


"84 Van Beneden and Julin. La Segmentation chez les Ascidien, etc. *Arch. de Biologie.* T. 5.


"94 Whitman, C. O. The Inadequacy of the Cell-Theory of Development. *Biological Lectures delivered at Wood's Hall, Session of 1893.*


"95 Wilson, E. B. The Embryological Criterion of Homology. *Biological Lectures delivered at Wood's Hall, Session of 1894.*


DESCRIPTION OF PLATES.

All the figures were drawn with the camera lucida under Zeiss apochromatic lenses, Obj. 16mm., Occ. 18. The positions of all the cell walls and nuclei were represented with as great faithfulness as possible. With the exception of Figs. 69-73, Pl. VI, which represent ova of Crepidula plana, all the preparations figured are of C. fornicata. In Pls. II-VI the mesoblast is colored red, the enteroblasts (intestinal cells) blue, mesentoblast violet. In Pl. VII the violet indicates the nervous system. In Pls. VIII and IX yellow indicates the yolk cells, neutral tint ectoderm, and a darker shade of neutral tint mesoderm.
### Reference Letters

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AB</td>
<td>Anterior branch of velum.</td>
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<tr>
<td>AC</td>
<td>Apical cell plate.</td>
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<td>An. C.</td>
<td>Anal cells.</td>
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<tr>
<td>Ant.</td>
<td>Anterior.</td>
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<td>as.</td>
<td>Aster.</td>
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<tr>
<td>Bl.</td>
<td>Blastopore.</td>
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<td>CC</td>
<td>Cerebral commissure.</td>
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<td>CG</td>
<td>Cerebral ganglion.</td>
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<td>C. P.</td>
<td>Cerebro-pedal connective.</td>
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<tr>
<td>Dor.</td>
<td>Dorsal.</td>
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<tr>
<td>Ect.</td>
<td>Ectoderm.</td>
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<td>Ent.</td>
<td>Entoderm.</td>
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<td>E.N.</td>
<td>Egg nucleus.</td>
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<tr>
<td>Ex. K.</td>
<td>External kidney (Urnierc).</td>
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<tr>
<td>Int.</td>
<td>Intestine.</td>
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<td>L.</td>
<td>Left.</td>
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<tr>
<td>Men.</td>
<td>Mesenteron.</td>
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<td>Mes.</td>
<td>Mesoderm.</td>
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<td>O.</td>
<td>Mouth.</td>
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<tr>
<td>Oc.</td>
<td>Ocellus.</td>
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<tr>
<td>O.M.</td>
<td>Opening between yoke cells into mesenteron.</td>
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<td>Ot.</td>
<td>Otocyst.</td>
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<td>P.</td>
<td>Foot.</td>
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<td>PB</td>
<td>Posterior branch of velum.</td>
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<tr>
<td>PC</td>
<td>Posterior cell plate.</td>
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<tr>
<td>P. Cav.</td>
<td>Cavity of foot.</td>
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<td>P. Com.</td>
<td>Pedal commissure.</td>
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<tr>
<td>PG</td>
<td>Pedal ganglion.</td>
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<tr>
<td>ff</td>
<td>Polar furrow.</td>
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<tr>
<td>Post.</td>
<td>Posterior.</td>
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<tr>
<td>Post. O. V.</td>
<td>Post-oral velum.</td>
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<tr>
<td>Pre. O. V.</td>
<td>Pre-oral velum.</td>
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<tr>
<td>PP</td>
<td>Pedal cell plate.</td>
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<tr>
<td>R.</td>
<td>Right.</td>
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<tr>
<td>Sh.</td>
<td>Shell.</td>
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<td>Sh. G.</td>
<td>Shell gland.</td>
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<td>Sh. G. E.</td>
<td>Margin of shell gland.</td>
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<tr>
<td>SN</td>
<td>Sperm nucleus.</td>
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<td>St</td>
<td>Stomodaeum.</td>
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<tr>
<td>T.</td>
<td>Tentacle.</td>
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<tr>
<td>UC</td>
<td>Umbrella cavity (head vesicle).</td>
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<td>V.</td>
<td>Vellar ridge.</td>
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<tr>
<td>V. 1</td>
<td>First cell row of velum.</td>
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<td>V. 2</td>
<td>Second cell row of velum</td>
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<tr>
<td>L.</td>
<td>First cleavage plane.</td>
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<tr>
<td>II</td>
<td>Second cleavage plane.</td>
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<tr>
<td>1st. pb.</td>
<td>First polar body.</td>
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<tr>
<td>2nd. pb.</td>
<td>Second polar body.</td>
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**A.** Left anterior macromere.

**B.** Right anterior macromere.

**C.** Right posterior macromere.

**D.** Left posterior macromere.

1a, 1b, 1c, 1d, 1a', etc. First quartette of ectomeres.

2a, 2b, 2c, 2d, 2a', etc. Second quartette of ectomeres.

3a, 3b, 3c, 3d, 3a', etc. Third quartette of ectomeres.

4A, 4B, 4C, 4D. Fourth quartette (Entomeres and mesomeres).

5A, 5B, 5C, 5D. Fifth quartette (Entomeres).

**ME, ME, Me, Me.** Mesentoblasts.

**M, M.** Mesoblastic teloblasts.

**E, E, e, e.** Enteroblasts (intestinal cells).
EXPLANATION OF PLATE I.

Fig. 1. Egg of Crepidula fornicata, from side, showing male and female pronuclei in contact.

Fig. 2. First cleavage spindle, seen from above.

Fig. 3. Appearance of first cleavage furrow, seen from side. Daughter nuclei not yet reconstituted.

Fig. 4. Same egg as Fig. 3, seen from above.

Fig. 5. Completion of first cleavage furrow. Nuclei and asters opposite each other in the two blastomeres. Polar bodies between the two nuclei.

Fig. 6. "Resting stage" after first cleavage, showing flattening of blastomeres against each other and dextrorotary turning of nuclei, asters, and protoplasmic areas.

Fig. 7. Beginning of second cleavage. Laeotropical turning of spindles and protoplasmic areas.

Fig. 8. Three-cell stage; an unusual condition, in which one of the first two blastomeres divides before the other.

Fig. 9. Second cleavage; usual condition, in which the two blastomeres divide simultaneously. Polar furrow appearing at $pf$.

Fig. 10. Completion of second cleavage. Asters nearly in position of the poles of preceding spindles. Polar furrow well formed.

Fig. 11. "Resting stage" after second cleavage. Four cells.

Fig. 12. Third cleavage. Spindles nearly radial.
EXPLANATION OF PLATE II.

Fig. 13. Completion of first quartette. Position of poles of preceding spindles as indicated by asters show that division was dexiotropic. Eight cells.

Fig. 14. Fourth cleavage, laeotropic. First quartette has rotated into furrows between macromeres.

Fig. 15. Completion of second quartette and laeotropic rotation of ectomeres. Twelve cells.

Fig. 16. Fifth cleavage. Laeotropic division of first quartette and formation of "turret cells" (trochoblasts), 1a, 1b, 1c, 1d.

Fig. 17. Sixth cleavage, dexiotropic. Formation of third and last quartette of ectomeres. Sixteen cells.

Fig. 18. First division of second quartette, dexiotropic. 3d has recently been separated from macromere D and still shows astral radiations. Twenty cells.

Fig. 19. "Resting stage," showing quadrangular plate of ectomeres with angles of plate in furrows between macromeres. Twenty-four cells, 4 apicals, 4 turrets, 12 belt cells, and 4 macromeres.

Fig. 20. Ectoblastic plate removed from macromeres, showing the overlapping of cells.

Fig. 21. Laeotropic division of D and formation of first member of fourth quartette, the mesentoblast 4d (ME). Twenty-four cells.

Fig. 22. Second division of first quartette (dexiotropic) and formation of basal cells of cross. The spindle has not yet appeared in 1d. Twenty-five cells.

Fig. 23. Complete separation of basal cells of cross (1a1\(^2\), 1b1\(^2\), 1c1\(^2\), 1d1\(^2\)). Twenty-nine cells.

Fig. 24. Side view of egg of about the same stage as Fig. 23, showing the relation of the mesentoblast to macromere D. 3d dividing.
EXPLANATION OF PLATE III.

**Fig. 25.** Dexiotropic division of the mesentoblast, 4D. The cell 3d is dividing almost radially. Twenty-nine cells.

**Fig. 26.** Separation of 4D into right and left halves. Radial division of 3c and 3b (3a divides a little later). Dexiotropic division of 2a', 2b', 2c', 2d' and formation of tip cells of cross (2d'+, 2c'+, etc.).

**Fig. 27.** Same egg seen from the posterior side, showing position of right and left mesentoblasts and direction of spindles in some of the outer belt cells.

**Fig. 28.** Same egg seen from right side, showing direction of spindles in outer belt cells.

**Fig. 29.** "Resting stage" after the divisions shown in preceding figures. The cross is shown here and elsewhere in heavier outline. Forty-two cells, 4 apicals, 3 cross, 4 turrets, 20 belt cells, 2 mesentoblasts, 4 macromeres.

**Fig. 30.** Bilateral division of mesentoblasts.

**Fig. 31.** Completion of cleavage shown in preceding figure and formation of enteroblasts, E' and E''. *Dexiotropic* division of basal cells of cross, 1a', 1b', (1c'. divides a little later). Forty-four cells.

**Fig. 32.** Completion of division of basal cells in arms a, b, and c, and formation of middle cells, 1a', 1b', 1c'. Second bilateral division of mesentoblasts. Forty-seven cells.

**Fig. 33.** Completion of division of mesentoblasts shown in preceding figure and formation of the primary mesoblast cells m' and m''. *Laeotropic* division of the macromeres A, B, and C and formation of the remaining members of the fourth quartette, 4A, 4B, 4C. *Laeotropic* rotation of whole ectoblastic plate. Fifty-two cells.

**Fig. 34.** Side view of same egg, showing laeotropic formation of fourth quartette. Cf. Fig. 24.

**Fig. 35.** Division of 2c', 2c', 2b', 2b' (2a' and 2a' divide immediately after). Flattening of cells 4A, 4B, 4C into furrows between macromeres.

**Fig. 36.** Completion of divisions shown in preceding figure. Bilateral cleavage of 3c' and 3d' (3a' and 3b' divide later, see Fig. 38). Sixty cells.
EXPLANATION OF PLATE IV.

Fig. 37. Anterior view of egg shown in Fig. 36.

Fig. 38. Dextrotropic division of 3a1 and 3b1. Division of 2d1.2 and 2d1.1 (the corresponding divisions in the other quadrants are shown in Fig. 36). Sixty-four cells.

Fig. 39. Posterior view of same egg.

Fig. 40. Anterior view of another egg of nearly the same stage, showing division of 3b1.

Fig. 41. Third bilateral division of mesentoblasts. Belated division of 2a1.1.

Fig. 42. Complete separation of mesoblast and entoblast. Formation of enteroblasts, e1 and e1, and of mesoblastic teloblasts, M1 and M2. Division of primary mesoblast cells, m1 and m2. Transverse division of the middle cells in the right, left, and anterior arms of the cross; teloblastic division of the basal and terminal cells of the posterior arm. Division of 3b2 a little before the corresponding cells in the other quadrants. Sixty-eight cells.

Fig. 43. Anterior view of another egg of similar stage, showing the division of 3b2 and 3c2.

Fig. 44. "Rosette division" of the apical cells. Transverse division of the tip cells in arms a, b, and c. The cell 3c1.2 is dividing, 3d1.2 has divided. Eighty to eighty-six cells.

Fig. 45. Same egg seen from the posterior side.

Fig. 46. Transverse division of the basal cells in the arms a, b, and c. Nearly horizontal division of 2a1.1, 2a1.2, 2b1.1, 2b1.2, etc. Lactotropic division of 2a1.2, 2b1.2, etc. Dextrotropic division of 3b1.1, lactotropic division of 3b1.2 (the corresponding cells in the quadrant A divide soon after, 3c1.2 and 3d1.2 have already divided, 3c1.1 and 3d1.1 do not divide). One hundred and nine cells, — 4 apicals, 4 rosette, 4 turrets, 22 cross cells, 58 outer belt cells, 6 mesoblasts, 4 enteroblasts, 7 entoblasts.

Fig. 47. Same egg seen from anterior side, showing direction of spindles in outer belt cells.

Fig. 48. Posterior view of slightly older stage, showing teloblastic divisions of posterior tip cells (2d1.1.1 and 2d1.1.2) and other cells of the same group (2d).
EXPLANATION OF PLATE V.

Fig. 49. Division of the right and left middle cells in the arms a, b, and c, and the expansion of these arms into a cell plate. The posterior arm is much elongated, and the posterior turrets and adjoining cells are much enlarged, forming the posterior cell plate. The apical cells lie anterior to the polar furrow.

Fig. 50. Apical view, showing the cross in heavy outline. The anterior turret cells (1a' and 1b') have divided, and their products, together with those of 2b1a,2c, form a belt of six cells around the anterior side of the cross; this belt, together with the tip cells of the right and left arms (2a1,1,2, 2a1,1,2, and 2b1,1,2, 2b1,1,2) form the first velar cell row, or prototroch. The posterior turrets (1c' and 1d') are undivided. (See Note, p. 204.)

Fig. 51. Bilateral division of the outer rosette cells (1a1,1,2, etc.), forming four "rosette series." The last stage in which the polar bodies remain attached. Continued anterior shifting of the apical pole.

Fig. 52. Ventral view of nearly the same stage as preceding, showing quadrangular blastopore, the enteroblasts in its posterior angle.

Fig. 53. Division of the right, left, and posterior apical cells and of the right and left basal cells in the transverse arms; the basal cells of the anterior arm have already divided.

Fig. 54. Ventral view of a slightly older stage, showing the narrowing of the blastopore and the division of the macromeres A and C.

Fig. 55. Dorsal view, showing great enlargement of the proximal cells of the posterior arm, and the continued forward shift of the apex.

Fig. 56. Apical view of about same stage as preceding figure. Cross shown in heavy outline. First velar row (prototroch) surrounds cross on anterior side.

Figs. 57-60. The ectoblast has been omitted from these figures in order to show more clearly the entoblast cells. The extent of overgrowth of the ectoblast is indicated by the margin of the blastopore.

Fig. 57. Formation of the fifth quartette; 5A and 5B on the ventral side of A and B, 5C posterior to C. Antero-posterior elongation especially on right side (left in figures).

Fig. 58. Fourth-quartette cells (4A and 4C) dividing. 4B divides immediately after.

Fig. 59. Fourth quartette (4A, 4B, 4C) divided; macromere D dividing. Turning of the posterior end to the left and beginning of final asymmetry.

Fig. 60. Completion of the 5th quartette by the formation of 5D, which lies opposite 5C. Division of the enteroblast E'.
EXPLANATION OF PLATE VI.

**Fig. 61.** A stage after the formation of 5A, 5B, and 5C, but before the formation of 5D, showing the ectoblast in position. Mesoblastic bands hard to distinguish and not shown.

**Fig. 62.** Anterior view of egg of about same stage as Fig. 61. The apical cells, rosette series, and turret cells are shown. In this and the following figure the cells 2b1.2.2.1.1 (V') and 2b1.2.2.1.2 (V') should probably be designated 1b1.2.2.2.1.2 and 1b1.2.2.2.2, while the first velar row is probably formed, just ventral to these cells. (See Note, p. 204.)

**Fig. 63.** Narrowing of the blastopore.

**Fig. 64.** Dorsal view, showing apical cells, rosette series, posterior turrets, and proximal cells of posterior arm. The apex is far in front of the polar furrow.

**Fig. 65.** Closing of the blastopore and beginning of the stomodaenum. The apex has moved forward until it can be seen from the ventral side; it lies to the right (left in figure) of the mid line. Between the apex and the first velar row are the seven large cells of the apical cell plate. Both first and second velar cell rows are indicated. Many rows of cells radiate from the anal cells, running forward over the ventral surface posterior to the blastopore. The enteroblasts are turned to the right (left in figure) by the laeotropic torsion of the posterior region. In Figs. 65-73 the cells labelled 1b1.2.2.2.2.2 and 1b1.2.2.2.2.2 should probably be 1b1.2.2.2.2.2 and 1b1.2.2.2.2.2 respectively, and the arrows showing the derivation of these cells should be moved one cell nearer the apex so as to connect 1b1.2.2.2.2.2 and 1b1.2.2.2.2.2.

**Fig. 66.** Stage similar to the preceding, showing still more clearly the apical cell plate and the first and second velar rows.

**Fig. 67.** Apical view of same, showing apical cells, rosette series, posterior cell plate, apical cell plate, and first and second velar rows.

**Fig. 68.** Stage similar to the preceding, but showing in addition the stomodaenum, the shape and extent of the mesenteron, the division of the cell 5D and its rotation over to the ventral side, and the consequent looping of the intestine to the right (left in figure).

**Fig. 69.** Egg of C. plana, showing some of the cells of the apical cell plate and of the first and second velar rows. In Figs. 69-71 the cell marked 2b1.1-1 is probably 1b1.2.2.2.2.2 whereas the median cells of the first velar row (V) probably represent the derivatives of the anterior tip cells (2b1.1).

**Fig. 70.** Egg of C. plana, showing further stages in the degeneration of the cells marked 2b1.1-1 (7).

**Fig. 71.** Egg of C. plana, showing the earliest stage observed in the degeneration of the cells marked 2b1.1-1 and 2b1.1-2.

**Fig. 72.** Egg of C. plana, showing apical plate and velar cell rows.

**Fig. 73.** Egg of C. plana a little older than the preceding, showing apical plate, velar rows, mesoblast, and enteroblasts.
EXPLANATION OF PLATE VII.

Fig. 74. Dorsal view of an embryo of C. fornicata. The apical cells lie at the anterior margin of the figure, the dorsum is covered by the large cells of the posterior cell plate, the shell gland is forming on the postero-dorsal surface a little to the left of the mid line. The four macromeres and the polar furrow are still recognizable.

Fig. 75. Embryo similar to the preceding, but showing the invagination of the shell gland.

Fig. 76. Ventral view of an older embryo, showing the beginnings of the nervous system and the laeotropic torsion of the intestine. The foot is appearing as a prominent area posterior to the mouth.

Fig. 77. Side view of same embryo, showing the branching of the velum on each side of the posterior cell plate, and the relation of the intestine to the shell gland and foot.

Fig. 78. Side view of older embryo, showing head and foot vesicles, apical plate and organ, cerebral ganglia and commissure, posterior and pedal cell plates, anterior and posterior branches of the velum, expanding shell gland, external kidney, stomodaeum and mesenteron.

Fig. 79. Apical view of same stage, showing apical, posterior and pedal cell plates, pre- and post-oral velum, apical organ and cerebral ganglia.

Fig. 80. Side view of older embryo. Intestine carried up on right side and opening at its proximal end into cavity between the yolk cells. Intestine surrounded by single layer of cells inclosing a clear cavity.

Fig. 81. Ventral view of similar embryo, showing circum oesophageal nerve ring, pre- and post-oral velum, etc.

Fig. 82. Apical view of still older embryo, showing pre- and post-oral velum, ocelli, otocysts, etc.
EXPLANATION OF PLATE VIII.

Fig. 83. Section of egg in four-cell stage, showing inclination of spindles in the formation of the first quartette.

Fig. 84. Section of egg similar to the one shown in Fig. 15. Formation of second quartette. Position of spindles not usually so nearly in the same plane.

Fig. 85. Section of egg similar to the one shown in Fig. 25. Extension of ectoblast over the yolk cells.

Fig. 86. Section of egg similar to Fig. 41 or 42. Further extension of ectoblast. Migration of nuclei and protoplasmic areas of the yolk cells in advance of ectoblast. Mesoblast cells seen in section.

Fig. 87. Transverse section of egg similar to Fig. 52.

Fig. 88. Vertical longitudinal section of embryo similar to Fig. 65 or 68. As the section is taken to one side of the mid line the opening from the stomodaeum into the mesenteron is not shown. Small yolk cells, derivatives of the fourth quartette, form the floor of the mesenteron.

Fig. 89. Median horizontal section through embryo of same stage as preceding, showing mesoblast and enteroblast cells at the posterior end.

Fig. 90. Median transverse section of same stage as preceding, showing opening from stomodaeum into mesenteron. Here and elsewhere the smaller yolk cells form the floor and sides of the mesenteron.

Fig. 91. Vertical longitudinal section of stage shown in Fig. 74.

Fig. 92. Vertical longitudinal section of stage shown in Fig. 75, showing invagination of shell gland and formation of intestine.

Fig. 93. Oblique longitudinal section of stage shown in Fig. 78. At the posterior end the section lies to the right of the mid line, and hence passes through the opening from the intestine into the mesenteron. The shell gland has evaginated, and the intestine has been carried to the ventral side. By the growth of the foot the mouth has been carried far forward. The mesenteron contains a coagulum derived from the albuminous fluid in which the embryos are immersed in the capsules.

Fig. 94. Horizontal section of the same stage as the preceding taken in the direction of a line connecting the points CC. and Int. of Fig. 93. The formation of the cerebral ganglia and the cerebro-pedal connectives is shown.
EXPLANATION OF PLATE IX.

Fig. 95. Vertical longitudinal section, stage similar to Fig. 78. At the posterior end the section cuts the intestine as a tube (cf. Figs. 76 and 81).

Fig. 96. Coronal section of embryo of stage shown in Fig. 78, taken through apical organ, cerebral ganglia, and foot.

Fig. 97. Section from same series as preceding, two sections farther back, showing cerebro-pedal connectives and otocysts.

Fig. 98. Section similar to preceding, taken just posterior to the opening of the stomodaeum into the mesenteron.

Fig. 99. Horizontal section of embryo similar to Fig. 79, taken in the direction of a line connecting the points O and V1 in that figure.

Fig. 100. Horizontal section of embryo similar to Fig. 76, showing formation of otocysts and intestine.

Fig. 101. Horizontal section of embryo similar to Fig. 80, taken a little above reference line V of that figure.

Fig. 102. Horizontal section of embryo similar to Fig. 80, taken near the dorsal side and through the intestinal cell plate which forms the dorsal boundary of the intestine at the point where it opens into the mesenteron (see Fig. 80).

Fig. 103. Section from same series as preceding, lying a little nearer the ventral side, and taken through the opening of the stomodaeum and of the intestine into the mesenteron.

Fig. 104. Horizontal section of an older embryo, taken nearer the ventral side than the preceding, about the level of the ocelli of Fig. 82.

Fig. 105. Section from same series as preceding, but nearer the ventral side, taken at the level of the otocysts in Fig. 82.