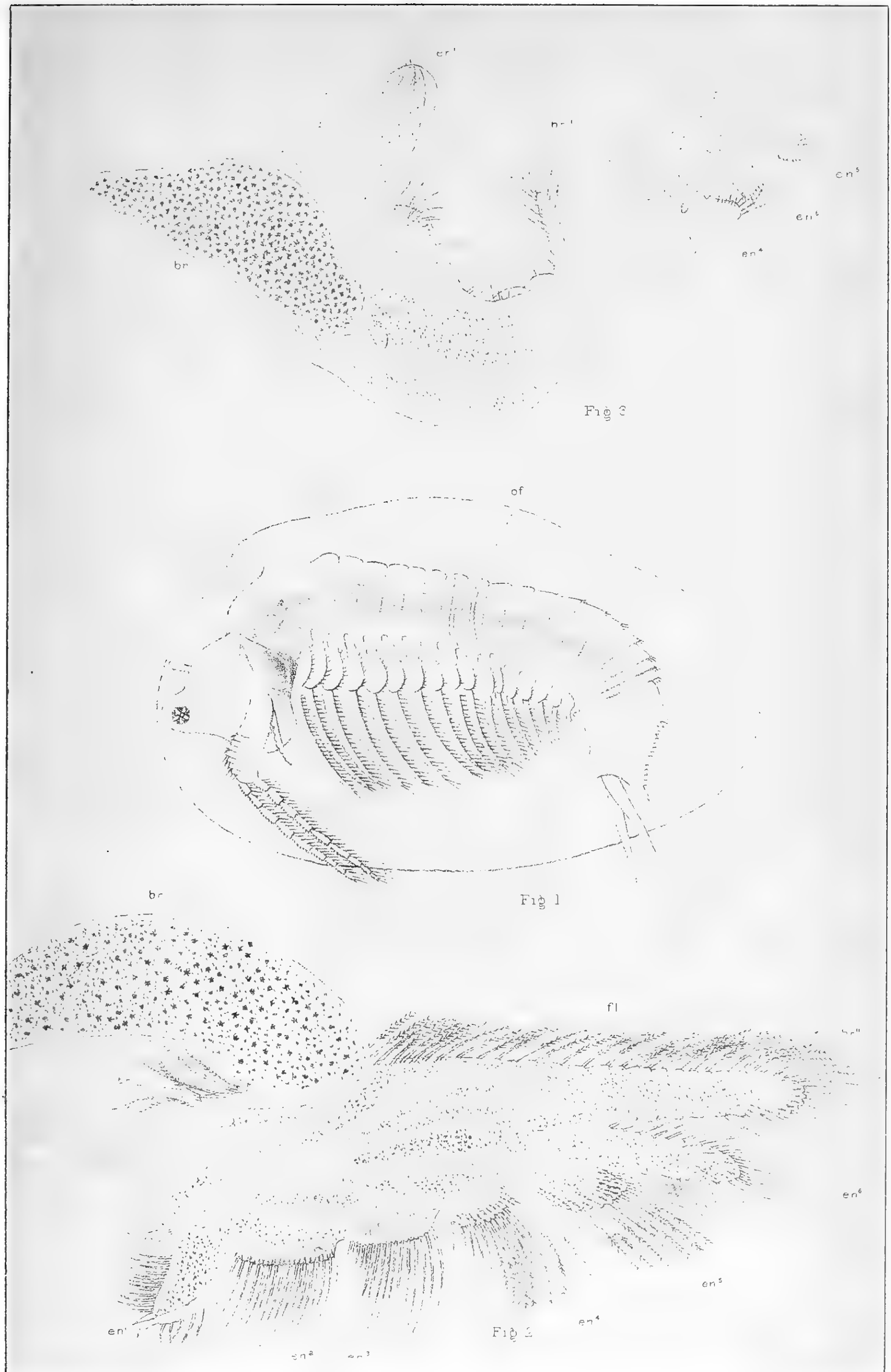
A. S. Packard and E. Burgess del.

T. Sinclair & Son, Lith.

EXPLANATION OF PLATE VI.

EULIMNADIA TEXANA Pack.

FIG. 1. *Eulimnadia texana;* female, much enlarged.
FIG. 2. One of the first pair of feet; en^1–en^6, endites 1–6; *fl*, flabellum.
FIG. 3. Second foot of the male; (ex^4 should read en^4).
Fig. 1 was drawn by Mr. Burgess; the others by the author.

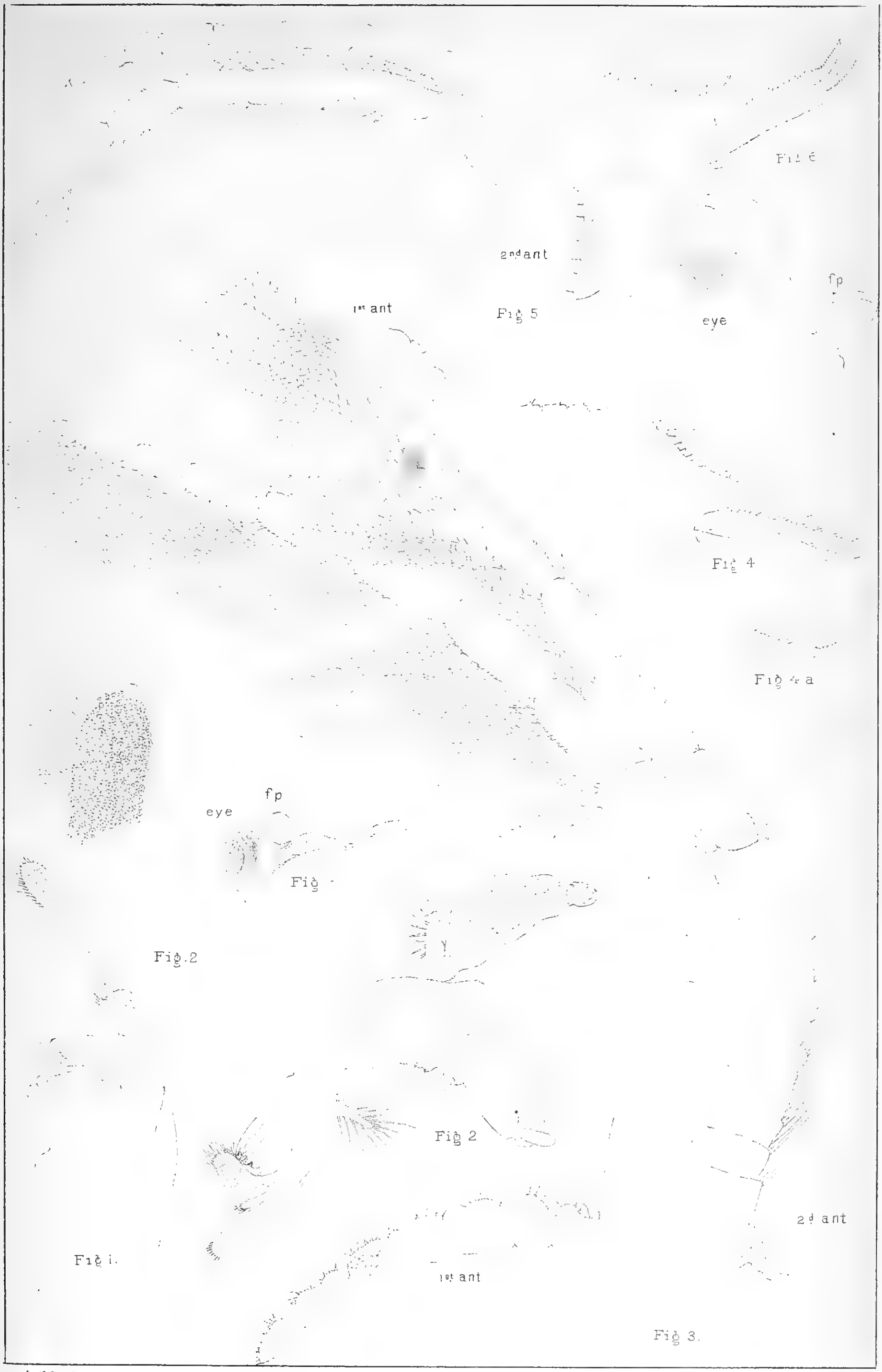


Burgess and Packard, del. T. Sinclair & Son lith.

EXPLANATION OF PLATE VII.

EULIMNADIA TEXANA and E. AGASSIZII.

FIG. 1. *Eulimnadia texana*, hand of second foot of male, enlarged.
FIG. 2. First foot of male.
FIG. 2*a*. Hand of extremity of fifth endite, much enlarged, showing the broad, flat setæ at tip, and the accumulation of sense-cells.
FIG. 3. Front of head, showing the eye and frontal process, or "haft organ."
FIG. 3 *bis*. First and second antennæ.
FIG. 4. Telson, 4*a*, end of caudal appendage, a little more enlarged.
FIG. 5. *Eulimnadia agassizii*, head, with frontal process (*fp*), eye, and first and second antennæ.
FIG. 6. *Eulimnadia agassizii*, telson.



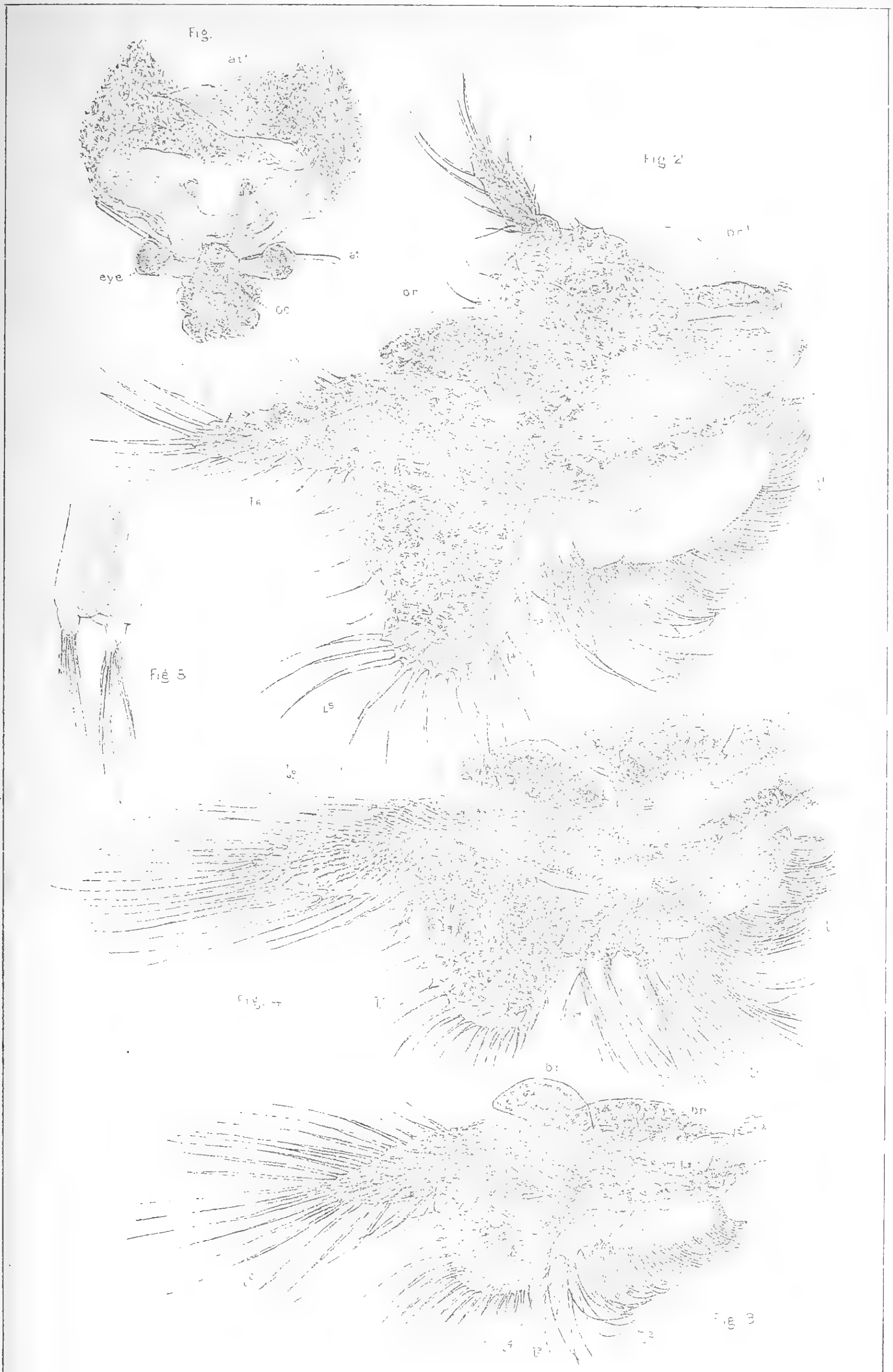
A. S. Packard, del. T. Sinclair & Son, lith. Phila.

EXPLANATION OF PLATE VIII.

ARTEMIA GRACILIS Verrill. (From Utah.)

FIG. 1. A dorsal view of male head and claspers; *oc*, ocellus; *at*, 1st antennæ; *at'*, 2d antennæ or claspers.
FIG. 2. An anterior leg.
FIG. 3. A middle leg.
FIG. 4. A last leg.
FIG. 5. End of abdomen.

Drawn and details filled in with camera lucida by the author.



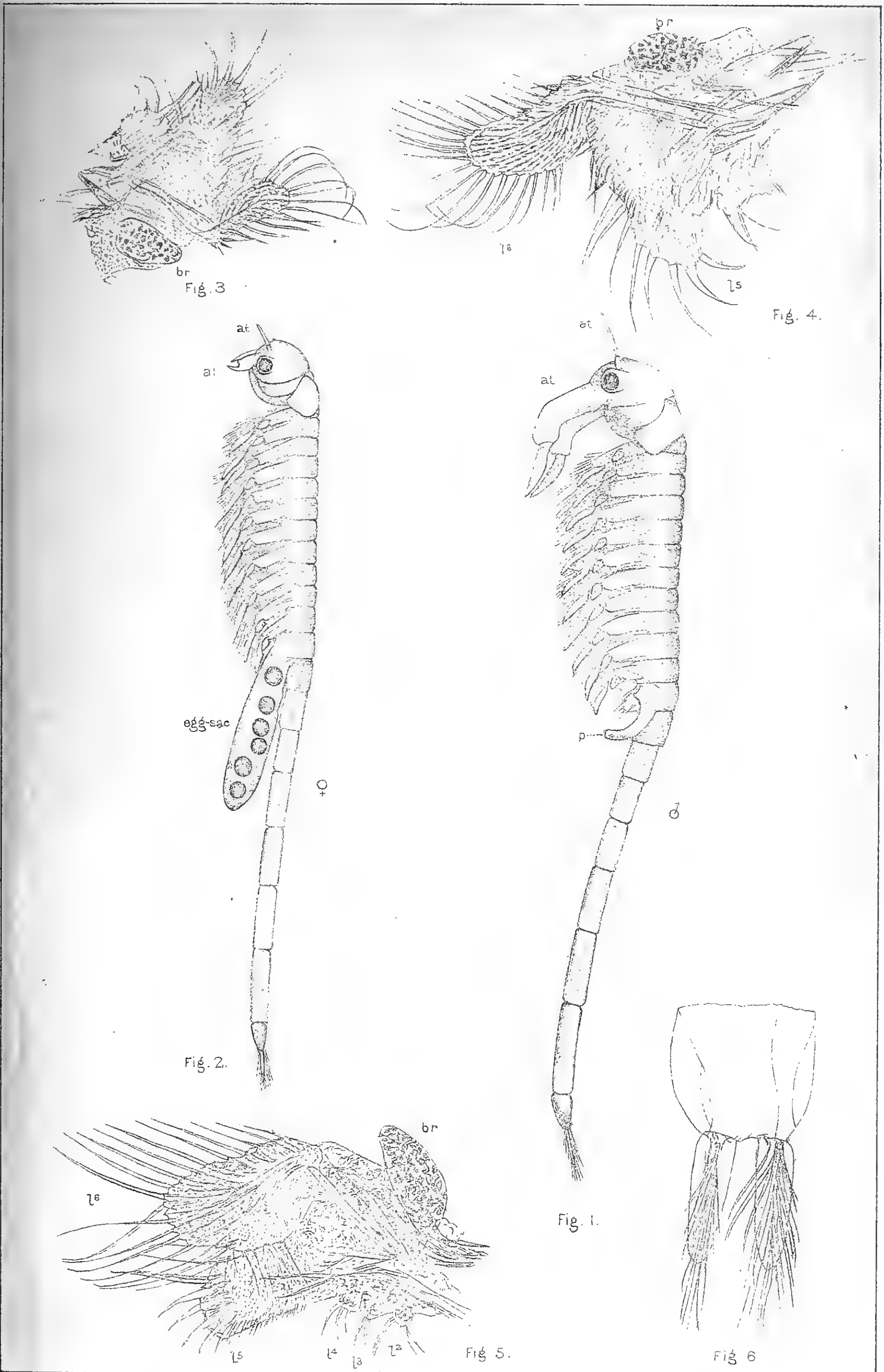
A.S Packard, del

EXPLANATION OF PLATE IX.

BRANCHINECTA PALUDOSA with details.

FIG. 1. Male, *at*, first antennæ; *at'*, claspers, or second antennæ; *p*, penis (gonopoda).
FIG. 2. Female. This and Fig. 1 enlarged several times.
FIG. 3. First foot of male, × 50 diameters.
FIG. 4. Second foot of male, × 50 diameters.
FIG. 5. Tenth foot of male, × 50 diameters.
FIG. 6. End of abdomen, with the caudal appendages.

Figs. 1 and 2 drawn by J. H. Emerton for Bessels' report on the Voyage of the Polaris; kindly loaned by Dr. Emil Bessels. Figs. 3–6 drawn and filled in with the camera lucida by the author.



J H Emerton, and A.S Packard, del.

Thos. Sinclair & Son, Lith.

EXPLANATION OF PLATE X.

BRANCHINECTA PALUDOSA and B. COLORADENSIS.

FIG. 1. *Branchinecta paludosa* Müll. (*arctica* Verrill.), first foot of male.
FIG. 2. *Branchinecta paludosa* Müll. (*arctica* Verrill.), second foot of male.
FIG. 3. *Branchinecta paludosa* Müll. (*arctica* Verrill.), tenth foot of male.
FIG. 4. *Branchinecta paludosa* Müll. (*arctica* Verrill.), eleventh foot of male.
FIG. 5. *Branchinecta paludosa* Müll. (*arctica* Verrill.), cercopoda.
FIG. 6. *Branchinecta coloradensis* Packard, first foot of male.
FIG. 7. *Branchinecta coloradensis* Packard, eleventh foot of male.
Author, del.

A.S Packard, del.

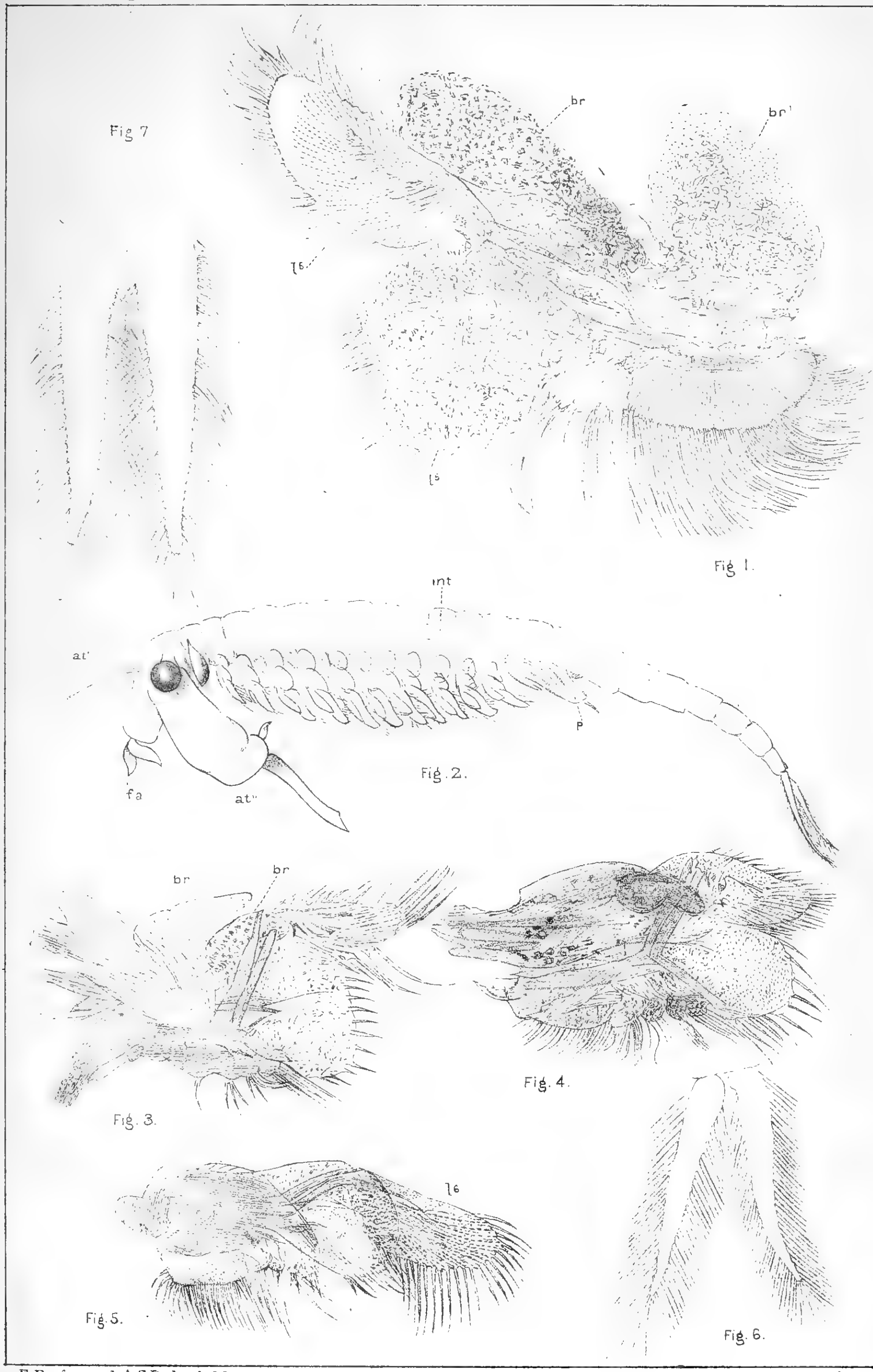
Thos. Sinclair & Son, Lith.

EXPLANATION OF PLATE XI.

BRANCHINECTA LINDAHLI and BRANCHIPUS VERNALIS Verrill, and details.

FIG. 1. *Branchinecta lindahli*, 10th foot, × 1½ B.
FIG. 2. *Branchipus vernalis* Verrill. Enlarged 3½ times; *fg*, frontal process; *int*, intestine; *p*, penis (gonopoda).
FIG. 3. *Branchipus vernalis*, first foot of male, × 30 diameters.
FIG. 4. *Branchipus vernalis*, first foot of female, × 30 diameters.
FIG. 5. *Branchipus vernalis*, eleventh or last foot, male, × 30 diameters.
FIG. 6. *Branchipus vernalis*, end of body (cercopoda) of male.
FIG. 7. *Branchinecta lindahli*, end of body of female, × 30 diameters.

Fig. 2 drawn by Mr. E. Burgess; the other figure by the author, with the camera lucida.



E. Burgess and A. S. Packard, del.

Thos. Sinclair & Son, Lith.

EXPLANATION OF PLATE XII.

STREPTOCEPHALUS TEXANUS Packard, **details.**

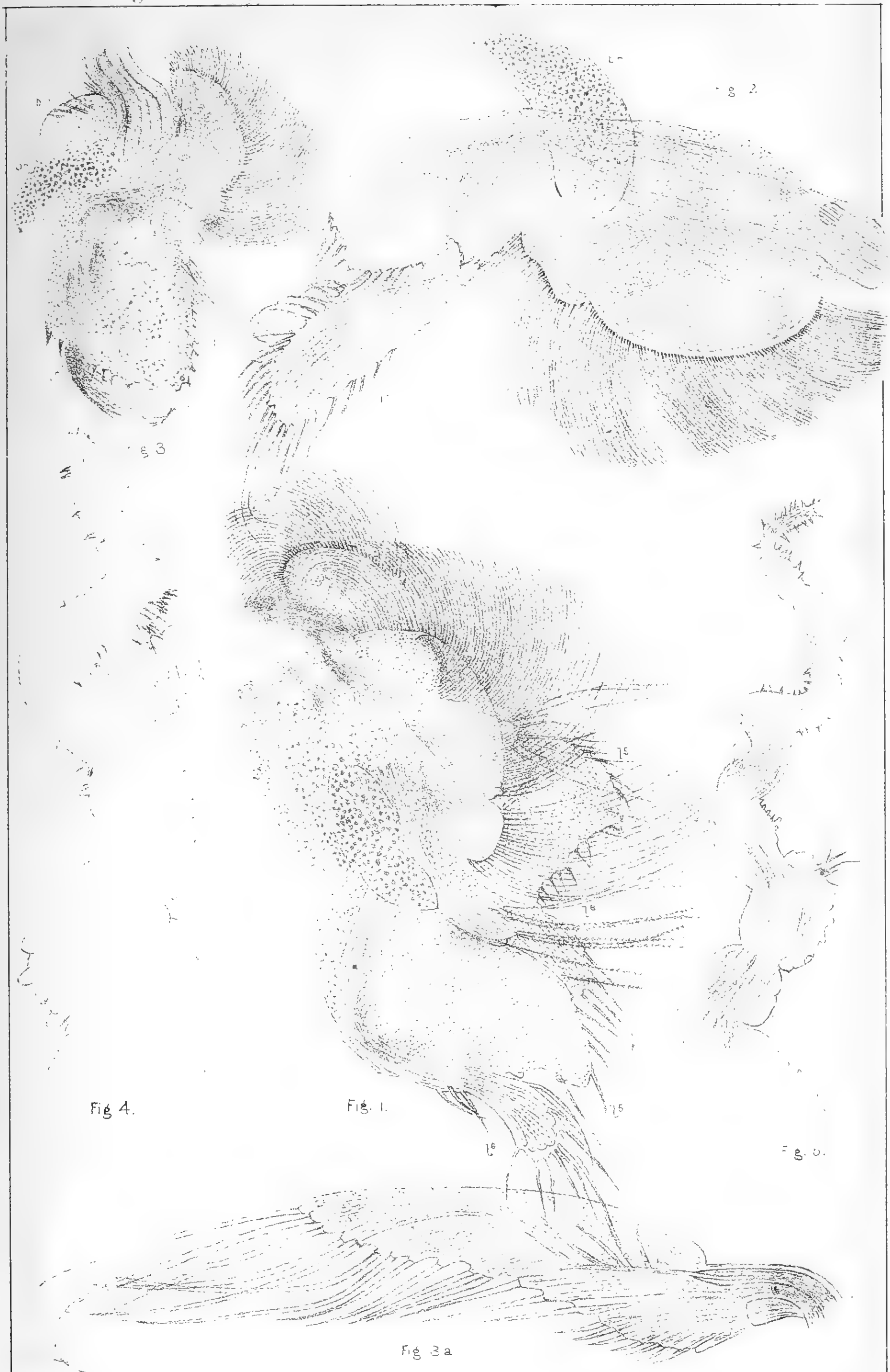
FIG. 1. First foot, male from Kansas, × ⅓ A.
FIG. 2. First foot, male from Texas, × 50 diameters.
FIG. 3. Sixth endite of 2d foot, from Texas, × 50.
FIG. 4. Sixth endite of 9th foot, from Texas, × 50.
FIG. 5. Tenth foot of specimen from Kansas, × 50.
FIG. 6. Eleventh foot of specimen from Kansas, × 50.
FIG. 7. End of body of specimen from Kansas, × 30.
Drawn by the author, with the aid of the camera lucida.

A. S. Packard del.

EXPLANATION OF PLATE XIII.

CHIROCEPHALUS HOLMANI Ryder, details.

FIG. 1. Foot of the first pair, with the following one, from a female; the 1st slightly overlapping the 2d foot, × ½ A.
FIG. 2. Tenth foot of a female; the sixth endite is turned down and the fifth turned up, × ½ A., the third and fourth endites not seen.
FIG. 3. Third foot, showing the third and fourth endites, between the 1st and 2d, and the 5th, only the latter designated by the sign l^5.
FIG. 3*a*. Sixth endite from the third foot.
FIG. 4. Frontal process of an old, large male.
FIG. 5. Frontal process of younger, smaller male.
Drawn by the author, with the aid of the camera lucida.



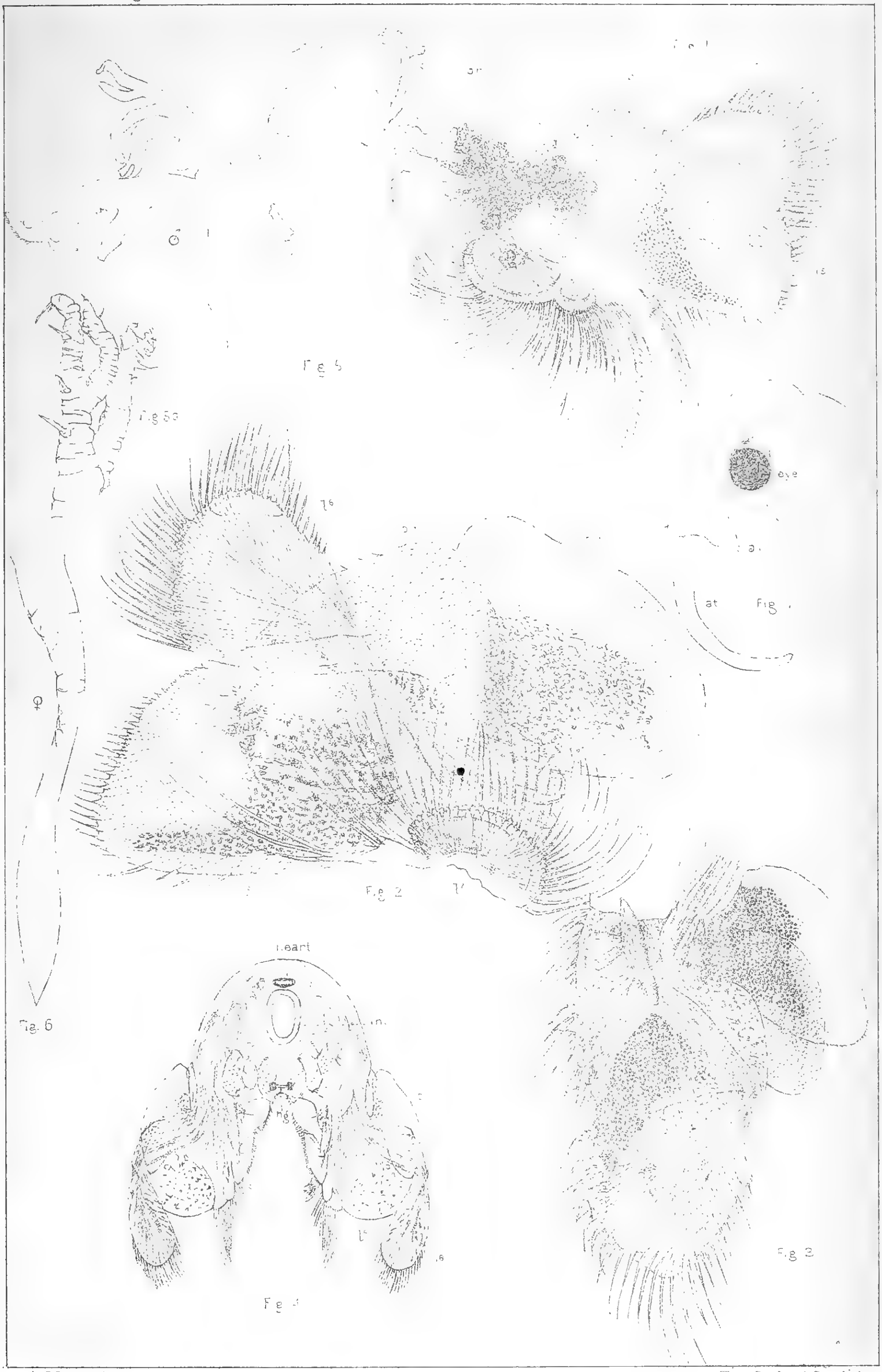
A. S. Packard, del.

Thos. Sinclair & Son, Lith.

EXPLANATION OF PLATE XIV.

THAMNOCEPHALUS PLATYURUS Packard, details.

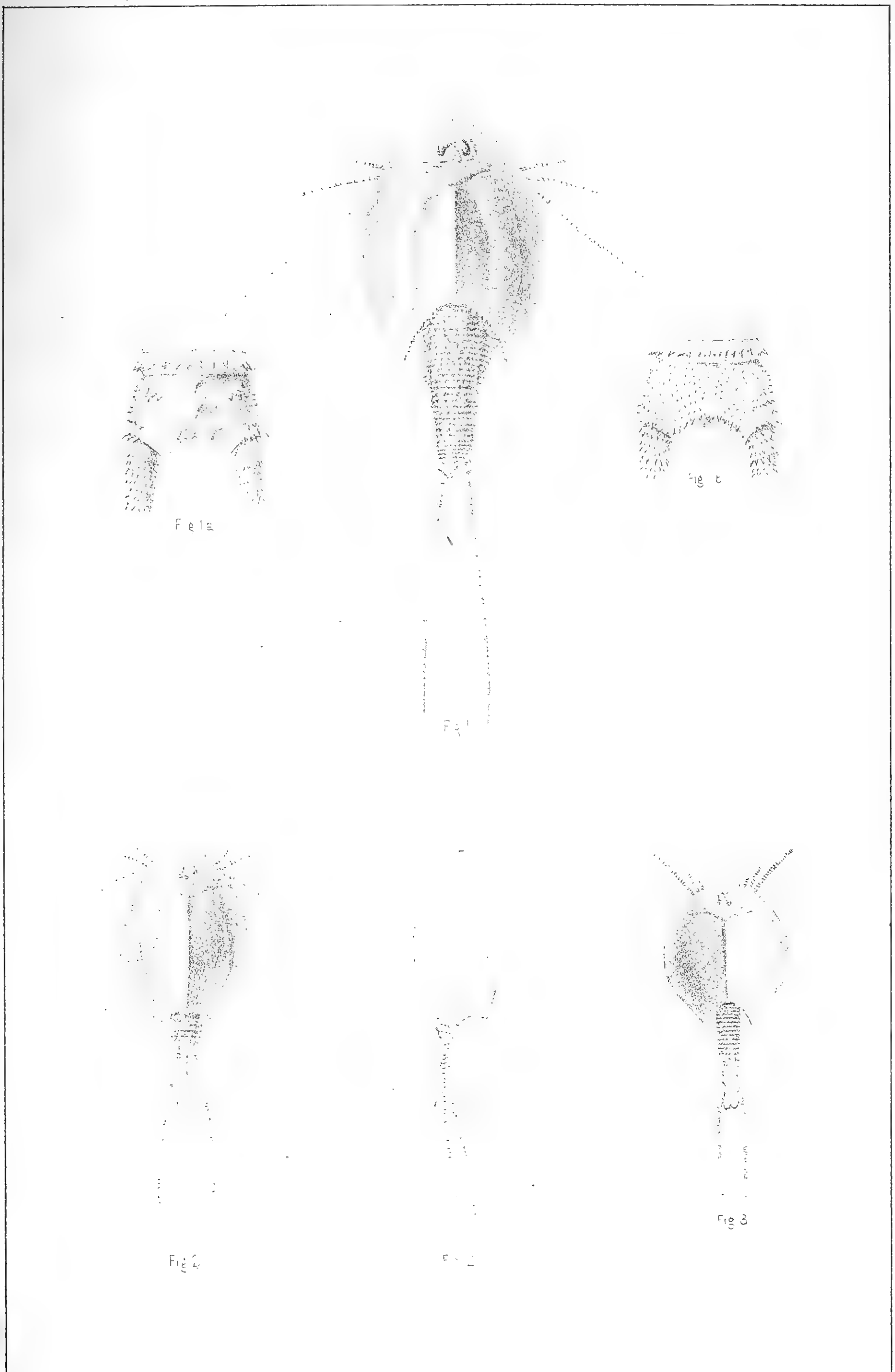
FIG. 1. An anterior leg.
FIG. 2. A middle leg.
FIG. 3. A posterior leg.
FIG. 4. Section through the body, showing the relation of the heart, intestine (*int*), and nervous cord (*n g*, a pair of nervous ganglia cut through) to the body walls and the appendages, l^5, l^6, the two last pair of endites, *br*, the gill.
FIG. 5. The male frontal appendage; 5*a*, end of a branch showing the twigs, and the wrinkles and spinules with which the appendage is armed.
FIG. 6. The female frontal appendage.
FIG. 7. Side view of the head of the female without the frontal appendage, *at*, first antenna; at^1, claspers or 2d antennæ; *eye*,—the eye and eye stalk.



A. S. Packard, del. Thos. Sinclair & Son, Lith.

EXPLANATION OF PLATE XV.

FIG. 1. *Apus æqualis* Packard, ♀ enlarged twice. 1*a*, upper; 1*b*, under side of the telson enlarged.
FIG. 2. *Lepidurus couesii* Packard, nat. size. 2*a*, side view of the same.
FIG. 3. *Lepidurus bilobatus* Packard, nat. size.
Drawn by J. H. Emerton.



J H Emerton, del. Thos. Sinclair & Son, lith.

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EXPLANATION OF PLATE XVI.

FIG. 1. *Lepidurus glacialis*, enlarged nearly 3 times. 1*a*, upper, 1*b*, under side of the telson enlarged.

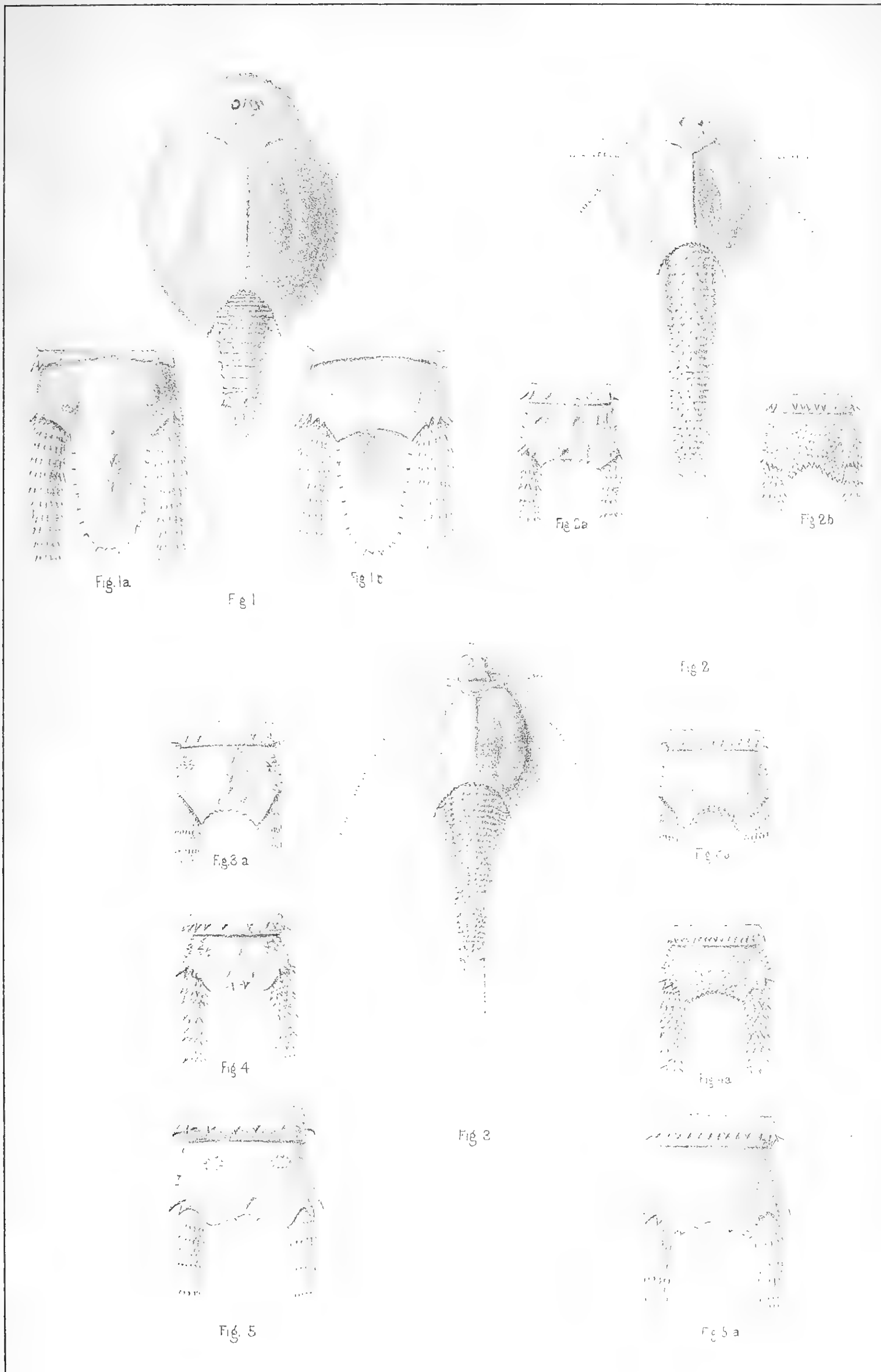
FIG. 2. *Apus lucasanus* Packard, nat. size. 2*a*, upper; 2*b*, under side of telson, enlarged.

FIG. 3. *Apus newberryi* Packard, nat. size. 3*a*, upper; 3*b* (on right-hand side), under side of telson, enlarged.

FIG. 4. *Apus longicaudatus* Le Conte, upper, 4*a*, under side of telson.

FIG. 5. *Apus himalayanus* Packard, telson. 5*a*, under side of telson, enlarged.

Drawn by J. H. Emerton.

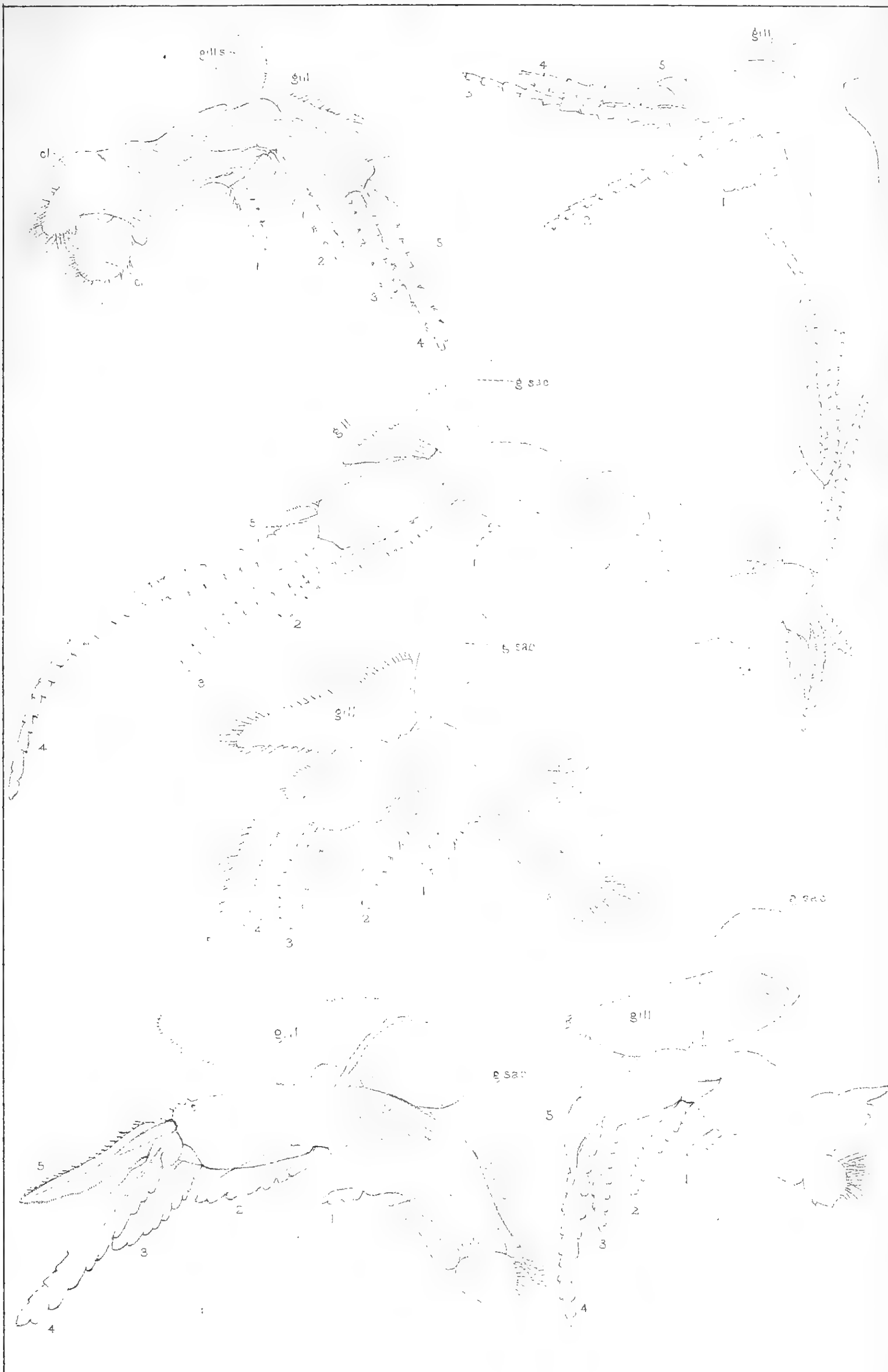


J.H.Emerton, del.

Thos. Sinclair & Son, Lith.

EXPLANATION OF PLATE XVII.

FIG. 1. *Lepidurus glacialis*, first foot; *cl*, gnathobase or coxal lobe; *cl*[1], the same of the succeeding limb.
FIG. 2. *Lepidurus couesii*, first foot.
FIG. 3. *Lepidurus couesii*, first foot of another (malformed?) individual.
FIG. 4. *Lepidurus bilobatus*, ♀, first foot.
FIG. 5. *Lepidurus glacialis* ♀, second foot.
FIG. 6. *Lepidurus bilobatus*, ♀, second foot.
FIG. 7. *Lepidurus couesii*, second foot.
All enlarged; drawn by the author, with the aid of the camera lucida.



A.S.Packard, del

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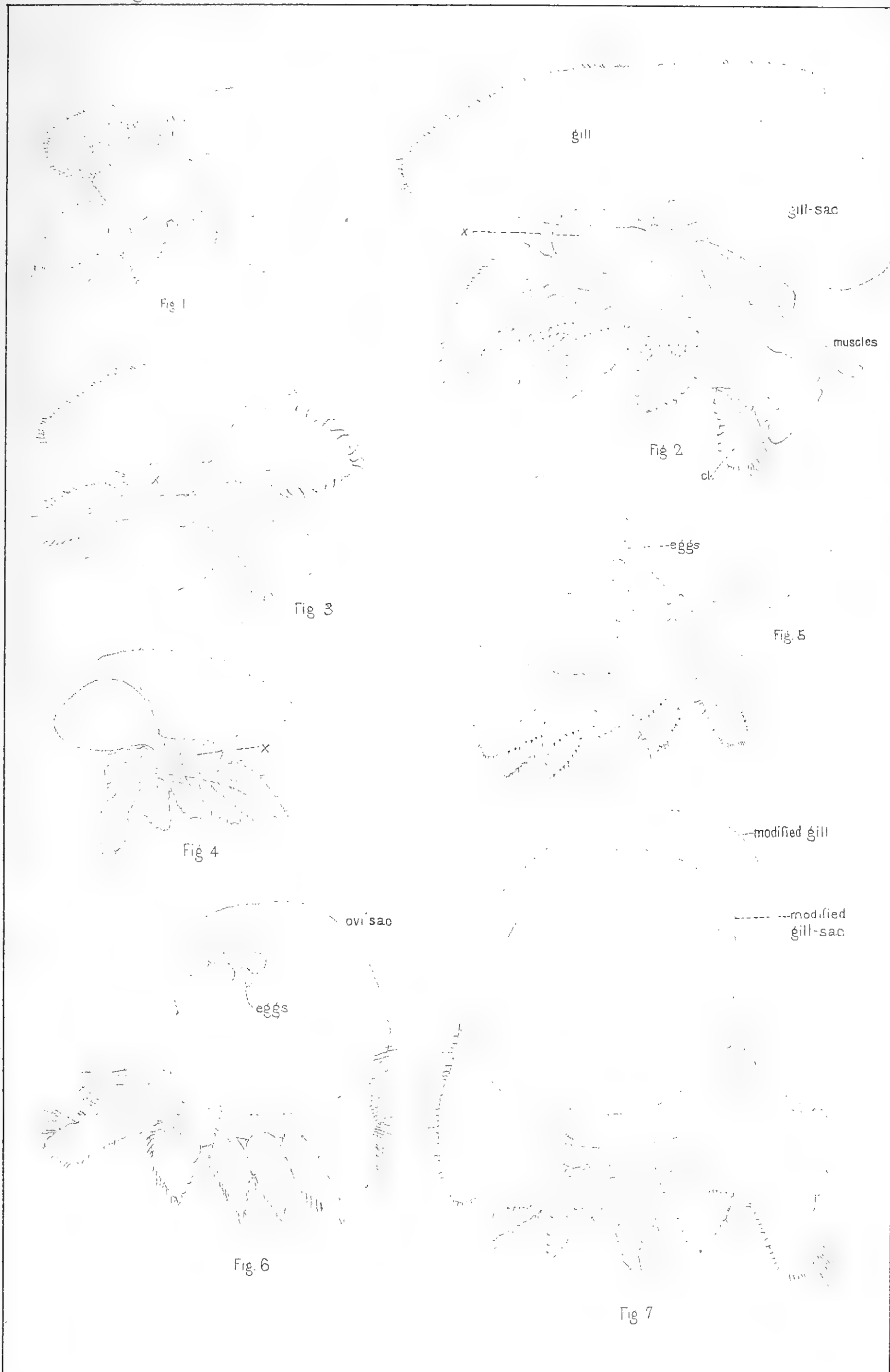
EXPLANATION OF PLATE XVIII.

FIG. 1. *Apus æqualis*, ♀, tenth foot.
FIG. 2. *Apus newberryi*, ♀, tenth foot, *x*, "subapical lobe."
FIG. 3. *Apus lucasanus*, tenth foot, *x*, as in Fig. 2.
FIG. 4. *Apus longicaudatus*, tenth foot.
FIG. 5. *Apus lucasanus*, eleventh foot of the female, with the ovisac, containing a few eggs.
FIG. 6. *Apus longicaudatus*, eleventh foot of female.
FIG. 7. *Apus newberryi*, eleventh foot of female.

All the figures on this and Plates XIX–XXI much enlarged, and drawn by the author with the camera lucida.



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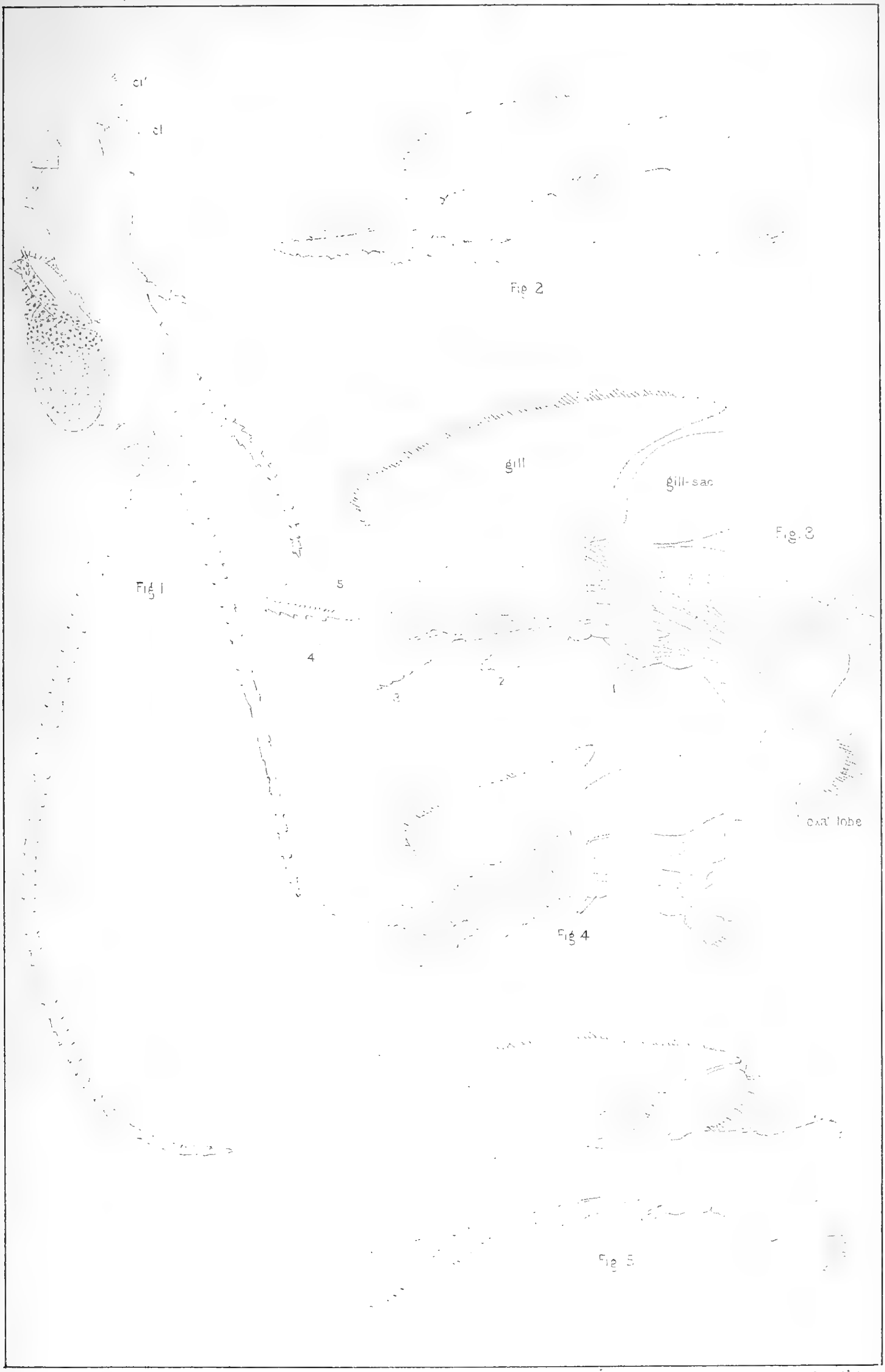
EXPLANATION OF PLATE XIX.

FIG. 1. *Apus lucasanus*, first foot; *cl*, gnathobase; *cl*, that of the following appendage.
FIG. 2. *Apus æqualis*, second pair of feet.
FIG. 3. *Apus newberryi*, ♀, second pair of feet.
FIG. 4. *Apus longicaudatus*, second pair of feet.
FIG. 5. *Apus lucasanus*, ♂; second pair of feet; differs from the female in having the filaments on the gill.



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EXPLANATION OF PLATE XX.

FIG. 1. *Apus newberryi*, ♀, first foot.
FIG. 2. *Apus æqualis*, ♀, first foot.
FIG. 3. *Apus longicaudatus*, ♀, first foot.
FIG. 4. *Apus longicaudatus*, ♂, first foot.

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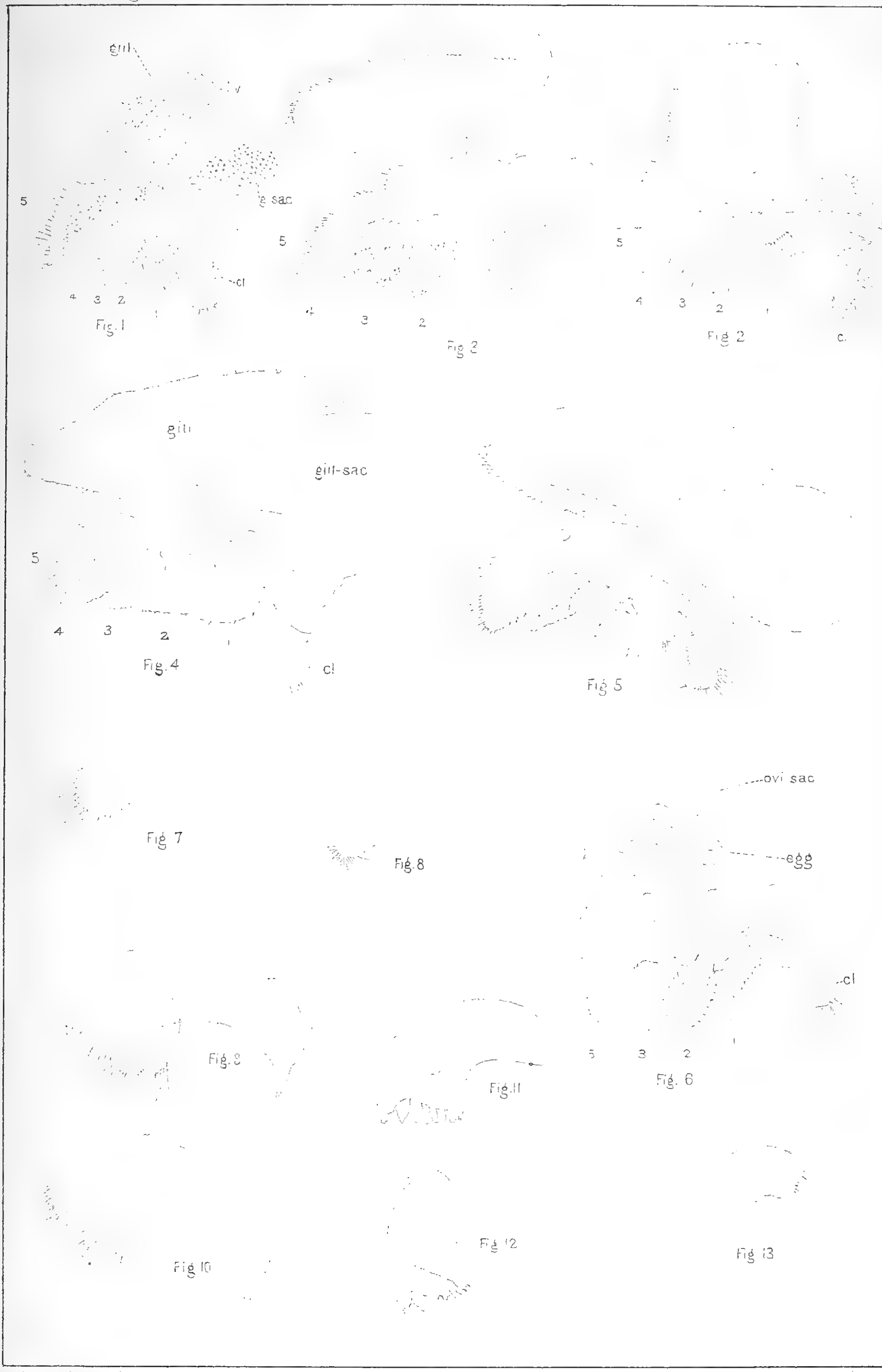
EXPLANATION OF PLATE XXI.

FIG. 1. *Lepidurus glacialis*, female; tenth appendage.
FIG. 2. *Lepidurus glacialis*, female; eleventh appendage, with ovisac.
FIG. 3. *Lepidurus bilobatus*, female; tenth appendage.
FIG. 4. *Lepidurus couesii*, male; tenth appendage.
FIG. 5. *Lepidurus couesii*, female; tenth appendage.
FIG. 6. *Lepidurus couesii*, female; eleventh appendage.
FIG. 7. *Apus lucasanus*, maxilla.
FIG. 8. *Apus lucasanus*, maxilla, seen from the inside.
FIG. 9. *Lepidurus couesii*, maxilla.
FIG. 10. *Apus lucasanus*, maxilla.
FIG. 11. *Lepidurus couesii*, mandible.
FIG. 12. *Apus lucasanus*, mandible.
FIG. 13. *Apus lucasanus*, outside view of the same specimen as Fig. 8 represents.



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EXPLANATION OF PLATE XXII.

Anatomy of Artemia and Branchipus vernalis.

FIG. 1. Nauplius or first larval state of *Artemia gracilis* from Great Salt Lake. I, first antennæ; II, second antennæ, III, mandibles.

FIG. 2. *Artemia gracilis*, from New Haven, ovisac and ovary; *c*, ovary; *d*, anterior points of attachment of the ovary, the intestine passing between them; *e*, *e*, oviducts.

FIG. 2*a*. *Artemia gracilis*, from New Haven, cells of the cement-gland.

FIG. 2*b*. The same; end of the long middle lobe, with the cement-gland cells (*ec*) and the fully developed eggs (*egg*).

FIG. 3. *Branchipus vernalis*. Male generative organs; *t*, testis; *t′*, first dilated portion of the testis; *t″*, contracted portion or *vas deferens*; t‴, second dilated portion, performing the function of seminal vesicle; *dt*, ductus ejaculatorius; *g*, glandular and accessory apparatus; *c*, cirrus; *br*, gill of last left foot; *int*, intestine; *ht*, heart or dorsal vessel; *hh*, ostium, or valvular opening of heart.

FIG. 4. *Branchipus vernalis*, pale variety, ovisac; *a*, external wall of the ovisac; *b*, internal wall of the same; *c*, the two ovarian tubes (somewhat twisted and stretched in living specimens); *d*, anterior continuation of the same; *e*, the two muscular oviducts; *f*, lateral portion of the cement-gland; *g*, median portion of the same; *h*, female valvular orifice; ab^3, third abdominal segment.

FIG. 4*a*. Ovaries (*ovt*) and oviducts (*ov*) of pale variety.

FIG. 4*b*. Side view of a contracted oviduct.

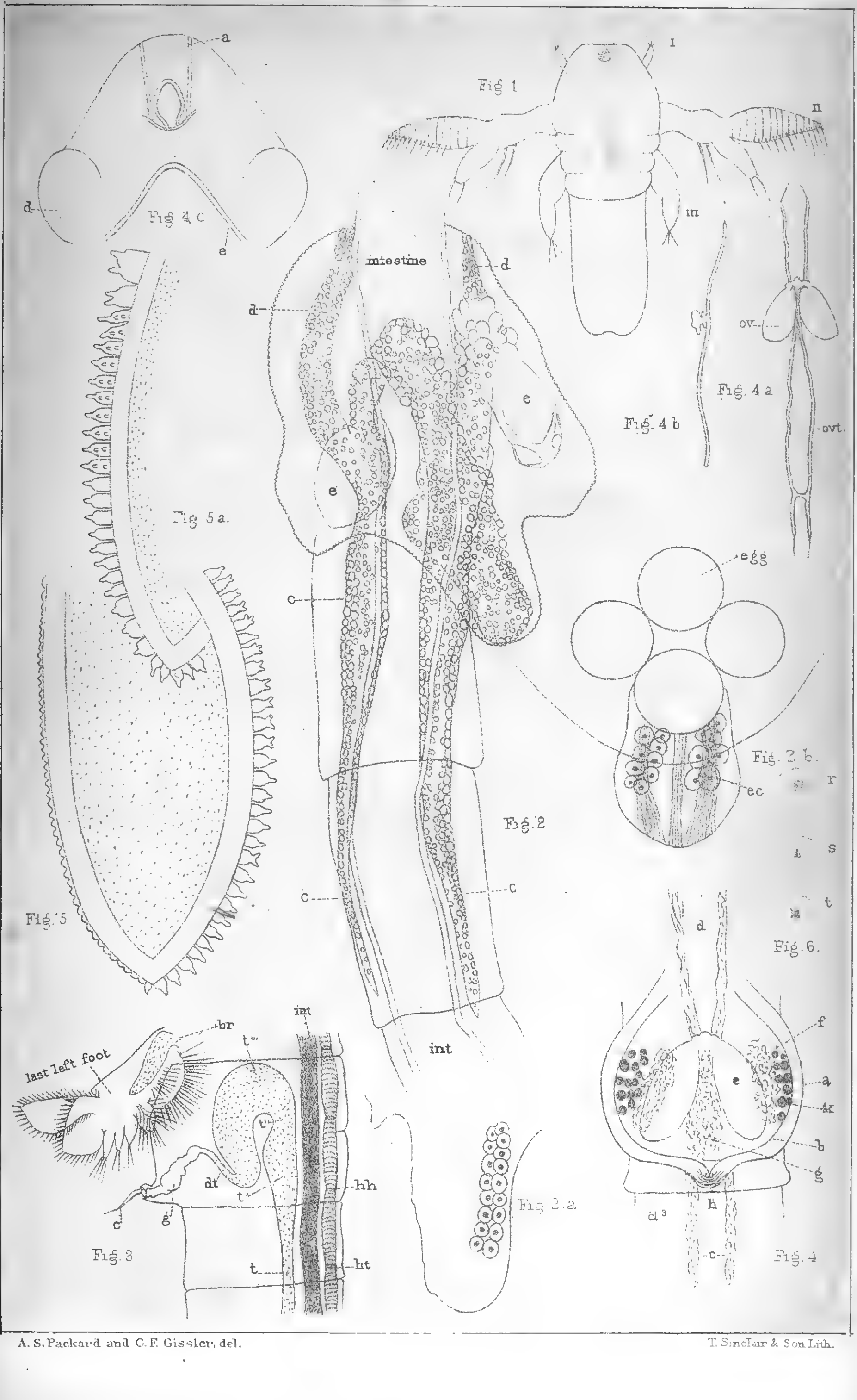
FIG. 4*c*. *Branchipus vernalis*, oviduct filled with eggs, of an old red female; *a*, valvule, below which is the orifice; *c*, transverse ridge; *d*, lateral protuberances; *e*, margin of the following segment.

FIG. 5. *Branchipus vernalis*, frontal process of a red male, the right side being the outer edge, with double-headed papillæ.

FIG. 5*a*. One side of same in a pale male.

FIG. 6. *r*, *s*, *t*, different forms of ocelli or median eye in pale races, ♂ and ♀.

Figs. 1, 2, 2*a*, 2*b*, drawn by the author; the others by C. F. Gissler, Ph. D.



A. S. Packard and C. F. Gissler, del. T. Sinclair & Son Lith.

EXPLANATION OF PLATE XXIII.

ARTEMIA GRACILIS Verrill (from New Haven), details.

FIG. 1. *Artemia gracilis* Verrill. Head, showing the relation of the brain to the eyes, optic nerves, and ocellus (*ocel*), with the stomach and liver; *md*, mandible; *gl*, rudimentary shell-gland.

FIG. 2. Front of the body, showing the circulation of the blood; *ht*, heart; the dots and arrows indicate the course of the blood-currents; *int*, intestine.

FIG. 3. End of the same individual represented by Fig. 2; *ht*, end of the heart, with the two valves (seen at Fig. 3*a*); *rec*, rectum; *m*, three pairs of muscular bands which hold the rectum in place.

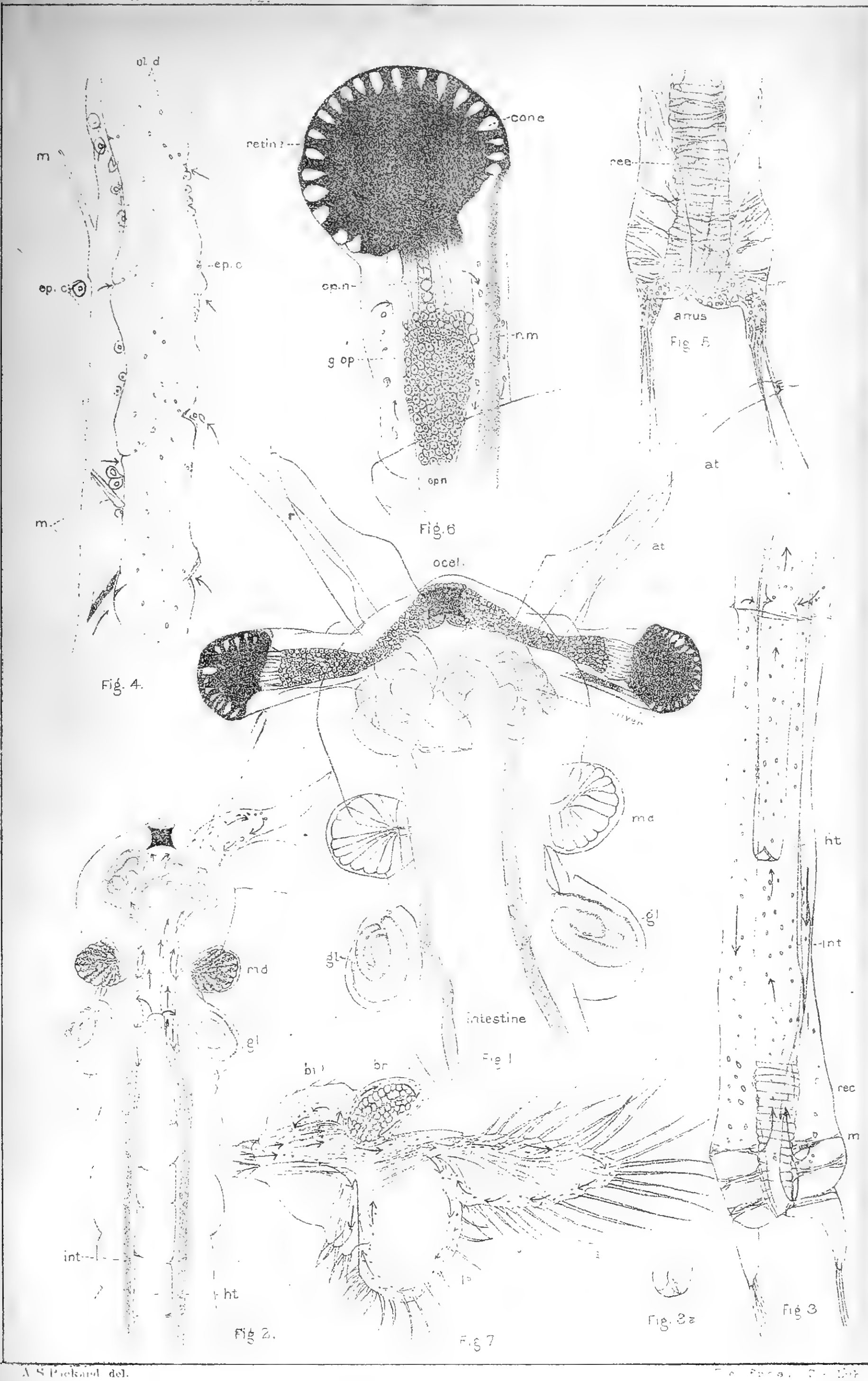
FIG. 4. Portion of the heart during action; the arrows on each side point towards the ostia or valvular openings; the blood discs are represented within the heart itself; *ep. c*, epithelial cells in the walls of the heart; *m*, muscles which hold the heart in place.

FIG. 5. End of the body; *rec*, rectum; *m*, muscles; *anus*, vent.

FIG. 6. One of the compound eyes; *cone*, one of the crystalline cones; *retina*, the black retina; *op. n*, the optic nervules; *opn*, the main optic nerve; *r. m*, retractor muscle of the eye; *g. op*, ganglion opticum, consisting of ganglionic cells, $\times \frac{1}{2}$ B.

FIG. 7. Circulation of the blood in a foot, the dots representing the blood discs; the arrows indicating the course of the blood.

Drawn from the living specimens, with the camera lucida. by the author.



A. S. Packard del.

EXPLANATION OF PLATE XXIV.

FIG. 1. *Estheria belfragei*, edge of carapace, greatly enlarged, $\times \frac{1}{8}$ Tolles, A. ocular
FIG. 2. *Estheria jonesii*, edge of shell, with a portion chipped off, $\times \frac{1}{4}$ A.
FIG. 3. *Estheria mexicana*, Ohio, $\times \frac{1}{8}$ A.
FIG. 4. *Estheria dawsoni* (fossil). Drawn by L. Trouvelot.
FIG. 4*a*. *Estheria dawsoni*, showing the granulated ridges, $\times \frac{1}{2}$ A.
FIG. 4*b*. *Estheria dawsoni*, showing the pits between the ridges.
FIG. 5. *Estheria californica*, $\times \frac{1}{2}$ A.
FIG. 6. *Estheria mexicana*, Kansas, $\times \frac{1}{2}$ A.
FIG. 7. *Estheria morsei*, Iowa; edge of the shell.
FIG. 8. *Estheria compleximanus*, Kansas; edge of shell, $\times$ 225 diameter.
FIG. 9. *Estheria mexicana*, section through the entire animal, through the front part of thorax; ant^1, antennæ; ant^2, base of second antennæ; *shg*, section through the shell-gland; *br'*, upper, *br''*, lower division of the flabellum; *int*, intestine; *ng*, nerve-ganglion; 1-6, first to sixth endites.
FIG. 10. *Estheria compleximanus*. Section through the posterior part of the thorax, the shell having been removed; lettering as in Fig. 9; *mus*, dorsal muscles.

All the figures, except Fig. 4 drawn by the author.

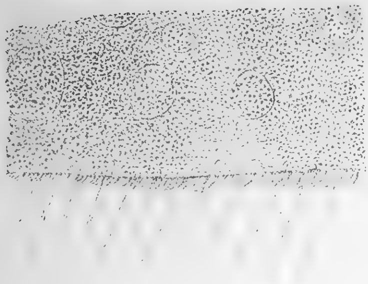


Fig. 1.

Fig 2.

Fig 3

Fig 4 a

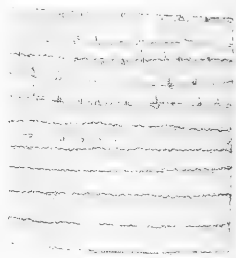


Fig. 4 b

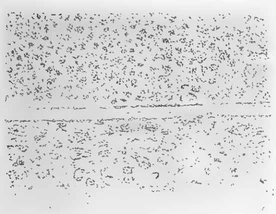


Fig 5

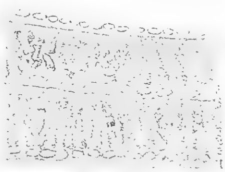


Fig 6

Fig 7

Fig 9

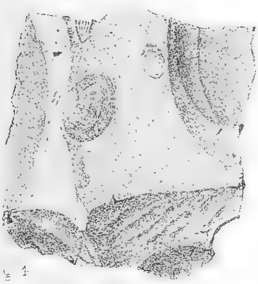


Fig 4

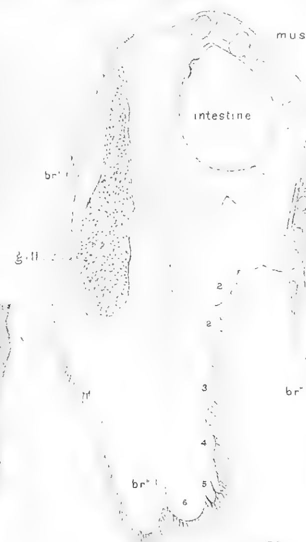


Fig 10

Fig 9.

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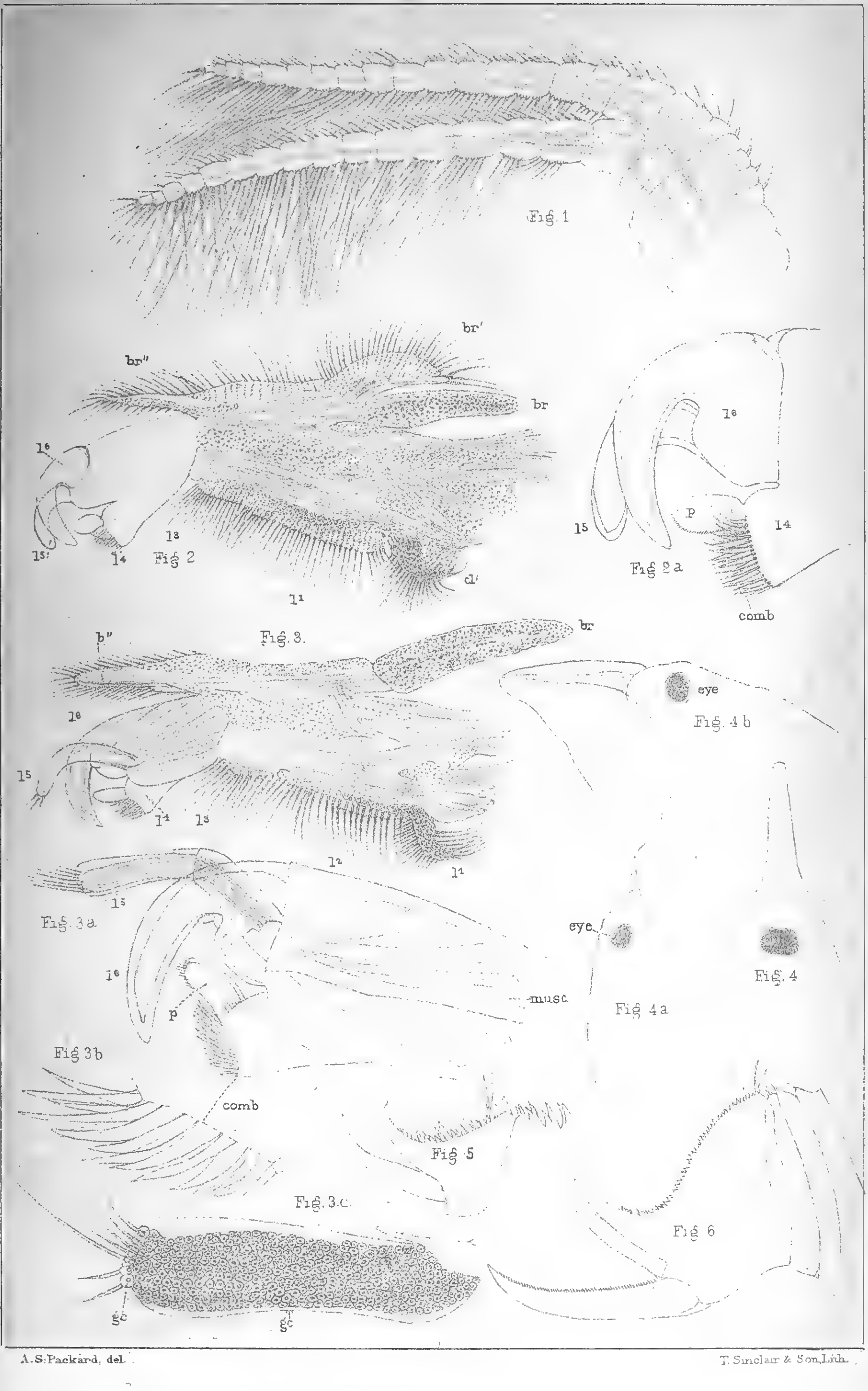
EXPLANATION OF PLATE XXV.

ESTHERIA MEXICANA AND E. COMPLEXIMANUS, details.

FIG. 1. *Estheria mexicana.* Second antenna.
FIG. 2. Leg of first pair; male; *cl*, 1st endite.
FIG. 2*a*. Hand, including the fourth endite with the palpiform thumb (*p*), and comb-like edge of the endite.
FIG. 3. Leg of second pair, male.
FIG. 3*a*. Hand of second pair of male, leg; *musc*, muscles of hand.
FIG. 3*b*. Comb, or spiney edge of the fourth endite.
FIG. 3*c*. Palpus-like terminal joint of the fifth endite, showing the sense-cells with which it is filled, and the tactile hairs at the extremity, $\times \frac{1}{5}$ A Tolles.
FIG. 4. View of the head with the double-eye, from above.
FIG. 4*a*. The same, seen from the side.
FIG. 4*b*. Another lateral view of the head and rostrum.
FIG. 5. End of the abdomen, including the telson of the male (female the same).
FIG. 6. *Estheria compleximanus* Packard. End of abdomen.
Drawn, and details filled in with the camera lucida, by the author.



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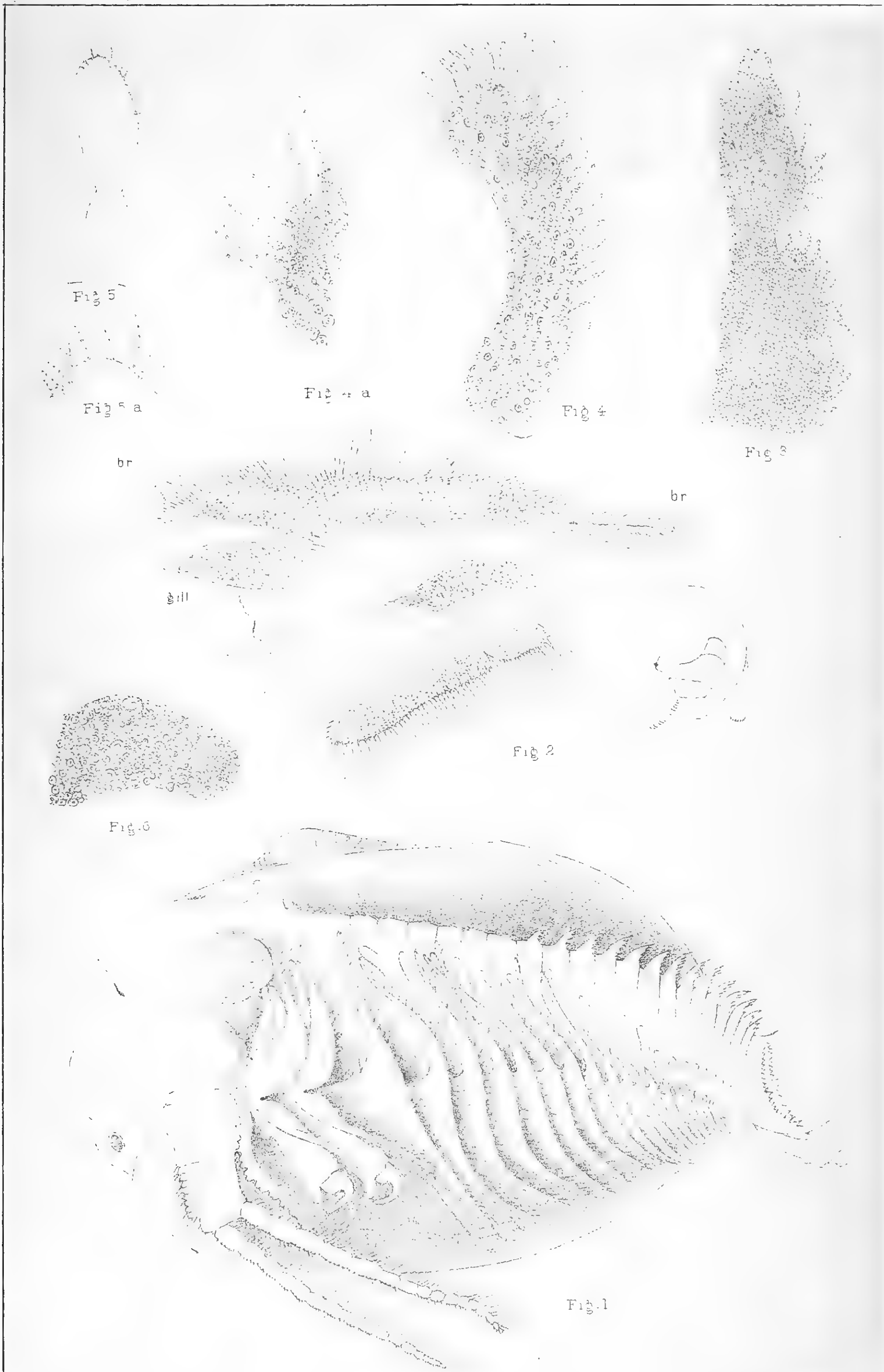
EXPLANATION OF PLATE XXVI.

FIG. 1. *Estheria morsei* Pack; male, much enlarged.
FIG. 2. *Estheria morsei*; male, first foot.
FIG. 3. *Eulimnadia texana* Pack.; end of first antennæ, showing the olfactory papillæ, and crowded nerve sense-cells.
FIG. 4. *Limnetis gouldii* Baird; end of first antennæ, showing the nerve-endings, the large nerve-cells, and the long, finger-like olfactory papillæ, × $\frac{1}{6}$ A.
FIG. 4*a*. Portion of end of the same, × $\frac{1}{8}$ B ocular, showing the nuclei in the papillæ and the series of nucleated sense-cells. (The line on the right side was drawn by mistake; it should form the left side of Fig. 4.)
FIG. 5. *Limnetis brevifrons* Pack.; first antenna.
FIG. 5*a*. End of the same (Fig. 5), much enlarged.
FIG. 6. *Limnetis gouldii*; portion of the ovary, × $\frac{1}{8}$ A.
Fig. 1 was drawn by Mr. E. Burgess; the other figures by the author.

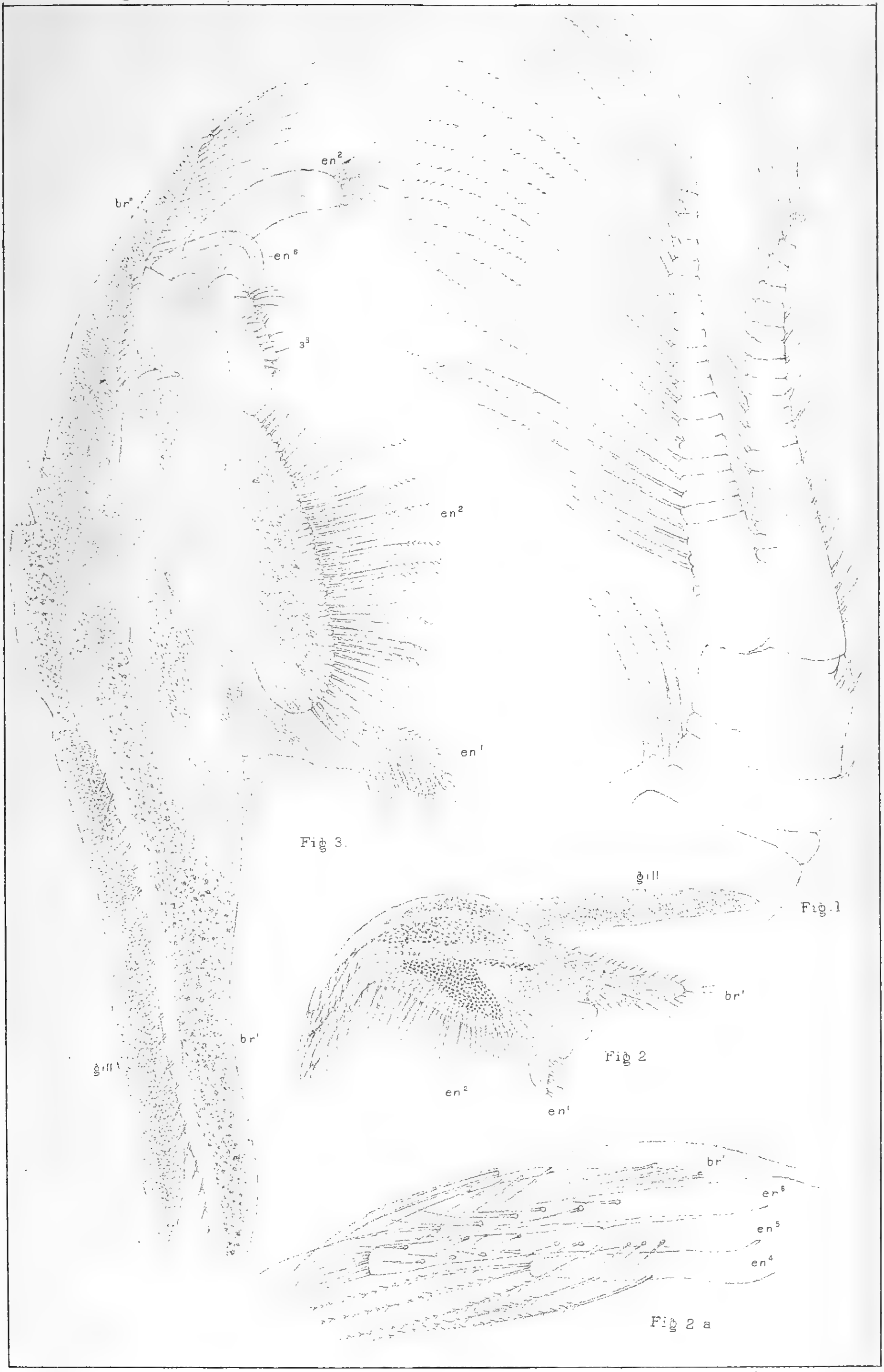


E. Burgess and A. Packard del.

T. Sinclair & Son Lith. Phila.

EXPLANATION OF PLATE XXVII.

FIG. 1. *Limnetis brevifrons* Packard; second antenna of female.
FIG. 2. *Limnetis brevifrons* Packard; first leg of female.
FIG. 2*a*. *Limnetis brevifrons* Packard; end of first leg of Fig. 2, showing endites 4–6 and the lower division of flabellum (*br''*).
FIG. 3. *Limnetis brevifrons* Packard; male, first leg (en^2 above en^6 should be en^5).
All the figures drawn by the author.



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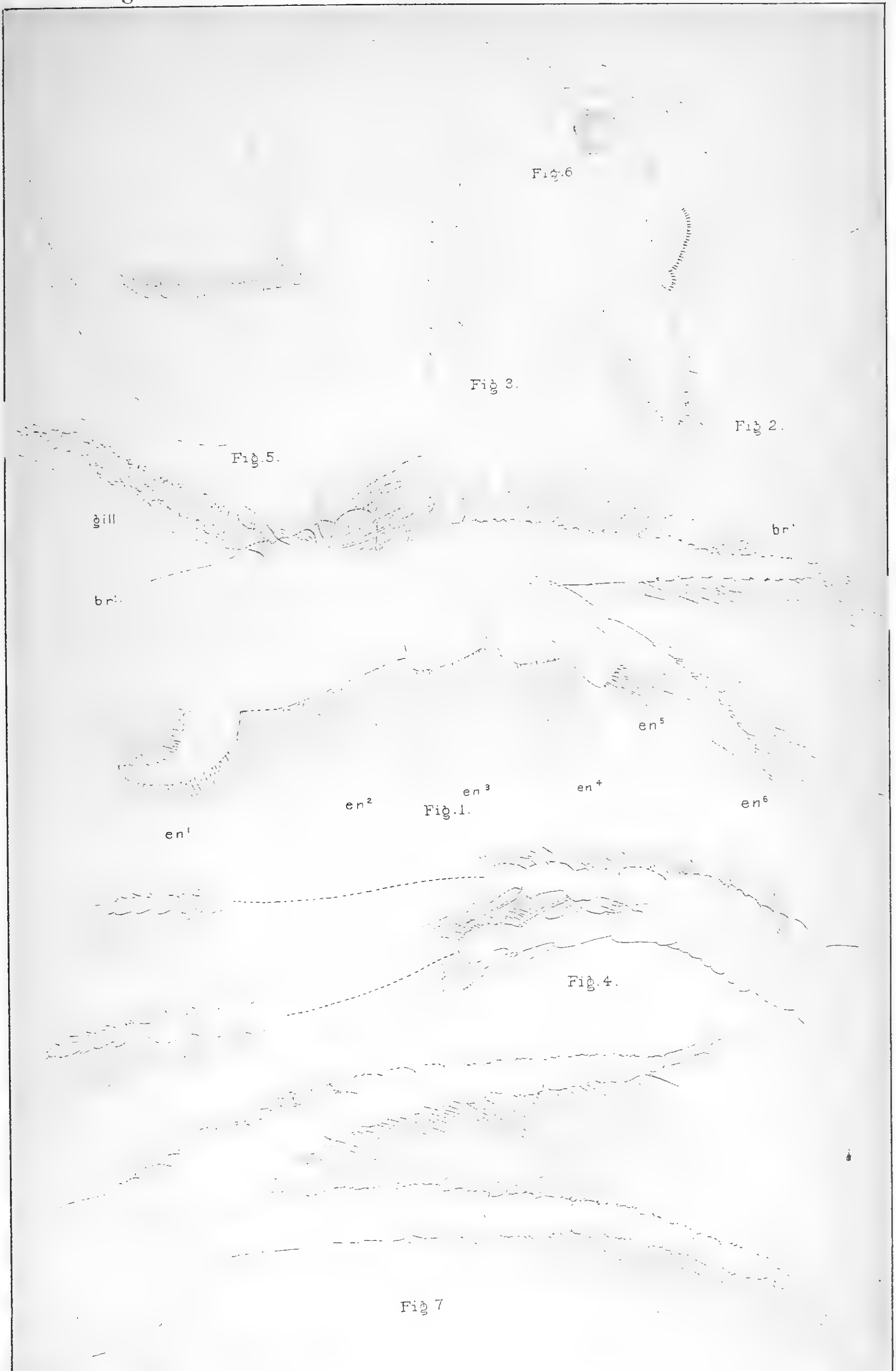
T. Sinclair & Son, lith. Phil.

EXPLANATION OF PLATE XXVIII.

FIGS. 1–5. *Estheria mexicana* Claus, immature specimens from Kentucky (*E. clarkii* Pack.).
FIG. 1. Thoracic leg, female.
FIG. 2. Fifth leg from the last.
FIG. 3. First antenna.
FIG. 4. Second antenna.
FIG. 5. Telson.
FIG. 6. *Estheria jonesii* Baird; second antenna.



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EXPLANATION OF PLATE XXIX.

FIG. 1. *Estheria mexicana* Claus, from Kansas (*E. caldwelli*); first antenna; *ol*, olfactory lobes; *at*, *n*, antennal nerve.

FIG. 1*a*. Terminal joints of the same, filled with olfactory cells; no papillæ present.

FIG. 1*b*. Olfactory lobes from near the middle of the antenna.

FIG. 2. *Estheria mexicana* (*caldwelli*); three terminal joints of the second antennæ, showing the nerve-endings and the sense-cells at the base of the setæ.

FIG. 3. *Estheria compleximanus*, edge of sixth endite (of Pl. V, fig. 7), showing the ends of the tactile nerves leading to base of tactile setæ and connecting with the marginal nerve; with the two series of independent nerve or ganglion cells, × 225 diameters.

FIG. 4. *Estheria compleximanus* Pack.; end of the dorsal lobe or oviger of one of the anterior legs (figured on Pl. V, fig. 7), showing the tactile nerve (*tn*) with its ganglionic enlargement near and at the end of the lobe; with the ganglion cells at the base of the setæ.

FIG. 5. *Estheria compleximanus*, end of 5th endite of 1st leg (Pl. V, fig. 5), showing the very large crowded ganglionic tactile cells (*gc*).

FIG. 6. *Branchipus vernalis* Verrill. End of 1st antenna, with the three tactile setæ at the tip; *n*, antennal nerve; *gc*, ganglion cells, × $\frac{1}{5}$ A.

FIG. 7. *Thamnocephalus platyurus* Pack. The 3d or 4th endite of the 1st foot, with *n* the nerve to the endite, the large ganglion cells arranged in quite regular series, and *tn* the origin of a tactile nerve passing into the seta (*s*); each seta is about to moult, as the new setæ with the fine setulæ are present.

FIG. 8. *Thamnocephalus platyurus* Pack. Portion of the edge of 1st or innermost endite of 1st pair of feet; *n*, nerve-fibres; *gc*, ganglion cells; *tn*, tactile nerves passing into the long, slender setæ (*s*), near *tn*, the marginal row of fine setæ.

FIG. 8*a*. *Thamnocepholus platyurus* Pack. Cuticle of flabellum with nuclei (*n*) and fine tubercles.

FIG. 8*b*. *Thamnocephalus platyurus* Pack. Cells at base of 5th endite containing fat granules.

FIG. 9. *Limnetis gouldii*. One eye with the cornea removed, the same specimen as represented on Pl. II, fig. 5. *Op. n*, optic nerve; the upper op. n. should be *op. g*, optic ganglion. From the peripheral nucleolated cells the nerves with the rods (if the latter are present) converge towards the optic ganglion; *tr. n*, transverse nerves arising from peripheral cells and connecting the two eyes.

All the figures drawn with the camera lucida by the author.

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EXPLANATION OF PLATE XXX.

FIG. 1. *Branchipus vernalis* Verrill. Sixth endite of an anterior leg, showing the muscles and tactile nerves, which arise independently of the central nervous system near the margin of the lobe; *nc*[1], inner series; *nc*[2], marginal series of ganglion cells; on the left side the origin of the setal nerves are seen.

FIG. 2. *Streptocephalus texanus* Pack. The 6th endite of an anterior foot.

FIG. 3. *Streptocephalus texanus* Pack. A portion of fig. $2 \times \frac{1}{5}$ A, showing the mode of termination of the muscle in the middle of the lobe; the origin of the setal nerves from the inner series of ganglion cells (*nc*); *s*, seta.

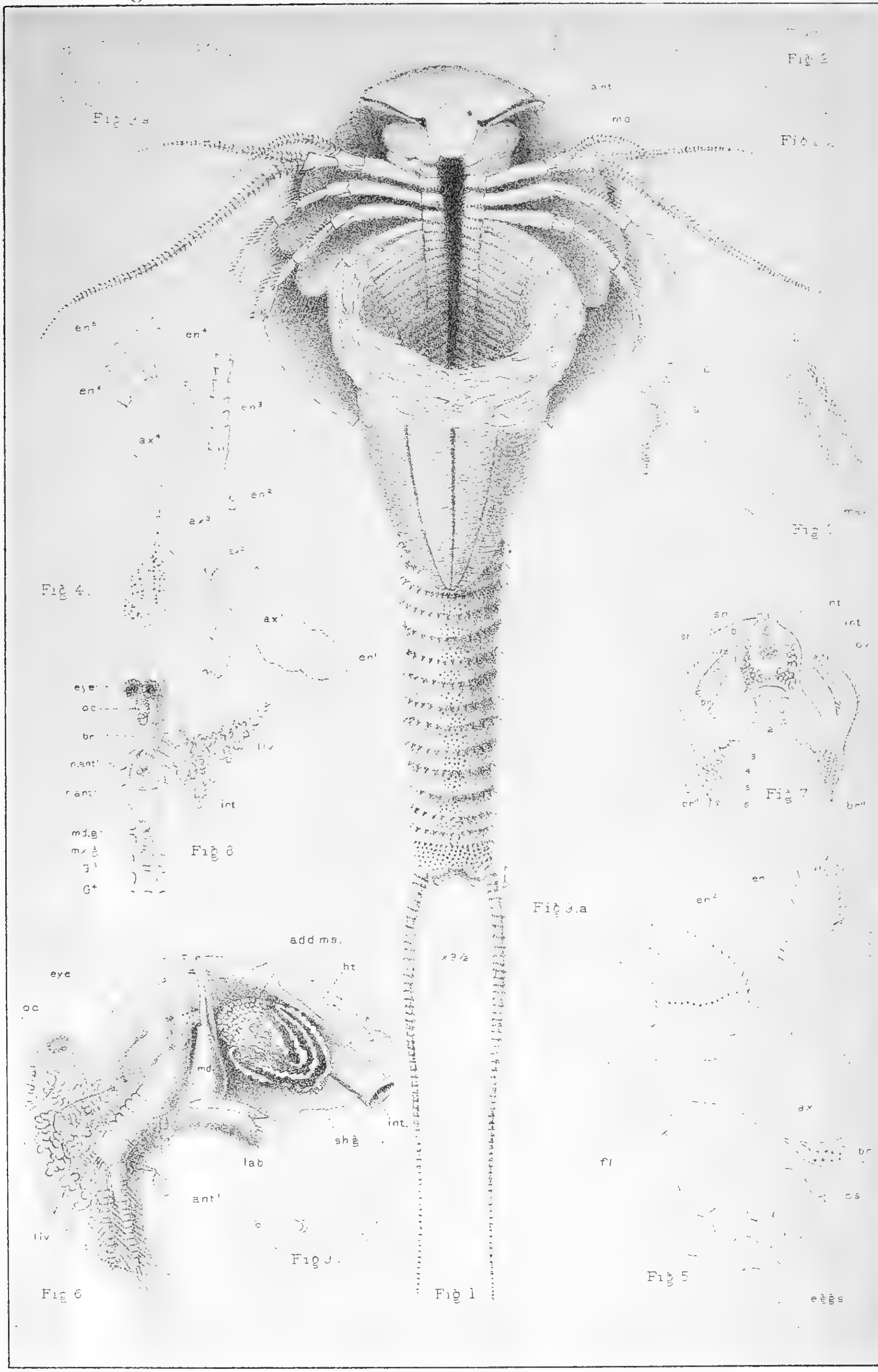
A. S. Packard, del.

T. Sinclair & Son, lith. Phila.

EXPLANATION OF PLATE XXXI.

FIG. 1. *Apus lucasanus* Pack. Seen from beneath. Enlarged 3½ times. *md*, mandibles.
FIG. 2. *Apus lucasanus* Pack. First antennæ.
FIG. 2*a*. *Apus lucasanus* Pack. End of the same magnified. The antennæ of both pairs drawn to the same scale.
FIG. 3. *Apus lucasanus* Pack. Maxilla, showing the (*a*) anterior and (*b*) posterior divisions of the free edge; *max*, the gill of the maxillipede.
FIG. 3*a*. *Apus lucasanus* Pack. Maxillipede, represented by the gill only.
FIG. 4. *Apus lucasanus* Pack. First leg giving (with some changes) Lankester's nomenclature of the parts; ax^1–ax^4, the pseudojoints; en^1–en^6, the six endites, with the gill and flabellum.
FIG. 5. *Apus lucasanus*. The oostegite, or part of the 11th pair of legs of the female containing the eggs; *os*, aperture of the sack; *fl*, modified flabellum; *x*, the greatly enlarged subapical lobe (compare Plate XVIII, figs. 2, 3, 4*x*, and Plate XXXII, fig. 2*x*); *br*, the gill.
FIG. 6. *Limnetis brachyura* (Europe). Ant^1, 1st antennæ; ant^2, 2d antennæ; *lab*, labrum; *sh. g*, shell gland; *int*, intestine; *ht*, heart; *add. ms*, adductor muscle; *oc*, ocellus; *md*, mandible; *liv*, liver.
FIG. 7. *Limnetis brachyura*. Section through the body and shell (*sh*); *ht*, heart; *int*, intestine; *ov*, ovary; 1–6, the six endites.
FIG. 8. *Limnetis brachyura*. Brain (*br*) and nervous cord; *n.* ant^1, origin of 1st antennal nerve; *n.* ant^2, 2d antennal nerve; *md. g*, mandibular ganglion; *mx. g*, maxillary ganglion; G^1, G^2, succeeding thoracic ganglia. Other letters as in Fig. 7.
FIG. 9. *Distomum apodis* Pack. Amer. Naturalist, vol. xvi, p. 142, Feb., 1882. Side view, greatly enlarged. A parasite in oostegite of Apus lucasanus.
FIG. 9 *bis*. The same; ventral view.

Fig. 1 drawn from nature by J. S. Kingsley; Figs. 6–8 copied from Grube; the others drawn with the camera by the author.



Kingsley - Grube Packard, del. T. Sinclair & Son Lith.

ANATOMY OF APUS.

EXPLANATION OF PLATE XXXII.

FIG. 1. *Apus lucasanus* Pack. Section through the body, with the intestine removed *md*, mandible; *ant*[1], *ant*[2], 1st and 2d antennæ; *leg*[1], first pair of legs; *br.* flabellum; *ov*, ovary; *ng*, ganglionic chain.

FIG. 2. Transverse section through the body at the 7th or 8th pair of feet, the shell removed, *mus*, dorso-ventral adductors of the feet, crossed by the adductors of the exites; *ht*, heart; *int*, intestine; *ov*, ovary; *n. g*, ventral ganglion; *en*[1]–*en*[6], endites; *br*, gill; *fl*, flabellum; *x*, subapical lobe.

FIG. 2*a*, 1st antenna; 2*b*, 2d antenna; 2*c*, the extremity of 2d antenna, with 4 bead-like joints, showing the three imperfect joints, the third ending in a moniliform portion.

FIG. 3. Maxillipede with the gill (*br*) and single endite.

FIG. 4, 4*a*, dorsal and lateral view of the brain of the European *Apus cancriformis*; *br*, brain; *com*, commissure to subœsophageal ganglion; *g op*, optic ganglion; *oc*, ocellus; *oes*, end of œsophagus.

FIG. 5. Brain and part of ventral cord of *Apus cancriformis*; *oc*, nerve to ocelli; *ant*[1], *ant*[2], first and second antennal nerves; G[1], œsophageal; G[2], mandibular ganglion, sending off three mandibular nerves (*n md*); *d*, descending œsophageal nerve; *h*, unpaired or lower œsophageal ganglion; *oes*, nerve passing to the muscles of the œsophagus.

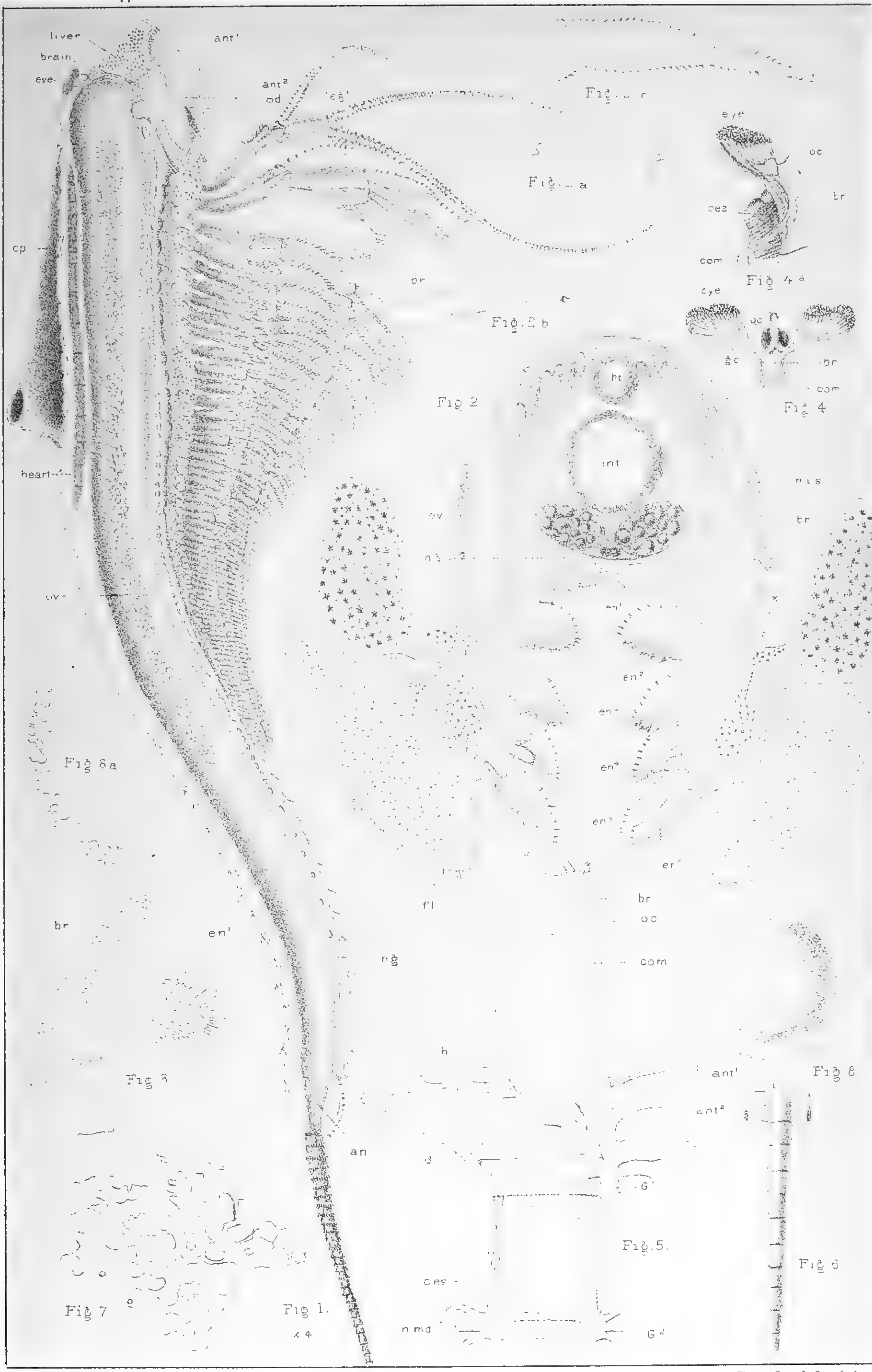
FIG. 6. Heart of *Apus cancriformis*.

FIG. 7. *Apus longicaudatus*, portion of embryonic membrane lying next to the chorion, and supposed to represent the amnion in Limulus; the nuclei in many of the cells have become absorbed.

FIG. 8. An egg of the same, showing the cellular nature of the amnion.

FIG. 8*a*. A portion of the same amnion seen sideways of the egg.

Fig. 1 drawn under the author's direction by J. S. Kingsley; Figs. 4, 4*a*, 5, and 6, copied from Zaddach; the remainder drawn with the camera by the author.



Kingsley Zaddach Packard, del.

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ANATOMY OF APUS.

EXPLANATION OF PLATE XXXIII.

FIG. 1. *Estheria mexicana* Claus (*Caldwelli*, from Kansas). Section through the shell, hinge, and body; *oes*, œsophagus; *oc*, larval eye or ocellus; *add, m*, adductor muscle of the valves; *md*, mandibles; *ov*, ovary; *gl*, liver

FIG. 2. The same, section through the stomach, showing the biliary ducts leading into the stomach from the convoluted liver lobules; *br*, brain.

FIG. 2*a*. Section through a biliary tube.

FIG. 3. Eye of *E. mexicana; c*, cones; *r*, rods.

FIG. 4. Oblique section through head of *E. mexicana; c*, cones; *ret*, retina.

FIG. 4*a*. Section of the œsophagus in Fig. 4, enlarged.

FIG. 5. Section through ganglia (*gang*) near but posterior to the maxillæ, and through the intestine (*int*).

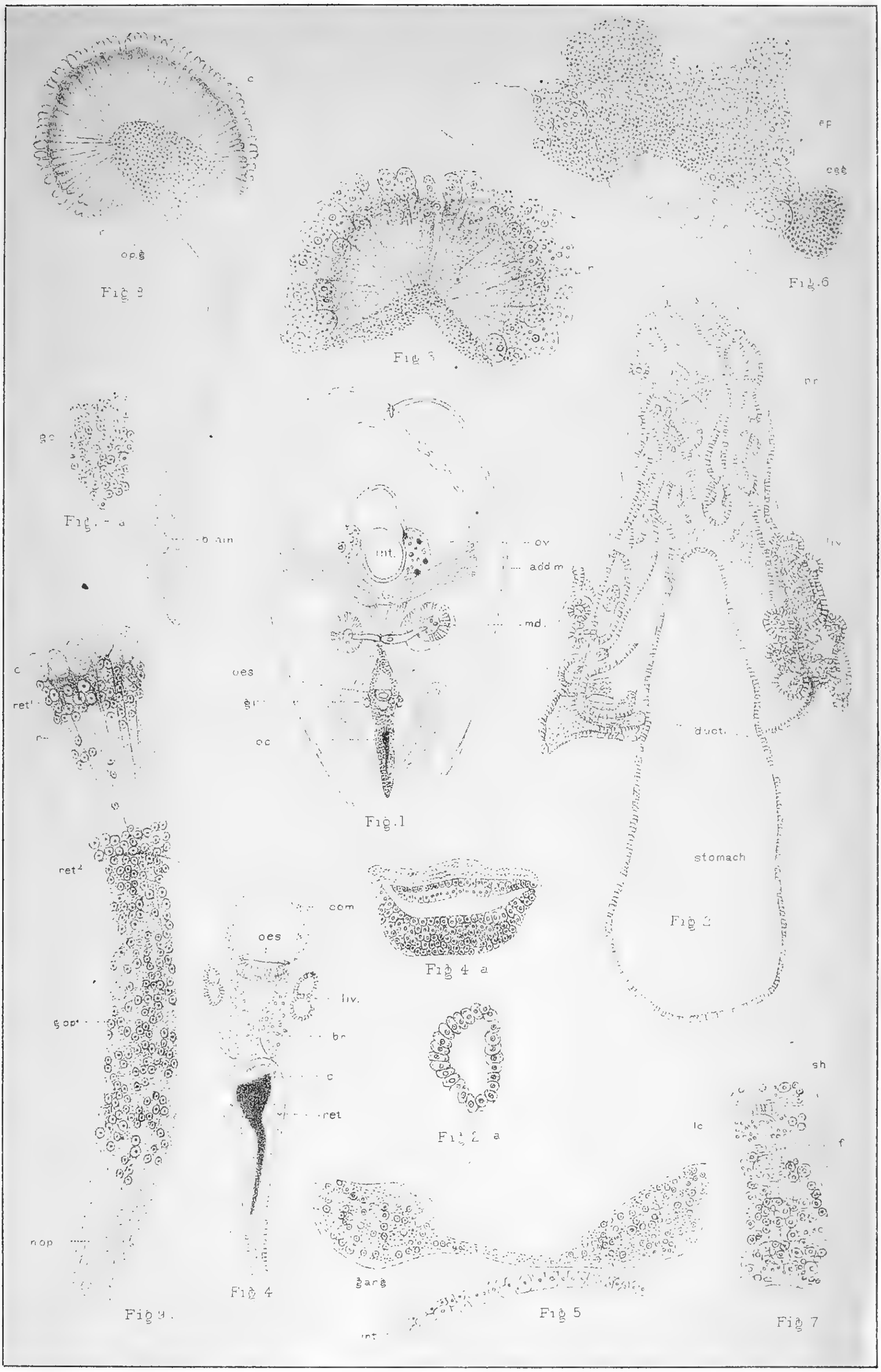
FIG. 6. *E. mexicana*, ovary; *ep*, epithelium.

FIG. 7. *E. mexicana*, section through the shell and hypodermis; *sh*, shell; *lc*, large secreting cells; *f*, fibers.

FIG. 8. *Branchipus vernalis* Verr. Section through the brain and eye, $\times \frac{1}{2}$ A; 8*a*, a portion from the middle of the brain, $\times \frac{1}{5}$ A.

FIG. 9. *Branchipus vernalis* Verr. Section through the eye; *c*, cones; ret^1, retina; ret^2, second retinal streak; *r*, rods; *g. opt*, optic ganglion; *n. op*, optic nerve.

Drawn by the author from sections made by Mr. N. N. Mason.



A. S. Packard, del. T. Sinclair & Son, Lith.

EXPLANATION OF PLATE XXXIV.

FIG. 1. *Streptocephalus texanus* Pack. Third developmental stage, dorsal view. Length 0.2^{mm}, *oc*, ocellus; *md*, mandibles; *mdp*, mandibular palpus; *sg*, shell gland; *m*, transverse muscle of the 2d antennæ; m^1, levator muscle of the labrum; m^2, rectal muscles; *int*, intestines; s^1, forked spine on 2d joint of 2d antennæ.

FIG. 1*a*. Union of the two muscles m^1 in Fig. 1.

FIG. 2. 2d antennæ seen from below. Larva 4.2^{mm} in length.

FIG. 3. 1st antennæ, 3d larval stage; *n*, antennal nerve; *mnc*, marginal nerve-cells; *sp. c*, bipolar spindle-shaped cells; *s*, setæ.

FIG. 4. 1st antennæ of larva when 3^{mm} in length; lettering as in Fig. 3; *gc*, terminal ganglion cells.

FIG. 5. 2d antennæ of larva 4^{mm} in length; s^1, s^2, spines of basal joints.

FIG. 6. Mouthparts of same larva as Fig. 5, and drawn to the same proportions; *md*, mandible; *mp*, mandibular palpus; mx^1, 1st maxilla; m^1p, 1st maxillary palpus; mx^2, 2d maxilla.

FIG. 7. The maxillæ (1st and 2d) of larva when 5^{mm} in length.

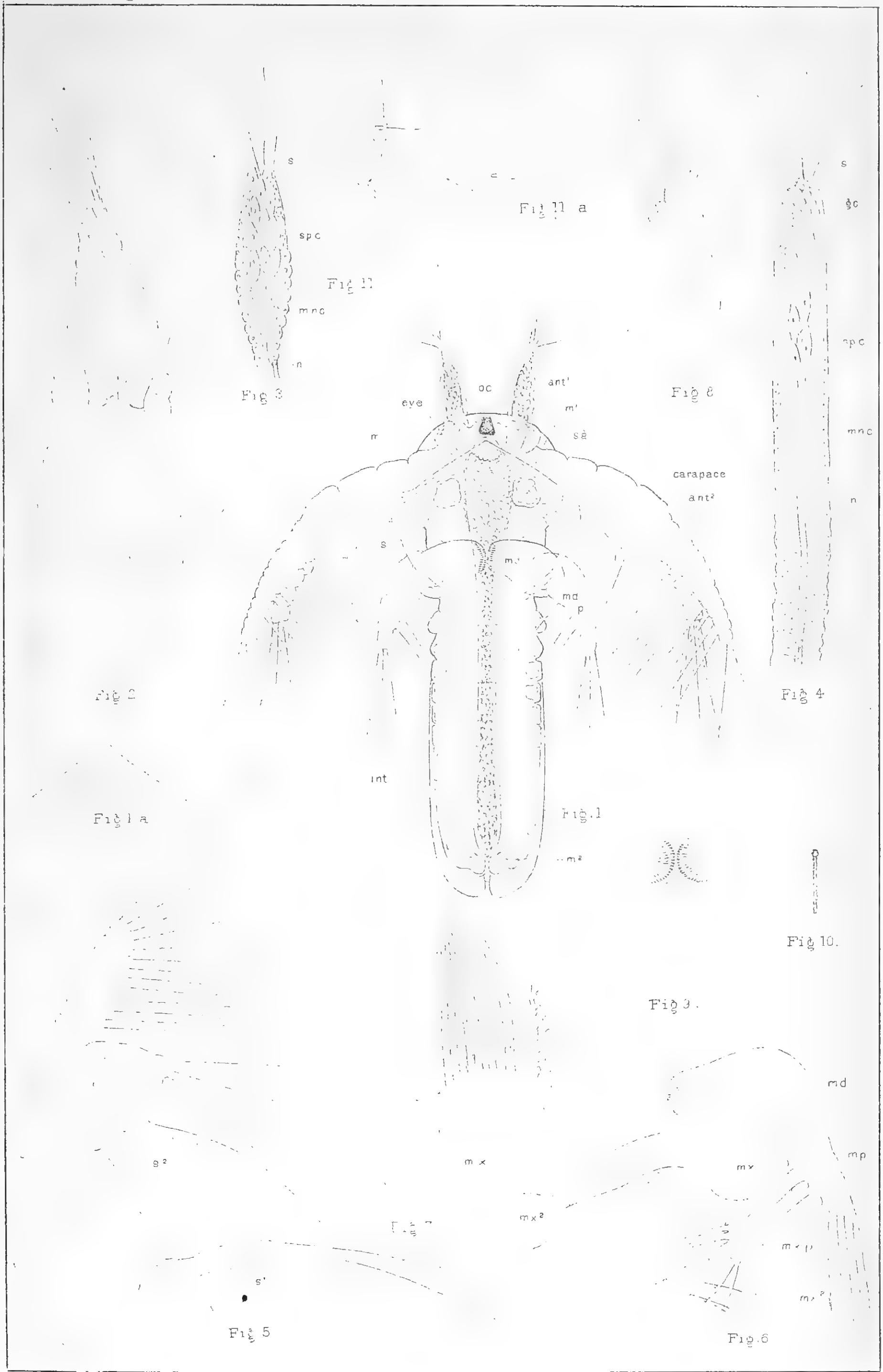
FIG. 8. *Chirocephalus holmani* Ryder (Glendale, L. I.), tip of 1st antennæ and olfactory seta.

FIG. 9. Mouth of larva of *S. texanus* when 5^{mm} in length.

FIG. 10. *Branchipus vernalis* Verrill. Olfactory seta.

FIG. 11. *Chirocephalus holmani* Ryder. Dorsal bristle of 3d segment, a little way from the articulation; Fig. 11*a*, the same on the 2d (genital) segment.

Note.—All the figures in this plate were drawn by C. F. Gissler, Ph. D.



C.F. Gissler, del.

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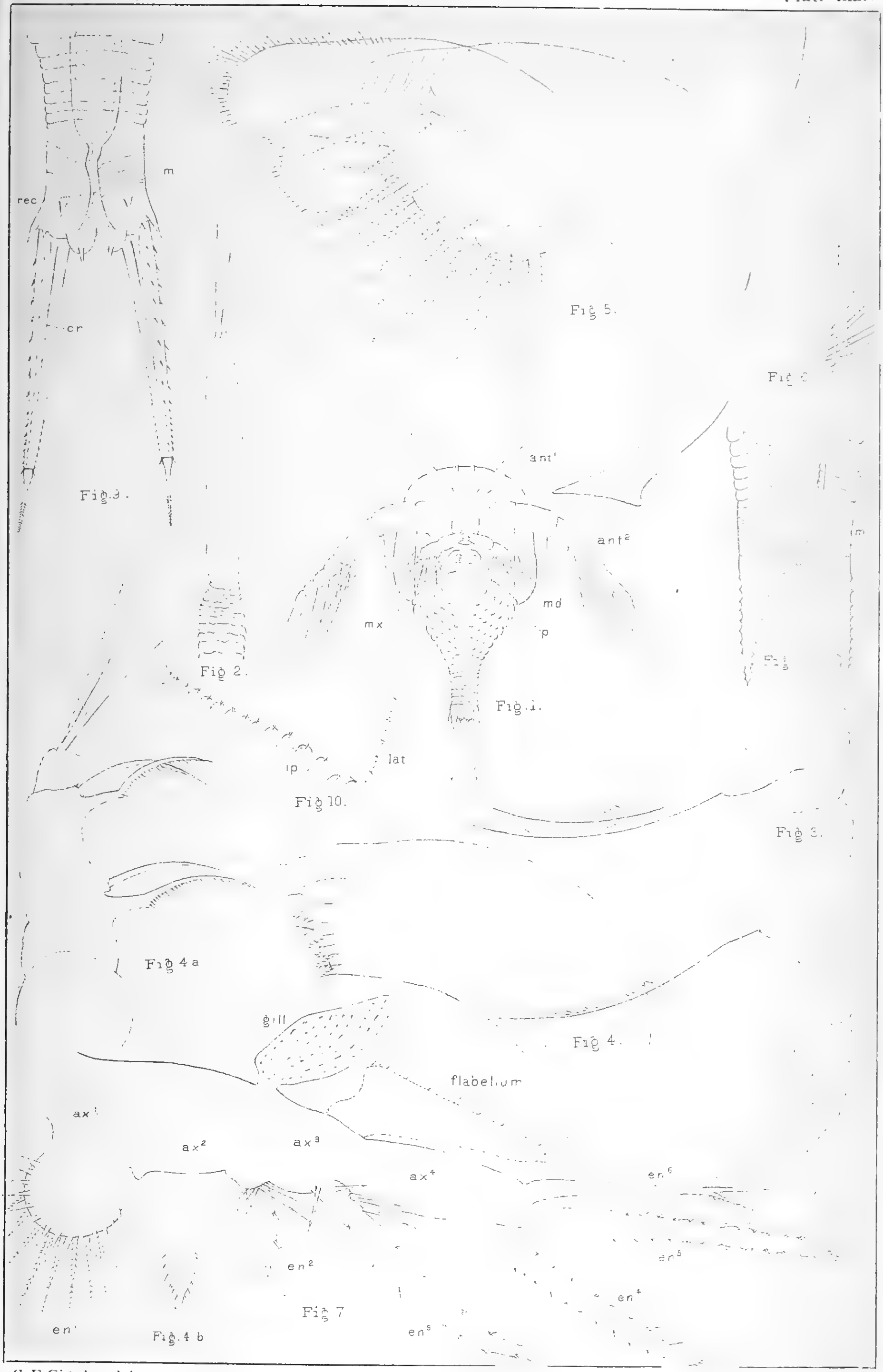
EXPLANATION OF PLATE XXXV.

FIG. 1. *Apus lucasanus* Pack., raised from mud from Kansas. Larva about 7^{mm} long.
FIG. 2. 1st antenna of larva 5^{mm} long,
FIG. 3. 2d antenna of *Eulimnadia texana* Pack.
FIG. 4. Mandible (left) of *Apus lucasanus* Pack.
FIG. 4*a*. Mandibular palpus of *Eulimnadia texana* Pack.
FIG. 4*b*. The last smallest tooth on the cutting edge of the mandible, enlarged.
FIG. 5. *Apus lucasanus;* 1st maxilla of larva 5^{mm} in length, with the maxillary lobes and the spinose portion.
FIG. 6. 2d maxilla of Fig. 5, drawn to the same scale.
FIG. 7. *Apus lucasanus;* 1st leg of male larva when 5^{mm} in length. en^1–en^6, endites 1–6. ax^1–ax^4, pseudo-joints of the axis of the limb; en^1, the gnathobase.
FIG. 8. *Apus lucasanus;* End of abdomen of larva 3–5^{mm} long.
FIG. 9. *Apus lucasanus;* End of abdomen of larva 1^{mm} in length. *rec*, rectum; *m*, sphincter muscles of anus; *cr*, chitinous rod.
FIG. 10. *Apus lucasanus;* Lower margin of shield of ♂ 5^{mm} in length; *lat*, lateral line becoming gradually obliterated; *ip*, inner posterior line.

Note.—All the figures on this plate were drawn by C. F. Gissler, Ph. D.



C. F. Gissler, del.

T. Sinclair & Son, lith. Phila.

EXPLANATION OF PLATE XXXVI.

FIG. 1. *Nebalia bipes* Kroyer; female, much enlarged.

FIG. 2. *Nebalia bipes* Kroyer; female, head; *ros*, rostrum; *car*, carapace; ant^1, 1st antenna, (1-5) five basal joints; *ex*, exopodite; *ed*, endopodite; ant^2, 2d antenna, with 1-3, three basal joints; pes^1, part of first pair of feet; *md*, mandible; mx^1, first maxilla; mx^2, second maxilla; *st*, stomach.

FIG. 3. The carapace flattened out to show relations of rostrum.

FIG. 4. Mandible, *md*, cutting edge; *p*, palpus.

FIG. 5. The two maxillæ; 1-4, the four lobes of the coxopodite.

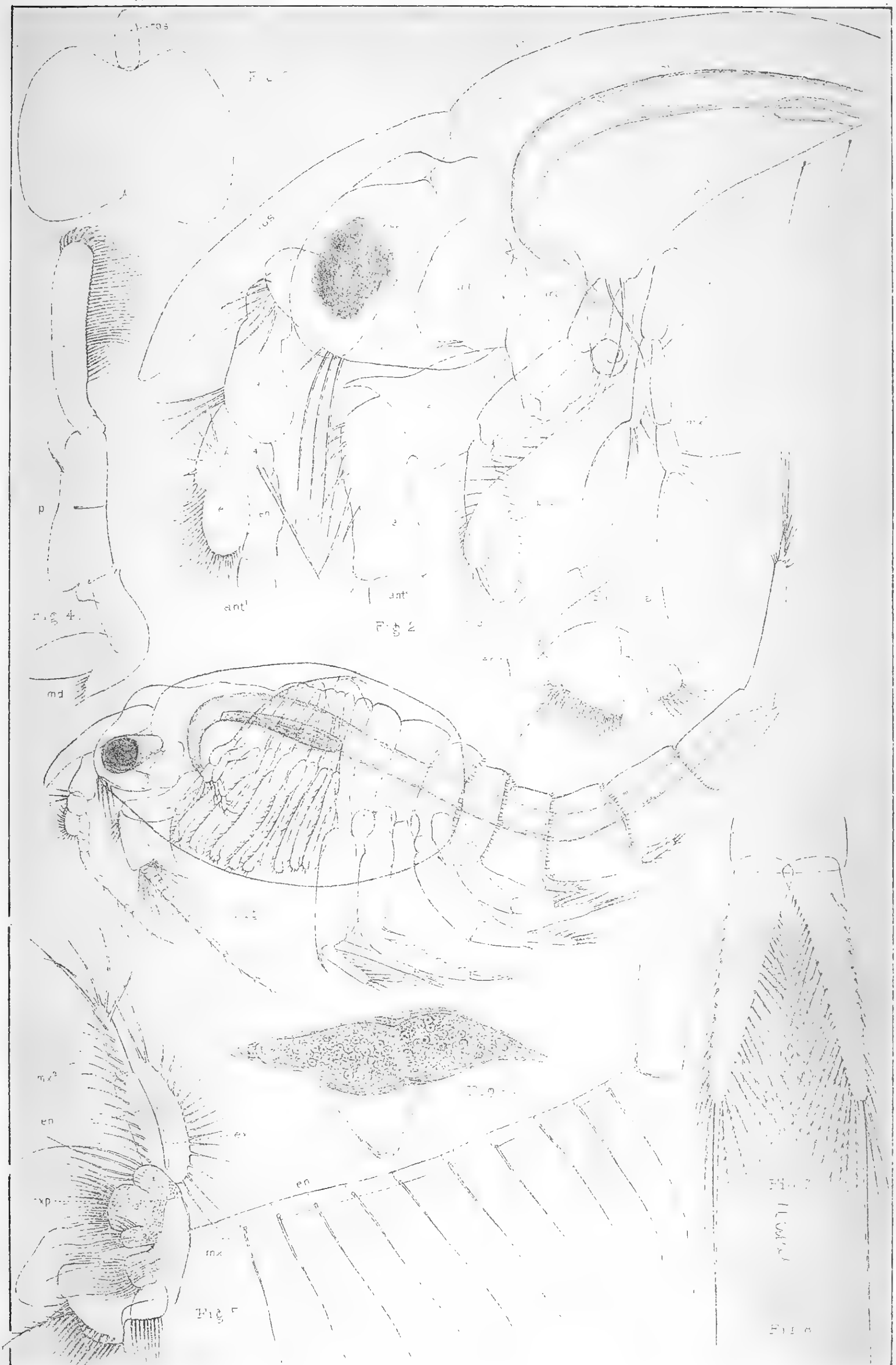
FIG. 5*a*. 1st maxilla; cx^1, cx^2, coxopodite; *en*, endopodite.

FIG. 6. (Omitted.)

FIG. 7. Cercopoda or caudal stylets.

FIG. 8. Portion of dentate edge of an abdominal segment.

FIG. 9. Section through a ventral ganglion. Author del.



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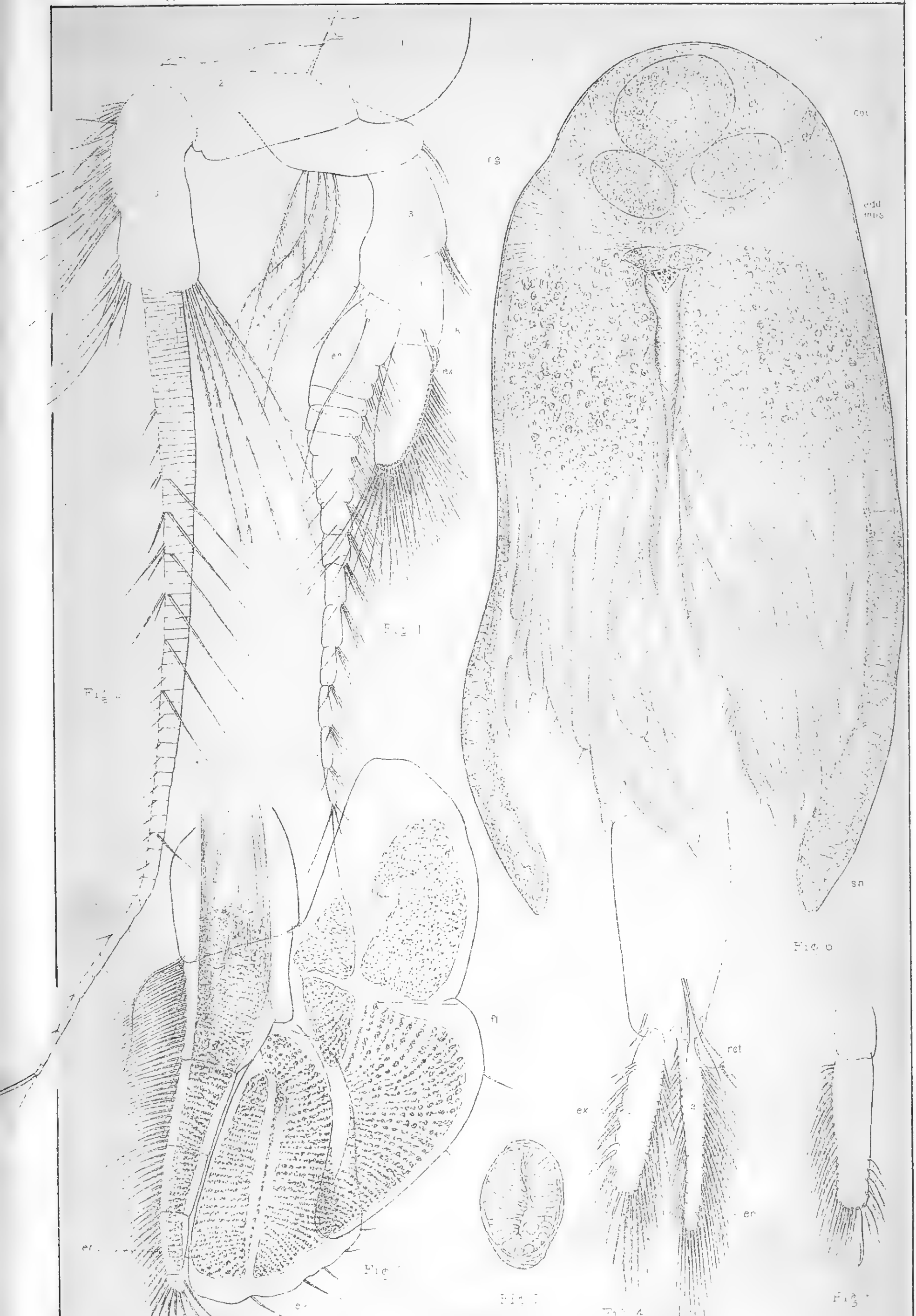
ANATOMY OF NEBALIA PIPES.

EXPLANATION OF PLATE XXXVII.

FIG. 1. *Nebalia bipes* Kr. ♀; 1st antenna; lettering as in Pl. 36; k, lobe from 4th joint.
FIG. 2. 2d antenna.
FIG. 3. One of the 3d or 4th pair of thoracic feet; *fl*, flabellum; *ex*, exopodite; *en*, endopodite.
FIG. 4. One of 2d pair of abdominal legs; *ret*, retinaculum; *en*, endopodite; *ex*, exopodite.
FIG. 5. One of the fifth pair of abdominal feet.
FIG. 6. Section through the body just behind the first pair of thoracic feet, through the stomach (*st*), and the two anterior cœca (*cœc*); *add. mus*, adductor muscle; *sh*, shell.
FIG. 7. Section through one of the cœca.



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ANATOMY OF NEBALIA PIPES

EXPLANATION OF PLATE XXXVIII.

Lettering.

a^1, first pair of antennæ.
a^2, second pair of antennæ.
md, mandibles.
mx^1, first pair of maxillæ.
mx^2, second pair of maxillæ.
pb', first pair of thoracic feet.
pb'', second pair of thoracic feet.
th. l, thoracic feet.
ab. f, abdominal feet.
œ, œsophagus.
ep, epithelium of stomach.
p. d, procephalic or antennal lobe.
st, stomach.

FIG. 1. Embryo of *Nebalia geoffroyi* in the Nauplius stage.
FIG. 2. The same, farther advanced, with the rudiments of the cephalic and first two thoracic appendages and the hind gut.
FIG. 3. The same, still more advanced, the biramous thoracic feet developed.
FIG. 4. Embryo of the same nearly ready to hatch.
FIG. 5. Embryo at the time of hatching.
Figs. 1–5 copied from Metschnikoff.
FIG. 6. Embryo of Schizopod *Pseudomma roseum*. Copied from Sars.

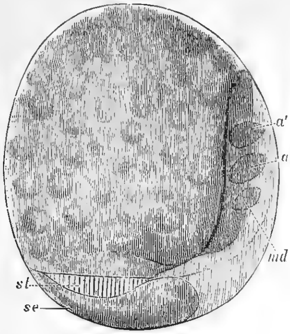


FIG. 1.

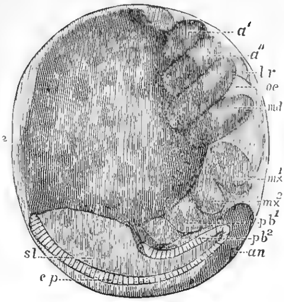


FIG. 2.

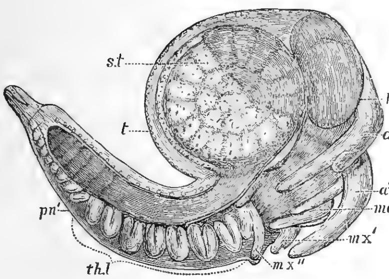


FIG. 3.

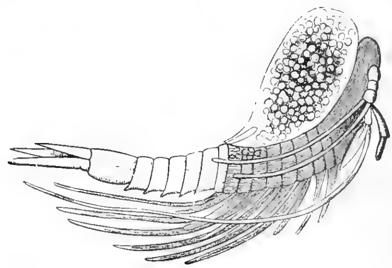


FIG. 6.

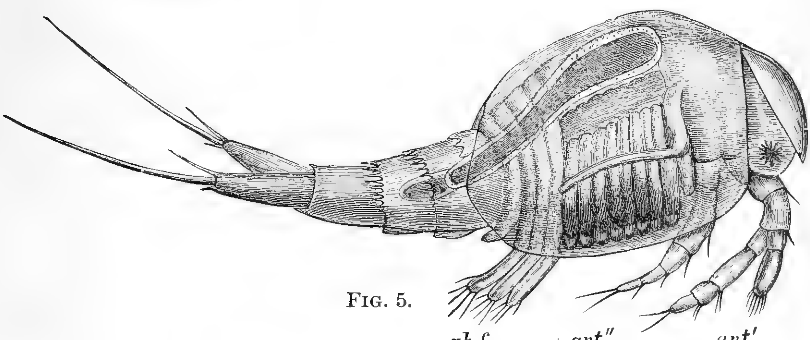


FIG. 5.

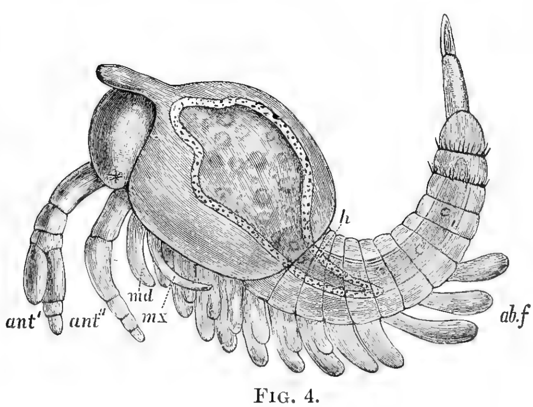


FIG. 4.

DEVELOPMENT OF NEBALIA.

EXPLANATION OF PLATE XXXIX.

FIG. 1. End of postabdomen with the furca of *Artemia salina* taken from the Kujalniker salt lake in spring, 1871, at 8° Beaumé, after an inundation.

FIG. 2. The same part of an *Artemia salina* taken in summer, 1872, at 14° Beaumé, from the Kujalniker salt lake.

FIGS. 3 and 4. The same parts of the already more changed *Art. salina*, taken from the same lake in summer, 1873, at 18° concentration.

FIG. 5. The same part of an Artemia forming a transition between *Art. salina* and *Art. milhausenii*. Taken from the same lake in the first half of August, 1874, at 23½° concentration.

FIG. 6. End of the postabdomen of an Artemia which I take for *Art. milhausenii*. Taken from the same lake in beginning of September, 1874, at 25° concentration, when salt began to deposit itself.

FIG. 7. One of the middle gills of *Art. salina*.

FIG. 8. One of the middle gills of *Art. milhausenii*.

FIG. 9. The lower part of the postabdomen of an *Art. salina* taken from the Hadschibei Lake at 10° concentration.

a, end of the sixth segment; *b*, seventh segment; *c*, long eighth segment with the furcal lobes; *d*, bristles occurring at the end of each segment before the articulation (but two have been drawn of each ring); *e*, the same bristles nearly in the middle of the eighth segment.

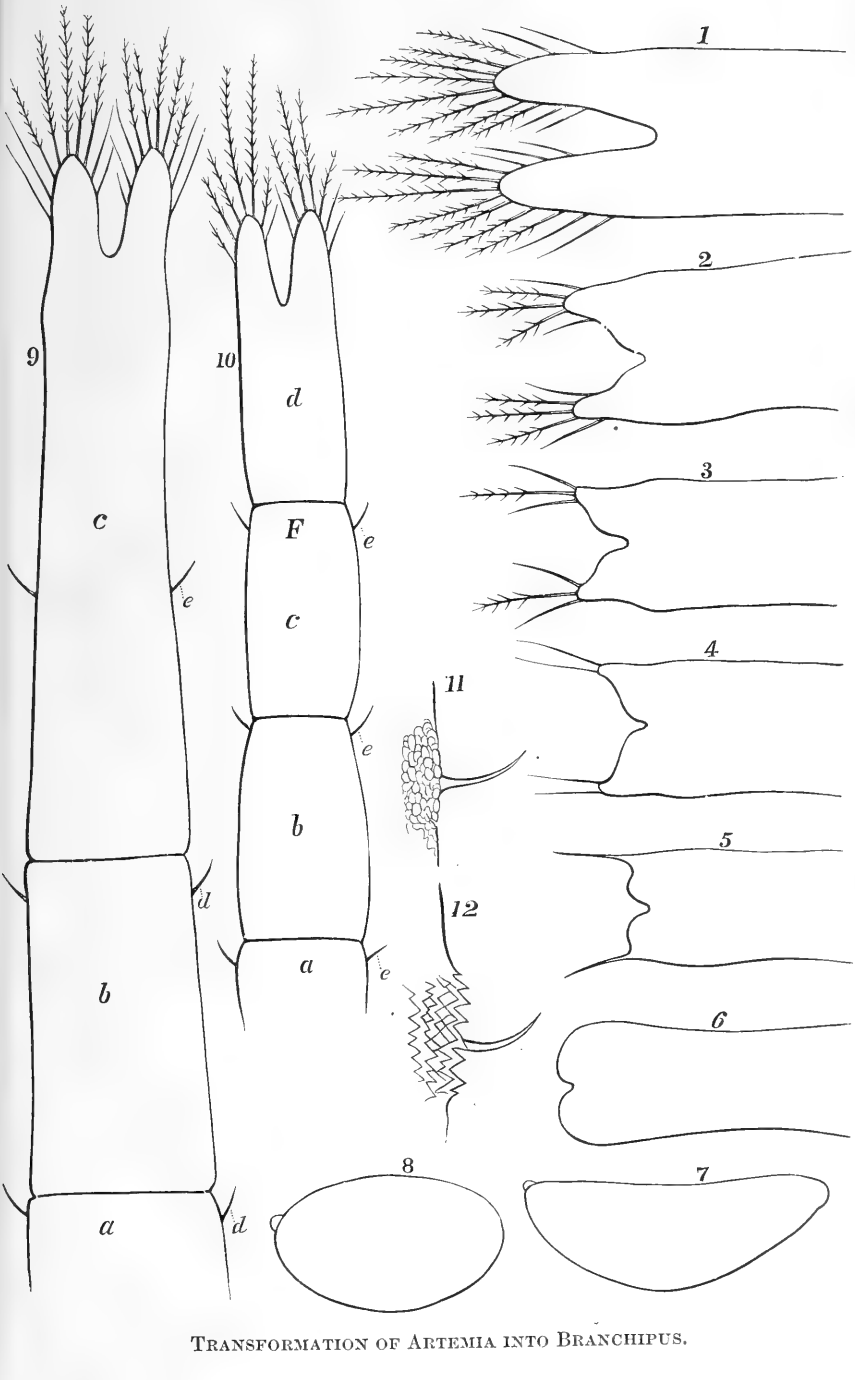
FIG. 10. The lower part of the postabdomen of a young specimen of the third generation of *Art. salina*, which was domesticated in gradually diluted salt water for the purpose of yielding progressive growth.

a, end of the sixth segment; *b*, seventh segment; *c*, eighth segment; *d*, ninth segment; *e*, two of the bristles from the bristle-ring occurring at the end of each segment before the articulation; *f*, spot where the long eighth segment divided into *two segments*, the eighth and ninth.

FIG. 11. A group of cuticular cells found near the base of the above-mentioned bristles of the postabdomen of *Art. salina*, whose lower part is illustrated by Fig. 9.

FIG. 12. A group of denticular spines found near the base of the bristles of the post abdomen of progressively changed individuals of *Art. salina*, whose lower part of the postabdomen is illustrated by Fig. 10.

Figs. 1 to 10 are 65 times, 11 and 12 are 330 times magnified. Copied from Schmankewitch.



TRANSFORMATION OF ARTEMIA INTO BRANCHIPUS.

INDEX.

PACKARD'S PHYLLOPOD CRUSTACEA.

A monograph of the phyllopod Crustacea of North America, with remarks on the order Phyllocarida. By A. S. Packard, Jun. Author's edition, extracted from the twelfth annual report of the U. S. geological and geographical survey. Washington, 1883. 298 p., 39 pl., map. 8°.

Although Professor Packard began publishing upon the Phyllopoda long ago, and has for several years been well known to be engaged upon a monograph of the North-American species, the bulk of the work just published, and the profusion of its illustrations, are a great surprise. It is the most extensive, and in many ways the most important, monographic contribution to American carcinology; and, however we may criticise the execution of the work, every student of the American fauna must feel grateful to the author for undertaking and accomplishing it.

The work is much more than a systematic monograph of North-American Phyllopoda, as the following table of contents will show: I. Classification of the living Phyllopoda, which includes the systematic description of the North-American species; II. Geological succession, including descriptions of the North-American fossil species; III. Geographical distribution; IV. Morphology and anatomy; V. Development, metamorphoses, and genealogy; VI. Miscellaneous notes on the reproductive habits of Branchipodidae, by Carl F. Gissler; VII. The order Phyllocarida, and its systematic position; VIII. Bibliography; Appendix, consisting of translations or abstracts by Gissler, of papers by C. T. von Siebold, on Artemia fertilis from Great Salt Lake, and on parthenogenesis in Artemia salina; and by Schmankewitsch, on the relation of Artemia salina to Artemia Muehlhausenii and to the genus Branchipus, and on the influence of external conditions of life upon the organization of animals. There is some confusion between the titles of the principal divisions, which are given above, and the table of contents in the work itself. Scarcely any of the titles are the same; and, in place of 'Miscellaneous notes on the reproductive habits of Branchipodidae,' we have, in the table of contents, 'Relation to their environment; habits,' — subjects nowhere treated under a separate heading; and all reference to the long appendix is omitted.

About a fourth of the entire work is devoted to the systematic account of the species and higher groups of Phyllopoda, regarded by Professor Packard as a sub-order of Branchiopoda, which is made to include Cladocera and Ostracoda also. The Phyllopoda are divided as follows into families and sub-families, which include the number of recognized North-American genera and species nearly as indicated: —

LIMNADIIDAE:
  Limnetinae (1 genus, 4 species).
  Estheriinae (3 genera, 11 species).
APODIDAE (2 genera, 9 species).
BRANCHIPODIDAE:
  Branchipodinae (5 genera, 12 species).
  Thamnocephalinae (1 genus, 1 species).

All the groups are described; nearly all the species are figured, many of them very fully; and important notes on variability and habits are given for some of the species. Artemia gracilis is treated more at length than any other species, and is made to include all the described North-American species; but, in regard to its relation to the European A. salina, there is certainly confusion, as the following paragraphs show.

"Upon comparing our species with the European, it is difficult to find good differential characters, as the portions of the body where specific differences would be expected to occur are liable to considerable variation. Upon comparing a number of females from Great Salt Lake with a number of females of the maleless generation from Trieste, Austria, received from Professor Siebold, there are really no differences of importance. Our A. gracilis (Verrill's fertilis) is slighter, with a smaller head; and perhaps the second antennae are a little slighter in build; I see no essential difference in the form of the ovisac, while the shape of the legs, especially the sixth endite, is essentially the same" (p. 331).

"On comparing a number of Salt Lake females with individuals of the same sex of the European Artemia salina, our species was found to be undoubtedly specifically distinct; the Utah specimens are slenderer, smaller, and the sixth endite of all the feet considerably slenderer and longer in proportion than in A. salina. The ovisacs were of the same proportion but slenderer, and the head is slighter and smaller in our American species" (p. 333).

Different conclusions on neighboring pages, in regard to the specific identity of closely allied forms, might be accounted for in a careless author; but differences like these in statements of observation betray inexplicable carelessness.

In the chapter on geological succession, a table of the geological and geographical distribution of the known fossil species is given, and also a diagram indicating the geological history of the orders of Crustacea, the sub-orders of Branchiopoda, and the families of Phyllopoda. It is said that this diagram "may also serve as a genealogical tree, showing the probable origin of the main divisions of the Crustacea:" but the genealogical part of the diagram consists simply of dotted lines connecting the points of first appearance in geological history of the Branchipodidae, Apodidae, and Cladocera, with the point of appearance of the Limnadiidae in the Silurian; the common stem from this point with the Ostracoda in the upper Laurentian; and the branchiopod stem thus formed, and continued to a hypothetical Protonauplius in the lower Laurentian, with the points of appearance of the Malacostraca, Phyllocarida, and Cirripedia. On what conceivable theory of evolution this would represent a possible, much less the probable, origin of the main divisions of the Crustacea, it is hard to imagine, and was probably not seriously considered by the author himself; for it is far less like a probable genealogical tree than the diagram on p. 448, illustrating the relations of the Phyllocarida to other Crustacea.

In the chapter on morphology and anatomy, Professor Packard discusses at length the morphology of the regions of the body and the appendages of Arthropoda in general, and of the crustacean limb in particular, and gives some account of the anatomy of the phyllopods, but adds very little to our previous knowledge of the anatomy of the group. The morphological discussion is an interesting contribution to the subject, and, with the numerous figures with which it is illustrated, will prove very useful, although most of the new nomenclature proposed for the regions of the body and appendages is very objectionable. Professor Packard says, "For the primary regions of the head (*sic*), the only scientific terms as yet in use are those proposed by Prof. J. O. Westwood, in Bate and Westwood's History of British sessile-eyed Crustacea (vol. i. p. 3). These are *cephalon* for the head, *pereion* for the thorax, and *pleon* for the abdomen; while the thoracic feet are termed *pereiopoda*, and the abdominal legs *pleopoda;* the three terminal pairs being called *uropoda*. As the names applied to the thorax and abdomen have no especial morphological significance, the Greek *περαιον*, simply meaning ulterior, and *πλεον*, more, we would suggest that the head be termed the *cephalosome*, the cephalic segments, *cephalomeres*, and the cephalic appendages in general, *protopoda*, the term 'cephalopoda' being otherwise in use. The thorax of insects and of most Crustacea might be designated the *baenosome* (*βαινο*, to walk, locomotion), and the thoracic appendages, *baenopoda*, the segments being called *baenomeres;* while *urosome* might be applied to the abdomen, the abdominal segments being called *uromeres*. Westwood's term *uropoda* might be extended so as to include all the abdominal appendages." If mere names of parts are to be rejected, simply for want of 'morphological significance,' the language of the morphologist would soon become a meaningless jargon, to which it is near enough already; but, even as to 'morphological significance,' there appears to be little choice between the new and old terms. Bate, when first proposing the terms 'pereion'[1] and 'pleon,' expressly states that he derives the terms from *περαιόω* ('*to walk about*') and *πλέω* (*navigo*). The proposed term 'protopoda' is quite as unfortunate as 'cephalopoda,' since 'protopodite' and 'protopod' are already in use for parts of crustacean appendages, the former even in the present work. The extension of the term 'uropoda' so as to make it synonymous with 'pleopoda' would also be unfortunate, since, as now employed, it is a very useful term to designate the modified caudal pleopoda, whether

[1] According to either Bate's or Packard's derivation, this would be more properly written *peraeon*, as has sometimes been done, or even *pereon*.

one, two, or three pairs.

In the chapter on development, metamorphoses, and genealogy, Professor Packard gives a short account of the nauplius form in Phyllopoda as an introduction to Dr. Gissler's interesting notes in the following chapter, and then briefly discusses the phylogeny of the group, in which he appears to find but one difficulty. He says, —

"The difficulty is (and this is a point apparently overlooked by Fritz Müller, Dohrn, Claus, and Balfour) to account for the origination of the phyllopods at all from any marine forms. The only explanation we can suggest, is that the phyllopods have arisen through Limnetis directly from some orginally marine cladocerous type like the marine forms now existing, such as Evadne. We imagine that when a permanent body of fresh water became established, as, for example, in perhaps early Silurian times, the marine forms carried into it in the egg-condition, possibly by birds or by high winds, hatched young, which, under favorable conditions, changed into Sida, Moina, and Daphnia-like forms."

Professor Packard appears to have overlooked the difficulty of the eggs of any marine cladocerous type of animals surviving a sudden transfer from salt to fresh water, and the absence of birds in the Silurian, which might well deter the boldest speculator from offering such an explanation; but when we consider that permanent bodies of fresh water were undoubtedly formed by the gradual freshening of bodies of salt water cut off from the ocean, and that such bodies of fresh water usually had outlets connecting them with the sea, it is not surprising that Fritz Müller, Dohrn, and others should overlook a difficulty which is no greater for Phyllopoda than for other groups of fresh-water animals.

In the chapter on his new order, Phyllocarida, and its systematic position, Professor Packard describes the anatomy and development of Nebalia, and discusses its fossil allies. The appendages of Nebalia bipes are described and fully figured, but on the internal anatomy very little that is new is given. The figures and text intended to elucidate the histology, like most of Professor Packard's similar work, leave much to be desired.

The bibliography consists of a hundred and thirty-eight titles, divided into four sections, — one for living and one for fossil Phyllopoda, and the same for Phyllocarida. The titles of many of the works referred to are omitted in the bibliography, which is evidently very incomplete; but its incompleteness is not so annoying as the entire want of system in its arrangement, and the frequency of typographical errors.

Typographical errors are very numerous in all parts of the work; and many of them cannot properly be charged to the proof-reader, who, however, ought to have corrected blunders like 'Yahresbericht' (several times) and 'zoogloical,' and the inexplicable punctuation of most of the bibliographical references in the systematic parts of the work. Errors due to careless writing or careless compiling are more common than purely typographical errors, and far more confusing. On p. 313 we have the following: "It is difficult to say whether this is a Limnadia or Estheria, as the description is too brief and inexact to enable us to determine the genus or species. It cannot be a Limnadia, and seems to approximate more closely to Estheria; though it cannot belong to that genus." On p. 335 it is said that 'Schmankevitch' found 'Branchinecta ferox (Fischer sp.)' transform by artificial means into Artemia; but in reality he found an Artemia change into a Branchinecta, or into what he considered a Branchipus. On p. 337, 'Labrador examples' are said to have been taken 'on the north side of Hamilton Inlet, Northern Greenland.' On pp. 313 and 314 the species of Estheriinae not recognizable are inserted between two species of Eulimnadia instead of at the end of the sub-family. Two paragraphs at the bottom of p. 349, under Streptocephalus Sealii, should have been placed under Chirocephalus Holmani, on p. 352. On pp. 356 to 358 the genus Leaia is inserted between two species of Estheria.

The plates, perhaps the most valuable part of the work, are nearly all lithographs from the establishment of Thomas Sinclair & son, and are apparently accurate representations of the original drawings. The general figures, mostly drawn by Emerton and Burgess, are excellent. The figures of details, drawn by the author, are not always so satisfactory: the figures of the appendages of Apus and Lepidurus, for example, are very rudely drawn, and badly arranged on the plates. Unfortunately, the amount of enlargement of scarcely any of the figures is given. S. I. Smith.

The specific distinctness of the American and European brine shrimps.

In Professor Smith's notice of our 'Monograph of phyllopod Crustacea,' he states, that, in the portion relating to the above subject, 'there is certainly confusion,' and quotes two paragraphs relating to the females alone, and finally remarks, "but differences like these in statements of observation betray inexplicable carelessness."

After quoting the two paragraphs relating to the *females alone*, it seems to us a careful critic would have also taken pains to have quoted the longer paragraph relating to the males, which directly follows the first paragraph quoted by our critic. To allow the two paragraphs relating to the females to be so widely separated was an oversight on the part of the author, who, however, thought that he had taken a good deal of pains to show the specific distinctness of the American and European species. Two sets of females from different localities, named by different persons, were examined at different times; and this explains how the two paragraphs became placed too far apart in the author's copy. It would have been better, of course, if the author had added a few words, and dogmatically stated that the two species were undoubtedly distinct. He preferred not to do, or omitted to do, this, but gave in considerable detail, and in as judicial a way as possible, the facts of the case. At first it was 'difficult to find good differential characters' between the females, and those found are but slight ones. The females of any of the species of Artemia, Branchinecta, or Branchipus, do not exhibit good specific characters; but the males do, as the author attempted to show. If the author failed in directness of statement on this subject, or led to any confusion in any one's mind, he sincerely regrets it: on the other hand, he doubts whether there were, in the case, reasons for the charge of 'inexplicable carelessness.'

The paragraph which Professor Smith would have done well to have quoted is the following one: —

"Upon comparing a good many males from Great Salt Lake with several, both stained with carmine and unstained, received from Cagliari, Sardinia, through Prof. J. McLeod of Ghent, the European A. salina is seen to be considerably stouter, the head wider, the eye-stalks longer and larger, and the eyes larger. The frontal button-like processes of the first joint of the claspers are nearly twice as large as in the American species, and a little more pointed, while the claspers themselves are larger and stouter. The legs and sixth endites are of about the same form. The most apparent difference is in the caudal appendages, or cercopods, which in A. salina are several times larger than in A. gracilis, being in the Sardinian specimens nearly three times as long and much larger than in our species. In this respect, the genus shows a close affinity to Branchinecta. However, in a lot of A. salina ♀ from Trieste, the cercopods are very much shorter than in the Sardinian females, and only a little longer than in our American specimens. These appendages do not differ in the two sexes."

A. S. PACKARD, Jun.