Suggested title for opus:

"An Atlas of the Brain Stem of the Cat."

A Stereotaxic Atlas of the Brain Stem of the Cat

by

Gordon Mathieson, M.B., Ch.B.

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Department of Neurology and Neurosurgery
McGill University, Montreal.

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I INTRODUCTION

The object of this work is to provide a morphological guide for the conduct and analysis of experiments carried out on the brain stem of the cat. In particular, the work contains a series of photomicrographic illustrations of the cat brain stem upon which are delineated the major nuclei as distinguished by the classical cytoarchitectural criteria and a set of stereotaxic coordinates referrable to modern adaptations of the Horsley-Clarke stereotaxic instrument.

This atlas may be used in two mutually complementary ways. In the first place, it provides stereotaxic coordinates to guide the experimenter in placing electrodes or other experimental devices in the nuclei or tracts with which he is concerned. Secondly, the series of plates may be used as an aid in the identification of structures observed in the sections from experimental animals. In this way they may serve as a ready source of reference to the cytoarchitecture of the cat brain stem. To enhance the value of the atlas in this respect, descriptions of individual nuclei have been added.

The choice of the cat as the species for study was determined by its frequent use in neurophysiological experiments and the present lack of a detailed guide to the microanatomy of its brain stem.

This atlas breaks with tradition in one respect. The plane of section chosen for study and illustration is not, as is usual, a coronal one at right angles to the Horsley-Clarke base line, but is angled at 45^{o} with the superior margin of the coronal plane tilted caudally. This modification, suggested by Dr. H. Jasper, is based on two considerations: the plane chosen lies approximately parallel with the inclination of the tentorium, a bony structure in the cat, and thus facilitates access to upper brain stem structures which would otherwise be "hidden" under the tentorium; and secondly, this tilted plane is more nearly perpendicular to the long axis of the lower brain stem, thus providing a more convenient angle of entry for electrodes and more conventionally transverse sections of the brain stem at this level (see fig. 2). This novel plane of section carries with it two disadvantages: first, it complicates calculations of horizontal planes, a matter which will be dealt with in detail under methods in chapter III; and second, it produces an unfamiliar obliquity of appearance in the oral sections. This latter objection, however, is one that arises no matter what plane of section is chosen as it follows from the curvature of the cat brain stem, illustrated in fig. 2. The obliquity of the standard frontal planes in relation to the upper midbrain is commentated upon by Jasper and Ajimone-Marsan (1954) in their work on the diencephalon of the cat. The advantages of an oblique plane of illustration were considered to outweigh the disadvantages.

II HISTORICAL REVIEW

The stereotaxic method and the family of instruments which has grown up to serve it, derive from investigations of Sir Victor Horsley and Dr. R.H. Clarke into the connections of of the cerebellum. In 1905 they reported their observations on Marchi preparations of cerebellum, brain stem and spinal cord following localised excisions of cerebellar cortex. Most of their experiments were done on cats. They concluded that no fibres issuing from the cerebellar cortex entered any of the peduncles, but that all passed either to neighbouring folia or to the deep cerebellar nuclei.

The next step in their experimental programme was to make discrete lesions in these deep nuclei. "An essential preliminary, therefore, to further progress was to find some method which would satisfy these conditions, viz., a means of producing lesions of the cerebellar nuclei which should be accurate in position, limited to any desired degree in extent, and involving as little injury as possible to other structures." (Horsley and Clarke, 1908, p. 47). It was to meet these requirements that Clarke devised the method and instrument which, with but little modification, are in use today. It is interesting to observe that, in this 1908 paper, credit for the invention of the technique is explicitly given to Clarke and the instrument referred to as "Clarke's instrument" whereas it has been customary in later years to speak of the Horsley-Clarke stereotaxic in-

strument. A brief account of the method was first published in 1906 (Clarke, R.H., and Horsley, V.), following presentation at a meeting of the British Medical Association in Toronto.

In the early stages of development of this technique, Clarke used as a guide "working 'charts'" which consisted of sections 2 mm. thick cut from the frozen head of an animal of the same species and as nearly as possible of the same size as that to be used in the experiment. These slabs were mounted in glycerine jelly between glass plates. Before cutting, fine ivory rods were inserted in the interaural axis and at the lower orbital margins. These rods appeared in every sagittal section and served as a base line for a calibrated glass plate applied to the surface of the section (Fig. 1). By this means, coordinates could be allocated to such structures as were discernible on naked eye examination.

The next development occurred in 1912 when Clarke and Henderson published a series of plates depicting the head of the cat cut sagittally in the frozen state. In this, the first of several stereotaxic atlases, only major structures could be distinguished, as the preparations were unstained and enlarged only two diameters.

Further work on the method and publication of charts to guide the experimenter was interrupted by the war and by Clarke's difficulty in obtaining the services of a skilled instrument maker, so that it was not until 1920 that Clarke and

Henderson published a further monograph giving a detailed account of stereotaxic technique and incorporating a series of photographs of the head and brain of the rhesus monkey. Again these were unstained, gross preparations.

Developments in neurophysiology made increasingly clear the need for a more detailed display of nervous structures in charts for use with the stereotaxic instrument. In response to this need Ingram, Hannett and Ranson in 1932 published a guide to the topography of the diencephalon of the cat in which the illustrations comprised ten times magnified histological sections of the diencephalon.

The degree of resolution and specificity theoretically possible with the method was thus greatly increased. Further detail of this region was added by Jiminez-Castellanos in 1949. Finally in 1954 Jasper and Ajmone-Marsan published, as a separate monograph, an atlas which included the diencephalon, portions of the rhinencephalon and other adjacent subcortical structures.

The lower brain stem, that is medulla, pons and midbrain, have received far less attention in the way of microanatomical study. It is, of course, included in the classic monograph of Winkler and Potter (1914) but this atlas is not designed for use with the stereotaxic instrument. More recently, in 1943, Marcel Monnier gave a brief account of the topography of the brain stem of the cat illustrated by twenty-one small

scale drawings but these were not related to stereotaxic co-ordinates. The most recent detailed study is that of Elizabeth Taber (1961) who gives a systematic cytoarchitectural account based on the brains of five cats embedded in either paraffin or celloidin. She was not concerned with the requirements of stereo-taxy.

There exists, therefore, a gap in the literature: the aim of the present study is to help, in some small measure, to fill this gap.

III MATERIALS AND METHODS

In the course of this study 31 cats were sacrificed. At the outset of the project, two alternative policies regarding selection of animals were considered. One alternative was to follow a restrictive course, using only animals of one sex within narrowly defined limits of weight and size. This might be expected, a priori, to reduce the degree of variation in size and shape of the brain and skull, and thereby increase the constancy and accuracy of the final Atlas. It would, however, reduce its utility by, theoretically at any rate, excluding from use the many animals lying outside the defined range. The second alternative, then, of picking cats randomly as they became available in the animal house, was followed. In this way the Atlas reflects the cat population available in the animal rooms. The weight and sex of the 13 animals finally used for quantitative study is given in Table 1, at the end of this thesis.

The stereotaxic instrument used throughout was the "Labtronics" model no. 4. Separate carriers were employed for the oblique and horizontal markers to avoid the necessity of recalibration during each experiment and to ensure consistency of angle from animal to animal. The arrangement of these carriers is shown in figs. 3,4 and 5 in which, for clarity, a dried skull has been mounted in the instrument.

The procedure employed was as follows. The cat was weighed and then anaesthetised with intraperitoneal veterinary

Nembutal (pentobarbital sodium, 50 mg. per ml.) in a dosage of 0.75 ml. per Kg. When the anaesthetic had taken effect, the animal was mounted in the stereotaxic instrument, the head and neck cleared of excess fur with animal clippers and the neck dissected to allow cannulation of the carotid arteries. The external jugular veins were then cut and the carotid circulation perfused with 100 ml. of physiological saline on each side. The animal was then carefully alined to ensure that the head, neck and trunk lay in a straight axial line. Each carotid artery was then perfused with 100 ml. of 10% formal saline. The vertebral circulation was not cannulated but there was sufficient cross circulation from the carotid circulation to ensure that excess blood was washed out of all major vessels in relation to posterior fossa structures and to ensure adequate early fixation of these structures. The scalp was then reflected and removed, and suitably placed craniectomies made in the calvarium. At this time, the plane of the upper margin of the foramen magnum was determined.

At this point an explanation will be given of the method of calibration of the instrument and a definition of the planes employed. The oblique frontal plane (usually abbreviated OF plane) is defined as a plane analogous to the coronal plane but tilted so that it slopes downwards and forwards and forms an angle of 45° with the Horsley-Clarke base line. This plane, when it passes through the Horsley-Clarke base line, that is 1 cm. superior to the interaural line is referred to as oblique frontal zero, that is, OF 0. Oblique frontal planes parallel

to this but obtained by moving the main lateral carrier orally through a horizontal distance of 1, 2, 3 or more mm. are referred to as planes OF plus 1, plus 2, plus 3, and so on. Similarly more caudally placed oblique frontal planes are referred to as OF minus 1, minus 2, minus 3 and so on. The illustrations in this Atlas are in these planes and each bears on the right hand side a figure indicating its relationship to the standard oblique plane of reference. Horizontal planes in this Atlas follow the usual Horsley-Clarke convention, that is a plane situated 1 cm. superior to the interaural-interorbital ridge plane and parallel to it is designated as the zero horizontal plane, H 0 for short.

In order to determine the sites of these planes in relation to the series of histological sections cut from each animal brain, six markers were placed in the brain of the animal while the head was still firmly fixed in the stereotaxic instrument. The marking was done immediately after perfusion of the cerebral vascular system with formal saline. It was found by experience that, at this stage, markers could be run into the brain without significant laceration (which occurred if fixation had been allowed to go on a day or two before the markers were put in) yet without danger of the markers sagging or moving within the brain substance as sometimes happened if marking preceded perfusion and the initiation of fixation.

In each animal, six markers were used. A symmetrical pair was placed anteriorly, usually in OF plus 10, and 10 mm. to the right and left of the midline. These markers were made of watchmaker's blued steel spindle stock 1.3 mm. in diameter,

cut to a suitable length and with a rounded tip. These two rather thick markers were used as a guide in trimming the brain and orienting the block in the microtome. More posteriorly, in the same oblique frontal orientation, two light, slender markers made of drawn glass about 0.7 mm. in diameter, varying in length from 11 to 35 mm., were inserted at known oblique frontal planes. These allowed allocation of frontal plane values to the sections subsequently prepared.

Similar fine glass markers were inserted in the horizontal plane with a separate carrier as illustrated in figs. 4 and 5 to allow allocation of horizontal planes to the sections subsequently.

Marking of the brain having been completed in this manner, the animal was decapitated and the head suspended freely in 10% formal saline. After three days of fixation, the skull was carefully removed from the brain with bone rongeurs. The brain was then cut in an oblique frontal plane using the two large anterior markers as guides. The excess length of upper cervical spinal cord was trimmed off. The markers were then removed.

Serial frozen sections each 50 microns thick were cut after the manner of Marshall (1940). The block of tissue for sectioning was immersed in 20% ethyl alcohol and then set oral end downwards on the chuck of a Bausch and Lomb rotary style freezing microtome. Adhesion of the tissue to the chuck was obtained by a layer of moistened filter paper. The freezing effect of carbon dioxide from a cylinder, circulating through

the microtome chuck,was supplemented by packing powdered carbon-dioxide ice around the specimen, which measured usually between 28 and 30 mm. in oral-caudal extent and could not therefore be frozen from the base upwards without gross over-freezing of the lower part.

Sections were then cut, each 50 microns in thickness. The sections were counted and each 10th section transferred to a numbered bath of 20% alcohol in distilled water. It was found that the sections cut better with less wastage and tearing if the leptomeninges and blood vessels were stripped off the surface of the brain stem with a fine pair of forceps before freezing the specimen.

In the construction of an Atlas which involves both cyto-architectural detail and measurement, the choice of an embedding and sectioning technique is difficult. Tissue embedded in paraffin wax or in celloidin undoubtedly gives more consistent sections with greater cytological detail and allows of the production of well stained sections showing fine myelinated fibres as well as cells. On the other hand, the process of dehydration and clearing produces shrinkage and distortion for which it is difficult to correct adequately. Frozen techniques, on the other hand, provide sections of poorer and less uniform quality; stains of the micro-anatomical type for myelin are erratic and have therefore not been included in the present study. Frozen sections avoid the inevitable shrinkage associated with dehydration and, if carefully mounted, show remarkably little distortion. In this study, two cats (nos.At2 and B16) were incorporated in

paraffin and sectioned serially to allow a detailed study of brain stem cytoarchitectonics. Other animals were cut in the frozen state, as described above.

In order to have a further check upon possible distortion of frozen sections by stretching during the mounting process, a technique of photographic control was devised. The essentials of this technique are shown in figs. 6 and 7. A Leica camera on a Leitz Focaslide suitably attached to a Palmer elevator was set above the chuck of the freezing microtome and centered on the tissue. A 50 mm. Elmar lens in a focusing mount was used to produce an image of the surface of the block, with a metric scale in the same plane, on Kodak high contrast copy film. The subject was illuminated by two No.1 photoflood bulbs set symmetrically 70 cm. from the subject and at an angle of 45°. An exposure of a 50th of a second at F8 was found to give a crisp, well exposed negative. The resolution of these negatives was such as to allow twenty times magnification without loss of significant detail. Throughout the cutting of serial frozen sections then, a picture was taken of the block face and adjacent scale immediately before the cutting of each 10th section which was to be mounted and studied.

In addition to providing a check on distortion of the frozen sections, this method allowed orientation of loose pieces of tissue, such as the cerebellum in which holes of the horizontal markers had occurred, and allowed their relationship to the brain stem to be exactly calculated.

Strips of negative film, mounted in a film strip adapter, were then projected in a Leitz Prados projector set on a high shelf and the image deflected down to the horizontal bench surface by a mirror set at 45°. (This device was made by Messrs. Otto C. Watzka to my design; see fig. 8) An outline drawing of the brain stem at each level and the main structures within it at this level were made on large sheets of paper. The film strip adapter was then removed from the projector and an alternative holder designed to carry histological slides was substituted. These two alternative holders are shown in fig. 9. Any discrepancy due to distortion or wrinkling during mounting of the histological section was than apparent; the sites of needle tracks in the cerebellum could be corrected or measurements made from them to the brain stem itself. A simple print, at moderate magnification, is reproduced in fig. 10 and illustrates the amount of detail that can be made out in these pictures of the frozen brain stem.

By these means, a system of stereotaxic coordinates was applied to the step serial sections of the brain stem. The appropriate oblique frontal plane value was allocated to each section. Lateral coordinates were simply applied by measuring from a standardised mid-sagittal plane as indicated by the general configuration of the brain stem and structures such as the raphae and ventral median sulcus.

A complication arises in the allocation of values to the horizontal planes. These planes lie parallel with the Horsley-Clarke base line but are projected, in the geometrical sense, onto

a plane lying at 45° to this base line and not perpendicular to it. Therefore, by the geometry of right angled triangles, they are longer by a factor of 1.414 than they would be if projected onto a vertical plane. Thus it will be observed in the plates of the brain stem that the scale divisions running up the left margin of each photomicrograph are larger than those across the foot of the photomicrograph. Not only does this factor apply in the Atlas, but it must also be borne in mind when using the Atlas to place the tip of a needle in any particular structure by its coordinates derived from this Atlas. All movements of the electrode carriage in the oblique frontal plane relative to the horizontal zero must be increased by a factor of 1.414 (in practice, a factor of 1.4 should be a sufficient approximation) to keep pace with this "magnification" due to obliquity.

Each 10th section was subsequently taken from its numbered bath of 20% alcohol, mounted on 2"x3" microscope slide coated with egg albumen and allowed to dry in an incubator at 37°C overnight. Being then firmly adherent to the slides, the sections were stained in 1% aqueous cresyl violet solution in the usual manner. Mounting and staining were carried out by Miss Barbara Nuttall, B.A. and her staff.

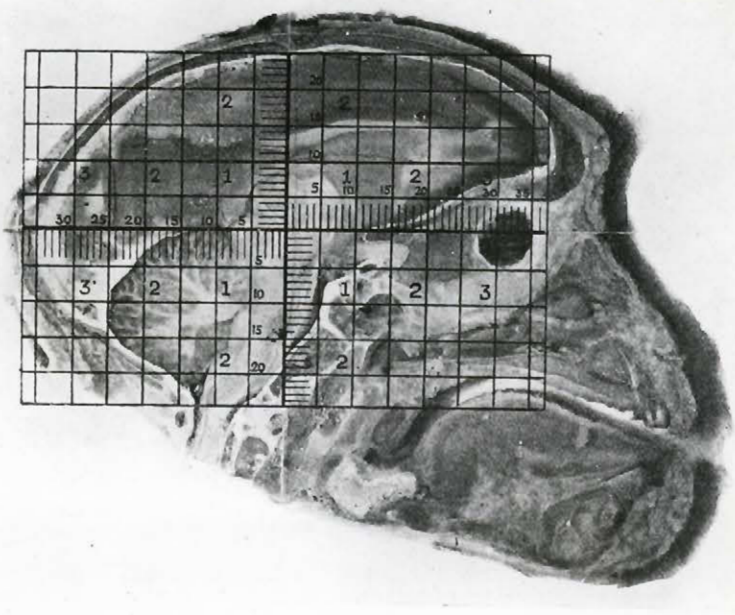


FIG. 1.

Sagittal section of frozen head of Rhesus, and millimetre glass plate.

Fig. 1 An illustration from Horsley and Clarke's 1908 paper showing the earliest form of stereotaxic guide.

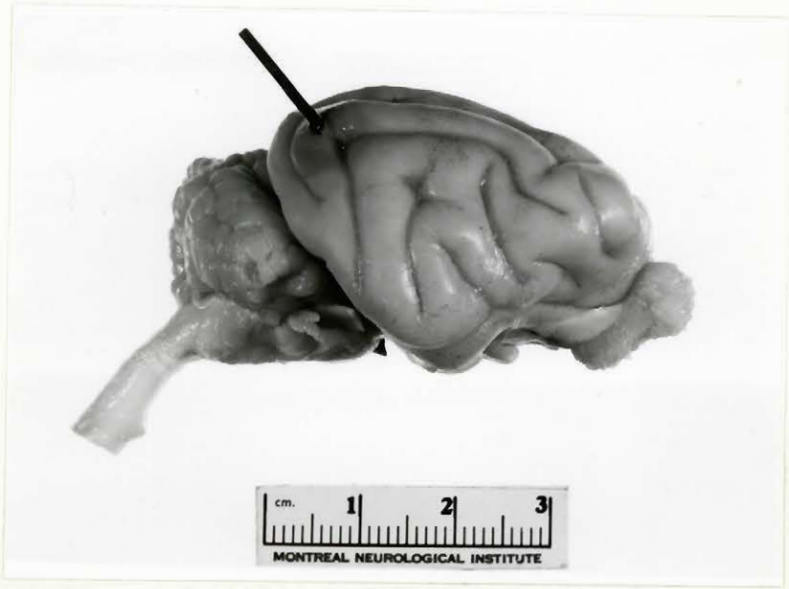


Fig. 2 Right lateral view of brain of cat B16 with most anterior oblique frontal markers in place.

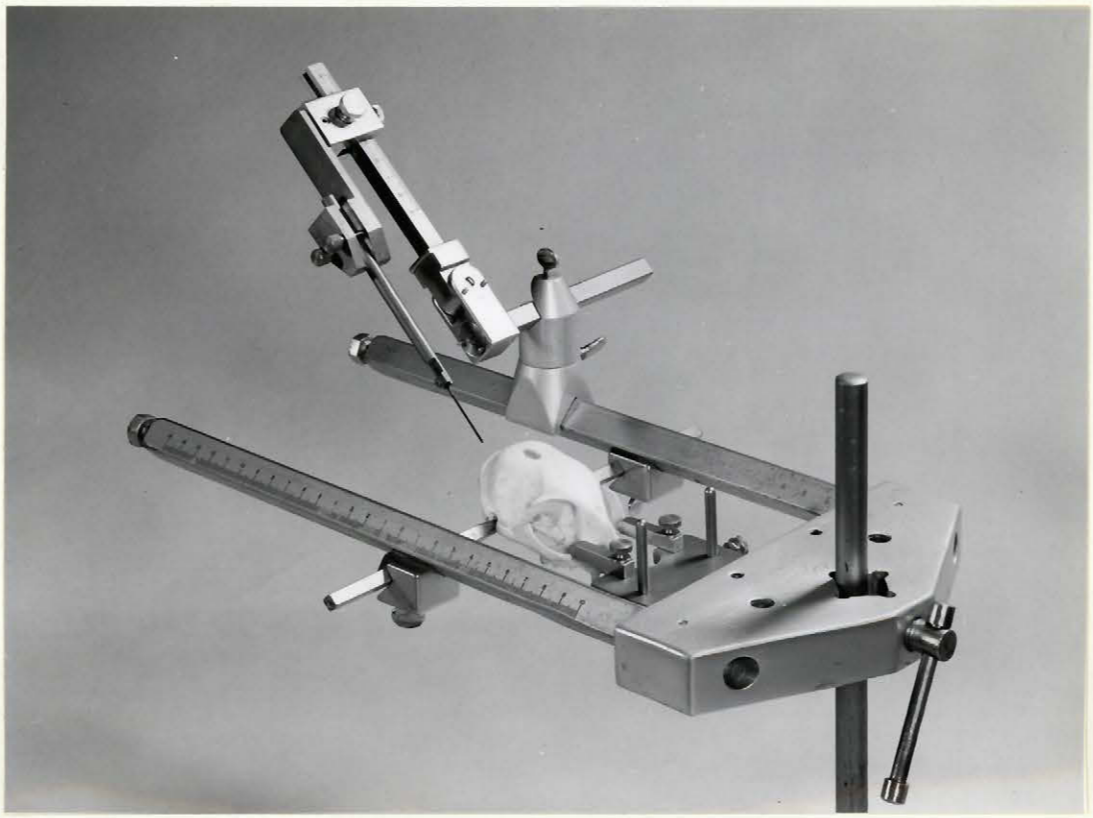


Fig. 3 Stereotaxic instrument as arranged for insertion of oblique frontal markers.

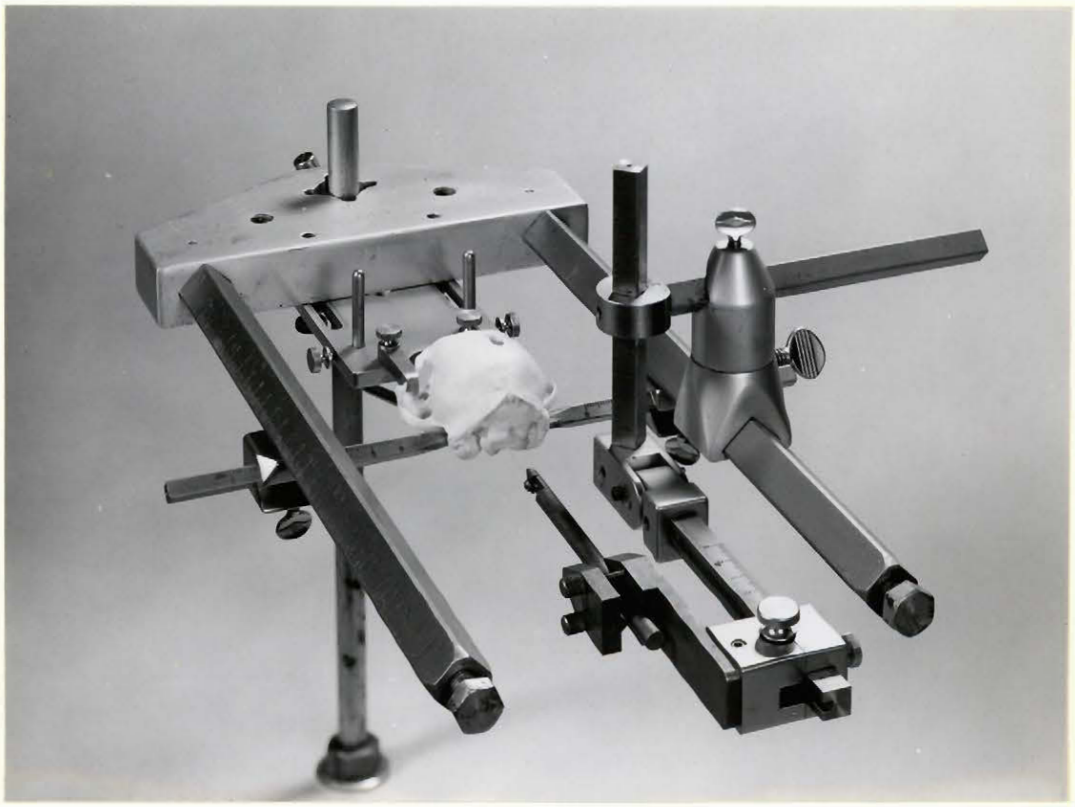


Fig. 4 Stereotaxic instrument as arranged for insertion of horizontal markers.

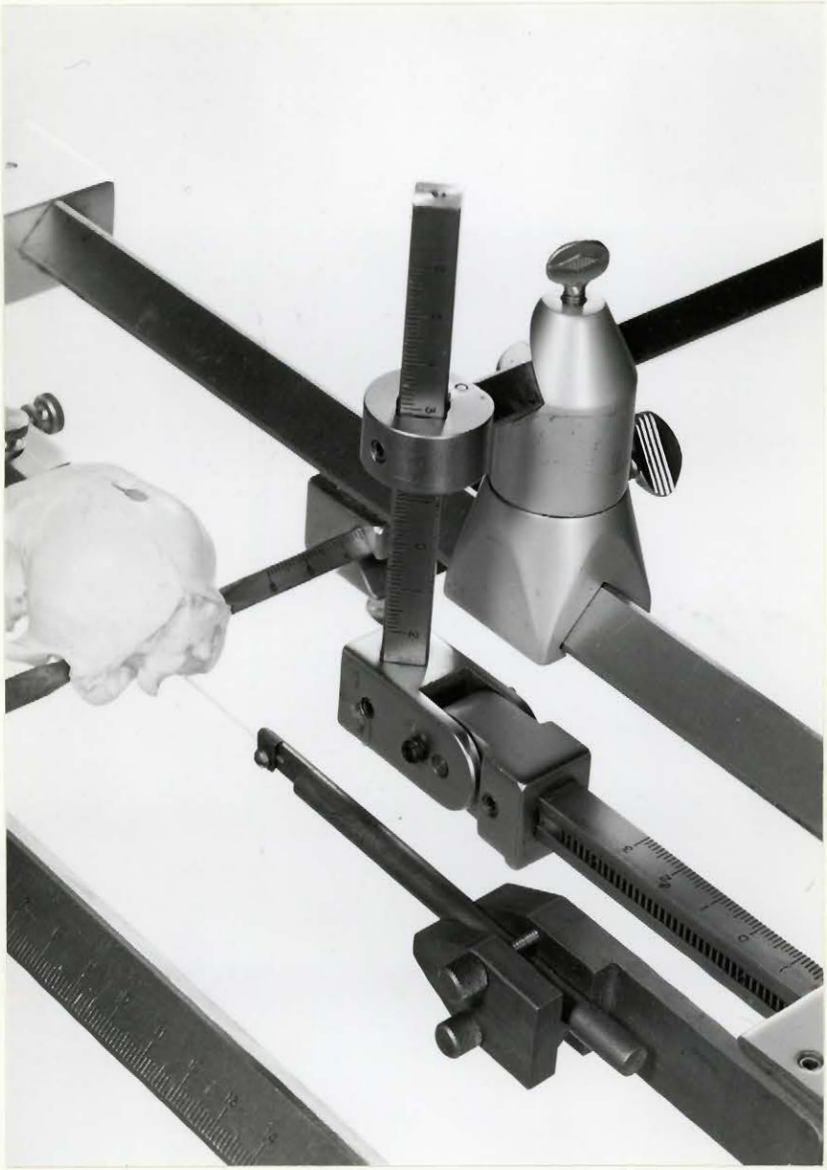


Fig. 5 Detail of arrangement shown in fig. 4 to illustrate method of holding drawn glass markers.

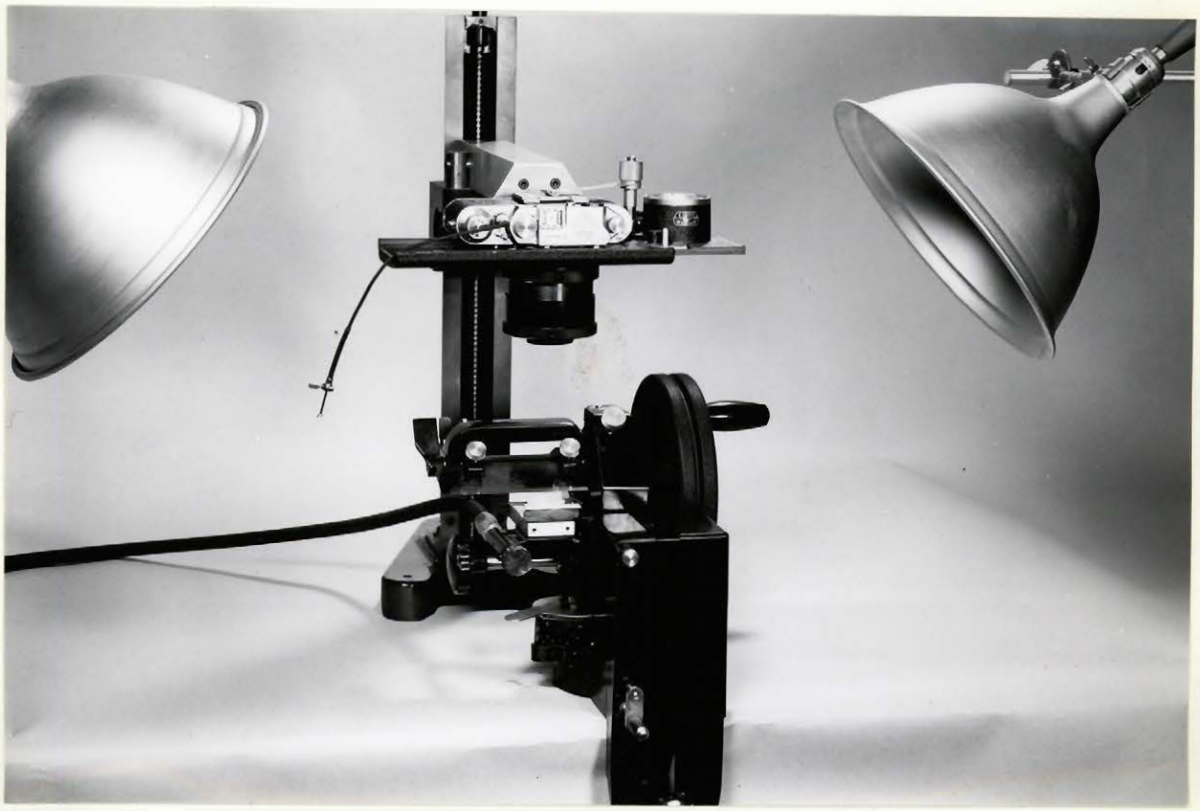


Fig. 6 Arrangement for photographic control during cutting of frozen sections.

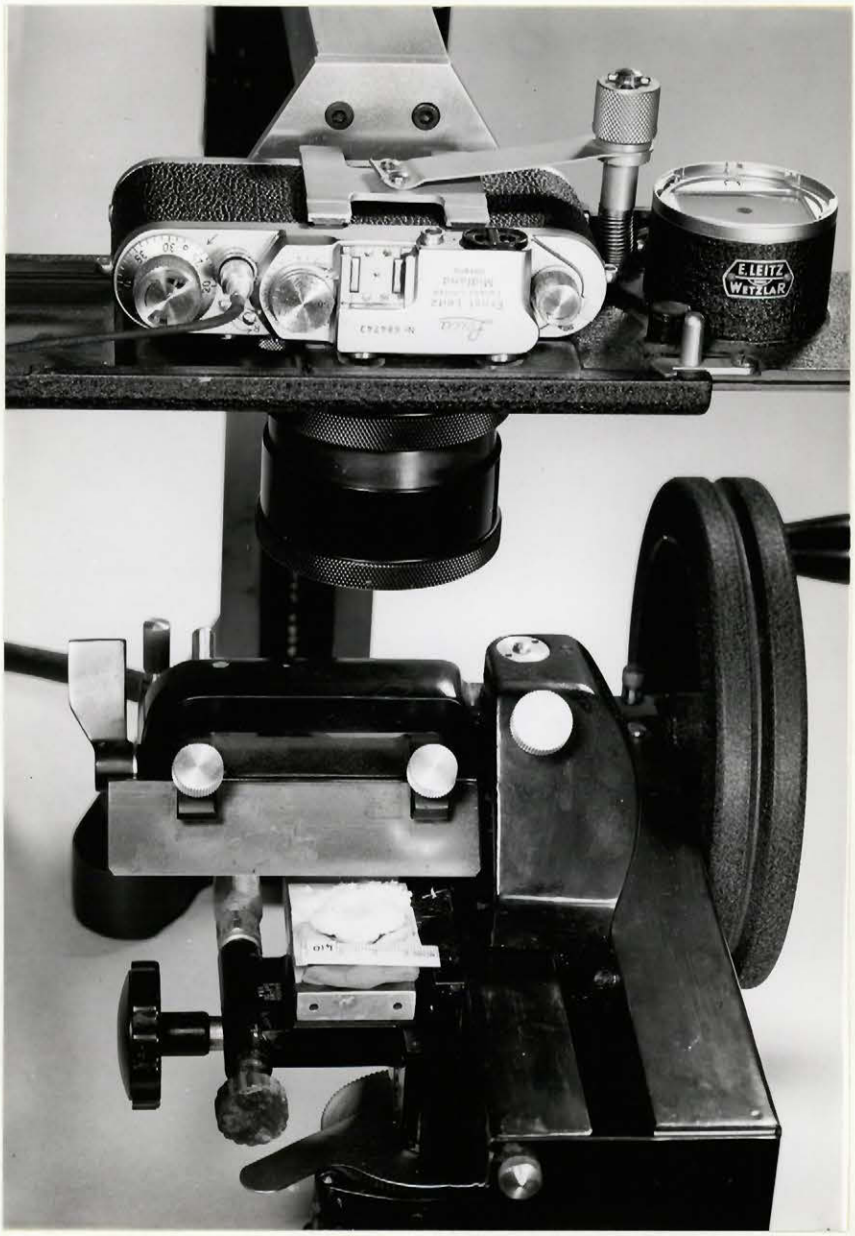


Fig. 7 Another view of the arrangement shown in fig. 6. The powdered dry ice surrounding the tissue has been omitted for clarity.

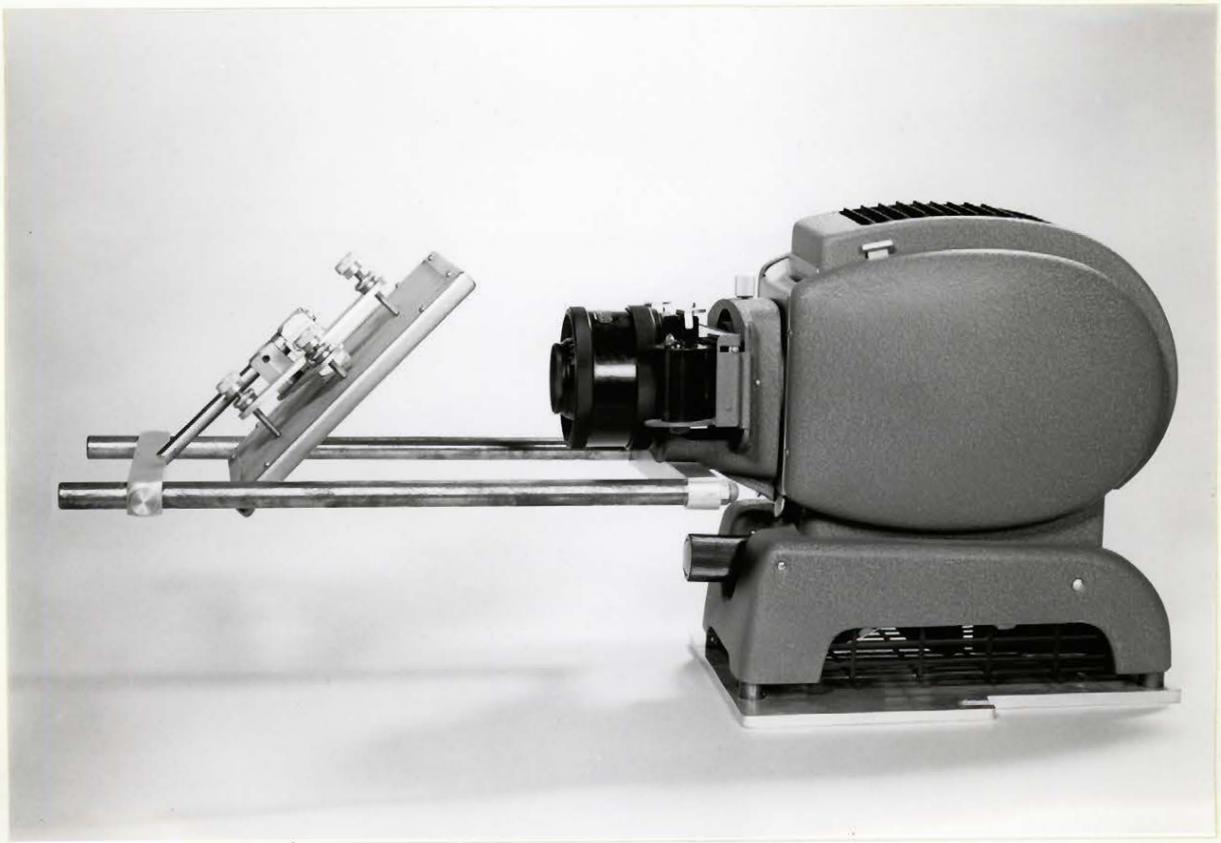


Fig. 8 Modified Leitz Prados device for projection of film strips or histological sections.

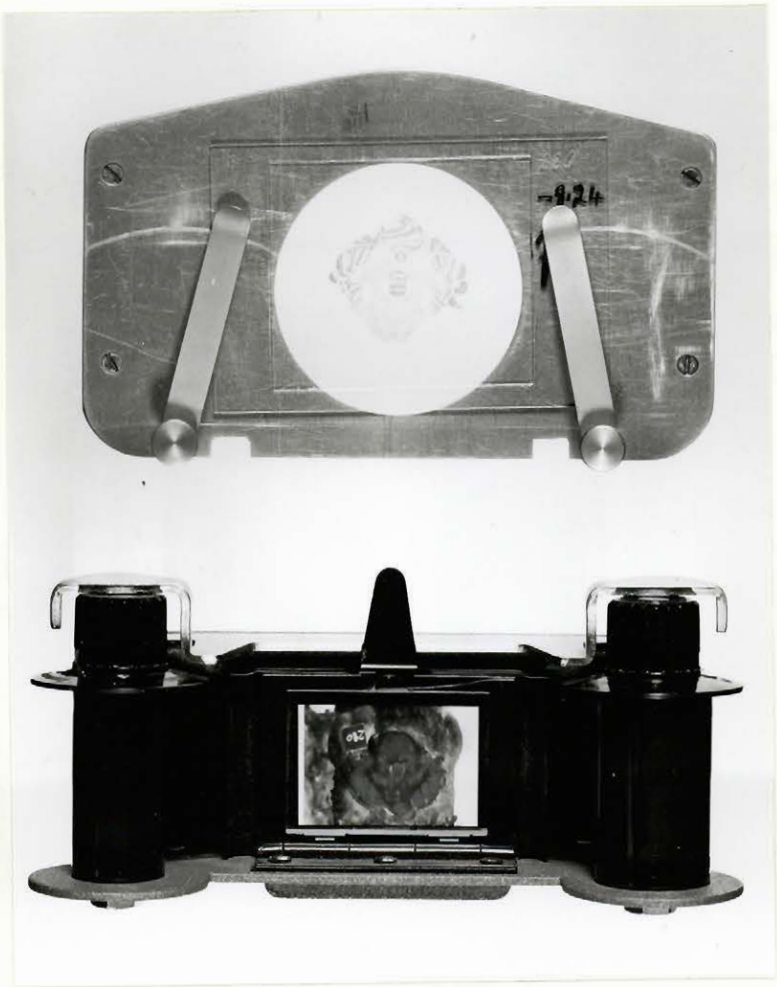


Fig. 9 Alternative holders for use in the projector illustrated in fig. 8.

Fig 10 A print from the 35 mm strip made during the cutting of cat B 17. Section 260 was cut from this surface immediately after the picture was taken.

IV INDEX TO NUCLEI WITH ABBREVIATIONS

Am	Nucleus ambiguus
Ar. pt	Area postrema
Br. col. i	Brachium colliculi inferioris
Caps. ru	Capsule of the nucleus ruber
Cn	Nucleus medullae oblongatae centralis
Cn. d	Nucleus medullae oblongatae centralis subnucleus dorsalis
Cn. s	Nucleus centralis superior
Cn. v	Nucleus medullae oblongatae centralis, subnucleus ventralis
Co. d	Nucleus cochlearis dorsalis
Co. v	Nucleus cochlearis ventralis
Coe	Nucleus locus coeruleus
Col. i	Nucleus colliculi inferioris
Col. s	Nucleus colliculi superioris
Cr. l	Nucleus cervicalis lateralis
Cu. l	Nucleus cuneatus lateralis
Cu. m	Nucleus cuneatus medialis
Cun	Nucleus cuneiformis
Dec. pe. ce. s	Decussatio pedunculorum cerebellorum superiorum
Dec. pyr	Decussatio pyramidum
D. mo. X	Nucleus dorsalis motorius nervi vagi
F. lo. m	Fasiculus longitudinalis medialis

Gc	Nucleus gigantocellularis
gl	Nucleus tractus spinalis trigemini, subnucleus gelatinosus
Gr	Nucleus gracilis
Gr. cn. me	Griseum centrale mesencephali
Gr. cn. me. l	Griseum centrale mesencephali lateralis
Gr. cn. me. m	Griseum centrale mesencephali medialis
Gr. cn. po	Griseum centrale pontis
Gr. po	Griseum pontis
G. VII	Genu of facial nerve
Gud	Nucleus of Gudden
Ic	Nucleus intercalatus
If. h	Nucleus interfasicularis hypoglossi
Ip	Nucleus interpeduncularis
L. d	Nucleus medullae oblongatae lateralis, subnucleus dorsalis
L. v	Nucleus medullae oblongatae lateralis, subnucleus ventralis
L. v. mc	Nucleus medullae oblongatae lateralis, subnucleus ventralis pars magnocellularis
L. v. pc	Nucleus medullae oblongatae lateralis, subnucleus ventralis, pars parvocellularis
Le. l	Lemniscus lateralis
Le. l. d	Nucleus lemnisci lateralis dorsalis
Le. l. v	Nucleus lemnisci lateralis ventralis
Le. m	Lemniscus medialis

mc	Nucleus tractus spinalis trigemini, subnucleus magno-cellularis
M.G.B.	Medial geniculate body
N III	Nucleus oculomotorius
N IV	Nucleus nervi trochlearis
N VI	Nucleus nervi abducentis
N VII	Nucleus nervi facialis
N XII	Nucleus nervi hypoglossi
Ol. i. d	Nucleus olivaris inferior accessorius dorsalis
Ol. i. m	Nucleus olivaris inferior accessorius medialis
Ol. i. pr	Nucleus olivaris inferior principalis
Ol. s. l	Nucleus olivaris superior lateralis
Ol. s. m	Nucleus olivaris superior medialis
Pb	Nucleus parabrachialis
Pc	Nucleus parvocellularis
Pe. ce. i	Pedunculus cerebelli inferior
Pe. ce. m	Pedunculus cerebelli medialis
Pe. ce. s	Pedunculus cerebelli superior
Pes. pe	Pes pedunculi
Pg. d	Nucleus paragigantocellularis dorsalis
Pn	Nucleus paranigralis
Po. cn. c	Nucleus pontis centralis caudalis
Po. cn. o	Nucleus pontis centralis oralis
Pp	Nucleus peripeduncularis
Ppl	Nucleus papillioformis

Prp	Nucleus praepositus hypoglossi
Pro. sl	Processus griseipontis supralemniscalis
Pro. tg. l	Processus greseipontis tegmentosus lateralis
Pyr	Pyramis
Ra. ma	Nucleus raphae magnus
Ra. ob	Nucleus raphae obscurus
Ram	Nucleus retroambigualis
Ro	Nucleus of Roller
Ru	Nucleus ruber
Ru. mc	Nucleus ruber, subnucleus magnocellularis
Ru. pc	Nucleus ruber, subnucleus parvocellularis
Sag	Nucleus sagulum
Sn. V pr	Nucleus nervi trigemini sensibilis principalis
Sol	Nucleus tractus solitarii
Sp. V c	Nucleus tractus spinalis trigemini caudalis
Sp. V ip	Nucleus tractus spinalis trigemini interpolaris
Sp. V o	Nucleus tractus spinalis trigemini oralis
Spt	Nucleus supratrochlearis
Ssp	Nucleus supraspinalis
Su. n. cm	Nucleus substantiae nigrae, subnucleus compactus
Su. n. r	Nucleus substantiae nigrae, subnucleus reticulatus
T. h. ip	Tractus habenulo - interpeduncularis
T. pyr	Tractus pyramidalis
T. sol	Tractus solitarius
T. sp. v	Tractus nervi trigemini spinalis

Tg	Nucleus tegmenti pedunculopontinus
Tr	Nucleus trapezoidalis
III	Nervus oculomotorius
V	Nervus trigeminus
V me	Nucleus and Tractus nervi trigemini mesencephalicus
V mo	Nucleus nervi trigemini motorius
VI	Nervus abducens
VII	Nervus facialis
VIII l	Nucleus vestibularis lateralis
VIII m	Nucleus vestibularis medialis
VIII s	Nucleus vestibularis superior
VIII sp	Nucleus vestibularis spinalis
α	Cell group alpha, a constant neuronal collection in the lateral part of the mesencephalic tegmentum.
β	Cell group beta, a median neuronal aggregation in the mesencephalon.

V CYTOARCHITECTONIC DESCRIPTION OF NUCLEI

General Considerations

The following brief account of individual nuclei is given as an aid to their identification and delineation and is not intended to be a complete and formal description, which is outside the scope of the present work. With this end in view, a roughly topographical arrangement has been followed, beginning at the caudal end of the medulla and proceeding orally. The extent and general relationship of the nuclei is portrayed in the large plates and therefore this present account will deal mainly with cytoarchitectural detail.

The descriptions are based on sections stained by Nissl's technique with cresyl violet. The classical criteria of size, shape, arrangement and staining characteristics are used. Thus the statement that dendrites are short or inconspicuous refers to the appearance in the Nissl stain and in no way reflects the conditions which would obtain in, for example, Golgi preparations. Such an approach lies outside the scope of this work.

In comparison with the neurones of the human brain stem, described in detail by Olszewski and Baxter (1954), those of the cat are lacking in certain features - for example melanin and lipochrome accumulation. They also show a narrower range of variation in some common characteristics such as size and arrangement of Nissl granules within the cytoplasm. They are, in short, less highly differentiated.

These descriptions are composite, being based on a study of all the cats used but, in general, the two brains embedded in paraffin (cats At 2 and B16) have proved most useful. The descriptions, however, apply to tissue sectioned in the frozen state although then the cytological detail is less clear.

Nucleus gracilis Gr

This nucleus consists of medium to large round or oval cells with finely divided but distinct Nissl granules evenly distributed throughout the cytoplasm. Some of the larger neurones have a triangular shape. There is a tendency for neurones to occur in groups especially in the mid portion of the nucleus, whereas towards the oral pole the pattern is one of evenly scattered medium sized cells.

Nucleus cuneatus medialis Cu.m

The cells of this nucleus resemble those of the nucleus gracilis but tend to be rather more angular in outline. Grouping of neurones is prominent in the middle and oral parts of the nucleus where, in general, the cells are larger and more polygonal in outline.

Nucleus supraspinalis Ssp

This nucleus, in the ventro-medial part of the lower medullary grey matter, is composed of large multipolar neurones of typical "motor" type with an admixture of smaller but essentially similarly shaped neurones. In the larger cells, the Nissl granules are coarse, distinct and evenly distributed throughout the cell body and dendritic bases.

Nucleus cervicalis lateralis Cr.l

This nucleus, first clearly described and named by Rexed and Brodal in 1951, is situated for the most part in the 1st and 2nd cervical segments but extends orally in an attenuated fashion into the lower medulla where it lies immediately ventral to the spinal trigeminal complex. It is formed by a small, closely

packed cluster of medium sized, rather rounded, polygonal cells with fine, moderately staining Nissl substance. A few smaller cells, with indistinct,pale staining Nissl substance are intermingled.

Nucleus medullae oblongatae centralis Cn

This nucleus is composed of a mixture of small, medium and large cells most of which are oval although some of the larger ones are polygonal. Nissl granules are coarse and well defined except in the smallest cells where they are pale staining and inconspicuous. In its oral part, two subnuclei are distinguished. The subnucleus dorsalis (Cn.d) comprises more compactly arranged, small, spindle shaped cells while the subnucleus ventralis (Cn.v) consists of a looser arrangement of more variable cells, with large neurones conspicuous.

Nucleus medullae oblongatae lateralis L.v and L.d

This nucleus, also called the lateral reticular nucleus of the medulla, has been subdivided in various ways. Here we have, in general, followed the schemes of Brodal (1943) and Walberg (1952). The subnucleus ventralis (their pars principalis) is further divided into magnocellular and parvocellular parts. That portion which Brodal and his colleagues call subtrigeminalis is here designated subnucleus dorsalis.

Cytologically, the three subdivisions show only modest differences. The pars magnocellularis of the subnucleus ventralis is composed of large, plump, round or slightly polygonal neurones. The neurones of the pars parvocellularis are similar but smaller and their Nissl substance stains less intensely.

The neurones of the subnucleus dorsalis are more variable in size with longer dendrites and some spindle shaped forms.

Nucleus retroambigualis Ram

This small, compact nucleus consists of triangular and spindle shaped neurones of medium size. Nissl granules are medium in size but stain deeply and, in the spindle shaped cells, are often elongated and oriented in the long axis of the cell.

Nucleus raphae obscurus Ra.ob

The cells composing this nucleus are of elongated, polygonal or fusiform shape and have long processes. Staining of the Nissl substance is variable but generally pale. Occasional small, very pale staining cells are also present.

Nucleus raphae magnus Ra.ma

This nucleus is composed of compactly arranged, medium to large, polygonal neurones. Nissl granules are irregular but tend to be large although they stain with only moderate intensity. In a few cells, a zone of perinuclear pallor is seen.

Area postrema Ar.pt

The identity of some of the cellular elements in this peculiar structure is debatable. There is certainly a rich vascular bed; numerous glial cells with large, vesicular round or oval nuclei are present. There are, in addition, rather larger spindle shaped cells, most having bipolar processes. These cells have a vesicular nucleus and prominent nucleolus; their cytoplasm stains rather diffusely with cresyl violet but discrete Nissl bodies are not apparent. Thus their appearance in Nissl

preparations suggest that they are neurones. Nevertheless, King (1937), in a study of this structure in the adult cat using mainly Hortega's silver carbonate methods, was unable to find any neurones and further states that nerve fibres were extremely rare. The overlying ependyma is much modified in this region.

Nucleus nervi hypoglossi N.XII

This well defined nucleus consists of compactly arranged, large, multipolar neurones of typical "motor" type. The large nucleus is centrally situated in the cell and is surrounded by coarse, evenly distributed, deeply staining Nissl granules.

Nucleus intercalatus Ic

In the caudal part of this nucleus, the neurones are small, spindle shaped and poorly endowed with Nissl substance. Orally, they are medium in size and oval. Here their rather indistinct, moderately staining Nissl substance is sometimes absent from the immediately perinuclear region. At all levels, therefore, this structure stands out sharply from the nearby hypoglossal nucleus.

Nucleus interfasicularis hypoglossi If.h

This nucleus consists of medium to large oval or polygonal neurones with large nuclei and finely divided but distinct, deeply staining Nissl granules.

Nucleus of Roller Ro

This small nucleus, lying immediately ventral to the nucleus hypoglossi, is composed of medium to large, round or ovoid cells in a fairly compact arrangement. Nissl granules are

fairly well defined but stain less intensely than those of the nearby hypoglossal nucleus.

Nucleus dorsalis motorius nervi vagi D.mo.X

Most of the neurones of this well defined nucleus are ovoid or even fusiform but some are round or polygonal. The large, rather irregular, but often rod shaped Nissl granules stain only moderately deeply.

Nucleus ambiguus Am

The neurones of this rather elusive nucleus are large and polygonal. They have irregular, coarse, deeply staining Nissl granules which tend to be most compactly arranged around the cell nucleus.

Nucleus cuneatus lateralis Cu.l

The neurones constituting this nucleus are large, round or polygonal and show a tendency to occur in groups. Coarse, deeply staining Nissl granules are present throughout the cytoplasm but tend to be more densely arranged around the nucleus. Occasional smaller, elongated cells are present.

Nucleus tractus solitarii Sol

This nucleus is composed of a uniform carpet of small, pale staining cells. Most of the cell bodies are ovoid.

Nucleus gigantocellularis Gc

In this nucleus very large, medium and small cells are intermingled. Most prominent are the very large neurones from which the nucleus derives its name. These are multipolar, have

large, densely staining Nissl granules and centrally situated nuclei. Secondly there are medium-sized often slender multipolar cells, again with abundant, coarse, densely staining Nissl granules. Thirdly there are small, inconspicuous, pale staining, fusiform cells. Neurones of the first type are more abundant in the caudal part of the nucleus.

Nucleus parvocellularis Pc

This nucleus provides a striking contrast to the nearby nucleus gigantocellularis. It presents a monotomous field of medium and small, oval or fusiform, pale staining cells. Occasional larger cells are seen in the oral part of the nucleus. Glial satellites are numerous throughout.

Nucleus paragigantocellularis dorsalis Pg.d

This nucleus, lying dorsal to the oral part of the nucleus gigantocellularis, has much in common with it. Very large neurones are numerous and cells of intermediate size infrequent, thus giving the nucleus a dimorphic appearance.

Nucleus olivaris inferior Ol.i.pr, Ol.i.m and Ol.i.d

The cellular constituents of the three parts of this nuclear group, that is the nucleus olivaris inferior principalis, nucleus olivaris inferior accessorius medialis and nucleus olivaris inferior accessorius dorsalis, are similar. The cells are round and plump with inconspicuous dendrites. Nissl granules are very indistinct although the neuronal cytoplasm stains fairly darkly. Lipochrome accumulation, so prominent in adult man, has not been observed. Glial nuclei are more densely packed within

the boundaries of this nucleus than elsewhere; the nuclei of these glial cells are characteristically large and sometimes reniform or even lobulated.

The sharply localised projection of the inferior olivary complex to the cerebellum was investigated experimentally by Brodal (1940) and the five anatomical subdivisions of the various parts are summarised by Taber (1961).

Nucleus praepositus hypoglossi Prp

This nucleus is composed mainly of plump, oval or polygonal cells of medium size. Occasional triangular forms are present. The Nissl granules, although fairly deeply staining, are indistinct and tend to form a band around the periphery of the cell body. A few smaller, pale staining, spindle shaped cells are also present; these become more numerous at oral levels.

Nucleus nervi trigemini motorius V mo

This prominent, well defined nucleus is composed of large multipolar neurones of typical motor type. They have large, deeply staining Nissl granules which are distinct although they densely and uniformly fill the cytoplasm. The cells occur in large ill defined groups.

Nucleus nervi trigemini sensibilis principalis Sn.V pr

This nucleus consists of uniformly arranged, round or oval neurones of medium size. Nissl granules are small, indistinct and stain lightly.

Nucleus nervi trigemini mesencephalicus N.V me

The neurones of this elongated nucleus, situated at the medial margin of the mesencephalic tract of the trigeminal nerve, are large and round. Their cytoplasm has a stippled appearance resulting from the densely packed, finely divided, darkly staining Nissl granules. Granules on the cell membrane are often larger.

Nucleus tractus spinalis trigemini caudalis Sp.V c

Three subnuclei are apparent in the cat and two of them are delineated in the photomicrographs of the whole brain stem. The subnucleus gelatinosus forms a cap on the external aspect of the nucleus. It is composed of small oval or spindle shaped neurones with scanty, pale staining cytoplasm; these have a tendency to radial orientation. The subnucleus magnocellularis lies within the concavity of the subnucleus gelatinosus and is composed of medium sized, pale staining,oval cells and larger polygonal cells with prominent deeply staining Nissl granules. The subnucleus zonalis comprises elongated medium sized cells arranged along the peripheral margin of the subnucleus gelatinosus; this subnucleus is not delineated in the large photomicrographs.

Nucleus tractus spinalis trigemini interpolaris Sp.V ip

This nucleus shows an irregular arrangement of round, oval and occasionally triangular neurones of small or medium size. Nissl granules are indistinct; they stain fairly darkly in the larger cells but poorly in the smaller cells.

Nucleus tractus spinalis trigemini oralis Sp.V o

In this part of the spinal trigeminal complex there are clusters of medium sized oval or polygonal neurones with indistinct, darkly staining Nissl substance intermingled with occasional small, pale staining fusiform neurones. The medial margin of this structure, where it abuts on the nucleus parvocellularis, is indistinct.

Nucleus cochlearis dorsalis Co.d

In the planes of section used in this study, the dorsal cochlear nucleus presents a curvilinear outline and is essentially trilaminate. The most superficial lamina, lying under the ependyma of the lateral recess of the fourth ventricle, consists of sparsely scattered, small, oval, pale staining cells. Internal to this is a more compactly arranged palisade of fusiform and triangular cells with their long axes perpendicular to the ependymal surface. A condensation of glial nuclei in this lamina contributes to the palisade appearance. Deep to this again, there is a broader zone of irregularly arranged polygonal and oval cells of varying size; the larger of these have deeply staining cytoplasm, while the smaller have scanty, pale staining Nissl substance.

Nucleus cochlearis ventralis Co.v

In contrast to the dorsal cochlear nucleus, this nucleus has a homogeneous structure, being composed of medium sized, ovoid cells with large eccentric nuclei. Nissl granules are medium in size and staining quality; in a few cells they show a faintly concentric pattern around the nucleus.

Nucleus vestibularis spinalis VIII sp

This nucleus consists of oval, fusiform and triangular neurones with long dendrites. They vary in size from medium to large. The texture and staining properties of the Nissl substance vary with the size of the cell.

Nucleus vestibularis medialis VIII m

The neurones of this nucleus are oval or triangular in shape and vary in size from small to moderately large. The larger cells have deeply staining Nissl substance while the small cells are very pale staining. The nerve cells in this nucleus are more compactly arranged than in the spinal vestibular nucleus. Glial cells are numerous throughout the nucleus.

Nucleus vestibularis lateralis VIII l

The relatively scanty neurones of this nucleus are very large or occasionally medium in size and multipolar in outline. Well defined, deeply staining Nissl granules fill the cytoplasm.

Nucleus vestibularis superior VIII s

The neurones of this thickly populated nucleus are variable in shape but mainly polygonal. They range in size from small to moderately large. The Nissl granules, which stain with moderate intensity, are, in many cells, more densely aggregated around the nucleus.

Nucleus olivaris superior medialis and lateralis Ol.s.m and Ol.s.l

The cytoarchitecture of these two nuclei as revealed by Nissl preparations is similar. The constituent neurones are

fusiform or ovoid with their long axes oriented perpendicular to the plane of the nuclei as seen in transverse section. This is especially well seen in the medial nucleus which is crescent shaped. Nissl granules are indistinct and stain only moderately well; in some neurones there is peripheral accentuation of Nissl substance. Glial nuclei are abundant and help in sharply delineating these nuclei.

The structure and connections of these nuclei in the cat is discussed in detail by Stotler (1953).

Nucleus trapezoidalis Tr

This horseshoe shaped nucleus embraces the superior olivary nuclei. It is composed of plump, polygonal neurones of medium size arranged in irregular, ill defined clusters. Nissl granules are indistinct and stain lightly. Glial nuclei are abundant especially in the caudal part but are not so closely packed as in the superior olivary nuclei.

Nucleus facialis N.VII

This nucleus is composed of large, multipolar neurones of typical "motor" type. Nissl granules are coarse and stain deeply. The cells show a strong tendency to occur in clusters.

Griseum pontis Gr.po

The neurones of this extensive nucleus in the basis pontis are round, oval or polygonal. They are remarkably uniform in size. Nissl granules, although indistinct, stain fairly deeply and, in many cells, are accentuated near the

margin of the cell body. The cytoarchitecture of the topographical subdivisions (processus griseipontis supralemniscalis and processus griseipontis tegmentosus lateralis) is uniform with that of the main body of the nucleus.

Nucleus papillioformis Ppl

The neurones of this prominent nucleus are large, plump, round or ovoid. Nissl granules are fine but stain deeply; they are often more numerous around the cell nucleus. The cells tend to occur in large, ill defined groups.

Nucleus pontis centralis caudalis Po.cn.c

In this nucleus large and medium sized, darkly staining, polygonal cells are irregularly scattered amongst small, pale staining, spindle shaped cells.

Nucleus pontis centralis oralis Po.cn.o

In this nucleus there is less divergence in cell size than in the nucleus pontis centralis caudalis and it is more cellular. The main feature distinguishing it from the nucleus pontis centralis caudalis is the absence of large cells.

Griseum centrale pontis Gr.cn.po

This nucleus is composed of closely packed, small, pale staining, oval, triangular and spindle shaped cells with long, delicate dendrites. In its lateral part it is overlapped by the nucleus locus coeruleus.

Nucleus locus coeruleus Coe

This large, prominent nucleus is made up of medium sized,

round or occasionally polygonal neurones having coarse, often clumped, deeply staining Nissl granules. Melanin pigment, so prominent in man, is not present.

Nucleus of Gudden Gud

The neurones of this compact nucleus are oval or pear shaped and medium in size. There is some tendency to orientation with the "stem of the pear" pointing dorso-medially. Nissl granules are irregular, often large, and stain deeply.

Nucleus sagulum Sag

This nucleus is made up of small and occasionally medium sized spindle shaped or oval cells. Cytoplasmic staining in the fusiform cells is pale while in the larger oval cells Nissl granules stain moderately well.

Nucleus tegmenti pedunculopontinus Tg

This extensive nuclear mass is composed of small, pale staining, fusiform cells and rather larger pyriform, oval or triangular neurones with large nuclei and indistinct Nissl granules which stain moderately well. In the dorso-lateral portion of the nucleus caudally, the neurones are more densely arranged - the subnucleus compactus. The rest of the nucleus constitutes the subnucleus dissipatus. These subnuclei have not been delineated in the diagrams.

Nucleus ruber Ru.mc and Ru.pc

The magnocellular part of this nucleus (Ru.mc) consists

of very large and a few medium sized multipolar cells with abundant deeply staining Nissl granules evenly filling the cytoplasm. The centrally placed nucleus is pale and has a prominent nucleolus. The parvocellular portion (Ru.pc) is made up of small to medium, oval and triangular cells with long dendrites and frequent glial satellites.

Nucleus substantiae nigrae Su.n

This nucleus is divided into two subnuclei - the subnucleus compactus and subnucleus reticulatus. Cytologically the subnucleus compactus is composed of medium sized, elongated, often triangular, multipolar cells with abundant, coarse, densely staining Nissl granules. Melanin pigment, so prominent in man, is not present. Grouping of neurones within this nucleus, described by Hassler (1937) in man is not readily apparent in the cat. The cells of the subnucleus reticulatus are similar in general form but are smaller and their cytoplasm stains less intensely; they are diffusely scattered and, in part, intermingle with the fibres of the cerebral peduncle.

Nucleus interpeduncularis Ip

This midline nucleus consists of closely packed, oval, triangular and spindle shaped cells. Their nuclei are large and the scanty cytoplasm stains poorly. Most of the cells are parasagittally oriented.

Nucleus paranigralis Pn

This paired nucleus lies on either side of the nucleus

interpeduncularis and consists of delicate, elongated cells with long bipolar processes. Occasional slightly larger cells with darkly staining cytoplasm are present.

Nucleus lemnisci lateralis ventralis Le.l.v

The cells of this nucleus are medium in size, and oval or occasionally triangular. The cytoplasm stains darkly but Nissl granules are very indistinct. The nucleus is often eccentrically situated in the cell. Glial nuclei are frequent throughout this structure.

Nucleus lemnisci lateralis dorsalis Le.l.d

This nucleus consists of ill defined groups of medium to large, round or polygonal cells; their Nissl granules are fine but stain well. Occasional small, usually fusiform, pale staining cells are present. Glial cells are again frequent.

Nucleus nervi abducentis N.VI

This nucleus is composed of medium sized, oval neurones with fairly well defined, moderately staining Nissl substance.

Nucleus trochlearis N.IV

This compact, well defined nucleus is made up of large polygonal cells with coarse, deeply staining Nissl granules. Glial nuclei are abundant.

Nucleus oculomotorius N.III

The oculomotor nuclear complex lies at and beyond the oral limit of this Atlas. Consequently, delineation and de-

scription of its various components is not feasible. Most of the constituent neurones are large, plump and polygonal; they have coarse, irregular, deeply staining Nissl granules.

Griseum centrale mesencephali Gr.cn.me and Gr.cn.me.l

The portion of this nucleus portrayed here is subdivided into a subnucleus medialis and a subnucleus lateralis. The third subdivision - the subnucleus dorsalis - lies beyond the oral limit of this series of sections. Both parts are made up of small, delicate, pale staining neurones with long processes. In the subnucleus lateralis these are closely packed. In the subnucleus medialis, the packing density is a little less and there are scattered larger, oval and polygonal neurones with deeply staining Nissl granules.

Nucleus centralis superior Cn.s

This nucleus consists of small or medium-sized, oval or triangular neurones with long processes. Nissl granules are large, poorly defined and stain moderately well. The cells are arranged parasagittally.

Nucleus supratrochlearis Spt

This unpaired, midline structure is made up of medium sized, irregularly oval, deeply staining neurones. At the lateral margins of the nucleus, there are, in addition, many small, spindle shaped, pale staining neurones which have numerous glial satellites. At some levels, the margins of this nucleus are difficult to delineate.

Nucleus cuneiformis Cun

This nucleus is made up of small, oval or spindle shaped cells, regularly arranged and predominantly oriented in a dorsolateral-ventromedial direction caudally, while at more oral levels the orientation is reversed and takes on a dorsomedial-ventrolateral direction. They have inconspicuous, pale staining Nissl substance. Occasional larger polygonal cells are scattered through this nucleus.

Nucleus parabrachialis Pb

This nucleus consists of polygonal neurones of medium size and staining quality irregularly scattered on a background of abundant glial cells.

Nucleus peripeduncularis Pp

The cells of this nucleus are fusiform and medium or small. The smaller ones are very pale staining while the medium sized elements have indistinct, moderately staining Nissl substance and numerous glial satellites.

Nucleus colliculi inferioris Col.i

This large, densely cellular nucleus is made up of an admixture of small, oval, pale staining cells and medium sized, pyriform or polygonal cells, the Nissl substance of which is moderate in amount and staining intensity. In the dorsal part of the nucleus the small cells predominate and are closely packed. Elsewhere the mixture is an even one. Glial nuclei are abundant throughout the nucleus.

Colliculus superior Col.s

The superior colliculus lies at the oral limit of this series of sections and is not wholly present in the illustrations. Its complex laminated structure, therefore, cannot be dealt with in detail. Suffice it to say that it is less compactly cellular than the nucleus of the inferior colliculus and that the disparity in size between the small and medium sized cells is greater.

Cell group alpha

The identity of this prominent and constant cell group in the lateral part of the midbrain (where it lies just under the pial surface) is uncertain. It does not seem to be a cell condensation in the lateral part of the nucleus cuneiformis. It lies dorsal to the lateral extremity of the nucleus substantiae nigrae and is separated from it by the nucleus tegmenti pedunculo-pontinus of which it is clearly not a part. Its component neurones are medium in size, polygonal or even triangular; they contain darkly staining, indistinct Nissl granules and large nuclei. Taber (1961) depicts this cell mass as the caudal pole of the nucleus paralemniscalis.

Cell group beta

The neurones within this area are medium sized or small; most are fusiform and the smaller ones commonly have elongated bipolar processes. In the larger cells Nissl granules are coarse and rather indistinct; in the smaller cells Nissl substance is pale staining. The nucleus lies oral to the decussation of the superior cerebellar peduncle and ventral to supratrochlearis from which it may be distinguished. Taber (1961) designates this

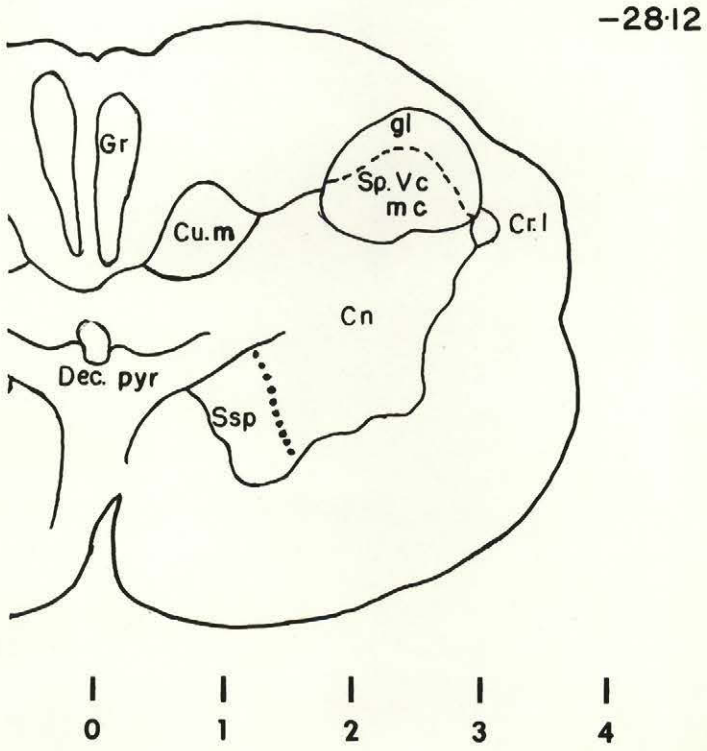
nucleus the nucleus linearis rostralis. A similarly situated cell group occurs in man (the nucleus parabrachialis pigmentosus, Olszewski and Baxter, 1954); many of these neurones in man contain melanin pigment.

VI PLATES OF BRAIN STEM SECTIONS WITH STEREOTAXIC COORDINATES

This series of plates of the brain stem sections cut frozen and stained with cresyl violet have been selected to illustrate most of the nuclei. They are derived from Cat B17, a 2.9 Kg. female. The original photomicrographs were made on the Zeiss horizontal instrument at a magnification of twenty times and have, along with the attached scales, been slightly reduced for convenience in binding. They have been assembled in a caudal-oral sequence.

The lettering of the abbreviations on the most caudal six levels was considered likely to obscure the cytological detail in the photomicrographs and was therefore put on separate outline traces.

At the most caudal level illustrated, that is OF minus 28.12, horizontal levels were not directly available and therefore have been omitted.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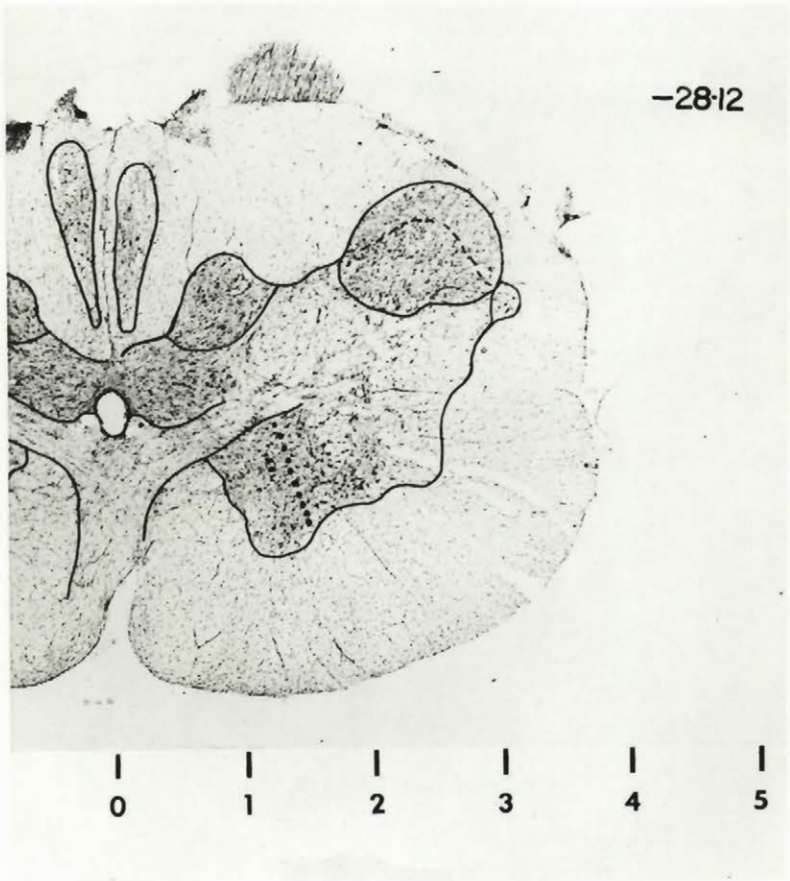
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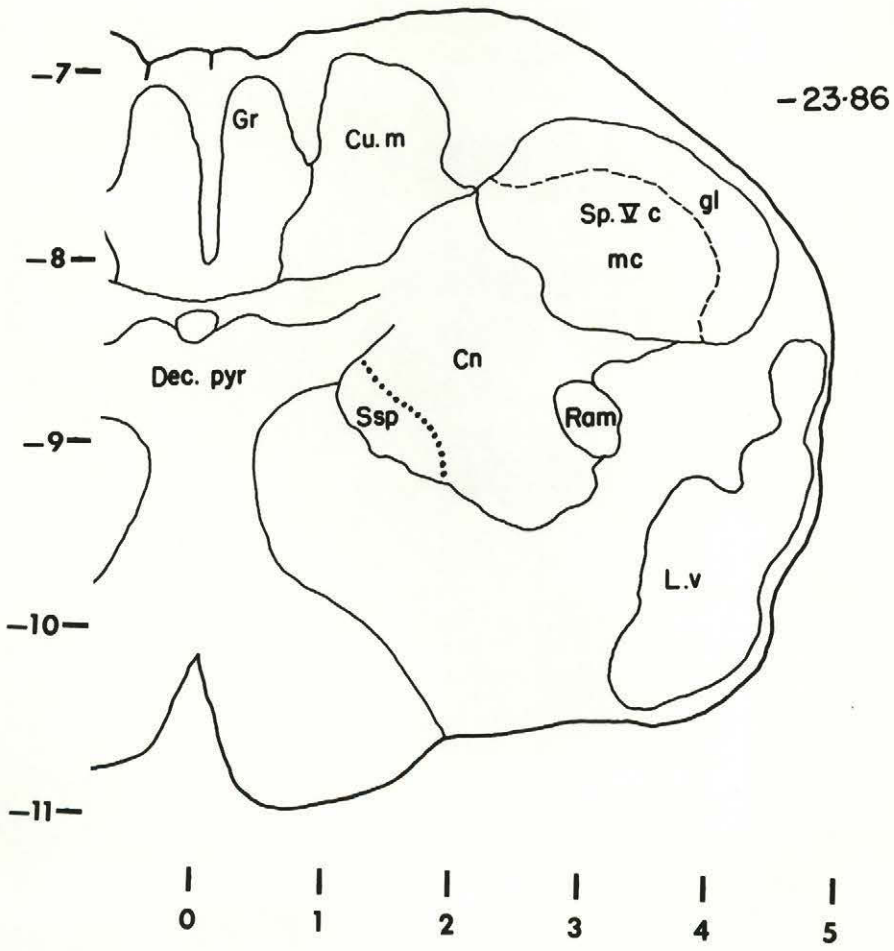
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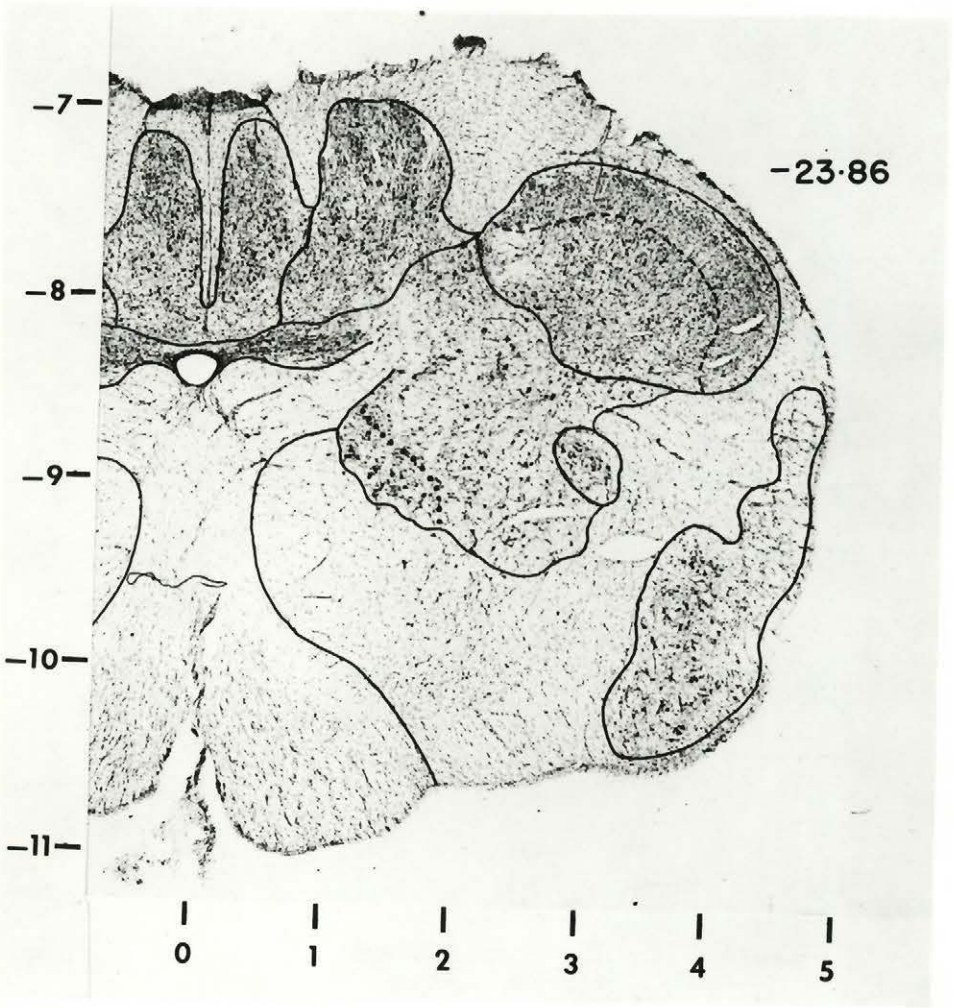
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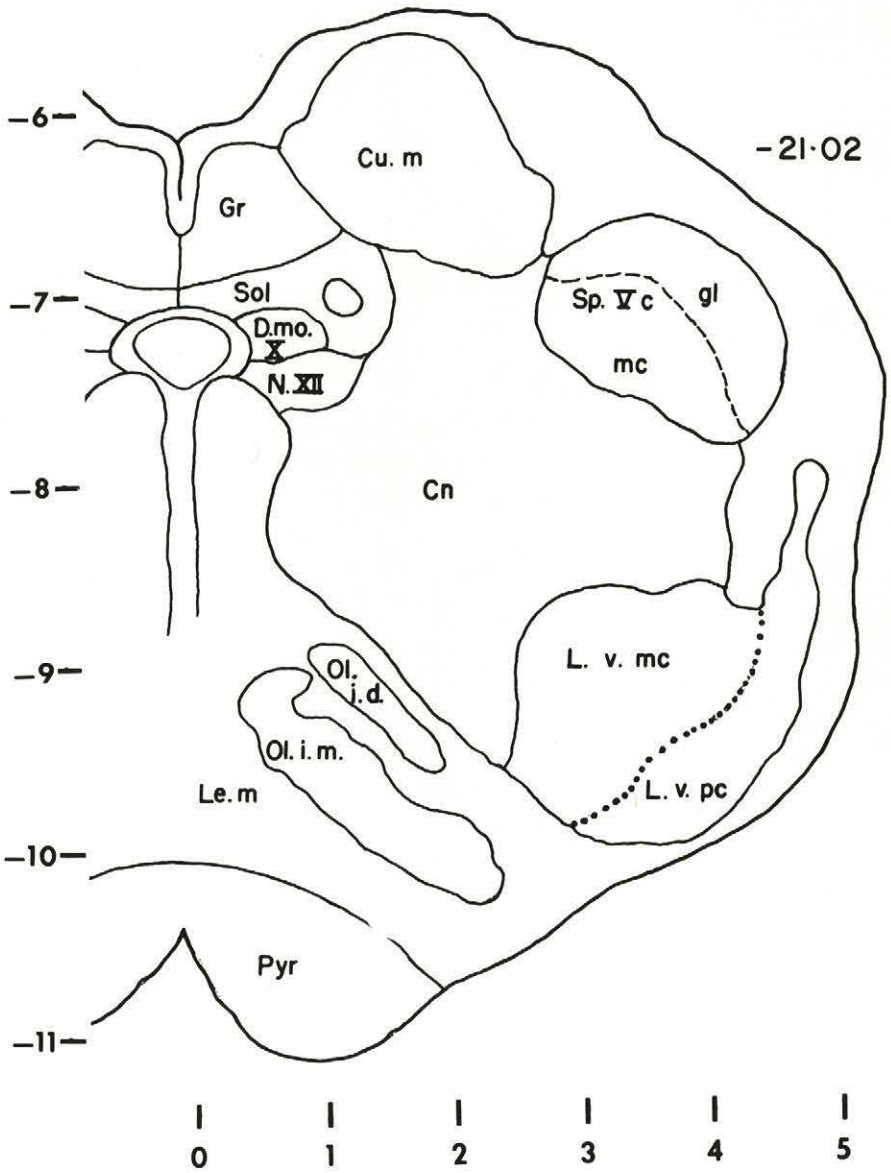
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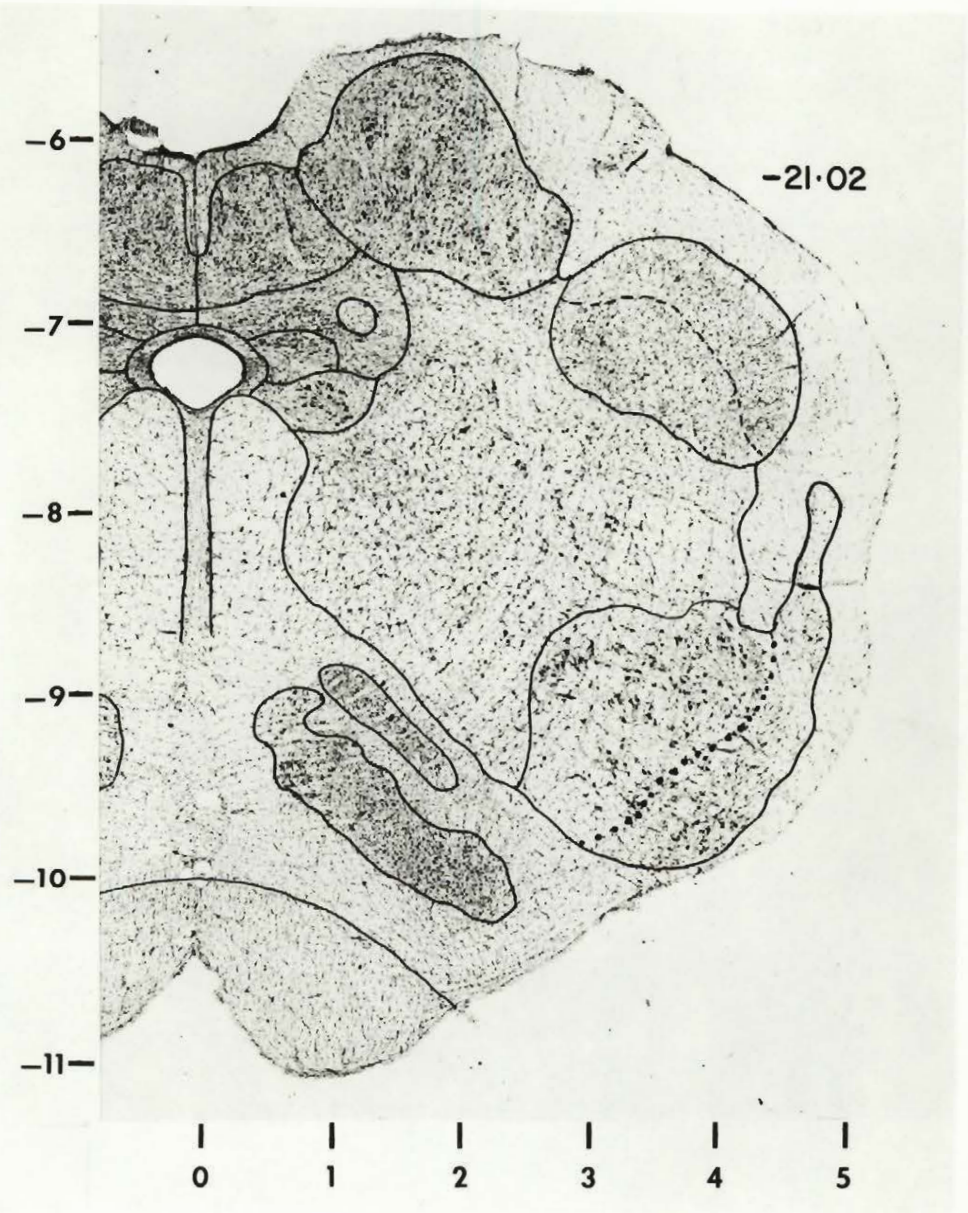
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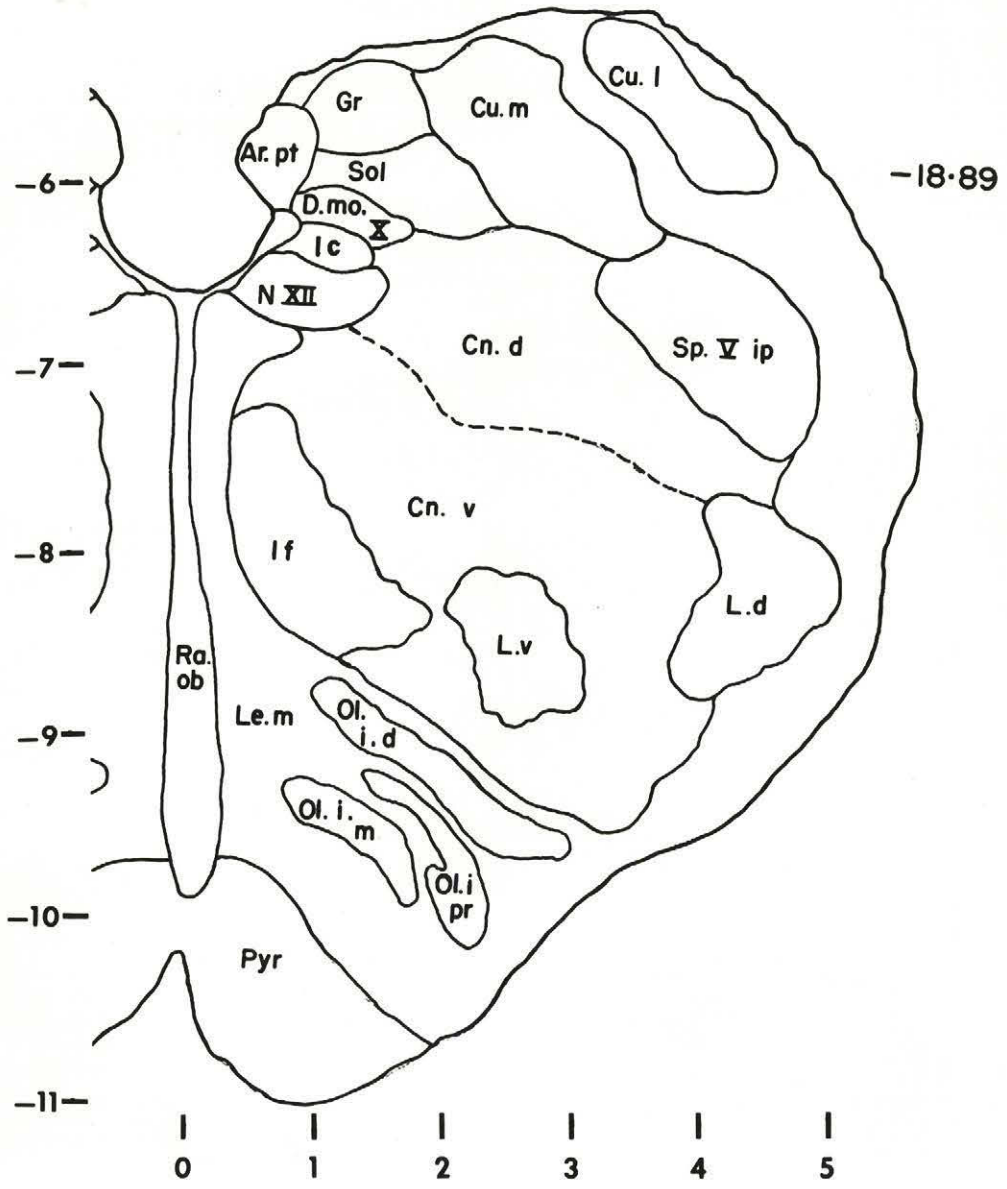
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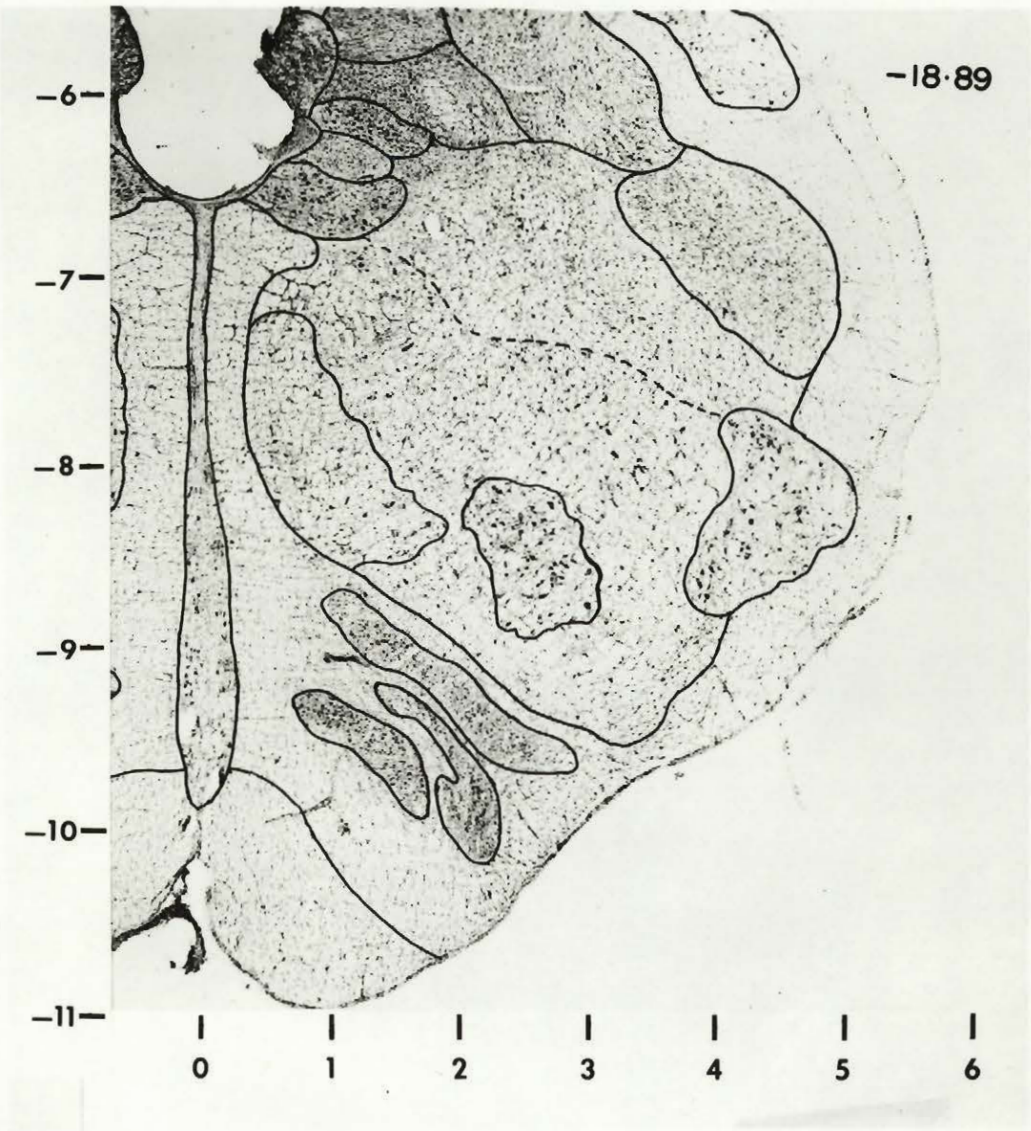
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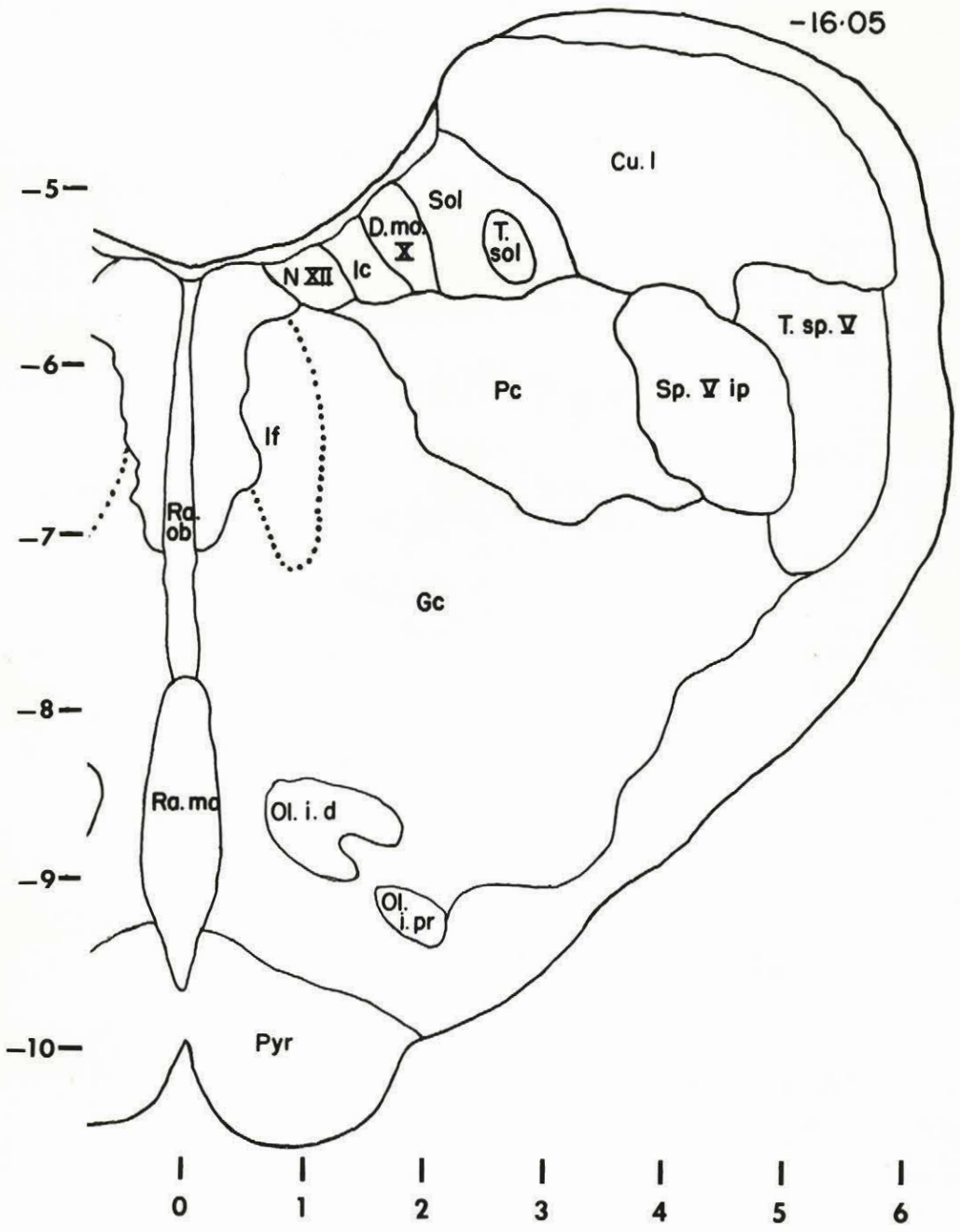
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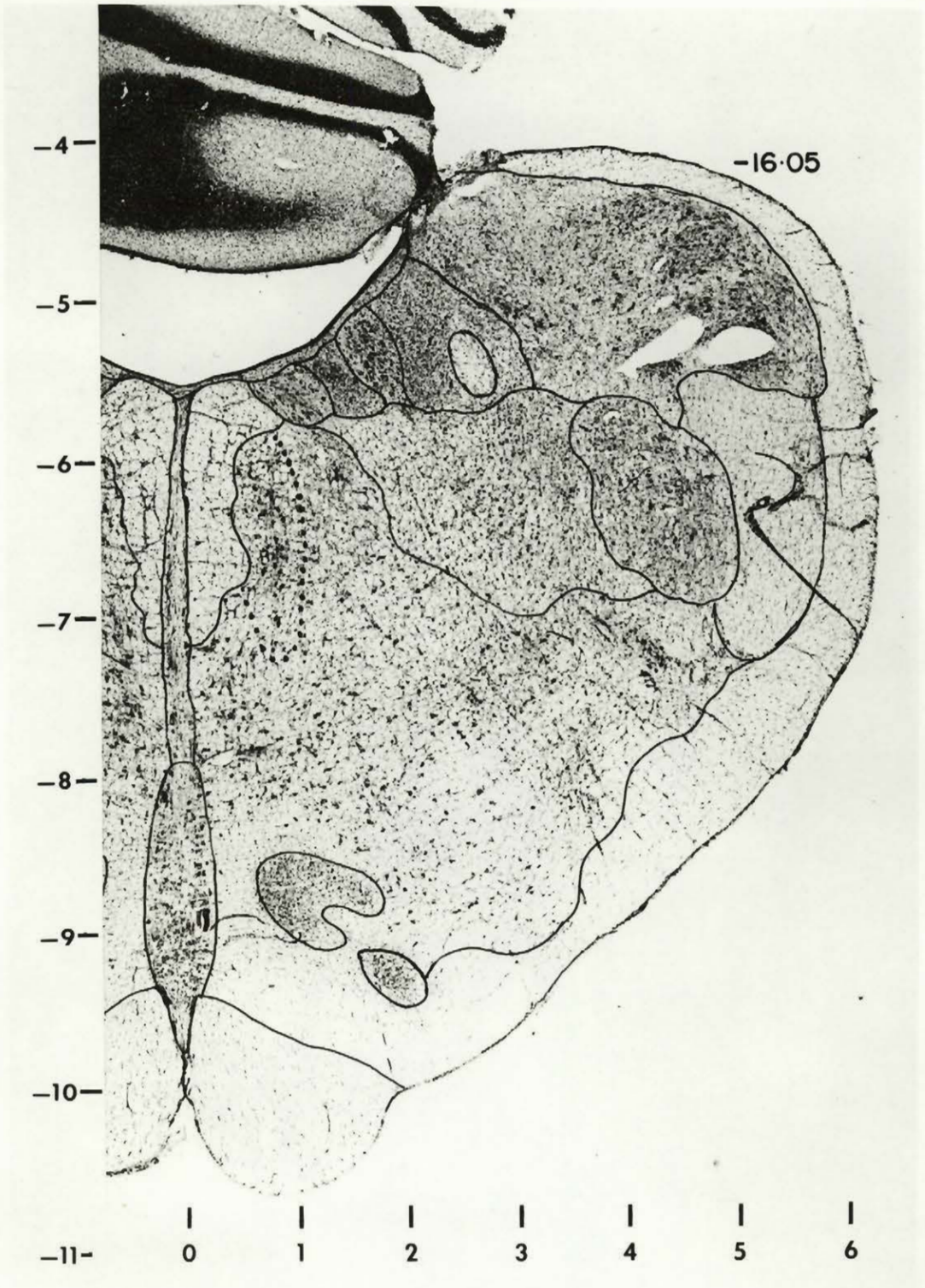
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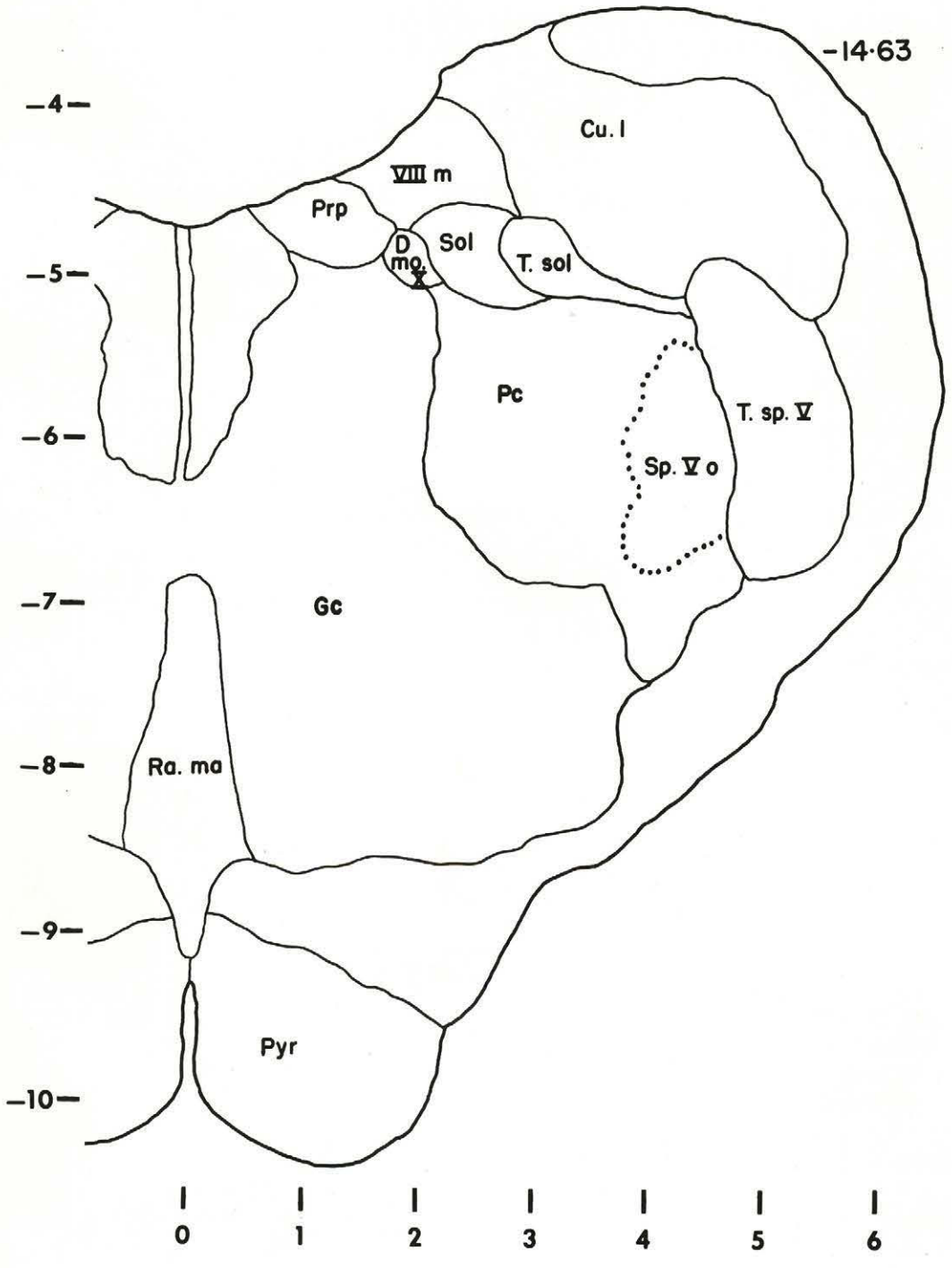
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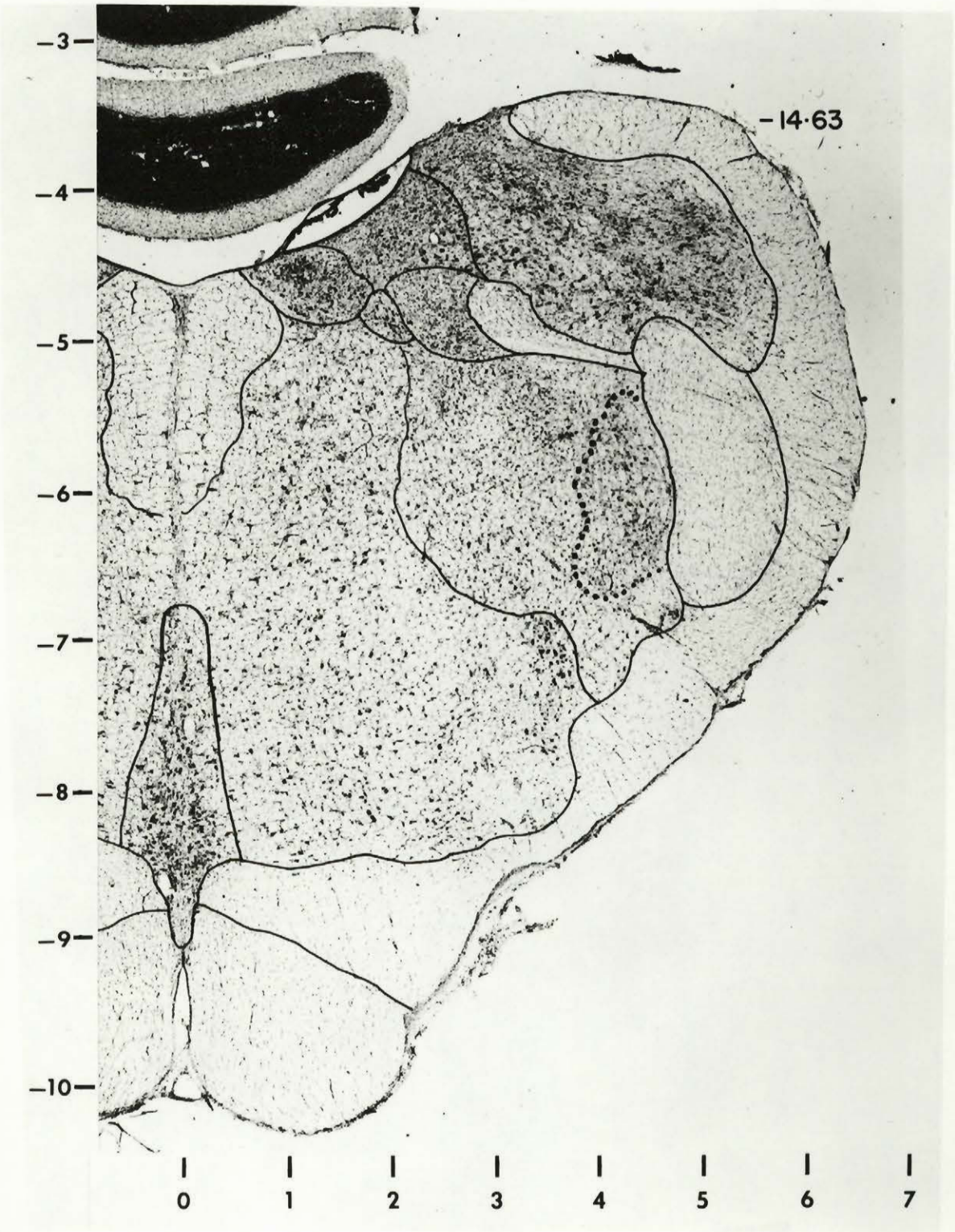
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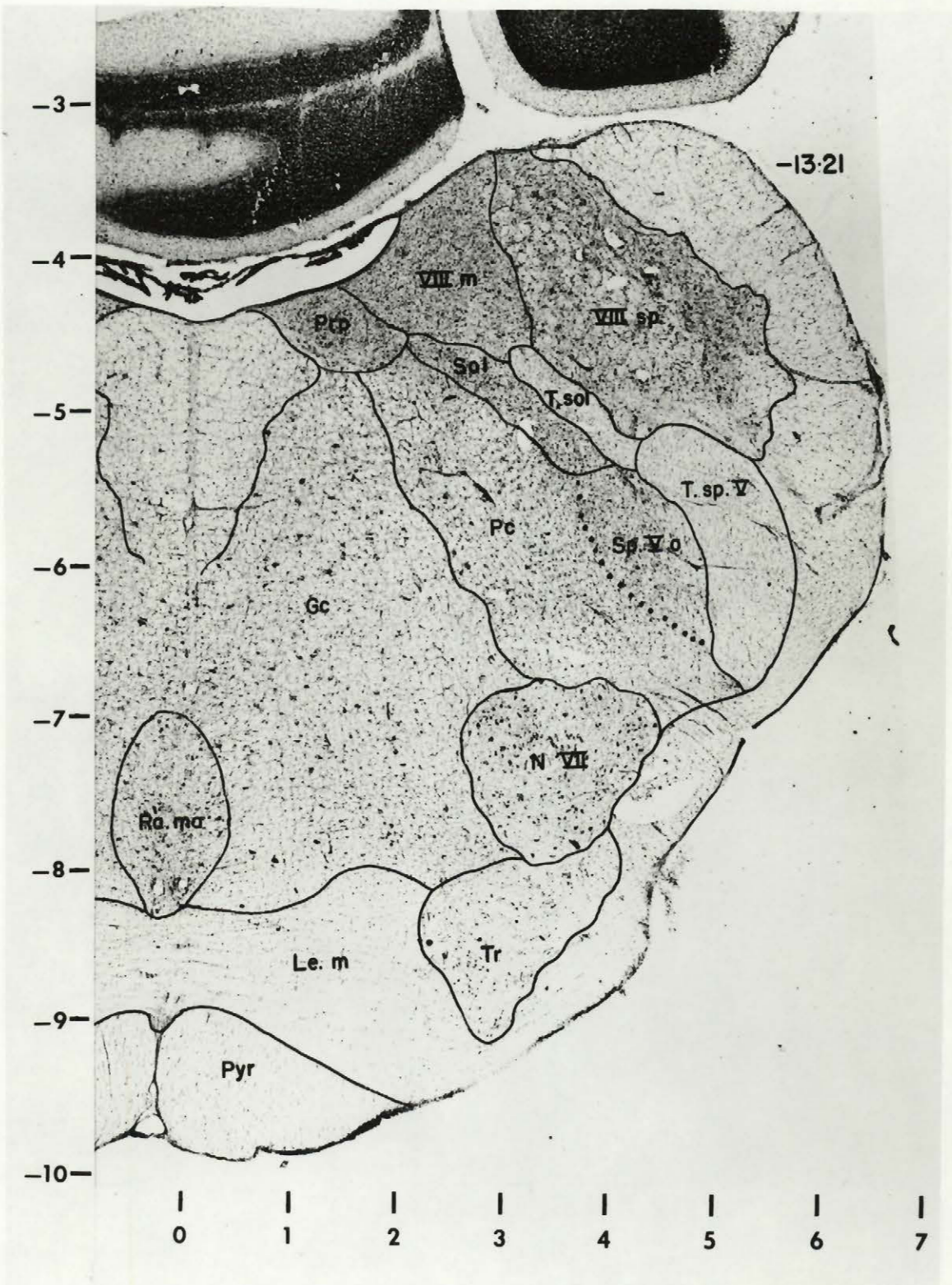
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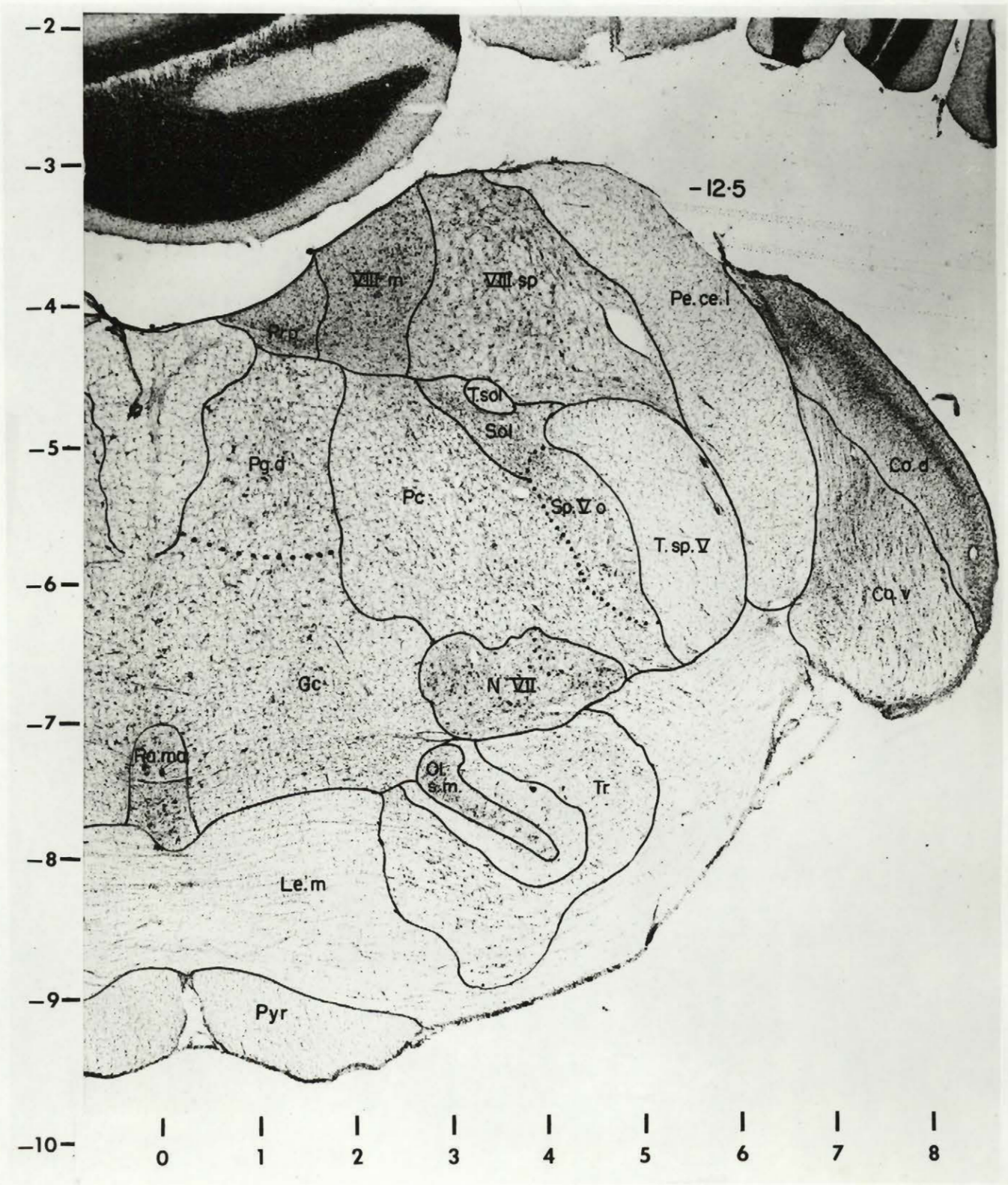
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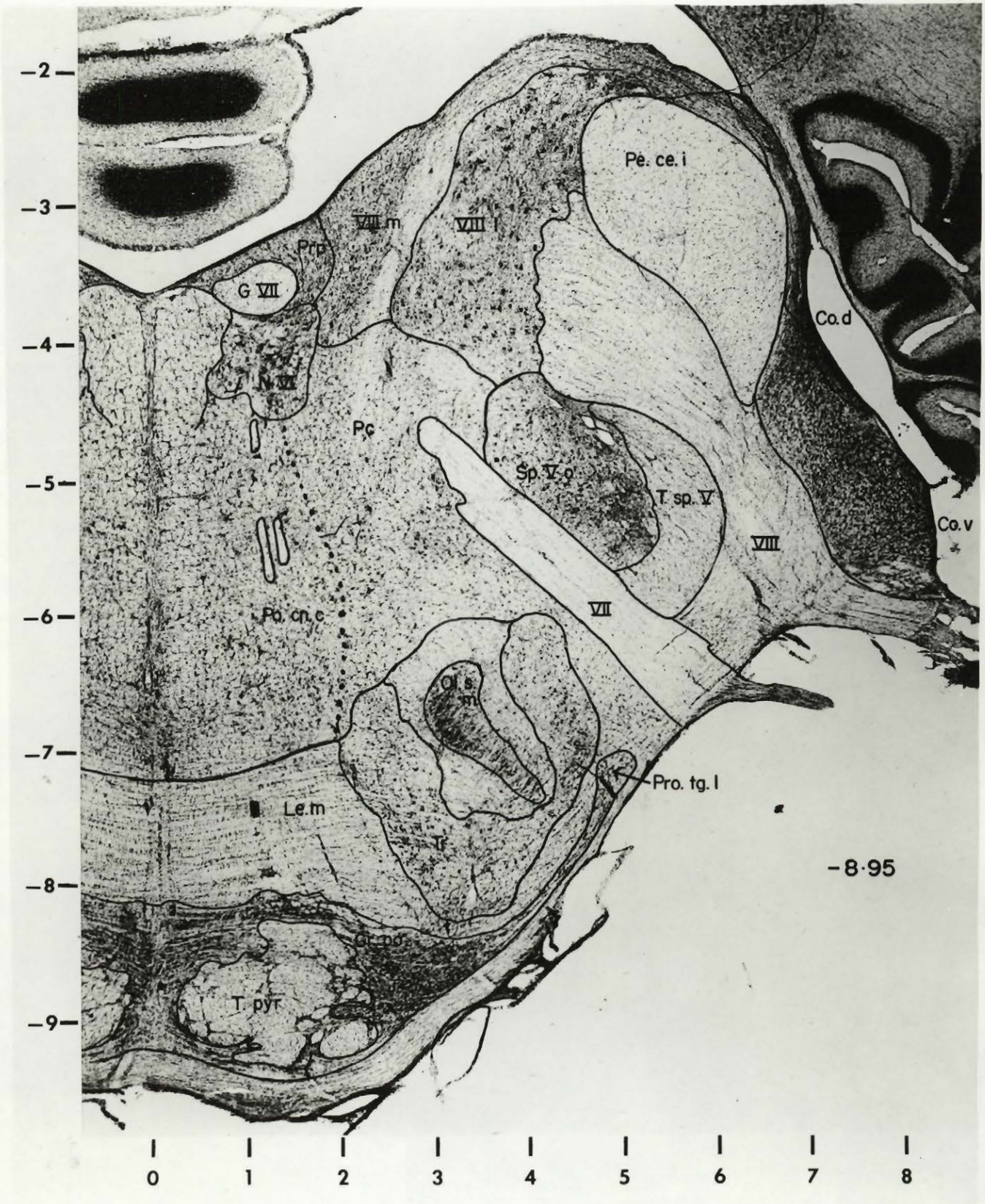
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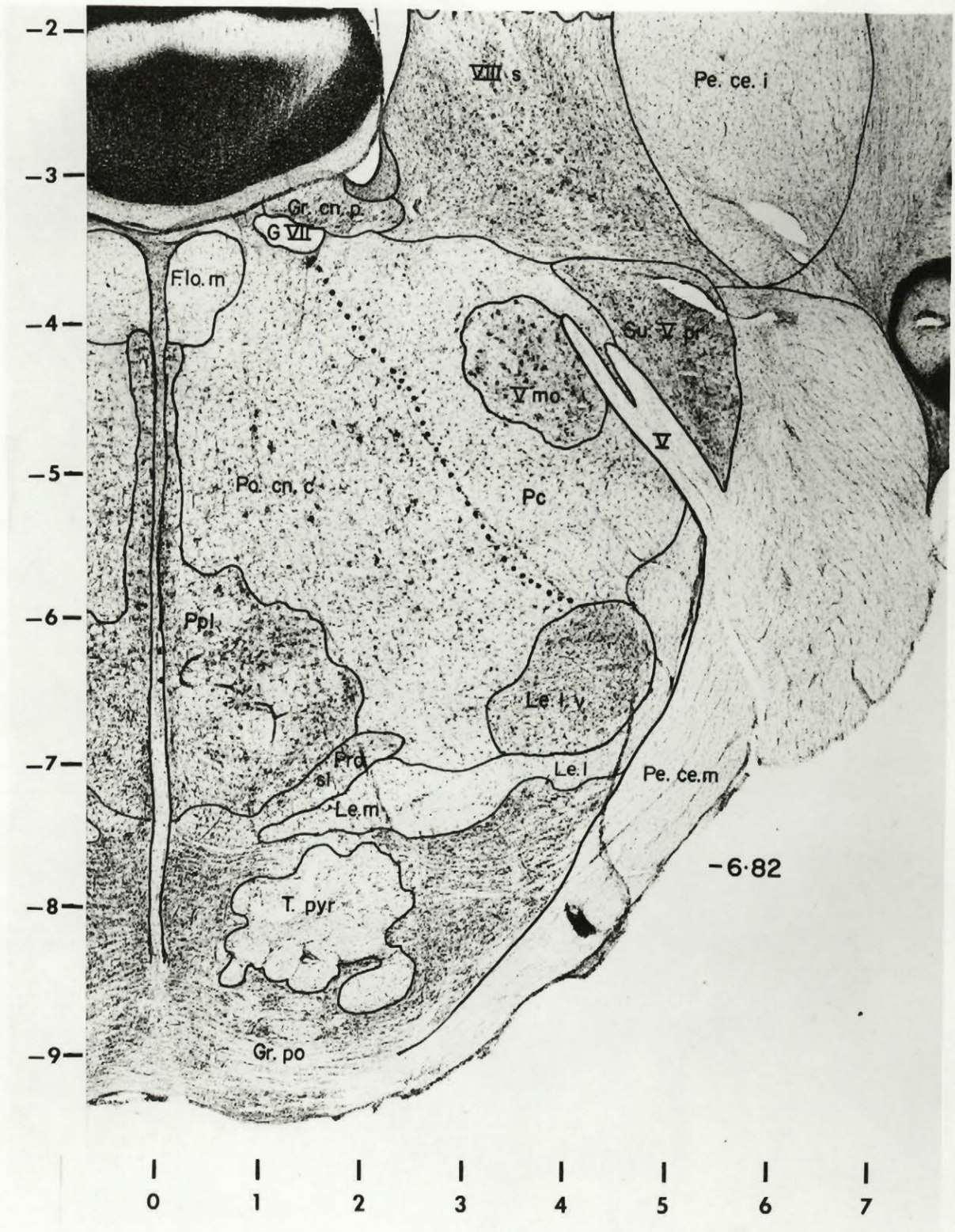
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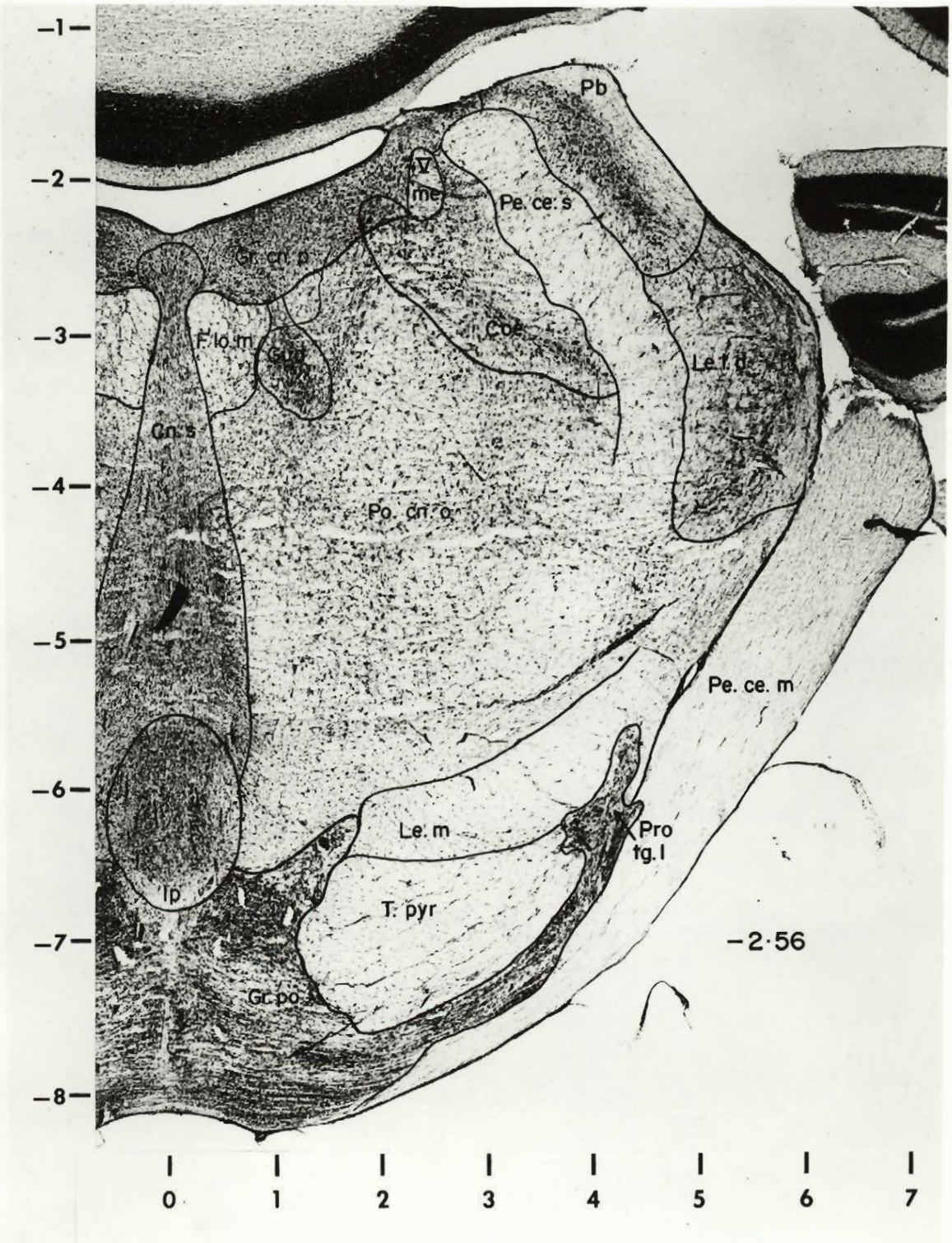
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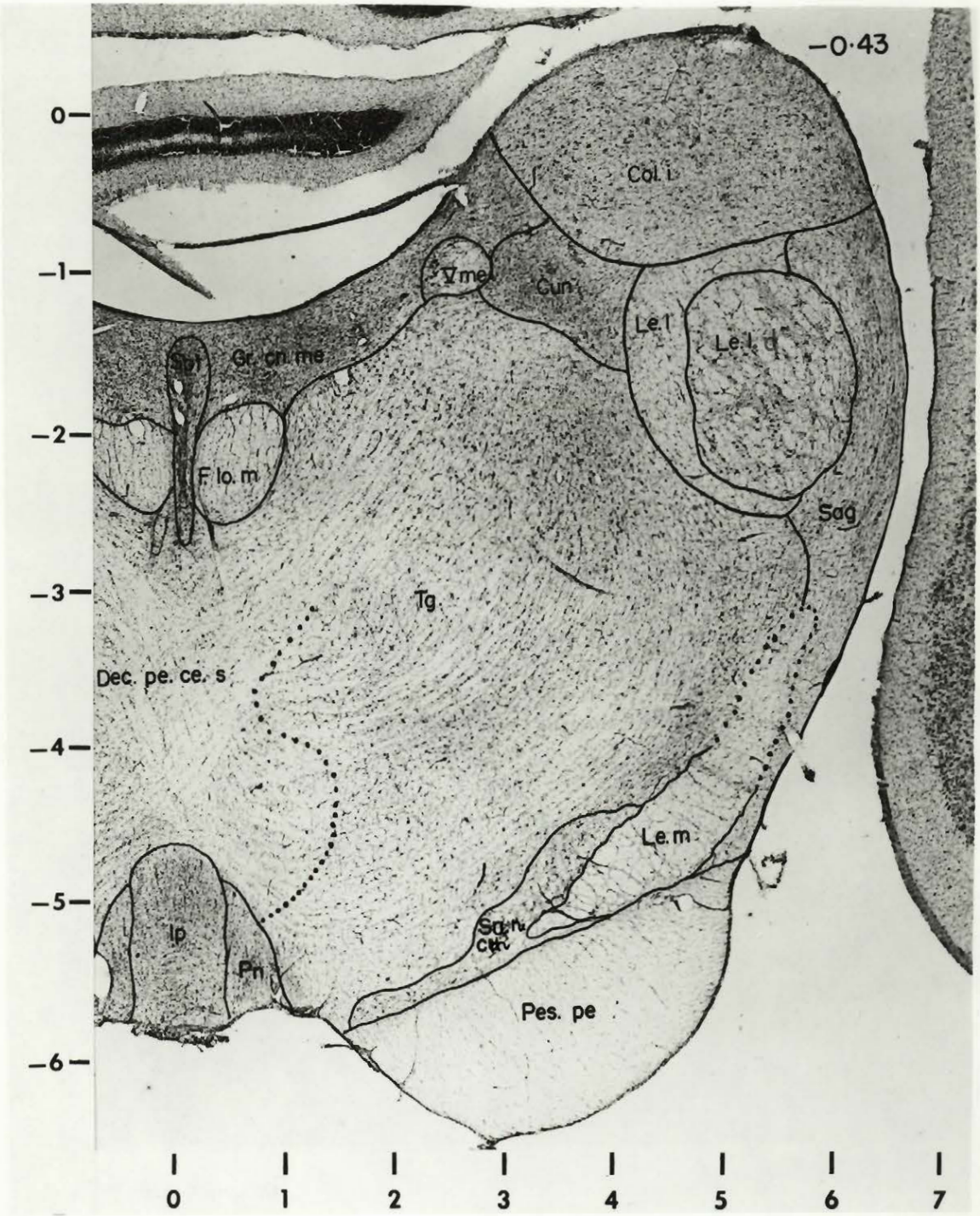
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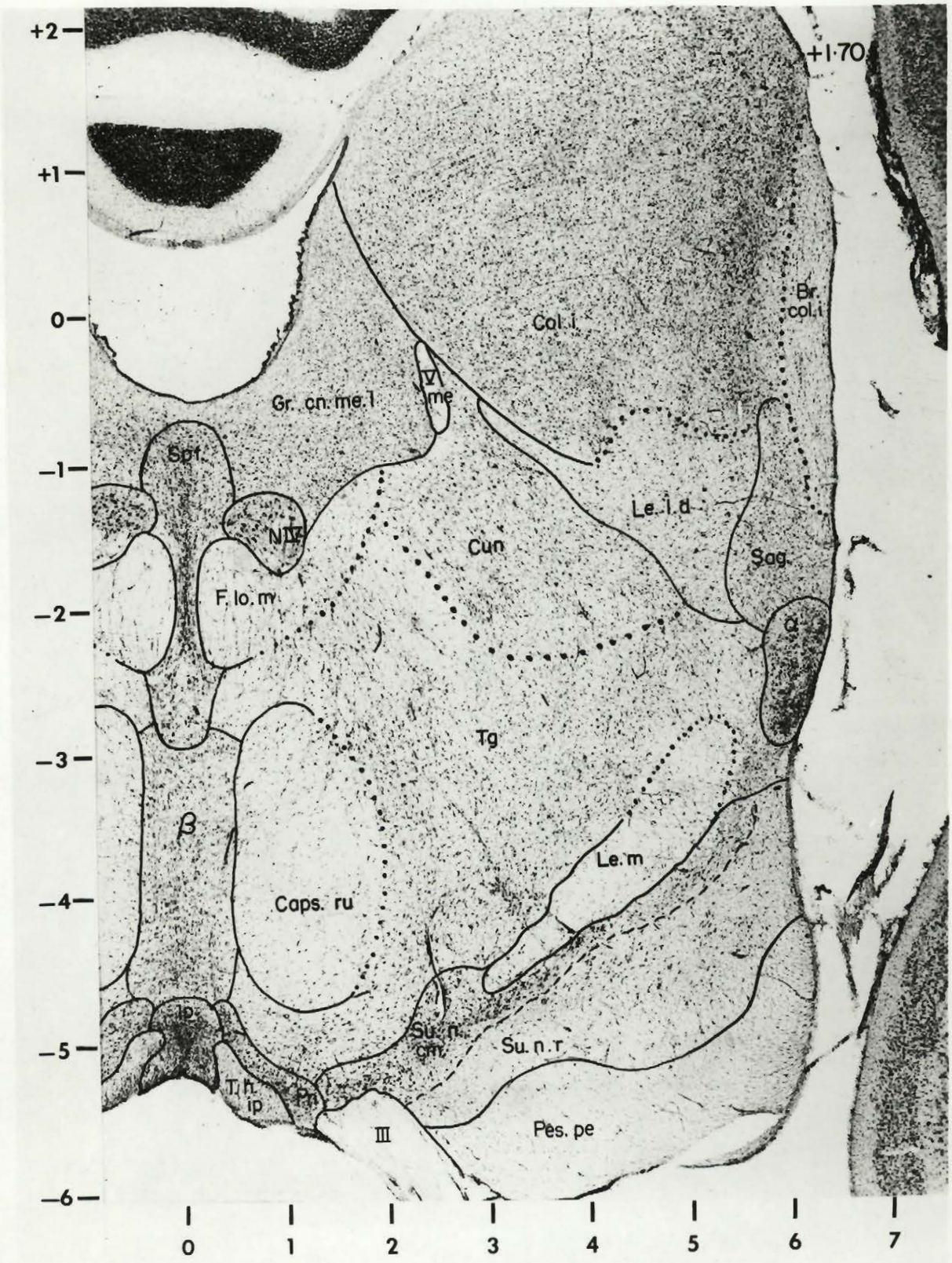
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Pes. pe
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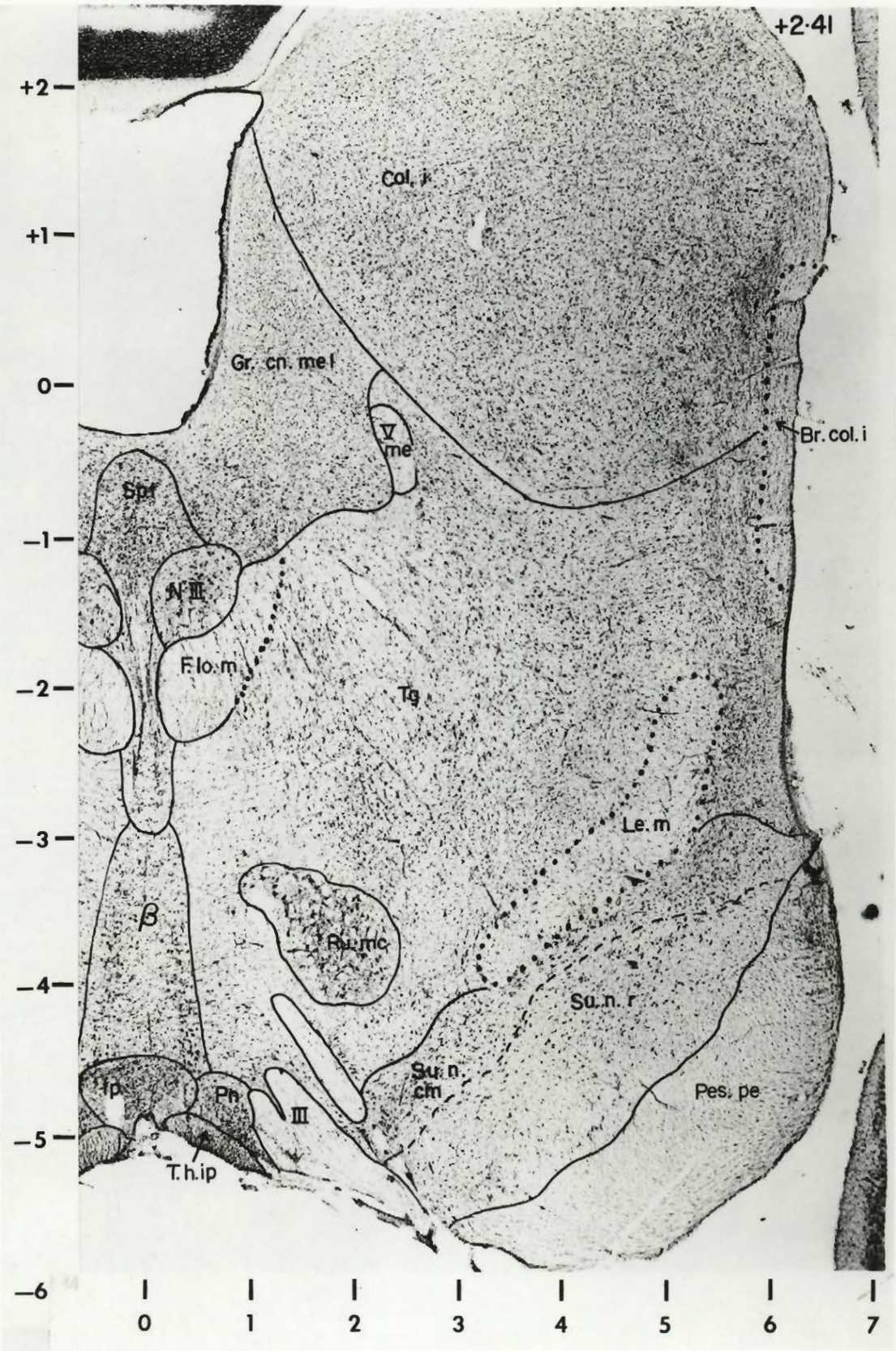
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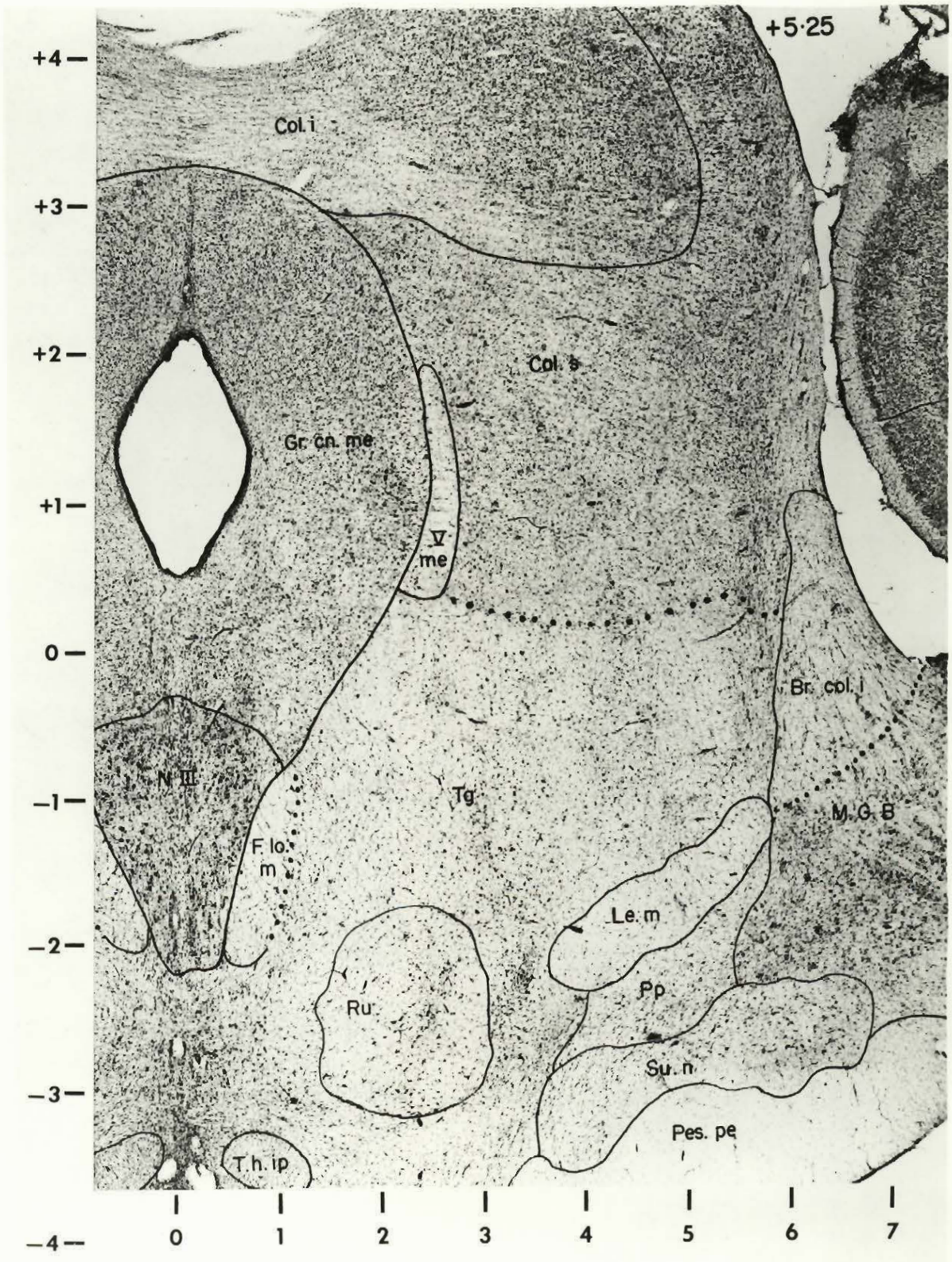
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VII. VARIABILITY AND OTHER SOURCES OF ERROR

Variability is a phenomenon common to most biological systems. It would be futile therefore in the present study either to attempt to eliminate it or to ignore its occurrence. What should be of value is to obtain some idea of its magnitude.

With this end in view, the oblique frontal planes of certain structures have been determined in 13 cats and are laid out in table 1. Similarly the horizontal planes of certain other landmarks in each of the 13 animals are displayed in table 2. In each table the weight of the animal in kilogrammes and the sex, when known, have been added. The choice of landmarks for these tables presented a problem. It was clearly desirable to use structures or other landmarks which were crisply definable and unambiguous so that exactly the same feature was being measured in each animal. It is not possible in a study such as this to distinguish with certainty between, for example, a difference in shape of the motor nucleus of the trigeminal nerve and a minor difference in its position along the oral-caudal axis of the brain stem. There are thus at least two factors involved in this variability. A further consideration in the choice of landmarks was the need to have them spread throughout the oral-caudal and vertical extents of the Atlas. A study of the tables shows that this has been to some extent achieved.

Before accepting the variations shown as intrinsic, and therefore inevitable in the use of this method and animal species, we must consider whether experimental error contributes to them in significant amount. Some experimental error is inevitable. Steps taken to minimize it are described in chapter III under materials and methods. The method of photographic control during cutting of frozen sections provides an excellent check on the histological phase of the work. In the earlier stages care was taken that calibration of the stereotaxic instrument was exact, that the angles of the markers were correct and that the animal was properly mounted in the machine. At this earlier stage, however, there are two factors which are difficult to control. In the first place, brain tissue swells during fixation with formalin, even isotonic formalin solution. Consequently, the presence of craniectomies, even though small, will combine with this swelling to produce distortion of brain structures. Markers which were inserted exactly parallel will no longer be exactly so after 48 hours of fixation. The amount of this distortion was observed to be small but it was present. The second source of error occurring early in the procedure was the tendency of thin, delicate markers to bend when advanced into the depths of the brain. This tendency was minimized by inserting the markers slowly and carefully, and by using markers of fine drawn glass which resists deformation. When excessive deformation did occur, the glass marker snapped and the animal was rejected from the series.

We are led to believe therefore that much of the variation shown in the tables is intrinsic to the animal studied. Certain trends emerge. Variability in oral-caudal position of structures is, in general, greater than their variation in vertical position. Contrary to expectation, caudally situated structures such as the caudal end of the nucleus medullae oblongatae lateralis and the opening of the obex were more constant than, for example, the position of the nucleus of Gudden or the trochlear nucleus. There was a disappointing lack of confirmation of the simple hypothesis that heavier cats would have bigger brains with longer brain stems. For example in cat B 11, weighing 2.7 kilogrammes, the distance from the caudal end of nucleus medullae oblongatae lateralis to the caudal end of the red nucleus was 26.81 mm., whereas in the heavier cat B 4 weighing 3.4 kilogrammes, the interval between these landmarks was 26.0 mm. In the even heavier cat B 7 weighing 3.7 kilogrammes, the interval between these landmarks was 24.5 mm.

It seems unlikely then that increased accuracy can be obtained by simple application of a weight factor to the coordinates given in the Atlas. It is possible that with the repeated use of this Atlas and the accumulation of data from many animals, a more complex pattern of predictable variation will emerge and that this pattern will serve as a guide for the experimenter in the future.

VIII. METHODS OF USE OF THE ATLAS

Little need be said of the methods of application of this Atlas as it follows, in most respects, the standard format for such atlases. The Atlas is designed for use with electrodes or other instruments oriented in an oblique frontal plane at 45° to the Horsley-Clarke baseline and its advantages are lost if other planes such as the horizontal plane are used.

The main point requiring care is the calculation of horizontal plane. After making the calibration for the horizontal 0, all movements of the electrode carriage (other than lateral) in the oblique frontal plane must have a factor of 1.4 applied to them to obtain the vertical displacement of the needle tip. Failure to observe this inherent geometrical feature of the atlas will vitiate all results.

As in all stereotactic work the experiment should include, at its termination, the cutting of histological sections to verify the sites of stimulation, recording and so on. The need for this is emphasized by the variability in position of structures demonstrated in this study.

Whether the degree of uncertainty of localization by stereotaxic technique described here will be acceptable to an experimenter clearly depends, inter alia, on the design of his experiments. Localization may be improved in the lower brain stem by observation of surface landmarks and correlation of them with the deeper structures portrayed in the Atlas.

Unfortunately this method cannot be applied to more oral structures lying under cover of the cerebellum and here one is restricted to the use of electrophysiological aids to localization.

IX SUMMARY

1. The purpose of this work is to provide an anatomical guide for stereotaxic localisation in the brain stem of the cat.

2. In order to facilitate the approach to the brain stem, an oblique 45° frontal plane was employed.

3. Technical difficulty due to distortion and shrinkage of the tissue during processing was given particular attention. Frozen section technique with photographic control was devised and its use is described.

4. A series of fifteen photomicrographic plates at selected levels is presented. The nuclei at these levels have been outlined. The cytoarchitecture of these nuclei is briefly described.

5. Considerable variation in the position of individual anatomical landmarks has been encountered. This appears to be mainly intrinsic rather than due to experimental error. Suggestions for use of the Atlas bearing this variability in mind are made.

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XI. ACKNOWLEDGEMENTS

This work was started some time ago at the suggestion of Dr. Herbert Jasper and has since had the benefit of his encouragement, advice and unfailing patience.

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Mr Charles Hodge and M. Jean Garneau did the photography.

Mrs. E. Campbell and Mrs. R. Fudge typed the manuscript.

My greatest debt is to Dr. Jerzy Olszewski of the Chair of Neuropathology, University of Toronto for his guidance on many aspects, more especially on the intracacies of brain stem cytoarchitectonics.

TABLE I. A COMPARISON OF OBLIQUE FRONTAL PLANES OF CERTAIN STRUCTURES

STRUCTURE ETC.	Cat At 2	Cat At 12	Cat B1	Cat B4	Cat B5	Cat B6	Cat B7	Cat B8	Cat B9	Cat B10	Cat B11	Cat B12	Cat B17	Range in mms
Wt. in Kg	1.3	2.3	2.1	3.4	3.0	2.2	3.7	3.4	3.0	2.7	2.7	2.7	2.9	
Sex	?	F	M	?	F	F	M	M	M	F	F	M	F	
Caudal end of L. v	-24.0	-24.0	-25.68	-24.6	-24.5	-23.8	-23.8	-24.3	-22.84	-25.38	-24	-24.8	-23.86	2.84
Obex - opening	-19.0	-19.5	-20.0	-19.2	-20.0	-18.5	-19.2	-19.35	-17.78	-19.32	-18.5	-20.0	-18.89	2.22
Oral end of Ol.i. pr	-16.0	-16.0	-18.49	-16.7	-16.4	-15.7	-16.8	-17.25	-14.23	-14.94	-15.65	-16.5	-16.05	4.26
Oral end of N. VII	-12.5	-12.0	-13.52	-12.1	-12.5	-11.8	-12.8	-13.05	- 9.97	-12.02	-11.39	-11.9	-11.79	3.55
Caudal end of V mo	-8.0	-7.4	-9.97	-7.5	-8.0	-7.4	-8.5	-8.85	-5.71	-6.91	-7.13	-8.0	-7.53	4.26
Nucleus of Gudden	-3.0	-2.0	-5.0	-2.9	-2.9	-2.2	-3.6	-3.25	-0.74	-1.07	-2.16	-2.41	-2.56	4.26
N. IV	+0.76	+1.48	-1.45	+0.7	+0.7	+1.4	0.0	+0.95	+3.5	+3.31	+1.8	+1.99	+1.70	4.95
Caudal end of red nucleus	+0.5	+2.5	-0.03	+1.4	+1.4	+2.0	+0.7	+1.65	+4.23	+4.04	+2.81	+2.72	+2.41	4.26
Postero-superior margin of foramen magnum	?	?	-23.75	-23.25	-24.25	-24.25	-23.25	-24.25	-23.25	-23.75	-22.75	-22.75	-23.75	1.50

TABLE 2. A COMPARISON OF HORIZONTAL PLANES OF CERTAIN STRUCTURES

STRUCTURE ETC.	Cat At 2	Cat At 12	Cat B1	Cat B4	Cat B5	Cat B6	Cat B7	Cat B8	Cat B9	Cat B10	Cat B11	Cat B12	Cat B17	Range in mms
Wt. in Kg.	1.3	2.3	2.1	3.4	3.0	2.2	3.7	3.4	3.0	2.7	2.7	2.7	2.9	
Sex	?	F	M	?	F	F	M	M	M	F	F	M	F	
Central canal at OF-24 (L.v)	-7	?	-7.7	-8.0	-8.7	-8.3	-6.25	-8.0	-8.0	-7.5	-8.	-6.6	-8.4	2.45
Ol. i. d at OF -18 (obex)	-8.5	-8.5	-9.4	-8.7	-9.4	-9.05	-7.7	-8.7	-8.8	-8.7	-9.26	-8.0	-8.7	1.7
Dorsal surface of pyramid at OF-16. (oral end ol. i)	-9	-8.7	-10.1	-9.4	-9.75	-9.7	-8.7	-9.4	-9.4	-9.05	-9.4	-9.1	-9.4	1.4
Head of Ol.s.m. at OF-12.5(oral NVII)	-6.75	-8.0	-8.0	-7.5	-8.0	-8.0	-7.3	-8.0	-7.16	-7.44	-7.6	-7.3	-7.2	1.25
Caudal end of V mo at OF-8	-3.5	-4.35	-5.4	-4.0	-4.85	-4.5	-4.05	-3.5	-3.0	-4.05	-4.6	-4.5	-4.3	1.85
Middle of Gud. at OF-3	-1.3	-2.81	-4.0	-1.5	-3.0	-3.0	-1.81	-1.6	-1.25	-2.2	-2.3	-3.0	-3.2	2.7
Middle of N IV	0	-1.2	-2.95	-0.5	-1.6	-1.25	-0.55	-0.2	+0.15	-0.55	-0.2	-1.64	-1.4	3.1
Middle of caudal red nucleus	-2.2	-3.5	-4.7	-3.65	-4.05	-3.5	-3.0	-2.7	-1.95	-2.8	-2.7	-4.4	-3.6	2.5