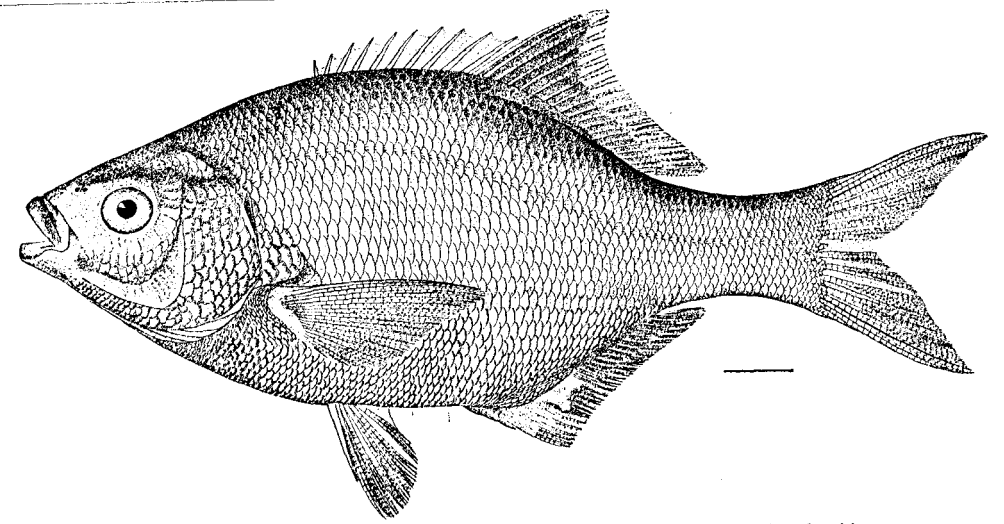
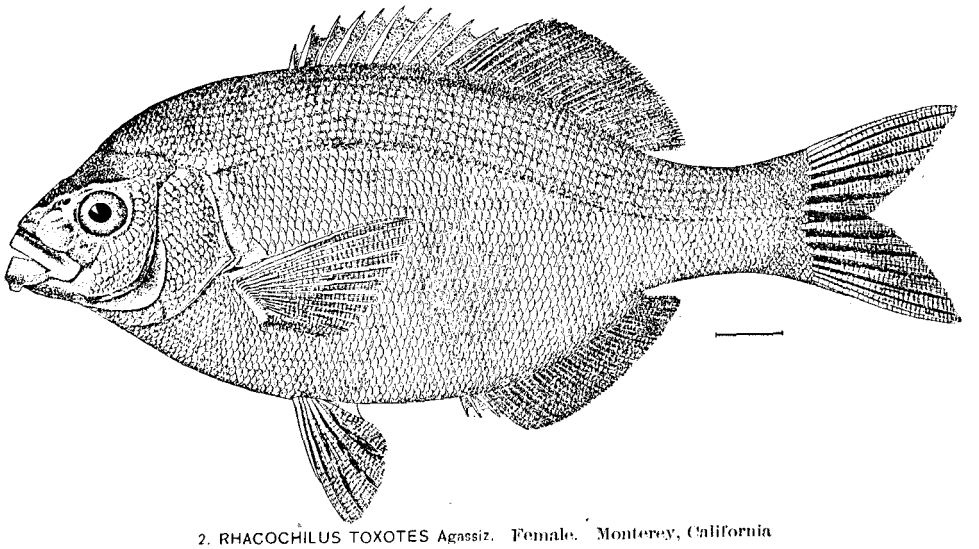
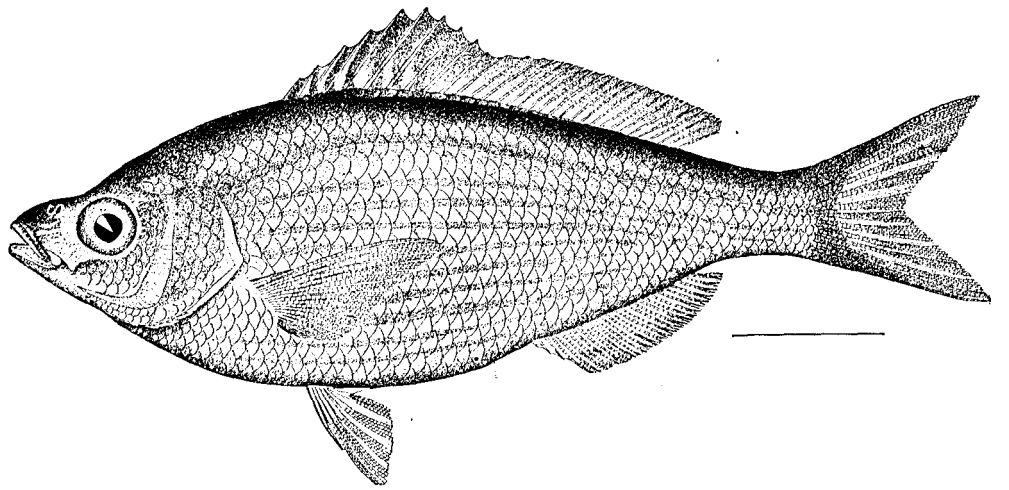


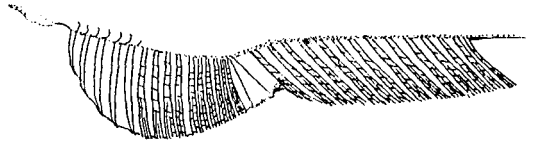
1. DAMALICHTHYS ARGYROSOMUS Girard. Male. Friendly Cove, British Columbia.



2. RHACOCHILUS TOXOTES Agassiz. Female. Monterey, California



3. CYMATOGASTER AGGREGATUS Gibbons. Female. Port Wrangel, Alaska.



4. ANAL FIN OF THE MALE OF HYPERPROSPON

9.—ON THE VIVIPAROUS FISHES OF THE PACIFIC COAST OF NORTH AMERICA.

BY CARL H. EIGENMANN,
Professor of Zoology, Indiana University.

INTRODUCTION.

During a stay of nearly three years on the coast of California at San Francisco and San Diego, viviparous fishes were daily seen in the markets and a large amount of material illustrating their development was collected. Few adult specimens of *Embiotocidæ* were preserved, since they were already well represented in most museums. The revision of this family is largely based on collections made by Drs. Jordan and Gilbert. Of the *Scorpænidae*, more specimens were collected, since many new forms were discovered. On the other hand, the embryology of this family is of much less interest than that of the *Embiotocidæ*, in which among teleosts viviparity has been carried to the greatest extreme.

The present paper gives a review of the *Embiotocidæ*, a bibliography of the viviparous fishes, and a detailed account, as far as my material permits, of the development of *Cymatogaster* from fertilization to hatching and the details of the development of the intestine and of Kupffer's vesicle. Outlines of the postembryonic development are also presented, but the details of the anatomy of the various postembryonic stages will be reserved for a future paper.

It is the intention of the writer to complete as rapidly as possible the following additional chapters: The development of the skeleton; the circulatory system, and especially the development of the sexual organs from the time of the segregation of the sex cells till sexual maturity (for which practically all the necessary material has been collected); and a revision of the *Scorpænidæ*. Several of these chapters have been sketched out and many of the drawings for them have been prepared.

Points in the embryology of *Cymatogaster*, which, on account of the scarcity of material have not been made out as fully as desired, are, the first formation of the embryo, its relation to the blastopore, and the development from the closing of the blastopore till three protovertebræ are completed. I have given full particulars as to when and where eggs are to be obtained with the hope that others will fill these gaps.

I am indebted to the San Francisco Microscopical Society for the use of its library and for many other courtesies. I am under many obligations to Dr. Theodore Gill, of the Smithsonian Institution. Several years ago he showed me an unpublished and abandoned work on west coast fishes, which, among other things, contained the various accounts of the early observers on the viviparity of *Embiotocidæ*. When, later, I was preparing the historical portion of this paper, Dr. Gill sent me the whole of this material so far as it related to the *Embiotocidæ* as well as all of his manuscript notes, accompanied by the following remarks: "Make such use of them as you wish and

keep them as long as you need them. You can use them as copy and thus avoid the task of transcribing."

The synonymy of the *Embiotocidæ* in the following review to 1868 is Dr. Gill's, with only slight alterations. The etymology of the generic names is also reproduced here as given in his unpublished work. Such other portions as I have incorporated in the paper, I have indicated by quotation marks, also giving direct credit for the same.

I wish to express my thanks to Dr. Silas M. Mouser, of San Francisco, in whose laboratory the sections necessary for the part of the work here presented were made. I wish also to acknowledge my indebtedness to ex-Governor (now United States Senator) G. C. Perkins, of San Francisco, for enabling me to visit various parts of the coast of California. I am under similar obligations to Mr. A. N. Towne, of the Southern Pacific Railroad Company. Dr. Howard Ayres kindly furnished me with references to the bibliography bearing on some of the points. Finally, Mrs. Eigenmann assisted me in all the stages of securing and preserving the material, rendered much assistance in preparing the paper, and corrected all the proofs.

A REVIEW OF THE EMBIOTOCIDÆ

[By Carl H. Eigenmann and Albert B. Ulrey.]

The writers have attempted in this paper to collate the various references to the species of *Embiotocidæ* and to present a synopsis of the genera, together with brief descriptions of the species.

Most of the American species have been examined by us, and in order to determine the number of valid genera skeletons have been prepared. These show that the earlier authors have been more fortunate in their opinions concerning genera of *Embiotocidæ* than the more recent ones. The genus *Ditrema* has been admitted on second-hand knowledge. As yet no one has given any very lucid characterization of this genus as distinct from *Embiotoca* and external differences seem to be wanting.

EMBIOTOCIDÆ.

Holconoti or *Embiotocoidæ* Agassiz, Am. Jour. Sci. and Arts (2), v. 16, 383, 1853.
Holconoti seu Embiotocoidæ Troschel, Archiv für Naturgeschichte, 20. Jahrg., B. 1, 167, 1854.
Holconoti or *Embiotocoidæ* Agassiz, Am. Jour. Sci. and Arts (2), v. 17, May, 1854.
Holconoti Troschel, Archiv. für Naturgeschichte, 21. Jahrg., B. 1, 347, 1855. (Synopsis of genera.)
Holconoti Canestrini, Verhandlungen der K. K. Zoologisch-Botanischen Gesellschaft in Wien, Jahrgang 1860.
Holconotoidei Bleeker, Enum. Sp. Piscium Archipel. Indico, XVIII, 1859.
Holconotidæ Eigenmann, Report State Board Fish Commissioners, California, 1890, 64.
Embiotocidæ Richardson, Encycl. Brit., 8th ed., v. 12, 268, 1856.
Embiotocoidæ Girard, Expl. and Surv. for R. R. Route to Pacific, v. 10, Fishes, 164, 1858.
Embiotocidæ Günther, Cat. Fish. Brit. Mus., v. 4, 244, 1862.
Embiotocoidæ Gill, Proc. Acad. Nat. Sci. Phila. 1862 [v. 14], 274.
Embiotocidæ Cope, Proc. Am. Assoc. Adv. Sci. 1872, v. 20, 343.
Embiotocidæ Jordan & Gilbert, Syn. Fish. N. A., 586, 1883. Jordan, Cat. Fish. N. A., 96, 1885.
Ditremata Fitzinger, Sitzungsber. K. Akad. der Wissensch. (Wien), B. 67, 1 Abth., 30, 1872.
Ditremidæ Eigenmann & Eigenmann, Proc. Cal. Acad. Sci. 1890, 2d ser., vol. III, 9.
Menidæ gen., Temm. & Schlegel, Bleeker (1858).
Labroidæ gen., Gibbons, 1854, Van der Hoeven.
Scombridæ gen., Günther, 1860.

Habitat: Coasts of California and Japan, Sacramento Valley.

Description of family of Embiotocidæ.—Viviparous teleosts with united lower pharyngeals; paired nasal openings; dorsal fin single, with 8 to 18 spines; a sheath of scales along the base of part of the dorsal, separated from the scales of the sides by a naked line; anal with three spines, its form differing in the sexes of some species; ventral fins thoracic, I, 5. No teeth on vomer or palatines; teeth in jaws small, some of those on pharyngeals larger, conical or paved. Pseudobranchiæ. No pyloric cœca. Oviduct opening behind the vent.

Common characters.—Body compressed, oblong. Cheeks, operculum, and interoperculum scaly; scales mostly cycloid. Lateral line arched, continuous. Mouth small, terminal; upper jaw protractile. Maxillary without supplemental bone. Gill membranes free from the isthmus.

ANALYSIS OF THE GENERA OF EMBIOTOCIDÆ.

a. Dorsal spines 8–11; anal spines graduated ..... (EMBIOTOCINÆ.)

b. Abdominal vertebræ 17; caudal 19; anal basis much shorter than the abdomen; A. III, 23; lips large, lower lip with a frenum; gill-rakers slender, short (7 + 13); anterior and lateral teeth of pharyngeals small, bluntly conic; a triangular posterior patch of larger teeth, all but the posterior row truncate, the posterior row conic. HYPSURUS, 1.

bb. Abdominal vertebræ 13–15; anal basis equaling, or longer than, the abdomen.

c. Teeth entire, usually bluntly conic.

d. Dentiferous surface of lower pharyngeals arched, the anterior teeth much worn, the posterior not at all, the cutting surface of the anterior teeth flattened, that of the posterior teeth not faced. Teeth of the upper pharyngeals similar to those of the lower pharyngeals, but the *posterior* teeth of the upper pharyngeal applied to the *anterior* of the lower pharyngeal; the posterior teeth of the upper pharyngeals thus resemble the anterior of the lower pharyngeals and the anterior of the upper the posterior of the lower ..... DAMALICHTHYS, 2.

dd. Dentiferous surface of lower pharyngeals flat or concave.

e. Teeth in two series in each jaw. Male with one of the anterior rays of the anal transformed into a triangular plate; anal basis forming a decided angle at this point; the rays in front of this point with a thick covering of skin; pharyngeal teeth mostly small, conic, only a few in the last two series enlarged, some of which are sometimes truncate molars.

f. Vertebræ 33–35; lower lip without a frenum; gill-rakers very long, slender, and tapering, 23 to 29; anal basis below 12–14 caudal vertebræ ..... HYPERPROSOPON, 3.

ff. Vertebræ 32 (14 + 18); lower lip without a frenum; gill-rakers moderate, stout, blunt, 6 + 11; anal basis below 11 caudal vertebræ ..... HOLCONOTUS, 4.

fff. Vertebræ 29 (13 + 16); lower lip with a broad frenum; gill-rakers short, stout, blunt, 5 + 11; anal basis below 10 caudal vertebræ ..... AMPHISTICHUS, 5.

ee. Teeth none, or in a single series in each jaw, anterior and lateral pharyngeal teeth small, conic, the median and posterior ones large, truncate, molars; males with a gland on some of the anterior anal rays, the anal basis without angle, none of the rays modified to form a definite plate.

g. Teeth none, lips thin; jaws greatly protractile ..... NEODITREMA, 7.

gg. Teeth in both jaws.

h. Lower lip very thick, lobed, without a frenum; gill-rakers long .... RHACOCHILUS, 6.

hh. Lower lip thin, normal, entire, with a frenum.

i. Scales small, 60–75 in lateral line.

j. The characters of *Ditrema* should be added here. No examination of internal organs has as yet been made ..... DITREMA, 8.

k. Vertebræ 14 + 18 or 19, anal basis below 9 caudal vertebræ; first hæmal spine small, applied to the second ..... EMBIOTOCA, 9.

kk. Vertebræ 14 or 15 + 21 to 24; anal basis below 11 or more caudal vertebræ; first hæmal spine as large as second, sometimes approximated with the second. PHANERODON, 10.

ii. Scales large, 40–50 in lateral line; vertebræ 13 + 21 or 15 + 19; gill-rakers short, blunt, wide set, 6 + 12; anal basis (*rosaceus*) below 9 caudal vertebræ. BRACHYISTIUS, 11.

hhh. Lower lip thin, without a frenum; vertebræ, 14+20; scales large, less than 40 in lateral line; gill-rakers long, slender, 10+21; anal basis below 12 caudal vertebræ; pharyngeal teeth as in *Brachyistius*, the central and posterior ones blunt molars..... CYMATOGASTER, 12.

cc. Teeth incisor-like, trilobed; vertebræ, 14+20; scales, large; outer series of pharyngeal teeth small, conic; the rest (about 32) large molars closely appressed; anal basis below 7 caudal vertebræ; gill-rakers long, slender, 6+14; sixth dorsal spine highest; male with a deep depression at the base of the anterior anal rays, a gland below the middle of the depression..... ABEONA, 13.

aa. Dorsal spines 16–18, the sixth or seventh highest; second anal spine largest; vertebræ, 14+20; about 12 of the median posterior teeth of pharyngeals large, all but the median three of these obliquely truncate molars, the remainder small; gill-rakers short, slender, 6+12; teeth in a single series; lower lip without frenum. (*Hysterocarpinæ*), HYSTEROCARPUS, 14.

1. HYPSURUS* A. Agassiz.

Embiotoca sp. Agassiz, Am. Journ. Sci. & Art, 1853, 389 (sp.).
Hypsurus A. Agassiz, Proc. Bost. Soc. Nat. Hist. 1861, 133 (*caryi*).

Type: *Embiotoca caryi* L. Agassiz.

1. HYPSURUS CARYI Agassiz.

Embiotoca caryi Agassiz, Am. Journ. Sci. & Art (2), v. 16, 389, 1853 (San Francisco); Agassiz, Am. Journ. Sci. & Art (2), v. 17, 366, 1854; *id.*, Archiv für Naturgeschichte, 21. Jahrg., B. 1, 32, 1855; A. Agassiz, Proc. Bost. Soc. Nat. Hist., v. 8, 126, 1861.

Hypsurus caryi A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 133, 1861; Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco to Santa Barbara, Cal.); Rosa Smith, A List of the Fishes of San Diego, Cal., Nov., 1880; Jordan & Jouy, Proc. U. S. N. M. 1881, 11 (Monterey, San Francisco, Santa Barbara, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1881, 11 (Tomales to Santa Barbara, Cal.); Jordan & Gilbert, Syn. Fish. N. A., 593, 1883 (Santa Barbara to San Francisco); Jordan, Cat. Fish. N. A., 96, 1885; E. & E., Annals N. Y. Acad. Sci., VI, June, 1892 (Santa Barbara to San Francisco).

Ditrema caryi Günther, Cat. Fish. Brit. Mus., IV, 247, 1862 (San Francisco).

Holconotus gibbonsii, Cal. Acad. Sci., MSS., 1854; Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 122; Archiv für Naturg., 21. Jahrg., B. 1, 333, 1855.

Habitat: Coast of California from San Diego to San Francisco. This species is but rarely found at San Diego, only one or two specimens having been seen there. It is, however, one of the commonest species of *Embiotocidæ* in the San Francisco markets.

Body elliptical, ventral profile much straighter than dorsal; caudal peduncle slender, head considerably depressed above the eye; lower jaw included; rays of dorsal fin equaling or higher than spines. The maxillary reaches about eight-ninths distance to front of orbit, included under the orbital; premaxillaries anteriorly about on a level with lower rim of pupil. The anal fin very short, placed far back, the rays closely crowded together and spines small; fourth to sixth dorsal spines highest.

Head, 3½; depth, 2½; D. X, 23; A. III, 24; Lat. line, 71.

* Ὑψι, high, and οὐρά, tail.

2. DAMALICHTHYS* Girard.

Damalichthys Girard, Proc. Acad. Nat. Sci. Phila. 1855, 321 (*vacca*); *id.* Pacific R. R. Survey, x, 181, 1859; Gill, Proc. Acad. Nat. Sci. Phila. 1855, 321; Jordan & Gilbert, Syn. Fish. N. Am., 597, 1883.

Embiotoca Girard, Proc. Acad. Nat. Sci. Phila. 1855, 136 (sp.).

Ditrema Günther, Cat. Fish. Brit. Mus., IV, 1862 (sp.).

Type: *Damalichthys vacca* Girard=*argyrosomus.*

2. DAMALICHTHYS ARGYROSOMUS Girard.

(Plate XCII, fig. 1.)

Embiotoca argyrosomus Girard, Proc. Acad. Nat Sci. Phila. 1855, VII, 136 (San Francisco); *id.* Pacific R. R. Survey, VI, 25, 1857; *id.* Pacific R. R. Survey, X, 180, 1859 (San Francisco); A. Agassiz, Proc. Boston Soc. Nat. Hist., VIII, 127, 1861; Cooper, Nat. Wealth Cal. by Cronise, 489.

Phanerodon argyrosoma Gill, Proc. Acad. Nat. Sci. Phila., v. 14, 274 (note).

Damalichthys argyrosomus Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (Puget Sound to San Pedro, Cal.); Jordan & Jouy, Proc. U. S. N. M. 1881, 11 (Puget Sound, Monterey, Santa Barbara, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1881, 49 (San Pedro to Puget Sound); Bean, Proc. U. S. N. M. 1881, 265 (Puget Sound, Vancouver Island); Bean, Proc. U. S. N. M. 1883, 360 (Departure Bay, B. C.); Jordan & Gilbert, Syn. Fish. N. A., 597, 1883 (Pacific coast north to Vancouver Island); Jordan, Cat. Fish. N. A., 97, 1885 (name); Eigenmann & Eigenmann, Proc. Cal. Acad. Sci., 2d ser., vol. III, 9, 1890 (San Diego); *id.* Ann. N. Y. Acad. Sci., VI, June, 1892 (San Diego, San Pedro to San Francisco, Puget Sound).

Damalichthys vacca Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 321, 1855 (Puget Sound); Archiv für Naturgeschichte, 21. Jahrg., B. 1, 318, 1855; Girard, Expl. and Surv. for R. R. Route to Pac., v. 10, Fishes, 182, pl. XXXIII, 1858; Suckley, Expl. and Surv. for R. R. Route to Pac., v. 12, Stevens' Report, book 2, 358, 1859; Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 127, 1861; Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; Lockington, Rpt. Comm. Fisheries California, 30, 1879.

Ditrema vacca Günther, Cat. Fish. Brit. Mus., IV, 246, 1862 (San Francisco).

Habitat: Pacific coast, from San Diego to Vancouver Island.

This species is not uncommon at San Diego and is quite abundant in the San Francisco markets.

Body ovate, dorsal and ventral profile nearly equally curved, tapering abruptly into a long slender caudal peduncle. Head rather large, occipital region little depressed; lower jaw included; maxillary reaching nearly to the front of the orbit. Eye large, a little longer than the snout. Teeth few, conical, bluntish, in one series. Gill-rakers slender, 7+13. Spines of dorsal fin stout, shorter than longest rays. Pectorals long, reaching beyond the ventrals. Color soiled white, with silvery luster; three or four obscure dusky bars, most distinct in the young: fins nearly plain, dusky.

* δάμαλις, calf; ἰχθύς, fish, in allusion to its viviparity.

3. HYPERPROSOPON * Gibbons.

Hyperprosopon Gibbons, Daily Placer Times and Transcript, May 18, 1854; Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 124 (*argenteus*); A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 132, 1861.
Ennichthys † Girard, Proc. Acad. Nat. Sci. Phila. 1855, v. 7, 322 (*megalops*).
Hyperprosodon ‡ Troschel, Archiv f. Naturg., 21. Jahrg., Band 1, 338–344.
Bramopsis § Agassiz, MSS. (fide A. Agassiz) (*mento*).
Hypocritichthys ‖ Gill, Proc. Acad. Nat. Sci. Phila. 1862, v. 14, 275 (*analis*).
Amphistichus Jordan & Gilbert, Syn. Fish. N. Am., 590, 1883 (sp.).
Holconotus Jordan, Cat. Fish. N. Am., 96, 1885 (sp.).

Type: *Hyperprosopon argenteus* Gibbons.

We have not been able to examine *H. analis* A. Agassiz, which may constitute a genus distinct from *Hyperprosopon*. The latter is distinguished from *Holconotus* by the characters indicated in the key to the genera.**

ANALYSIS OF SPECIES OF HYPERPROSOPON.

a. Anal fin, III, 23. (*Hypocritichthys* Gill.)

b. Body comparatively elongate; upper anterior profile nearly straight, depressed above the eyes. Snout sharp. Mouth large, very oblique, the tip of the lower jaw on a line with the upper profile of the snout; maxillary reaching front of orbit. Dorsal spines high and slender, longer than the soft rays, the middle longest; anal spines small; caudal fin short, not widely forked; pectorals short and broad, four-fifths the length of head. Eye, five-fourths the length of snout; Head, 3½; depth, 2½; D. IX, 22; A. III, 23; lat. l., 63. Color silvery; an inky blotch on the middle of the anal, and a fainter blotch on the spinous dorsal; front of anal yellow; fins otherwise plain. Axil black. (Jordan & Gilbert.) ..... ANALIS, 3.

aa. Anal fin, III, 29–32. Interorbital region rather abruptly depressed at the nape. Eye large. (*Hyperprosopon* Gibbons.)

c. Ventral fins broadly tipped with black; anal plain or with dusky margin, III, 33; D. IX, 27; lat. l., 72–74. Eye, 3. Body ovate, the ventral profile somewhat more curved than the dorsal. Snout very short, considerably shorter than the eye. Maxillary not included under the orbital, reaching almost to the front of the orbit; mouth oblique, the lower jaw projecting. Dorsal fin with middle spines higher than the last or than the soft rays; anal low, spines slender. Head, 3½; depth, 2. "Color, bluish black above; sides bright silvery, sometimes faintly barred." ..... ARGENTEUS, 4.

cc. Ventral fins plain; anal blackish anteriorly, III, 30; D. IX, 25; lat. l., 60–65. Eye, 3¼. Body elliptic ovate, the dorsal outline not curved as much as the ventral; snout very short, much shorter than the eye; maxillary not included under the orbital, reaching nearly to the front of the orbit; mouth oblique, the lower jaw projecting. Sixth dorsal spine highest, higher than the soft rays; anal low, the spines weak. Head, 3½; depth, 2. Color, "greenish olive above, sides bright silvery; 5 or 6 short blackish vertical bars on the sides, these sometimes obsolete; caudal reddish, dusky at tip." ..... AGASSIZII, 5.

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* *Hyperprosopon:* Ὑπέρ, above, and πρόσωπον, face; alluding to the production upward of the facial outline and snout.

† *Ennichthys:* Contracted from Ἐννεοσσεύω, to hatch, and ἰχθύς, fish; in allusion to the viviparity.

‡ *Hyperprosodon:* Probably due to a misapprehension of the etymology of *Hyperprosopon*, and perhaps supposed to have been derived from ὑπέρ, quasi, excessively, and πρόσοδος, sexual intercourse.

§ *Bramopsis: Brama*, type of a peculiar family of Acanthopterygian fishes, and ὄψις, form; in allusion to a superficial resemblance of the genus to *Brama*.

‖ *Hypocritichthys:* Ὑποκρῑτής, hypocrite, and ἰχθύς, fish; alluding to the deceptive nature of the external appearance, the genus having much superficial resemblance to *Cymatogaster* in form as well as size, disguising in a measure its close affinity to *Hyperprosopon*. Type, *H. analis*.

** Dr. Gill informs us that on the basis of the classification adopted the genus *Hypocritichthys* is valid and distinct from *Hyperprosopon*.

3. HYPERPROSOPON ANALIS A. Agassiz.

Hyperprosopon analis A. Agassiz, Proc. Boston Soc. Nat. Hist., VIII, 133, 1861 (name only); Eigenmann & Eigenmann, Ann. N. Y. Acad. Sci., VI, June, 1892 (Port Harford and Monterey).

Hypocritichthys analis Gill, Proc. Acad. Nat. Sci. Phila. 1862, v. 14, 275 (California); Cooper, Nat. Wealth Cal. by Cronise, 489, 1868.

Ditrema anale Günther, Cat. Fish. Brit. Mus., IV, 250, 1862 (California).

Holconotus analis Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (Monterey Bay, California); Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (Monterey, California); Jordan & Gilbert, Proc. U. S. N. M. 1881, 51 (San Francisco to San Luis Obispo, California); Jordan, Cat. Fish. N. Am., 996, 1885.

Amphistichus analis, Jordan & Gilbert, Syn. Fish. N. Am., 591, 1883.

Habitat: Port Harford to San Francisco. Rare.

4. HYPERPROSOPON ARGENTEUS Gibbons.

Hyperprosopon argenteum Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 105 (San Francisco); l. c. 125; *id.*, Archiv. für. Naturg., 21. Jahrg., B. 1, 338, 1855; A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 132, 1861; Gill, Proc. Acad. Nat. Sci. Phila. 1862, v. 14, 276 (California); Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; Eigenmann & Eigenmann, Ann. N. Y. Acad. Sci., VI, June, 1892 (San Diego, San Pedro to San Francisco).

Holconotus argenteus Rosa Smith, A List of the Fishes of San Diego, California, 1880, Nov.; Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco to San Diego, California); Jordan, Proc. U. S. N. M. 1881, 10 (Monterey, San Francisco, Santa Barbara, and San Diego, California); Jordan & Gilbert, Proc. U. S. N. M. 1881, 50 (Tomales to San Diego, California); Rosa Smith, West Am Scientist, 1885, June; Jordan, Cat. Fish. N. A., 96, 1885 (name).

Hyperprosopon argenteum punctatum Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 106 (fide Gill).

Hyperprosopon arcuatus Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 125; Archiv. f. Naturg. 1855, B. 1, 339; Gill, Proc. Acad. Nat. Sci. Phila. 1862, v. 14, 275 (California); Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; Jordan & Gilbert, Proc. U. S. N. M. 1880, 28 (San Diego, California).

Ditrema arcuatum Günther, Cat. Fish. Brit. Mus., IV, 249, 1862 (San Francisco).

Amphistichus arcuatus Jordan & Gilbert, Syn. Fish. N. A., 591, 1885 (Cape Mendocino and southward).

Holconotus megalops Girard, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 152.

Ennichthys megalops Girard, l. c., 323; Archiv. f. Naturg. 1855, B. 1, 351; Girard, Pacific R. R. Survey, v. 6, 26; *id.*, l. c., v. 10, 197, pl. XXXVII and XXVI, fig. 10 (Presidio, Humboldt Bay, Astoria).

Ditrema megalops Günther, Cat. Fish. Brit. Mus., IV, 249, 1862.

Habitat: Astoria to Ensenada.

5. HYPERPROSOPON AGASSIZI Gill.

Hyperprosopon arcuatum A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 133, 1861 (not of Gibbons).

Hyperprosopon agassizi Gill, Proc. Acad. Nat. Sci. Phila., v. 14, 276, 1862 (California); Eigenmann & Eigenmann, Ann. N. Y. Acad. Sci., VI, June, 1892 (Santa Barbara to San Francisco).

Ditrema agassizi Günther, Cat. Fish. Brit. Mus., IV, 250, 1862 (San Francisco).

Holconotus agassizi Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco to Santa Barbara, Cal.); Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (Monterey and San Francisco, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1881, 50 (Tomales to Santa Barbara, Cal.); Jordan, Cat. Fish. N. Am., 96, 1885 (name only).

Amphistichus agassizi Jordan & Gilbert, Syn. Fish. N. A., 592, 1883 (California).

Hyperprosopon punctatum Cooper, Nat. Wealth Cal. by Cronise, 486, 1868.

Habitat: Santa Barbara to San Francisco.

4. HOLCONOTUS* Agassiz.

Holconotus Agassiz, Am. Journ. Science and Art, v. 17, 367, May, 1854 (*rhodoterus*).
Cymatogaster Gibbons, Daily Placer Times and Transcript, June 21, 1854 (not *Cymatogaster*, l. c., May 18, 1854); Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 123.

As here understood, this genus is composed of but a single species.

6. HOLCONOTUS RHODOTERUS Agassiz.

Holconotus rhodoterus Agassiz, l. c. (San Francisco); Archiv. f. Naturg. 1855, B. 1, 34; A. Agassiz, Proc. Boston Soc. Nat. Hist., vol. 8, 132, 1861; Cooper, in Cronise Nat. Wealth Cal., 489, 1868; Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco to Santa Barbara); Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (Monterey, San Francisco and Santa Barbara); Jordan & Gilbert, Proc. U. S. N. M. 1880, 50 (Tomales to Santa Barbara, California); Jordan Cat. Fish. N. A., 96, 1885; Eigenmann & Eigenmann, Ann. N. Y. Acad. Sci., June, 1892 (San Diego, Santa Barbara, Monterey, San Francisco).
Ditrema rhodoterum Günther, Cat. Fish. Brit. Mus., IV, 250, 1862 (San Francisco).
Amphistichus rhodoterus Jordan & Gilbert, Syn. Fish. N. A., 592, 1883 (California); Eigenmann & Eigenmann, Proc. Cal. Acad. Sci., 2d ser., III, 9, 1890 (San Diego).
Cymatogaster pulchellus Gibbons, Proc. Acad. Nat. Sci. Phila., v. 8, 123, July, 1854; Archiv für Naturg., 21. Jahrg., B. 1, 335, 1855.
Holconotus pulchellus A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 132, 1862; Cooper, Nat. Wealth Cal. by Cronise, 489, 1868.
Cymatogaster larkinsii Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, 123 (San Francisco); Archiv f. Naturg. 1855, B. 1, 335.
Cymatogaster ellipticus Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, 124 (San Francisco); Archiv f. Naturg. 1855, B. 1, 336.

Habitat: Coast of California from San Francisco to San Diego.

Body ovate, dorsal and ventral outlines nearly equally curved. Profile above the eye little depressed; the snout a little longer than the eye. Mouth quite oblique, the lower jaw not projecting; maxillary not included under the orbital, reaching to the front of the pupil. Fifth dorsal spine highest, considerably higher than the soft rays; pectorals falcate, not reaching the tips of ventrals; color, "greenish above; sides silvery, profusely covered with spots and blotches of light orange-brown or coppery red, these mostly in the form of interrupted vertical bars; caudal, anal, and ventral fins bright reddish without black spots or markings" (Jordan & Gilbert). Head, $3\frac{1}{2}$; depth, $2\frac{1}{4}$. D. IX or X, 26; A. III, 29; Lat. line, 69.

5. AMPHISTICHUS Agassiz.

Amphistichus† Agassiz, Am. Journ. Science and Art, (2) v. 17, 367, May, 1854 (*argenteus*).
Mytilophagus‡ Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, 125 (*fasciatus=argenteus*).

Type: *Amphistichus argenteus* Agassiz.

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* Ὀλκός, furrow, and νῶτος, back; referring to the dorsal furrows common to all the species of the family.

† *Amphistichus:* Ἀμφί, used in the sense of double, and στοίχος, rows; referring to the two rows of teeth in each jaw.

‡ *Mytilophagus:* Μυτίλος, *Mytilus*, and φαγεῖν, to eat; in allusion to the supposed principal food of the genus.

7. AMPHISTICHUS ARGENTEUS Agassiz.

Amphistichus argenteus Agassiz, Am. Journ. Science and Arts (2), v. 17, 367, 1854 (California); Archiv für Naturg. 1855, B. 1, 34; Girard, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 141 and 153; *id.*, l. c., 323; *id.*, Archiv. f. Naturg. 1855, B. 1, 352; *id.*, Pacific R. R. Survey, v. 10, 201, pl. XXXIX, 1859 (San Francisco, Presidio); *id.*, l. c., Whipple's Report, 51, 1859 (San Francisco); *id.*, l. c., Williamson's Report, 88, 1859 (San Francisco); Agassiz, Proc. Boston Soc. Nat. Hist. 1861, 131; Gill, Proc. Acad. Nat. Sci. Phila. 1862, 275 (California); Cooper, in Cronise Nat. Wealth Cal., 489, 1868; Rosa Smith, A List of the Fishes of San Diego, Cal., Nov., 1880; Jordan & Gilbert, Proc. U. S. N. M. 1880, 28 (San Diego, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco to San Diego, Cal.); Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (Monterey, San Francisco, Santa Barbara, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1881, 50 (Tomales to San Diego, Cal.); Jordan & Gilbert, Syn. Fish. N. A., 593, 1883 (California); Jordan, Cat. Fish. N. Am., 96, 1885; Rosa Smith, West Am. Scientist, June, 1885 (San Diego); Eigenmann & Eigenmann, Ann. N. Y. Acad. Sci., VI, June, 1892 (San Diego to San Francisco).

Ditrema argenteum Günther, Cat. Fish. Brit. Mus., IV, 251, 1862 (San Francisco); Lord, Naturalist in Vancouver Isl. and Brit. Col., I, 120, pl. opposite p. 160, 1866.

Mytilophagus fasciatus Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 125 (San Francisco); *id.*, Archiv f. Naturg., 1855, B. 1, 340.

Amphistichus heermanni Girard, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 135.

Ennichthys heermanni Girard, l. c., 323; *id.*, Archiv f. Naturgeschichte, 1855, B. 1., 351; *id.*, Pacific R. R. Survey, v. 10, 199, pl. XXXVIII and XXVI, fig. 9, 1859 (Cape Flattery, San Francisco); *id.*, l. c., Williamson's Report, 88, 1859 (San Francisco).

Amphistichus similis Girard, Proc. Acad. Nat. Sci. Phila. 1854, v. 7, 153; *id.*, l. c., 323, 1855; *id.*, Archiv f. Naturg. 1855, B. 1, 353; *id.*, Pacific R. R. Survey, 203, pl. XXXVI, fig. 5–9, 1859 (San Francisco); *id.*, l. c., Williamson's Report, 88, 1859 (San Francisco).

Habitat: San Diego to Cape Flattery.

Body ovate, the dorsal profile much more curved than the straightish ventral outline. Mouth slightly oblique, comparatively large. Snout longer than the rather small eye. Interorbital region little depressed; maxillaries not included under the orbital, reaching to the front of the pupil; lower jaw included. Dorsal spines strong, the fifth or sixth longest, not so long as the soft rays; pectorals slightly falcate, reaching almost to the tips of the ventrals. Head, $3\frac{1}{2}$; depth, $2\frac{1}{4}$; D. X, 24; A. III, 26; lat. l., 67. Color, "silvery; sides with narrow vertical bars of a brassy olive color, alternating with vertical series of spots of similar color; fins plain; vertical fins sometimes edged with dusky." A few specimens have been observed in which the sides were uniformly brassy.

6. RHACOCHILUS Agassiz.

*Rhacochilus** Agassiz, Am. Journ. Science and Art, (2) v. 17, 367, May, 1854 (*toxotes*).

Pachylabrus† Gibbons, Proc. Cal. Acad. Sci. in Daily Placer Times and Transcript, San Francisco, June 21, 1854.

Type: *Rhacochilus toxotes* Agassiz.

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* *Rhacochilus:* Ῥάκος rag, and χεῖλος, lip; referring to the slashed lips of the adult.

† *Pachylabrus:* Παχύς, thick and *labrus*, lip; a hybrid word alluding to the thickened lips.

8. RHACOCHILUS TOXOTES Agassiz.

(Plate XCII, fig. 2.)

Rhacochilus toxotes Agassiz, Am. Journ. Sci. and Art (2), v. 17, 367, 1854; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 33; Girard, Proc. Acad. Nat. Sci. Phila., v. 8, 136, 1856; Girard, Expl. and Surv. for R. R. Route to Pacific, v. 10, Fishes, 188, pl. XL, 1859 (Tomales Bay); A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 130, 1861; Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco to San Pedro, California); Jordan & Jouy, Proc. U. S. N. M. 1881, 11 (Monterey, Wilmington, Santa Barbara, San Francisco, California); Jordan & Gilbert, Proc. U. S. N. M. 1881, 49 (San Pedro to San Francisco, California); Eigenmann, 1890; Jordan & Gilbert, Syn. Fish. N. A., 596, 1883 (California); Jordan, Cat. Fish. N. Am., 96, 1885; Eigenmann & Eigenmann, Ann. N. Y. Acad. Sci., VI, June, 1892 (San Diego to San Francisco).

Ditrema toxotes Günther, Cat. Fish. Brit. Mus., IV, 247, 1862 (San Francisco).

Pachylabrus variegatus Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, p. 126; Archiv für Naturgeschichte, 21 Jahrg., B. 1, p. 311, 1855.

Habitat: San Francisco to San Diego.

Body ovate, tapering abruptly into a long and robust caudal peduncle; mouth comparatively large, the lower jaw included; eye large; the soft dorsal rays considerably higher than the low spinous dorsal; caudal short, deeply forked, the upper lobe the longer; pectorals and ventrals long. Head, $3\frac{2}{5}$; depth, $2\frac{2}{5}$; D. X, 23; A. III, 30; lat. line, 76. Color olivaceous with brassy reflections and dusky points; fins plain.

7. NEODITREMA Steindachner & Döderlein.

Neoditrema Steindachner & Döderlein, Denk. Ak. Wiss. Wien, XLVII 32, 1883 (*ransonneti*).

Type: *Neoditrema ransonneti* St. & D.

This genus is described as a *Ditrema* without teeth in its jaws.

9. NEODITREMA RANSONNETI Steindachner & Döderlein.

Neoditrema ransonneti Steindachner & Döderlein (Yokohama, Tokio).

Habitat: Japan.

Strongly compressed, especially below the pectorals; profile to occipital process concave; mouth greatly protractile; head pointed, mouth oblique; lower jaw included; maxillaries concealed under preorbital, reaching to eye. Dorsal spines graduated from the first to the last, which is equal to the snout and half the eye in length; caudal widely forked, about equal to the head exclusive of snout. Back dusky, golden yellow below lateral line; base and tip of caudal dusky, remainder of fin yellow. Head, $3\frac{2}{3}$ to $3\frac{3}{4}$; depth, $3\frac{1}{3}$; D. VI–VIII, 21 or 22; A. III, 26–27. Lat. l., 70. Br., 5. (Steindachner.)

8. DITREMA* Schlegel.

Ditrema Schlegel, Fauna Japonica, 77, pl. XL, fig. 2.

Ditrema Bleeker, Verh. Batav. Genootsch, XXV, 33 (*temminckii*).

Ditrema Brevoort, Narrative U. S. Exped. to Japan (Perry's), II, 265, 1856 (first referred to the family *Embiotocidæ*).

Ditrema Günther, Cat. Fish Brit. Mus., IV, 244, 1862 (=*Embiotocidæ*).

Ditrema Jordan & Gilbert, Syn. Fish N. A., 594, 1883 (=several genera).

Type: *Ditrema temminckii* Bleeker.

**Ditrema:* Δις, double, and τρῆμα, hole; referring to the presence of the special generative aperture in addition to the anal one.

10. DITREMA TEMMINCKII Bleeker.

Ditrema, Schlegel, l. c. (abundant in spring in Bay of Nagasaki); Gill, Proc. Phil. Acad. Sci. 1862, 126.

Ditrema temminckii Bleeker, l. c.; Brevort, l. c. (Hakodadi, in latitude 41° 49′ N.); Günther, Cat. Fish. Brit. Mus., IV, 246, 1862 (Japan); Bleeker, "Notices Ichthyologiques No. X."; Putnam, "Bull. Mus. Comp. Zool."; Nyström, Sv. Ak. Hand., XIII, afd. 4, No. 4, p. 32 (Japan).

Ditrema lævе Günther, Cat. Fish. Brit. Mus., II, 392, 1860 (Japan.)

Habitat: Japan.

Brevoort says, l. c.:

The genus *Ditrema* was established by Schlegel upon examination of two stuffed specimens and a native figure of a fish which offered the peculiarity of two anal orifices. * * * He gave the fish no specific name. * * * The figure by the artists of the United States Japan Expedition is identical with the one in the Fauna Japonica, though rather darker in coloring. It does not show the specific characters distinctly. * * * Upon showing the published figure of the *Ditrema*, and the figure of it by the American artist, to Diengkitch, he immediately described its viviparous faculty. * * * In the list of fishes * * * is one called in Chinese *Ju* or *Lian*, in Japanese *Tanako*, "a fish which swims in pairs"; and in a footnote Mons. A. Remusat (Notices et Extraits des Manuscrits, tome XI, part 1, 1827, p. 216) says: "It is asserted that this fish is viviparous * * *." This very interesting note, the authority for which is not given, induced me to compare the *Ditrema* with a specimen of the California viviparous fish procured by Dr. John LeConte in that country in 1851, and with the descriptions of the *Embiotocidæ* and *Holconoti*, by Agassiz * * * "when no doubt remained on my mind that species of the same family of fish were thus proved to occur on the Asiatic coast of the Pacific also.

11. DITREMA SMITTII Nyström.

Ditrema smittii Nyström, Sv. Ak. Handl., XIII, 4, afd. No. 4, p. 32, 1887 (Japan).

We add here the original description, a copy of which has been furnished by Dr. Theo. Gill:

No. 86. Ditrema smitti* n. sp.

Diagn.—Kroppens höjd ungefär ⅓ af totallängden; bakre delen af analfenan betydligt högre än den främre, och 17:de—20:del strålarne tradformigt förlängda; brostfenornas spetsar nå till analfenans början.

R. f. 11+21. A. f. 3+27. Br. f. 17. L. lat. 78. l. tr. 1½.

Kroppsformen är något mera långstrackt än hos föregående, med hvilken denna art för öfrigt synes visa närmaste slägtskapen, och största kroppshöjden utgör ungefär ⅓, och hufvudets längd ¼ af total-längden. Ögats diameter innehålles i det närmaste 4 ggr., och nosens längd, som är lika med pannans bredd mellan ögonen, 3½ ggr. i hufvudets längd.

Nosen öfre profilkontur är svagt konvex, och mellan ögonen är en framskj utande knöl, bakom hvilken pannan åter är något intryckt. Bakre delen af hufvudet är mera konvex och starkare uppstigande, dock ej så mycket som hos föregående art. Ryggen år temligen jämnt böjd till slutet af ryggfenan, och afståndet från basen af den sista ledade strålen till spetsen af stjärtfenans öfre flik är något större än hos *D. laeve*, och lika med afståndet från nosspetsen till bukfenornas rot.

Främre afdelningen af ryggfenan är låg och taggstrålarne tilltaga successivt i längd bakåt; den sista är dock något lägre än den första ledade strålen, och dess längd uppnår ungefär ⅓ af hufvudets. Den mjukstråliga delen af ryggfenan är temligen jämnt afrundad, och de mellersta strålarne, som äro de längsta, innehållas omkring 2ggr. i hufvudets längd.

Analfenan har den bakre afdelingen, från med den 16:de strålen, betydligt högre än den främre, och öfvergången mellan de båda afdelnidgarne sker hastigt, så att den 16: de strålen är i det närmaste dubbelts å lång som den före gående. 17:de—20:de fenstrålarne äro trådformigt förlängda, och af dessa äro de båda mellersta längst och ungefär lika långa som bröstfenorna.

* Arten är uppkallad after en af gifrarne, Herr J. C. Smitt i Japan.

Dessa äro spetsiga och temligen långa, ungefär ⅓ af hufvudets längd, och deras bakåtlagda spetsar nå till analfenans början; bukfenorna äro betydligt kortare och innehålla 2 ggr. i hufvudet.

Öfre kanten af ryggfenans taggstråliga del svart, och vid basen af den mjukstråliga en smal linie af samma färg. Bröstfenorna gulaktiga, bukfenorna i spetsen svarta, den första strålen hvit med en svart fläck vid basen. Praeoperculum har strax bakom underkäkens ledgång en temligen liten, svart fläck och bakom denna en något större af samma färg.

Endast ett exempl, l. 18 cm.

9. EMBIOTOCA* Agassiz.

Embiotoca Agassiz, Amer. Journ. Science and Art (2), v. 16, 386, Nov., 1853.
Embiotoca Agassiz, Amer. Journ. Science and Art, v. 17, 366, May, 1854.
Holconotus† Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, 122, July, 1854 (*Agassizii* = *lateralis*).
Embiotoca Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 320, Apr. 1855; v. 8, p. 136 (sine desc.), 1856.
Embiotoca A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 126 (133), 1861.
Ditrema Günther, 1862 (sp.).
Ditrema Jordan & Gilbert, 1883 (sp.).

Type: *Embiotoca jacksoni* Agassiz.

12. EMBIOTOCA JACKSONI Agassiz.

Embiotoca jacksoni Agassiz, Am. Journ. Sci. and Art (2), v. 16, 387, 1853; Archiv für Naturgeschichte, 20. Jahrg., B. 1, 157, 1854; Agassiz, Am. Journ. Sci. and Art (2), v. 17, 366, 1854; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 32, 1855; Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 151, 1854; Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 320, 1855; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 345, 1855; Girard, Expl. and Surv. for R. R. Route to Pac., v. 10, Fishes, 168, pl. XXVII, XXVIII, and XXVI, f. 3 and 4, 1855 (Tomales Bay, San Francisco); A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 126, 1862; Gill, Proc. Acad. Nat. Sci. Phila. [v. 14], 275, 1862 (California); Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; Rosa Smith, A List of the Fishes of San Diego, Cal., 1880, Nov.; Jordan & Gilbert, Proc. U. S. N. M. 1880, 28 (San Diego, Cal.); E. & E., Ann. N. Y. Acad. Sci., VI, June, 1892 (San Diego to Puget Sound).

Ditrema jacksoni Günther, Cat. Fish. Brit. Mus., IV, 245, 1862 (San Francisco); Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (Puget Sound to San Diego, Cal.); Jordan & Jouy, Proc. U. S. N. M. 1881, 11 (Monterey, San Francisco, Santa Barbara, Wilmington, Santa Catalina Island, California); Jordan & Gilbert, Proc. U. S. N. M. 1881, 50 (Puget Sound to San Diego, Cal.); Bean, Proc. U. S. N. M. 1881, 265 (Puget Sound); Jordan & Gilbert, Syn. Fish. N. Am., 595, 1883 (Pacific Coast U. S.); Jordan, Cat. Fish. N. Am., 96, 1885; Rosa Smith, West Am. Scientist, June, 1885; Eigenmann, Am. Nat., March, 1889 (Development).

Holconotus fuliginosus Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, 123, 1854; Archiv für Naturgeschichte, 21. Jahrg., B. 1, p. 334.

Embiotoca cassidyi Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 151, 1854; Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 320; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 346, 1855; Girard, Expl. and Surv. for R. R. Route to Pac., v. 10, Fishes, 171, pls. XXIX and XXVI, f. 12, 1859 (San Diego).

Embiotoca webbi Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 320, 1854; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 346, 1855; Girard, Expl. and Surv. for R. R. Route to Pac., v. 10, Fishes, 173, pl. XXX, 1859 (San Diego).

Habitat: San Diego to Puget Sound.

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* *Embiotoca: Ἐμβίος*, living, and *τόκος*, bringing forth; having reference to the viviparity which the species of the genus share with all the other members of the family.

† The name *Holconotus* was invented by Gibbons independently, and is not synonymous with the *Holconotus* of Agassiz.

Body ovate, rather thick, the outlines nearly equally convex; snout blunt and rounded, as long as the eye; occipital region considerably depressed. Lower jaw included; maxillary not reaching to the front of the orbit; gill-rakers rather slender and weak. Dorsal fin with spines all shorter than the rays; the pectoral fins long, reaching nearly to the tips of ventrals. Head, 3½; depth, 2; D. IX or X, 20; A. III, 25. Lat. l., 58. Colors "extremely variable, pattern of color not definite. Brownish, tinged with green, blue, red, or yellowish. Sides with about 10 faint vertical dusky bars; belly usually yellowish; head with blue spots; fins dusky, tinged with blue or red"; anal frequently with yellow blotches.

10. PHANERODON* Girard.

Phanerodon Girard, Proc. Acad. Nat. Sci. Phila., v. 7, pp. 153, 321, 1854 (*furcatus*).
Phanerodon (Gd.), Gill, Proc. Acad. Nat. Sci. Phila., v. 14, p. 274, 1862.
Embiotoca sp. Girard, A. Agassiz.
Ditrema sp. Günther, 1862; J. & G., 1883.
Tæniotoca† A. Agassiz, Proc. Boston Soc. Nat. His., v. 8, 133, 1861 (*lateralis*).

Type: *Phanerodon furcatus* Girard.

ANALYSIS OF THE SPECIES OF PHANERODON.

a. Vertebræ 35–37 (21–22 abdominal); caudal peduncle deep, short.....(TÆNIOTOCA.)
b. Body oblong, the dorsal and ventral profile nearly equally curved, tapering abruptly to the deep caudal peduncle; snout blunt and rounded; occipital region little depressed; mouth slightly oblique, lower lip with a frenum; gill-rakers slender and rather weak. The last spine of the dorsal fin highest, but shorter than the soft rays; soft dorsal and anal high. D. X or XI, 23; A. III, 31. Lat. l., 63. Color, "reddish olive above, becoming bright orange-red below, everywhere thickly dusted with black points; a continuous bright-blue streak along the edges of each row of scales; streaks of thoracic region formed by isolated blue spots on the middle of the scales; head with several series of blue spots and streaks; fins all olivaceous dusky; ventrals with some light orange".....LATERALIS, 13.
aa. Vertebræ, 37–38; (23–24 abdominal).....(PHANERODON.)
c. Body oblong elliptical, dorsal and ventral outlines nearly equally curved, tapering into a slender caudal peduncle; snout projecting somewhat, a little longer than the eye; occipital region not much depressed; lower jaw included; last spine of the dorsal fin highest, nearly as high or higher than the rays; pectorals reaching a little farther than the tips of the ventrals; caudal strongly forked. Head, 3¾; depth, 2½; D. XI, 22; A. III, 30. Lat. l., 69. Color, "light-olivaceous, silvery below, sometimes yellowish; scales with bright reflections, but no red markings; usually a round dusky spot on the anal; ventrals plain; caudal fin edged behind with dusky; fins usually yellowish tinged".....FURCATUM, 14.
cc. Body elongate oblong, tapering gradually into a long slender caudal peduncle. Head rather small; snout projecting somewhat, as long as eye; occipital region moderately compressed; dorsal fin with highest spine about as high as the highest rays; pectorals long, reaching tips of ventrals. Head, 3½; depth, 2½; D. X, 22. A. III, 28. Lat. l., 70. Color, "light olivaceous above, pearly below; scales above the axis of the body each with an orange spot at base, its outer margin tinged with blue, these forming faint reddish streaks along the rows of scales; anal with a dusky spot; ventrals broadly tipped with blackish; caudal not dark-edged."
ATRIPES, 15.

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* *Phanerodon:* Φανερός, evident, and ὀδούς, tooth; referring to the size of the teeth, which were supposed to be larger than in the allied genera. Type, *Ph. furcatus* Grd.

† *Tæniotoca:* Ταινία, band, and τόκος, the terminal component of *Embiotoca*, intended to suggest the characteristic longitudinal lateral bands of the species of the genus, which is closely related to *Embiotoca*. Type, *T. lateralis*.

13. PHANERODON LATERALIS Agassiz.

Embiotoca lateralis Agassiz, Am. Journ. Sci. and Art (2), v. 17, 366, 1854; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 32, 1855; Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 151, 1854; A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 126.

Tæniotoca lateralis A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 133, 1862; Cooper, Nat. Wealth Cal. by Cronise, 489, 1868.

Damalichthys lateralis Gill, Proc. Acad. Nat. Sci. Phila. [v. 14], p. 275, 1862 (California).

Ditrema laterale Günther, Cat. Fishes, v. 4, 245, 1862 (San Francisco, Puget Sound); Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (Puget Sound to Santa Barbara, Cal.); Jordan & Jouy, Proc. U. S. N. M. 1881, 11 (Puget Sound, Monterey, San Francisco, Santa Barbara, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1881, 50 (Santa Barbara, Cal., to Puget Sound); Bean, Proc. U. S. N. M. 1881, 265 (Vancouver Island); Jordan & Gilbert, Syn. Fish. N. Am., 594, 1883 (Pacific coast of the United States); Bean, Proc. U. S. N. M. 1883, 361 (Departure Bay, British Columbia); Rosa Smith, West Am. Scientist, June, 1885.

Phanerodon laterale Eigenmann & Eigenmann, Ann. N. Y. Acad. Sci., VI, June, 1892 (San Diego to Puget Sound).

Holconotus agassizi Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, 122, 1854; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 332, 1855.

Embiotoca lineata Girard, Proc. Acad. Nat. Sci. Phila., v. 7, pp. 134, 141, 151, 1854; Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 320; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 346, 1855; Girard, Expl. and Surv. for R. R. Route to Pac., v. 6, Abbot's Report, Zoölogy, 25, 1857; Girard, Expl. and Surv. for R. R. Route to Pac., v. 10, Fishes, 174, pl. XXXI and XXVI, f. 5 and 6, 1859 (San Francisco, Tomales Bay, Presidio); Girard, Expl. and Surv. for R. R. Route to Pac., v. 10, Whipple's Report, Zoölogy, p. 51, 1859 (San Francisco).

Embiotoca ornata Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 321, April, 1855; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 347, 1855; Girard, Expl. and Surv. for R. R. Route to Pac., v. 10, Fishes, 176, pl. XXVI, f. 11.

Embiotoca perspicabilis Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 321, 1855; Archiv für Naturgeschichte, v. 1, 347, 1855; Girard, Expl. and Surv. for R. R. Route to Pac., v. 10, Fishes, 178, pl. XXXII and XXVI, f. 1, 2, 1859 (Puget Sound); Suckley, Expl. and Surv. for R. R. Route to Pac., v. 12, Stevens's Report, book 2, Zoölogy, 357.

Habitat: Vancouver Island to San Diego; rare southward.

14. PHANERODON FURCATUS Girard.

Phanerodon furcatus Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 153, 1854; Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 322, 1855; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 348; Girard, Expl. and Surv. for R. R. Route to Pacific, v. 10, Fishes, 184, pl. XXXIV, f. 1-5, 1859 (Presidio, Tomales Bay); A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 128, 1862; Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; E. & E., Ann. N. Y. Acad. Sci., VI, June, 1892 (San Diego to San Francisco).

Ditrema furcatum Günther, Cat. Fish. Brit. Mus., IV, 247, 1862 (San Francisco); Jordan & Gilbert, Proc. U. S. N. M. 1880, 28 (San Diego, California); Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco to San Diego, California); Jordan & Jouy, Proc. U. S. N. M. 1881, 11 (Monterey, Santa Barbara, San Diego); Jordan & Gilbert, Proc. U. S. N. M. 1881, 50 (San Diego to San Francisco); Jordan & Gilbert, Syn. F. N. A., 596, 1883 (coast of California); Jordan, Cat. Fish. N. Am., 96, 1885; Rosa Smith, West Am. Scientist, June, 1885 (San Diego).

Embiotoca furcata Rosa Smith, A List of the Fishes of San Diego, California, 1880, November.

Habitat: San Diego to San Francisco.

15. PHANERODON ATRIPES Jordan & Gilbert.

Ditrema atripes Jordan & Gilbert, Proc. U. S. N. M. 1880, 320 (California); Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (Monterey Bay, California); Jordan & Jouy, Proc. U. S. N. M. 1881, 11 (Monterey, California); Jordan & Gilbert, Proc. U. S. N. M. 1881, 50 (Monterey Bay, California); Jordan & Gilbert, Syn. Fish N. Am., 595, 1883 (Monterey Bay); Eigenmann & Eigenmann, West Am. Scientist, Nov., 1889, 147 (Cortes Banks).

Phanerodon atripes Eigenmann & Eigenmann, N. Y. Acad. Sci., VI, June, 1892 (Cortes Banks, Monterey).

?Ditrema orthonotus E. & E., West Am. Scientist, Oct., 1889, 127 (Cortes Banks)

Habitat: Monterey to Cortes Banks.

This species has so far been taken at only two localities. *D. orthonotus* will probably prove identical with *atripes*. At the time *orthonotus* was described *atripes* had not been found within 400 miles of the locality of *orthonotus*.

11. BRACHYISTIUS * Gill.

Brachyistius Gill, Proc. Acad. Nat. Sci. Phila. 1862, 275 (*frenatus*).

Type: *Brachyistius frenatus* Gill.

ANALYSIS OF THE SPECIES OF BRACHYISTIUS.

a. Maxillary not reaching to the front of the orbit; mouth very small, oblique; head slender, pointed. Dorsal fin, VIII, 15, the sixth or seventh spine highest; body elongate, regularly elliptical. Color "dark olive-brown above, each scale with a dark spot at base, followed by a light mark; below bright coppery-red; each scale with a blue spot and dark punctulations; head colored like the body; fins all light reddish." (Jordan & Gilbert.) Head, 3¾; depth, 3; lat. l., 40..... FRENATUS, 16.

aa. Maxillary reaching slightly beyond the vertical from the front of the orbit; mouth comparatively large, little oblique; teeth large, conical-truncate, none on the sides of the lower jaw; eye very large, its diameter about one-third the length of the head. Dorsal fin, X, 18, the spines high, the fourth or sixth highest, the fifth to tenth about equal and higher than the soft rays; anal III, 20, the spine more or less curved; pectorals not reaching tips of ventrals. Body oblong-ovate, deepest at the shoulders, dorsal and ventral outlines nearly equally curved, occipital region considerably depressed. Color "rose-red with silvery luster, darker above; top of head orange; a very distinct chocolate-colored spot above the lateral line at the origin of the soft dorsal fin; another smaller one just below the end of the soft dorsal. Fins immaculate, tinged with reddish." (Jordan & Gilbert.) Head, 3⅓; depth, 2½; scales, 6-50-16 .....ROSACEUS, 17.

16. BRACHYISTIUS FRENATUS Gill.

Brachyistius frenatus Gill, Proc. Acad. Nat. Sci. Phila. 1862, 275 (California); Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; Jordan & Gilbert, Proc. U. S. N. M. 1880, 300 (Los Angeles to Vancouver Island); Jordan & Gilbert, Proc. U. S. N. M. 1880, 465 (Puget Sound to San Pedro, California); Jordan & Jouy, Proc. U. S N. M. 1881, 10 (Monterey, Santa Barbara, California); Jordan & Gilbert, Proc. U. S. N. M. 1881, 51 (Catalina Island to Puget Sound); Rosa Smith, West American Scientist, June, 1885 (San Diego); Jordan, Cat. Fish. N. Am., 93, 1885; Eigenmann & Eigenmann, Ann. New York Acad. Sci., VI, June, 1892, 353 (San Diego to Puget Sound).

Micrometrus frenatus Bean, Proc. U. S. N. M. 1881, 265 (Puget Sound, Vancouver Island); Jordan & Gilbert, Syn. Fish. N. Am., 589, 1883 (entire Pacific coast of United States).

Ditrema brevipinne Günther, Cat. Fish. Brit. Mus., IV, 248, 1862 (Esquimault Harbor); Lord, Naturalist in Vancouver Island, v. 2, 354, 1866; Bean, Proc. U. S. N. M. 1881, 265 (Vancouver Island).

Habitat: San Diego to Puget Sound.

Very rare about San Diego, but quite abundant in some localities to the north.

**Brachyistius:* βραχυς, short, and ἱστίον, sail, referring to the short dorsal fin, and formed in analogy with *Histiophorus, Temnistia*, etc.

17. BRACHYISTIUS ROSACEUS Jordan & Gilbert.

Cymatogaster rosaceus Jordan & Gilbert, Proc. U. S. N. M. 1880, 303 (San Francisco).
Brachyistius rosaceus Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco, California); Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (San Francisco); Jordan & Gilbert, Proc. U. S. N. M. 1881, 51 (San Francisco, California); Jordan, Cat. Fish. N. A., 96, 1883; Eigenmann & Eigenmann, Ann. New York Acad. Sci., VI, June, 1892 (San Francisco).
Micrometrus rosaceus Jordan & Gilbert, Syn. Fish. N. A., 589, 1883 (San Francisco).

Habitat: Off San Francisco in deep water.

12. CYMATOGASTER * Gibbons.

Cymatogaster Gibbons, Proc. California Acad. Nat. Sci., in Daily Placer Times and Transcript, San Francisco (*aggregatus* and *minimus*) May 18, 1854, *fide* Agassiz (not *Cymatogaster* Gibbons, May 30, 1854, *Holconotus*); Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, 106 (*sine desc.*), June, 1854 (not *Cymatogaster* Gibbons, Aug., 1854); Gill, Proc. Acad. Nat. Sci. Phila. 1862, 275.
Micrometrus † Gibbons, Proc. California Acad. Nat. Sci., in Daily Placer Times and Transcript, San Francisco (*sine desc.*), May 30, 1854, *fide* A. Agassiz (first species *aggregatus*); Gibbons, Proc. Acad. Nat. Sci. Phila. 1854, 125; Jordan & Gilbert, Syn. Fish. N. A., 588, 1883 (sp.).
Holconotus Girard, Proc. Acad. Nat. Sci. Phila. 1885, 322 (not *Holoconotus* Agassiz, 1854).
Metrogaster Agassiz, MSS. (*fide* A. Agassiz); A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8 (128), 133, 1861.
Ditrema sp. Günther, 1862.
Sema ‡ Jordan, Bull. U. S. Geol. and Geog. Survey, IV, No. 2, 1878 (*signifer*).

Type: *Cymatogaster aggregatus* Gibbons.

The name *Cymatogaster* was first published by Gibbons, May 18, 1854, and applied to two new species, *Cymatogaster aggregatus* and *Cymatogaster minimus*. Since these two species belong to two quite distinct genera the name can be used for but one of them. A few days later (May 30), Gibbons applied the name *Micrometrus* to the same two species. On June 21 he restricted the name *Cymatogaster* to *pulchellus*, a nominal species not known at the time (May 18) the name was first proposed. The later use of the name is entirely untenable, since *Cymatogaster* was a name preoccupied by its use of May 18, just as much as if it had been used for a genus of reptiles fifty years before. This seems self-evident and it ought not to be necessary to defend this view. *Cymatogaster*, if used at all, must be used for *aggregatus* or *minimus*. The same is true of *Micrometrus*.

The first species to be eliminated from these two under a separate generic name was *minimus*. Girard described a species, *trowbridgii*=*minimus*, under the new generic name *Abeona*, thus restricting both *Cymatogaster* and *Micrometrus* to the only other species of the original *Cymatogaster*, viz, *aggregatus*.

There seems, then, no other way out of the difficulty than to retain the name *Cymatogaster aggregatus*, to which it was restricted by Dr. Gill in 1862.

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* *Cymatogaster:* Κῦμα(ατος), fœtus, and γαστήρ, belly, alluding to the viviparity common to the whole family, first sp., *C. aggregatus*.

† *Micrometrus:* Μικρος, small, and μετρον measure (quasi size), referring to the comparatively small size of the representatives of the genus, first sp., *M. aggregatus*.

‡ *Sema:* σῆμα, a banner, in allusion to the high fins.

18. CYMATOGASTER AGGREGATUS.

(Plate XCII, Fig. 3, and Plates XCIII to CXVIII.)

Cymatogaster aggregatus Gibbons, Proc. Cal. Acad. Nat. Sci., in Daily Placer Times and Transcript, May 18, 1854, *fide* A. Agassiz; *id.*, Proc. Acad. Nat. Sci. Phila. v. 7, 106; Gill, Proc. Acad. Nat. Sci. Phila. 1863, 275; Cooper, in Nat. Wealth Cal. by Cronise, 489, 1868; Streets, Bull. U. S. N. M., No. 7, 45, 1877; Rosa Smith, A list of the Fishes of San Diego, California, Nov., 1880; Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (Puget Sound to San Diego, California); Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (Puget Sound, Monterey, San Francisco, and Santa Barbara, California); Jordan & Gilbert, Proc. U. S. N. M. 1880, 28 (San Diego, California); Eigenmann & Eigenmann, Ann. New York Acad. Sci., VI, June, 1892 (San Diego to Puget Sound.)

Micrometrus aggregatus Gibbons, Proc. Cal. Acad. Nat. Sci. in Daily Placer Times and Transcript, May 30, 1854, *fide* A. Agassiz; Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, 125; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 339, 1885; A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 128, 1861; Jordan & Gilbert, Proc. U. S. N. M. 1881, 51 (Puget Sound to San Diego, California); Bean, Proc. U. S. N. M. 1881, 265 (Puget Sound, Vancouver Island; *id.*, Proc. U. S. N. M. 1883, 361 (Port Simpson, Departure Bay, B. C.; Port Wrangel, Alaska); Jordan & Gilbert, Syn. Fish. N. Am., 590, 1883 (Pacific Coast United States); Jordan, Cat. Fish. N. Am., 96, 1885 (name); Rosa Smith, West Am. Scientist, 1885, June; Eigenmann, Amer. Nat., March 1889 (Development); Eigenmann & Eigenmann, West Am. Scientist, June, 1889.

Metrogaster aggregatus A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 133, 1861.

Ditrema aggregatum Günther, Cat. Fish. Brit. Mus., IV, 248, 1862 (San Francisco, Humboldt Bay, Vancouver Island).

Holconotus rhodoterus Girard, Proc. Acad. Nat. Sci. Phila. 1854, 141, 152; Girard, Proc. Acad. Nat. Sci. Phila. 1855, 322; Girard, Archiv für Naturgeschichte, 21. Jahrg., B. 1, p. 350, 1855; Girard, Pacific R. R. Survey, v. 6, Abbot's Report, Zoölogy, 26, 1857 (San Francisco Presidio, Humboldt Bay, Astoria, Cape Flattery, San Diego, Puget Sound, Shoalwater Bay, Petaluma); Girard, Pacific R. R. Survey, v. 10, Fishes, 193, pl. XXXV, XXXVI, f. 1–4, XXVI, f. 78, 1859; Girard, Pacific R. R. Survey, v. 10, Whipple's Report, Zoölogy, 51, 1859; Girard, Pacific R. R. Survey, v. 10, Williamson's Report, Zoölogy, 87, 1859.

Metrogaster lineolatus Agassiz, MS., 1861.

Sema signifer Jordan, Hayden's Geol. and Geogr. Survey, vol. IV, No. 2, 1878, 399 (recorded from Texas by mistake).

Habitat: Pacific Coast of United States.

Body elliptical, elongate, the dorsal outline somewhat more curved than the ventral; mouth small, oblique; dorsal spines high, the fifth or sixth spine longest, the last shorter than the soft rays; anal with weak spines; pectorals reaching a little farther than the tips of the ventrals. Head, $3\frac{1}{3}$; depth, $2\frac{2}{3}$; D. IX, 20; A. III, 22. Color, silvery, back dusky; middle of sides anteriorly with the scales each with a cluster of dark points, these forming a series of longitudinal stripes, which extend to opposite the base of the anal; these stripes are interrupted by three vertical light yellow bars on which are no black specks in the adult. Adult males in spring almost entirely black.

13. ABEONA* Girard.

Cymatogaster Gibbons, Daily Placer Times and Transcript, May 18, 1854 (sp.).
Micrometrus Gibbons, l. c., May 30, 1854 (sp.); A. Agassiz, Proc. Bost. Soc. Nat. Hist. 1861, 128 and 133 (restricted to *minima*).
Abeona Girard, Proc. Acad. Nat. Sci. Phila. 1855, 322 (*trowbridgii*).

Type: *Abeona trowbridgii=A. minima* Gibbons.

ANALYSIS OF THE SPECIES OF ABEONA.

a. Color greenish above with bluish reflections, thickly dusted with black dots; an irregular longitudinal black band along axis of body, and two vertical dark bars downward from base of dorsal fin on which they appear as blotches; sides often with much light yellow; axil of pectorals black." (Jordan & Gilbert.) Body ovate, dorsal and ventral outlines nearly evenly curved; mouth small, jaws about equal, the maxillary reaching about half the distance to the front of orbit. Scales of cheeks in two and a half rows. Dorsal fin high, the last spine about as long as the first soft ray; pectorals not reaching as far as ventrals. D. IX, 44; A. III, 17; scales, 4-45-12; head, 3¼; depth, 2 ..... MINIMA, 19.

aa. Color bluish black above, becoming lighter on the sides and silvery below. Opercles and lower half of sides punctate with black dots and shaded with light orange, the latter more intense on the centers of the scales and forming a diffuse lateral band; a broad, grayish streak backwards from pectorals to opposite origin of anal, this streak without orange points; young specimens with the bright lateral shades more distinct, and rosy instead of orange; fins marked with more or less blackish, the anal with some yellowish, a conspicuous black triangular blotch in the axil of the pectoral. Body elongate, with a very long and rather thick caudal peduncle. Head transversely very convex above and with a blunt snout. Mouth small, oblique; maxillary reaching but two-thirds the distance to front of orbit; caudal forked for half its length. Scales on cheek in three distinct series. Head, 4; depth, 2¾. D. IX, 17; A. III, 20; lat. l., 45. (Jordan & Gilbert.) ..... AURORA, 20.

19. ABEONA MINIMA Gibbons.

Cymatogaster minimus Gibbons, Proc. Cal. Acad. Nat. Sci., in Daily Placer Times and Transcript, May 18, 1854; *id.*, Proc. Ac. Nat. Sci. Phila., v. 7, 106, 1854.
Micrometrus minimus Gibbons, Proc. Cal. Acad. Nat. Sci., in Daily Placer Times and Transcript, May 30, 1854; *id.*, Proc. Ac. Nat. Sci. Phila., v. 7, 125, 1854; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 339, 1855; A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 129, 1861.
Ditrema minima Günther, Cat. Fishes Brit. Mus., IV, 249, 1862 (San Francisco).
Abeona minima Gill, Proc. Acad. Nat. Sci. Phila. 1862, 275 (footnote); Cooper, Nat. Wealth Cal. by Cronise, 489; Jordan & Gilbert, Proc. U. S. N. M. 1880, 28 (San Diego, Cal.); Rosa Smith; A list of the Fishes of San Diego, Cal., November, 1880; Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco to San Diego, Cal.); Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (Monterey, Santa Barbara, and San Diego, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1881, 51 (Tomales to San Diego, Cal.); Jordan & Gilbert, Syn. Fish. N. Am., 587, 1883 (Pacific Coast of the United States); Rosa Smith, West. Am. Scientist June, 1885; Jordan, Cat. Fish. N. Am., 96, 1885; Eigenmann & Eigenmann, Ann. N. Y. Acad. Sci., VI, June, 1892 (San Diego to San Francisco).
Holconotus trowbridgii Girard, Proc. Acad. Nat. Sci. Phila., v. 7, 152, 1854
Abeona trowbridgii Girard, Proc. Ac. Nat. Sci. Phila., v. 7, 322; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 349, 1855; Expl. and Surv. for R. R. Route to Pacific, v. 10, Fishes, 186, pl. XXXIV, f. 6-10.

Habitat: San Diego to San Francisco.

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* *Abeona*, an Indian name, probably.

20. ABEONA AURORA Jordan & Gilbert.

Abeona aurora Jordan & Gilbert, Proc. U. S. N. M. 1880, 299 (Monterey, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1880, 456 (San Francisco, Cal.); Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (Monterey, San Francisco, Cal.); Jordan & Gilbert, Proc. U. S. N. M. 1881, 51 (Monterey Bay, Cal.); Jordan & Gilbert, Syn. Fish. N. A., 588, 1883 (Monterey Bay); Jordan, Cat. Fish. N. A., 96, 1885; Eigenmann & Eigenmann, New York Acad. Sci., VI, June, 1892 (Monterey to San Francisco).

Habitat: Monterey Bay.

HYSTEROCARPINÆ.

Hysterocarpinæ Gill, Proc. Acad. Nat. Sci. Phila. 1862, v. 14, 275.

14. HYSTEROCARPUS.*

Hysterocarpus Gibbons, Proc. California Acad. Nat. Sci., in Daily Placer Times and Transcript, San Francisco, May 18, 1854 (*fide* A. Agassiz).
Hysterocarpus Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, 124, July, 1854.
Hysterocarpus Girard, Expl. and Surv. for R. R. Route to Pacific, v. 10, Fishes, 190, 1858.
Hysterocarpus Günther, Cat. Fishes in Brit. Mus., IV, 251, 1862.
Sargosomus † Agassiz, MSS. (*fide* A. Agassiz). (*traskii.*)
Dacentrus Jordan, Bull. U. S. Geol. Surv., 1878, 667 (*lucens*).

21. HYSTEROCARPUS TRASKII Gibbons.

Hysterocarpus traskii Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, 105, 1854; Gibbons, Proc. Acad. Nat. Sci. Phila., v. 7, 124; Archiv für Naturgeschichte, 21. Jahrg., B. 1, 336, 1855; Girard, Proc. Acad. Nat. Sci. Phila., v. 8, 136, 1854; Girard, Expl. and Surv. for R. R. Route to Pacific, v. 6, Abbot's Report, Zoology, 26, 1857; Girard, Expl. and Surv. for R. R. Route to Pacific, v. 10, Fishes, 190, pl. XXVI, f. 14, 1858; A. Agassiz, Proc. Boston Soc. Nat. Hist., v. 8, 130, 1861; Günther, Cat. Fishes Brit. Mus., IV, 251, 1862; Cooper, Nat. Wealth Cal. by Cronise, 489, 1868; Jordan & Jouy, Proc. U. S. N. M. 1881, 10 (Sacramento River, California); Jordan & Gilbert, Proc. U. S. N. M. 1881, 51 (Sacramento and San Joaquin rivers to San Luis Obispo, California); Eigenmann, Ann. Report State Fish Comm. California, 1890; Ann. New York Acad. Sci., VI, June 1891 (Sacramento Valley).
Sargosomus fluviatilis Agassiz, MSS., 1861 (*fide* A. Agassiz).
Dacentrus lucens Jordan, Bull. U. S. Geol. Surv., 1878, 667.

Habitat: California (Sacramento River in fresh water).

Body ovate, dorsal outline strongly convex; head small, snout bluntly conic; mouth small, oblique, maxillary not reaching the orbit, lower jaw included. Spinous dorsal long, the fifth or sixth spine highest, thence gradually lower each way, the last spines shorter than the soft rays; anal spines strong and curved. Head, 3½; depth, 2. D. XVI, 11; A. III, 22; Lat. line, 40.

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* *Hysterocarpus:* Ὑστέρα, the womb, and καρπός, fruit.

† *Sargosomus: Sargus.* the Latin name of a Mediterranean sparoid, allied to the sheepshead (*S. ovis*), and σωμα, body, alluding to a superficial resemblance of the embiotocoid to the sparoid genus.

A list of the nominal species of Embiotocidæ in the order of their discovery, together with the names by which they are designated at present.

Nominal species.	Date.	Identification.
Ditrema temminckii Bleeker	1849	Ditrema temminckii.
Embiotoca jacksoni Agassiz	1853	Embiotoca jacksoni.
Embiotoca caryi Agassiz	1853	Hypsurus caryi.
Holconotus rhodoterus Agassiz	May —, 1854	Holconotus rhodoterus.
Rhacochilus toxotes Agassiz	1854	Rhacochilus toxotes.
Cymatogaster aggregatus Gibbons	May 18, 1854	Cymatogaster aggregatus.
Cymatogaster minimus Gibbons	May 18, 1854	Abeona minima.
Hysterocarpus traski Gibbons	May 18, 1854	Hysterocarpus traski.
Hyperprosopon argenteum Gibbons	May 18, 1854	Hyperprosopon argenteus.
Mytilophagus fasciatus Gibbons	May 30, 1854	Amphistichus argenteus.
Hyperprosopon arcuatum Gibbons	May 30, 1854	Hyperprosopon argenteus.
Pachylabrus variegatus Gibbons	June 21, 1854	Rhacochilus toxotes.
Cymatogaster pulchellus Gibbons	June 21, 1854	Holconotus rhodoterus.
Cymatogaster larkinsii Gibbons	1854	Holconotus rhodoterus.
Amphistichus argenteus Agassiz	1854	Amphistichus argenteus.
Holconotus megalops Girard	1854	Hyperprosopon argenteus.
Holconotus gibbonsii, California Academy	1854	Hypsurus caryi.
Holconotus fuliginosus Gibbons	1854	Embiotoca jacksoni.
Cymatogaster ellipticus Gibbons	1854	Holconotus rhodoterus.
Mytilophagus fasciatus Gibbons	1854	Amphistichus argenteus.
Embiotoca lateralis Agassiz	1854	Phanerodon lateralis.
Embiotoca lineata Girard	1854	Phanerodon lateralis.
Amphistichus heermanni Girard	1854	Amphistichus argenteus.
Holconotus rhodoterus Girard	1854	Cymatogaster aggregatus.
Embiotoca cassidyi Girard	1855	Embiotoca jacksoni.
Holconotus trowbridgii Girard	1854	Abeona minima.
Phanerodon furcatus Girard	1854	Phanerodon furcatum.
Amphistichus similis Girard	1854	Amphistichus argenteus.
Embiotoca webbi Girard	1854	Embiotoca jacksoni.
Embiotoca argyrosomus Girard	1855	Damalichthys argyrosomus.
Damalichthys vacca Girard	1855	Dama ichthys argyrosomus.
Embiotoca ornata Girard	1855	Phanerodon lateralis.
Embiotoca perspicabilis Girard	1855	Phanerodon lateralis.
Ditrema læve Günther	1860	Ditrema temminckii.
Hyperprosopon arcuatum A. Agassiz	1861	Hyperprosopon agassizi.
Metrogaster lineolatus Agassiz	1861	Cymatogaster aggregatus.
Hyperprosopon analis A. Agassiz	1861	Hyperprosopon analis.
Brachyistius frenatus Gill	1862	Brachyistius frenatus.
Hyperprosopon agassizi Gill	1862	Hyperprosopon agassizi.
Ditrema brevipinne Günther	1862	Brachyistius frenatus.
Sema signifer Jordan	1878	Cymatogaster aggregatus.
Dacentrus lucens Jordan	1878	Hysterocarpus traski.
Brachyistius rosaceus Jordan & Gilbert	1880	Brachyistius rosaceus.
Abeona aurora Jordan & Gilbert	1880	Abeona aurora.
Ditrema atripes Jordan & Gilbert	1880	Phanerodon atripes.
Neoditrema ransonneti St. & D	1883	Neoditrema ransonneti.
Ditrema smittii Nyström	1887	Ditrema smittii.
Ditrema orthonotus Eigenmann & Eigenmann	1889	Phanerodon atripes.

CYMATOGASTER AGGREGATUS GIBBONS; A CONTRIBUTION TO THE ONTOGENY OF VIVIPAROUS FISHES.

[By Carl H. Eigenmann.]

INTRODUCTORY NOTE.

When, in the winter of 1888, I arrived on the coast of southern California, I immediately set about to procure the earliest stages possible of the different species of *Embiotocidæ* that were to be found about San Diego. Prof. Ryder (1885*a*, p. 140) had estimated that the much desired early stages of this family were to be obtained during October and November and I had some misgivings about obtaining them. On the first day (about December 14, 1888), however, I obtained the eggs of *Embiotica jacksoni* and the early larva of another species, and after I had interested the Italian, Greek, and Portuguese fishermen there was nc lack of specimens.

Little more was done during this season than to determine the size of the eggs and the places where different species of viviparous fishes are to be obtained, and when they are with eggs. Among other things I discovered the remarkable egg of *Cymatogaster aggregatus*, which I have chosen as the subject of this paper.

The following summer was devoted to a study of the pelagic eggs of fishes of San Diego Bay, to serve as a basis of comparison between the oviparous and related viviparous species.

The winters of 1889 and 1890 were occupied almost exclusively in procuring the eggs of *Cymatogaster*, of which I intended to make a special study.

VIVIPAROUS FISH OF THE PACIFIC COAST.

The prominent feature of the ichthyological fauna of the west coast of America is the presence of large numbers of viviparous forms. There is probably no other region in the world naturally so favorable to a study of viviparous fishes, and there is furthermore no month in the year during which the developing eggs of viviparous teleosts can not be procured at San Diego. Over 30 per cent of the teleosts found at San Diego are viviparous and the extremes of viviparity are found among them. All the species known to be viviparous belong to two families—the *Embiotocidæ* and the *Scorpænidæ*.

The *Embiotocidæ* are found principally along the western coast of America. One species occurs in the Sacramento Valley, and three species inhabit Japan. The species found on the American coast inhabit quiet bays, beaches on which the surf breaks, and rocky pools. The range of distribution varies greatly with the different species. Some are found along the entire coast from San Diego to Puget Sound, while others seem to be restricted to a few miles. None of them descend to great depths and none inhabit the open ocean; they are shore fish.

The following species are found in American waters:

List of the species of Embiotocidæ found in American waters.

[Shore fishes unless otherwise specified.]

Species.	Distribution.
Hypsurus caryi Agassiz	San Diego to San Francisco
Damalichthys argyrosomus Girard	San Diego to Puget Sound.
Hyperprosopon analis Agassiz	Port Harford to San Francisco.
Hyperprosopon argenteus Gibbons	Encenada to Astoria.
Hyperprosopon agassizi Gill	Santa Barbara to San Francisco.
Holconotus rhodoterus Agassiz	San Diego to San Francisco.
Amphistichus argenteus Agassiz	San Diego to Cape Flattery.
Rhacochilus toxotes Agassiz	San Diego to San Francisco.
Embiotoca jacksoni Agassiz	San Diego to Puget Sound.
Phanerodon lateralis Agassiz	San Diego to Puget Sound.
Phanerodon furcatus Girard	San Diego to San Francisco.
Phanerodon atripes Jordan & Gilbert	Cortes Bank to Monterey.
Brachyistius frenatus Gill	San Diego to Puget Sound.
Brachyistius rosaceus Jordan & Gilbert	Off San Francisco, deep water.
Cymatogaster aggregatus Gibbons	San Diego to Puget Sound.
Abeona minima Gibbons	San Diego to San Francisco.
Abeona aurora Jordan & Gilbert	Monterey Bay.
Hysterocarpus traskii Gibbons	Fresh waters of Central California.

Of all these, *Cymatogaster aggregatus* is one of the most abundant species between San Diego and San Francisco.

In the deeper water the viviparous species of *Scorpænidæ* replace the *Embiotocidæ*.

The following species of viviparous *Scorpænidæ* are found on the west coast of America:

List of species of viviparous Scorpænidæ found on the West Coast of America.

Name of species.	Vertical distribution.	Horizontal distribution.
Sebastolobus alascanus Bean	960 feet	Off Trinity Islands.
Sebastolobus macrochir (Günther)	2,100 feet	Southern California to Japan.
Sebastichthys nigrocinctus (Ayres)	Deep water	Monterey to Vancouver Island.
Sebastichthys serriceps J. & G	10 to 90 feet	Cerros Island to San Francisco.
Sebastichthys rubrovinctus J. & G	300 to 600 feet	San Diego to Monterey.
Sebastichthys diplaproa Gilbert	740 feet	Southern California.
Acutomentum melanostomus (E. & E.)	600 to 1600 feet	San Diego.
Acutomentum macdonaldi E. & B	600 feet	San Diego.
Acutomentum ovalis (Ayres)	300 feet	San Diego to San Francisco.
Acutomentum alutus (Gilbert)	900 feet	Southern California.
Primospina mystinus (Jordan & Gilbert)	100 feet	San Diego to Puget Sound.
Primospina entomelas (Jordan & Gilbert)	(?)	Port Harford to Monterey.
Sebastosomus flavidus (Ayres)	90 feet	San Diego to San Francisco.
Sebastosomus serranoides (E. & E.)	100 to 300 feet	San Diego to San Francisco.
Sebastosomus melanops (Girard)	90 feet	Monterey to Sitka.
Sebastosomus ciliatus Tiles	(?)	Alaska.
Sebastodes paucispinis (Ayres)	90 to 600 feet	San Diego to San Francisco.
Sebastodes goodei E. & E	600 to 900 feet	San Diego to San Francisco.
(?) matzubaræ Hilgendorf	(?)	Alaska.
Sebastomus capensis Linnæus	(?)	Coast of Chili and Cape Seas.
Sebastomus rufus (E. & E.)	600 feet	San Diego.
Sebastomus miniatus (J. & G.)	100 to 600 feet	San Diego to San Francisco.
Sebastomus pinniger (Gill)	600 feet	San Diego to Puget Sound.
Sebastomus levis (E. & E.)	250 to 600 feet	San Diego to Monterey.
Sebastomus æreus (E. & E.)	250 to 600 feet	San Diego.
Sebastomus constellatus (J. & G.)	90 to 300 feet and deeper?	San Diego to San Francisco.
Sebastomus umbrosus (J. & G.)	(?)	Santa Barbara.
Sebastomus rosaceus (Girard)	100 feet	San Diego to San Francisco.
Sebastomus rhodochloris (J. & G.)	Deep water	Monterey to San Francisco.
Sebastomus gilli (E.)	600 feet	San Diego.
Sebastomus rupestris (Gilbert)	900 feet	Southern California.
Sebastomus eos (E. & E.)	600 feet	San Diego.
Sebastomus chlorostictus (J. & G.)	300 feet	San Diego to San Francisco.

List of species of viviparous Scorpænidæ found on the West Coast of America—Continued.

Name of species.	Vertical distribution.	Horizontal distribution.
Sebastomus ruber (Ayres)	300 feet	San Diego to Puget Sound.
Pteropodus sinensis (Gilbert)	870 feet	West coast Lower California.
Pteropodus saxicola (Gilbert)	960 feet	Southern California.
Pteropodus atrovirens (J. & G.)	(?)	San Diego to San Francisco.
Pteropodus elongatus (Ayres)	300 feet	San Diego to San Francisco.
Pteropodus proriger (J. & G.)	300 to 600 feet	San Diego to San Francisco.
Pteropodus brevispina (Bean)	(?)	Alaska.
Pteropodus zacentrus (Gilbert)	900 feet	Southern California.
Pteropodus maliger (J. & G.)	(?)	Monterey to Sitka.
Pteropodus rosæ E	30 feet above high water.	Port Harford. Fossil.
Pteropodus dallii (E. & B.)	(?)	San Francisco.
Pteropodus caurinus (J. & G.)	(?)	Puget Sound to Sitka.
Pteropodus vexillaris (J. & G.)	60 to 600 feet	San Diego northward.
Pteropodus rastrelliger (J. & G.)	(?)	San Diego to San Francisco.
Pteropodus nebulosus (Ayres)	Deep water	Port Harford to Vancouver Island.
Pteropodus carnatus (J. & G.)	Shallow water	San Diego to San Francisco.
Pteropodus chrysomelas (J. & G.)	100 feet	San Diego to San Francisco.
Auctospina aurora (Gilbert)	1,600 feet	Southern California.
Auctospina auriculatus (Girard)	Surface	Cerros Island to Vancouver Island.

The depths are only approximate. I have given the shallowest and deepest waters recorded (mostly in my notes) for each species. I have found them very abundant, both in individuals and in species, to a depth of about 600 feet, the depth at which much of the winter fishing is done in the neighborhood of San Diego. Dr. Gilbert, when with the *Albatross*, found a number of species at a depth of 1,600 feet.

A contemplation of these long lists of viviparous fishes naturally leads one to suppose that peculiar conditions must exist, or must have existed, to develop such an amazing number of viviparous forms. The action of environment, or the production of similar results by similar causes acting upon so widely separated families as the *Embiotocidæ* and *Scorpænidæ*, seems evident. The conditions must here have been, and probably are, more favorable to the survival of those species producing living young than elsewhere. That the conditions must have been favorable to viviparous species for a long period is evidenced by the large number of species now existing and by the advanced stage of viviparity of the *Embiotocidæ*. *Cymatogaster* far surpasses all other known species of fishes in the degree of its viviparity.

If the degree of viviparity is a criterion, the *Embiotocidæ* have been much longer viviparous than the *Scorpænidæ*, and I have discovered a fossil *Pteropodus** (*rosæ*) in the cretaceous at Port Harford. The *Embiotocidæ* would, therefore, date back still earlier. What these conditions are, or have been, is of course a difficult question to determine.

*There is a possibility that the deposit from which the fragments of this species were taken is in part a prehistoric refuse heap, in which case this observation loses much weight. At Port Harford a rather steep hill rises several hundred feet from the beach. At about 20 feet from high-water mark there is an old railroad cut. In the bank thus exposed, which was water-worn at the time I visited it, there were found many fragments of fish bones, chiefly vertebræ, and crustacean shells and mollusks. The mollusks, which were unquestionably fossil, were similar to those found all over the hill, even to its top; crustacean shells and fish bones I found only at this cut, about 2 feet from the surface. Among the fragments of fish bones I found a part of a preopercle of a *Pteropodus* allied to *nebulosus*. The most of the fragments have not been identified.

TYPES OF VIVIPARITY IN TELEOSTS.

At least two types of viviparity may be distinguished in fishes: first, those in which the yolk furnishes all the intraovarian food (*Pœcilia*,* *Gambusia*, *Scorpænidæ*†); and second, those in which the greater part of the food is furnished by the ovary (*Blennius*, ‡ *Anableps*, § and *Embiotocidæ*).

In the first type the number of young is usually not less than in related oviparous forms, while the number of young in the second is always greatly reduced.

In the largest of the *Scorpænidæ*, *Sebastomus levis*, which reaches a weight of about 30 pounds, the ripe eggs, about 1 mm. in diameter, would fill several quarts;¶ since each of these develops into a larva before it is freed from the ovary, the maximum number of living young produced by this class of viviparity reaches many thousands. Stuhlmann in 1887 recorded 405 young for *Zoarces*; this he considered a remarkable number.

The size and comparative development of the young of this class of fishes at the time of birth is of course much less than in the second class of viviparous fishes.

The number of young observed in different species of viviparous fishes is as follows: *Sebastomus*, many thousands; *Sebastes marinus* (*fide* Ryder), 1,000; *Gambusia patruelis* (*fide* Ryder), 20 to 25; *Anableps gronovii* (*fide* Wyman), mother 7 inches long, with 4 to 5; 10 inches long, 18; 10 inches long, 7, each about 2¼ inches long.

Embiotocidæ.—The number of young in any species varies greatly with the age of the parent: *Hysterocarpus traski*, 16; *Hyperprosopon argenteus*, 7 to 12 (Dec. 17); *Hypsurus caryi*, 8; *Ditrema jacksoni*, 8 || to 60; *Phanerodon lateralis*, 21 to 80; *Phanerodon furcatus*, 10 to 23; *Amphistichus argenteus*, 47 to 80.

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*In *Pœcilia* (Duvernoy, 1844) and in *Gambusia* (Ryder, 1885) the egg is fertilized and the embryos remain in the original ovarian follicle till near the close of gestation.

†In the *Scorpænidæ* (Ryder, 1886; Eigenmann & Eigenmann, Proc. U. S. Nat. Mus. 1892) the follicle is ruptured before impregnation takes place, but the egg remains mechanically inclosed within it, and the blood supply of the follicles is continued till near the end of gestation. The term of gestation in *Sebastichthys* (*rubrovinctus*) lasts perhaps little over two months.

‡In *Blennius* (Rathke, 1883; Stuhlman, 1887) the egg is impregnated while still in the follicle, in which it undergoes the early stages of its development. At the end of three weeks it is freed; the embryos remain three months longer in the ovary. The food supply seems to be furnished through the old follicles, and this method is but an extension of that found in *Sebastes* and its relatives.

§In *Anableps* (Wyman, 1850), whose early stages have not been observed, the larvæ are surrounded by a vascular membrane, which is connected with the ovarian wall, even in embryos an inch long. The stages before the absorption of the yolk have not been observed. The yolk bag increases in size and is provided externally with a series of papillæ.

¶A very moderate estimate would be 2 quarts.

||The small number of young in Agassiz's specimens was probably due to the *lateness of the season*, a time when only small individuals are still with young.

HISTORICAL NOTICE OF EMBIOTOCIDÆ.

The fact that the species of *Embiotocidæ* are viviparous was nearly simultaneously discovered by J. K. Lord, at Vancouver Island; A. C. Jackson, at San Francisco, June 7, 1852; W. P. Gibbons, at San Francisco; and Dr. Thomas H. Webb, May 3, 1852, at San Diego.*

Prof. Agassiz published the first account of these fishes in 1853 (collected by Jackson).

The interest excited by the announcement of the discovery is shown by the following account from Prof. Gill's "Prefatory" of his Bibliography of the Fishes of the Pacific Coast of the United States to the end of the year 1879. He states:

> The fishes of California remained absolutely unknown till 1839, when a glimpse, but an entirely inadequate one, was furnished by Lay and Bennett in their notes and account of species collected during the voyage of the English vessel *Blossom*; a long silence then supervened, and, with the exceptions thus signalized, and the addition by Storer of a single species of *Syngnathus* in 1846, west-coast ichthyography commenced in 1854 with the announcement by Prof. Agassiz of the discovery of the remarkable family of Embiotocoids. This was speedily followed by numerous communications by Dr. Gibbons, Dr. Girard, and Dr. Ayres, on new species of fishes, mostly from the Californian waters, but partly from Oregonian ones. As early as 1858 nearly two hundred species had been made known.

The exact date of Lord's and Gibbons's† observations I do not know, but Webb has a whole month's priority over Jackson. Jackson, however, communicated his discovery to Louis Agassiz, so that his observations were made public in the fall of 1853, and Dr. Webb's not until May, 1854, and more fully in 1858, while Lord's account did not appear till 1866. Since the notes are brief I will give in their own words the observations of these gentlemen. Gibbon's account I have not seen. Mr. Jackson, in a letter to Agassiz, states:

> On the 7th of June I arose early in the morning for the purpose of taking a mess of fish for breakfast; pulled to the usual place, baited with crabs, and commenced fishing, the wind blowing too strong for profitable angling. Nevertheless on the first and second casts I fastened the two fishes, male and female, that I write about, and such were their liveliness and strength that they endangered my slight trout rod. I however succeeded in bagging both, though in half an hour's subsequent work I got not even a nibble from either this or any other species of fish. I determined to change the bait to put upon my hook a portion of the fish already caught and cut for that purpose into the largest of the two fish caught. I intended to take a piece from the thin part of the belly, when what was my surprise to see coming from the opening thus made a small live fish. * * * I was vastly astonished to find next to the back of the fish and slightly attached to it a long very light violet bag so clear and so transparent that I could already distinguish through it the shape, color, and formation of a multitude of small fish (all facsimiles of each other) with which it was well filled. * * * There can not remain in the mind of any one who sees the fish in the same state that I did, a single doubt that these young were the offspring of the fish from whose body I took them, and that this species of fish gives birth to her young alive and perfectly formed, and adapted to seeking its own livelihood in the water. The number of young in the bag was nineteen and every one as brisk and lively and as much at home in a bucket of salt water as if they had been for months accustomed to the water.

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* Brevoort records a specimen of viviparous fish discovered by Dr. John L. LeConte in 1851. See *ante* under "*Ditrema temminckii*," and Prof. Geo. Davidson, of the U. S. Coast Survey, tells me that he had noted their viviparity long before any published notices of the fact appeared.

† Agassiz (1854, 368), states: "I have just been informed (February 28 [1854]) that the California Academy of Natural Sciences claims for Dr. W. P. Gibbons the discovery of the viviparous fishes upon which I had established the family *Holconoti*. * * * Dr. Thomas H. Webb, one of the scientific corps of the Mexican Boundary Line Commission, has sent me * * * the following abstract from his diary dated San Diego, May 3, 1852: 'Caught * * * a number of small fish, about 2 or 3 inches long, each of which contained ten or twelve living young.'"

This species was *Ditrema jacksoni*. Agassiz adds a note as follows:

It will be a matter of deep interest to trace the early stages of growth of these fishes, to examine the structure of the ovary and the eggs before fecundation takes place, etc.

This was, however, not done in the forty years after the above was written.

Prof. Agassiz described the structure of the ovary as follows:

It consists of a large bag. * * * Upon the surface of it large vascular ramifications are seen, and it is subdivided internally into a number of distinct pouches, opening by wide slits into the lower part of the sack. This sack seems to be nothing but the widened lower end of the ovary, and the pouches within it to be formed by the folds of the ovary itself. In each of these pouches a young is wrapped up as in a sheet and all are packed in the most economical manner as far as saving space is concerned, some having their head turned forwards and others backwards. This is therefore a normal ovarian gestation.

He further gives the relative sizes of adult and young.

Dr. Webb's account as given by Girard is as follows:

On May 3 (1852), during boisterous and cold weather, Capt. Ottringer caused his seine to be drawn across the harbor (San Diego). Caught many tiger and shovel-nose sharks, two flounders, two specimens of a fish somewhat like our sculpin, also a number of small fish about 3 or 4 inches long, each of which contained ten or twelve living young.

Girard (1858, p. 165) adds the following to Webb's account:

Eggs are formed within the texture of the ovarian membranes themselves. * * * The sheath (ovarian walls) and the ovaries are gradually increasing in bulk, as the eggs themselves first increase in size and the embryos afterwards. The sheath is chiefly a muscular membrane, whilst the ovaries are altogether vascular.

When mature, the eggs either fall into the space between the membrane or ovarian pouches, or else remain attached to the ovaries until the embryos issue out of them. We are inclined to think that they drop into the pouches as eggs. At any rate we found very young embryos loosely contained in the ovarian pouches, when no trace of the egg membrane could be seen within the tissues of the ovaries.

After leaving the eggshell they have an abdominal bag containing the remaining yolk,* which is gradually absorbed during a period when neither the mouth nor the œsophagus are formed. * * * The soft and articulated portions of the dorsal and anal fins next assume a development reaching extraordinary proportions, which they again gradually lose as soon as free from parental sheltering.

Under the head of *Embiotica jacksoni* he states:

To the upper roof of the sheath are firmly attached some highly vascular membranes hanging downwards and dividing the whole tube into elongated pouches or compartments. Five of these vascular membranes were found to be present, and by an attentive examination it was soon discovered that they were in fact the true ovaries, two in number, as required by the law of symmetry.

Mr. Lord (1866, pp. 106–114, 116–119) gives the following account of his discovery and observations:†

At San Francisco, as early as April, I saw large numbers of viviparous fish in the market for sale; but then it is an open question whether these fish really arrive at an earlier period of the year in the Bay of San Francisco than at Vancouver Island. I think not. That they are taken earlier in the year is simply due to the fact that the fishermen at San Francisco have better nets and fish in deeper water than the Indians, and consequently take the fish earlier. The habit of the fish is clearly to come into shallow water when the period arrives for producing its live young; and from the fact that some of these fish are occasionally taken at all periods of the year, I am induced to believe that they do not in reality migrate, but only retire into deeper water along the coast, there to remain during the winter months, reappearing in the shallow bays and estuaries in June and July, or perhaps earlier, for reproductive purposes; here they remain until September, and then entirely disappear.

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* Prof. Ryder has already shown that this observation is erroneous.

† For this account I am indebted to Dr. Theodore Gill.

They swim close to the surface in immense shoals, and numbers are very craftily taken by the Indians, who literally frighten the fish into their canoes. At low tide, when a shoal of fish is in the bay or up one of these large inlets that intersect the coast line, the savages get the fish between the banks (or the rocks, as it may be) and the canoe, and then paddle with all their might and main among the terror-stricken fish, lashing the sea with their paddles and uttering the most fiendish yells. Out leap the fish from the water, in their panic to escape this (to their affrighted senses) terrible monster; and if not out of the "frying pan into the fire," it is out of the sea into the canoes—which in the long run I take to be pretty much the same thing.

It appears to be a singular trait in the character of viviparous fish, that of leaping high out of the water on the slightest alarm. I have often seen them jump into my boat when rowing through a shoal, which is certainly most accommodating. The Indians also spear them; they use a long, slender shaft with four barbed points, arranged in a circle, but bent so as to make them stand at a considerable distance from each other. With this spear they strike into a shoal of fish, and generally impale three or four; many are caught with hooks, but they bite shily, the only baits I have seen taken being salmon roe nearly putrid, or bits of crab.

Just prior to my leaving Vancouver Island, numbers were netted by Italian fishermen who had a seine. They found a ready sale for them in the market, but as a table dainty they are scarcely worth eating; the flesh is insipid, watery, and flabby, and I am convinced that no system of cooking or culinary skill would ever convert it into a palatable fish.

The geographical range of viviparous fish, as far as I have any opportunity of judging, is from the Bay of San Francisco to Sitka. It may, perhaps (and I have but little doubt that it does), extend much farther south along the Mexican coast; but this I can only surmise, never having seen them beyond the limits above stated. It frequents all the bays and harbors on the east and west sides of Vancouver Island, and is equally abundant in the Gulf of Georgia and the Straits of Juan de Fuca; making its appearance about the same period, or perhaps somewhat earlier, in the various inlets on the Oregon coast, from Cape Flattery to the Bay of San Francisco. It will be just as well, perhaps, before I go into the subject of its specific characters and singular reproductive organs, I should mention how I first stumbled upon the fact of its being viviparous.

Soon after I arrived at Vancouver Island, I at once set to work to investigate, as far as it lay in my power, the habits and periods of migration of the different species of fish periodically visiting the Northwest coast. The sole means then at my disposal to obtain fish for examination, or as specimens to send home, was to employ Indians or catch them myself; so it happened, some of these were first brought me by Indians. Cutting one down the side (the plan I usually adopt to skin a fish, keeping the opposite side untouched), to my intense surprise, out tumbled a lot of little fish. My wildest dreams had never led me to suppose a fish I then thought was a bream, or one of the perch family, could be viviparous. I at once most hastily arrived at the conclusion that the greedy gourmand had eaten them; dropping my knife, I sat in a most bewildered state looking at the fish.

The first ray of light that shone to illumine my mystification seemed to spring from the fact that each little fish was the model, counterpart, and facsimile of the larger, and in shape, size, and color were exactly alike; from the position, too, they occupied in the abdomen of the larger fish, I was led at once to see the error of my first assumption, that they had been swallowed. Carefully dissecting back the walls of the abdomen, I discovered a delicate membranous bag or sac having an attachment to the upper or dorsal region, and doubled upon itself into numerous folds or plaits, and between each of these folds was neatly packed away a little fish; the bag was of bluish-white color, and contained fourteen fish. I had no longer any doubt that the fish was viviparous, and that it was a true and normal case of ovarian gestation. So much for my first discovery; the details of my subsequent examinations I shall again have occasion to refer to. * * [Here is added an account of Jackson's discovery.]

I have spoken of this at some length, because it is a curious coincidence that the same fact should have been discovered by two men, a long distance apart, about the same date, and by both in the same way—by sheer accident.

Now we come to the ticklish question: How are the young fish vitalized in the abdomen of the mother? In this case I shall adopt what I conceive to be the most straightforward course, which is candidly to give my own thoughts, and solicit from abler, older, and better physiologists their opinions or theories, for I sincerely think this is a question well worth careful investigation. I believe the ovum, after impregnation, at first goes through the same transformations in the ovarium as it would do, supposing it to have been spawned and fecundated in the ordinary spawning-bed, but only up to a

certain point; then, I think, the membrane enfolding the ova, that have by this time assumed a fish-like type, takes on the character and functions of a placental membrane, and the young fish are supplied by an umbilical cord, just as in the case of a fœtal mammal. But a third change takes place. There can be no doubt that the young fish I cut out, and that swam away, had breathed before they were freed from their mother; hence I am led to think that, a short time prior to the birth of the young, sea-water has access to this marsupial sac, washes over the infant fish, the gills assume their normal action, and the regular systemic circle is established. Maturity attained, the umbilical attachment snaps, and the little fish, perfect in every detail of its organization, is launched into the deep to brave its many perils and shift for itself. The strong transverse muscles attached to the powerful sphincter (constituting the genital opening acting from the abdominal walls), I imagine are in some way concerned in admitting the sea-water, and it appears a contrivance admirably adapted to effect such a purpose; but how impregnation takes place I may at once honestly confess—I do not know.*

The male is much like the female, but more slim, and the milt just like that of other fish. I can only conjecture that fecundation is accomplished through the medium of the sea-water, admitted by the curiously cell-contrived floodgate of the female, carrying in the milt-germs and washing them over the ova.

The actual period of utero-gestation I am by no means sure about, but I am inclined to think they breed twice in the year. It is worthy of remark that the young mature fish are very large, when compared with the size of the mother. In a female fish 11 inches in length, the young were 3 inches long, the adult fish 4½ inches high, the young an inch.

* * * * * * * * * *

But now for the most important feature in the history of these fish—that of bringing into the world their young alive, self-dependent, and self-supporting, as perfect in their minutest organization as the parent fish that gives them birth. The generative apparatus of the female fish when in a gravid state may be defined as a large bag or sac. Ramifying over its surface may be seen a most complicated and strangely beautiful vascular arrangement—a network of vessels, the use of which is clearly to convey the life-giving fluid to the infant fish, and carry it back again, after having served its destined purpose, to be revivified for future use. The way the sac is, as it were, folded, and the different compartments made for the accommodation of embryonic fish, is most singular, and very difficult to describe clearly.

The best illustration I can think of is an orange. You must imagine the orange divided into its regular number of little wedged-shaped pieces, and each to represent a fish; that the rind of the orange is a delicate membrane, having a globular shape, and easily compressed or folded. You now desire to fit the pieces together again in the original orange-shape, but you must begin on the outside of the globular membrane, pressing in with each section a fold of the membrane (remember that each represents a fish); when each piece is in its place, you will still have the sac in its rounded form, but the rind or membrane has been folded in with different pieces. If I have made myself understood, it will be seen that there must be a double fold of membrane for each portion of orange. This is exactly the way the fish are packed in this novel placental sac. If it were practicable to remove each fish from its space, and the sac retain its normal shape, there would be twelve or fourteen openings (depending upon the number of young fish), the wall of each division being a double fold of membrane, the double edges wrapping or, as it were, folding over the fish. Now make a hole in the end of this folded bag, and *blow* it full of air, and you get at once the globe-shaped membranous sac I have likened to an orange.

The fish are always arranged to economize space; when the head of a young fish points to the head of its mother, the next to it is reversed, and looks towards the tail. I am quite convinced that the young fish are packed away by doubling or folding the sac in the same way I have endeavored to describe. I have again and again dissected out this ovarian bag, filled with fish in various stages of development, and floating it in salt water, have, with a fine pointed needle, opened the edges of the double membranous divisions that enwrap the fish (the amount overlapping is of course greater when the fish is in its earlier stages of development). On separating the edges of the sac, out the little fishes pop. I have obtained them in all stages of their growth, but sometimes (and this not once or twice, but often) have set free the young fish from its dead mother. Thus prematurely cut loose from its membranous prison, the infant captive, reveling in its newly-acquired liberty, swam about in the salt water, active, brisk, and jolly, in every particular, as well able to take care and provide for itself

* It is perhaps needless to state that the above paragraph is far from stating what does take place.

as its parent. The female external genital opening is situated a little posterior to the anal opening, the orifice is at its apex, and in the center of a fleshy conical protuberance, which is in fact a powerful sphincter muscle, *moored*, as it were, in its place by two strong muscular ropes, acting from and attached to the walls of the abdomen.

The above account by Lord, as far as it deals with the embryology, is largely conjecture and of no value. It is here given simply to complete the history of the work done on these fishes.

James Blake, Proc. Cal. Acad. Nat. Sci., III, 314–317, gives somewhat more reliable information. His paper is given in full:

I am not aware that the process by which the embryo of the Embiotocoid fishes receive the nourishment necessary for its growth, has ever been pointed out. It certainly differs from the three most common forms in which the embryo of other animals is nourished, as there is nothing like a placenta by which they can receive nourishment from the mother; there is no supply of nutriment surrounding the embryo as in the case of most oviparous animals, nor is the embryo brought into direct contact with the water, so as to derive nourishment by absorption from the surrounding medium, as is the case in oviparous fishes generally and in most of the lower forms of animal life. The young fish is contained in a uterus which, in the undeveloped state, resembles very much the ovaries of the common oviparous fishes, except that its walls are thicker, and that the number of ova it contains is very much smaller. In the interior of the uterus, projecting from its sides, are a number of processes analogous to those to which the ova are usually attached. These processes vary in number in different examples, but they are so arranged that each fœtal fish is in contact on every side with a surface of one of these processes. They consist apparently of a membrane composed of a cellular tissue, and scattered over their surface are a number of small mammillary elevations with an orifice in the center, and which are probably the organs by which the peculiar secretion of the uterus, to be hereafter noted, is poured out.

In an example I examined, in which impregnation had apparently just taken place, numerous ova were found adhering to these processes, although not at all in such numbers as in the ordinary fishes. I counted thirty-eight in about the space of an inch; of these, however, but few can be developed, as the number of fœtuses seldom exceeds forty, and is sometimes only eight. In the whole of the uterus there probably were from one hundred to one hundred and fifty ova. Of the earlier stages of development, however, it is not my object to treat in the present memoir, as I did not commence my investigation sufficiently early to be able to fully make it out; as soon, however, as the embryo has advanced sufficiently for the fins to be formed, these appendages are found to be terminated by a number of digitations, which project from the free edges of the fin, and are usually found situated one between each ray or spine. They are composed almost entirely of fine capillary blood-vessels, united apparently by a very delicate and structureless membrane. They are so delicate that unless great care is taken in removing the specimen from the uterus, they are destroyed; nor have I ever been able to discover them in specimens that have been preserved in alcohol. These processes seem continuous with the membrane extended between the rays of the fins, but are much more delicate; they project from the free edge of the fin, sometimes as much as the eighth of an inch, and are, in the fully developed embryo, the fifteenth of an inch broad. On the free margin of each digitation, a larger capillary can be observed, which appears to be continuous all around; it is about the .003 inch in diameter, the intermediate space being filled with a network of smaller capillaries. This system of digitations projects from the entire edge of the dorsal, ventral, and caudal fins, but not from the pectorals. They in fact form a fringe around the entire body with the exception of the head and that part of the abdomen in front of the anus.

Such is the structure of the organ that evidently has some connection with the fœtus, resembling as it does so closely the early formation of the vascular villi and the placental tufts that proceed from the chorion of the mammiferous embryo, and through which it derives its nourishment before the placenta is fully formed.

The question now presents itself as to how nourishment is conveyed from the parent to the fœtus through these tufts? As before stated, the lining membrane of the uterus sends off processes which surround each fœtus, without however forming shut sacks; but although these processes are very freely supplied with blood-vessels, yet the finest injection failed to show any more vascular spots where the fœtal digitations might have been brought into more immediate contact with the blood of

the parent. I however was fortunate enough to obtain a fish, in the uterus of which I discovered a considerable quantity of fluid, and on collecting it and submitting it to chemical tests, I found that this fluid contained a considerable quantity of animal substance, resembling, to a certain extent, some of the compounds that are formed from albumen during the progress of digestion. The fluid was of yellowish color, translucent, deposited on standing some small globules which under the microscope strongly refracted the light, were not altered by acetic acid, but dissolved in ether; probably fat globules; when heated there was no coagulation, although the fluid was not quite so clear; solution of $HgCl_2$, caused no precipitate; tannin in solution caused a yellowish precipitate. In adding ether to a portion of the fluid, there was a free disengagement of gas, a white flocculent precipitate was formed, and on allowing the vessel to stand the fluid separated itself into three portions: the upper portion consisting of pure ether apparently, then a layer containing white flocculi, which occupied about the fourth part of the fluid, and below this the remains of the original fluid, but little altered in appearance. There can, I think, be little doubt but that it is through the medium of this fluid that the fœtus obtains its nourishment. The considerable portion of animal matter it contains, and that too in a state particularly fitted for absorption and for conversion into tissue, fits it for furnishing the fœtus with the elements necessary for its growth by absorption through the large surface of capillary vessels which are found in the vascular digitations that surround the fœtus, and which are constantly bathed in the fluid. The difficulty that up to the present time has attended every attempt to trace the connection between the parent and fœtus in these embiotocoid fishes is owing, in the first place, to the extreme delicacy of the vascular digitations of the fœtus, which prevents their being observed in preserved specimens, and also to the fact that in almost every case the fluid secreted by the uterus is entirely expelled by the violent struggles of the fish when removed from the water, so that it was almost by a rare accident that I succeeded in obtaining any. I hope, however, during the coming season to be able more fully to carry out these researches. (San Francisco, January 21, 1867.)

Later he published the following note, v, 371–372:

Some months since I presented a communication to the Academy pointing out the manner in which the fœtus of the embiotocoid fishes was nourished whilst it was being developed within the ovisac. I there stated that the ingress of water into the ovisac would not take place at all freely, as the organ communicated with the surface by a narrow canal surrounded by muscular fibres. This structure of the oviduct would evidently oppose an obstacle to the entrance of the semen into the ovisac for the purpose of impregnation, unless some means exist by which the ventral surfaces of the fish can be maintained in contact during the act of copulation, as the penis consists of a slightly developed tubercle which can not penetrate for any distance into the oviduct. From the direction of the orifices of the penis and oviduct it is evident that anything like a perfect contact of these organs can only be maintained whilst the fishes are in a reversed position, so that the head of one fish is towards the tail of the other. In order that contact may be maintained whilst in this position, we find the anal fin of the male fish furnished with certain appendages which enable it to give a firm hold to the ventral fins of the female, so that close contact of the ventral surfaces can be maintained.

These appendages are of two kinds. In *Embiotoca*, *Damalichthys*, and some other genera we find a well-developed mammary elevation situated near the anterior part of the anal fin on both sides, terminating in front by a teat-like process. In *Amphistichus*, *Holconotus*, and some other genera this mammary appendage is wanting; but its place is supplied by a bony transverse plate with serrated edges, inserted in the fin some distance farther back and parallel to the fin rays. In addition to these plates there are also found cartilaginous ridges with roughened borders, placed in front of the plates and running parallel with the edge of the fin. I think there can be no doubt but that these fin appendages serve the purpose I have assigned to them, for on placing the fish in the reversed position, with the orifice of the oviduct and penis in contact, it will be seen that they enable the ventral fins of the female to secure a firm hold on the anal fin of the male, so as to keep the fish in contact during the process of copulation. At the season of copulation the anterior surface of the anal fin in the male becomes covered with a thick layer of firm epithelium. As this commences at a short distance from the ventral attachment of the fin, a well-marked groove is formed at the base of the fin, which affords an additional hold for the ventral fin of the female. After the season of copulation is over and the testicles regain their quiescent state, this epithelium almost disappears. At the same time the mammary sack diminishes very much in size, so that when the testicles are reduced to their smallest size hardly a trace of the sack remains. One or the other of these forms of appendages have been found on the anal fin of the male in all the species of embiotocoid fishes I have examined.

Prof. Ryder (1885) discovered that what had been taken for a yolk bag by Girard was a projection of the abdominal profile, caused by the hypertrophied hind gut, and that the inner lumen of the hind gut is filled with "villi of the most extraordinary length. * * If extended, some of these villi would more than reach across the lumen of the intestines." Since no such structure is found in the adult he thinks it "obvious that this hypertrophy of the hind-gut and remarkable development of elongated villi in the embryos of the surf perches has some important function to subserve during fœtal life." This function he considers to be the digestion of the fluids secreted by the walls of the "ovarian sack."

Ryder studied material collected by Rosa Smith at San Diego, and from the date at which this material was taken he concludes "that during the months of October and November one would probably find the earlier stages, which are so desirable to clear up what must evidently be a most interesting chapter in vertebrate embryology." He redescribes the highly vascular larval fins, and adds that all of the vascular digitations at the edges of the vertical fins receive their blood supply from the median aortic trunk, which reaches them through trunks given off from the aorta at irregular intervals of one, two, or even six muscular segments. At the base of the fins they subdivide into from two to six branches, which pass up a little to one edge of the interradial space, giving off smaller trunks to the highly vascular interradial membrane and ending in a flat sieve-like capillary mesh. The vascular trunks do not correspond to the number of rays, a fact which indicates "that this singular vascular supply of the vertical fins of embiotocoid embryos has attained great specialization and must be of very great physiological importance."

He further describes the peculiar vascular supply of the caudal and of the skin. He finds that nothing is found in the adult which corresponds to this larval condition. All this arrangement he considers to be for the purpose of respiration and not for the purpose of absorbing nutriment from the ovarian space, as Dr. Blake supposed.

As will be seen later, I consider that both these functions are in part subserved by this highly specialized vascular system.

I have published several notes on the eggs and development of the *Embiotocidæ*, but since these observations will be extended and corrected in the following pages, it is not necessary to mention them further here.

CYMATOGASTER AGGREGATUS Gibbons.

Cymatogaster aggregatus is probably the most abundant species of the *Embiotocidæ*, and is found along the entire western coast of the United States and part of Lower California.

Breeding habits.—During the summer and fall this species is rarely seen, as it then probably lives a short distance off shore in deep water or among fields of *Zostera*. In November and December it approaches the shore in large numbers, and is caught with hook and line off the wharves in San Diego and San Francisco bays. The greater part of the specimens so caught are females, there being rarely a male among them. This is probably due in part to the facts that the male is much smaller than the female and, farther, that this is not the period of copulation. The largest females become gravid about the first of December (one very large one was found with developing eggs on November 1, at San Francisco); by the middle and latter part of the same month the greater number of those taken are with eggs in various stages of development. During January the smaller ones caught are with developing eggs, while the smallest, those which do not take the hook and can only be procured with a seine, have eggs in similar stages during February.* The oldest are, as a rule, sexually ripe earlier in the season. The same variation of the time of maturation was observed in the other species of this family.

Methods of studying living eggs.—The fishes were kept alive in salt water until needed. The spinal cord was severed and the ovary immediately excised and brought entire on a glass slip. The ovary was then slit open and the oviferous sheets unfolded. If there were free eggs they were placed together near a fragment of the ovary and the whole covered with a glass slip. The eggs could thus be examined in their natural fluid, and I have succeeded in keeping them alive for an hour. The oviferous sheets being very thin, a fragment of one could be spread out, covered and

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* TIME OF MATURATION AND SIZE OF EGG OF OTHER SPECIES OF EMBIOTOCIDÆ.

Embiotoca jacksoni: The first one with eggs was noticed November 12 (1889). One of the eggs found at this time was in the two-cell stage, all were free from the follicle. The diameter of the egg membrane is about .7 mm., the smallest observed being .53 mm., the largest .92 mm. The diameter of the yolk is about .45 mm.

Amphistichus argenteus. Diameter of the egg membrane .65 to .68 mm.; yolk .441 to .49 mm.; oil-globules .14 mm.; green eggs near maturity .65 mm. The water space is therefore, as in *Cymatogaster*, formed by the contraction of the yolk during maturation.

The specimens taken at San Diego, where I had an opportunity of examining large quantities, are of three sizes. The largest measure about 300 mm., the second in size 160 mm., and much smaller ones of variable sizes. There are, of course, intermediate sizes between the largest, 300 mm., and the second, 160 mm., but the groups are quite well marked. The largest have ripe eggs as early as November 12 (1889). The second in size have eggs near the middle of December. The following is from my notes, December 19, 1889: "A large number of individuals taken to-day, 160 mm. long; all have the eggs nearly equally developed. The germ is nearly at the close of segmentation; the eggs are still inclosed in the follicle. Only in one specimen were the eggs free. In these the gastrula covered the entire yolk. December 27 one female 160 mm. long was obtained; the embryo is hatched; the yolk is almost all absorbed. There is a continuous dorso-ventral fin-fold. These eggs, therefore, hatch in less than a week."

I did not determine the maturing period of the smallest individuals, but on December 10 I made the following note: "The smallest have eggs quite green."

On December 10 the largest contained young from 5 to 7 mm. long. The larvæ at the end of the first month would probably average 7 mm.

examined, fresh. In this way many stages of growth of the egg could be observed *in situ*. The ovaries containing embryos or larvæ are slightly translucent and, after some practice, can be distinguished from those not yet mature.*

Methods of studying living larvæ.—The same process of procuring the larvæ is used as for obtaining the eggs. The very young are, however, much more difficult to see than the eggs, and it is frequently necessary to spread out the tissues and examine them microscopically before the larvæ can be found. It is to be borne in mind that in this species the maximum number of eggs maturing in a season is only 22, and since the eggs are minute it would frequently be difficult to determine whether an ovary was immature or contained young embryos if it were not for the slight difference in the ovary itself as mentioned before. In these earliest stages the larvæ are very sensitive to the condition of the mother. It has frequently happened that the larvæ have become distorted if the mother had been confined in a pail of water for half an hour and before she showed any signs of exhaustion. They are most sensitive when the circulation is just established, but are frequently found to be nearly dead after they have attained 20 mm. in length, if the mother has been confined in standing water for several hours. For many stages this fact is very useful, since the young can be thus stupefied and studied more readily. For the latest intraovarian stages this method again produces distortions and coagulations in the vessels of the fins before the young is sufficiently stupefied. Partly asphyxiated larvæ, 10 to 20 mm. long, can frequently be revived by simply placing them in some of the ovarian fluid on a glass slip, where they are exposed to the air. The method of removing a blood clot from the blood vessels can thus be observed very readily.

Connection of the developing egg and larva with the ovarian structures.—Part of the maturation processes of the egg are undergone in the follicle, but in all probability the egg is freed from the follicle before segmentation. Unsegmented eggs have been found free between the ovarian lamellæ. The larvæ always fall out of the lamellæ if the ovary is immersed in any preservative fluid, and in the older stages the young can be seen to change head for tail in the ovary, so it may be safely said that the eggs and young are, during no stage of their development, connected with any portion of the ovary. Sections of some stages of ovaries containing eggs and young tell the same story.

Position of larvæ in the ovary.—Girard stated that in some species the embryos were regularly arranged in the ovary and that in *Hysterocarpus traski* (1859, p. 16) in which the young were nearly ready to be born "all of them had their heads in the same direction as that of the mother, a circumstance for the first time noticed." That the larvæ are not definitely arranged in the species examined by me has already been mentioned and is emphasized by the fact that in later stages they can change their position.

* It will be found to be more difficult to study the different stages of the developing egg of these fishes than pelagic eggs, or even mammalian eggs, because the age of the contained eggs can not be known, as in the case of mammals, and the different stages, if they are not incidentally procured, must, therefore, be sought by chance, a process which often necessitates the examination of many individuals and consumes much time. To add to the difficulty, the fishes, after heavy rains or a slight fall of temperature, seek deeper water and can not be procured. Stages thus lost had to be sought in the next series (smaller specimens) to mature—a process which did not always prove successful. To balance this, there is an almost unlimited supply of specimens when the conditions are favorable.

To show their position in the ovary I have tabulated the following series:

Total No. of young.	Size.	No. in ovarian sacks.	No. between ovarian sacks and ovarian walls.	Axis corresponding to that of mother.	Axis reversed to that of mother.
11	18 mm.	3	8	8	3
14	21	6	8	6	8
12	20	4	8	3	9
11	.....	6	5	6	5
17	40	.....	.....	16	1
14	14	.....	.....	10	4
10	32	.....	.....	7	3
12	18	.....	.....	5	7

From this it is evident that there is no definite arrangement of the larvæ as far as the ovarian sack is concerned, and scarcely any as far as the axis of the embryo is concerned, but the condition indicated by the larvæ 40 mm. long in the above list is repeated in all the largest larvæ. That is, when they approach the period of extrusion they come to lie with their heads forward. This may be due to the fact that the gills being now well formed the heads of the larvæ are turned to the origin of the oxygenated blood supply, which is at the anterior end of the ovary.

Intraovarian food.—The yolk, both on account of its small size and because it is not absorbed until very late, is evidently not sufficient to account for the growth of the embryo and larva. It disappears months before the intraovarian development is complete. There is probably general surface absorption through the whole of the ovarian life and, as we shall see, there is evidently intracellular digestion in the epidermal cells in the eggs. The yolk is scarcely if at all diminished before the zona bursts, and yet growth is so rapid that the mere size of the embryo bursts the zona long before any movements are evident on the part of the young. This process of absorption by the general surface practically supplies all the food until the first gill-slit is open.

With the opening of the first gill-slit a new process begins—the absorption by the intestinal canal. Before the mouth is opened a continuous stream of the fluid contents of the ovary enters the first gill-cleft, and passes apparently unchanged through the anus. This process can frequently be observed.

This continuous stream is due to the presence of cilia in the intestinal tract. The blood corpuscles and solid particles of the ovarian fluid seem to get into small whirlpools if they approach the side of the tract. Part of this may be due to the presence of spermatozoa, which frequently fasten themselves in clusters on the inner surface of the intestinal tract while their tails are kept in active vibration. The spermatozoa remain in the ovary during several weeks of gestation.

In one individual the stream into the gill-cleft was especially noticeable, as the stream contained many blood corpuscles which had been freed when the ovary was slit open and a large number of highly active spermatozoa. With the opening of the mouth long villi appear in the hind gut, and the process of digestion proper is established. Soon after this the spermatozoa disappear from the ovarian fluid, being in all probability digested in the hind gut. Succeeding the opening of the mouth, a solid mass of substance is frequently found in the intestines, which is composed of the solid particles of the ovarian fluid and which in part is composed of these spermatozoa.*

* In my first notice of this fish I did not know the meaning of the mass nor did I then know that food is taken in through the hyomandibular slit before the mouth is open.

As I have stated before, food absorption is probably continued by parts of the general surface throughout intraovarian existence, and is greatly facilitated in later stages by the highly vascular fins.

The food absorbed and digested is furnished by the ovarian lamellæ themselves. These structures are much greater than is necessary to bear the few eggs, and they are so constructed that they offer the greatest uninterrupted surface possible.

The intraovarian food entering the intestines consists in great part of solid cell-like particles. These are found both in the gravid ovary and in the intestine of the embryo. They, together with the ovarian fluid, are the product of the lining epithelium. The individual cells of this structure become distended with an unstainable fluid. At the outer margin of these distended cells are seen nucleated bodies in all stages of separation from the epithelium. At first I supposed them to be the product of the epithelial cells, but am more inclined now to consider them the cells themselves deprived of their fluid contents. These cells are found in the intestine of the larvæ, in early stages, few in number, in later stages forming a solid mass.

The amount of fluid in the ovary at any time is very small in *C. aggregatus*, but is very much greater in some other species. Till the young has attained a length of several millimeters there is no more of it than there is serum in the body cavity. In the later stages, when the lamellæ are stretched to their utmost and the highly vascular surface of the fins is brought in contact with them, direct dialysis, primarily for oxygenation, probably takes place between the cells of the ovarian lamellæ and those of the young.

Intraovarian respiration.—That there is the closest intimacy between the respiration of the mother and young has been proved by the fact that the latter shows signs of asphyxiation before the former shows exhaustion, *i. e.*, if the mother is kept in stale water; if she is taken from the water she will die before the young. The embryo and larvæ are at all times in contact with the structures of the ovary which derive their blood directly from the gills. During the early stages the highly active spermatozoa keep the ovarian fluid in circulation and thus help the ciliated lining of the intestine of the larva to bring oxygenated albumen from distant parts of the ovary; while later the highly vascular fins and general surface of the body are in direct contact with the ovarian sheets. As the body becomes covered with scales the surface of the fins increases. It has already been stated that partly asphyxiated young can readily be revived by exposing them to the air in some of the ovarian fluid, a fact which seems to demonstrate the affinity of this fluid for oxygen. Respiration is probably also carried on through the stream of ovarian fluid flowing through the intestine, as Stuhlmann has suggested for *Zoarces*. The young, unless they have nearly reached maturity, invariably die if they are placed in either fresh or salt water.

Duration of gestation and adolescence, and number of young.—The exact date at which the young are set free I am not able to tell. Some are freed as early as April, while others are not freed till June. The probable duration of gestation, counting from December 1 to May 1, is five months. The following February the smallest individuals are sexually mature. The time from the birth of one generation to the beginning of the next is therefore about ten months. Usually all the eggs in an ovary are equally developed; only rarely was any marked difference observed. In one case one young was apparently four weeks older than the others.

Malformations are rare. Double-headed monsters or similar forms have never been seen. In one case the lower jaw was distorted; in another one eye was destroyed; in fact all the malformations found were evidently due to causes acting after hatching, overcrowding, etc., and entirely different in kind from those producing double monsters. Nonfertilized eggs were not found unless the single dead egg found among all of those examined died because of nonfertilization. It is of course not to be expected that any eggs should escape fertilization when they are permanently surrounded by a fluid highly favorable to the longevity of spermatozoa.

The following table will enable us to form some estimate of the number of young and the rate of growth. Most of the individuals obtained during one season are recorded. It must be borne in mind, however, that no small mothers were obtained in the early part of this season. Some valuable embryos and larvæ can not be recorded here because I could neither beg nor buy the mothers and secured the young only by offering to clean the fish for the captor.

The first column gives the ovaries in the numerical order in which they were procured. The headings sufficiently explain the remaining columns.

No.	Date.	Length of mother.	Condition of young.	Number of young.	No.	Date.	Length of mother.	Condition of young.	Number of young.
	1890.	*mm.*				1891.	*mm.*		
1	Nov. 1	160	1 to 8 cells	18	45	Jan. 4	120	Not ripe	.....
2	Nov. 30	140	36 (?) cells	21	46	Jan. 4	145	12 mm	20
3	Nov. 30	150	.....	.....	47	Jan. 8	125	5 mm	7
4	Nov. 30	120	About complete segmentation.	.....	48	Jan. 8	120	Just hatched	11
					49	Jan. 8	122	Segmenting	14
5	Dec. 15	106	Not ripe	.....	50	Jan. 8	124	Segmenting	13
6	Dec. 15	106	Complete segmentation.	9	51	Jan. 8	144	6 mm	17
					52	Jan. 8	140	6 mm	18
7	Dec. 15	137	.....	13	53	Jan. 8	138	5 mm	22
8	Dec. 15	150	.....	.....	54	Jan. 8	137	5½ mm	16
9	Dec. 18	105	Complete segmentation.	10	55	Jan. 8	120	Segmenting	12
					56	Jan. 8	121	Segmenting	(?)
10	Dec. 18	120	Not ripe	.....	57	Jan. 11	155	6-11 mm	17
11	Dec. 18	135	Just hatched	11	58	Jan. 11	120	Hatched	.....
12	Dec. 18	125	Not ripe	.....	59	Jan. 11	118	Segmenting	7
13	Dec. 18	125	.....	15	60	Jan. 11	134	2.5 mm	9
14	Dec. 18	135	.....	16	61	Jan. 11	133	.....	.....
15	Dec. 23	150	5 mm	17	62	Jan. 11	135	.....	.....
16	Dec. 23	150	8th segment (?)	10	63	Jan. 11	140	.....	.....
17	Dec. 23	140	Yolk inclosed	14	64	Jan. 21	145	7 mm	.....
18	Dec. 23	135	.....do	10	65	Jan. 21	155	5½ mm	17
19	Dec. 28	110	.....	7	66	Jan. 25	165	6 mm	20
20	Dec. 28	98	Not ripe	(5 eggs)	67	Jan. 25	147	7 mm	18
21	Dec. 28	103	.....	6	68	Jan. 25	162	15 mm	15
22	Dec. 28	140	.....	19	69	Jan. 25	120	5 mm	9
	1891.				70	Jan. 25	112	2 mm	.....
23	Jan. 1	135	4 eggs ripe	.....	71	Jan. 25	145	2 mm	.....
24	Jan. 1	122.	Blastopore closing	11	72	Jan. 25	120	2 mm	.....
25	Jan. 1	140	7 mm	.....	73	Apr. 19	80	6 mm	6
26	Jan. 1	110	.....	16	74	Apr. 19	85	4 mm	7
27	Jan. 1	140	Not ripe	.....	75	Apr. 19	100	14 mm	8
28	Jan. 1	130, 140	Hatched	.....	76	Apr. 24	110	10 mm	9
29	Jan. 1	140	Just hatched	.....	77	May 24	160	Empty. Ovary still very large.	.....
30	Jan. 1	120	.....	.....					
31	Jan. 1	130	No protovertebræ	13	78	May 24	140	....do	.....
32	Jan. 1	115	.....	13	79	May 24	150	Empty. Ovary reduced to normal.	.....
33	Jan. 1	140	6 mm	11					
34	Jan. 1	145	12 mm	.....	80	May 24	120	Empty. Ovary reduced to normal.	.....
35	Jan. 1	140	6 mm	.....					
36	Jan. 1	120	2.6 mm	.....	81	May 24	100	18 mm	5
37	Jan. 1	140	4 mm	.....	82	May 31	118	25 mm	8
38	Jan. 1	145	8 mm	.....	83	May 31	112	22 mm	8
39	Jan. 4	110	Segmenting	7	84	May 31	107	22 mm	7
40	Jan. 4	115	Segmenting	10	85	May 31	100	20 mm	6
41	Jan. 4	110	Segmenting	8	86	May 31	100	22 mm	5
42	Jan. 4	140	3 mm	19	87	May 31	90	Not mature	.....
43	Jan. 4	115	2 mm	12	88	May 31	100	20 mm	6
44	Jan. 4	112	Segmenting	.....	89–95	May 31		♂ with large testes	.....

These lists, arranged according to the size of the parent, give the following results:

Date.	Length of mother.	Condition of young.	Number.	Date.	Length of mother.	Condition of young.	Number.
1890.	*mm.*			1891.	*mm.*		
Nov. 1	160	1 to 8 cells	18	Jan. 21	155	5½ mm	17
Dec. 23	150	5 mm	17	25	165	6 mm	20
23	150	Eighth segmentation	10(?)	25	162	15 mm	15
1891.				May 24	160	Just born	
Jan. 11	155	6 to 11 mm	17	24	150	Born some time	

Average number of young, about 16. Duration of gestation, about 5 months.

1890.				1891.			
Nov. 30	140	36 cells	21	Jan. 1	145	12 mm	
Dec. 15	137		13	1	140	6 mm	
18	135	Just hatched	11	1	140	4 mm	
18	135		16	1	145	8 mm	
23	140	Yolk inclosed	14	4	140	3 mm	19
23	135	do	10	4	145	12 mm	20
28	140		19	8	140	6 mm	18
				8	138	5 mm	22
1891.				8	137	5½ mm	16
Jan. 1	135	4 ripe eggs		11	134	2.5 mm	9
1	140	7 mm		21	145	7 mm	
1	140	Not ripe		25	147	7 mm	18
1	140	Just hatched		25	145	2 mm	
1	140	6 mm	11	May 24	140	Just born	

Average number of young, about 16. Duration of gestation, about 5 months.

1890.				1891.			
Nov. 30	120	Segmentation about complete		Jan. 8	120	Just hatched	11
				8	122	Segmenting	14
Dec. 18	120	Not ripe		8	124	do	13
18	125	Not ripe		8	120	do	12
18	125		15	8	121	do	
22	122	Blastopore closing	11	11	120	Hatched	
1891.				25	120	5 mm	9
Jan. 1	120	2.6 mm		25	120	2 mm	
8	125	5 mm	7	May 24	120	Born some time	

Average number of young, about 11½. Length of gestation (longest possible time, 6 months 24 days; shortest, 4 months 16 days), about 5 months.

1890.				1891.			
Dec. 15	106	Segmentation complete	9	Jan. 11	118	Segmenting	7
				25	120	5 mm	9
18	105	do	10	25	112	2 mm	
28	110		7	Apr. 19	100	14 mm	8
28	103		6	24	110	1 mm	9
1891.				May 24	100	18 mm	5
Jan. 1	115		13	31	118	25 mm	8
4	110	Segmenting	7	31	112	22 mm	8
4	115	do	10	31	107	do	7
4	110	do	8	31	100	20 mm	6
4	115	2 mm	12	31	100	22 mm	5
4	112	Segmenting		31	100	20 mm	6

Average number of young, about 8. Duration of gestation, somewhat over 5 months.

1891.				1891.			
Apr. 19	80	6 mm	6	May 31	90	Not mature	
19	85	4 mm	7				

From these lists the fact mentioned before, that the larger individuals are with ripe eggs earlier than the small, becomes quite evident.

The very largest, 150 to 160 mm., have ripe eggs as early as November 1.

Those from 120 to 140 mm. have ripe eggs by November 30 or about December 1.

Those from 100 to 120 mm. have ripe eggs from December 15 to January 1.

These observations were taken at San Francisco. At San Diego, 500 miles farther south, I have taken the very smallest, less than 100 mm., with ripe eggs, March 3, 1889, and segmenting eggs could be obtained throughout January.

No definite time can, of course, be set for the maturation of the different sizes, because there is considerable variation even within small limits of size. This may again be due to the age of the fish. The age of the fish would be partly indicated by its size, but two fish of the same size may not necessarily be of the same age, since the rate of growth is in all probability not uniform in different individuals.

What I have endeavored to show for *Cymatogaster* is much more evident for *Amphistichus*, where there does not seem to be so much gradation in size, but several distinct sizes can be separated. These different sizes have also distinct maturation periods. It is also quite evident from these lists, and scarcely needs mention, that the number of young is directly proportional to the size. I obtained very minute mothers at San Diego with but three young, while, as is evident from the above, the average number for the largest mothers is 16, the maximum number observed by me being 22.

The ovary.—The ovary is a spindle-shaped bag, divided anteriorly into two arms which indicate the bilateral origin of the present structure. One of these arms, the left, is usually much smaller than the other, and the blood vessel entering the ovary by this smaller horn is also much smaller than that of the other horn. The testes of the right and left side are distinct. The ovaries of the two sides have evidently been united from behind forward, so that externally only the two anterior horns show the bilateral structure, and one of these horns seems to be in process of phylogenetic resorption. From the inner upper margin of this bag are suspended two sacks with their open ends near the posterior end of the bag. Each one of these sacks is divided by a vertical partition similar to their sides into two compartments.

The ovary lies, in the normal condition, just above the rectum and is suspended from the dorsal wall of the abdomen by a mesoarium which is directly continued below the ovary as the mesorectum.

The ovarian walls are composed, first, of the thin peritoneal membrane; second, of a layer of longitudinal muscle fibers; third, of a layer of circular muscle fibers, inside of which there is, in places, another layer of longitudinal fibers; fourth, of a very thin layer of cells with flattened, deeply stainable nuclei; fifth, of a layer of epithelium. This layer is derived from the peritoneum. The cavity of the ovary arises as a groove on the outer lateral portion of the germinal ridge. The raised margins of the groove unite and form the ovarian cavity, which remains for some time connected with the body cavity by a ciliated opening. The inner linings of the ovary are thus of peritoneal origin. Laterally and ventrally the two inner layers form simple thin linings; dorsally they are thrown up into a number of low ridges. Besides these ridges there are on either side of the median dorsal line three broad sheets which are simply ridges enormously exaggerated. These sheets are united to form the sacks mentioned above. Cross-sections of these sheets show them to be composed externally of a continuation of the epithelium lining the ovarian sheath and internally by a continuation of the membranous tissue lying immediately outside the lining epithelium of the ovarian walls. In other words, Nos. 4 and 5 of the structures enumerated above are raised and greatly prolonged to form these sheets. Ventrally

the three sheets of each side have become united. The inner layers of these sheets sometimes form a solid tissue, but frequently they are well separated or connected by occasional fibers only. The latter is probably an artificial condition.

The blood vessels found in the sheets lie between the two inner layers of cells and are surrounded by tissues derived exclusively from the ovarian *walls*. They are always quite distinct from the surrounding tissues.

At a glance the conditions appear quite different from those obtaining ordinarily in fishes, but a closer inspection shows the chief difference to lie in the nonformation of numerous eggs and of a large amount of yolk. If the oviferous sheets of *Perca*, for instance, should be deprived of all but a few eggs they would be similar to those in *Cymatogaster*. The difference between them would lie in the size of the cells. The minute structure of the ovary will be more fully dealt with in a later part of this work, when the growth of the ovarian eggs is considered.

The blood supply* is derived from two vessels entering the two horns of the ovary. These are divided up in the front end of the ovary and traverse the ovarian sheets like the rays of a fan.

Secondary sexual characters in Cymatogaster.—1. The male is much smaller than the female; the latter reaches a length of about 160mm., while 120mm. is the length of the longest male recorded (figs. 180*a*, *b*).

2. The anal fin of the female is normal. In the male there is a slight depression on either side at the base of the anterior anal rays and the rays themselves are provided with a gland-like structure with a free duct pointing forward (fig. 108 *b*).

3. The median region of the belly in the male is naked. The anus (which is reached by the tips of the ventrals) is succeeded by a broad, low, blunt papilla, behind which lies a deep pit. In the female the papilla gives place to a circular opening of the oviduct.

4. The male is much darker than the female. Each row of scales is provided with series of pigment spots which form lateral bands. Dorsally the pigment spots sometimes become so numerous as to give the fish a black appearance. There is also a conspicuous black spot on the preorbital.

In the female the ventral regions, belly, and breast are free from pigment and the cheeks and lower parts of the head are also but sparingly pigmented. The lateral bands of dark are quite inconspicuous except in three vertical bars on the sides of the abdomen. In other regions they are overlaid by a golden tinge. The preorbital spot is either absent or inconspicuous.

Copulation.—The act of copulation has never been observed in the *Embiotocidæ*. Blake suggested that the ventral surfaces are appressed, the heads of the fish pointing in opposite directions. Ford supposes that "fecundation is accomplished through the medium of the sea water." It has lately been shown that contacts of the genital openings is not necessary for the transference of spermatozoa to the cloaca of *Diemyctelus*. The same may be true for *Cymatogaster*.

* In *Amphistichus* the ovarian sheets are not united below, but hang free, and the blood supply, instead of being derived from vessels radiating from the anterior end, are derived from a vessel running along the dorsal part of the ovary.

Copulation takes place in Cymatogaster during June or early July, although the eggs are not fertilized till the following December! This fact strongly bears out my opinion expressed in the American Naturalist (1890, p. 925), that the small size of the eggs of *Cymatogaster* is due to a hastening in the process of maturation, and the consequent nonformation of yolk. (See chapter on the egg and segmentation, p. 421.) The normal or former period for maturation of the oviparous ancestors of *Cymatogaster* very probably coincided with the present time of copulation, or nearly with the present time of extrusion of the young; the eggs, however, which should be fertilized by these spermatozoa, have just been set free in the shape of living young. They, therefore, remain in the ovary in a dormant condition till the *next* series of eggs become mature, which they fertilize. It is difficult to imagine why the maturation of the male has not been similarly hastened with the hastening of the maturation period of the female, for the process must have been a gradual one. We must imagine a time when the result of the ovarian gestation was much less perfect than now, and the larvæ were freed in a much less mature stage than at present. Under such circumstances it would be quite possible for a number of spermatozoa to live through the period of gestation, and protract their stay in the ovary till other eggs were mature, and it is possible that the presence of spermatozoa may incite the eggs to the earliest maturation possible. If the eggs of a given season should be fertilized before the maturity of the males the spermatozoa introduced during the subsequent maturity of the males would necessarily remain in the ovary till the next series of ova were mature or else be destroyed. The hastening in the maturation of the ova of an oviparous fish would not be followed by the disastrous consequences to the offspring that would result in the too early maturation of an oviparous egg, and in the consequent reduced amount of food material, since the food necessary in the eggs of the oviparous fishes for their larval existence is supplied by the ovary.

It is in some such manner that we must explain the peculiar conditions existing in *Cymatogaster*.

Since the statement that copulation takes place about five months before the eggs are ready to be fertilized is somewhat paradoxical, it is perhaps best to state upon what facts I base this conclusion.*

During the period of segmentation few males are found with the females, which are then in shallow water, near wharves, etc. The testes of the males at this season are small and evidently during their period of physiological rest. The latter part of May I found a male with enormous testes, which I supposed to be in a pathological condition. Shortly afterward, May 31, 1891, I obtained in San Francisco a large number of males, all of which had enlarged testes, but none of which were mature. The males were now common in shallow water. The next lot of males was obtained nearly two months afterward, July 29, 1891, at San Diego. In these males the testes were nearly reduced to their resting condition again. On examining a

* This was written before Jordan's and Gage's papers on *Diemyctelus* appeared, from which it is evident that the spermatozoa can live a considerable time in the female *Diemyctelus*. A still more striking observation has been made by Bumpus in invertebrates. In the young lobster the transfer of spermatozoa may occur a year or even two years before fertilization takes place. I have not seen his paper and do not know whether Bumpus has demonstrated that the spermatozoa live from the time of the transference to the fecundation of the first lot of eggs or whether a new transference takes place

large number of females at this same time (July 29) spermatozoa were found in all or nearly all the ovaries, *but the spermatozoa were inactive*, not showing a particle of their great mobility of December. Sections made through the entire length of the ovaries of this time showed large quantities of spermatozoa, extending between the ovarian sheets to the anterior end of the ovary, but especially abundant in the oviduct, just behind the ovarian sheets. Sections of ovaries of October and November also show spermatozoa, so that there is no doubt about the early transfer of spermatozoa.

Development of ovarian eggs.—This subject, which properly belongs here, will be dealt with in a subsequent part of the paper when the development of the sexual organs themselves is described.

The mature egg.—I have not succeeded in keeping eggs alive for more than an hour after they were taken from the mother; and, in most cases, they perished after they had been removed from the ovary but a few minutes. The successive processes of segmentation and gastrulation could not therefore be observed. The methods could only be inferred from the different stages obtained from different individuals. Although I opened several hundred individuals, the series is not as complete as desired, because the individuals had to be opened when they were found, and there was no means of telling externally the length of time the contained eggs had been developing. In order to section developing eggs it is absolutely necessary to cut the zona. Many of the first eggs collected were not available for study because this was not done. The eggs are freed from the follicle before segmentation begins. In all probability fertilization takes place just before or just after they are freed. In a single case observed the second polar globule is being extruded and the male pronucleus is formed in an egg still inclosed in the follicle. The cells of the follicle show evident signs of degeneration. In other members of the family (*Amphistichus*) segmentation is carried on (to completion?) before the eggs become free from the follicle. In an ovary with eggs with two cells there were also found others with four and with eight cells.

The egg before it is freed from the follicle, measures on an average about 280 μ (sometimes more than 300 μ). During maturation the size of the egg proper is reduced to a diameter of 200 to 230 μ, or to half to one-third of its original volume. In this manner a considerable breathing chamber is formed within the zona which retains its original extension. If younger eggs are put under pressure a similar contraction sometimes takes place, leaving a space between the egg and the zona, which is traversed by a multitude of fine threads. That these green eggs can be made to contract by rupturing the zona probably indicates that the contraction of the ripe egg is due to the fact that at maturity the ovarian fluid gains access to the yolk on account of withdrawal of the granulosa cells from the zona. Similar reductions in the bulk of the yolk take place in other teleost eggs, as has been noted by several observers.

The mature egg, just before segmentation, is divided into two portions by a well-marked constriction. The larger of these and the one of an apparently homogeneous substance is the germ; the smaller, composed of very small spheres, the yolk spheres, is the *deutoplasm*. Situated in the middle point of the surface of the latter, or just at the entodermic pole of the egg, is a more homogeneous transparent mass sometimes containing one or two small spheres. The appearance of this structure is similar to the germinal vesicle and its nucleoli of the green egg, with the exception that its outlines are less regular, angles projecting in among the yolk spheres. A like structure has

not been observed in any other egg (see under *yolk nucleus*, p. 423). The proportions of yolk and germ as found in other teleosts being reversed, at first glance the two structures might be taken for each other, and, indeed, I observed the yolk in a favorable egg for a considerable time, expecting it to show some signs of segmentation, before I became aware of the true state of affairs. The axis of the egg is slightly longer than the transverse diameters. The yolk, being the smaller segment of the sphere, is of a smaller diameter than the overlying germ.

Several eggs measured have the following dimensions in μ.

Total diameter from zona to zona.	Axis.	Diameter of germ.	Diameter of yolk.	Height of yolk.	Yolk nucleus.
300	276	258	230	98	
	231	213		89	
		249	179	53	36×45
244		200			

The proportion of the yolk is seen to vary considerably, as is also the size of the germ (200 to 258)—I did not look for extremes—all of which shows that the size of the egg of *Cymatogaster* is in a state of unstable equilibrium.

Intimately connected, of course, are the small size of the egg and the great reduction of deutoplasm. The nearest approach to the size of the egg of *Cymatogaster* is probably that of *Clupea*, in which the germ also has a comparatively large size. There are very few yolk spheres in the germ of *Cymatogaster*, so that the small amount of yolk present if evenly distributed in the germ would scarcely prevent it from undergoing complete and regular segmentation. As large a proportion of deutoplasm is probably found in some holoblastic eggs. The meroblastic condition of segmentation is here a purely ancestral trait. The small size of the yolk is unquestionably the result of viviparity and may have been brought about through natural selection. We need only hasten the time of maturation of the average teleostean egg by two or three months to produce an egg not unlike that of *Cymatogaster*, for, as I have shown elsewhere, the growth of the teleostean egg—*i. e.*, yolk formation—takes place *chiefly* during the two or three months before maturation. Should any eggs of an oviparous fish show any tendency to so early maturation the young would invariably perish during its larval stages, owing to the lack of food. Not so in a viviparous species. As will be seen later, in *Cymatogaster* intracellular digestion of the ovarian fluid takes place *before the embryo is freed from the zona*, which occurs very early. Eggs of such viviparous species with a tendency to early maturation, having all food necessary for their development in the surrounding liquid, would not necessarily perish, but would in fact have an advantage over eggs maturing later, which they could deprive of nourishment, if they did not feed on them. It would need but the hastening of the processes of maturation, as stated above, to produce an egg similar to that of *Cymatogaster*.

The teleostean ovary has a period of physiological rest and a period of great physiological activity, the latter in oviparous forms occupying the months just before oviposition. A hastening of the process of maturation and reduction of the number of eggs would therefore deprive viviparous forms of the type of the *Embiotocidæ* of their periods of greatest activity; but they are not deprived of this activity because the young, where only a few are born, remain for a long period in the ovary and are

supplied by it with food during all that period. The period of gestation is the period of greatest activity—corresponding to the period of greatest growth of ova in oviparous species. The reduction of the yolk has taken place after the reduction of the number of eggs, as may be seen by comparing the number and sizes of eggs of viviparous forms. The reduction of the yolk and of the number of young has evidently gone hand in hand with the lengthening of the time the young remain in the ovary. In those viviparous species in which the yolk and the number of eggs have not at all been reduced (*Sebastes*, etc.) the young are liberated as larvæ as soon as hatched. In those viviparous species in which the young remain for a long period in the ovary, from which they derive their food (*Embiotocidae*, *Anableps*, *Zoarces*) the number of young has been reduced. In *Cymatogaster* (and *Abeona*), where the reduction of the number of young is very great, the average number being but 12, the reduction has also been carried to the yolk.

Though the size of the yolk can thus be satisfactorily explained and charged to the account of viviparity, greater difficulty is met when we attempt to determine whether other peculiar conditions observed during development, which are due to the small size of the yolk, are atavistic, or whether they are further modifications and should also be charged to viviparity. To this, however, we shall return later.

Of especial interest is the yolk nucleus,* since it is also found in *Abeona*, in which the proportions of the egg are similar to those of *Cymatogaster*.

Entodermic aggregations of protoplasm have been described by List (Z. W. Z., 1887, 595) for *Crenilabrus tinca*, which "zeigt also was die Anordnung der Keimsubstanz auf dem Dotter betrift grosse Uebereinstimmung mit dem durch Kupffer's Untersuchungen bekannt gewordenen Ei des Herings" (p. 598). I have not seen Kupffer's work, but have examined the eggs of another species (*Clupea mirabilis*), which, since the germinal matter is yellow, show the entodermic mass of protoplasm to good advantage. In the case of this species, as well as in the case of *C. tinca*, the entodermic mass is not a "selbständige Masse," but is *merely a thickening of the periblast*, which extends over the whole yolk and which disappears at the expense of the growing germ. But even in these cases this thickening is of doubtful significance, and it is still more so in *Cymatogaster* and *Abeona*, in which it forms an isolated mass sunk deep into the yolk without any apparent connection with the germ, and where it remains intact until the closing of the blastopore. It might be possible that the entodermic mass has here collected in a space formed in the yolk by the phylogenetic degeneration of an oil-globule, if the oil-spheres in teleosts occupied a fixed position. But all those that I have been able to examine can change their positions without a greater disturbance than would be created by changing a floating ball from one part of a vessel of water to another. The fact also that angles from this mass sometimes project in between the surrounding yolk-spheres argues against the supposition that it represents a degenerate oil-sphere. On the other hand, Wilson has lately shown that there is a cap of protoplasm covering the oil-globule in some

* This has been identified with the yolk nucleus of ovarian eggs. It is not homologous with the entodermic aggregations of protoplasm mentioned in the succeeding paragraph, with which it was at first identified. For a history of the early stages of this, see Hubbard, 1894; for the later stages see paragraphs headed *yolk nucleus*, p. 440.

pelagic eggs. But Wilson's figure (1) does not show conclusively that the protoplasmic cap is not the result of reagents. The oil-globule figured by Wilson is not of the shape of the oil-globules seen in living eggs and the space occupied by the protoplasmic cap may be due to contraction. I have seen similar spaces in other eggs filled with stainable material. Its position remains fixed at the entodermic pole of the egg till the closing of the blastopore, and is therefore an excellent landmark for orientation.

Segmentation.—The first segmentation plane is meridional and divides the germ into two equal blastomeres. The surface views of this stage are represented in figs. 1 and 3. The groove separating the sphere varies in depth according to the stage of division. The constriction between the yolk and germ also differs in different eggs. The nuclear figures can not be distinctly made out, and it was but once that I was able to definitely distinguish the resting nuclei (fig. 3). Sections show that the dividing plane reaches entirely through the germ to the yolk before the second division begins and that the line dividing the germ from the yolk, though irregular, is well marked (figs. 4 and 5). The division is further indicated by the fact that yolk and germ readily part. The yolk shows no signs of segmentation, and if the yolk ever does segment in teleosts it ought certainly to show some signs of it where so little resistance is to be overcome as in *Cymatogaster*. The conditions described by M. Kowalewski, 1883, for the goldfish are probably not due to the segmentation of the yolk, but to the retarded segregation of yolk from germ and the consequent indistinct boundary between the two. During this first segmentation there is still considerable protoplasm scattered through the yolk, and the lower margin of the blastoderm, though quite distinct, is not yet as well defined as in later stages. The germ, on killing with strong O. C. A. and staining with Grenacher's hæmatoxylin, is seen to be finely granular, with a few larger granules, many of them arranged along the division planes. A granular network of protoplasm extends also through the yolk. A few yolk-spheres are, on the other hand, found in the germ (4), some of them being arranged along the division plane. The yolk nucleus at this stage is stained darker than the germ, has an irregular outline, and is apparently composed of protoplasmic granules similar to those of the germ, but more compact, and of a few yolk-spheres (fig. 4, *yk. pr.*).

The second segmentation plane is also meridional and at right angles to the first. This is seen both in segmentation spindles of mounted 2-celled eggs and in the division plane itself (fig. 2).

Authors in general have been agreed that the third segmentation planes are parallel to the first in fishes. List, 1887, on the other hand, claims that the second segmentation appears almost simultaneously with the first in *Crenilabrus tinca* and is equatorial, and that the third is again meridional and at right angles to the first; while Brook, 1886, maintains that in the herring the third is the equatorial segmentation. Hoffmann, 1888, claims to have found the fourth segmentation to be horizontal in the salmon, but since Brook found the third to be horizontal or equatorial, he concludes that this is the rule, considering *Amphioxus*, Cyclostoms, and Amphibians. The fourth cleavage of Rauber, Kowalewski, Ryder, Agassiz, and Whitman, that is, the cleavage which according to them divides the germ into 16 cells, is not the fourth, but the fifth, etc. (Hoffman, 1888, p. 532). Wilson considers the third cleavage, the one parallel to the first, the homologue of the fourth in the frog.

I have seen nothing of a horizontal third cleavage in the various species of eggs I have examined, and, in the face of so much evidence to the contrary, am doubtful whether the third cleavage is equatorial in the sense used by Hoffmann, *i. e.*, horizontal. If the first equatorial segmentation is the third cleavage and horizontal, then, indeed, the large yolk accumulated at one pole is an intimate part of the *lower* cells with which it is represented to be connected and does not divide for lack of sufficient energy in the comparatively small cytoplasm overlying it. But in *Cymatogaster*, in which the yolk is much smaller than the germ, it is just as distinct from the germ as it is in large-yolked species, and much more so than is represented for some large-yolked species by other authors (Kowalewski). It shows, however, no signs of segmentation or other interest in the changes of the cytoplasm; on the contrary, it is during the early stages of segmentation as impassive as so much dough might be. While I am not prepared to believe that it is not an intimate part of the ovum, I do believe that, in those large-yolked species in which the yolk and germ are well separated before segmentation begins (pelagic eggs, for instance), the nuclear spindles guided by the forced shape of the germ may be displaced from their primitive direction. In other words, owing to the presence of a large yolk the four blastomeres have a greater lateral than vertical dimension. The effect on cleavage is what it might be expected to be. The third cleavage spindles, instead of being vertical, have been forced by the depressed condition of the germ to lie in a horizontal or slightly inclined position, and the third cleavage of the teleostean egg instead of being normal (equatorial) has become parallel to the first cleavage. A similar result has been obtained by compressing the segmenting eggs of the frog between two glass plates. By the compression the horizontal cleavage was changed into vertical cleavage.

An examination of the figure of the external features of an 8-celled egg, and the cross-section constructed from a wax model and made after a series of 13 oblique sections of an 8-celled egg, will lend force to the supposition that the third segmentation was originally equatorial. For now that the yolk has been greatly reduced, and the germ is no longer a comparatively flat particle, but has approached the spherical form again, the third segmentation is no longer vertical, but is oblique (figs. 6 and 8); that is, it has approached the original horizontal or equatorial segmentation. This third segmentation is probably not similar to the horizontal segmentation which Hoffmann claims for the salmon, and which is said to divide the germ into an upper and a lower layer. It may, however, be similar to that described by Brook in the herring, since the proportion of yolk to germ in *Clupea* approaches more to the proportions found in *Cymatogaster*. In the 8-celled stage, all of the cells, with perhaps one or two exceptions, touch the yolk, and all without exception form part of the external surface of the germ; they do not form distinct layers of four upper and four lower cells.

Of the 16-cell stage I found but one egg. It was killed, as usual, with Flemming's strong osmic chromic acetic, but stained with Gren. alcoholic borax carmine. It was examined *in toto* and a series of optical sections made, the planes passing through the resting nuclei. The cells are still but one layer deep, unless possibly one occupies the center of the group of cells (figs. 11–14).

After the 16-cell stage the blastoderm becomes two cells deep. Such striking bilateral symmetry as is seen in pelagic eggs I have not observed, and after the 16-cell stage is passed the determination of the first and second cleavage planes becomes largely conjectural. The stages between 16 and 70 cells are represented in vertical and horizontal sections in figures 16 to 23.

Up to this time the marginal cells have had boundaries quite as distinct as any other cells of the blastoderm. At the end of the seventh segmentation (fig. 44) some of the marginal cells have the lower margin ill defined and continuous with the yolk. This is never the case in more central cells. The nucleus is also slightly more refringent in these marginal than in the neighboring cells. At the end of the eighth segmentation (fig. 45) there is still a distinct dorsal wall to the periblast cell, but its nucleus is now much larger than that of the surrounding cells. At the end of the ninth segmentation the periblast consists of a few large, refringent nuclei imbedded in protoplasm, which is restricted to the immediate neighborhood of the blastoderm (figs. 47–49). At this time the outermost layer of the blastoderm has begun to creep over the yolk, so that the periblast cells are partly covered exteriorly by the rim of the blastoderm formed by the outermost cells. Dorsally the periblast cells are covered by the row of cells just within this outer projecting series. The periblast does not extend beneath the central cells of the blastoderm and the nuclei do not reach this region till later, after the nuclei are all that remains of the periblast. So much has been written concerning the fate of the periblast that a detailed account of it in *Cymatogaster*, where it has been reduced to its simplest formula, will follow (p. 437).

After the seventh segmentation and up to the time of the formation of the first protovertebræ the development of *Cymatogaster* shows little in common with other fishes, and an egg of this species found floating during this period would scarcely be recognized as belonging to a teleost. The rapidity characterizing the formation of the periblast characterizes the whole of this development and the difference of the blastoderm at the beginning and at the end of any segmentation is sometimes considerable. The age of each of these stages was determined by the number of nuclei in the blastoderm. While the method of counting nuclei is probably not as satisfactory as observing the successive segmentations in the same egg, this method is almost as exact, because the number of nuclei present must be doubled or diminished by half in order to change the serial number of the segmentation under consideration.

During the ninth segmentation the marginal series of cells of the blastoderm creep over the yolk. At the same time they become flattened (fig. 27). Near the end of the tenth segmentation about three series of cells (only one cell deep) have crept over the yolk and cover it from the blastoderm, which has scarcely changed shape, to the yolk nucleus, the margins of which have been extended to meet this layer of thin cells. The yolk at the end of the tenth segmentation is therefore entirely inclosed (fig. 29).

During the eleventh segmentation the yolk sinks into the blastoderm, or, in other words, the blastoderm spreads over the yolk; but the former expression is more apt, since the process in no way resembles the epibolic growth of the blastoderm over the yolk in other teleosts. In other fishes the inclosing of the yolk is accomplished by the growth of the gastrula margin, while in *Cymatogaster* it is accomplished before there is any sign of gastrulation. The inclosing of the yolk by the blastoderm during the eleventh segmentation corresponds rather to the spreading of the blastoderm in pelagic eggs just before the beginning of the marginal infolding. The yolk in *Cymatogaster* appears to sink into the blastoderm on account of its small size. At the end of the eleventh segmentation the cells of the blastoderm are not yet divided into two layers and the yolk nucleus is still exposed. (Figs. 32 to 34.) A noteworthy feature is that near the end of the tenth segmentation the outermost layer of the blastoderm consists of flat cells, which contrast strikingly with the remaining more rounded cells. This differentiation does not exist except at the margin before the

tenth segmentation, at least it is not so evident, and it disappears some time after the diplastic gastrula has been formed. These outer cells seem to become distended with extraneous matter.

The changes are so rapid from one segmentation to another that a much larger series of eggs than I possess is necessary to illustrate all the phases. At this point it will be worth while to compare the results of the successive stages of the segmentation of *Cymatogaster* with those of some large-yolked teleost. Since Agassiz & Whitman have so ably discussed and figured the segmentation of *Ctenolabrus*, that species may be taken. Agassiz & Whitman, 1883, p. 45, state that the ninth generation of amphiasters is reached in two hours and sixteen minutes, and that the time between the eighth and ninth generations is fifteen minutes. From these data I estimate that their figure 3 contains amphiasters of the ninth generation, or more than 250 cells and less than 500; their figure 4, amphiasters of the thirteenth generation, or more than 4,000 cells. As stated above, the segmentation could not be directly observed in *Cymatogaster*, and in order to determine the serial number of my segmentation I had recourse to counting the nuclei, a method more laborious and inexact with each generation. Since, however, the number of the segmentation, as already stated, can not be missed unless the number of nuclei present is actually doubled or diminished by half, except at the beginning or end of a segmentation, the result thus obtained is sufficiently exact for purposes of comparison.

If we compare Agassiz & Whitman's fig. 3 (24*a*), containing amphiasters of the ninth segmentation, with fig. 24, at the beginning of the ninth segmentation, and their fig. 4 (30*a*) during the thirteenth segmentation, with figs. 41 and 42 during the twelfth segmentation, the contrast will be seen to be very great, and the work accomplished by *Cymatogaster*, between the ninth and the thirteenth segmentation, comparatively enormous. The actual time consumed in reaching these stages (three hours and sixteen minutes in *Ctenolabrus*) is in all probability different, but that does not concern us since the time of successive generations of amphiasters differs greatly in oviparous fishes in which the generations are more alike. *Cymatogaster* accomplishes in twelve generations of nuclei what is not accomplished by *Ctenolabrus* till much later. To anticipate somewhat, the stage of *Cymatogaster* just before the closing of the blastopore does not correspond to the same stage in *Ctenolabrus*, but rather to the beginning of the epibolic growth of the blastoderm. Just before the marginal infolding of the blastoderm of oviparous fishes it spreads over the yolk. This spreading probably corresponds to the sinking of the yolk into the blastoderm in *Cymatogaster*. By the time *Cymatogaster* reaches a stage homologous to that reached by *Ctenolabrus* at the closing of the blastopore, *Cymatogaster* is hatched.

The hastening in the inclosing of the yolk on account of its small size in *Cymatogaster* and the rapidity of the spreading of the blastoderm at the time of the infolding of its edge in most oviparous fishes result in the diplastic gastrula in *Cymatogaster* and the familiar condition in other fishes. The lack of a two-layered gastrula in fishes seems to be due to the rapid spreading of the epiblastic portion of the blastoderm. A large vitellus permits this spreading to take place more rapidly than the margin grows inward, so that the inner anterior and posterior margins of the embryonic ring do not ordinarily meet. An interesting egg bearing on this subject is that of *Stolephorus*, in which the blastoderm is placed at the end of an ovate egg. The lateral spreading of the blastoderm is here almost impossible, and at the beginning of gastrulation the

tip of the embryonic shield is separated from the inner margin of the anterior part of the embryonic ring by but a very narrow space, through which are scattered cells; in other words, there is a very close approach to a diplastic gastrula. It is not at all improbable that in this genus eggs may sometimes occur in which the lower layer is quite continuous, and that a two-layered gastrula is formed. This condition, however, lasts but a very short time. With the epibolic growth the lower layer becomes more and more incomplete. The two-layered condition of *Cymatogaster* seems to be homologous to this early two-layered condition of *Stolephorus*.

Gastrulation.—On account of the difficulty of orientation of the stages during gastrulation, and because the contents of the zona soon fill the entire space within it, and some structures are invariably injured, owing to the necessity of cutting the zona, the process of gastrulation has not become very lucid. It will be best, therefore, to describe in detail the few favorable series of sections.

To repeat the description of the stage during the eleventh segmentation or just before the beginning of gastrulation: An egg, near the end of the eleventh segmentation (containing about 1,700 cells) was cut into twenty sections, of which, sections 3 to 15 cut through the yolk. The sections run somewhat obliquely to a meridian plane, as is indicated in the diagram, fig. 31. A section (the ninth) through near the middle of the yolk (the sixth section cutting through the yolk) is represented in fig. 33. As will be seen by the figure and by the diagram, the yolk has sunk into the blastoderm. At the ectodermic pole the blastoderm is about five cells deep. It becomes shallower towards the entodermic pole and gives out altogether at the yolk nucleus which has spread to some extent over the yolk. The yolk is, therefore, entirely inclosed, and the margins of the blastoderm are separated only by the yolk nucleus. There is no indication of a division into entoderm and ectoderm; in other words, *gastrulation has not yet begun.* There are present about 14 periblast nuclei. The breathing chamber has not been greatly reduced. The height of the egg is ·054 mm., the width ·064 mm., the diameter of the zona ·073 mm.

The next stage satisfactorily made out is of several eggs during the twelfth segmentation. There are, however, two stages of development, which, according to the estimate of cells, belong to this segmentation. Although the two stages differ considerably, it is difficult to state at a glance which is the older. In the one case (fig. 38) the blastopore is still open, and the yolk nucleus forms a plug which fills it. The ectoderm and entoderm are well separated, while the cells have become nearly evenly distributed over the yolk. In the other (fig. 35) the shape is much more like that of the eleventh segmentation; the ectoderm and entoderm are scarcely separate and the cells are still heaped up at the ectodermic part of the yolk, but the blastopore is much smaller.

Thus, while the shape and relation of ectoderm to entoderm indicate the latter (fig. 35) to be less advanced, the large blastopore points to the former (fig. 38) as the earlier stage. Everything considered, it is evident that fig. 35 represents the younger stage. The two stages are very close together and also near fig. 41. The ovary from which the egg represented in fig. 35 was taken contained several different stages, and in fact one egg in an *earlier* stage than the one represented in fig. 33 and another in about the stage represented by fig. 38.

In fig. 35 the outermost layer of cells is quite distinct from the others. The cells are mostly flat, quite small and stain (with Grenacher's alcoholic borax carmine)

slightly deeper than the other cells. *The cells of this layer are the only ones which cover the yolk nucleus*, leaving but a minute naked portion, the blastopore (fig. 36). They are more distinct in some sections than in others, but are everywhere quite evident. The axes of the remainder of the cells are more alike. These cells do not extend much, if any, beyond the margins of the yolk. The plane of the sections of this egg is meridian, probably but slightly inclined to the sagittal. The lower layer of cells is well separated from the upper layer. At the median portion the blastoderm is still many (6 to 7) cells deep and the separation between ectoderm and entoderm is not yet so distinct. The cells, however, which will form the entoderm are smaller than those overlying them.

Figure 38 represents a section of a gastrula in all probability cut in a sagittal plane. The yolk in this section is pear-shaped, the narrow end being composed of the yolk nucleus. The latter is composed of a more granular refringent portion and a more uniform part resembling the protoplasm of the cells. The cells are grouped into a one- to three-cell-deep ectoderm and a one-cell-deep entoderm which becomes two and then several cells thick towards the dorsal edge of the blastopore. The outer layer of the ectoderm is flattened in places; the inner cells are rather loosely connected. On the upper part the entoderm cells lie close against the yolk and form a continuous series. The division in this case between the entoderm and ectoderm is well marked by a space which was probably produced by the reagents (osmic, chromic, and acetic strong mixture). Near the blastopore, in what would correspond to the embryonic ring in other teleosts, the two layers merge more or less.

Figs. 41 and 42 represent two parallel sections from another egg of the same ovary, cut transversely or in a vertical plane at right angles to the sagittal. All these eggs are in the same stage of development. In the eggs represented in fig. 40 the yolk nucleus consists of an irregularly biconvex portion, whose peripheral part stains deeper, and which contains some bodies which stain less and a more uniform part forming the matrix of the former. The cells, as in fig. 38, are divided into an ectodermic layer and an entodermic layer. Some of the outer layer of cells of the ectoderm have become greatly distended, probably by absorption of the intra-ovarian fluid, which fills the breathing chamber and stains as these distended cells do. The line separating the entoderm from the ectoderm is quite distinct, but along the median portion, or at the axis of the embryo, the entoderm is several cells thick. The same is indicated in the horizontal sections. The shape of the yolk is different in the three eggs, but they agree in all essential respects, and figs. 38 and 41 must represent a normal stage in the development of *Cymatogaster*. The question now arises as to how this gastrula has been formed from the condition represented in fig. 33.

The fact that there is a marginal ingrowth of cells to form the lower layers in teleosts generally has been observed by so many authors, and is so evident from the fact that the space between the inner margins of the embryonic ring is reduced in some cases, notably *Stolephorus*, that it is beyond dispute. Does the method of the formation of the gastrula in *Cymatogaster* form an exception to the rule? It must be borne in mind that the changes undergone between the stages represented by figs. 33, 35, and 38, all take place during the time occupied by the latter half of the eleventh segmentation and the first half of the twelfth. During this time, if the usual course is followed, all but the outermost layer of the blastoderm must be

inflected at the margin of the blastopore and must *meet* somewhere below the ectoderm; and, by a further comparison of figs. 33 and 41, it becomes evident that the bulk of the cells of the median portion of the blastoderm of fig. 33 must migrate toward the margin before the infolding can produce the conditions seen in fig. 38. If the formation of the gastrula of *Cymatogaster* follows the usual method, fig. 38 is derived from fig. 33, after the manner just described, granting, of course, that both figs. 33 and 38 represent *normal* conditions. Considering, however, the great rapidity with which this process takes place, and examining fig. 41 in connection with fig. 38, it seems probable that the infolding process may be slurred over, and the lower layer, or primitive entoderm, be formed by a process of delamination.*

In this connection the stage represented in fig. 35 becomes interesting. If this stage be compared with the one represented in fig. 33 the great probability that the condition represented in fig. 35 is derived by simple delamination from fig. 33 becomes quite evident.

The shape of fig. 33 is retained by fig. 35, which can readily be derived from the former by further division and a slight progress of the epidermal layer over the yolk nucleus. But in fig. 35 the entoderm is already well separated from the ectoderm near the margin, and the division, while not so distinct at the median portion, is evident both as a line and in the size of the cells. While, then, figs. 41 and 38 make it seem possible that the lower layer is formed by delamination, fig. 35 makes it certain that it is so formed.

Now, as to the changes in fig. 35 necessary to produce fig. 41. We see in the fig. 35 the beginning of the constriction of the yolk at the margin of the entoderm which gives the yolk in fig. 41 its peculiar shape. The margin of entoderm has advanced toward the entodermic pole at a uniform rate on all sides while the epidermal layer of cells has been apparently passive. In fact, the blastopore in fig. 41 is larger than in figs. 35 and 36, but the margins in fig. 41 do not correspond to the margin of the epidermal blastopore of figs. 35 and 36, but to the shaded portion of fig. 36. The epidermal layer in fig. 41 is not everywhere evident, and where it is most conspicuous the cells are distended and feebly stained. This is probably due to intracellular digestion, as was mentioned above, but it may be due to the degeneration of this layer of cells. Certain it is that in this stage the epidermal layer is not distinguishable near the blastopore, where it is so evident in stage 35.

In the stages immediately succeeding those represented in fig. 41 the yolk nucleus disappears and the yolk assumes a more or less spherical outline. Its fate will be discussed later. With its disappearance, the "fixed point" so useful in orientation is lost.

From the fact that the entoderm is formed by delamination and the anterior end of the embryo lies at one margin of the blastopore and the posterior end at the other (?), the fundamental difference between the gastrula of *Cymatogaster* and that of teleosts in general may be gathered. The embryo of teleosts in general is formed by the concrescence of the embryonic ring from before backward, and the embryo rarely encircles more than half of the yolk. (*Clupea*, a genus with a small yolk, forms a notable exception.)

* Wilson, p. 220, says: "It is, to be sure, very doubtful whether there is any vertebrate in which the primitive hypoblast is really delaminated from the upper layer."

The methods of concrescence employed by teleosts in general are obscured in *Cymatogaster* beyond recognition. In fact they are slurred over entirely, for just at the time when in other teleosts the infolding process and the formation of the embryo begin, the blastopore is in the act of closing in *Cymatogaster*. Though the gastrulas appear to have nothing in common, the conditions in *Cymatogaster* after the embryo has been formed can readily be derived from large-yolked teleost eggs by simply imagining the yolk to be reduced. Ryder has shown that the arc formed by the larva varies inversely as the yolk. For example, in large-yolked species, as the trout, the embryo forms an arc of but 90 degrees. From this, as an extreme, there is a complete series of intermediate forms till we reach *Clupea*, in which the embryo, just before the tail buds out, encircles almost the entire yolk. In *Cymatogaster* the head and tail overlap just before the tail begins to grow out, or shortly after the time of hatching. Bearing these facts in mind, the incongruous gastrula of *Cymatogaster* becomes more intelligible.

With the reduction of the yolk, unless this is proportionate to the reduction of the germ, which it is not, the embryo must necessarily form a greater and greater arc, until it finally forms a complete circle. From this it is evident that, although the methods employed by *Cymatogaster* have become greatly modified, the result is perfectly homologous with the result of gastrulation of other fishes. Ziegler* (1882) homologizes the yolk and periblast of teleosts with the yolk cells of the amphibia. Wilson (1891) indorses this view and explains the steps by which the amphibian egg was changed into the teleostean egg in the following words :

> The alimentary canal is formed from the roof of the archenteron exclusively. How this was effected is easy to see. The increase in the size of the mass of yolk cells (of *Amphibia*) brought it about that the dorsal parts of the embryo were early folded off—some time before the alimentary canal was completed ventrally. The division of labor, already far advanced between the dorsal and ventral hypoblast of the gastrula, next took the final step; the dorsal hypoblast assumed the entire function of forming the gut, while the ventral hypoblast became transformed into pure food material. The yolk is consequently to be looked on as an organ of the gastrula, which has lost its original function, but which, in doing so, became adapted to another function to which it owes its large size.

The major premise in this argument is that the yolk in teleosts is much larger than in *Amphibia*. But is it larger? It is larger in certain forms—*Salmo*, for instance.† This accounts for Ziegler's view, since he studied a large-yolked form. It is just as certainly smaller in certain other eggs, *Abeona*, *Cymatogaster*, and *Clupea*, and it seems to me as proper to take the extremes in one direction for comparison as those in another. If the egg of *Cymatogaster*, for instance, is compared with the amphibian egg, we can not with Wilson say that the teleostean conditions are due to "the *increase* in the size of the yolk cells of amphibia," for there is a *decrease* in the bulk of the yolk, and therefore in the yolk cells, if the yolk is formed by the union of such cells. Of course it may be argued that *Cymatogaster* is not a fair representative of teleostean ova, because a reduction of the yolk has been brought about by viviparity. If, however, the teleostean egg has been *immediately* derived from the amphibian egg, through increase of yolk, we may properly suppose that with the reduction of this same yolk the egg will show some atavistic features in the partial or occasional segmentation of the reduced yolk. But the tenacity with which the egg

* For this statement of Ziegler's views I am indebted to Wilson (1891), pp. 264, 265.

† It is very large in *Tachysurus*.

of *Cymatogaster*, which contains much less yolk than the amphibian egg, persists in segmenting only the germ and not the yolk tends to show that the teleostean egg is not immediately derived from an egg similar to the amphibian, as Wilson states, but that the teleostean condition is deep-rooted and of very long standing.

Balfour's (1885, p. 68) view (which Wilson does not mention) is thoroughly in harmony with the conditions found in *Cymatogaster*, as well as with those of *Salmo*, and I see no valid reason for changing it. His view very tersely expressed is:

> The peculiarities of the development of the teleostean ovum can best be understood by regarding it as an elasmobranch ovum, very much reduced in size.

Agassiz & Whitman (1884) indorse this view, and Miss Clapp's discovery of the closing of the blastapore behind the embyro in *Batrachus*, a large-yolked teleost, brings the final proof of this view. It is probable that conditions will be found in *Tachysurus* which are similar to those in *Batrachus*.

There can be no question but that teleostean ova, as all other telolecithal ova, have been derived from *alecithal* ova, such as those of *Branchiostoma*. The question at issue is whether the conditions found in the fishes have been derived immediately from some egg resembling the amphibian egg, or whether from some egg like that of elasmobranchs. The nonsegmentation of the yolk in small-yolked teleosts, the discogastrula of *Cymatogaster*, and the close approach to the discogastrula in the oval egg, in which the germ lies at the narrow end of the yolk, as in *Stolephorus*, all point to the fact that the teleostean egg was not directly derived from an amphibian-like egg.

Ryder's (1887, p. 493) modification of Hæckel's theory seems to me much nearer the truth. Both suppose the yolk to fill the archenteron of the primitive *Branchiostoma* gastrula—very nearly the condition found in *Cymatogaster*. Wilson admits "that this theory offers an explanation of the early teleost gastrula, but it becomes utterly unsatisfactory as soon as what Balfour has called 'the asymmetry of the vertebrate gastrula' begins to appear in the fish embryo. For the teleost gastrula of Ryder and Henneguy is a symmetrical gastrula, and they are consequently unable to explain why it is that (continued) *invagination takes place at one pole of the blastoderm, while the other pole grows epibolically round the yolk.*" The major premise of this argument lies in the words I have italicized. Wilson takes it for granted that this premise is correct, although he has not proved that this is really the condition in *Serranus*—the form he studied (see page 436). Certainly it is not the case in *Cymatogaster*, in which the gastrula is a symmetrical gastrula, and the blastopore closes at exactly the entodermic pole of the egg. It is not the case in two species of pelagic eggs (*Stolephorus*), in which I have examined the gastrulation, for these also have symmetrical gastrulas, and the blastopore closes at the entodermic pole of the egg. The preceding italics, describe exactly what does not take place in *Cymatogaster* and in *Stolephorus*, in which the anterior and the posterior margins of the blastoderm grow equally over the yolk. In *Stolephorus*, as I have stated elsewhere (1891), the germ lies over the narrow end of a very elongate yolk. To all intents and purposes we have, therefore, a small-yolked teleost ovum, and when gastrulation takes place the marginal ingrowth exceeds (on account of the narrow yolk) the restricted lateral spreading of the blastoderm. The result is that the tip of the embryonic shield comes in close proximity to, if not in contact with, the inner margin of the anterior portion of the blastodermic ring—an almost complete diplastic gastrula is formed. Nothing

could more forcibly illustrate the manner in which the discontinuity of the lower layer of cells was formed by the addition of yolk to the *Branchiostoma* gastrula and the result of subsequent reductions, than the early gastrula of *Stolephorus* and the condition in *Cymatogaster*. A comparison of the gastrula of *Cymatogaster* with that of *Branchiostoma* and of the frog is interesting. The gastrula of *Cymatogaster*, exclusive of the yolk, is remarkably like the gastrula of *Branchiostoma* as figured by Kowalewsky. In fact the peculiar conditions in *Cymatogaster* are just what might be expected if the ventral hypoblast cells of *Branchiostoma* should in some way become eliminated. This elimination has probably been brought about by the fusion of these cells, through their enormous surcharge with yolk and by the subsequent reduction of this yolk without a restoration of its original cellular constitution. In those cases (elasmobranchs and teleosts in general) in which the yolk is functional it occupies the space originally occupied by the ventral hypoblast cells; *i. e.*, the region between the tip of the head and the anterior or ventral margin of the embryonic rim.

Detailed homologies between parts of the *Branchiostoma* and parts of the *Cymatogaster* gastrula can not with certainty be pointed out till the first stages in the formation of the embryo of *Cymatogaster* have been observed. Both the gastrulas are formed by a layer of epiblast and a layer of hypoblast, and the region of the dorsal lip of the blastopore of *Cymatogaster* is in all probability homologous with the dorsal lip of the blastopore of *Branchiostoma*. The ventral portion of the former gastrula has, however, been so reduced that the embryonic axis extends over more than half the circumference of the gastrula. While the gastrula of *Cymatogaster* is thus seen to approach that of *Branchiostoma*, it is by no means primitive, but is highly specialized by the reduction of the yolk, or, in other words, by viviparity. This is to be expected, for, as Balfour long ago expressed it (II, 342):

> If the descendants of a form with a large amount of food yolk in its ova were to produce ova with but little food yolk, the type of formation of the germinal layers which would thereby result would be by no means the same as that of the ancestors of the forms with much food yolk, but would probably be something very different, as in the case of Mammalia.

Cymatogaster appears to me to stand at the very end of the series of teleostean eggs which have been derived from large-yolked elasmobranch eggs.

A glance at the gastrulas of *Cymatogaster* (fig. 41) and of the frog (Balfour, fig. 71, B) shows an interesting similarity. The yolk in the frog bears the same relation to the blastopore that it does in *Cymatogaster*, the yolk plug of the frog being represented by the yolk nucleus in *Cymatogaster*. But here again the embryo occupies less than half the circumference of the entire egg. The conditions in this case would be nearer those of *Cymatogaster* were there less yolk. There is, however, a very serious objection to deriving the teleost gastrula directly from the amphibian gastrula, for by such a supposition the periblast of the teleost must arise *de novo* from the yolk cells of the amphibian and stand in no relation phylogenetically to the yolk nuclei of the elasmobranch, a supposition very absurd on its face.

In Wilson's opinion one of the prime objections to deriving the teleost gastrula from the *Branchiostoma* is that "the theory leads us nowhere; it does not admit of any *exact* comparison between the teleostean embryo and those of other vertebrates." It will be well to bear this statement in mind in further considering the homology between the amphibian and the teleostean egg.

According to Wilson's view the whole course of the fish development becomes

easy to understand if we admit of the homologies between the gastrulas of the amphibian and the fish pointed out by Ziegler. The homologies are as follows:

Fish.		*Amphibian.*
Yolk+periblast	=	Yolk cells
Invagination at posterior pole of the fish blastoderm.	=	Invagination around the dorsal lip of the amphibian blastopore =Chorda-entoblast.

The gastrula cavity of the fish lies between the invaginated layer and the periblast.

The growth of the anterior pole of the blastoderm round the yolk represents the growth of the the small cells round the yolk cells in amphibian gastrulation.

This takes it for granted, again, that the posterior margin of the fish blastoderm is stationary, which it is not, and it has recently been shown by Morgan that the "small cells" of amphibian eggs do not spread over the yolk cells, but are split off from them. The "exact" comparison can no more be instituted here than between *Branchiostoma* and the teleost. He nowhere explains how the periblast has arisen from the yolk cells. The condition in *Cymatogaster* shows that the periblast (composed of but 12 nuclei) is a waning structure and is in direct proportion to the size of the yolk, a condition which very strongly presupposes a larger yolk and a more active periblast, as is found in other teleosts and in the elasmobranchs.

Wilson's discussions of concrescence do not directly concern us, but the chief objections to his views should be stated. His theory and observations need to be stated to enable us to form a fair judgment. He says, p. 260:

In the growth of the blastoderm round the yolk, the head end of the embryo does not remain a fixed point. * * On the contrary, the *tail end of the embryo* * * *remains a comparatively* fixed point, as Oellacher first showed, while the anterior pole of the blastoderm travels rapidly round the yolk.

I have already shown that this is certainly not the case in some fishes.

The point where the blastopore closes is thus but a short distance from the original position occupied by the posterior pole of the blastoderm. Owing to the constant position of the single oil-globule, these facts can easily be made out.

Compare figs. "35," "36," and "38." In other words, these statements hinge on the fixity of the oil-globule. Now, I have certainly seen the oil-globule in a number of eggs shift its position if the egg was forced to lie in a position in which the vertical line passing through the oil-globule did not also pass through the center of gravity of the egg; that is, if the globule did not occupy the highest point in the egg. Bearing this in mind, and also the fact that the protoplasm is heavier than the yolk, as is seen in the position of the germ in pelagic eggs *without oil-globules* and the position of the newly-hatched larvæ of such eggs, the conditions figured by Wilson, 33, 36, and 38, can be explained as being due to purely mechanical causes, by supposing that the egg, on account of the change in position of the mass of protoplasm during the formation of the embryo, rotates 90° and that the oil-sphere, in order to remain at the highest point of the egg, gradually shifts its position 90°. To make this clear I reproduce Wilson's figures and add diagrams. These figures represent the egg in a vertical median section through the axis of the embryo; the germinal ring is also indicated.

Since the center of gravity of the yolk lies approximately at the center of the egg, and the oil-sphere occupies the highest position, while the germ occupies the lowest, the center of gravity in fig. "35" lies somewhere in or very near the line joining the center of the oil-sphere, the center of the egg, and the center of the blastoderm.

By the equal growth of the blastoderm over the yolk and the formation of the embryo along its posterior part (*B*) the center of gravity of the blastoderm is changed from a point in a line joining *C* and *a* (fig. *A*) to a point in the line joining *C'b* (fig. *B*). This change of the center of gravity rotates the egg till the line *cb* coincides with the vertical. The oil-globule in the meanwhile shifts its position so that its center lies in the extended line joining *b* and *C'*. The globule must move if its position is not absolutely fixed, and it certainly is movable in some pelagic eggs, and probably is in *Serranus atrarius*=*Centropristis striatus*. The rotation of the egg is as gradual as the growth of the embryo, and the change of position of the oil-sphere can not be observed on that account during natural development. The conditions of diagram *C* are produced by the continuation of the same process. Since the center of gravity of the embryo will naturally be somewhere near its middle, the head and tail will be kept approximately equidistant from the oil-globule. The center of gravity travels with growth from the tip of the head in *A* to the middle of the body in *C*, and since the embryo encircles about half the yolk the change amounts to about 90°. The center of gravity of the yolk being fixed, the egg, which is free to respond to the slightest change, rotates an amount equal to the change of position of the center of gravity of the germ. This does not seem to have occurred to Wilson, else this explanation would not be necessary, especially since Ryder gave a similar explanation in 1886, p. 10.

The above supposition, which is entirely warranted by the conditions figured for the bass and by the conditions observed in other eggs, explains why the anterior and posterior margins of the blastoderm progressing evenly, the blastopore does not close over the oil-globule. It does close over the position originally occupied by the globule or very near it. On this supposition the embryo is formed by the continuous concrescence of the embryonic rim, the head being the first part formed and remaining fixed. It may be worth stating that, at the beginning of development by the more rapid ingrowth of cells at the posterior margin of the blastoderm, the embryo, so to speak, is pushed towards the anterior rim of the blastoderm, as in *A*. But this process ceases when the more active epibolic growth begins.

Now let us examine the explanation Wilson gives for this simple matter, using the same figures and diagrams, bearing in mind that he considers the oil-globule a fixed point:

> On comparing figs. 35 and 36, it is seen that while the posterior pole of the blastoderm remains comparatively fixed, the head end (*a*) of the embryo follows, though at a much slower rate, the anterior pole of the blastoderm in its growth round the yolk.

In other words, if we compare the figures the backward growth of the posterior margin of the blastoderm plus the anterior growth of the embryo represented by *xa'* equals the advance of the anterior margin of the blastoderm represented by *y'y*.

> The comparison of the two figures inevitably leads to the conclusion that the increase in length which the embryo undergoes in passing from one stage to another is due to intussusception and not to concrescence. Extending the comparison to the later stage (fig. 38, just before the blastopore closes), it is seen that the increase in length which the embryo undergoes between the stages represented by figs. 36 and 38 is brought about in a different way from that between figs. 35 and 36 (!). This is shown by the following examination: At the beginning of the older period (fig. 36) the head and tail end of the embryo are approximately equidistant from the oil-globule, and at the end of the period (fig. 38) the case is the same. The head end of the embryo has, therefore, continued to grow round the yolk, as in the period figs. 35 to 36, and the body has also lengthened at the opposite end in an opposite direction. The increase in length at the tail end of the embryo deserves especial attention. The great increase in length which the body undergoes by the growth round the yolk of the

head end of the embryo (figs. 35 to 36, and also figs. 36 to 38) can only be explained as ordinary growth by intussusception. If this is so, it is perfectly fair to assume, until the contrary is proved, that the comparatively small increase in length which the body receives at the tail end is due to the same sort of growth.

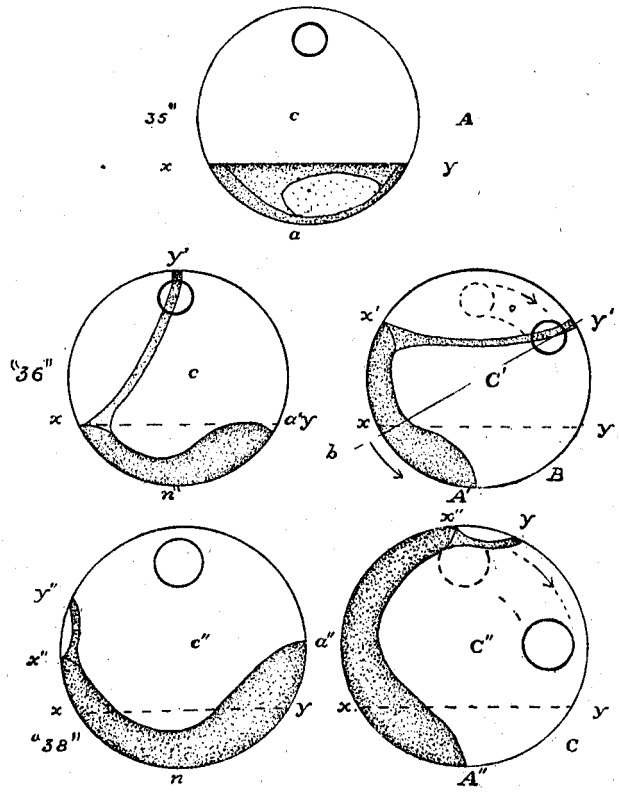
I think myself that if the head end grows by intussusception the tail end does also. But if the greater amount of growth takes place at the head end, does that not imply that this is the last part to be formed? The oil-globule being a fixed point, the embryo has added to its length between figs. "35" and "38" at the head end the distance between *n* and *a''*, *or half its entire length*, while only one-sixth of its length was added to the posterior end between figs. "35" and "38" (the distance between *x* and *x'*). The first part formed by the embryo must necessarily be, according to this view, the region (nearly) between *x* and *n* in fig. 38, which corresponds to *xa* in fig. 35. To put this more precisely, the fifth and sixth sixths of the embryo are the first parts formed, and to this rump is added the whole of the head and anterior part of the trunk and the neurenteric region. All this comes from the necessity of considering the posterior margin of the blastoderm a comparatively fixed point to make out the homology with the amphibian egg. It is very probable that the anterior margin of the blastoderm does grow over the yolk more rapidly than the posterior *in those eggs in which the embryo* encircles less than half the circumference—*Tachysurus*, *Salmo*, and *Batrachus*, for instance—and it is just as probable that the *posterior margin* grows over the yolk more rapidly than the anterior *in those eggs in which the embryo encircles more* than half the circumference of the yolk. There are intermediate eggs, *Stolephorus*, *Serranus*,* and most other pelagic eggs, in which the anterior and posterior margins of the blastoderm grow over the yolk at an even pace. Since writing the above I find that these supposed conditions were actually observed, and Wilson was consequently refuted by Ryder as long ago as 1882, p. 114. Wilson does not mention another possibility than his own observations.†

Explanations of figures and diagrams.—Figs. "35," "36," and "38" are copies of Wilson's figures bearing the same numbers. The position the blastoderm originally occupied is shown by the line *x-y*, and the relation of the embryo to the blastoderm and the relative growth of the anterior and posterior margins of the embryonic ring can be seen at a glance. Between figs. "35" and "36" the anterior margin of the embryonic ring has traveled from *y* to *y'*, and the tip of the head from *n* to *a'*. Between figs. "36" and "38" the head end of the embryo travels to *a''*, while the posterior end travels to *x''*. It should be noticed that the tip of the head in "36" and "38" retains approximately the same position in relation to the center of the blastopore that it does at the beginning of its formation in figure 35. During all this time the oil-globule has remained stationary. This is Wilson's explanation of these figures.

* In *Serranus atrarius*, as figured by Wilson, the embryo encircles slightly more than half a circumference and the posterior margin may travel very slightly faster than the anterior.

† In this connection, the following from the American Naturalist, January, 1894, is of interest. The statement occurs in an abstract of Morgan's experimental studies on teleost eggs: "It can also be shown by marking the membrane with carmine that the head is a fixed point, the elongation of the body being posterior to this. The experiment bears out my observation on the oval pelagic eggs of *Stolephorus*, referred to above and figured and described in the Proceedings U. S. Nat. Mus. for 1892 (p. 139, pl. XII).

A, *B*, and *C* are precisely the same figures except that the vertical axes of *B* and *C* correspond to the vertical axis of *A*. They are placed in this position to make clear the necessity of rotation of the egg and the change of position of the oil sphere, if, as I hold, the anterior and posterior margins travel equally over the yolk. The original position of the blastoderm in *B* and *C* is represented by *x y*. (This does in no way agree with *x y* of "36" and "38"). In the development growth takes place at the posterior end of the embryo while the tip of the head remains fixed. Since growth takes place in this manner the embryo, if the original axis is maintained, comes to have a lateral position, and the blastopore will close at the entodemic pole of the egg. This explains why the tip of the head is equidistant from the anterior and from the posterior margins of the blastoderm. But owing to the fact that the germ is heavier than



the yolk the egg rotates in the direction of the arrow at *x*, and the oil-globule at the same time travels from its original position, indicated by the dotted line, in the direction of the arrow. This explains why the oil-globule remains equidistant between the head and tail of the embryo.

Periblast.—So many accounts have appeared during the past eight years describing the origin of the periblast, that it is not necessary to open the main question again, especially since the later accounts agree in the chief points. The first clear account of the origin of the free nuclei was given by Agassiz & Whitman, 1884. Since then several observers have verified their results. Concerning the function and ultimate fate of the periblast nuclei there is still some difference of opinion. Henneguy (1889, pp. 46–52) has given an excellent résumé of these opinions.

Kupffer, Van Beneden, Henneguy *et al.* believe that cells are added to the germ from the periblast without stating that the cells will play any definite rôle. Klein and Van Bambeke believe that the entoderm is derived from the periblast. Hoffmann (1883) formerly believed that the periblast had nothing to do with the formation of the blastoderm; but later (1888) he inclined to the view that the entoderm with all its derivatives comes from the periblast.

Kowalewski (1886) states that the free nuclei increase in size, and finally disintegrate. The function (p. 455) of the periblast he considers "eine ernährende und seine Bedeutung die eines provisorischen Organes das nach der Beendigung seiner Function zu Grunde gehet." Hoffmann (1883) and Ziegler are of similar opinion. In the goldfish Kowalewski found the periblast to arise below the whole of the blastoderm. In *Polyacanthus viridiamatus* they arise only at the margin.

Wenckebach (1886) in studying *Belone* found that the periblast nuclei arise as early as the 64-cell stage, and that they increase at the margin of the blastoderm both by fission and by the disappearance of the cell walls of two or three series of cells. The same conditions he finds in *Perca fluviatilis.*

In another egg (the largest pelagic egg, 4 mm., a *Stolephorus*) a number of cells of the lower side of the blastoderm swell, become loose, assume an irregular form, and fall to the bottom of the segmentation cavity and unite with the periblast. The periblast in this case arises at the base as well as the margin of the blastoderm. A similar condition was also found by Oellacher, (Z. W. Z. XXIII, 12) in the brook trout. Wenckebach further found that the periblast nuclei undergo a slow degeneration (p. 231) and have no part in the formation of the embryo. They become enlarged and in colored preparations show an irregular, large-meshed structure which is evidently due to the formation of vacuoles in the nucleus. They no longer divide. The ultimate fate of the periblast nuclei is degeneration and absorption. He found the residue after yolk absorption rich in protoplasm in which the nuclei were heaped. They become irregular in outline, structureless, and finally merge into one mass before final absorption. He is not certain as to their function.

Hoffmann (1888) states that the third segmentation in the salmon is horizontal and separates the lower four periblast cells from the upper. At this stage the lower cells have distinct lateral boundaries. As soon, however, as the first merocytes (cells derived from the periblast) are formed the margins of the periblast cells are lost. Through equatorial cleavage new merocytes are continually produced by the free nuclei, while through meridional cleavage the number of free nuclei which remain in the plasma of the yolk is increased and they soon extend over the yolk beyond the margin of the blastoderm. As soon as a large number of merocytes appear the periblast nuclei are transformed into bodies which may be larger than the overlying cells.

McIntosh and Prince (1890) also give a long discussion of the various theories of the origin and meaning of the periblast, without, however, touching the vital points. Wilson (1891) finds that the periblast nuclei become greatly vacuolated and that their outlines become irregular. The physiological use of the periblast he does not know. He supposes that the periblast is finally absorbed by the liver.

The periblast seems to me to have been studied and discussed a great deal more than its importance warrants and I shall confine myself to describing the actual conditions found in *Cymatogaster.* I may only say that Agassiz and Whitman's conclusions as to the origin of this layer are borne out by this fish, and the accounts, when

these are based on actual observations differing from theirs, are probably all due to a modification of the process in different fish. The present function of the periblast nuclei is the appropriation of the yolk for the blastoderm—a view well borne out by the reduction of these nuclei with the reduction of the yolk to a mere vestige in *Cymatogaster*.

At the closing of the blastopore the periblast consists of about 12 (10 to 18) large irregular nuclei embedded in the cortical layer of the yolk. There is no layer of protoplasm connected with these nuclei. They are usually grouped in pairs and sometimes are almost entirely confined to that portion of the yolk which originally was not covered by the blastoderm. Its origin is similar to that in *Ctenolabrus* as described by Agassiz and Whitman. It becomes, however, an independent layer much earlier than in *Ctenolabrus* where the nuclei do not become independent till close of segmentation. Not nearly all the marginal cells of the blastoderm take part in its formation. "At the end of the seventh segmentation (fig. 44) some of the marginal cells have the lower margin ill-defined and continuous with the yolk. This is never the case in more central cells. The nucleus is also slightly more refringent than in the neighboring cells. At the end of the eighth segmentation (fig. 45) there is still a distinct dorsal wall to the periblast cell, but its nucleus is now much larger than that of the surrounding cells." In shape it does not differ greatly from the surrounding cells. It is thus seen that before the nuclei are well separated from the blastoderm they begin the change to the characteristic of later stages of other teleosts. "At the end of the ninth segmentation (figs. 46 to 51) the periblast is an independent structure consisting of a few large, refringent nuclei embedded in protoplasm which is restricted to the immediate neighborhood of the marginal cells of the blastoderm." Exteriorly these cells are partly covered by the epidermal cells, dorsally they are covered by the cells just within the epidermal cell. The plasmodium of the periblast does not extend beneath the central cells of the blastoderm and the nuclei do not reach this region till much later, if at all. There is never a continuous layer of protoplasm at the base of the blastoderm. In fig. 51, of an egg sectioned horizontally, there are 10 periblast nuclei, one of them dividing and all of them lying just below the marginal cells of the blastoderm. This egg is near the end of the ninth segmentation, containing about 450 nuclei. Up to this stage the nuclei retain their spherical outline, but from this on they increase in volume and lose their regular contours and the surrounding protoplasm is greatly reduced or disappears entirely (figs. 38, 40, 41, etc.).

The fact that the nuclei are very frequently in pairs would indicate that they undergo division, and indeed some sections show this to be the case. It is, however, doubtful if more than two generations of nuclei are produced in this manner.

At the end of cleavage (fig. 29) there are several series of flat cells covering the greater part of the yolk. Beneath them the periblast nuclei lie. In *Ctenolabrus*, at the end of cleavage, the periblast forms a wreath of flattened cells.

The exact number of nuclei arising directly by a change of the cells containing them I was unable to determine, but their ultimate number rarely, if ever, reaches 20. Reduced to such simple conditions and differing as the nuclei do from the nuclei of the blastoderm even before they are entirely free, I can state with the greatest confidence that these nuclei have no share whatever in forming the embryo or in giving rise to even a single cell of the embryo. The number of periblast nuclei probably remains the same from the closing of the blastopore to the final disappearance of the

yolk. In larvæ 7 mm. long all there remains of the yolk and periblast is a small nodule scarcely larger than the combined bulk of the periblast nuclei which are now all huddled together (figs. 53 to 54).

There is no evidence that these cells had any share in forming the blood corpuscles. The yolk at this late stage is almost entirely surrounded by the liver (fig. 54), but I think it is erroneous to suppose, as Wilson has done, that the liver finally absorbs the yolk. It is still in contact with the sinus venosus and the final absorption is accomplished by the blood as truly as the earlier stages of its absorption before the liver is formed. In this late stage the yolk no longer shows the yolk cells, which are still evident in larvæ 5 mm. long.

Yolk nucleus.—The appearance of this structure at the time of maturity was described under the head of "the mature egg." In sections of stages with 60 and 72 nuclei the yolk nucleus consists of a central denser (more deeply stained) portion which is surrounded by a thinner substance. In other sections of about the same stage the mass is not so divided. In some there are spherical (yolk) bodies scattered through it.

The appearance in many of the stages resembles that of the germinal vesicle of the green eggs. In vertical sections the margin is seen to correspond to the surrounding yolk spheres. Cross-sections of the deeper portions show the same. In a somewhat older stage (fig. 32) the outer part of the mass is continued as a thin layer over the yolk.

A peculiar condition is represented by figure 41, in which there is a large mass corresponding to the original mass, in which there are scattered larger yolk granules. Surrounding this on the yolk side is a deep layer of lighter-stained protoplasm.

About the time of the closing of the blastopore the yolk nucleus disappears. In several eggs in which the blastopore is not yet closed no trace of it can be found, while in one egg stained with fuchsine a number of granules are collected in the region where this mass of protoplasm was situated. These granules are similar to others arranged about the periphery of the yolk, and it is doubtful whether they represent a portion of this mass.

The absorption of this protoplasm must be very rapid, for in but slightly younger stages the whole mass is still present.

Since the above was written, about three years ago, this body, so prominent during the early stages of development of the egg, has been identified by one of my students, Mr. J. W. Hubbard, with the yolk nucleus, which is a conspicuous body in the ovarian eggs from the time they measure 20 μ to maturity. The yolk nucleus originates as an extrusion from the germinal vesicle and reaches the entodermic pole at the time of maturity, when the yolk becomes collected about it.

It was found that during the extrusion of the yolk nucleus the germinal vesicle is reduced in size and amount equal to that of the newly formed yolk nucleus. The extrusion of nuclear matter which takes place here lends weight to the supposition of De Vries and Weismann that definite particles may be extruded from the nucleus into the morphoplasm and control it. The functions the yolk nucleus possessed before extrusion are retained some time after extrusion in large-yolked eggs, and according to the recent theories its functions need not be lost at once, even in those in which its

constituent biophors are scattered* at the time or soon after its extrusion from the germinal vesicle.

Significance of the yolk nucleus.—A yolk nucleus, metanucleus, Nebenkern, of one description or another, has been observed in the eggs of all groups of metazoa exclusive of those of the Porifera and of the Echinoderms. While it has been observed in such a variety of animals, the explanations it has received have not been commensurate with its distribution. It is true that a yolk nucleus has not been observed in species whose near relatives have this structure well distinguishable. It very frequently disappears soon after its formation, and we need only go a step farther to a condition when it is distributed through the cytoplasm during its formation, and from this condition there is but a step to the separate extrusion of its constituent parts. This may explain its absence in species whose near relatives have it.

While in many eggs it appears early, in others (*Forskalia*) it is not formed till the time of maturation. In all cases in which its formation has been traced it originates from the nucleus as something cast out without the usual formalities of cell division. Its function has been supposed to be that of yolk formation, but it is found in some eggs in which yolk is never formed or, after all the functions of the egg as a cell, aside from its hereditary functions, have disappeared. It has been supposed to give rise to the follicle, but it sometimes does not appear till the follicle has begun to degenerate. It has been supposed to represent the male element in the egg, and in the case of parthenogenetic ova to replace the spermatozoon, and thus has been attributed with the function later assigned to the second polar globule. This last explanation may have a grain of truth in it, but it is far from being satisfactory.

Moreover, while attempts have been made to homologize every other structure or action of the egg with a structure or action in the spermatozoon, I am not aware that this body has received the same distinction. And yet there arises in the spermatozoon a body called by the same name (Nebenkern) in very much the same manner.

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*While the theory of the germplasm is admirably delineated, some objections to the ideas of a biophor as described by Weismann (The Germplasm, Am. Ed. 1893) may be added here. These objections may be answered by the statement that Weismann is not endeavoring an explanation of life. But it is fair to insist that the definition of the theoretical units should not exclude the possibility of life.

The biophor is said to be the smallest unit which exhibits the primary vital forces, viz, assimilation and metabolism, growth and reproduction by fission. The difference between biophors of various kinds "depends on either the absolute relative number of molecules, their chemical constitution (isomerism included), or their grouping." Both suppositions can not hold. For instance, a particular biophor may be composed of 7 (or any other number) of molecules, 3 of one sort, 3 of another, and 1 of a third sort. It would be impossible for such a biophor to give rise by division to another biophor containing the same number of molecules of the same sort arranged in the same manner.

We must imagine that this biophor during growth appropriates molecules like those composing it until double the original number are present of each particular sort of molecules. A division into two similar halves would thus be made possible, but the character of the biophor, according to the sentence quoted above, would have been changed with each molecule added. Or, we must imagine that all the molecules necessary for the formation of a new biophor are appropriated simultaneously, in which case the biophor would suddenly enlarge to double its normal size. This sudden growth might indeed be the agent causing fission. This last alternative verges dangerously near forbidden ground—*i. e.*, the formation of new biophors outside of the original biophor through the simple presence of the latter, after the manner Nägeli supposed new micellæ to arise.

The Nebenkern has, among other things, been supposed to be homologous with the polar globules. I consider it the homologue of the yolk nucleus. It, like the yolk nucleus, arises from the nucleus not by any cell division, although closely associated with it. However we may homologize the reducing division in the male and in the female, or spermatozoon and egg, it is clear that in both cases the Nebenkern arises from the nucleus *after the sex cell has assumed its final role of egg or spermatozoon.*

I wish here to point out the close resemblance of the yolk nucleus in *Cymatogaster* to the macronucleus of ciliate infusoria. Plate XCIII will make the resemblance clearer. The resemblance of the different processes of conjugation of these protozoa to the processes of maturation of fertilization in metazoa has been pointed out by others, but I wish to carry this resemblance several steps further. It will be of advantage to give a brief review of the results which have been obtained recently in the study of the conjugation of ciliate infusoria. For plate XCIII and its explanation, see page 446.

The infusoria contain two nuclei:

First, a large macronucleus which presides over nutrition and growth, repairs injury, and by its division enables the protozoon to multiply for a certain number of generations. If the micronucleus disappears through senescence, the macronucleus may still divide and enable the protozoon to multiply for a certain length of time, but afterward it loses this power and the individual containing it perishes. Its functions are all ontogenetic, of use to the race only in so far as they are of use to the individual. It may be looked upon as the somatic portion of the nucleoplasm of the protozoon, which, by simple divisions, builds a large number of individuals which collectively are comparable to the metazoon soma. It divides directly.

Second, a smaller micronucleus, which divides indirectly, but whose division and indeed whose presence is not essential to the life and multiplication of the individual. It presides over the preservation of the race, and its function must come into play during a time corresponding to the period of maturity of metazoa. If it does not come into play at this time, it disintegrates and the individuals containing it are doomed to ultimate destruction. If it does come into play, the individuals containing it may continue to divide. It is of use to the individual only through its use to the race. It is of no direct use to the individual containing it. Its functions are all phylogenetic.

In short, the macronucleus under any and all conditions is doomed to destruction; the micronucleus may live forever under favorable circumstances.

The macronucleus is dissolved at the time of or shortly after conjugation. A new one is formed from the segmentation nucleus.

We are now prepared to observe the similarities and the differences between these conditions and those obtaining in metazoa.

The segmentation nucleus of metazoa contains, as in the infusorian, both micro and macro nuclear elements, but these are retained in varying proportions in its descendants, *i. e.*, in the cells of the adult organism. Through a process of division of labor the power of rejuvenescence becomes restricted to comparatively few of the cells derived from the segmentation nucleus. The fate of all the remaining cells is final death.

Those cells which under certain conditions have the power to reconstruct the whole organism are the sex cells. But it was seen that in the infusorian the macronucleus has its function suspended soon after preparations are made for conjugation and that it entirely disappears after conjugation. The macronuclear functions of the sex cells ought therefore also to become suspended if the comparison between the two organisms is to be complete. This suspension must take place the moment of the ultimate division of the germinal epithelial cell or soon after, and the egg has become irrevocably an egg or the spermatozoon irrevocably a spermatozoon. A partial suspension of these functions is evidenced by the absence of further divisions except during the formation of the polar globules, which in the infusorian are seen to be formed from the micronucleus. The formation of the polar cells may therefore be looked upon as products of the micronuclear elements of the germinal vesicle and do not vitiate the supposed suspension of macronuclear divisions. The macronuclear element of the germinal vesicle is eliminated as the yolk nucleus in eggs, and as the Nebenkern in spermatozoa. In eggs without yolk (*Forskalia*), and whose ovarian history is consequently short, it is eliminated just before maturation, as the metanucleus. In eggs developing a large amount of yolk and whose ovarian history is prolonged it arises at a time corresponding to the maturation of non-yolked species, *i. e.*, at the beginning of yolk formation as the yolk nucleus. In those in which it appears comparatively late (*Forskalia*, *Cymatogaster*) it may remain during some of the early stages of development. In those species in which it appears early it is lost in the yolk long before maturation. I have explained why it may be present in one species and absent in another closely related one. Its suspension of activity need not be sudden, and it is not unlikely that it retains some of its functions in some eggs even after it is expelled from the germinal vesicle, and it may then be active and entirely used up in the building up of the yolk, as has been suggested by a number of observers. That its functions are in some way connected with the yolk is certain from the close association between yolk and yolk nucleus, which has given it its name in eggs.*

The direct nuclear division frequently seen in degenerate tissues extends the possibility of comparison between protozoa and metazoa. Such cells may be compared with infusoria which have passed the period of maturity and in which the micronuclear element, which is always accompanied by indirect division, has been lost.

The reason for the complicated process of cell division seen in karyokinesis is evident in all cases where an exact distribution of the halved chromosomes is essential. In cases like the macronucleus in protozoa and the degenerate cells of metazoa where an exact division can be of no advantage, direct division takes place. I do not mean by this to insist that there is a further comparison than the above between the direct division of the macronucleus and that of degenerate cells of metazoa. The former is primitive.

* The above account of the yolk nucleus was written before the appearance of Weismann's "The Germplasm." In the phraseology used in this theory I hold that each cell (except the degenerate ones in which direct nuclear division takes place) contains germplasm aside from ids from which all the determinates but those controlling the cell have been removed in carrying the cell to its final destination. All cells, the reproductive cells included, are controlled by determinants which are not directly derived from the ids of germplasm contained in the nucleus but from ids which have been simplified during ontogeny. These simplified ids are removed as the yolk nucleus.

Karyokinesis is an adaptation to insure the exact division necessitated by phylogeny; the direct division of gland cells *et al.* is a reversion or a degeneration to a primitive semblance.*

* While reading the proof of these pages I obtained two papers bearing on this subject. "Contributions à l'histoire de la constitution de l'œuf" by Ch. Van Bambeke and "Le corps vitellin de Balbiani dans l'œuf des vertébrés", by L. F. Henneguy. In its explanation of the yolk nucleus, the latter paper corresponds almost exactly with the views presented here. Since this theory of the macronuclear nature of the yolk nucleus was arrived at independently, it is but just both to Mr. Henneguy and myself that his considerations should be presented here. He says, p. 32:

"On sait que dans un infusoire cilié il existe deux sortes de noyaux: le noyau proprement dit, ou macronucléus, et un autre noyau plus petit, improprement appelé nucléole, ou micronucléus, ou encore endoplastule. Le premier tient sous sa dépendance les phénomènes de la vie organique de l'infusoire, le second intervient pendant la conjugation, véritable reproduction sexuelle; aussi Bütschli le désigne-t-il sous le nom de noyau sexuel (Geschlechtskern). Dans les cellules qui constituent les différents tissus des animaux et des végétaux, il n'existe qu'un seul élément nucléaire, le noyau, qui régit à la fois les phénomènes vitaux de la cellule, et les phénomènes reproducteurs, lesquels ont toujours lieu par division ou gemmation, c'est a dire par voie non sexuelle. Ce noyau renferme deux sortes d'éléments figurés bien distincts, le réseau chromatique formé de microsomes et les nucléoles. Ceux-ci ont été considérés comme des matériaux de réserve pour le noyau (Strasburger, Carnoy), mais leur rôle dans la physiologie de la cellule est encore inconnu. Ils ne paraissent pas prendre une part active à la cytodiérèse et cessent d'être visible quand se prépare la division indirecte du noyau. Dans la vésicule germinative de l'œuf des animaux, il existe toujours un ou plusieurs gros nucléoles, situés à la périphérie de la vésicule, plus rapprochés par conséquent du protoplasma ovulaire que le réseau chromatique qui occupe généralement le centre du noyau, surtout dans les ovules voisins de la maturité. Ces taches germinatives disparaissent quand les vésicule germinative se transforme en globule polaises et en noyau femelle; elles sont resorbées soit dans la vésicule germinative, soit dans le vitellus après y avoir pénétré lorsque la membrane de la vésicule germinative a disparu.

"Si, avec la plupart des embryogénistes, on considère l'œuf comme représentant le stade protozoaire des Metazoaires, et les phénomènes de la fécondation comme correspondant aux phénomènes de conjugation des Infusoires, on doit se demander ce qui, dans l'œuf, est l'homologue du macronucléus et du micronucléus des ciliés.

"De même que chez les Infusoires ciliés le micronucléus intervient seul dans la conjugation, le macronucléus disparaissént par résorption, de même dans la fécondation, le réseau chromatique de la vésicule germinative entre seul en jeu, les taches germinatives étant resorbées. De même que dans les Infusoires conjugués, il y a fusion d'un micronucléus de l'un des individus avec un micronucléus provenant de l'autre individu, pour donner naissance à un nouveau noyau, qui se dédouble en macronucléus et micronucléus; de même, dans l'œuf, le noyau femelle s'unit au noyau mâle, pour former un nouveau noyau qui jouera simultanément dans les cellules, provenant de la division de l'œuf, le rôle de macronucléus et de micronucléus.

"Dans les cellules ordinaires le macronucléus, représenté par le nucléole, et le micronucléus, représenté par le réseau chromatique, sont confondus dans un même élément; il en est de même dans l'œuf Cependant le corps reproducteur femelle se rapprochant plus du type ancestral infusoire que les autres éléments cellulaires de l'organisme, on conçoit qu'il puisse manifester une tendance à la disjonction des deux éléments nucléaires de l'Infusoire. Cette tendance se traduit, au moment où la cellule génitale prend le caractère ovulaire et s'accroît sans se multiplier, par la sortie d'une portion de la substance nucléolaire, sous forme d'un corps vitellin de Balbiani. Celui-ci tantôt continue à jouer dans le plasma ovulaire le rôle d'un macronucléus, dirige les phénomènes d'assimilation des matériaux nutritifs accumulés dans l'œuf, et devient le centre de formation du germe, ainsi que l'a constaté M. Balbiani chez beaucoup d'animaux; tantôt il n'a qu'une existence tout à fait transitoire et disparaît peut de temps après sa formation, par résorption et dégénérescence; tantôt enfin, comme cela s'observe souvent dans l'ontogénie des animaux, il y a accélération des phénoménes embryogéniques, certaines phases de l'évolution sont supprimées: dans l'œuf, le corps vitellin, organe ancestral, n'apparaît à aucune phase de l'oogenèse."

In a foot-note he adds:

"S'il existe dans l'œuf un élément représentant le macronucléus des infusoires, cet élément doit se retrouver également dans la cellule mâle ou la spermatide. La présence, dans la cellule de développement du spermatozoïde, d'un noyau accessoire (Nebenkern), dont l'aspect et les réactions rapellent ceux du corps vitellin, justifie cette manière de voir."

Henneguy's comparison of the yolk nucleus and nebenkern of the reproductive cells with the macronucleus of ciliate infusoria agrees with my comparison, with this exception: Henneguy supposes the yolk nucleus to be homologous with the macronucleus. I hold that a genetic connection between macronucleus and yolknucleus has not and can not be shown, and that the two structures are due to similar causes acting on similar material. He locates the macronuclear element in the nucleoli. I hold that this is erroneous, as is shown by the formation of the yolk nucleus in *Cymatogaster* without the intervention of nucleoli. The same has been shown in the paper quoted above by

Balbiani has suggested that the yolk nucleus supplies the place of the spermatozoa in the case of the parthenogenetic eggs. I do not know whether it has been found in parthenogenetic eggs or not, but will venture a suggestion.* If, as I suppose, this yolk-nuclear element corresponds to the macronucleus of protozoa, we may imagine a condition in some eggs in which the macronuclear elements or ontogenetic elements, and the micronuclear element or the phylogenetic elements are evenly balanced. In such eggs the macronuclear element (the ontogenetic element) could provide for continued growth and division which in eggs in which the micronuclear element predominates is only provided by the union with the male. The micronuclear element, on the other hand, could provide for the building up of the ancestral form. This explanation seems sufficient to account for parthenogenetic eggs. It is desirable now to reëxamine parthenogenetic eggs with this hypothesis in mind.

The notices of this body in literature have been mostly at haphazard. This or that author says: "I have seen it," and another has given its origin in one egg, while another has endeavored to expla in its function in still another. While the literature bearing on this subject is largely incidental, enough has been said to show its presence in such a variety of animals that only a deep rooted explanation is sufficient.

That the yolk nucleus is the lineal descendant of the macronucleus may be doubted. Both are probably similar results due to similar causes. It is certain that the germinal epithelial cells contain both the functions of the micro and the macro nucleus. How have the nuclear substances presiding over these different functions become united in a single nucleus in metazoa? The answer seems evident. Both micro and macro nuclei are derived from a single nucleus. In protozoa they are the product of the second segmentation of the conjugation nucleus. We have here a single segmentation between copulation and macronucleus, whereas in metazoa a large number of segmentations intervene, and in this lies the chief difference. (Two more segmentations intervene in the case of spermatozoa than in the case of ova.) Macro and micro nuclear substances are both found in the germinal epithelial cells because the substances have not yet been separated.

Which of the two second generation nuclei becomes the micro, which the macro nucleus is determined by their position anterior or posterior in the new infusorian.

Bambeke in *Scorpæna scrofa* L. There are other minor points of difference that will appear on reading the two accounts.

I have given this full statement of Henneguy's theory to avoid any possible claim of injustice on my part to the propounder of a theory, which in so many points agrees with mine. Space and time do not permit me to consider Bambeke's paper and one by Dr. O. Jordan, 1893. It seems, however, that Jordan has entirely underestimated the significance of the yolk nucleus. It may be true that structures in certain eggs have been described as yolk nuclei, which were not homologous with the yolk nucleus of *Cymatogaster* and of other fishes, or of Batrachians. But this does not warrant the sweeping statement that "the various structures usually grouped together under the name Dotterkern have nothing but the name in common." This seems but trifling with facts. I have explained why the yolk nucleus may not become visible in one species and be present in another closely allied species. The absence is apparent rather than real. But supposing its absence should be real in some cases, that would not in the slightest vitiate the importance of a structure whose wide distribution in metazoa is admitted. Certain fishes do not have ventral fins, and some mammals do not possess posterior limbs, but these facts do not destroy the homology of ventral fins of fishes which do possess them with the posterior limbs of mammals which have these structures. The three papers mentioned in this note give a very complete history of the literature bearing on the yolk nucleus.

*Balbiani's yolk nucleus is not homologous with the structure here considered, and his view is, therefore, not identical with the one here given.

Their structure must therefore be the same at the time of segmentation. We have here a differentiation due to external conditions similar to those found in the differentiation of sex from like cells by external conditions. While in infusoria this differentiation into macro and micro nuclear elements takes place after the division of a whole into two equal halves, the differentiation takes place before division in metazoa.

Comparison between the processes of conjugation in ciliate infusoria (modified from Weismann after Maupas) and of maturation and segmentation in Cymatogaster aggregatus.—The modifications of the male cells are purely theoretical, and modified from the conditions often observed in a number of invertebrates. Nothing is yet known of spermogenesis of *Cymatogaster*. The black circles represent micro or germ nuclei, the blank circles the polar nuclei, the shaded parts the macronuclear elements. Note well that between stages H and A of protozoa there intervenes a large number of generations of nuclei-individuals, and that a similar number of generations of nuclei, all of which collectively represent an individual, intervene between I and a=A in metazoa. In series I the macronuclear elements disappear in stage G, while in series III they do not disappear till much later than stage I. Usually in metazoa they disappear in stage A2, *i. e.*, before the nucleus from which they have been derived loses its entity. While in series I the macronuclear elements are segregated in stage F or at the beginning of the series of daughter nuclei, in series III this process does not take place till stage A2 is reached or the end of the series of daughter nuclei or concomitantly with the production of a new mother nucleus; in all the intervening stages between I and A 2 macro and micro nuclear elements are united in the same nucleus.

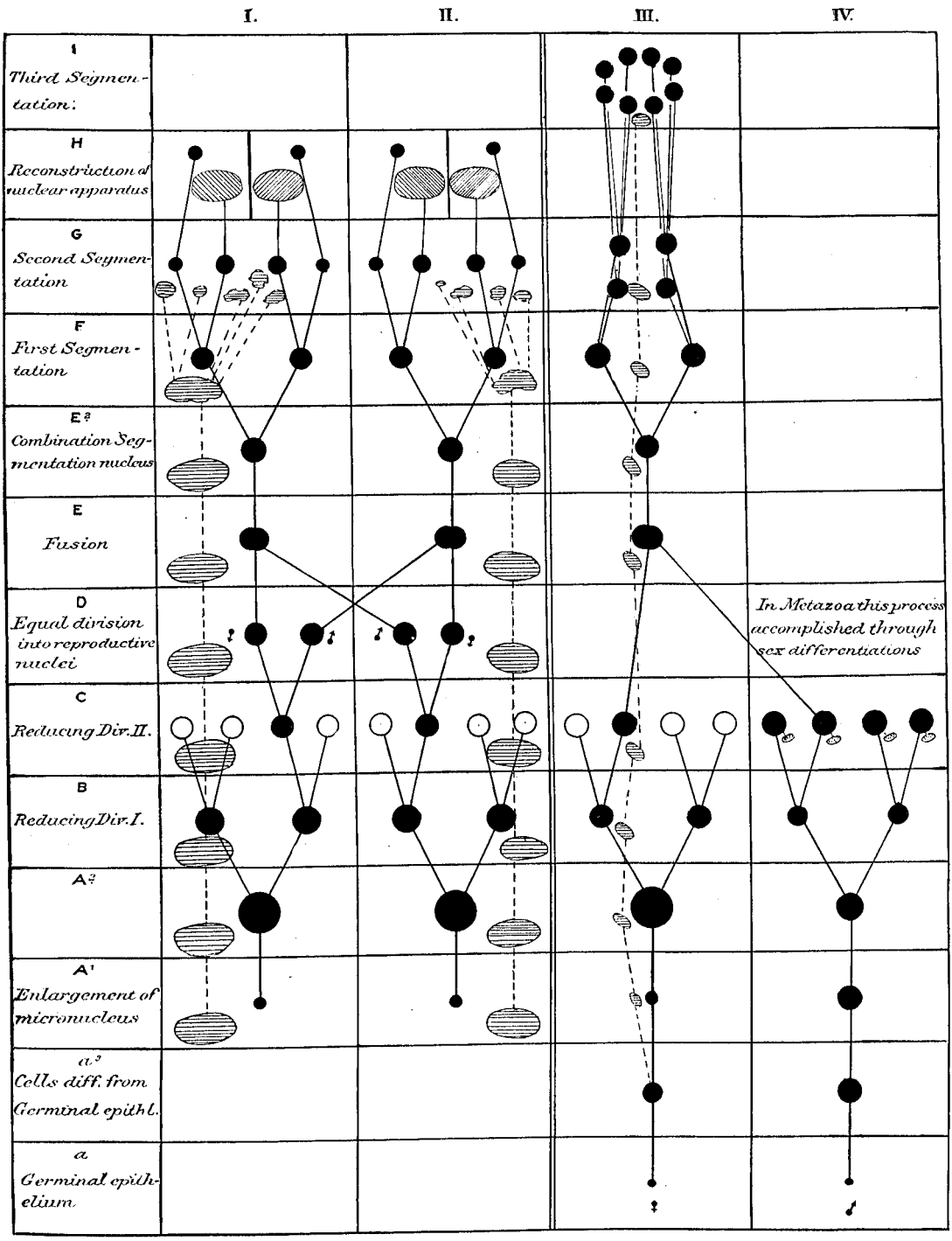
Formation of the mesoderm.—Dr. Minot has said (Am. Nat., 1890, 877): "Scarcely an embryologist can be found who has not published opinions on this question (origin of the mesoderm) considerably at variance with those of most authors." To these already numerous accounts I must add that of *Cymatogaster*. Without question the mesoderm arises here from the entoderm, as has been observed in a number of other fishes by various authors. Instead, however, of being restricted to and arising from a narrow space, it is split off from the entoderm and forms a layer over the whole entoderm, exclusive of the axial line, or the region occupied by the chorda.

Hertwig states, p. 119:

> Bei kinem Wirbelthiere entstehen die Keimblätter durch Abspaltung, sei es vom auseren, sei es vom inneren Grenzblatt, da sie von beiden mit Ausnahme eines sehr beschränkten Keimbezirks überall durch einen Spaltraume scharf abgegrenzt werden.

I have nowhere seen any figures in *Cymatogaster* which favor Hertwig's view of the origin of the mesoderm, and since it apparently appears simultaneously over the whole entoderm exclusive of the middle line, and is closely applied to the entoderm when it usually is widely separate from it, the only explanation tenable seems to be that the mesoderm is split off from the entoderm everywhere except at the median line. In all cases I have been able to examine the entoderm formed a layer beneath the chorda, but I am not positive whether a layer is always present beneath the chorda at the time the latter structure is differentiated, or whether the whole central portion of the entoderm is differentiated into notochord, and a new layer of entoderm is formed beneath this by ingrowth from the sides. The former seems the more probable view.

The development of the chorda and of the mesoderm is still obscure, since I obtained but one or two marked stages between the closing of the blastopore and embryos with three protovertebræ. On reconsideration I am not so certain as to what


I.
II.
III.
IV.
I
Third Segmentation.
H
Reconstruction of nuclear apparatus
G
Second Segmentation
F
First Segmentation
E²
Combination Segmentation nucleus
E
Fusion
D
Equal division into reproductive nuclei
In Metazoa this process accomplished through sex differentiations
C
Reducing Div. II.
B
Reducing Div. I.
A²
A'
Enlargement of micronucleus
a²
Cells diff. from Germinal epith.
a
Germinal epithelium

relation the cephalic end of the embryo bears to the blastopore as I was formerly, but I am inclined to think that in my paper on sex cells I mistook the primitive streak for the head. I am sure that in the embryo with three protovertebræ thus described I mistook the head for the tail. This misconstruction does not affect the results as to the early segregation of the sex cells, but changes their place of origin. The needed corrections to be made in the account of the sex cells will be made in the chapter bearing on this subject. At the closing of the blastopore the embryo usually consists of two layers—the ectoderm and the primitive entoderm. Each of these is several cells deep, and they both extend over the entire yolk, merging into each other at the blastopore. Just before the closing of the blastopore the entoderm is but one cell deep in all places but the axial line. Immediately after the blastopore closes cells are heaped up, probably in the region of the closed blastopore, certainly in the caudal region of the body. With this heaping up of cells the lower and upper layers become merged into a solid mass (figs. 55 to 59). Shortly afterward the mesoderm is split off from the entoderm over the whole of the egg except along this region (figs. 58 to 59).

In some eggs (fig. 43) the mesoderm is not definitely separated from the entoderm after the closing of the blastopore. In others, on the other hand, the mesoderm is at least partly separated even before the closing of the blastopore. In all the sections the mesoderm is seen to be intimately associated with the entoderm, so there can be no doubt as to the source from which it is derived, although the ectoderm at this time is quite thick. Two eggs cut in nearly the same planes and representing the earliest and latest stages found between the closing of the blastopore and the three-protovertebræ stage may be described in some detail. The sections are at right angles to the median plane of the embryo and the first in each of the two embryos is tangential to the primitive streak or thickened caudal mass.

Fig. 55 is the sixth section of the early stage and the first that cuts the yolk. The ectoderm is here several cells deep, being cut obliquely. The outer layer of cells is much lighter than the deeper layer—a fact due to the absorption of the surrounding ovarian fluid. The entoderm is also several cells deep, and at this place no distinction between entoderm and mesoderm can be made out. At the axis the entoderm is much thicker and so intimately joined to the ectoderm that but a very faint line of division is perceptible. The ectoderm at this point is reduced in thickness.

Fig. 56 is the eighth section of the series. The relation of the parts to each other is very much as in the preceding figure. The axial entoderm forms, however, a more rounded mass.

Fig. 57 is the tenth section of the series. This section, being more median, differentiates the parts much better. Over the *ventral* half the outer layer of ectodermal cells is enlarged and much less densely stained; over the dorsal half no such differentiation is seen. Laterally the entoderm is thinner than ventrally and, in places at least, a distinct dividing line can now be seen between mesoderm and entoderm. The axial primitive entoderm is still as important a structure as in the preceding section.

Fig. 58, which represents the twelfth section, differs little from the tenth. The primitive entoderm is still thinner laterally and the distinction between entoderm and ectoderm is still harder to make.

Fig. 59 represents the fifteenth section. All the sections following this are damaged along the axial line. In this section some of the entoderm cells have evidently been misplaced at the embryonic axis, where it is impossible to detect any line sepa-

rating entoderm from ectoderm. There are in all twenty-six sections in this egg (ovary 23); maximum diameter of egg, ·272 mm.

Of the second stage I have obtained several fair series of sections. The chorda is now well marked off for some distance and the mesoblast is split off from over the entire entoderm except at the caudal mass, where it is not possible to distinguish the three layers from each other. In all other regions the ectoderm is separated from the mesoderm by a large segmentation cavity. The sections, figs. 60 to 63, are parallel to a tangential over the caudal mass.

Fig. 60 is the sixth section of the series and has not yet reached the yolk. The mesoblast is not distinguishable from the entoderm, owing to the fact, perhaps, that near the margin of the section the plane of the section is oblique to the plane separating mesoblast from entoderm. The embryonic region is indicated by the strand of cells between ectoderm and entoderm, and, in fact, by the whole of the central mass of cells. The grouping of the sex cells in this region is as usual in this stage (ovary 31).

Fig. 61 is the eighth section of the series and the first which cuts the yolk. The entire outline of the notochord is evident at this place. The dividing line between mesoderm and entoderm is not yet evident.

Fig. 62 is the twelfth section of the series, and therefore near the middle of the egg. The greatest diameter of the egg is 3 mm. The line separating mesoblast from entoderm is here evident over the whole yolk; the chorda is a little thicker than the mesoblast on either side and touches the slightly thickened ectoderm above. The mesoderm is about two cells deep.

Fig. 63 is the eighteenth section of the series. The thickness of both chorda and mesoblast is reduced. The ectoderm consists of an outer layer of flattened cells and an inner irregular layer of semicolumnar cells; it also does in other sections, but the fact is not so apparent. It is not thickened over the chorda as far forward as this section. The chorda extends some distance farther, and appears finally to merge into the indifferent mesoblast seen along its sides in other regions. As far forward as I can trace it the entoderm forms a layer below it. It is very probable that the cells forming it are separated from the entoderm with the mesoderm by delamination. In that case a layer of entoderm cells would always be found below it. The chorda is formed some distance farther forward in another egg from the same ovary. In this egg the entoderm extends under the chorda as far as that structure can be followed, but near its end the sections become tangential again and the boundaries between tissues are not well marked.

Fig. 65 is a section from the anterior portion of the chorda of this egg. The lower layer of ectoderm cells is in contact or approximated with the chorda for its entire length, and in the section figured the ectoderm is thickened and slightly depressed just over the chorda, the cells being somewhat radially arranged.

As stated above, in the caudal region the three layers merge into each other so they can not be separated (64). Another characteristic of the caudal region in all the eggs of this stage is the presence of numerous large sex cells.

In the caudal region the neurula in eggs of this stage consists of the previously described thickened mass. In front of the caudal mass it rapidly narrows to a thickening about as wide as the chorda and immediately overlying it. The region above it is depressed into a perceptible shallow groove. Its lower surface (fig. 62) remains for some distance in contact with the chorda after quite a space is found

between the mesoderm and ectoderm. In the anterior region the cells of the neurula (fig. 65) are seen to radiate from the dorsal depression.

The ectoderm is everywhere about three cells deep. The outermost layer is differentiated into a flattened epithelium.

While the relation of the head end of the embryo to the blastopore can not be certainly decided, it seems probable that at this period the embryo encircles considerably more than half a circumference of the yolk. The length of the embryo is now increased, chiefly at the expense of the caudal mass of cells.

Anatomy of an embryo with three protovertebræ.—Of this stage I have two good series of sections. One of the embryos was cut in the sagittal plane, the other at right angles to it. The former was figured (figs. 5, 6) in my account of the sex cells, but the anterior was mistaken for the posterior.

The entoderm in this stage forms a layer over nearly the entire yolk. The only region where it could not be distinguished was over the small portion of yolk between the caudal mass of cells and the head of the embryo. In the anterior region it gradually merges into the one-cell-deep mesoderm. Along the axial line, beneath the notochord, the entoderm is about two cells deep. Just to one side of this median line the entoderm is three or four cells deep; at the sides of the yolk it dwindles to an attenuated layer but one cell deep (figs 72, 73), and along the ventral line it is merged with the mesoderm. In longitudinal sections the entoderm is still evident, even in this region (fig. 67). Just in front of the caudal region, where the three layers merge into each other, the entoderm has a columnar arrangement and is raised some distance from the yolk (fig. 68 *kv*). This is the first indication of Kupffer's vesicle. In cross-section the raised region is seen to be quite wide, with the outer angle projecting upward and outward (fig. 73). The further development of Kupffer's vesicle will be described in another chapter.

The principal difference between the entoderm of *Cymatogaster* and other teleosts during this stage lies in the fact that it is composed of several layers of cells and that it covers the greater part if not the whole of the yolk.

The notochord is well formed and has assumed its final outline back to the neurenteric region, where its outlines merge into the general mass. In front it tapers to a point. The notochordal cells are as yet but little different from the cells of the other structures. The outlines of the nuclei and of the cell itself are a little more prominent and the cells are anteroposteriorly compressed. This gives their nuclei in the saggittal section (67) vertical oval outlines and gives the impression that the cells have a vertical columnar arrangement which they do not in reality have.

The mesoderm consists of a single layer of cells in the anterior cephalic region (fig. 71). It rapidly thickens backward on either side of the notochord and neural ridge (fig. 70). The cephalic region, or the region in front of the first protovertebræ, is about the third of the entire length. There is no cavity in the protovertebræ, but the nuclei are arranged in an epithelial manner around a central region. The three protovertebræ extend over one-fifth of the length of the embryo. In the embryo cut in a sagittal direction the mesoderm just behind the third protovertebra contains numerous sex cells; behind these the mesoderm disappears as a distinct layer. From the thickened masses along the notochord the mesoderm extends over the yolk in all directions, thinning out to two and further laterally to a single layer of cells, the two sheets meeting along the ventral line of the embryo. It is only in cross-sections

through the caudal mass (fig. 74) that the mesoderm can not be distinguished over the whole yolk.

The ectoderm forms a layer two to three cells deep over the whole egg. The outer layer of cells is in places well separated from the inner layers, the nuclei are slightly larger than those of the inner layers, and the cytoplasm stains lighter. The neural thickening consists of a solid ridge of cells extending down from the ectoderm to the notochord. From the sections it would appear that there is little difference between different points along this region. The ridge appears deeper just in front of the notochord than elsewhere, and here the lower layer of cells has a columnar arrangement.

The diameters of these embryos are respectively 0·27 mm. and 0·3 mm. The embryo has grown till it fills the shell and with but a slight further increase it hatches, the membrane bursting with the further expansion of the embryo. In other teleosts the hatching process is largely due to the muscular efforts of the embryo, while in this case the muscle cells can scarcely, if at all, be distinguished from other cells at the time of hatching. The yolk measures 158 μ to 200 μ.

I have not been able to secure stages between this and the embryo with six (?) or more protovertebræ, which is hatched.

General development of the larvæ.—At the time of hatching, the tail has not begun to bud out. The larva encircles the entire yolk and is so transparent that it can only be found with a lens. Groups of spermatozoa are found attached to its surface. No lumen has appeared in the intestine and muscles have not begun to be differentiated, so that the larva is entirely incapable of motion.

Shortly after hatching, the head and tail, exteriorly almost identical, sometimes overlap, the body being bent over the yolk (fig. 83). However, the larva rapidly straightens itself if this overlapping is normal at all. The lumen of the intestine appears when 10 protovertebræ have been formed (fig. 77) and Kupffer's vesicle has become enormously enlarged. The muscle cells have now become somewhat elongate, though motion is probably not yet possible. The tail is not yet free and the larvæ measure about 0·6 mm. By the time the larva has reached a length of 0·8 mm. the tail forms a thick blunt projection beyond the yolk and the intestine has a continuous lumen from near the anterior end of the notochord back to the future anus (figs. 78 and 84). The heart is represented by a large mass of cells below the head and about 12 protovertebræ have been formed. A swelling is evident in the gill region and shortly afterwards (by the time the larva is 0·9 mm. long) the first gill-slit is opened. The eye and auditory organs now become more prominent, but no otoliths are formed as yet. About 14 protovertebræ are present in larvæ 0·9 mm. long. Spermatozoa are now found in the intestine, which they reach through the first gill-slit.

If larvæ are examined from this stage till the mouth is formed a stream of the ovarian fluid is usually seen entering the gill-slit and escaping through the anus. This stream is kept in motion by very active cilia in the gullet.

When the larva has reached 1 mm. in length, the tail is formed to a considerable extent and terminates in a blunt lobe. The hypertrophy of the hind gut has begun and reaches some distance beyond the yolk-sack. One of the most peculiar structures of the larva, the enormous yolk-sack, has now become well developed. The yolk is quite minute and lies at the posterior end of this cavity, and all the remaining yolk-sack is utilized as a pericardium (figs. 88 and 90.) The heart is now a simple, slender

tube extending from the posterior wall of the pericardium upward and forward; the yolk lies in the sinus venosus. About 22 protovertebræ are formed.

There is little change in general outlines for some time after a length of 1 mm. is reached. The tail elongates and fin folds are developed. One striking feature is that the fin-fold is very narrow at the tip of the tail, while the dorsal and caudal portion may be well developed.

The segmentation of the hind brain (fig. 93) becomes very prominent when the larva has reached a length of 2 mm. and remains so till the larva is 5 or more mm. long. During this period the hind brain (figs. 91, 93, 96) is divided by lines which are conspicuous during life, and quite evident in preserved specimens.

In larvæ 5 mm. long (figs. 94 and 95) the notochord extends to the tip of the tail, and a caudal fin-fold proper is not developed; the dorsal and anal folds are present. The posterior part of the anal fold shows a thickening where the caudal is finally formed. The pectoral has also made its appearance as a small flap on the shoulder. The liver has become well developed and fills a part of the space formerly occupied by the yolk, some of which still remains. The heart is still a simple tube without any differentiations. The intestine has become much enlarged, and in the protruding hind gut, which is distinctly differentiated, ridges have been formed on the inner side, which later become transformed to villi. The whole tube is still simple at this time without any loops.

The circulatory system (fig. 92) consists of an arch extending upward and forward from the heart, thence abruptly backward to beyond the middle of the tail, forward to near the anus, downward to the lower surface of the intestine, along which it extends till before reaching the yolk *it bends upward around the intestine* and then down over the yolk and into the heart. Shortly afterwards the intestine bends down at the vascular loop and forms the familiar sigmoid curve (figs. 96–100). By this means the portal vein runs straight forward along the ventral surface of the hind gut and then directly to the liver. The succeeding changes in the relative size and the curves of the various parts of the intestine may be gathered from figs. 93*a* to 93*c*.

Concomitant with the changes in the intestine the simple tube of the heart is transformed into auricle, ventricle, and bulbus arteriosus. While it is a simple tube it arises from the sinus venosus near the bottom. This origin is translocated upward till it arises from the top of the sinus. At the same time the tube has been lengthened and two constrictions have appeared. The posterior section comes to lie over the middle section; finally the upper is moved forward, and by the elongation of the bulbus the middle section is pushed backward so that the relation obtaining in figs. 96–99 results. The definite fins appear when the larva has reached a length of about 9 mm. (fig. 99). The further externally visible changes may be gathered from the accompanying figures (101–108). Pigment does not make its appearance till very late, and then only sparingly, except in the eye.

Formation of the intestine.—The fundament of the intestine can first be distinguished in my sections when three protovertebræ are formed and several others are outlined (figs. 67–74). The conditions are similar in a number of embryos sectioned, and I have selected for description one sectioned longitudinally and another transversely.

In a section in the sagittal plane (fig. 67) the line separating the chorda from the neural thickening is well marked. The line separating the chorda from the underlying hypoblast is quite distinct in the anterior part of the embryo where the chorda

cells have become very different from the hypoblast beneath and have become rearranged. In the caudal swelling the two structures are not separated by any distinct line, and the difference between the cells of the future chorda and the gut are not so well differentiated. In the head the hypoblast underlying the chorda is quite thin; caudad it becomes gradually thicker and finally columnar in arrangement. This columnar region stains darker than the surrounding cells. In the posterior part of this region the columnar hypoblast is raised from the yolk to form a distinct arch, or rather, as is seen in transverse section, a transverse fold raised from the yolk (fig. 73).

The outer edges of this fold are raised a little higher than the median portion, and it extends and gradually disappears backward. The floor of this arch is very largely formed by the yolk, its posterior extension entirely so. Below the arch there are a few cells which are very probably derived from its own roof, from which several cells project (figs. 68–73). This space is the first observed condition of Kupffer's vesicle. Cross-sections show that at this time the hypoblast extends over the greater part of the yolk, if not entirely over it (figs. 71–74; hypoblast cells have nucleoli indicated). Near the middle it is several (5) cells deep over nearly half the circumference of the yolk. It is columnar only below and a short distance on either side of the chorda; latterly it becomes thicker, but thins out again to a thickness of one cell (fig. 72). The section extending through Kupffer's vesicle shows that at its outer margins it extends as short pockets toward the ectoderm. In this fact it resembles very closely the conditions found later in the region of the forming gills, which arise as similar outward extensions from the alimentary tract.

In an embryo just freed from the zona radiata, and which still greatly resembles the stage just described, nine protovertebræ are formed, and the development of the intestine has made great progress. The anterior part of the chorda is well formed, and the hypoblast below it is but one cell deep. Caudad the thickness of the hypoblast increases till it is about five cells deep (fig. 75). In the anterior part, where the hypoblast is but one cell deep, evaginations extend upward and outward toward a point below the fundaments of the ear. These folds are of considerable cephalocaudad extension, reaching in one embryo through nineteen cross-sections (figs. 109, 115). These outpushings are for the most part solid at this stage. The peripheral cells of this structure (the gills) are columnar. The outer layer of cells extends some distance over the yolk. Immediately behind the gill region the method of the formation of the floor of the intestine becomes evident (fig. 110). The upper cells of the hypoblast have a dorsoventral columnar arrangement. The lower cells, on the other hand, have the longer axes of their nuclei in a horizontal position, the edges of the hypoblast having become turned in. No space is at first evident between this lower and the upper layers, the infolding resulting in a solid bilateral mass of cells. The lateral extent of the hypoblast is no longer as great as it was in the preceding stage (figs. 110–112). Farther back, where the ingrowth to form the potential floor of the intestine does not take place until some time later, and where the intestine, as will be seen later, is very wide from the beginning, the hypoblast still extends over a considerable portion of the yolk (figs. 112, 113). The same process of forming the intestine takes place in this region later, *i. e.*, the hypoblast becomes columnar and cells grow from the margin inward to form a layer between the yolk and the main mass of hypoblast cells without at once forming a lumen.

Some of the cells of the floor of the intestine may be derived from the roof directly. If so, such cells are derived from the region just below the chorda (fig. 127) and demonstrate the bilateral condition of the enteron. The same bilateral condition becomes still more evident later, when frequently two lumina make their appearance, especially in the anterior region (fig. 122). Kupffer's vesicle has now become much larger (figs. 75, 110, 113), but since it is such a striking feature of the stages succeeding the one under consideration it will be dealt with in a separate chapter.

In a slightly older larva (fig. 76), which differs from the one just described in being straightened out, the hypoblast presents in a sagittal section the same appearance seen in the preceding stage. But a layer of horizontal cells is now present between the yolk and the main mass of hypoblast (figs. 117, 125, 126, 127). In other words, the ingrowth of hypoblast has now reached the median line, and the floor of the enteron has been completed. Transverse sections demonstrate the completion of the floor in the whole of the postcephalic region exclusive of Kupffer's vesicle, which is now a very large cavity (fig. 76).

Soon after the completion of the floor as far as just described, the lumen appears both anteriorly and posteriorly (fig. 77). It is formed by the separation of the two layers of cells already formed. The separation usually begins laterally and grows towards the middle line. This is especially true of the cephalic portion (figs. 121, 122, 127, 130). In the front part of the body the hypoblast is about as high as wide (figs. 23, 130, 131), while in the posterior region it is many times as wide as high, encircling the whole of this portion of the yolk, and the lumen formed here is a Λ-shaped slit with very long arms, and occasionally an upward extension at the median line (figs. 124, 133, 134). The posterior lumen is, therefore, from the first potentially very wide, for as soon as the lower layer is separated from the upper to its full extent the intestine is relatively very large in this region.

As stated above, the lumen is formed in front and behind simultaneously. The *gullet or middle region remains a solid rod* (figs. 77, 131, 132). This appearance led me at first to suppose that the posterior intestine is precociously developed; but, as we have seen, the floor of the entire intestine is formed continuously from before backward, and the solid mass is the result of the retardation of the formation of the lumen between the two layers of the hypoblast, after such a separation has taken place in front and behind. I am not aware that a similar condition has been found in other teleosts more than once before. A similar condition is, however, described by Balfour (Elasmobranch Fishes, p. 217) for elasmobranchs. In elasmobranchs the œsophagus has a well-developed lumen like the remainder of the alimentary tract, but "its lumen becomes smaller and finally vanishes, and the original tube is replaced by a solid rod of uniform and somewhat polygonal cells." Although a lumen does not at first appear in *Cymatogaster*, its equivalent does, if we bear in mind that the floor is formed after the exact method used in elasmobranchs to form a lumen, *i. e.*, by the ingrowth below of the marginal cells of the hypoblast. What morphological significance this retrogressive development of the part of the intestine in elasmobranchs and in teleosts has I am unable to suspect, unless indeed Balfour's conjecture (II, 61) may be correct. He has found a solid œsophagus in the salmon (sp.) long after hatching. "It appears not impossible that this feature in the œsophagus may be connected with the fact that in the ancestors of the present types the œsophagus was perforated by gill-slits; and that in the process of embryonic abbreviation the

stage with the perforated œsophagus became replaced by a stage with a cord of indifferent cells (the œsophagus being in the embryo quite functionless) out of which the nonperforated œsophagus was directly formed."

The extent of the gill-pouches in the stage figured in 76 is seen in figs. 115 and 116.

A large part of the gill-pouches lies in front of the auditory thickenings. A little later the two layers composing the rudiments are beginning to separate and touch the ectoderm (fig. 128). An opening does not exist. The hypoblast grows out and up till it reaches the ectoderm, when its distal cells separate. Later the ectoderm also gives way and the first gill-slit, the *hyobranchial*, is formed in front and below the auditory capsule. I have never found the spiracular opening which some authors (Hoffmann) claim to be the first opened. The hypoblast of the spiracle extends out to the epiblast, but a canal is never formed in *Cymatogaster* and the ectoderm never parts. The remaining gill-slits are not formed till much later. The hyobranchial is functional as soon as opened, the ovarian fluid entering the intestine through it. Its early formation is another of the precocious features of *Cymatogaster* due to its viviparity. The fact that the hyobranchial is formed by an upper outward growth makes it resemble the formation of the spiracular slit in the fish described by Hoffmann.

In the stage with 12 protovertebræ (fig. 78) the intestinal lumen is continuous from a little ways behind the origin of the chorda to Kupffer's vesicle, part of which now forms a dilation of the intestine at the posterior end. An anus has not been formed. As will be seen in the chapter on Kupffer's vesicle, this structure has separated into three parts, only the middle one of which remains connected with the intestine. By an ingrowth of cells similar to that found in the formation of the floor of the anterior part of the intestine, a floor has been formed to Kupffer's vesicle and the depression in the yolk separated from the upper parts. A new roof has also been formed for this part of the intestine, separating a dorsal, dome-shaped upper part from the median portion which remains permanently as part of the intestine (fig. 38).

The walls of the intestine at this 12-protovertebræ stage are everywhere two or more cells thick. The lumen does not grow forward to form the mouth until much later, and the cephalic portion with the development of the gills will be described in another chapter. I shall here continue the description of the postcephalic portion, to which growth is mostly restricted at this time.

An outline of a larva about 0·9 mm. long, with 15 protovertebræ, is represented in fig. 5. Spermatozoa are now found in large numbers in the intestine, to the walls of which they are seen to cling by their heads. Their tails at this time are still very mobile. Large numbers are seen in cross-sections. They have gained entrance through the hyomandibular gill-slit. The anus is probably formed at this time, though I was unable to determine this in living specimens. In a stage with only one additional protovertebra (20) it is certainly open (figs. 86, 136). The thickness of the walls has been reduced to a single layer of cells, except in the region of the gullet, where two layers are frequently found. The cells are highest behind the yolk, and here the nuclei of the cells are nearer the bases of the cells than in other regions (figs. 136, 141, 142). Over the yolk the cells are lower and have the nuclei nearer their center. In the gullet, where the walls are largely two cells deep, the inner layer of cells has become ciliated (not shown in figures). This ciliated region remains an important structure, as will be seen in later stages. In life the cilia are so active that they can not be seen, nor are they very evident in sections. When particles of food

come in contact with them they are whirled about so that the presence of cilia becomes very evident. In later stages they become conspicuous in sections and smaller cilia seem also to be formed in the wider parts of the intestine, but I have not been able to demonstrate them in sections.

Cilia have recently been described in the intestine of fishes by McIntosh and Prince, 1891, p. 772: "Many preparations show a lining apparently of cilia, and there is thus great probability that the enteric tract—the œsophageal portion at least—of young teleosteans is ciliated."

The intestine is now a single tube from the hyobranchial slit to the anus, with four well-defined regions: the gill-cavity into which the gill-slit opens, the ciliated gullet, a narrow indifferent region (the future stomach), and the wide hind gut with high columnar cells. So far none of the glands to be derived from the enteron have appeared. The liver and air-bladder appear in the stages immediately succeeding the one described in the third region enumerated. The hypophysis and the thyroid gland are derived still later from the lining of the buccal cavity and the hypoblast extending forward from this region.

Before describing the further development of the alimentary tract it will be necessary to go back and follow the modifications of Kupffer's vesicle which, at the last stage described, has disappeared.

Historical on alimentary canal.—Hoffmann, 1882, p. 5, found the hypoblast to consist of a single layer of spindle-shaped cells whose lateral extent was not equal to that of the mesoderm. He found the tube to be formed from in front backward. In the head region the hypoblast has a great lateral extent, and it is here that two lateral infoldings occur. The second or lower layers so formed grow toward each other till they meet. The two layers lie close upon each other, so that a lumen is not evident from the first. The gills are formed by a still further outgrowth in definite regions and are developed from in front backward. He considers the formation in the region of the ear-capsule peculiar, since the hypoblast which is here folded first of all extends *upward* so that it lies close to the auditory vesicle. These outpushings move forward later when the gill formation has begun and finally break through to the outside and form a larval spiracle. It soon disappears. In the trunk the intestine is formed by two infoldings, as in the head, but the hypoblast is much more restricted laterally and the intestine consequently much narrower. A lumen does not appear at once, and this is formed in the hind gut first.

Agassiz and Whitman, 1884, found the secondary entoderm one cell deep. This is divided into two masses by the chorda, but the two parts unite below the chorda later. About the time the blastopore closes the strip beneath the chorda becomes two or three cells deep. This thickened mass gives rise to the alimentary canal, but how the tube is formed they were unable to say.

Henneguy, 1884, found in the trout (*Salmo fario*) that at the time of the differentiation of the secondary entoderm it is composed of one or two layers of cells. (Later, p. 122, he says three or four.) During a stage with from 12 to 18 protovertebræ, when Kupffer's vesicle is well formed, the entoderm begins to become infolded below the anterior end of the notochord to form the intestine. The entoderm at this time extends forward to in front of the auditory vesicle. It is raised on each side of a median line, below the auditory vesicle, and it is here that the first infolding becomes evident. The infolding at this time does not extend beyond the anterior third of the

embryo. The lumen in this region appears when the embryo is 3·2 mm. long and has about 22 somites. In the formation of the gill the hypoblast extends out to the epiblast without any invagination of the latter. The intestine in the anterior portion is formed as I have described it for *Cymatogaster*. Towards the middle the intestine is said to be formed in a different manner, the hypoblast being raised in the middle line to form a canal bounded below by the periblast.

McIntosh and Prince find that in the embryo whose optic vesicles are in process of formation the hypoblast is a thin sheet over the entire ventral surface save at the posterior extremity. Later it becomes a massive cylinder and the oral tract a wide flattened sheet of hypoblast, the pharynx being a separate and later formation than the mesenteron proper. They consider Kupffer's vesicle as the first indication of the alimentary tube, and it is only in this region that the alimentary tract is ever open to the yolk below. The hypoblast reaches as far as the cardiac region, where it thins out. With the thickening of the hypoblast the embryo is raised from the yolk. Beneath the eyes the hypoblast becomes thickened as two longitudinal ridges. The ventral wall is formed by hypoblast cells pushed in from the side, or of periblast cells. They seem to think that the periblast contributes in some degree to build up the entire mesenteron. The mid and fore portions are said to form a dense cord, in which a lumen appears later by a forward extension of the posterior enteric chamber. In other words, the lumen is formed from behind forward, the mouth and anus being the last parts formed. The œsophageal portion they found ciliated in later stages. On the thirteenth day the alimentary tract of the gurnard is differentiated into the following regions: (1) Oral chamber large, but depressed. (2) A wide œsophagus, the lumen of which is a horizontal fissure; from this part the pneumatic duct is given off. (3) An enlarged stomach with the hepatic mass below. (4) A pyloric portion into which the ductus choledochus passes. (5) The intestine.

Wilson, 1890, found that the alimentary canal was formed "by a process of folding, essentially akin to that found in amniota. After the formation of the notochord the entoderm is one cell thick, the cells being uniform. In the trunk region the cells become thicker and a fold rises up at this point, the two sides being separated by a slight slit. In the anterior region there is a fold on each side which grows up and forms the embryonic gill-slits. In the posterior part of the trunk the entoderm becomes thickened along the median line" but is not raised up in a fold; this region is transformed into the postanal gut.

Kupffer's vesicle.—Kupffer's vesicle, as has been hinted in the preceding pages, has a remarkable history in *Cymatogaster*. It arises as an up-pushing of the hypoblast which has previously become columnar, in the posterior part of the embryo when about three protovertebræ have been formed (figs. 67, 68, 70, 73). It later develops a floor of hypoblast as usual among fishes. But here comparison must stop. While in teleosts in general it is quite a minute structure* and entirely disappears behind the region of the anus in some teleosts, in *Cymatogaster* it becomes frequently half the length of the yolk into which it pushes or eats a large pit and finally is divided into three distinct vesicles, each one of which is larger than the ordinary Kupffer's vesicle, and each of which has a different history and fate. The middle one remains as an enlargement

*In *Ctenolabrus* it measures 0·03 mm. during its largest stage. In *Cymatogaster* it reaches a length of 0·13 mm., which is about half the length of the yolk. Its maximum height, exclusive of the depression formed in the yolk, is about 0·05 mm.

of the hind gut, which, however extends even further in later stages, the anus forming some distance behind the original place of the vesicle. The lower one remains for some time as a space in the yolk and the upper one is pushed upward and disappears through a proliferation of the cells of its wall when about fifteen protovertebræ have been formed. I will describe the successive phases of this structure as they could be made out by my material. The conditions described by Henneguy for the trout approach nearer those of the middle vesicle of *Cymatogaster* than any others made known so far.

As stated above, Kupffer's vesicle makes its appearance early; when three protovertebræ have been formed it is a well-defined structure. Before this stage it has not been seen. At this time it is a broad, short, low space between the yolk and the hypoblast, a short distance behind the end of the notochord. The hypoblast cells forming its roof are high columnar. The greater part of the floor is composed of the yolk, but in a few places cells are also found on the floor of the vesicle, but these are not regularly arranged. (Longitudinal sections 67, 68, 70; cross-section, fig. 73.) The columnar arrangement of the hypoblast cells is continued forward for some distance in front of the vesicle. The antero-posterior extent of the vesicle is much less than its lateral extent. The outer angles of the vesicle are pushed slightly upward and outward, giving the roof an angular appearance and greatly resembling the conditions of the gills in slightly older larvæ. For these reasons I at first considered this stage of Kupffer's vesicle as the first indication of the lumen of the alimentary canal in the region of the gills.

In a larva with ten protovertebræ it has become a large shallow subcircular cavity in the entoderm and is still floored by the yolk. From its roof a small dome-shaped cavity extends still deeper into the indifferent or hypoblastic mass of cells forming this part of the larva. The contour of the yolk is not affected by the vesicle (fig. 75). The cells in the tail of this larva are somewhat disarranged, so that the relations of the vesicle with the surrounding structure can not be definitely made out. It is, however, only in this region that the entoderm and yolk are not in close contact. The lumen of the intestine has nowhere appeared as yet.

The larva at this time forms an almost complete circle around the yolk. As the larva is straightened out and the lumen of the intestine is formed, and even before any lumen appears (fig. 76), Kupffer's vesicle enlarges rapidly. The arrangement of the entoderm cells in front of the vesicle shows that it is from the first an enlarged portion of the alimentary tract, which remains without a floor long after a floor is formed in all other parts. At this time the vesicles differ greatly in shape in different specimens, but all the larvæ examined show the following structure:

First. A low cavity in the entoderm with considerable lateral extent. Its dorsal wall of columnar hypoblast is a direct continuation of the roof of the alimentary tract.

Second. A dome-shaped cavity usually in the anterior half of the vesicle extending dorsad (figs. 76, 77, 144). This dome-shaped portion, which was evident in the earlier stage, forms, as will be seen later, the lower half of the neurenteric canal.

Up to this stage the vesicle is formed exclusively at the expense of the entoderm which surrounds it above and on the sides, and frequently forms a floor at the margin of the vesicle. The contour of the yolk has not been affected. Over the center of the dome the cells are usually somewhat irregularly placed as compared with those of its sides, but a neurenteric canal I have not been able to find in this stage.

With the further growth of the vesicle the yolk is usually infringed upon (fig. 145). Whether this is accomplished by the absorption of a part of the yolk, or whether it is simply crowded down, I am not able to say. I am inclined to believe that it is pushed down by the contents of the vesicle; otherwise the rearrangement of the yolk particles would soon fill up the gap made by absorption. However, in later stages of yolk absorption (fig. 136) the yolk is frequently eaten into in very much the same way without any apparent rearrangement of its parts.

After the vesicle has reached its largest size it acquires a cellular floor which corresponds with the *original* outline of the yolk (fig. 146). The vesicle is thus cut in two, a larger yolk vesicle and an upper vesicle which forms the enlarged portion of the hind end of the intestine. The cellular floor seems to be formed by an ingrowth from all sides. Both sagittal and transverse sections show that in earlier stages hypoblast cells extend in below the margin of the vesicle. These would simply have to extend still further centripetally to form a floor for the whole vesicle. The depression in the yolk is at the same time converted into a spherical vesicle, which may be termed the yolk vesicle. It is sometimes partially filled with a brightly staining substance, and as it is quite evident in entire specimens (figs. 84 to 86) I supposed it to be the yolk nucleus before I examined sections and learned the fate of that structure. In one larva the yolk vesicle was found at the ventral side of the yolk (fig. 85). The yolk vesicle remains longer than Kupffer's vesicle, and in fact the intestine extends some distance beyond it before it disappears. There seems to be no regularity in its disappearance, and probably no importance attaches to it after it is separated from the main vesicle.

The cellular floor of the vesicle rapidly thickens as the tail begins to grow out, while its communication with the alimentary canal is maintained (fig. 147). The dome-shaped part is probably constricted off at this time (12 protovertebræ), and the remainder of the vesicle is reduced to the caliber of the rest of the alimentary tract. My sections tell conflicting stories about the exact processes. Figure 78 shows an irregular cavity at the end of the mesenteron, which I consider the remains of the main vesicle. This cavity is connected by an area of disconnected cells with a vesicle lying dorsad of it. Figure 148, on the other hand, in which the tail is not as long as in figure 78, shows a dilation of the intestine dorsad, at the end of which lies a triangular cavity. It would appear that a part of the body of the original vesicle had been constricted off with the dome. The same appears to be true of figure 149. In both these larvæ the cells below this cavity are disarranged. The connection of this dorsal cavity, or vesicle, with the alimentary canal is now represented by the disarranged cells only. The two different structures, vesicle and disarranged cells, may, however, be harmonized. The dorsal vesicle disappears by the proliferation of cells from its wall into its cavity. These cells would at first be expected to be arranged somewhat differently from those in the older structure. In figure 78, which represents the older condition, the process has gone far enough to obliterate all of the body of the vesicle which had remained with the dome.

Neurenteric canal.—Several of the larvæ described above leave no doubt as to the meaning of the dome-shaped structure of Kupffer's vesicle. It is part of the neurenteric canal. In all late stages, as in figure 148, there are fewer cells above the neurenteric canal than in neighboring regions, and in several cases a tubular connection undoubtedly exists between the remains of the dorsal vesicle and the neural region.

In three cases (78, 148, 149) the dorsal portion is wholly or partly filled with cells. This is especially well seen in fig. 78, where the boundaries of the dorsal half of the canal are as well marked as those of the ventral half, but in which the dorsal half contains cells. The same is true of another larva (fig. 148), but in this instance the walls of the dorsal half are not so well defined. In another larva (fig. 149) a narrow but well-defined canal extends from the remains of the vesicle upward and then curves forward. This is probably only the posterior wall of the neurenteric canal. More or less well-defined lines extend from the anterior portion of the dome upward. The same condition can be traced in series of transverse sections. There seems then to be but little room for doubt about this structure. All the evidence indicates that in part at least it is the neurenteric canal.*

Kupffer's vesicle in general.—Kupffer's vesicle is evidently a rudimentary structure, without function in the majority of fishes. Several quite distinct views have been held as to the significance of this structure.

Kupffer, who first described it, and recently Henneguy, considered it to be the allantois of higher vertebrates.

Balfour homologized it with the postanal vesicle of elasmobranchs.

Cunningham, Ziegler, McIntosh and Prince, consider it to represent the invaginated gastrula (archenteron) of cyclostomes and plagiostomes.

Kowalewski holds in the main to the same opinion.

Henneguy formerly considered it the homologue of the primitive intestine of cyclostomes and amphibians. Many others who have seen the structure are noncommittal as to its significance.

The variety of opinions may in part be due to the variation of this structure in different fishes, for there is no doubt about the variability of the vesicle. It is difficult to see how a waning structure can represent a condition that has not appeared before phylogenetically and does not appear till in much higher vertebrates. I can not see how it can represent the allantois. Cunningham's theory is based on the presence of a canal between the vesicle and the blastopore. This canal is certainly not present in *Cymatogaster*, where the vesicle does not appear till long after the blastopore is closed.

Wilson considers the early stages homologous with the terminal part of the archenteron of amphibians and the later stages homologous with the postanal vesicle of elasmobranchs.

The fact that in the majority of fishes it arises long before the alimentary canal and disappears, or at least diminishes, before the alimentary canal is formed argues against its homology with the postanal vesicle of elasmobranchs. It must be conceded, however, that in fishes the alimentary canal is late in making its appearance as compared with elasmobranchs. The alimentary tract is retarded in teleosts for some reason or other. The caudal vesicle is functionless in elasmobranchs and the

* I want to point out here the possibility that the neurenteric vesicle alone represents the caudal vesicle of other teleosts, and that its connection with the lower part of the vesicle which is converted into the hind gut is after all due to the precocious development of the hind gut, which thus extends past the region of the original Kupffer's vesicle before the growth of the tail has carried the latter farther back. In that case the postanal gut would be represented by the dorsal wall of the hind gut; *i. e.*, the region between the hind gut and the neurenteric vesicle. This would account for the fact that I have not been able to find any other structure which might be homologized with the postanal gut frequently described for teleosts. The lower or main part of the vesicle may then be looked upon as the archenteric cavity.

causes which brought about a retardation of the functional intestine would not necessarily affect the functionless postanal section. It thus happens that the postanal vesicle in teleosts appears as Kupffer's vesicle before any lumen is formed in the intestine. In *Serranus*, at least, it lies at the end of a postanal gut. In the trout, according to Henneguy, and in *Cymatogaster* it is at least in part incorporated in the intestine. Kupffer's vesicle is, moreover, the only part of the intestine raised from the yolk before a floor is acquired. [In *Serranus* (Wilson, 1890) this raised portion is not confined to Kupffer's vesicle.] Kupffer's vesicle, in *Cymatogaster* at least, is more than the postanal vesicle of elasmobranchs. The archenteron, the postanal vesicle, and neurenteric canal all seem represented by it.

In *Cymatogaster* it is seen that a part of this vesicle is for a time the direct continuation of the alimentary tube and that during this time a narrow slit (neurenteric canal) extends upward from its anterior half. This upward extension is formed in *Ctenolabrus*, according to Agassiz and Whitman, at the closing of the blastopore. But the condition described by them I have never been able to see in any of the pelagic eggs examined by me.

If we consider a part of the vesicle the homologue of the postanal vesicle of elasmobranchs it remains to be shown why in *Cymatogaster* it forms part of the permanent intestine. The cause is not far to seek. The embryo, in the first place, is shortened on account of the small yolk at the periphery of which it is formed, the tail being represented by a large knob of undifferentiated cells. On the other hand, the alimentary canal is precociously developed, owing to viviparity, and the whole of the hypoblastic area is utilized in forming the permanent alimentary tract.

Agassiz and Whitman (1884) traced Kupffer's vesicle in several species of pelagic eggs. In the formation they found what Kingsley and Conn had already well described. It "arises by the fusion or confluence of a cluster of granules. * * * In *Ctenolabrus* the granules appear soon after the embryonic ring passes the equator, when the length of the embryo is about four-fifths of the diameter of the ovum. Its maximum diameter when fully formed is seldom more than 0·03 mm. During its formation, till it reaches its maximum size, it lies beneath the chorda and the entodermic stratum and has no sort of relation with any tubular structure whatever. * * Ventrally and laterally it is bounded by periblast material. * * * It grows smaller after the closure of the blastopore, and during this period in a number of species it rises from the periblast into the entoderm, where it vanishes." Behind this they have found a variable number of secondary caudal vesicles.

Henneguy (1889) describes some of the distinguishing phases of Kupffer's vesicle in the trout (*Salmo fario.*) (He first described it as early as 1880.) The first indications of a modification in the region of the future vesicle were noticed very early and the vesicle itself was quite large when but two or three protovertebræ had been formed. The cells in this region are larger than the others and are undergoing division. There are but few of these cylindrical cells, and they are in contact with the periblast, and later one sees "une invagination se produise dans l'embryon pour former la vésicule." This mass of cells is the first indication of Kupffer's vesicle. Its growth must be quite rapid, for it is 0·11 mm. long and 0·09 wide when but two or three protovertebræ are formed, and occupies "la place de la corde dorsale," *i. e.*, it is entirely surrounded by hypoblast. It lies just in front of the caudal swelling "au point où commence à se differencier le mésoderm." He points out that it differs in its position in the entoderm

from the condition usually prevailing in fishes where it projects into the vitellus. He then states that this difference is of no importance (1881), for in a later stage the vesicle "peut faire saillie hors de l'embryon" and thus become as in other fishes. In other words, the process described by Agassiz and Whitman is here said to be inverted. In a stage with twenty-two protovertebræ it is figured as the enlarged posterior end of the alimentary canal. It would here, then, permanently form a part of the intestine, and in this respect agree with the middle vesicle in *Cymatogaster*. It elongates antero-posteriorly and becomes pyriform. It comes directly in contact with the nervous thickening above. It is only the first indication of the digestive tube. It is important on account of its relation with the nervous system and the notochord and the region corresponds to the region of the neurenteric canal of other vertebrates. He has never found a canal leading to the exterior. He considers the opinion of Kingsley and Conn, Agassiz and Whitman, Cunningham, Ziegler, that the vesicle lies between the periblast and the hypoblast, to be based on an error of observation.

Frequently there exists below the vesicle or in its neighborhood a hemispherical depression in the surface of the vitellus. (It is possible that in this case the vesicle divides into two, a yolk vesicle and the intestinal vesicle seen in *Cymatogaster*.) He thinks the original opinion of Kupffer may still be defended when one considers that it is the first indication of the alimentary canal in the neurenteric region and that the allantois of higher vertebrates is but a diverticulum of the intestine appearing very early in front of the neurenteric canal.

In *Serranus*, according to Wilson, the vesicle appears as an up-pushing of the hypoblast, which had previously become columnar, and a down-pushing of the periblast. It disappears by the proliferation of cells from its own walls. It is formed some distance behind the future anus and lies in the postanal gut. In this respect it greatly resembles the postanal vesicle of elasmobranchs, with which it is homologous. "Before Kupffer's vesicle is folded off it represents the terminal dilatation of the archenteron itself, and in this phase is to be compared with the dilated posterior extremity of the archenteron in certain amphibian gastrulas."

McIntosh and Prince (1890) observed the vesicle in a number of species. They find that it arises, as Kingsley and Conn have described, by the union of a number of granules or small vesicles. They found secondary vesicles quite frequently, sometimes extending "all along the ventral line almost to the pectoral region." Its contents are usually homogeneous and clear, though granules are occasionally present. They claim to have traced a neurenteric canal from the vesicle to the blastopore at the time the latter closes.

Formation of liver and air bladder, mouth, thyroid gland, and hypophysis.—In a preceding chapter the intestine was described from its first appearance until, in larvæ 1 mm. long, it forms a simple tube from the hyobranchial gill-slit to the anus. In the stages succeeding that the rudiments of the liver and of the air-bladder make their appearance. Parts of the tract are at the same time otherwise modified.

In larvæ 1·8 mm. long (figs. 150, 156, 157) the intestine is broad and depressed just behind the hyobranchial slit, and its walls are composed of ciliated cells 18μ high. In the roof the nuclei of the cells are slightly nearer the free ends of the cells and nearly all are on the same level.

In the floor there are besides this layer of cells a few scattered ones among the bases of the others (figs. 156, 157). Towards the back part of the gullet the lumen

becomes narrower and higher, and the cells at the same time lose their great height and their cilia; just behind the gill swelling the lumen is subcircular or horizontally oval. Its walls are composed of a single layer of cells but 5μ high. Still farther back the lumen becomes vertically oval, and the cells of the floor lose their columnar nature and multiply so that a thickened floor is formed. The change in shape of the lumen (159 and 160) is due to a longitudinal groove, shallow in front, becoming deeper behind, abruptly stopping still farther back just in front of the hind gut. Behind this place the lumen is again contracted. This ventral groove and thickening of the floor is the rudiment of the liver. The region through which this groove extends is quite extensive, reaching through 19 sections of the 85, making up the entire length of the intestine, or through almost the entire region from the ciliated gullet to the hind gut (fig. 162). A short distance behind the pronephros another thickening appears in the walls of the intestine, this time in the roof, which is at the same time extended laterally (fig. 160). This upper thickening is not so extensive, reaching through 10 sections and extending in the early condition as far back as the lower mass. This upper thickening is the rudiment of the air bladder. The mesoderm surrounding the alimentary tract in these regions is also considerably thicker than in other regions. At the beginning of the ventral groove the lumen of the intestine has a diameter of 45μ, the cells a height of 9μ. At the end of the groove the lumen has a diameter of 68μ, and the cells lining it have a height of 13μ. Just behind the groove the height of the lumen is again reduced to 45μ. From this point the intestine rapidly widens till it reaches a diameter of 160μ (fig. 161). The cells lining this portion are 22μ high. Just in front of the anus the lumen becomes a vertical slit and the inner layer of the ectoderm becomes reinforced along the ventral line to form a keel. For four sections the anus is a vertical slit, the sides of which flare outward below. Behind the slit it is continued as a median groove with equally flaring sides, on the crests of which the nephridial ducts empty. On either side of the vertical portion of the intestine, just in front of the anus, the splanchnic and the somatic mesoblast are united in a solid mass in which the sex cells are embedded. Behind the anus a short, solid cord of hypoblast extends into the tail, between the aorta and the caudal vein. In older larvæ the ridges behind the anus meet in the median line and the segmental ducts thus come to empty in the median line. The relations of the liver to the air-bladder in older larvæ may be gathered from figs. 162 and 163. Their further development in a larva 2·5 mm. long is shown in fig. 165, where the gall-bladder has begun to develop.

In larvæ a little over 3 mm. long, the thyroid gland and the hypophysis are well along in their development. These larvæ measured 3·2 mm. after hardening, and were probably longer in life. The intestine (figs. 166 to 174) has not changed much except in the regions of the gills. The lumen extends forward to in front of the thyroid gland. Anterior to this point the two layers of hypoblast cells are still in contact with each other. The mouth has, however, become evident laterally, as will be seen from fig. 169. The anterior opening of the intestine is still the hyobranchial gill-slit. The ciliated gullet has now reached its full development. In the entire gill region the intestine is depressed; its width decreases in this region from 181μ to 112. Behind the gullet it dwindles to a diameter of but 22μ; in the hind gut it reaches 136. In the anterior gill region the walls of the enteron are less than 4μ thick and consist of a layer of pavement cells unquestionably of hypoblast origin and of a layer of very thin cells (fig. 172). This thinner layer I take to be ectodermal cells

migrated in through the gill-slit. In the ciliated gullet the cells are 22μ high. On the roof this tract extends farther caudad than on the floor, where it does not extend beyond the gill thickenings. The walls of the mid gut are again of a low epithelial nature, while the cells lining the hind gut are of quite another nature. They are high and the small nucleus is situated near the base of the cells, where the contents are slightly granular. The center of the cells is a large unstainable space very variable in size. The free ends of the cells are again granular. Some of these cells contain deeply stained bodies similar to those found in the lumen, and it seems very probable that these bodies have been swallowed by the cell and are in process of reduction by intracellular digestion. At the anus the epithelium of the roof of the intestine is continuous with that of the floor of the combined segmental ducts. The cells of the floor of the intestine are continuous with those of the ventral surface. The segmental duct empties just behind the anus and not into a cloaca or into the intestine.

In an earlier stage it was noticed that the mouth was first indicated just behind the eye. The conditions obtaining in larvæ of this stage are shown in figs. 167 to 171 (3·2 mm.); the mouth is essentially like the other gills, especially the spiracular, and agrees in all major points with the condition described by Dohrn. That is, the mouth is further developed laterally than medially and some distance behind the point where it attains its full development. In the larvæ 1 mm. long I was unable to trace the hypoblast cells much beyond the notochord. In other words the alimentary tract begins in the hyobranchial region in those larvæ. It soon extends forward in the median line and, as far as I could determine, the outgrowth of hypoblast to form the hyomandibular slit takes place later than that to form the hyobranchial. In larvæ 1·8 mm. long the hypoblast extends outward to the ectoderm just behind the eye. This I have identified as the first indication of the future mouth (figs. 154, 181). In these larvæ the hypoblast does not yet extend to the anterior end, and the mouth is a strictly bilateral structure. The hyomandibular evagination is separated from the mouth evagination by a more restricted region of hypoblast (fig. 153). This evagination does not differ materially from the mouth evagination. In each case the ectoderm is two layers thick where the hypoblast touches it. But one of the gill evaginations has been completed and the second is in process of formation (figs. 150 and 151). The details of the completion of the mouth have not been traced. It is not functional when the larvæ are 4 mm. long and in fact the lumen does not extend forward any farther than in the 3 mm. larvæ.

The mouth is completed shortly after the larvæ have reached 4 mm. This lateness of the appearance of the mouth seems to me to be one of the most remarkable circumstances connected with the development of the alimentary tract. Thus while the intestine becomes functional when the larvæ have reached a length of 1 mm. the mouth is not formed till they are over 4 mm. long—not in fact till the liver has long been functional, the air-bladder well developed—not till all the glands derived from the hypoblast are well developed. Not only is the mouth late in appearing but the whole canal from the gill-cavity forward is also late in forming. While this may be due to retardation, since ingress to the canal is had through the first gill-cleft, the conditions impress one with the suggestion of Dohrn that the present mouth of vertebrates is not the original mouth, but is of comparatively late origin. How one structure may replace another as a mouth is well illustrated by *Cymatogaster*, where a new structure, the hyobranchial gill-cleft, functions as a mouth for a long time. It would

need but continued conditions, such as exist in the ovary for the hyobranchial cleft, to entirely replace the present mouth. To discover where the primitive mouth was is quite another question. We may assume that it opened into the gill-cavity in the region of the first gill-slit, since here a lumen exists long before it is formed forward. In this connection a strand of hypoblast cells extending up from the wall of the intestine in the median line just in front of the chorda becomes of great interest. It is indicated quite early (fig. 152), or as soon as the lumen is continuous from the gill-slit to the anus, and it is still striking in larvæ over 3 mm. long (fig. 166), after which it gradually disappears. This structure is not connected with the gills nor have I been able to connect it with the history of any other structure. This strand of hypoblast cells may indeed be the vestige of the primitive gullet. I have so far not been able to trace it through or even into the brain.

The thyroid gland and the hypophysis make their appearance when the larvæ are about 1·8 mm. long. The thyroid appears as a thickening in the ventral layer of hypoblast just in front of the anterior end of the heart (figs. 171*b* and 171*c*). The hypophysis is somewhat different from the start. The cells of the roof become columnar and several layers thick and a refold is formed. This condition is well demonstrated in fig. 166.

Shortly afterward the infolded cells are constricted off from the rest of the hypoblast and lie as an independent structure at the base of the brain (fig. 177).

Gills.—The formation of the first gill-slit has been described in connection with the intestine, and the hyomandibular and mandibular slits have also been considered. It remains now to trace the formation of the posterior slits. Soon after the formation of the hyobranchial a thickened mass is formed behind it; this mass extends out beyond the outline of the body of the embryo, and owing to its well-defined limits is conspicuous in the living larva (figs. 83–91) as well as in sections. (Figs. 137, 139, 150–157, 172 to 174.)

This mass is largely composed of mesoblastic cells. It grows very rapidly and from it are derived the skeleton and the soft parts of the gill-arches. The gill-clefts arise as pouches extending out from the entoderm. These may be met by shallow ingrowths of ectoderm (fig. 150, *br.* 8). The pouches are formed from the hyobranchial backward. They seem to be somewhat irregular at first and hollow (figs. 151 and 156), but later the layers of hypoblast forming them are closely appressed, all the space between them having disappeared. The second is forming when the larva is about 1 mm. long (figs. 136 and 137); the third when it has reached a length of 1·8 mm. These measurements are after hardening; the living larvæ were probably somewhat longer.

The fifth slit is nearly completed at 2·5 mm. Though the slits are potentially completed so early, the two layers of hypoblast composing them are not separated from each other till the larvæ have attained twice this length. They are seen to be separating in a larva 4 mm. (fig. 137). The slits are not vertical, but extend downward and forward. In the early stages the thickened mass containing the rudiments of the gills are entirely lateral. Below there is but a single layer of mesoderm (139). After the potential slits have been formed the mesoderm between them grows downward and forward till it reaches nearly the median line in larvæ a little over 3 mm. long.

SUMMARY OF CONCLUSIONS.

1. Copulation takes place in June or early July. This statement is based on the fact that the testes of the male are very much enlarged at this time and on the fact that the ovaries from now on are filled with spermatozoa. The act of copulation has not been observed.

2. The secondary sexual differences are considerable—among them may be mentioned a small gland or bag on either side of the anal of the male. From it extends a papilla forward to beyond the anterior margin of the fin.

3. The spermatozoa have a long rod-shaped head in place of the globular one usual in fishes.

4. The spermatozoa remain dormant in the ovary till December, when they become exceedingly active.

5. The eggs mature and are fertilized between November 1 and February 1, the largest fishes maturing the eggs earliest, the next in size a little later, and the smallest individuals last.

6. Those spermatozoa not utilized in fertilization remain in the ovary for several weeks longer. They are finally eaten by the larvæ when the digestive tract of the latter has been sufficiently developed.

7. During the early stages of gestation the females remain in shallow water; males are then rarely seen. Later they become scarce, but near the time the young are freed and shortly afterwards they are again found in shallow water.

8. The largest ovarian eggs measure about 0·3 mm. in diameter. During the process of maturation the egg contents shrink to a diameter of 0·2 mm., or to less than one-third of its maximum size.

9. The egg of this fish (*Cymatogaster aggregatus*) is 130 times smaller than the normal fish egg, which has an average diameter of 1 mm.

10. This small size is largely if not entirely due to the nonformation of deutoplasm.

11. The egg is fertilized while still in the follicle. Some sections show the extrusion of the second polar globule and the presence of the male pronucleus in an egg still surrounded by the cells of the follicle. The latter have begun to degenerate.

12. The development begins after the egg has been freed from the follicle. Eggs with 1, 2, 4, 8, and 16 cells, as well as many later stages, were found free in the ovary.

13. Neither the developing eggs nor the young are in later stages at any time connected with the parent, nor is the position of these in relation to the ovarian structures a fixed one.

14. The duration of gestation is probably five months and the number of young from 3 to 20, according to the size of the parent. In less than a year after birth the young are gravid.

15. The food of the young is supplied by the epithelium of the ovary. The cells enlarge and become clear, when they collapse, their contents are emptied into the lumen of the ovary, and the framework of the cells soon follows. When the intestine begins its work the spermatozoa serve as part of the food. The ovary at no time was observed to contain more fluids than the peritoneal cavity. (In other species considerable fluid is sometimes present.) Before the development of the alimentary tract the ovarian fluid is probably appropriated by a process of intracellular digestion on the part of the epidermal cells.

16. The yolk is a waning structure and can scarcely be taken into consideration in accounting for the growth of early stages.

17. During the whole of gestation respiration is carried on by the osmotic action between the general surface and the closely applied ovarian structures. When the alimentary tract is opened a current is kept flowing through it and aëration is, in all probability, effected by the alimentary tract. In later stages the fins become highly vascular and doubtless serve both for purposes of aëration and food absorption.

18. There is present in the entodermic pole of the developing egg a body the like of which has not been observed in any other egg. It consists of a mass of protoplasm imbedded in the yolk. It is dissolved near the time of the closing of the blastopore. Mr. J. W. Hubbard, one of my students, has connected its history with that of the yolk nucleus, which is a conspicuous structure in the ovaries of adult fishes in eggs from 20 μ up to maturity. It is a general extrusion from the nucleus of the young ovum, and probably represents the histogenetic or somatic portion of the nucleus, and this in part at least corresponds to the macronucleus of ciliate infusoria.

19. Before segmentation begins the whole of the germ is separated from the deutoplasm. The first cleavage plane extends entirely through the germ to the yolk before the second cleavage begins.

20. A segmentation cavity is not formed during segmentation, but appears later by a separation of the ectoderm and entoderm.

21. The third cleavage plane is not parallel with the first, as is usual in fishes, but is semiequatorial. This has nothing to do with the horizontal cleavage claimed to have been seen by Hoffmann and by Brook. It is taken to be a pseudoreversion to primitive methods of segmentation, with the reservation that this condition is not perfectly homologous with the third segmentation of the frog or *Branchiostoma* and would not be, had the yolk entirely disappeared.

22. The periblast is formed from a few of the marginal cells. Like the yolk it is a waning structure. Only about 12 cells are ever formed. They take no part whatever in the formation of the embryo. All of them persist as long as a trace of the yolk is left. It, with the final part of the yolk, is absorbed by the blood of the sinus venosus. The liver has nothing to do with its final absorption, as Wilson has claimed, but simply mechanically incloses the nuclei above and behind.

23. During an early stage of segmentation some of the marginal cells of the blastoderm creep over the yolk till they nearly, if not entirely, cover it.

24. Before gastrulation the yolk sinks into the mass of the blastoderm, the cells of which rearrange themselves about it and nearly inclose it.

25. The gastrula is finally formed by a process of delamination of entoderm from ectoderm and is completely diplastic and symmetrical, the blastopore closing at the entodermic pole of the egg.

26. Before any other organs become evident the sex cells become conspicuous. Their fate I have discussed elsewhere.

27. The earliest stages of the formation of the embryo have not been clearly made out with the material at hand. It is, however, certain that in one of the figures published by me in the "Journal of Morphology," I mistook the tail for the head. The conditions are extremely similar to those found in the mammalian embryos, except that the central cavity is filled with yolk instead of fluid.

28. The mesoderm is formed by a process of delamination from the entoderm. It is formed as two sheets and over the whole of the entoderm exclusive of the axial line.

29. The young fish is freed from its membrane in a very immature condition. It completely encircles the yolk; in fact the head and the tail overlap. It is incapable of motion at this time and indeed the cells which will form the muscles have scarcely become differentiated. The hatching process is due to the growth of the embryo and not to its activity, as is usually the case. The fin-folds do not appear till much later.

30. Kupffer's vesicle appears very early and is very large. It consists when fully formed of a dome-shaped roof over a large cavity surrounded on the sides by entoderm. It at first rests on the yolk, but soon the yolk is forced down and presents a deep impression just beneath the vesicle. Later the vesicle is divided into three distinct cavities. The upper dome-shaped portion persists for some time and probably represents parts of the neurenteric canal. The middle portion remains for some time as an enlarged part of the intestine. The lowest portion is the cavity formed in the yolk. It has acquired a roof by the ingrowth of the entoderm cells to form the floor of the intestine. This cavity usually remains for a considerable time.

31. The entoderm at first extends over the entire yolk. It later becomes restricted to a comparatively narrow strip along the axial line.

32. The floor of the alimentary canal is formed by the ingrowth below of the marginal cells of the entoderm. The ingrowth progresses from in front back. A lumen is not formed at once. The lumen is formed in the hind gut and in the gill region at the same time and gives abundant evidence that the alimentary tract is bilateral. The middle anterior part remains a solid mass of cells after the lumen has appeared both in front and behind this tract.

33. The anterior opening of the alimentary canal to the exterior is through the gill-slit in larvæ 1 mm. in length, *i. e.*, long before the mouth is formed. The first food enters through this gill-slit. The food current before the fish can swallow is kept up by a very highly ciliated gullet which extends from behind the gill region to near the hind gut.

34. The mouth does not appear till the larva has increased 3 mm., *i. e.*, to a length of about 4 mm., and during all this time the hyobranchial gill-slit functions as mouth. There is here found a condition similar to the one supposed by Dohrn to explain the replacement of the annelid mouth by a gill mouth.

35. Just in front of the notochord and near the region of the hyobranchial slit a strand of hypoblast cells extends up from the median portion of the alimentary tract to above the notochord. This strand of hypoblast cells lies in the region where Dohrn supposes the annelid œsophagus to have disappeared.

36. The hind gut soon becomes enormously enlarged and later a large number of long villi are developed.

37. The larvæ retain as an ancestral trait a large yolk sack, the yolk being quite minute. The sack is largely taken up by the large pericardium through which the long tubular heart extends from below and behind, upward and forward.

38. In conclusion: The fish in almost all its stages has become highly specialized. Many stages resemble very closely primitive conditions, but the conditions can probably in but few cases be looked upon as a simple reversion. Its development has, on the other hand, become extremely ichthyized and its egg stands at the end of the chain of eggs in which the *Branchiostoma* egg, the *Elasmobranch* egg, and the *normal fish* egg form links.

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1880*e*. Description of seven new species of Sebastoid fishes, from the coast of California, l. c., 287.

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1880*g*. Description of a new Embiotocoid fish (*Ditrema atripes*) from the coast of California, l. c., 320.

1880*h*. Description of a new Scorpænoid fish (*Sebastichthys maliger*) from the coast of California, l. c., 322.

1880*i*. Description of a new Scorpænoid fish (*Sebastichthys proriger*) from Monterey Bay, California, l. c., 327.

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EXPLANATION OF PLATES.

All the figures except those of plate XCII and 108*a* and 108*b* were drawn by the author with the aid of the Abbe camera, either from living specimens or from balsam preparations.

al. Alimentary tract.
an. Anus.
ao. Dorsal aorta.
au. Auditory capsule.
aur. Auricle.
au. v. Auditory vesicle.
br. 1, br. 2, etc. First, second, etc., gill-slit.
ca. v. Cardinal vein.
cer. Cerebrum.
cb. Cerebellum.
ch. Notochord.
ep. Epiblast.
fb. Fore brain.
hb. Hind brain.
ht. Heart.
hy. Hypoblast.
hyp. Hypophysis.
K. v. Kupffer's vesicle.
l. Liver.
mes. Mesoblast.
n. Spinal chord.
nc. Neural canal.
ne. c. Neurenteric canal.
nl. per. Periblast nuclei.
ol. Olfactory organs.
op. Optic vesicle or stalk.
per. Periblast.
pl. Pectoral.
po. Sex cells.
pro. Protovertebra.
s. c. Segmentation cavity.
s. d. Segmental duct.
so. Somatic mesoblast.
sp. Splanchnic mesoblast.
spi. Spiracular slit.
spn. Spermatozoa.
thy. Thyroid.
v. ao. Ventral aorta.
ven. Ventricle.
yk. Yolk.
yk. pr. Yolk protoplasm=yolk nucleus.
yk. v. Yolk vesicle.

PLATE XCII.

Fig. 1. *Damalichthys argyrosomus* Girard, ♂. Friendly Cove, British Columbia.
Fig. 2. *Rhacochilus toxotes* Agassiz, ♀. Monterey, California.
Fig. 3. *Cymatogaster aggregatus* Gibbons, ♀. Fort Wrangel, Alaska.
Fig. 4. Anal fin of the male of a *Hyperprosopon*.

PLATE XCIII.

Diagram showing the process of maturation, conjugation, and segmentation in Protozoa and Metazoa and the segregation of the macronuclear substance. *See* p. 446.

PLATE XCIV.

Fig. 1. Surface view of a living egg at the completion of the first segmentation.
Fig. 2. A living egg at the end of the second segmentation, seen from the entodermic pole. The four blastomeres are seen to project beyond the yolk, which is represented as a transparent object. The yolk nucleus *yk. pr.* shows projections which extend in between the yolk particles.
Fig. 3. Another egg from the same ovary, showing resting nuclei.
Fig. 4. Cross-section (somewhat oblique to the dividing plane) of a two-celled egg showing amphiaster of second division.
Fig. 5. Another section from the same egg showing the complete division of the germ from the yolk and the total segmentation of the germ. Only the germinal portion shaded.
Fig. 6. Living egg with 8 cells. Supposed sequence of cleavage planes indicated by Nos. 1, 2, 3.
Fig. 7. A diagrammatic cross-section of a similar egg from a section of a wax model constructed from oblique sections.
Fig. 8. A diagrammatic representation of the surface lines of the cleavage planes at the end of the third cleavage, viewed from the ectodermic pole, constructed from fig. 6 and from the wax model mentioned under 7.
Fig. 8*a*. Diagram of ordinary teleost germ at end of third segmentation.
Fig. 9. Section of an 8-cell egg. The probable plane of the section is indicated in fig. 6, *x-y*. The egg was cut into thirteen sections, of which this is the fifth, × 4.
Fig. 10. Another section, the tenth, from the same egg, indicated by *x'y'*.
Figs. 11–14. A series of optic sections of an egg with 16 cells; the planes of the sections pass through the resting nuclei. (Figs. 13 and 14 are on the next plate.)

PLATE XCV.

Figs. 13, 14. Optical sections of an egg with 16 cells.
Fig. 15. Surface view of early stage of segmentation from a living egg.
Fig. 16. Slightly later stage, surface view from a living egg.
Fig. 17. Surface view of another egg.
Fig. 18. Section of an egg with about 32 cells.
Fig. 19. Median vertical section of an egg with 32 to 64 cells.
Fig. 20. Two sections toward the margin from fig. 19.
Fig. 21. Section slightly oblique from the horizontal from an egg with 32 to 64 cells.
Fig. 22. Section slightly oblique to horizontal of an egg with about 50 nuclei. Upper portion of section touches yolk. The probable first and second cleavage planes indicated by heavy lines.

Fig. 23. Horizontal section of another egg.
Fig. 24. Section of an egg at the end of the eighth segmentation, with about 278 nuclei.
Fig. 24*a*. Outline of Agassiz & Whitman's figure of the ninth segmentation, more than 250 nuclei of *Ctenolabrus*.

PLATE XCVI.

Fig. 25. Section, median, vertical, of another egg, from the ovary from which the egg figured in 24 was taken, showing a periblast nucleus and the yolk nucleus.
Fig. 26. Surface view of an egg in an advanced stage of segmentation.
Fig. 27. Median vertical section of an egg probably near the end of the ninth segmentation.
Fig. 28. Oblique section of another egg from same ovary, plane of the section indicated in fig. 27.
Fig. 29. Median vertical section of an egg during the eleventh segmentation (with 730 nuclei). The yolk nucleus has spread over the yolk and meets the layer of epiblast cells.
Fig. 30. Oblique vertical section of another egg in about the same stage as fig. 29.
Fig. 30*a*. Outline of Agassiz & Whitman's figure, representing a section of an egg with amphiasters of the thirteenth segmentation, or with between 4,000 and 8,000 cells.
Fig. 31. Diagram of an egg during the eleventh segmentation, showing the directions of the planes of figs. 32, 33, and 34.
Figs. 32, 33, 34 are from an egg during the eleventh segmentation (with about 1,700 nuclei). The egg is cut into 21 sections; fig. 32 is the 7th section; fig. 33, the 10th; fig. 34, the 13th.
Figs. 35, 36. Sections through early gastrula and blastopore. Egg contained about 3,000 nuclei; 12th segmentation. Egg was cut into 17 sections, of which fig. 35 represents 10th and fig. 36 a portion of 11th. The sections cut through the embryonic axis obliquely. The entoderm is well separated from the ectoderm and contains smaller cells. The outermost layer of cells is continued beyond underlying layers, and nearly covers yolk nucleus.

PLATE XCVII.

Fig. 37. The ninth section through the same egg shown in figs. 35 and 36.
Fig. 38. A section through another gastrula of the twelfth segmentation, slightly older than the one figured in 37. The yolk nucleus, *yk.pr*, is brightly stained. It is bluntly conical, forming a plug in the blastopore.
Fig. 39. A section through the blastopore of an egg from ovary 26.
Fig. 40. A section through the blastopore of another egg from the same ovary (26).
Figs. 41, 42. Sections from an egg during the twelfth segmentation (containing about 3,100 nuclei). The yolk nucleus forms a large plug in the blastopore, and has a decided purple tinge, while the blastoderm cells have been colored blue by hæmatoxylin. Some of the peripheral cells are distended and very lightly stained. Fig. 41 represents a section through the middle of the blastopore; fig. 42 is a few sections removed from fig. 41.
Fig. 43. Section of an egg shortly after the closing of the blastopore. The division between entoderm and ectoderm is indicated by a heavy line. Some of the outer cells, as in fig. 41, are faintly stained with an alcoholic solution of fuchsine. A mass of dark granules are collected near the blastopore, and probably represent the remnant of the yolk nucleus.

PLATE XCVIII.

Figs. 44–54 illustrate the formation and fate of the periblast.
Fig. 44. Section through the margin of a blastoderm with about 120 cells.
Fig. 45. Portion of a cross-section of an egg with about 220 cells; nucleus 11 μ in diameter.
Fig. 46. Section through margin of blastoderm of egg with about 450 cells; nucleus 9 μ in diameter.
Figs. 47, 48, 49. Three successive sections from the same egg. There are about 11 periblast nuclei in this egg. The nuclei are about 10 μ in diameter.
Fig. 50. The second section of the egg from which figs. 47–49 were drawn. The nuclei in this section, as in fig. 6, are in pairs near the margin of the blastoderm. The egg from which figs. 46–50 are drawn contains 5 pairs of such nuclei. The fact that they are in pairs is probably due to the recent division of the nuclei. Paired nuclei were also found in the egg from which fig. 45 is taken, at end of ninth segmentation.
Fig. 51. Section slightly inclined from the horizontal of an egg in the same stage as figs. 47–50, showing the grouping of the periblast nuclei and the relation of the periblast protoplasm (shaded) to the blastoderm and to the yolk.

Fig. 52. The yolk of a recently hatched larva as a transparent object, showing the position of the peri-blast nuclei.

Fig. 53. Longitudinal sagittal section through the yolk of a larva 5 mm. long. It lies beneath the anterior part of the liver. There are still yolk bodies present.

Fig. 54. Longitudinal horizontal section through yolk of larva 7 mm. long. Yolk cells have disappeared. The yolk has been reduced to a granular mass surrounded by the liver, except at anterior margin which faces the sinus venosus. There are 11 nuclei in yolk of this larva.

Figs. 55-59. Origin of the mesoderm and embryonic axis. Five sections through an egg of ovary (23) in some eggs, of which the blastopore was not yet closed. Sections are parallel to tangential of anterior end of embryo. The whole egg was cut into 25 sections, of which fig. 55 represents the sixth from anterior end; fig. 56, the eighth; fig. 57, the tenth; fig. 58, the twelfth; fig. 59, the fifteenth. Figs. 57-59 on plate XCIX.

PLATE XCIX.

Figs. 57-59. Three sections of an egg about the closing of the blastopore. See explanation of fig. 55.

Figs. 60-63. The sixth, eighth, twelfth, and portion of the eighteenth sections of an egg cut into 33 sections, the first of which is tangential to a point over the anterior part of the head.

PLATE C.

Fig. 64. Portion of a section through the posterior part of an egg cut in a plane about at right angles to that of the preceding egg.

Fig. 65. Section near the head of an embryo of the same stage, the plane at right angles to that of the first egg.

Fig. 66. The sixth section further back of the same egg.

Fig. 67. Sagittal section of an embryo with three protovertebræ.

Fig. 68. A portion of a section to one side of 67, through Kupffer's vesicle.

Fig. 69. Portion of another section from same embryo, showing position of the sex cells in the head.

Fig. 70. A section to one side of fig. 67 and parallel with it, to show the position of the protovertebræ and sex cells.

Figs. 71-74. Four sections of another larva from the same ovary as figs. 67-70, but at right angles to those figures. The planes of the sections are indicated in 67. In fig. 71 the section passes through the anterior end of the notochord and through the median portion of the body. The lower portion of fig. 72 passes through the region just in front of the head, while the upper portion passes through the posterior region of the notochord. Fig. 73 passes through Kupffer's vesicle. In this section the entoderm can no longer be traced over the whole yolk, but merges into the mesoderm. Fig. 74 passes through the caudal thickening, where the germinal layers are merged. (Figs. 73 and 74 are on plate CI.)

PLATE CI.

Fig. 73. Sections through a larva at the region of Kupffer's vesicle. For details see under fig. 71.

Fig. 74. Section through the caudal thickening of the same larva.

Fig. 75. Sagittal section of a newly-hatched larva reconstructed from a number of slightly oblique sections.

Fig. 76. Sagittal section of an older larva about 0·45 mm. long.

PLATE CII.

Fig. 77. Sagittal section of a larva 0·63 mm. long.

Fig. 78. Sagittal section of a slightly older larva.

PLATE CIII.

Fig. 79-108. Illustrate general changes of larva from time of hatching till shortly after birth.

Fig. 79, 80, 81. Three views of a living larva just before hatching.

Fig. 82. Usual appearance of the larva at hatching.

Fig. 83. A larva shortly after hatching, the tail and head in contact, encircling the entire yolk.

Fig. 84. Outlines of a larva 0·8 mm. long, showing the three divisions of the original Kupffer's vesicle. Reconstructed from a series of sections.

Fig. 85. A slightly older larva; the eye has now become evident.

Fig. 86. A larva 0·85 mm. long, showing the thick caudal lobe. The yolk vesicle is evident in the posterior end of the yolk.
Fig. 87. A larva 1·1 mm. long; the heart is now formed.
Fig. 88. A larva 1·2 mm. long, showing the first gill-slit, through which the nourishment is now taken.
Fig. 89. Outline of the circulation in the head of a larva older than fig. 91.
Fig. 90. A larva 1·8 mm. long, showing the enormous yolk sack, of which the yolk occupies but a very small part. The posterior wall of the pericardial chamber is here pushed much too far forward, a condition due to partial asphyxiation.

PLATE CIV.

Fig. 91. Enlarged head of a slightly older larva than that of fig. 90, in which the liver *l* has been partly formed and the segmentation of the hind brain has become very conspicuous.
Fig. 92. Outlines of the circulation in a larva about 2 mm. long.
Fig. 93. A larva 4 mm. long; the liver is well formed and the yolk *yk* lies at its lower anterior angle. The segmentation of the hind brain is evident; Canada balsam preparation.
Fig. 93*a*. Relation of liver to intestine in a larva 32 mm. long.
Fig. 93*b*. The relative size of the fore and hind guts in the same larva. This difference is reduced during the growth of the next 5 mm. in length, larvæ 37 mm. long, showing the condition seen in larvæ 45 mm. long.
Fig. 93*c*. The intestine in a fish 45 mm. long.
Fig. 93*d*. The same in a fish 62 mm. long.
Fig. 93*e*. Diagram of the loops of the intestine of the largest fish observed, 160 mm., in which an extra dorsal loop had developed.
Fig. 93*f*. One of the villi of the hind gut, much enlarged, from a living specimen 10 mm. long; showing the vascular loop.
Fig. 94. A larva 5 mm. long; the pectoral is formed; long ridges have appeared on the inner surface of the hind gut; these are later transformed into papillæ. A fin fold runs along the tail, above and below; the pericardial chamber has been greatly reduced.
Fig. 95. The tail of another larva more enlarged, showing the tip of the notochord and the first indications of the caudal fin.

PLATE CV.

Fig. 96. An older larva. The tubular heart of fig. 94 has been transformed into the three-chambered auricle, ventricle, and bulbus arteriosus.
Figs. 97 and 98. Slightly older larvæ than fig. 96.
Fig. 99. A larva 8 mm. long; the definitive fins of the adult have begun to develop.
Fig. 100. Another larva younger than fig. 99.
Fig. 101. A larva 10 mm. long.
Fig. 102. A larva 11 mm. long.
Fig. 103. A larva 12 mm. long.
Fig. 104. A larva 13 mm. long.
Fig. 105. A larva 16 mm. long.

PLATE CVI.

Fig. 106. A larva 23 mm. long.
Fig. 107. A larva 22 mm. long.
Fig. 108. A larva 34 mm. long, shortly after birth.
Fig. 108*a*. Adult female of *Cymatogaster aggregatus*.
Fig. 108*b*. Adult male of *Cymatogaster aggregatus*.

PLATE CVII.

Figs. 109, 110, 111, 112. Four sections, slightly oblique, of a larva but little more advanced than the stage figured in 75, and taken from the same ovary. The larva is straighter than 75, and the sections can not be represented as parallel planes in that figure. The embryo was cut into 42 sections. Fig. 109 is 4 sections behind the origin of the notochord or the 14th from in front backward. Fig. 10 is the 22d section, fig. 111 the 29th, and fig. 112 the 30th section of the same series. This series represents the extent of the hypoblast in different regions of the body and the character of the evaginations to form the gills. This evagination extends through 19 sections in this series. Hypoblast shaded.

Fig. 113. Outlines of another larva of the same ovary showing Kupffer's vesicle.
Fig. 114. Outlines of a median section of another larva of the same stage.

PLATE CVIII.

Figs. 115–118. Sections further illustrating the hypoblastic areas of the stage represented in fig. 76. Hypoblast shaded.
Fig. 115 is a section parallel to fig. 15, and much more lateral in its position, showing the relation of the hypoblast (shaded) to the auditory thickening.
Fig. 116. A cross-section passing just above the anterior end of the chorda. It cuts the auditory thickening at *"an"* and the lateral gill-pouches. See *aa'* in fig. 76.
Fig. 117. Another section of the same series through the middle of the body, showing the floor cells of the alimentary tract. See *bb'* in fig. 76.
Fig. 118. Another section through Kupffer's vesicle. See *cc'* in fig. 76.
Figs. 119–124. Outlines of 6 sections from a larva slightly older than fig. 76. The larva was cut into 46 sections. Fig. 119 represents the 36th section from behind; fig. 120, the 35th; fig. 121, the 34th; fig. 122, the 31st; fig. 123, the 18th; and fig. 124, the 13th section. The lumen of the intestine is just forming. Figs. 119-122 represent the gill region, the remainder the posterior region; fig. 124 showing especially well the wide potential slit of the intestine just in front of Kupffer's vesicle.
Figs. 125–127. Three sections of the intestine of another larva from the same ovary between the regions represented by figs. 122 and 123.

PLATE CIX.

Figs. 128–135. Eight cross-sections of a larva in the stage represented by fig. 77. The larva was cut into 59 sections. The figures represent the following sections from in front backward.

Figures.	Section.
128	12
129	17
130	18
131	22
132	24
133	41
134	46
135	53

The sections are somewhat oblique, so that the dextral half of the figures are further forward than the sinistral. Figs. 129, 132, and 133 are magnified less than the others.
Fig. 128. The section passes through the left hyobranchial slit, the auditory thickening, and the heart, which is still a solid mass of mesoblast cells.
Fig. 129. The alimentary canal just behind the gill invagination.
Fig. 130. The next section, the sinistral half of the alimentary tract, solid.
Fig. 131. A section through the solid œsophagus, the floor cells distinct from the roof cells
Fig. 132. Outlines of a section a little farther back.
Fig. 133. Outlines of the intestine much farther back.
Fig. 134. Section through the widest part of the intestine and through Kupffer's vesicle.
Fig. 135. Section through the neurenteric portion of Kupffer's vesicle.

PLATE CX.

Fig. 136. Sagittal section of a larva about 1 mm. long and with about twenty protovertebrae; somewhat diagrammatic, from a number of sections. The heart is shortened and the pericardial chamber reduced by reagents. A large number of spermatozoa are seen in the intestine. The yolk has been eaten into. The auditory capsule is much nearer the surface and has been added to show the relation of the parts at this time.
Fig. 137. Details of the gill region near the side of a similar larva.

PLATE CXI.

Figs. 138-143. A series of six sections through a similar larva as that represented in fig. 136.
Fig. 138. Through the auditory vesicle and first gill-slit.
Fig. 139. Through the posterior part of the branchial region.
Fig. 140. Through the middle of the yolk.
Fig. 141. Through the posterior part of the yolk and the yolk vesicle.
Fig. 142. Between the yolk and the anus.
Fig. 143. Through the anus.

PLATE CXII.

Figs. 144-149. Sections showing Kupffer's vesicle.
Fig. 144. Sagittal section through the end of a larva in which the neurenteric canal persists, ending in a small vesicle in the neural chord. There is apparently an anterior and a posterior canal. These probably represent the anterior and posterior margins of the primitive canal, the space having become partly filled with cells.
Fig. 145. Sagittal section, showing continuation of endothelium of intestine over Kupffer's vesicle.
Fig. 146. A later stage, showing Kupffer's vesicle in connection with the alimentary canal, the neurenteric canal, and the yolk vesicle.
Fig. 147. Kupffer's vesicle reduced by the formation of a thick cellular floor.
Fig. 148. Sagittal section through the tail of a larva 0·85 inch long. The vesicle has been reduced. In the region it formerly covered the cells are much more loosely arranged than elsewhere. The space in which cells or nuclei are seen in neighboring sections has a sharp outline.
Fig. 149. A canal extends from the remains of Kupffer's vesicle upward to the neural canal. The vesicle has been greatly reduced.

PLATE CXIII.

Figs. 150-154. A series of horizontal sections of a larva, 1·8 mm. long, the region in front of the chorda being bent nearly at right angles to the main axis; the sections in front of this region are cross-sections. The hypoblast is shaded.
Fig. 150 passes just above the opening of the hyobranchial slit. The chorda is cut obliquely.
Fig. 151 passes through the hyobranchial slit and also through the spiracle (*spi*) or hyomandibular slit, which is seen to greatly resemble the bars and slits behind the hyobranchial.
Fig. 152 passes through the anterior end of the notochord, and the hypoblast is seen to extend up at this place so that it is in contact with the chorda. Laterally, the section passes through the spiracle and the hyobranchial slit. A layer of flat epiblast cells is seen to extend into the opening for some distance.
Fig. 153 is four sections farther forward and shows the restricted hypoblast.
Fig 154 is two sections farther forward and passes through the posterior portion of the right eye. Just beneath it the hypoblast is seen to extend out to the epiblast, and this is the fundament of the right half of the mouth. The similarity between this and the spiracular hypoblast of fig. 153 is very striking. In neither case is there any evident ingrowth of epiblast.

PLATE CXIV.

Figs. 155-160*a* represent a series of cross-sections of a larva 1·8 mm long.
Fig. 155. The section passes through the upper posterior part of the hyobranchial slit and the lower anterior part of the second branchial slit. The section is at right angles to the one represented in fig. 151 at the point *br* 1.
Fig. 156. Three sections farther back, through the first and second gill-slit on the left, through the third on the right.
Fig. 157. Behind the third gill-slit on the left, near the end of the gill-thickening on the right.
Fig. 158. A short distance behind the pronephros, the liver forming below, the air bladder above; the pectoral plates are noticed on the sides.
Fig. 159. Through the alimentary canal at the rudiments of the liver.
Fig. 160. The same farther back.
Fig. 161. Through the hind gut of another larva in the same stage of development.
Fig. 161*a*. Outline of a section through the anus not so highly magnified.

PLATE CXV.

Fig. 162. Outlines of a sagittal section of a larva about 1·9 mm. long, to show the relative positions of the liver, air-bladder, and yolk.
Fig. 163. Cross-section of a similar larva through the air-bladder.
Fig. 164. Another section a little farther back.
Fig. 165. Sagittal section through the midgut of a larva 2·5 mm. long. The yolk is reduced and the liver much more highly developed. The bile sac is just forming.
Fig. 165*a*. An enlarged sagittal section through the anus and nephridial opening of a larva 3·2 mm. long. The rudiments of the reproductive organs are seen in *po*.
Fig. 166. Sagittal section of alimentary tract of larva 3·2 mm. long. Posterior part on right below.
Fig. 166*a* and *b*. Some of the cells of the hind-gut enlarged.

PLATE CXVI.

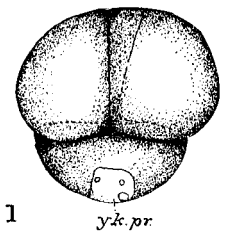
Fig. 167–171. A series of sections from the same larva as fig. 166. The sections are successively nearer the lateral surface of the embryo. These sections show the relation of the hypoblastic evaginations to each other at varying distances from median plane. The gill-structures do not yet meet below and are not visible in fig. 166.
Fig. 167. Several sections removed from 166.
Fig. 168. The next section, showing the mandibular, spiracular, and three gill evaginations.
Fig. 169. The next section, the mandibular, spiracular, and hyobranchial not connected by hypoblast laterally.
Fig. 170. Two sections removed from 169.
Fig. 171. Two sections removed from 170.
Figs. 171*a*–174*a*. Cross-sections through the thyroid and gill regions of a larva 3·2 mm. long. (Figs. 173, 174 are on plate CXVII.)
Fig. 171*a*. Cross-section of the thyroid gland.
Fig. 171*b*. Through the same one section behind 171*a*. Showing connection with hypoblast cells.
Fig. 172. Oblique section through spiracle on left and just behind hyobranchial on right.

PLATE CXVII.

Figs. 171*a*–174*a*. Cross-sections through the thyroid and gill regions of a larva 3·2 mm. long. (Figs. 171*a*, 172 are on plate CXVI.)
Fig. 173. Six sections behind 172; the right through the posterior part of the auditory capsule, the left through the hyobranchial.
Fig. 174. Through the posterior part of the gill region; the left through the upper (posterior) part of a gill pocket, the right through the anterior (lower) of another. Ciliated region of the gullet.
Fig. 174*a*. Lateral margin of the gullet, two sections farther back.
Fig. 175. Right half of a horizontal section of a larva 2·5 mm. long. All the gill-slits potentially complete.
Figs. 176–178. Three parallel sections; 176, sagittal of a larva 4 mm. long; the mouth not yet open; some of the posterior gill-slits open. The ciliated gullet highly differentiated from the other alimentary region.

PLATE CXVIII.

Figs. 179–183. Development of gills as seen in living larvæ viewed as transparent objects.
Fig. 179. Larva, 0·9 mm. long.
Fig. 180. Gill region of a larva 2·5 mm. long.
Fig. 181. A little older larva, showing the mandibular and hyomandibular slits and their relations to the hyobranchial and succeeding slits.
Fig. 182. Gill region of a larva 4·1 mm. long. × 2.
Fig. 183. Gill region of an older larva in which the conditions seen in figs. 94–100 are approached.



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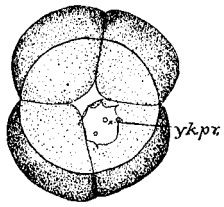

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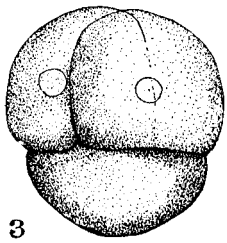

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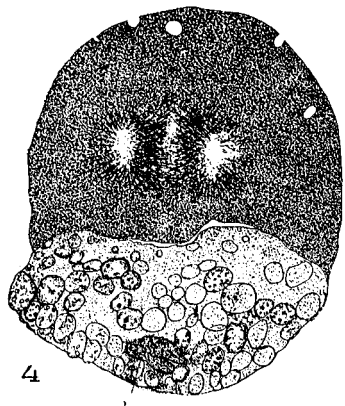

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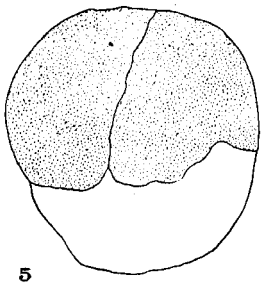

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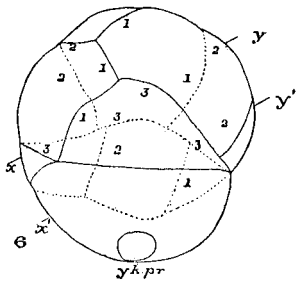

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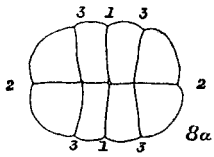

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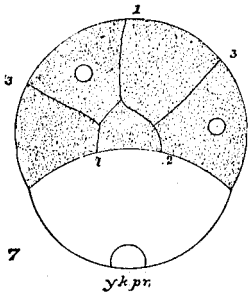

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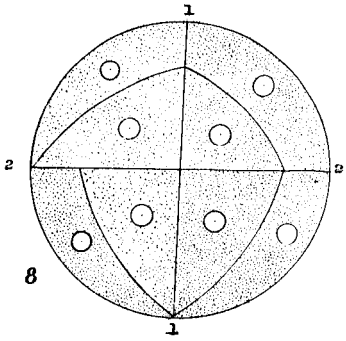

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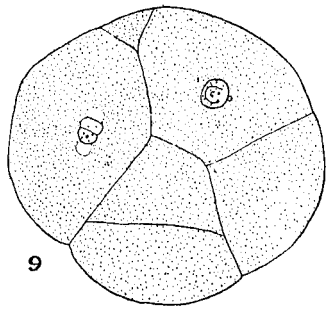

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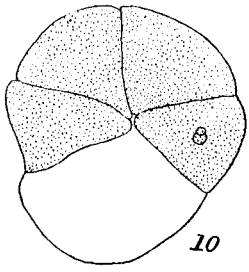

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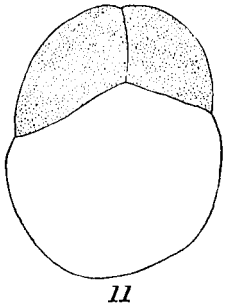

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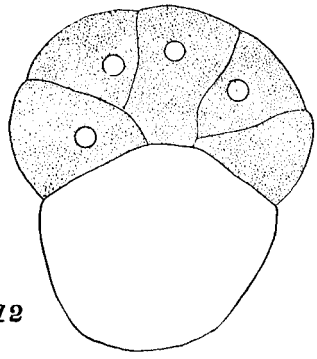

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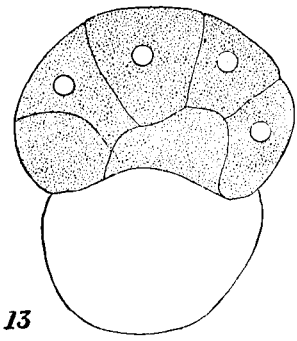
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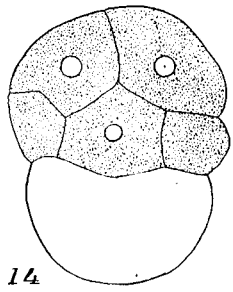
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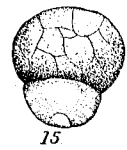
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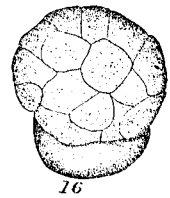
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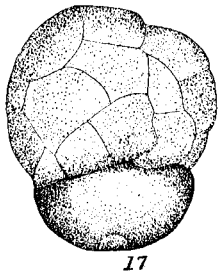
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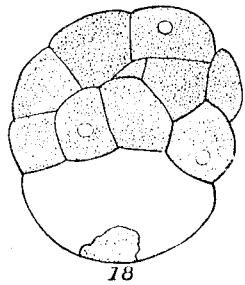
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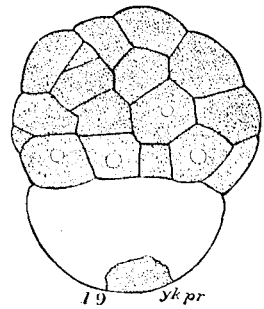
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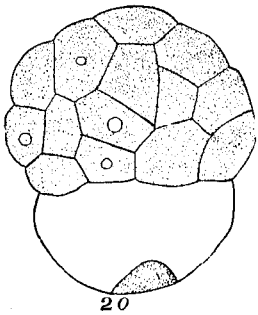
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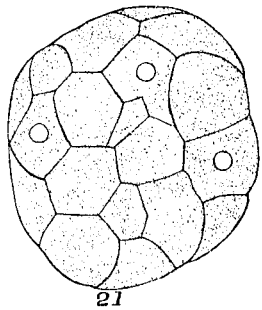
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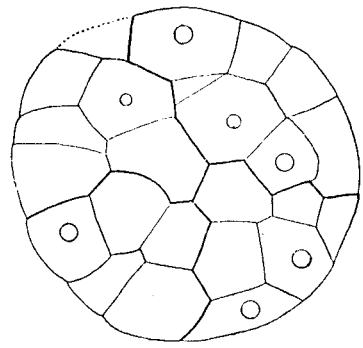
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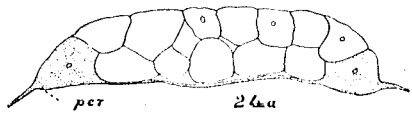
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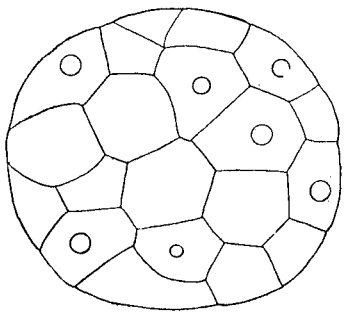
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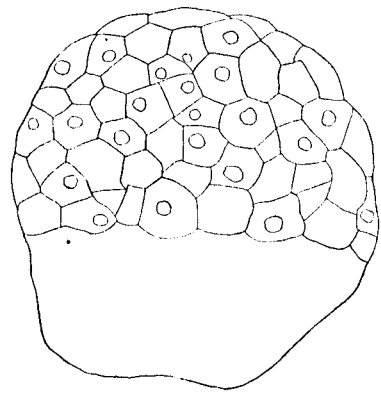
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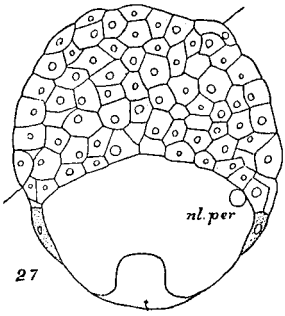

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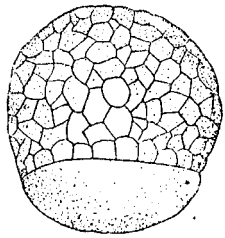
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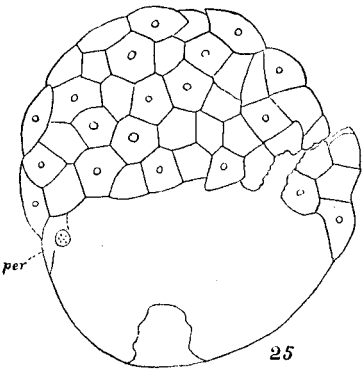

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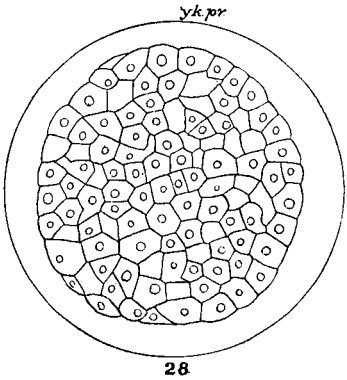

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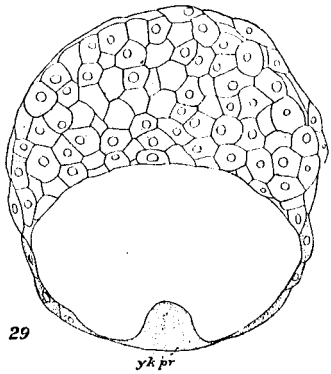

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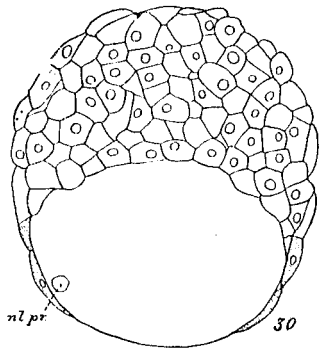

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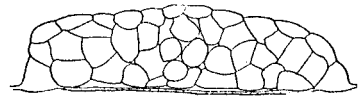
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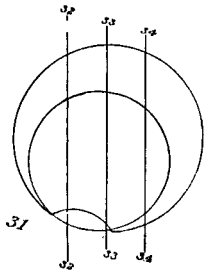

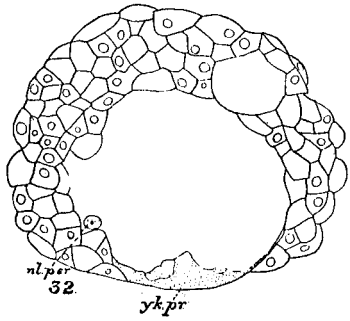

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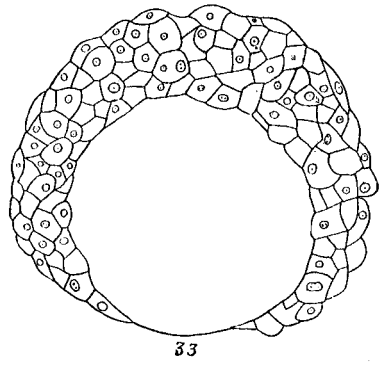
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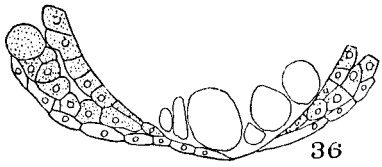
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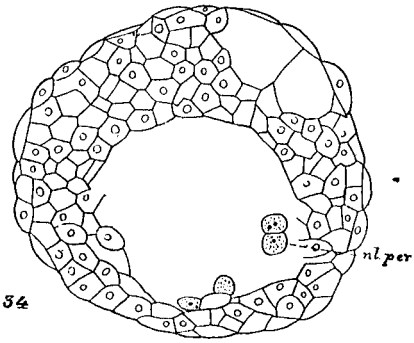

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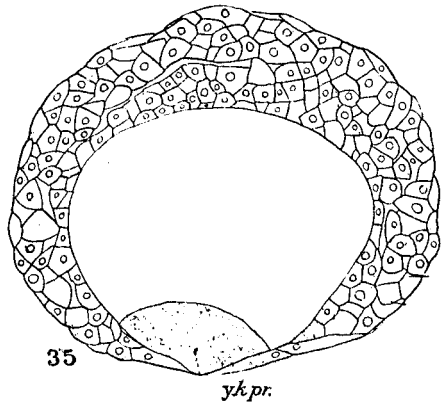

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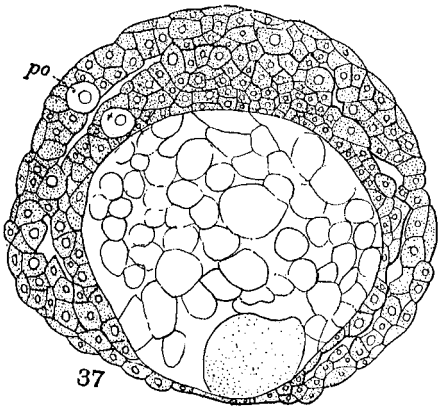

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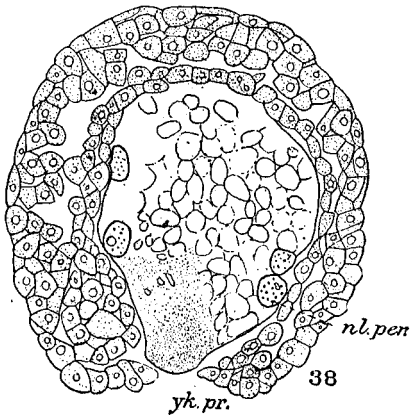

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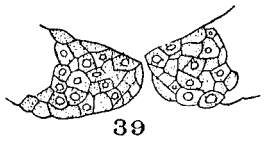
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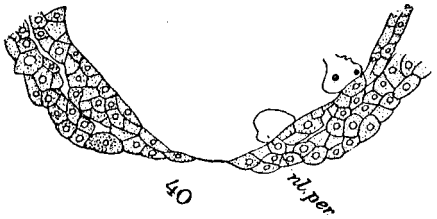

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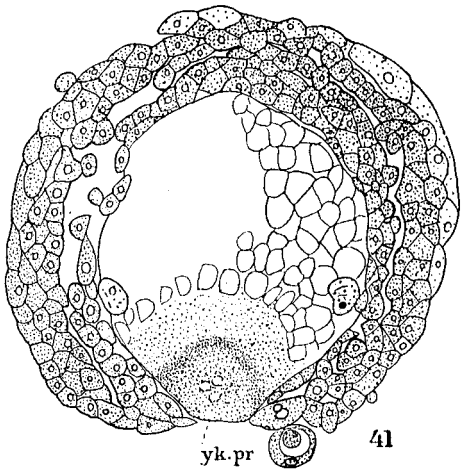

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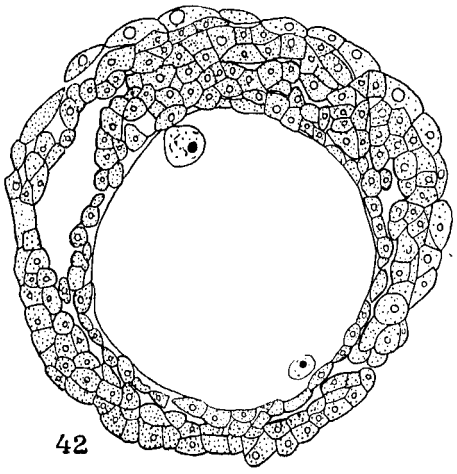
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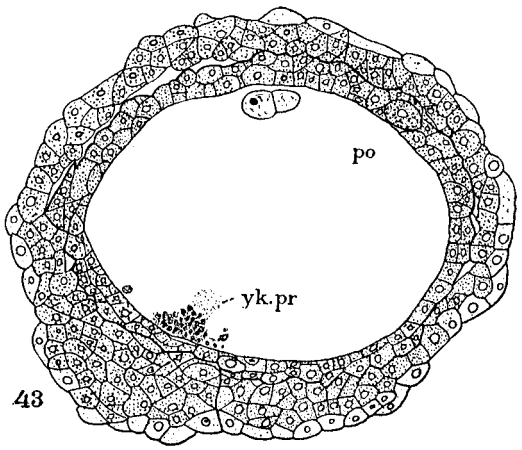

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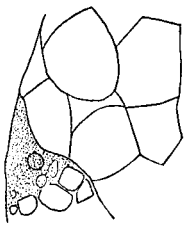
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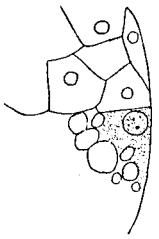
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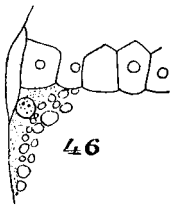
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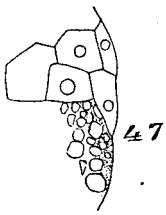
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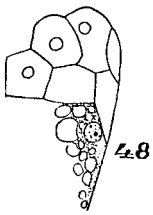
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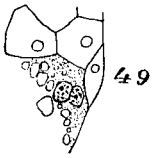
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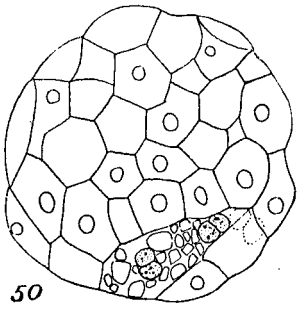
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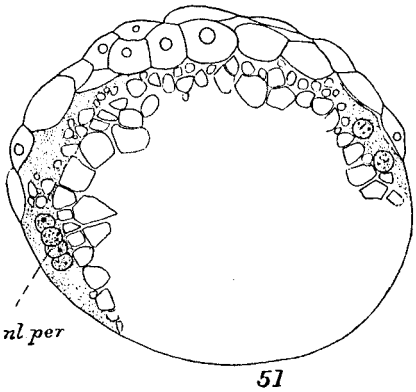

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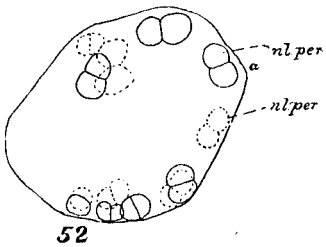

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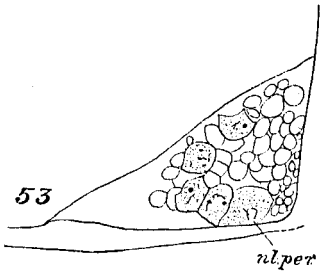

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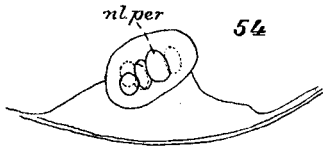

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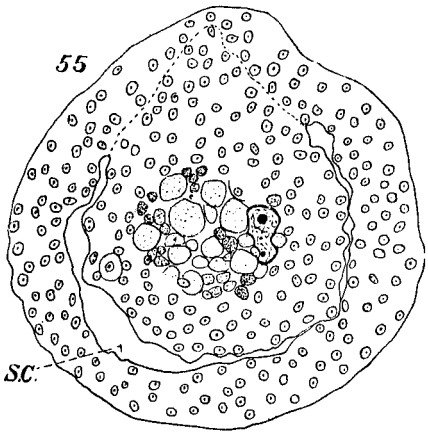

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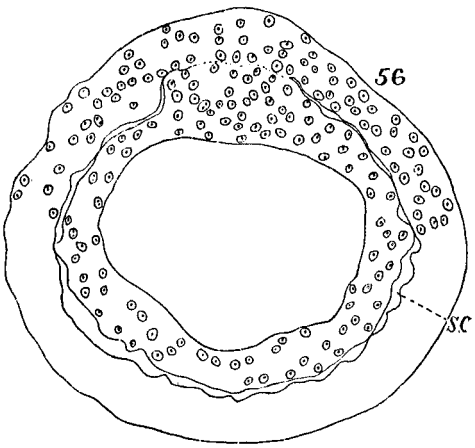

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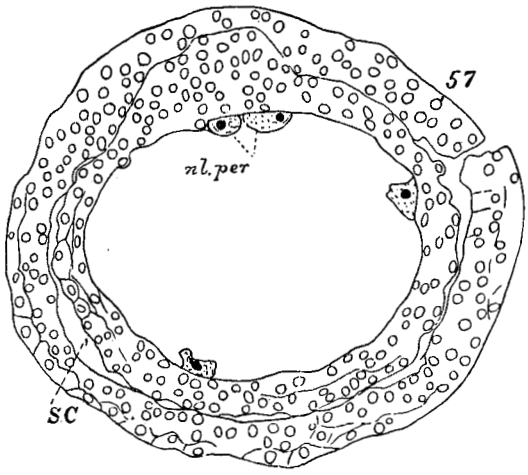
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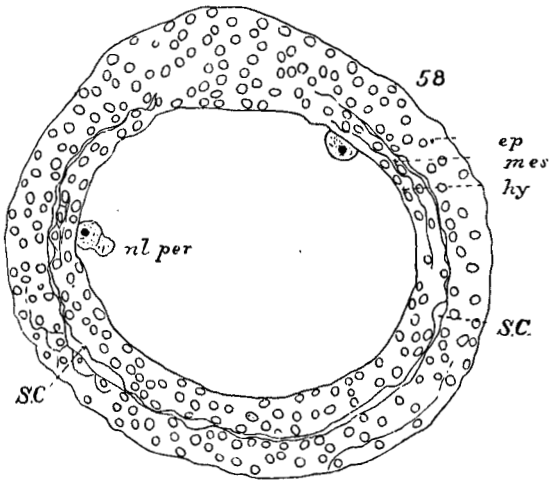
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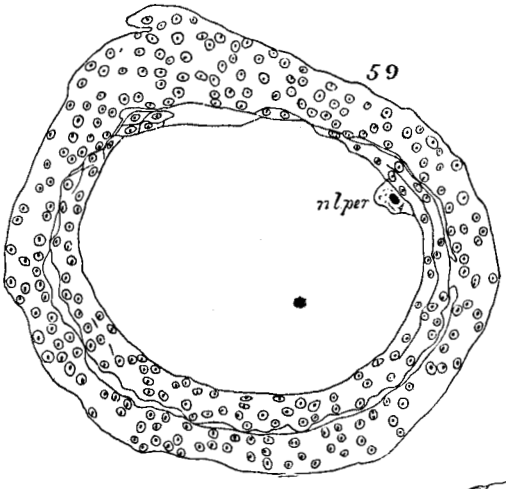
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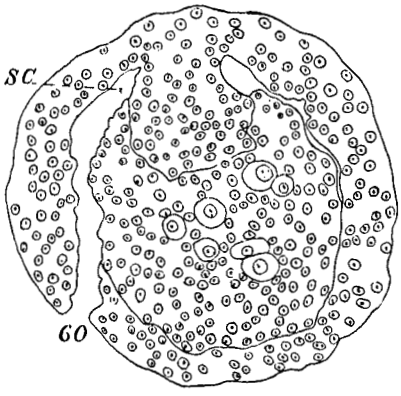
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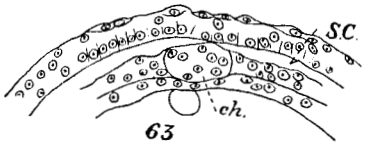
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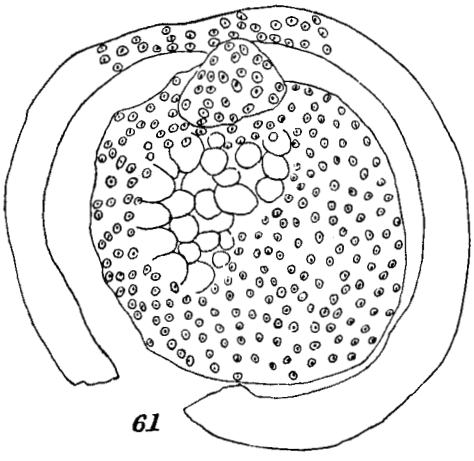
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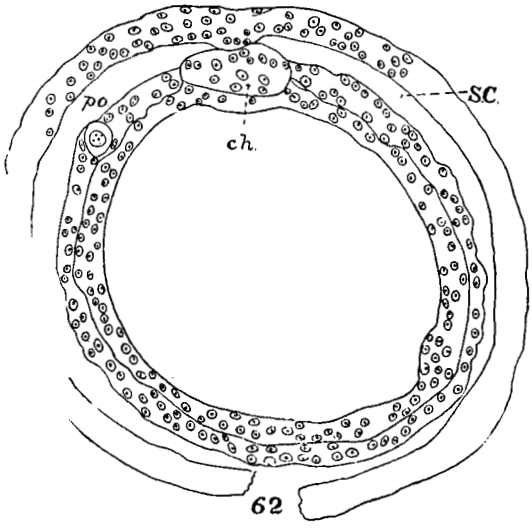
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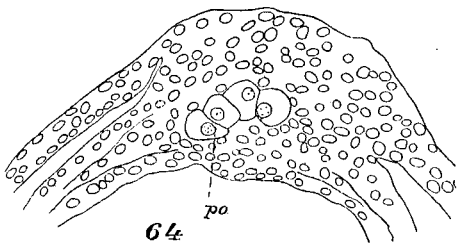

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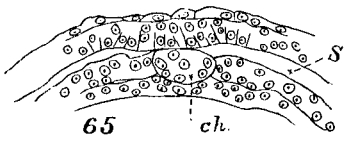

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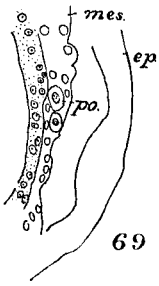

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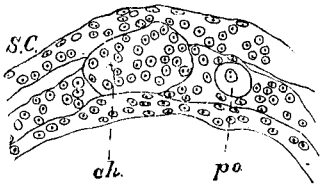

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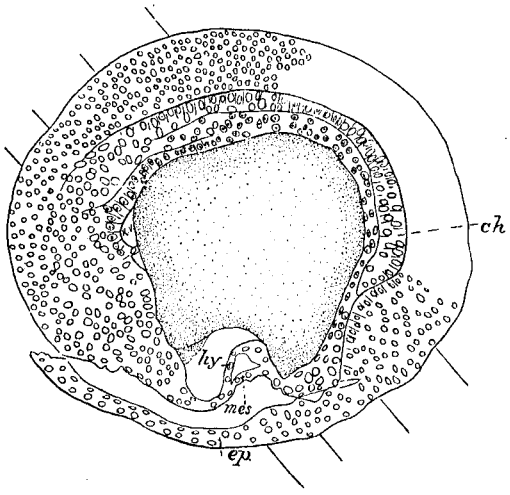

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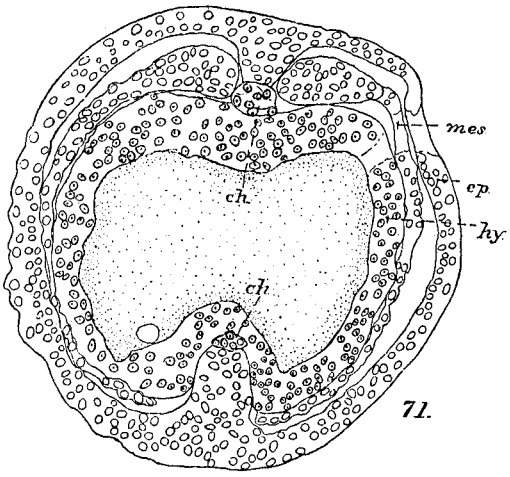

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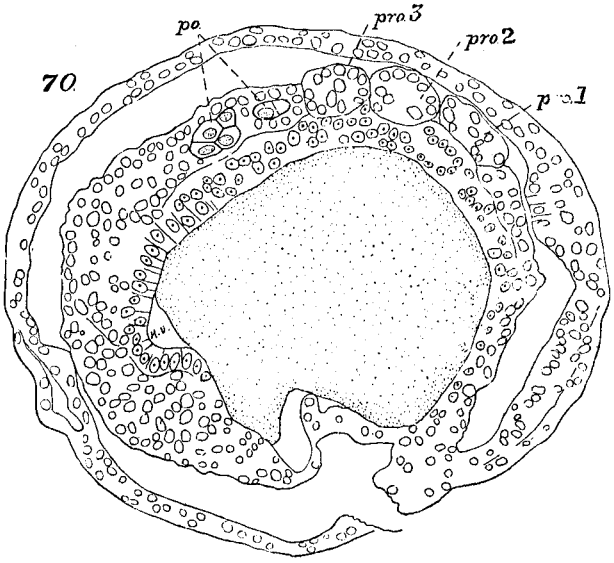

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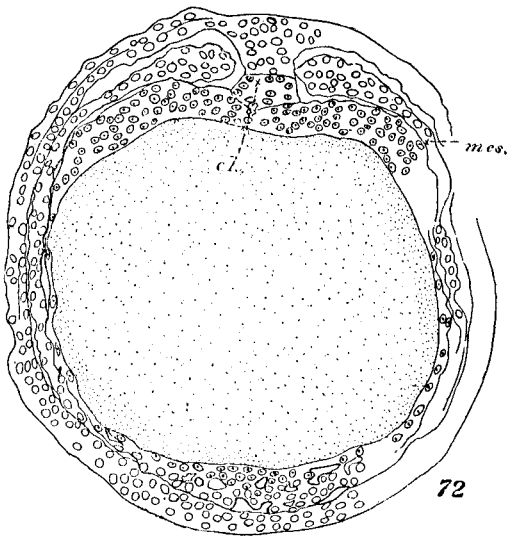

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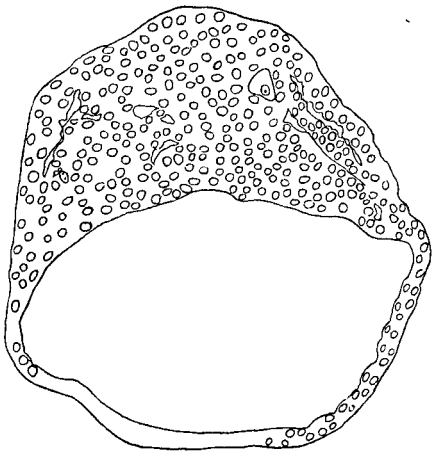

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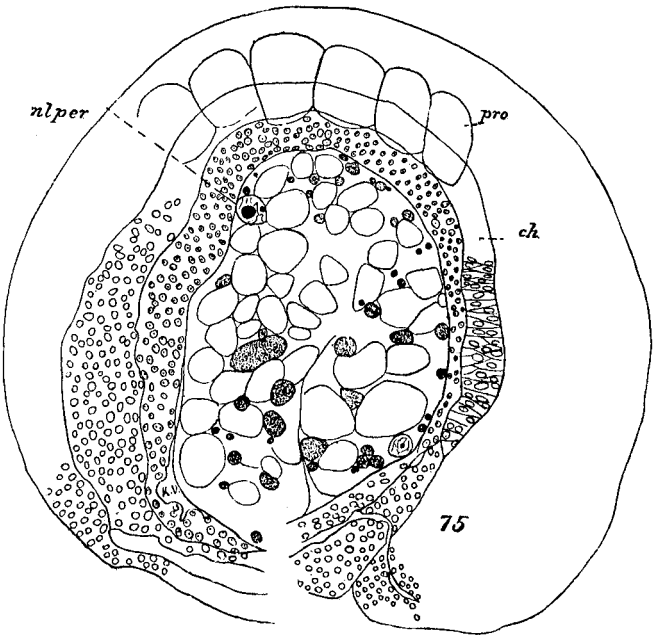

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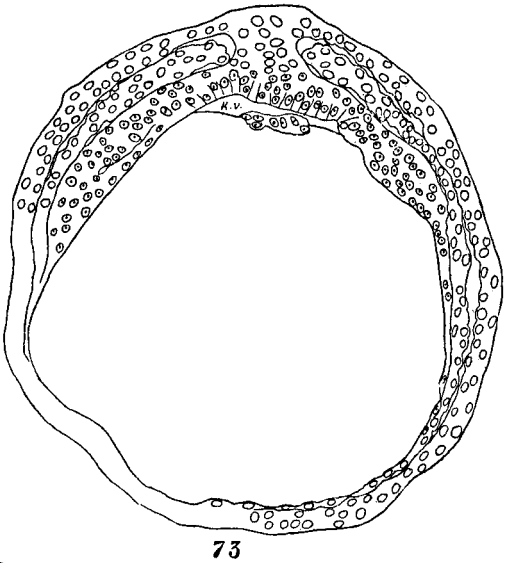

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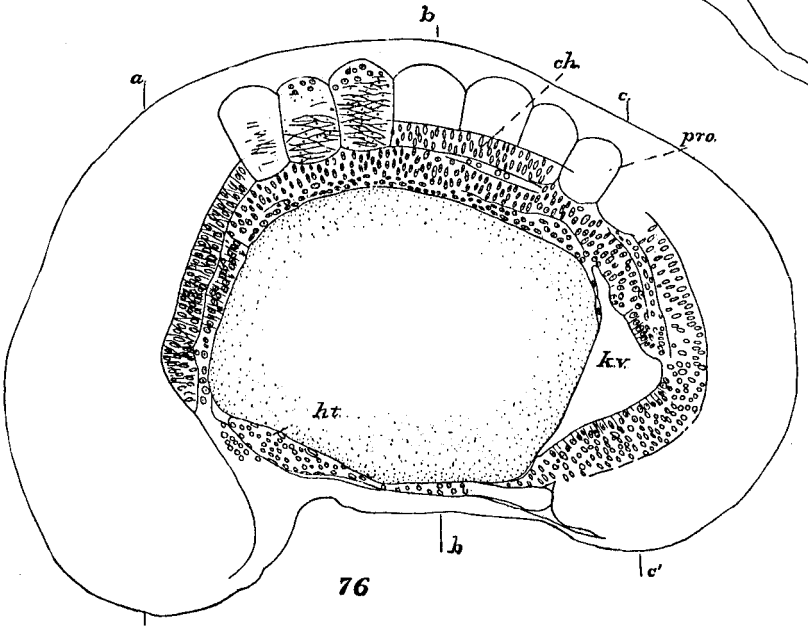

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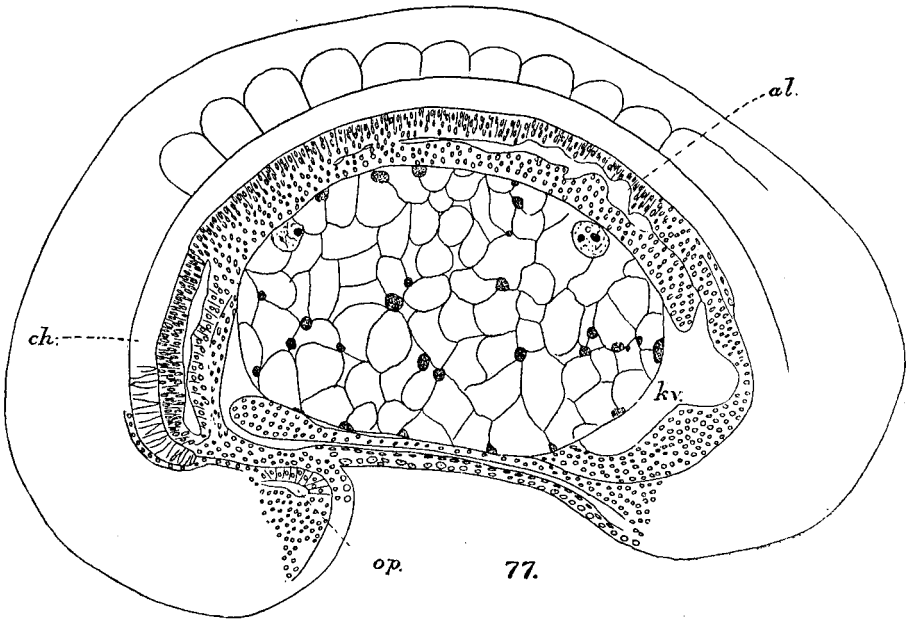

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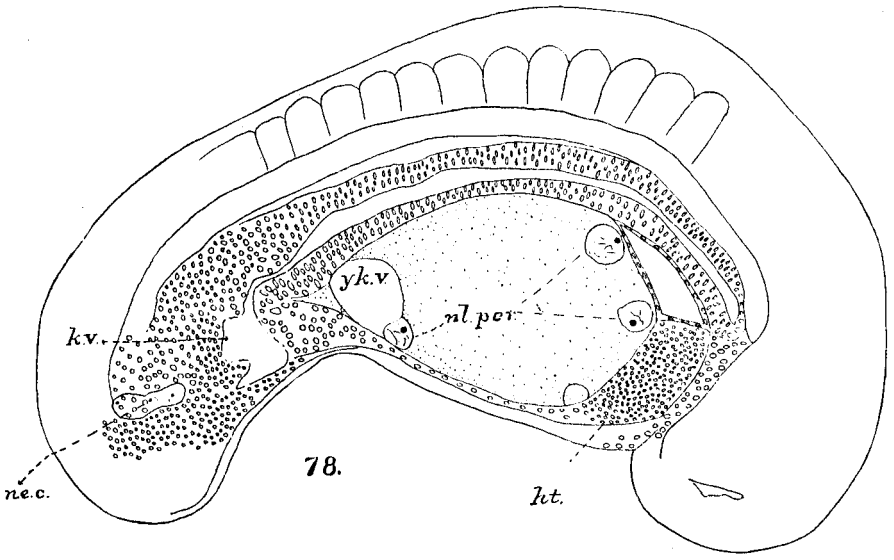

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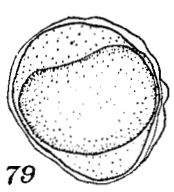
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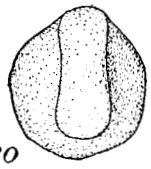
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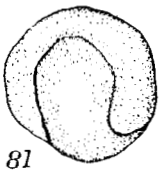
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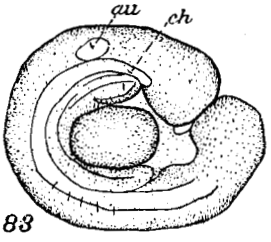

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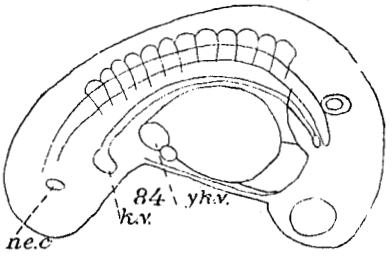

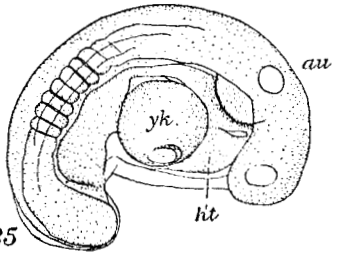

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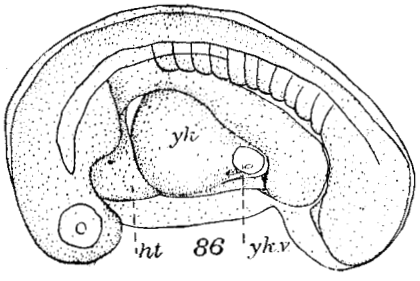

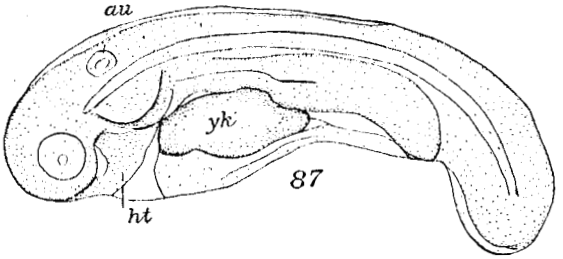

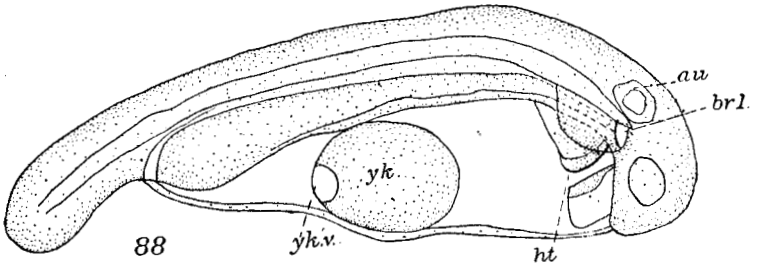

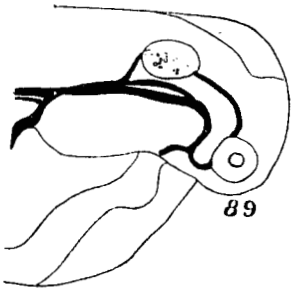
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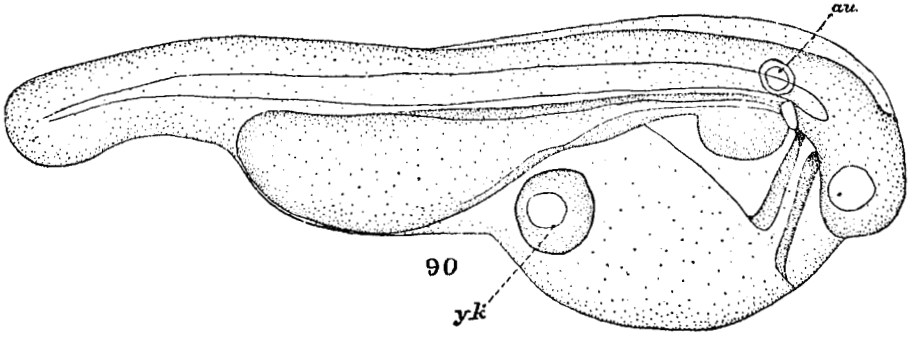

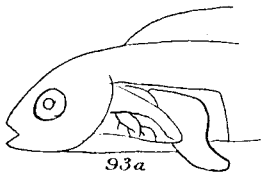
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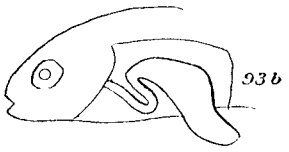
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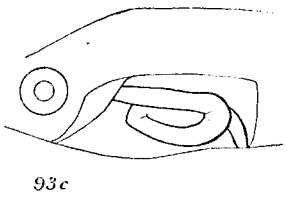
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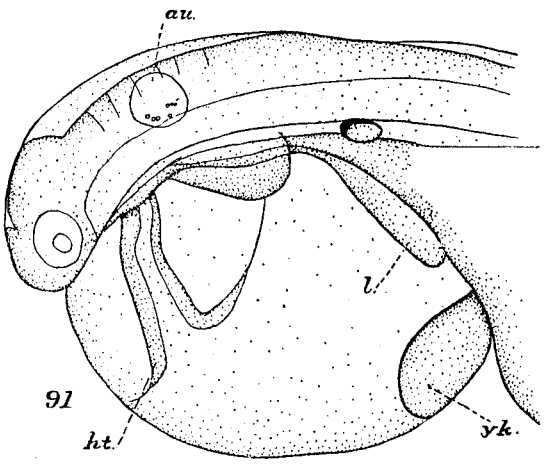
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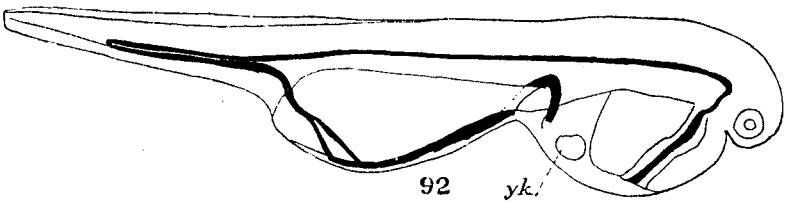
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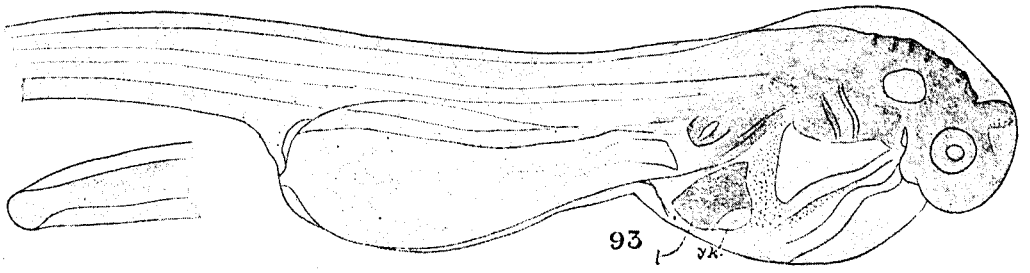
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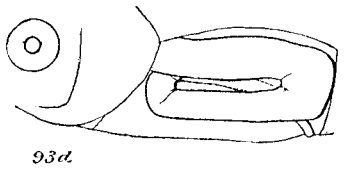
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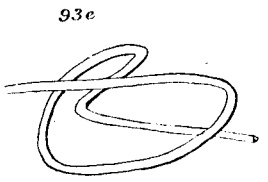
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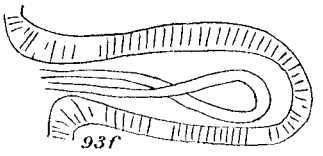
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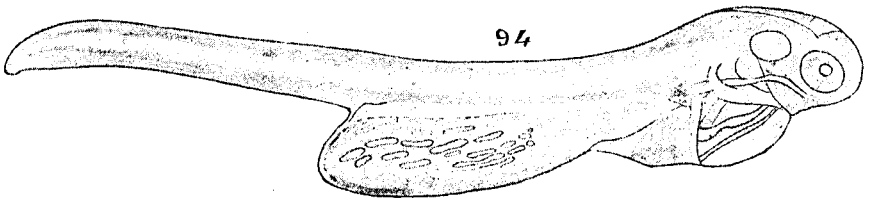
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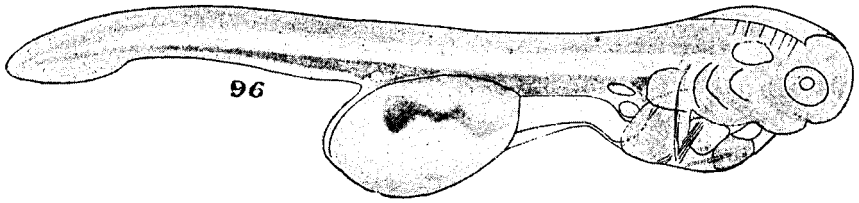
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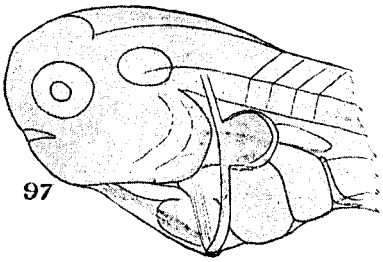
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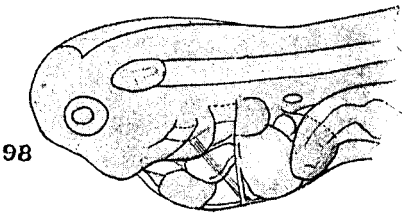
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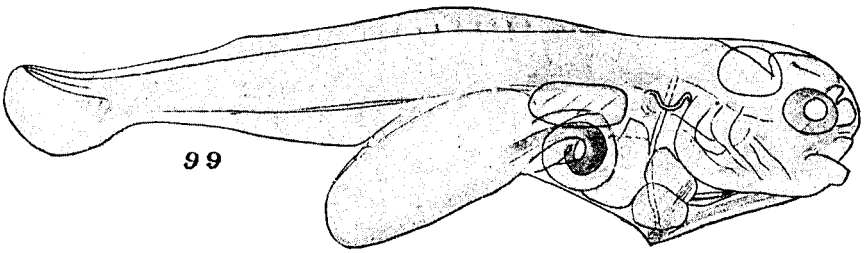
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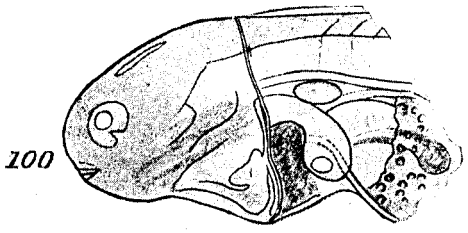
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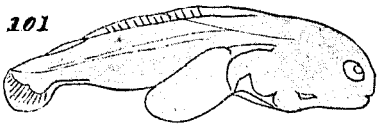
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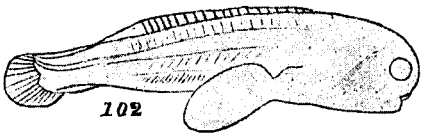
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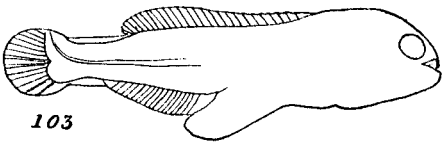
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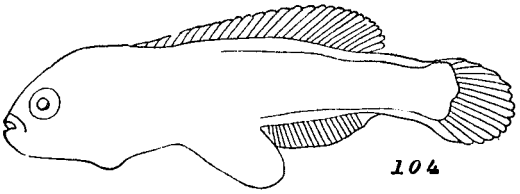
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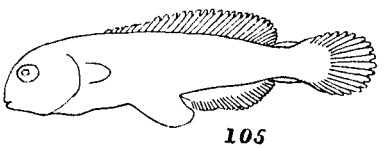
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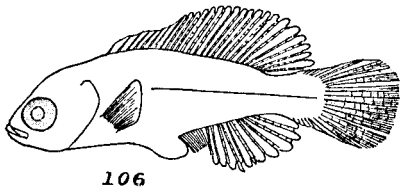

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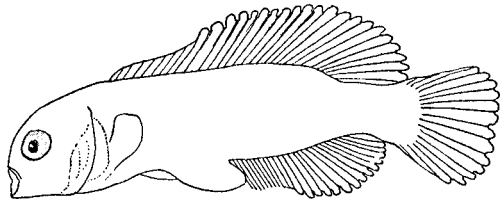

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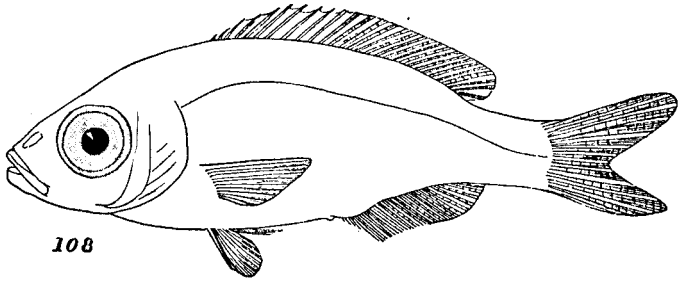

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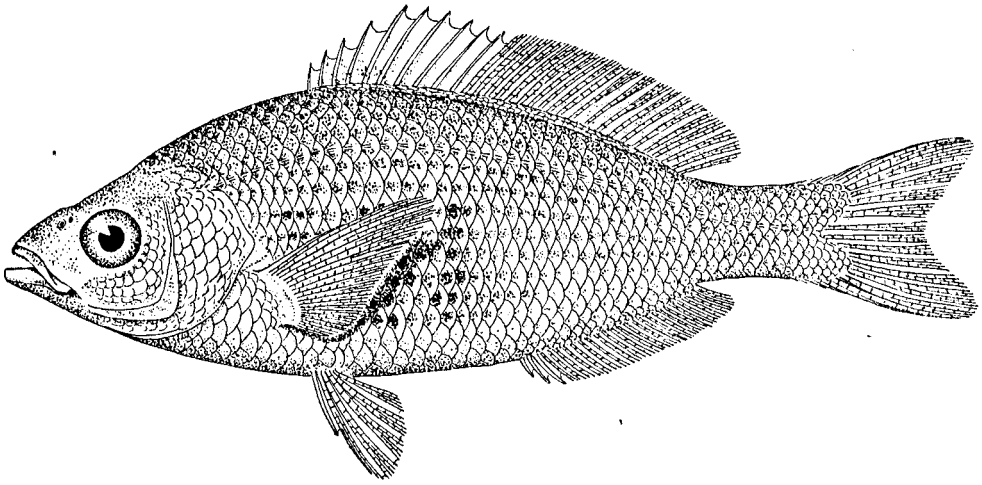
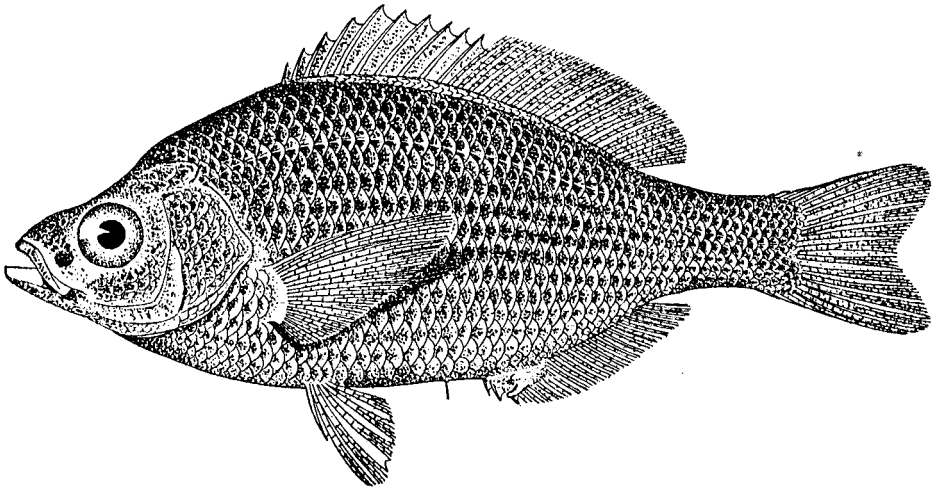
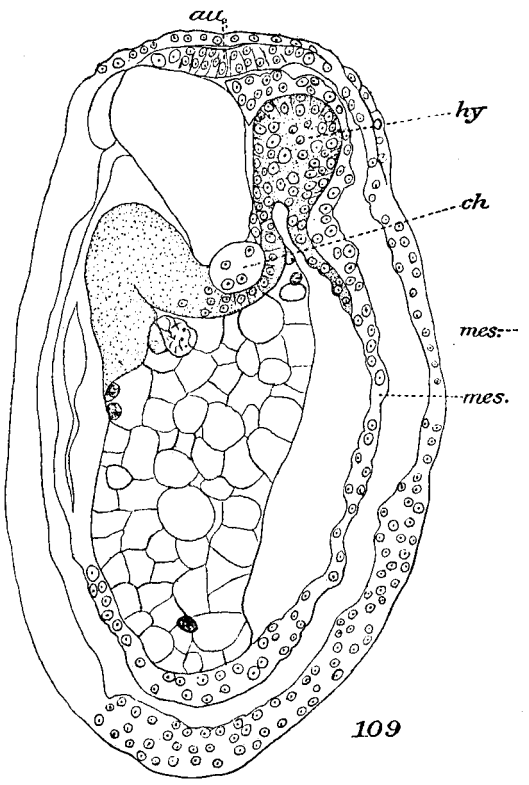


108*a*. CYMATOGASTER AGGREGATUS. Adult female.



108*b*. CYMATOGASTER AGGREGATUS. Adult male.



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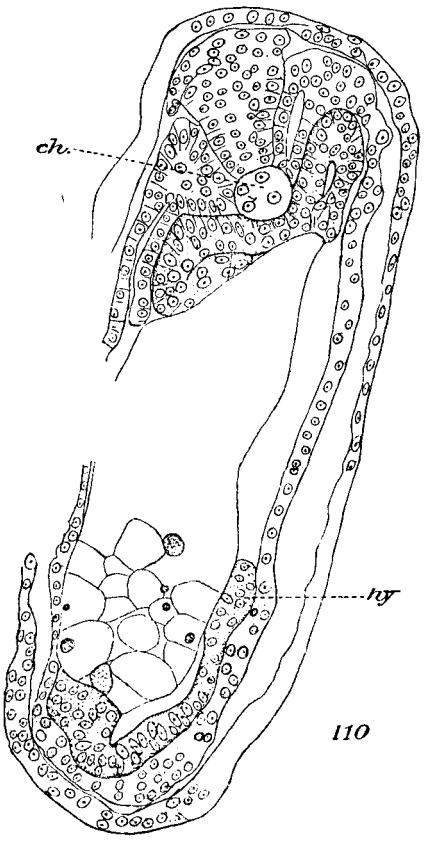

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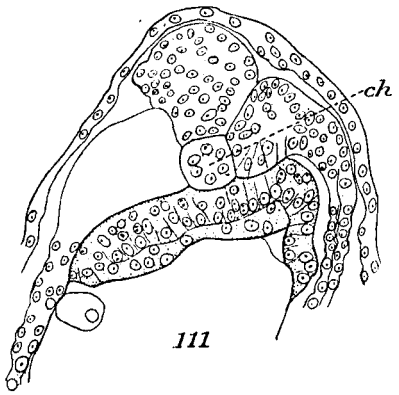

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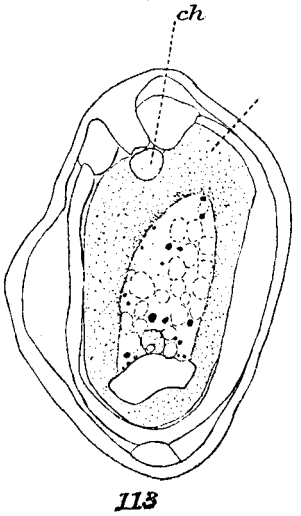

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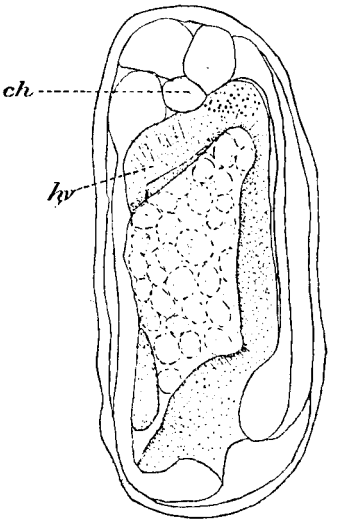

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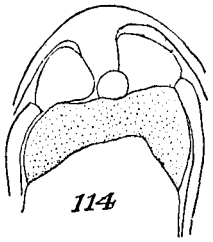

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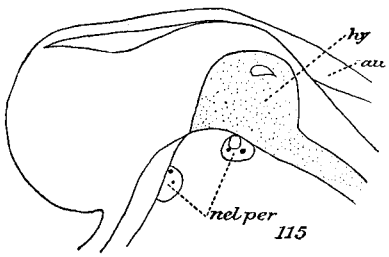

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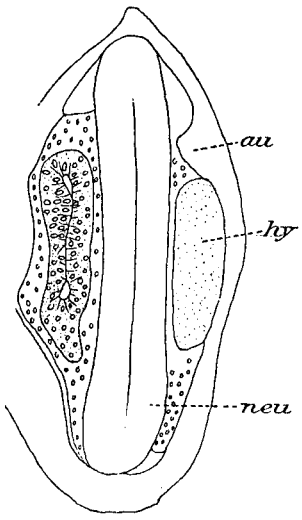

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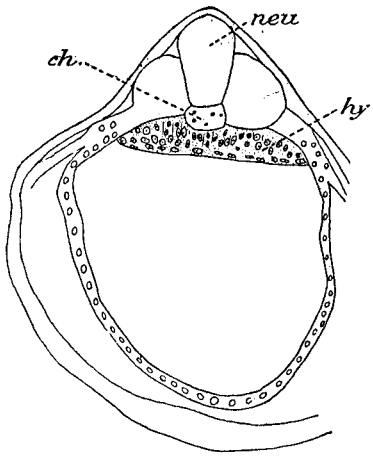

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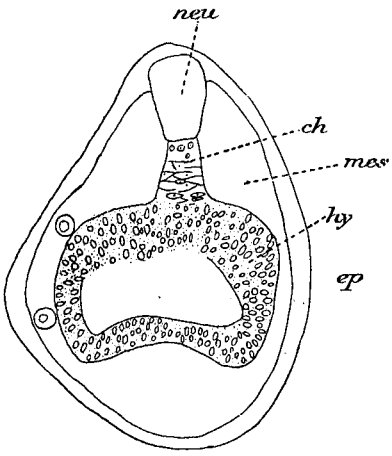

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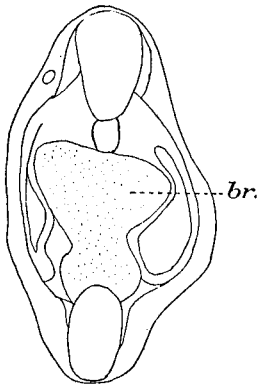

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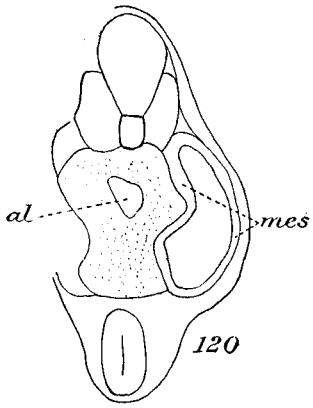

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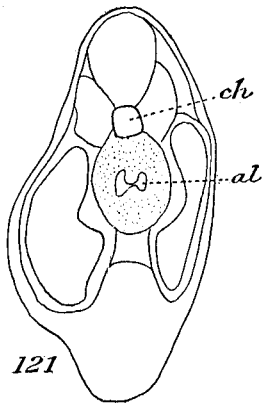

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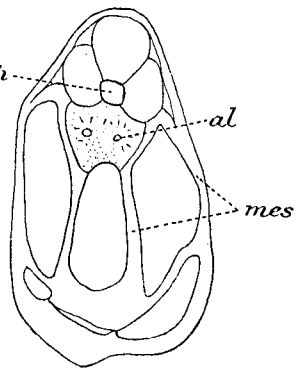

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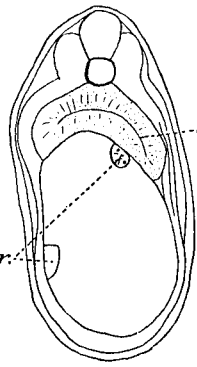

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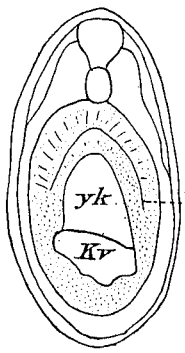

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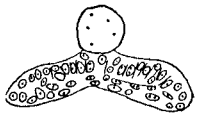
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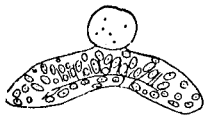
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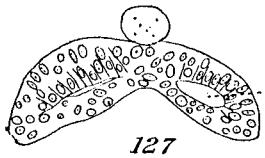

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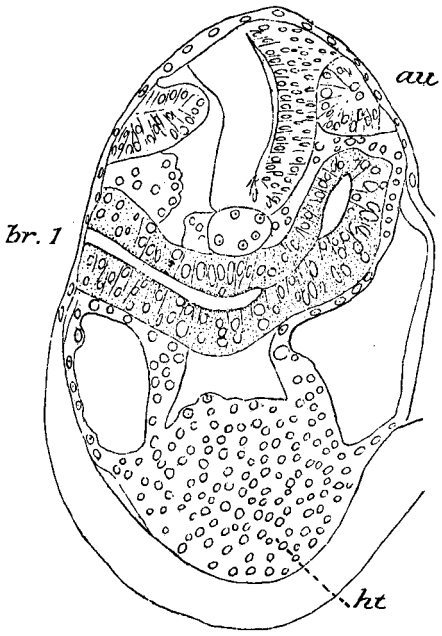

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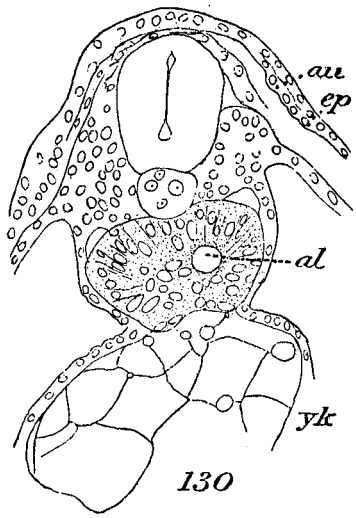

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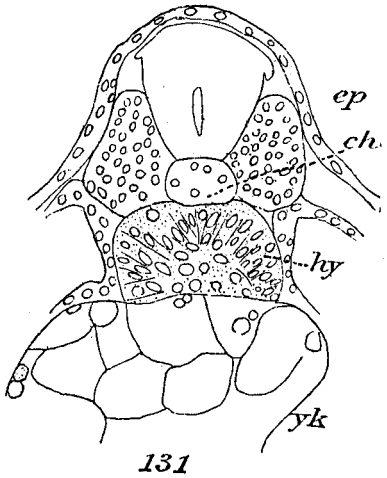

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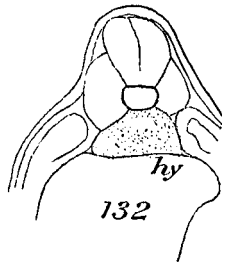

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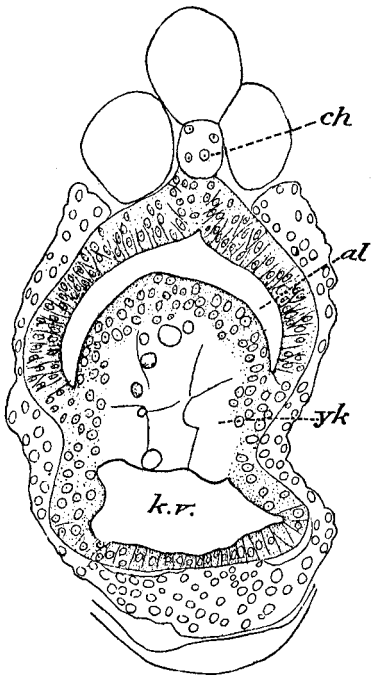

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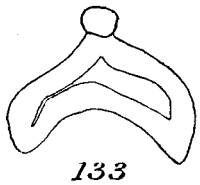

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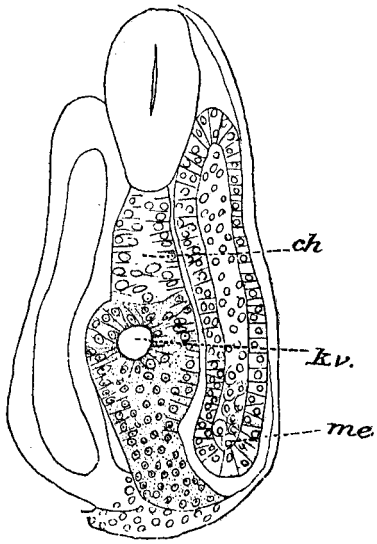

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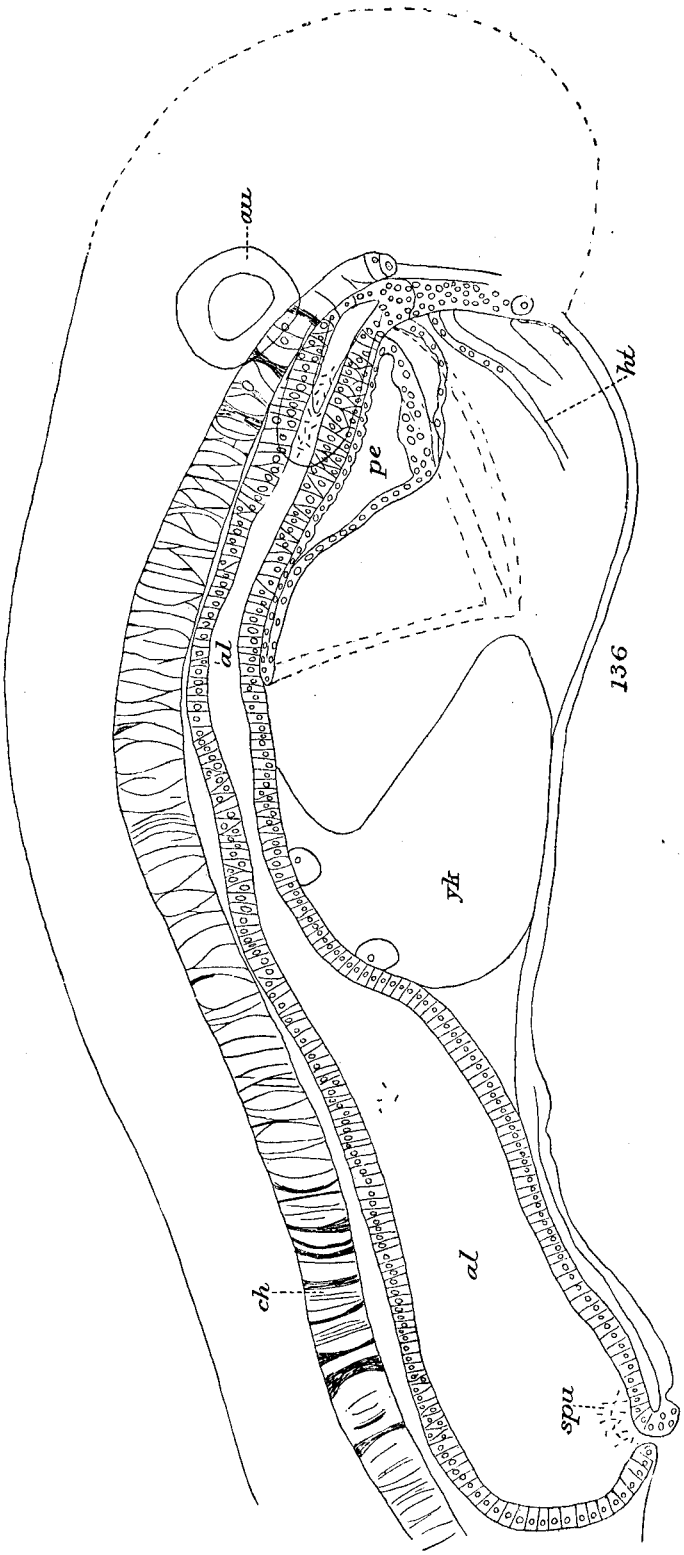

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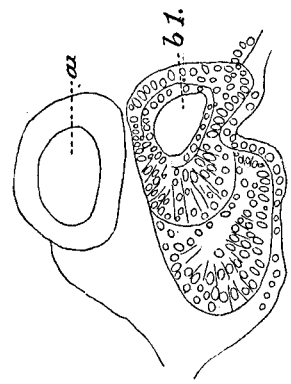

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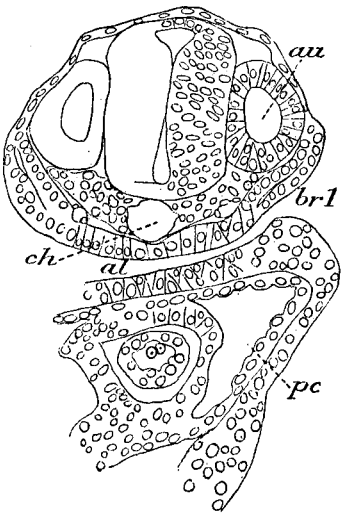

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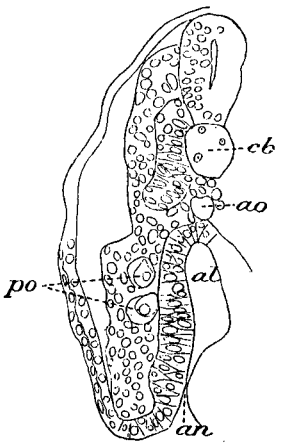

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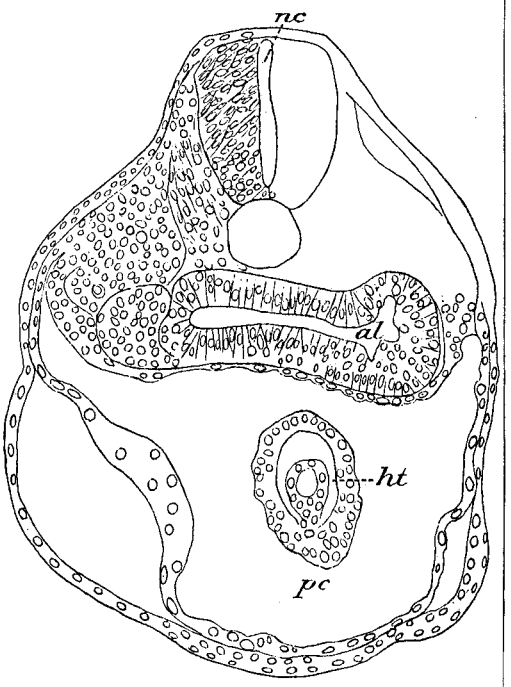

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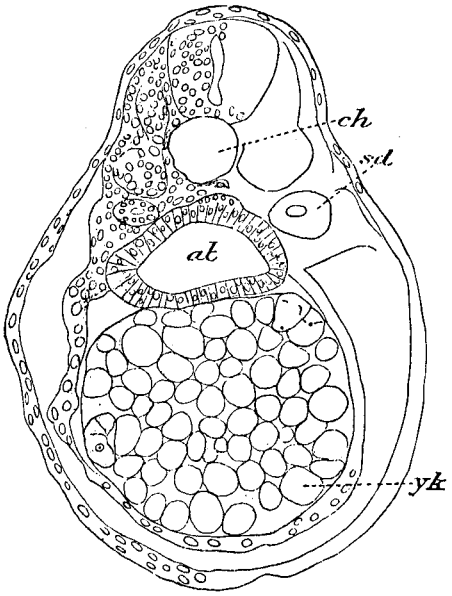

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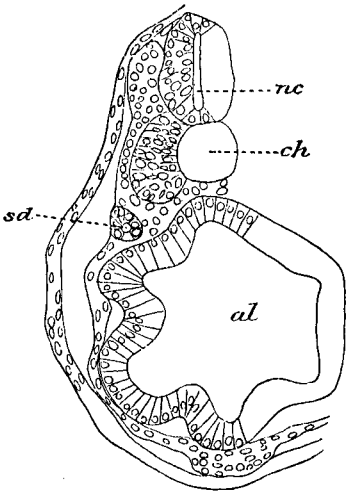

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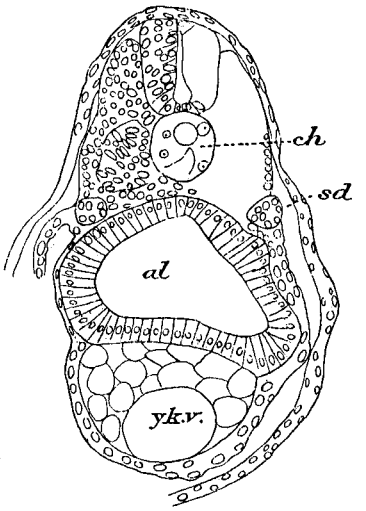

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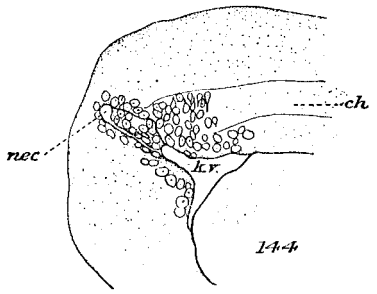

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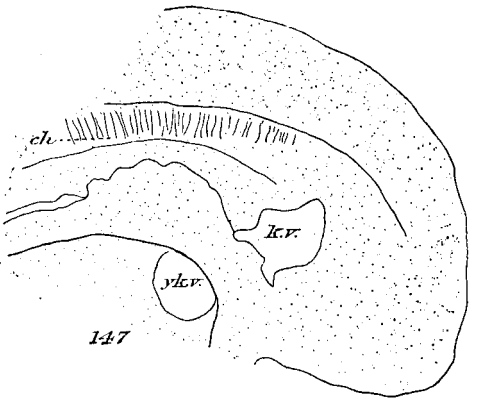

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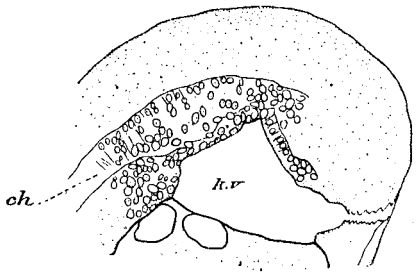

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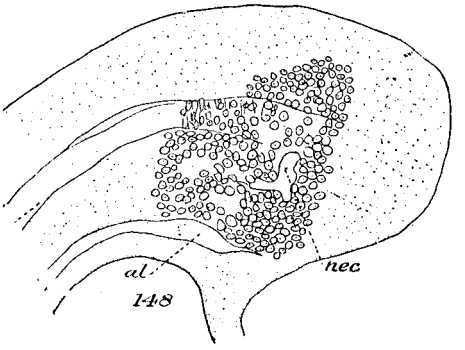

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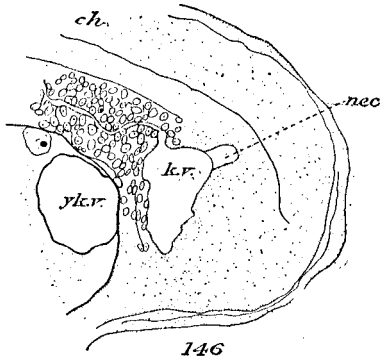

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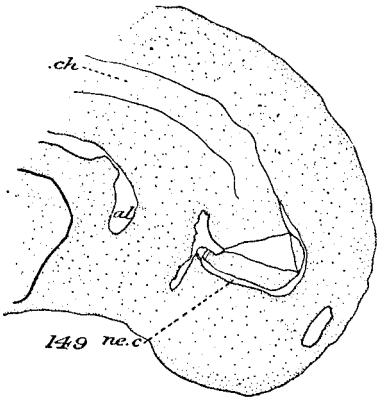

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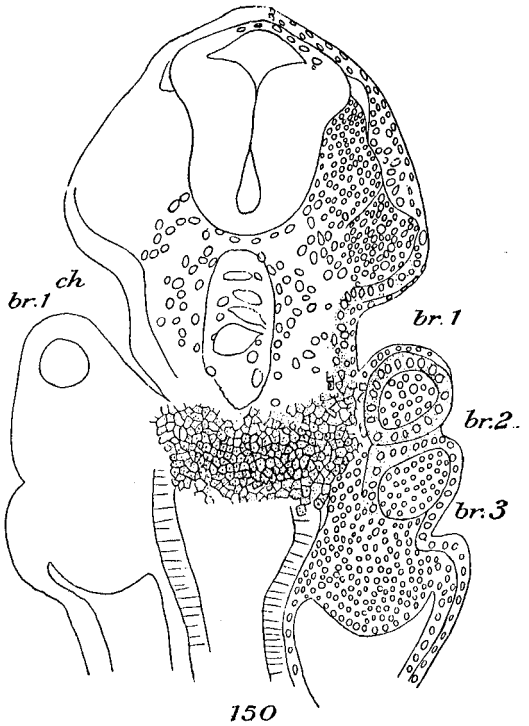

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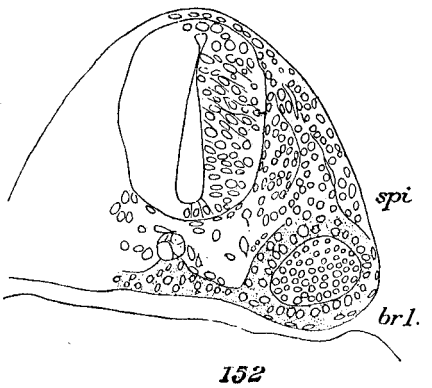

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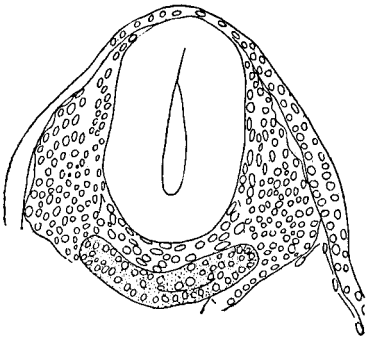

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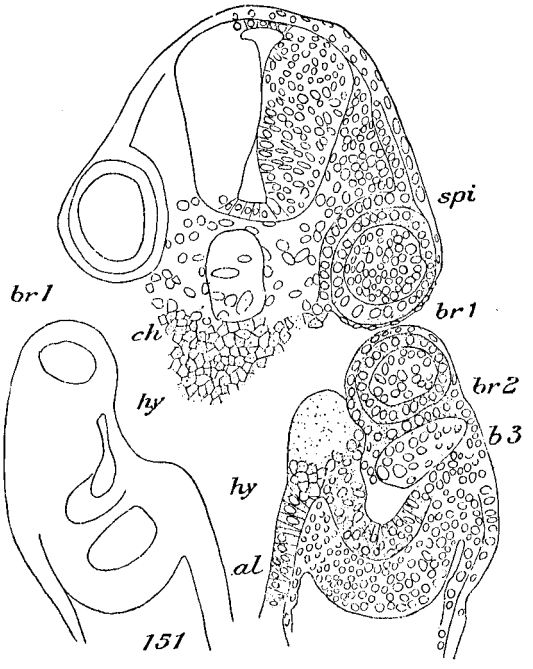

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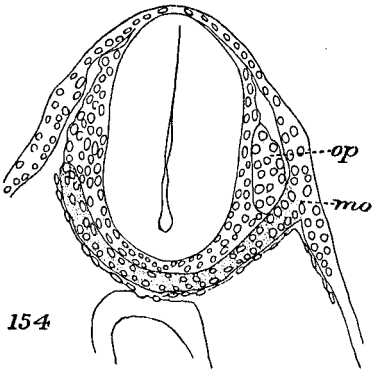

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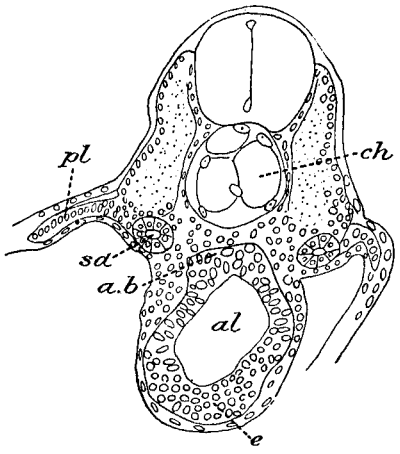

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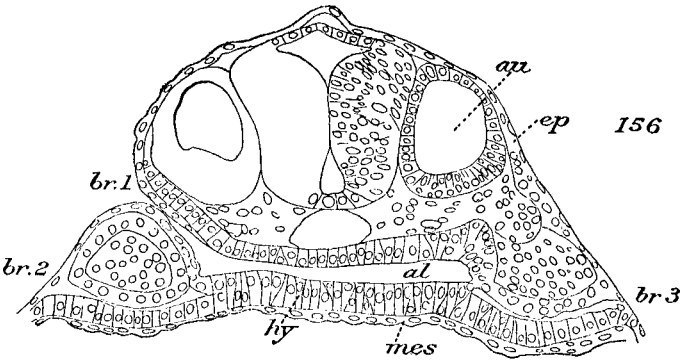

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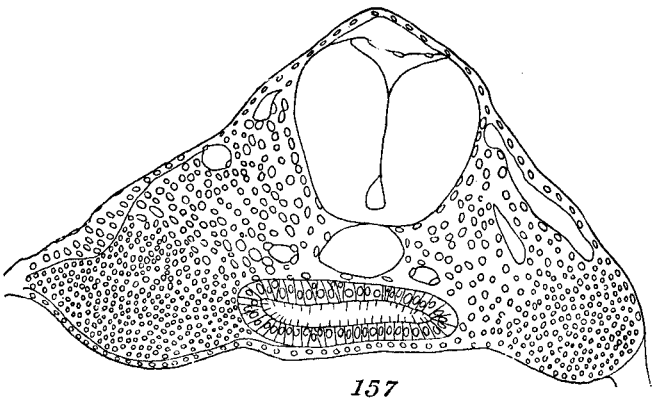

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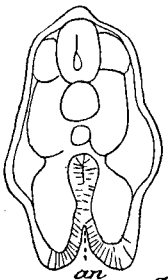

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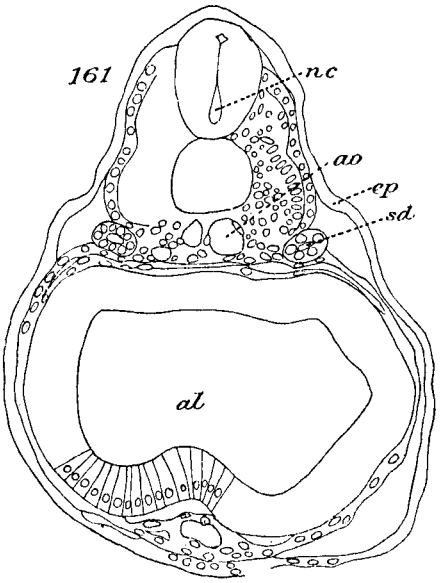

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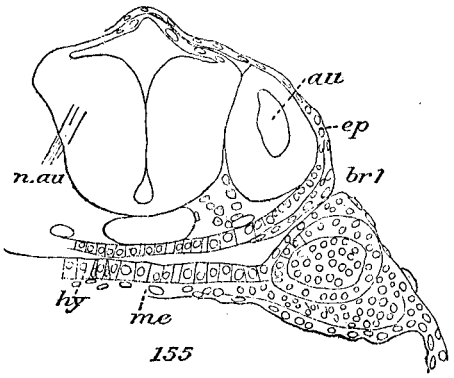

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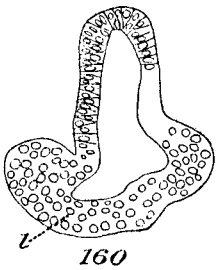

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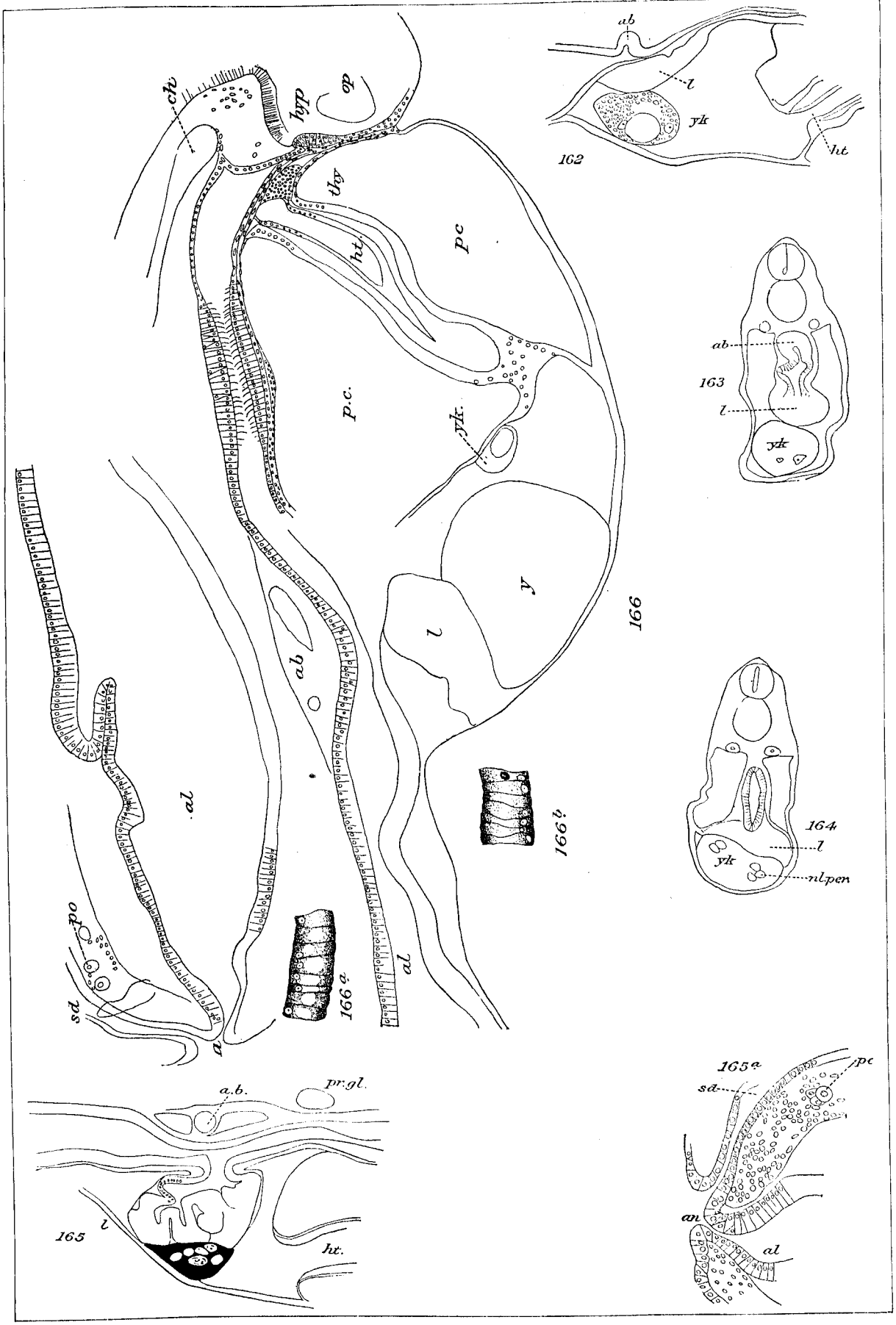
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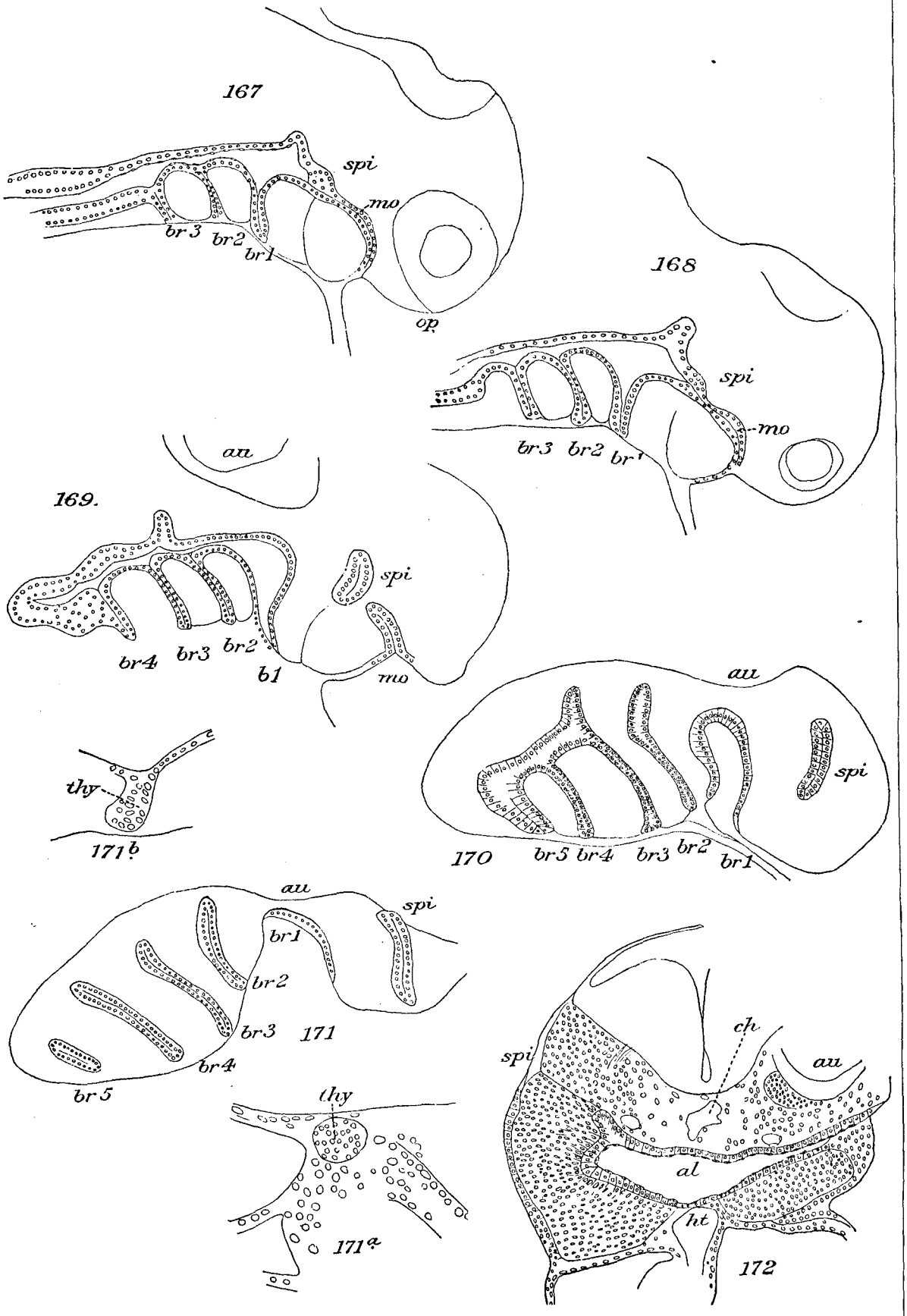
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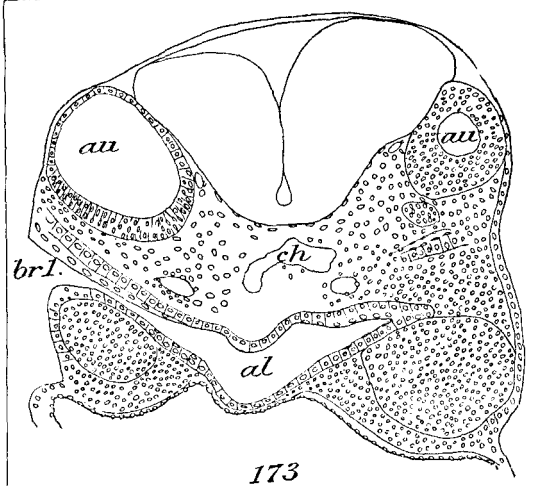

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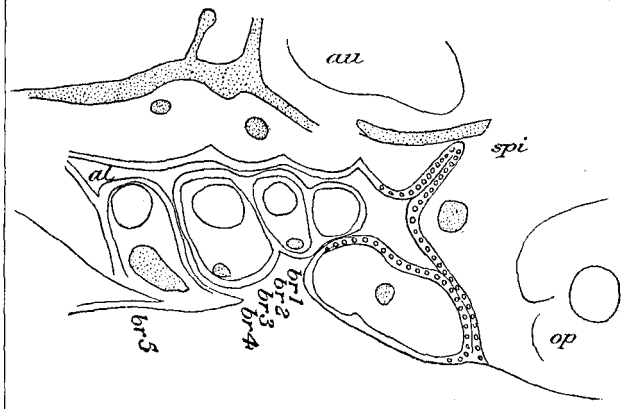

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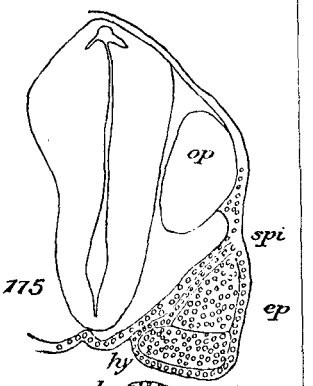

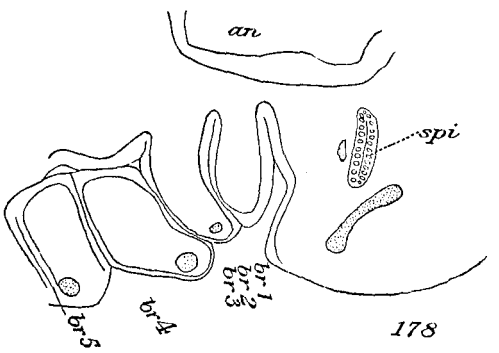

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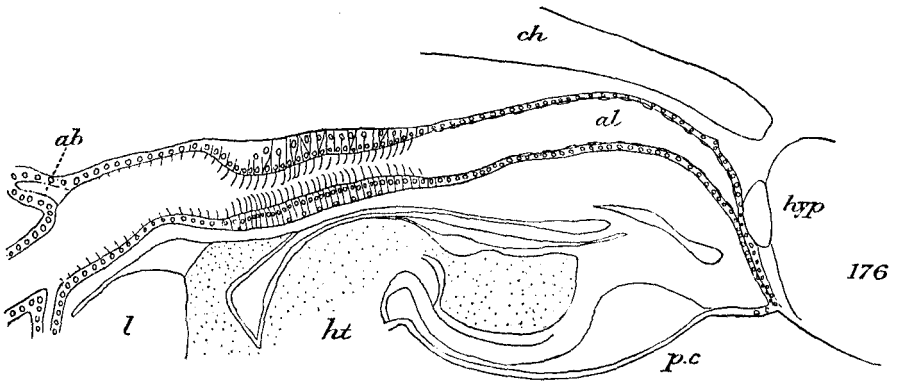

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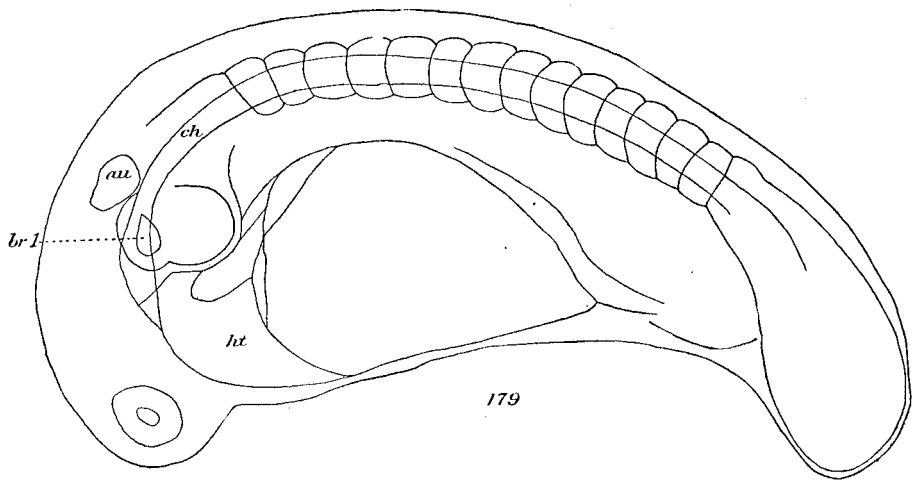

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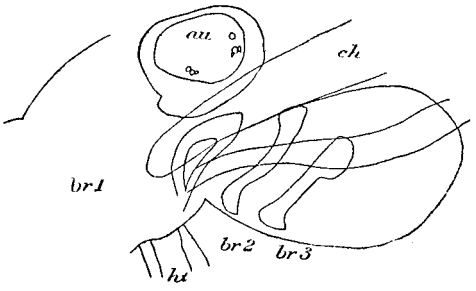

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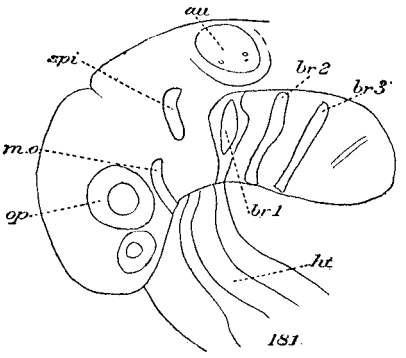

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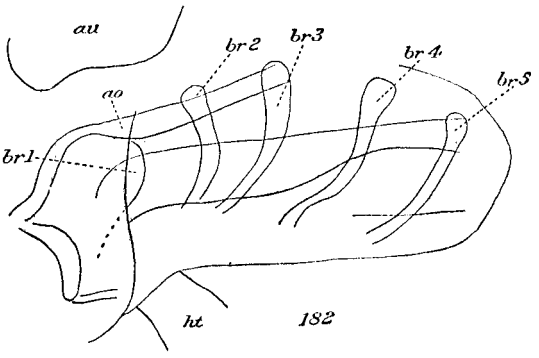

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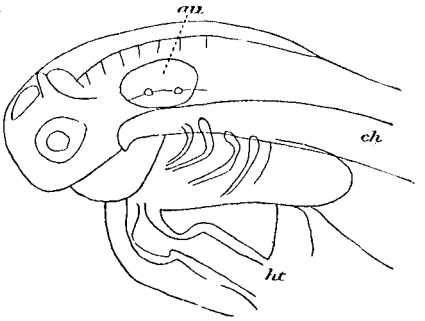

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