Memoirs of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. IX. No. 1.

# SELECTIONS
FROM
# EMBRYOLOGICAL MONOGRAPHS.

COMPILED BY

ALEXANDER AGASSIZ,
WALTER FAXON, AND E. L. MARK.

## I.—CRUSTACEA.

By WALTER, FAXON.

WITH FOURTEEN PLATES.

CAMBRIDGE:
Printed for the Museum.
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# NOTICE.

The present number of the Memoirs is the first of a series of "Selections from Embryological Monographs," which it is proposed to issue as Vol. IX. of the Memoirs of the Museum, so as to give to the student in an easily accessible form a more or less complete iconography of the embryology of each important group of the animal kingdom. This selection is not intended to be a hand-book, but rather an atlas to accompany any general work on the subject. The plates will be issued in parts, as fast as practicable, each part covering a somewhat limited field, and occasional appendices may be published to prevent the plates from becoming antiquated.

The quarto illustrations will be accompanied by a carefully prepared explanation, and by a bibliography, *in octavo*, to be made as complete as possible. The Bibliography (by Walter Faxon) which accompanies this number (Crustacea) has been published as No. 6 of Vol. IX. of the Bulletin of the Museum.

The parts devoted to Echinoderms, Acalephs, and Polyps are well advanced.

The phenomena connected with the fecundation and maturation of the egg, and the history of the formation of the embryonic layers, will be treated in a separate part, without regard to the systematic zoölogical connection of the observations.

A number of original drawings will be incorporated with these selections wherever they supplement published material.

The work was planned as early as 1873. I hoped then to publish it with the collaboration of Dr. A. S. Packard, Jr. Other duties prevented this plan from being carried out. In 1875, Professor John McCrady kindly consented to become my collaborator, but his removal from Cambridge stopped the undertaking in its earliest stages.

ALEXANDER AGASSIZ.

Museum of Comparative Zoölogy,
Cambridge, Mass., U. S. A.

July, 1882.

## PLATE I.

1 – 16. *Development of* PYCNOGONIDA. *Figures from* ANTON DOHRN, P. P. C. HOEK, *and* GEORGE HODGE.

*a b.* Abdomen.
*n.* Nerve-ganglion.
*o c.* Eye.
*r.* Proboscis.
*α.* Spine on first segment of first pair of appendages.
*β.* Rectum.

The Roman numerals indicate the appendages in their consecutive order.

1, 3 – 14, from Dohrn, Untersuchungen über Bau und Entwicklung der Arthropoden. 2. Ueber Entwicklung und Bau der Pycnogoniden. Jenaische Zeitschr., V., Taf. V., VI., 1870.

1. Egg of *Pycnogonum littorale* after cleavage. The nuclei are seen within the cleavage-spheres. Double egg-membrane.
2. Section of segmented egg of *Nymphon brevicaudatum*, hardened in absolute alcohol, and colored with picro-carmine. The protoplasm and deutoplasm have not yet separated, and the cleavage is total. Each segment has a nucleus. The faint lines within the segments denote the yolk particles, which appear as if vesicular, an appearance perhaps caused by the action of the alcohol. The egg is furnished with a distinct but very thin membrane. From Hoek, Report on the *Pycnogonida* of the Challenger Expedition, Pl. XIX. fig. 3, London, Edinburgh, and Dublin, 1881.
3. Egg of *Pycnogonum littorale* at a later stage than fig. 1. I, II, III, rudiments of anterior three pairs of appendages of embryo.
4. Embryo of the same, later stage. *r*, proboscis.
5. The same, later stage, profile view. *o c*, eye. *α*, spine arising from base of first pair of appendages.
6. Nearly fully developed embryo of the same, from ventral side.
7. Hatched larva of the same, ventral view. The protonymphon stage of Hoek. The anterior pair of appendages is chelate, and the two following pairs are furnished with a sharp terminal claw. The spine on the first pair of appendages emits a byssus-like thread secreted by a gland in the proximal segment of the appendage. This thread probably serves to fasten the larva to the ovigerous legs of the adult.
8. Eye of larva of *Achelia lævis.*
9. Intermediate stage between larva and adult of *Achelia lævis.* The three pairs of appendages of the larva have become much reduced, especially the second and third. The spine (*α*) on the mandible is disappearing. The fourth and fifth pairs of appendages (IV, V) are well developed, and behind them are seen the rudiments of the two remaining pairs (VI, VII) as lateral outgrowths of the body. The mouth at the end of the proboscis leads into an œsophagus provided with masticating apparatus (seen at the base of the proboscis in the figure). The intestine sending diverticula into the appendages is represented by heavy shading. *β*, rectum. *a b*, abdomen. $n^1 - n^4$, first to fourth sub-œsophageal nerve-ganglia.
10. The same, older. The proboscis has increased in size. The spine on the mandible has disappeared. The second pair of appendages has lost its claw. The third pair is reduced to a short stump, which develops again in the male into the ovigerous or accessory appendages. The sixth and seventh pairs have attained their complete form. $n^5$, fifth sub-œsophageal nerve-ganglion.
11. Second appendage (palpus) of adult male *Achelia lævis.*
12. Third appendage (ovigerous or accessory) of the same.
13. Second appendage of female.
14. Third appendage of the same.
15. Adult *Achelia lævis*, dorsal view. At the base of the palpi is seen the oculiferous tubercle bearing the eyes. From Hodge, List of the British Pycnogonoidea, with Descriptions of several new Species. Ann. Mag. Nat. Hist., [3.] XIII., Pl. XIII. fig. 12, 1864.
16. Adult *Nymphon gracile.* The three pairs of larval appendages are now represented by I (antennæ, pedipalpi, or mandibles, of authors), II (palpi), and III (ovigerous or accessory appendages). The anterior pair are innervated from the supra-œsophageal ganglion, and may be homologous with the antennæ of Crustacea. The second and following pairs receive nerves from the sub-œsophageal ganglia. The third pair of appendages serves, in the male, to carry the eggs. The nervous system is represented by the dotted lines. From Hoek, Ueber Pycnogoniden. Niederländisches Arch. Zool., III., Taf. XVI. fig. 18, 1877.

17 – 30. *Development of* TRILOBITA. *Figures from* JOACHIM BARRANDE, *Système Silurien du Centre de la Bohême*, I., Pl. VII., XXX., Prague et Paris, 1852.

*17 – 22. Sao hirsuta.*

17. Youngest stage. The body is unsegmented, the future thorax being only faintly indicated by transverse furrows in the hinder part of the median lobe, and by three pairs of minute lateral spines. The small upper figure shows the natural size of this stage, the figure on the right a profile view.
18. Later stage. The thorax is now clearly differentiated from the head, and consists of three ankylosed segments.
19. Older form. The hinder division of the body now consists of five ankylosed segments, with no division into thorax and pygidium.
20. Still later stage, signalized by the appearance of two *free* segments behind the head, which allow a demarkation to be now drawn between a thorax, composed of free segments, and a pygidium of ankylosed segments. As the trilobite develops, the thorax gains new segments at the expense of the temporary pygidium, until in the adult the thorax contains seventeen segments, the permanent pygidium being formed of two.
21. Stage with four free or thoracic segments, and three or four ankylosed (pygidium).
22. Stage with six free and three ankylosed segments.

23 – 30. *Trinucleus ornatus.*

23. Young stage, with head and pygidium, no thoracic segments. The pygidium shows traces of segmentation indicating two or three rings.
24. Older stage, with one thoracic segment. As development proceeds, new thoracic segments are interposed between the one last formed and the pygidium, until in the adult the thorax consists of six segments. These new thoracic segments are probably formed from the anterior part of the pygidium at the successive moults.
25. Stage with two thoracic segments.
26. Stage with three thoracic segments.
27. Stage with four thoracic segments.
28. Stage with five thoracic segments.
29. Smallest known individual with the full number (six) of thoracic segments. Natural size.
30. Fully grown adult.

# PLATE II.

*Development of* XIPHOSURA (*Limulus Polyphemus*). *Figures from* A. S. PACKARD, ANTON DOHRN, *and* ALEXANDER AGASSIZ.

*h.* Dorsal vessel.
*l.* Liver.
*m.* Mouth.
*mt.* Metastoma.
*n.* Nerve-cord.
*oc.* Compound eye.
*ocl.* Ocellus.
*a.* Inner egg-membrane.
VII. Seventh pair of appendages.
VIII. Eighth " "
IX. Ninth " "

1–17, 20, from Packard, Development of *Limulus Polyphemus.* Mem. Boston Soc. Nat. Hist., II., Pl. III.–V., 1872.

1. Spermatozoa, magnified about 400 diameters.
2. Early form of ovarian egg, magnified 130 diameters.
3. Embryo within the egg. *m,* mouth. *a,* inner egg-membrane, the "protoderm" or "amnion" of Packard, "chorion" of Dohrn. Outside the inner membrane is seen the outer egg-membrane, the "chorion" of Packard, "exochorion" of Dohrn. The rudiments of the six anterior pairs of appendages have appeared. The anterior pair of appendages of *Limulus,* as shown by A. Milne-Edwards and Packard, are innervated from the œsophageal commissure, and are probably homologous with the mandibles of Crustacea. Balfour, moreover, has shown that in the spiders the anterior pair of appendages (cheliceræ) in the embryo are innervated from a post-oral ganglion, and are equivalent to the mandibles of insects, rather than to the antennæ as commonly supposed. Around the edge of the oval germ is a thin ridge, destined to be the lower edge of the carapace.
4. The embryo in a later stage. Letters as before.
5. Older stage seen from below. The seventh and eighth pairs of appendages, VII, VIII, have appeared. Above the lower margin of the carapace are seen the indications of the somites, the sutures extending upward, but not reaching the dorsal side of the egg. The six anterior pairs of appendages have lengthened and become bent upon themselves.
6. Later stage of the embryo, viewed from the side. The body has now a decided ventral flexure. The ninth pair of appendages, IX, have made their appearance, the posterior division of the body has become clearly differentiated from the anterior portion, and its somites well marked. The six anterior pairs of appendages have become jointed. *l,* liver.
7. Rudimentary gills from an older individual.
8. Terminal part of sixth pair of appendages.
9. Dorsal view of the embryo just before hatching. Trilobitic stage. The egg-membrane, "amnion," (the outer, or "chorion" of Packard, having been cast off before this period,) is not represented in the figure. The egg is now .13 in. in diameter. The embryo has already undergone its first moult within the egg. *h,* dorsal vessel. *o c,* compound eye. *o c l,* ocellus. At an earlier period than that represented in this figure the ocelli are situate on the under side of the head, just in front of the mandibles. A little later they appear on the front edge of the carapace. By the expansion and extension of this edge they are finally brought to the upper side of the head, a little way from the front edge, as in the figure.
10. Ventral view of the same stage. *m t,* metastoma or lower lip. *n,* nerve cord.
11. Terminal portion of third pair of appendages. Same stage as the two preceding figures.
12. Newly hatched young, viewed from in front and above.
13. The same, viewed from behind and above.
14. Dorsal view of newly hatched young. The segmentation of the posterior division of the body has become obscured.
15. Ventral view of the same.
16. Seventh pair of appendages of larva, which form the operculum of the adult.
17. One of the eighth pair of appendages of larva, bearing the gills. The two-jointed inner ramus is distinctly formed.
18. Young at the time of hatching. From Dohrn, Untersuchungen uber Bau und Entwickelung der Arthropoden. 12. Zur Embryologie und Morphologie des *Limulus Polyphemus.* Jenaische Zeitschr., VI., Taf. XIV. fig. 4, 1871.
19. Larva, from a sketch by A. Agassiz, made at Naushon Island, Mass., Dec. 19, 1864. The line on the right of the figure indicates the natural length of the larva.
20. Larva after the first moult subsequent to hatching (about three weeks after hatching). It is now $\frac{1}{4}$ in. long. The spine has acquired a considerable length. The arrows indicate the course of the circulation as seen in the living larva, the feathered arrows denoting the arterial currents, the simple arrows the course of the venous blood. The dendritic outline in the head is the liver sending two lobes backward into the hinder part of the body alongside the dorsal vessel, which lies in the median line. The dorsal vessel, is furnished with seven pairs of venous openings. Below the dorsal vessel, indicated by the fine lines within it, the intestine is seen extending back toward the spine.

# PLATE III.

*Development of* Cirripedia. *Figures from* Fritz Müller, W. Lilljeborg, Charles Darwin, P. P. C. Hoek, Carl Claus, Alexander Agassiz, *and* C. Spence Bate.

| | | | |
|---|---|---|---|
| 1. | Dorsal spine. | *o v.* | Ovary. |
| 2. | Ventral spine. | *p c.* | Polar cell. |
| *a.* | Fold of blastoderm. | *p h.* | Posterior horn. |
| *a b.* | Abdomen. | *p p.* | Protoplasm. |
| *b.* | Fold of blastoderm. | *s.* | Spermatozoa ? |
| *b l.* | Blastoderm. | *t.* | Testis. |
| *c p.* | Carapace. | *v t.* | Yolk. |
| *c t.* | Embryonic cuticle. | $\alpha$. | Orifice of brood-cavity. |
| *d.* | Suctorial disk. | $\beta$ | Chitinous shield. |
| *d p.* | Deutoplasm. | $\gamma$. | Crown. |
| *f.* | Frontal sense-thread. | $\delta$. | Chitinous plate. |
| *f h.* | Frontal horn. | $\epsilon$. | Rootlike organs. |
| *g l.* | Gland at base of frontal horn. | $\zeta$. | Cleavage sphere. |
| *i.* | Intestine. | $\xi$. | Tail. |
| *lb.* | Labrum. | $\phi$. | Anterior part of adult *Peltogaster*. |
| *n c.* | Nucleus. | $\omega$. | Thorax. |
| *ocl.* | Ocellus. | | |

The Roman numerals denote the appendages of the body in their consecutive order.

1–7. Development of *Rhizocephala.*

1–6, from Müller, Die Rhizocephalen, eine neue Gruppe schmarotzender Kruster. Arch. Naturgesch., XXVIII., Taf. I., 1862 ; Die zweite Entwickelungstufe der Wurzelkrebse (*Rhizocephala*). Ibid., XXIX., Taf. III., fig. 1, 1863.

1. Egg from the brood-chamber of *Lernæodiscus Porcellanæ*, with four cleavage spheres. Magnified 90 diameters.
2. First larval stage, or nauplius, of the same, from below, magnified 180 diameters. *c p*, margin of carapace. *l b*, labrum. *o c l*, ocellus. *vt*, remains of the yolk. I, II, III, first, second, and third pairs of swimming-feet. There is no mouth at this stage. A pair of frontal sensory threads is present, although not represented in the figure.
3. Second or pupa stage in the development of the same. The dark oval body is the nauplius eye, now of extraordinary dimensions. Paired eyes are not present. The carapace has become folded together so as to enclose the body. The second and third pairs of appendages of the nauplius have been discarded, the first pair have become prehensile, adapted for the attachment of the larva, and six pairs of swimming-feet (VI–XI) are present on the thorax. $\xi$, posterior or abdominal part of the body, ending in a pair of two-jointed processes, each bearing two terminal setæ. The pupa attaches itself by the prehensile antennæ to the abdomen of its host, throwing out rootlike filaments which entwine about its intestine or ramify through its liver, drawing nourishment therefrom. The remaining appendages are cast off.
4. Adult, attached to the ventral side of the abdomen of a *Porcellana*. Slightly magnified.
5. A smaller specimen removed from its host, viewed from the ventral side, magnified 15 diameters. *o v*, ovary, *t*, testis. $\alpha$, orifice of the brood-chamber. $\beta$, chitinous shield. $\gamma$, crown.
6. The portion of the adult *Lernæodiscus* which lies within the *Porcellana*, magnified 25 diameters. *i*, intestine of the *Porcellana*. $\gamma$, crown. $\delta$, chitinous plate. $\epsilon$, rootlike processes growing about the intestine of the *Porcellana*.
7. Exuviæ of *Peltogaster sulcatus*, pupa stage, fixed by the prehensile antennæ (I) in the opening of the mantle of the adult, magnified 200 times. $\phi$, anterior end of adult *Peltogaster*. From Lilljeborg, Supplément au Mémoire sur les Genres *Liriope* et *Peltogaster* H. Rathke. Nova Acta Reg. Soc. Scient. Upsal. [3.] III., Pl. VIII. fig. 34, 1860.

8–12. Development of *Cryptophialus minutus*, from Darwin, A Monograph on the Subclass *Cirripedia*. *Balanidæ*, Pl. XXIV., London, 1854.

8. Oval embryo. 35 times the natural size.
9. Later stage. Two horns (I) are developed at the anterior part of the body, and one, representing the abdomen (*a b*), at the posterior end. On same scale as the last figure.
10. Later stage. The posterior horn has shrunk. The two anterior horns have approached each other on the future ventral surface and contain within them the prehensile antennæ of the later stage. At this stage the larvæ adhere by the tips of the anterior horns to the inner tunic of the sac of the parent. On same scale as the last figure.

11. Pupa stage, on four times the scale of three previous figures. In this stage it crawls freely about in the sac of the mother. I, prehensile antennæ with a disk-segment. There are no other appendages developed. *o c*, compound eye. The ventral surface between the sides of the carapace is formed of thin structureless membrane. On this surface, close to the posterior end, is a small orifice through which three pairs of bristles project, attached to a rudimentary abdomen. No mouth exists.

12. Adult male on same scale as the last figure. The prehensile antennæ now serve to fix the male, by a cement, to the female. *a*, orifice of sac.

13–25. Development of *Balanus*.

13–21. *Balanus balanoides*, from Hoek, Zur Entwickelungsgeschichte der Entomostraken. I. Embryologie von *Balanus*. Niederländisches Arch. Zool., III., Taf. III., IV., 1876.

13. Egg some time after fecundation. *p c*, polar cell? *s*, spermatozoa?

14. Later stage. The formative yolk (*p p*) has collected at the blunt pole of the egg and become sharply separated from the nutritive yolk (*d p*).

15. The formative yolk has divided into four cleavage products, which enclose a part of the nutritive yolk at the centre of the egg. *n c*, nucleus of one of the cleavage spheres. *ζ*, third cleavage sphere, the fourth being entirely concealed in the figure.

16. Optical section of the same at a later phase. The formative yolk (*b l*) has completely surrounded the nutritive yolk (*dp*), which has also split up into numerous parts. *a*, *b*, folds in the blastoderm which are the commencement of the formation of the appendages of the embryo.

17. More advanced stage from the dorsal side. The three nauplius appendages are seen. *c p*, dorsal shield or carapace. *c t*, cuticle shed by the embryo.

18. Embryo nearly ready to hatch. *l b*, labrum or proboscis. *o c l*, nauplius eye. *ω*, hinder extremity.

19. Nauplius larva, just escaped from the egg. *i*, intestine.

20. The same after the first moult. *f*, frontal sensory thread. The frontal horns of the carapace, and many of the setæ of the swimming appendages are shortened through a partial invagination.

21. The dorsal spine in the process of evagination.

22. *Balanus* larva from Naples before passing into the pupa stage, seen from below. I, anterior antenna. Through the transparent cuticle is seen the anterior appendage of the next stage, with the sucking-disk on the third segment whereby the pupa attaches itself. The mandibles of the adult are probably developed in the base of the third pair of nauplius appendages (III). IV, first pair of maxillæ. V, second pair of maxillæ. VI–XI, six pairs of thoracic biramous swimming-feet of the Cypris stage, corresponding to the five pairs of natatory feet of *Copepoda*, and the generative appendages of the following segment. *f h*, frontal horns of the carapace. *g l*, gland at base of frontal horn. This gland is connected with a hollow spine lying within the frontal horn, and its function is doubtful. *p h*, posterior horns of the carapace. *o c*, compound eye. 1, dorsal spine of abdomen. 2, ventral spine of abdomen. From Claus, Untersuchungen zur Erforschung der Genealogischen Grundlage des Crustaceen-Systems, Taf. XVI. fig. 1, Wien, 1876.

23. About the same stage of a *Balanus* from Newport, R. I., profile view. From a sketch by A. Agassiz, August 26, 1872.

24. Cypris stage of a *Balanus* from Newport, R. I., reared from the stage of Fig. 23, August 26, 1872, profile view. Median and paired eyes are present as before. The carapace has become a bivalve shell, the two valves united along their dorsal margin. The anterior antennæ are now furnished with a suctorial disk for attachment, in the centre of which is the opening of the duct of the antennary or cement gland. The second and third pairs of nauplius appendages have disappeared, unless a small papilla, the rudiment of the mandible of the adult, is a vestige of the third. The six posterior pairs of feet (VI–XI) have developed into long two-branched swimming-feet, replaced in the adult by the six pairs of cirrhi. *ξ*, abdominal portion of the body. From a sketch by A. Agassiz, August 26, 1872.

25. Anterior antenna of Cypris stage of *Balanus balanoides*. *d*, suctorial disk by means of which the larva attaches itself. From Bate, On the Development of the *Cirripedia*. Ann. Mag. Nat. Hist., [2.] VIII., Pl. VIII. fig. 18, 1851.

## PLATE IV.

| | | | |
|---|---|---|---|
| *a e n.* | Anterior hypoblast cell. | *p n* ♂. | Male pronucleus. |
| *a n.* | Anus. | *p n* ♀. | Female pronucleus. |
| *c e n.* | Central hypoblast cell. | *t.* | Testis. |
| *c r.* | Cirrhi. | *v d.* | Vas deferens. |
| *e c.* | Epiblast. | *v m.* | Vitelline membrane. |
| *g e n.* | Beginning of the genital system. | $\alpha$. | Frontal papilla. |
| *i.* | Intestine. | $\beta$. | Spiral canal. |
| *l b.* | Labrum. | $\gamma$. | Gland. |
| *l e n.* | Lateral cells, containing hypoblastic elements. | $\epsilon$. | Gland. |
| *m s.* | Cells containing the elements of the mesoblast. | $\varsigma$. | Tactile organ. |
| *m t.* | Metastoma or paragnathite. | $\eta$. | Cement gland. |
| *n.* | Nervous system. | $\vartheta$. | Receptaculum seminis. |
| *n'.* | Secondary supra-œsophageal nerve-ganglion. | $\lambda^1$. | Tergum. |
| *n c.* | Nucleus. | $\lambda^2$. | Scutum. |
| *o c.* | Eye. | $\lambda^3$. | Carina. |
| *o c l.* | Simple eye. | $\lambda^4$. | Carino-lateral compartment. |
| *o e s.* | Œsophagus. | $\lambda^5$. | Lateral compartment. |
| *o v d.* | Oviduct. | $\lambda^6$. | Rostrum. |
| *p c.* | Polar cell. | $\xi$. | Tail. |
| *p m s.* | Primitive mesoblast cell. | | |

The Roman numerals denote the appendages in their consecutive order. See explanation of Fig. 28, *infra*.

### 1 – 5. *Development of* CIRRIPEDIA, *continued. Figures from* ALEXANDER AGASSIZ *and* CARL CLAUS.

1 – 4. Stages in the development of a *Balanus* from Newport, R. I., reared in confinement directly from the larvæ represented on Pl. III. figs. 23, 24, and showing the metamorphosis of the free-swimming larva into the sessile adult. From drawings by A. Agassiz, August 29, 1872.

1. The bivalve shell of the Cypris stage is becoming split up through calcification into the compartments and opercular valves of the adult. *c r*, cirrhi, representing the swimming-feet of the Cypris stage.
2. Later stage, seen from above. The cirrhi are retracted within the shell.
3. Still older stage, side view. $\lambda^1$, tergum. $\lambda^2$, scutum.
4. Seen from above, cirrhi retracted within the operculum. $\lambda^1$, tergum. $\lambda^2$, scutum. Surrounding these opercular valves are seen the marginal compartments. $\lambda^3$, carina. $\lambda^4$, carino-lateral compartment. $\lambda^5$, lateral compartment. $\lambda^6$, rostrum.
5. Pupa stage of *Lepas fasciculata*. *o c l*, median eye. *o c*, paired eye. $\xi$, abdomen. I, prehensile antennæ. From Claus, Die Cypris-ähnliche Larve (Puppe) der Cirripedien. Schriften Gesellsch. Beförd. gesammt. Naturwissensch. Marburg, IX., Suppl. 5, Taf. I. fig. 2, 1869.

### 6 – 28. *Development of* COPEPODA. *Figures from* CARL CLAUS, ALEXANDER V. NORDMANN, *and* CARL GROBBEN.

6 – 13. *Achtheres percarum.* 6 – 11, 13, from Claus, Ueber den Bau und die Entwicklung von *Achtheres percarum*. Zeitschr. wissensch. Zool., XI., Taf. XXIII., XXIV., 1861.

6. Larva at the time it leaves the egg. Only the two anterior pairs of appendages of the typical nauplius are present (I, II), and both of them are simple and unsegmented. Beneath the cuticle may be seen the six following pairs of appendages: mandibles (III), maxillæ (IV), maxillipeds (V, VI), and two pairs of swimming-feet (VII, VIII), which become functional after the next moult. $\alpha$, frontal papilla, in which is the opening of the coiled canal, $\beta$. This is filled with a viscid secretion probably brought into play when the larva attaches itself to its host.
7. Mouth-parts under the cuticle of the same stage, seen from the side. The letters *l b* are in the place of the labrum. Directly below is seen one of the pair of protuberances which lie on each side of the labrum, followed by the mandibles (III), maxillæ (IV), and two pairs of maxillipeds (V, VI).
8. Hinder part of the body of same stage, the cuticle having been removed so as to expose the swimming-feet and the caudal fork.

9. Larva after first ecdysis, about twelve hours after leaving the egg. Cyclops stage. The larva now has a large dorsal shield and four free posterior segments. Eight pairs of appendages are present, two pairs of antennæ (the second pair two-branched), mandibles, maxillæ, two pairs of maxillipeds, and three pairs of swimming-feet. The longer branch of the second antennæ is furnished with a claw for fixing the larva. The two pairs of maxillipeds (V, VI) are said by Claus to be developed as two branches of one appendage, representing the second maxillæ of the higher Crustacea. The three pairs of swimming-feet are then probably homologous with the three pairs of maxillipeds of Decapoda. The first free segment of the body carries the second pair of swimming-feet. *o c l*, ocellus. *γ*, glands lying on each side of the eye.

10. Mouth-parts of the same stage, magnified 400 times. The mouth is situated at the end of a sort of proboscis formed by the prolongation of the labrum, *l b*, and the lower lip. The mandibles (III) are small, and the maxillæ (IV) are small and furnished with a palp.

11. Later stage of male larva, already parasitic on the perch. The posterior segmented part of the body has acquired a new segment at the expense of the anterior unsegmented portion. The swimming-feet have disappeared as well as the spiral duct, although a remnant of the frontal papilla (*α*) persists. The outer maxillipeds (V) have become united at their ends, whence a long rod (*δ*) projects, which attaches the young animal to its host. *i*, intestine. *n*, nerve. *t*, testis. *v d*, vas deferens. *ε*, gland near the end of vas deferens.

12. Adult male, lateral view. The outer maxillipeds separate again. From v. Nordmann, Mikrographische Beiträge zur Naturgeschichte der wirbellosen Thiere, Zweites Heft, Taf. V. fig. 2, Berlin, 1832.

13. Sexually mature female, seen from below. Natural length, $3^{mm}$. The female is five times as long as the male. The outer maxillipeds remain fused and develop a sucking-disk. *o v d*, oviduct. *ζ*, tactile organ. *η*, cement gland (part of the female sexual apparatus, opening into the oviduct near the genital orifice). *ϑ*, receptaculum seminis.

14–29. *Cetochilus septentrionalis*, from Grobben, Die Entwicklungsgeschichte von *Cetochilus septentrionalis* Goodsir. Arbeiten Zoolog. Inst. Univ. Wien, III., Taf. XIX.–XXII., 1881.

14. Egg before the first cleavage, in optical section. Natural size, $.17^{mm}$ diameter. The protoplasm and deutoplasm are evenly distributed, and the egg is colorless. *v m*, vitelline membrane, a product of the yolk. *p c*, second polar cell, the first usually being formed before the vitelline membrane, and hence escaping from the egg. *p n* ♀, female pronucleus. *p n* ♂, male pronucleus. The exact origin of the polar cells was not traced in this case, but there seems little reason to doubt Grobben's interpretation of the structures as above given.

15. After the union of the male and female pronuclei, the resulting cleavage nucleus lies excentrically nearer the animal pole of the egg, as indicated by the polar cell. A total meridional cleavage is followed by an equatorial cleft, and four cleavage-spheres are formed, as shown in the figure. *n c*, nucleus of one of the cleavage-spheres. At the core of the egg a small segmentation-cavity is already observable. The next cleavage is meridional, and the resultant eight-celled stage passes by equatorial cleavage into a sixteen-celled phase. The enclosed segmentation-cavity has now enlarged, and become the receptacle for the deutoplasm ejected from the yolk. The polar cell now becomes involved with the cleavage products and pressed into the interior of the egg.

16. The next cleavage is in a plane perpendicular to the preceding, and thirty-two cells are thus formed. A period of rest of several hours' duration ensues before the cleavage is carried further. At this stage a differentiation appears among the constituent cells. In the two previous figures, the egg was seen from the side. In this figure, the egg is turned so that the ventral side is toward the reader. It is now seen that one of the ventrally situated cells has divided into two unequal parts, a small cell (*a e n*) and a large one (*c e n*), the other cells being arranged bilaterally with reference to them. The central larger cell (*c e n*) is prominent on account of the greater amount of deutoplasmic elements and coarsely granulated protoplasm. From this cell are formed later the central portion of the hypoblast. From the subsequent development, it appears that the smaller cell (*a e n*), too, is a hypoblast cell. The four cells (*l e n*) lying on each side of the larger and smaller cells, contain hypoblastic and epiblastic elements. The cell (*m s*) in the median line behind the central hypoblast cell contains, besides epiblastic elements, all the elements of the mesoblast.

17. Optical section of a later stage, lateral view. The polar cell (*p c*) has been pressed in between the cleavage cells into the cleavage cavity. All the cells take part in bounding this cavity, excepting the small anterior hypoblast cell (*a e n*). In one of the cells at the upper left hand is seen a nuclear amphiaster preliminary to the division of the cell.

18. Later stage. The cleavage has now proceeded much further. The central hypoblast cell (*c e n*) is divided into two. The four lateral are in the process of division, and of the resulting cells those lying near the central hypoblast cells and marked *l e n* in the figure, together with the central (*c e n*) and small anterior cell (*a e n*), go to form the hypoblast, while the rest of the cells formed from the lateral cells belong to the epiblast. From the division of the cell marked *m s* in Fig. 16, we now have four cells. The two larger, anterior (*p m s*), contain all the elements of the mesoblast, and are called the primitive mesoblast cells. The two smaller, posterior, are epiblast cells. The anterior hypoblast cell (*a e n*) alone is undivided. All three germinal layers are now formed, and show a bilateral arrangement. In the next stage the central hypoblast cells are divided by a transverse cleft into four. The primitive mesoblast cells have also divided, so that there are four cells in this layer.

19. The mesoblast cells now retreat from the periphery of the egg into the cleavage cavity. The hypoblastic cells also sink in toward the centre, and the formation of a gastrula is thereby brought about. The figure shows the gastrula stage in horizontal optical section.

20. Gastrula at a somewhat earlier stage, in longitudinal optical section. Owing to the small size of the cleavage cavity, and the large size of the hypoblast cells, the gastrulation is slow and difficult. When the (now eight) lateral and anterior hypoblast cells begin to sink, the four central hypoblast cells also sink a little, but as the former sink deeper, they compress the latter in such a way that they present the appearance shown in the figure. *e c*, epiblast.

21. Gastrula seen from the side. The epiblast is seen in optical section. *g m*, gastrula mouth.

22. Later stage. The gastrula mouth is closing up. Later it disappears entirely. That this side answers to the later ventral side is highly probable.

23. Stage when the second pair of antennæ, II (the first appendages to appear), have begun to appear. Optical cross-section. The other two pairs of nauplius appendages soon follow. The œsophagus of the nauplius arises from an invagination of the epiblast.

24. Nauplius just hatched, seen from below. The intestine (*i*) as yet has no anal opening. Under the bilaterally disposed ectoderm cells, at the posterior extremity of the body, are seen the primitive mesoblast cells (*p m s*). From these are developed the mesodermic structures of the later-formed somites. The duration of the egg-development is about twenty-four hours.

NOTE.—In the nauplius of *Cyclops serrulatus* and *Ergasilus Sieboldi*, Grobben detected the presence of a dorsal organ equivalent to that in *Phyllopoda*, &c. See Arbeiten Zoolog. Inst. Wien, II, p. 262, Taf. XVI. figs. 61, 62, 1879.

25. Later stage, lateral view. In the posterior part of the body, the rudiment of the genital system (*g e n*) has already appeared. The intestine is now furnished with an anus (*a n*).

26. A little older metanauplius larva, lateral view. The fourth pair of appendages (maxillæ) have appeared. *n*, brain. *n′*, secondary brain, a thickening of the ectoderm, interpreted by Grobben as a rudimentary organ representing the compound eyes of *Phyllopoda* and their ganglia, which do not develop further in the *Copepoda*.

27. Anterior portion of the same stage, seen from below. *o e s*, œsophagus. *o c l*, eye.

28. A little older metanauplius than that represented by Fig. 26, from below. The anterior and posterior maxillipeds (V, VI) have now made their appearance, as well as the first pair of swimming-feet (VII). Under the cuticle is also seen the second pair of swimming-feet (VIII), which become free at the next moult. According to Claus and Grobben the so-called two pairs of maxillipeds of *Copepoda* really represent but one pair of appendages, the anterior pair being the outer branches, the posterior pair the inner branches. Both together will then represent the second pair of maxillæ of other Crustacea, and the first pair of swimming-feet will be the homologue of the first maxillipeds of *Decapoda*. Assuming this view to be correct, the reader must bear in mind that, in the figures of *Copepoda* on this plate, the Roman numerals higher than V must be lessened by one.

29. First Cetochilus stage, from ventral side. The third pair of swimming-feet (IX) has appeared. *m t*, metastoma or paragnathite. At subsequent moults, new thoracic segments and appendages are developed, until the adult state is attained.

## PLATE V.

| | | | |
|---|---|---|---|
| *a.* | Anus. | *o v.* | Ovary. |
| *b r.* | Gill. | *p c.* | Polar cell ? |
| *dp.* | Deutoplasm. | *s t.* | Stomach. |
| *e p.* | Epiblast. | *v m.* | Egg membrane. |
| *g e n.* | Genital cells. | α. | Adductor muscle of the shell. |
| *g m.* | Gastrula mouth. | β. | Antennary muscle. |
| *h.* | Heart. | γ. | Shell gland. |
| *hy.* | Hypoblast. | δ. | Muscular impression. |
| *i.* | Intestine. | ε. | Chitinous support of the caudal fork. |
| *l.* | Liver. | ζ. | Threads (nervous ?) connected with the setæ of the shell. |
| *l b.* | Labrum. | η. | Cephalic plate. |
| *m.* | Mouth. | ϑ. | Maxillary somite. |
| *m s.* | Mesoblast. | ι. | Rudiment of sensory seta. |
| *m t.* | Metastoma. | κ. | Shell. |
| *n'.* | Primary brain. | λ. | Dorsal organ. |
| *n''.* | Secondary brain. | μ. | Inner membrane of fold over the eye. |
| *o c.* | Compound eye. | ν. | Seta. |
| *o c l.* | Simple eye. | ν'. | Olfactory setæ. |
| *o e s.* | Œsophagus. | ξ. | Caudal fork. |

The Roman numerals denote the appendages of the body in their consecutive order.

1 – 12. *Development of* OSTRACODA (*Cypris*). *Figures from* CARL CLAUS, Beiträge zur Kenntniss der Ostracoden. I. Entwickelungsgeschichte von *Cypris*. Schriften Gesellsch. Beförd. gesammt. Naturwissensch. Marburg, IX., Taf. I., II., 1868.

1. First larval (nauplius) stage of *Cypris ovum*. Differs from the typical nauplius form in having a bivalve shell, and in the second and third pairs of appendages not being biramous. **α**, adductor muscle of the shell. **β**, antennary muscle. *s t*, stomach. *i*, intestine.
2. Third appendage of the same stage, locomotive in function. At its base is seen the rudiment of the future mandible. The appendage terminates in a hooklike seta.
3. Second stage of *Cypris fasciata*. Two new pairs of appendages have appeared, viz. the first pair of maxillæ (IV) and the first pair of feet (VI). The fifth pair of appendages (second maxillæ, "maxillipeds" of some authors) are not developed till later. The first pair of feet (VI) bear a terminal claw for adhering. The masticatory part of the mandible (III) is well developed. III', mandibular palpus. *m t*, metastoma.
4. Third stage of *Cypris fasciata*. V, rudiment of second maxilla. The first maxilla (IV) has acquired its large setose appendage (IV').
5. Fourth stage of *Cypris fasciata*.
6. Fifth stage of the same. The second maxillæ (V) have developed into ambulatory appendages, terminated by a hook similar to that borne during the previous stages by the sixth pair of appendages. The latter have lost their hook. **γ**, shell gland. *l*, liver. **δ**, muscular impression on the shell.
7. Second maxilla (V), first foot (VI), and caudal fork (ξ) of the same stage.
8. Sixth stage of the same. All the appendages of the adult are now present, the second pair of feet (VII) having appeared. The second maxillæ (V) are beginning to lose their ambulatory function, and become converted into masticatory organs through the enlargement of their cutting blades and reduction of the palp. The hook at the end of these appendages has disappeared, and one reappears at the end of the first pair of feet (VI). **ξ**, abdomen or caudal fork. **ε**, chitinous support of the caudal fork.
9. First foot of the same, sixth stage.
10. Caudal fork of the same, sixth stage.
11. Seventh stage of the same. All the appendages have practically acquired their permanent form. I, first antenna. II, second antenna. II', basal segment of second antenna. III, mandible with four-jointed palpus. IV, first maxilla with gill-plate. V, second maxilla with jaw-process and leg-like palpus. At the base of the latter there is a small gill-plate, not seen in the figure. VI, first leg. VII, second leg. Both pairs of legs are now jointed. *o v*, rudiment of the ovary.
12. Adult female of the same. **ζ**, network composed of groups of cells from which fine threads proceed to the setæ of the cuticle.

The marine genera of *Ostracoda* have an abbreviated metamorphosis.

13 – 24. *Development of* CLADOCERA. *Figures from* CARL GROBBEN *and* G. O. SARS.

13 - 22. Development of the summer egg of *Moina rectirostris*. From Grobben, Die Entwickelungsgeschichte der *Moina rectirostris*. Arbeiten Zoolog. Inst. Univ. Wien, II., Taf. XI. - XIV., 1879.

The summer eggs are parthenogenetically developed within the brood-cavity of the parent.

13. Egg during the cleavage process. The cleavage is superficial. *p c*, a body supposed to be a polar cell, although its origin from the germinative vesicle was not ascertained. It is present at the time the egg is laid.

14. Gastrula stage in longitudinal optical section. *g m*, gastrula invagination. The gastrula mouth seems to close completely at a later stage. *h y*, hypoblast. *e p*, epiblast. *m s*, mesoblast. The mesoblastic cells are withdrawn from the surface of the blastosphere into the interior just before the gastrula invagination takes place. *g e n*, two of the four cells which subsequently are split into eight and pass into the interior of the embryo, take a position under the hypoblast, and develop into the genital organs. These genital cells were distinguishable before the cleavage was completed. *d p*, deutoplasm. $\eta$, cephalic plate, from which the supra-œsophageal ganglion and eye are developed.

15. Embryo in the nauplius stage, ventral view. I, anterior antennæ. II, posterior antennæ. These first appeared in an earlier stage as simple buds, before the first and third pairs of appendages began to form. They are now two-branched. III, Mandible. The mouth (*m*) and œsophagus (*o e s*) are forming from an invagination of the epiblast. The œsophagus is short and abuts blindly against the intestine (*i*).

16. Later stage, ventral view. Behind the mandibles is seen a maxillary segment ($\vartheta$), although no trace of the maxillæ has yet appeared. Behind the maxillary segment are two thoracic segments with slight rudiments of their appendages (VI, VII). $\eta$, cephalic plate in optical section. *i*, mid-gut, the product of the hypoblastic germ-layer. The œsophagus (*o e s*) is longer, but still terminates blindly. The place where the rectum is to arise is indicated by a thickening of the body-wall at the posterior extremity.

17. Later stage from ventral side. Four pairs of feet (VI – IX). The two maxillary segments are united, and show no appendages yet. On the outer side of the second antennæ is a protuberance ($\iota$) connected with the development of a sensory seta which occupies the corresponding part in the adult. The genital cells have divided into a right and left portion. The shell ($\kappa$) begins to appear as a fold of the dorsal integument in the maxillary region.

18. The next stage, from below. The fifth foot (X) has appeared. The four anterior feet are becoming differentiated into an inner branch, outer branch, and branchial appendage (in the third foot, these parts are indicated by the characters VIII, VIII′, and *b r‴*). The first maxilla (IV) has appeared.

19. Embryo in the next following stage, lateral view. Observe the dorsal flexure of the body. *l b*, labrum. The second antennæ (II) begin to show segmentation in both their branches. The second maxilla (V) has now made its appearance. This is commonly said to be wanting in the adult *Daphnidæ*, but persists in a rudimentary condition in adult *Moina*, according to Grobben. All five pairs of feet have outer branches, except the first (VI), the single branch here corresponding to the inner branch of the other legs. Near the origin of the shell there is seen a group of cells ($\lambda$) higher than their neighbors and furnished with larger nuclei. These go to form the dorsal organ. $\gamma$, shell gland, as yet unprovided with an outlet, and probably developed from the mesoblast. The cephalic plate, at a period earlier than this, separated into an anterior portion ($n'$) and a posterior portion ($n''$). The former develops into the brain proper (in the stage figured it has not yet become freed from the integument), the latter forms the retina of the eye. This has already separated from the surrounding epiblast which closes over it and develops into the compound eye. This eye is a paired structure at its first appearance. *a*, anus opening into the invagination of the epiblast which forms the rectum. $\pi$, rudiment of the large posterior sensory seta.

20. Next stage, from below. The mandible (III) now shows a division into a palp and masticatory portion.

21. Later stage, from below. $\nu$, primary sensory seta on first antenna. The pigment is forming in the eye. In the median line is seen a furrow, widening posteriorly, formed by an invagination of the epiblast which makes the nerve-cord. The mandible (III) has lost its palp.

22. Embryo shortly before hatching, lateral view. The embryo has now essentially the characters of the adult, excepting the secondary sexual characters. $\nu'$, olfactory setæ. *h*, heart. About two days and a half are consumed in the development of the embryo. The dorsal organ is become reduced to a rudiment at the time of hatching, and is not found in the adult *Moina rectirostris.* In *M. paradoxa*, on the contrary, it persists throughout life.

23. Young *Sida crystallina* at the time of quitting the brood-cavity of the mother, lateral view. $\lambda$, provisional dorsal organ. This is the homologue of the dorsal organ in other *Cladocera.* $\lambda'$, unpaired horseshoe-shaped dorsal organ. $\lambda''$, paired dorsal organ. $\gamma$, shell gland. $\nu$, primary sensory seta. $\nu'$, olfactory setæ. From Grobben, Ibid., Taf. XVI. fig. 56.

24. *Leptodora hyalina.* Larva just escaped from the winter egg, seen from below. The body shows no trace of segmentation. I, first pair of antennæ. II, second pair of antennæ (only the basal portion is represented on the left-hand side of the figure). III, third pair of appendages, representing the mandibular palpi. In the adult the mandibles are destitute of a palpus, as in other *Cladocera.* Behind the third pair of appendages are seen the rudiments of the six pairs of feet of the adult in the form of small buds. *o c l*, ocellus, which persists in the adult. The adult form is gradually attained after the third moult. While the young developed from the winter eggs thus undergo a postembryonal metamorphosis, the summer eggs develop without metamorphosis, as is the case with most *Cladocera.* No ocellus is present at any stage in the development of the summer eggs. From G. O. Sars, Om en dimorph Udvikling samt Generationsvexel hos *Leptodora.* Forhandl. Vidensk.-Selsk. Christiania, Aar 1873, Tab. I. fig. 1.

## PLATE VI.

*a.* Anus.
*ap.* Appendage.
*bl.* Blastoderm.
*br.* Gill.
*cp.* Carapace.
*ep.* Epiblast.
*f.* Frontal sensory papilla.
*h.* Heart.
*hy.* Hypoblast.
*i.* Intestine.
*l.* Liver.
*lb.* Labrum.
*m.* Mouth.
*ms.* Mesoblast.
*mt.* Metastoma.
*n.* Nerve.
*oc.* Paired eye.
*ocl.* Unpaired eye.
*pd.* Proctodæum, or hind-gut.
*re.* Outer branch of appendage.
*ri.* Inner branch of appendage.
*sd.* Stomodæum, or fore-gut.
α. Five anterior thoracic somites.
β. Antennal gland.
γ. Shell gland.
δ. Papilla through which the shell gland opens.
ε. Outer egg-membrane.
ζ. Inner egg-membrane.
η. Contour of body.
ϑ. Cellular membrane.
ι. Muscular wall of intestine.
κ. Epithelium of intestine.
λ. Dorsal organ.
μ. Appendage connected with sexual function.
ν. Larval membrane.
ξ. Caudal fork.
π. Rudiment of dental apparatus in stomach.
ρ. Communication between liver and intestine.
σ. Hypodermis.

The Roman numerals indicate the appendages of the body in their consecutive order.

1–10. *Development of* PHYLLOPODA (*Apus cancriformis*). *Figures from* CARL CLAUS, Zur Kenntniss des Baues und der Entwicklung von *Branchipus stagnalis* und *Apus cancriformis.* Abhandl. Königl. Gesellsch. Wissensch. Göttingen, XVIII., Taf. VI.–VIII., 1873.

1. Nauplius larva, on its escape from the egg, from the ventral side. Behind the mandibles (III) is seen the beginning of the formation of the five anterior somites. *ocl*, ocellus. The darker portion is the intestine.
2. The same larva seen from above, the appendages removed. *cp*, rudiments of dorsal shield or carapace. *i*, intestine. *l*, liver. α, five anterior thoracic somites. λ, dorsal organ.
3. Second larval stage, from ventral side. IV, first maxilla. *f*, frontal sense papilla. New thoracic somites have been added posteriorly. VI, VII, VIII, appendages of three anterior thoracic somites. ξ, caudal fork.
4. The same, from dorsal side.
5. Third larval stage, from below. 1 mm. long. The mandibles have developed a powerful cutting blade at their base. The rudimentary second maxillæ (V) have appeared, and four new thoracic appendages. β, antennal gland, probably homologous with the "green gland" of *Malacostraca.*
6. Fourth larval stage, from below. 1 to 1¼ mm. long. New somites continue to form at the hinder end of the body, and appendages to arise from the somites already formed. There are now seventeen pairs of appendages, including the three pairs of nauplius limbs, formed or in the process of formation. Behind the unpaired eye the paired eyes are beginning to be formed. The so-called liver forms three diverticula on each side of the head. γ, shell gland. The dorsal shield has grown backward so as to cover the four anterior thoracic somites. III, mandible. III′, mandibular palp. *lb*, labrum.
7. Fifth larval stage, from below. 1½ mm. long. The appendages have begun to appear as far back as the nineteenth (XIX), and about six somites are marked off by transverse segmentation back of this. The mandibular palp is now much reduced. *oc*, paired eye.
8. Mouth parts of the same stage. III, mandible. III′, mandibular palp. IV, first maxilla. V, second maxilla. δ, papilla in which the shell gland opens.
9. Foot of the twelfth pair from a female larva with dorsal shield 2 mm. long. *ri*, ramus internus, comprising six joints or lobes. *re*, ramus externus. *br*, branchial sac or epipodite.
10. Foot of the first pair from a larva with dorsal shield 2½ mm. long. Letters as in the last figure. Through successive moults the nauplius appendages become atrophied, the second antennæ being especially reduced in size, and the mandibular palp disappearing altogether.

## 11–21. *Development of* ISOPODA. *Figures from* ANTON DOHRN, HEINRICH RATHKE, *and* N. BOBRETZKY.

11–18. *Asellus aquaticus.* From Dohrn, Die embryonale Entwicklung des *Asellus aquaticus.* Zeitschr. wissensch. Zool., XVII., Taf. XIV., XV., 1867.

11. Segmented egg. $\epsilon$, outer egg-membrane, chorion. According to Dohrn an inner membrane lies close upon the yolk.
12. The blastoderm (*bl*) now envelopes the whole food-yolk.
13. The blastoderm has become thickened on what will become the ventral side of the embryo.
14. The inner egg-membrane ($\zeta$) has separated from the yolk. *ap*, rudiments of the two first-formed appendages, referred by Dohrn (correctly ?) to the two pairs of maxillæ.
15. Embryo twelve hours later than fig. 14. $\eta$, contour of the median portion of the body. $\lambda$, dorsal organ. Rudiments of the two pairs of antennæ (I, II), mandibles (III), two pairs of maxillæ (IV, V), maxillipeds (VI), and the six anterior pairs of thoracic legs (VII–XII) have appeared.
16. The embryo lies coiled within the egg, the *dorsal* flexure being so strong that the end of the abdomen and back of the head are in contact. The abdominal part of the body is now well developed and bears four pairs of appendages, the three anterior of which are rudiments of the gills, the fourth (XIX) being the terminal appendage of the adult. VII–XII, six pairs of thoracic legs. $\mu$, appendage developed between the sixth pair of legs and the first pair of gills, later connected with sexual functions. The metastoma (*mt*) is now present. *l*, liver. *a*, anus.
17. Later stage. The abdominal appendages are now bilobed. Previous to this stage the chorion has been cast off. The former inner membrane ($\zeta$) now becomes the outer egg-membrane. The blastoderm at a stage much earlier than this has shed a cuticle ($\nu$) which now, as a larval membrane, forms a sac enveloping the embryo up to the time of hatching.
18. Mouth parts of young before leaving the brood-sac of parent. *lb*, labrum. III, mandible. III′, mandibular palp. *mt*, metastoma. IV, first maxilla. V, second maxilla. VI, VI′, VI″, maxilliped. Within the transparent cuticle of the appendages are seen the setiferous appendages of the next stage.
19. Young *Asellus aquaticus* before leaving the brood pouch of parent. The seventh thoracic somite and its appendages are not yet developed. Beneath the abdomen are seen three pairs of gills and the terminal appendages (XIX). From Rathke, Abhandlungen zur Bildungs- und Entwickelungs-Geschichte des Menschen und der Thiere, Erster Theil, Taf. I. fig. 17, Leipzig, 1832.

20, 21. *Oniscus murarius.* From Bobretzky, Zur Embryologie des *Oniscus murarius*, Zeitschr. wissensch. Zool., XXIV., Taf. XXII., 1874.

20. Longitudinal section through embryo. *sd*, fore-gut, or stomodæum. *pd*, hind-gut, or proctodæum. *ep*, epiblast. *ms*, mesoblast. *hy*, hypoblast cells. According to Bobretzky these cells originate from the blastoderm and pass into and gradually absorb the food-yolk, increasing until they occupy the whole of the yolk space. *n*, thickening of the epiblast along the median ventral line of the embryo from which is developed the nerve cord. *n′*, thickening of the epiblast which goes to form the brain. $\vartheta$, cellular membrane lying within the inner egg-membrane. This membrane, which partially engirdles the embryo at this stage, originates as a heap of thickened epiblastic cells on the dorsal side of embryo. These cells become attached to the inner egg-membrane (which seems to be made up of vitelline membrane and a larval skin together), spread and separate from the embryo excepting at one point where the connection persists by means of a short neck ($\lambda$). This structure is homologous with the dorsal organ of *Asellus*, *Moina*, &c.
21. Longitudinal section through an embryo at a much later stage. The invaginated portion of the epiblast which forms the stomodæum is becoming differentiated into œsophagus and stomach. $\pi$, rudiment of masticatory apparatus in the stomach. From the hypoblast cells have been formed the epithelial lining of the liver (*l*) and the mid-gut, or mesenteron. The mesenteron is not in communication with the stomach, and there is no line of demarkation between it and the epiblastic proctodæum. *m*, mouth. *a*, anus. *i*, intestine. *lb*, labrum. Below the mouth the section passes through the lower lip or metastoma. *h*, heart, arising in the mesoblastic tissue. $\kappa$, epithelium of intestine. $\iota$, muscular outer coat of intestine, derived from the mesoblast. The outer part of the wall of the liver is also formed at the expense of the mesoblast, and below the stomach is seen a mass of mesoblast cells out of which is developed at a later stage the muscles which move the masticatory apparatus of the stomach. $\rho$, communication between liver and intestine. The nervous system (*n*, *n′*) has become separated from the outer epiblast which now covers it in ($\sigma$).

## PLATE VII.

| | | | |
|---|---|---|---|
| *a.* | Anus. | *o c.* | Eye. |
| *ap.* | Appendage. | *o c l.* | Ocellus. |
| *b l.* | Blastoderm. | α. | Larval skin. |
| *dp.* | Deutoplasm. | β. | Egg-membrane. |
| *ep.* | Epiblast. | δ. | Amœboid cell. |
| *i.* | Intestine. | ε. | Segmentation cleft. |
| *m s.* | Mesoblast. | ζ. | Yolk sphere. |
| *n.* | Nerve. | λ. | Dorsal organ. |
| *n c.* | Nucleus. | | |

The Roman numerals indicate the appendages of the body in their consecutive order.

### 1–10. *Development of* AMPHIPODA. *Figures from* B. ULIANIN *and* ADOLPHE DE LA VALETTE ST. GEORGE.

1–7. *Orchestia.* From Ulianin, Zur Entwicklungsgeschichte der Amphipoden. Zeitschr. wissensch. Zool., XXXV., Taf. XXIV., 1881.

1. Egg with four cleavage spheres. β, chorion. The cleavage is superficial. In each of the four cleavage products is a nucleus surrounded by protoplasm (δ) which sends amœboid processes out into the investing deutoplasm. These nuclei with the investing layer of protoplasm are the "amœboid cells" of Ulianin. They afterwards increase by division, come to the surface of the yolk, and from them is formed the blastoderm.
2. Section through one of the cleavage spheres of the same. δ, amœboid cell, not yet transported to the surface.
3. Section of egg at later stage. The "amœboid cells" (δ) have migrated to the periphery of the egg, divided, and from them has been formed the blastoderm (*b l*).
4. Later stage, superficial view. The blastoderm has largely increased at the expense of the "amœboid cells."
5. Section of an egg a little younger than the one represented in Fig. 4, to show the formation of the mesoderm cells by division of the blastoderm cells.
6. Section of egg at later stage, passing through the dorsal organ or "micropyle apparatus." *e p*, epiblast. *m s*, mesoblast. λ, micropyle apparatus, arising as a patch of thickened epiblastic cells.
   NOTE. — Ulianin homologizes the dorsal organ of Crustacea with the shell gland of Mollusca.
7. Section through embryo after the appearance of the appendages. λ, dorsal organ. The cells have become invaginated so as to form a sac. *dp*, deutoplasm. ζ, yolk sphere. *n c*, nucleus of yolk sphere, with protoplasmic investment.

8–10. *Gammarus pulex.* From La Valette St. George, Studien über die Entwickelung der Amphipoden. Abhandl. naturforsch. Gesellsch. Halle, V., 1860.

8. Egg from brood-pouch of parent, showing the enclosed embryo. All the limbs are formed before the embryo quits the egg. Note the ventral flexure of the embryo compared with the dorsal flexure of the Isopod embryo (Pl. VI.). λ, dorsal organ, connecting the embryo with the first larval skin which surrounds the whole embryo. *d p*, food-yolk.
9. Portion of the dorsal surface of the same, more highly magnified, to show the connection of the embryo with the larval skin through the dorsal organ. After the epiblastic invagination is formed, as shown in Fig. 7, the whole surface of the epiblast secretes a thin structureless cuticula (larval membrane), which separates from the underlying epiblast at all points excepting within the invagination. Here the cuticula remains attached to the epiblast until the atrophy of the dorsal organ. β, egg-membrane. α, larval skin. λ, dorsal organ.
10. Portion of the upper half of the body. *o c*, eye. *d p*, remains of food-yolk. α, larval skin with the so-called micropyle (λ) torn away from the sac of the dorsal organ (λ′) which lies in fourth segment of the body.

### 11–19. *Development of* STOMATOPODA. *Figures from* WALTER FAXON, CARL CLAUS, *and* W. K. BROOKS.

11. Youngest known stage of Stomatopod larva of the *Erichthus* type of development (*Erichthoidina*), seen from below. The line on the left of the figure indicates the length of this larva. The body consists of an anterior unsegmented portion bearing an ocellus (*o c l*), a pair of stalked eyes (*o c*), two pairs of simple antennæ (I, II), a pair of mandibles (III) without palpi, and two pairs of maxillæ (IV, V). From the dorsal side of this head portion is developed a large shield or carapace produced into a rostrum in front, and extending backward so as to cover most of the middle or thoracic region of the body, but entirely free from the underlying segments back of the head. Behind the head is a region composed of eight segments, the five anterior of

which are provided each with a pair of two-branched swimming appendages, the three posterior being destitute of limbs. The five pairs of swimming legs represent the five pairs of grasping legs or maxillipeds of the adult stomatopod. (These are homologous with the three pairs of maxillipeds and two anterior pairs of legs of the *Decapoda.*) The three following segments, which are without limbs, are the three posterior thoracic somites of the adult, which are destined to bear the three pairs of ambulatory limbs. The posterior, broad, unsegmented tail represents the long segmented abdomen of the adult. The specimen here figured was on the point of moulting and within the anterior part of the tail plate are seen two abdominal segments which will become free after the moult. The posterior border of the tail of the next stage is also seen through the transparent cuticle. *a*, anus. On either side of the anus is seen a cœcal, glandular body. From a sketch by Faxon, made at Newport, R. I., August 23, 1876.

12. Part of the border of the tail fin of the same, more highly magnified. In the next stage known, the two abdominal somites seen within the telson in Fig. 11 become free, and the anterior one develops a pair of rudimentary bilobed appendages. These appendages are the first abdominal. The first pair of antennæ become two-branched. As the development proceeds the inner branch of the second pair of maxillipeds increases in size and acquires a terminal claw, while the outer branch is aborted. The abdominal somites and appendages develop gradually in succession from before backwards.

13–16. From Claus, Die Metamorphosen der Squilliden. Abhandl. Königl. Gesellsch. Wissensch. Göttingen, XVI., Taf. II., III., 1871.

13. Older Erichthoid larva (*Erichthoidina spinosa*) of 7 mm., lateral view. Both pairs of antennæ are now furnished with a lateral branch. The first and second maxillipeds (VI, VII) have lost their external branch and approximate the form of the same parts in the adult. Gill-plates have developed from the basal joint of each (not shown in the figure). The three following pairs of limbs have become much reduced in size. The abdomen now consists of the full number of somites, each with its pair of appendages (XIV–XIX). The last pair (XIX) is very small.

14. Older stage (*Erichthoidina armata*), seen from the ventral side. 9 mm. long. The three posterior pairs of maxillipeds (VIII–X) have undergone atrophy, being now reduced to mere rudiments. The three posterior thoracic segments are still without a trace of appendages. *n*, abdominal nerve-cord.

15. Still older form, or Erichthus stage (*Erichthus Edwardsi*), 16 mm. long, from the Indian Ocean. The three posterior pairs of maxillipeds (VIII–X) have again grown out in their permanent shape, and behind them each of the three posterior segments of the thorax has developed a pair of small buds (XI–XIII), the first rudiments of the three pairs of ambulatory appendages of the adult. The third flagellum of the first antenna is present. VII′, gill-plate attached to base of the large grasping leg (VII).

16. Later or Squillerichthus stage (*Squillerichthus triangularis*) of a Stomatopod from Zanzibar. The three pairs of ambulatory appendages are much enlarged and two-branched. On the five anterior pairs of abdominal limbs are seen the rudiments of gills. The sixth abdominal appendage has now outgrown the others and has its permanent form.

From Claus's observations it is probable that the larvæ of the Erichthoid type of development belong to the genus *Gonodactylus*.

17–19. Development of *Squilla empusa*, from Beaufort, N. C., to illustrate the *Alima* type of Stomatopod development. From Brooks, The Larval Stages of *Squilla empusa* Say. Chesapeake Zoölogical Laboratory, Scientific Results of the Session of 1878, Pl. IX., X., 1879. The outline of Fig. 18 is corrected after a drawing of the same stage by Alexander Agassiz.

17. Youngest stage observed, magnified about 75 diameters, seen from below. This is probably the stage in which the larva leaves the egg. (Cf. Paul Mayer, Mittheil. Zoolog. Stat. Neapel., II. p. 219, who has seen an *Alima* larva come out of the egg of a *Squilla*, probably *S. mantis.*) This stage corresponds in a general sense to the stage in the development of the *Erichthus* type where the three posterior pairs of maxillipeds have atrophied (fig. 14). There are no two-branched swimming-feet on the thorax, and no thoracic limbs of any kind back of the great grasping legs or second maxillipeds (VII), although three free somites are present. The three posterior thoracic somites are represented by a long unsegmented region. The abdomen has five segments and the terminal fin, the four anterior segments carrying swimming-feet (XIV–XVII), represented only on one side of the figure. *n*, nerve-cord. *o c l*, ocellus.

18. Next stage observed, ventral view. All the thoracic segments are now present.

19. Older stage, ventral view. The ocular segment has become marked off at the front end of the body. The six posterior pairs of thoracic limbs (three posterior pairs of maxillipeds and the three ambulatory limbs of the adult) have begun to form as minute buds (VIII–XIII). The fifth pair of abdominal limbs (XVIII) is present in a very rudimentary condition, and the nerve-ganglion of the sixth abdominal somite is seen, although the somite itself is not yet freed from the telson.

## PLATE VIII.

| | | | |
|---|---|---|---|
| *a.* | Anus. | *n.* | Nerve ganglion. |
| *ab.* | Abdomen. | *oc.* | Eye. |
| *br.* | Gills. | *ocl.* | Ocellus. |
| *cp.* | Carapace. | *pp.* | Protoplasm. |
| *ct.* | Cuticle, larval skin. | *r.* | Rostrum. |
| *dp.* | Deutoplasm. | α. | Contour of body. |
| *f.* | Frontal sense-organ. | β. | Larval skin. |
| *i.* | Intestine. | γ. | Chorion. |
| *l.* | Liver. | ε. | Place of attachment of branchial apparatus. |
| *lb.* | Labrum. | ζ. | Abdominal muscles. |
| *mt.* | Metastoma. | λ. | Dorsal organ. |

The Roman numerals denote the appendages of the body in their consecutive order

### 1–4. *Development of* STOMATOPODA, *continued.* *Figures from* W. K. BROOKS *and* WALTER FAXON.

1. Larva of *Squilla empusa*, older than the one represented on Plate VII. fig. 19. Ventral view. The antennulary segment has become marked off at the anterior end of the body, and the third flagellum of the adult antennule is present. The second antenna has a rudimentary three-jointed inner branch or flagellum. The six posterior thoracic appendages have acquired essentially their permanent form. The sixth abdominal somite has become free and bears a pair of large swimmerets (XIX) similar in form to those of the adult. The abdominal appendages of the left side are omitted in the figure. From Brooks, Ibid., Pl. XI.
2. Still older stage of the same, dorsal view. Length 17 mm. The abdominal appendages are not shown in the figure, excepting the last pair (XIX). From a sketch by Faxon, made at Newport, R. I., August 24, 1876.
3. The specimen represented in fig. 2, moulted on the 25th of August, assuming the form shown in fig. 3, from the lower side. It is now 19 mm. long, and has the characters of the adult *Squilla empusa*. All the abdominal limbs are present, but are omitted in the figure with the exception of the last pair (XIX) and the right one of the first pair. From a sketch by Faxon.
4. Part of the border of the telson of the same, more highly magnified.

### 5–8. *Development of* CUMACEA. *Figures from* ANTON DOHRN, Untersuchungen über Bau und Entwickelung der Arthropoden. 1. Ueber den Bau und die Entwickelung der Cumaceen. Jenaische Zeitschr., V., Taf. II., 1870.

5. Early stage in the development of the embryo of *Cuma Goodsiri*. α, contour of the body. β, larval skin. γ, chorion. λ, dorsal organ. Behind the dorsal organ a deep fold gives the embryo a marked dorsal flexure. Through this dorsal flexure and dorsal organ the embryo exhibits a striking resemblance to the embryo of Isopods. Cf. Plate VI. The sixth pair of appendages, however, unlike the corresponding pair in the Isopod embryo, at this early stage is two-lobed and resembles the six following pairs of appendages. Rudiments of all the appendages are present from the first to the twelfth. *cp*, carapace commencing as a fold in the region of the maxillæ. *l*, liver.
6. Later stage of the same. The outer membrane has been cast off. The caudal appendages (XIX) are present.
7. Later stage. The embryo now approaches the Decapod type. The larval skin has been shed, the dorsal organ has disappeared, and the dorsal flexure is exchanged for a ventral one. The bulk of the first maxilliped (VI) is formed from the exopodite while the similar second maxilliped (VII) represents the endopodite alone, the external branch having entirely disappeared. X′, XI′, rudimentary exopodites of the tenth and eleventh pairs of appendages. The twelfth pair is now devoid of external branch.
8. Larva ready to leave the brood-sac. ε, place of attachment of the branchial apparatus. The last pair of thoracic legs has not yet developed, nor the appendages of the abdomen except the last pair (XIX). The abdominal appendages are never developed in the female. The eyes, which are not shown in the figures, are developed on each side of the head, and coalesce at a later period to form the median sessile eye of the adult.

**9 – 17.** *Development of* NEBALIA GEOFFROYI. *Figures from* ELIAS METSCHNIKOFF, ИСТОРІЯ РАЗВИТІЯ *NEBALIA*. ЗАПИСОКЪ ИМП. АКАДЕМІИ НАУКЪ, XIII., САНКТПТЕРБУРГЪ, 1868 [Development of *Nebalia*. Mem. Imper. Acad. Sci., XIII., St. Petersburg, 1868].

9. Early stage showing partial segmentation (telolecithal). $\frac{75}{1}$.
10. Later stage. The blastoderm cells now form a cap over one pole of the egg. $\frac{75}{1}$.
11. So-called nauplius stage of the embryo. The rudiments of the two pairs of antennæ and mandibles are present (I, II, III). *a b*, abdomen.
12. Later stage in the development of the embryo. The seven anterior pairs of appendages are now present. *l b*, labrum. *a*, anus.
13. Still older phase. The dotted line from VIII passes a little forward of its proper place in the figure.
14. Embryo at the time of leaving the egg. Most of the appendages are present. The body is still enveloped in a larval skin, *c t*, and the abdomen is bent upwards. $\frac{75}{1}$.
15. Older larva after the larval skin has been cast off. IV′, external branch of first maxilla. *o c*, eye. *c p*, carapace. $\frac{75}{1}$.
16. Later stage. *r*, rostrum. IV′, appendage of the first maxilla extending backwards over the branchial feet. VI–XIII, branchial feet. Behind these are four pairs of abdominal swimming-feet. $a\,b^8$, eighth somite of abdomen bearing the two terminal styliform appendages ($\xi$). $\frac{75}{1}$.
17. One of the phyllopod appendages. 1, inner branch. 2, middle branch. 3, outer branch. $\frac{150}{1}$.

**18 – 22.** *Development of* SCHIZOPODA. *Figures from* ELIAS METSCHNIKOFF *and* CARL CLAUS.

18. Nauplius of *Euphausia*, just hatched. A mouth opening is seen between the bases of the third pair of appendages, but there is no anal orifice. From Metschnikoff, Ueber den Naupliuszustand von *Euphausia*. Zeitschr. wissensch. Zool., XXI., Taf. XXXIV., 1871.
19. Later stage of the same. *o c l*, ocellus. *l b*, labrum. *m t*, metastoma or lower lip. IV, rudiment of first maxillæ. V, second maxillæ. VI, first maxilliped. The carapace is now present. The specimen figured was about to moult, and within the third pair of nauplius appendages are seen the mandibles of the next stage, when the function of these appendages becomes masticatory. From Metschnikoff, *op. cit.*
20. Later stage (protozoëa) of a *Euphausia* larva from the Atlantic Ocean, seen from the ventral side. $1\frac{1}{3}$ mm. long. The hind body (thorax and abdomen) has now acquired great length. The segmentation of the body is beginning in the region back of the first maxillipeds, i. e. in the thoracic region, the hinder or abdominal portion being yet uninvaded by segmentation. *f*, frontal sense-organ, similar to that shown on previous plates in larvæ of *Cirripedia*, *Apus*, &c. Grobben (Arbeiten Zoolog. Inst. Wien., II. p. 262, Taf. XVII. figs. 74–76, 1879) has shown that the larva of *Euphausia* also has a "dorsal organ" equivalent to that which we have seen in the embryos of many of the lower Crustacea. *i*, intestine. *a*, anus. $\zeta$, longitudinal muscles of the abdomen. From Claus, Untersuchungen zur Erforschung der Genealogischen Grundlage des Crustaceen-Systems, Taf. I., 1876.
21. Still later stage (zoëa) of the same, lateral view. $2\frac{1}{3}$ mm. long. The thoracic region behind the first maxilliped (VI) is divided into its full number of seven somites, although they are extremely short. The abdomen is also divided into six somites. The telson is not yet separated by a suture from the sixth segment. Underneath the cuticle of the anterior portion of the terminal segment are the rudiments of the posterior pair of abdominal appendages (not seen in the lateral view). The larva, unlike the typical zoëa, lacks the second pair of maxillipeds, and the antennæ are still large swimming-organs. As the development proceeds, the thoracic and abdominal appendages develop as two independent series from before backwards, the abdominal series being completed before the thoracic series. *o c*, eye. From Claus, *loc. cit.*
22. Second and third maxillipeds (VII, VIII) and the first and second ambulatory appendages (IX, X) of a *Euphausia* $4\frac{1}{2}$–5 mm. long. VII′, etc., outer branches of appendages. *b r*, gills. From Claus, *loc. cit.*

## PLATE IX.

*a.* Anus
*a b.* Abdomen.
*c p.* Carapace.
*c t.* Cuticle.
*d p.* Deutoplasm.
*f.* Frontal sensory organ.
*i.* Intestine.
*l.* Liver.
*l b.* Labrum.
*o c.* Compound eye.
*o c l.* Simple eye.
*p l.* Procephalic lobe.
*r.* Rostrum.
*α.* Tail fold.
*λ.* Dorsal organ.

The Roman numerals signify the consecutive order of the appendages.

### 1 – 10. *Development of* SCHIZOPODA, *continued* (*Mysis*). *Figures from* ÉDOUARD VAN BENEDEN *and* P.-J. VAN BENEDEN.

1 – 6. *Mysis ferruginea*. From Édouard Van Beneden. 1 – 3, Recherches sur la Composition et la Signification de l'Œuf, Pl. X. Mém. Cour. Acad. Roy. Belgique, XXXIV., 1869. 4 – 6, Recherches sur l'Embryogénie des Crustacés. II. Developpement des Mysis. Bull. Acad. Roy. Belgique, [2.] XXVIII., Pl. III., 1869.

1. Egg showing the commencement of partial segmentation.
2. Later stage in the segmentation. The blastoderm now forms a zone of small extent at one pole of the egg.
3. The blastoderm has extended over the whole surface of the yolk. On the ventral side the cells have a roundish form, while on the dorsal side they are very much flattened.
4. Later stage. *p l*, anterior expansion of the ventral side of the blastoderm to form the procephalic lobes. *α*, fold of the blastoderm which separates the hinder portion (*a b*) of the embryo from the anterior section of the body.
5. Later stage. The embryo is now ready to leave the egg. The three nauplian appendages, two pairs of antennæ, and mandibles (I, II, III) are present, and the embryo is invested with a delicate cuticle. λ, dorsal organ. While within the egg, it will be observed that the body has a ventral flexure, as in Decapod Crustacea.
6. Embryo after it is freed from the egg-membranes. The body now assumes a dorsal flexure.

7 – 10. *Mysis chamæleo*. From P.-J. Van Beneden, Recherches sur les Crustacés du Littoral de Belgique. Mém. Acad. Roy. Belgique, XXXIII., 1860.

7. It has been seen by the previous figures that the *Mysis* embryo leaves the egg with three pairs of appendages like a nauplius. The larva undergoes its further development within the incubatory pouch of the parent. The nauplius skin is not discarded, but accommodates itself to the growth of the larva, forming a protective case, within which the young *Mysis* develops. In the species here figured, the nauplius skin terminates in a pair of setiferous appendages. Within the nauplius skin, the larva has become provided with the full number of cephalo-thoracic appendages in the form of simple buds. These afterwards assume the schizopodous character, the abdominal appendages appear, and the segmentation of the body sets in.
8. Larva just after the nauplius skin has been cast off, much less enlarged than the preceding figure. The stalked eyes (*o c*) are now conspicuous. They have developed from the procephalic lobes of the embryo. The full number of abdominal appendages (XIV – XIX) is now seen, the posterior pair largely developed.
9. Later stage, shortly before leaving the incubatory pouch of the parent.
10. Appendages from the first to the fourteenth (first abdominal) inclusive, to show the double nature of the appendages.

### 11 – 21. *Development of* PENEUS. *Figures from* FRITZ MÜLLER *and* CARL CLAUS.

11 – 16. From Müller, Die Verwandlung der Garneelen. Arch. Naturgesch., XXIX., Taf. II., 1863.

11. Nauplius stage of a *Peneus*, from Desterro, Brazil. .4 mm. long.
12. Older stage (metanauplius), seen from the side. .5 mm. long. The carapace (*c p*) has commenced, a large labrum (*l b*) is present, together with the rudiments of four pairs of appendages (two pairs of maxillæ and two pairs of maxillipeds) behind the nauplian appendages. A short forked tail has also formed.
13. Third pair of nauplius appendages of a somewhat older stage. At its base is seen the rudiment of the masticatory mandible of later stages.

14. Later stage (protozoëa). The carapace has increased in size. Compound eyes and frontal sense organs (*f*) have appeared, and the appendages (IV–VII) which before were functionless rudiments have developed into biramous swimming organs. The mandible has become reduced to a cutting blade without palpus. The hinder portion of the body has greatly increased in size, and behind the seventh pair of appendages is the indication of a number of somites.

15. Mouth parts of the same, seen from below. The labrum (*l b*) is produced into a prominent spine.

16. Paired eyes of a little older larva.

NOTE.— Although the stages represented in the preceding figures were captured free-swimming on the surface of the sea, and no connection directly established between the several stages or with the parent, there is no reason to doubt the correctness of Müller's identification of the forms as young stages of *Peneus.*

17–21. From Claus, Untersuchungen zur Erforschung der Genealogischen Grundlage des Crustaceen-Systems, Taf. II., III., Wien, 1876.

17. Protozoëa stage of *Peneus.* 1¼ mm. long. *o c l*, ocellus. *o c*, paired eyes under the carapace, as in adult of genus *Alpheus.* *f*, frontal sense-organ, similar to that of *Phyllopoda.* Behind the second maxillipeds (VII) are six free thoracic segments. Under the cuticle of the first of these are seen the rudiments of the third maxillipeds (VIII). The abdomen (*a b*) has no free segments yet, but under the skin can be seen the segmentation which causes the six abdominal somites of the next stage.

18. Six thoracic somites and abdomen of a somewhat larger larva, zoëa form. The five anterior somites are now free, the sixth is not yet separated from the telson. It appears that the somites of the thorax and abdomen develop in regular succession from before backwards. The third maxilliped (VIII) is now a free bilobed bud, and behind it are seen the rudiments of the following five pairs of thoracic feet. In the abdominal section of the body the last pair of limbs is apparent as a small bilobed process (XIX) on the sixth somite, and perhaps the slightest trace of the other five pairs is already perceptible.

19. Older zoëa form of the same. The paired eyes are now freed from the carapace and mounted on long stalks. The five posterior pairs of thoracic appendages (those of the left side have been removed in the figure) have developed into prominent biramous sacs, while the third maxillipeds (VIII) are furnished with setæ on each branch. The abdomen has become very long, the telson is separated from the sixth somite by a movable joint, and the posterior appendages (XIX) have assumed the shape of powerful swimmerets. The second antennæ still serve as locomotive organs, in which office the muscular abdomen now assists. The five anterior abdominal somites have not yet developed appendages, at least to any functional degree. The development of the sixth abdominal appendages thus anticipates the development of the anterior pairs, probably on account of their functional importance as swimming organs.

20. Schizopod or Mysis stage of a *Peneus.* 16 mm long. As in the adult *Mysis,* the biramous thoracic feet now serve as swimming organs. All the abdominal limbs are present. The first antennæ have lost their long setæ, and grown an inner branch which becomes the inner flagellum of the adult appendage. The second antennæ have resigned their locomotive office, and their outer branch has become reduced to the antennal "scale" (II′). The nauplius eye has disappeared, and mandibular palpi have developed. The transition from the Mysis stage to the adult is easy, the most marked change consisting in the reduction of the external branches of the five pairs of ambulatory appendages to rudimentary structures.

21. Telson of the same stage.

# PLATE X.

## *Development of* SERGESTIDÆ (*Lucifer*). *Figures from* W. K. BROOKS.

NOTE. — The figures on this plate are copied from the original drawings. I am greatly indebted to Dr. Brooks for sending me his drawings and proof of the text of his memoir in advance of its appearance in the Philosophical Transactions of the Royal Society of London, 1882. The memoir is entitled "*Lucifer:* a Study in Morphology."

| | | | |
|---|---|---|---|
| *a.* | Anus. | *n'.* | Supra-œsophageal nerve ganglion. |
| $a^1$. | First somite of abdomen. | *o c.* | Compound eye. |
| $a^4$. | Fourth somite of abdomen. | *o c l.* | Simple eye. |
| *a b.* | Abdomen. | *o e s.* | Œsophagus. |
| *c p.* | Carapace. | *r.* | Rostrum. |
| *c t.* | Embryonic cuticle. | *r e.* | External branch of appendage. |
| *g m.* | Gastrula mouth. | *r i.* | Internal branch of appendage. |
| *h.* | Heart. | *s t.* | Stomach. |
| *i.* | Intestine. | $\alpha$. | Cells which form food-yolk, or possibly mesoblast. |
| *l b.* | Labrum. | $\beta$. | Auditory organ. |
| *l.* | Yolk-cells around stomach. | $\gamma$. | Antennal gland. |
| *m t.* | Metastoma. | $\vartheta$. | Shell gland. |
| *n.* | Sub-œsophageal portion of nervous system. | $\xi$. | Posterior extremity of abdomen or telson. |

The Roman numerals indicate the appendages of the body in their consecutive order; the Arabic numerals denote the somites. In *Lucifer* the thirteenth somite and its appendages (last thoracic) are not developed in any stage.

1. Egg undergoing segmentation. There are eight segmentation spheres in the stage figured. The segmentation is regular and total, and a segmentation cavity is formed in the centre of the egg.
2. Optical section of egg at later stage. One pole has become flattened, and the cell, $\alpha$, which lies in the centre of the flattened area, has its broad end directed toward the segmentation cavity, while the other cells have their broad ends at the surface of the egg. Most of the food-yolk has disappeared from the other cells, which are now quite transparent, while the cell $\alpha$ contains as much food-yolk as ever.
3. As the segmentation proceeds, the flattened area in fig. 2 becomes a deep pit, and a gastrula results as shown in fig. 3. The cell $\alpha$ divides in two and becomes pushed into the segmentation cavity. Whether the two cells $\alpha$ in fig. 3 represent the whole of the cell $\alpha$ in the preceding figure, or whether they are only the inner ends of the same, into which the deutoplasmic elements have withdrawn, and which have then become split off from the outer ends, was not determined. Their further history was not obtained. Brooks inclines to the belief that they represent the inner ends of the cell $\alpha$ in fig. 2, and are not mesoblastic, but go to form a food-yolk like the inner ends of the yolk pyramids in centrolecithal eggs.
4. Ventral view of embryo artificially removed from the egg thirty hours after oviposition. *l b*, labrum. *m t*, metastoma. I, first antenna. II, second antenna. III, mandibles. IV, V, VI, buds representing the two pairs of maxillæ and the first pair of maxillipeds of the adult. When the embryo was set free, the body was enveloped in a delicate cuticle, which in the individual figured has been torn off from all the appendages except the first antennæ.
5. First free nauplius stage, about thirty-six hours after oviposition, lateral view. $\frac{8}{1000}$ in. long. The swimming appendages have become segmented, and the rudiment of the abdomen or telson ($\xi$) is apparent. The anus is yet absent. *o c l*, ocellus.
6. Second larval stage, or metanauplius, lateral view. $\frac{9}{1000}$ in. long. *c p*, carapace. *o e s*, œsophagus. *i*, intestine. *l*, yolk-cells around the stomach (*s t*). *n*, sub-œsophageal part of nervous cord. *n'*, supra-œsophageal nerve ganglion. The anus is now present on the ventral side of the terminal portion of the abdomen.
7. Third larval stage, or first protozoëa stage, raised from the stage represented in fig. 6, dorsal view. $\frac{20}{1000}$ in. from tip of rostrum to base of spines on telson. The hind-body is now about as long as the carapace, and is divided into four somites and a long unsegmented portion (*a b*). The four somites (8–11) are those which subsequently bear the third pair of maxillipeds and the three following pairs of legs. A larva was taken from the sea agreeing with this one in size and every respect except that the free segments of the hind body were wanting. It is therefore probable that the larva figured is near the end of the first protozoëa stage. VII, second maxilliped. *r*, rostrum. *h*, heart. The mandibles have become reduced to cutting blades in this stage.
8. Fourth larval stage, or second protozoëa stage, raised from the preceding form, lateral view. $\frac{27}{1000}$ in. from tip of rostrum to fork of telson. *o c*, rudiment of compound eye. $\vartheta$, shell gland opening at the base of the first or second maxilla.

9. Mandibles, same stage, seen from below. The right and left mandibles are not symmetrical.
10. First maxilla of left side, same stage, posterior surface.
11. Second maxilla of left side, same stage, posterior surface. *r e*, exopodite or rudimentary scaphognathite.
12. First maxilliped of left side, same stage.
13. Second maxilliped of left side, same stage. Resembles the first maxilliped, but is much smaller.
14. Fifth larval stage, or last protozoëa stage, raised from the preceding stage, ventral view. $\frac{35}{1000}$ in. long. This stage is Dana's genus *Erichthina*. The second antennæ are still the chief organs of locomotion. The hind-body has increased in length, and now consists of nine free somites and an unsegmented posterior portion. The outer edges of the first (8) are marked by enlargements which appear to be rudiments of the third maxillipeds. 12, twelfth somite (counting the first antenna as the appendage of the first somite). This is the posterior thoracic somite, the thirteenth or last thoracic of the typical Decapod, being never developed in *Lucifer*. Following immediately upon the thirteenth somite is the first abdominal ($a^1$). $a^4$, fourth abdominal somite. The posterior unsegmented portion represents the fifth and sixth abdominal somites and the telson.
15. Sixth larval stage, or zoëa stage, raised from the preceding stage, ventral side. About $\frac{50}{1000}$ in. long. This stage is comparable, so far as the appendages are concerned, with the Elaphocaris stage of *Sergestes*. The third maxillipeds (VIII) and the four following pairs of thoracic appendages (IX–XII), as well as the swimmerets or appendages of the sixth abdominal somite (XIX), are present in a rudimentary shape as bilobed buds. All the somites of the abdomen are now well marked except the sixth, which is not yet clearly separated from the telson. The somite which carries the last pair of thoracic legs in the typical Decapod is wanting here and throughout the development of *Lucifer*. *n*, abdominal nerve ganglion.
16. Lateral view of the same stage.
17. Seventh larval stage, or first schizopod stage, viewed from below. About $\frac{70}{1000}$ in. long. This stage is Dana's genus *Sceletina*, and represents in a general way the Acanthosoma stage of *Sergestes*. Up to this time the larva has swam chiefly by means of the antennæ. In this stage the antennæ lose their locomotor function, which is now assumed by the long biramous appendages which have developed from the bud-like processes on the thoracic segments of the preceding stage. The compound eyes are mounted upon short stalks. The second antennæ have become quite small. The thoracic appendages (VI–XII) are much alike in structure and with the telson and swimmerets (XIX) serve to propel the animal through the water. The telson is separated from the sixth abdominal somite.
18. Ninth larval stage, or third (last) schizopod stage, lateral view. Between this stage and the one represented by fig. 17 one intervenes similar to fig. 17, but a little larger and furnished with abdominal appendages in the form of small buds. In the stage represented by fig. 18 the abdominal appendages are quite large, but still rudimentary. The abdomen is now very much longer in proportion to the carapace than it was in the zoëa stages, and flattened from side to side. The outer branch of the second antennæ is reduced to a scale.
19. Second and third maxillipeds (VII, VIII) and the four following appendages of the thorax, left side, seen from above, same stage.
20. Young *Lucifer* produced from the moulting of a larva like that shown in fig. 18, lateral view. About $\frac{1}{5}$ in. long. It now corresponds in many respects with the Mastigopus stage of *Sergestes*, and has a form essentially like that of the adult *Lucifer*. The flagellum of the first antenna, however, is much shorter than in the adult, and the neck of the carapace is short. The thorax is relatively smaller than in the last stage. The last pair of thoracic feet (XII in fig. 18) have disappeared, together with the outer branches of all the other thoracic appendages, maxillipeds included. The abdominal appendages have their perfect form. II, inner branch or flagellum of second antenna. II′, outer branch or scale of second antenna. $\beta$, auditory organ in proximal segment of first antenna. $\gamma$, antennal gland.
21. Inner surface of mandible of adult.
22. Second maxilla of adult. *r i*, inner branch. *r e*, outer branch, or scaphognathite.

# PLATE XI.

*Development of* Decapoda, *continued.* *Figures from* N. Bobretzky, Walter Faxon, Paul Mayer, Fritz Müller, Carl Claus, *and* Ferd. Richters.

| | | | |
|---|---|---|---|
| *a.* | Anus. | *o c.* | Eye. |
| *a b.* | Abdomen. | *o c l.* | Ocellus. |
| *b l.* | Blastoderm. | *p d.* | Proctodæum, or hind-gut. |
| *b r.* | Gill. | *p l.* | Procephalic lobe. |
| *c p.* | Carapace. | *p p.* | Protoplasm. |
| *d p.* | Deutoplasm. | *p y.* | Yolk pyramid. |
| *e p.* | Epiblast. | *r e.* | Exopodite. |
| *g m.* | Gastrula mouth. | *r i.* | Endopodite. |
| *h.* | Heart. | *s d.* | Stomodæum, or fore-gut. |
| *hy* | Hypoblast. | *v m.* | Vitelline membrane. |
| *l b.* | Labrum. | *α.* | Tail fold. |
| *m s.* | Mesoblast. | *β.* | Epipodite. |
| *m t.* | Metastoma. | *γ.* | Antennal gland. |
| *n.* | Nerve. | *δ.* | Palpus. |
| *n c.* | Nucleus. | *ε.* | Epipodite. |

1–9. *Palæmon.* From Bobretzky, КЪ ЭМБРІОЛОГІИ ЧЛЕНИСТОНОГИХЪ. Запис. Кіевскаго Общества Естествоиспытателей, III., T. IV., V., VI., 1873. [On the Embryology of Arthropods. Mem. Kieff Naturalists' Soc., III., Pl. IV., V., VI., 1873.]

1. Egg undergoing cleavage, superficial view. The cleavage is regular. Whether the first clefts reach the centre of the yolk or not Bobretzky was unable to determine, owing to the imperfection of his sections. At any rate the deutoplasm soon invades the core of the egg to such a degree that the subsequent clefts do not attain to the centre, and the segmentation becomes superficial.
2. Section of later stage of the cleavage. The cleavage products now have the form of long pyramids whose apices are fused in the deutoplasmic mass in the centre of the egg. The clear protoplasm, involving the nuclei, has collected at the bases of the pyramids. Later the boundaries of the pyramids become obliterated, while their protoplasmic bases become separated from the deeper food-yolk and form the cells of a superficial blastoderm.
3. Gastrula stage, superficial view.
4. Gastrula stage, section. *b l*, epiblastic layer. *h y*, hypoblast. *d p*, deutoplasm.
5. Section showing the closure of the blastopore or gastrula mouth. *m s*, mesoblast, originating from the walls of the gastrula cavity.
6. Nauplius stage. *l b*, labrum. *a b*, abdomen. I, first antenna. II, second antenna. III, mandible. *p l*, procephalic lobe.
7. Longitudinal section through nauplius stage. The hypoblast cells have increased and passed into and absorbed the whole yolk, forming a solid mass of hypoblast in which the outlines of the cells are almost obliterated. *p d*, invagination of epiblast which forms the hind-gut. *s d*, invagination of epiblast which forms the fore-gut (œsophagus and stomach). *α*, tail fold, between which and the proctodæum lies the rudimentary abdomen. *l b*, labrum.
8. Superficial ventral view of embryo at a later stage. The maxillæ (IV, V) and maxillipeds (VI, VII, VIII) are seen as bilobed buds. *c p*, fold which forms the carapace. *o c*, eye, formed in the procephalic lobes.
9. Longitudinal section of late stage in the development of the embryo. A portion of the nuclei of the hypoblast cells have migrated to the periphery of the yolk, and the cells have assumed a pyramidal form, similar to the cleavage pyramids in Fig. 2. The protoplasm segregates in the bases of the pyramids, while their apices become lost in the central deutoplasmic mass, in which all trace of nuclei has disappeared. The wall of the mesenteron thus comes to form a single layer of pyramidal cells enclosing, and merging into, a central mass of food-yolk. The protoplasmic ends of the hypoblast pyramids finally separate as cellular layer, which forms the lining of the mid-gut and liver in the adult. Connection is formed first with the proctodæum, or hind-gut, and later with the stomodæum (œsophagus and stomach). The latter connection is not made until all the food-yolk in the mesenteron has been absorbed. *n*, ventral nerve cord ; *n′*, supra-œsophageal nerve ganglion. These originate from the epiblast; the latter from the procephalic lobes. *h*, heart arising in the mesoblastic tissue.

10–14. *Palæmonetes vulgaris*. From Faxon, On the Development of *Palæmonetes vulgaris*, Pl. I., III., IV. Bull. Mus. Comp. Zoöl., V., 1879.
10. First larval (zoëa) stage, ventral view. The three pairs of maxillipeds (VI–VIII) serve as swimming organs. Behind these are the rudiments of the two following pairs (IX, X). The hinder thoracic somites are not distinguishable, while the abdomen has six well-developed somites. Compare with this retardation in the development of the thoracic region (which obtains generally among the higher *Decapoda*) the order of development of the somites in the more primitive *Decapoda* like *Peneus* (Pl. IX.) and *Lucifer* (Pl. X.), in the *Schizopoda* (*Euphausia*, Pl. VIII.), or in *Apus* (Pl. VI.). These show the normal order of appearance of the somites to be a regular sequence from before backwards. The terminal segment of the body, which represents the sixth abdominal somite and the telson, ends in a broad plate instead of a fork like that in the larva of *Peneus* (Pl. IX.). The caudal plate bears seven setæ on each side. The line on the right indicates the natural length of the larva.
11. Fifth larval stage, cephalo-thorax viewed from below. All the thoracic legs are functional excepting the penultimate pair (XII). All of them are two-branched excepting the last pair (XIII).
12. Later larval stage, seen from the side. The last thoracic legs lack exopodites. The telson is separated by a movable joint from the sixth somite of the abdomen.
13. Rostrum of a later stage.
14. Rostrum of adult.
15–20. *Palæmonetes varians*, from fresh water, Italy. From Mayer, Carcinologische Mittheilungen. IX. Die Metamorphosen von *Palæmonetes varians* Leach. Mitth. Zoolog. Station Neapel, II., Taf. X., 1880. This species, which is also found in salt water in Northern Europe, has an abbreviated development compared with *P. vulgaris*. In the first larval stage it is furnished with the full number of functional cephalo-thoracic appendages, the last three pairs being simple. The first five pairs of abdominal appendages are also present in a rudimentary form.
15. First maxilliped, first larval stage.
16. First maxilliped, third stage.
17. First maxilliped, fifth stage.
18. First cheliped, first stage.
19. First cheliped, third stage.
20. First cheliped, fifth stage.
21. *Palæmon Potiuna*, a fresh-water prawn from Blumenau, Brazil, in the condition in which it leaves the egg. All the appendages, including those of the abdomen, are present, as well as the gills. From a photograph of a drawing by Müller. See Zoolog. Anzeig., III., p. 152, 1880.
22–37. Development of *Loricata* (*Palinurus*, *Scyllarus*).
22–25. From Claus, Ueber einige Schizopoden und niedere Malacostraken Messina's. Zeitschr. wissensch. Zool., XIII., Taf. XXV., XXVI., 1863.
22. Embryo of *Palinurus vulgaris* before hatching. The body when extended measures about 1½ mm. in length. The last two thoracic and all the abdominal appendages are wanting. *o c l*, ocellus.
23. Young Phyllosoma larva (*Scyllarus* ?) 2 mm. long. The head and thorax now have the characteristic disk-shape of Phyllosoma. The abdomen is reduced to a rudiment, and the last two thoracic somites are no longer distinguishable. The first maxillipeds are wanting in this stage.
24. Older Phyllosoma, 4 mm. long. The first maxillipeds (VI) are sprouting out again, and rudiments of the last two pairs of thoracic appendages (XII, XIII) have appeared. $\gamma$, antennal gland. In the head are seen the bilateral diverticula of the stomach, the median cephalic artery, and anteriorly the brain ganglion.
25. Older Phyllosoma, 14 mm. long, 6½ mm. broad. All the thoracic legs are now developed and also the abdominal appendages.
26–37. From Richters, Die Phyllosomen. Zeitschr. wissensch. Zool., XXIII., Taf. XXXI., XXXII., 1873.
26. Mandible of Phyllosoma (larva of *Palinurus*).
27. Mandible of a *Palinurus* 25 mm. long. $\delta$, palpus.
28. First maxilla of Phyllosoma.
29. First maxilla of a *Palinurus* 25 mm. long. $\delta$, palpus.
30. Second maxilla of Phyllosoma. *r e*, scaphognathite.
31. Second maxilla of a *Palinurus*, 25 mm. long.
32. First maxilliped of Phyllosoma. *r e*, exopodite. $\epsilon$, epipodite.
33. First maxilliped of a *Palinurus* 25 mm. long.
34. Abdominal appendage of Phyllosoma.
35. Abdominal appendage of a young *Palinurus*.
36. Telson and last pair of abdominal appendages of Phyllosoma.
37. Telson and last pair of abdominal appendages of a young *Palinurus* 25 mm. long.

# PLATE XII.

*Development of* DECAPODA, *continued.* *Figures from* T. H. HUXLEY, N. BOBRETZKY, HEINRICH REICHENBACH, HEINRICH RATHKE, WALTER FAXON, WILLIAM STIMPSON, ALEXANDER AGASSIZ, *and* PAUL MAYER.

| | |
|---|---|
| *a.* | Anus. |
| *a b.* | Abdomen. |
| *b r.* | Gill. |
| *c p.* | Carapace. |
| *e p.* | Epiblast. |
| *d p.* | Deutoplasm. |
| *g m.* | Gastrula mouth. |
| *h.* | Heart. |
| *h y.* | Hypoblast. |
| *l b.* | Labrum. |
| *m.* | Mouth. |
| *m e.* | Mesenteron, or mid-gut. |
| *m s.* | Mesoblast. |
| *n.* | Ventral nerve cord. |
| *n′.* | Supra-œsophageal nerve ganglion. |
| *n c.* | Nucleus. |
| *o c.* | Eye. |
| *p d.* | Proctodæum, or hind-gut. |
| *p l.* | Procephalic lobe. |
| *r e.* | External branch of appendage. |
| *r i.* | Internal " " |
| *s d.* | Stomodæum, or fore-gut. |
| *s p.* | Spine. |
| *v.* | Yolk. |
| *v m.* | Vitelline membrane. |
| α. | Epithelium of ovisac. |
| β. | Membrana propria. |
| γ. | Stalk of ovisac. |
| δ. | Basal portion of abdominal appendage. |
| ε. | Inner branch " " |
| ζ. | Outer " " " |
| η. | Egg-case. |
| ϑ. | Median spine. |
| ι. | Lateral spine. |
| μ. | Mesoblast cell splitting off from hypoblast cell. |

The Roman numerals denote the appendages in their consecutive order.

1–10. Development of *Astacus.*

1–3. From Huxley, The Crayfish, London and New York, 1880.

1. Spermatozoön of *Astacus fluviatilis* developing in a seminal cell. × 850.
2. Mature spermatozoön of the same, viewed *en face.*
3. Two-thirds grown egg of the same, contained in its ovisac. *α*, epithelium of ovisac. *β*, membrana propria, or structureless membrane investing the ovisac. *v m*, vitelline membrane. *v*, yolk. *n c*, germinative vesicle containing germinative spots. *γ*, stalk of ovisac.

4–7. From Bobretzky, КЪ ЭМБРІОЛОГІИ ЧЛЕНИСТОНОГИХЪ. Зап. Кіев. Об. Ест., III., Т. I., 1873. [On the Embryology of Arthropods, Mem. Kieff Naturalists' Soc., III., Pl. I., 1873.]

4. Portion of egg of *Astacus* in the gastrula stage. *d p*, food-yolk. *g m*, gastrula mouth. *e p*, epiblast. *h y*, hypoblast. *m s*, mesoblast.
5. Smaller portion of the same, more highly magnified, to show the origin of the mesoblast cells. *μ*, mesoblast cell splitting off from one of the hypoblast cells at the mouth of the gastrula cavity.

   NOTE. — According to Reichenbach there are formed later, during the nauplius stage of the embryo, secondary mesoblast cells by a sort of endogenous formation within the hypoblast cells on the ventral side of the embryo. These cells wander out from the hypoblast, spread under the epiblast, and mingle with the primary mesoblast cells.
6. Later stage of the same. The gastrula mouth has closed, and the gastrula cavity has become the mesenteron (*m e*). *a b*, abdomen. *p d*, proctodæum, or hind-gut. *s d*, stomodæum, or fore-gut.
7. Later stage of the same. The hypoblast cells have absorbed the whole yolk, and assumed the form of long pyramids, enclosing the cavity of the mesenteron. The bases of these pyramids are directed outward, and contain the nuclei and protoplasmic portion of the cells. The protoplasmic bases of the pyramids then separate from the deeper portions to form the epithelial lining of the mid-gut of the adult (liver and anterior portion of the intestine). The inner portion of the pyramids becomes food-yolk in the cavity of the mesenteron. In the stage represented, the fore-gut (œsophagus and stomach) and hind-gut (posterior part of the intestine) have not yet opened into the mid-gut. *h*, heart, formed in the mesoblastic tissue. *n′*, *n*, supra- and sub-œsophageal portions of nervous system, formed from the epiblastic germ-layer. *c p*, fold which forms the carapace.
8. Nauplius stage of the embryo of *Astacus fluviatilis.* I, first antenna. II, second antenna. III, mandible. *l b*, labrum. *a*, anus. *c p*, carapace. *p l*, procephalic lobes. *o c*, optic pit, epiblastic invagination in the procephalic lobes concerned in the formation of the supra-œsophageal ganglion and nervous elements of the eye. *h*, heart. From Reichenbach, Die Embryonalanlage und erste Entwicklung des Flusskrebses. Zeitschr. wissensch. Zool., XXIX., Taf. X. fig. 8, 1877.

9. Embryo of *Astacus fluviatilis* just before leaving the egg. The carapace has been cut away from the side turned toward the observer, in order to show the gills. The first and last pairs of abdominal appendages are undeveloped ; otherwise the embryo has the essential characters of the adult, and undergoes no marked metamorphosis after leaving the egg. From Rathke, Untersuchungen über die Bildung und Entwickelung des Flusskrebses, Taf. I. fig. 16, Leipzig, 1829.
10. *Astacus fluviatilis*, two lately hatched young attached by their chelipeds to one of the abdominal appendages of the mother. Four times natural size. $\delta$, protopodite ; $\epsilon$, endopodite ; $\zeta$, exopodite of the abdominal appendage of the mother. $\eta$, ruptured egg-cases. From Huxley, *op. cit.*, p. 41.
11. Spermatozoön of *Homarus Americanus*. From a drawing by Faxon.
12. Embryo of *Homarus Americanus*. VIII, third maxilliped. The dotted line rests on the exopod. The longer endopod extends beyond the tip of the exopod. The endopods of the succeeding pairs of appendages are concealed by the exopods. *h*, heart. From a drawing by Stimpson, June 6, 1852.
13 – 16. From drawings by Faxon, Newport, R. I., July 18, 1881.
13. First antenna of embryo of *Homarus Americanus* just before hatching. The shaded part indicates the antenna of the larva seen through the cuticle of the embryo.
14. Second antenna of the same.
15. Tail of the same. $\vartheta$, median spine of the tail of the first larval stage. $\iota$, lateral spine of tail of first larval stage. All the spines of the enclosed larval tail are shortened by invagination.
16. Tail of first larval stage of the same. The larva is about to moult, and the tail of the following larval stage is seen through the cuticle.
17. First larval stage of *Homarus Americanus*. Leaves the egg in the Mysis condition. Natural size, about 8 mm. long. From a drawing by A. Agassiz, Nahant, Mass., July 1, 1866.
18 – 30. Development of *Paguridæ*.
18. Section of egg of *Eupagurus Prideauxii* before cleavage. The nucleus has divided into eight, four of which are seen in the section. Each nucleus is surrounded by a thin layer of protoplasm which sends out thread-like processes into the surrounding yolk. The segmentation is at first total, but after the fourth phase the cleavage spheres fuse in the deutoplasmic centre of the egg, and the subsequent cleavage is superficial. From Mayer, Zur Entwicklungsgeschichte der Dekapoden. Jenaische Zeitschr., XI., Taf. XIII. fig. 1, 1877.
19. The same after the fourth cleavage. *n c*, nuclei surrounded with a layer of protoplasm. From Mayer, *op. cit.*, Taf. XIII. fig. 4.
20 – 23, 25–30. From drawings by Faxon, Newport, R. I., August, 1881.
20. First larval stage of *Pagurus*. Leaves the egg in the zoëa form, the first and second maxillipeds serving as locomotive organs, the third maxillipeds (VIII) present but rudimentary. No thoracic or abdominal appendages. The sixth abdominal segment is fused with the telson. The posterior thoracic segments are potential merely.
21. First antenna of the same.
22. Second antenna of the same. *s p*, spine. *r i*, rudimentary flagellum. *r e*, squamiform appendage.
23. One half of the hind border of the tail of the same, armed with seven setæ, the sixth of which (counting from inner side) is reduced to a small curved hair. Within the tail, represented by light shading in the figure, are seen the caudal setæ of the next larval stage. It appears that the inner seta of the first stage will be replaced by two (1′, 1) in the second larval stage.
24. Tail of embryo of *Eupagurus Prideauxii*. The seta numbered 6, which becomes a rudiment in the first larval stage, is well developed. All the setæ are feathered except the outer ones, 7. From Mayer, *op. cit.*, Taf. XV. fig. 43.
25. Tail of second larval stage of *Pagurus*, from Newport, R. I. Comparison with Fig. 23 shows that a new seta (1′) has been developed on the inner side of the seven primary setæ of the first larval stage.
26. Mouth parts of the same. *l b*, labrum. *m t*, metastoma. III, mandible. IV′, IV″, IV‴, first maxilla. V′, V″, V‴, V⁗, second maxilla.
27. Third larval stage of *Pagurus*. The exopods of the third maxillipeds have become functional swimming organs. Rudiments of the chelipeds (IX) and two or three following pairs of thoracic appendages have appeared, and they are simple from the time of their first appearance. There is thus a syncopation of the Mysis stage in *Pagurus* and in *Anomoura* generally. In the suppression of the Mysis stage and in the late functional development of the third pair of maxillipeds, the *Anomoura* resemble the *Brachyura* rather than the typical *Macroura* like *Palæmonetes vulgaris* (see Pl. XI.). In the structure of the second antennæ, spatulate form of the terminal segment of the abdomen, and the appearance of the posterior abdominal appendages (XIX) in advance of the rest, *Pagurus* agrees in its development with *Palæmonetes vulgaris*. XIX, last pair of abdominal limbs. Their inner branch is commencing to grow as a small lobe from the proximal end. The sixth segment of the abdomen is now a free segment.
28. First antenna of the same.
29. Second antenna of the same.
30. Telson and appendage of sixth abdominal somite. $\kappa\epsilon$, rudimentary inner branch of appendage. The Arabic numerals indicate the correspondence of the setæ of the telson with those in the earlier larval stages.

# PLATE XIII.

*Development of* DECAPODA, *continued. Figures from* ALEXANDER AGASSIZ *and* WALTER FAXON.

| | | |
|---|---|---|
| *b r.* Gill. | *l b.* Labrum. | *r e.* External branch of appendages. |
| *c t.* Embryonic cuticle. | *m t.* Metastoma | *r i.* Internal " " |
| *h.* Heart. | *o c.* Eye. | *s t.* Stomach. |
| *i.* Intestine. | *r.* Rostrum. | |

The Roman numerals denote the appendages of the body in their consecutive order.

1 – 9. Development of *Paguridæ* (continued from Pl. XII.).

1. Larva of *Pagurus*, from Newport, R. I. Later stage than the one represented by fig. 27 on the previous plate. Viewed from the dorsal side. The abdomen now carries five pairs of appendages, on the second to the sixth somites. From a drawing by A. Agassiz, Newport, R. I., August 4, 1875.

2 – 4. From drawings by Faxon, Newport, R. I., August, 1878.

2. Larva of *Pagurus* of about the same age as the one represented by fig. 1. Lateral view.
3. The same, ventral view.
4. One half of the hind border of the telson of the same. Seta 4 has become very short, so that the armature of the telson at first sight appears to be the same as in the first larval stage (Pl. XII. fig. 23).

5 – 9. From drawings by A. Agassiz.

5. Older stage of a *Pagurus* from Naushon Island, Mass., August 23, 1865. $2\frac{1}{2}$ mm. long. This is the genus *Glaucothoë* of Milne-Edwards, *Prophylax* of Latreille. The two sides of the body and the appendages are still symmetrical, except in the greater development of the chela of the right side. The two posterior pairs of thoracic appendages are much shorter than the anterior pairs. All the abdominal somites bear appendages except the first.
6. Abdomen of the same, from the ventral side.
7. One of the abdominal appendages of a little older stage, when the abdomen begins to curl to one side.
8. Young *Pagurus* from Newport, R. I., August 23, 1875, at the age when it takes up its abode in a Molluscan shell.
9. Abdomen of a little younger specimen than fig. 8, showing the atrophy of the curled side. Newport, R. I., July 24, 1876.
10. Zoëa stage of *Porcellana* (*Polyonyx*) *macrocheles*. First stage after shedding the embryonic cuticle. VIII, rudimentary third maxilliped. From a drawing by A. Agassiz, Newport, R. I., August 31, 1865.
11. Last zoëa stage of the same. 16 mm. from tip of rostrum to tips of posterior horns of carapace. The first antennæ are now two-branched. The five posterior thoracic appendages (IX–XIII) are present in a rudimentary shape, bent up under the carapace. The telson is not distinct from the sixth abdominal somite. The second, third, fourth, and fifth abdominal somites carry simple unsegmented appendages. From Faxon, On some Young Stages in the Development of *Hippa*, *Porcellana*, and *Pinnixa*, Pl. II. fig. 1. Bull. Mus. Comp. Zoöl., V., 1879.
12. Third maxilliped of the same stage, more highly magnified. *r i*, inner branch. *r e*, outer branch. From axon, *op. cit.*, Pl. II. fig. 12.
13. Five posterior pairs of thoracic appendages (chelipeds and ambulatory limbs) of the same stage, removed from the body. *b r*, gills.
14. Young *Polyonyx* following at a single moult the zoëa represented in fig. 11. Dorsal view. Length of carapace, 2 mm. It has now all the essential characters of the adult. The sixth abdominal segment is now separated from the telson by a movable joint, and bears a pair of appendages (XIX). From a drawing by A. Agassiz, Newport, R. I., August 30, 1865.
15. Adult specimen of the same, from South Carolina, twice the natural size, viewed from above. Observe the width of the carapace compared with that of the young stage represented by fig. 14. From Faxon, *op. cit.*, Pl. III. fig. 11.

16 – 18. *Carcinus mænas.* From Faxon, On some Points in the Structure of the Embryonic Zoëa, Pl. I. Bull. Mus. Comp. Zoöl., VI., 1880.

16. Young just after it leaves the egg (protozoëa stage). $\frac{1}{4}$ mm. long. Within the transparent embryonic cuticle may be seen the zoëa as it will appear at the next moult. The cuticle of the abdomen is unsegmented, has no rostral or dorsal spines, nor appendages back of the second maxillipeds. The two pairs of antennæ are enormously developed as in nauplii or the protozoëa of *Peneus*, &c. VIII, IX, X, third maxilliped and first two ambulatory appendages of the adult, seen through the cuticle.
17. Caudal fin of the same stage. The tail is forked and bears on each side seven spines (1–7). At this stage the tail of the Brachyuran larva can be compared part for part with the fourteen-spined caudal fork of the larvæ of the lower *Decapoda*, e. g. *Peneus*. (See Pl. IX. figs. 14, 18.) The shaded portion represents the tail of the following stage, seen through the transparent cuticle. 1′– 5′, spines on the tail of the next (zoëa) stage, much shortened by invagination. 4′ becomes the great lateral prong of the tail of the zoëa. (See Pl. XIV. fig. 2.)
18. The same in the process of moulting the protozoëa cuticle. *c t*, cuticle peeling off from the abdomen. After the cuticle has fallen off from the tail the little hooks which terminate the caudal fork of the zoëa are used to tear the embryonic membrane from the anterior parts of the body. The great dorsal spine of the zoëa which has been bent down forwards upon the back is now unfolding and lifting the cuticle as it rises.

## PLATE XIV.

*Development of* DECAPODA, *continued.* *Figures from* WALTER FAXON *and* CARL CLAUS.

| | | | |
|---|---|---|---|
| *a.* | Anus. | *s p.* | Spinous process of second antenna of zoëa. |
| *a b.* | Abdomen. | *s t.* | Stomach. |
| *b r.* | Gill. | *α.* | Dorsal spine. |
| *h.* | Heart. | *β.* | Ophthalmic artery. |
| *i.* | Intestine. | *γ.* | Spine on the second somite of abdomen. |
| *l b.* | Labrum. | *δ.* | Lateral spine of carapace. |
| *o c.* | Eye. | *ε.* | Mandibular palpus. |
| *r.* | Rostrum. | *ζ.* | Tendon of mandibular muscle. |
| *r e.* | Exopodite. | *η.* | Retinaculum. |
| *r i.* | Endopodite. | | |

1 - 4. *Carcinus mænas* (continued from Pl. XIII.). From Faxon, *op. cit.*, Pl. II.

1. First zoëa stage, immediately succeeding the stage figured on the preceding plate. VIII, IX, X, rudimentary third maxillipeds and first and second ambulatory appendages. The abdomen has six segments, the telson being not yet separated from the sixth somite.
2. Tail of the same stage. The Arabic numerals indicate the homology of the spines with those of the tail of the protozoëa (Pl. XIII. fig. 17).
3. First antenna of the same stage.
4. Second antenna of the same stage. *s p*, spinous process corresponding to the spine on the second antenna of larvæ of prawns (Pl. XI. fig. 11, &c.) and *Paguridæ* (Pl. XII. fig. 22). *r e*, squamiform process, homologous to the external branch of the antenna of larval *Macroura*, to the antennal scale of adult *Macroura*. Both of these parts become aborted in the adult. The flagellum (endopodite) of the second antenna of the adult is wanting in the youngest zoëa stages, or represented only by a small tubercle at the base of the squamiform process.

5 - 11. From Claus, Untersuchungen zur Erforschung der Genealogischen Grundlage des Crustaceen-Systems, Taf. X., XI., Wien, 1876.

5. Later zoëa stage of a Portunid from Chili. 4 mm. long. This is probably the last zoëa stage, preceding the megalopa. The first and second maxillipeds still serve as swimming organs. The five ambulatory legs (IX - XIII) are quite largely developed but still functionless. From the time of their first appearance they are simple appendages destitute of external swimming branches. The chela is already prominent on the first pair (IX). The second to the sixth abdominal somites are now provided with appendages. The last pair (XIX) do not anticipate the others, as in *Pagurus* (Pl. XII.) and most *Macroura* (e. g. *Peneus*, Pl. IX., *Lucifer*, Pl. X.).
6. First antenna of the same. *r e*, outer branch. The inner flagellum, wanting in the earlier zoëa stages, is developing as a sac-like process.
7. Second antenna of the same. The flagellum (*r i*, wanting in fig. 4) is now quite well developed and segmented.
8. Mandible of a younger zoëa stage of a Brachyuran (*Fissocaris*) showing the commencement of the growth of the mandibular palp (*ε*) which is wanting in the earliest zoëa stage.
9. Mandible of the late zoëa stage of the Portunid represented in figs. 5 - 7. *ε*, palpus.
10. First maxilla of young zoëa stage of *Thia polita*. 1, 2, basal joints (protopodite of Huxley). *r i*, endopodite in the form of a two-jointed palpus.
11. Second maxilla of the same. 1, 2, basal joints or protopodite, each joint presenting a bilobed blade. *r i*, endopodite, also bilobed. *r e*, exopodite or scaphognathite.

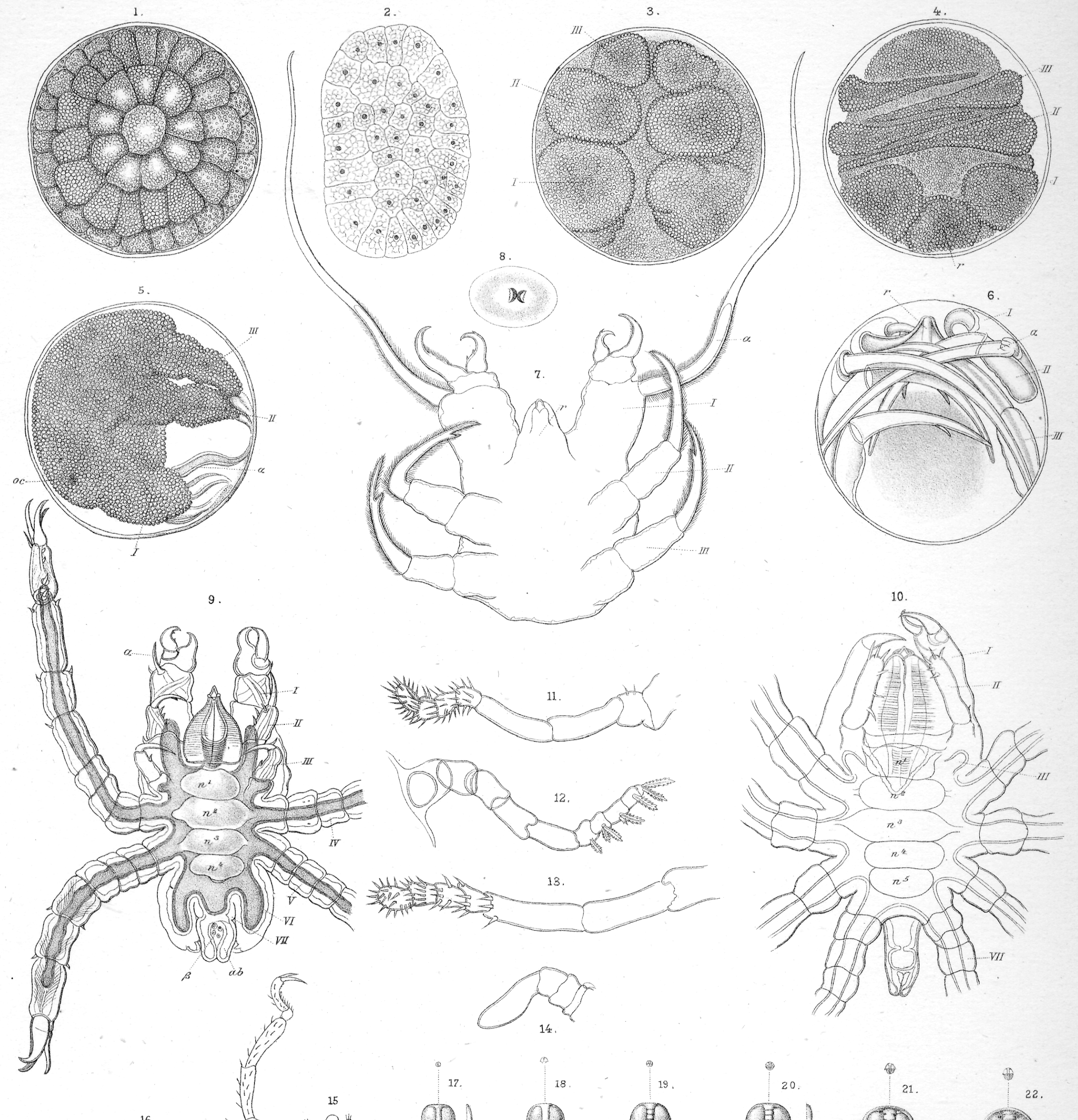
12 - 26. *Cancer* from Newport, R. I. From drawings by Faxon, July, 1879.

12. Megalopa stage. Among the *Brachyura* no schizopod stage is found, but the zoëa passes into the megalopa phase, in which most of the characters of the adult are seen. The abdomen, however, is largely developed, and provided with swimming-feet. The megalopa stage of the Brachyuran corresponds very closely with the adult Anomouran. The maxillipeds are now converted into mouth parts, and the five Decapodal legs have their full development. The caudal fork of the zoëa has become a telson plate similar to that of the adult. The crossed lines on the left of the figure indicate the natural size.
13. First antenna of the same.

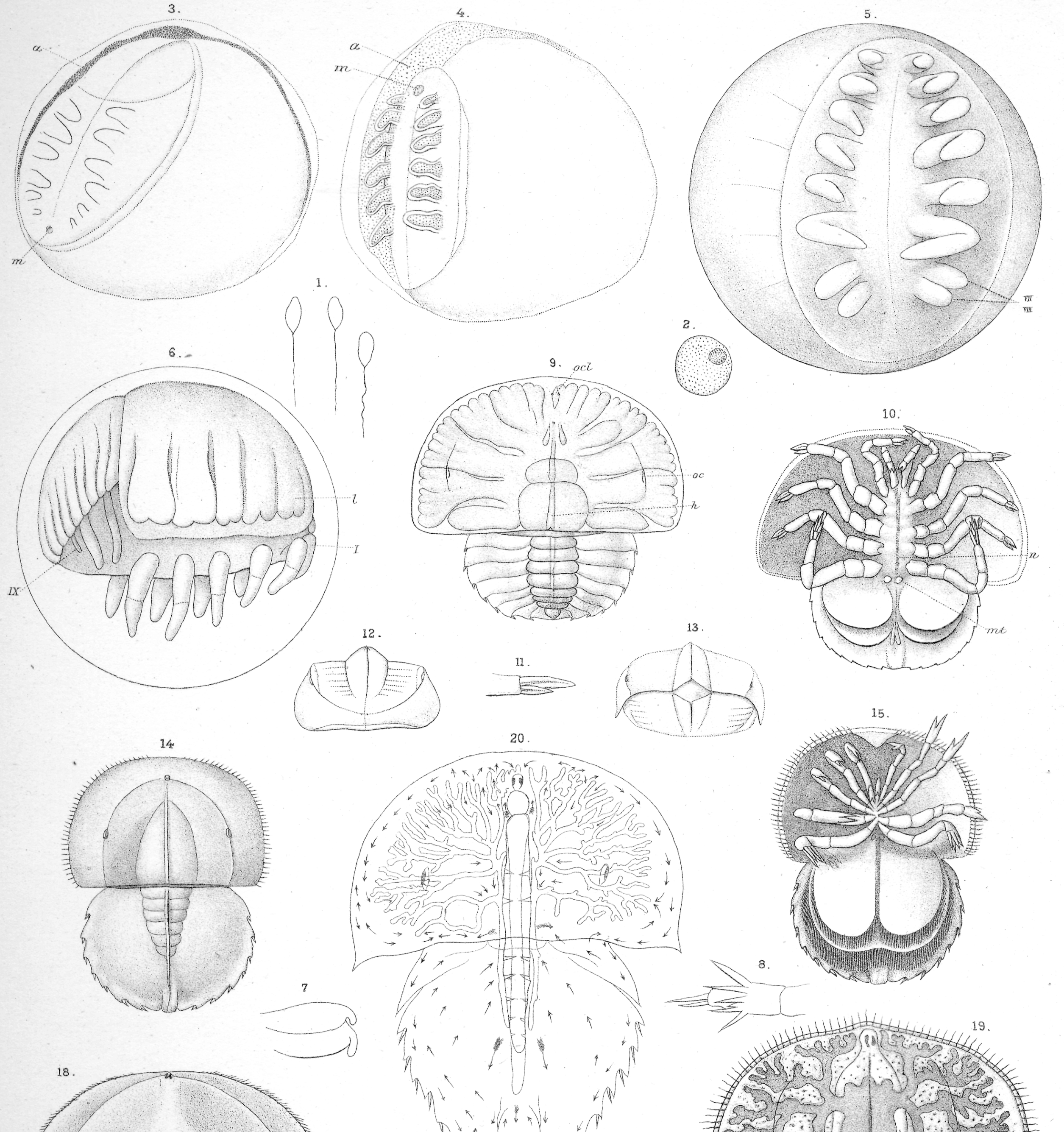
14. Mandible of the same. The palpus has been removed. $\zeta$, tendon of the mandibular muscle.
15. Mandibular palpus of the same.
16. Second maxilla of the same.
17. First maxilliped of the same, with endopodite (*r i*), exopodite (*r e*), and epipodite.
18. Second maxilliped of the same.
19. Third maxilliped of the same. *b r*, gills.
20. Proximal end of left cheliped of the same, furnished with a stout hook. Seen from ventral side.
21. Proximal end of left leg of the second pair, with two hooks, seen from ventral side. From the same stage.
22. One of the three long curved setæ on the terminal segment of the last pair of legs of the same (see fig. 12). The other two setæ are destitute of the teeth with which this one is furnished.
23. One of the abdominal limbs of the same. The endopodite is provided with hooked setæ ($\eta$), which serve to lock together the abdominal limbs of the two sides.
24. Posterior abdominal appendage. No endopodite.
25. The megalopa represented by fig. 12 passes by a single moult into the crab stage of the form represented in this figure, dorsal view. The eyes are much larger than in the adult, the antennæ longer, and the length of the carapace much greater in proportion to its breadth, and of very different outline. Breadth of carapace, 4 mm.
26. The same, ventral view. The form of the abdomen would seem to indicate that this specimen is a young male. The third, fourth, and fifth abdominal segments, which, in the adult male, are fused together, are still free.
27. Carapace of adult *Cancer borealis*, half natural size. The megalopa and young crab represented in figs. 12, 25, and 26 belong either to this species or to the closely allied *C. irroratus*. This figure is introduced to show the marked difference in proportions and outline between the young and adult stages. Drawn on stone, from nature, by A. Meisel.

28 – 30. Young stages of *Pinnixa* (*Sayana ?*) from Newport, R. I. From Faxon, On some Young Stages in the Development of *Hippa*, *Porcellana*, and *Pinnixa*, Pl. IV., V. Bull. Mus. Comp. Zoöl., V., 1879.

28. Last zoëa stage, seen from above and in front. *a b*, penultimate abdominal segment, produced on each side into a rounded lobe. Through the transparent carapace are seen the rudimentary and as yet functionless ambulatory appendages. The cross denotes the natural size.
29. The third maxilliped and five ambulatory limbs removed from the body. VIII, endopodite of third maxilliped. VIII′, exopodite of third maxilliped. VIII″, epipodite of third maxilliped.
30. The zoëa (fig. 28) passes directly, at one moult, into the adult form shown in fig. 30. This abbreviation of the developmental history whereby the megalopa stage is eliminated is very unusual among the marine *Brachyura* which leave the egg in the zoëa form. S. I. Smith has shown that another species of *Pinnixa* passes through a megalopa stage. Some land-crabs, as has long been known, leave the egg in the adult form, like *Astacus* among the *Macroura*.




A. Meisel, lith. Boston.

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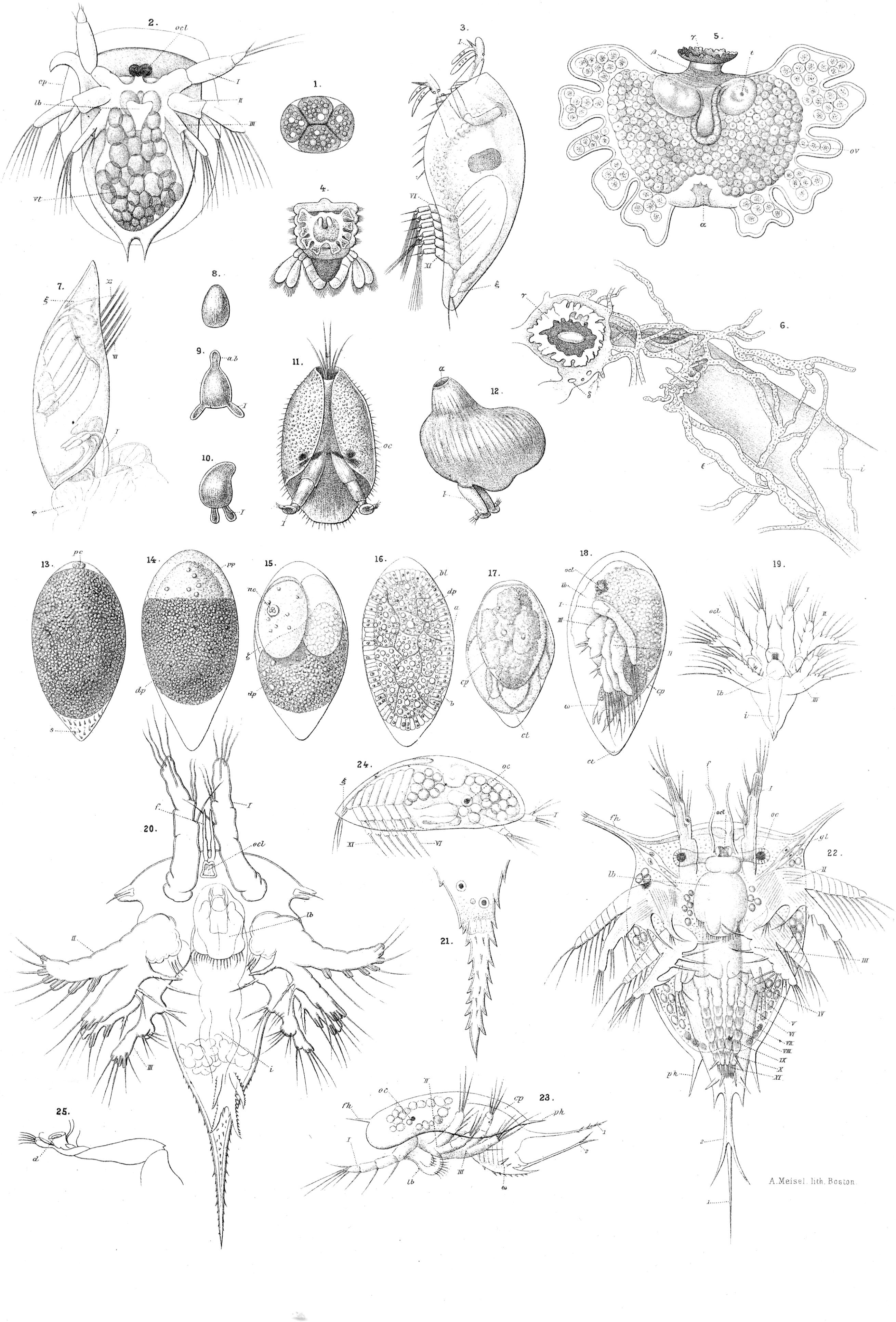


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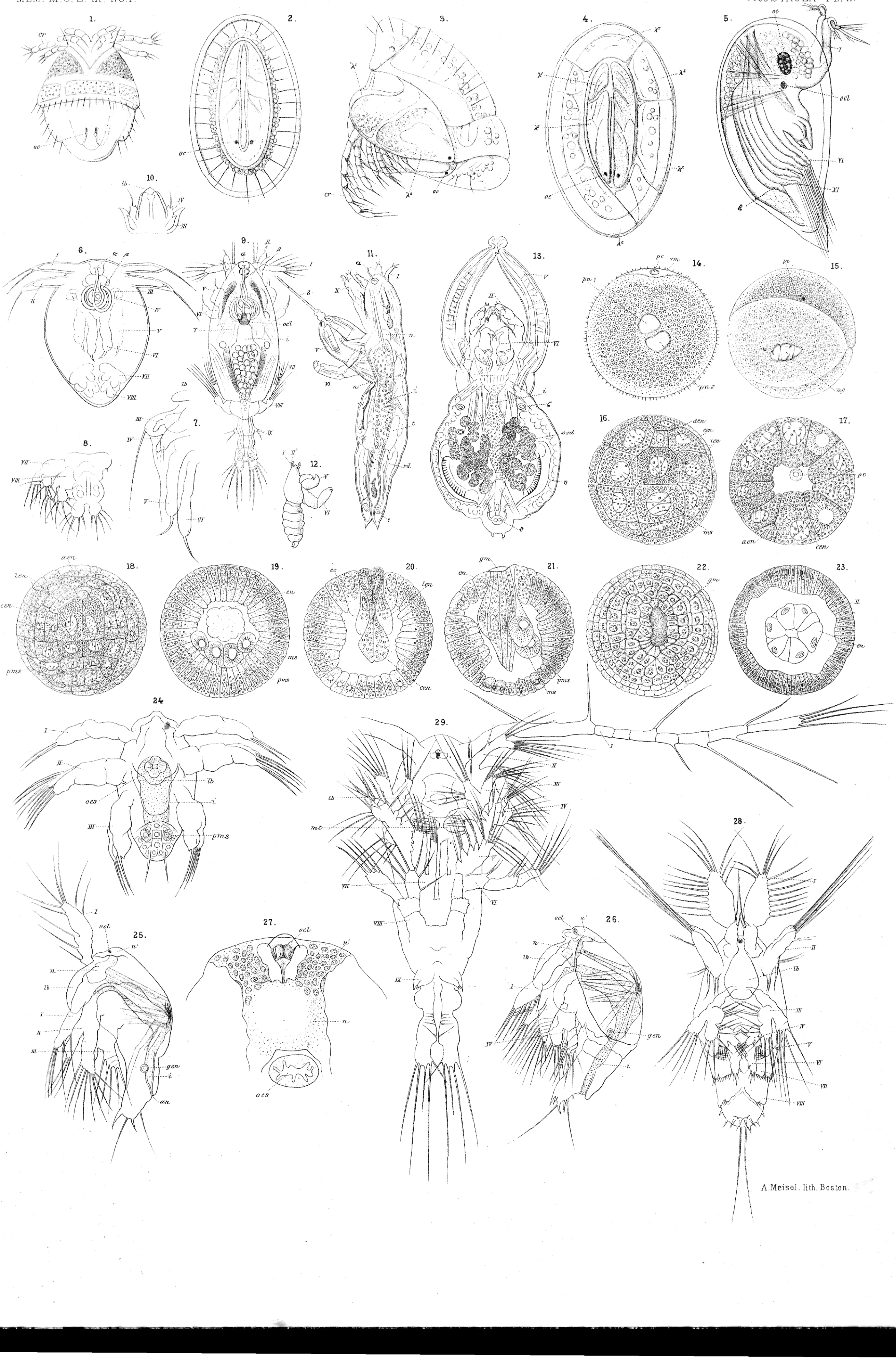

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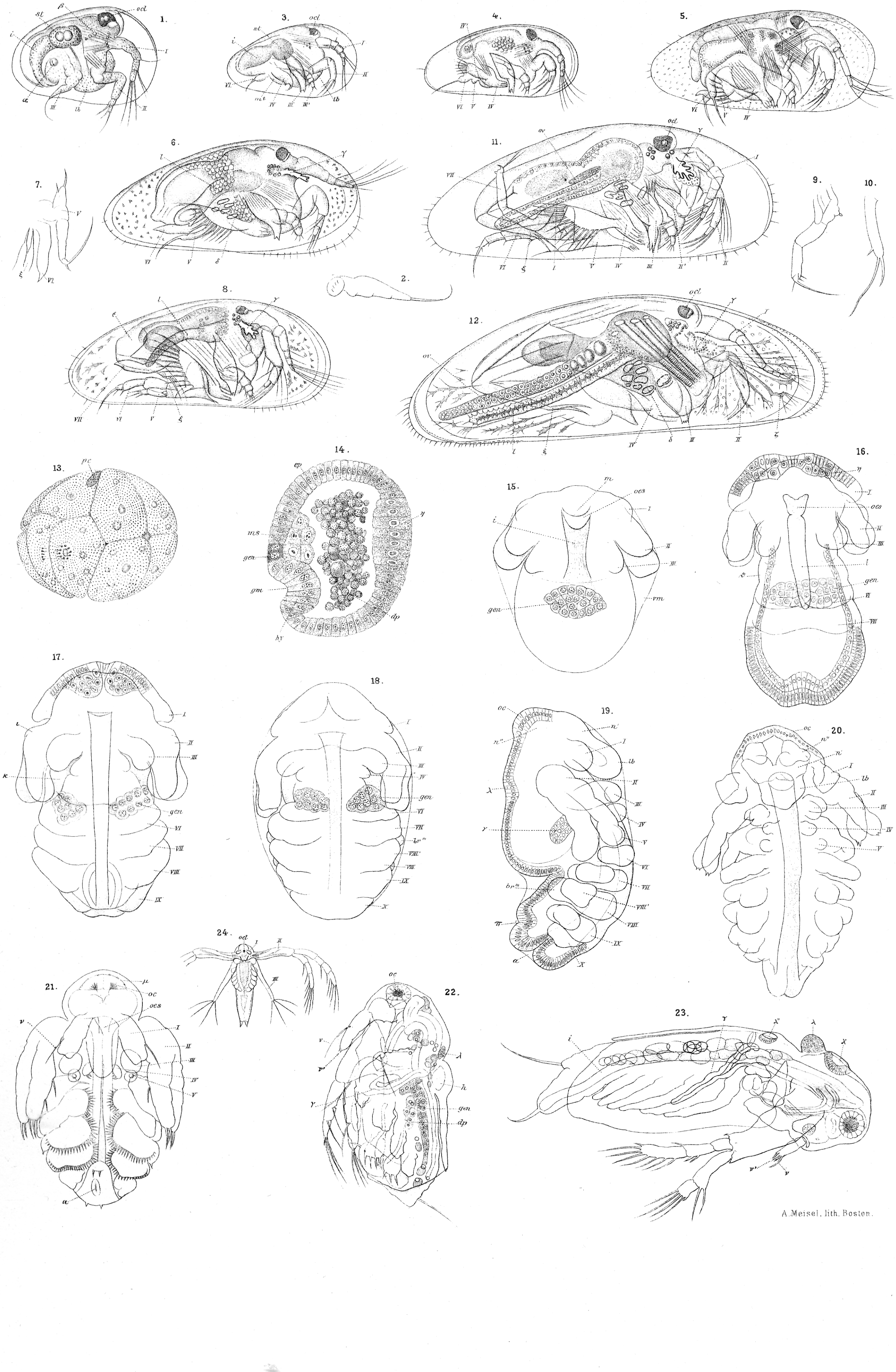


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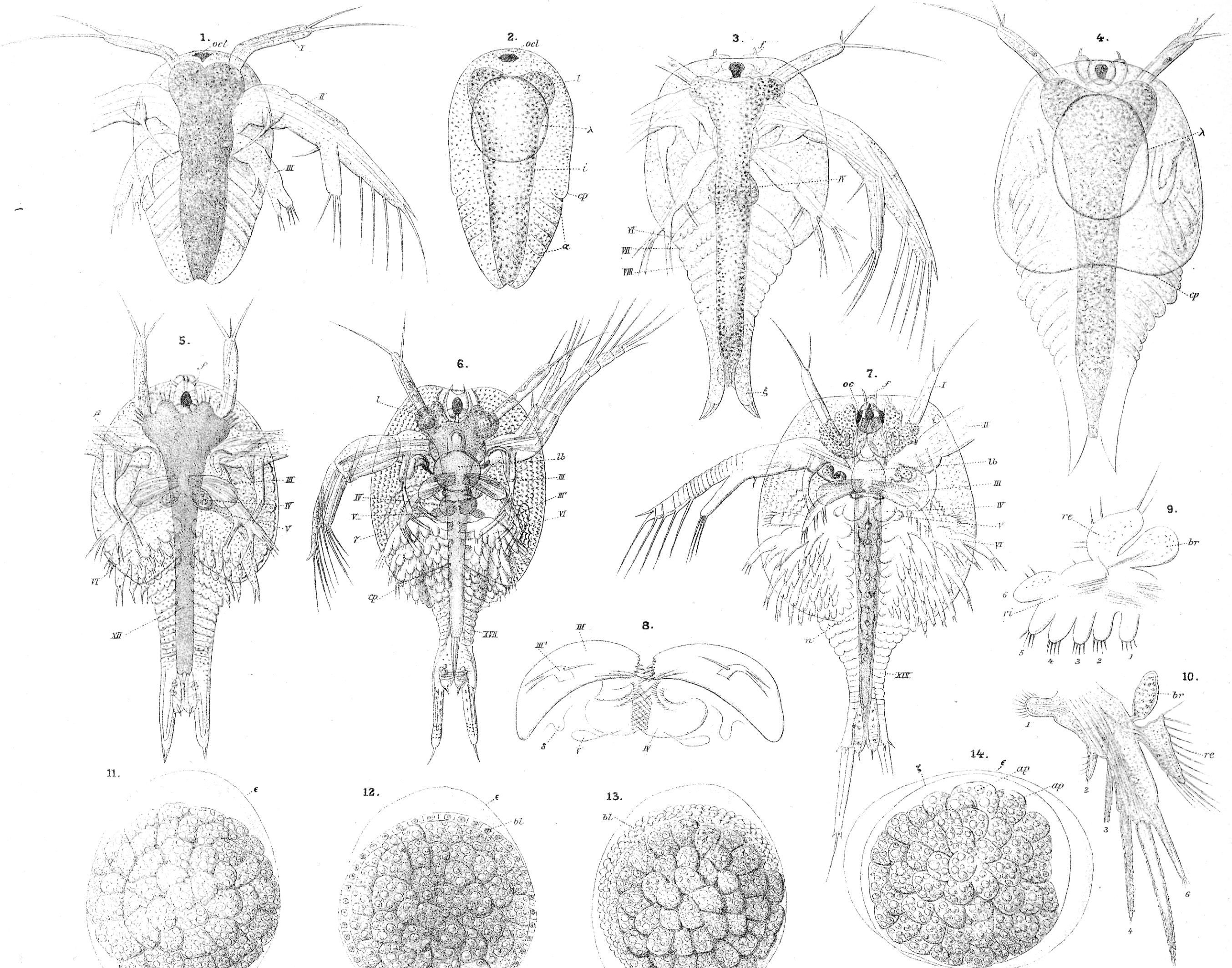


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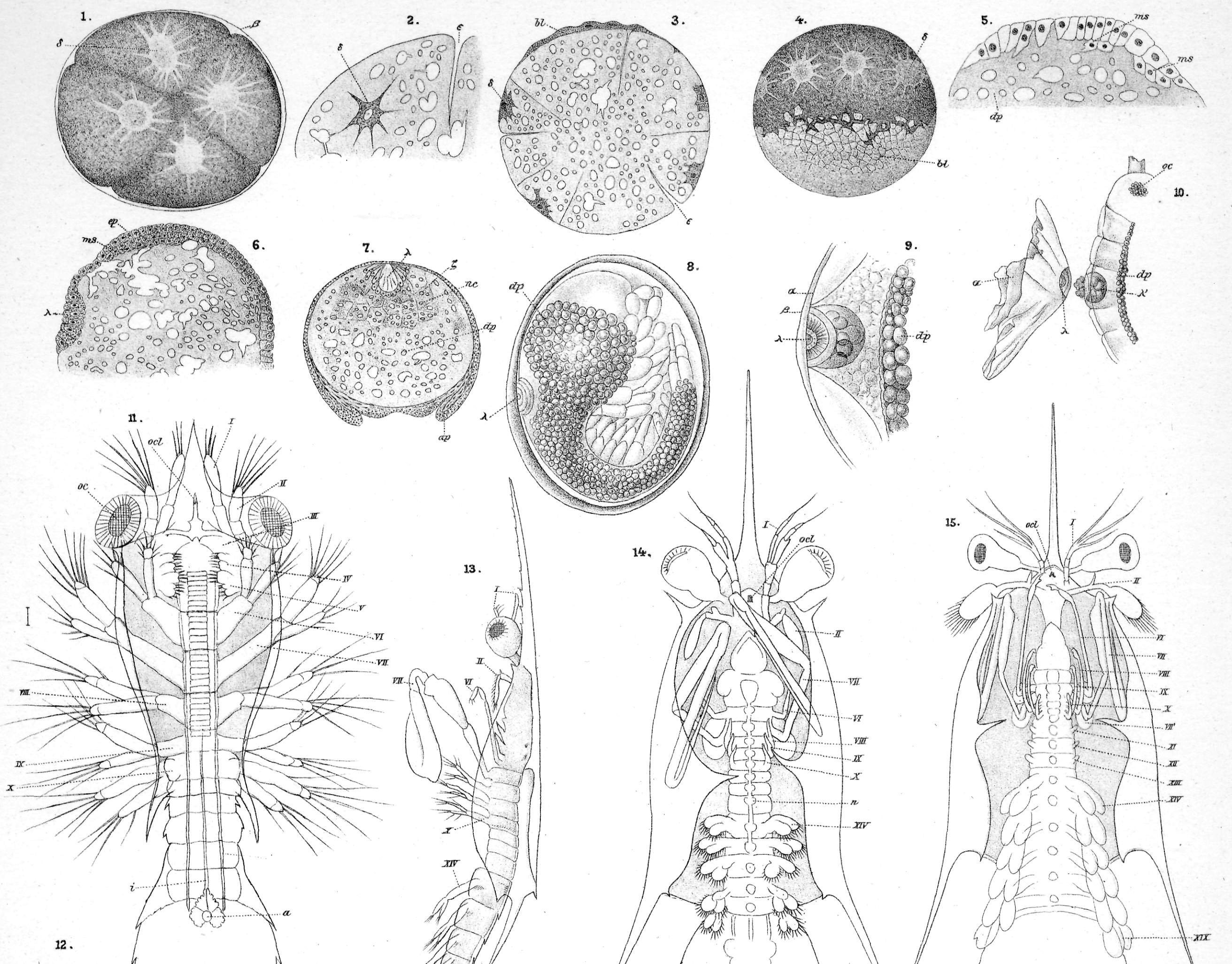

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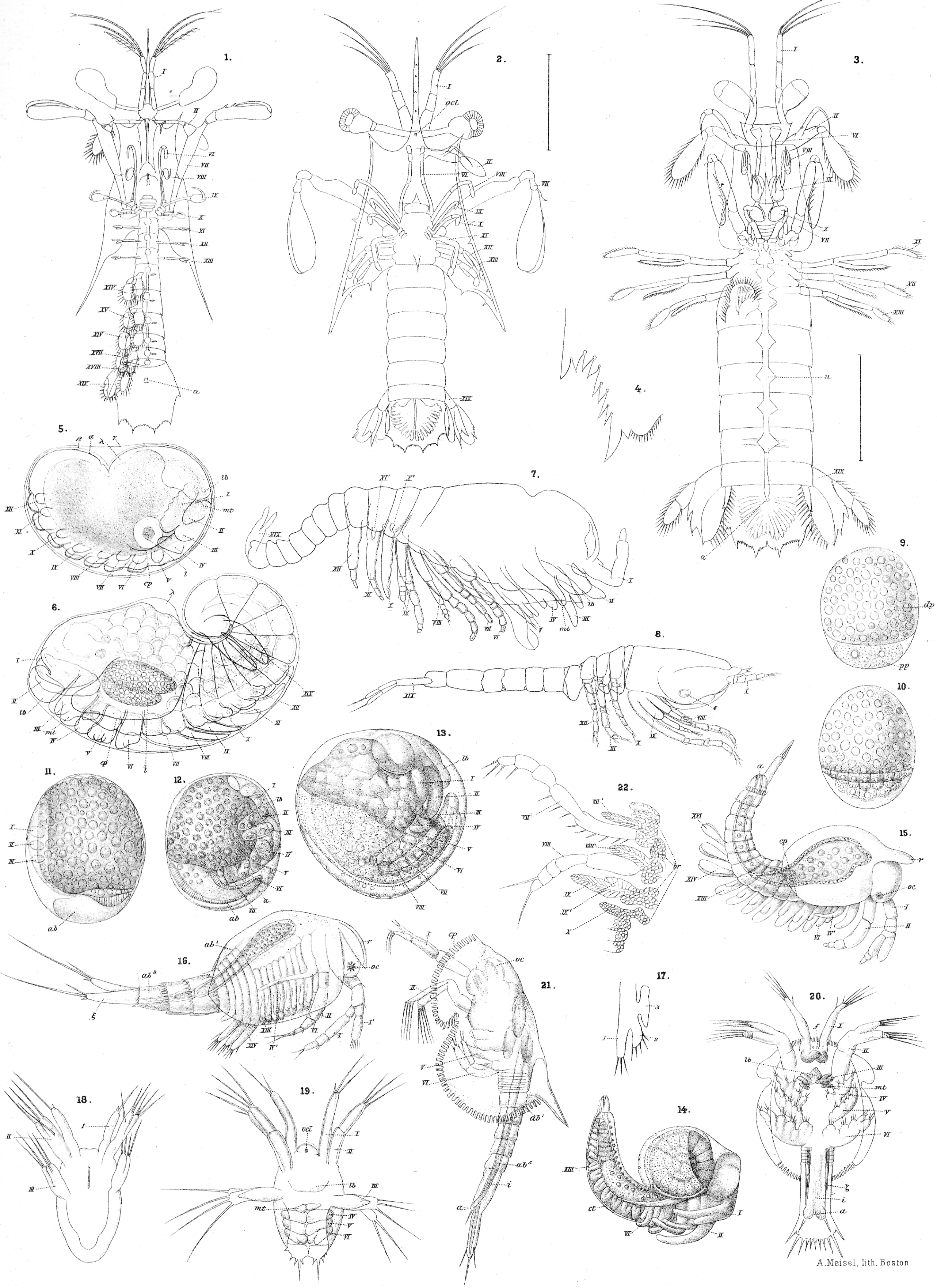

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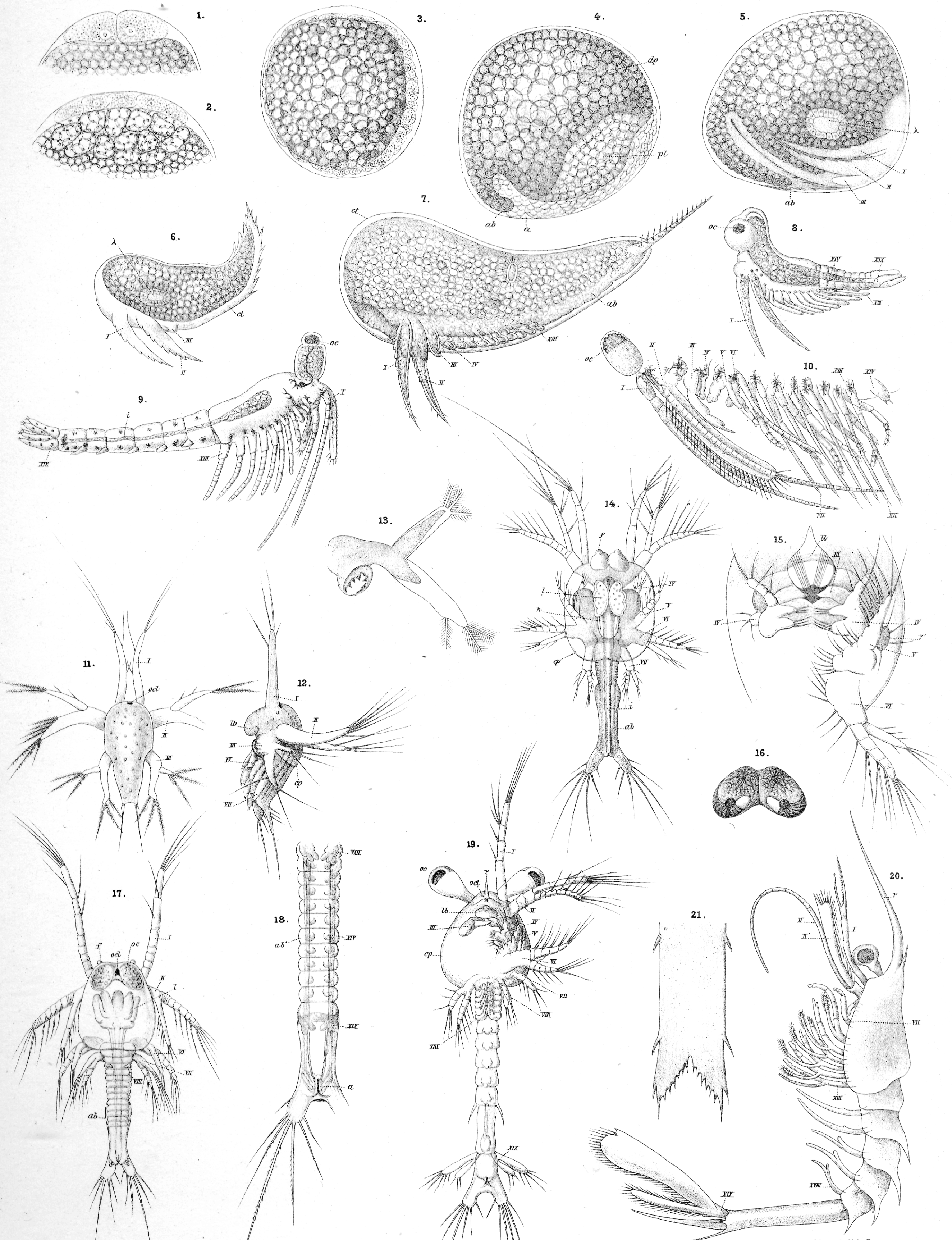

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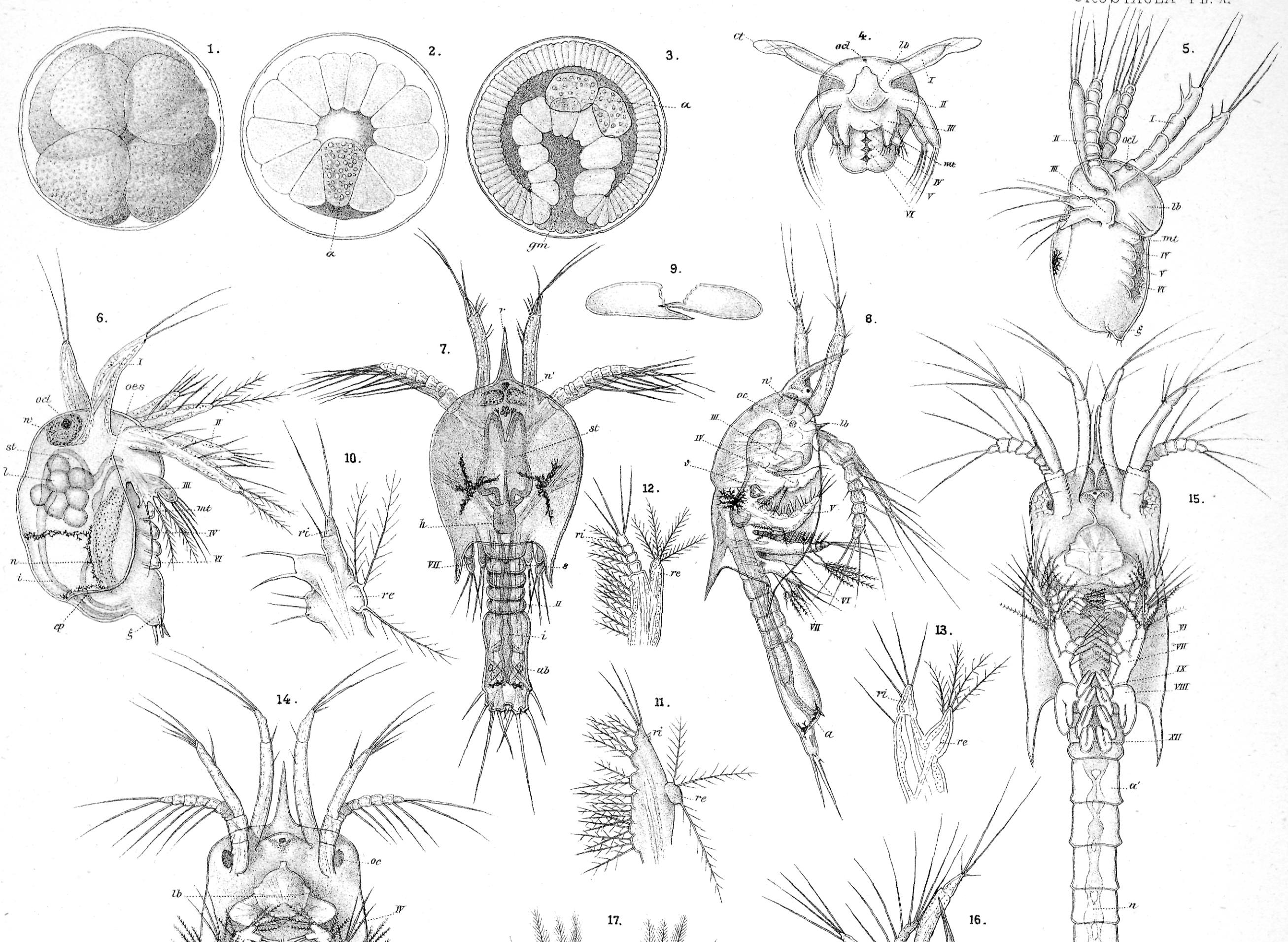

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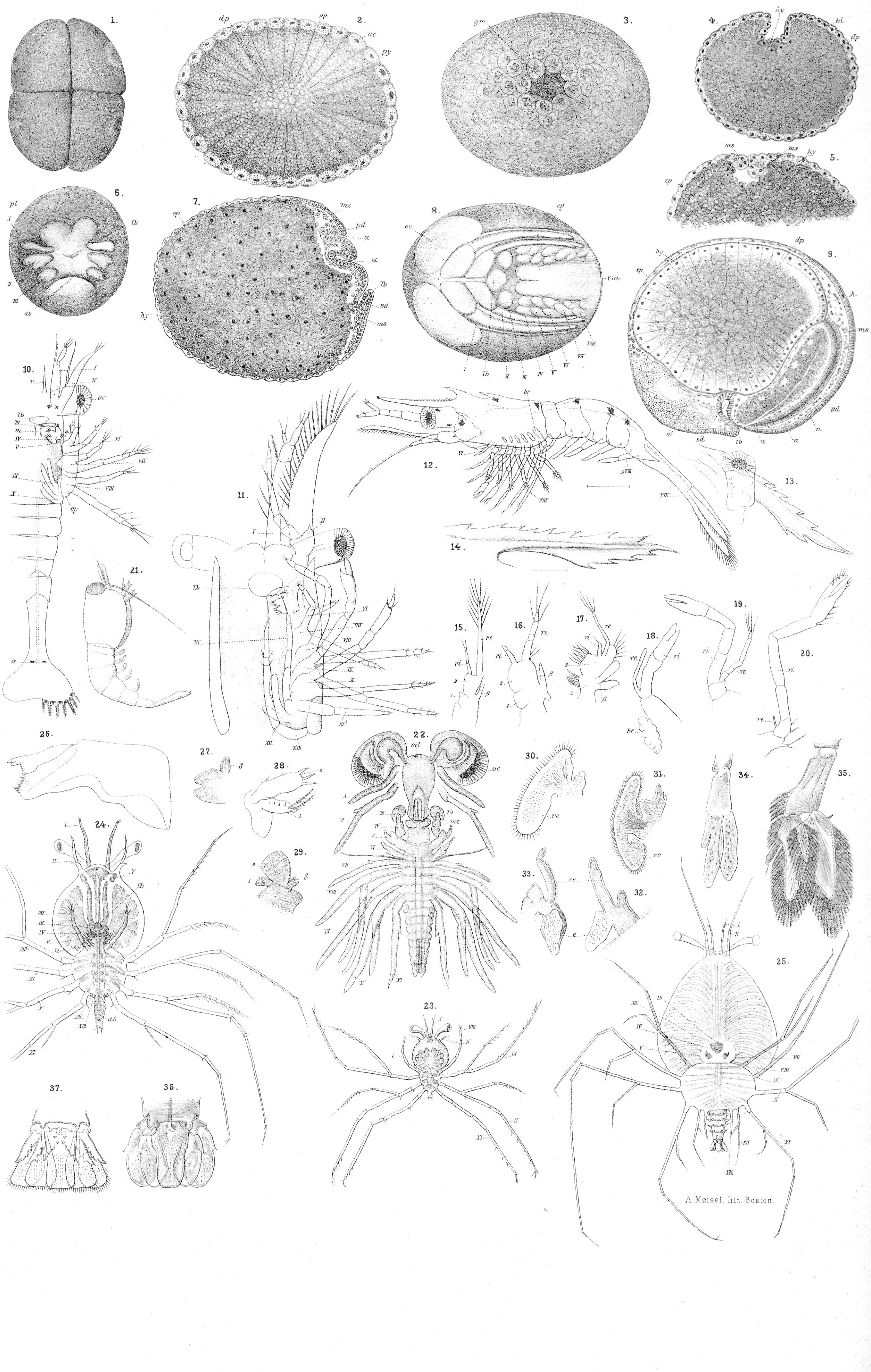

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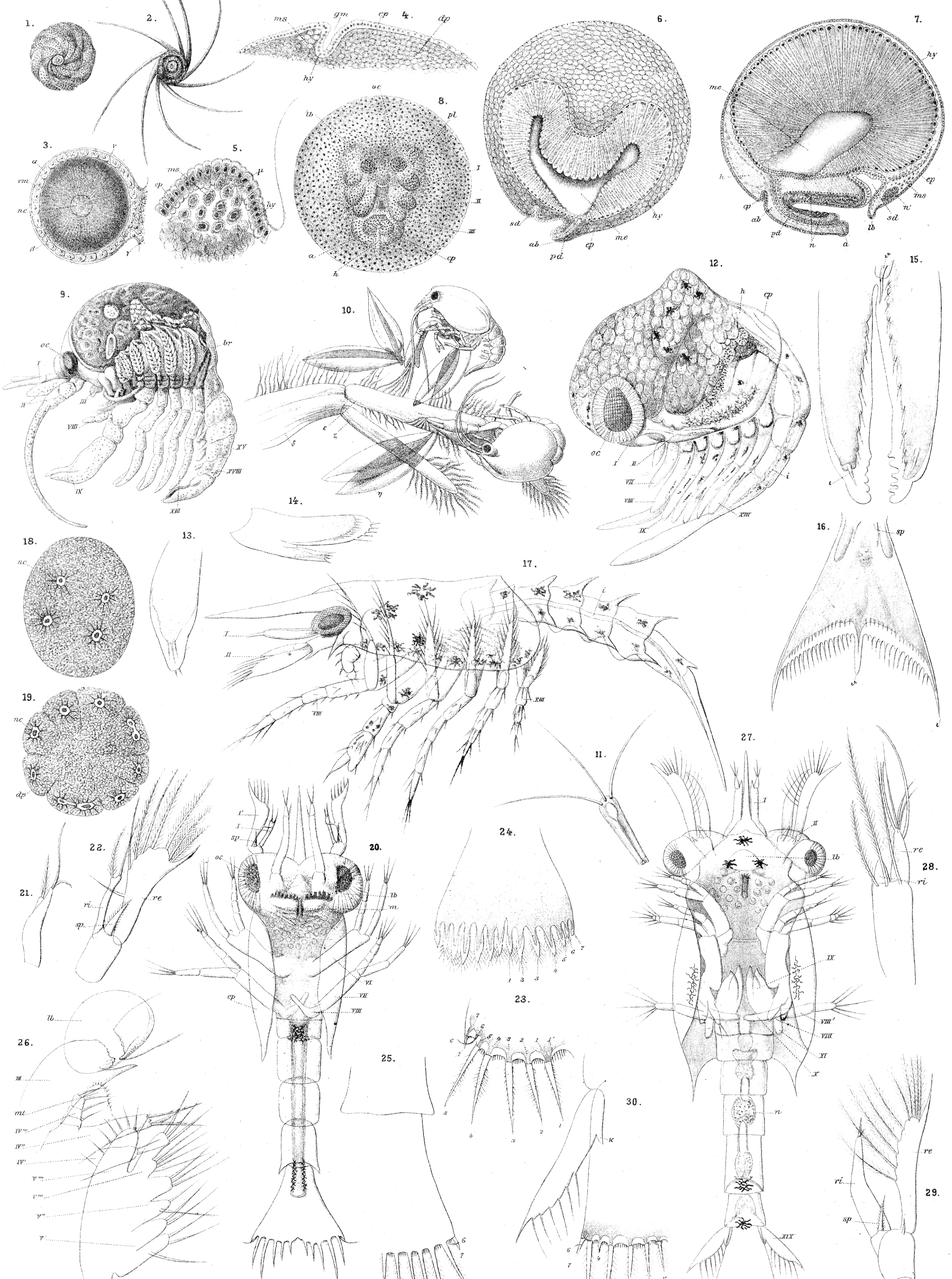
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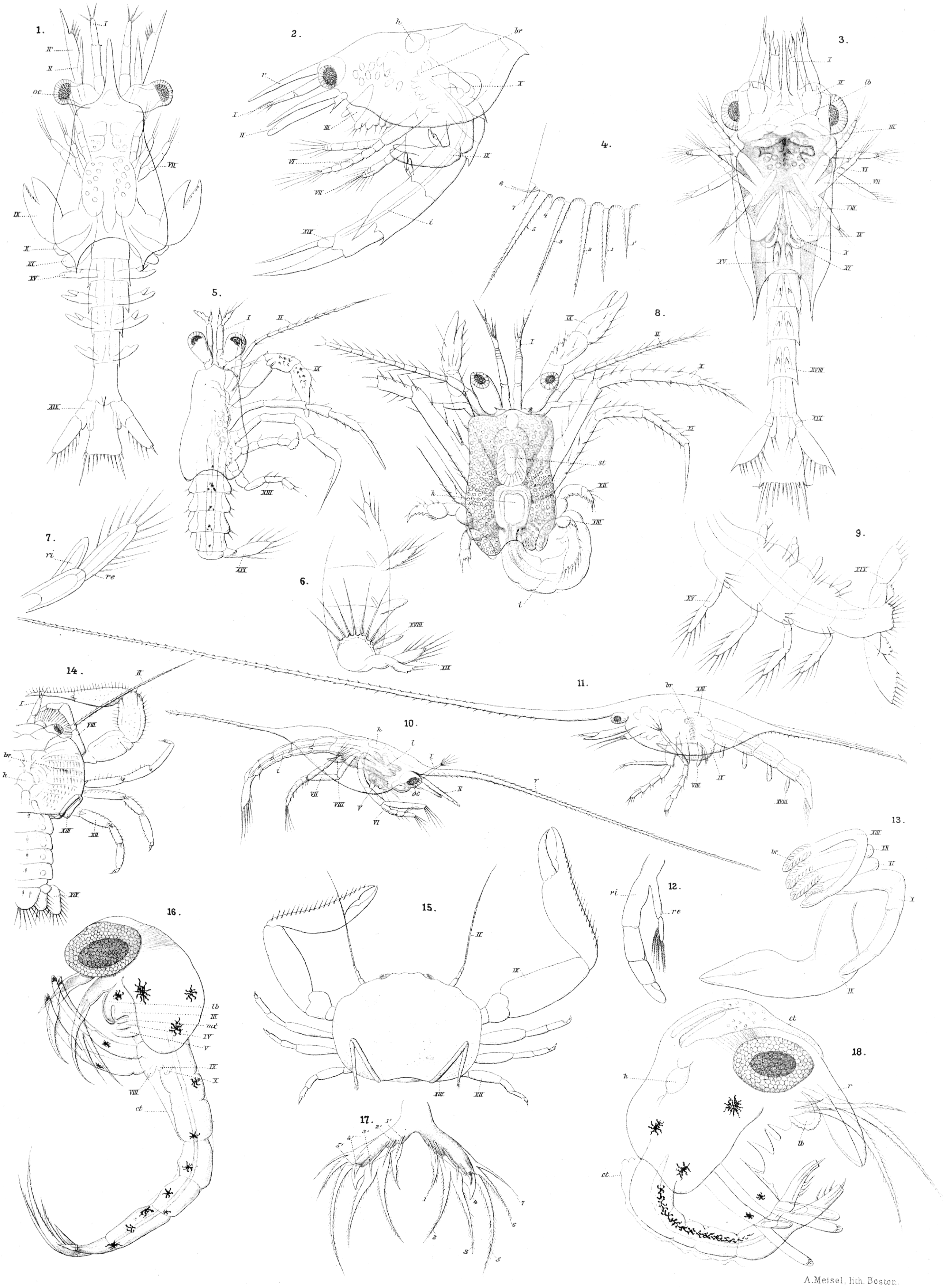

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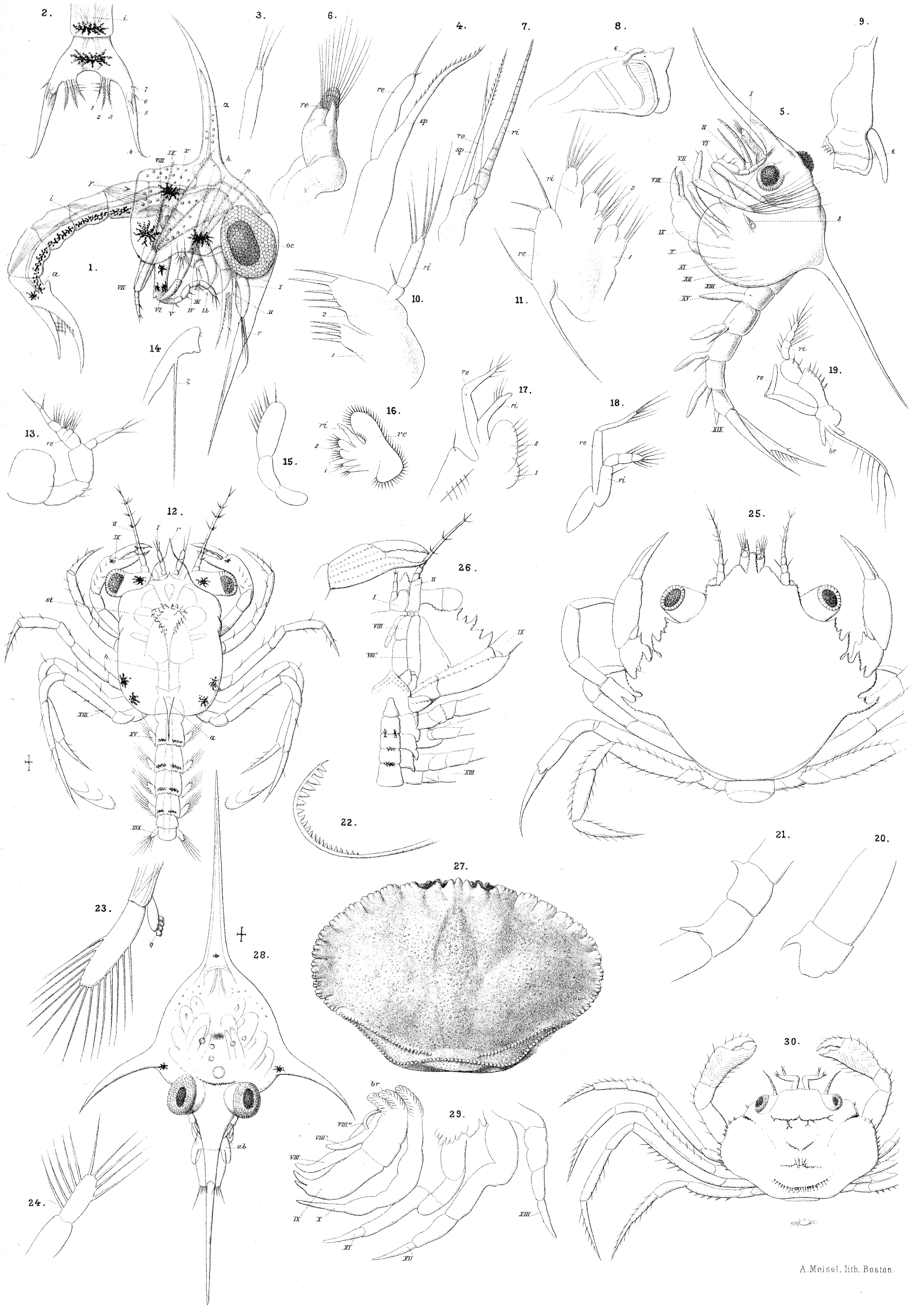

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