THE EMBRYOLOGY OF THE WHITEFISH *COREGONUS CLUPEAFORMIS*, (MITCHILL)[1]

PART III.

THE SECOND HALF OF THE INCUBATION PERIOD

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As pointed out in the second paper of this series, it is during the first half of its normal incubation period that the embryo of *Coregonus* undergoes a differentiation of its primitive embryonic tissue into definitive organs. This differentiation applies to every organ system. It remains for the second half of the incubation period to develop these structures to such a state as to produce a self-supporting, highly co-ordinated individual organism at the time of hatching. Thus it is to be expected that the major changes which occur during this latter period involve chiefly such processes as growth, change in proportion of parts, and further differentiation of tissues.

Stage 608. O. S. U. Series.—(Incubation period, 102 days, 4 hours; 191 T. U. Total length of embryo, 10 mm.; 64 pairs of somites. Reconstruction drawings, Plate V., Figs. A. B. C.)

The embryo has continued its growth in size and length since the stage last described, and now has acquired a distinct fish-like appearance within the egg shell. It lies prominently above the constantly diminishing yolk sac, to which it is still broadly attached in the middle of the body. Anterior to this attachment, the head is flexed downward to conform to the curvature of the yolk. The body of the embryo, however, is sharply bent, usually in the form of a flat dextral coil on the yolk surface. The tail completes the circle and in many cases extends just past the head, beginning a second loop. This sharp torsion and flexion of the body make it impossible, as in Stage 400, to reconstruct more than the anterior portion of the embryo. The drawings of this stage are drawn at the same magnification as previous stages, and therefore permit comparative studies.

The brain is shown in Fig. C of Plate V, with the sense organs removed. The precocious development of the nervous system that has been apparent since the closure of the blastopore is possibly even more clearly shown here. The brain at this stage appears to be roughly twice its former size. This may be seen by comparing Stages 400 and 608 of Plate VI, where corresponding points on the two drawings are

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connected by lines. In the latter stage is seen a great overarching of the brain, due to the expansion of the midbrain, which now overshadows all other parts in size. The optic lobes have enlarged and have grown upward, backward, and outward until laterally they greatly overhang the infundibulum. The infundibulum retains its formerly described position ventral to the midbrain, but whereas it formerly extended to well beneath the myelencephalon, its tip now barely reaches past the middle of the metencephalon. This apparent shift in position may be due to the great growth of the dorsal portions of the brain. The infundibulum itself has increased in length, and at its posterior tip is divided into a dorsal and ventral portion. The cerebellum is now a prominent transverse plate on the posterior face of the midbrain. It is confluent at its base with the midbrain in front and the walls of the medulla behind. It is flexed backward upon the latter, its backward movement being due to the expansion of the midbrain. The drawing, Fig. A, Plate V, through the median axis of the head shows that the cerebellum also penetrates the cavity of the optic lobes to a slight extent. The floor of the myelencephalon is arched through the center (Fig. B, Plate V). Laterally and immediately behind the cerebellum, its outer walls are scarcely raised above the floor. Behind this point, however, the walls rise rapidly into lateral ridges which bend toward the center and draw the fourth ventricle into a triangular cavity which rapidly diminishes to a minute canal which continues down the length of the nerve cord as the neurocoele. The forebrain at this stage bears a transverse suture which divides it into the telencephalon and diencephalon.

The anterior end of the notochord in Stage 608 (Figs. A and C) is somewhat in advance of its position in Stage 400. In the earlier stage, the notochord ended at a level somewhat behind the middle of the otic capsule. Now it extends slightly beyond the anterior margin of this capsule. This changed relationship probably is brought about through the growth and backward crowding of the brain and its sense organs, rather than any forward growth of the anterior end of the notochord, which is to be regarded as a relatively fixed point. The changes described above also have resulted in bringing the tip of the infundibulum and the anterior end of the notochord into close proximity, a relation which persists for the remainder of the embryo's development.

The prominent lateral branchial folds ventral to the otic capsule are in the same relative position as seen in Stage 400. However, the anterior end of the pharynx now extends much farther forward than previously described. Apparently a marked forward growth of the anterior end of the pharynx has occurred (see Plate VI). The upper and lower sheets of epithelium which line the primitive mouth cavity now run forward beneath the infundibulum from the level of the branchial folds to the level of the optic nerve. Here the epithelium is in contact with the superficial layer. Between the oral epithelium above and the floor of the brain lies a sheet of cartilage, which forms the base of the chondrocranium.

The three sense organs, namely, the nasal pit, the eye, and the otic vesicle, have undergone enlargement and marked development since being last described (Fig. B, Stage 608). The nasal pit is deeper, larger and more terminal. The eye, by comparison, is considerably larger and somewhat rotated in position. The semicircular canals of the otic capsules have continued their development and now occupy a large portion of the space within the inner ear.

The roots of the olfactory, optic and trigeminus nerves were traceable in earlier stages and were plotted on the reconstruction drawings of them. Now they are larger and more clearly defined. In addition, it is possible to plot the placodes of cranial nerve III, and a placode composed of components of cranial nerves IX and X.

Stage 784. O. S. U. Series.—(Incubation period, 131 days, 12 hours; 324.5 T. U. Total length of embryo, 12 mm.; 64 pairs of somites. Reconstruction drawings, Figs A_1, B_1, C_1, of Plate V.)

Hatching occurred in this series of embryos at stage number 803, at a total of 355 thermal units of incubation. The present stage is therefore within a few days of hatching, and for purposes of this study can be regarded as equivalent to that stage. Mrs. Fish (1929) has described a specimen of the Whitefish at the time of hatching, and gives its total length as 12 mm., the same as recorded above for embryos at this stage. The actual length of the incubation period of the Whitefish probably depends upon a variety of both extrinsic and intrinsic factors which have yet to be studied experimentally for this species.

At the stage listed above, or just before hatching, the yolk sac is reduced to a vestige of its former size and it is more narrowly attached to the embryo than in earlier stages. The embryo itself is tightly coiled, with its tail passing around the head to describe one and one-half circles. The head and body have undergone changes in proportion which give it the appearance of the newly hatched fish. The eye is prominent and heavily pigmented with stellate chromatophores on a golden ground color. The pectoral fins are well developed and active in their "fluttering" movements, although they lack the definitive pterygiophores of the adult. The median fin fold is continuous from the dorsal to the ventral median line around the tail. The tail is active, and the movements of the embryo within its shell are conspicuous in living material.

Figures A_1, B_1 and C_1, of Plate V, represent reconstruction drawings of the head of such an embryo, drawn in the sagittal plane and from the surface view, with and without the sense organs. By comparison of the second figure, Fig. B_1, with the corresponding one of Stage 608, Plate V (also Plate VI), it is seen that in the interval between these two stages, there has been a marked prolongation of the anterior portion of the head into a snout, a change which has greatly modified the contour of the head and which has been accompanied by important changes in the relative positions of the neighboring parts. For instance, the telencephalon has grown in size and has become projected into the snout. It has carried with it the nasal pit, which was thereby shifted from a position subventral on the head to one that is terminal. The epiphysis has arisen as a conspicuous outgrowth from the roof of the diencephalon. The meso-diencephalic fold, which was so prominent in Stage 608, is less conspicuous laterally and at this stage is to be seen only in the median line. Internally, Fig. A_1, the diencephalon is more clearly delimited from the adjacent portions of the brain. The velum transversum and the meso-diencephalic fold appear as distinct ingrowths from the dorsal wall in the median line and indicate the anterior and posterior limits of the roof of the diencephalon. Below, the recessus opticus and the tuberculum posterius serve as corresponding landmarks. The major change that has occurred in this region is the very marked thickening in the floor, lateral walls and roof of the infundibulum. These form the thalami and optic chiasma. The large fiber tracts within them are now clearly differentiated. This thickening of the infundibular walls has greatly reduced the size of the diocoele and compressed it laterally until it remains little more than a vertical slit. The dorsal, anterior, median wall of the infundibulum continues uninterruptedly into the greatly thickened floor of the midbrain which constitutes the crura cerebri. The mesencephalon has undergone a process of general enlargement, brought about by a thickening in its walls. The direction of growth has largely been lateral, in such a way that this portion of the brain now greatly overhangs the infundibulum and overarches the eyes. The thickened walls have developed at the expense of the mesocoele, compressing it laterally to reduce it to a relatively narrow ventricle. The metencephalon likewise has grown laterally to an extent equal to that of the mesencephalon, and appears externally as a transverse plate. Internally, however, the forward wall of the cerebellum is expanded to form two large lobe-shaped masses, the "valvuli cerebelli" (Herrick, 1924), typical of Teleosts. These valvuli project into the cavity of the midbrain, completely filling it in its posterior portion. Since the greater bulk of these valvuli is lateral to the midline, it is not shown on the drawing of the median section.

The nasal pit and the eye are completely differentiated as described above. The semi-circular canals can be seen as of typical adult structure. At their apices they bear ampullae lined with cilia whose beating motion can readily be seen in the newly hatched larva. It is possible to locate and follow to a limited extent the course of several cranial nerves, although no special staining methods were employed in the preparation of the sections of this stage. Cranial nerves I, II, and III appear essentially as described in previous stages. The trochlearis (NIV.) arises from the lateral wall of the cerebellum as a very small nerve, which cannot be traced in this material beyond its base. The large prootic ganglion which was interpreted in Stage 608 as being composed of cranial nerves V and VII remains as a single mass. A single ganglion with two principal roots which emerge in close proximity to the inner surface of the ear is interpreted as being composed of components of the cranial nerves IX and X. The writer has been unable to identify a separate auditory nerve. An unidentified ganglionic mass lies ventral to the ear.

From the foregoing descriptions it is very apparent that before *C. clupeaformis* hatches, it possesses well differentiated sense organs. They are developed far in advance of corresponding organs in *Serranus* and in certain other species.

Several significant changes have occurred in the bucco-pharyngeal region. It will be recalled that in Stage 608, the foregut had begun its migration forward from its primitive position and at that stage it had progressed to the level of the optic nerve. Since that stage, with the development of the snout, this forward migration of the anterior end of the pharynx has continued, being carried forward with the anterior end of the head. The mouth opening has broken through terminally in its adult position. The bucco-pharyngeal cavity is lined with an epithelium which is laden with spherical, glandular taste buds, irregularly distributed. These resemble the taste buds of the Carp, as described by Edwards (1930), and probably are similar histogenetically. The sides of the pharynx are now perforated by five pairs of fully developed visceral clefts, separated by four pairs of visceral arches. In each arch can be traced the supporting strand of cartilage which bears a ridge of primary gill filament. The secondary, finger-like gill filaments do not form on these primary gill filaments until after hatching. This failure of the secondary gill filaments to develop before hatching may be widespread in the teleosts. The author (1931) has found a similar condition in *Micropterus dolomieu*, where the secondary filaments are first developed a few days after hatching. M. Plehn (1901) describes their differentiation in the perch apparently from larval material. An aortic arch extends through each gill arch at the base of the filament, and the circulation of blood through these vessels can be clearly observed in living material. The heart has considerably increased in size since stage 608, and the ventral aorta running forward from it enters the floor of the pharynx at the point of attachment of the first anterior gill arch. In the previous stage, it disappeared in the floor of the pharynx at a point correspondingly much more posterior.

The branchial cartilages are attached ventrally to the median hyoid cartilage and dorsally to the cartilage in the floor of the chondrocranium, both of which are developed at this stage. The base of the chondrocranium extends as a sheet beneath the brain for the entire length of the head forward from the anterior end of the notochord. The lower jaw is supported by Meckel's cartilage. To its posterior angle is attached the base of a rudimentary operculum. At the time of hatching, the operculum extends backward to cover the first two pairs of gill arches.

Posterior to the region shown in the reconstruction drawings, a relatively advanced state of differentiation has been attained by the various organs. The pectoral fins and median fin fold are described above. Body, tail, and pectoral fin movements are strong and vigorous for some time before hatching. The body wall muscles have well differentiated striated myofibrils. The pronephric ducts can be traced backward throughout the length of the body. They converge in the median line caudally and fuse into a single tube in the region of the anus. The blood vessels throughout the body are well differentiated. They are lined by a distinct endothelium and many are congested with blood cells. Such vessels as the internal carotid artery, jugular vein, hepatic portal vein, duct of Cuvier, the aortic trunks and dorsal aorta fall in this category. In living, newly hatched larva, the circulation of the blood in the main vessels can be clearly traced throughout the body.

DISCUSSION

It is clearly evident from the description of the later stages of embryonic development of the Whitefish that this species attains a high degree of differentiation in its tissues previous to hatching. As pointed out earlier in this paper, the anlagen of all of the major organ systems are clearly established during the first half of the greatly prolonged period of incubation. This condition leaves the embryo free to undergo extensive development and differentiation of these tissues for the remainder of its incubation period. Since the eggs are normally laid during the months of November and December, and do not hatch until the first few days of April, the period of incubation in point of time is comparatively long. In the present series, the incubation period lasted 134 days, at winter lake temperatures, slightly above freezing (1.5° C.). This is equivalent in thermal units to an incubation period of almost nine days at a temperature of 22° centigrade. In comparison with species whose eggs normally are developed under this higher temperature, in the late spring or in the laboratory, the Whitefish has a relatively long period of incubation. Such a period then may be regarded as permitting a high degree of differentiation to occur. These two factors of length of incubation period and the degree of differentiation attained by the embryo before hatching are undoubtedly closely co-ordinated.

The whitefish is typically teleostean in its embryology. The cleavage pattern of the egg and its mode of early development compares very closely with the classical descriptions of Wilson for *Serranus*, of Klein and Henneguy for the trout, of Kuntz and others for other teleosts. The process concerned with gastrulation and closure of the blastopore, and the subsequent organogenesis is in general consistent with such processes in other teleostean species, so well summarized by Brachet. However, a review of the three papers in this study will reveal several outstanding features in which *Coregonus* is distinct in its embryological development.

The astral systems are unusually conspicuous in the mitotic figures of the segmenting blastomeres in the early cleavage stages. The astral rays extend from the centrosphere in all directions to the periphery of the cell. Those rays which radiate from opposite centrosomes cross each other in the center of the mitotic figure. They are not obscured in this region by the chromosomes, since the latter are extremely minute.

The anlagen of all the organ systems are definitely established in the first half of the incubation period. By the end of that period, Stage 400, O. S. U. Series, all the definitive parts of the adult brain are present as such. The eye is fully formed. The nasal and auditory pits have already sunken in from the surface ectoderm and have established a nervous connection with the brain. The heart and the chief definitive vessels contain blood cells and circulation has become established. The pharyngeal pouches are well developed, and the gut is closed over for most of its length and possesses a lumen. The liver is present. The notochord is fully vacuolated, and the adult number of paired muscle somites is present. Even the anlagen of the paired lateral fins are distinct. The embryo has attained two-thirds of its hatching length. In short, all the significant phases in the development of these various structures occur during the first half of the incubation period.

The whitefish serves admirably for the study of certain embryological features peculiar to teleosts. The process of the proliferation of erythrocytes from the intermediate cell mass in the median line of the embryo's body can be clearly traced. Again, the brain is precocious in its development. By the hatching stage, the relatively large size of the optic lobes, infundibulum, and the thalamus indicate an unusual degree of development in these regions.

The valvuli cerebelli, the gills, and fins are all well-known characters peculiar to teleosts. But it is of some interest to observe that these are among the last structures in the whitefish embryo to become differentiated, a fact which points to their specialized character. The swim bladder does not develop until after the hatching stage.

The whitefish undergoes a very radical shift in the position of its mouth during the latter half of the embryonic period. The primary ventral position of the forward end of the pharynx in close apposition to the infundibulum is unquestionably primitive and is suggestive of the ventral mouth of more primitive fishes. The migration forward of the anterior end of the pharynx to bring the mouth opening to the tip of the head is a conspicuous feature of whitefish development.

SUMMARY

This paper is the result of a preliminary study of the embryology of the whitefish, *C. clupeaformis*, of the Great Lakes, from fertilization to hatching. It is based upon a series of 803 egg stages. The eggs were taken at four hour intervals, day and night, throughout the period of incubation, a total of 134 days and 16 hours. In this series, those stages involving early cleavage, germ ring formation, the primitive streak, the formation and closure of the blastopore, and the differentiation of the primary germ layers are described in Paper I. Organogenesis from this point to hatching is discussed in Papers II and III, accompanied by reconstruction drawings. These trace the general development of the brain, sense organs, cranial nerves, notochord, muscle somites, pronephric tubules, the gut, branchial folds, and the heart.

The whitefish is in general typical of the teleosts in its major embryological processes. Its extended period of incubation makes it favorable embryological material, because of the possibility of obtaining closely graded series of embryonic stages. Outstanding features in the embryology of this series include (1) conspicuous astral systems in the segmenting blastomeres, (2) precocious differentiation of organs during the first half of the incubation period, (3) the marked forward migration of the mouth from a ventral to a terminal position, and (4) the relatively high degree of differentiation of the brain, gills and other organs just previous to hatching.

TABLE I

SYNOPSIS OF THE EMBRYOLOGY OF THE WHITEFISH, *Coregonus clupeaformis*

Stage No. O. S. U.	Age in Days	Age in Thermal Units	Total Length, mm.	No. of Somites	Description
1	1	8	....	....	8-celled blastodisc.
8	2	15	....	....	Blastodisc 4 cells deep. Epidermic stratum forming. Early periblastic ridge.
16	3½	30	....	....	Blastodisc 8-10 cells deep. Blastomeres reduced in size.
32	6	42	....	....	Formation of germ ring and subgerminal cavity. Syncytium of scattered nuclei in central periblast.
48	8	60	....	....	Germ ring is migrating around yolk. Blastoderm envelops upper one-third of yolk. Embryonic bud and primitive entoderm appear.

TABLE I—Continued

Stage No. O. S. U.	Age in Days	Age in Thermal Units	Total Length, mm.	No. of Somites	Description
64	11	82	....	....	Germ ring lies in equatorial plane. Embryonic shield forming. Ectodermal layer differentiated beneath epidermic stratum. Notochordal area outlined. First step in formation of the neurenteric streak.
80	14	93	....	....	Primary germ layers are established. Blastoderm encloses two-thirds of yolk.
96	16	97	2.0	....	Large yolk plug stage. Formation of primitive streak. Kupffer's vesicle appears. Lateral mesodermal plates distinct from surrounding layers. Neural keel forming in anterior end.
112	19	103	2.32	3 prs.	Optic primordia appear as solid cell masses. Narrow yolk plug stage.
128	22	108	2.96	11 prs.	Closure of blastopore. Three primary cerebral vesicles have developed. Solid neural keel. Notochord extends forward to level of midbrain. Kupffer's vesicle has reached its maximum development. Sensory plate appears laterally on the head.
144	24	112.5	....	14 prs.	Embryo extends one-half distance around curvature of the yolk, without torsion. Small cavities within optic sacs and forebrain. Auditory pit anlagen. Conspicuous but incomplete branchial folds. Incipient stages in formation of pericardial cavities.
160	27	115	3.5	21 prs.	Increased size of brain and optic vesicles. The latter are invaginated to form a two-layered optic cup, with choroid fissure and primordium of lens. Nasal pit anlagen appear. Single endocardial mass beneath pharynx, in midline. Incipient stage in formation of pronephric chamber and duct.
176	30	117.8	....	24 prs.	Progressive development of features listed above.
192	32	120	....	28 prs.	Midbrain divided into two distinct optic lobes, hindbrain into meten- and myelencephalon. Fourth ventricle formed. Optic stalk. Tail is distinctly raised above yolk, and is undercut by tail fold.
208	35	123	....	32 prs.	Forebrain differentiated into telen- and diencephalon. Infundibulum in initial stages of development. Hyomandibular and first branchial pouches in contact with surface ectoderm. Small lumen in gut.

TABLE I—Continued

Stage No. O. S. U.	Age in Days	Age in Thermal Units	Total Length, mm.	No. of Somites	Description
224	38	126	4.2	39 prs.	Nasal pit is elliptical, lined with columnar epithelium. Increased size of brain and eye is conspicuous. Prominent 4th ventricle. Vacuolation of cells of notochord is evident throughout its length. First anterior branchial pouch has broken through to form an open gill cleft. The second branchial pouch is formed. Gut is closed throughout its length. Position of future anus appears at level of 36th–37th somites. Paired dorsal aortae appear. Heart progressively developed. Pronephric chamber possesses a distinct cavity. Its duct extends to anal region. Continuous fin fold around tail.
272	46	134	....	49 prs.	Liver appears, as ventral outgrowth from midgut, at level of sixth somite.
288	48	136.4	....	52 prs.	The 3rd and 4th branchial pouches appear. Myofibrils have formed in somites throughout middle of trunk. Embryonic coelom is conspicuous at this level.
304	51	139	....	56 prs.	Pectoral fins appear.
320	54	142	....	62 prs.	Notochord surrounded by hyaline sheath. The dorsal aorta is traceable into tail region. Caudal vein and subintestinal vein appear. Gut possesses distinct lumen throughout its length.
352	59	147	....	62 prs.	Pronephric chambers at level of 4th and 5th somites possess glomeruli in their walls, receiving branches from the dorsal aorta.
368	62	150	....	64 prs.	The complete hatching number of somites is attained with this stage. Cross-striations occur in myofibrils of anterior somites.
400	67	155	8	64 prs.	Embryo forms an almost complete circle on yolk. Brain lobes have become greatly expanded laterally. Columnar epithelium is well differentiated in gastric region of gut. The heart is looped in the form of a U-tube and is suspended by mesocardium. Vitelline veins are large and filled with erythrocytes. Auditory vesicle irregular in outline, with ampullae and semi-circular canals developing within. Pectoral fins definitely raised above surface of lateral somatopleure. The pre-auditory sensory placode is evident, lying on the side of the head, anterior to hyomandibular pouch.

TABLE I—Continued

Stage No. O. S. U.	Age in Days	Age in Thermal Units	Total Length, mm.	No. of Somites	Description
608	102	191	10	64 prs.	Embryo forms a complete circle on yolk, with tail extending past the head, beginning a second loop. It has a distinct fish-like appearance. Yolk sac diminishing in size. This stage is marked by a great enlargement of the brain lobes, and a shift in their relative position. The posterior tip of infundibulum is divided into a dorsal and ventral portion. The anterior end of the pharynx has migrated forward beneath the infundibulum to the level of the optic nerve. Semicircular canals of inner ear are distinct. Roots of cranial nerves I, II, III, V, VII, IX, and X are plotted on reconstruction drawings.
784	131	324.5	12	64 prs.	Embryo forms 1½ circles on yolk. Approximately hatching condition. Yolk sac reduced to a vestige of former size. Eye heavily pigmented with stellate chromatophores. Active movements of pectoral fins, tail and tail fin in living material. Prolongation of head into a snout, with corresponding changes in forward portion of brain. Fiber tracts are differentiated within the thalamus and optic chiasma. Valvuli cerebelli project into cavity of midbrain. Progressive development of sense organs and cranial nerve roots. Mouth cavity has broken through in its adult terminal position on the head. Taste buds line the mouth cavity. Four pairs of gill arches are open on sides of head, partly covered by operculum. Primary gill filaments present. Meckel's cartilage and the base of the chondrocranium are differentiated. The principal diffinitive blood vessels are traceable throughout the body.
803	134	355	12	64 prs.	Hatching stage.

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EXPLANATION OF PLATES

Plate V

Reconstruction drawings of Stages 608 and 784, O. S. U. Series, anterior end of embryo.

Figs. A and A_1—Median sagittal sections of the head in Stages 608 and 784, respectively.

Figs. B and B_1—Lateral view of head, in Stages 608 and 784, respectively, showing sense organs.

Figs. C and C_1—Surface of brain, without sense organs, in Stages 608 and 784, respectively, showing bases of cranial nerves, branchial arches, etc.

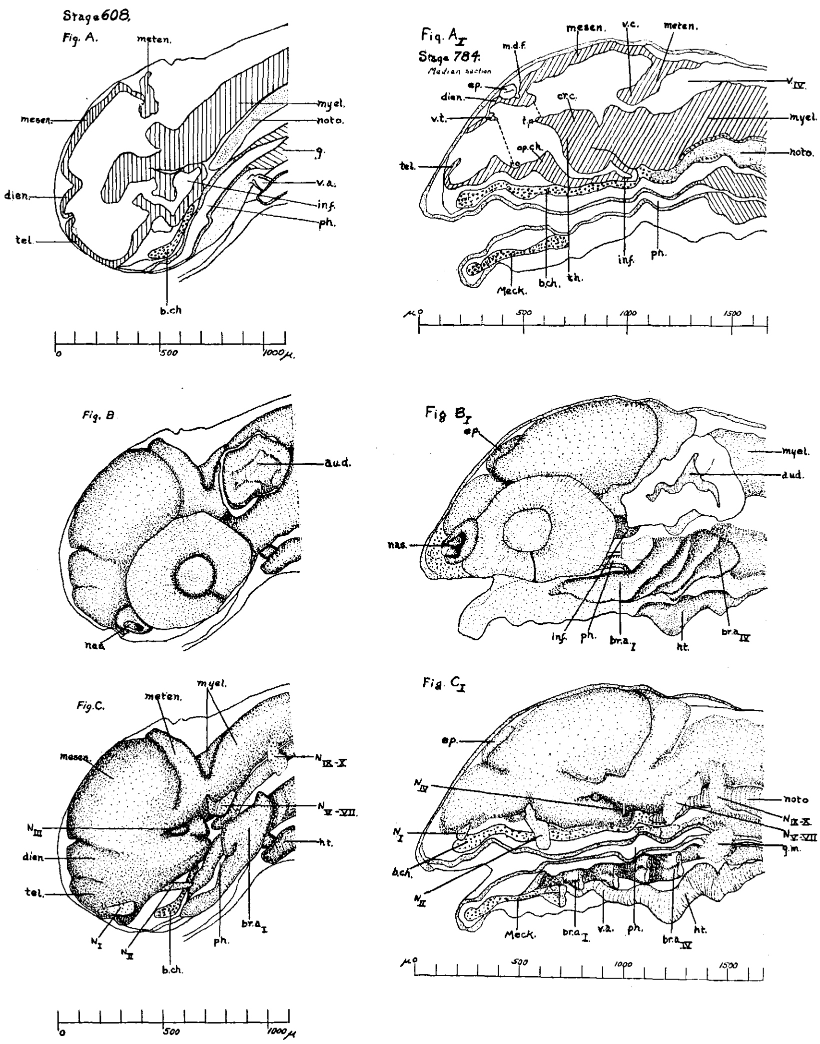
Plate VI

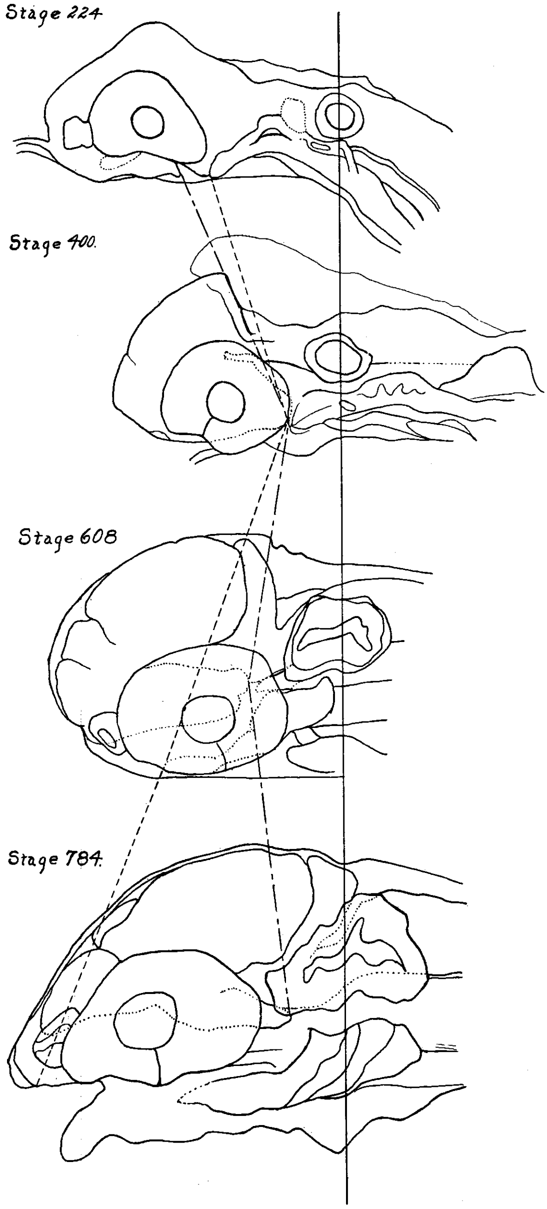
Reconstruction drawings of Stages 224, 400, 608, and 784, with the corresponding areas or points connected by lines, to show the changes in proportion and relationships during development. The base line is drawn through the center of the auditory vesicle.

(All figures are drawn at the same magnification.)

ABBREVIATIONS USED IN PLATE V

aud.—auditory vesicle.
br. a. I–IV—branchial arches, 1–4.
b. ch.—basis cranii.
cr. c.—crura cerebri (caudal peduncle).
dien.—diencephalon.
ep.—epiphysis.
g.—gut.
g. m.—ganglionic mass.
ht.—heart.
inf.—infundibulum.
m. d. f.—meso-diencephalic fold.
Meck.—Meckel's cartilage.
mesen.—mesencephalon.
meten.—metencephalon.
myel.—myelencephalon.
n. I, II, etc.—cranial nerves.
nas.—nasal pit.
noto.—notochord.
op. ch.—optic chiasma.
ph.—pharynx.
r. o.—recessus opticus.
t. p.—tuberculum posterius.
tel.—telencephalon.
th.—thalamus.
v. IV—fourth ventricle.
v. a.—ventral aorta.
v. c.—valvuli cerebelli.
v. t.—velum transversum.


Stage 608.
Fig. A.
meten.
myel.
noto.
g.
v.a.
inf.
ph.
mesen.
dien.
tel.
b.ch
0
500
1000μ.
Fig. A I
Stage 784.
Median section
mesen.
v.c.
meten.
m.d.f.
ep.
dien.
cr.c.
v.t.
t.p.
op.ch.
tel.
v IV
myel.
noto.
inf.
ph.
b.ch.
th.
Meck.
μ 0
500
1000
1500
Fig. B
aud.
nas.
Fig B I
ep.
myel.
aud.
nas.
inf.
ph.
br.a I
ht.
br.a IV
Fig. C.
myel.
meten.
mesen.
N IX-X
N V-VII
ht.
N III
dien.
tel.
br.a I
ph.
N I
N II
b.ch.
0
500
1000μ
Fig. C I
ep.
N IV
N I
b.ch.
N II
noto
N IX-X
N V-VII
g.m.
Meck.
br.a I
v.a.
ph.
br.a IV
ht.
μ 0
500
1000
1500


Stage 224
Stage 400.
Stage 608
Stage 784.