

ANATOMICAL STUDIES ON THE CELL COLUMN LOCATED CLOSELY MEDIAL TO THE NUCLEUS OF THE SPINAL ROOT OF THE TRIGEMINAL NERVE IN THE SPERM AND THE PYGMY SPERM WHALES

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ABSTRACT

A specific cell column was examined anatomically, which was located closely medial to the nucleus of the spinal root of the trigeminal nerve of the medulla oblongata in two sperm whales and a pygmy sperm whale.

This cell column was observed extending at the level from the obex to the uppermost medulla in the sperm whale and at the level of the middle one third of the medulla oblongata in the pygmy sperm whale.

After the precise comparative anatomical and histological investigations, the author has come to the conclusion that the cell column is thought to be the structure corresponding to the lateral cervical nucleus which has highly developed in the level of the medulla oblongata.

INTRODUCTION

In the previous report (1977) of a noteworthy cell group located closely medial to the nucleus of the spinal root of the trigeminal nerve in the sperm whale, the author pointed out the high possibility that the cell group might belong to the spino-bulbo-thalamic relay system because of the striking similarity between the characteristics of the cell group and those of the lateral cervical nucleus.

While Matsumoto (1953) described a specific cell group situated closely medial to the nucleus of the spinal root of the trigeminal nerve in the pygmy sperm whale. He thought the cell group might belong to the sensory trigeminal nucleus because of the partial continuance of the gray substance at the oral level of the cell group to that of the spinal trigeminal nucleus.

In this research, the author investigated comparative anatomically and histologically the specimens of two sperm whales and a pygmy sperm whale, and found out that the cell group Matsumoto described in the pygmy sperm whale showed just the same characteristics as those of the cell group reported by the author in the sperm whales.

MATERIALS AND METHODS

Two adult sperm whales (*Physeter catodon* Linnaeus) were parts of those which had been collected by Dr T. Kojima when he was on a whaling expedition in the

Antarctic Ocean in 1949–50. The first sperm specimen was the portion covering almost full length of the medulla oblongata and the first cervical cord, and the second sperm was the part, extending from the level 10 mm above the obex to that part which included the first cervical cord. Both materials, after having been preserved in formalin, cut off to meet the purpose, and refixed in Müller's solution in 37°C for 2 to 3 weeks and mounted in celloidin through the usual manner. Serial sections of 30 to 45 μm in thickness, along the transverse plane for the first sperm, and the horizontal plane for the second sperm, were made. Each 5th sections (the first and sixth and so forth with the last order of each figure being 1 and 6)

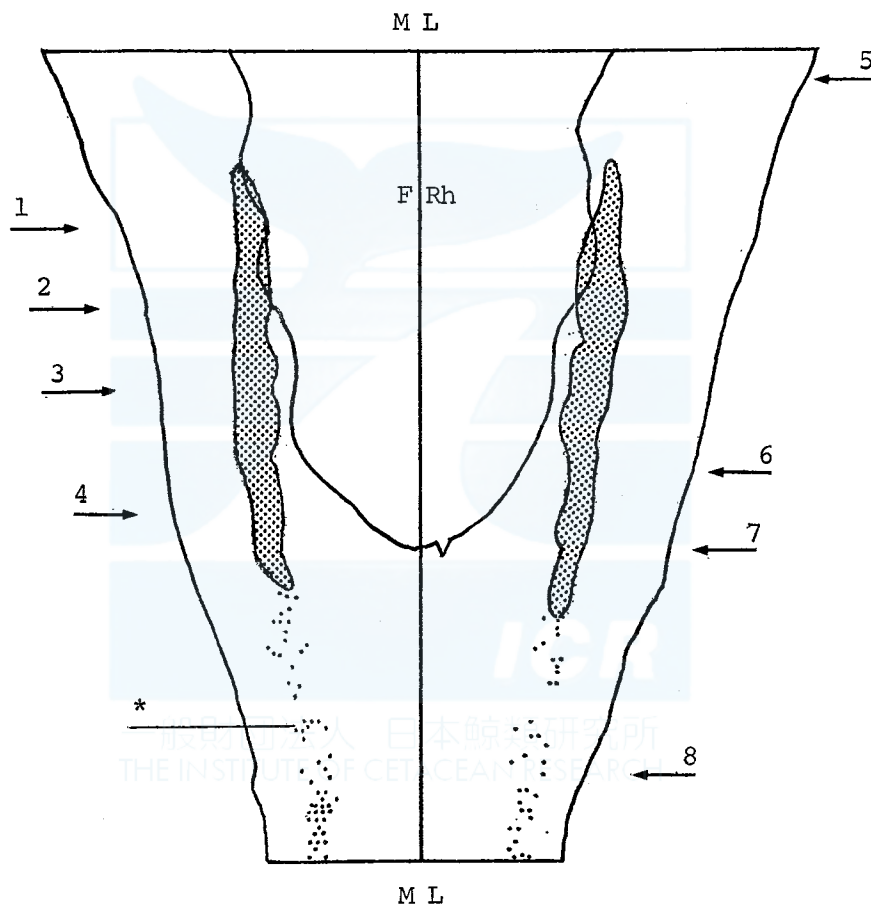


Fig. 1. Approximate location and size of the cell column in question projected from transverse sections on the horizontal plane (dorsal view) in the 1st sperm whale, Klüver-Barrera, $\times 3$, Arrows show levels: 1=Plate 1, Fig. 1, 2=Plate 1, Fig. 2, 3=Plate 2, Fig. 3, 4=Plate 2, Fig. 4, 5=cranial end of the nucleus of the posterior funiculi, 6=caudal end of the inferior olive, 7=level of the obex, 8=cranial limit of the dorsal roots. *: Cranial extension of the lateral cervical nucleus. ML: Midline, FRh: Fossa rhomboidea.

were stained by the Klüver-Barrera's method and each 10 sections (10th, 20th, 30th—etc.) were treated by the Weigert-Pal's or Kultschitzky's method for myelin staining. Silver impregnation method was also applied sporadically on some sections according to needs.

The pygmy sperm (*Kogia breviceps* Blainville) whale specimen was a case which had been collected by Dr T. Ogawa in 1937 at Shiogama, and the whole brain stem was treated into the serial section preparates stained by the Pal carmin method at the Brain Research Institute of the University of Tokyo.

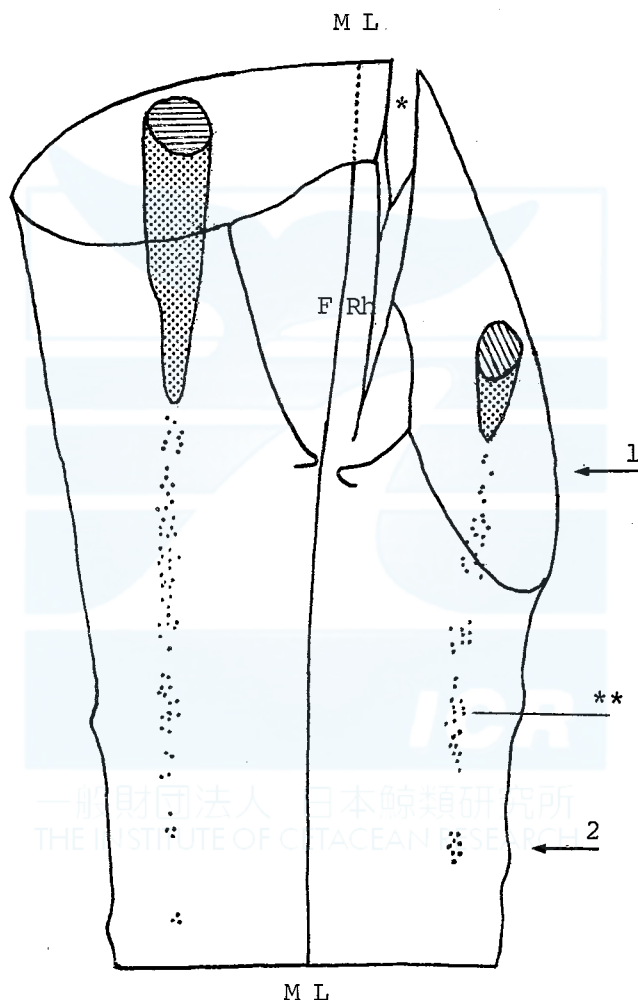


Fig. 2. Approximate location and size of the cell column in question superimposed from horizontal sections on the horizontal plane (dorsal view) in the 2nd sperm whale, Klüver-Barrera, $\times 4$, Arrows show levels: 1=level of the obex, 2=cranial limit of the dorsal roots. *: Artificial cleft, **: Cranial extension of the lateral cervical nucleus, ML: Midline, FRh: Fossa rhomboidea.

RESULTS

In the sperm whales, the cell group in question was found as an evident cell column extending longitudinally from the level of the obex to the uppermost medulla and located closely medial to the nucleus of the spinal root of the trigeminal nerve (Plate 1 and 2).

This cell column was surrounded by the coarse myelinated fibers of the lateral funiculus and seemed oval, fusiform or club shape in appearance at the transverse sections, and measured 4.0–3.2 mm in dorso-ventral direction, 1.5–1.2 mm in width at the midmost level of the column, and extended 21 mm on the left side and 23 mm on the right side in rostrocaudal direction (Figs 1 and 2).

Inside the cell column, it was filled by rather dense net of fine myelinated fibers, and some of small bundles of coarse fibers were seen penetrating longitudinally through the gray substance of the column. Such penetrating fiber bundles were observed numerous in the caudal levels and decreased in number gradually in the higher levels of the column (Plates 1, 2 and 5, Fig. 9).

Nerve cells contained in the column were thought to be classified in two types; one was quite numerous and middle sized, somewhat rounded polygonal or sometimes spindle shaped, measured 60–40 μm in long diameter and 40–20 μm in short one, enclosed fine Nissl granules and stained in light colour, the other one was less in number and a little smaller in size, measured 50–30 μm in long diameter and 25–18 μm in short one, triangle or multipolar in shape, usually stained darkly. These cells were disseminated almost evenly in the cell column and they scarcely made clusters or groups of cells inside the gray substance of the column (Plate 6, Fig. 11).

These structures noted above were quite characteristic to the cell column in question, and made it easy to discriminate from certain other structures in the neighbourhood, *i.e.* nucleus of the spinal root of the trigeminal nerve, nucleus ambiguus, nucleus reticularis lateralis etc. (Plates 1, 2, 5 and 6, Figs 11–14).

At the level near the rostral end of the column, although the gray substance of the column was observed contacting partly with that of the nucleus of the spinal root of the trigeminal nerve (Plate 1, Fig. 1), identification of both structures was easily recognized as the characteristics of the nerve cells were different from each other (Plate 6, Figs 11 and 12).

In the sperm whales, a small lateral cervical nucleus was able to recognize at the uppermost cervical segment, though less distinct. This nucleus, slender and reticular in appearance, was observed continuous farther cranialwards to the medulla oblongata and finally reaching and fused with the cell column in question at the level of the obex (Figs 1 and 2).

In the pygmy sperm whale, the cell group Matsumoto described was observed as a conspicuous cell column extending longitudinally at the level of the middle one third of the medulla oblongata and located closely medial to the nucleus of the spinal root of the trigeminal nerve (Plates 3 and 4).

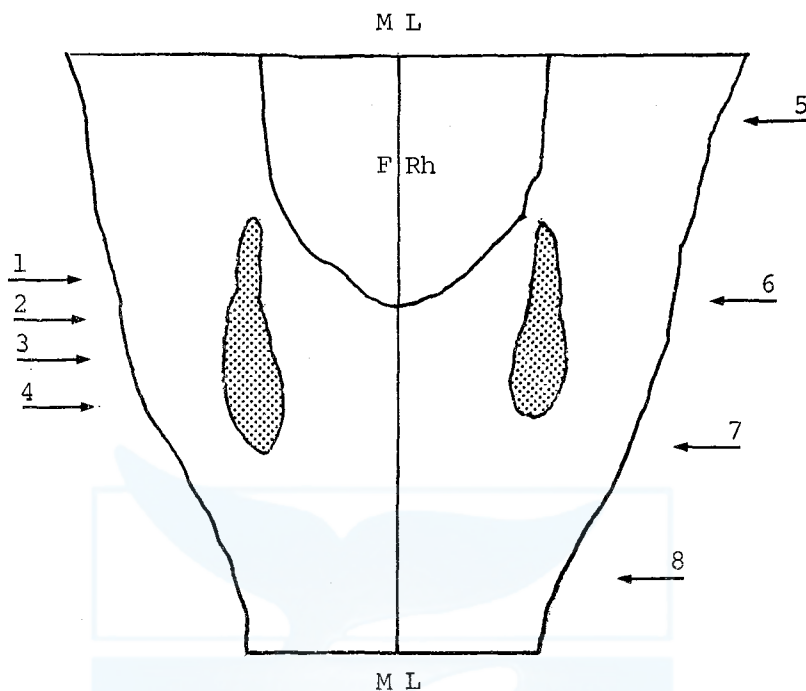


Fig. 3. Approximate location and size of the cell column in question projected from transverse sections on the horizontal plane (dorsal view) in the pygmy sperm whale, Pal carmin, $\times 4$, Arrows show levels: 1=Plate 3, Fig. 5, 2=Plate 3, Fig. 6, 3=Plate 4, Fig. 7, 4=Plate 4, Fig. 8, 5=caudal end of the lateral recessus, 6=level of the obex, 7=caudal end of the inferior olive 8=rostral limit of the dorsal roots. ML: Midline, FRh: Fossa rhomboidea.

This cell column was surrounded by the coarse myelinated fibers of the lateral funiculus and seemed oval, fusiform or club shape in appearance at the transverse sections, and measured 4.2–3.8 mm in dorso-ventral direction, 1.3–1.0 mm in width at the level of the obex, and extended 8.8 mm on the left side and 7.3 mm on the right side in rostro-caudal direction (Fig. 3).

Inside the cell column, it was filled by rather dense net of fine myelinated fibers, and some of small bundles of coarse fibers were seen penetrating longitudinally through the gray substance of the column. Such penetrating fiber bundles were observed numerous in the caudal levels and decreased in number gradually in the higher levels of the column (Plates 3 and 4).

Two types of nerve cells were investigated in the column; one was numerous and middle sized, somewhat rounded polygonal or sometimes spindle shaped, measured 40–30 μm in long diameter and 30–20 μm in short one, stained in light colour, the other one was less in number and a little smaller in size, measured 30–20 μm in long diameter and 25–15 μm in short one, triangle or multipolar in shape, usually stained darkly by the carmin. These cells were disseminated almost evenly in the cell column and they scarcely made clusters or groups of cells inside the

gray substance of the column.

These structures noted above were quite characteristic to the cell column in question in the pygmy sperm whale, and made it easy to discriminate from certain other structures in the neighbourhood, *i.e.* nucleus of the spinal root of the trigeminal nerve, nucleus ambiguus, nucleus reticularis lateralis etc. (Plates 3 and 4).

At the level near the rostral end of the column, although the gray substance of the column was observed contacting partly with that of the nucleus of the spinal root of the trigeminal nerve, identification of both structures was easily recognized as the characteristics of the nerve cells were different from each other.

In the pygmy sperm whale, the lateral cervical nucleus was hardly recognized at the uppermost cervical segment or the lower medulla in the Pal carmin stained sections.

DISCUSSION

Dr Matsumoto was the earliest researcher who described the cell column in question. In his anatomical studies on the brain stem of the pygmy sperm whale (1953), he made precise and accurate descriptions on the cell column. Although he paid attention to the fact that the cells were observed disseminating in the cell column, he thought this column might belong to the sensory trigeminal nucleus because of the partial continuance of the gray substance at the oral level of the cell column to that of the nucleus of the spinal root of the trigeminal nerve. He also emphasized that the cell column is a quite exceptional structure to the pygmy sperm whale, and denied such a structure in the dolphin, Sei and Beaked whales.

In the previous report (1977), present author described a noteworthy cell group observed at the level from the obex to the uppermost medulla and located closely medial to the nucleus of the spinal root of the trigeminal nerve, and pointed out the high possibility that the cell group might belong to the spino-bulbo-thalamic relay system because of the striking similarity between the characteristics of the cell group and those of the lateral cervical nucleus.

In this research, specimens of the sperm whales were examined carefully, and further, with the permission of the Institute of the Brain Research, University of Tokyo, the serial section preparate of the specimen of the pygmy sperm whale was investigated, which was the case Dr Matsumoto examined before. After the precise comparative anatomical and histological investigations, the author found out that the noteworthy cell group in question in the sperm whales showed quite the same characteristics as those of the specific cell group in the pygmy sperm whale described by Dr Matsumoto, with the exception of the levels of location of these cell groups; the former was higher in the medulla and the latter was lower and at the level almost middle one third of the medulla oblongata.

In the previous study on the comparative anatomy of the lateral cervical nucleus (1965), present author reported that the nucleus was observed at the uppermost cervical segment in the common dolphin (*Delphinus delphis* Linnaeus), and

pointed out an interesting fact that the nucleus was extended farther cranialwards to the lower medulla up to the level of the *obex* as the gray substances arranged longitudinally in stepping stone pattern. From the findings of the present investigation, the cell column in question was thought to be locating on the upwards elongated line of the lateral cervical nucleus, and moreover, in the sperm whales, the lateral cervical nucleus was found also in the uppermost cervical segment, though less distinct, and the nucleus was observed continuous farther cranialwards to the medulla oblongata, as islands-like cell collections in appearance, and finally reaching and fused with the cell column in question at the level of the *obex*.

According to these findings noted above, the cell column in question, found in the sperm whales and a pygmy sperm whale, was considered to be the structure corresponding to the cell group highly developed in the level of the medulla oblongata showing just the same characteristics as those of the lateral cervical nucleus.

Matsumoto (1953) noted certain degree of asymmetrical development of the cell column in question; the left side column being larger than the right side one, and he thought it might be some relation with the asymmetrical structure of the nasal meatus in the pygmy sperm whale, without an explanation of the reason on this fact. From the present examination, Matsumoto's finding about the asymmetrical development of the column was reconfirmed distinctly. Ogawa (1949, a and b), in the pygmy sperm whale, described the striking development of the facial nucleus of the right side than that of the left side, and suggested that there should be certain relation with the asymmetrical structure of the nasal meatus in this whale. Hosokawa (1950) reported some asymmetrical structure of the larynx in the sperm whale. In spite of the extraordinarily asymmetrical nasal passage, after the present examination, as far as the extent of the gray substance is concerned, the cell column in question in the sperm whale was hardly recognized the significant asymmetry. At the present stage of the research, it is thought to be difficult to say something on the relation between the difference of the largeness of the cell column in each side and the asymmetrical structures of the nasal meatus or the larynx in these whales.

Matsumoto (1953) stated that the partial continuance of the gray substance at the oral level of the cell column in question with that of the nucleus of the spinal root of the trigeminal nerve, and accordingly he thought that the cell column might belong to the sensory trigeminal nucleus. In the present examination of the specimen of the pygmy sperm whale, the characteristics of the cell column in question was observed different from those of the nucleus of the spinal root of the trigeminal nerve, and the situation was interpreted as the gray substance of the cell column being in contact with that of the trigeminal nucleus. Concerning this matter, in this research, the structural difference of both gray substances was reconfirmed clearly in the first specimen of the sperm whale, after the examination of the additional sections treated by the Klüver-Barrera's and silver impregnation methods.

In the cat or in certain other mammals, it is well known that the lateral cervical nucleus receives afferent fibers originating from the lower levels (Brodal and

Rexed 1953, Morin 1955, Ha and Liu 1966, Craig 1978, etc.). Craig (1978) reported medullary input of the lateral cervical nucleus originating from the nucleus of the posterior funiculi and the nucleus of the spinal root of the trigeminal nerve. Similar relationships, referring the findings of the present examination, could be suggested also in the whales, such as the possibility that a certain amount of fibers of the lateral funiculus might terminate in the cell column.

Although holding a different opinion from that of Dr Matsumoto as to the meaning of the cell column in question, the present author should like to make a proposal, in memory of his first description, to name the cell column as "the nucleus of Matsumoto", at least for some time until it receives an adequate nomenclature in the future.

SUMMARY

A specific cell column was examined anatomically, which was located closely medial to the nucleus of the spinal root of the trigeminal nerve of the medulla oblongata in two adult sperm whales and an adult pygmy sperm whale.

This cell column was observed extending at the level from the obex to the uppermost medulla in the sperm whales and at the level of the middle one third of the medulla oblongata in the pygmy sperm whale.

The cell column was surrounded by the coarse myelinated fibers of the lateral funiculus and bordered in an oval, fusiform or club shape in appearance at the transverse sections and seemed considerably outstanding from the neighbouring structures.

Inside the cell column, two types of nerve cells were contained; one was middle sized and polygonal, somewhat rounded or spindle shaped, palely stained, and the other one was a little smaller in size, triangle or multipolar, stained darkly. The characteristics of these cells contained seemed very similar to those of the lateral cervical nucleus.

This cell column was thought to be located on the upwards elongated line of the lateral cervical nucleus and moreover, in the sperm whales, the direct continuance was recognized between the lateral cervical nucleus and the cell column at the level of the obex.

According to these findings noted above, the cell column in question was considered to be the structure corresponding to cell group highly developed in the level of the medulla oblongata showing just the same characteristics as those of the lateral cervical nucleus.

Although none of the definite finding about the fiber connection of the cell column was obtained, at the present stage of research, it seems there is a high possibility that the cell column belongs to the spino-bulbo-thalamic relay system.

ACKNOWLEDGEMENTS

I should like to express my sincere gratitude to Dr T. Kojima, Professor of Anatomy, Nihon University School of Medicine, for his kind offering to me the

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EXPLANATION OF PLATES I—VI

PLATES I AND II

Figs 1 and 2 and Figs 3 and 4: Transverse sections of the medulla oblongata in the 1st Sperm, arranged from cranial to caudal, Kultschitzky, $\times 6$.

PLATES III AND IV

Figs 5 and 6 and Figs 7 and 8: Transverse sections of the medulla oblongata in the Pygmy sperm, arranged from cranial to caudal, Pal carmin, $\times 8$.

PLATE V

Fig. 9: The same section as Plate I, Fig. 2, a little enlarged ($\times 10$), left side; note the location and shape of the cell column in question and neighbouring structures.

Fig. 10: The section very near to that of Fig. 9, $\times 20$, silver impregnation; note the structural difference of the cell column and the neighbouring nuclei.

PLATE VI

Nerve cells in high magnification ($\times 100$), Klüver-Barrera.

Fig. 11: The cell column in question.

Fig. 12: Nucleus of the spinal root of the trigeminal nerve.

Fig. 13: Nucleus reticularis lateralis.

Fig. 14: Nucleus ambiguus.

ABBREVIATIONS IN PLATES

| | |
|------|--|
| FL | Funiculus lateralis |
| FLM | Fasciculus longitudinalis medialis |
| FP | Funiculus posterior |
| NA | Nucleus ambiguus |
| NFP | Nucleus funiculi posterioris |
| NQ | The cell column in question |
| NRL | Nucleus reticularis lateralis |
| NSV | Nucleus tractus spinalis nervi trigemini |
| NXII | Nucleus nervi hypoglossi |
| OL | Nucleus olivaris inferior |
| RX | Radix nervi vagi |
| RXII | Radix nervi hypoglossi |
| S | Fasciculus solitarius |
| TSV | Tractus spinalis nervi trigemini |

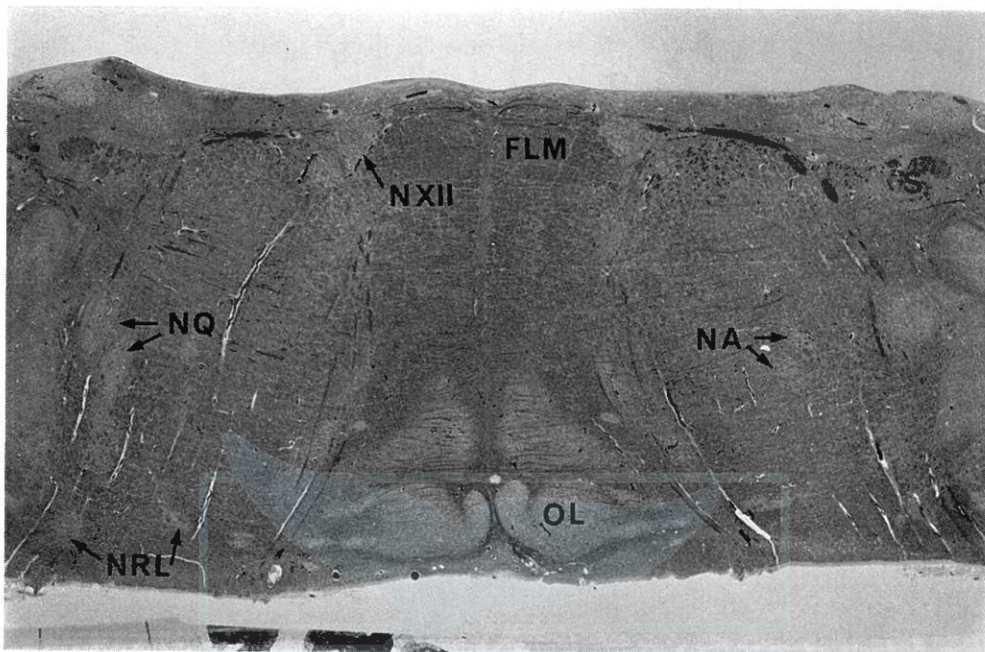


Fig. 1.

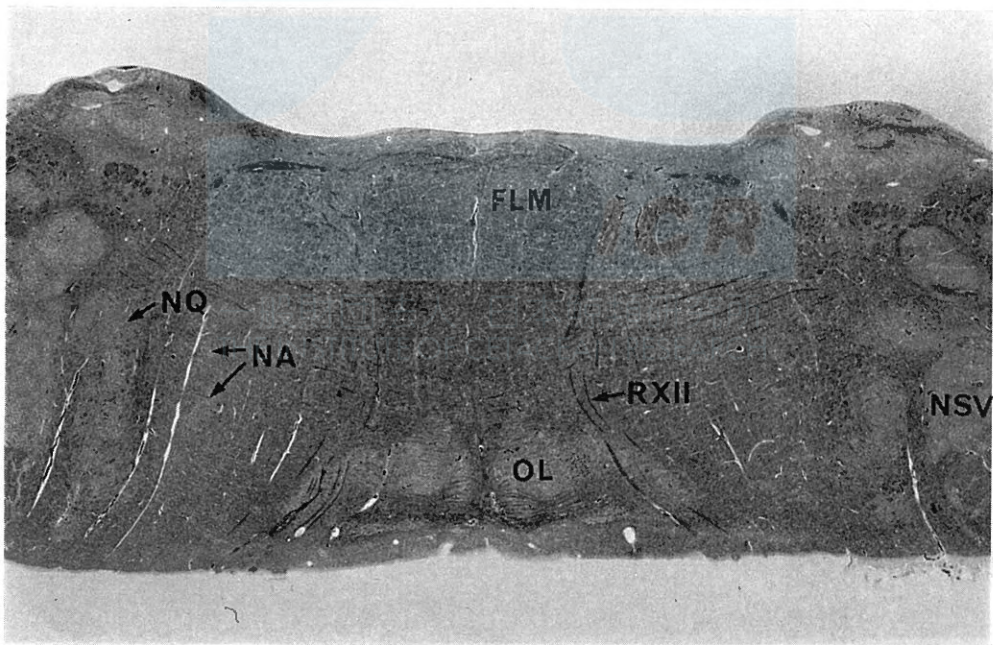


Fig. 2.

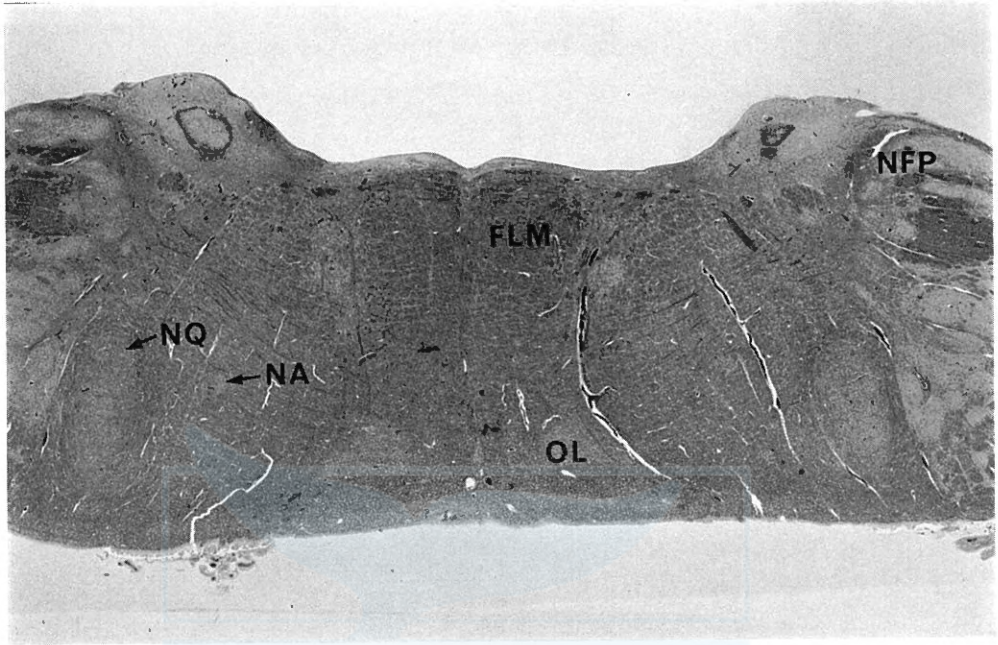


Fig. 3.

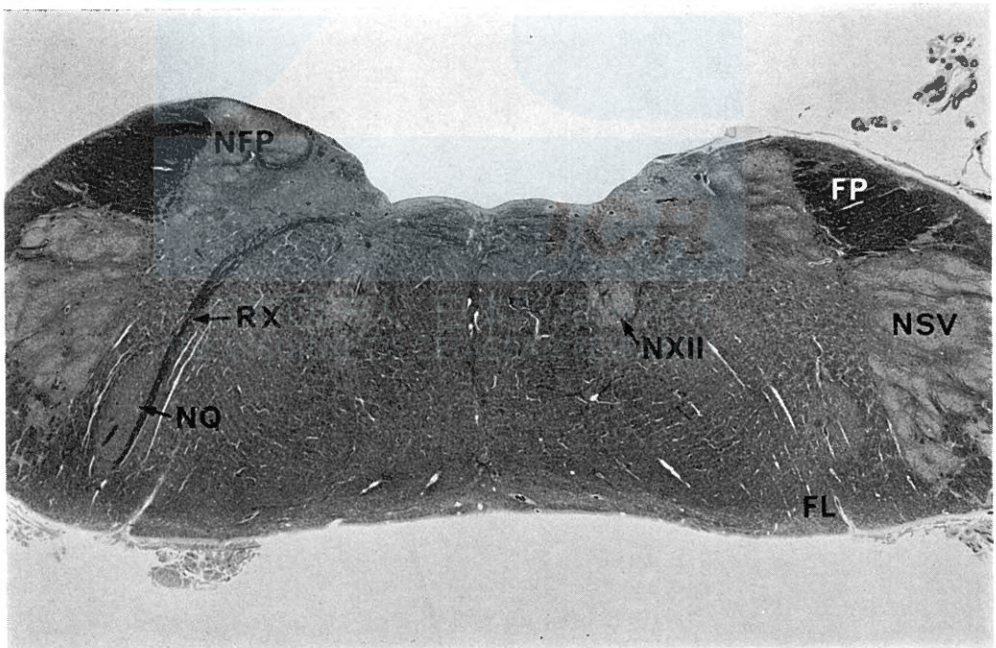


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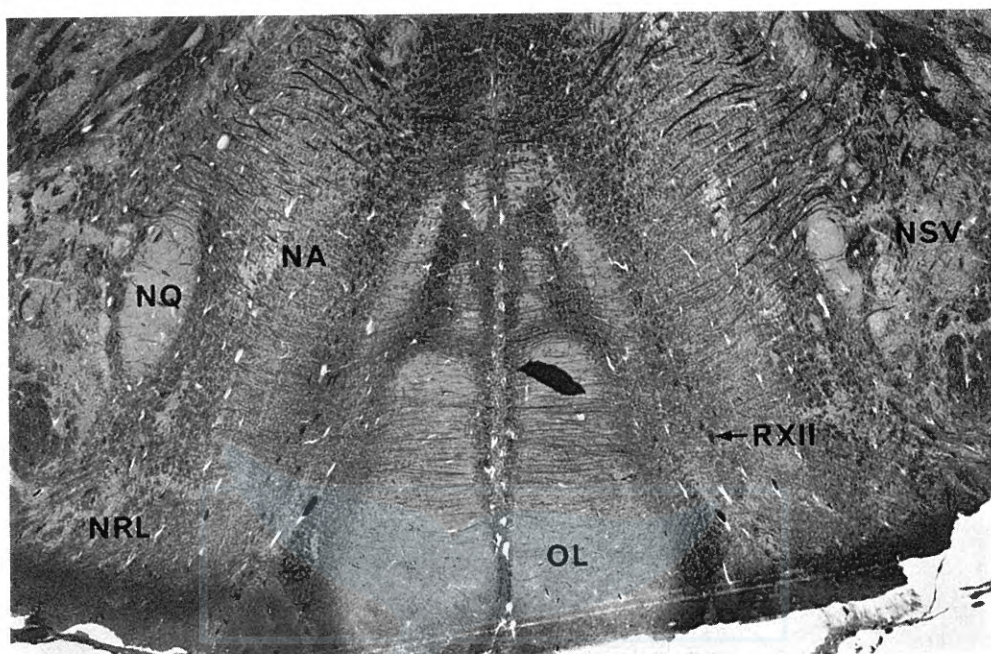


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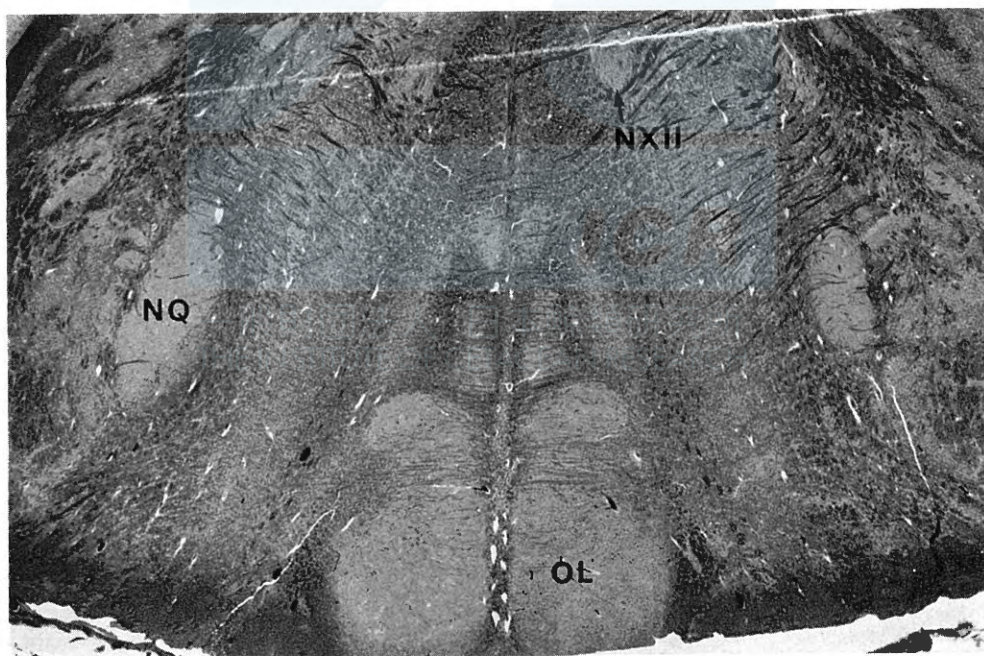


Fig. 6.

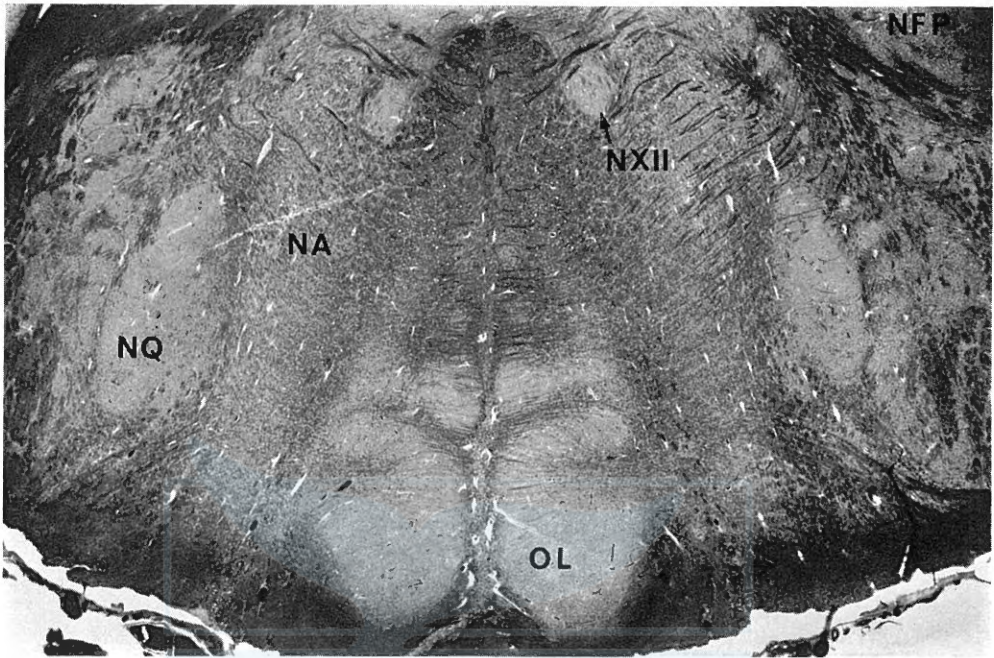


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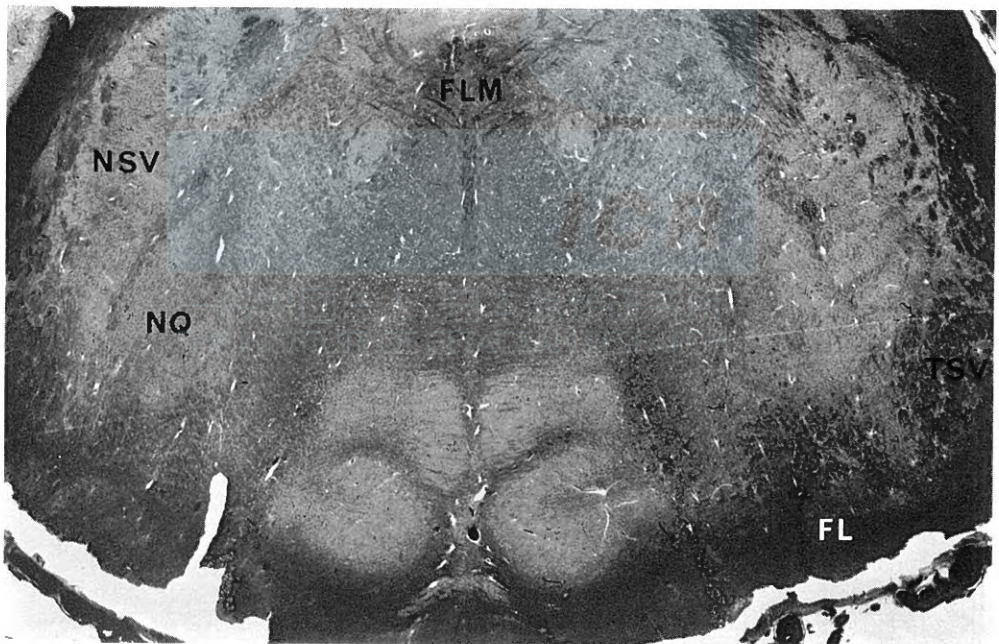


Fig. 8.

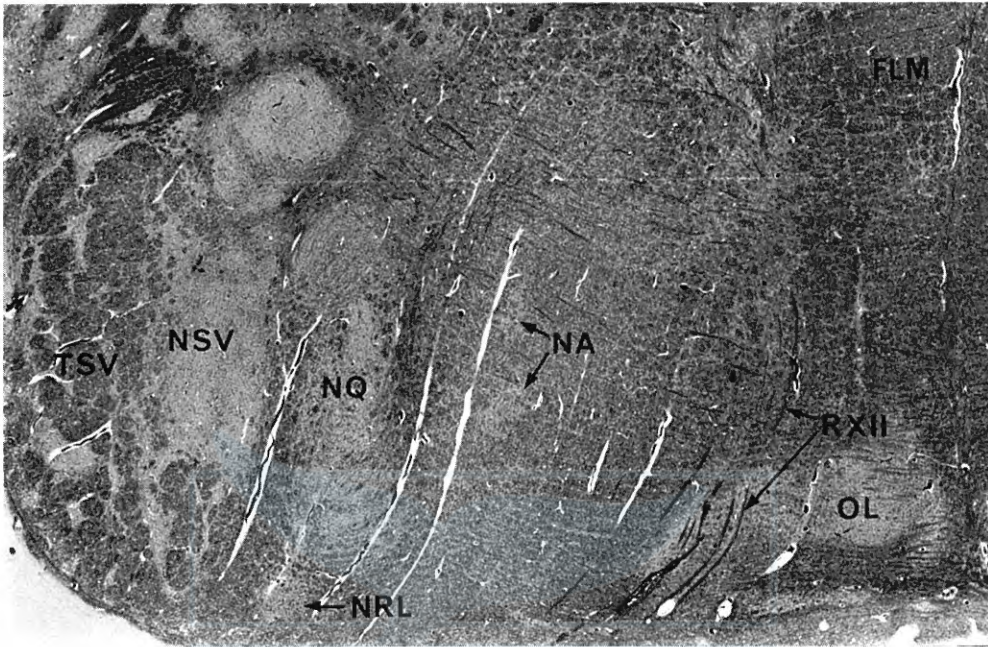


Fig. 9.

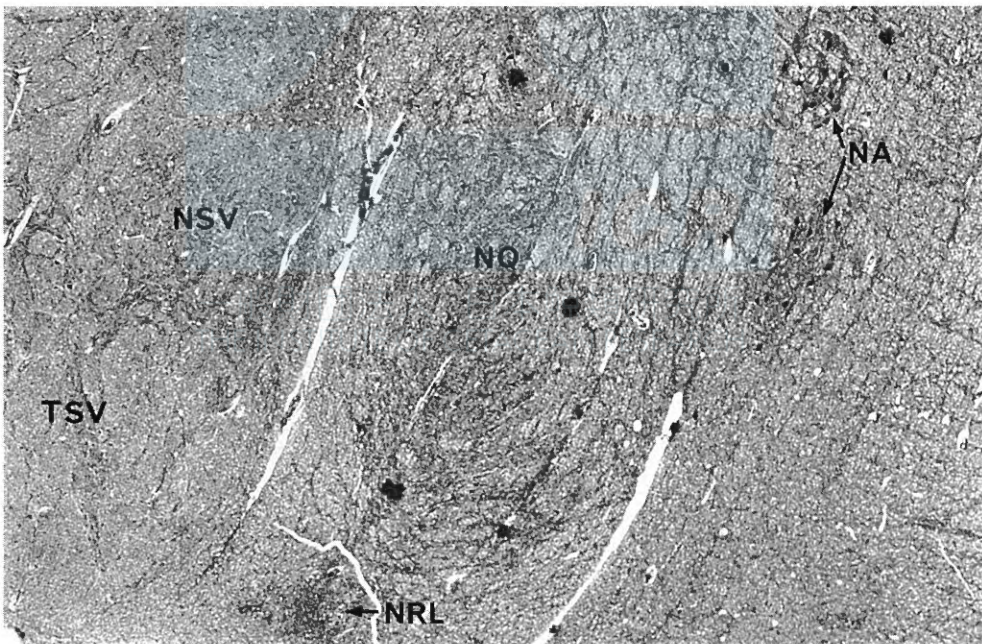


Fig. 10.

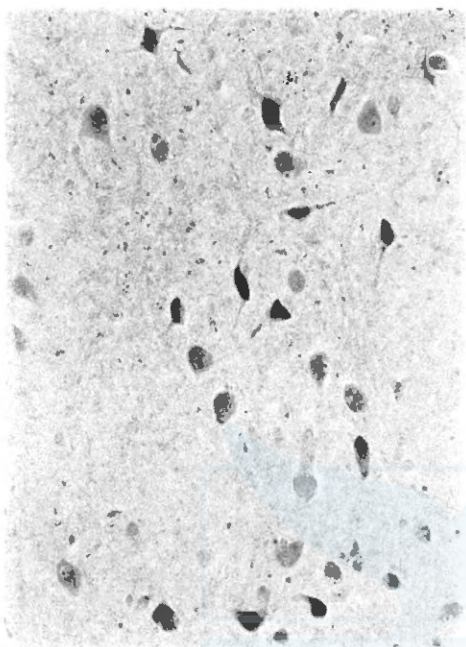


Fig. 11.

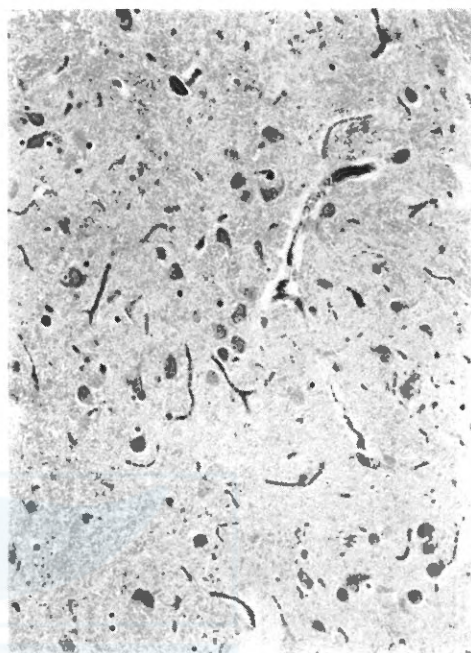


Fig. 12.

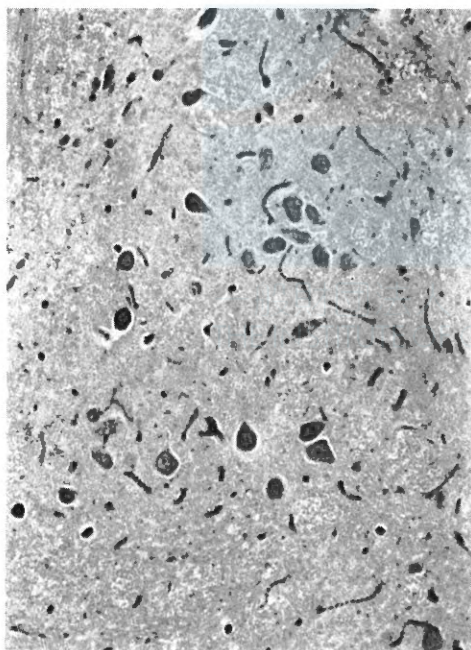


Fig. 13.

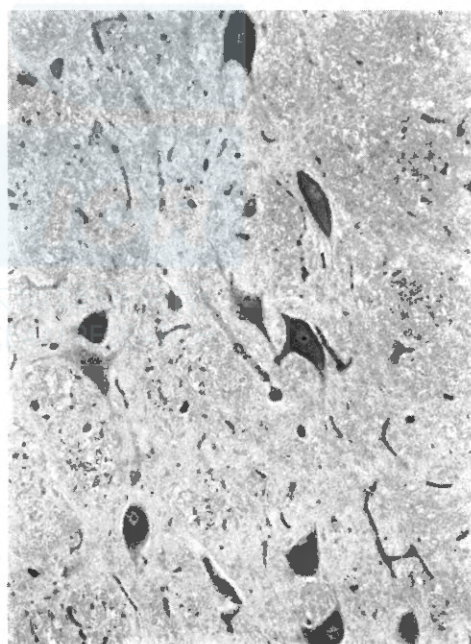


Fig. 14.