

SECTIONS OF THE DOLPHIN'S HEAD (*STENELLA CAERULEOALBA*)*

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For the past years one of the authors, Hosokawa, has dissected several specimens of the *Stenella (Prodelphinus) caeruleoalba* (Meyen), paying special attention to the peripheral distribution of cranial nerves. In order to supplement the ordinary anatomical observations, a couple of heads of this animal were sectioned transversely or lengthwise with the hand-saw. Anatomical features of each section surface were very interesting and instructive for understanding the three-dimensional structures of the dolphin's head. Such cross-sectional observation was adopted partially by Slijper (1936) in his comparative-anatomical study of the cetacean blood vessels, by Lawrence and Schevill (1956) in their functional anatomical study of the delphinid nose as well as by Nakajima (1961) in his work on the cetacean rete mirabile, although they did not give detailed explanation of each structure on the section surfaces.

Materials used in the present study comprise two heads of adult *Stenella caeruleoalba* from Kawana, Shizuoka Prefecture, which had been soaked and fixed thoroughly in 10% solution of formalin. One of the specimens was sectioned transversely into six slices (Fig. 1), and each section surface was photographed and sketched from rostral direction. The total length of the head was 45 cm, and each slice was successively some 16, 5, 6, 4.5, 4.5 and 9 cm in thickness. The second specimen, 46 cm in length, was sectioned at first in the median plane. Then the right half was cut lengthwise 5 cm apart from the median surface. In the following pages each section surface will be shown with brief explanations. Since the cross-sections are seen from rostral, the right side of the head is on the left side of the figures.

CROSS-SECTIONS

Section I (Fig. 2-a, b)

The section passes through the root of the *snout* or *rostrum*. The upper and lower jaws are separated from each other by the gap of the *oral cavity*. The skeleton of the upper jaw is represented by the *maxilla*, *premaxilla*, *vomer* and *mesethmoid cartilage*. The last one lies on the median line, enclosed in the canal formed by the premaxillae of both sides and the vomer. The dorsal part of the premaxilla is composed of particularly compact bony substance. Inside the maxilla and premaxilla we see small canals for conducting the *superior alveolar arteries* and *nerves*, which supply small branches to the alveolar plexus around the root of the teeth. For reference, the peripheral distribution of the *trigeminal nerve* is shown in Fig. 13.

* To the memory of late Prof. emeritus Tsunetaro Fujita.

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Needless to say, the *Stenella* is, like all the other odontocetes, furnished with *homodont teeth*, of which the number amounting to some forty or fifty pairs in both upper and lower jaws. On the left side of the figure the whole contour of one tooth is shown. Approximately half of the total length is inside the maxilla (*radix dentis*), while the other half, conical in shape and somewhat curved mediad, is out of the gingiva.

Dorsal to the premaxilla and maxilla is a white area occupied by adipose connective tissue. This is the anterior extremity of the so-called "melon". This peculiar structure, characteristic of most dolphins, lies on the snout and forms the prominence in front of the nostrils. Although there have been proposed many hypotheses about the function of this unique structure, we do not know yet anything definite. Probably the *spermaceti organ*, characteristic of the sperm whale, represents the highly differentiated "melon" of other odontocetes. The "melon" and spermaceti organ have been very often thought in relation to the respiration of the cetacea (Raven & Gregory, 1933; Slijper, 1962, etc.).

Under the melon we see the anterior end of the *m. rostralis* or the *pars labialis* of *m. maxillonasolabialis* (Huber, 1934). These muscle bundles arise from the upper surface of maxilla and run up- and forwards, so as to insert to the thin fibrous capsule of the melon. Some of the muscle bundles, which arise from the lateral border of the maxilla, are directed up- and backwards, so as to border the anterior end of the narial muscle group, *pars nasalis* of *m. maxillonasolabialis* (see Fig. 10).

The *mandibula* is cut on both sides in the lower jaw. This bone is furnished with a wide internal space filled with spongy, adipose tissue (*mandibular canal* or *fossa*), and the *inferior alveolar vessels* and *nerves* are seen to pass through this fatty substance (confer Fig. 13).

In the middle of the lower jaw is the cut surface of the *tongue*, representing a peculiar quadrangular shape. Inside the tongue we see the inverted V letter of the *genioglossus* muscle, as well as many *internal lingual muscle bundles* arranged irregularly. Beneath the tongue are sections of the *mylohyoid* muscle and of the *panniculus carnosus*, which covers the ventral surface of the lower jaw.

Section II (Fig. 3-a, b)

It represents a section through the middle of the "melon". Anatomical features of this section do not show significant differences from those of the preceding one, while the melon and the rostral muscle have considerably increased in size.

In the lower jaw the tongue is cut at about the middle of the *corpus linguae*. In addition to *mm. genioglossus* and *mylohyoideus*, which were already observed in Section I, the *geniohyoideus* and *hyoglossus* are seen in the floor of the oral cavity. The arrangements of these muscles are shown in Figures 11 and 12. As seen in Fig. 11, the *panniculus carnosus* is considerably well-developed on the ventral surface of the lower jaw. Systematic description of the cetacean muscles is to be referred to Stan-
nius (1849), Schulte (1916, 1918), Howell (1930), Slijper (1936), etc.

Section III (Fig. 4-a, b)

This is a section at the *oral angle* or the posterior end of the oral cleft. The bony framework of this section, shaped like a flying bird with extended wings, is composed of *premaxilla*, *maxilla*, *vomer*, *os malare* or *jugale*, *os palatinum*, *os pterygoideum* as well as of the *mesethmoidal cartilage*. The maxilla and os malare form a double-layered bony plate (confer Fig. 9). On the left side of the figure the malar bone shows on its lower surface a pointed prominence representing the root of the *zygomatic process*.

Noteworthy there are peculiar cavernous sinuses inside or in close apposition to the skeleton. The largest one is inside the pterygoid fossa surrounded by os palatinum and pterygoideum (postpalatine air sinus of Flower, 1876). Hence it is called *sinus pterygoideus*. Other sinuses on the section are secondary expansions of the pterygoid sinus.

All the sinuses are traversed by fibrous trabeculae and give spongy appearances. These sinuses belong to the *pneumatic sinus system*, which characterizes especially the odontocetes. All the sinuses such as *pterygoid*, *epitympanic*, *peripetrosal*, etc. are continuous with the tympanic cavity. The pneumatic sinus system was described by Boenninghaus (1904), Gruhl (1911), Yamada (1953) etc., who did not however explain the physiological significance of this peculiar structure. Nerve bundles belonging to V_2 (*n. maxillaris*) are seen in the trabeculae of the *frontal* and *maxillary sinus expansions* (confer Fig. 13).

Above the bony frame the "melon" is seen in the middle of the section, being abutted on by the *m. narialis* on both sides (Fig. 10). The narial muscle of blowhole muscle, *pars nasalis* of *m. maxillonasolabialis* of Huber (1934), is formed by many layers and subdivisions, of which the direction of muscle bundles is somewhat different from one another. Lawrence and Schevill (1956) recognized six layers and called them posteroexternus (pe), intermedius (i), anteroexternus (ae), posterointernus (pi), anterointernus (ai), and profundus (pr).

At the center of the lower half of the section is a transverse slit which is lined with the thick wall of mucous membrane. This is the posterior part of the *oral cavity*, of which the floor is represented by the *radix linguae* (see Section VI). Ventral to the oral cavity we see *m. hyoglossus*, *genioglossus*, *geniohyoideus*, *monogaster*, etc. *M. mylohyoideus* is cut obliquely on each side of the oral cavity.

The *pterygoideus medialis* muscle is seen to occupy the space between the pterygoid process and mandibula, showing close relationship to the frontal sinus expansion. The *n. facialis* is cut under the bony shelter formed by the maxilla and os malare. This nerve trunk can be traced to the rostral until the antorbital notch, where it turns upwards, returns backward on the dorsal surface of the maxilla, so as to supply the whole musculature of the nostril (see Fig. 13).

Section IV (Fig. 5-a, b)

The section passes through the *bony nasal canal*, which courses along the anterior wall of the cranial case. The nasal canals of both sides are separated by the oval-shaped *mesethmoid bone*. Above the *bony naris* the nasal canal continues to the *pre-*

maxillary sac and still further to the *vestibular sac* just under the thick blubber layer.

The complicated structure of the dolphin's *nasal passages* has been subjected to investigations of many scholars such as Rawitz (1900), Gruhl (1911), Burne (1952), Lawrence and Schevill (1958), etc. So the present authors do not intend to go into its details. A somewhat schematic illustration will outline this labyrinthous nasal passage (Fig. 14).

On both sides of the nasal ways we see massively developed *narial muscle, pars nasalis* of *m. maxillonasolabialis*. The intimate topographical relations between this muscle and nasal passage imply their close functional correlations.

The bony frame of the section is composed of *premaxilla, maxilla, os frontale* and *os pterygoideum*. The plate-like lateral projection is formed by the maxilla and *os frontale*. This peculiar modification and dislocation of the cranial bones are associated with the famous phenomenon called "telescoping" of the cetacean skull (Kernan, 1918; Kellog, 1928, etc.). Branches of *nn. alveolares superiores* are seen between these two bony laminae (see Fig. 13). Lateral to the pterygoid process is seen the *sinus pterygoideus* of the pneumatic sinus system. Upwards it is elongated and continuous to the maxillary and frontal expansions.

On the left side of the section we see the cut surface of the *eye ball* as well as of *extrinsic eye muscles*. The eye ball is characterized by the extraordinarily thick scleral wall, an adaptation to the hydrodynamic environment of the cetacea. The floor of the orbit is formed by a tough fibrous membrane, and the facial nerve runs just under this orbital floor. The *zygomatic arc* is also cut near the tip of the orbital cone.

It is noteworthy that the eye muscles are covered by a thick cavernous layer composed of spongy substance. This is nothing but the *rete mirabile*, or the peculiar network of arterial blood vessels. As well known, the extraordinary development of the *rete mirabile* is one of the most remarkable characteristics of the cetacean anatomy (Stannius, 1841; Wilson, 1879; Ommanney, 1932; Slijper, 1936; Kock, 1959; Nakajima, 1961; Slijper, 1962, etc.). The *rete* is distributed mainly in the trunk and neck. In the cranial region it is found in the orbit (*rete orbitale*) and in the floor of the cranial cavity (*rete basis cranii*) (see Section V).

In the lower part of the section we see the oral cavity, which is cut at its posterior end.

Section V (Fig. 6-a, b)

The cranial cavity is cut open and the brain, which is poorly fixed, is exposed. The brain lies on the cushion of the *rete basis cranii*. Meningeal coverings of the brain are quite same as those of man and other mammals.

The bony frame of the section is formed by the *maxilla, os frontale, os parietale, os ethmoidale* and *vomer*. The lateral dislocation of *os parietale* is a part phenomenon of the "telescoping" of dolphin's skull. The zygomatic process of the *squamosal* is cut on the left side, while the zygomatic arc is still seen on the right.

The *mandibula* is cut near its posterior extremity. As seen already in the preceding section, the medial wall of the mandibula is lost and the *mandibular fossa*

is filled with massive fatty substance, which extends forward into the wide mandibular canal (Sections I-III). Medially the mandibular adipose substance is abutted on by the *pterygoid muscles* and *pterygoid sinus*. Because of these intimate topographical relationships, Yamada (1953) guessed that the movements of the lower jaw might effect strongly upon the distension of the pterygoid sinus.

The *pharynx* and *larynx* are shown on the median line. This peculiar situation that the pharynx is cut in front of the larynx can be understood by checking the guide line in Fig. 6-a. The pharynx is surrounded by muscle groups such as *m. monogaster*, *mylohyoideus*, *styloglossus*, *hyoideus*, *sternothyroideus*, etc. *Os hyoideum* is cut at the basihyal as well as at the stylohyal.

The larynx is cut at the tip of the *arytenoepiglottideal tube*, which protrudes uniquely into the choana. This peculiar tube, characteristically well-developed in the odontocetes, was described by Hosokawa (1950) in the sperm whale (see Fig. 7).

LONGITUDINAL SECTIONS

Section VI (Fig. 7-a, b)

This is the median section of the *Stenella's* head. Because of the slight asymmetry of dolphin's skull, the right *nasal passage* is cut through, showing the strange disposition of the *nostril (blowhole)*, *vestibular sac*, *tubular sac*, *nasal plug*, *premaxillary sac*, etc. The *m. narialis* is seen in close topographical relationship to the nasal passage, especially to the nasal plug. In front of the nasal passage we see the "melon", a peculiar mass of adipose tissue on the dolphin's rostrum.

The skull is represented by the brain case and the long rostrum. The former is cut through *os frontale* fused with *mesethmoidale*, *os supraoccipitale*, *basisphenoidale* and *basioccipitale*, while in the elongated snout we see *os mesethmoidale*, *mesethmoid cartilage*, *premaxilla*, *maxilla*, *os palatinum*, *os pterygoideum*, etc.

The *brain* shows a remarkable dorsal flexion in the pontine region, representing a noteworthy characteristic of the cetacean brain. As seen in this section the brain stem is relatively well developed. The *cerebral hemisphere* shows a very complicated pattern of convolutions and sulci. As well known, the cetacean brain stands highest in the mammalian kingdom, so far as the complexity of the cerebral fissural configuration is concerned. The *corpus callosum* is relatively small.

The *tongue* is very long and its greater part is attached to the floor of the oral cavity. Intrinsic and extrinsic *lingual muscles* are fairly well developed, implying the considerable motility of the tongue. The *arytenoepiglottideal tube* of the larynx is clearly shown at the left and lower end of the figure. As explained in Section V, this tubular structure formed by modified arytenoid and epiglottic cartilages protrudes into the *choana*. Probably the dolphin can breathe and swallow foods simultaneously.

Section VII (Fig. 8-a, b)

This section shows a sagittal plane 5 cm to the right side from the median plane. The medial wall of the section is seen from outside. The section passes through

the *foramen jugulare* (*foramen lacerum posterius*), which is represented by a wide gap between the basi-exoccipital and alisphenoidal bones. The gap is filled with vascular plexus, *rete mirabile*, and nn. IX—XI are cut along the posterior bony wall, while the n. XII is seen inside the *hypoglossal canal* within the exoccipital bone.

The *os tympanicum* is seen under the jugular foramen, surrounded by remarkable spongy cavernae of the *peripetrosal pneumatic sinus*. The latter continues forward into the larger pterygoid sinus.

The *mandibula* is cut at the mandibular fossa, which is filled with adipose mass containing branches of the n. *mandibularis*. In the hyoid region we see *os basihyale* and *stylohyale*, surrounded by muscle groups such as *m. monogaster*, *m. mylohyoideus*, etc.

IN CONCLUSION

For the purpose of supplementing the ordinary anatomical dissections and observations of the dolphin's body, heads of the *Stenella caeruleoalba* (Meyen) were sectioned transversely or lengthwise. Then each section surface was photographed, sketched and described. Anatomical features of these sections are very interesting and instructive for understanding the three-dimensional structures of the dolphin's head.

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Addendum

After this paper went to press, we had the opportunity to see the following article which gave brief outline of cross-sections of the *Stenella graffmani*.

- BOICE, R. C., SWIFT, M. L., & ROBERTS, J. C. (1964). Cross-sectional anatomy of the dolphin. *Norwegian Whaling Gazette*, 53: 177-93.



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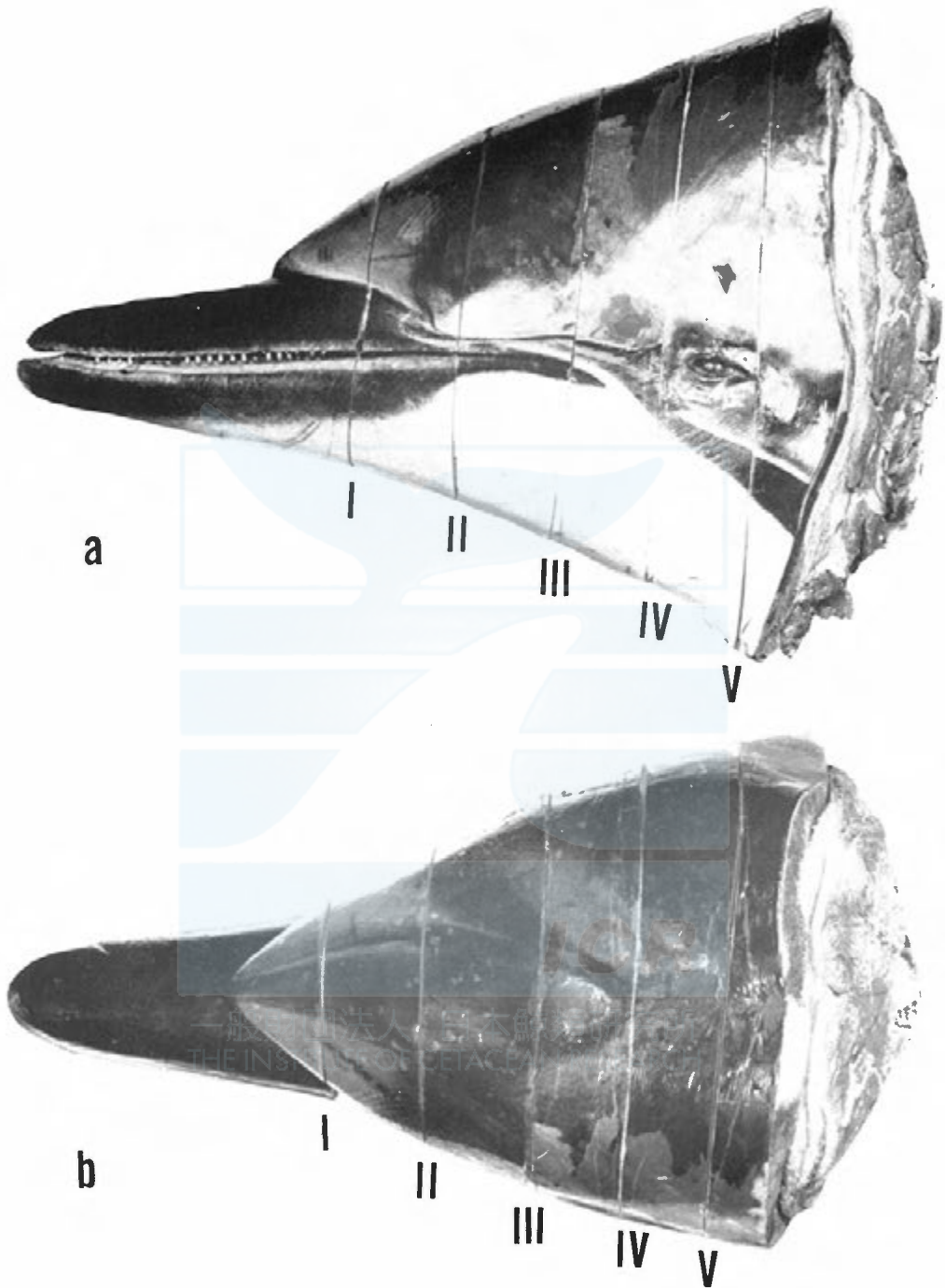


Fig. 1. Guide lines to show the sites of sections. a—lateral view, b—dorsal view.

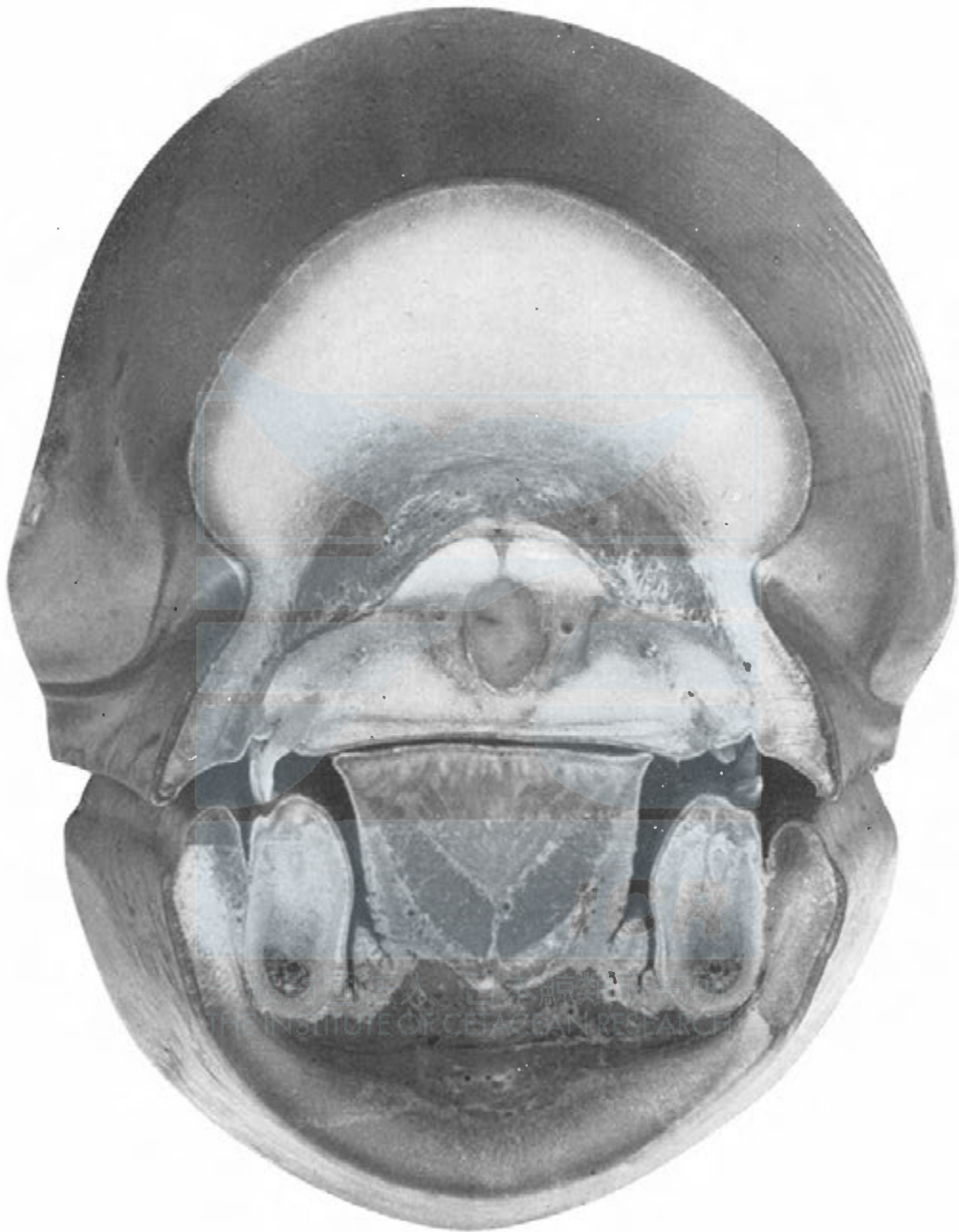


Fig. 2-a. Section I.

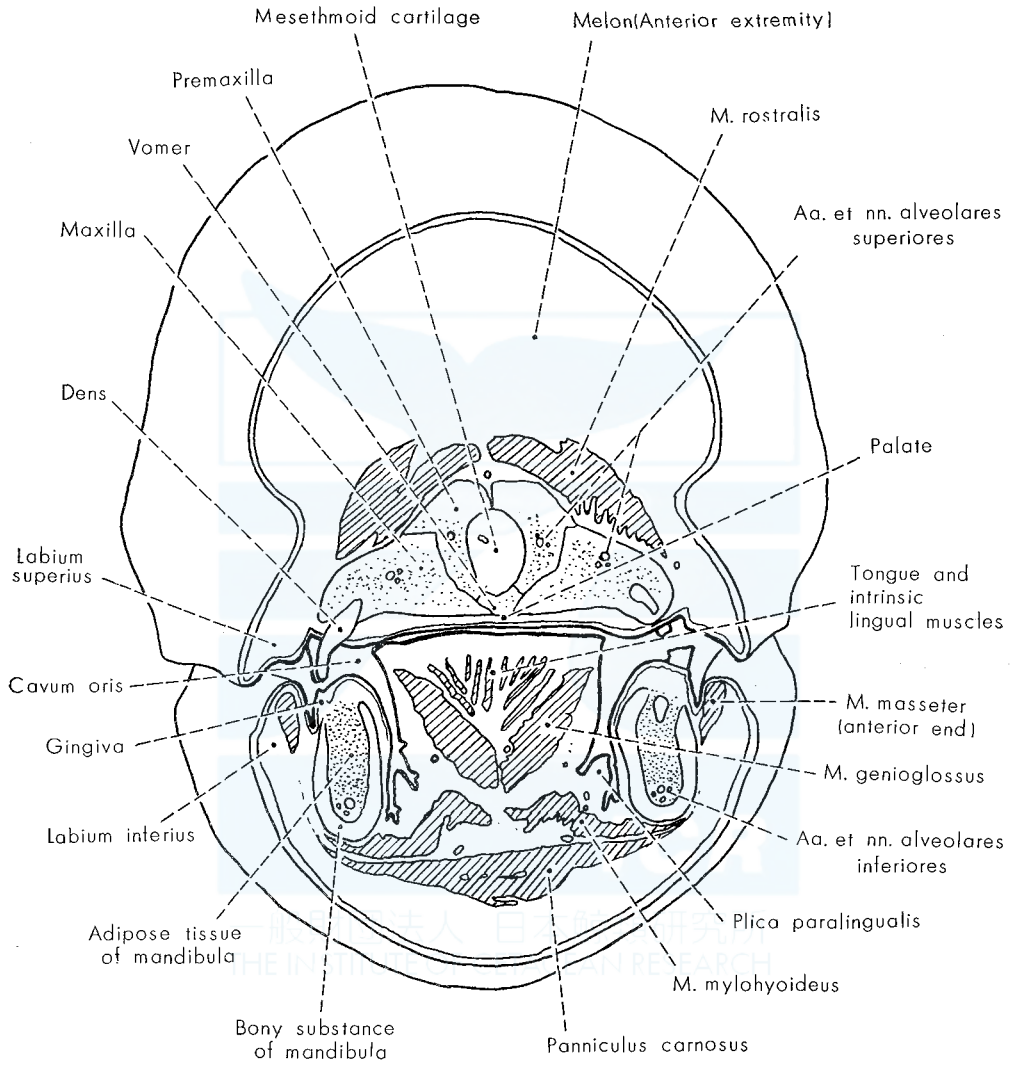


Fig. 2-b. Section I.

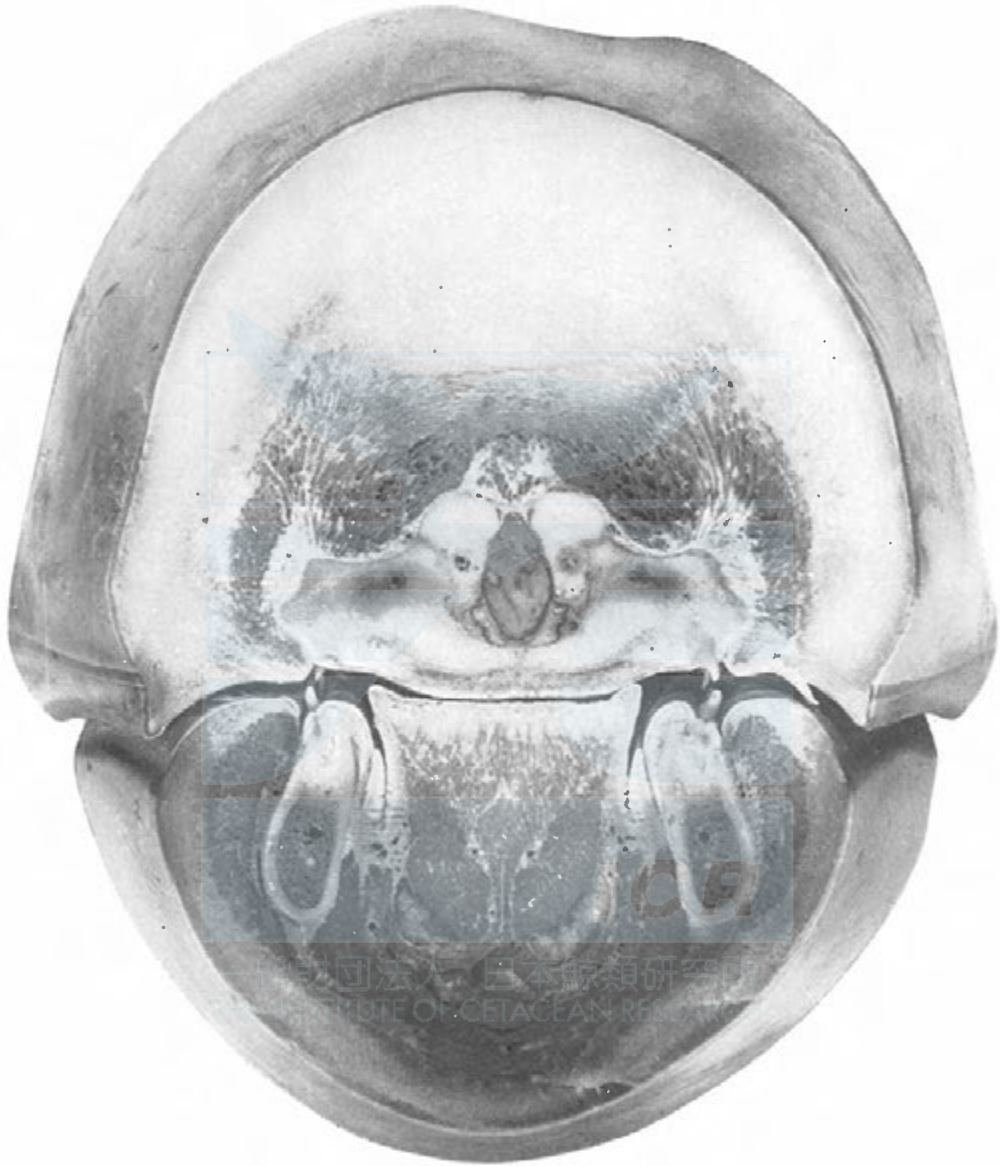


Fig. 3-a. Section II.

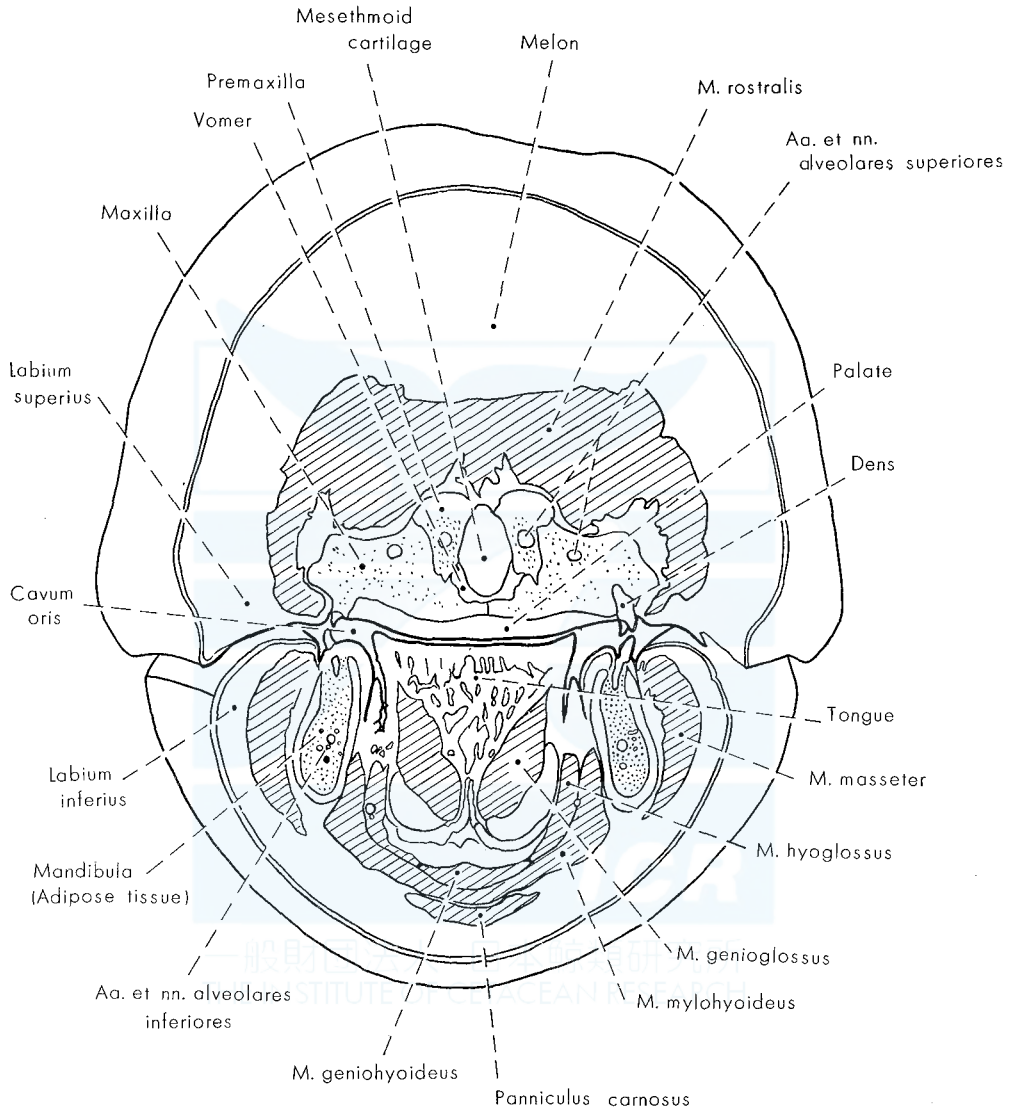


Fig. 3-b. Section II.

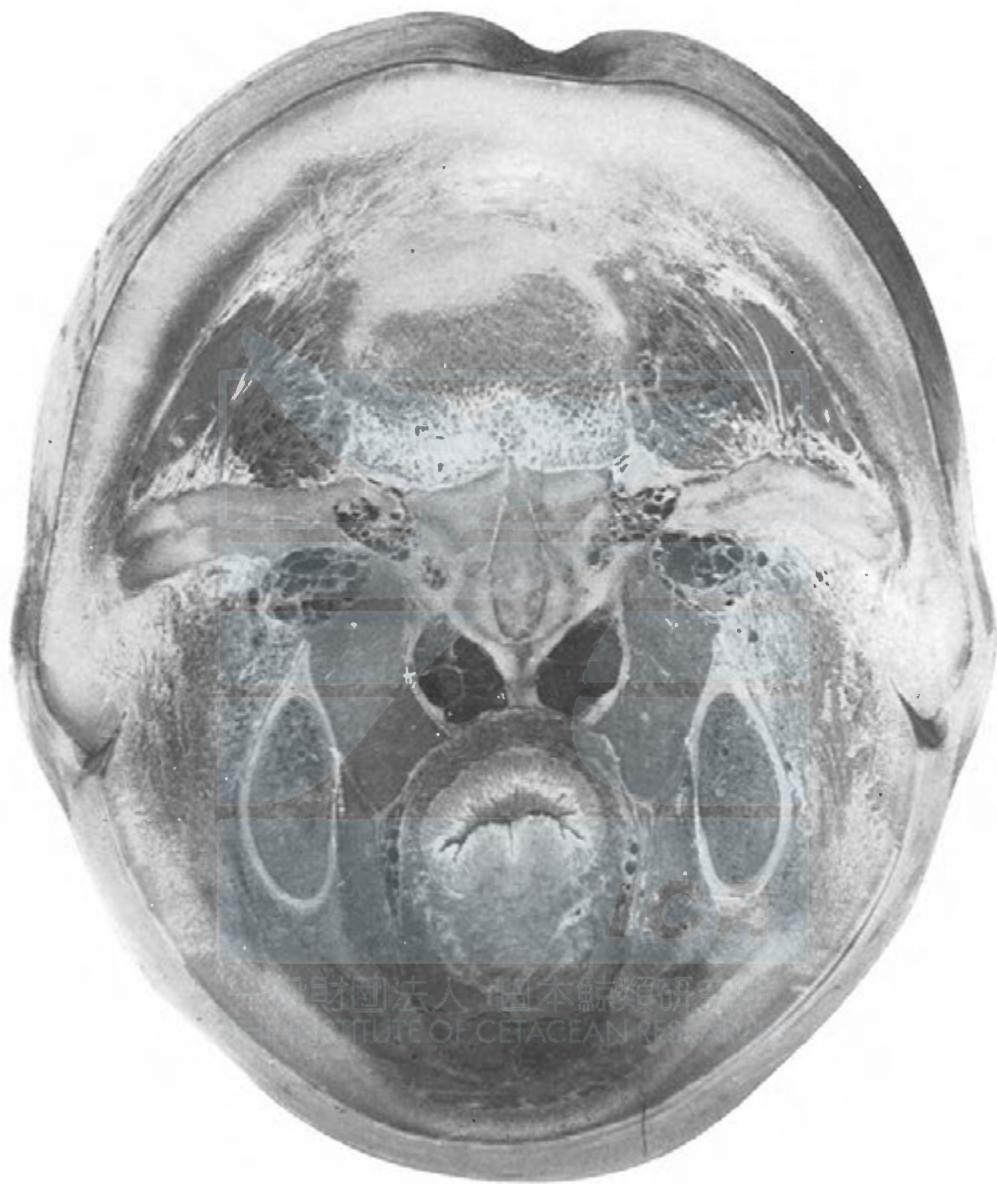


Fig. 4-a. Section III.

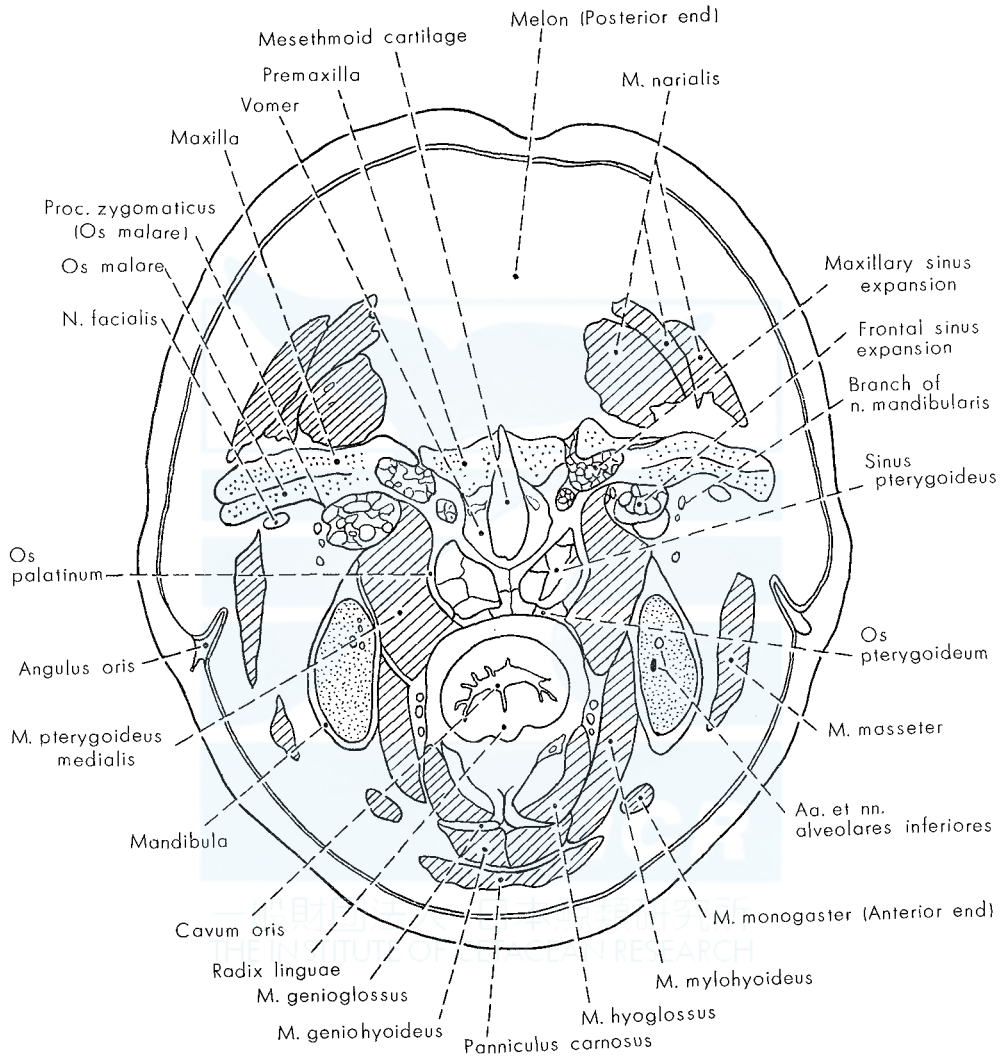


Fig. 4-b. Section III.



Fig. 5-a. Section IV.

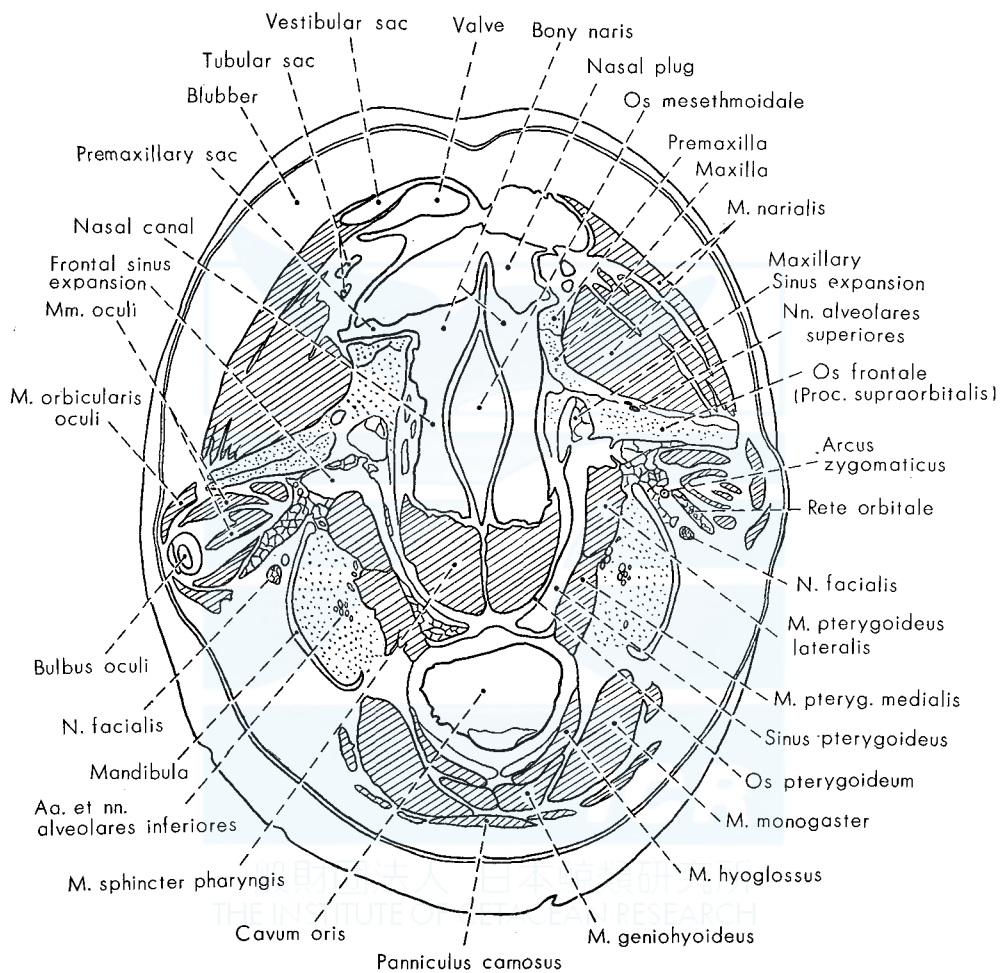


Fig. 5-b. Section IV.



Fig. 6-a. Section V.

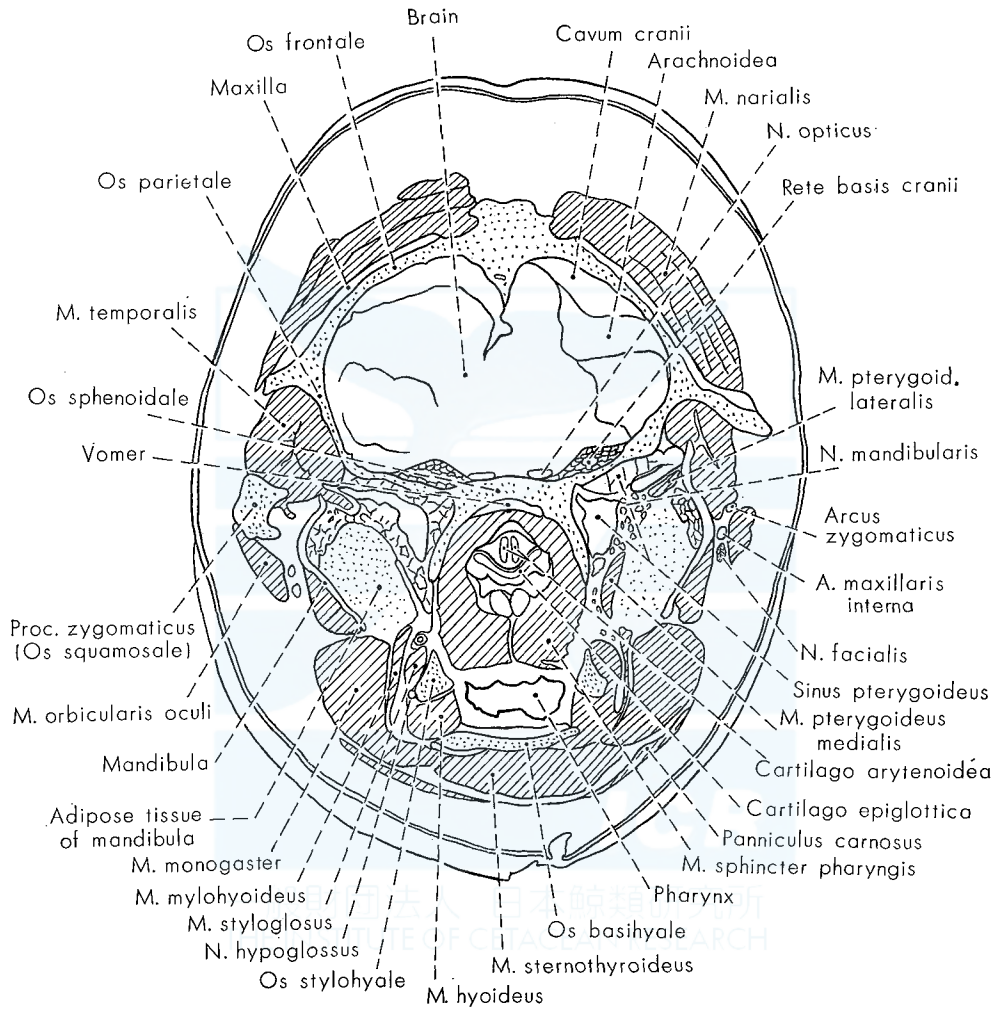


Fig. 6-b. Section V.

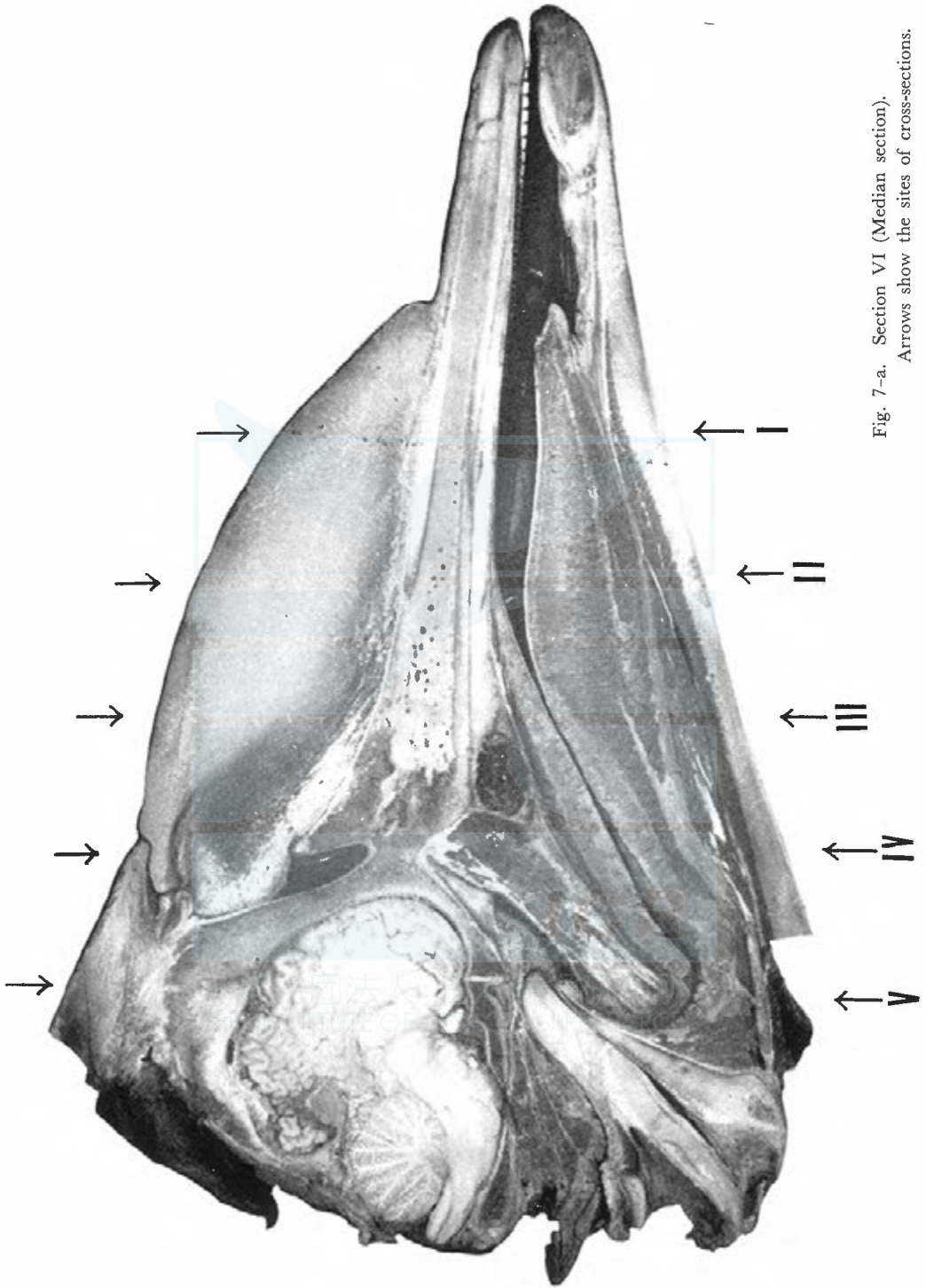


Fig. 7-a. Section VI (Median section).
Arrows show the sites of cross-sections.

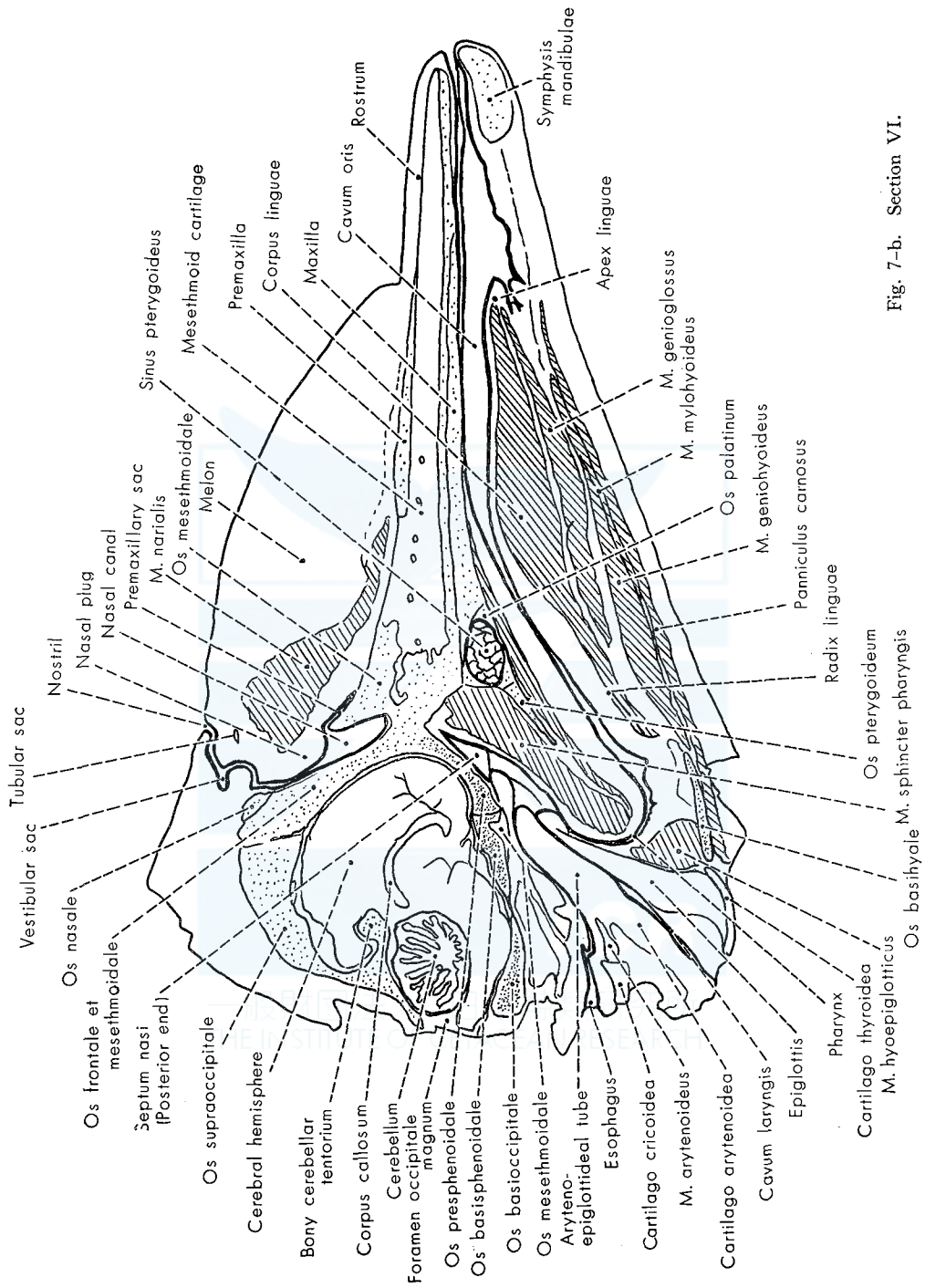


Fig. 7-b. Section VI.



Fig. 8-a. Section VII (Paramedian section).

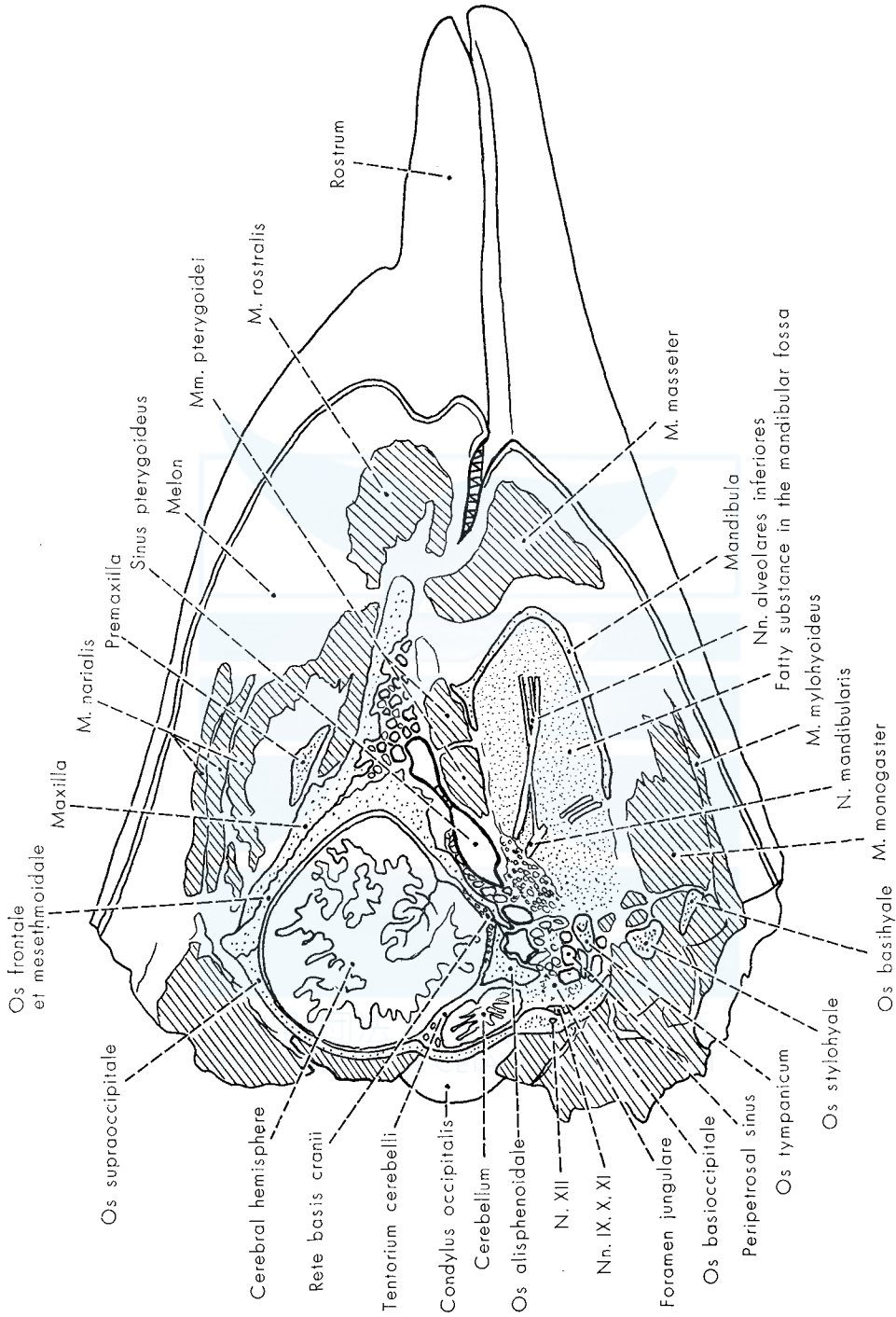


Fig. 8-b. Section VII.

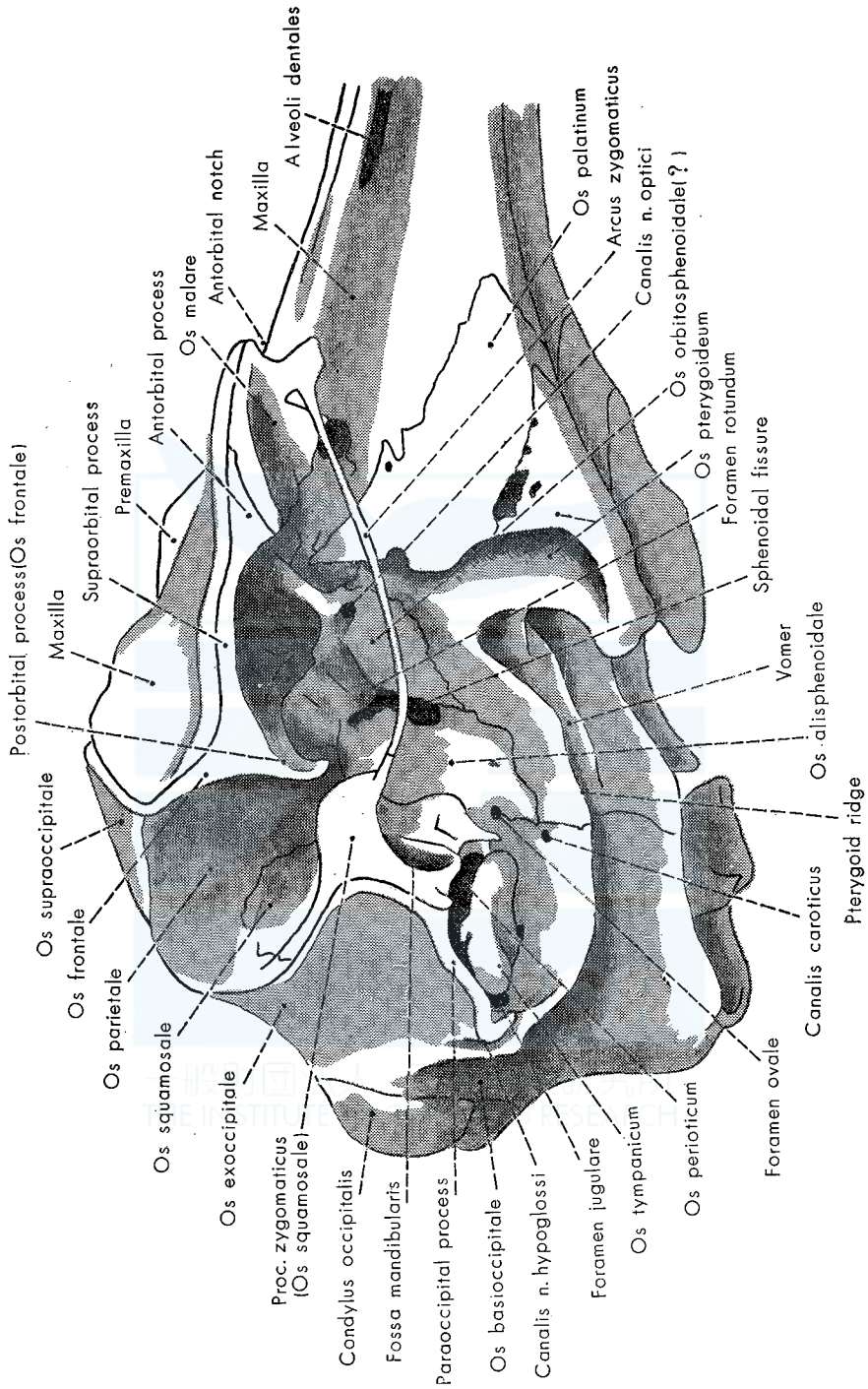


Fig. 9. Skull of the Stenella. Seen from right and below.

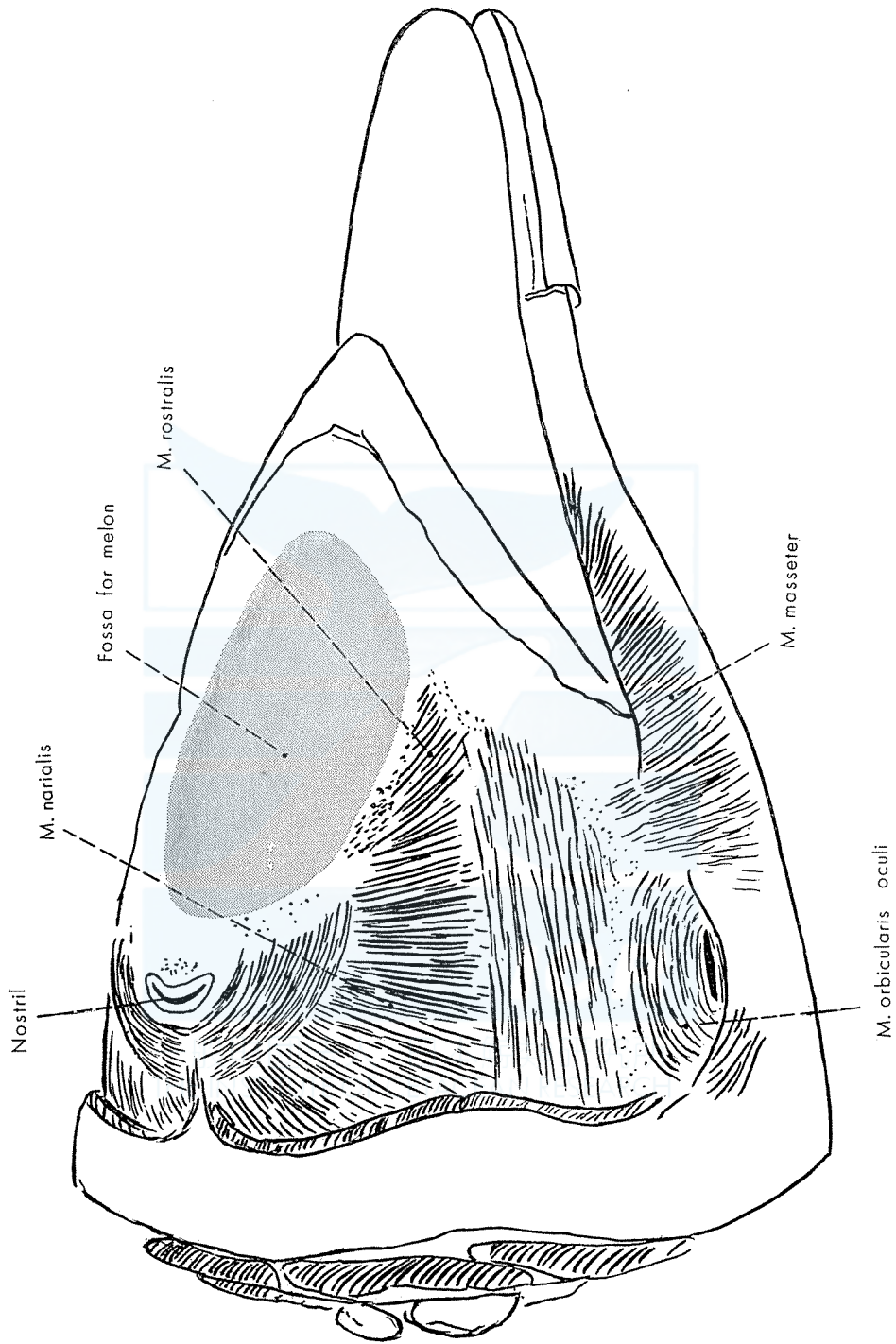


Fig. 10. Muscles (1).

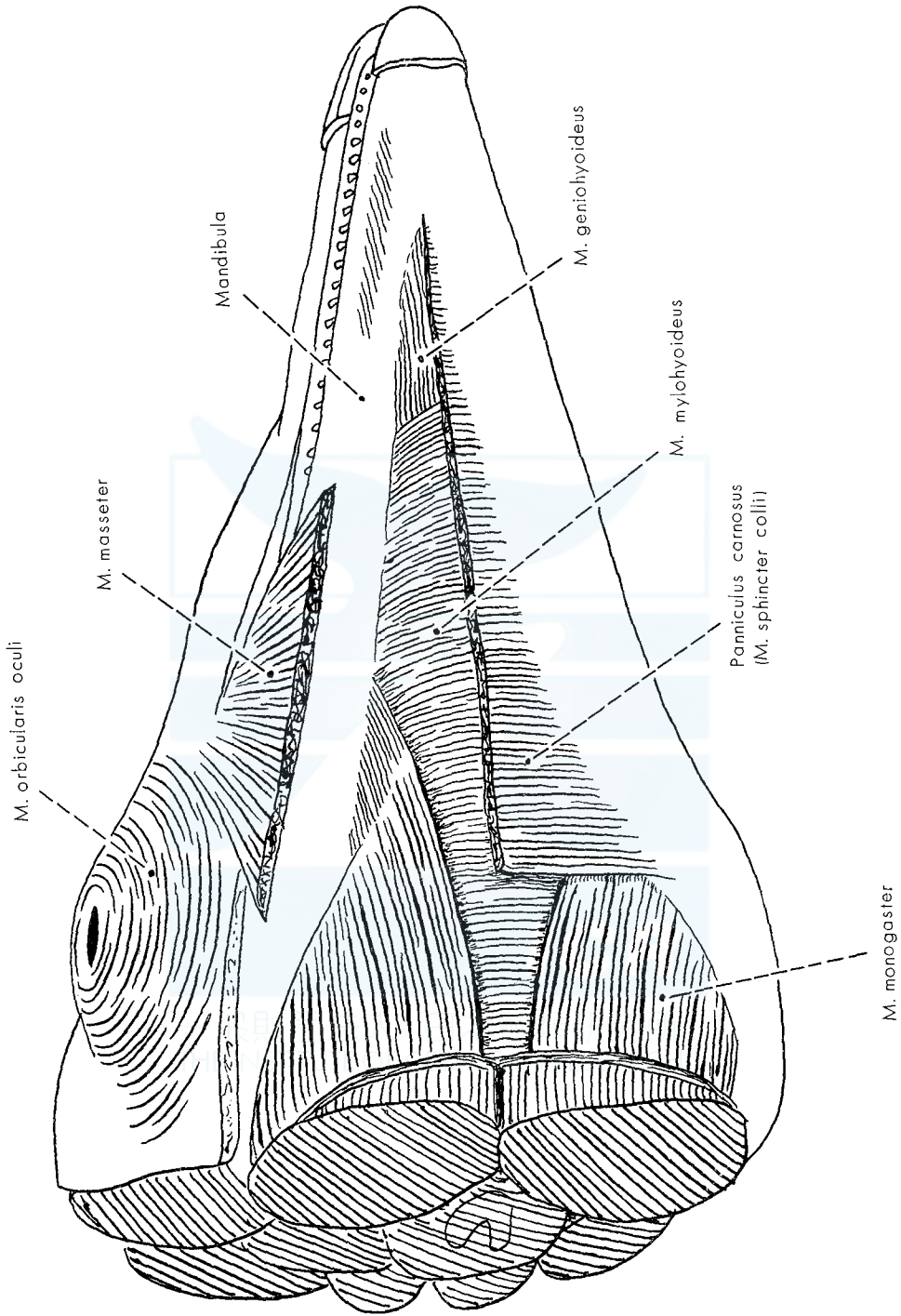


Fig. 11. Muscles (2).

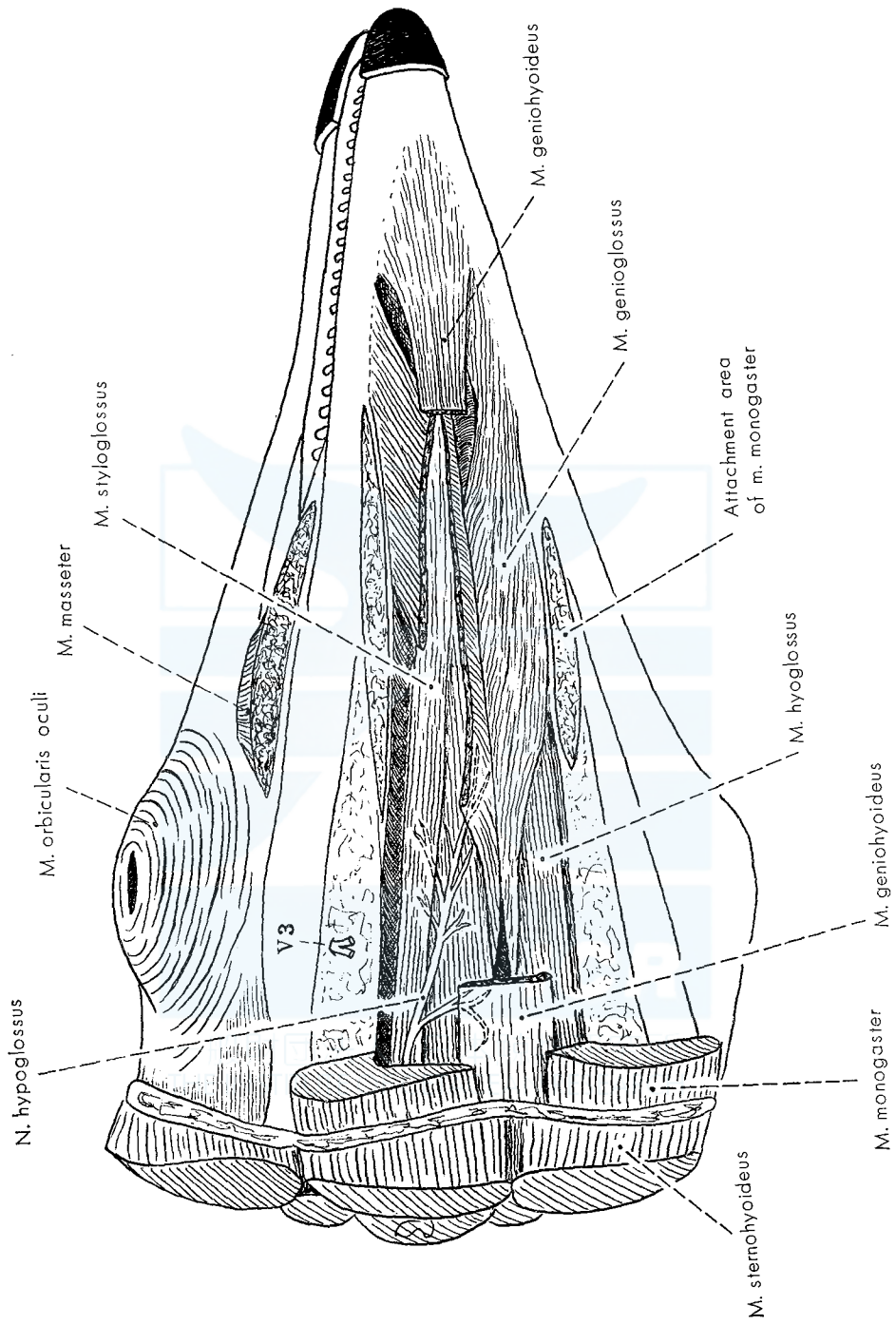


Fig. 12. Muscles (3).

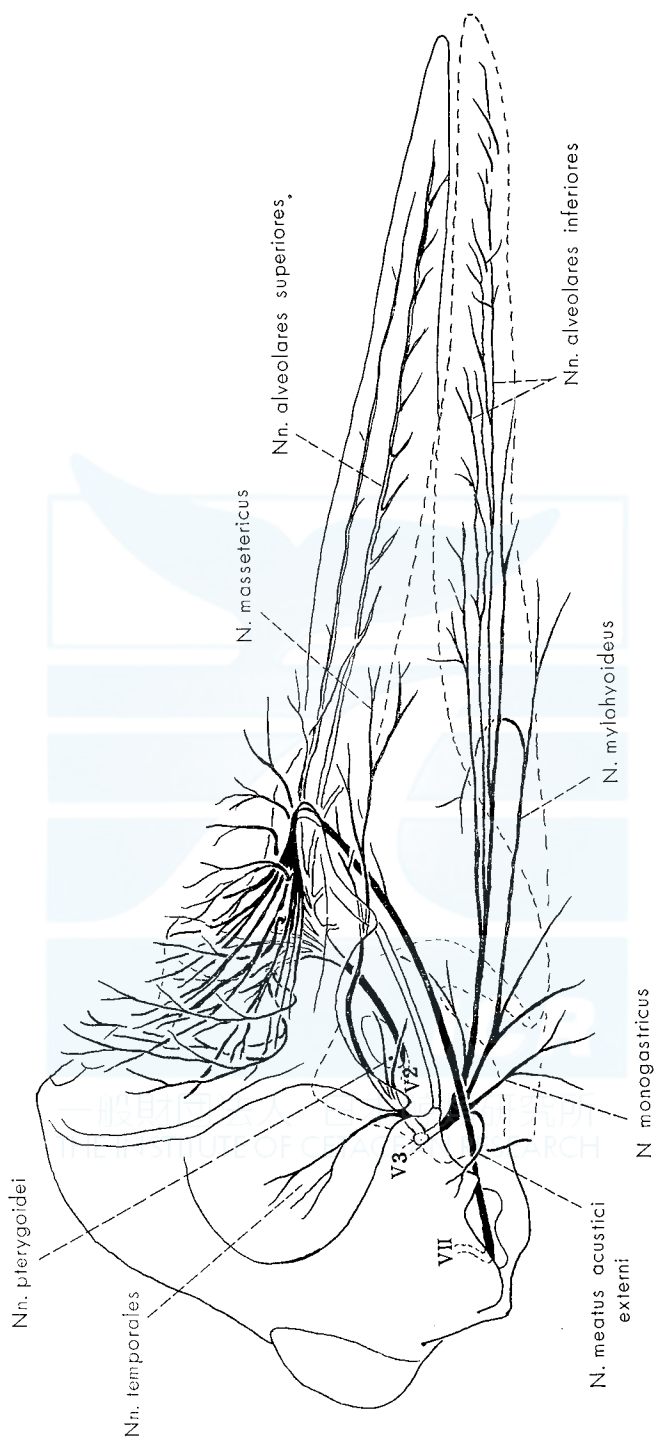


Fig. 13. Peripheral distribution of n. maxillaris (V_2), n. mandibularis (V_3) and n. facialis (VII).

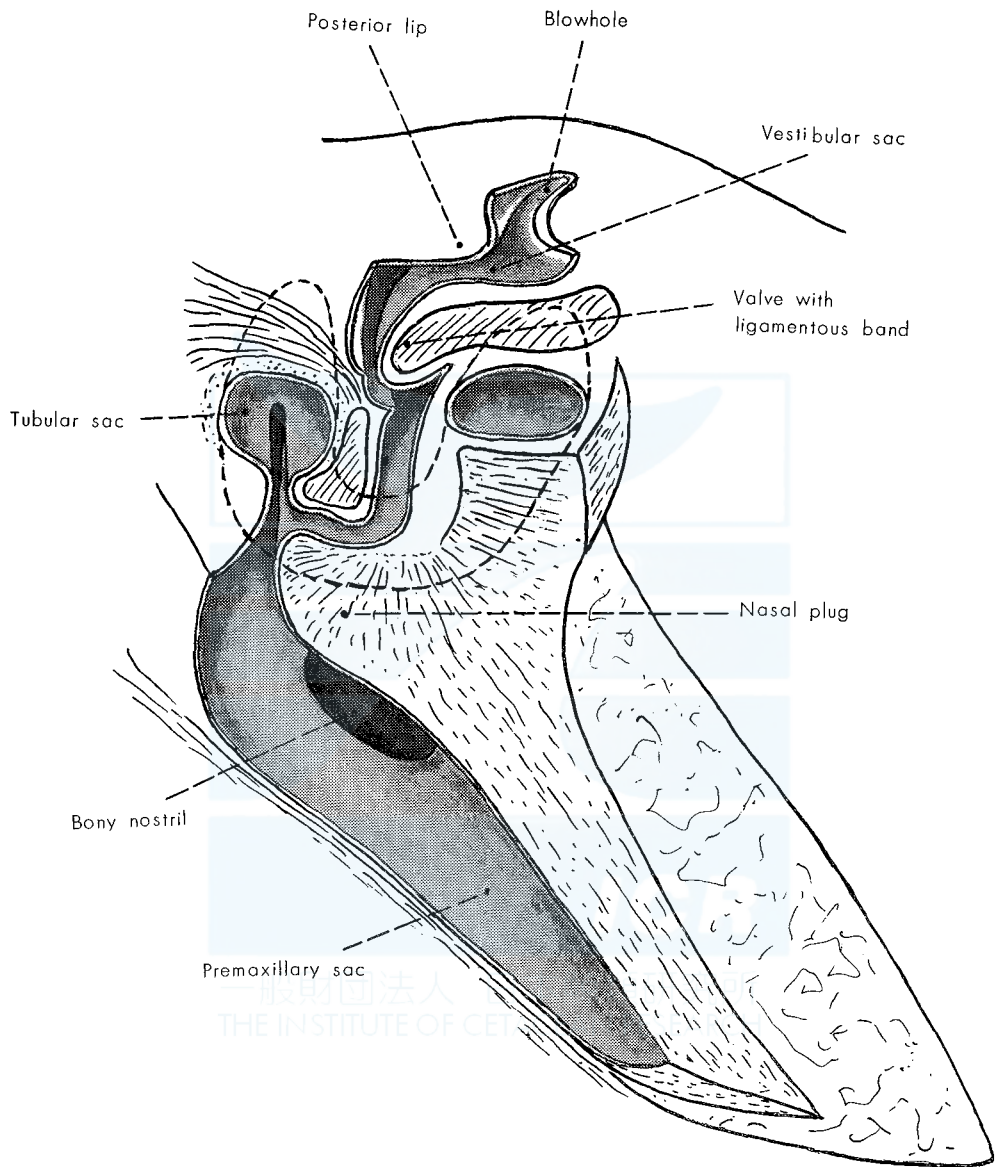


Fig. 14. Nasal passage.