Cross-Sections of a 12-mm. Dolphin Embryo

By
HIROSHI HOSOKAWA[1)]

A 12-mm. embryo of a dolphin (Prodelphinus caeruleo-albus, Meyen) shown in Fig. 1 was embedded in celloidin, sectioned transversely and serially, 15 μ in thickness. Every other section of the series was stained with hematoxylin and eosin; and studied microscopically.

In the following, some of the important levels as indicated by guide lines on Fig. 2 are illustrated or photographed, together with brief descriptions. All sections are seen from the cephalic side. Hence the right side of the embryo is on the left side of figures.

There have been published only a few literatures upon the fetal development of whales or cetacea, among which Guldberg and Nansen's book (1894) is probably the most important and extensive one. They dealt mainly with the external features of dolphin fetuses (Lagenorhynchus acutus, Gray; Lagenorhynchus albirostris, Gray; Phocaena communis, Lesson; Orca gladiator, La Cépède; etc.), accompanied by some microscopic observation of partial sections.

In the present study, serial sections of a human embryo of some 10-mm. in length as well as of pig embryos of 11 and 13-mm. were used for comparison. Several books of embryology helped the observations, too. Among the referred are such books as written by Arey (1946), Baxter (1953), Boyden (1947), Grosser & Politzer (1953), Huettner (1952), Patten (1927, 48, 53), etc.

Fig. 3. Section through the Isthmus Rhombencephali and Pontine Flexure (Serial No. 57).

Because of the *pontine flexure*, the head is cut twice at this level. The section passes through the *mesencephalon*, *isthmus rhombencephali* and *metencephalon* on the anterior half, and the *myelencephalon* is cut on the posterior half. The cavity within the mesencephalon, the forerunner of the *aquaeductus mesencephali*, is still large, retaining the feature of the mid-brain vesicle. The *ventriculus quartus* is cut apart into two portions, each of which being covered by a very thin *ependymal roof* on one side.

1) from the Department of Anatomy (Director: Prof. Dr. T. Ogawa), University of Tokyo Faculty of Medicine, Hongo, Tokyo.

The wall of the neural tube has differentiated into three successive layers; (1) an inner, *ependymal layer*, (2) a middle, *mantle layer*, and (3) an outer, *marginal layer* (Plate I, 1). The ependymal layer, the contributor of neuroblasts and neuroglia to the mantle layer, is provided with multitudes of cells which are arranged radially. In the innermost zone of this layer, abutting on the internal limiting membrane, many mitotic cells are distinguished (Plate I, 2, 3). The mantle layer, which is to make up the gray substance in future, contains many cell bodies of the primitive neurons and neuroglial cells. The marginal layer, the progenitor of the white substance, is noncellular, consisting of processes of the mantle-layer cells or of the peripheral sensory cells.

The outer surface of the neural tube is surrounded by a thin, mesenchymal layer. This is the primitive *pia mater* or *leptomeninx* and its rich blood vessels in the area of the ependymal roof will participate in forming the *choroid plexus*.

In the mesenchyme between the neural tube and the epidermis are distributed many blood vessels, some of which are branches of the internal carotid or of the basilar artery, while others represent tributaries of the anterior cardinal vein (*anterior* and *medial dural plexus*).

The tip of the *endolymphatic duct* is cut along both sides of the ventral end of myelencephalon. The tiny section of the *trochlear nerve* is also noticed on each side of the rhombic isthmus.

Fig. 4. Section through the Fourth Ventricle (Ser. No. 69).

The *fourth ventricle* is sectioned nearly horizontally above its middle height. Due to the pontine flexure and probably also due to the shrinkage by the fixation, two fragments of its roof are cut.

Among new structures shown at this level are the rootlets of the *nervus oculomotorius* and of the *n. accessorius*. The former fibers are just leaving the wall of the mesencephalon.

The pricipal three-layered structure of the neural tube is a little rearranged in the anterior portion and the mantle layer is transformed to make up the primitive *nucleus n. oculomotorii*. Posterior to this is a part of the *trochlear nucleus*, too. A few of the mitotic cells are scattered in these primitive nuclei, although the mantle layer cells usually do not show cell-division. The primitive nuclei may be better regarded as outwards migrating cells of the ependymal layer.

The root fibers of the *accessory nerve*, emerging from the wall of the myelencephalon as well as of the spinal portion, form a somewhat thick trunk and run anterolaterad to join the vagus nerve.

Fig. 5. Section through the Apex of an Otocyst (Ser. No. 95).

On the right half of the section the apex of the left *otocyst* is cut laterally to the *endolymphatic duct*, while only a shaving of the left otocyst is in view on the opposite side.

The wide cavity occupying almost the middle one third of the section represents the metencephalic portion of the *fourth ventricle*, of which the inner surfaces of both sides bear *rhombic grooves* (III–VI) as well as the intervenient prominences, *rhombomeres* or *neuromeres* (III–VI).

Because of the cervical flexure, the anterior greater part of the *myelencephalon* is cut through the floor plate, although its posterior end is seen well as it approaches the spinal cord.

Alongside the myelencephalon are rootlets of the *nervus hypoglossus*, anterior to which the *n. vagus* leaves the brain wall. The *accessory nerve* is now adjacent the vagus trunk.

In the interval between the mesencephalon and metencephalon are the cut *oculomotor nerves*, surrounded by the *anterior dural plexus*. The left *trochlear nerve* is not grown down to this level, while the tip of the right one is still seen.

Fig. 6. Section through the Floor of Metencephalon (Ser. No. 109).

The section passes through the floor of the metencephalic portion of the fourth ventricle, leaving a narrow space on the median line. The fundamental three-layered structure of the neural tube is distorted not a little around here. For the nerve fibers begin to extend in all directions in the mantle layer, dividing the latter into more or less isolated cellular masses, which will become the so-called nuclei. Also the mixture of the gray and white substances, the formatio reticularis, will be formed.

About midway along the metencephalon is the *n. statoacusticus*, just issuing from the brain wall and directed to the *otocyst*. This nerve is composed of two nerves, the *nervi cochleae* and *vestibuli*.

The *endolymphatic duct* is now annexed to the otocyst. Posterior to the latter are the *nn. glossopharyngicus* and *vagus*, together with the *ganglia intracraniale* and *jugulare* respectively. The cells in the jugular ganglion are said to be sensory in function and to send fibers to the auricular branch of the vagus nerve. No trace of this tiny branch is, however, noticed in this dolphin embryo.

The *spinal cord* is cut obliquely at the level of the first cervical ganglion, although the corresponding ventral root does not occur yet. Along the inner margin of the spinal ganglion is the tiny cut of the *spinal accessory nerve*, which can be traced a little more distance below the present level.

Considerable number of mitotic cells are identified in the *spinal ganglia* (Plate I, 4). The same holds good for the semilunar ganglion as well as for the nodosoal, jugular, extra- and intracranial, sympathetic ganglia.

Fig. 7. Section through the Infundibulum, Ganglia Semilunare and Geniculi (Ser. No. 135).

The metencephalon has disappeared and the wide interval between the two cuts of the neural tube, the *diencephalon* and *spinal cord*, is occupied by the mesenchymal area.

On the midplane of this area are the *notochord* and *arteria basialis*, both of which cut lengthwise. The unpaired basilary artery is formed by the fusion of the paired vertebral arteries. On each side of the basilary artery is the *n. abducens*, which has emerged from the floor of metencephalon and is directed anterolatero-caudad to the primitive eye muscles.

Anterior to the *otocyst* in the middle of the section is the ganglion associated with the statoacoustic nerve. The *n. facialis*, situated lateral to the ganglion just mentioned and cut longitudinally, bears the *ganglion geniculi* on its anterior end.

The *ganglion semilunare* stands out as a large, oval cell mass circumscribed sharply. The *portio minor* of the trigeminal nerve is attached to the inner side of this ganglion.

The vascular space between the semilunar and geniculate ganglion represents the *vena capitis prima* that is the main tributary of the anterior cardinal vein and receives the anterior as well as the medial dural plexus.

The anterior cut of the neural tube, the diencephalon, has a midventrally directed pouch, the *infundibulum*, which will furnish the posterior lobe of the hypophysis.

Between the facial nerve and spinal cord, named in order, are the *n. glossopharyngicus*, *anterior cardinal vein* (vena jugularis interna), *nn. vagus* and *accessorius*, *n. hypoglossus*, the first cervical nerve and the *vertebral artery*. The 1st cervical nerve is seen as it divides into the vental and dorsal rami, surrounded by the thick, mesenchymal cell mass destined to form the cervical muscles.

Fig. 8. Section through the Fornix Pharyngis, Ganglia Extracraniale and Nodosum (Ser. No. 145).

New structures occurring on the present section are the *fornix pharyngis*, the *ganglion extracraniale* of the glossopharyngeal nerve, the cranial end of the *ganglion nodosum* of the vagus nerve, the *1st*

branchial groove, the *1st pharyngeal pouch*, the *nervus petrosus superficialis major*, the primitive *eye muscles*, a bit of the *Rathke's pouch*, etc.

The *n. petrosus superficialis major*, whose existence in the adult whales or dolphins is not yet ascertained, is represented distinctly in the present fetus by a tiny nerve bundle that has arisen from the geniculate ganglion of the facial nerve and runs anteromedio-caudad.

The *1st branchial groove*, the future external acoustic meatus, is cut midway along each side of the embryo. Althogh it seems to be continuous with the lateral end of the *1st pharyngeal pouch* lined with thick epithelium, this communication must be due to the artificial rupture of the *closing membrane*.

The *Rathke's pouch* which has originally budded from the stomodeal epithelium and is destined to furnish the glandular hypophysis shows on this section as two cuts that flank the *infundibulum* on both sides.

The *semilunar ganglion* is bordered mediad by the *cavernous sinus*. Anteromedial to these structures is the accumulated mesenchymal mass representing the primordial *eye muscles*, *nn. abducens* and *oculomotorius* being located within it.

Fig. 9. Section through the Optic Cup (Ser. No. 153).

Inside the *pharyngeal cavity* is a shaving of mesenchymal tissue lined with epithelium, which represents the *root of tongue*.

Anterior and posterior to the pharynx are two cuts of the *notochord*, the anterior one of which is close to its cranial end.

The *facial nerve* located lateral to the pharynx has just given off a small branch, the *chorda tympani*, which is, like the n. petrosus superficialis major, not yet ascertained in the adult whales or dolphins. The *1st pharyngeal pouch* and the *internal carotid artery* are cut lengthwise, the latter being crossed externally by the *n. petrosus superficialis major*.

The semilunar ganglion has disappeared at this level and two branches of the trigeminal nerve, *nn. maxillaris* and *mandibularis*, have occured. The mesenchymal condensation surrounding the latter nerve represnts the primordium of the *chewing muscles*.

The *Rathke's pouch* shows now as a vesicle, of which the anterior and posterior wall will furnish respectively the *anterior lobe* and the *pars intermedia* of hypophysis (Plate II, 5).

Anterolateral to the primordial eye muscles is the cut *optic cup* that is a double-walled vesicle now. The inner thick layer of this vesicle is the forerunner of the *retina* and the outer thin coat, the progenitor of the *pigment epithelium*, is provided with pigment granules

already (Plate II, 6).

Among new structures appeared on the dorsal half of this section is the sympathetic nerve which is situated close to the vagus nerve. Traced caudad it joins the *ganglion cervicale craniale* of the *sympathetic trunk*.

Fig. 10. Section through the Root of Tongue and Lens Vesicle (Ser. No. 163).

This section passes approximately 150 μ below the previous level. What marks this level is the wide *pharyngeal cavity* with the cut *first* and *second pharyngeal pouches* extending respectively anteromediad and posterolaterad. Needless to say, the former pouch is to furnish the *tympanum* as well as the *tuba pharyngotympanica*, while the latter one foreshadows the *tonsillar sinus*.

The root of tongue shows as a large, separate mass in the pharyngeal cavity. Its anterior portion must be the *tuberculum impar* and the middle, lateral expansions may represent the *copula*.

Posterior to the 2nd pharyngeal pouch are *nn. glossopharyngicus, vagus* and *hypoglossus*. The nerve bundle cut lengthwise laterally to the left vagus nerve is the *ramus externus of the accessory nerve*. On the right side the whole accessory nerve is still accomanying the vagus trunck. The *cranial cervical ganglion* of the *sympathetic trunk* has come into view on the dorsal side of the vagus.

In the anterior part of the section, *n. maxillaris* is diminishing in size considerably. The *optic vesicle* is cut nearly through its center and therefore the *lens vesicle* is sectioned on this plane. A thin ectodermal layer, the *corneal epithelium*, borders outside.

Fig. 11. Section through the Origin of Rathke's Pouch, Epiglottis and Optic Stalk (Ser. No. 173.)

Characteristic of this section is the division of the pharyngeal cavity into two parts. The anterior one is the *oral cavity* or *stomodeum*, of which the epithelium is ectodermal. Although the *oral* (or *pharyngeal*) *membrane* marking the boundary between the ectodermal and entodermal epithelium has disappeared at this stage, the *Rathke's pouch* that has arisen just in front of this membrane is shown to continue with the anterior wall of the oral cavity on the midline.

The *pharynx* is now a transverse slit compressed antero-posteriorly and the prominence boundering its anterior wall represents the *epiglottis*. Antero-laterad to this pharyngeal slit is the cut apex of the *2nd pharyngeal pouch*.

Flanking the vagus trunk mediad are two arteries, of which the

anterior and the posterior are respectively the *3rd aortic arch* and the *internal carotid artery.*

The *glossopharyngeal nerve* has given rise to a small branch, *n. tympanicus,* to the antero-medial direction. The main trunk of this nerve is diminishing in the size.

The *optic stalk,* the connection between the *optic cup* and the *diencephalon,* is a thin tube, of which the lumen continues with the third ventricle on one side and with the space between the inner and outer layer of the optic cup on the other side.

Fig. 12. Section through the Foramen Interventriculare, Oral Opening, 3rd Pharyngeal Pouch and Glottis (Ser, No. 187).

The *telencephalon* is cut at the level of the *foramen interventiculare* connecting the *3rd ventricle* with the *lateral ventricle.* So the *cerebral hemisphaerium* is cut near its caudal end.

The *oral cavity* is now open to the external through the slit between the *maxillary* and *mandibular process.* The *n. mandibularis* in the mandibular process is still within view as tiny rootlets, while the *n. maxillaris* in the maxillary process does not reach this level.

The *pharynx* is an inverted V-shaped slit, of which the both feet represent the *3rd pharyngeal pouches.* The apex of this pouch is provided with two wings, the ventral and the dorsal, that are to furnish the *thymus* and the *parathyroid gland* respectively (Plate II, 7). Also the fourth pouch participates in this formation.

The triangular space located on the midline anterior to the pharynx represents the cranial portion of the *larynx,* while the linear, epithelial connection between the pharyngeal and laryngeal lumen is the primitive *glottis.* This is bordered on each side by a pair of the *arytenoid swellings,* which are said to be of the fourth and fifth arch origin.

The *3rd aortic arch* has shifted its position anterior to the 3rd pharyngeal pouch. Needless to say, it has crossed above the latter. Anterior to this aortic arch is the *external carotid artery,* the cranial extension of the ventral aorta. The *dorsal aorta* is located posterolateral to the pharynx, being flanked posteriorly by the *sympathetic trunk.*

Fig. 13. Section through the 4th Aortic Arch, 4th Pharyngeal Pouch and Thyroid Gland (Ser. No. 203).

On each side of the *pharynx* and *larynx* which are now separated completely from each other the *4th aortic arches* are cut lengthwise. Obviously the left one is larger than the right one. The anterior and posterior end of this arch are continuous with the *ventral* and *dorsal aorta,* although the right aortic arch meets the right ventral aorta

slightly below the present level. The ventral aorta at this level is the progenitor of the *common carotid artery*.

Between the ventral aortae on each side is a mass of cell cords that represents the primordial *thyroid gland* (Plate II, 8). This is originally an entodermal pocket invaginating from the ventral floor of the pharynx, although the epithelial connection between this gland and the pharynx has disppeared already. The site of origin was in the midplane at the level of the 1st pharyngeal pouches.

The pharynx is sectioned through the proximal portion of the *4th pharyngeal pouch*. A portion of the primordial *parathyroid* derived from the dorsal wing of this pouch is also seen. The mesenchymal cell mass surrounding the larynx foreshadows the *laryngeal cratilages* and *muscles*.

Lateral to the 4th aortic arch are the *n. vagus*, *n. hypoglossus* and *vena jugularis interna*. The hypoglossal nerve has continued to shift ventrad and is now cut lengthwise as it courses ventromedio-caudad. The *ramus communicans* connecting between the *spinal nerve* and the *sympathetic trunk* is seen on the left side.

On the left side of the embryo a proximal portion of the *upper limb bud* is coming into view. The *mandibular nerve* in the same-named process is now beginning to disappear.

Fig. 14. Section through the Ventral Aorta and Primitive Choana (Ser. No. 215).

The section passes through the paired *dorsal aortae* and the single *ventral aorta*. The right dorsal aorta is, together with the right fourth aortic arch, to form the *right subclavian artery*, while the left one is to persist as the cranical portion of the permanent *descending aorta*. The *ductus arterious*, the sixth aortic arch of the left side, is also cut as it joins the left dorsal aorta. The unpaired ventral aorta is the cranial extension of the aortic trunk. It may be called the forerunner of the *ascending aorta*.

The *pharynx* and *larynx* are sectioned close to the caudal ends. Both of them are traced caudad respectively to the *oesophagus* and *trachea*. Ventromedial to the larynx is a portion of the primordial *thymus* which belongs to the ventral wing of the fourth pharyngeal pouch.

Nerve rootlets situated between the larynx and the dorsal aorta represent the *n. recurrens*, a branch of the vagus nerve. The vagus trunk is located laterally together with the caudal end of the *ganglion nodosum*.

The *mandibule* is now separate from the body of the embryo and

retains no trace of the mandibular nerves.

The head is cut through the *nasal vesicle* and the *primitive choana*. The latter is the site of the ruptured *bucco-nasal membrane*.

Fig. 15. Section through the Apex of Pericardial Cavity (Ser. No. 223).

The section is marked by the appearance of the *pericardial cavity* as well as of tip of the *heart*. In the left portion of the pericardial cavity is a shaving of the *left atrium*, within which are many sinusoids filled with blood. The atrial wall and the trabeculae partitioning the sinusoids are provided with primitive muscles.

When the ventral aorta shown on the preceding section is traced caudad, it joins the *aortic trunk* which at the present level makes a prominence into the pericardial cavity.

On the midplane posterior to the pericardial cavity are, named in order, the *trachea* and *oesophagus* lined with thick epithelium. The mesenchymal masses surrounding these tubes foreshadow the connective tissues, cartilages or muscles of the tracheal and oesophageal walls.

The *right vagus* nerve is sectioned at the level of the caudal end of the *nodosal ganglion*. The branching of the right *recurrence nerve* and the right *cardiac rami* are shown, too. On the left side a portion of the *ductus arteriosus* or the left sixth aortic arch is still in view.

The *upper limb bud* is encountered on each side of the embryo: a nerve bundle belonging to the *brachial plexus* is inside the left one. The right and left *mandibular processes* are cut apart from each other.

In the head the *fila olfactoria* make connection between the brain wall and the epithelium of the *nasal vesicle*. The medial wall of the nasal vesicle lined with thick epithelium represents the *Jacobson's vomero-nasal organ*.

Fig. 16. Section through the Pulmonary Trunk (Ser. No. 235).

What characterises this section is the *pulmonary trunk* or the *common pulmonary artery* cut lengthwise on the left side of the aortic trunk. The distal or posterior end of this trunk divides into the *right* and *left pulmonary arteries* that have originated from the ventral halves of the 6th aortic arches. A little distance above the present level, the dorsal half of this arch or the connection between the pulmonary artery and the dorsal aorta is preserved well on the left side as the *ductus arteriosus*, while it has disappeared on the right side. On the anterior of the pulmonary trunk is the primordial *semilunar valve*.

Medial to the *anterior cardinal veins* which are now flowing into

the *common cardinals* are the *vagus nerves*. This nerve on each side has just given rise to the *tracheal* and *oesophageal rami* caudad.

Fig. 17. Section through the Bulbus Cordis, Common Cardinal Veins and Origin of Right Apical Bronchus (Ser. No. 249).

The section passes through the undivided *bulbus cordis*, in which the lumen of *aorta* and *common pulmonary artery* are connected with each other through a narrow slit. The parenchyme masses abutting on this intervening slit on both sides represent the ventral and dorsal *bulbar ridges*, which have shifted position to the right and left side respectively.

The apex of the *pleural cavity* has come into view on each side of the *trachea*. The latter is just giving off the *right apical* or *eparterial bronchus*. Ventral to the trachea are the paired *pulmonary arteries*. The pleural cavity is continuous with the *pericardial cavity* through the *pleuro-pericardial communication* which is guarded laterally by the *pulmonary ridge* of Mall.

Lateral to the pleural cavity is a large space representing the *common cardinal vein* or the *duct of Cuvier*. This is approaching the sinus venosus now.

The *upper limb bud* is sectioned on each side of the embryo, provided with mesenchymal condensations foreshadowing the future bones and muscles. Also the cranial end of *brachial plexus* as well as the *phrenic nerve* is encountered on the section.

The head is cut through the *fronto-nasal process*, retaining only tips of the *nasal vesicles* inside. The cerebral hemisphaeria are lost to sight.

Fig. 18. Section through the Foramen Ovale I, Bifurcatio Tracheae and Nasal Pit (Ser. No. 261).

What marks this level is the *foramen ovale I* that is a perforation in the *septum primum*. Thus the right and left atrial chamber are partitioned incompletely from each other at this level. The right *common cardinal vein* has emptied into the right horn of the *sinus venosus*, while the connection between the sinus and the right atrium is to occur a little more caudad. The *right vertebral vein* is seen as it flows into the right common cardinal.

The root of the *bulbus cordis* is cut together with the apexes of right and left *ventricles*. In the center of the cut bulb is the triangular space of the aorta, while pulmonary trunk has just joined the right ventricle. The slit between the ventricles and artia represents the *transverse sinus*.

Posterior to the heart, on the midline, is the *bifurcatio tracheae*, and the cut apical bronchus is on each side. The *bronchial buds* in the primordial lung are continuing to grow and branch. They are lined with thick, ciliated epithelium at the present stage (Plate III, 9). The mesenchymal mass surrounding the bronchial buds is to furnish the cartilages, muscles, vascular channels as well as the interstitial tissues for the lung.

The head is sectioned close to its rostral end, and the *nasal pits* or the primitive *external nasal orifices* are shown at this level.

Fig. 19. Section through the Sinus Venosus (Ser. No. 273).

The *heart* is marked by the *sinus venosus* (right horn), which now drains into the right atrium through a silt-like opening. The projections guarding this opening on both sides represent the right and left *valves of the sinus venosus*. The *left common cardinal* is located in the pericardial cavity. Caudad it is traced to the *left horn* of the sinus venosus. *The septum primum* is complete at this level.

The *ventricles* have increased in size, the *aorta* being sectioned on the midplane. In the right ventricle a portion of the *atrioventricular canal* is cut obliguely. In the thich ventricular wall three layers can be discriminated, 1) the external, *pericardial* layer, 2) the middle, *myocardial* layer, and 3) internal, *endocardial* layer. The external furrow marking off the ventricles from the atria is the *coronary sulcus*.

In the primordial lung the left main bronchus is seen to give off craniad the *left apical bronchus*, of which the distal cut was observed already on the preceding section.

Among other structures which mark this level is the apex of the *peritoneal cavity*, which lies antero-lateral to the left dorsal aorta. Posterior to the dorsal aortae which are still separate from each other are the *vertebral arteries* and the *postcardinal veins*.

Fig. 20. Section through the Trunk of Pulmonary Vein (Ser. No. 287).

The section passes through the *trunk of the pulmonary vein*, which drains into the postero-caudal wall of the *left atrium* at the left of the *septum primum*. Later, this venous trunk will be progressively drawn into the left atrium, as the latter grows.

The septum primum is attached to the *endocardial cushion*. The structure just mentioned is originally endocardial thickenings which bulged from the ventral and dorsal walls of the common atrio-ventricular canal and have fused midway, dividing the single canal into the right

and left one.

The *sinus venosus* (right horn) as well as some of the trabeculae are shown in the right atrium. The sinal valves are elongated ventro-caudad. The *right valve* will remain even in the adult heart, being subdivided and forming the *crista terminalis*, the *Eustachian valve* of the inferior vena cava as well as the *Thebesian valve* of the coronary sinus. *The left valve* is merely to fuse with the septum primum and secundum, in order to form a portion of the permanent atrial septum.

The internal cavity of the left ventricle has come into view, connected with the left atrium through the *left atrio-ventricular canal*, the primordium of the left atrio-ventricular ostium. This canal is guarded on each side by the cut endocardial cushions which foreshadow the *mitral valve*. The opening of the *aorta* into the left ventricle is also seen.

The thick, muscular partition between the ventricles represents the *septum interventriculare*. Posteriorly it joins the endocardial cushion.

Postero-lateral to the left atrium is attached the *left horn of the sinus venosus*, which has received the left common cardinal vein. This sinal horn is destined to disappear excepting its tip that is to furnish the stem of the *Marshall's vein*.

The *peritoneal cavity* occurs on each side, being separated from the pleural and pericardial cavity by the *pleuro-peritoneal membrane* and the *septum transversum* respectively. Both of these partitions will participate in forming the *diaphragma*, in cooperation with derivaties from the body wall and a part of the meso-oesophagus. At the left of the left phrenic nerve the *diaphragmatic muscle* is foreshadowed by a mesenchymal condensation.

Fig. 21. Section through the Anastomosis between Right and Left Dorsal Aortae (Ser. No. 293).

Most characteristic of the section is the confluence of the right and left *dorsal aortae*, thus forming the unpaired *descending aorta*. The *peritoneal cavity* has increased in size and a shaving of the left part of the *liver* occurs on the left side. In the primordial diaphragma the left phrenic nerve is cut close to its peripheral end, while the right one is still considerably large.

The heart is sectioned through the *transverse portion of the sinus venosus*, which is destined to receive the veins of the heart itself and is, roughly speaking, foreshadows the sinus coronarius.

The *right horn* of the sinus venosus is seen to receive the cephalic end of the *common hepatic vein*. The connection between the trans-

verse portion and the right horn of the venous sinus is, however, not in view. It occurs slightly caudal to the present level.

Fig. 22. Section through the Pleuro-peritoneal Communication (Ser. No. 303).

The section is marked by the distinct appearance of the *liver* on each side as well as of the *common hepatic vein* on the miplane. The *heart* is cut through its basis and shows, excepting the caudal extension of the transverse portion of the sinus venosus, only the dorso-caudal walls of the ventricles.

The partition between the pleural and peritoneal cavity by the *pleuro-peritoneal membrane* is now incomplete on each side. For these two cavities are connected through the intervening foramen, the *pleuro-peritoneal communication*. The latter increases in size as the sections are traced caudad.

The *vagus nerves* adjacent to the oesophagus have shifted position to some extent, the left one moving to the ventral surface of the oesophagus and the right one dorsad. It means that the alimentary canal itself has rotated clockwise around its longitudinal axis.

Fig. 23. Section through the Ductus Venosus (Ser. No. 315).

Ventral half of the section is occupied by the *liver*, although a slice of the *heart* is still in view, restricted to the ventral border of the embryo. The liver nearly fills the *peritoneal cavity* and its parenchyme is permeated with network of cell cords and the intervening sinusoids (Plate III, 10). The former is a spongework of the primordial hepatic cells with oval nuclei and is stained lighter than the sinusoids, while the latter, filled with proliferative blood cells such as megaloblasts, normoblasts, myeloblasts, etc., is stained darker. Nucleated erythrocytes are found also in the circulating blood (Plate III, 11).

Even though traced the whole length of the liver, it does not show any sign of lobulation, while it is plainly lobulated in the human and pig embryos of the similar size.

The large vescular space in the center of the liver represents the *ductus venosus*, which receives several efferent veins from inside the liver and continues craniad with the common hepatic vein.

The right *vagus nerve* dorsal to the oesophagus bears peculiarly several ganglion cells at the present level. The *lung buds* approach their caudal ends and the *mesonephric ridges* have occured posterior to the former. Furthermore, the cranial tip of the left *mesonephros* or the *Wolffian body* is already in view.

Fig. 24. Section through the Stomach (Ser. No. 341).

The section is marked by the appearance of the *stomach*, *bursa omentalis*, *vena cava inferior*, *genital ridges*, etc., while the lung and heart are now lost to sight.

The *stomach* is a dilated portion of the fore-gut, which is connected with the liver and the dorsal body wall by the *omentum minus* (*gastrohepatic ligament*) and the *dorsal mesogastrium* (*omentum majus*) respectively. The internal surface of the stomach is lined with entodermal epithelium, although the foveolae and the gastric glands are not yet indicated.

The *vena cava inferior* is cut slightly below its confluence with the ductus venosus. Traced caudad it takes its course dorsad through the *caval mensentery*. The narrow space flanked by the caval mesentery, liver, omentum minus and the stomach represents the rostral extension of the *bursa omentalis* or the *lesser peritoneal sac*.

On each side of the *descending aorta* is the distinctive *mesonephros*. Together with secretory and collecting tubules, a *glomerulus* is also seen. The aorta supplies it with the *mesonephric artery*. Ventromedial to the mesonephric ridges occur the *genital ridges*.

The ventral attachment of the liver to the body wall is the *mesohepaticum ventrale*, on both sides of which the mesothelial lining of the liver reflects to the internal surface of the body wall.

Fig. 25. Section through the Adrenal Cortex and Vestibule of Omental Bursa (Ser. No. 363).

Because of the rotation of the *stomach* about its long axis, the original ventral wall (lesser curvature) is on the right side and the primitive dorsal wall (greater curvature) is on the left. The cut *omental bursa* is necessarily enlarged at this level, bordered behind by the elongated *dorsal mesogastrium*. The right portion of the bursa reprents the *vestibule* and it is bounded on the right side by the *caval mesentery*, within which the *inferior vena cava* passes.

On each side between the aorta and the mesonephros is the *adrenal cortex*. It is round in shape and consists of remarkable condensation of mesenchymal cells (Plate III, 12). This is not the primordium of the permanent cortex but represents the *provisional* or *fetal cortex* that is later to be replaced by cells of another type to furnish the permanent cortex. Both of these two kinds of cells are, however, thought to be traced origin to the same proliferative focus. The chromaffine cells to form the adrenal medulla are not yet identified. Very soon they will differentiate from the sympathetic ganglia and invade the medial side of the cortical mass.

Inside the liver the *umbilical vein* and the *portal vein* are cut as

they flow into the ducts venosus.

Fig. 26. Section through the Foramen Epiploicum and Splenic Primordium (Ser. No. 371).

The Section passes through the *foramen epiploicum* which connects the omental bursa (vestibule) with the peritoneal cavity. Because of this communication the *inferior vena cava* is separate from the liver, although it still runs in the caval mesentery. *Right subcardinal vein* located just medial to the right mesonephros is seen to join the inferior vena cava.

The latero-dorsal surface of the dorsal mesogastrium shows a slight swelling which represents the primordial *spleen*. This swelling is due to the accumulated mesenchymal cells just beneath the lining, peritoneal epithelium (Plate IV, 13). Later on the splenic bulge increases in size and the mesenchymal mass will differentiate into red and white pulp, vascular channels, capsule, trabeculae, etc.

The *mesonephros* increases in size, too, and the *mesonephric duct* or *Wolffian duct* is cut inside the ventro-lateral margin of the mesonephric ridge. The *Müllerian duct* is, however, not identified.

Fig. 27. Section through the Root of Coeliac Artery (Ser. No. 379).

The *aorta* is cut as it gives off the unpaired *coeliac artery* and the paired *intersegmentary arteries* ventrad and dorsad respectively. These are originally ventral and dorsal intersegmentary branches of the aorta. The lateral branches are represented by the *mesonephric arteries*.

The *portal vein* is now shifting into the omentum minus and the *hepatic duct* is also seen anterior to the just mentioned vein.

The *adrenal cortex* and the primordial *spleen* are in almost the same condition as in the previous section. The vascular supply of the latter is through the *splenic artery* and *vein*, of which the former is a branch of the coeliac artery and the latter is a tributary of the portal vein.

The *gonad* in the genital ridge becomes larger as it is traced caudad. The gonad at this stage is indifferent or sxless. It's minute structure consists of internal cell mass lined with thick, *germinal epithelium* (Plate IV, 14, 15).

Fig. 28. Section through the Primordial Pancreas (Ser. No. 401).

The *liver* is cut near its caudal end, the right and left part being separate from each other. In the intervening space between these two is the *umbilical vein*, which is fastened to the ventral body wall

by the *falciform ligament*.

The most conspicuous feature appearing on this section is, however, the primordium of the *pancreas* in the *mesoduodenum* (Plate IV, 16). It consists of two portions, the *ventral* and the *dorsal pancreas*. Both are originally outpouchings from the entodermal epithelium of the duodenum, and they are contorted as they grow. The duct of the ventral pancreatic primordium is shown at its union with the *hepatic duct* (antrum), thus froming the common duct for the bile and the pancreatic juice.

The *gall bladder* is not recognisible all through the series concerned, while it is well developed in the human and pig embryos in the similar stage of the fetal development. Therefore the lack of gall baldder must be characteristic of the whale or dolphin embryos as well as of the adult whales and dolphins.

The *portal vein* is now in the mesoduodenum, situated between the ventral and the dorsal pancreas. The *inferior vena cava* has, as already mentioned, fused with the right *subcardinal vein* which is located just medial to the right mesonephros. The left *subcardinal* is in view, too. The narrow spaces along the dorsal border of the mesonephroi represent the *postcardinal veins*.

Fig. 29. Section through the Exit to Superior Mesenteric Artery and Umbilical Cord (Ser. No. 419).

What marks the present level is the fusion of the *umbilical cord* with the fetus. The tip of the recurved *tail* of the embryo is also cut near the anterior border of the figure.

Concerning the body of the fetus itself, the mesenteric connection between the alimentary canal and the liver has disappeared, thus leaving only the dorsal mesentery or *mesoduodenum*. In this area the *duodenum* is cut just before its union with the *common bile duct*.

The splenic vein has jointed the portal vein already. So the caudal continuation of the portal vein at the present level represents the *vitelline vein*. The confluence of the superior mesenteric vein into the vitelline occurs still a little distance below the present section.

The *umbilical vein* is located in the ventral body wall of the fetus. It is large, being sectioned at the union of the right and left umbilical vein.

The cut *umbilical cord* shows such structures as the paired *umbilical arteries*, unpaired *urachus*, and the *extra-fetal coelomic extension*. Inside the last mentioned cavity are the shaving of the tip of the loop of herniated *small intestine*, the *superior mesenteric vein* as well as the rudimentary *vitelline vein*.

Fig. 30. Section through the Subcardinal Anastomosis (Ser. No. 443).

The section is characterised by the *subcardinal anastomosis* or the wide communication between the right and the left subcardinal vein. The *postcardinals* on both sides are also continuous with the anastomosis.

The *vitelline vein* cut somewhat lengthwise on the left of the small intestine is prominent into the peritoneal cavity. Traced caudad it becomes separate from the mesentery and runs independently in the coelom, although it receives the *superior mesenteric vein* while it is still in the mesentery. The distal portion of the vitelline is seen in the coelomic extension in the umbilical cord.

Inside the coelomic extension the small intestine is cut twice, the right section and the left one representing the cranial and caudal limb of the *intestinal loop* respectively.

Fig. 31. Section through the Coelomic Extension into Umbilical Cord (Ser. No. 469).

The section passes through the extra-fetal extension of the peritoneal cavity (*coelom*) into the umbilical cord. Within this cavity is the *instestinal loop* in the condition of the *physiological hernia*. The cranical and caudal limb of the loop are on the right and the left respectively. The former portion is the *small intestine*, while the latter may represent the *colon*.

The protrusion of the intestinal canal into the umbilical cord is thought to be caused by so rapid elongation of the intestine that the peritoneal cavity can no longer contain it. In case of the human fetus, the withdrawal of the hernia occurs at about ten weeks of the fetal life.

Along the intestinal canal are the *superior mesenteric artery* and *vein*. The latter is a tributary of the vitelline vein, which is no longer seen on the section.

In the cut *tail* of the fetus such features as *spinal cord*, *notochord*, *somite* and *caudal artery* are identified.

Fig. 32. Section through the Caudal Limb of Intestinal Loop (1) (Ser. No. 485).

In the center of the wide *coelom* protruding into the *umbilical cord* is the *caudal limb* of the intestinal loop (*colon*) and is connected to the dorsal body wall by the elongated mesentery (*mesocolon*). The *right umbilical vein* is peculiarly cut as it extends into the umbilical cord.

The *mesonephros* as well as the *gonad* is shown at about the largest section. The mesonephros or the *Wolffian body* consists of *glomeruli*,

mesonephric tubules, *mesonephric duct* (*Wolffian duct*), vascular channels and intervening mesenchymal tissue (Plate V, 17). Needless to say, the mesonephric duct is the retained *pronephric duct*. It is lined with dark-staining, cuboidal epithelium.

In the perplexingly convoluted *mesonephric tubules* two different portions or segments can be discriminated. One is the thicker, light-staining *secretory segment* and the other is the thinner, dark-staing *collecting segment*. The former is proximal to the glomerulus and is nothing but the direct, tubular extension of the *Bowman's capsule*. The Bowman's capsule itself is, however, lined with low epithelial cells. The collecting segment is the distal continuation of the secretory segment and drains into the mesonephric duct.

Fig. 33. Section through the Caudal Limb of Intestinal Loop (2) (Ser. No. 501).

All the structures and features are almost the same as in the previous figure, excepting that the *mesentery* is somewhat shortened and the superior mesenteric blood vessels have disappeared.

The *urachus* or the *allantoic stalk* is an irregular, slit-like space with epithelial lining of cuboidal cells. This epithelial lining is entodermal. For the *allantois* is originally an outpouching from the ventral floor of the primitive gut, although it had furthermore an external layer of splanchnic mesoderm.

Figs. 34 & 35. Sections through the Root of Umbilical Cord (1, 2) (Ser. No. 525 & 541).

These two figures show sections through the root of the umbilical cord at different levels. So far as the body of the embryo is concerned, there are no remarkable differences from a couple of preceding sections. The only thing to be mentioned is that the *gonads* now dwindle away and disappear.

In the *umbilical cord*, which is decreasing in size, are umbilical blood vessels, urachus, etc. The *coelomic extension* is shown as one or two separate cavities.

The paired *umbilical arteries* and unpaird urachus are cut twice or thrice, depending on their courses and the height of section. The proximal portion of these arteries as well as of the urachus are now along the internal surface of the ventral body wall of the fetus.

The right *umbilical vein* is just rudimentary, while the left one is very large. The latter is the main venous channel carrying back the blood from the placenta.

Fig. 36. Section through the Metanephroi and Inferior Mesenteric Artery (Ser. No. 555).

The section is marked by the *metanephroi* or the primordium of the permanent kidneys. They arise from the caudalmost portion of the *nephrogenic cord*, from which also the pro- and mesonephros originate. On the section they are on each side of the aorta, just behind and somewhat mediad to the *mesonephros*.

The vetral margin of the mesonephric ridge has become prominent and the *mesonephric duct* is within it, turning its course ventro-caudad.

The *aorta* is cut at the level of exit of the *inferior mesenteric artery*. Like the coeliac and superior mesenteric artery this is one of the ventral branches of the aorta which were originally very imperfectly segmentary. While the former two supply the stomach-pancreas region and the small-intestine region respectively, the last one carries blood mainly to the large-intestine region.

Fig. 37. Section through the Metanephroi (2) (Ser. No. 565).

This section is slightly below the previous one, cutting the metanephros at about its middle height. The *mesonephros* has been lost to sight on the left, while the caudal tip of the right one is scarcely in view.

The *metanephros* is composed of two elements, 1) the tubular epithelial portion and 2) condensed mesenchymal tissue (Plate V, 18). The former is the distal end of an evagination from the caudal portion of the *mesonephric duct* and represents the primitive *renal pelvis* and *calyces*. It will further differentiate and furnish the *collecting segments* of the *uriniferous tubules*.

The second component of the metanephros or the condensed mesnchymal mass surrounding the epithelial tubules is the *metanephrogenic tissue* in narrow sense. For it is destined to make the *secretory segments* of the uriniferous tubules. The interstitial connective tissue as well as the renal capsule will differentiate from the external layer of the same mesenchymal mass.

Fig. 38. Section through the Ureter, Genital Tubercle and Hind Limb Bud (Ser. No. 577).

The section passes through the caudalmost portions of the *metanephroi*, and the *ureters* descending from the former are cut ventral in position. The epithelial lining of the ureter, which is continuous with the epithelial tubules in the metanephros, is formed by low cuboidal cells. A thin layer of accumulated mesenchymal mass envelopes

it externally.

The ventral end of the section shows a peculiar prominence which represents the *genital tubercle*. Of course, it is sexless at this stage and two or three months will elaspe before the distinctive *penis* or *clitoris* is formed.

Another new feature occuring on the present section is the bud of *lower extremitiy*(1). As shown in several succeeding figures, too, it is internally just a somewhat condensed mesenchymal mass. So it is uncertain, whether or not there may occur some primordial cartilages or muscles belonging to the lower extremity before it dwindles away in accordance with the further growth of the fetus.

Fig. 39. Section through the Primitive Bladder (Ser. No. 583).

Because of the dorsal shifting of the *umbilical arteries*, the *coelom* is cut three times, being separated into the unpaired median and paired lateral parts. The *postcardinal veins* have also changed position gradually to the dorsal and are now alongside the *aorta*.

The *urachus* which has been kept in the midplane of the ventral body wall is enlarged and triangular in shape, lined with thick epithelium. It means that the cavity mentioned represents the cranial portion of the *urogenital sinus* or of the *cloaca*. This is the primitive *bladder*.

Fig. 40. Section through the Urogential Sinus and Membrane (Ser. No. 589.)

The *urogenital sinus* or *cloaca* is cut at the level of its fusion with the *mesonephric duct*. The communication between the urogenital sinus and the *ureter* is shown at the same time. In other words, the mesonephric duct and ureter make very short common stem just before they join the urogenital sinus. The sinus itself is connected with the outer surface of the *genital tubercle* by an epithelial cell. cord that represents the *urogenital* or *cloacal membrane*.

Strictly speaking, the bladder and the urogenital sinus are to be discriminated from each other, although the former is merely a cranial continuation of the latter. The joints of the mesonephric ducts and ureters to the urogenital sinus mark the caudal limit of the bladder, the remaining portion representing the urogenital sinus in narrow sense.

(1) It is well known that the whale- and dolphin fetuses have rudimentary lower extremities in their very early fetal stage. C.f. Guldberg (1894, 99), Guldberg & Nansen (1894), Kükenthal (1895), Hosokawa (1952) and Ogawa (1953).

Fig. 41. Section through the Bifurcation of Aorta into Umbilical Arteries (Ser. No. 593).

In the middle of the section is the *aorta* which now separates away into the right and left *umbilical arteries*. On each side of the aorta is the *postcardinal vein*.

The intestinal canal (*rectum*) approaches its caudal end, surrounded by loop-like slit of the *coelom*. The *ureters* are lateral in position and show nearly tangential sections due to their concurve course.

The mesenchymal portion behind the *urogenital sinus* is the *cloacal* or *uro-rectal septum*, which fills the interval between the sinus and the hind-gut in the wedge-like fashion.

The section of the recurved tail of the fetus has increased in size. A couple of pairs of *somites* are seen alongside the cut *spinal cord* and *notochord*.

Figs. 42 & 43. Sections through the Caudal Artery and Tail Gut (Ser. No. 601 & 603).

These two figures show two successive sections around the caudal end of the alimentary canal. The features and structures in both are almost the same, and the only noteworthy difference is that the former shows the connection between the *rectum* and *urogenital sinus* (*cloaca*), while the latter is provided with a section of the *tail gut* or the *postanal gut*. This is the caudalmost extention of the entodermal canal a little beyond the cloacal membrane and is destined to dwindle and disappear very soon.

The presence of the *caudal artery* in the center of these figures may be worthy of notice. It is the caudal continuation of the aorta.

Fig. 44. Section through the Lumbal Curvature (1) (Ser. No. 655).

The section passes through the curvature of the lumbal region of the fetus, the *spinal cord* being cut twice at the anterior and posterior ends of the section. The tangential shaving of the *notochord* is in the center.

On each side of the section is a series of *somites*, which comprises myotomes, sclerotomes and dermatomes. The *myotomes*, which are most conspicuous in the section, are oval condensations of *myoblasts* of the mesenchymal origin. Needless to say, it is the forerunner of the skeletal muscles in regions of the neck, trunk and possibly of the limbs.

The *dermatomes*, which from a layer of aggregated mesenchymal cells under the surface epithelium, have arisen from the external portion of each somite and will furnish connective tissue for the skin.

The *sclerotomes* have come from the ventro-medial walls of somites, migrated, and have surrounded the notochord. Each of them, lying in paired segmental masses, has furthermore differentiated into two parts, the *cranical looser* and the *caudal denser half*. When they proceed further in development, these two parts of each sclerotome will separate and the caudal denser half will unite with the cranial half of the next sclerotome, thus forming the primordium of the *vertebra*. It is well known that, because of these procedures, the myotome and the vertebra become to lie in alternation, and that this alternation makes it possible for the myotomic muscles to move the spine.

Intersegmental arteries are cut in between the successive somites, while the spinal, *segmental nerves* are within each somite.

Figs. 45 & 46. Sections through the Lumbal Curvature (2, 3) (Ser. No. 669 & 673).

These figures show two sections of very close levels. The main difference consists in the fact that the *spinal cord* is cut twice in the first figure, while it is cut longitudinally extending almost the whole length of the second section.

In both of them *spinal ganglia* arranged serially are shown, together with some of the *ventral roots*.

Other features and the arrangement of *somites* resemble that of the previous figure very much, excepting that the *sclerotomes* have *lateral projections* which lie intervening the myotomes. These projections are possibly to be regarded as the primordia of the *costal processes*.

Résumé

From the foregoing observation of serial sections, it may be concluded that the internal structures and features of a 12-mm. embryo of the Prodelphinus caeruleo-albus, Meyen, resemble very much that of human embryos of some 10–12 mm. in length (5–6 weeks in fetal age) as well as that of pig embryos of the similar size.

There are, however, several remarkable differences or interesting things worthwhile to be mentioned from the comparative anatomical view-point. Some of them will be summarized in the following.

1) All of the primordia of cranial nerves are present already, and even such nerves as n. petrosus superficialis major and chorda tympani, of which the existance in the adult whales is not yet ascertained, occur distinctly just like in the human and pig embryos.

2) The gall bladder, in which the adult whales lack, is not foreshadowed at all in the present fetus.

3) As in the adult whales, the fetus does not show any indication of hepatic lobulation, while the human and pig embroys of the similar size have distinctly lobulated liver.

4) The hind limb buds appearing only in the early developmental stage of whale's fetuses are represented by prominences permeated with accumulated mesenchymal mass inside, showing no indication of the primitive muscles or cartilages at the present stage.

References

Arey, L. B.: Developmental Anatomy. Fifth Ed., Philadelphia & London, 1946.

Baxter, J. S.: Frazer's Manuel of Embryology. Third Ed., London, 1953.

Boyden, E. A.: A Laboratory Atlas of the Pig Embryo. Third Ed., Philadelphia, 1947.

Grosser, O. and *Politzer, G.*: Grundriss der Entwicklungsgeschichte des Menschen. Vierte Aufl., Berlin-Göttingen-Heidelberg, 1953.

Guldberg, G.: Ueber temporäre äussere Hinterflossen bei Delphinembryonen. Verh. anat. Gesellsch., 8. 92–95. 1894.

———: Neue Untersuchugen über die Rudimente von Hinterflossen und die Milchdrüsen bei jungen Delphinembryonen. Internat. Monatsschr. f. Anat. Physiol., 16. 301–321. 1899.

——— and *Nansen, F.*: On the Development and Structure of the Whale. Part I; On the Development of the Dolphin. Bergen, 1894.

Hosokawa, H.: On the Pelvic Cartilages of the Balaenoptera-Foetuses, with Remarks on the Specifical and Sexual Difference. Scient. Repts. Whales Res. Inst., No. 5. 5–15. 1951.

Huettner, A. F.: Fundamentals of Comparative Embryology of the Vertebrates. Rev. Ed., New York, 1952.

Kükenthal, W.: Ueber Rudimente von Hinterflossen bei Embryonen von Walen. Anat. Anz., 10. 534–537. 1895.

Ogawa, T.: On the Presence and Disappearance of the Hind Limb in the Catecean Embryos. Scient. Repts. Whales Res. Inst., No. 8. 127–132. 1953.

Patten, B. M.: The Embryology of the Pig. 1st Ed., Philadelphia, 1927.

———: The Early Embryology of the Chick. Third Ed., Philadelphia & Toronto, 1948.

———: Human Embryology. 2nd Ed., New York & Toronto, 1953.

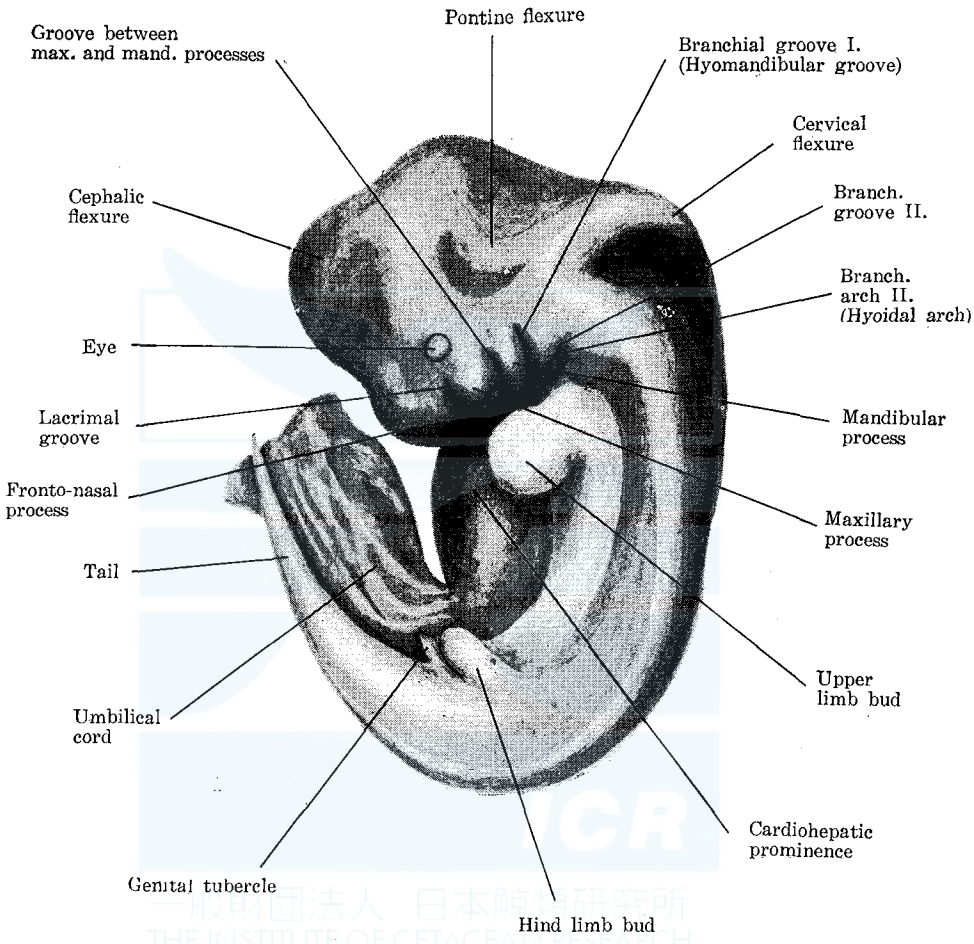


Fig. 1. 12 mm. embryo of Prodelphinus caeruleo-albus.

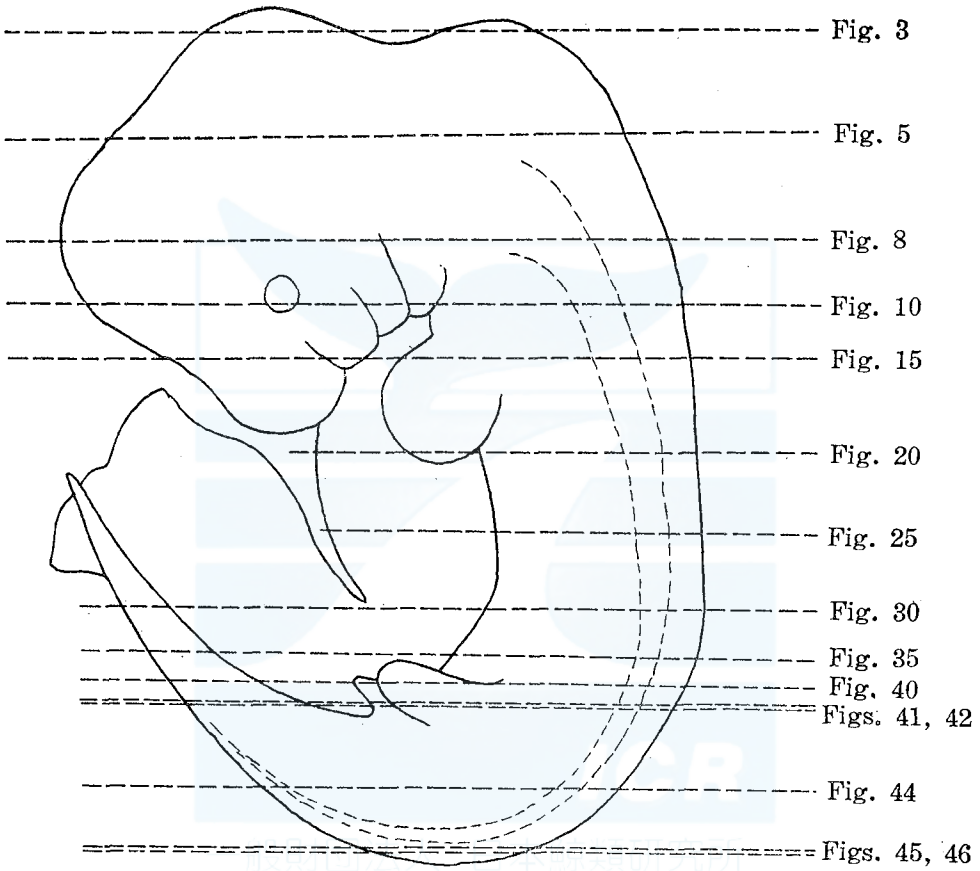


Fig. 2. Guide lines to indicate the levels of sections shown as Fig. 3—46.

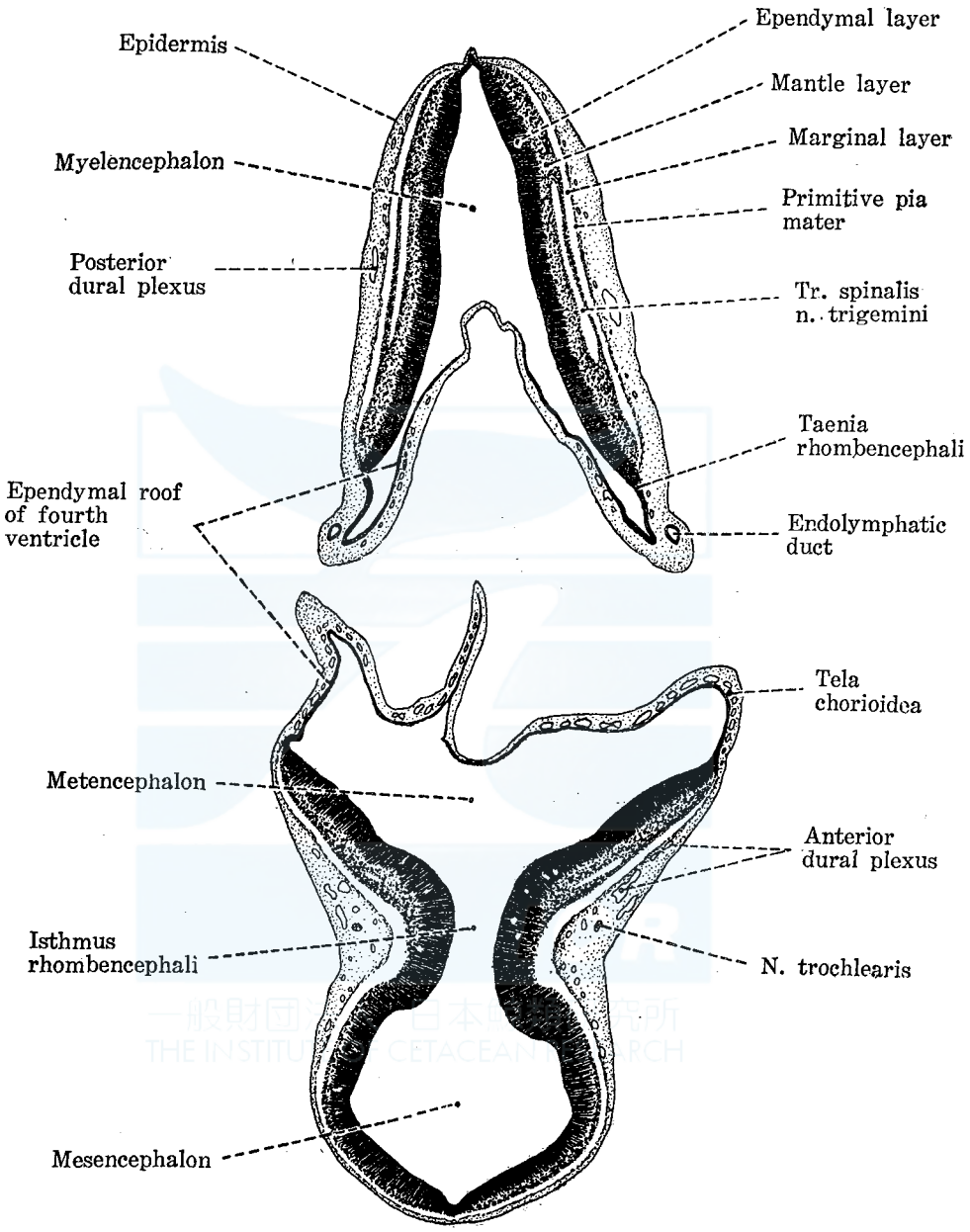


Fig. 3- Section through the isthmus rhombencephali and pontine flexure.

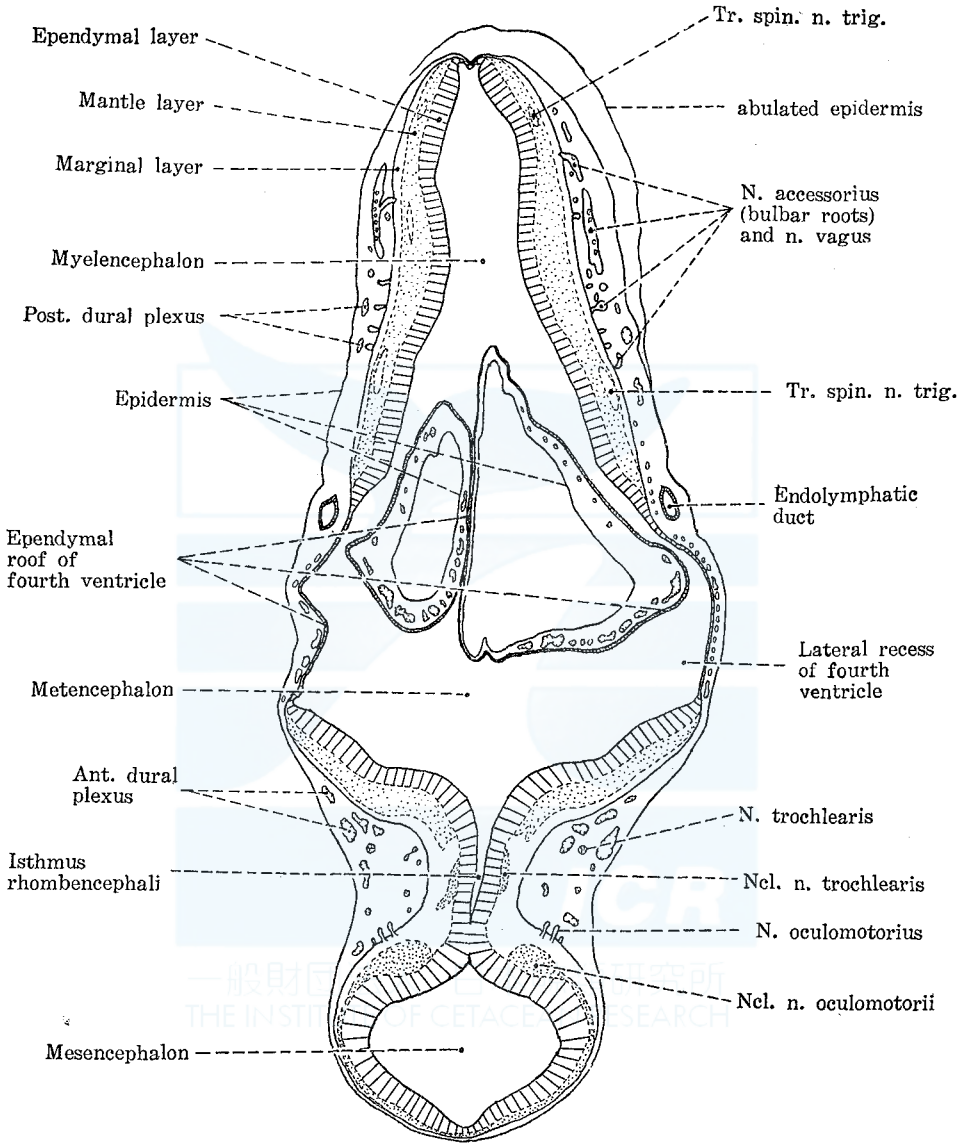


Fig. 4. Section through the fourth ventricle.

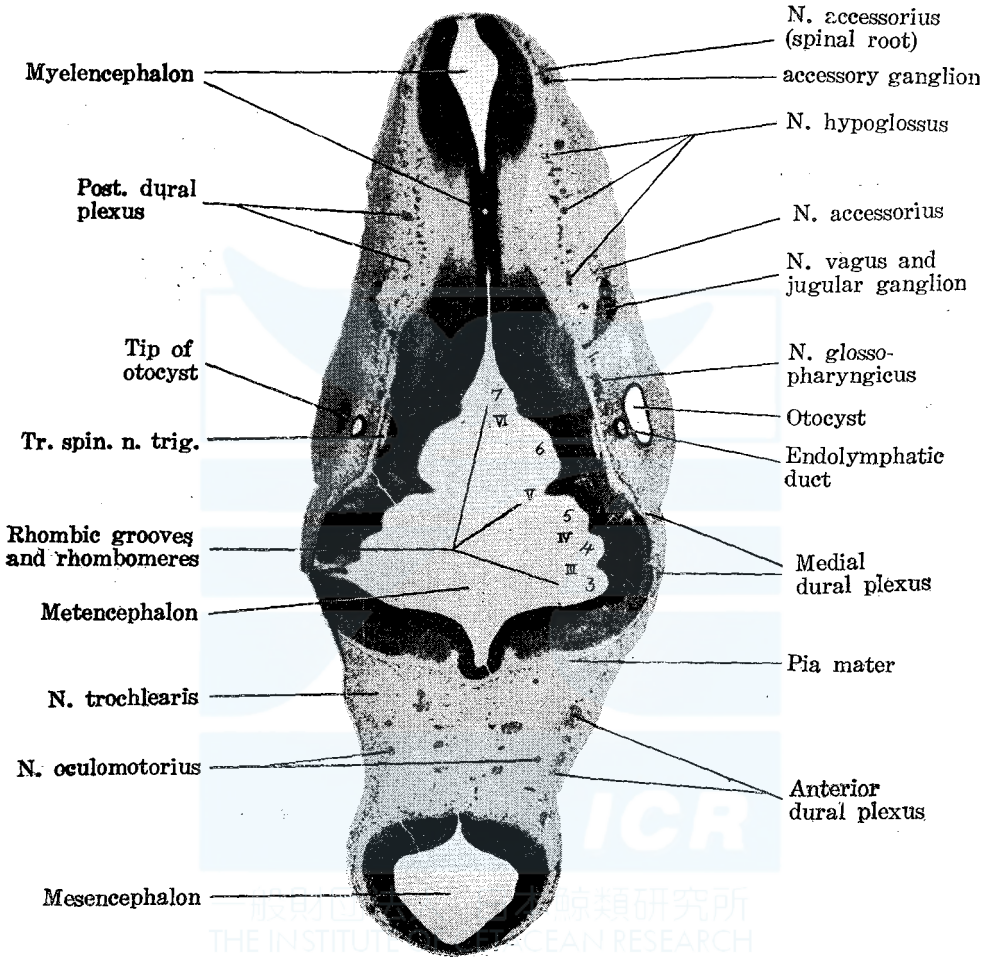


Fig. 5. Section through the apex of an otocyst.

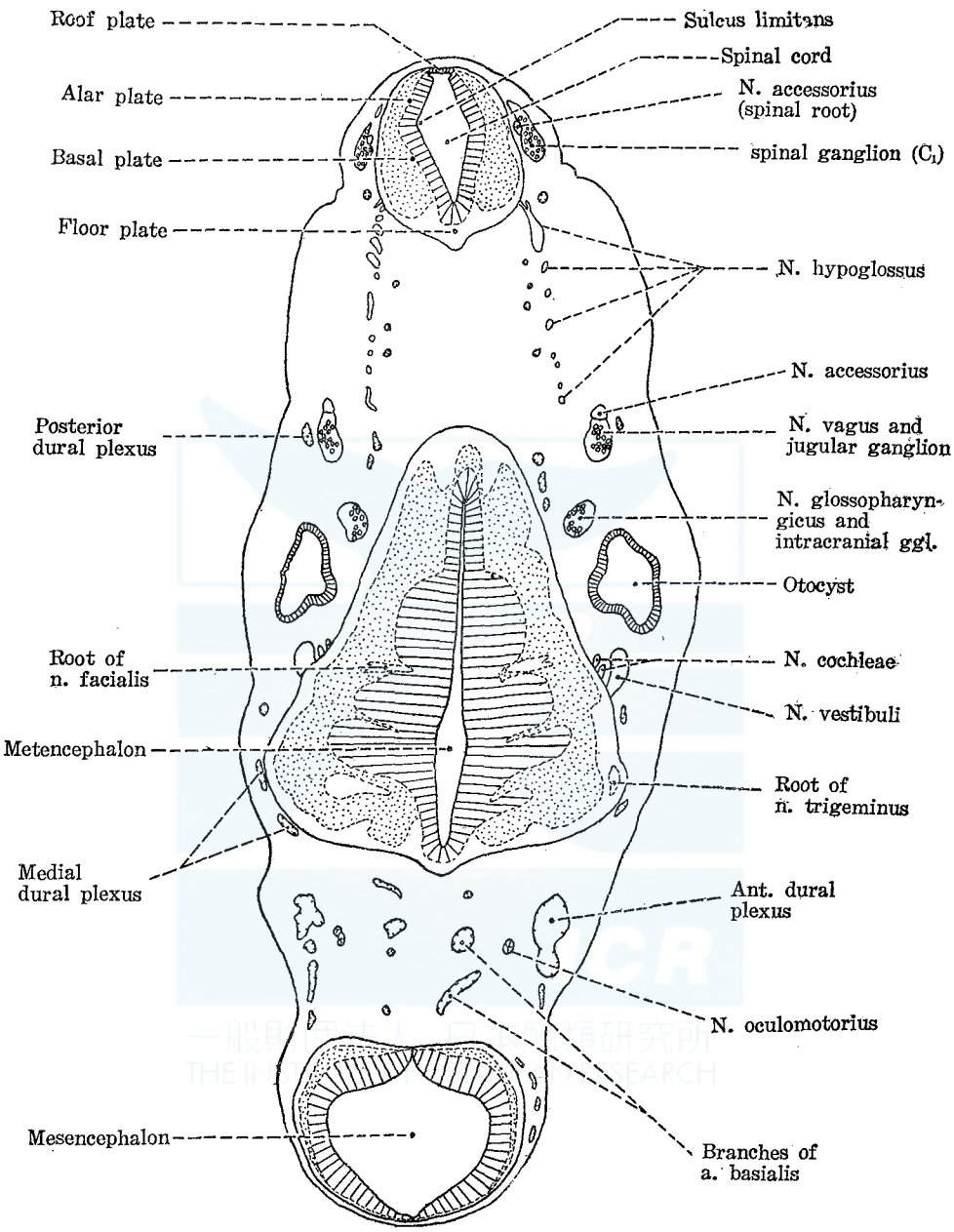


Fig. 6. Section through the floor of metencephalon.

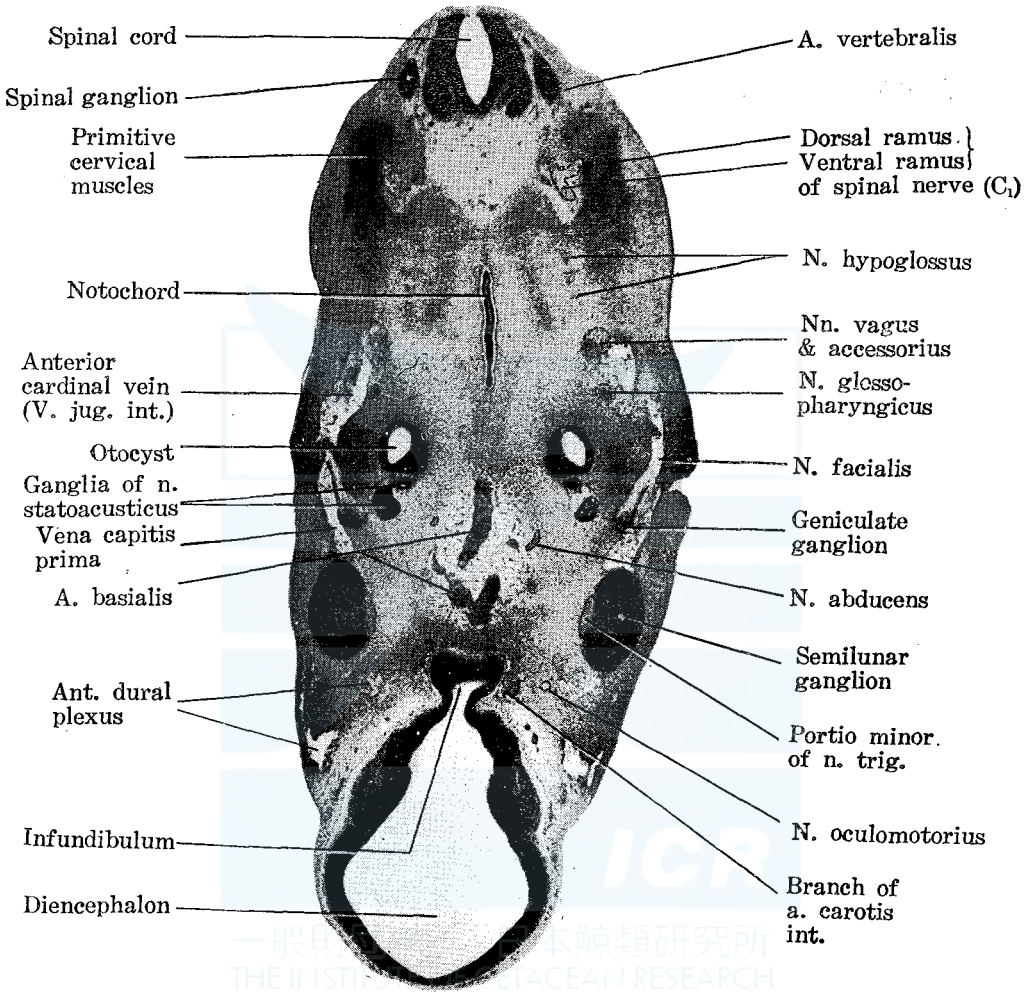


Fig. 7. Section through the infundibulum, ganglia semilunare and geniculi.

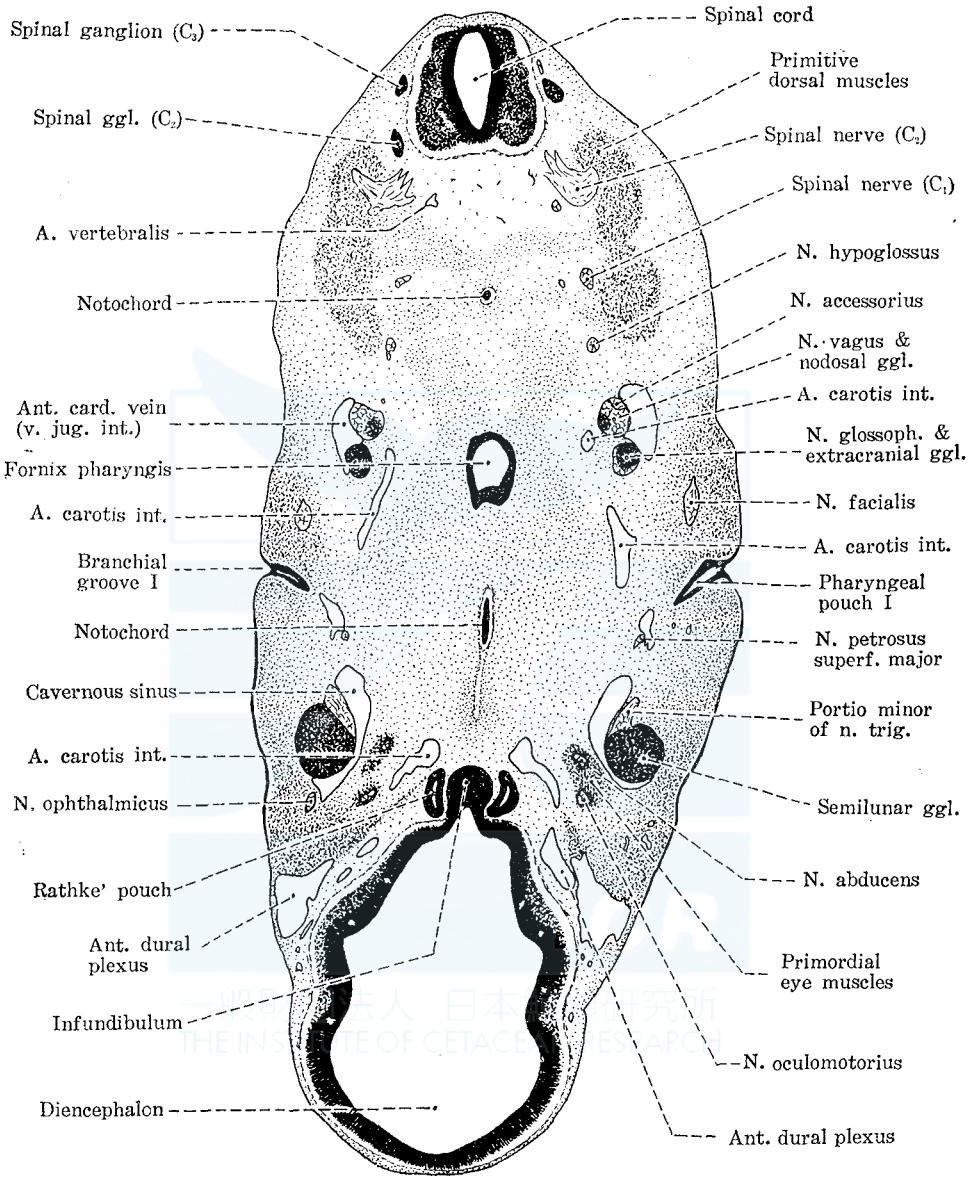


Fig. 8. Section through the fornix pharyngis, ganglia extracraniale and nodosum.

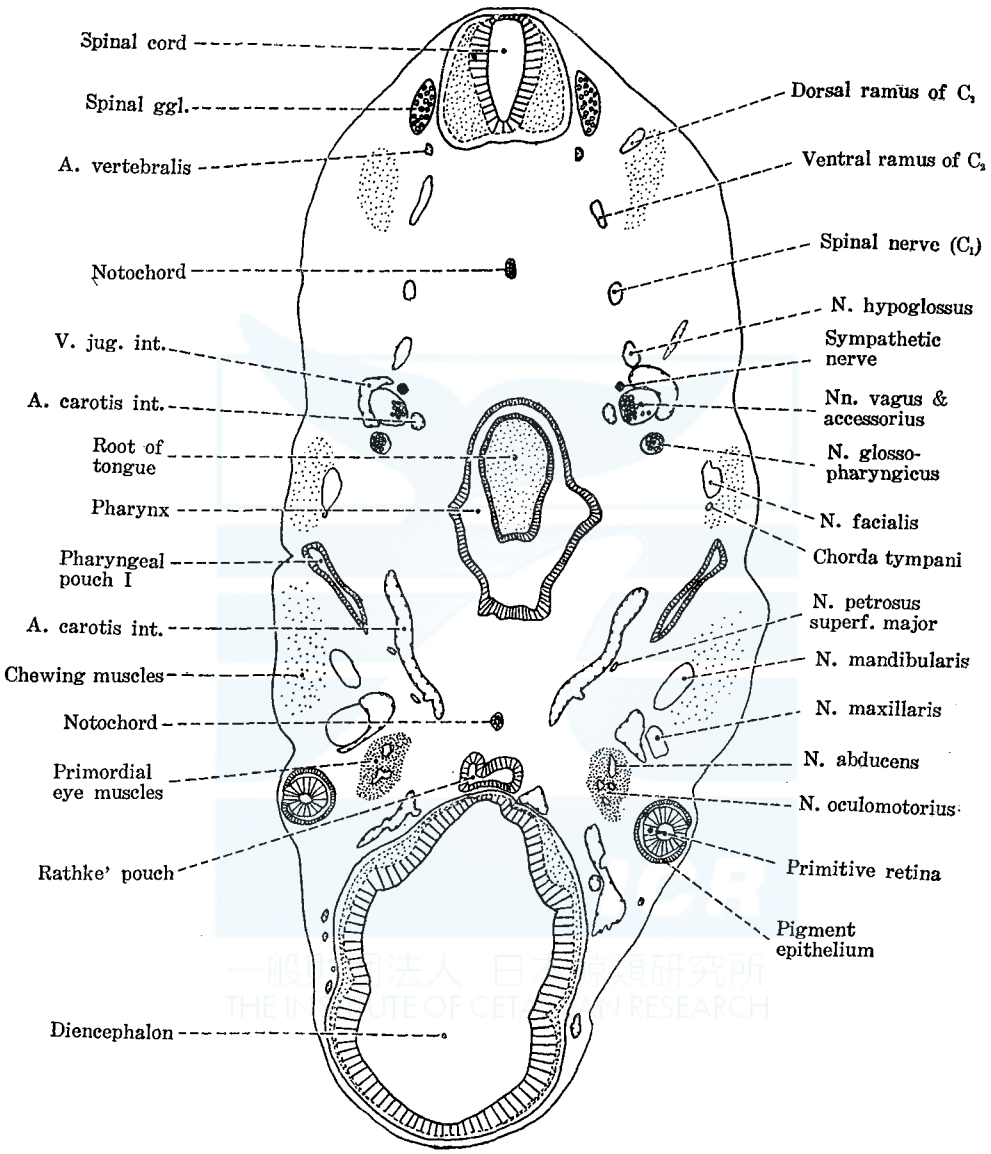


Fig. 9. Section through the optic cup.

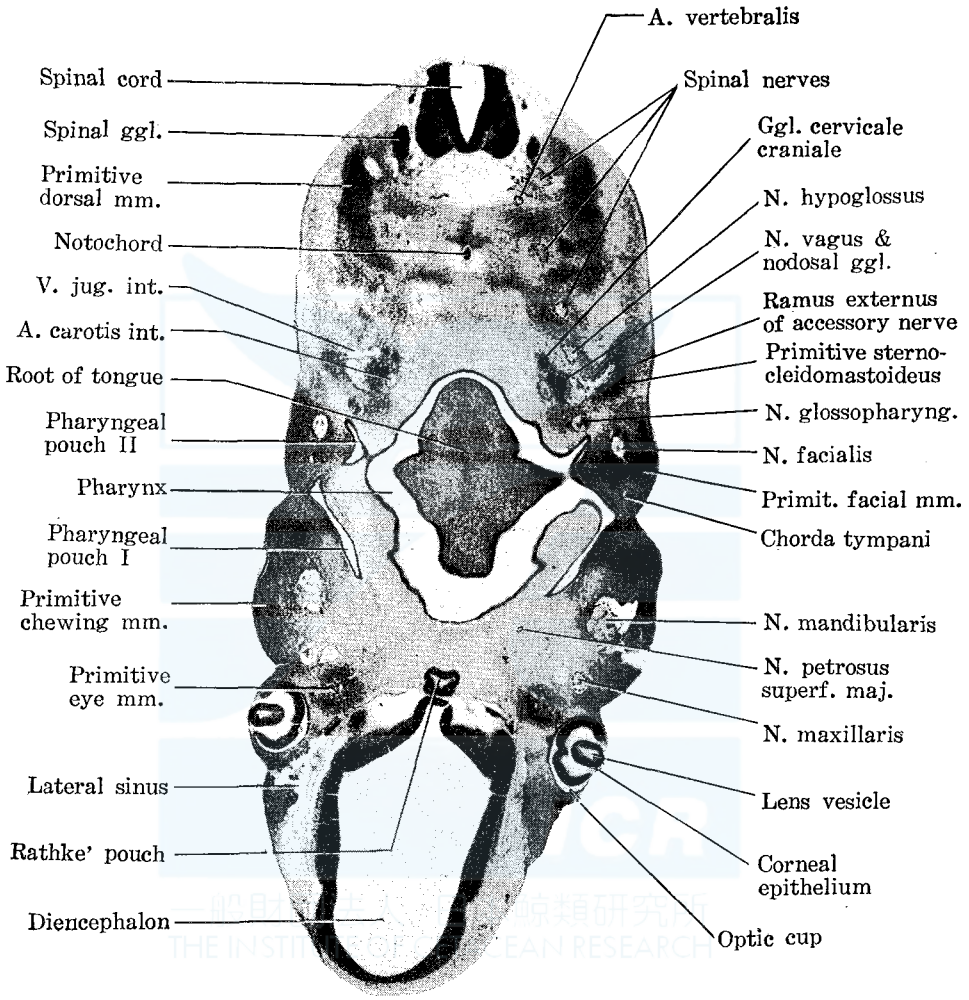


Fig. 10. Section through the root of tongue and lens vesicle.

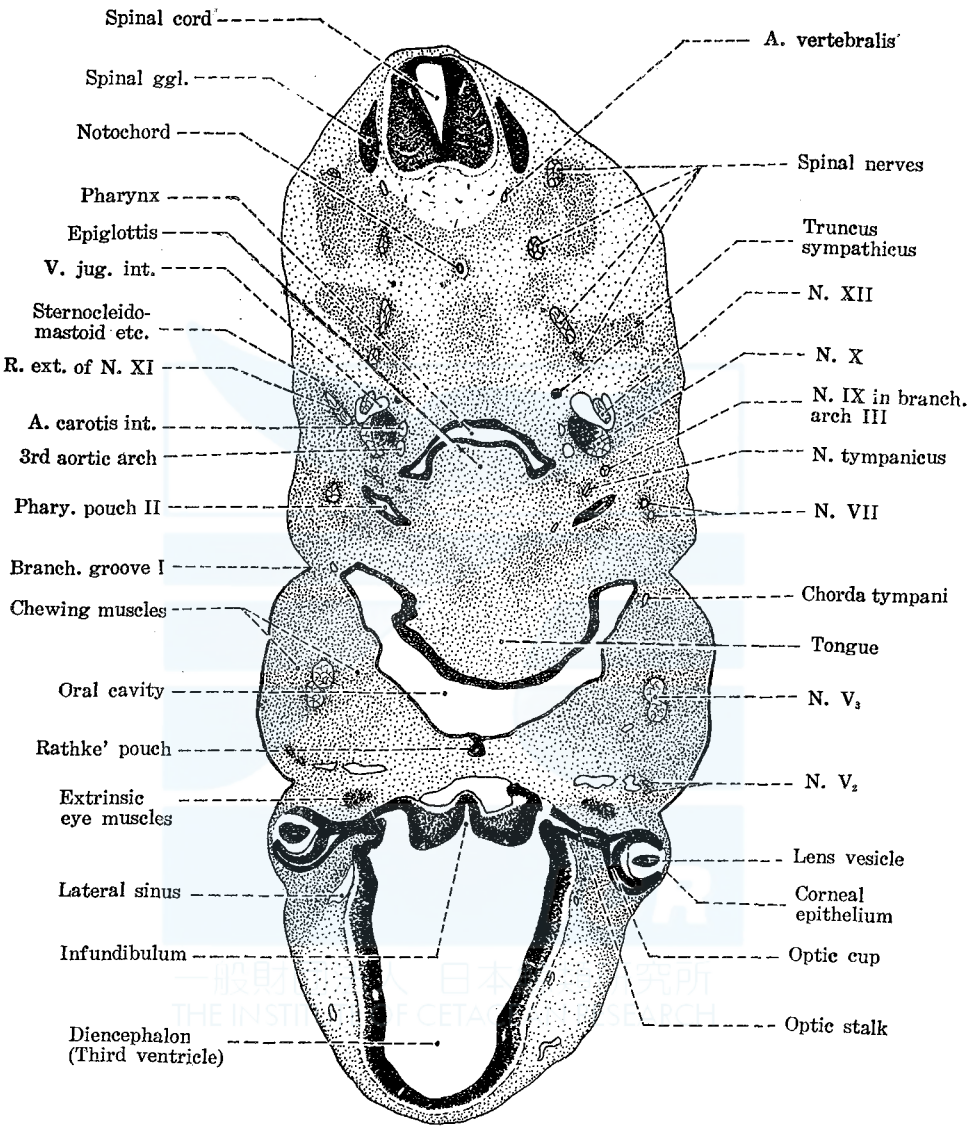


Fig. 11. Section through the origin of Rathke's pouch, epiglottis and optic stalk.

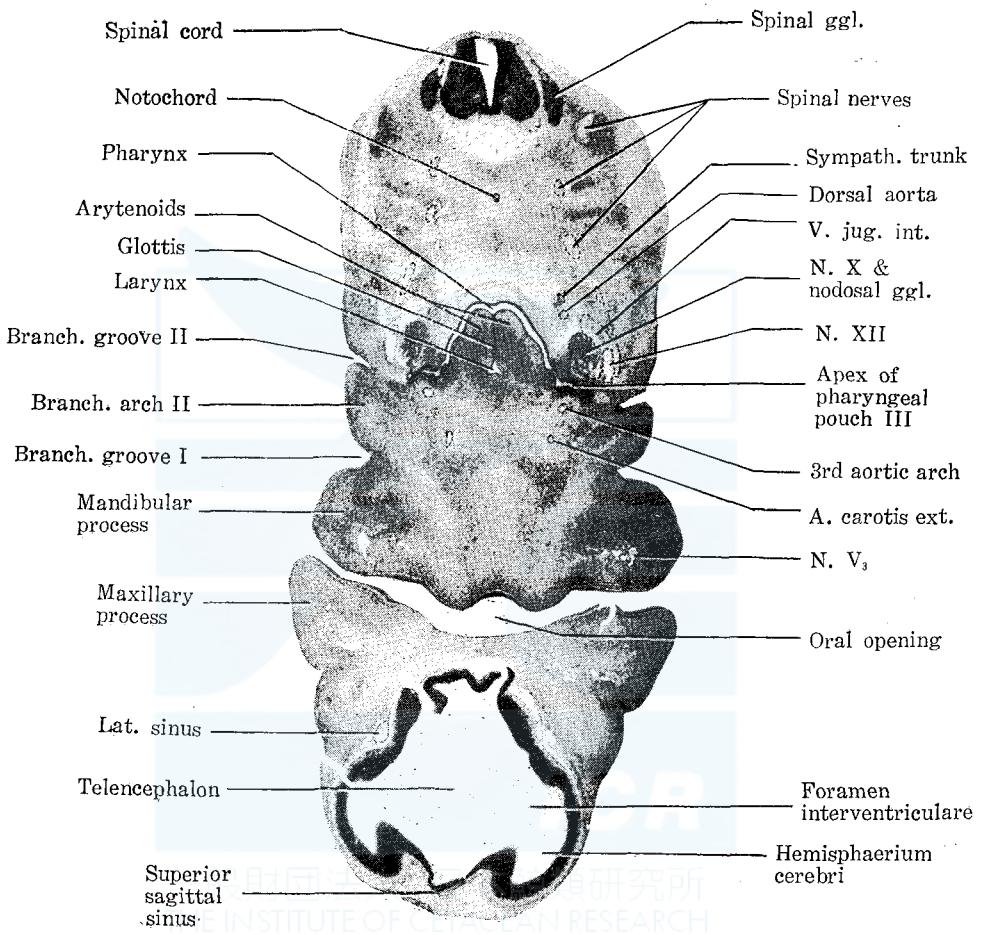


Fig. 12. Section through the foramen interventriculare, oral opening, third pharyngeal pouch and glottis.

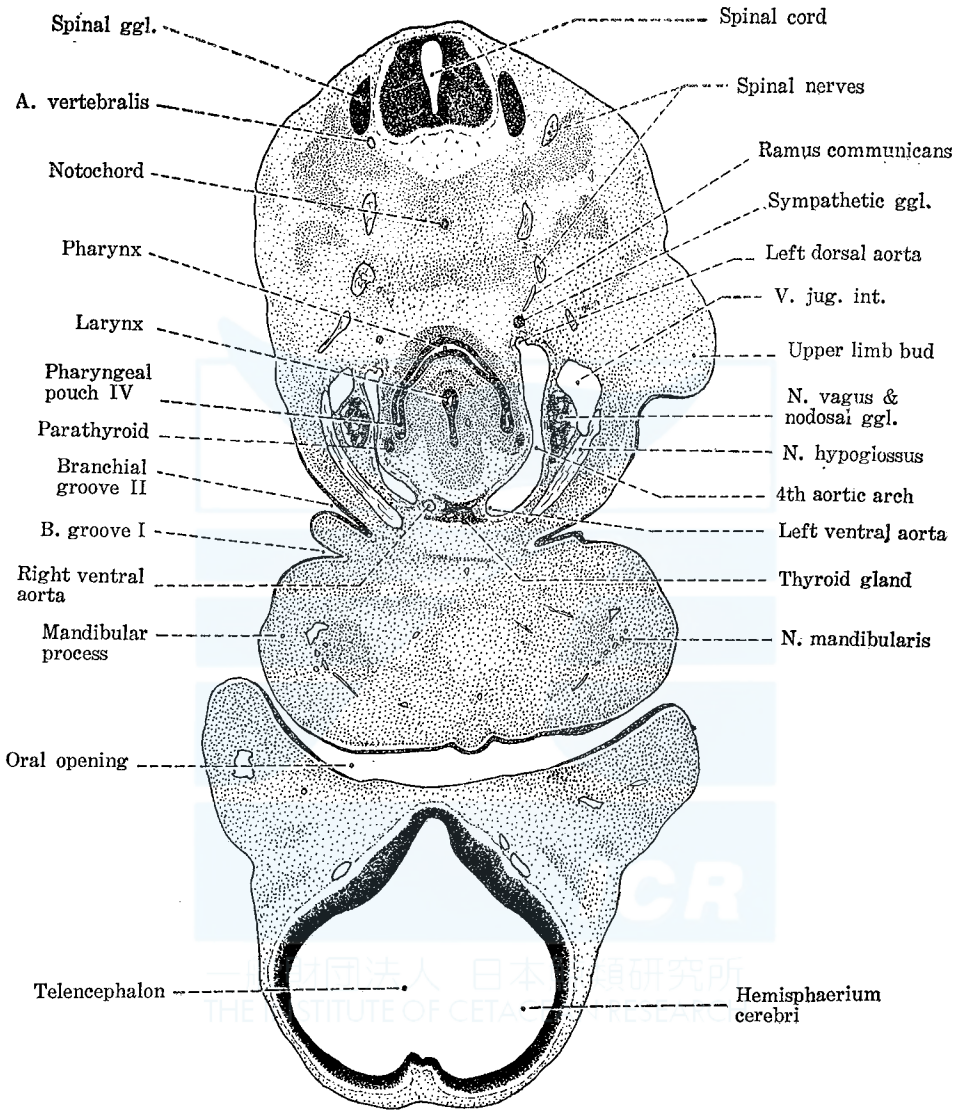


Fig. 13. Section through the fourth aortic arch, fourth pharyngeal pouch and thyroid gland.

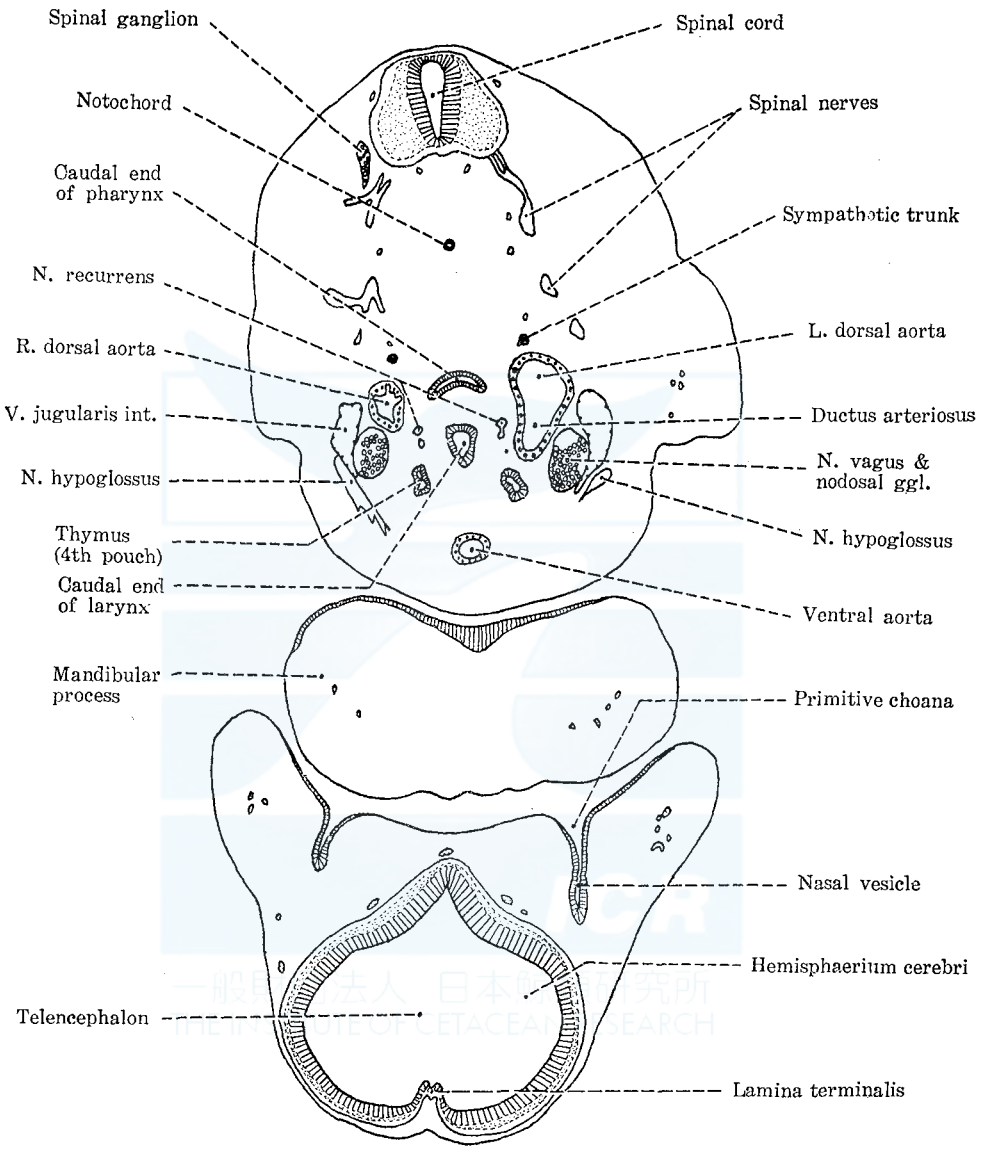


Fig. 14. Section through the ventral aorta and primitive choana.

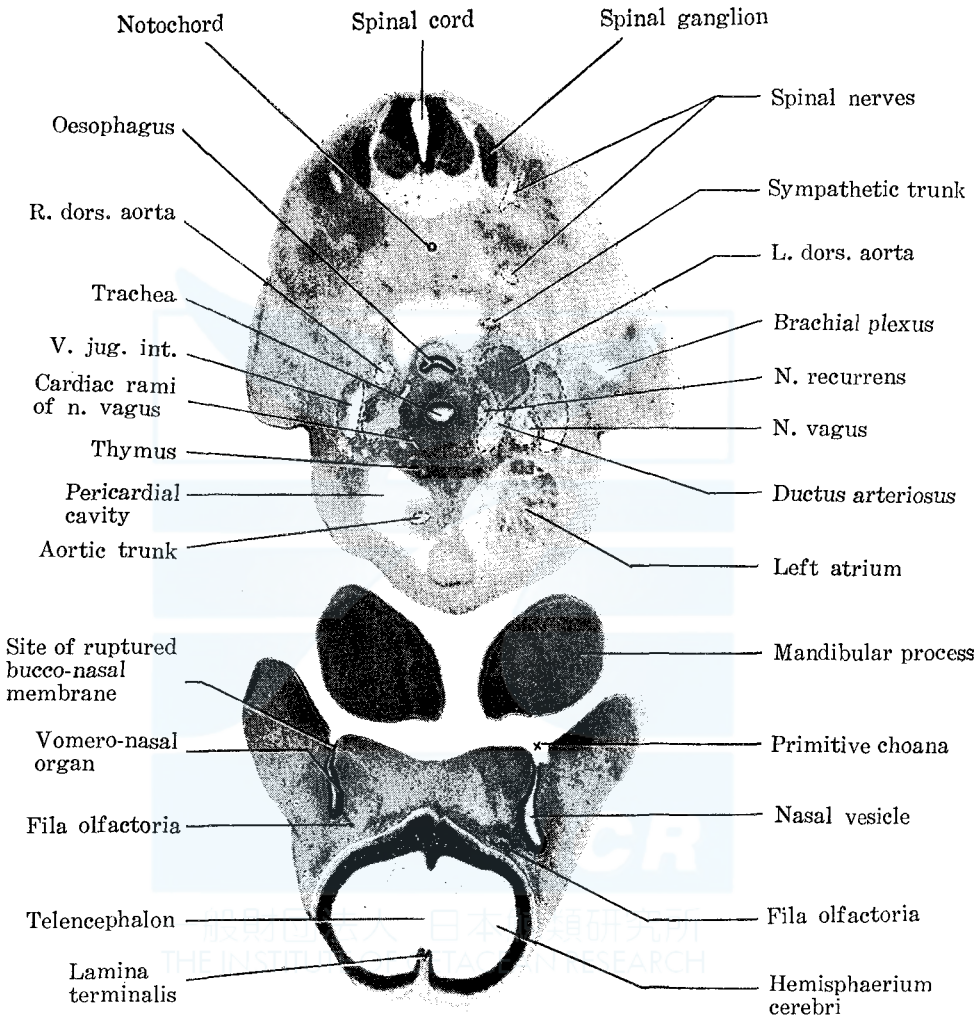


Fig. 15. Section through the apex of pericardial cavity.

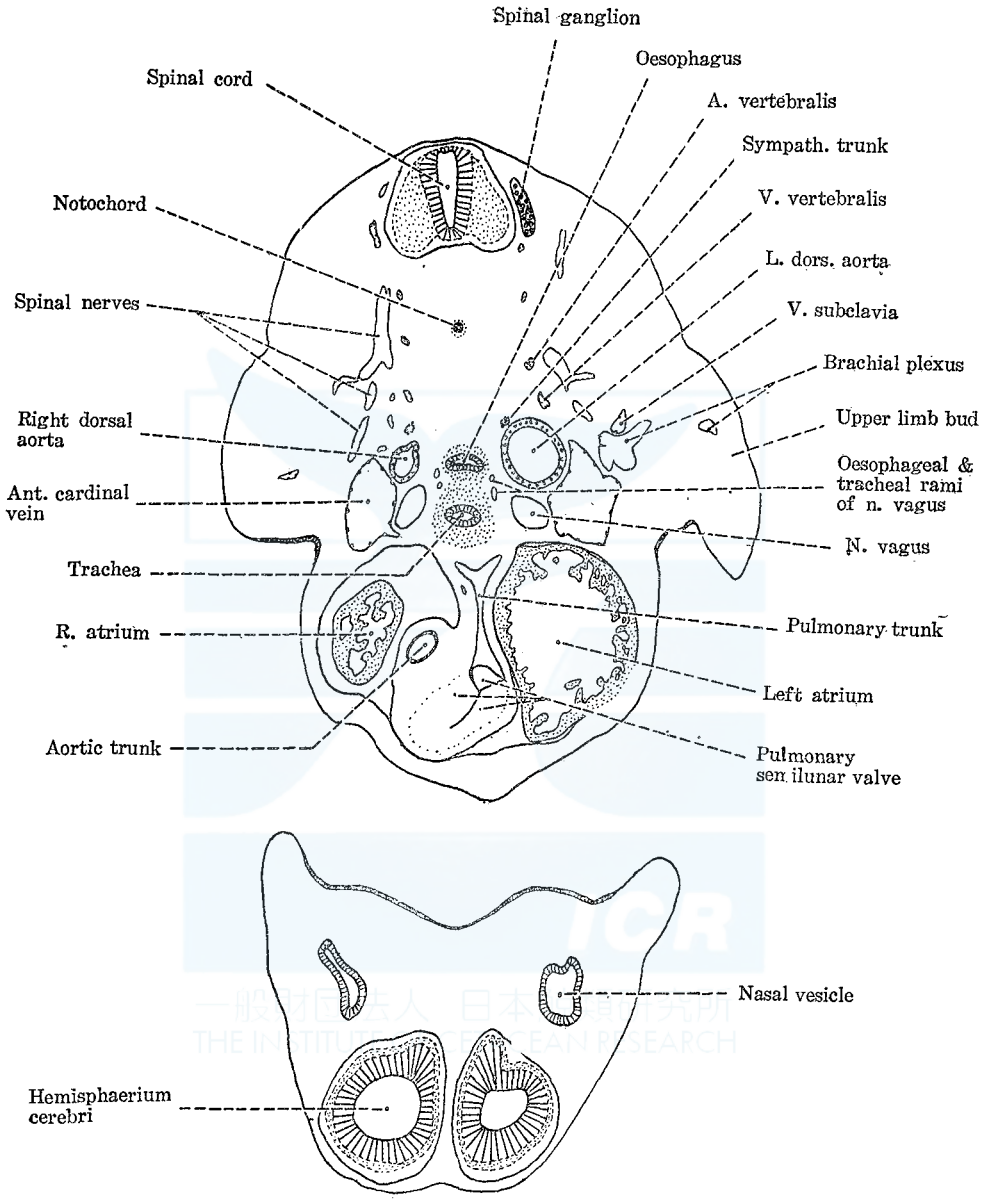


Fig. 16. Section through the pulmonary trunk.

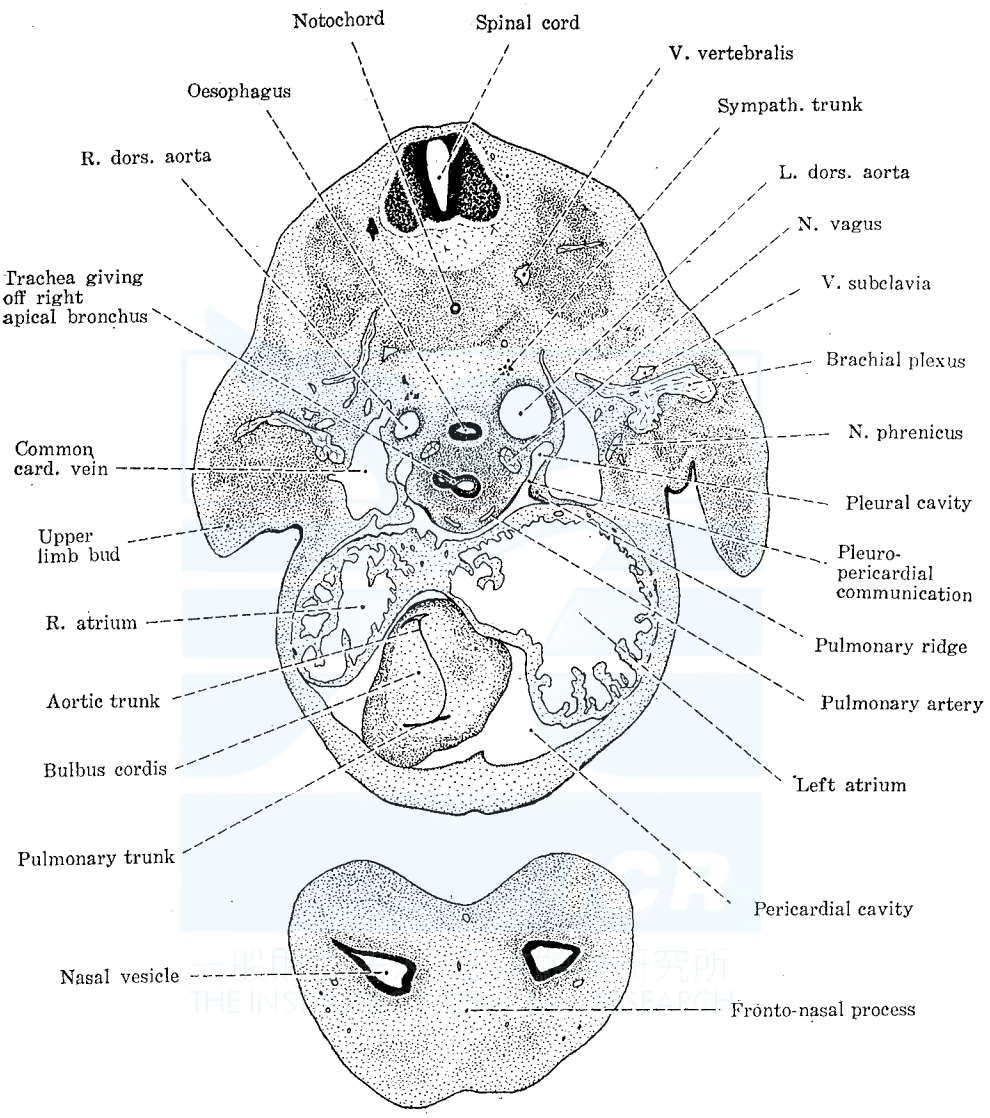


Fig. 17. Section through the bulbus cordis, common cardinal veins and origin of right apical bronchus.

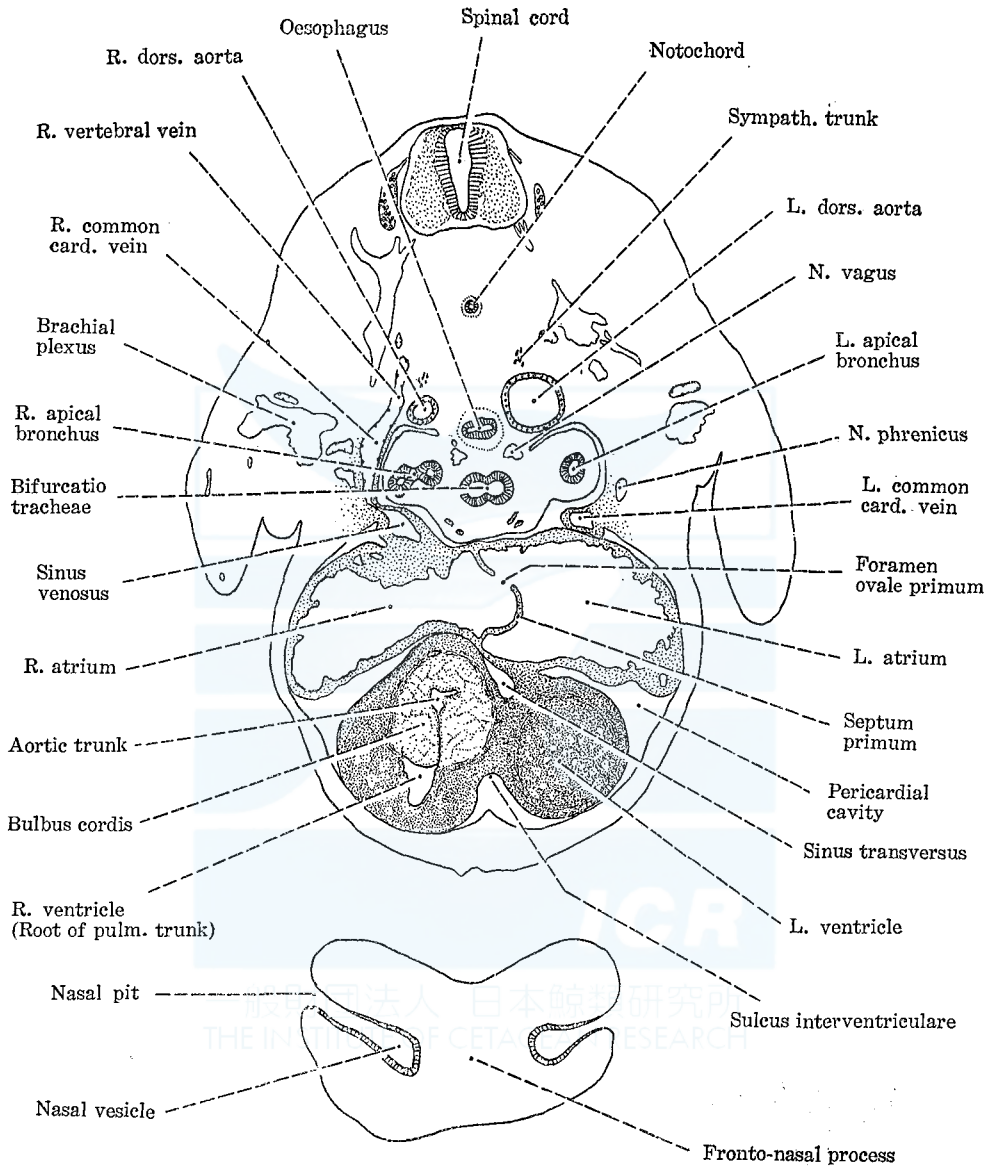


Fig. 18. Section through the foramen ovale I, bifurcatio tracheae and nasal pit.

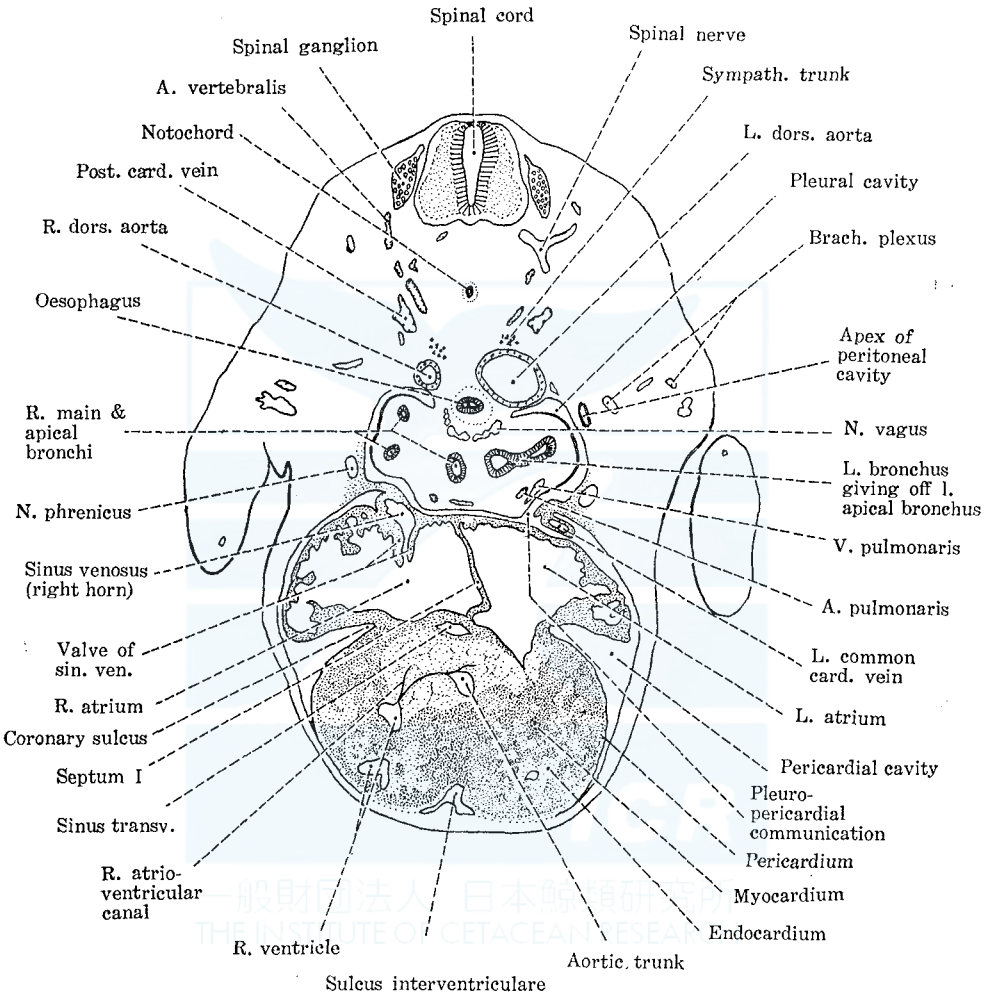


Fig. 19. Section through the sinus venosus.

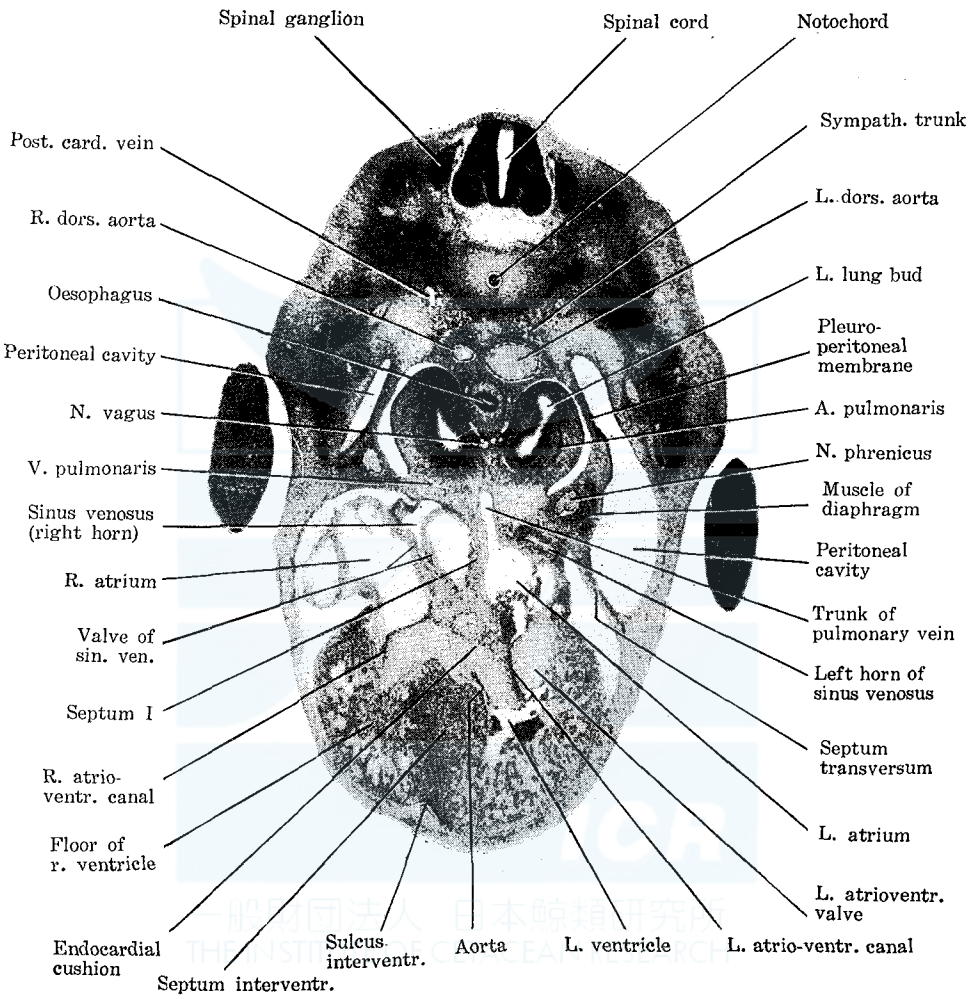


Fig. 20. Section through the trunk of pulmonary vein.

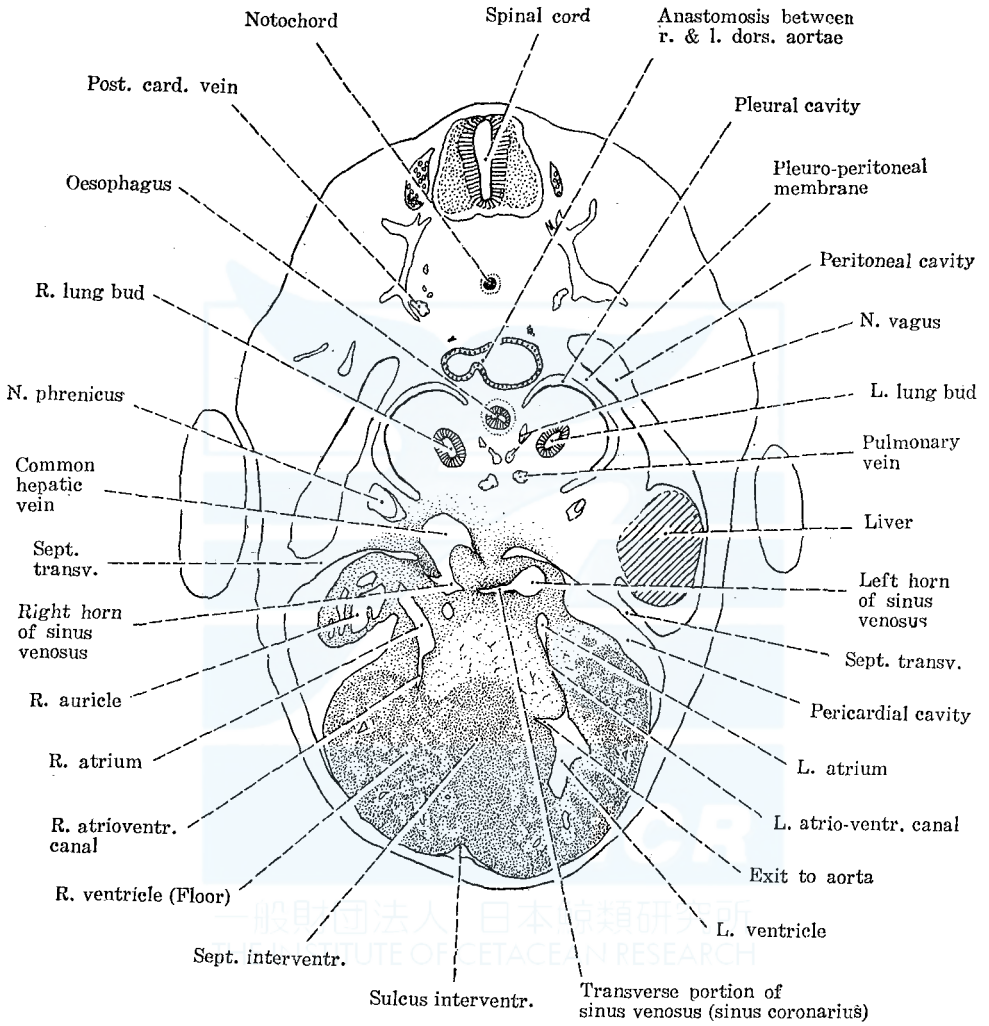


Fig. 21. Section through the anastomosis between right and left dorsal aortae.

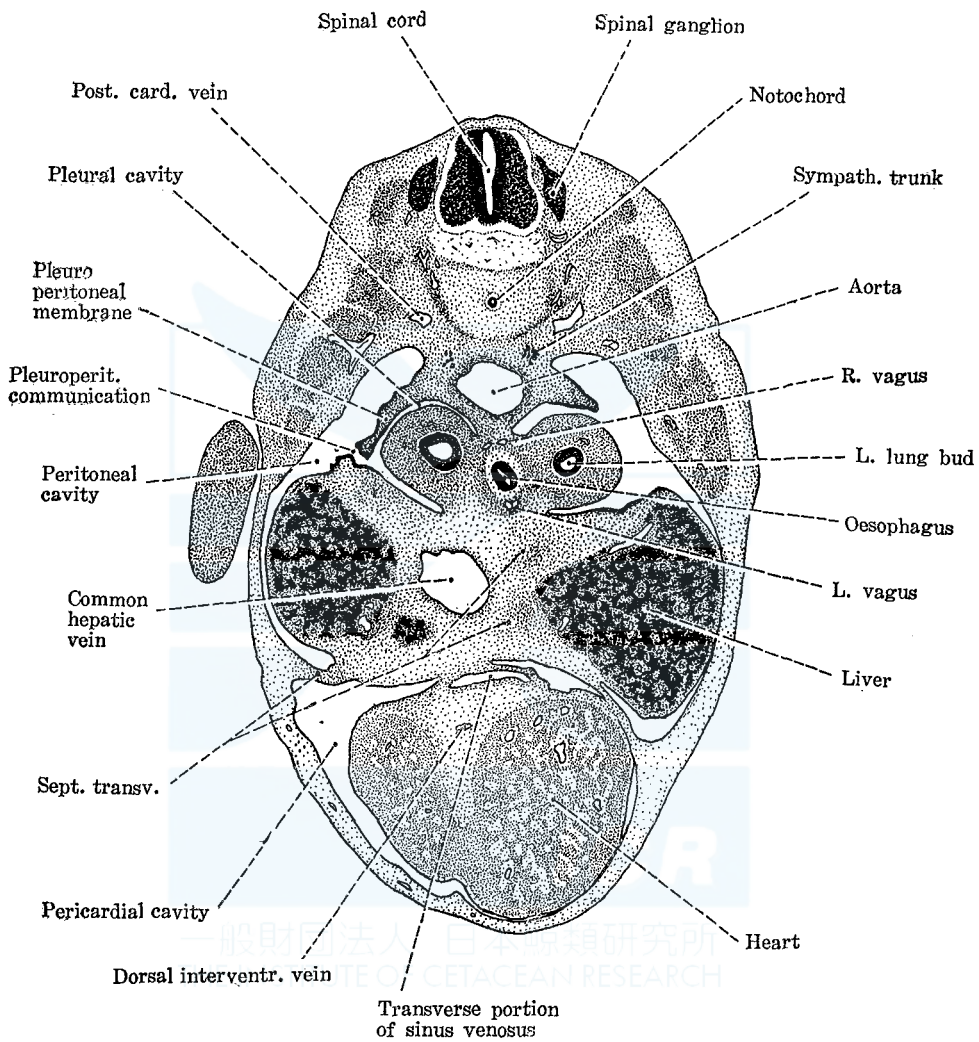


Fig. 22. Section through the pleuro-peritoneal communication.

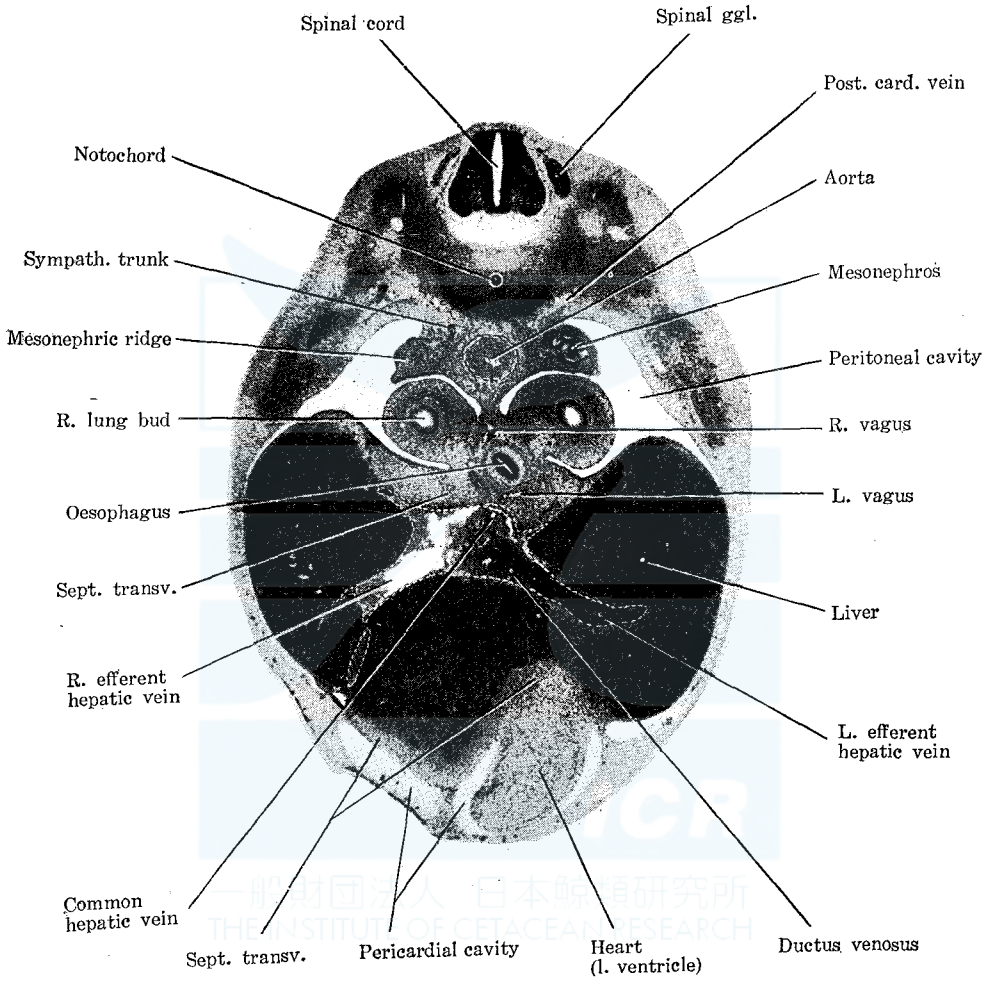


Fig. 23. Section through the ductus venosus.

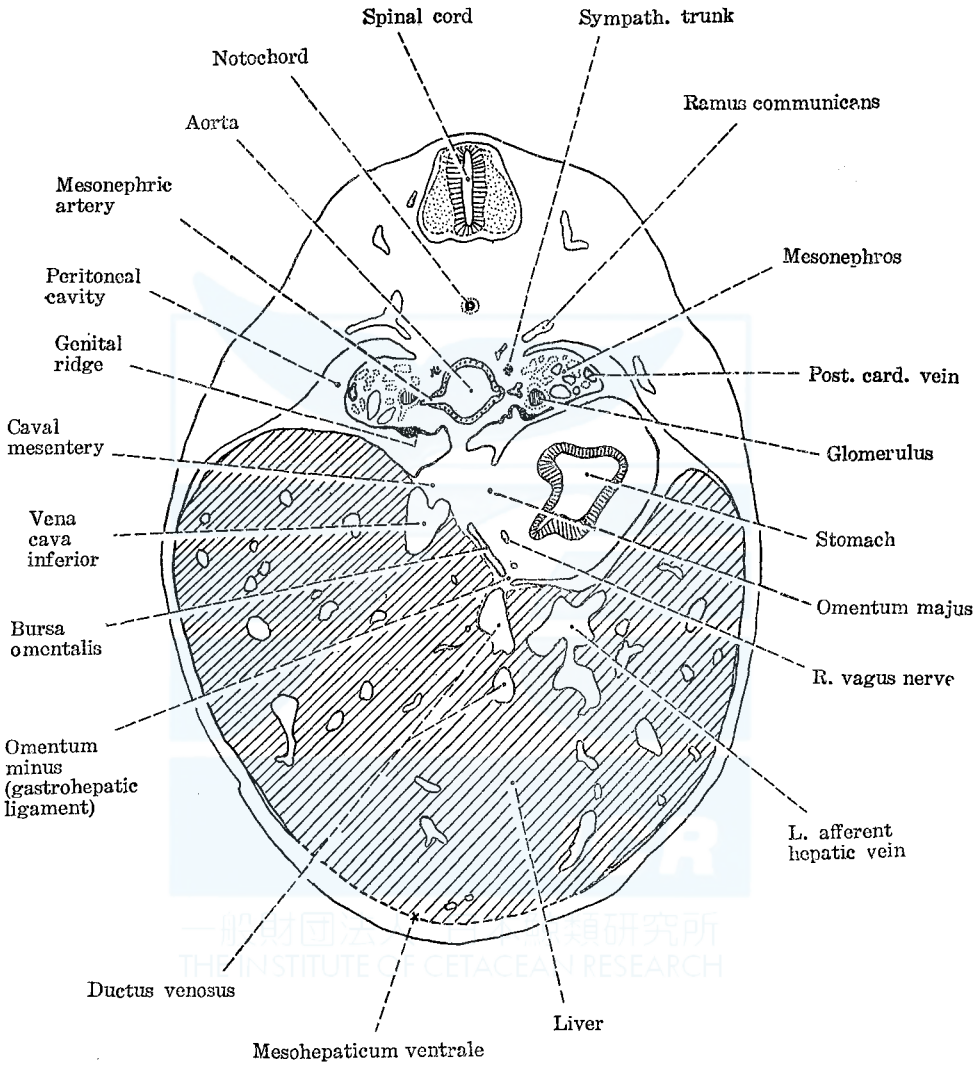


Fig. 24. Section through the stomach.

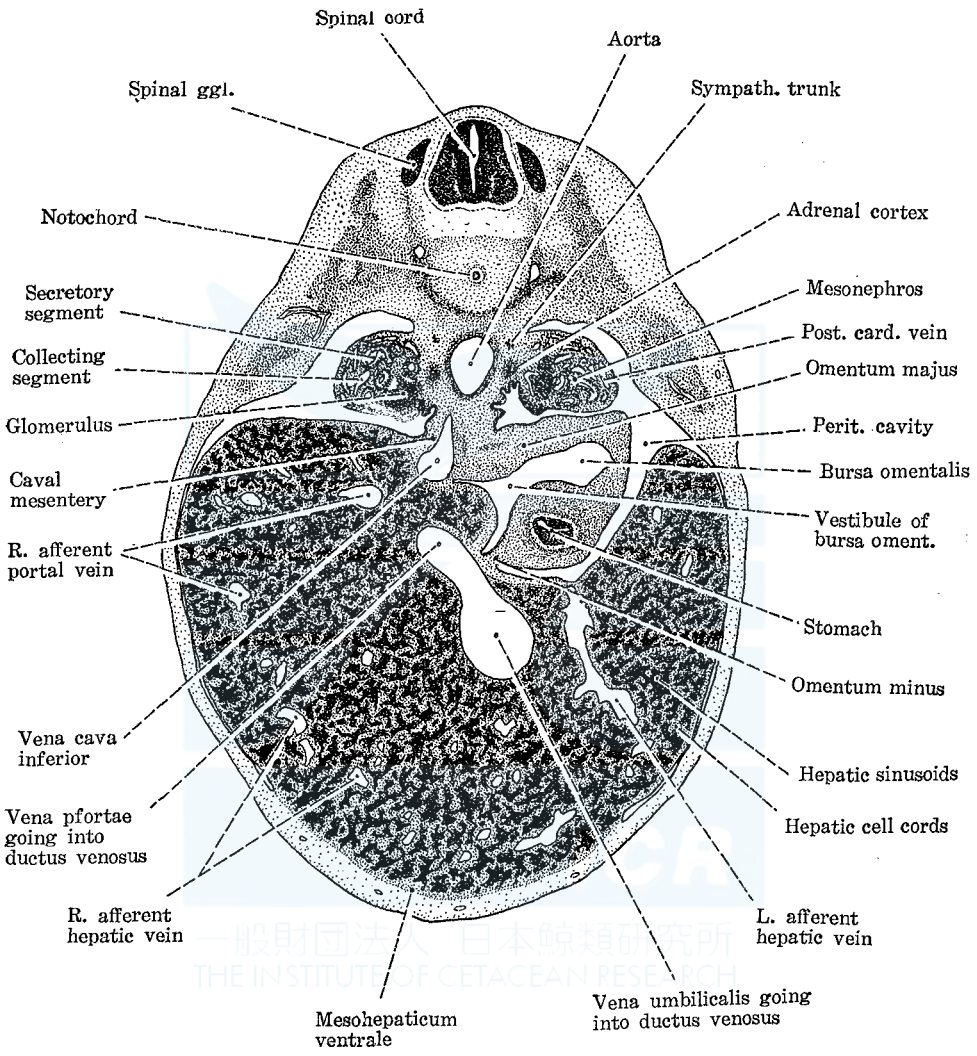


Fig. 25. Section through the adrenal cortex and vestibule of omental bursa.

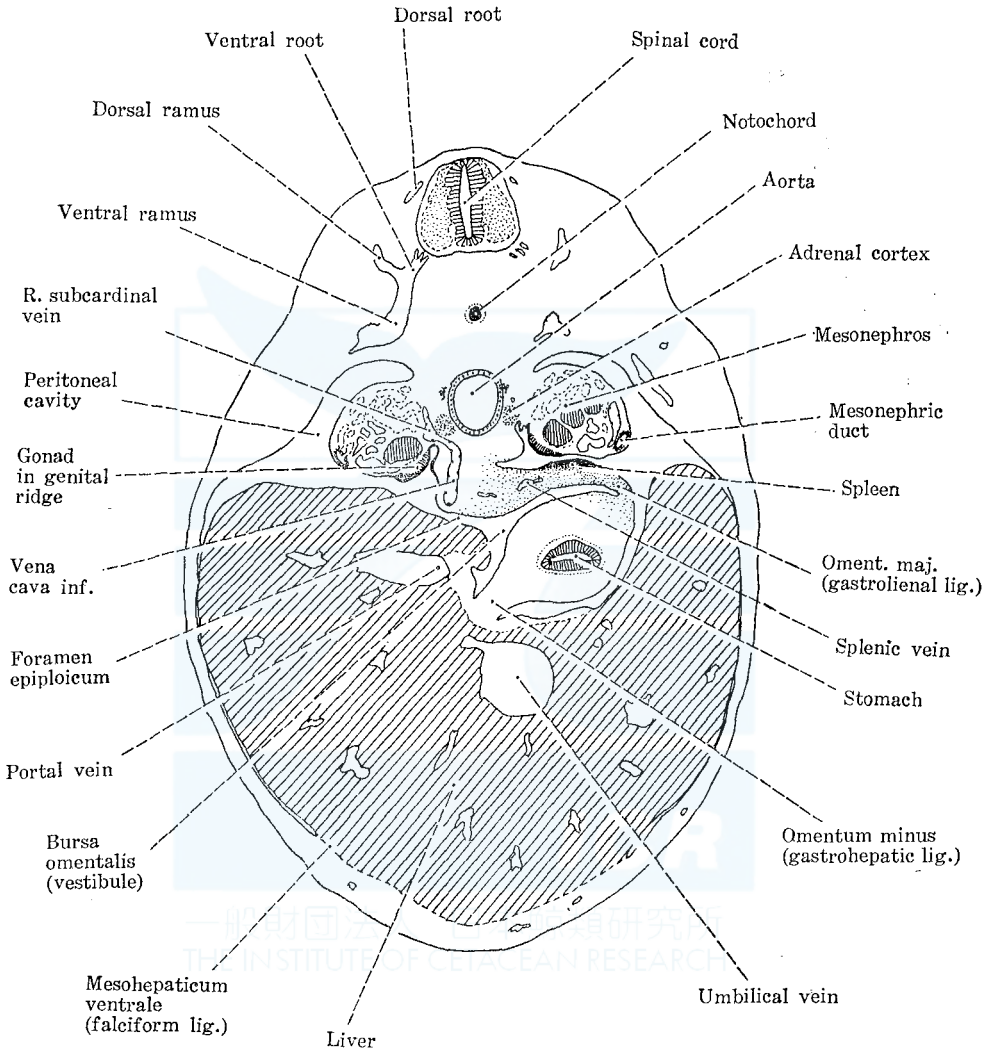


Fig. 26. Section through the foramen epiploicum and splenic primordium.

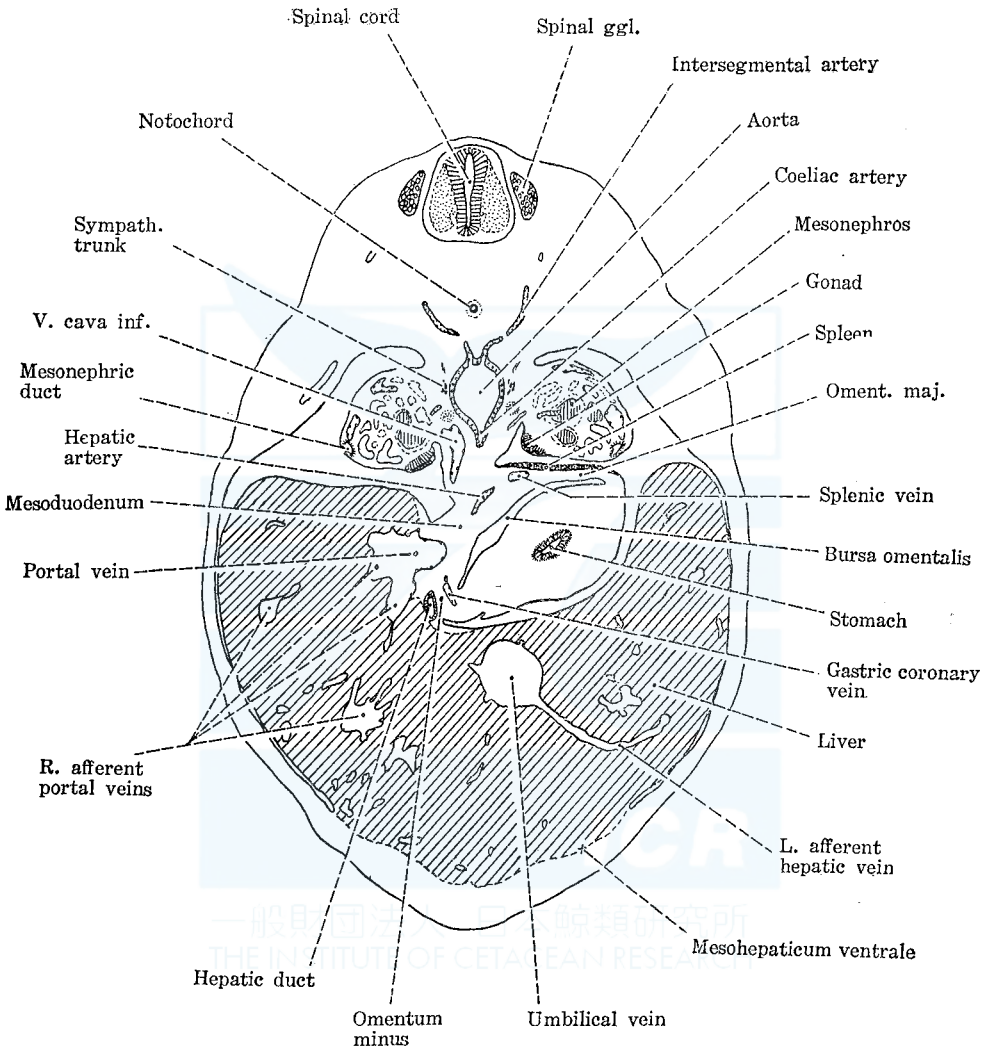


Fig. 27. Section through the root of coeliac artery.

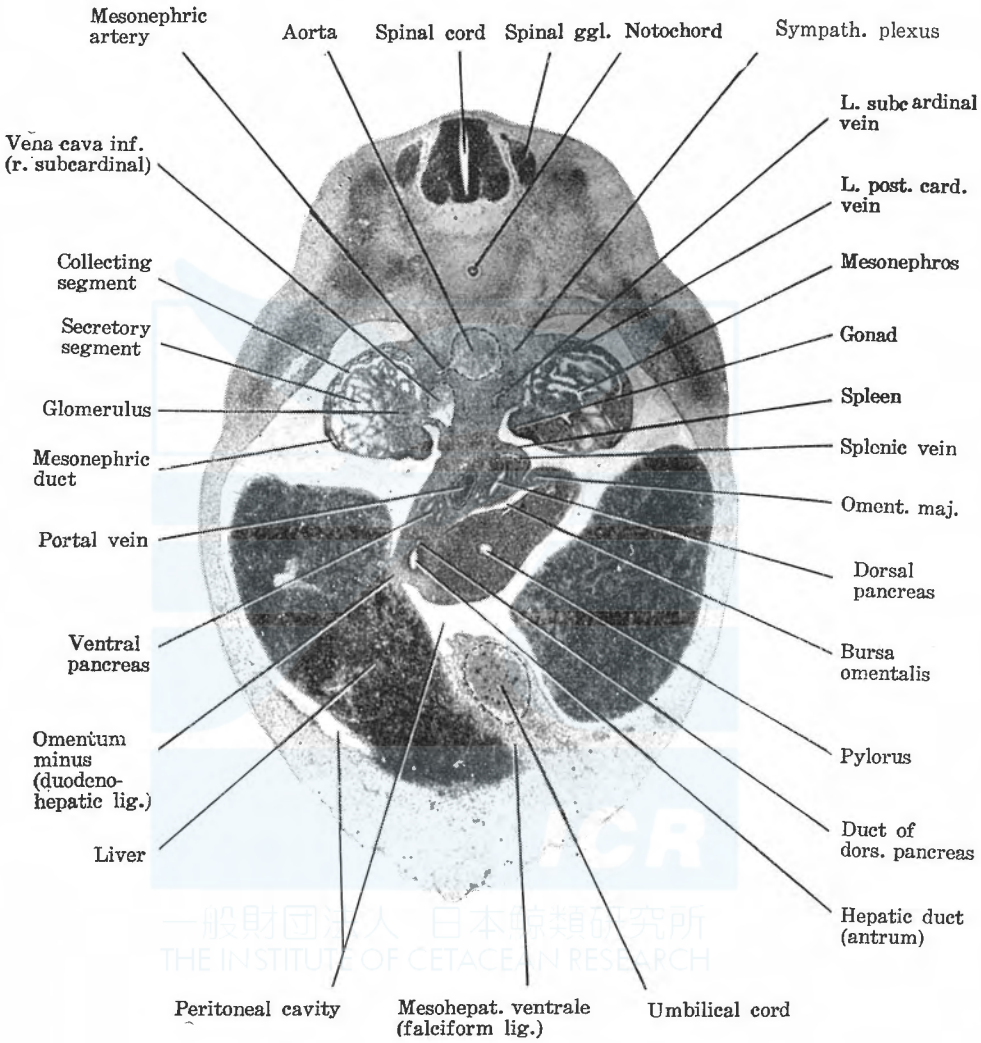


Fig. 28. Section through the primordial pancreas.

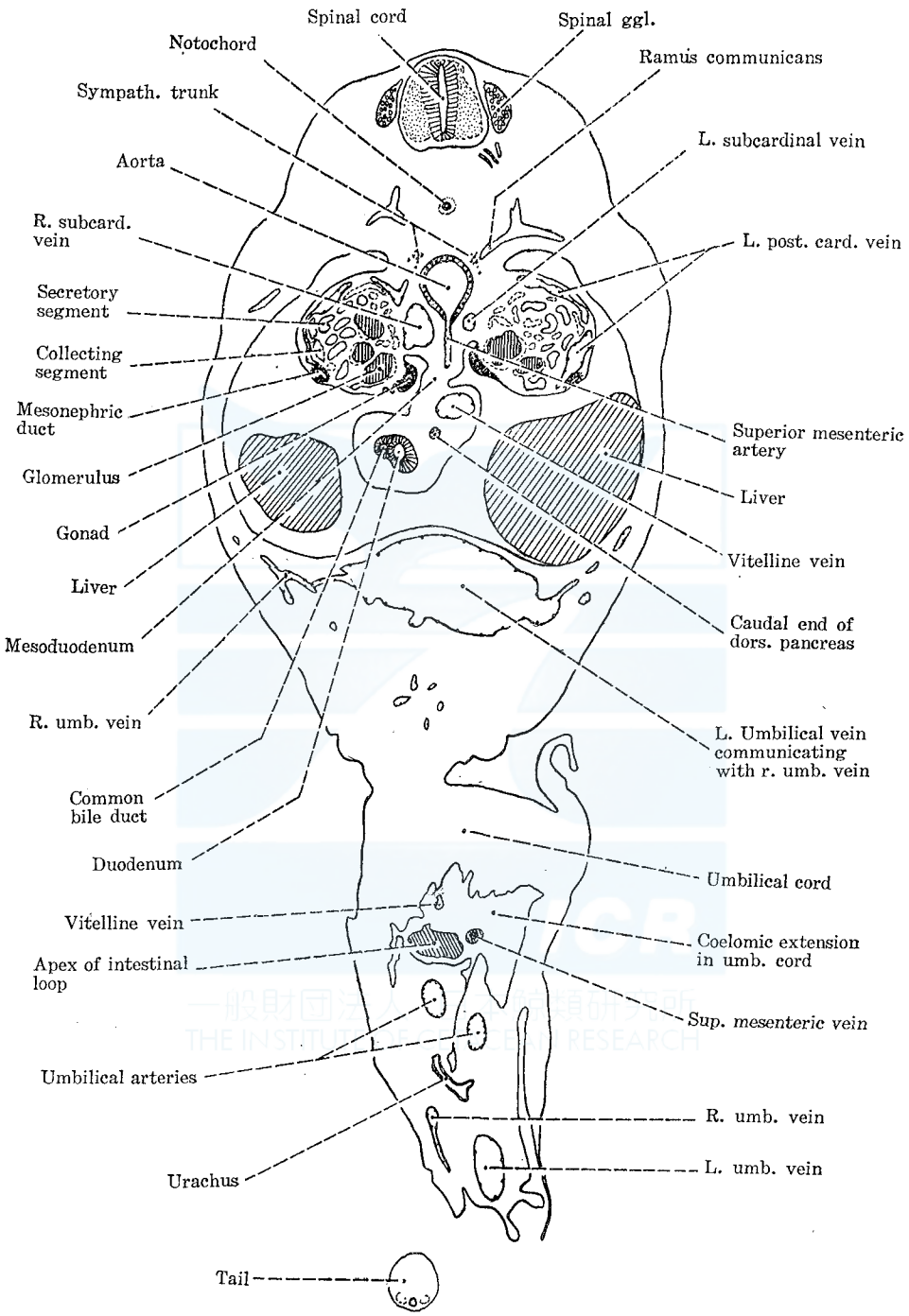


Fig. 29. Section through the exit to superior mesenteric artery.

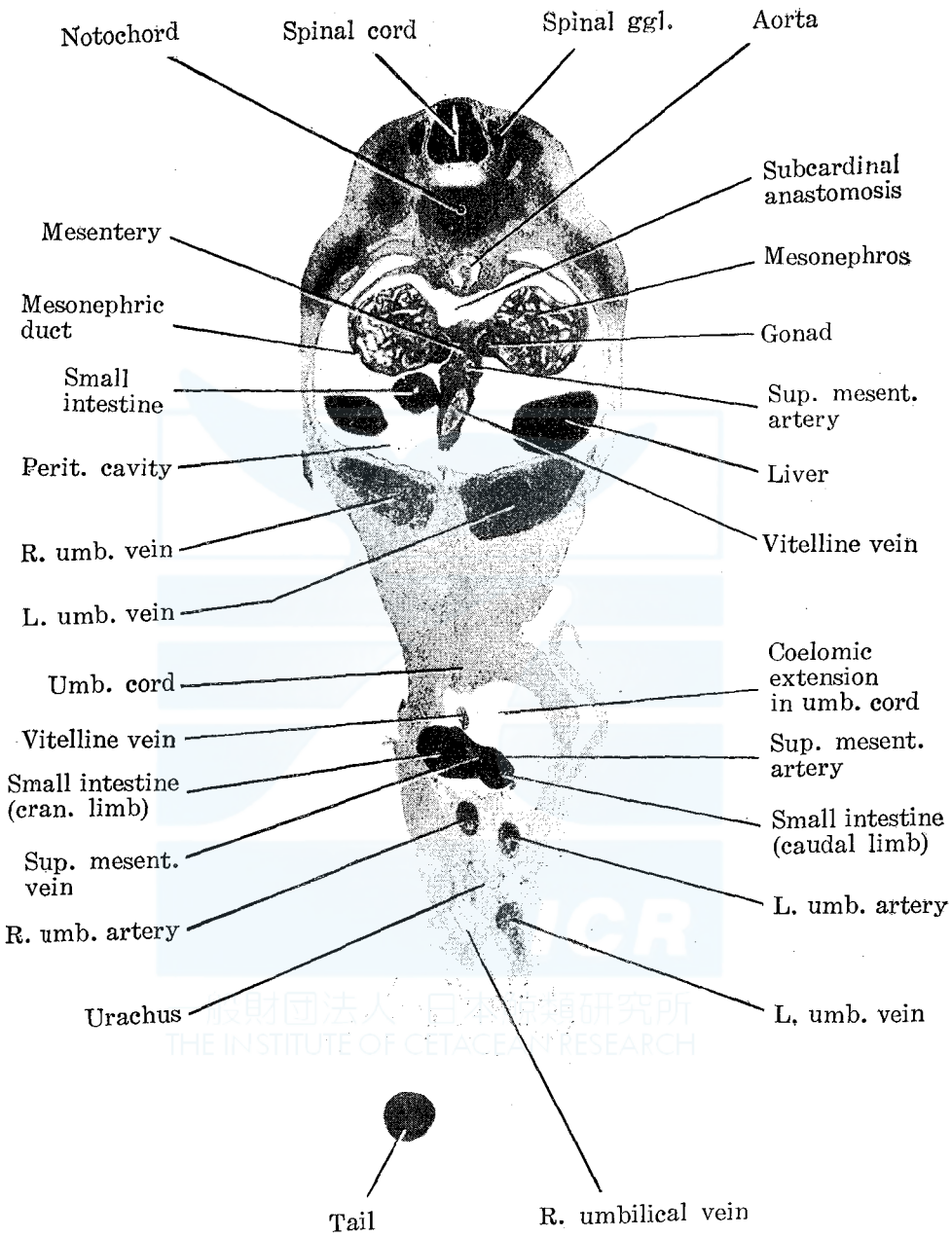


Fig. 30. Section through the subcardinal anastomosis.

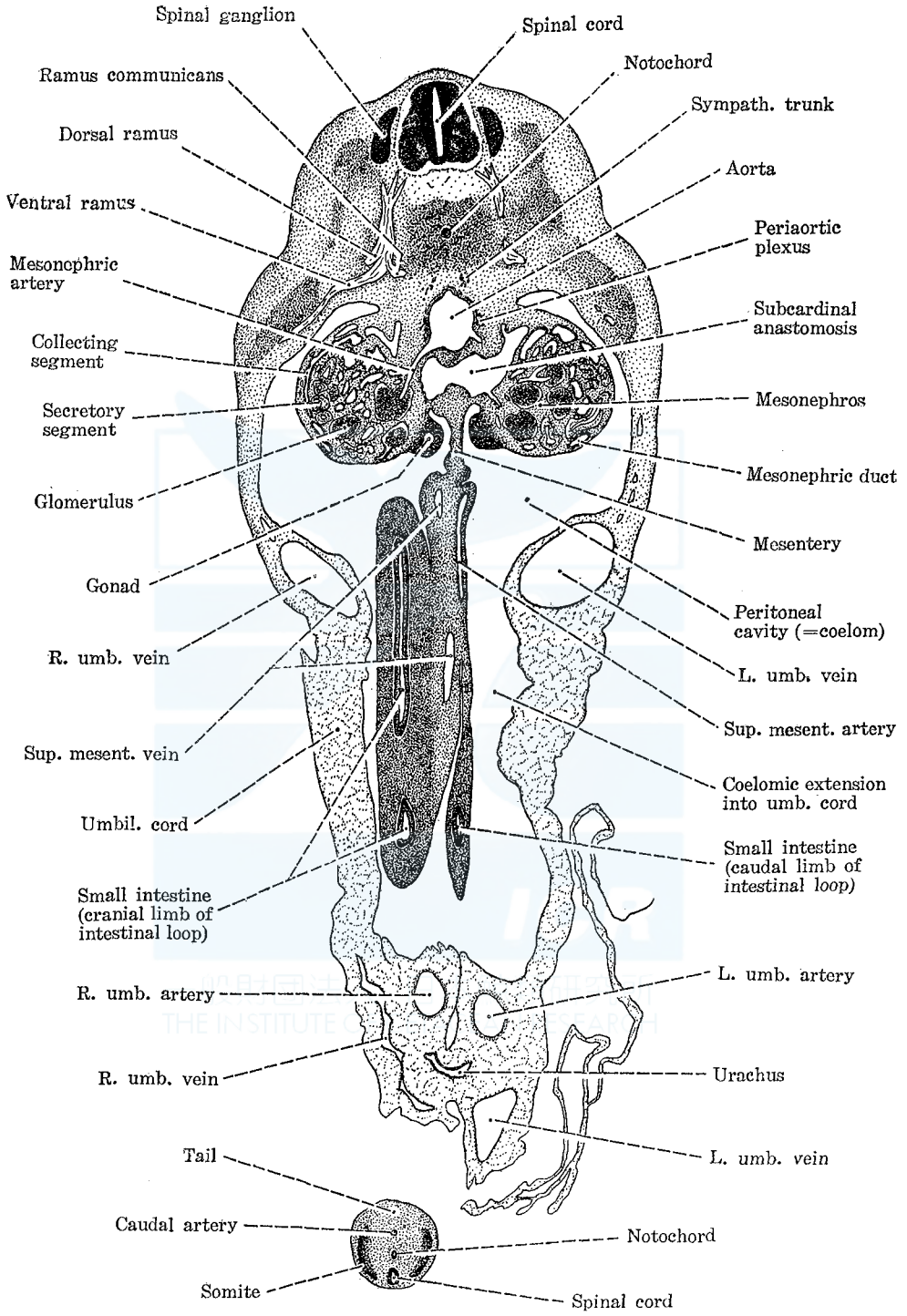


Fig. 31. Section through the coelomic extension into umbilical cord.

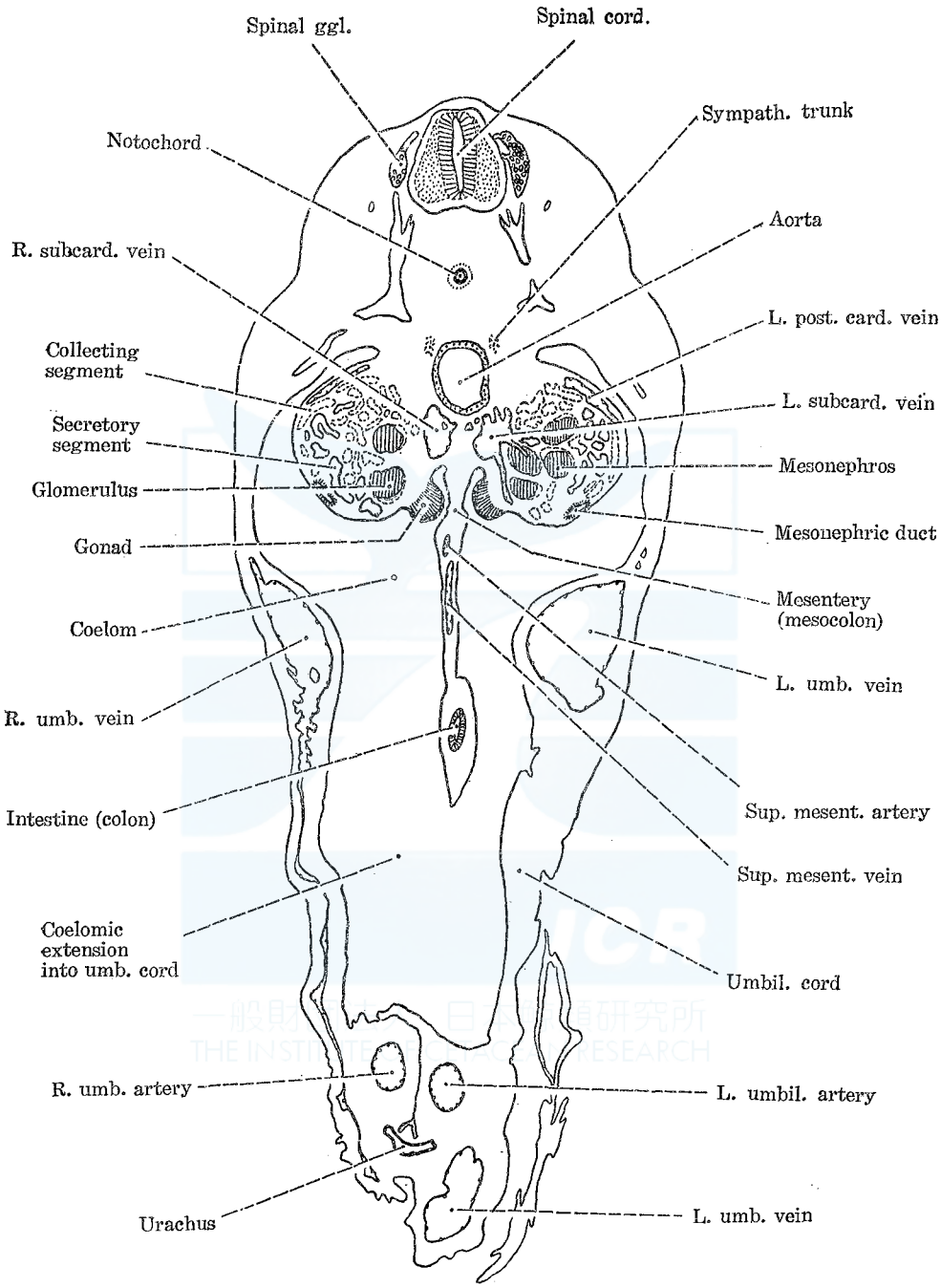


Fig. 32. Section through the caudal limb of intestinal loop (1).

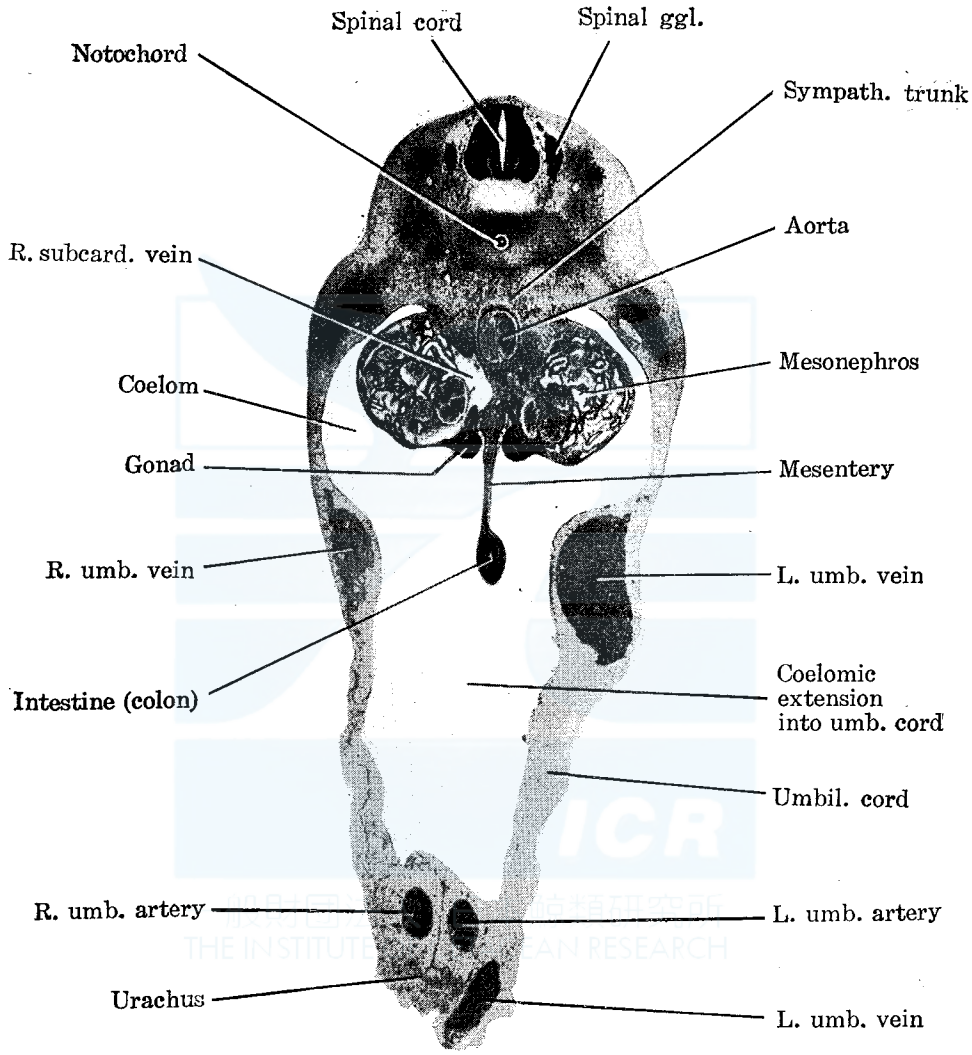


Fig. 33. Section through the caudal limb of intestinal loop (2).

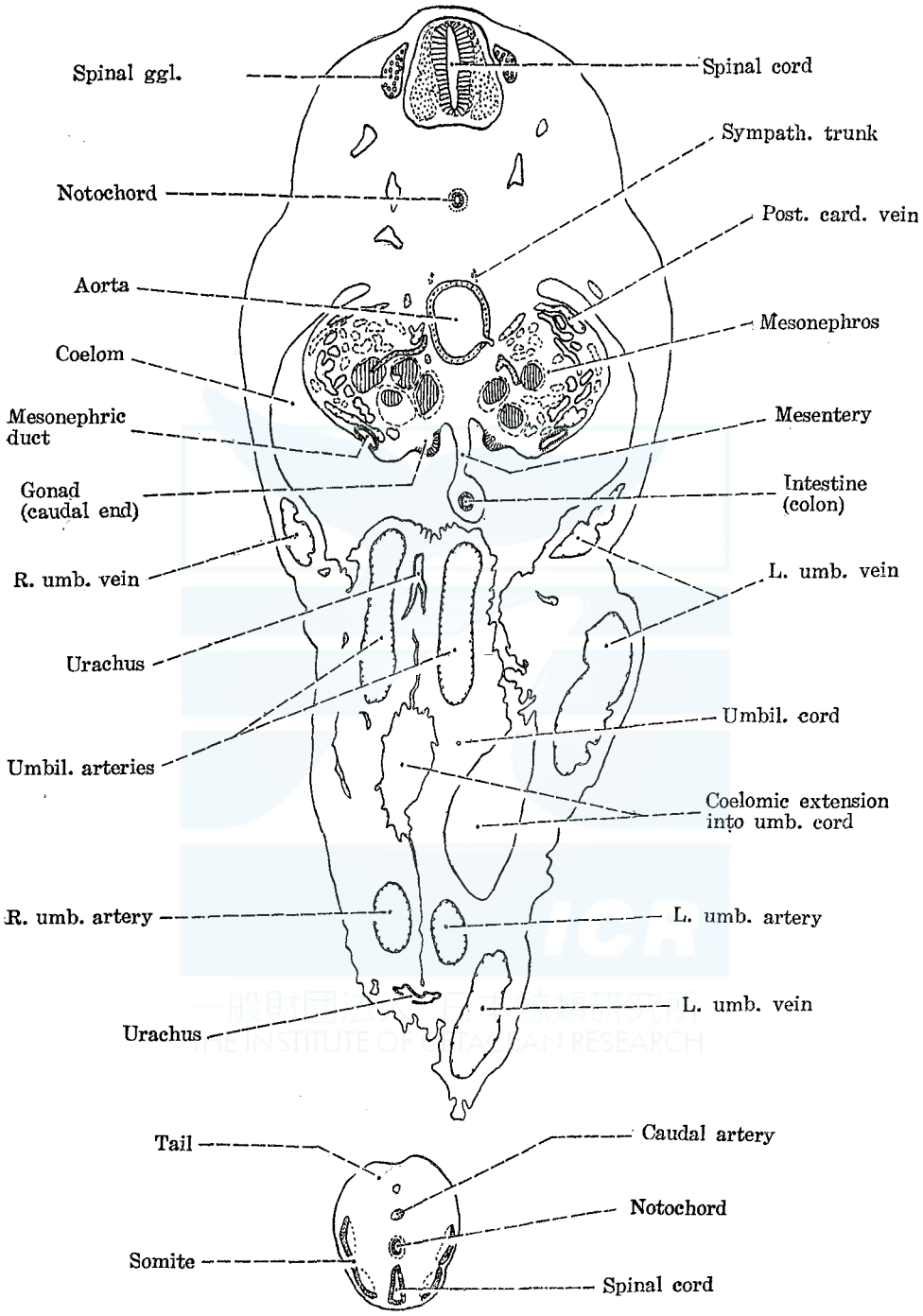


Fig. 34. Section through the root of umbilical cord (1).

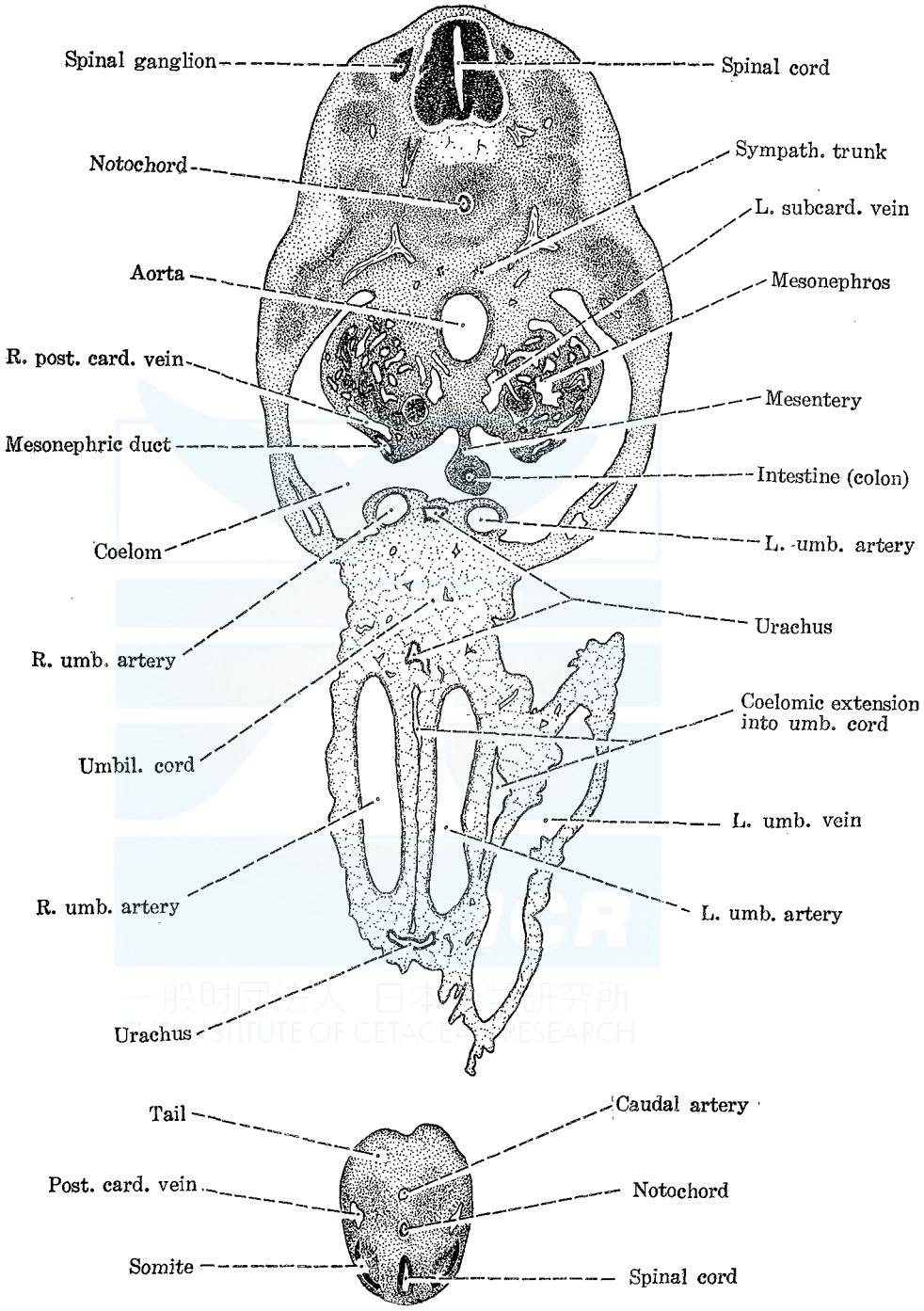


Fig. 35. Section through the root of umbilical cord (2).

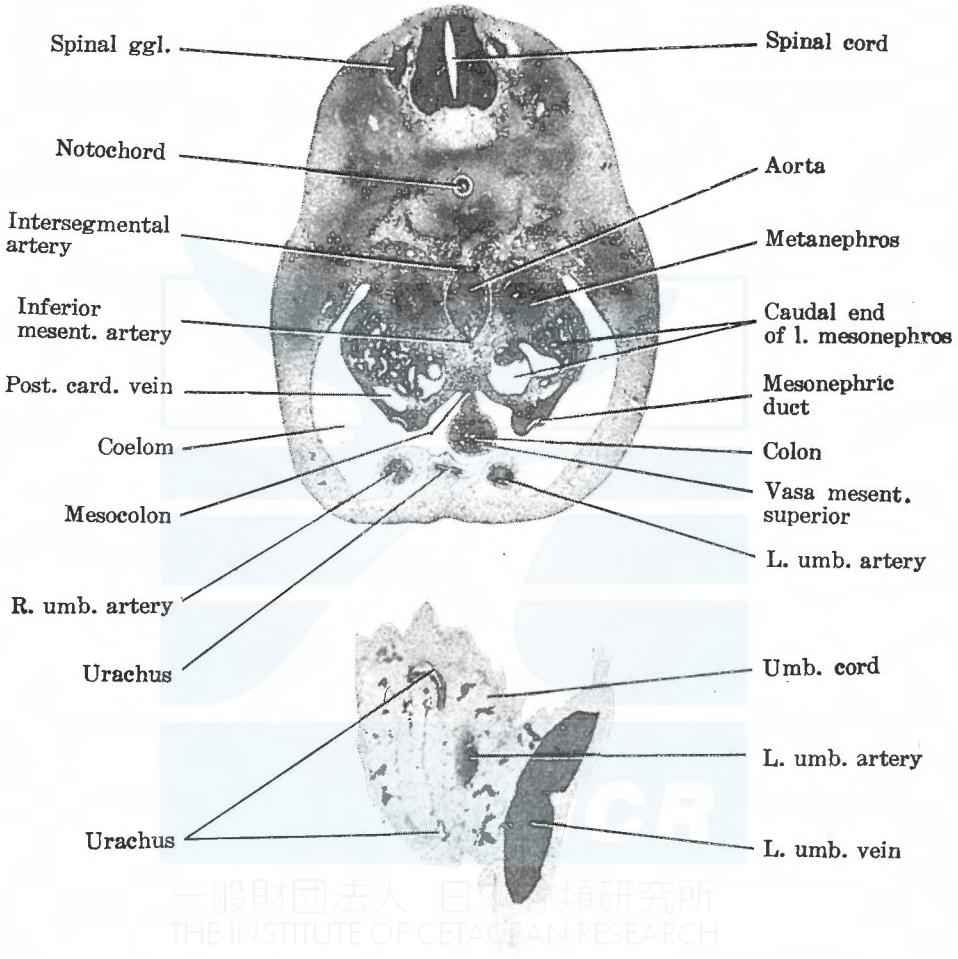


Fig. 36. Section through the metanephroi and inferior mesenteric artery.

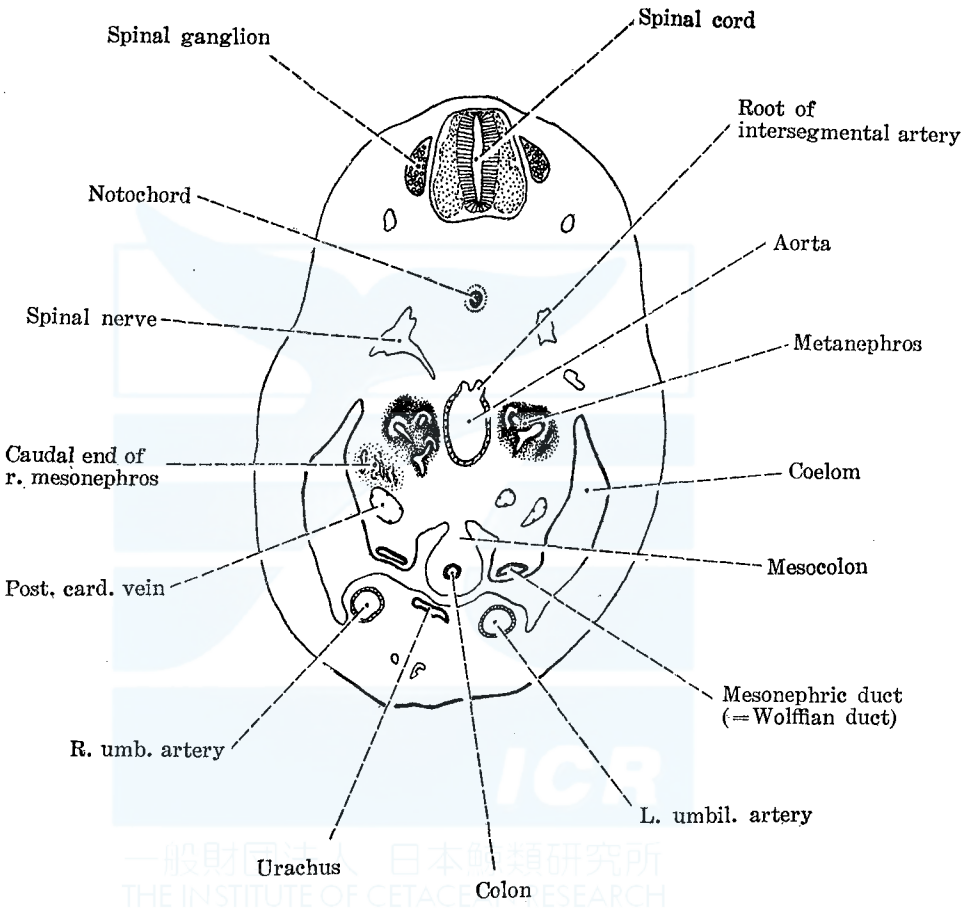


Fig. 37. Section through the metanephroi (2).

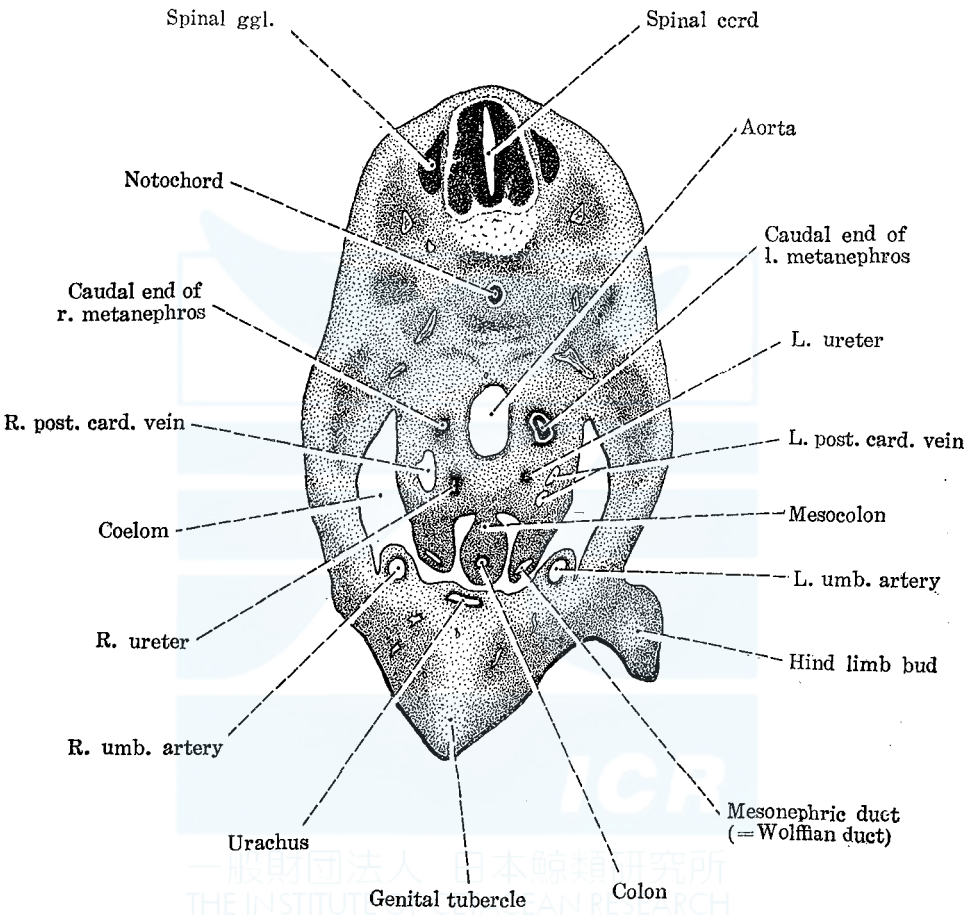


Fig. 38. Section through the ureter, genital tubercle and hind limb bud.

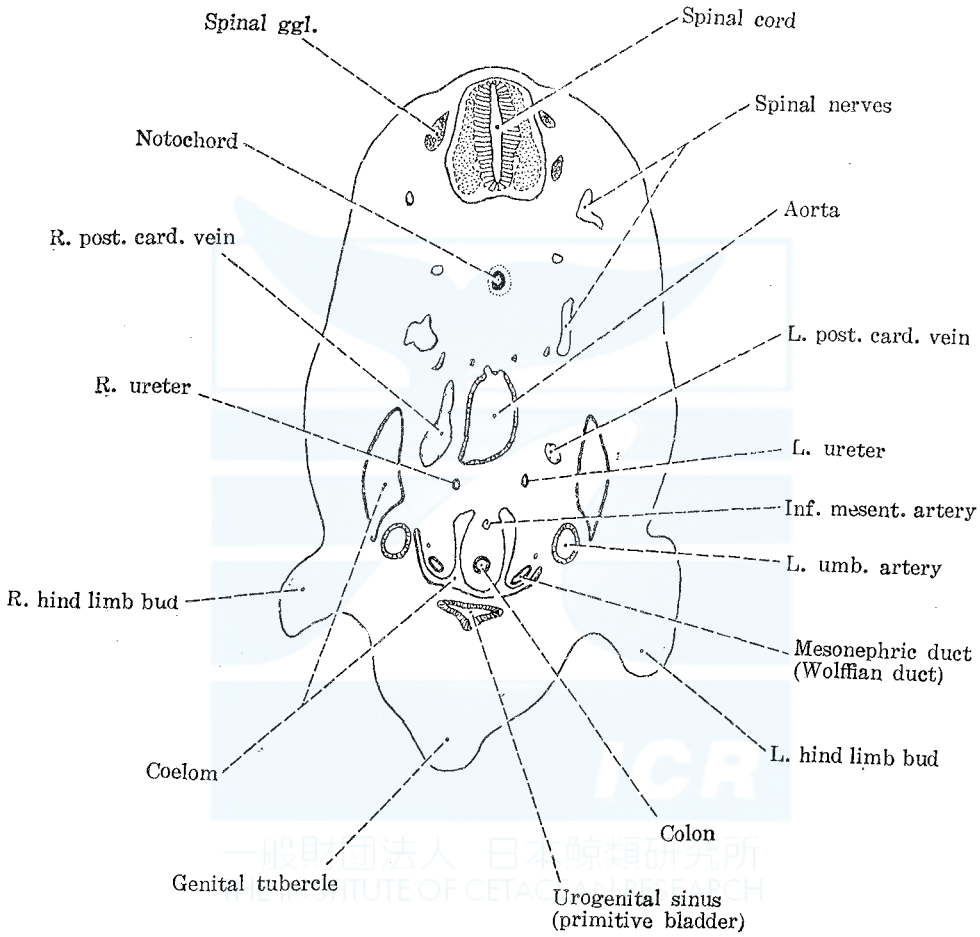


Fig. 39. Section through the primitive bladder.

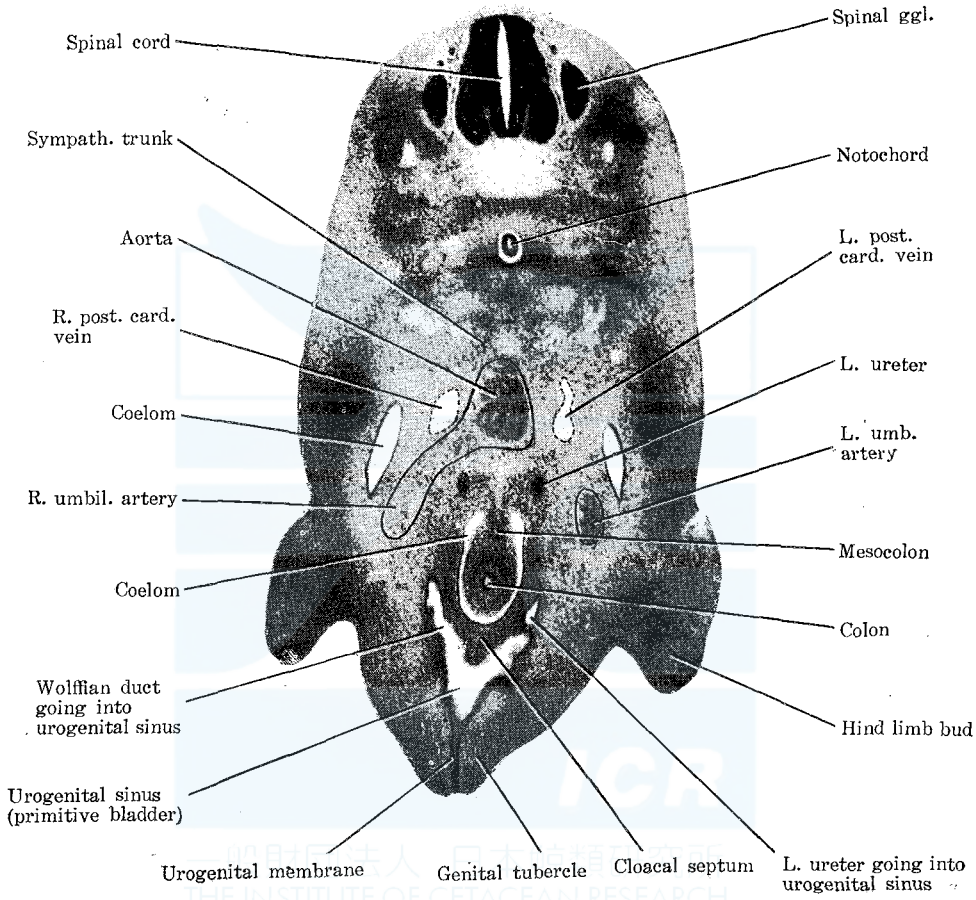


Fig. 40. Section through the urogenital sinus and membrane.

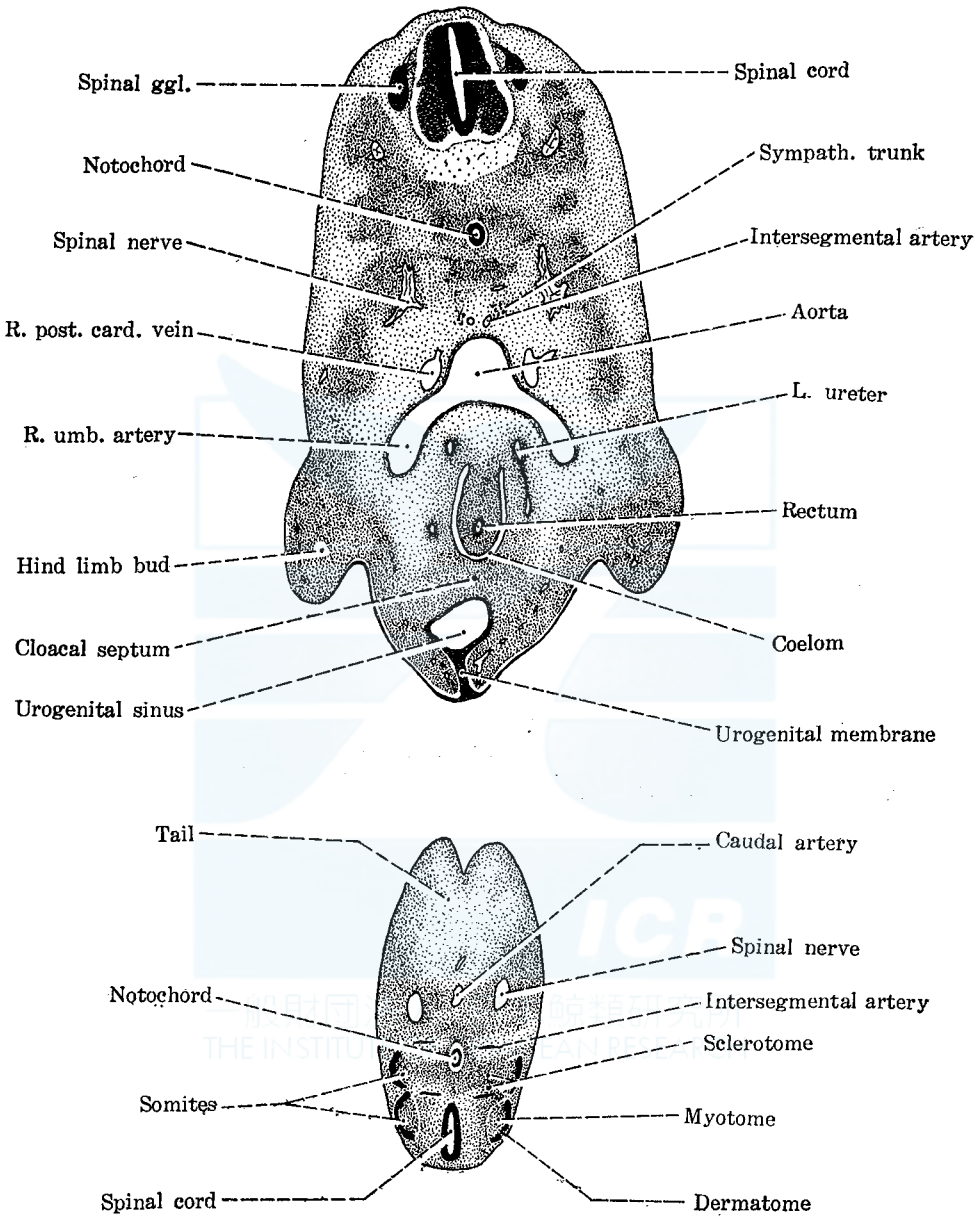


Fig. 41. Section through the bifurcation of aorta into umbilical arteries.

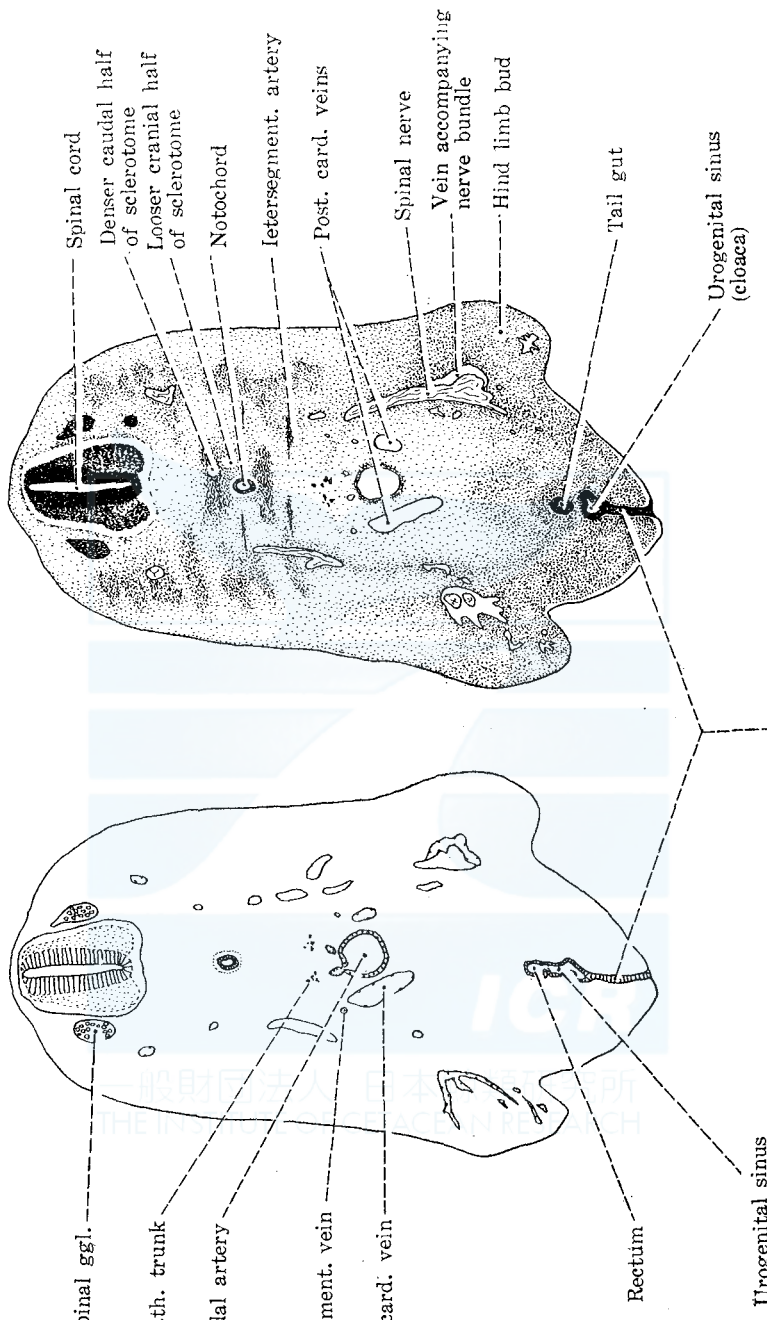


Fig. 42. Section through the caudal artery. Fig. 43. Section through the tail gut.

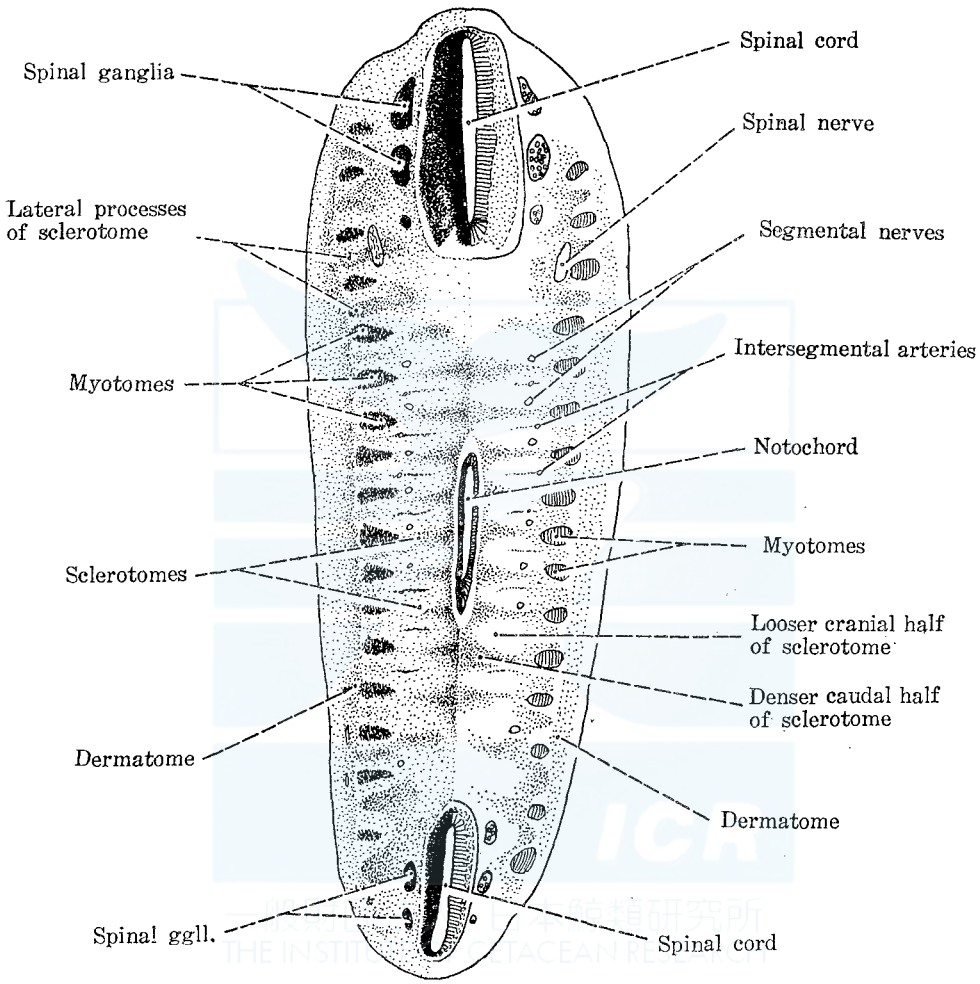


Fig. 44. Section through the lumbal curvature (1).

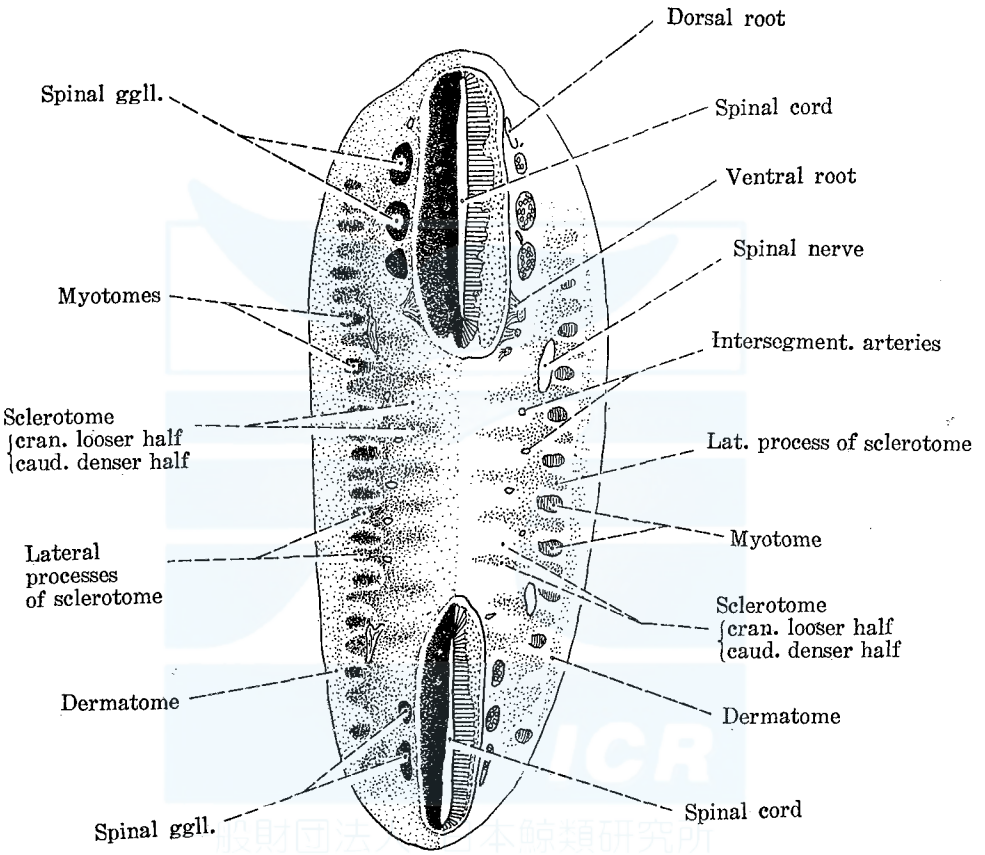


Fig. 45. Section through the lumbal curvature (2).

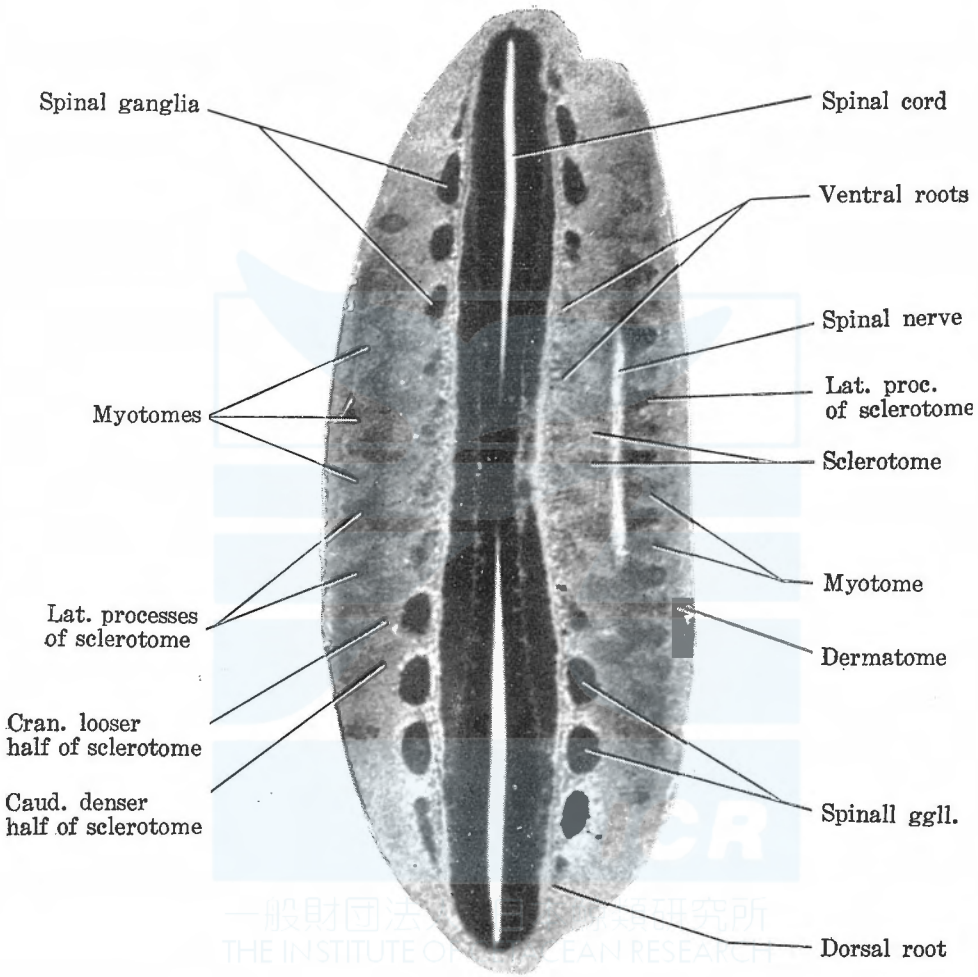


Fig. 46. Section through the lumbal curvature (3).

PLATE

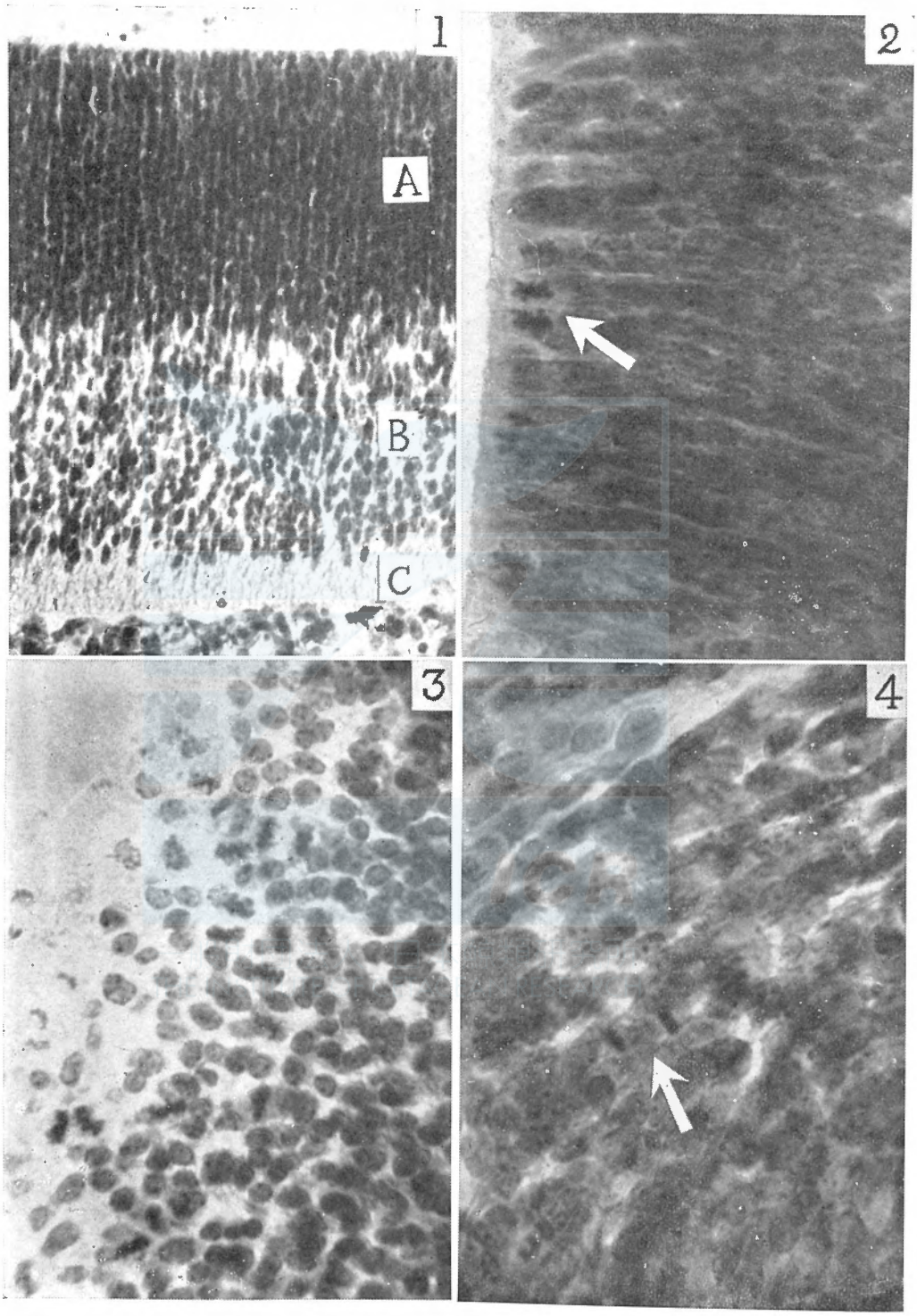
Explanation of Plate I.

1. Three-layered wall of the neural tube. A Ependymal layer. B Mantle layer. C Marginal layer. (Cf. explanation of Fig. 3)

2. Mitotic cells in the ependymal layer. The arrow points two mitotic cells in the innermost zone of the ependymal layer of the neural tube.

3. Mitotic cells in the ependymal layer, which is cut tangentially. Some twenty cells are found in various stages of mitosis.

4. Mitosis in the spinal ganglion. The arrow points a mitotic cell in the anaphase.


1
A
B
C
2
3
4

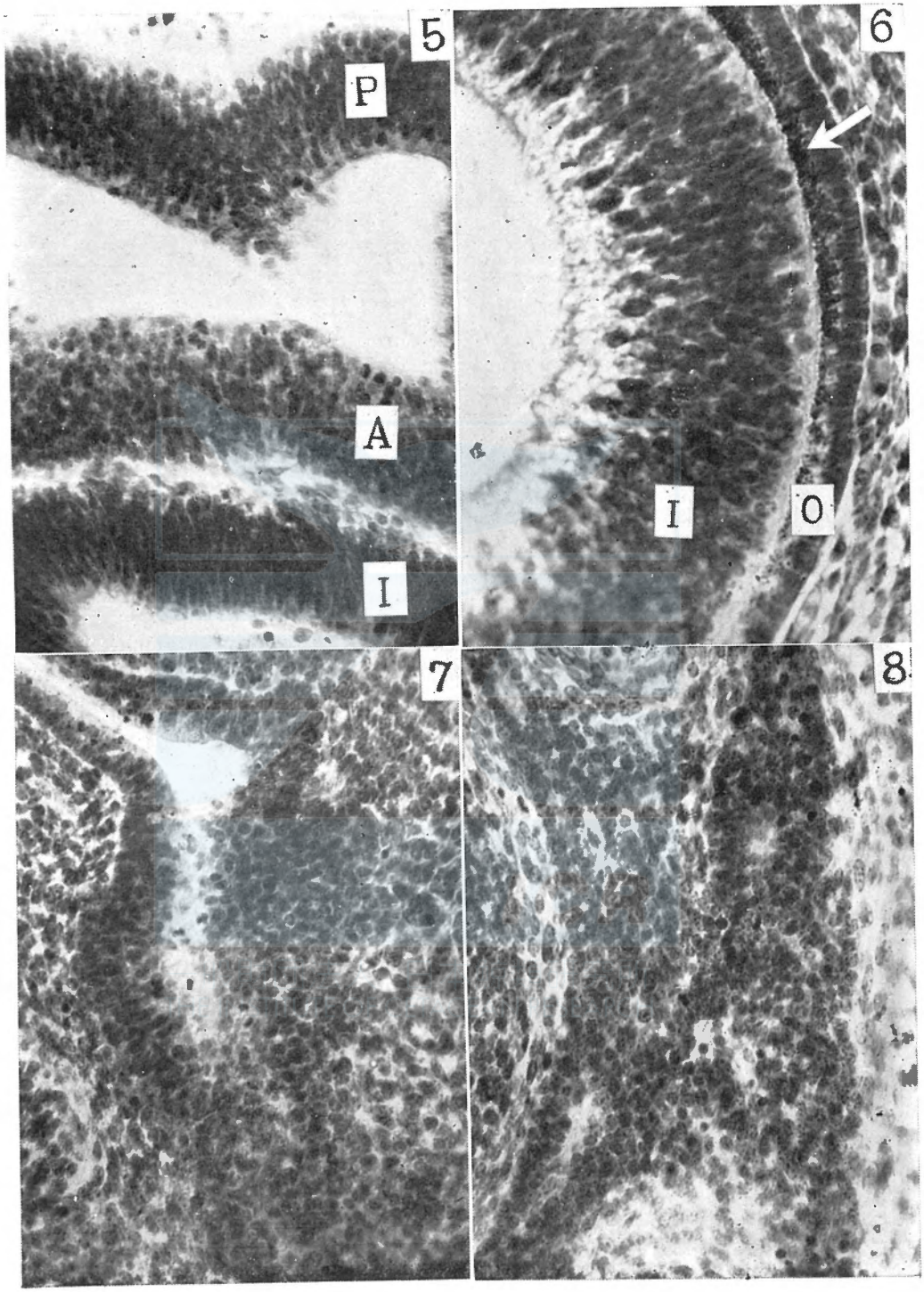
Explanation of Plate II.

5. Transverse section of the Rathke's pouch. (Cf. explanation of Fig. 9) P Posterior wall. A Anterior wall. I Infundibulum. Mitotic cells are encountered in these epithelial walls.

6. Optic cup. (Figs. 9–11) I Inner layer or the primitive retina. O Outer layer to furnish the pigment epithelium. The latter is provided in its inner zone with many pigment granules, some of which are indicated by the arrow.

7. Primordial thymus. (Figs. 12–15) It arises from the ventral wings of the third and fourth pharyngeal pouches. These cells of entodermal origin will proliferate and transform later into a syncytium that resembles reticular tissue, thus forming the framework of the thymus.

8. Primitive thyroid gland. (Fig. 13) It is represented by a cell mass which has originally invaginated from the ventral floor of the pharynx. Mitotic cells are scattered around. Several lumens inside the cell mass may be the remnants of the thyroid diverticulum. A couple of weeks will elaspe before the follicular cavities appear.


5
P
A
I
6
I
O
7
8

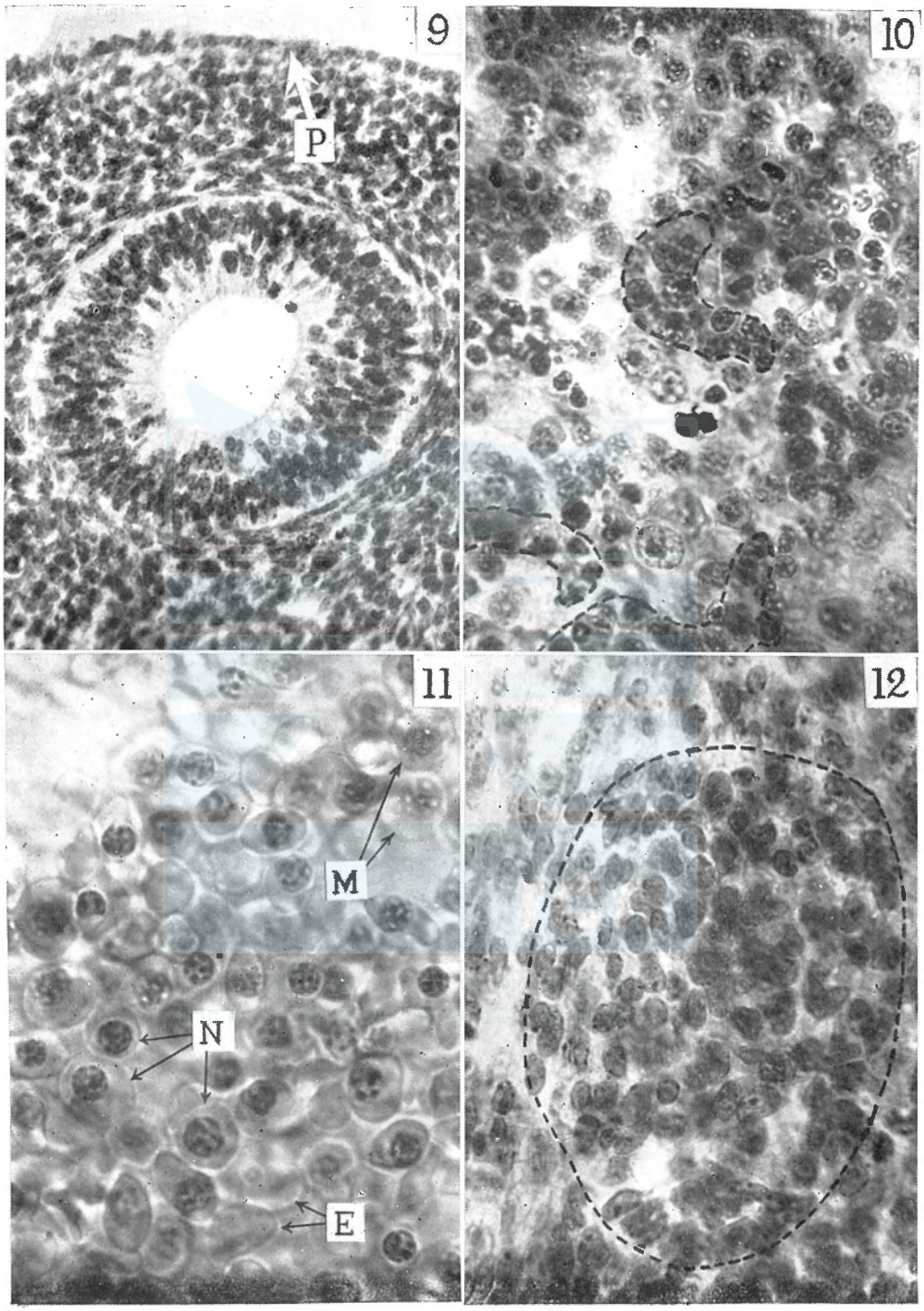
Explanation of Plate III.

9. Lung bud. (Figs. 17–23) The bronchial bud shown in the center of the figure is lined with ciliated, thich epithelium. When the bronchial buds continue to grow and branch, the epithelial lining of the terminal portions become thin-cuboidal; and the alveolar primordia will occur in the later half of the felal life. The mesothelial lining indicated by an arrow (P) represents the primitive pleura.

10. Liver. (Figs. 21–30) Larger cells with oval, coarse nuclei are the primitive hepatic cells, some of which are in mitosis. Hepatic cell cords are separated from each other by the intervening sinusoids, a couple of which are encircled by broken lines. The hepatic sinusoids are the site of hematopoiesis and are filled with various kinds of primordial blood cells. The mesenchymal invasion to furnish the interstitial tissues will be prosperous later on.

11. Nucleated red cells in the circulating blood. In addition to the nucleated erythrocytes (E), there can be identified megaloblasts with larger nuclei (M) and normoblasts with smaller, denser nuclei (N). The former is rather basophilic in the cytoplasm, while the latter is very rich in hemoglobin and stained deep red.

12. Primordial adrenal cortex. (Figs. 25–27) It is represented by mesenchymal accumulation, which is encircled by broken line. The invasion of the primitive medullary cells is not yet in view. (Cf. explanation of Fig. 25)


9
P
10
11
M
N
E
12

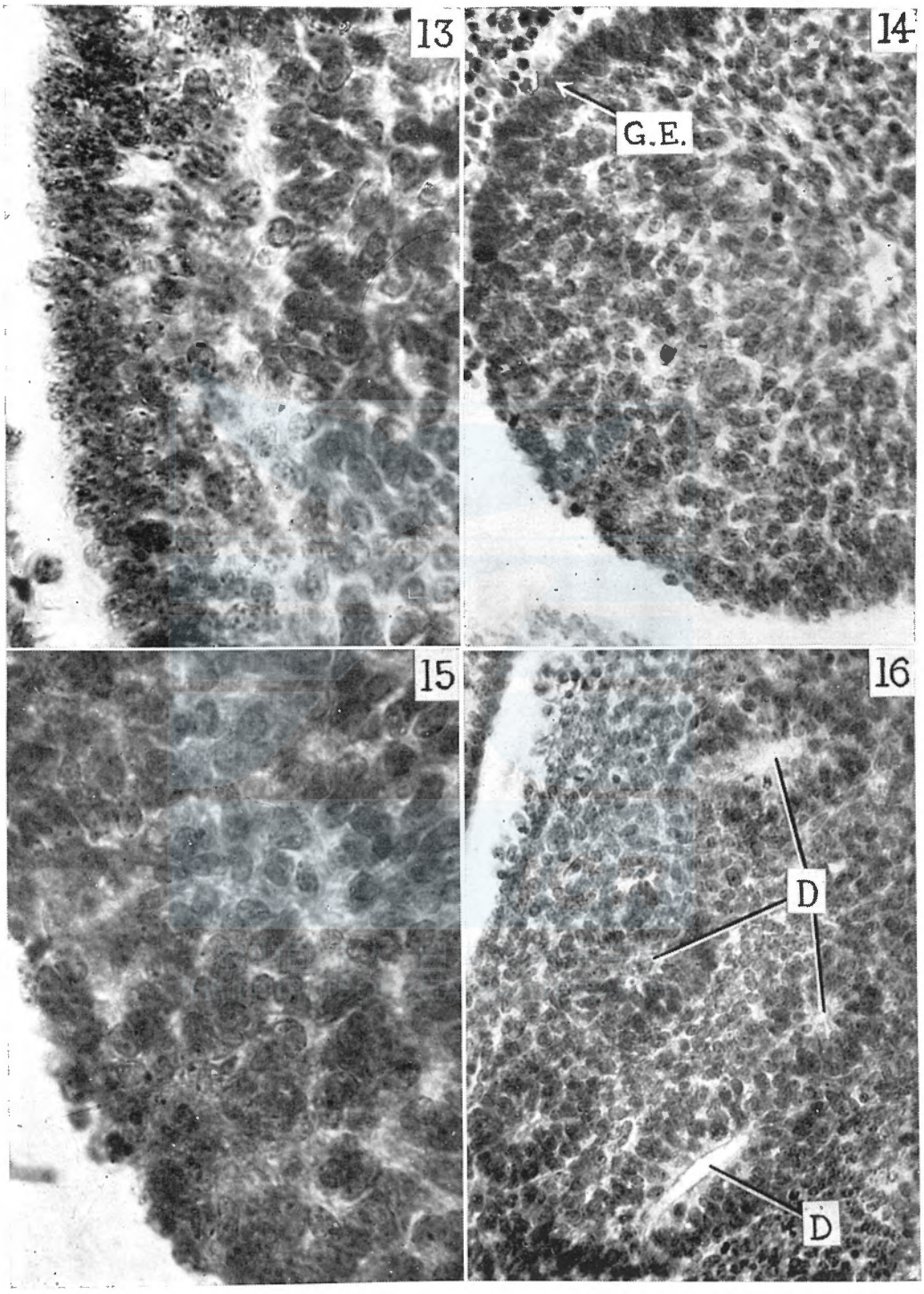
Explanation of Plate IV.

13. Splenic primordium. (Figs. 26–27) It consists of the mesenchymal condensation just beneath the mesothelial lining of the dorsal mesogastrium. (Cf. explanation of Fig. 26)

14. Gonad in the genital ridge. (Figs. 25–34) The sexual gland is indifferent or sexless at this stage, composed merely by inner cell mass covered by the germinal epithelium (G. E.). Some mitotic cells are found in the latter.

15. Inner cell mass of the gonad. These cells have derived by the proliferative ingrowth of the germinal epithelium. They are, however, not the progenitors of the real germ cells. For, the primordial germ cells are thought to originate in the yolk-sac entoderm, migrating afterwards into the genitial ridges.

16. Primitive pancreas. (Figs. 28–29) The future pancreas is indicated by outpouchings from the duodenum into the dorsal mesentery. As they continue to grow, they become contorted, thus forming the primitive pancreatic ducts lined with entodermal epithelium (D). Later on, the acini begin to appear as terminal and side buds from the ducts. Also the Langerhans' islands will differentiate from the same source.


13
14
G.E.
15
16
D
D

Explanation of Plate V.

17. Cross section of the mesonephros. (Fig. 23–37) (Cf. explanation of Fig. 32) G Glomerulus. S Secretory segment. C Collecting segment. W Mesonephric or Wolffian duct. B Connection between the Bowman's capsule and the secretory segment.

18. Metanephros. (Figs. 36–37) The tubal, epithelial portion (C) is the primordial pelvis, calyces as well as of the collecting segments. The mesenchymal accumulation (S) surrounding the tubules represents the primordium of the secretory segments. (Cf. explanation of Fig. 37)