OBSERVATIONS ON THE SPINAL CORD OF THE RIGHT WHALE

YASUSHI SEKI*

The spinal cord of a female Eubalaena glacialis captured on May 23rd, 1956, off Kinkazan, was investigated morphologically. The body length measured 11.65 m (38 feet 4 inches). The spinal cord was removed two days after the capture (May 25th) and fixed in formalin. After measuring, photographing and macroscopical observations, it was cut in each segment corresponding to the spinal nerve roots. For microscopical studies they were refixed then in Müller's solution for 2 weeks in 37°C, imbedded into celloidin, sectioned transversely or longitudinally and stained with Pal-carmine method, hematoxylin-cell-staining method and Masson-Goldner's method**.

RESULTS

GROSS ANATOMY OF THE SPINAL CORD, THE SPINAL NERVE ROOTS AND THE MENINGES

Following measurements were done outside of the vertebral canal, so that the spinal cord might be somewhat contracted from the natural state of the cord. After Hosokawa, this contraction rate is 2 to 3 per cent of the total length of the spinal cord.

The total length of the spinal cord		ca. 174 cm,
Cervical cord	(consisting of 8 segments)	ca. 23 cm,
Thoracic cord	(,, 14 segments)	ca. 105 cm,
Lumbal cord	(,, 10 segments)	ca. 36 cm,
Coccygeal cord	(,, 8 segments)	ca. 10 cm.

It is remarkable that the spinal cord is very short (174 cm) for the body length (11.65 m). The cord length ratio for the body length is 14.9%, while that of the matured fin-whale is said 24.3% (Hosokawa). There are in all 40 segments in the spinal cord, though the total number of the vertebral bones of the Eubalaena amounts to 56 or 57. Of course, the spareness in number of the segments in the cord is caused by shortening of the coccygeal cord (8 segments in the coccygeal cord

---

* Department of Anatomy, *School of Medicine*, University of Tokyo. Formerly Institute for Brain Research, University of Tokyo.

** Many thanks are due to Miss T. Koide, Miss T. Ogisaka and Miss M. Suda, technicians in the Institute for Brain Research, for their great efforts to manufact the microscopical preparates.

against 25 or 26 of the coccygeal vertebrae). None of the spinal nerve root is recognized below Co. 8. The caudal end of the conus medullaris is seen ca. 1 cm below the caudal border of the radix of Co. 8. The lower border of the dural sack is found at nearly the same level with the caudal end of the conus medullaris; thus the filum terminale internum is difficult to see. The filum terminale externum i.e. the portion of the filum mantled with the dura mater, runs farther caudalward.

At most levels of the spinal cord, the points where the dura mater is penetrated by the spinal nerve roots are not so far distant from the places where the fila of the roots are connected with the cord. The cauda equina can not be recognized inside the dura mater. The internal lamina of the dura is markedly thick (3 mm in the cervical roots portion, 2 to 3 mm in the thoraco-lumbal roots portion and 1.5 to 2 mm in the coccygeal roots portion), and outside this membrane, there is a very wide epidural space filled with extremely rich blood vessels and fatty tissue. After penetration of the dura, the radices descend side by side making *epidural* cauda equina, and reach the corresponding intervertebral foramina. There the radices of the lower thoracic, the lumbal and the coccygeal nerve roots have to run in the epidural space for very long distance (for several meters). In the subarachnoidal space i.e. between the arachnoid and the pia mater, many blood vessels are seen, too. They are chiefly made of arterial network, with fine and dense arachnoid trabeculae, surrounding the surface of the spinal cord. In Fig. 1, an

---

EXPLANATION OF FIG. 1

1. Pons Varoli, Medulla oblongata, C. 1, 2 and 3.
2. from C. 4 to Th. 2.
3. Th. 3.
4. Th. 4.
5. a little part of Th. 4 and uppermost part of Th. 5.
6. a little part of Th. 5 and uppermost part of Th. 6.
7. a little part of Th. 6 and upper two thirds of Th. 7.
8. lower third of Th. 7 and uppermost part of Th. 8.
9. a little part of Th. 8 and upper two thirds of Th. 9.
10. lower third of Th. 9 and upper two thirds of Th. 10.
11. lower third of Th. 10 and Th. 11.
12. The 12 and upper half of Th. 13.
13. lower half of Th. 13 and Th. 14.
14. L. 1, 2 and upper two thirds of L. 3.
15. lower third of L. 3, from L. 4 to L. 6 and upper two thirds of L. 7.
16. lower third of L. 7, from L. 8 to Co. 5 and upper half of Co. 6.
17. lower half of Co. 6, Co. 7 and 8, lower end of conus medullaris and filum terminale.

C: Cervical cord Th: Thoracic cord
L: Lumbal cord Co: Coccygeal cord

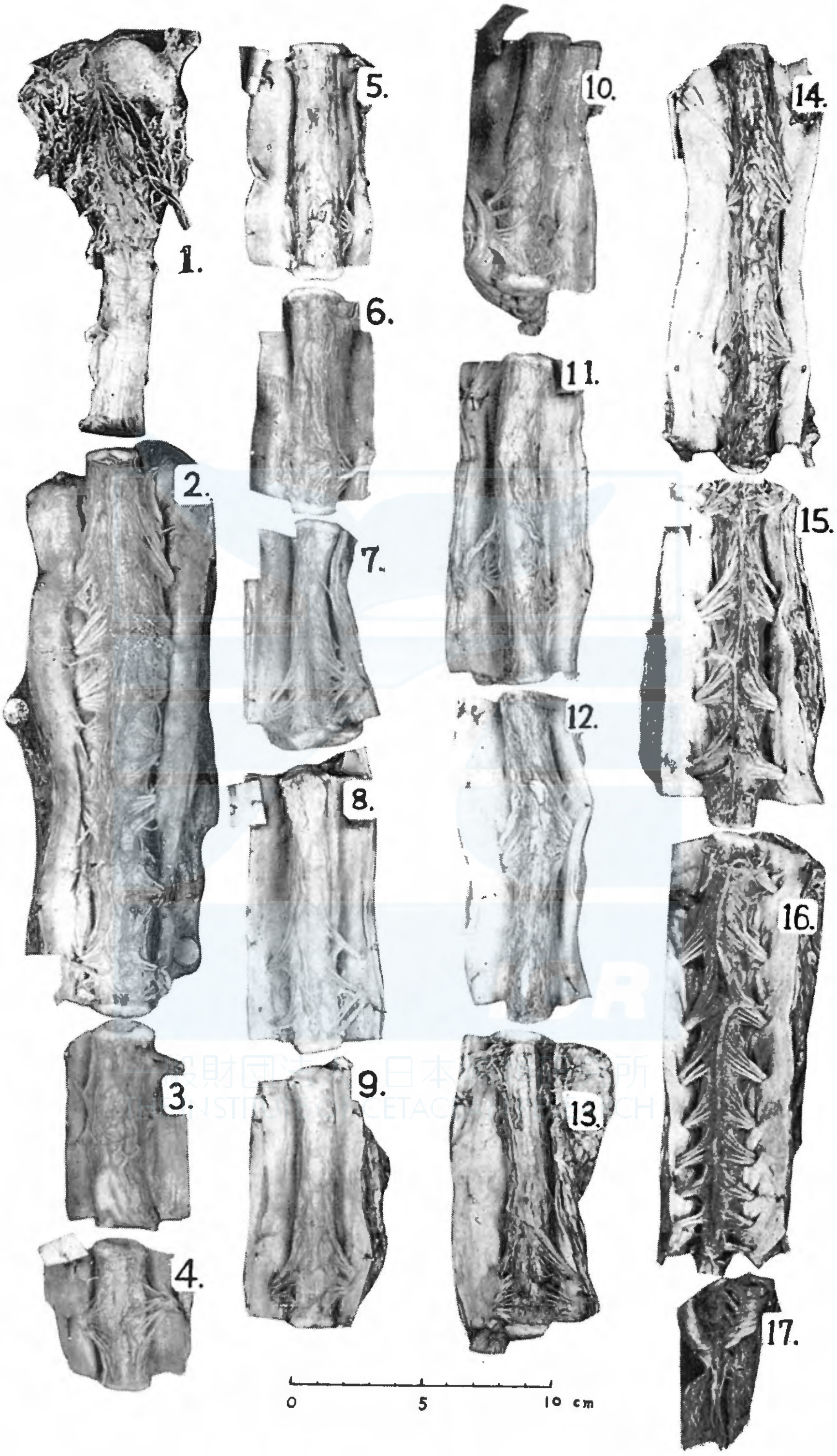

Fig. 1

external view, the cervical enlargement is clearly visible ; however, the lumbal one is hardly to recognize. Table 1, showing the thickness of the spinal cord, indicates the same also.

TABLE 1. THICKNESS OF THE SPINAL CORD (diameter in mm)

	Transverse	Ventro-dorsal		Transverse	Ventro-dorsal
C 1	15.0	14 0	Th 10	13.0	13.5
4	15.0	14.0	14	12.5	12.5
6	17.0	16.0	L 3	13.5	12.0
8	17.5	14.0	7	13.0	11.0
Th 2	17.0	15.0	Co 1	12.5	10.0
5	13.0	13.0	5	8.0	7.0

DIMENSION OF THE CROSS SECTIONS OF EACH SEGMENT

In Fig. 2, our measurements on the extent of the cross section area of each segment are indicated by curves. They are acquired from the celloidin sections stained by Pal-carmine method. In the curves denoting the entire area and the white substance, the cervical enlargement is shown clearly, but the lumbal one not distinctly. In the curve presenting the gray substance, both the cervical and the lumbal enlargement are recognized moderately. It is significant that the maximum extent of the lumbal enlargement is found not in the lumbal, but in the coccygeal level, which results perhaps from the formation of the huge tail (not the flukes) of the cetacea. Guldberg (1885) described the lumbal enlargement in embryos of some Balaenopterae, Cunningham (1877) observed

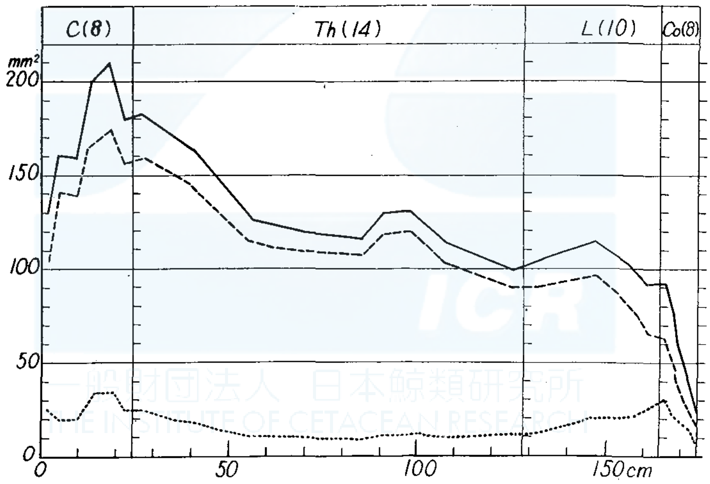

Fig. 2. Curves showing the variations in sectional area of the gray substance (····), the white substance (----) and the entire area (——) in each segment of the spinal cord.

it also in matured Phocaena, though, as a rule, the lumbal enlargement has not been definitely recognized in the cetacea. In our material an external view, the lumbal enlargement is not so clearly developed, but gray substance in the same levels are doubtless expanded.

ANTERIOR COLUMN

The anterior columns are developed well, even in the thoraic level, occupying nearly half of the total gray substance in the cross section. At the levels from cervical to upper thoracic (cervical enlargement) and from middle lumbal to upper coccygeal (lumbal enlargement) cord, the gray substance is occupied over half by the anterior column (Fig. 3—13). In the cervical enlargement the anterior columns are developed very much to the lateral direction ; on the contrary, in the lumbal enlargement the anterior columns are larger in the ventrodorsal extent than in the transverse one. It is said that the motor cells innervating the musculature of the extremities are situated in the lateral part of the anterior column, and so it seems quite natural, that they are poorly developed in the lumbal enlargement of the Eubalaena.

Most of the cells of the anterior column are deeply stained with carmine or hematoxylin, large sized and polygonal shaped ; among these large cells there are also small sized, triangle, spindle or polygonal shaped, scattered cells. Moreover, we find light coloured, somewhat roundish-polygonal or spindle shaped, large or medium sized (50 to 100 μ) cells, situating at the medial and lateral periphery and the dorsal part of the anterior column, sometimes as a few scattered cells among the deep coloured polygonal larger cells of this column. Majority of them are seen in the cervical, lower lumbal and coccygeal levels ; they are rather scanty in the thoracic and upper lumbal cord. Hatschek (1896) described chromophobe cells in the anterior column of the common dolphin (Delphinus delphis), but it is not clear that they correspond or not with the light coloured cells we found. He noted the chromophobe cells are in number over that of the chromophile cells in the lumbal cord ; but they are never so in our material. In the thoracic and upper lumbal levels, the light coloured cells are only of small amount ; on the other hand, as later mentioned, the lateral horn cells are very well developed in the same levels ; in addition, as most of these cells exist in the neighbourhood of the pars intermedia, we supposed that the cells might be associated with some autonomic function.

When we examine the cells of the anterior column in longitudinally sectioned preparates, most of their long axis are parallel with that of the spinal cord in the thoracic levels, but not always just so in the cervical or the lumbo-coccygeal levels mingling here with cells extended in oblique or transverse plane.

Is it true that the cells in such giant sized animals as the Eubalaena are larger than the cells in man? In Table 2, the sizes of the cells are indicated concerning the anterior columns of Eubalaena and man. The human cells seem somewhat smaller than the cetacean cells but not so distinctly in the cervical or thoracic level; however, in the lumbal enlargement, the cetacean cells are doubtless much larger than those of man. In man, the differences of the cell size between the cervical, the thoracic and the lumbal level are not so remarkable, while in the cetacea, the cell size in the coccygeal level is conspicuouly larger than those in the other levels. From the data as above mentioned we considered that the size of the nerve cells seems more related to the length of the nerve fibers originating from them than to the body size of the animals; in the Eubalaena the spinal nerves in the lower levels have to run for very long distance.

TABLE 2. CELL SIZE OF THE ANTERIOR COLUMN
(measurements of 100 cells in each level)

Eubalaena gracialis

	Average (μ)	Maximum (μ)	Minimum (μ)
C 6	56 × 21	69 × 46	17 × 6
Th 8	44 × 16	69 × 29	23 × 6
Co 1	94 × 36	171 × 69	40 × 11

Homo sapiens

	Average (μ)	Maximum (μ)	Minimum (μ)
C 6	46 × 16	93 × 37	17 × 11
Th 8	30 × 13	57 × 20	11 × 6
L 4	48 × 25	97 × 40	19 × 7

The anterior roots appear at a wide range of the anterior surface of the cord, extending from the anterior to the lateral funiculus. Some of them start even in the anterior median fissure (Fig 8).

POSTERIOR COLUMN

At almost all levels, the posterior columns are far less developed than the anterior columns on the same section, especially so in the middle cervical, the whole thoracic, the lower lumbal and the upper coccygeal cord. The poor development of the posterior column in the cetacea was previously described by many authors (Guldberg 1885, Hatschek 1896, Sano '09 usw.). In addition, the border of the gelatinous substance of Rolando looks not so distinct in most levels of the cord. The same results were mentioned by Hatschek (1896) in Delphinus delphis and by

Sano ('11) in Delphinus tursio (=Tursiops truncatus), and these were considered chiefly due to less developed cutaneous sensibility and lack of the hair in the whales (Kappers '36).

At C. 1, however, the posterior column is moderately large assuming nearly the same size as the anterior column at the same level. More rostrally, in the medulla oblongata, the spinal root and its nucleus of the trigeminal nerve are very well developed, and the lower extension of this nucleus reaches down to the level of C. 1 (Fig. 3, 14, 15). It is to consider that the Eubalaena has a great many sensory organs in the skin or the mucous membrane of the head portion. In fact, in our laboratory, Ogawa and Shida recently confirmed the existence of structures, which seem to be sensitive apparatuses having rich nerve endings, in the lips, tongue, palate and basis of the mouth cavity of the Eubalaena. The presence of these structures must be related to the marked development of the trigeminal sensory nuclei in the central nervous system.

The postero-marginal cells are developed well in the cervical or especially in the lumbo-coccygeal, but less in the thoracic levels in the zona spongiosa of the posterior column. Their size are 15 to 50 μ in the transverse, 15 to 120 μ in the longitudinal direction. Namely, most of their long axis are directed longitudinally.

The nucleus proprius of the posterior column is chiefly composed of small sized (5 to 20 μ) spindle shaped cells and medium sized (10 to 40 μ) polygonal or somewhat rounded cells, and the long axis of the former are directed longitudinally and measured up to 30 μ. In the lumbo-coccygeal levels they contain sometimes the typical cells of the Clarke's column.

It is peculiar that the posterior columns of both sides come to adhere on the midline in the lower half of the thoracic and the coccygeal cord. (Fig. 8, 13).

CLARKE'S COLUMN

The Clarke's columns of the Eubalaena are well developed in the thoraco-lumbal levels, but it is not easy to determine their upper and lower limits, as in the cord more cranial or caudal than the portion above mentioned, there are also a few cells at the same position. It is especially so in the upper cervical cord, where the cells in question represent possibly the cervical nucleus of Stilling ; on the other hand, some of quite the same type of Clarke's cells are seen not only in the lowest lumbal levels but also in the whole coccygeal cord. The caudal extension of the Clarke's column is well known in the spider monkey (Chang '51), and we meet here with the resembling structure in the Eubalaena ; it deserves attention, that both animals have very well developed tails.

At the levels from lowest thoracic to middle lumbal cord, the Clarke's column shows its maximum development, and it is composed of some cell groups, involving many large, roundish nerve cells (20 to 90 μ). Most of these cells are directed longitudinally and their long axis are measured up to 180 μ, but some cells appear round still in longitudinal sections. Our noteworthy finding is the fusion of the dorsal cell groups of both sides on the midline, but the ventral cell groups are separated from the contralateral ones at the same levels (Fig. 8, 9, 10). Dexler ('11) in Halicore dugong, Hatschek (1896) and Schacherl ('02) in Delphinus delphis, mentioned also the fusion of the Clarke's column on the midline.

PARS INTERMEDIA

In comparison with the spinal cord of other mammals, the territory occupied by the intermediate zone is moderately wide in the Eubalaena and there we see a great many nerve cells and a large amount of nerve fibers. Because of the well developed gray commissure, in most levels of the cord, the dorsal funiculus are far distant from the anterior funiculus. These findings upon the pars intermedia, suggest certain functional (especially of autonomic nature) differences of this part between the cetacea and the other animals.

On the transverse sections, the anterior white commissure in the thoracic levels are hardly recognized, but on the longitudinally sectioned preparates, many fibers are crossed in the thoracic cord making small angles (5° to 10°) to the median plane. On the other hand, in the cervical or lumbo-coccygeal levels, the anterior commissural fibers are clearly seen on the transverse sections. Hatschek (1896) noted also the characteristic anterior white commissure extended in the sagittal direction in the dolphin.

The nucleus of the lateral column is recognized in the levels from D. 1 to L. 8, showing the group of middle sized (20 to 60 μ), roundish or spindle shaped cells in the light coloured gray substance at the lateral border of the intermediate zone. In most heights, this column makes the lateral horn protruding into the lateral funiculus (Fig. 7, 8, 9, 10). Takahashi ('13) mentioned the gelatinuous substance in the lateral horn nucleus; and in our material, just the same findings are obtained.

The reticular formation is well developed in C. 1; it is represented by many scattered cells at the part adjacent to the lateral border of the intermediate zone and in the neighbouring white substance of the lateral funiculus. In C. 2, it is similarly found but a little less developed than in C. 1. At the other levels of the cord, the cells in question are far poorly developed than at C. 1 and 2; only a few cells are seen in the dorso-lateral border of the intermediate zone and sometimes also in the neighbouring white substance.

It is a peculiar finding that the central canal is completely obliterated at any level of the cord. Although the border of the central gelatinous substance is considerably distinct in the upper portion below the obex and also in the coccygeal levels, traces of the ependymal cells are nowhere to be recognized. Hatschek (1896) in Delphinus delphis, Biach ('06) in Phocaena communis, described also that the central canal was fully obliterated. In man, the central canal of the spinal cord is in the adults often closed and changed into a cord-like structure formed by the remaining ependymal cells. Biach ('06), however, noted an opened central canal in the lower portion of the spinal cord in Delphinus tursio.

ACCESSORY NERVE ROOTS

In the Eubalaena, the spinal roots of the accessory nerve are very poorly developed, and only in the 1st cervical level. They are recognized there as few fascicles consisting of a small number of thick fibers. This finding is contradictory to the description Hatschek's (1896) that the spinal root of the accessory nerve was observable as "Respirationsbündel" of Krause until the level of the cervical enlargement. On the other hand, the accessory nerve roots are developed well in the lower portion of the medulla oblongata of the Eubalaena.

At C. 1, the lateral part of the anterior column makes a somewhat reticular appearance protruding into the lateral funiculus, where groups of deeply stained, large sized polygonal cells are present. When we follow it up to the medulla oblongata, this structure separates gradually from the anterior column, and makes independent and *beaded* cell islands extending longitudinally. At the lower level of the rhomboid fossa, these islands become larger in the lateral funiculus and continue directly to the nucleus ambiguus (Fig. 3, 14, 15). Namely, in the Eubalaena, it is confirmed that the lower extension of the nucleus ambiguus is fused into the lateral part of the anterior column in the 1st cervical level. From this lower extension of the nucleus ambiguus, perhaps some parts of the bulbar roots of the accessory nerve take origin.

Ogawa and Chen ('47) remarked the lower extension of the dorsal vagal nucleus continuing to the medial border of the lateral funiculus of the 1st cervical level in some ungulates. The same facts were confirmed also by Mannen and Seki ('58) in some pinnipedia. However, in the Eubalaena, a similar finding is not obtained.

NUCLEUS CERVICALIS LATERALIS

Rexed and Brodal described the lateral cervical nucleus in the cat ('51); the corresponding cell groups are seen also in the 1st cervical cord of the Balaena (Fig. 3). They are found in the dorso-medial part of the lateral funiculus as a spindle, oval or irregularly reticular shaped gray substance, having middle sized (20 to 35 μ) roundish and somewhat deeply stained polygonal cells. It shows no sharp limit to the medial situating reticular formation. This nucleus changes its shape and largeness from section to section, and sometimes disappears on one side. The upper limit of this nucleus is in the lowest level of the medulla oblongata, while caudalward it is present, though less distinctly, until in the 2nd cervical level.

PYRAMIDAL TRACT

The pyramids are flat assembly of bundles of longitudinally running thin fibers, which lie on either side of the midline at the ventral border of the medulla oblongata (Fig. 15). At the lower levels of the medulla oblongata, the pyramidal tracts of both sides come to fuse together and make a wedge-shaped unpaired white substance area between the anterior funiculi of both sides (Fig. 14). More caudalward, the pyramid, decreasing the quantity of its fibers, changes into a spindle shaped tract and its location shifts slowly to dorsal and reaches then in the 1st cervical level (Fig. 3). During the course above noted almost all fibers of this tract remain seemingly in the longitudinal direction, so that the decussation of the pyramidal fibers is very hard to recognize.

However, in the upper levels of the hypoglossal nucleus, we see some fiber bundles, which are mediated between the medial parts of the pyramids of both sides (Fig. 15), but we can not yet ascertain the decussation i.e. the interchange of the fibers of the pyramidal tracts. In the lower level of the medulla oblongata, most fibers of the pyramids are stil uncrossed.

At the 1st cervical cord, the pyramidal tract appears on the midline as a spindle shaped longitudinal bundle, which decreases gradually its dimension, and then it disappears in the 2nd cervical level.

Neither in the medulla oblongata nor in the spinal cord, we can trace further course of the pyramidal fibers branching off from their main tract.

Rawitz ('09) and Gans ('16) in Phocaena, and Matsumoto ('53) in Cogia breviceps and Berardius bairdii, described the pyramidal decussation, but some previous authors could not confirm it (Hatschek and Schlesinger '02, Wilson '33, Jelgersma '34 usw.). We have to examine further the preparates sectioned parallel to the long axis of the medulla oblongata, in order to determine the problem whether the pyramidal decussation exists or not in the cetacea.

The pyramidal tracts of the Eubalaena are composed chiefly of very fine medullated nerve fibers, showing light coloured area in the myelin-stained preparates sharply contrasted to deep coloured neighbouring white substances.

POSTERIOR FUNICULUS AND ITS NUCLEI

Hatschek (1896) described in the dolphin the posterior funiculus as a bundle, in which the posterior median septum is dismissed. In the spinal cord of the Eubalaena, we see no definite posterior median septum on most sections of the thoracic and cervical levels except at C. 1, but in the lumbo-coccygeal levels the septum is clearly visible. The border between the Goll's and Burdach's funiculus is not definitely recognized even in the upper cervical levels.

At the levels beneath the obex, because of the disappearance of the posterior median septum and the neighbouring fibers in the posterior funiculi, the Goll's nuclei of both sides come to adhere on the midline (Fig. 14), and in the levels upper to the obex, of course, they are separated again.

The lower extensions of the Goll's nucleus of both sides are fused together in the Bischoff's nucleus in the lowest level of the medulla oblongata. The Bischoff's nucleus is situated on the midline of the posterior funiculus in this level and sometimes also in the 1st cervical cord (Fig. 3), and has been considered as remarkably present in the animals which have a well developed tail. In the Eubalaena, however, this nucleus is not so large developed.

FIBER TRACTS IN THE WHITE SUBSTANCE OF THE SPINAL CORD

In our preparates of the spinal cord of the Eubalaena, any long fiber tract is not certainly traceable in the ventro-lateral funiculi. But only the areas corresponding possibly to the dorsal spino-cerebellar tract of Flechsig are seen at the dorsal margin of the lateral funiculi of both sides. These areas are composed of many large nerve fibers (10 to 15 μ), begin at the lowest level of the cord, and show deeply stained zone in sections of the lower thoracic and the lumbo-coccygeal cord, but they are hardly to distinguish from neighbourhood in the upper thoracic and the cervical level. In the levels from C. 1 to the medulla oblongata, they appear clearly at the same position as deep coloured areas.

SUMMARY

The results of macroscopical and microscopical observations upon the spinal cord of female Eubalaena glacialis are summarized as follows:

1. The length of the spinal cord is very short (14.9% of the body length). The cauda equina is not present inside the dura mater, but exists only in the epidural space, where we see also extremely rich blood vessels and fatty tissue. Externally, the lumbal enlargement is not distinctly seen, but in the curve indicating the dimension of the gray substance of each level in the cross section, we can recognize clearly the lumbal enlargement, the maximum extent being in the coccygeal level.
2. The anterior column of the cervical enlargement is very well developed in the transverse direction, but in the lumbal enlargement, the anterior column is elongated rather in the ventro-dorsal direction. These results are due perhaps to the lack of the lateral part of the anterior column in the lumbal enlargement, which innervates the musculature of the lower extremities.
3. In addition to the commonly deep coloured motor cells, there are light coloured cells in the dorsal part and the lateral or medial periphery of the anterior column. We guess that the latter might be associated to the autonomic function.
4. Comparing the cell size of the anterior column between the Eubalaena and man there is little difference in the cervical or the thoracic level; but in the lumbal enlargement, the cells of the Eubalaena are doubtless much larger than those of man. We are of the opinion that the size of the nerve cells is more related to the length of the nerve fibers originating from them than to the body size of animals.
5. The posterior column is as a whole less developed; only in C. 1 it is moderately large. The largeness in C. 1 is caused probably by the lower extension of the spinal root and its nucleus of the trigeminal nerve, which are well developed in the medulla oblongata.
6. Fusion of the posterior columns of both sides is seen in the lower thoracic and the coccygeal levels.
7. The Clarke's column is well developed especially in the lower thoracic and the upper lumbal levels. Rostrally, the Clarke's column is continued to the cervical nucleus of Stilling in the upper cervical levels; also the caudal extension of the Clarke's column is clearly developed.
8. The pars intermedia occupies a wide territory. The fibers of the anterior white commissure are crossed in the thoracic levels, making small angles to the median plane.

9. The lateral horn cells exist in the levels from D. 1 to L. 8 in the light coloured gray substance at the lateral border of the intermediate zone.

10. The reticular formation is relatively well developed in the levels of C. 1 and 2, but far less in the other levels.

11. The central canal is fully obliterated for the whole length of the spinal cord.

12. The spinal roots of the accessory nerve are very poorly developed, and only in the 1st cervical level.

13. The lower extension of the nucleus ambiguus is directly continuous to the lateral part of the anterior column in the 1st cervical cord.

14. In the Eubalaena, cell groups corresponding to the lateral cervical nucleus are recognized in the 1st cervical level.

15. The pyramidal tract forms an unpaired bundle between the anterior funiculi of both sides in the lowest level of the medulla oblongata and in C. 1. The pyramidal decussation is not demonstrated in spite of careful pursuit down to its lower disppearance.

16. At the dorsal margin of the lateral funiculus, an area possibly corresponding to the dorsal spino-cerebellar tract is traceable.

ACKNOWLEDGEMENT

I am grateful to Prof. T. Ogawa for his constant direction and revision. My thanks are also due to Ass. Prof. H. Hosokawa and Mr. T. Shida for their kind advices and offering of the unpublished data.

REFERENCES

CHANG, H. T. (1951). Caudal extension of Clarke's nucleus in the spider monkey, *J. comp. Neurol.* 95, 43.

CUNNINGHAM, D. J. (1877). The spinal nervous system of the Porpoise and Dolphin. *J. Anat. Physiol.* 11, 209-228.

DEXLER, H. & O. EGER (1911). Beiträge zur Anatomie des Säugerrückenmarkes. I Halicore dugong Erxl. *Morphol. Jahrb.* 43, 107-207.

GANS, A. (1916). Die Pyramidenbahn der Phocaena. *Anat. Anz.* 49, 281-284.

GULDBERG, G. A. (1885). Ueber das Centralnervensystem der Bartenwale. Christiania Vid. Selsk. Forhdl. No. 4.

HATSCHEK, R. (1896). Ueber das Rückenmark des Delphins (Delphinus delphis). *Arb. a. d. neurol. Inst. a. d. Wien. Univ.* IV, 286-312.

HATSCHECK, R. und H. SCHLESINGER (1902). Der Hirnstamm des Delphins. *Arb. a. d. neurol. Inst. a. d. Wien. Univ.* IX, 1-117.

JELGERSMA, G. (1934). Das Gehirn der Wassersäugetiere. Leipzig.

KAPPERS, C. U. ARIENS, G. C. HUBER and E. C. CROSBY (1936). The comparative anatomy of the nervous system of vertebrates, including man. New York.

LANGWORTHY, O. R. (1932). A description of the central nervous system of the Porpoise (*Tursiops truncatus*). *J. comp. Neurol.* 54, 437-499.

MANNEN, H. et Y. SEKI (1958). Quelques résultats d'observation de la partie supérieure de la moelle cervicale anatomie comparée. *Psychiat. et Neurol. Japon.* 60, 441–449.

MATSUMOTO, Y. (1953). Contributions to the study on the internal structure of the cetacean brainstem. *Acta Anat. Nippon.* 28, 167–177.

OGAWA, T. and Y. CHEN (1947). KAIBOGAKU ZASSI (=Acta Anat. Nippon.) 23, 9. (in Japanese) Proceedings of the 51st meeting of the Japanese association of anatomists.

RAWITZ, B. (1903). Das Zentralnervensystem der Cetaceen. I. Das Rückenmark von *Phocaena communis* Cuv. und das Cervikalmark von *Balaenoptera rostrata* Fabr. *Arch. f. mikrosk. Anat. u. Entw.* 62, 1–40.

RAWITZ, B. (1909). Das Zentralnervensystem der Cetaceen. II. Die Medulla oblongata von Phocaena communis Cuv. und *Balaenoptera rostrata* Fabr. *Arch. f. mikrosk. Anat. u. Entw.* 73, 182–260.

REXED, B. & A. BRODAL (1951). The nucleus cervicalis lateralis, a spinocerebellar relay nucleus. *J. Neurophysiol.* 14, 399–407.

SANO, T. (1909). Vergleichend-anatomische und physiologische Untersuchungen über die Substantia gelatinosa des Hinterhorns. *Arb. a. d. neurol. Inst. a. d. Wien. Univ.* XVII. 1–71.

SCHACHERL, c.m. M. (1902). Ueber Clarke's "posterior vesicular columns". *Arb. a. d. neurol. Inst. a. d. Wien. Univ.* VIII, 314–395.

TAKAHASHI, D. (1913). Zur vergleichenden Anatomie des Seitenhorns im Rückenmark der Vertebraten. *Arb. a. d. neurol. Inst. a. d. Wien. Univ.* XX, 62–83.

WILSON, R. B. (1933). The anatomy of the brain of the whale (*Balaenoptera sulfurea*). *J. comp.* Neurol. 58, 441–479.

ABBREVIATIONS USED IN FIGS. 3—13.

ac,	anterior column	lf,	lateral funiculus
af,	anterior funiculus	nB,	nucleus of Bischoff
amf,	anterior median fissure	ncl,	lateral cervical nucleus
an,	arterial network in the subarachnoidal space	nppc,	nucleus proprius of the posterior column
ar,	anterior root fibers	pc,	posterior column
awco,	anterior white commissure	pf,	posterior funiculus
ccl,	lateral horn cells	pi,	pars intermedia
ceCl,	caudal extension of Clarke's column	pms,	posterior median septum
		pr,	posterior root fibers
cl,	lateral column	py,	pyramidal tract
cnSt,	cervical nucleus of Stilling	sgc,	Substantia gelatinosa centralis
cpm,	postero-marginal cells	sgd,	Substantia gelatinosa dorsalis
dlfL,	dorso-lateral fascicle of Lissauer	vcCl,	Clarke's column
fr,	reticular formation	zsp,	Zona spongiosa
gco,	gray commissure	★▲ •	deep coloured cells
ld,	denticulate ligament	○△	light coloured cells

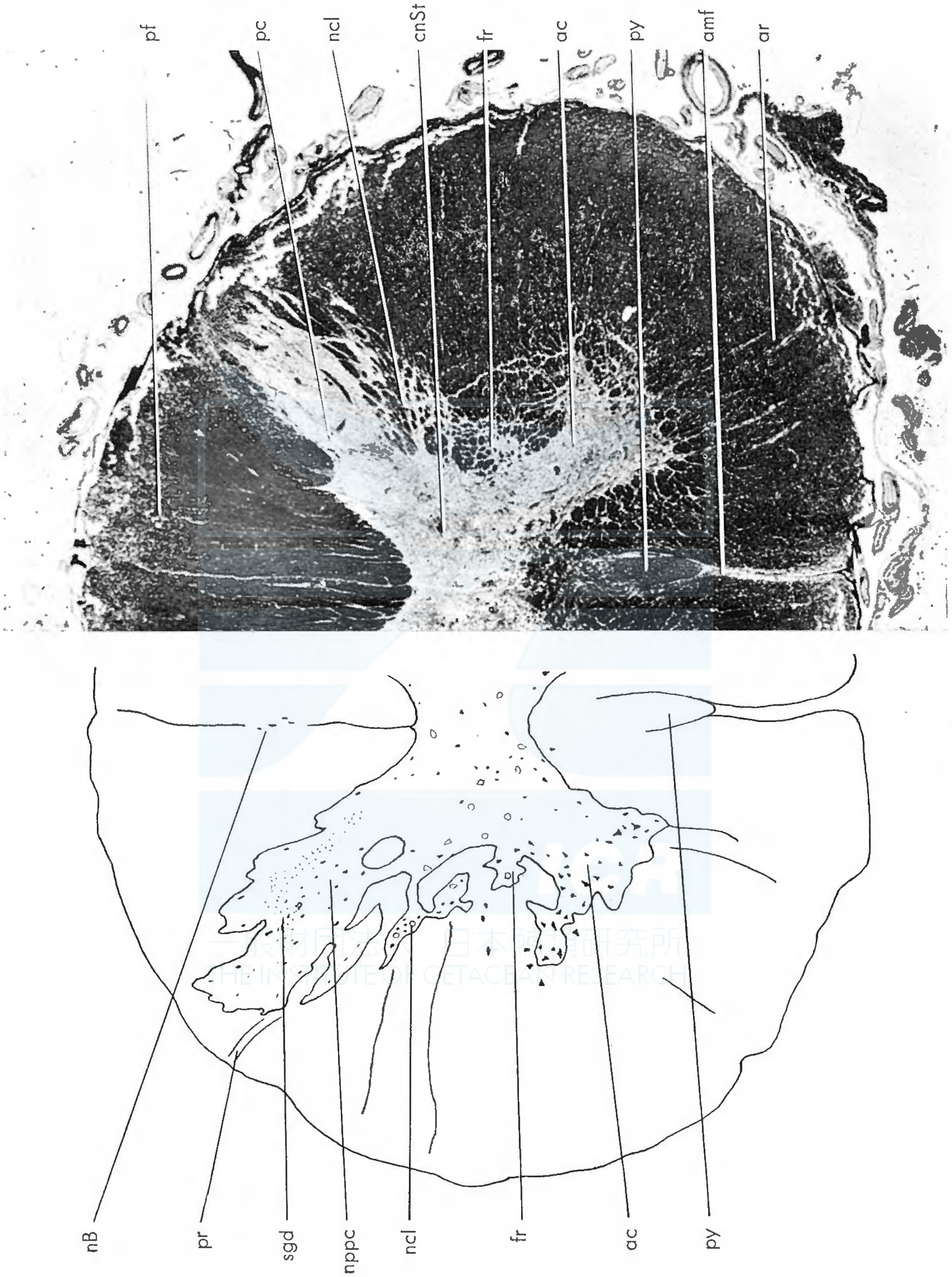

Fig. 3. 1st cervical cord (×10)

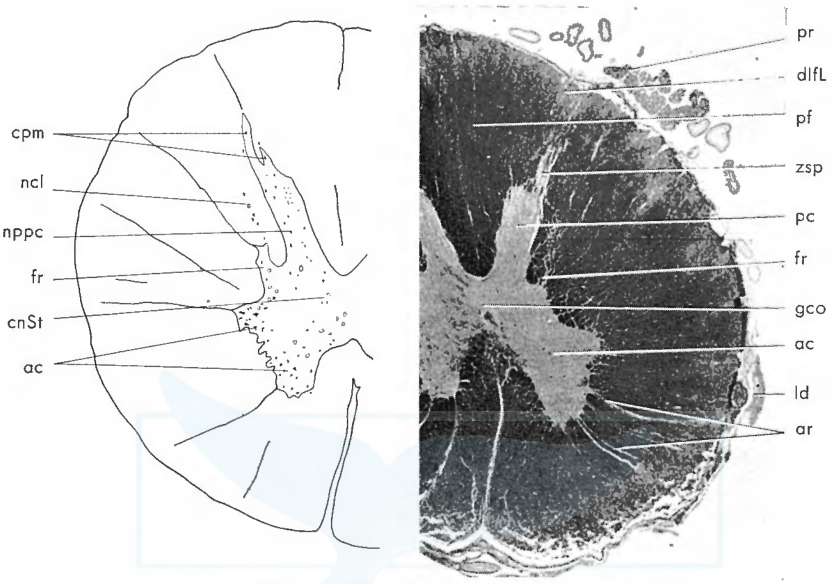

Fig. 4. 2nd cervical cord (×5)

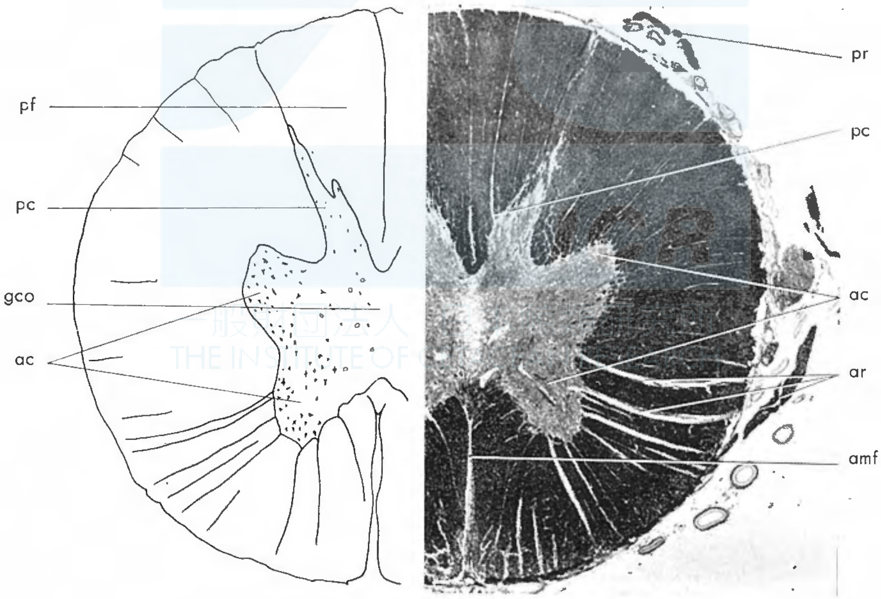

Fig. 5. 5th cervical cord (×5)

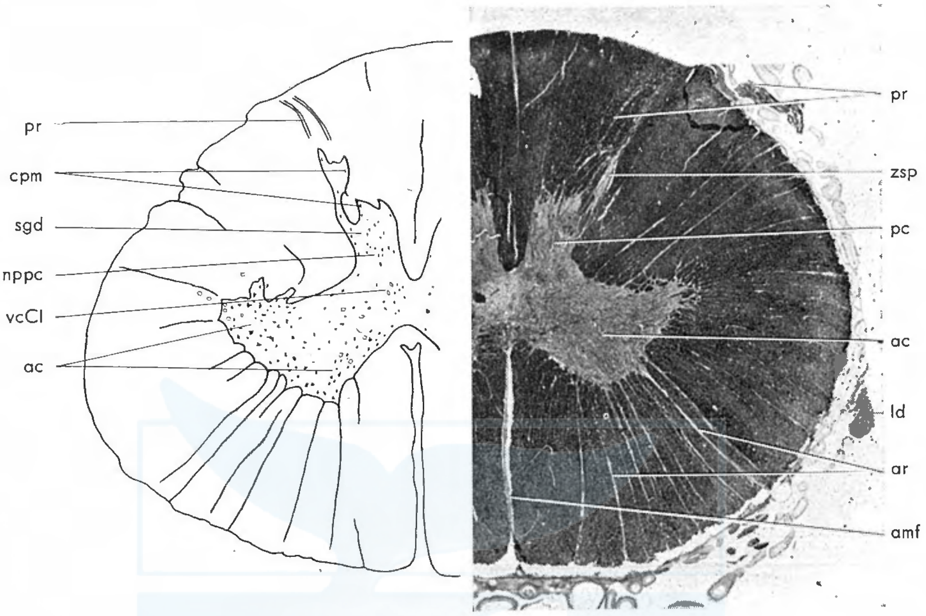

Fig. 6. 8th cervical cord (×5)

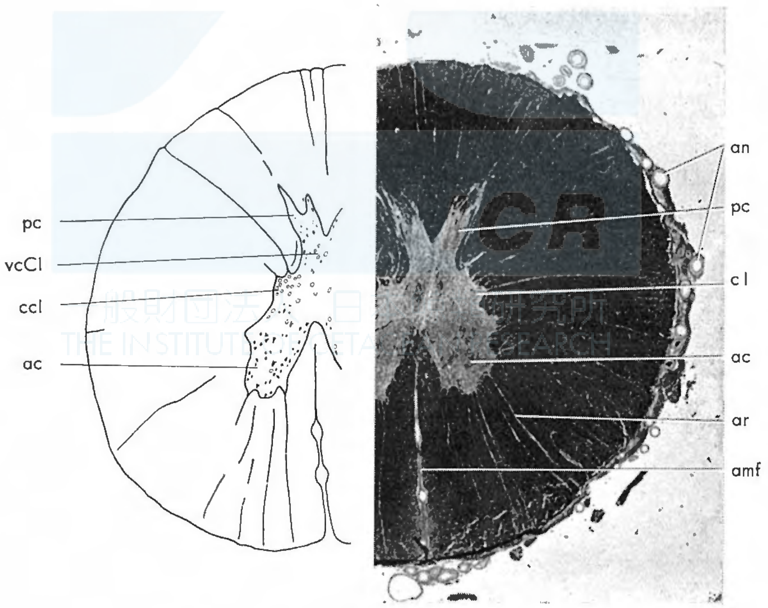

Fig. 7. 5th thoracic cord (×5)

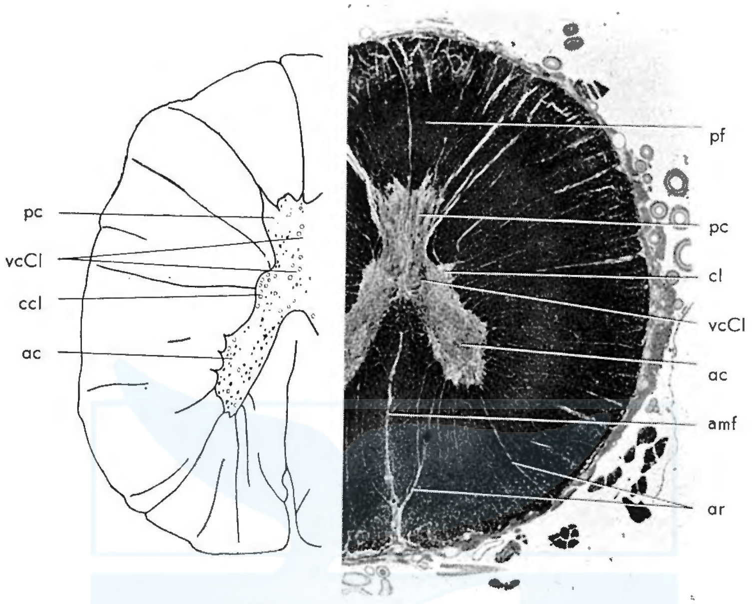

Fig. 8. 10th thoracic cord (×5)

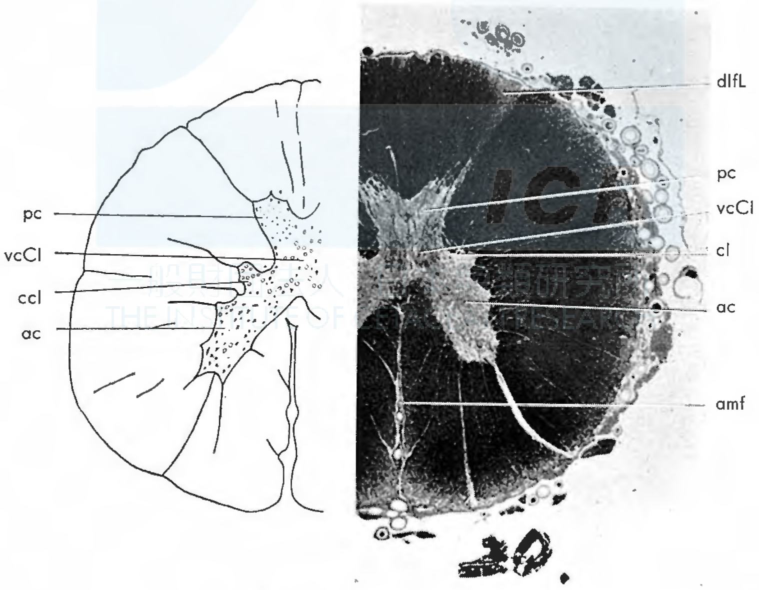

Fig. 9. 14th thoracic cord (×5)

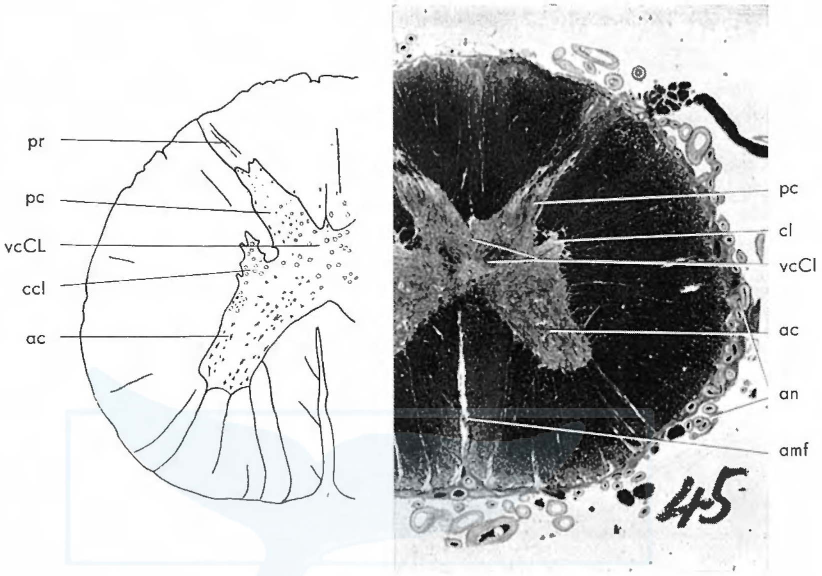

Fig. 10. 3rd lumbal cord (×5)

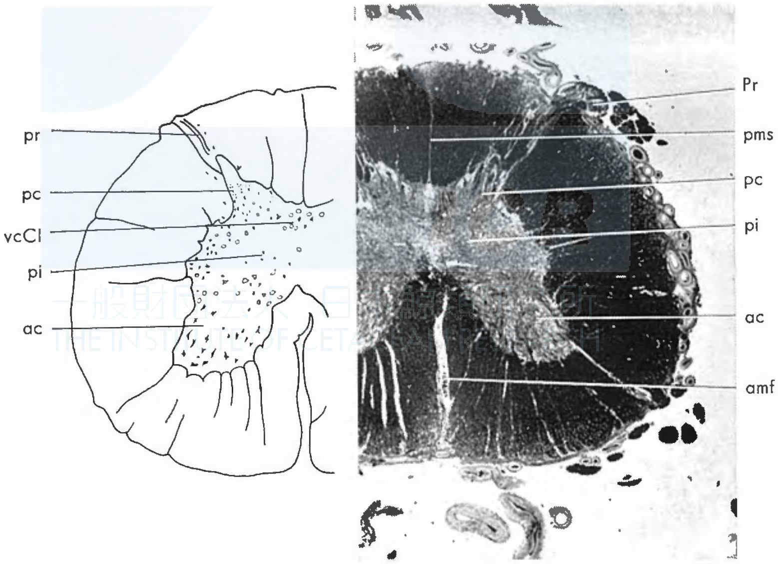

Fig. 11. 7th lumbal cord (×5)

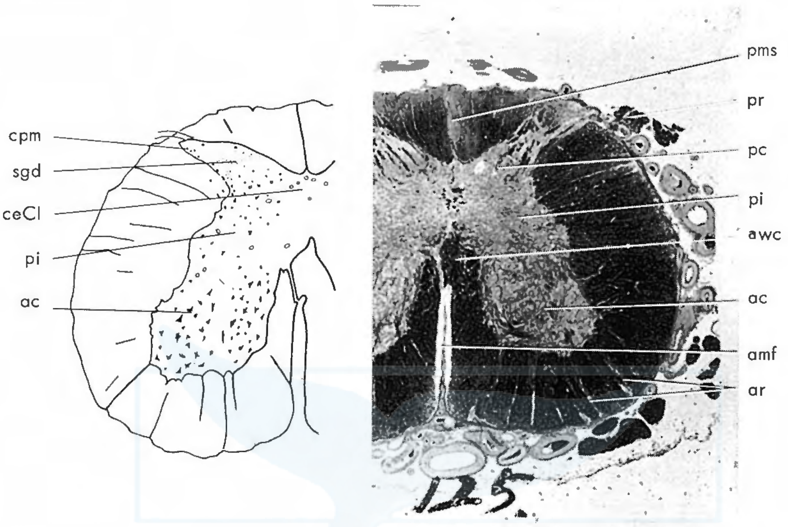

Fig. 12. 1st coccygeal cord (×5)

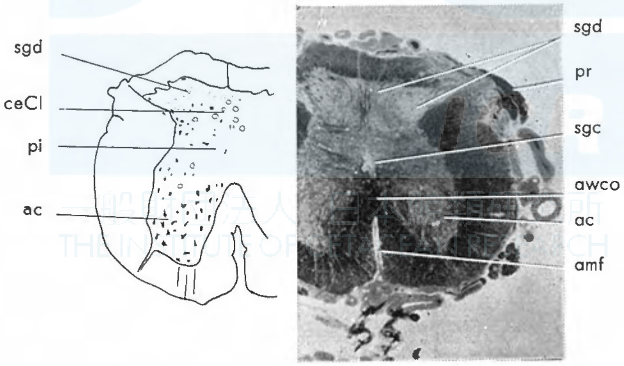

Fig. 13. 5th coccygeal cord (×5)

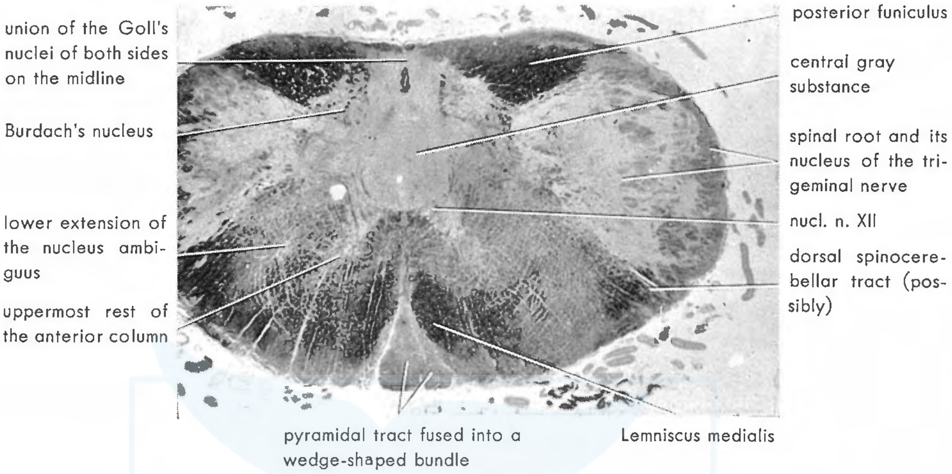

Fig. 14. Lower level of the medulla oblongata

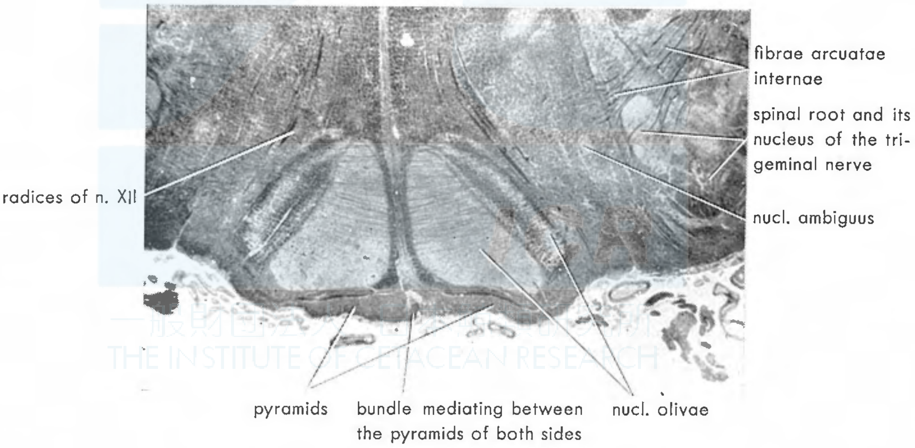

Fig. 15. Upper level of the medulla oblongata