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https://doi.org/10.4224/21273363

A STEREOTAXIC ATLAS

OF THE

DIENCEPHALON OF THE CAT

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Published by

THE NATIONAL RESEARCH COUNCIL OF CANADA
OTTAWA 2, CANADA

INTRODUCTION

NEW conceptions of the functional organization of the brain have been developed during recent years from neurophysiological studies of dynamic interrelationships between the cerebral cortex and subcortical structures in diencephalon and brain stem. Such studies are made possible by a stereotaxic instrument. By means of a rigid metal frame attached to the skull of the cat, fixed in position by reference to standard skull landmarks, this instrument makes it possible to direct an electrode, with three-dimensional control, into local points in the depths of the brain with considerable accuracy.* Local electrical stimulation or destruction by coagulating currents can then be carried out in the diencephalon or brain stem without significant damage to overlying structures. Recording electrodes can also be used, or local injections of chemical substances may be made by means of a microsyringe.

A stereotaxic instrument has been in use for a variety of problems in our laboratories during the past 15 years. We were aided greatly in this work by the development of instruments and the anatomical studies of Professor Ranson and his colleagues. The atlas of Ingram, Hannett, and Ranson (1932) and the modifications introduced by Gerard Marshall and Saul (1936) have been found most useful. For the thalamus of the cat the three-dimensional drawings of Jimenez-Castellanos (1949) by the method of Krieg are of considerable interest and value. However, in the course of our experiments, a number of corrections in the coordinates were found to be necessary for accurate experimental work. Extension of our studies have made necessary additional maps of portions of the rhinencephalon and other subcortical structures (septal region, amygdaloid nucleus, striatum, hypothalamus, and upper mid-brain) so that a variety of experiments can be carried out with the same atlas and coordinate system.

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*For further discussion of the principles and aims of the stereotaxic instrument reference should be made to the original publication of Horsley and Clarke (1908) and the excellent treatise by Clarke (1920). A stereotaxic method and atlas for use in man has recently been published by Spiegel and Wycis (1952).

In the initial stages of our work we were fortunate in having the collaboration of Dr. J. Droogleever-Fortuyn, whose thorough knowledge of the anatomy of the thalamus has been of great assistance. With the constant advice and assistance of Dr. Olszewski, who published a splendid stereotaxic atlas of the thalamus of the monkey (1952), we have gradually revised our atlas of the cat in the light of numerous experimental studies with many colleagues during the past 5 years.

An outline of the principal subdivisions of the amygdaloid nucleus is a recent addition. We wish to acknowledge the assistance of Dr. Peter Gloor in its preparation. Physiological studies which he and Dr. W. Feindel and many others have been carrying out on the Amygdaloid and related structures has prompted us to include this area with other diencephalic structures.

PRINCIPLES OF THE STEREOTAXIC METHOD

Two points on each side of the skull form the basic landmarks upon which the three-dimensional coordinate system is developed. Most important of these is the inter-aural line connecting the center of each external auditory meatus. The center of the inferior orbital ridge forms the second reference point.

The basal horizontal plane of the instrument passes through the inter-aural line and the inferior orbital ridges, right and left. Although this forms the basal plane it is not the zero horizontal plane of the coordinate system suggested by Clark and now used by most workers. The zero horizontal plane is arbitrarily taken 1 cm. above the inter-aural basal plane in the cat. Since the total distance from the inter-aural line to the vertex of the brain in the cat is 28–30 mm. the zero horizontal plane (1 cm. above the inter-aural line) is about ⅓ this distance above the basal plane. This is a rather arbitrary convention, but it has been adopted in most laboratories. In our work we habitually take, as the horizontal zero of the instrument, a plane 1 cm. above the inter-aural line. Horizontal planes above zero are indicated by H 1, H 2, etc., while those below zero are designated H -1, H -2, etc. in millimeters (see fig. 1).

Frontal planes are coronal sections of the brain at

right angles to the basal plane. The zero frontal plane passes through the inter-aural line. Rostral to this line successive frontal planes are indicated by F 1, F 2, etc. (see figs. 1, 2, and 4). Caudal to the inter-aural line frontal planes are indicated by F -1, F -2, etc. in millimeters. The entire diencephalon lies rostral to the inter-aural line so that only positive F numbers appear in this Atlas.

Examples of coronal sections taken through frontal planes F 2 to F 14 are shown in Figure 4. It will be noted that F 2 passes through the upper mid-brain and pons in an oblique direction as compared to the usual coronal section for anatomical studies. The thalamus lies between frontal planes F 3 and F 13; F 14 shown in Figure 2 passes through the optic chiasm, anterior commissure, septum and the head of the caudate nucleus.

Lateral planes are sagittal sections measured from the midline between the two hemispheres (see fig. 3). Those to the left of the midline are designated LL 1, LL 2, etc., while those to the right are RL 1, RL 2, etc., in millimeters. Lateral and frontal planes, looking at the base of the cat's brain, are shown in Figure 4.

The stereotaxic method is most accurate in the cat because of the relatively constant relations existing between skull landmarks and brain structures, and because of the relatively constant size and shape of the brain. With experience, and with sufficient care in the calibration of electrodes in the instrument prior to an experiment, one should be able to place the tip of an electrode at any desired point within ± 0.5 mm. However, anatomical controls are always necessary.

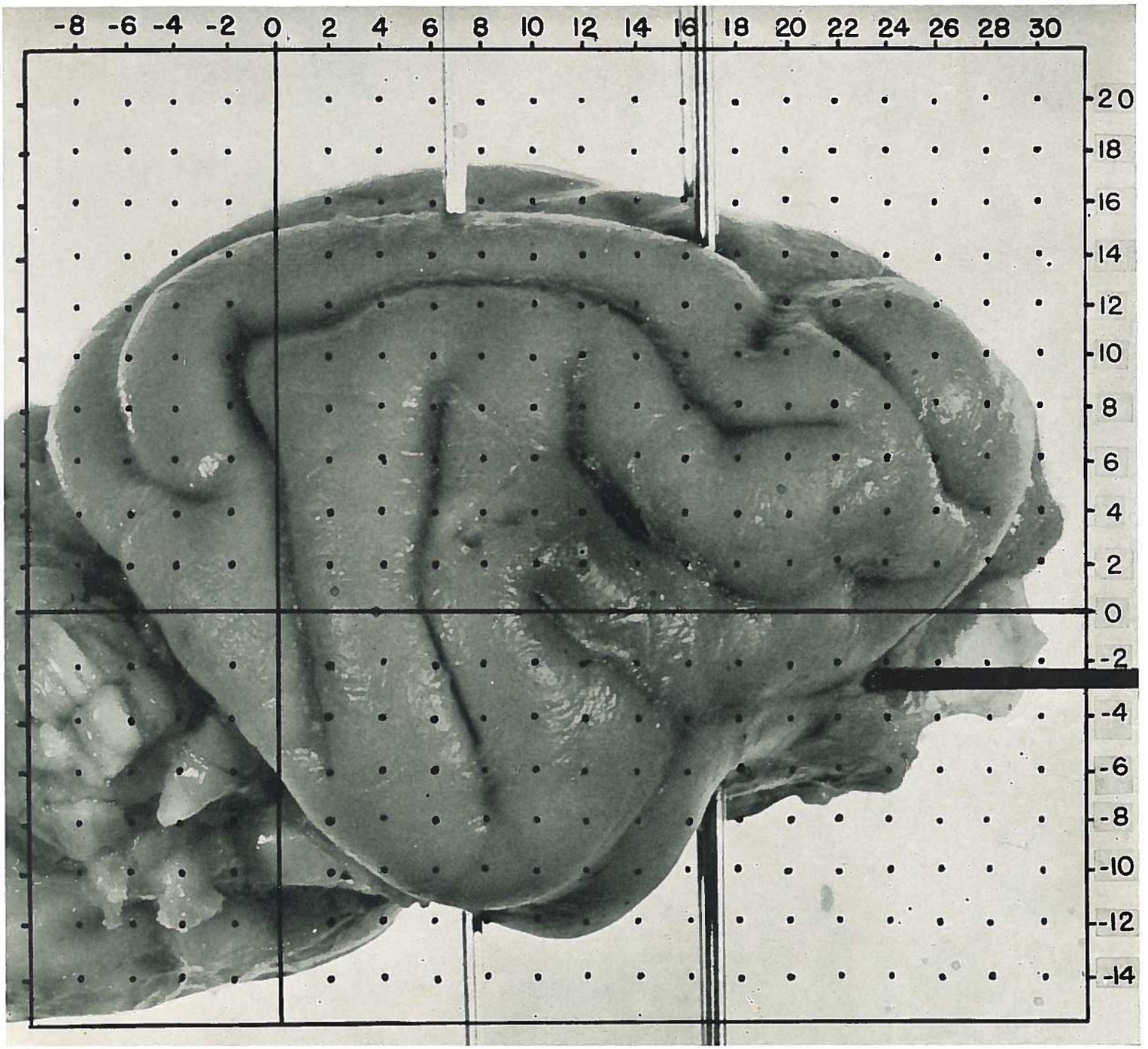

FIG. 1

Photograph of the cerebral cortex of the cat upon which has been superimposed the horizontal and frontal coordinates of the Horsley-Clark stereotaxic system. This is a lateral view of the right hemisphere, frontal to the right. Steel marking needles had been placed with the stereotaxic instrument before removing the brain from the skull. The horizontal needle was placed at H –2.5 (calibrated at its inferior surface). Vertical needles were placed at frontal planes F 16.5 and F 6.5 (anterior calibration). Note that the distance between horizontal zero and the vertex was about 18 millimeters in this cat; this is about an average figure. The measurements are indicated in millimeters.

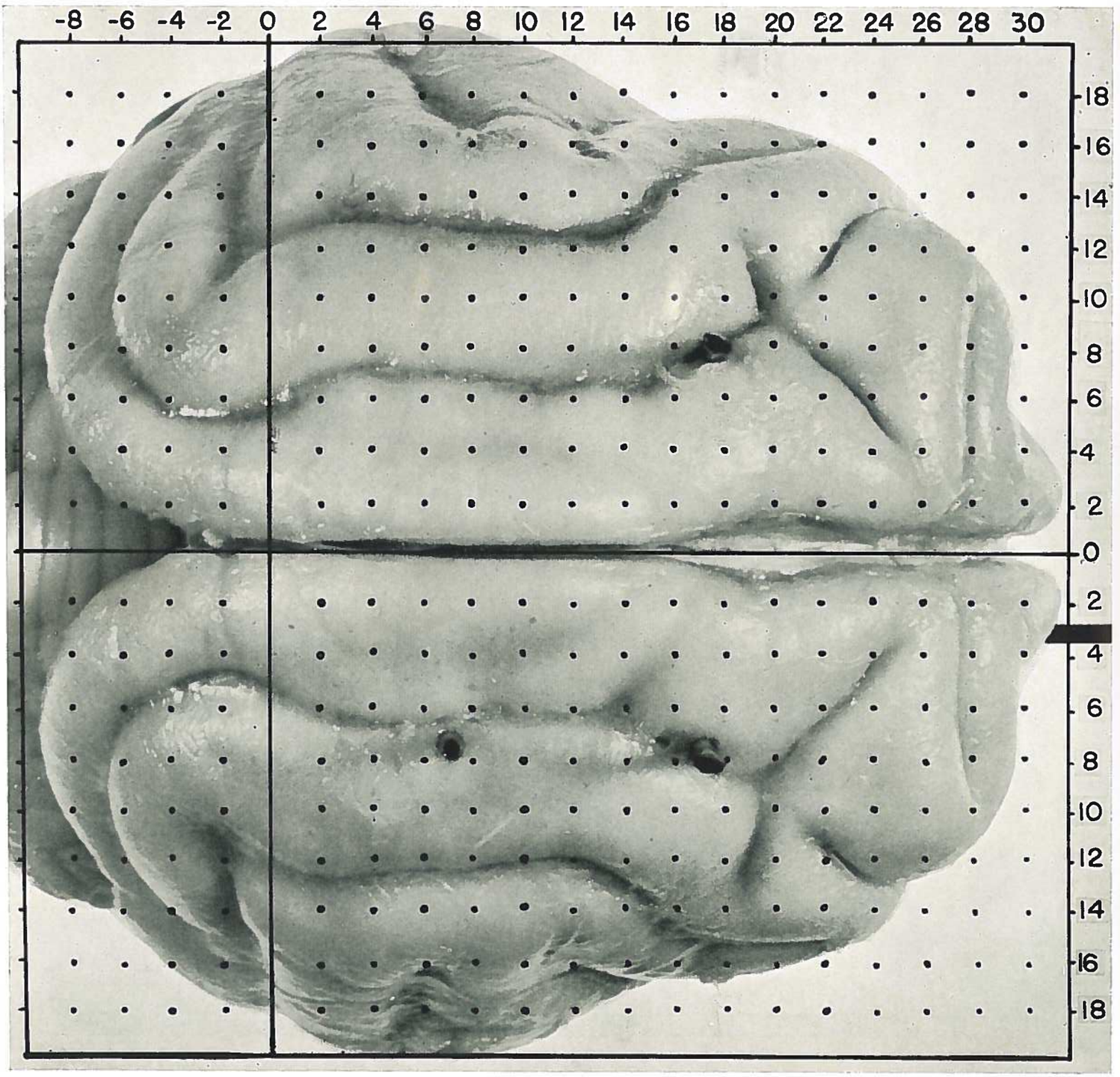

FIG. 2

Photograph looking down on the superior surface of the cerebral hemispheres of the cat brain. The lateral and frontal planes of the stereotaxic coordinates are superimposed, measurements indicated in millimeters.

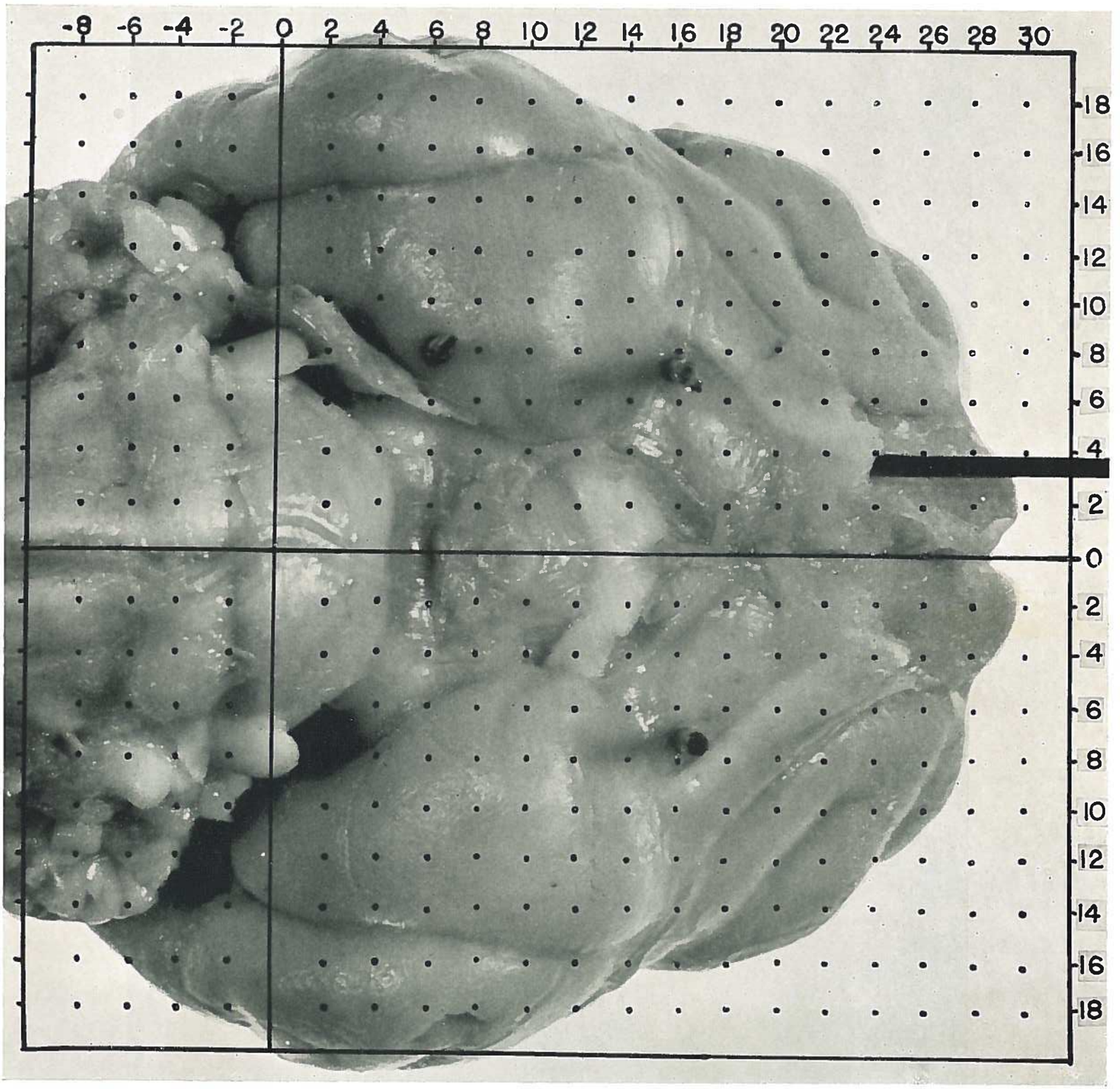

FIG. 3

A basal view of the cat brain showing superimposition of lateral and frontal stereotaxic coordinates measured in millimeters.

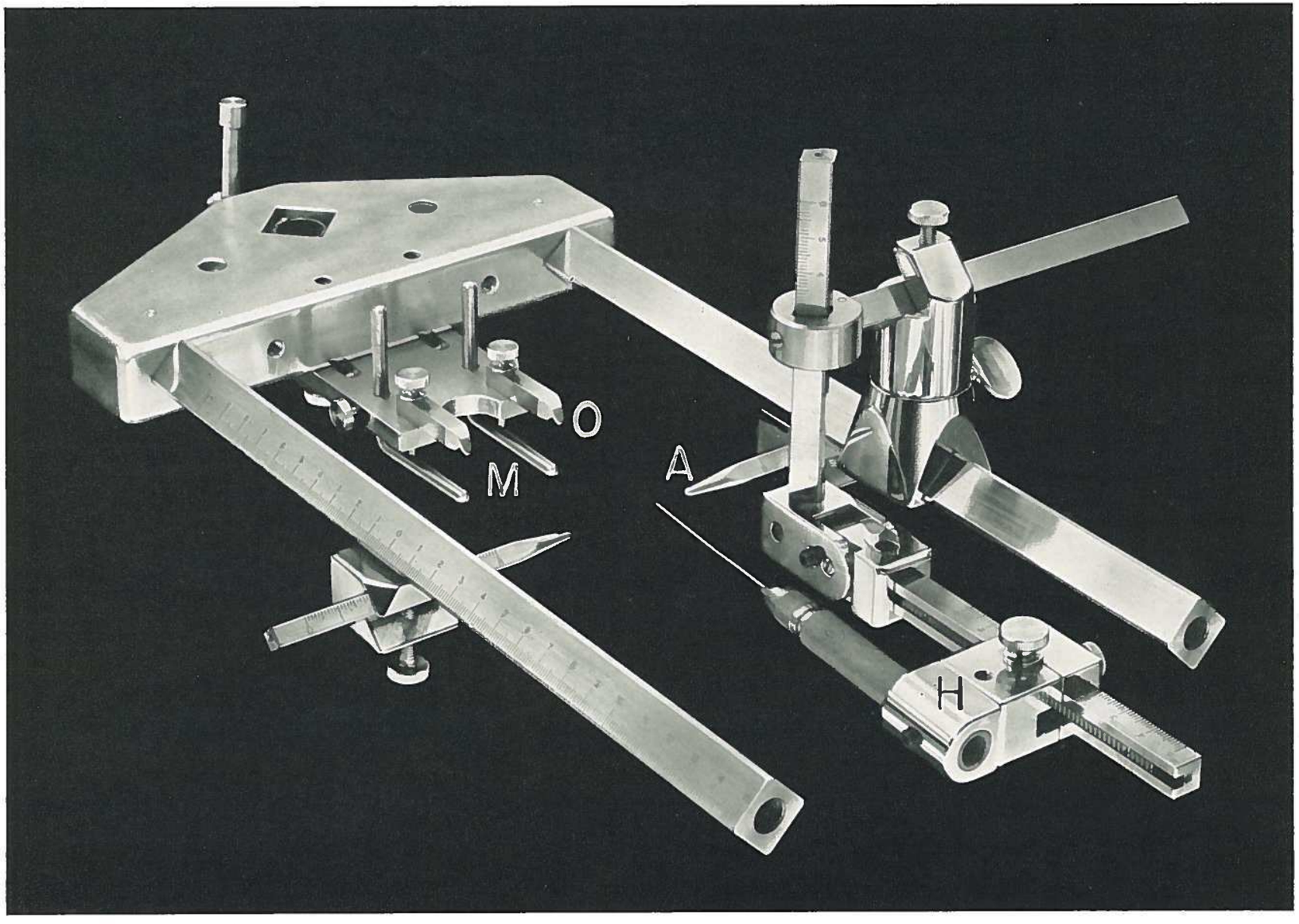

FIG. 4

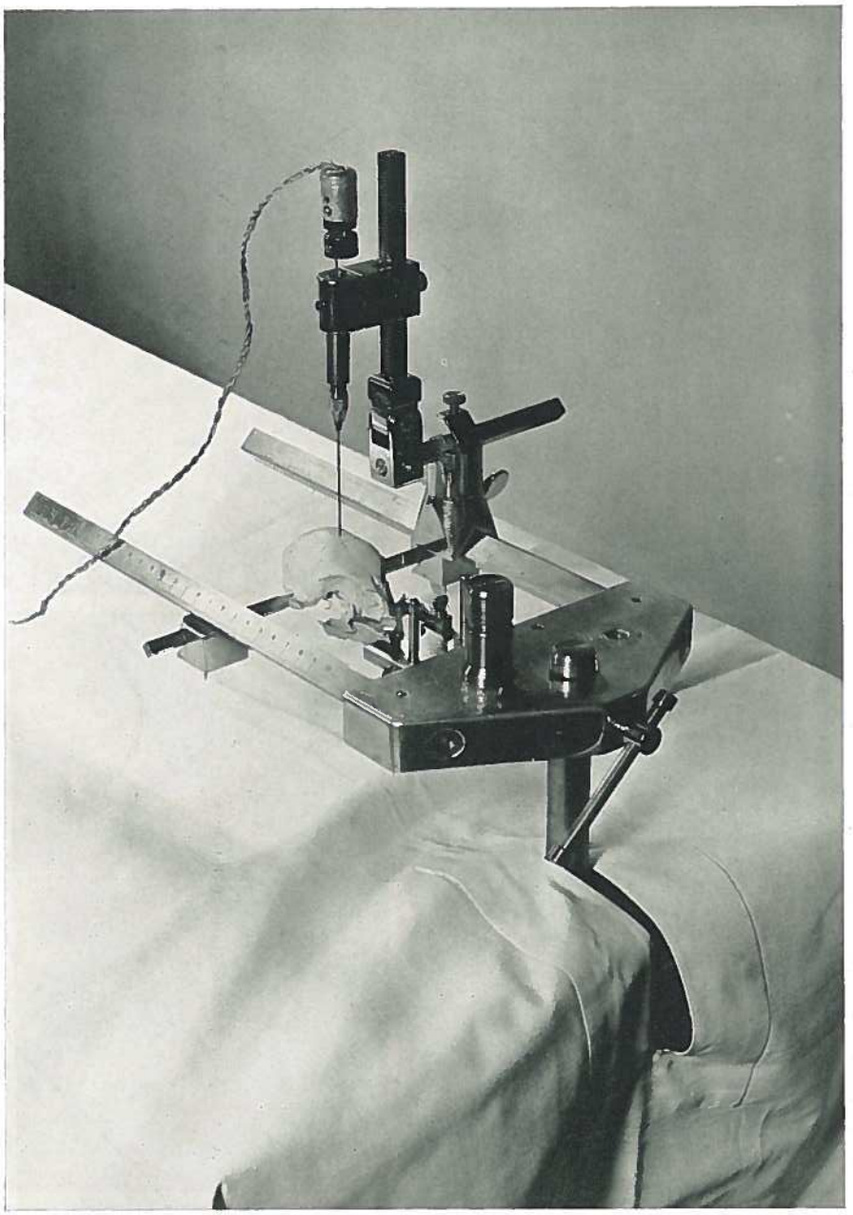

FIG. 5

STEREOTAXIC INSTRUMENTS

THERE are several good stereotaxic instruments of different design now available. The one we are now using will serve as an example. They all provide for firm fixation of the skull by means of rigid bars inserted into the external auditory meati (fig. 4 A). Hooked bars are then placed on the inferior orbital ridges (fig. 4 O) and the head clamped solidly in place by two bars (fig. 4 M) inserted into the mouth against the upper teeth. Adjustable electrode carriers are provided for insertion either in the vertical direction or in the horizontal direction (H). Radial adjustments provide for insertion at oblique angles as well. In Figure 5 is shown another view of this instrument mounted on the table with a cat's skull in place and a needle electrode in the vertical position, as used most frequently.

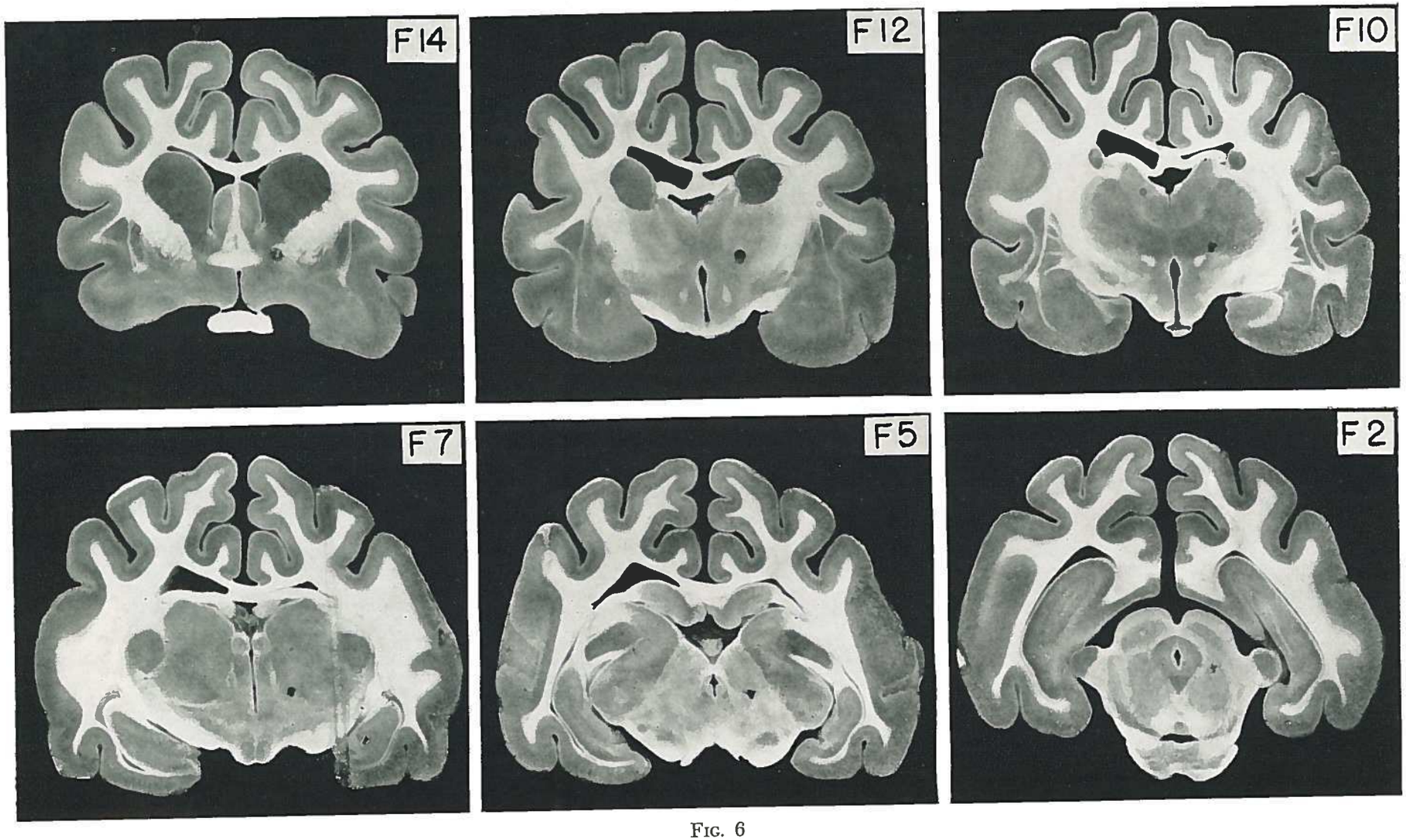

FIG. 6

ANATOMICAL TECHNIQUE

SERIAL coronal sections of the diencephalon of one adult cat were used as the original basis for this atlas, though the coordinate measurements have been corrected by reference to at least 50 cat brains during the course of anatomical controls for various experiments.

Critical electrode positions are marked during the course of an experiment by the electrolytic deposit of iron from the tip of a steel electrode, and the point is stained by the Prussian blue reaction during preparation for histological study, as described by Hess (1932)* and Marshall (1940). The electrode is connected to the positive pole of a 1.5 V battery and the negative pole connected to the frame of the stereotaxic instrument. A current of about 1 to 3 milliamperes for 10–20 seconds usually provides a good mark, depending somewhat upon the size of the exposed tip of the electrode.

Preparation of the brain to obtain the serial section from which microphotographs were taken for this atlas was as follows:

(1) the cat was deeply anaesthetized with Nembutal and its head fixed firmly in the stereotaxic instrument;

(2) the skull was trephined in several places to permit the insertion of stainless steel wire markers;

(3) two horizontal markers were inserted through the posterior fossa extending the entire length of the diencephalon. These were placed at H —4.5 and at L 3 on either side of the midline. Their position is indicated by the two round holes in each of the microphotographs;

(4) vertical marking wires were inserted from above, one on either side of the midline, at F 18 and at F 2. This not only gave a calibration for the frontal planes but provided a guide to the plane of section for setting the microtome;

(5) leaving the needle markers in place in the instrument, the brain was exsanguinated and perfused with 10% formalin and left to harden before the marking wires were removed to take the brain out of the skull;

(6) after adequate fixation portions of the cortex were removed to reduce the size of the block. The anterior end of the block was carefully sectioned in the frontal plane of the stereotaxic instrument along the markers left in place for this purpose. The block was then mounted on the microtome and frozen for serial sections according to the method of Marshall (1940). Frozen sections were chosen, instead of paraffin, to avoid the shrinkage and distortion of the paraffin method, even though the histological results with frozen sections are less perfect, as will be noted on some of the microphotographs presented here;

(7) serial sections were made at 50 micra thickness. A pair of adjacent sections at 0.5 mm. intervals were mounted on slides. One of these was stained for cells by the method of Nissl and the other for myelinated fibres by the method of Weil;

(8) the sections were then projected, enlarged exactly ten times, onto sheets of drawing paper. The principal nuclear outlines and fibre tracts were traced directly on the projection. These tracings were then corrected in detail by microscopic study. Nuclear structures were first differentiated on a cytoarchitectural basis, but their location was corrected for the average cat brain by reference to the anatomical controls of numerous physiological studies.

*The ferrocyanide formalin alcohol method of fixation of Hess makes it possible to stain the electrode positions with perfusion fixation of the brain. The fixing solution is prepared as follows: 15 mg. potassium ferrocyanide, dissolved in 1350 cc. dist. water, 150 cc. formalin (40%) and 750 cc. abs. alcohol. To this stock solution are added a few drops of glacial acetic acid (2 cc. per 100 cc.) just at the time perfusion is carried out. The brain is then kept in 10% formalin for 6–8 days before sectioning.

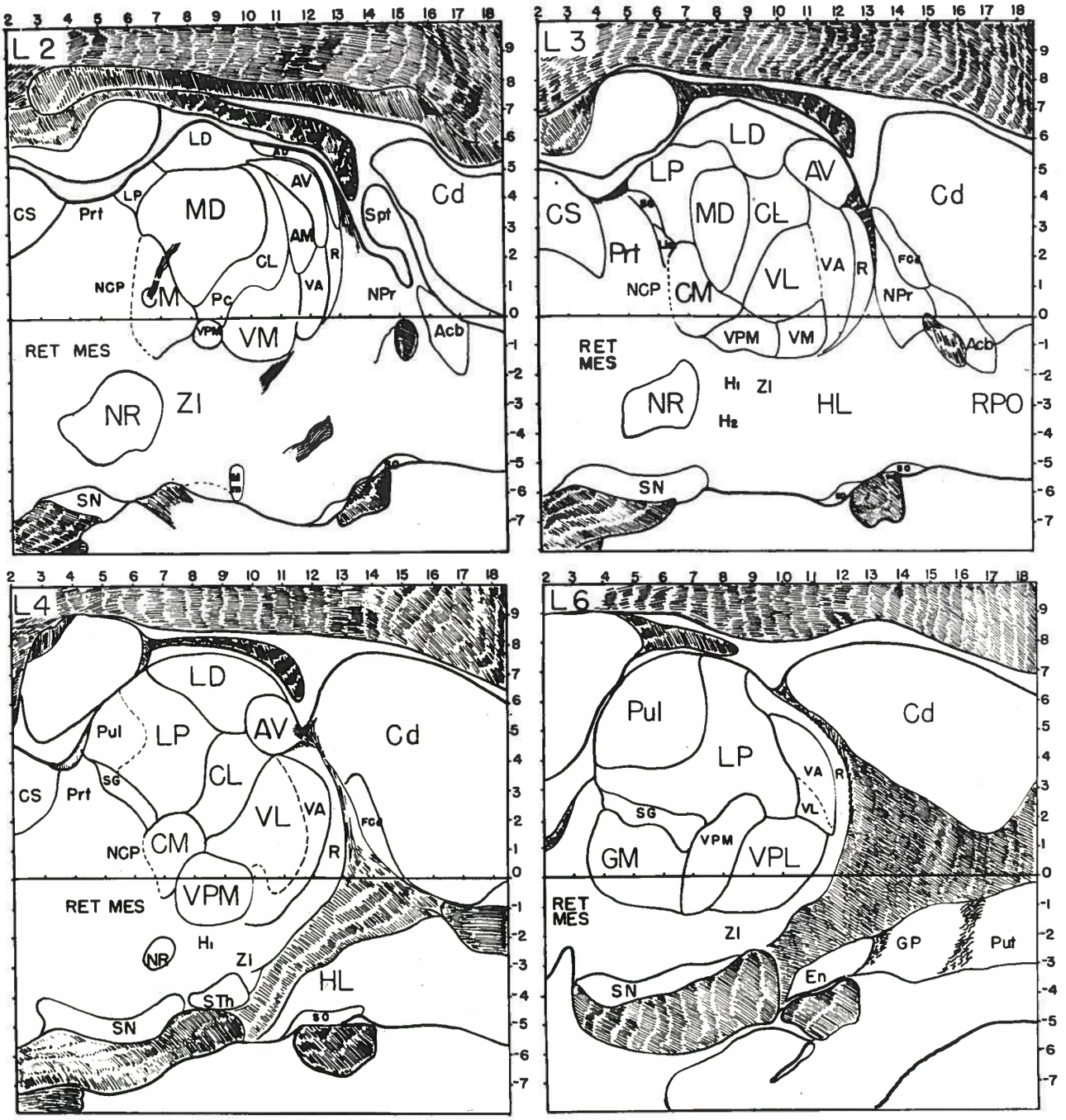

FIG. 7

Serial sagittal sections were made from the brain of another cat prepared in a manner similar to that described above. After marking and fixation in the stereotaxic instrument, the two hemispheres were divided in the midline. Serial frozen sections were made in sagittal planes, alternate sections being stained for cells and fibres each 0.5 mm. as described above.

Drawings of principal nuclear outlines were made by projection and microscopic study. The location of nuclei was then checked carefully against a detailed reconstruction of the sagittal planes from the location of structures outlined from the coronal sections. In this manner a concordance of coordinates between the coronal and sagittal drawings was obtained. Sagittal section diagrams in four lateral planes, L 2, L 3, L 4, and L 6, are shown in figure 7. These drawings are reproduced five times natural size.

EXPLANATION OF CORONAL SECTIONS

THE series of photomicrographs and drawings of coronal sections which follow are reproduced ten times natural size so that measurements can be made directly with a centimeter rule expressed in millimeters. Frontal planes F 2 to F 18.5 are presented. Between F 6 and F 16 these are at 0.5 mm. intervals, the remainder at 1.0 mm. intervals. The zero horizontal line in the drawings represents the zero plane of the stereotaxic instrument, 1 cm. above the basal plane of the inter-aural line.

Facing each drawing are microphotographs of adjacent sections at the same frontal plane, the one on the left representing the Nissl stain and one on the right the Weil stain for fibres.

The nomenclature employed was largely that used by Walker for the monkey (1938) with occasional modifications suggested by Olszewski. There were a number of places where division lines were uncertain. For example, the division line between the caudal portion of the n. Centrum Medianum and the pretectal region was rather obscure, and in the lateral border of n. Medialis Dorsalis there were a group of large cells which may not properly belong to this nucleus. Such regions are indicated by dotted lines. In frontal planes F 11.5, F 12, and F 12.5, there was a group of cells in the mesial portion of the thalamus, mesial to the n. Antero-Medialis, which seemed distinct but for which we have no name. Other corrections will undoubtedly have to be made with further work. Latin terms have been used to avoid language difficulties.

Although the location of structures in the cat brain is remarkably constant, slight individual variations do occur and some allowance must also be made for experimental errors. Consequently, careful histological controls must be made for each experiment, with attention to cytoarchitectural detail in each case. The Atlas must be considered only a guide, not to be followed blindly by reference only to its coordinate system, but rather by reference to careful microscopic study of electrode positions marked in each experiment.

The drawings of the coronal sections have been found to be useful for the plotting of electrode positions during the course of a series of neurophysiological experiments. In order to facilitate their use in this manner separate sheets may be purchased from the National Research Council, Ottawa, Canada, under whose auspices this Atlas is published.

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NOMENCLATURE: KEY TO ABBREVIATIONS

Aa	Area amygdaloidea anterior
Ab	N. amygdaloideus basalis
Abm	N. amygdaloideus basalis (pars magnocellularis)
Abp	N. amygdaloideus basalis (pars parvocellularis)
Ac	N. amygdaloideus centralis
Acb	N. accumbens
Acl	N. amygdaloideus centralis (pars lateralis)
Acm	N. amygdaloideus centralis (pars medialis)
Aco	N. amygdaloideus corticalis
AD	N. anterior dorsalis
aHd	area hypothalamica dorsalis
AL	ansa lenticularis
Al	N. amygdaloideus lateralis
AM	N. anterior medialis
Am	N. amygdaloideus medialis
ATR	anterior thalamic radiations
AV	N. anterior ventralis
BCI	brachium colliculi inferioris
BCS	brachium colliculi superioris
CA	commissura anterior
CC	corpus callosum
Cd	N. caudatus
Ch	chiasma opticum
CI	capsula interna
CL	N. centralis lateralis
Cl	Claustrum
CM	N. centrum medianum
CP	commissura posterior
CS	colliculus superior
Da	N. of Darkschewitsch
DBB	Diagonal band of Broca
DBc	Decussatio brachiorum conguntivorum
En	N. entopeduncularis
EW	N. of Edinger Westphal
FCd	fundus caudati
Fil	N. filiformis
FLM	fasciculus longitudinalis medialis
fsc	fasciculus sub-callosum
FT	fasciculus thalamicus
FX	fornix
GC	griseum centrale
GL	corpus geniculatum laterale
GLV	corpus geniculatum laterale (pars ventralis)
GM	corpus geniculatum mediale
GP	Globus pallidus
GX	commissura of Gasser
H_1, H_2	Forel's fields
Ha	Hypothalamus anterior
HbL	N. habenularis lateralis
HbM	N. habenularis medialis
HL	Hypothalamus lateralis
Hp	Hypothalamus posterior
Hvm	Hypothalamus ventromedialis
IAM	N. interanteromedialis
IP	N. interpeduncularis
Is	N. interstitialis
IV	N. interventricularis
LD	N. lateralis dorsalis
Lim	N. limitans
LM	Lemniscus medialis
LME	Lamina medullaris externa
LP	N. lateralis posterior
mc	pars magnocellularis
MD	N. medialis dorsalis
MFB	median forebrain bundle
Ml	N. mamillaris lateralis
Mm	Corpus mamillare
NIII	N. third nerve
NCM	N. centralis medialis
NCP	N. commissurae posterioris

N Hvm	N. hypothalami ventromedialis
NPL	N. paralemniscalis
NPr	N. prothalamicus
NR	N. ruber
NTof	N. tracti olfactorii lateralis
P	N. posterior
Pc	N. paracentralis
Ped	Pedunculus cerebralis
Pf	N. parafascicularis
Pir	lobus piriformis
PMm	pedunculus mamillaris
Prt	praetectum
Pt	N. parataenialis
PTI	Pedunculus thalamicus inferior
Pul	Pulvinar
Put	Putamen
PVA	N. periventricularis anterior
PVH	N. periventricularis hypothalami
R	N. reticularis
RE	N. reuniens
RET. MES.	Substantia reticularis mesencephalica
Rh	N. rhomboidens
RPO	Regio praeoptica
S	Stria medullaris
Sch	N. supra chiasmaticus
SG	N. suprageniculatus
Sm	N. submedius
SMX	commissura supramamillaris
SN	Substantia nigra
SO	N. supraopticus
Spf	N. subparafascicularis
Spt	Area septalis
ST	Stria terminalis
STh	N. subthalamicus
TbOf	tuberculum olfactorium
THP	tractus habenulo-peduncularis
TMT	tractus mamillo-thalamicus
TO	tractus opticus
TOf	tractus olfactorius
tt	taenia tecta
TTC	tractus tegmentalis centralis
VA	N. ventralis anterior
VL	N. ventralis lateralis
VM	N. ventralis medialis
VPL	N. ventralis postero-lateralis
VPM	N. ventralis postero-medialis
ZI	Zona incerta
III	third nerve

SERIAL CORONAL SECTIONS

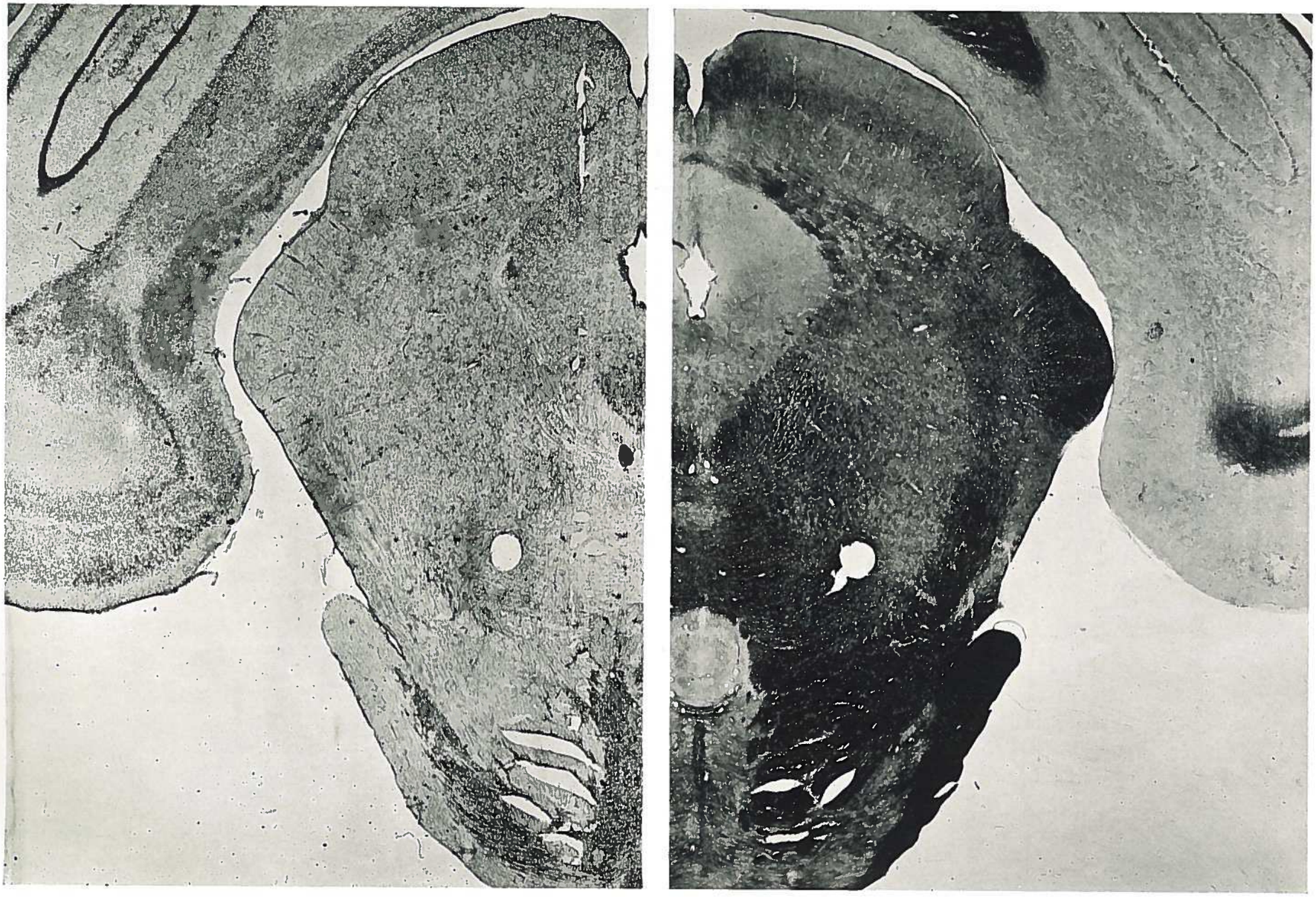
FRONTAL PLANES F 2 to F 18.5

MICROPHOTOGRAPHS

and

DRAWINGS

Magnification X 10



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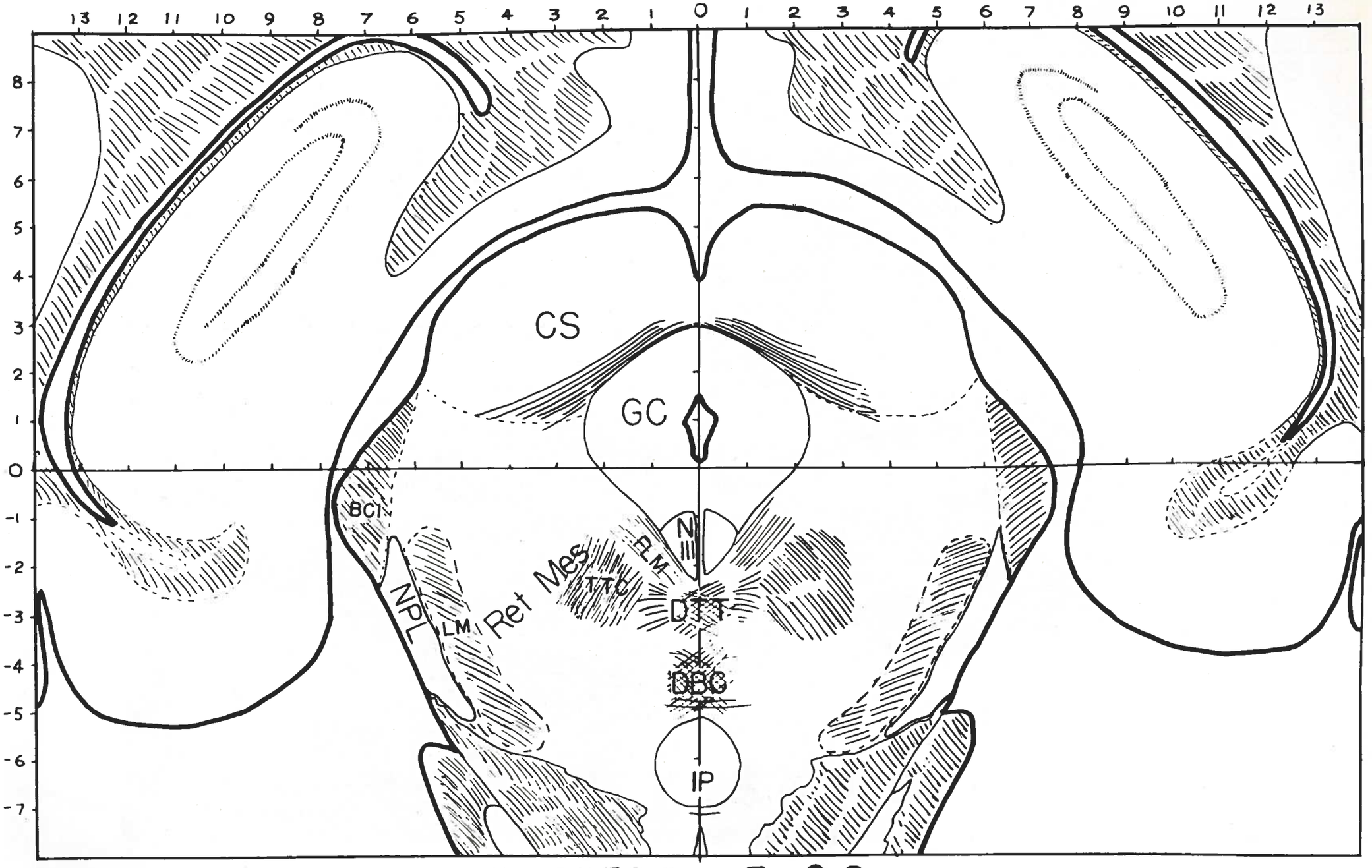

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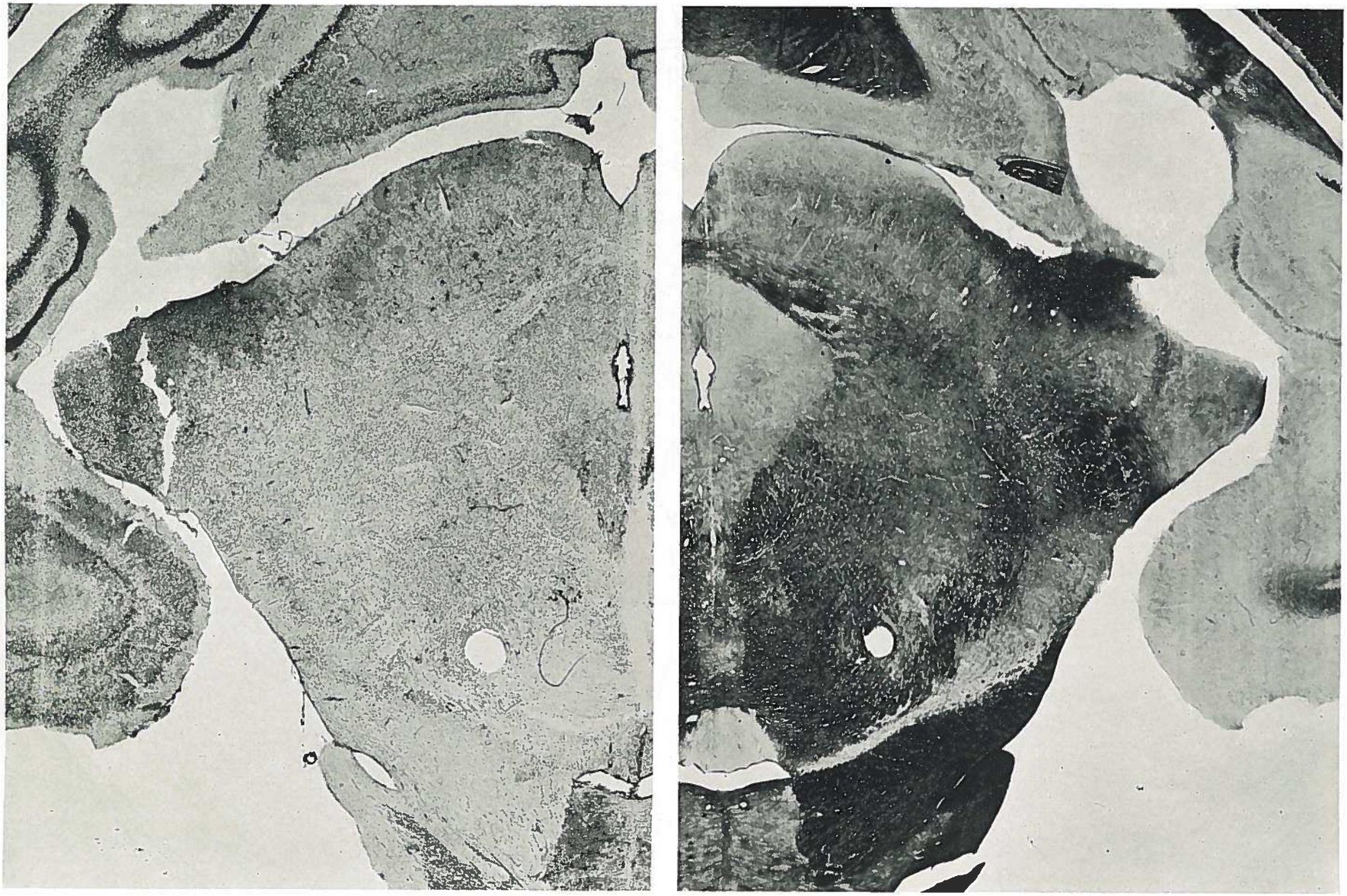

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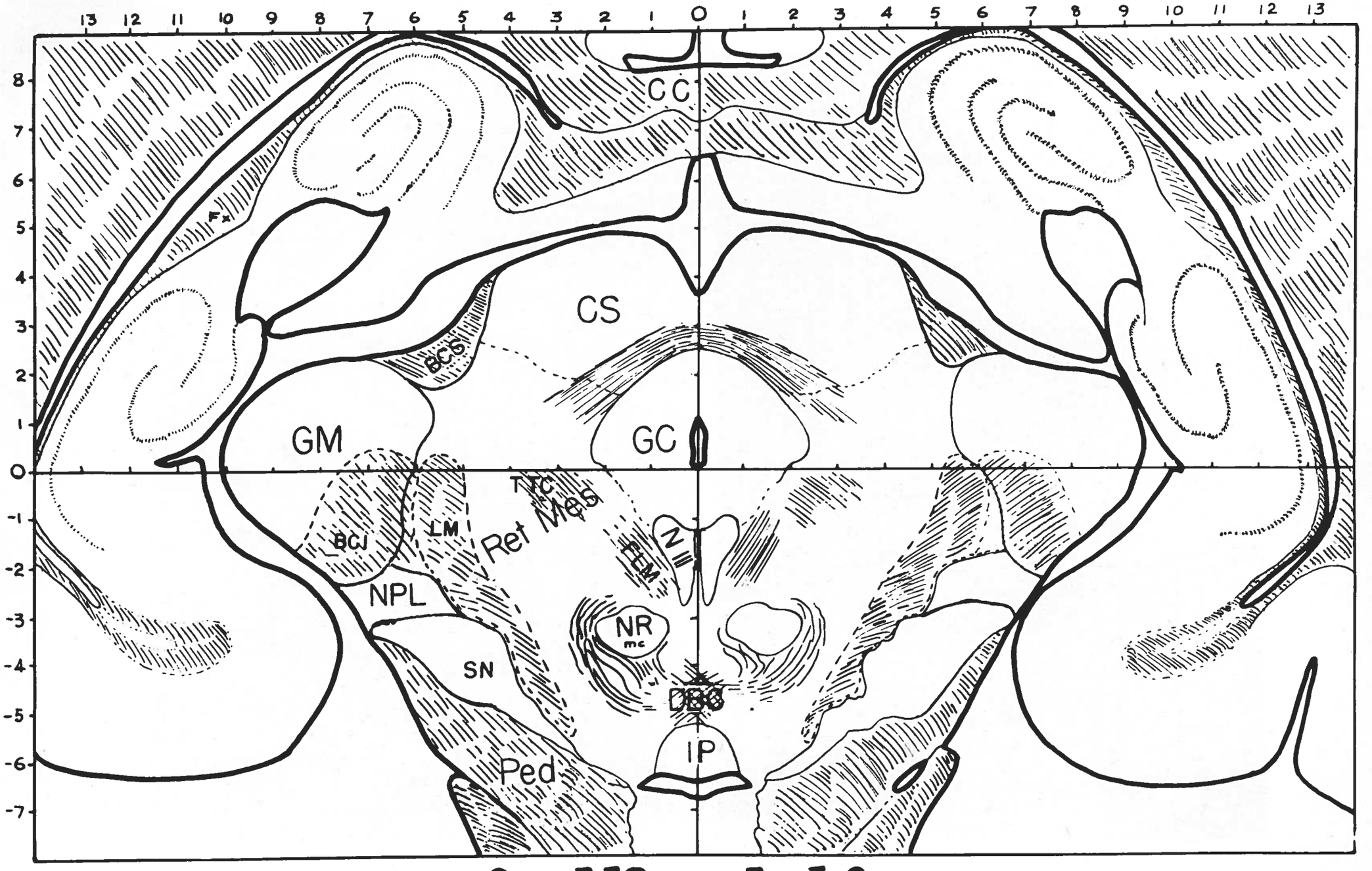
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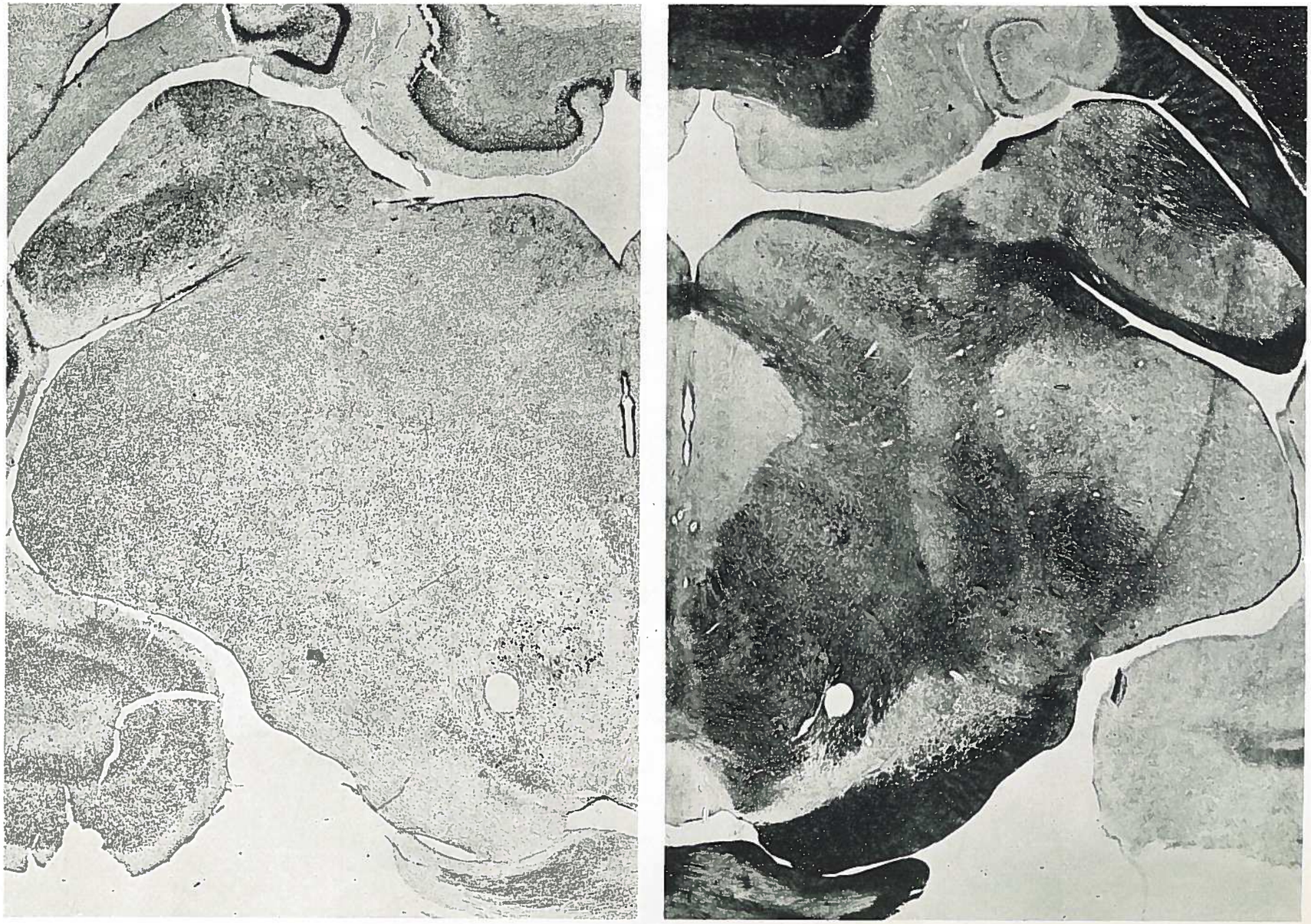

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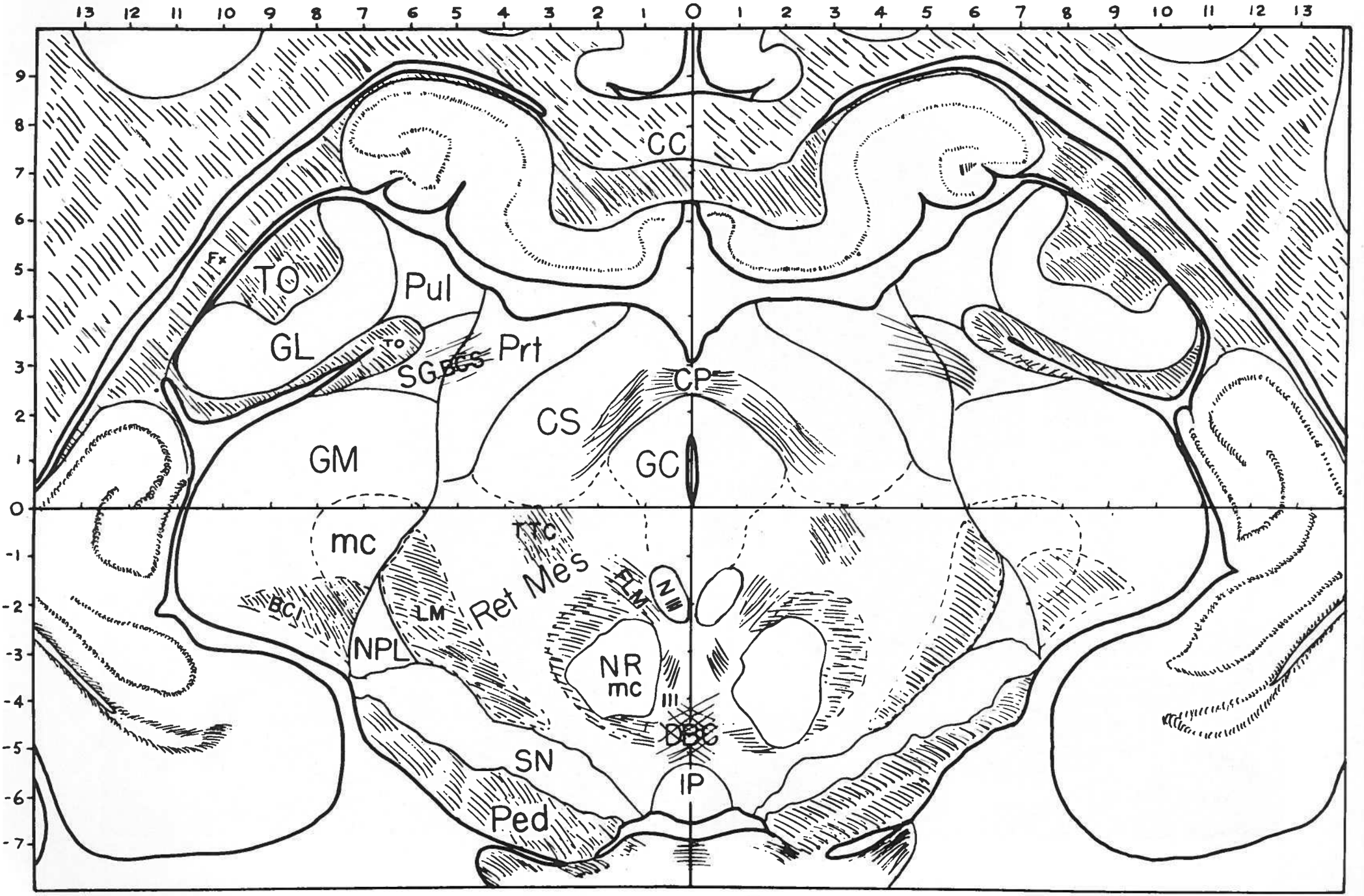
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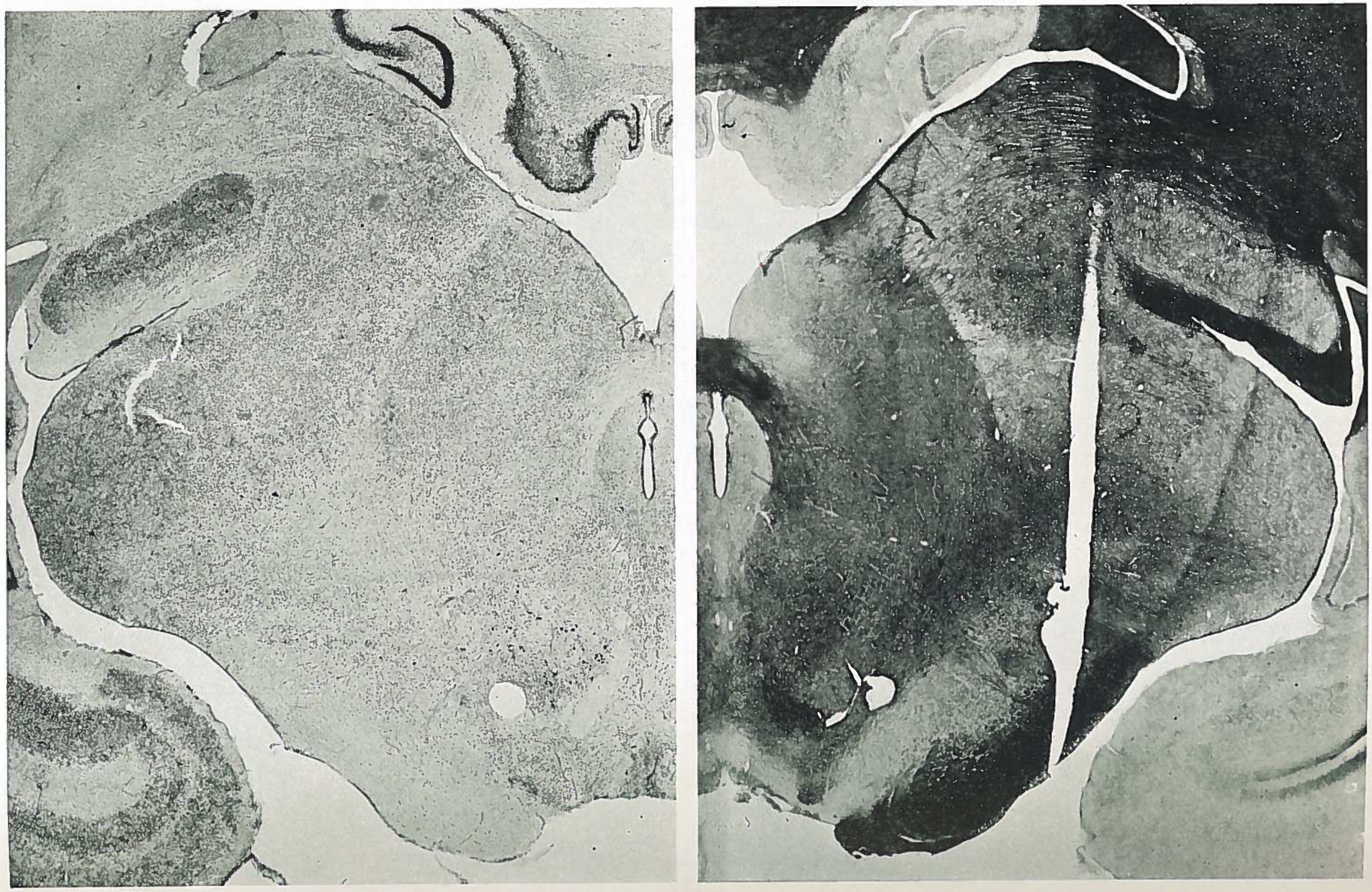

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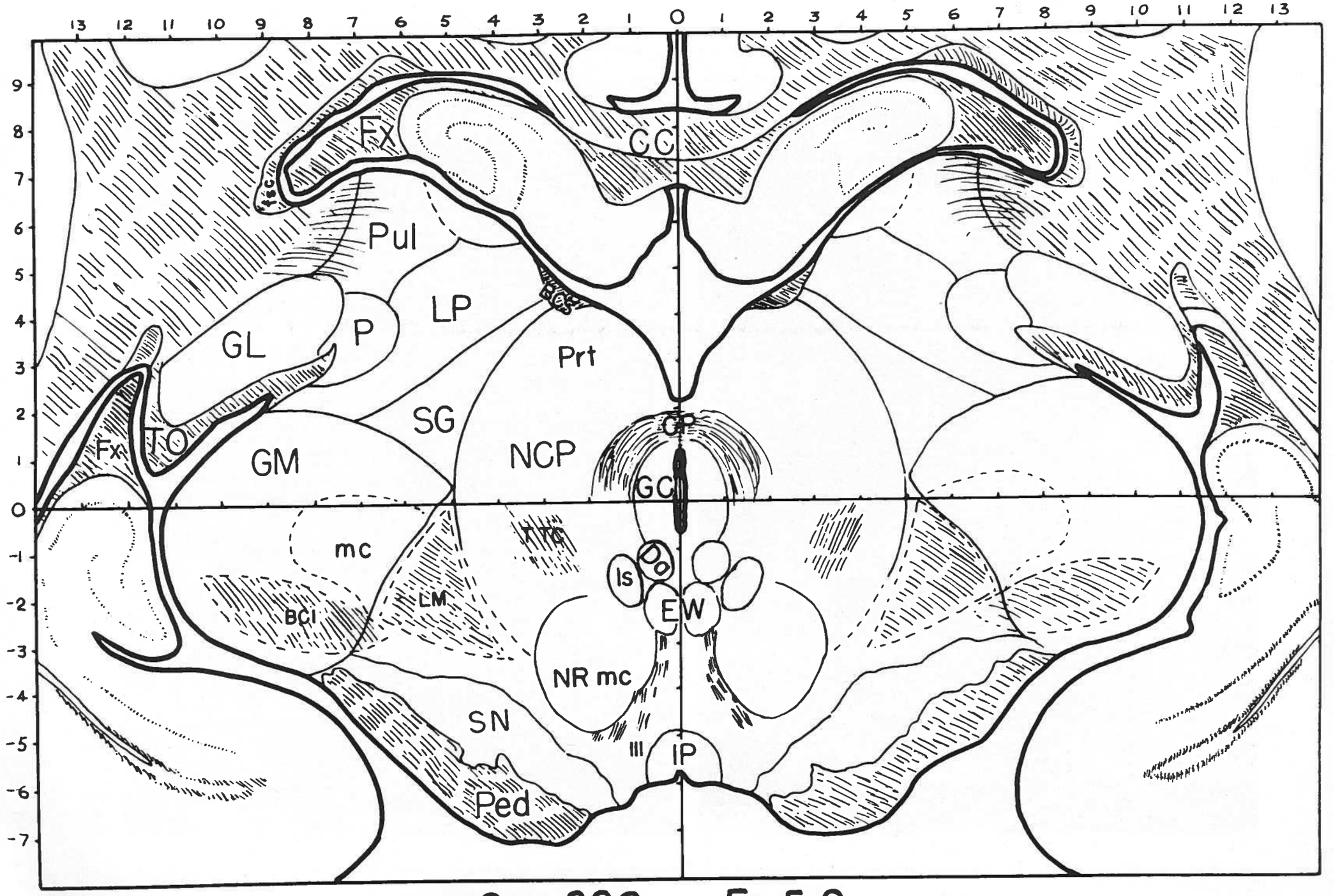
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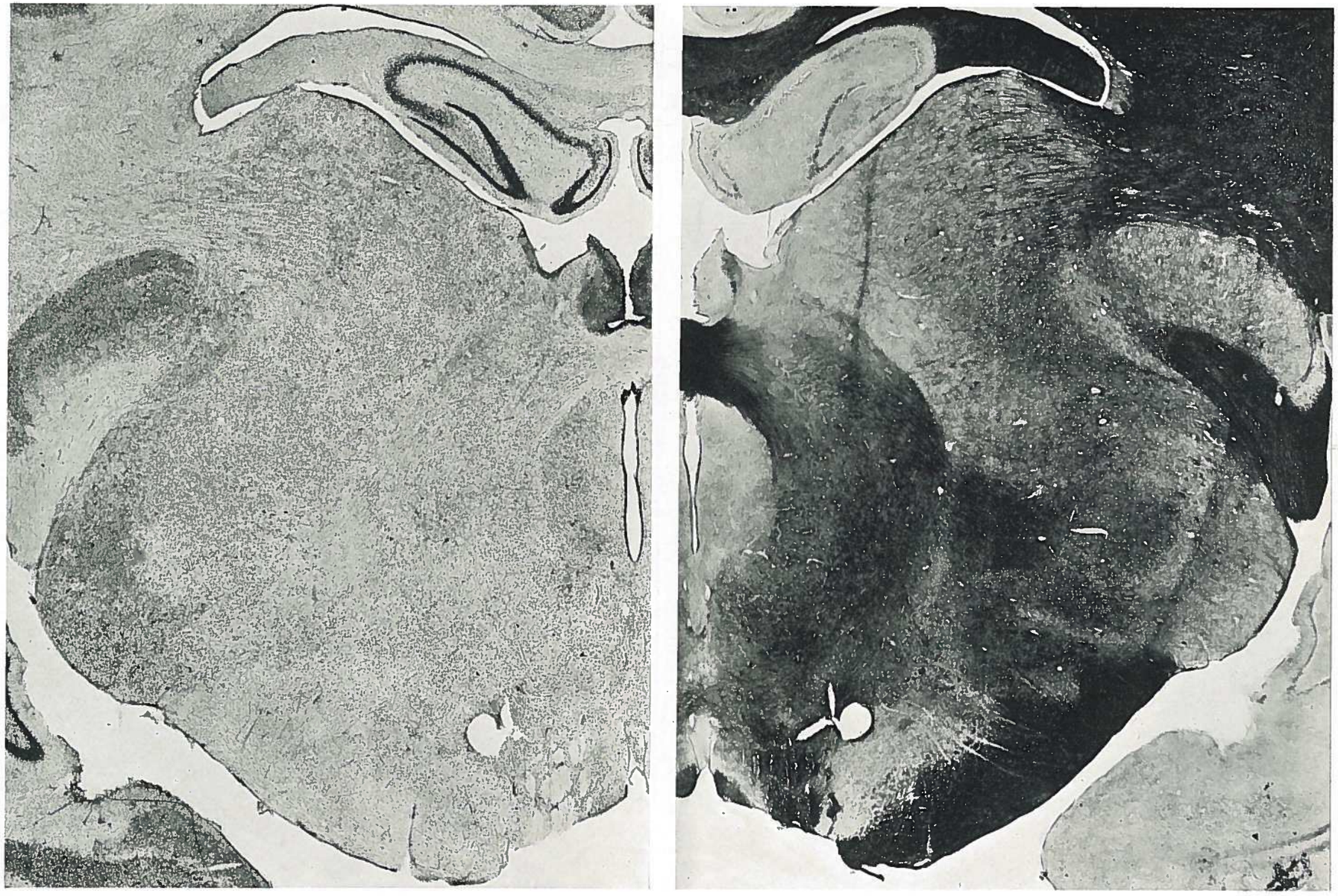

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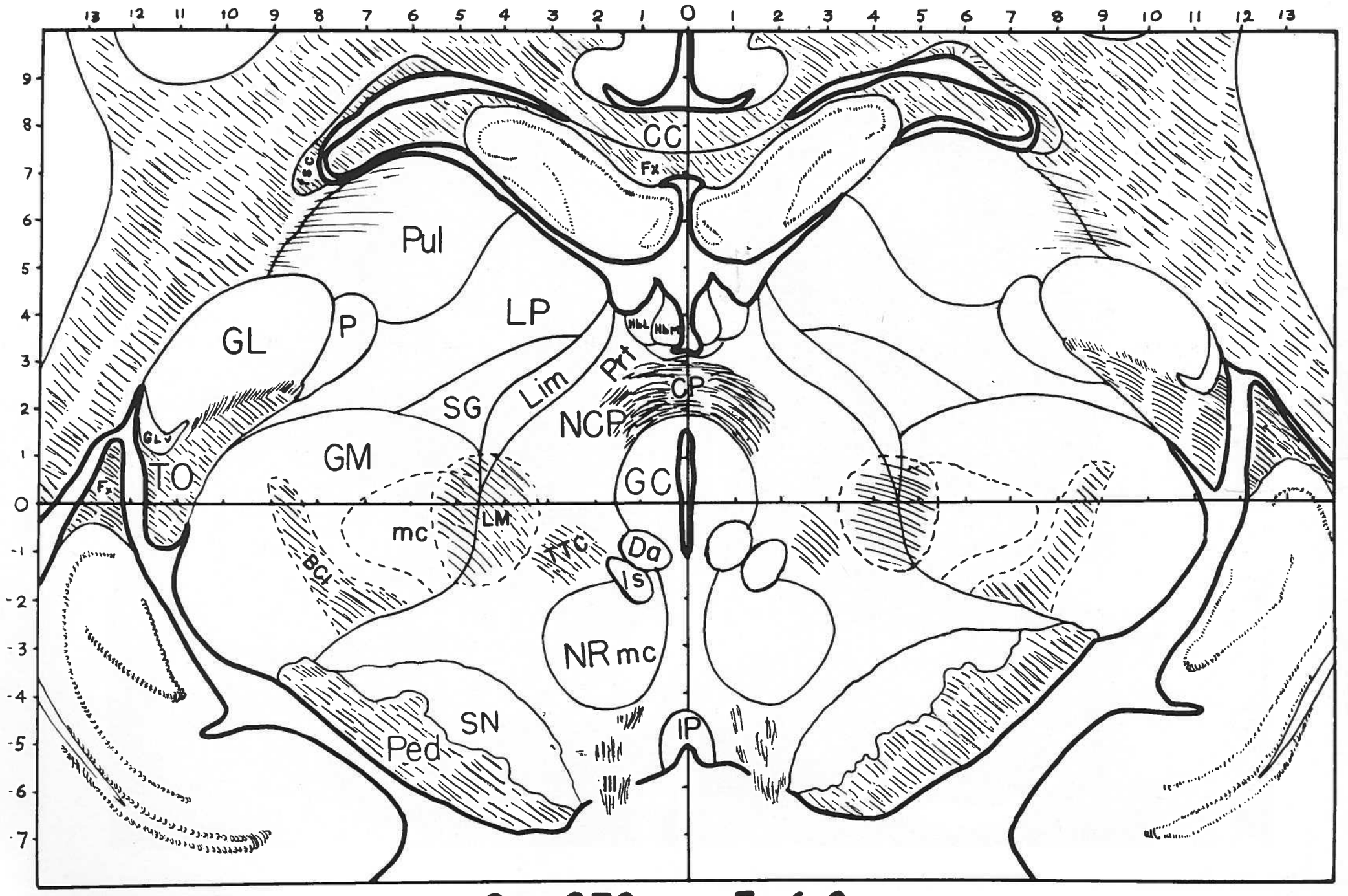
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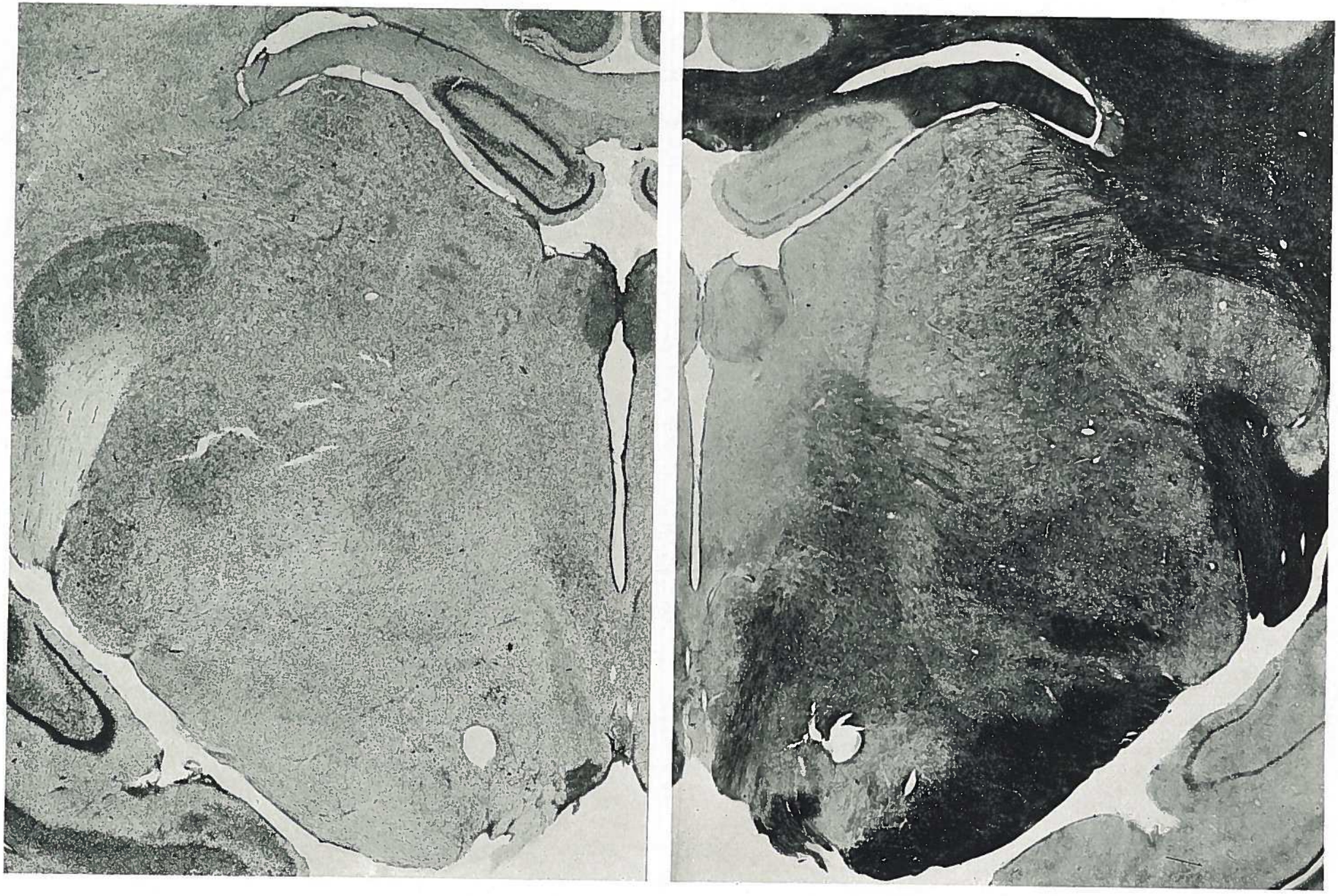
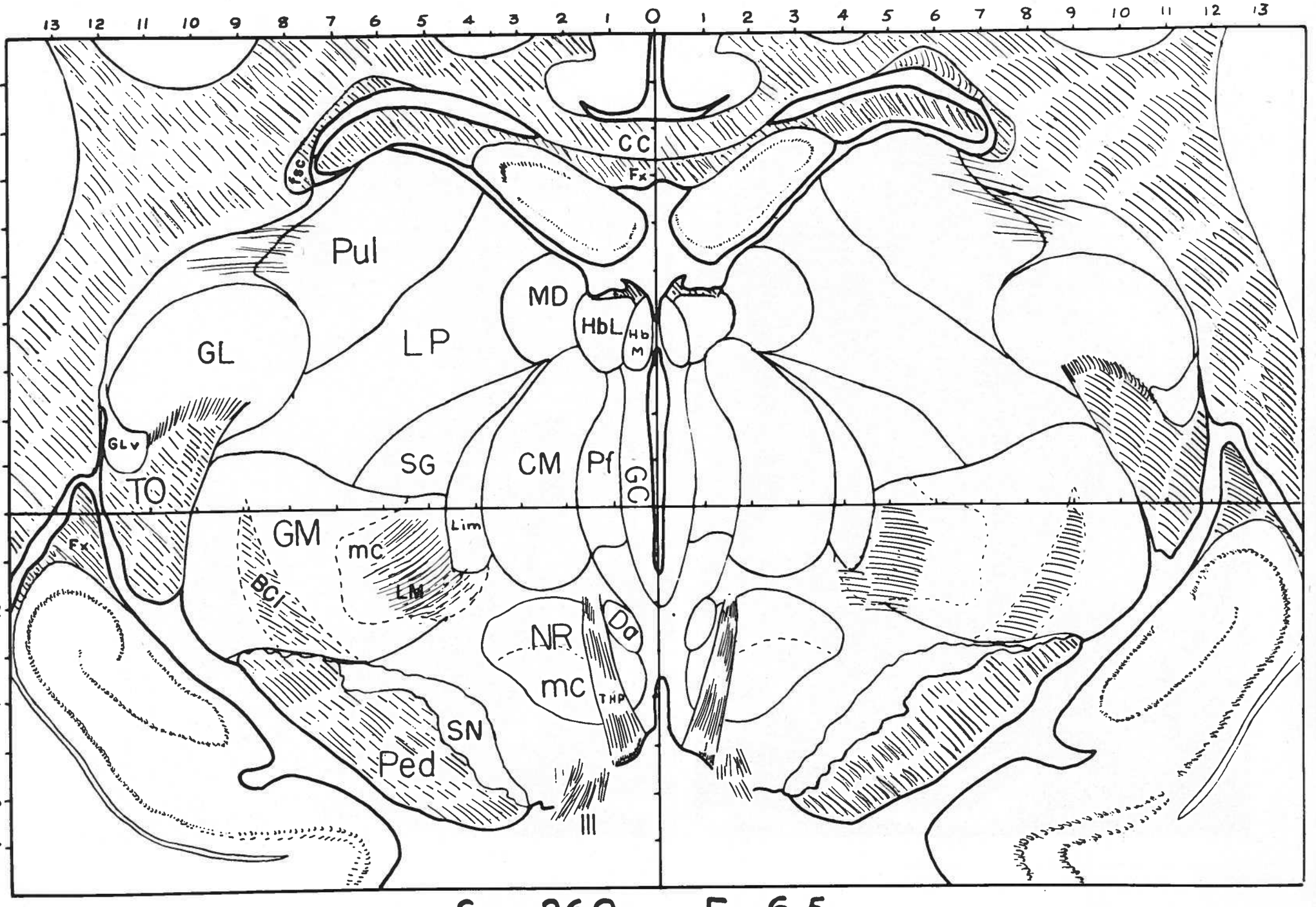
P
LP
HbL
HbM
Prt
CP
SG
Lim
NCP
GM
TO
GC
mc
LM
BCI
TTC
Da
Is
NR mc
SN
Ped
IP

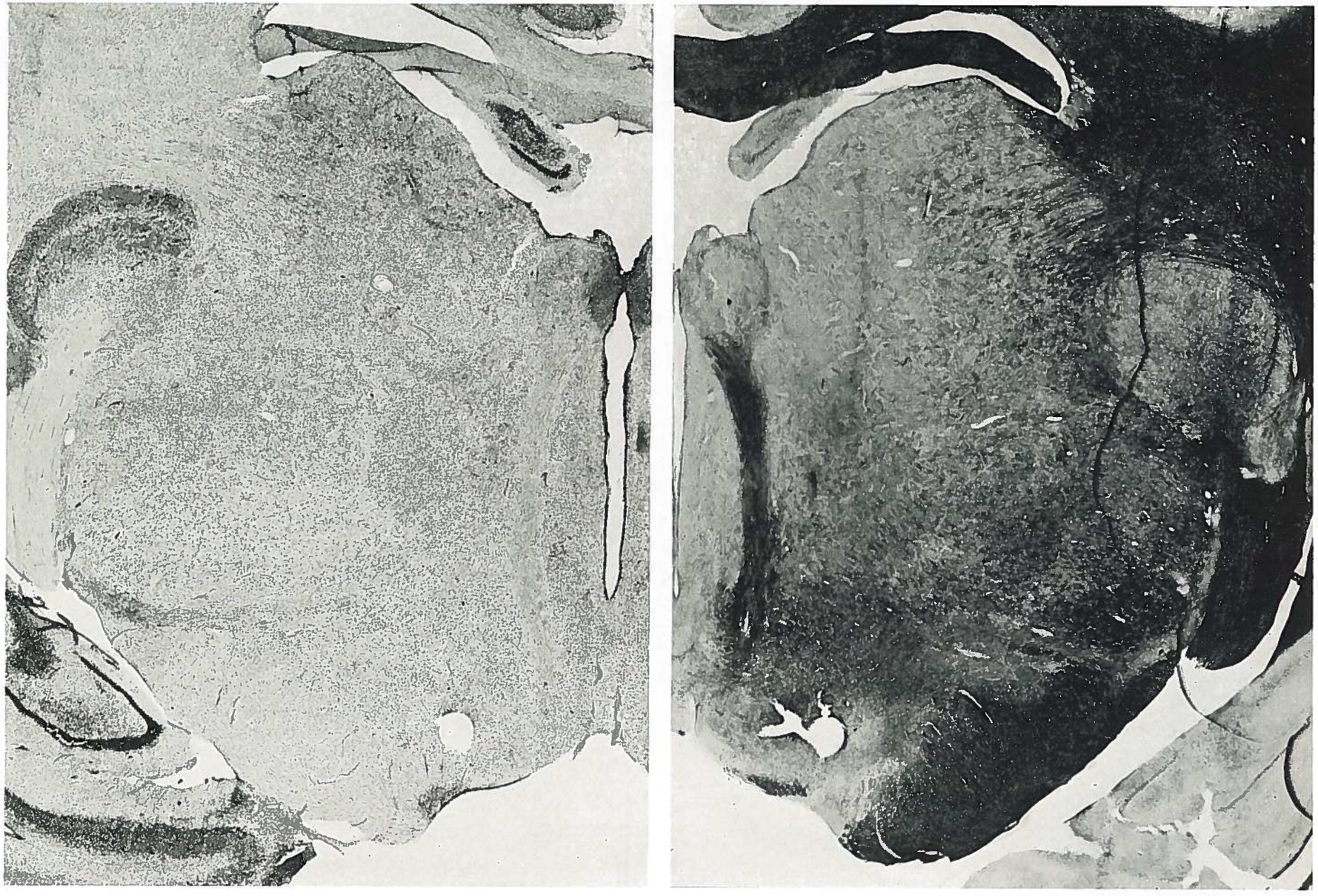
Sec. 270 Fr. 6.0



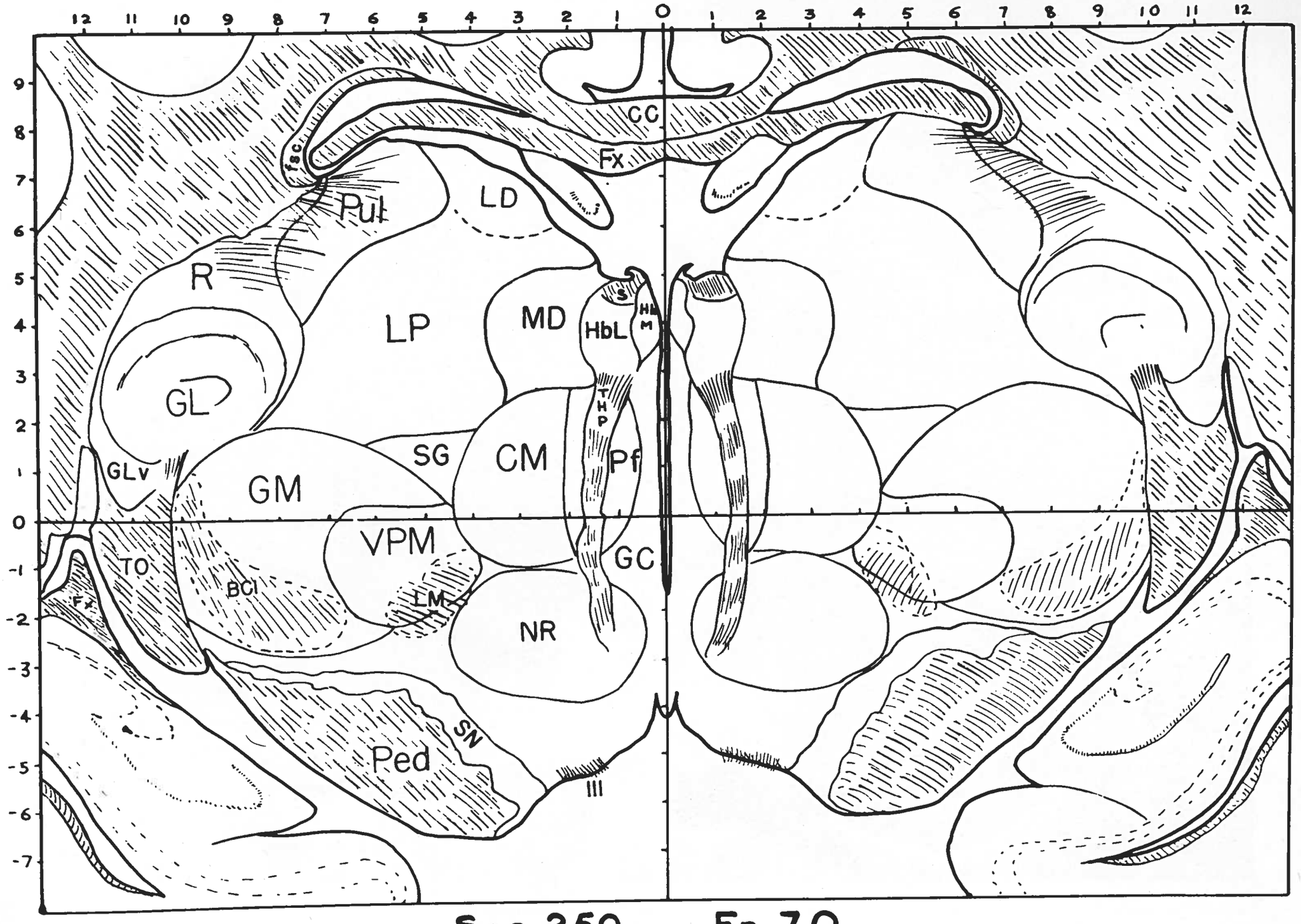
SEC. 260 FR. 6.5


13 12 11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13
9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7
fsc
CC
Fx
Pul
MD
HbL
Hb
M
GL
LP
GLv
TO
SG
CM
Pf
GC
GM
Lim
mc
LM
BCI
Fx
NR
Da
mc
THP
SN
Ped
III

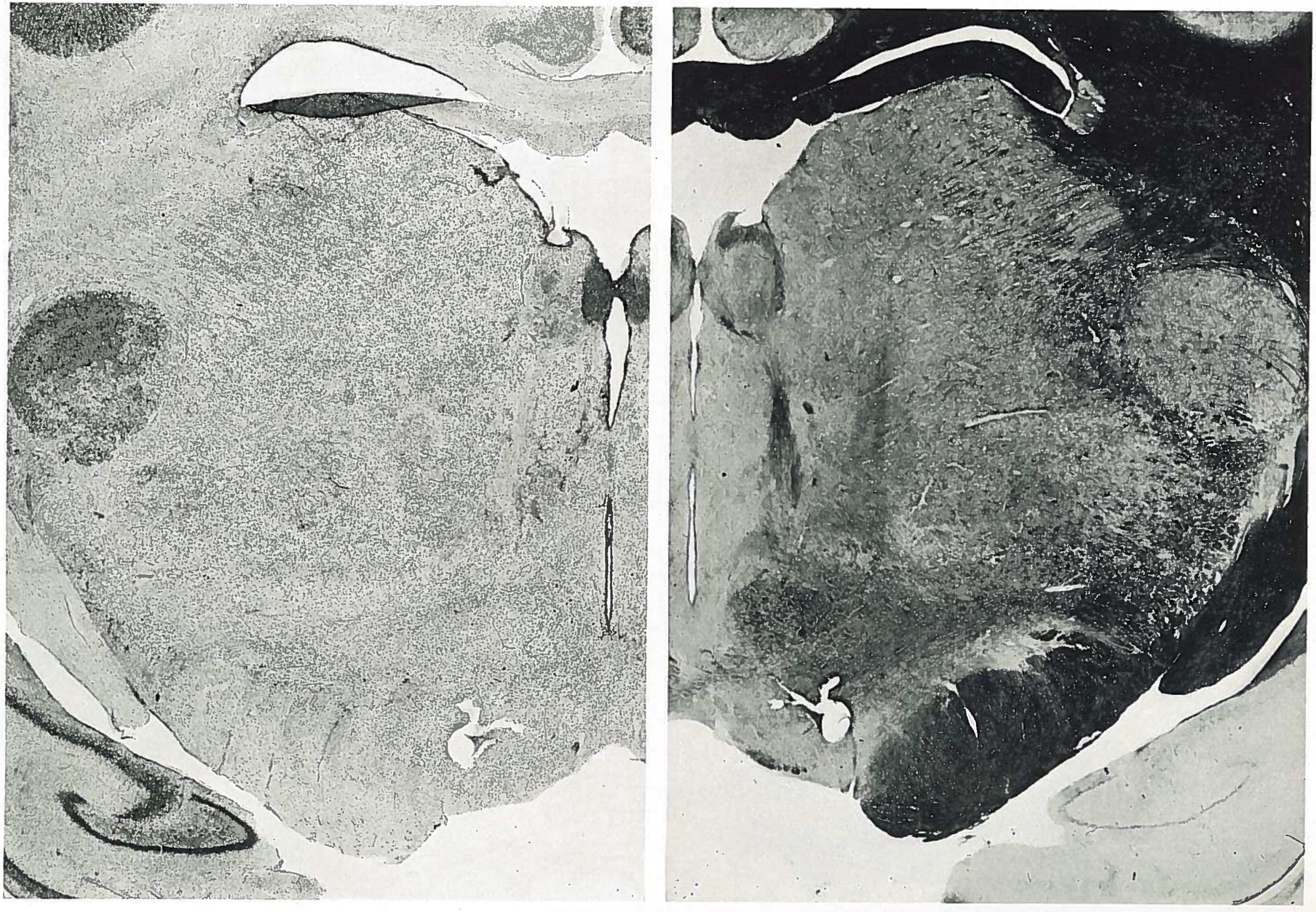
Sec. 260 Fr. 6.5



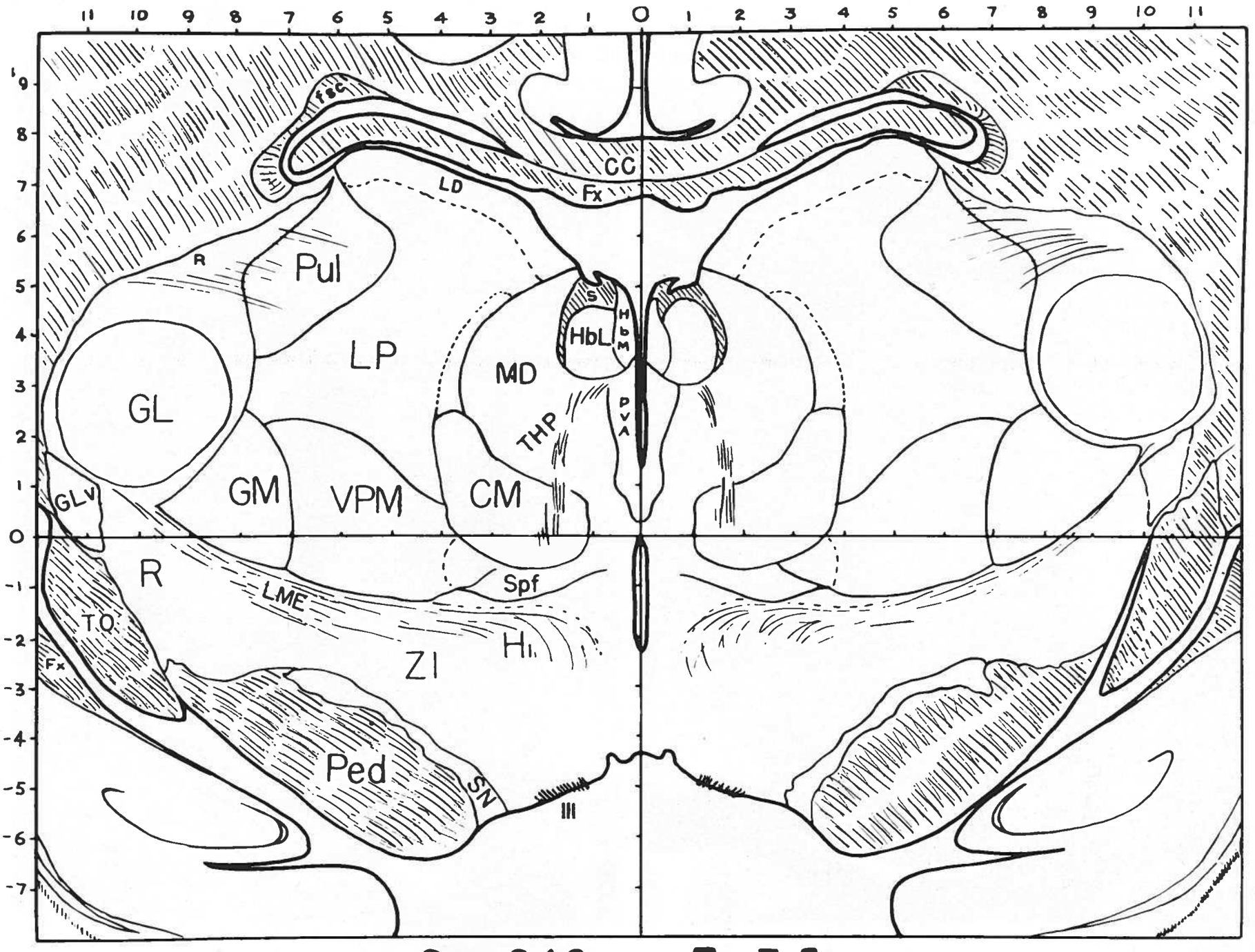
SEC. 250 FR. 7.0


CC
Fx
fsc
Put
LD
R
LP
MD
HbL
S
HbM
GL
THP
SG
CM
Pf
GLv
GM
VPM
GC
TO
BCl
FX
LM
NR
SN
Ped
III

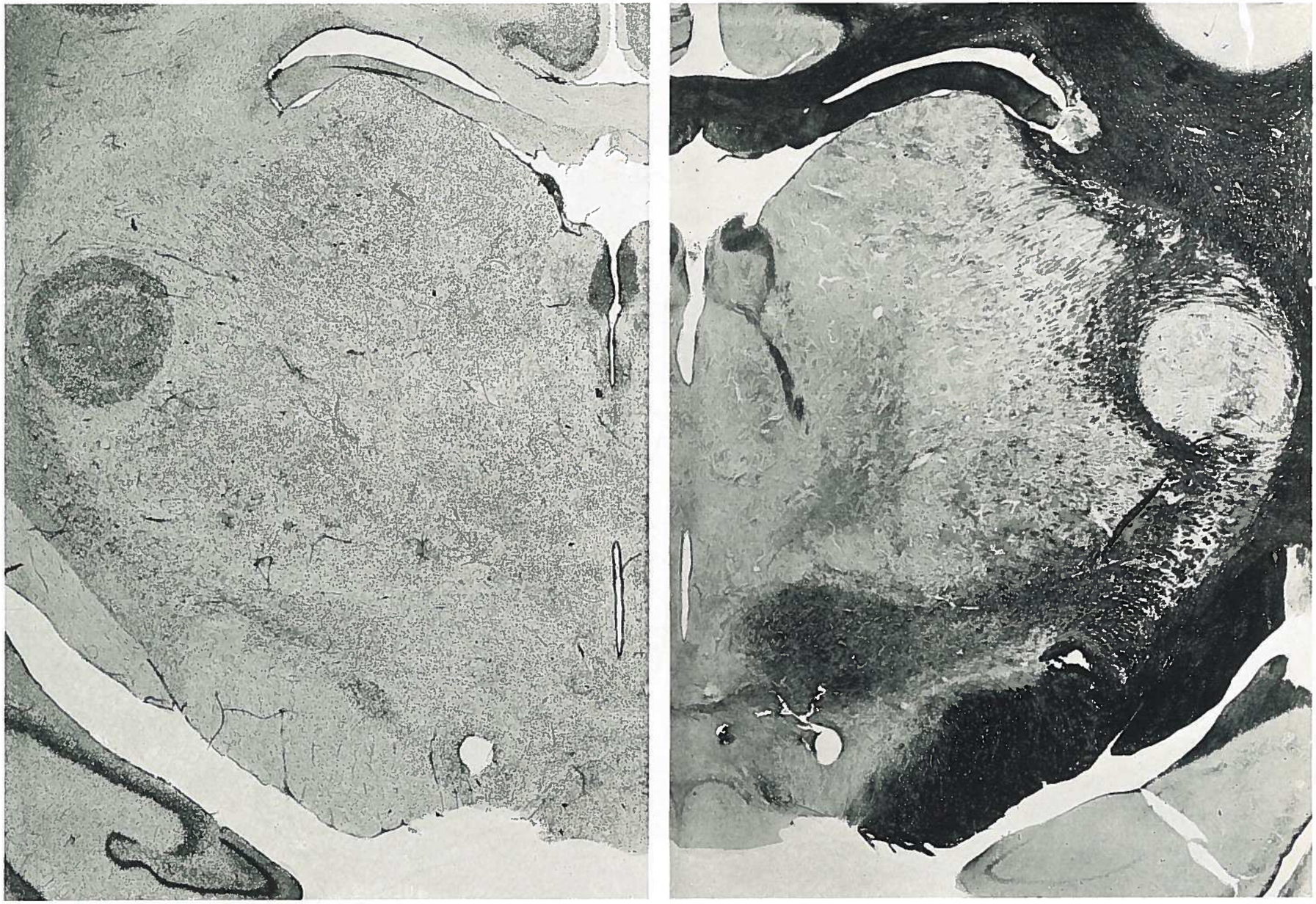
Sec. 250 Fr. 7.0



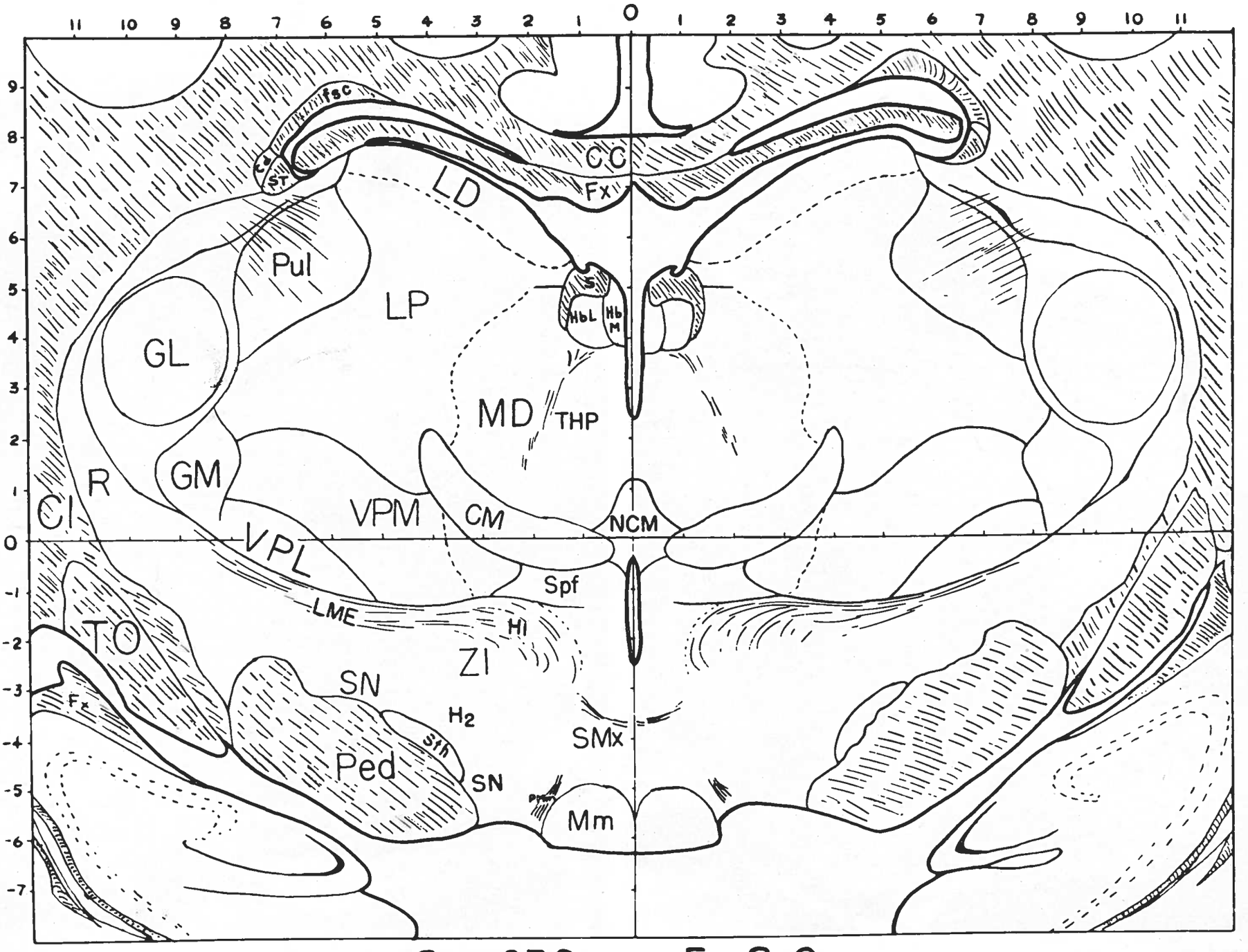
SEC. 240 FR. 7.5


fsc
CC
LD
Fx
R
Pul
S
HbM
HbL
LP
MD
GL
PVA
THP
GLV
GM
VPM
CM
R
Spf
LME
TO
Fx
ZI
H1
Ped
SN
III

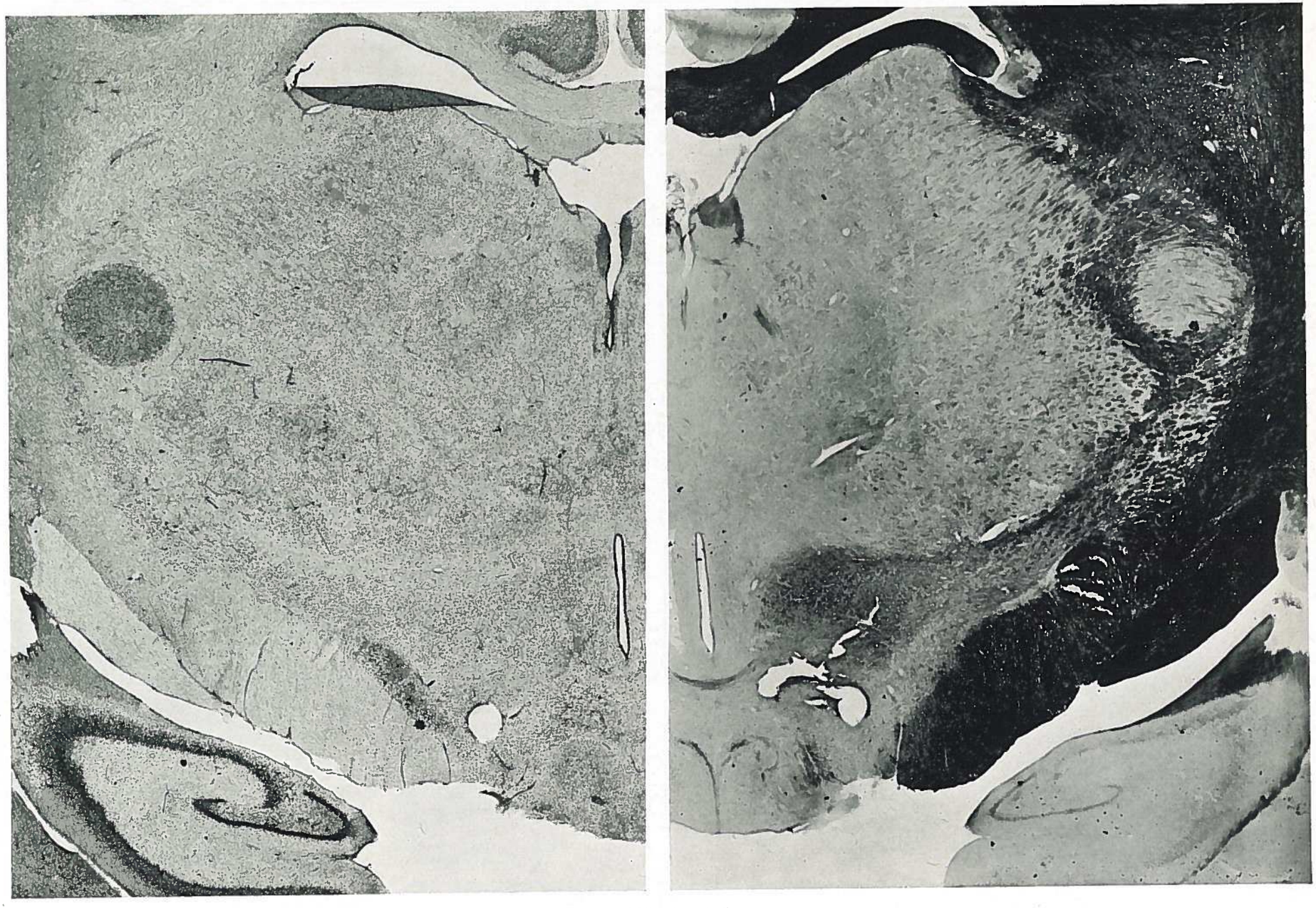
Sec. 240 Fr. 7.5



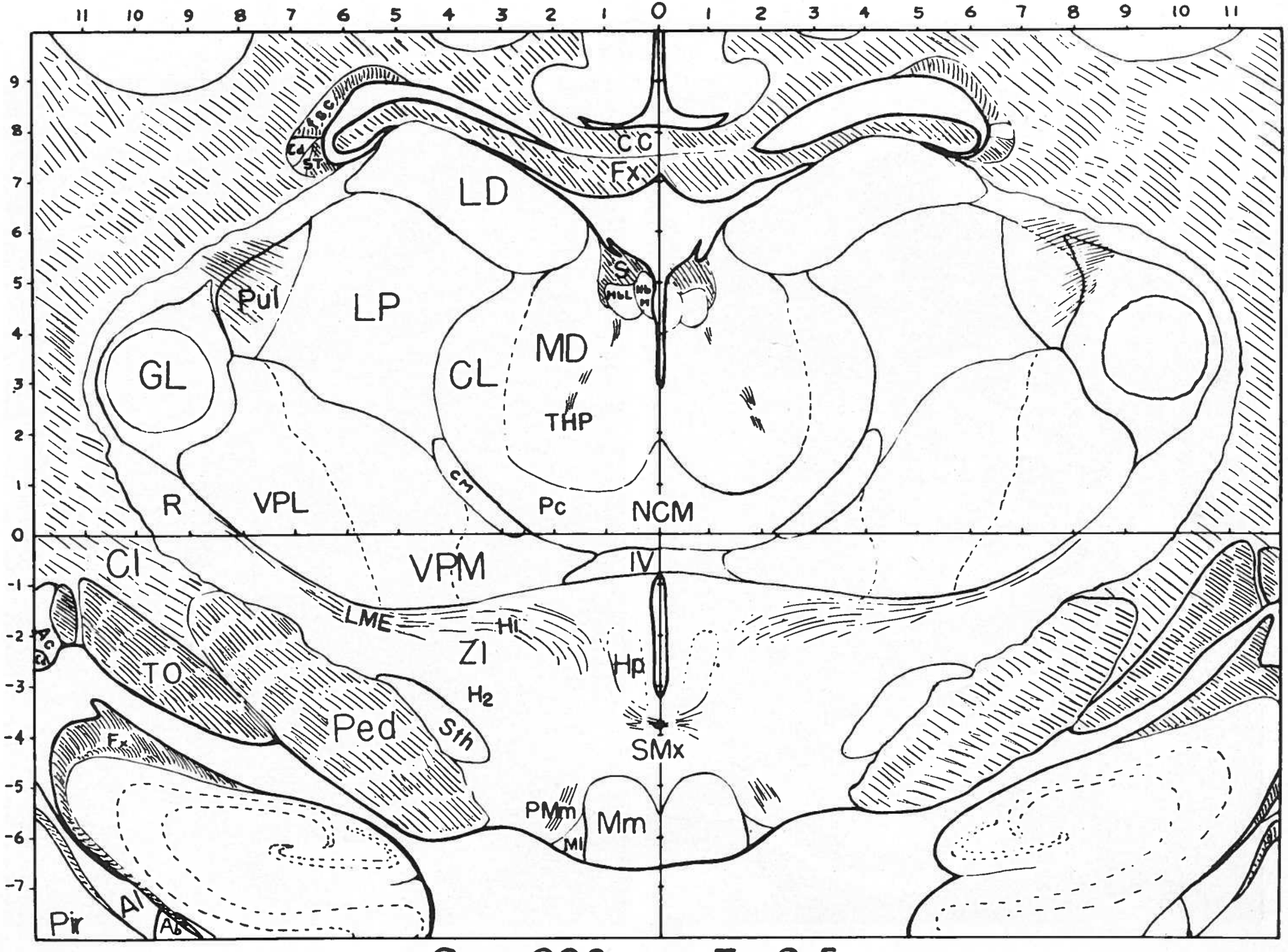
SEC. 230 FR. 8.0


11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11
9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7
fsc
ST
CC
Fx
LD
Pul
LP
GL
S
HbL
Hb M
MD
THP
GM
R
Cl
VPM
CM
NCM
VPL
Spf
LME
Hl
TO
ZI
SN
Fx
H2
SMx
Ped
sth
SN
Mm

Sec. 230 Fr. 8.0



SEC. 220 FR. 8.5


11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11
9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7
CC
Fx
LD
Pul
LP
GL
CL
MD
THP
R
VPL
Pc
NCM
CI
VPM
IV
LME
Hl
ZI
H2
Hp
TO
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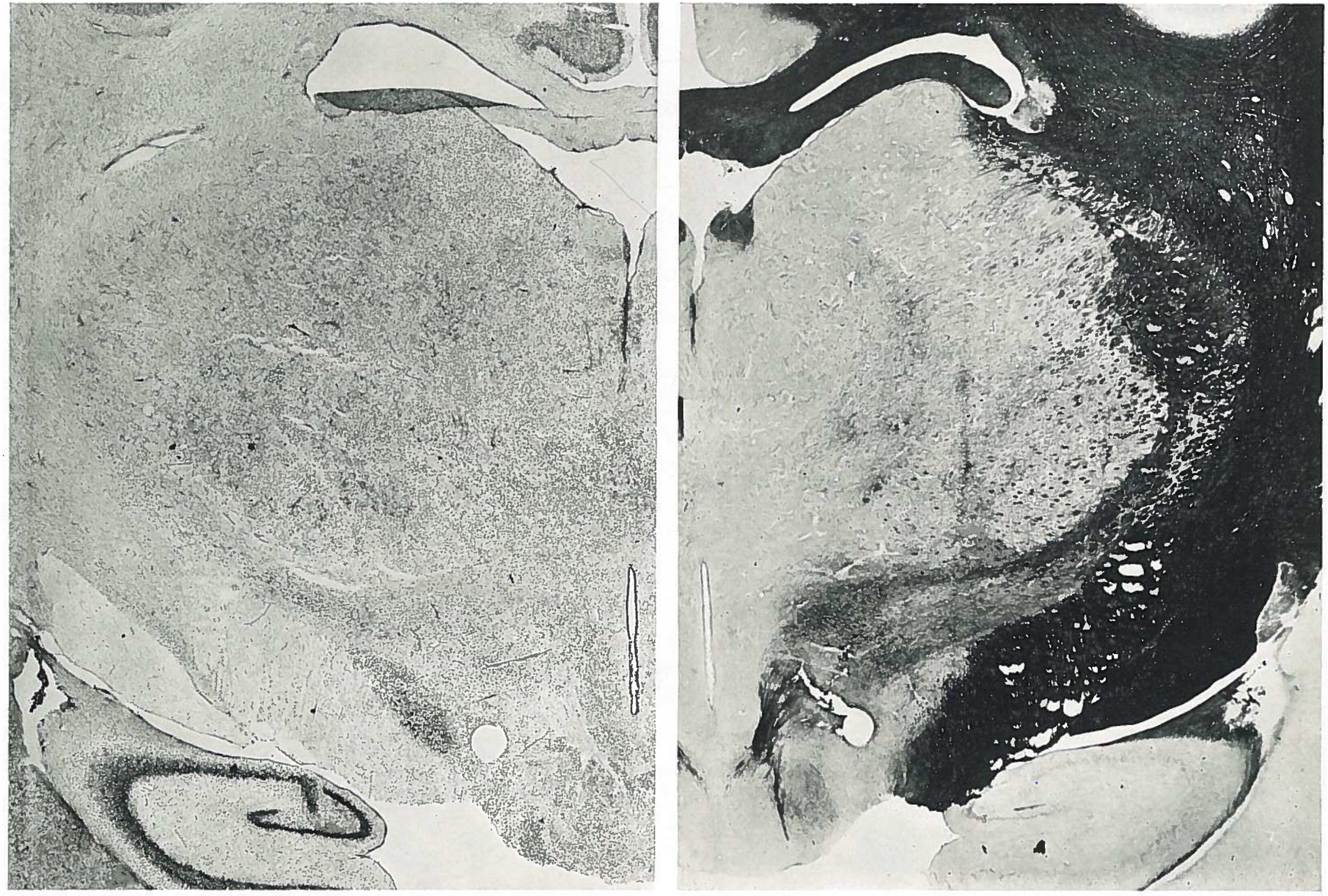
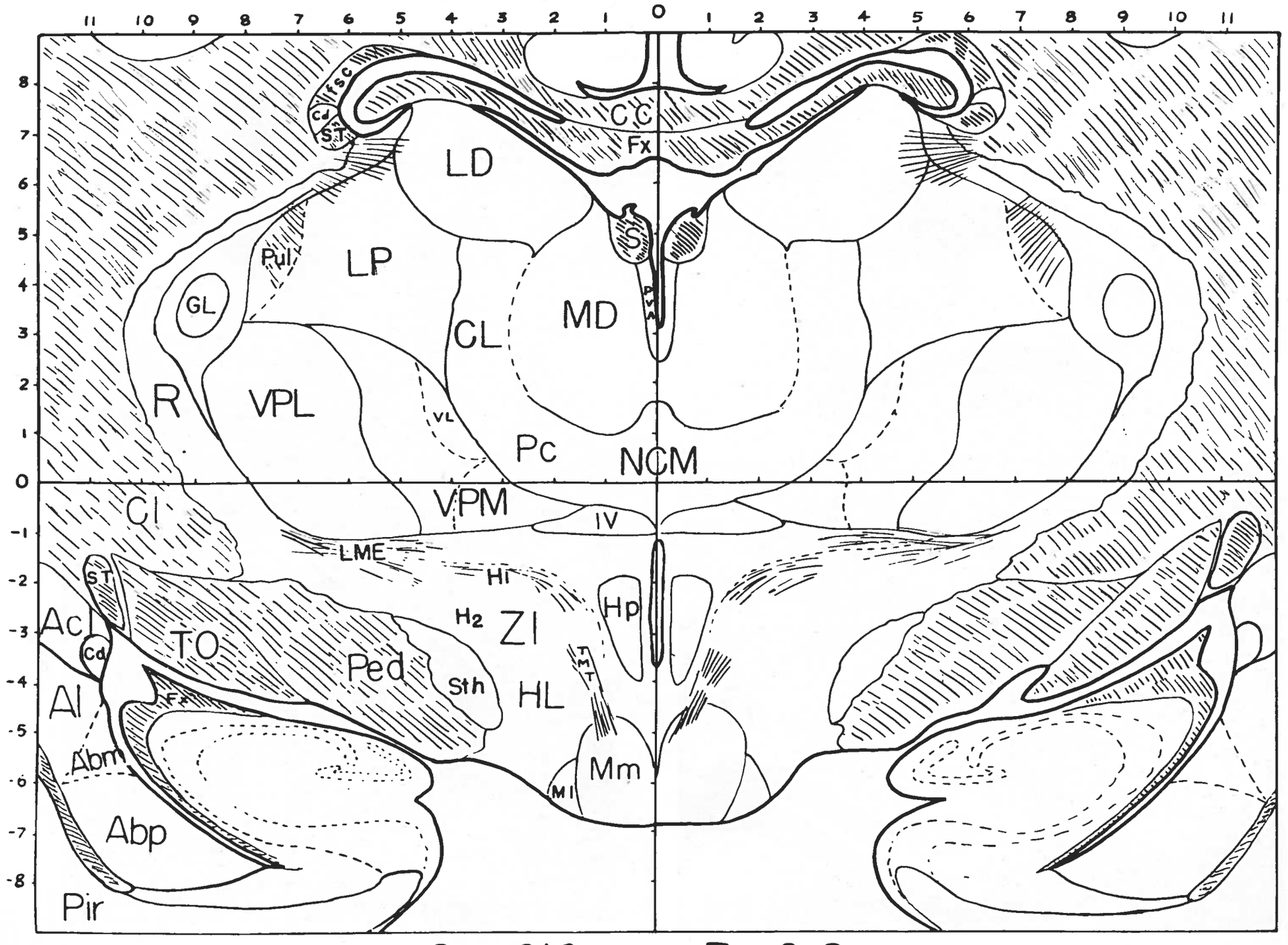
Sth
SMx
Fx
PMm
Mm
Pir
Al
Ac

Sec. 220 Fr. 8.5



SEC. 210 FR. 9.0


11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11
8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8
fsc
Cd
ST
CC
Fx
LD
S
Pul
LP
GL
MD
CL
R
VPL
VL
Pc
NCM
VPM
IV
Cl
LME
Hl
H2
ZI
Hp
ST
Ac
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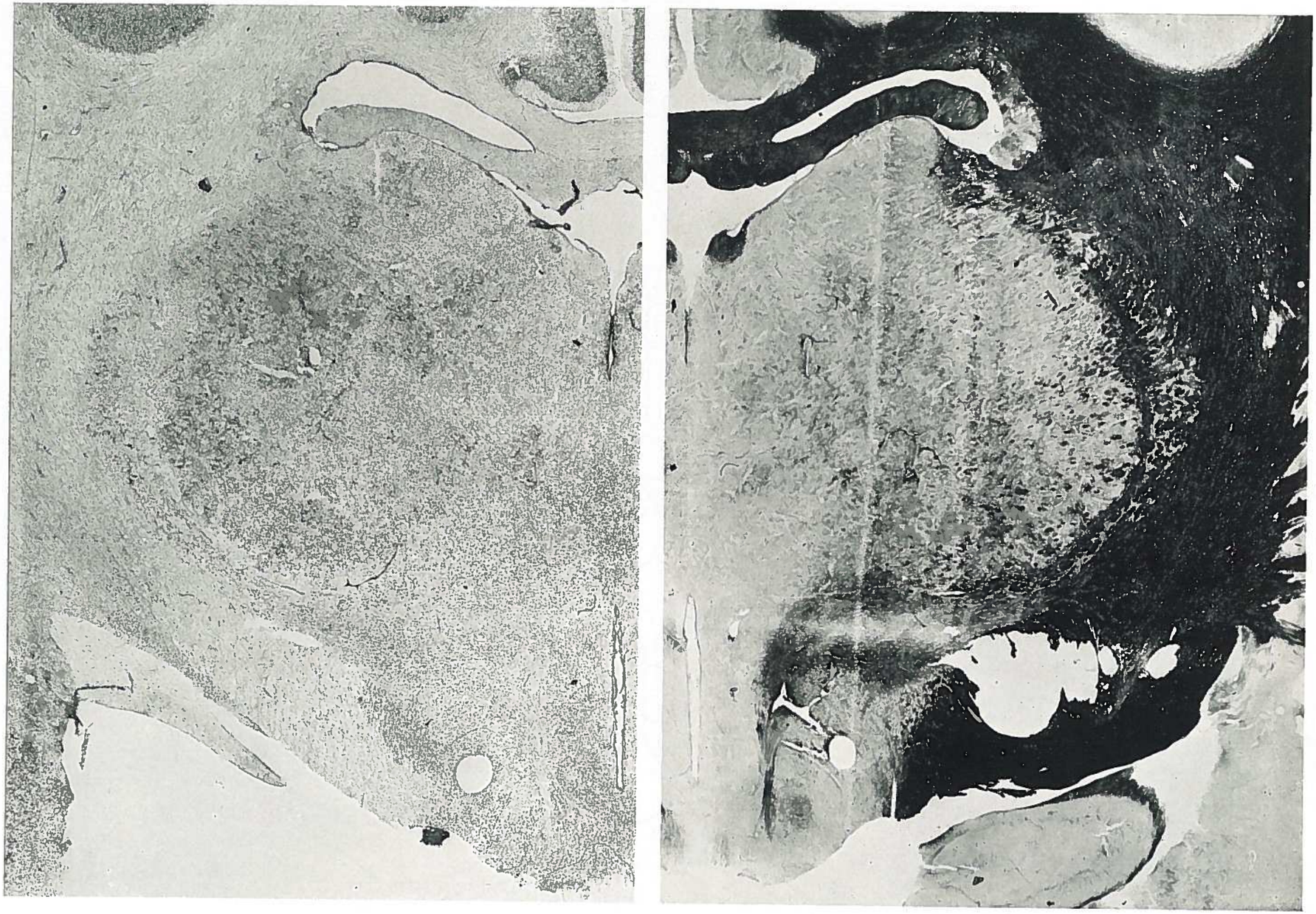
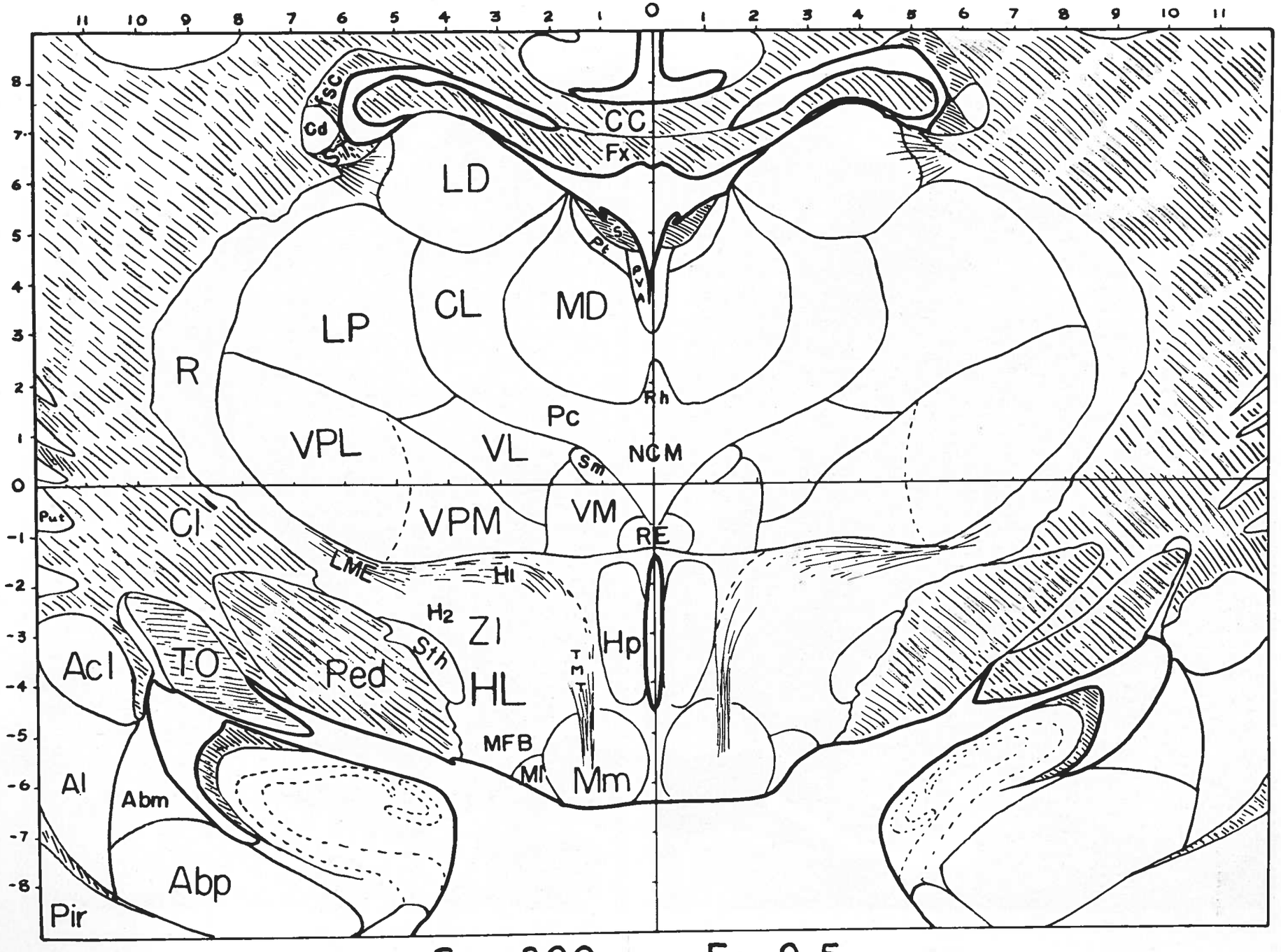
Cd
Ped
Sth
HL
FMT
Al
Abm
Mm
Ml
Abp
Pir

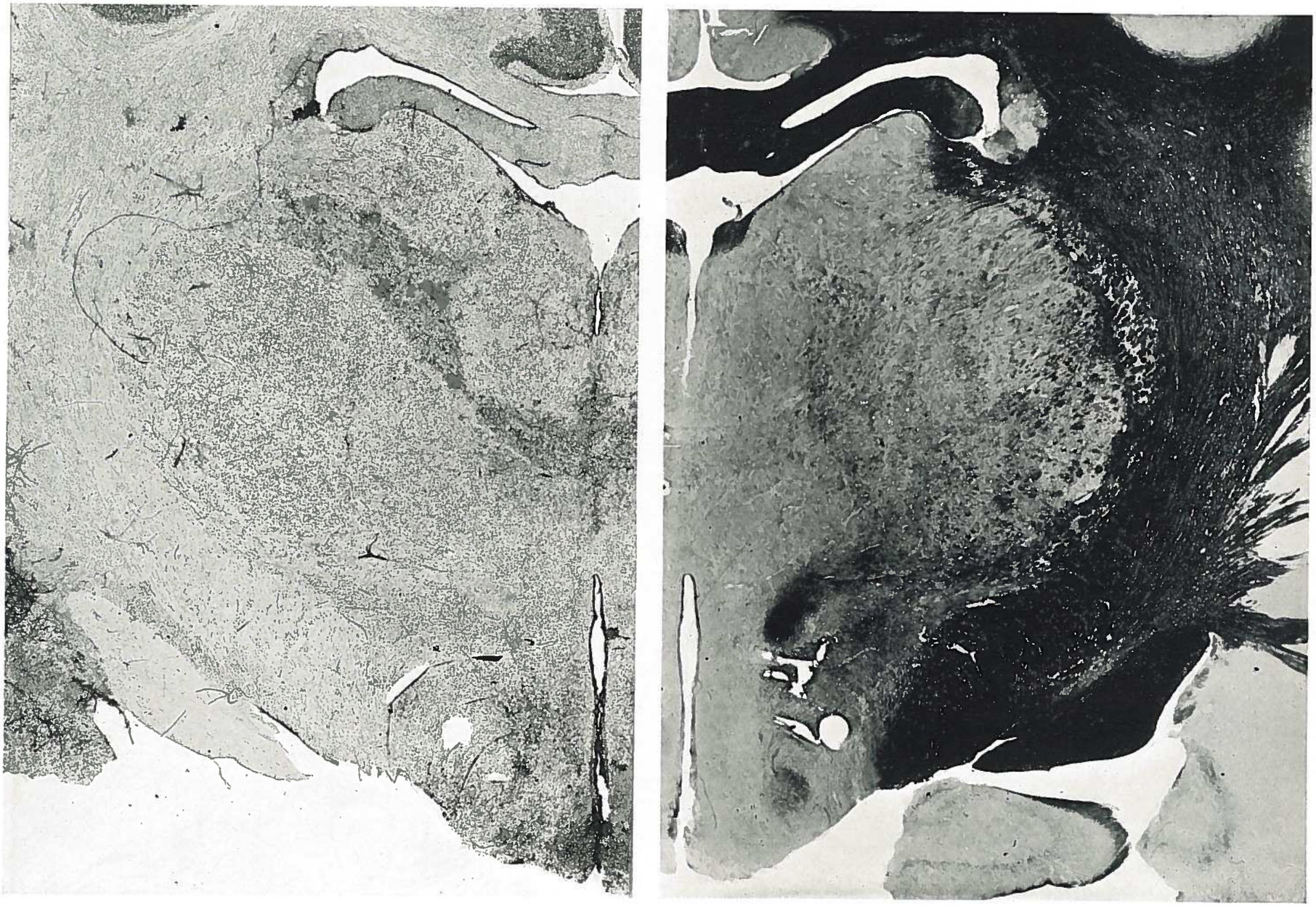
Sec. 210 Fr. 9.0



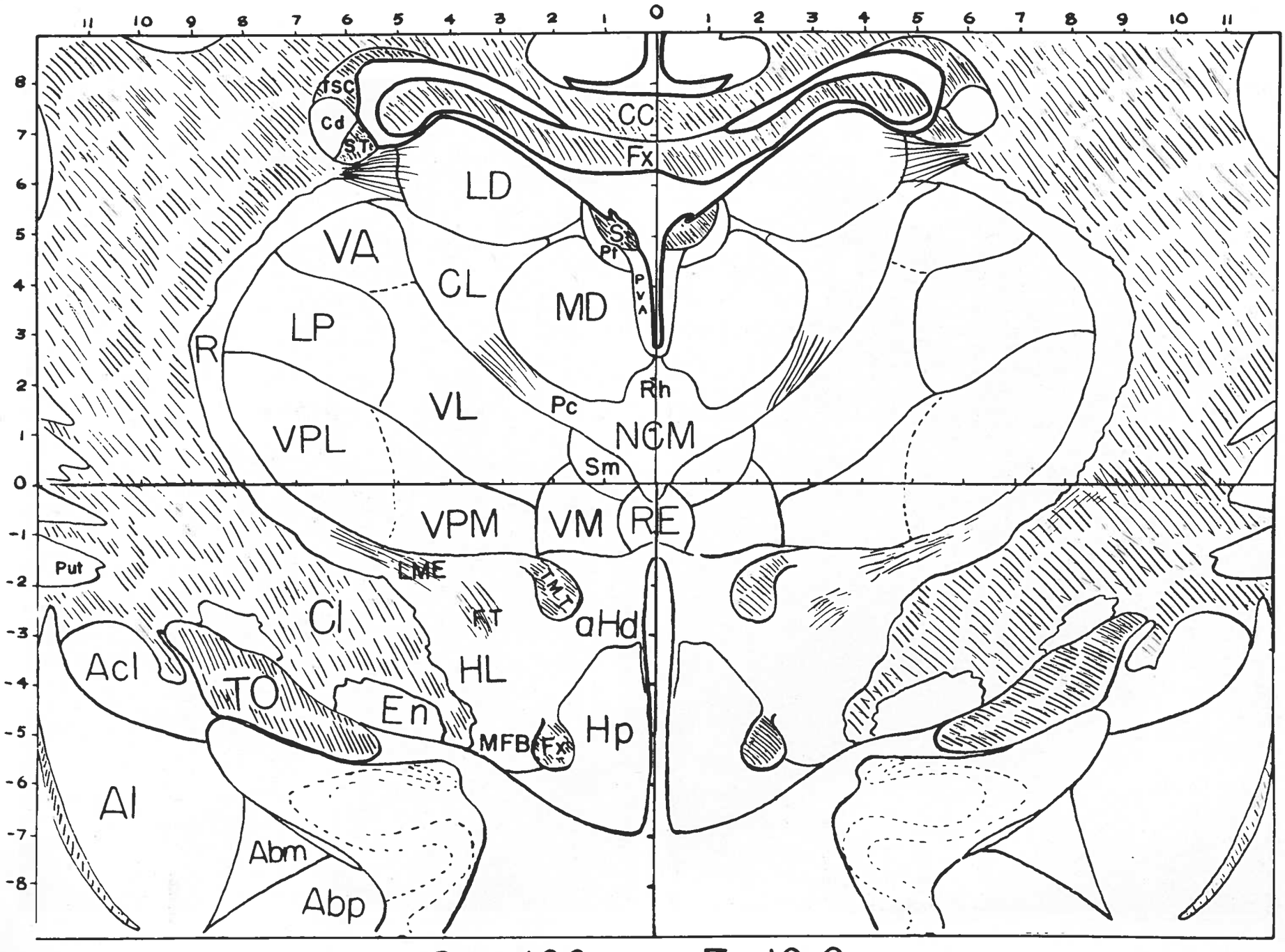
SEC. 200 FR. 9.5


11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11
8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8
Tsc
Cd
CC
Fx
LD
Pt
PVA
LP
CL
MD
R
Rh
Pc
VPL
VL
Sm
NCM
Put
Cl
VPM
VM
RE
LME
Hl
H2
Zl
Hp
Sth
Ped
HL
Acl
TO
MFB
Mf
Mm
Al
Abm
Abp
Pir

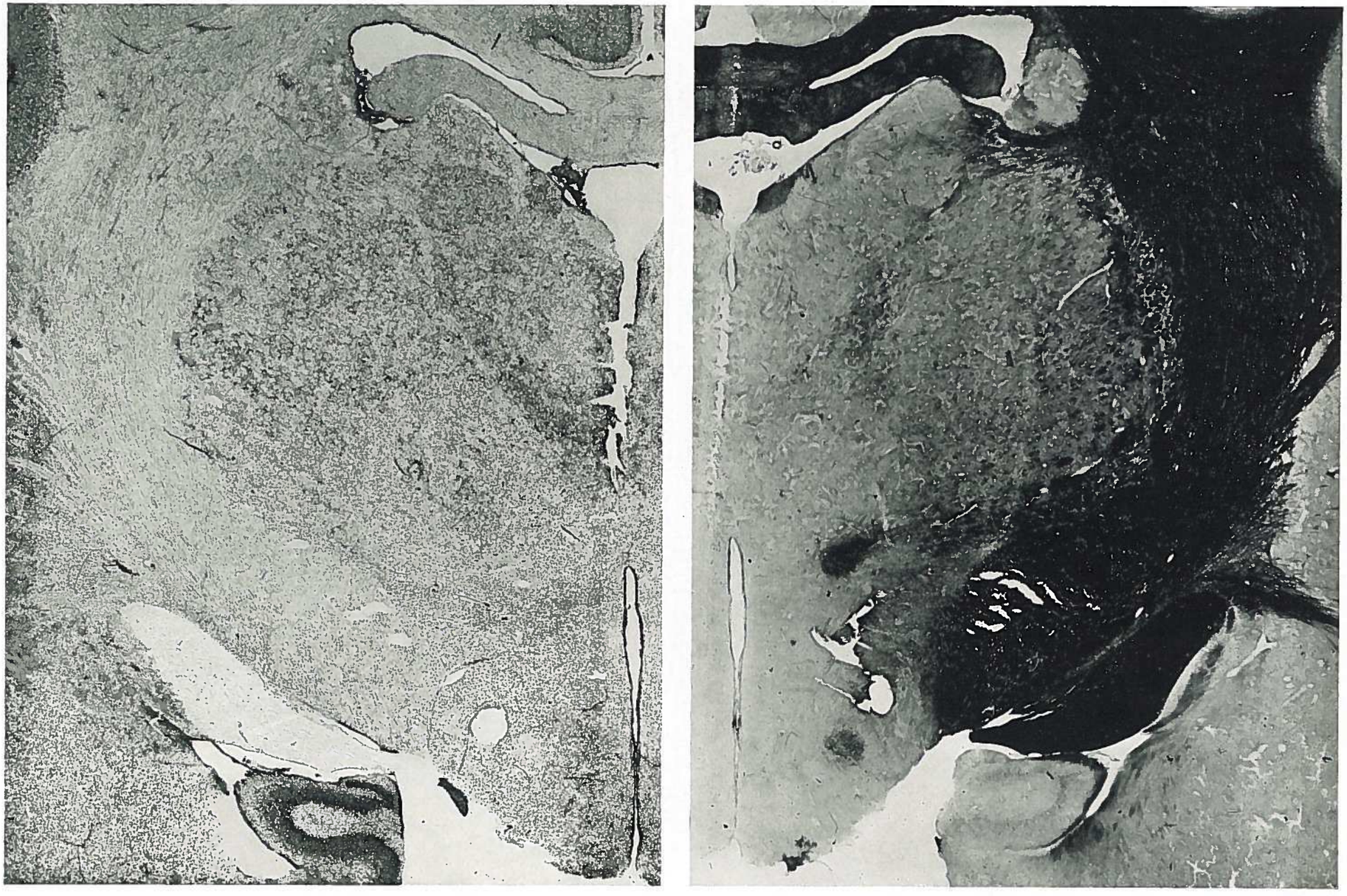
Sec. 200 Fr. 9.5



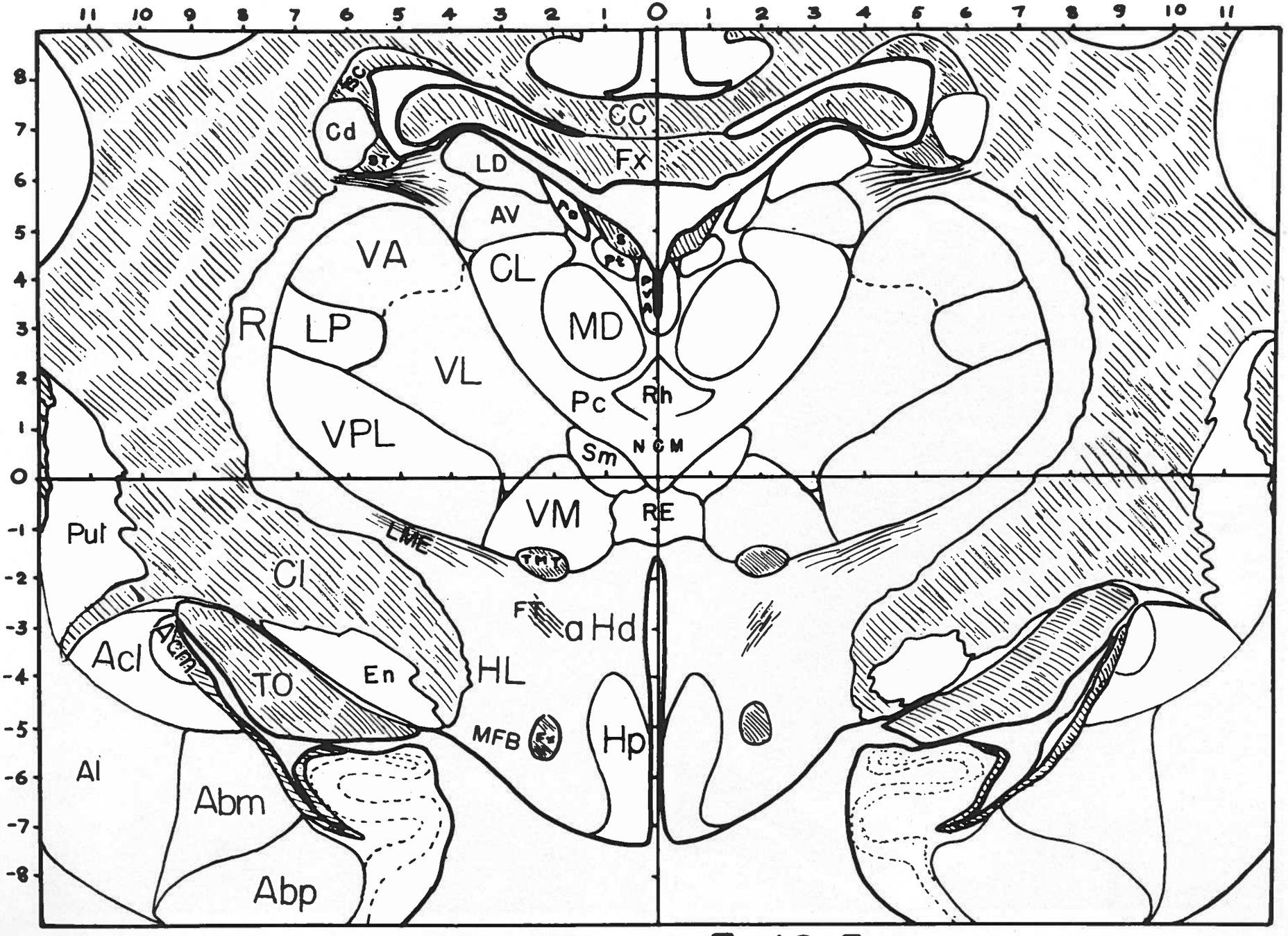
SEC. 190 FR. 10.0



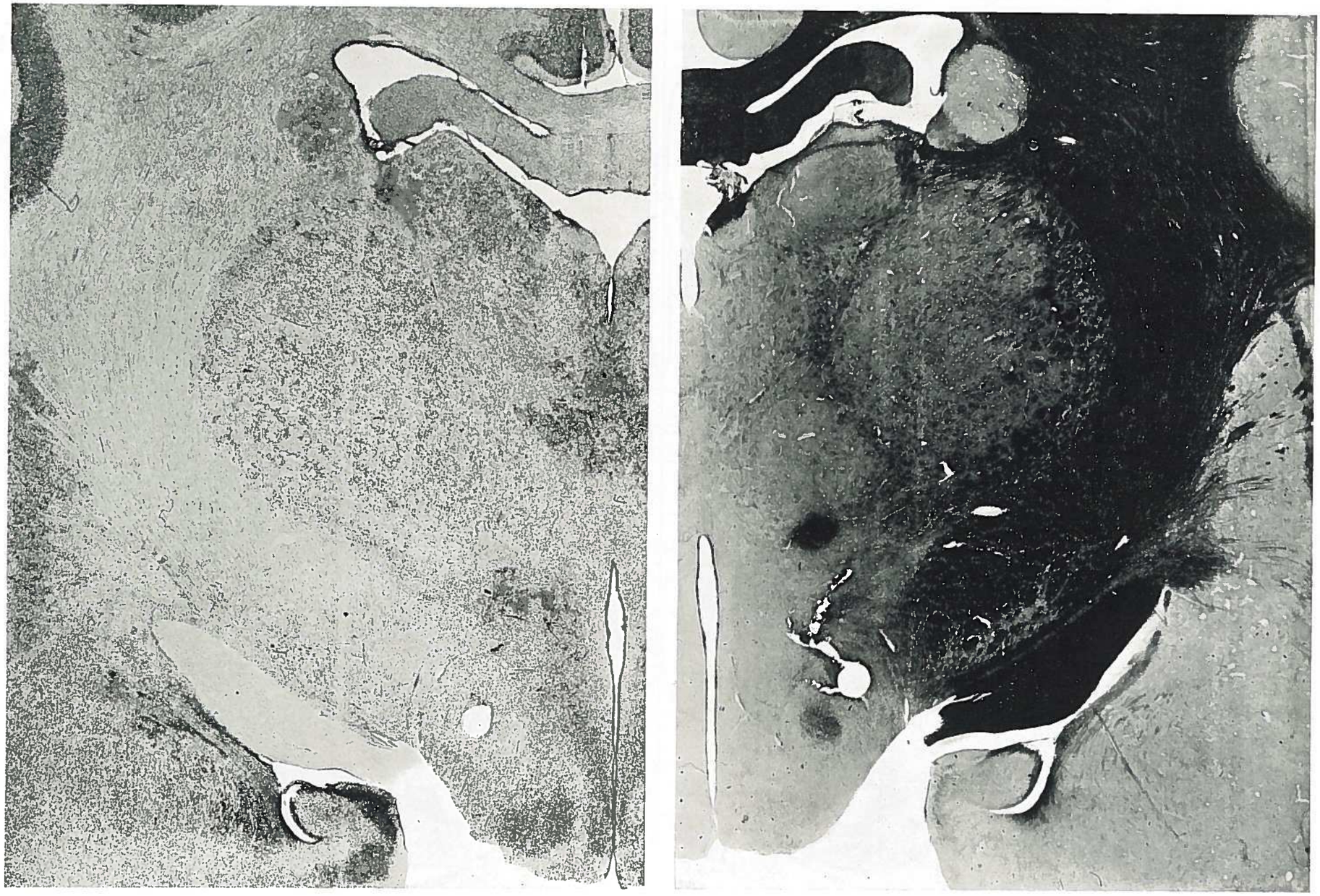
Sec. 190 Fr. 10.0



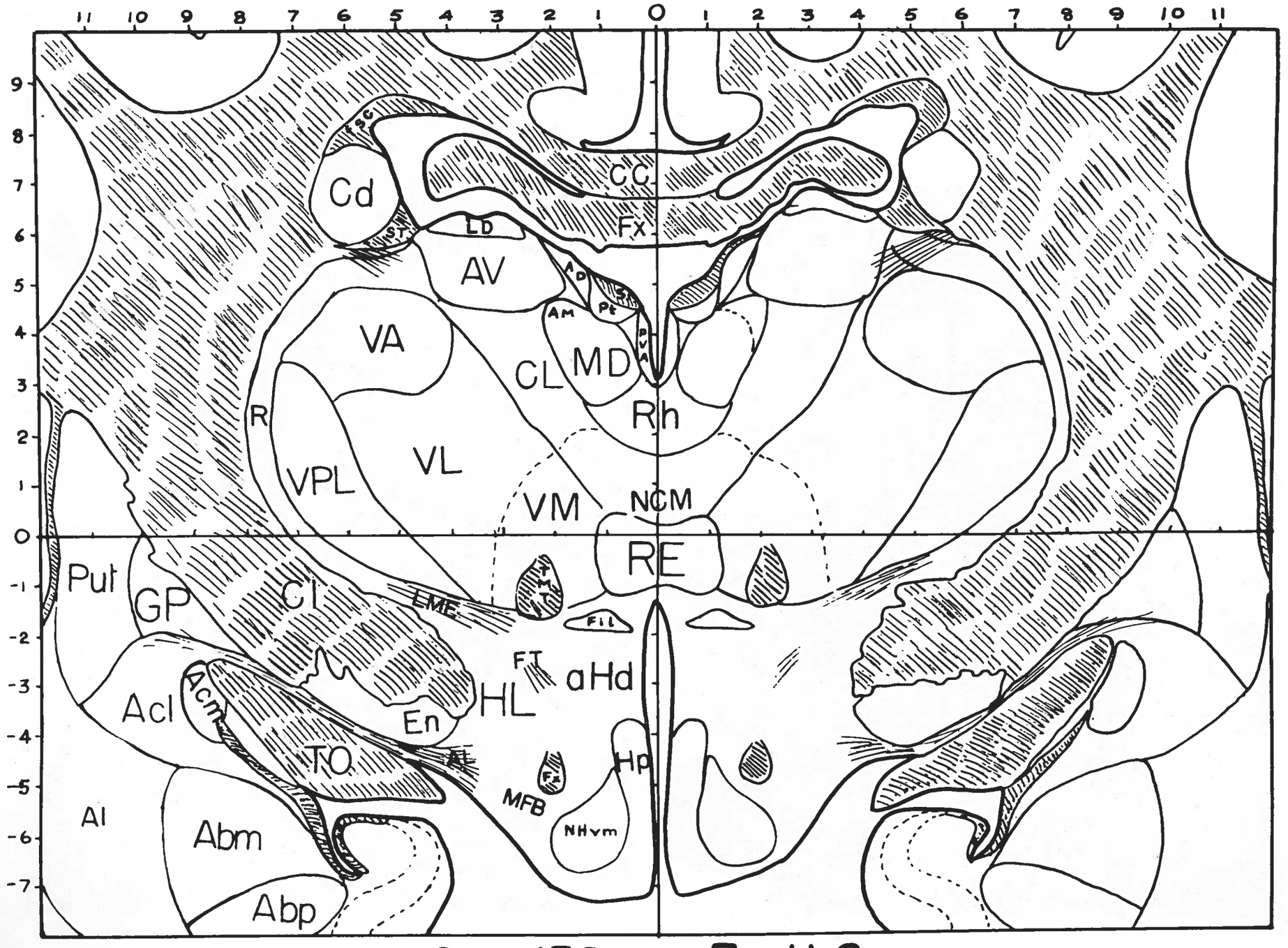
SEC. 180 FR. 10.5



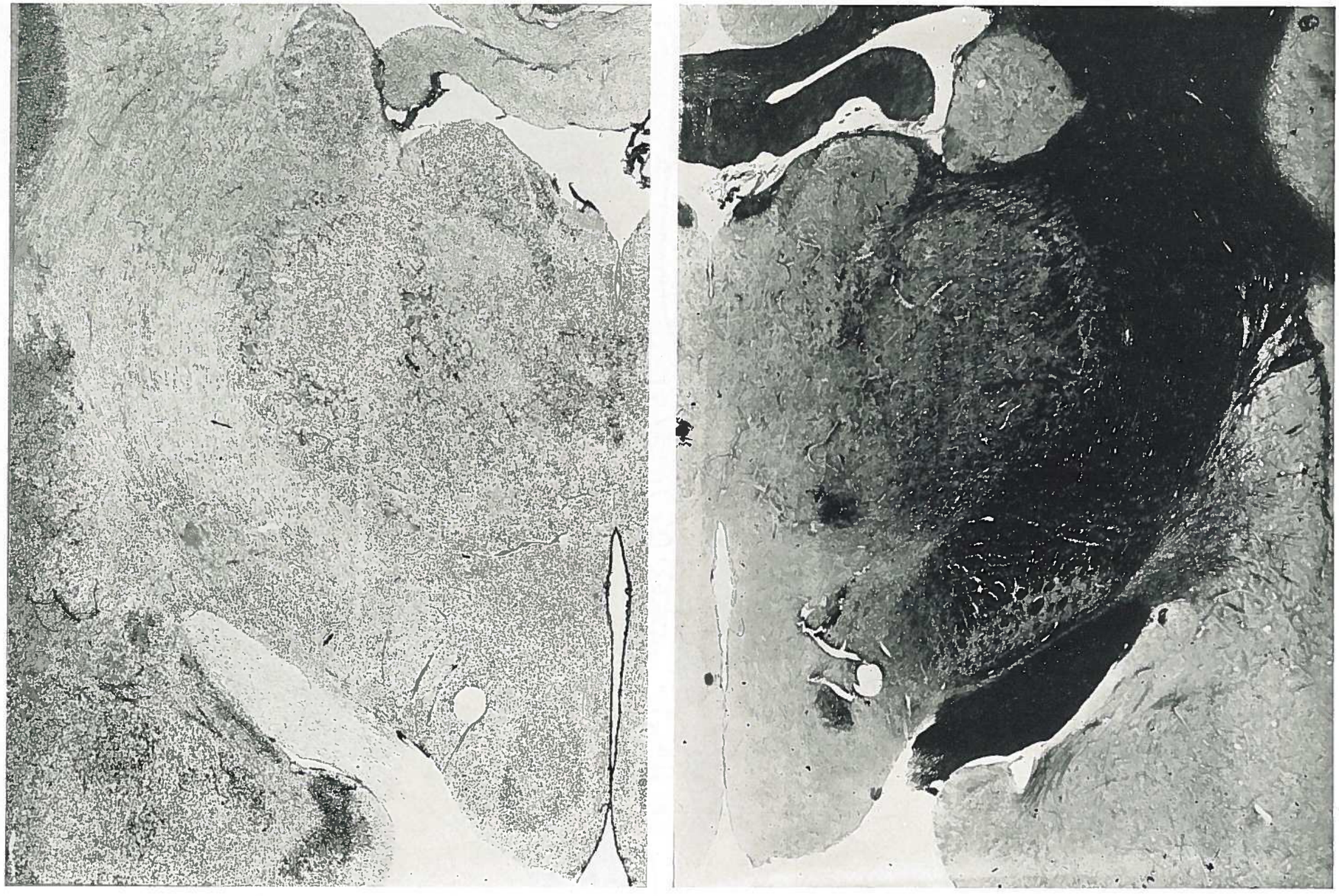
Sec. 180 Fr. 10.5



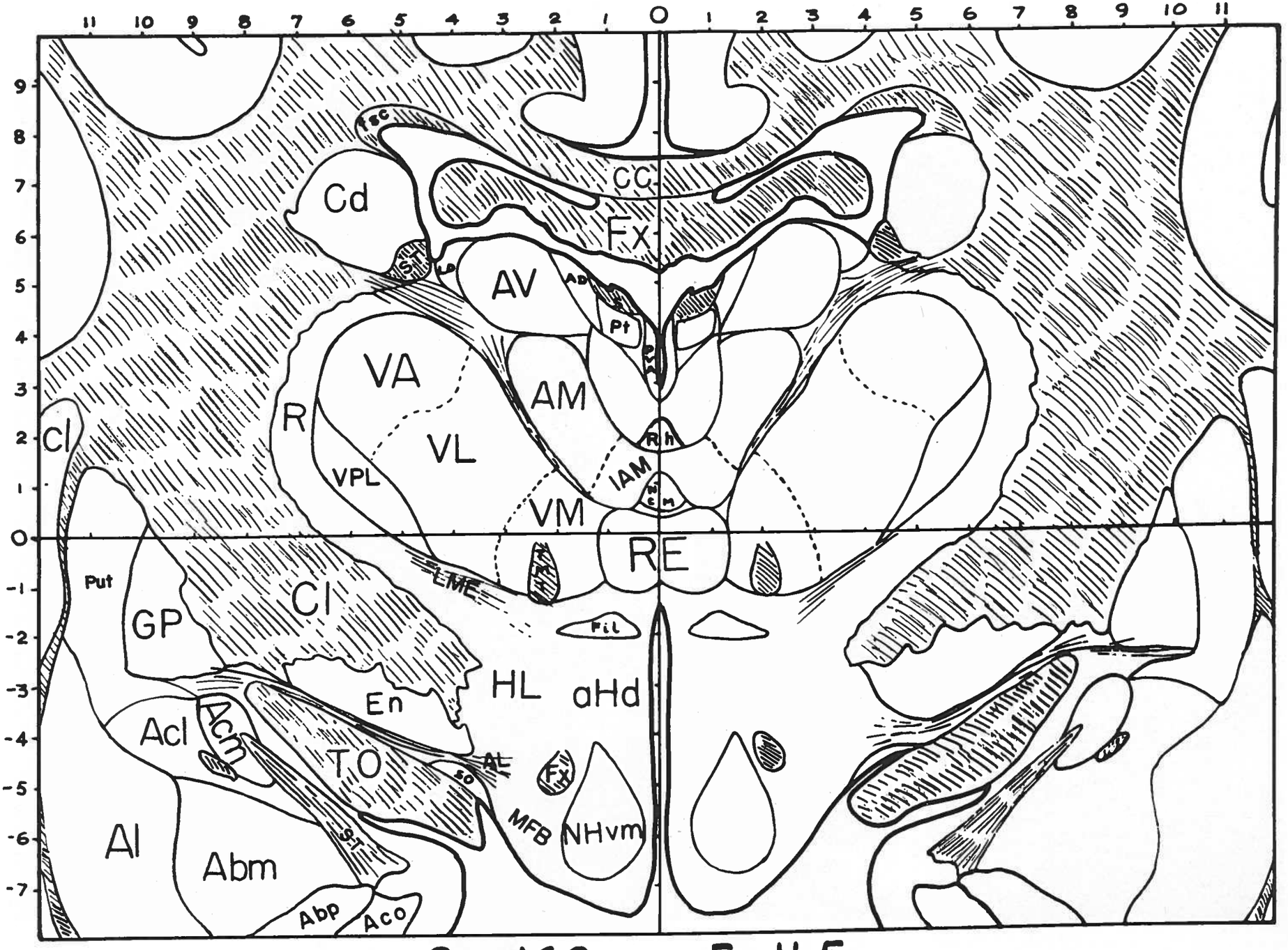
SEC. 170 FR. 11.0



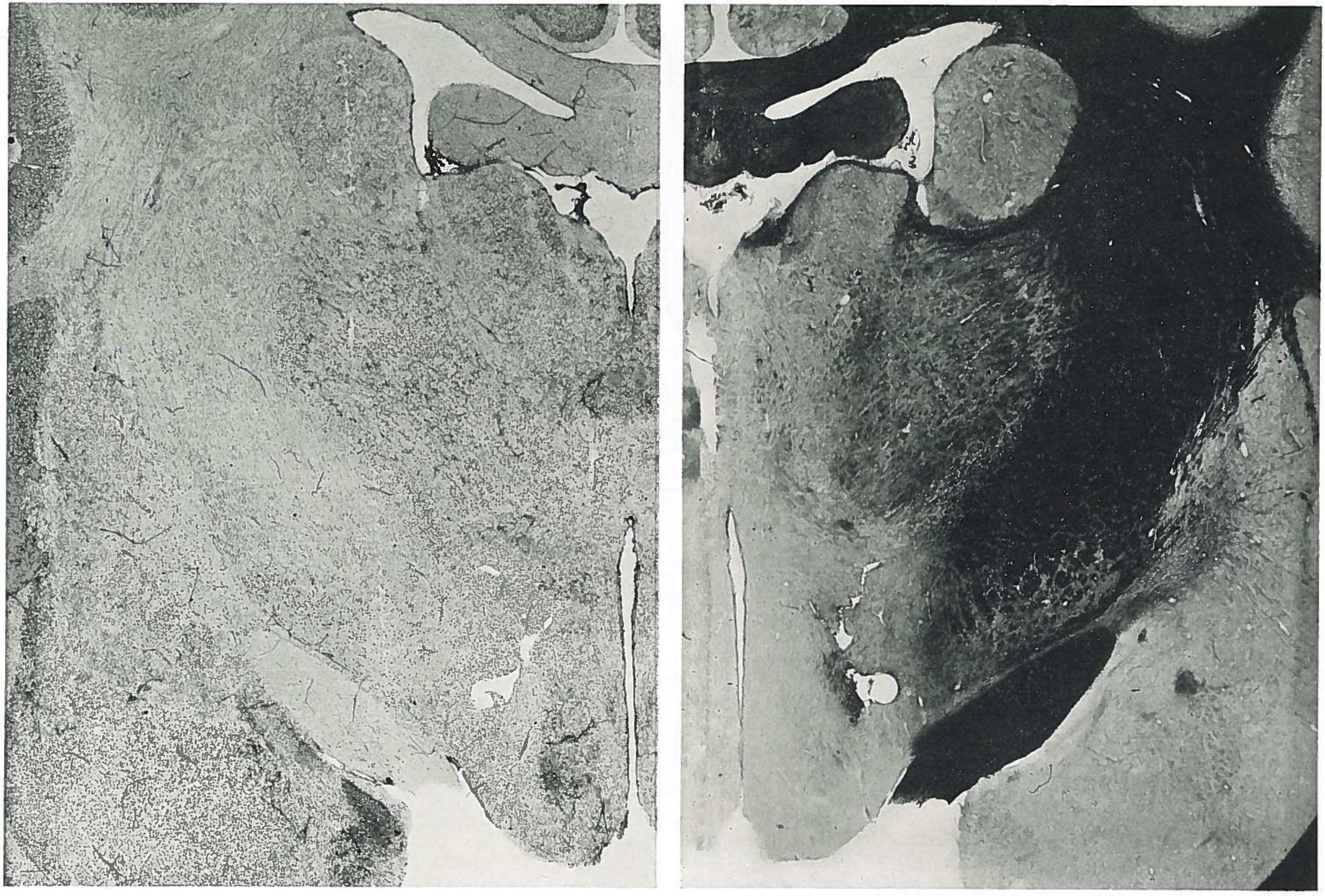
Sec. 170 Fr. 11.0



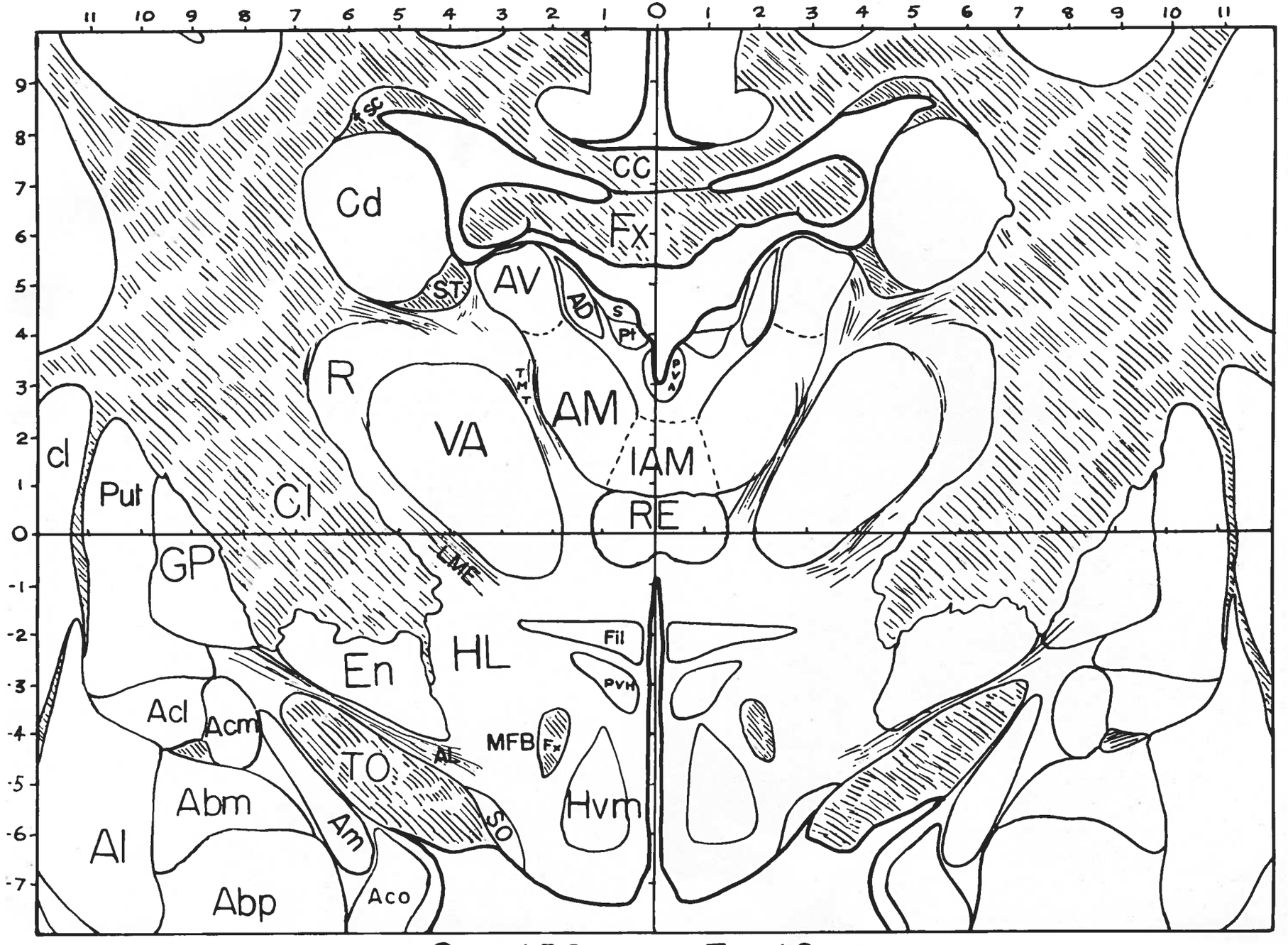
SEC. 160 FR. 11.5



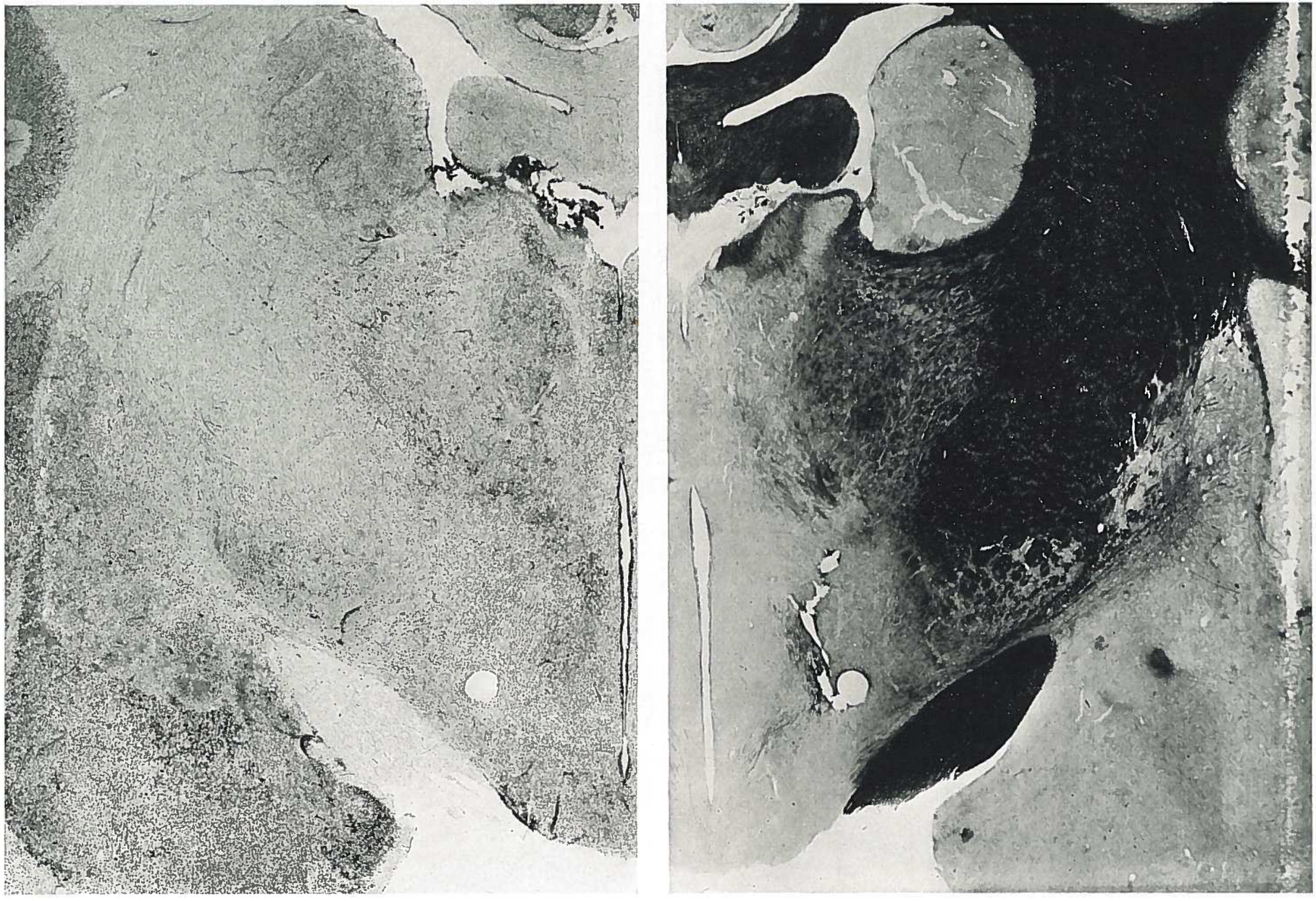
Sec. 160 Fr. 11.5



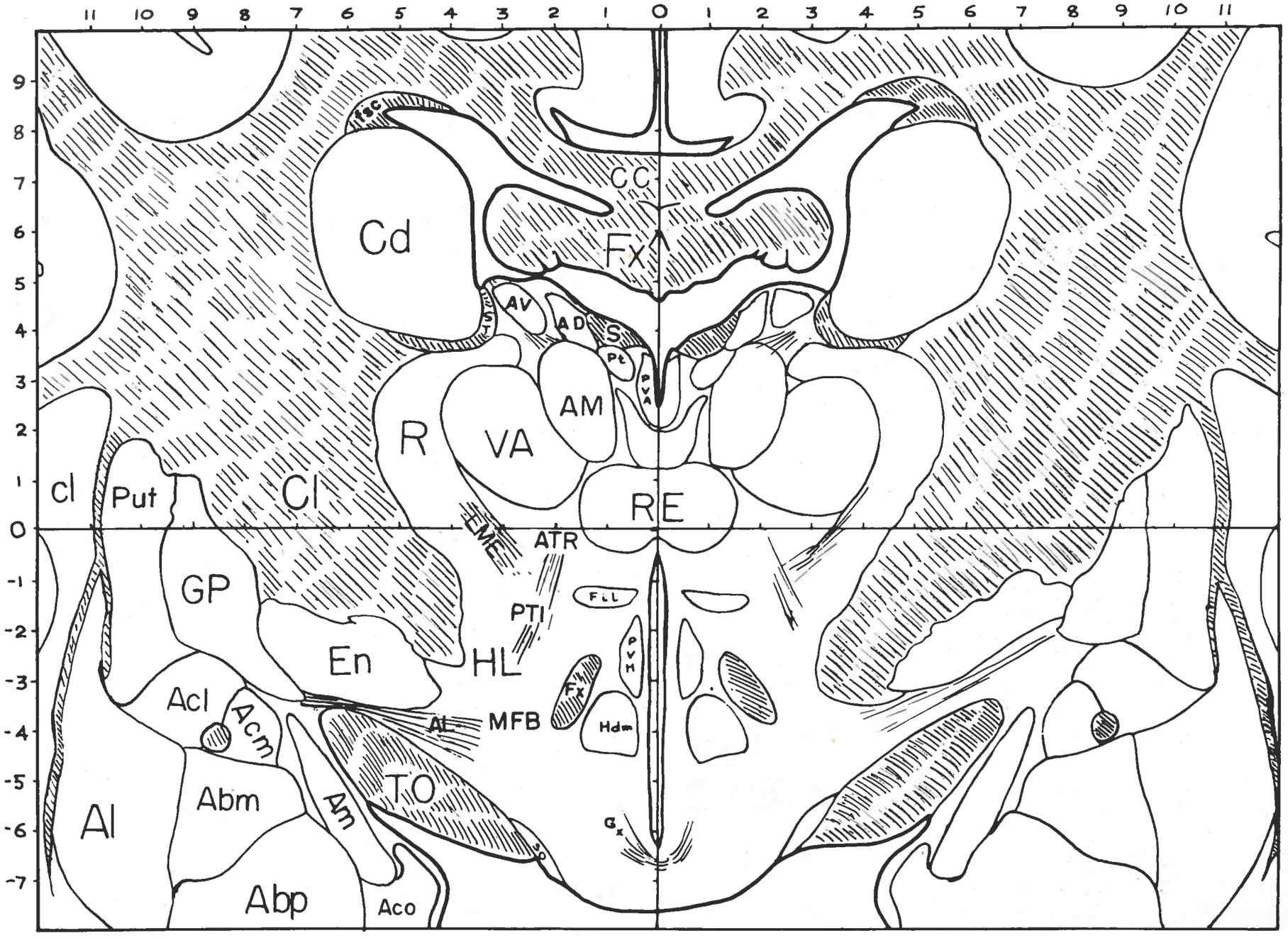
SEC. 150 FR. 12.0



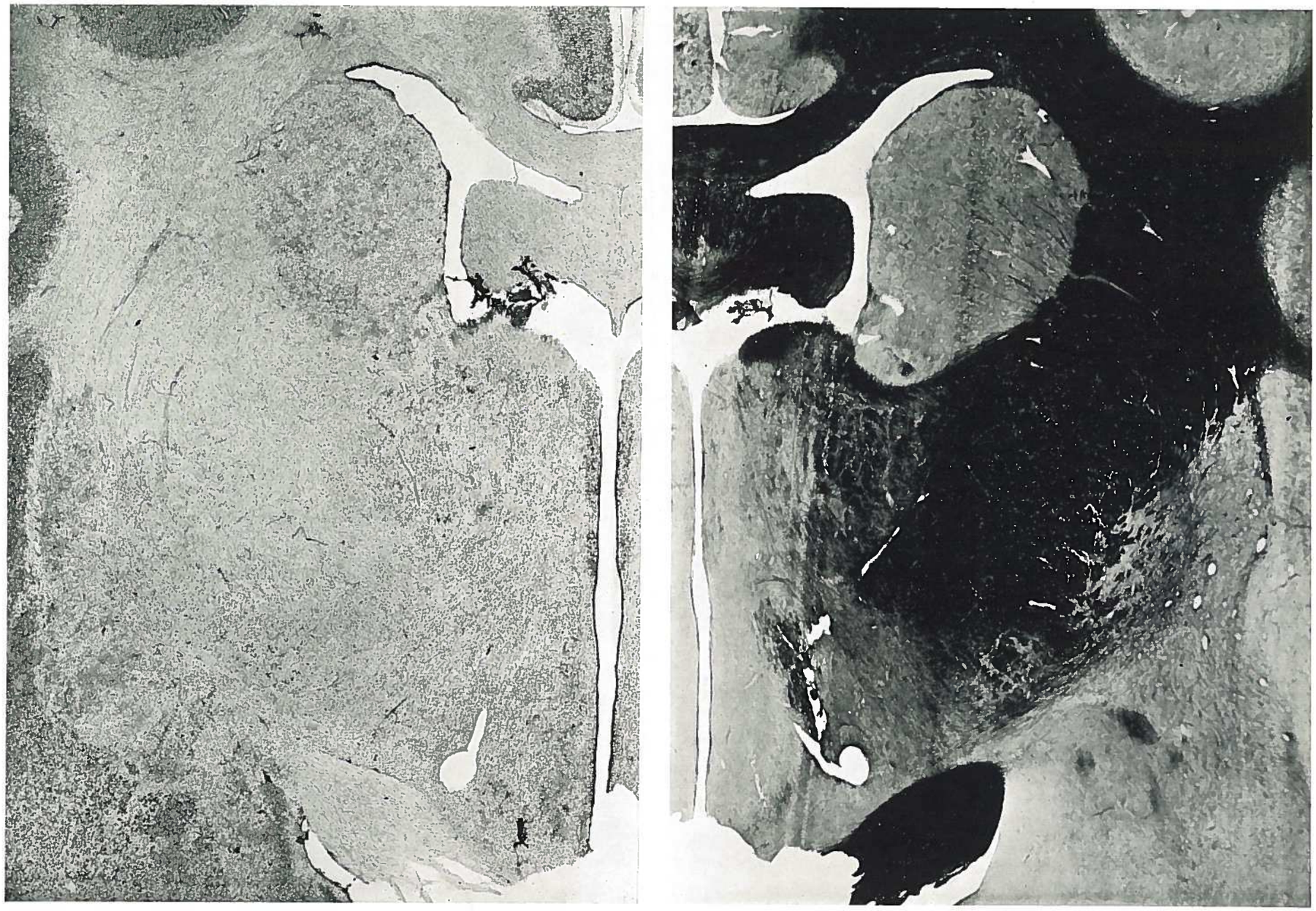
Sec. 150 Fr. 12.0



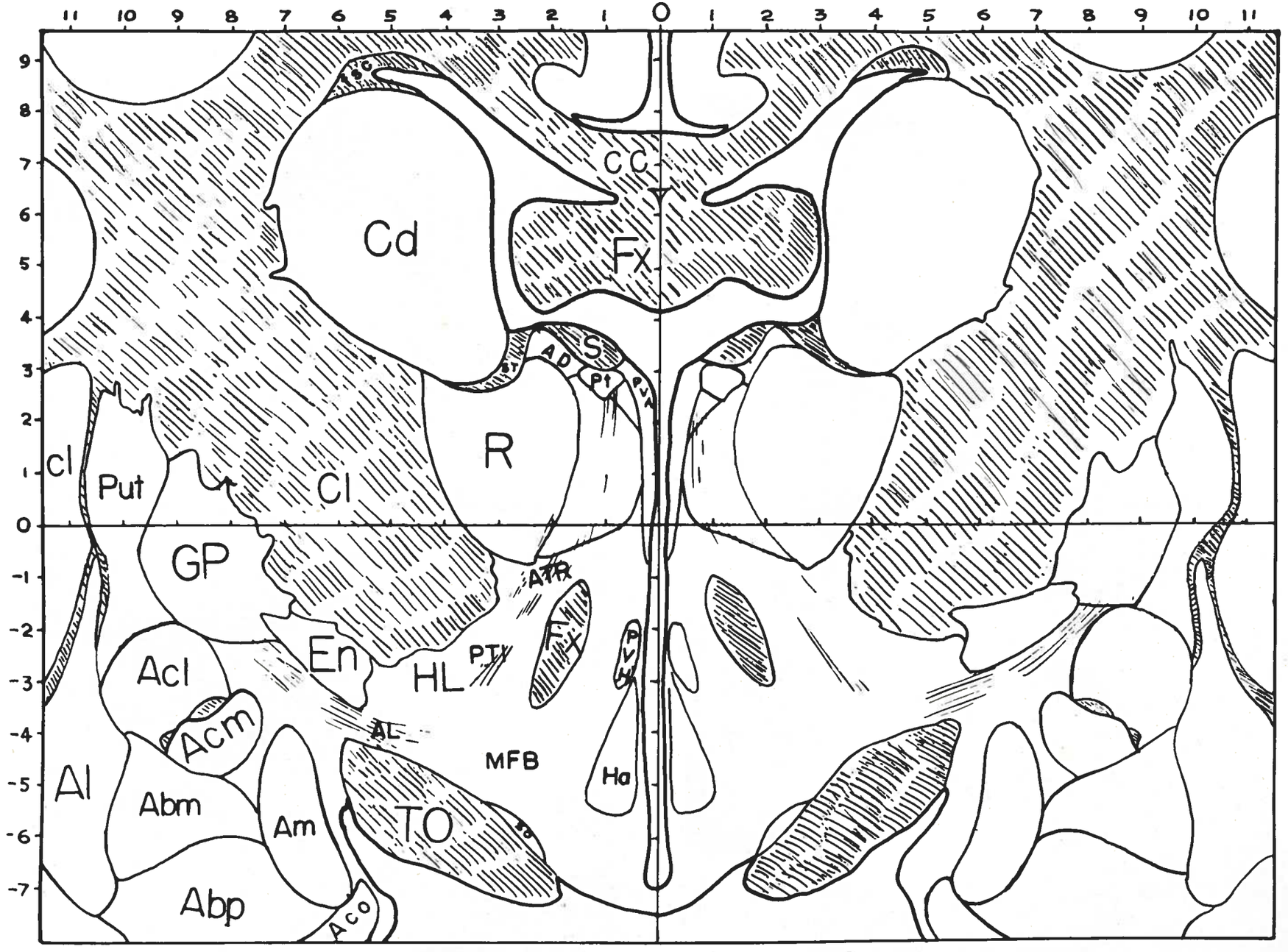
SEC. 140 FR. 12.5



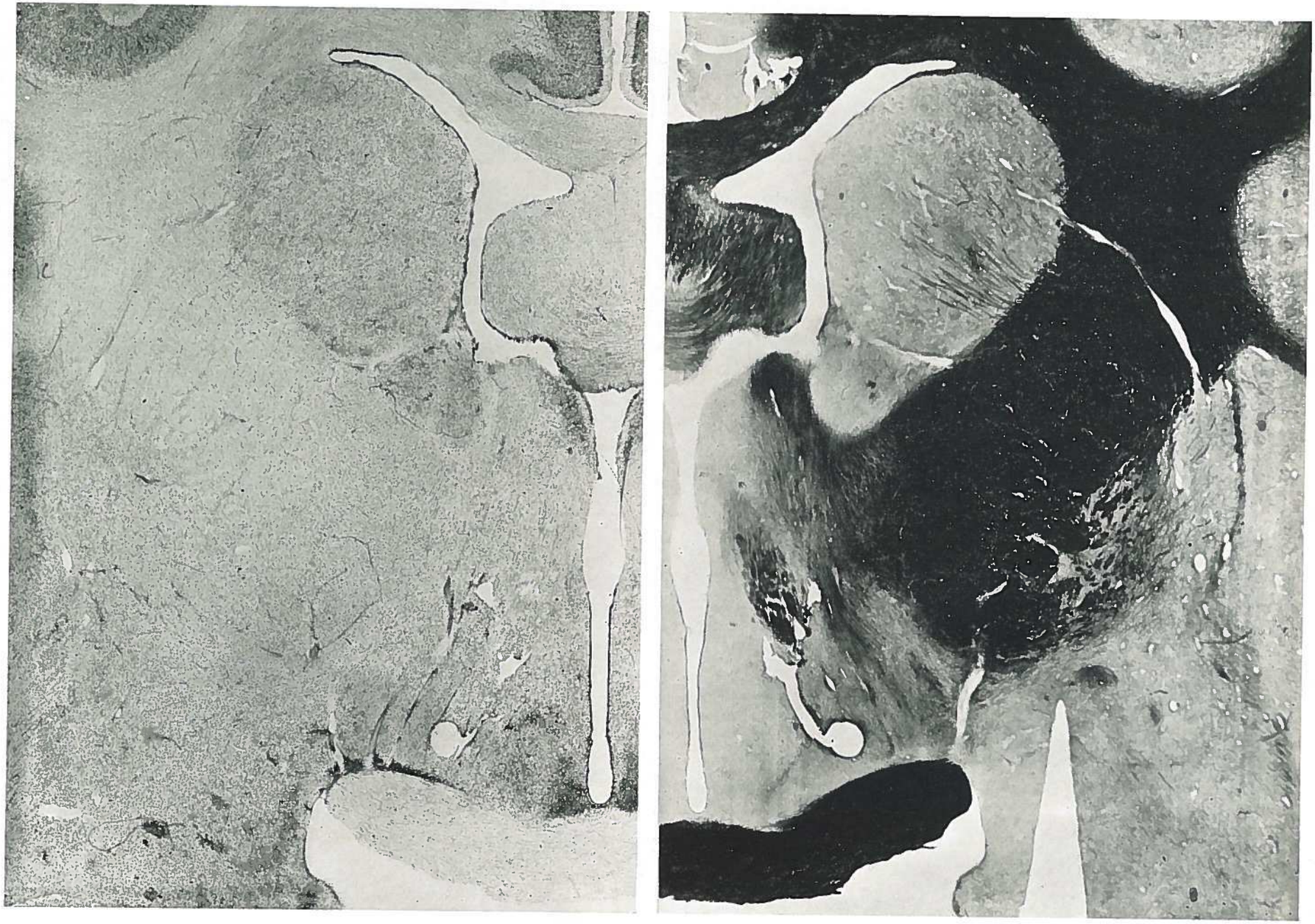
Sec. 140 Fr. 12.5



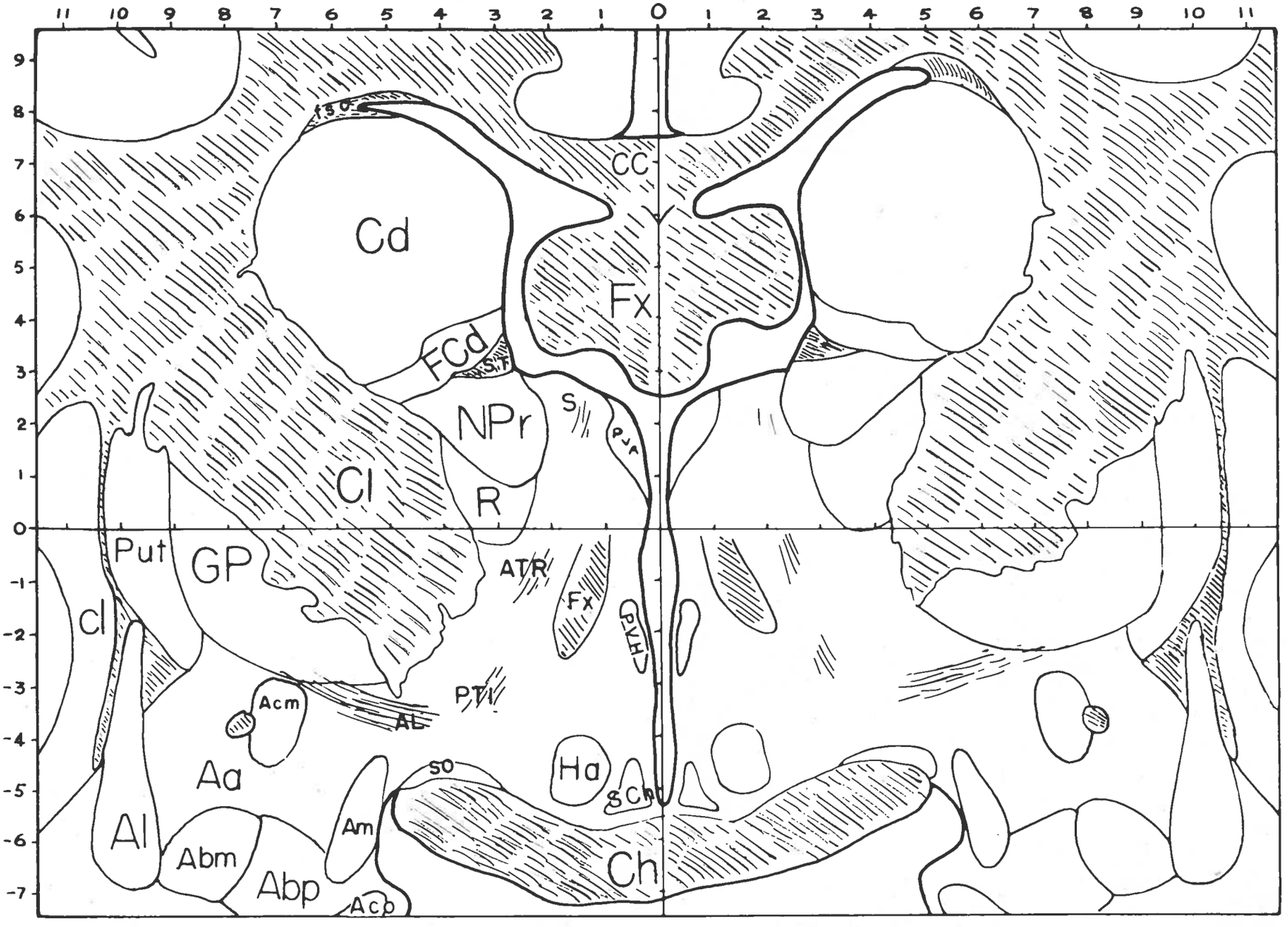
SEC. 130 FR. 13.0



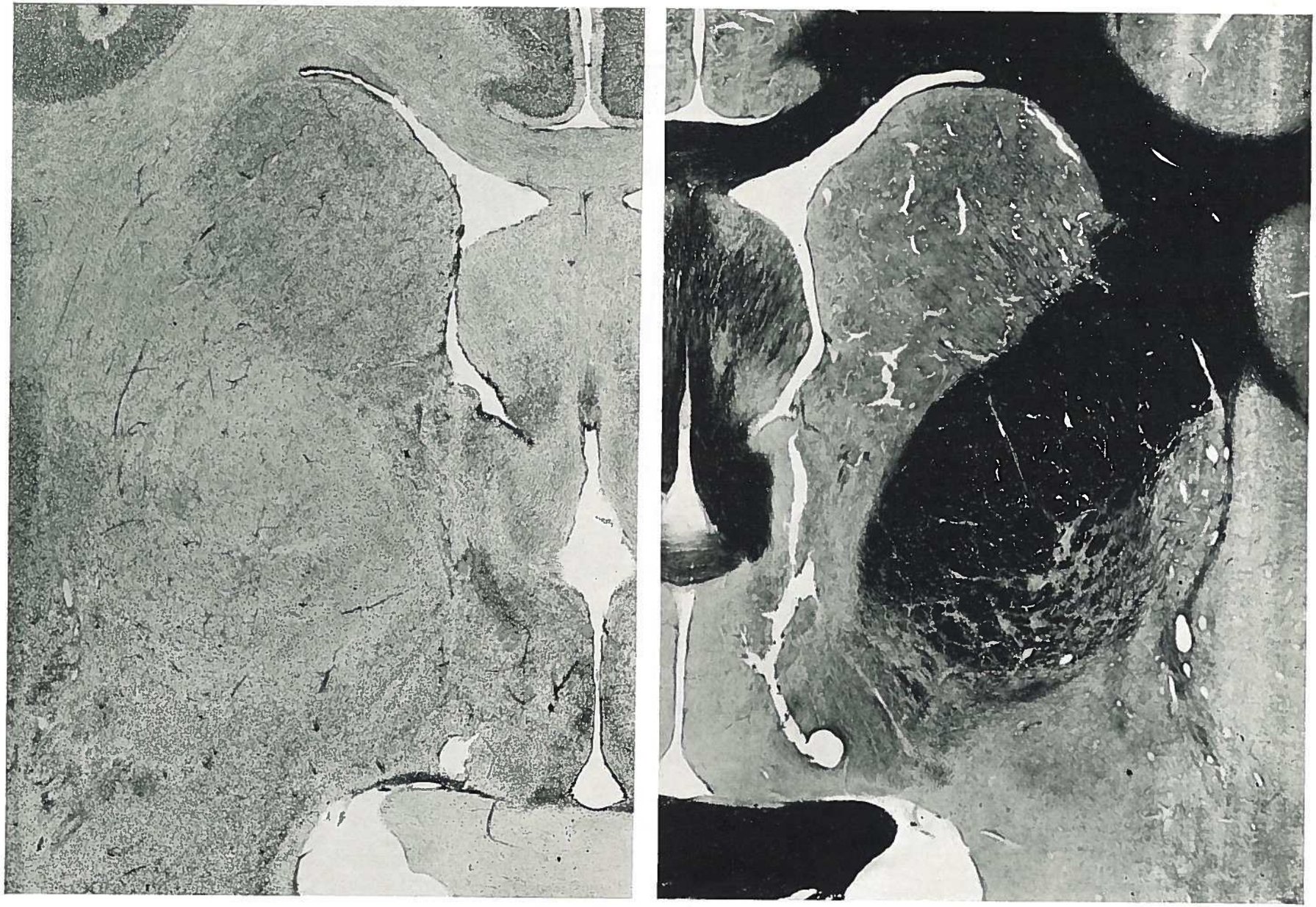
Sec. 130 Fr. 13.0



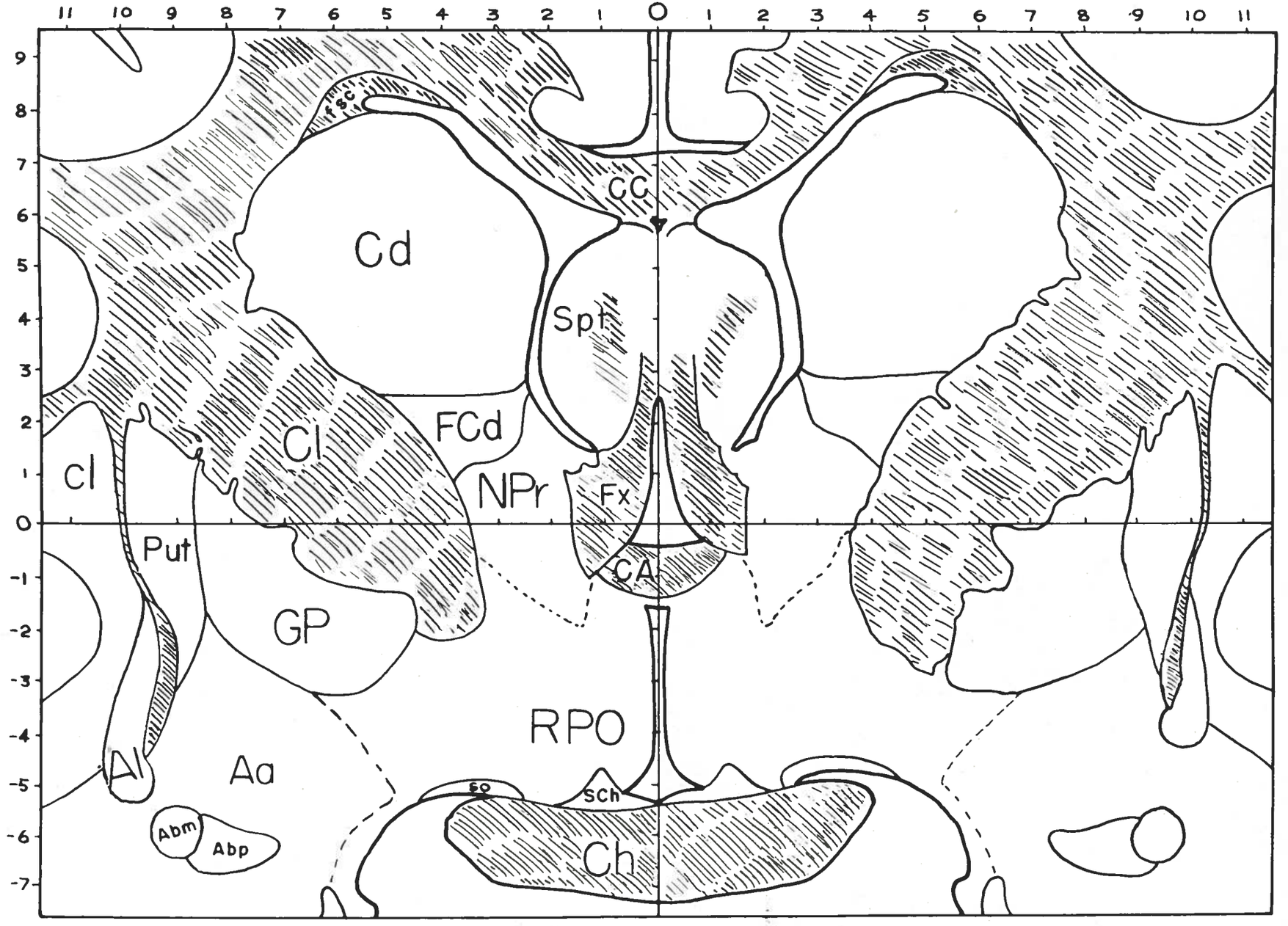
SEC. 120 FR. 13.5



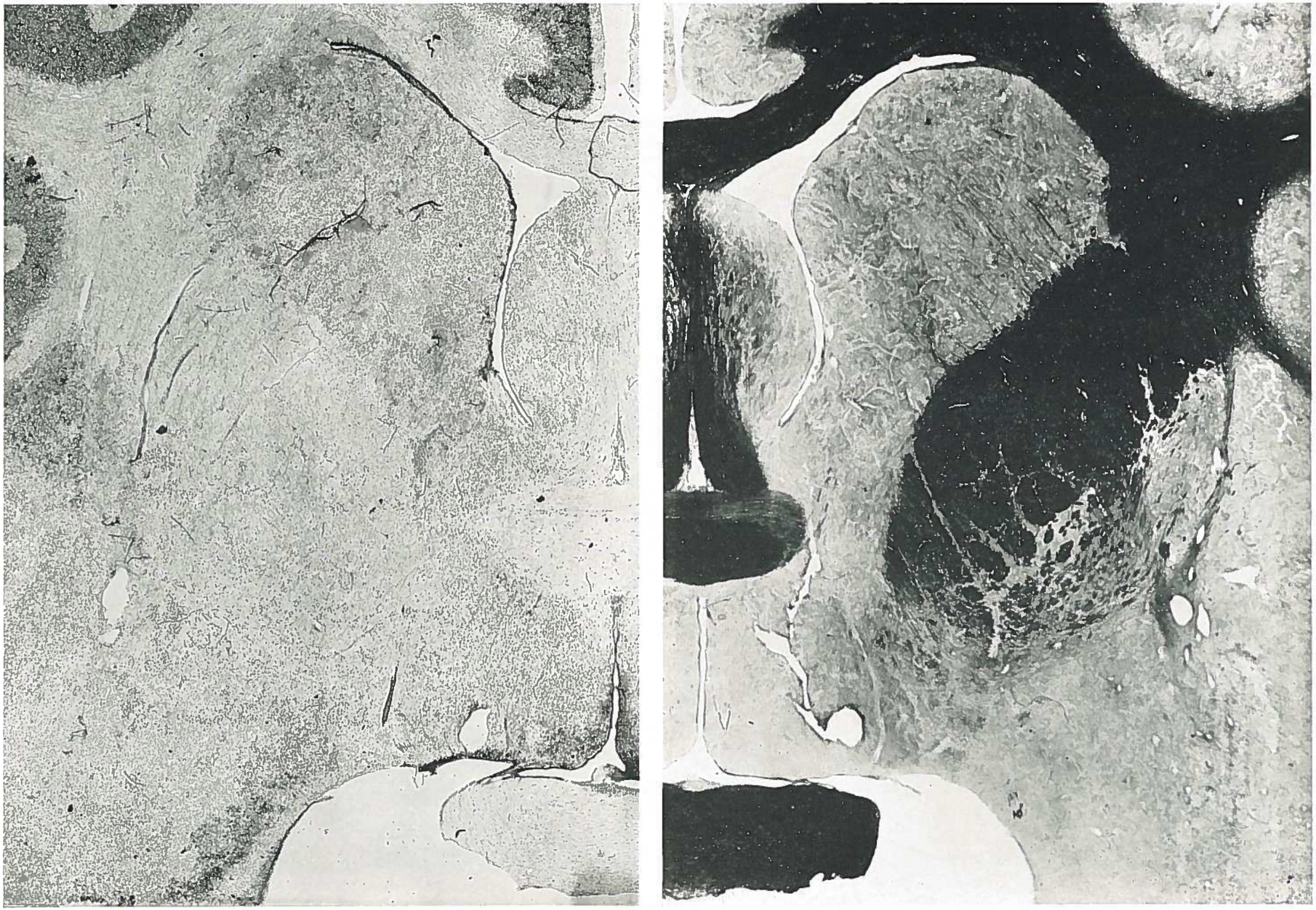
Sec. 120 Fr. 13.5



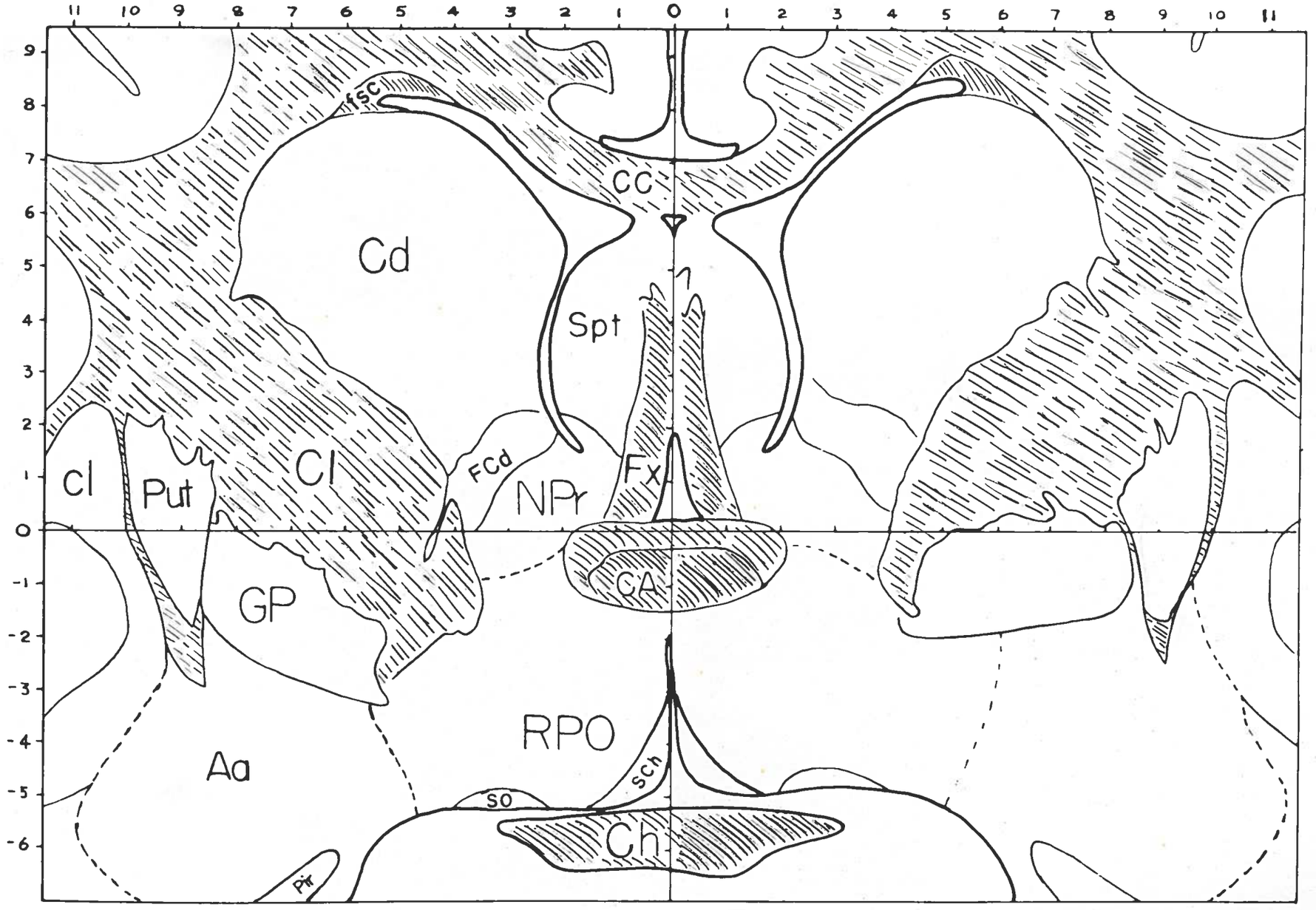
SEC. 110 FR. 14.0



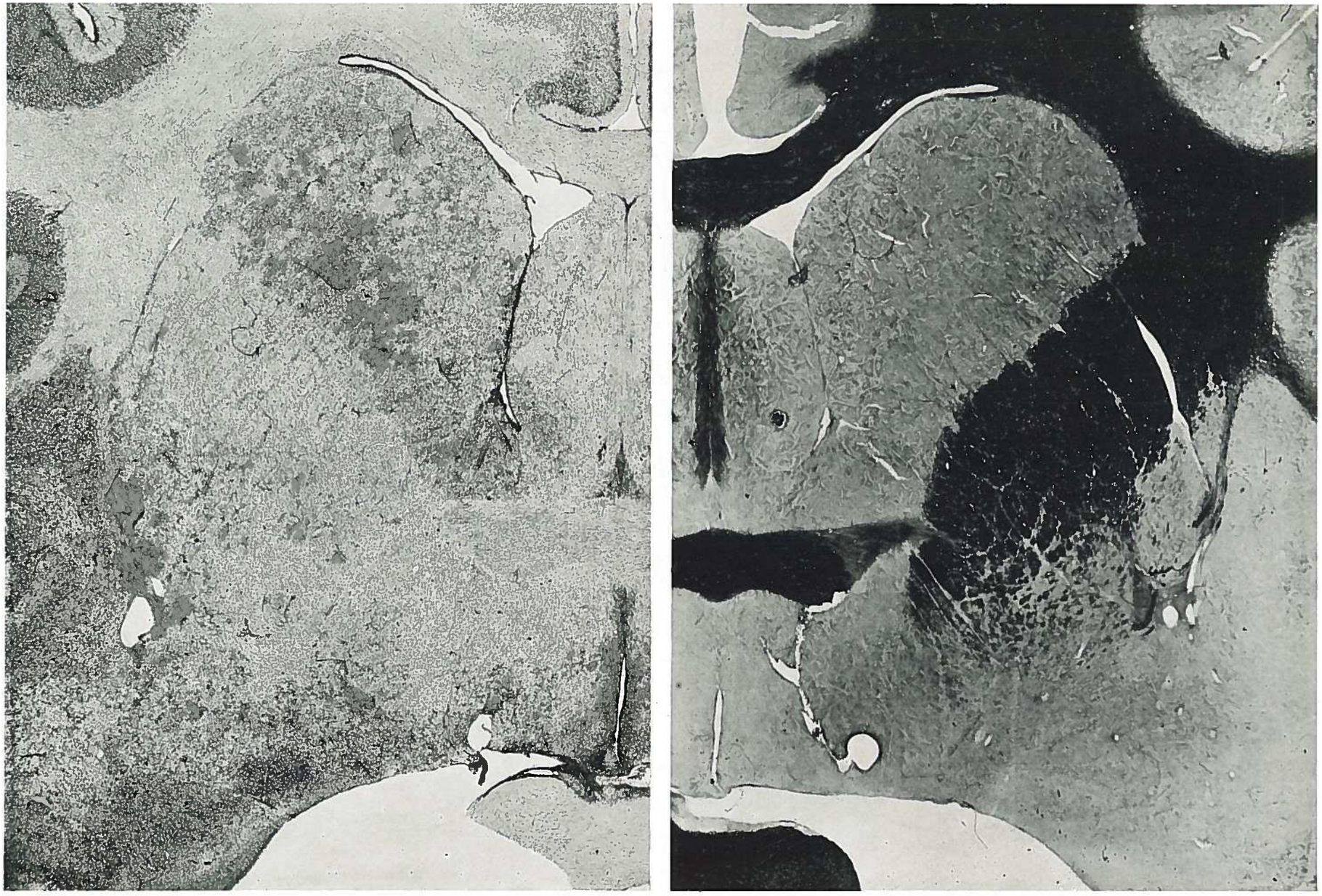
Sec. 110 Fr. 14.0



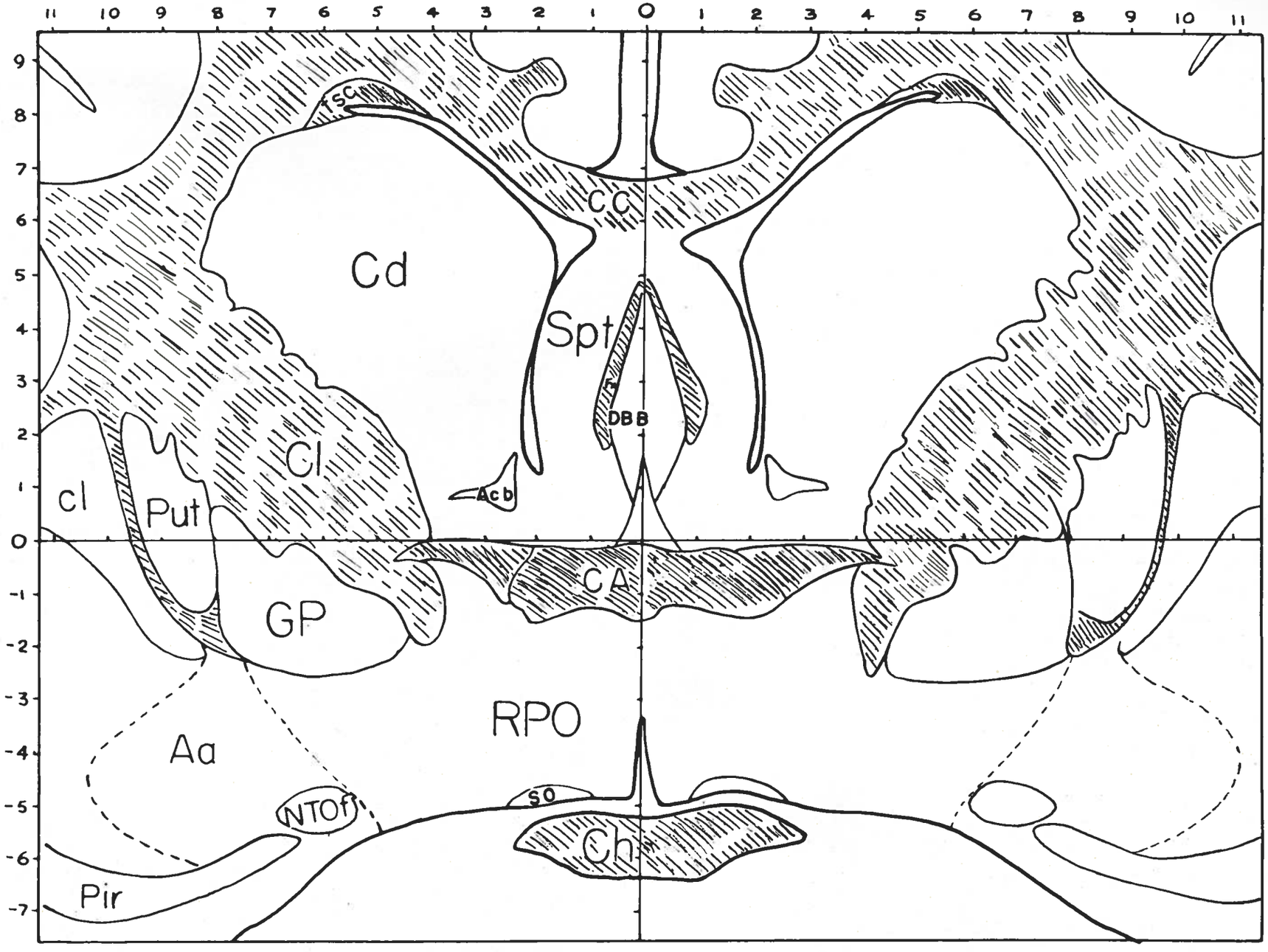
SEC. 100 FR. 14.5



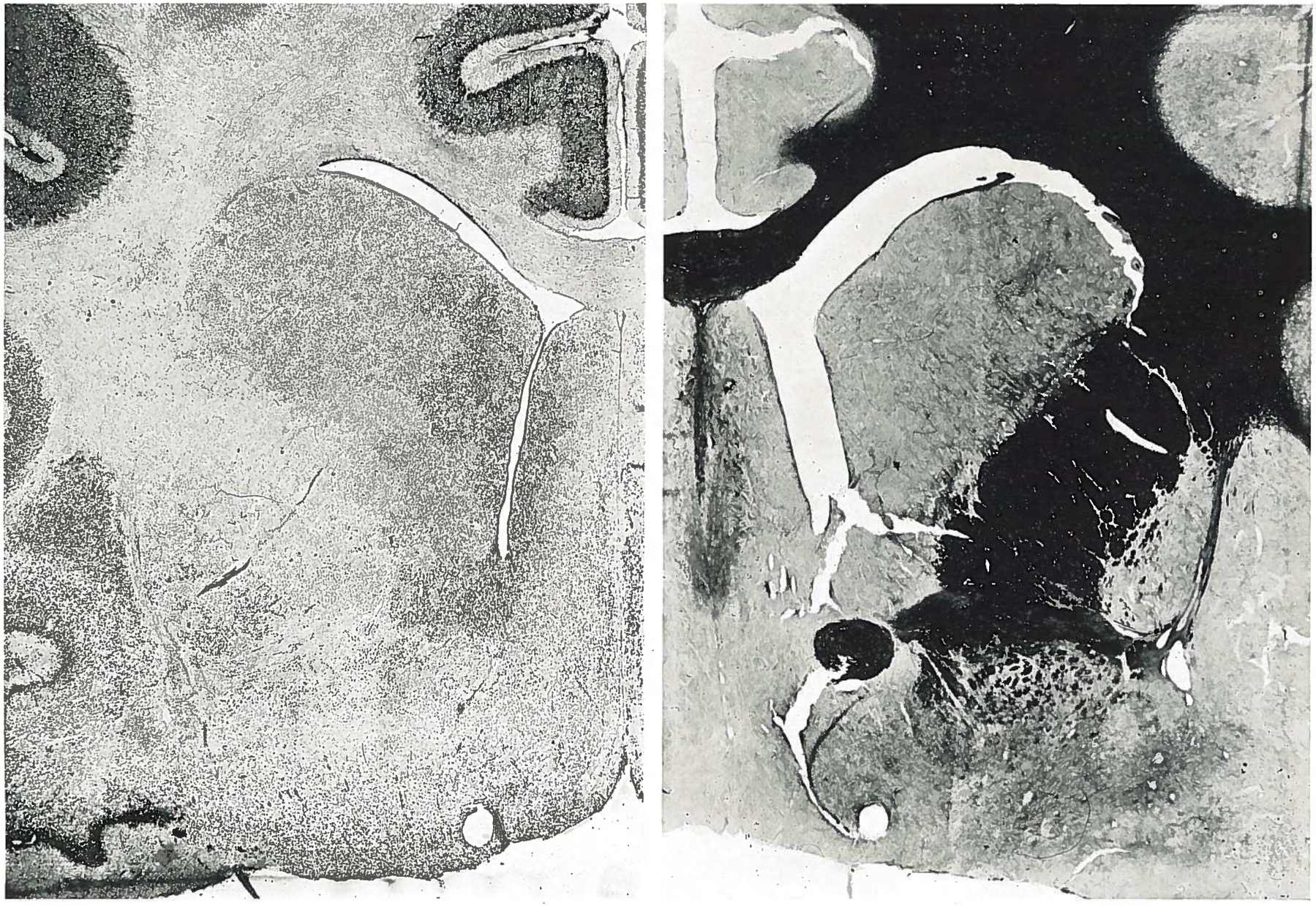
Sec. 100 Fr. 14.5



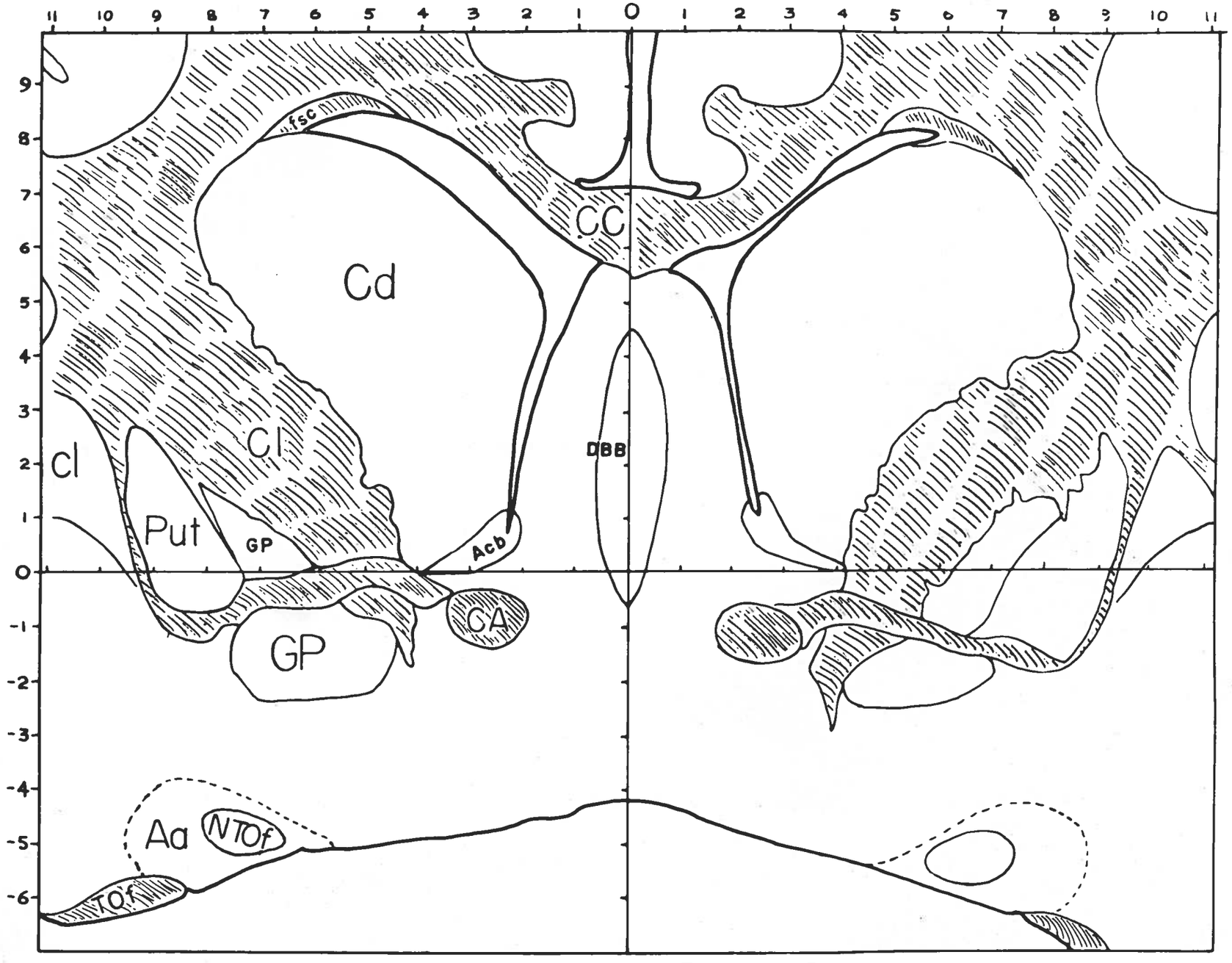
SEC. 90 FR. 15.0


11 10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10 11
9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7
fsc
CC
Cd
Spt
DBB
Cl
cl
Put
Acb
CA
GP
RPO
Aa
NTOf
SO
Ch
Pir

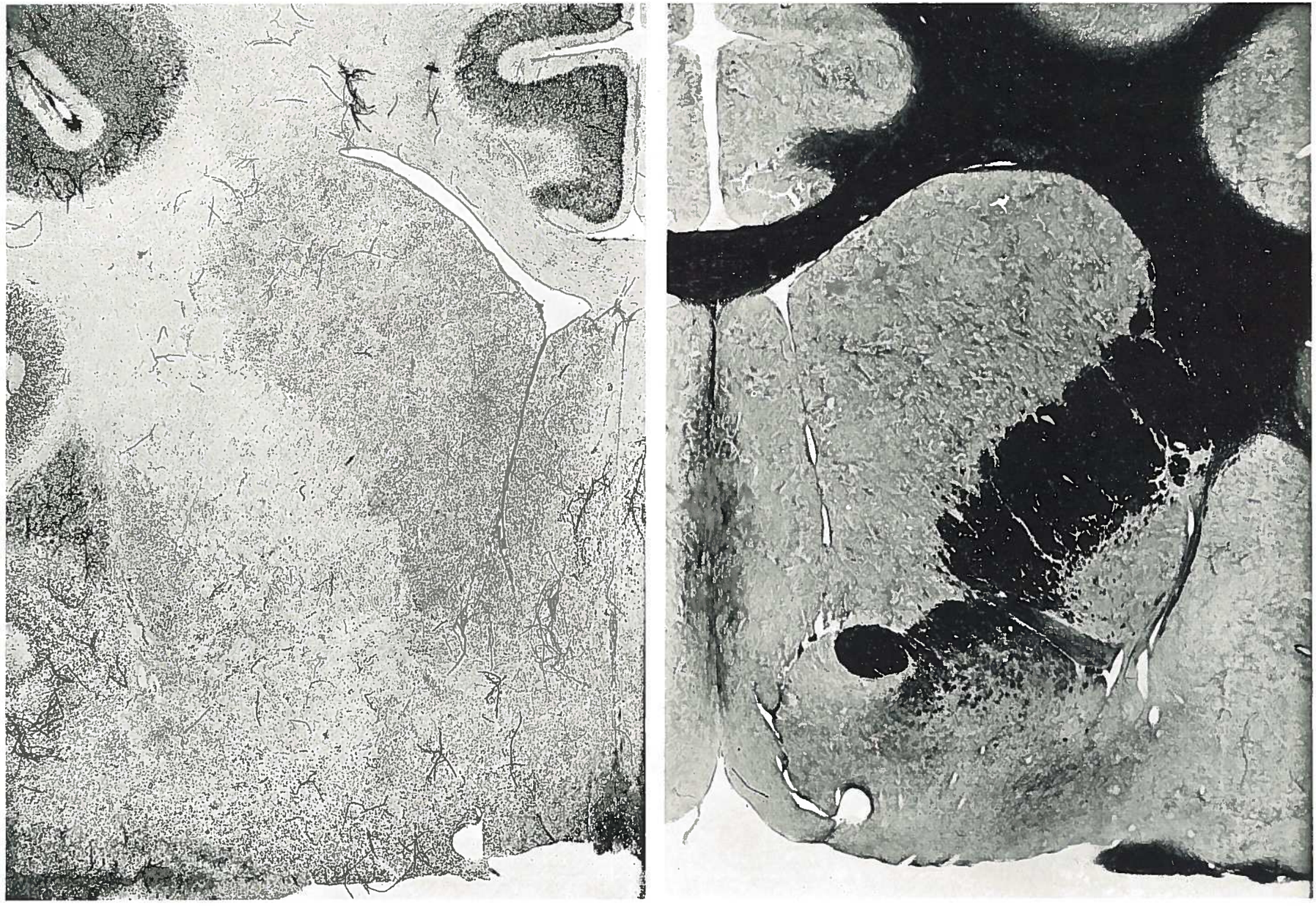
Sec. 90 Fr 15.0



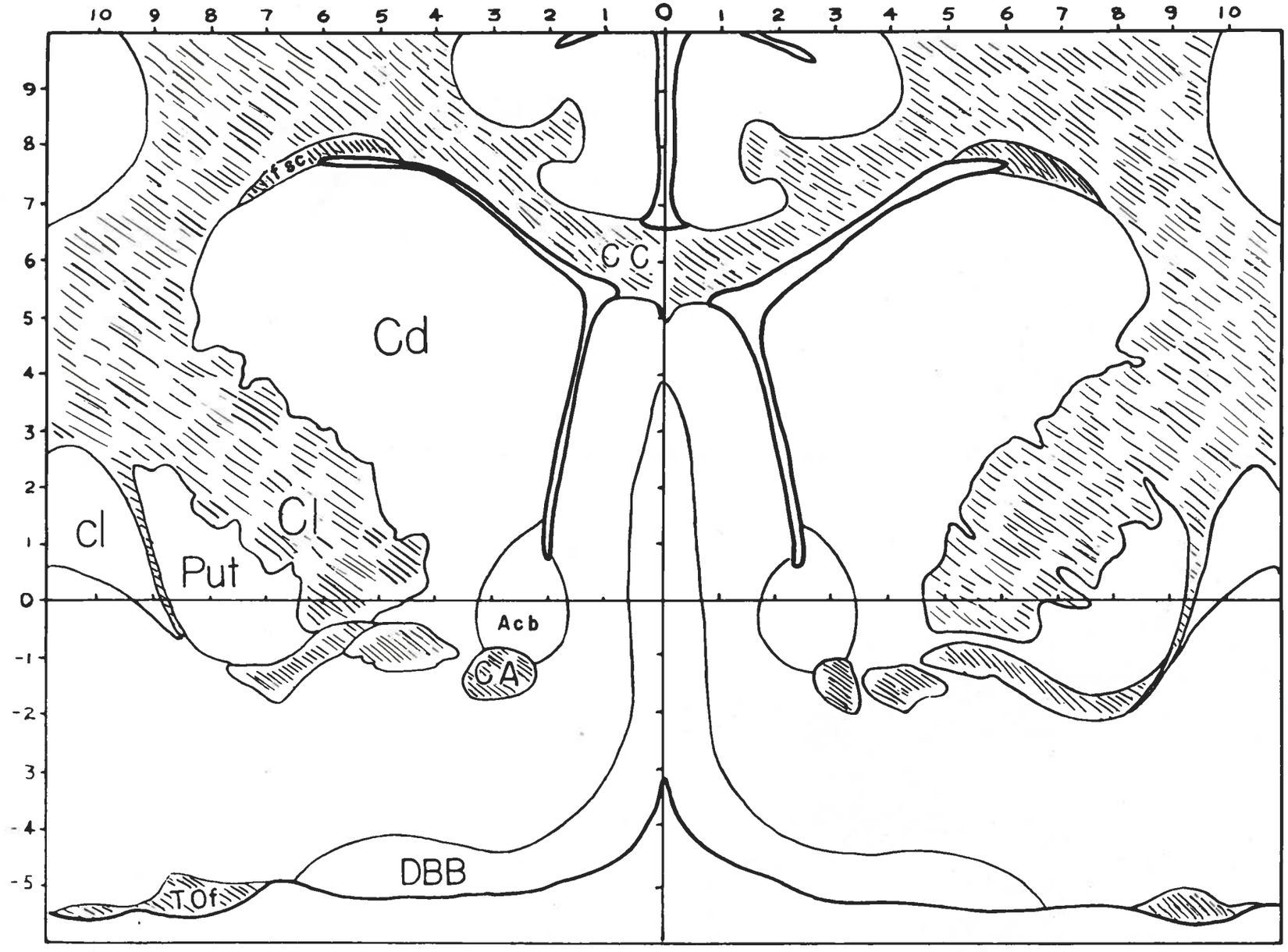
SEC. 80 FR. 15.5



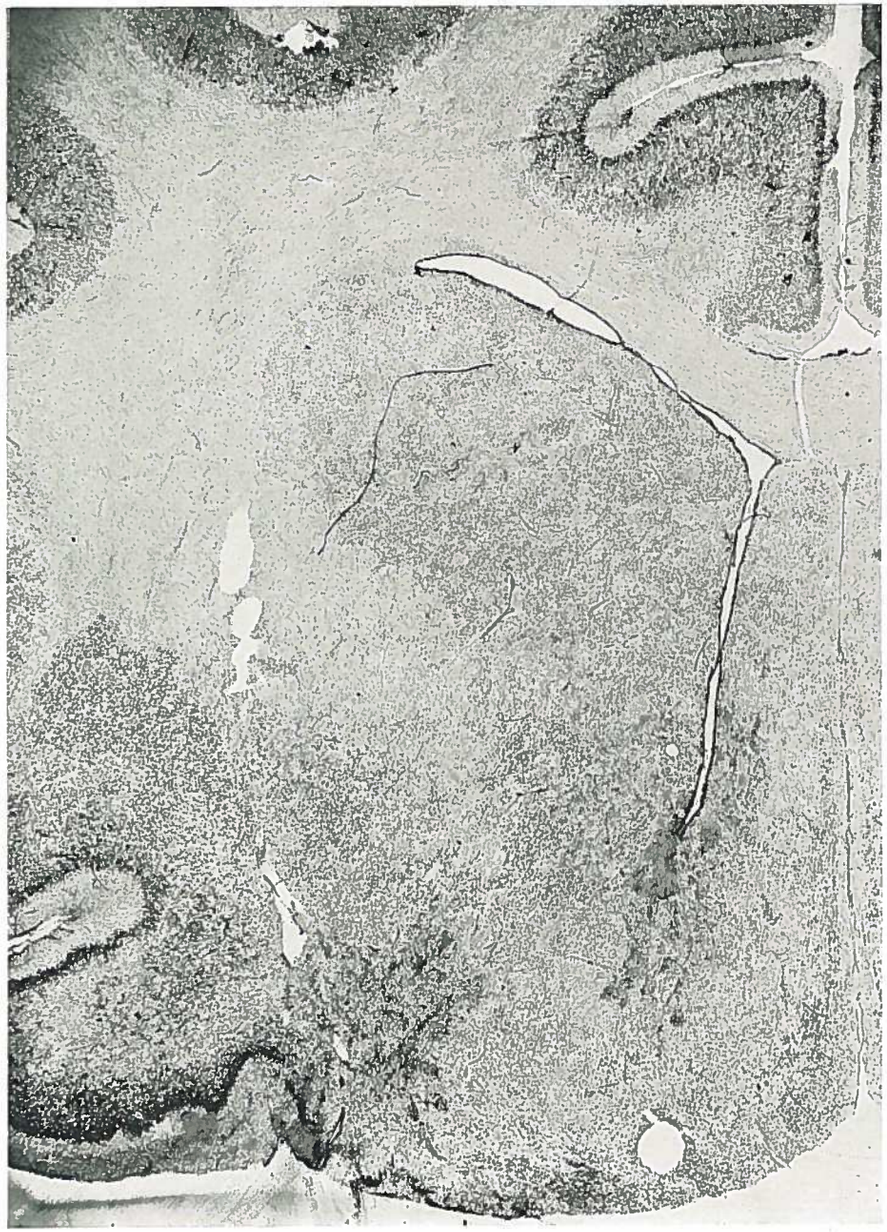
Sec. 80 Fr. 15.5

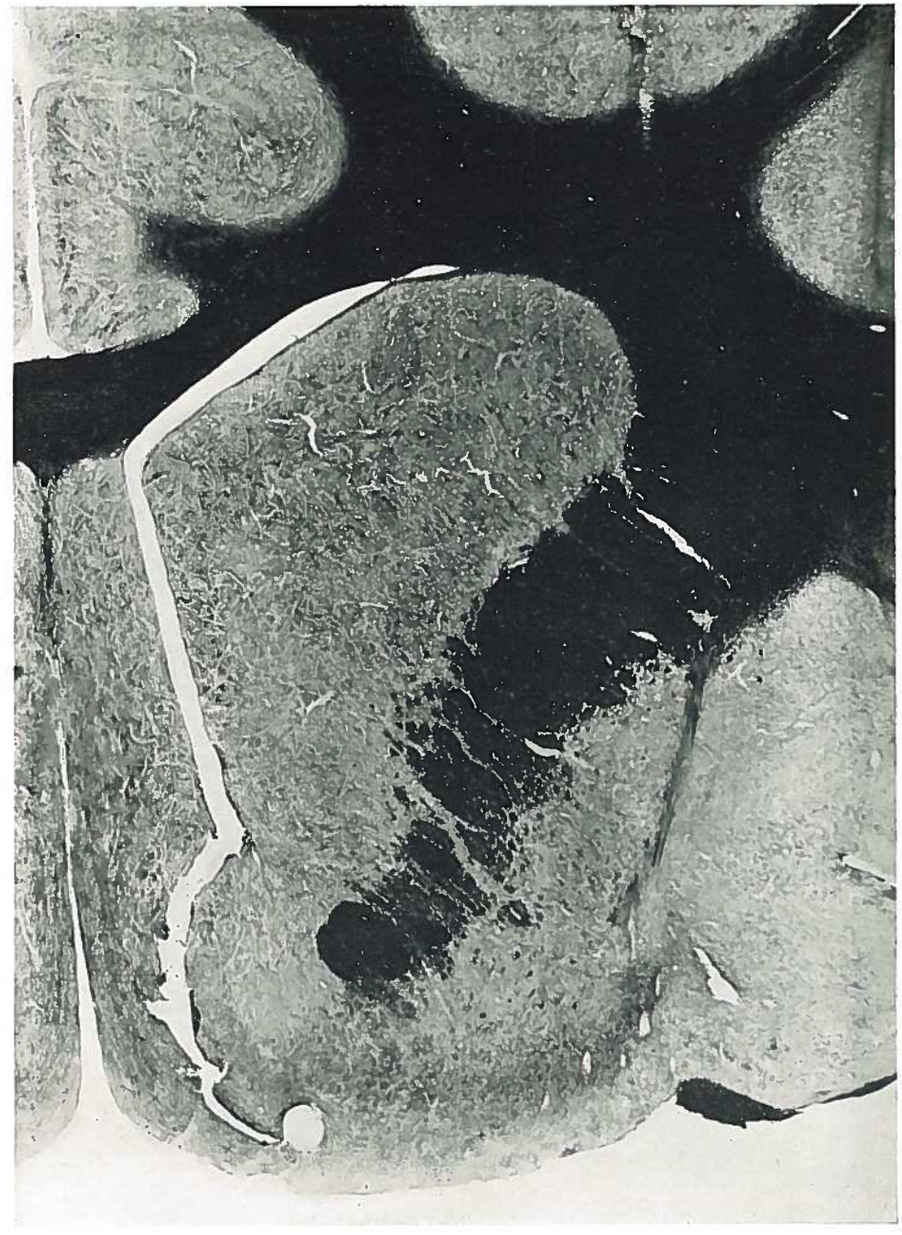


SEC. 70 FR. 16.0

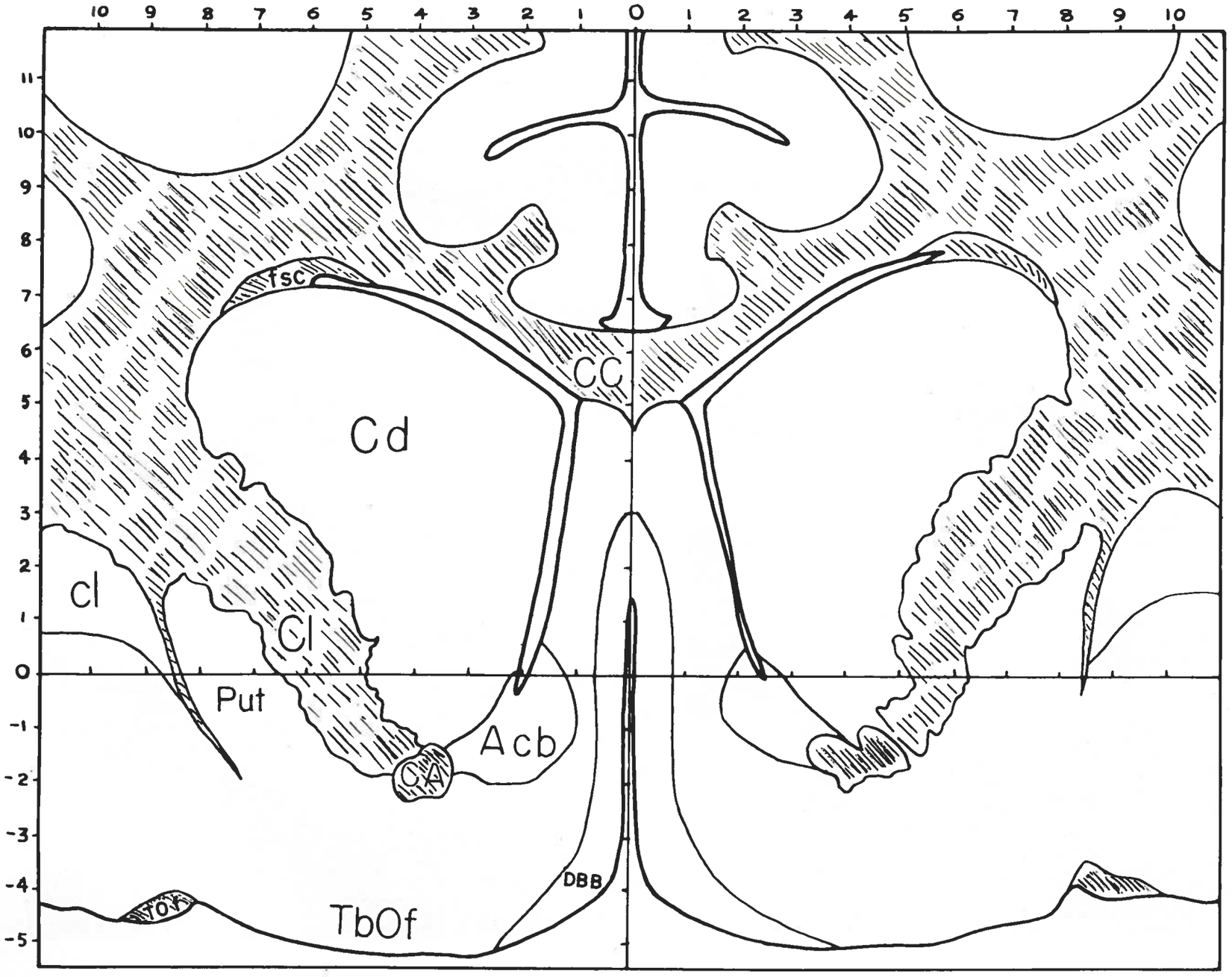

10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10
9 8 7 6 5 4 3 2 1 0 -1 -2 3 -4 -5
f sc.
CC
Cd
Cl
Put
Cl
Acb
CA
DBB
T.Of.

Sec. 70 Fr. 16.0

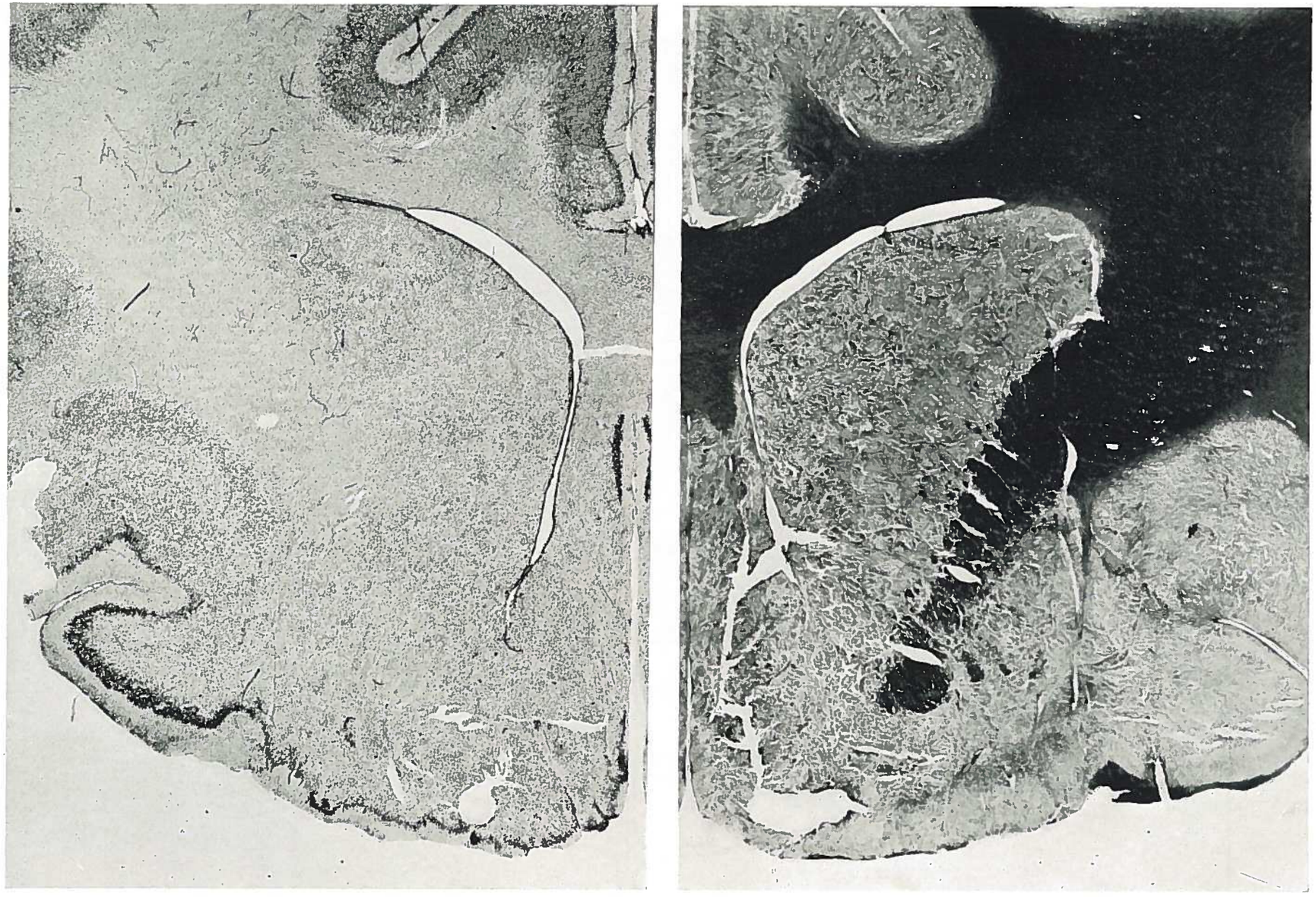




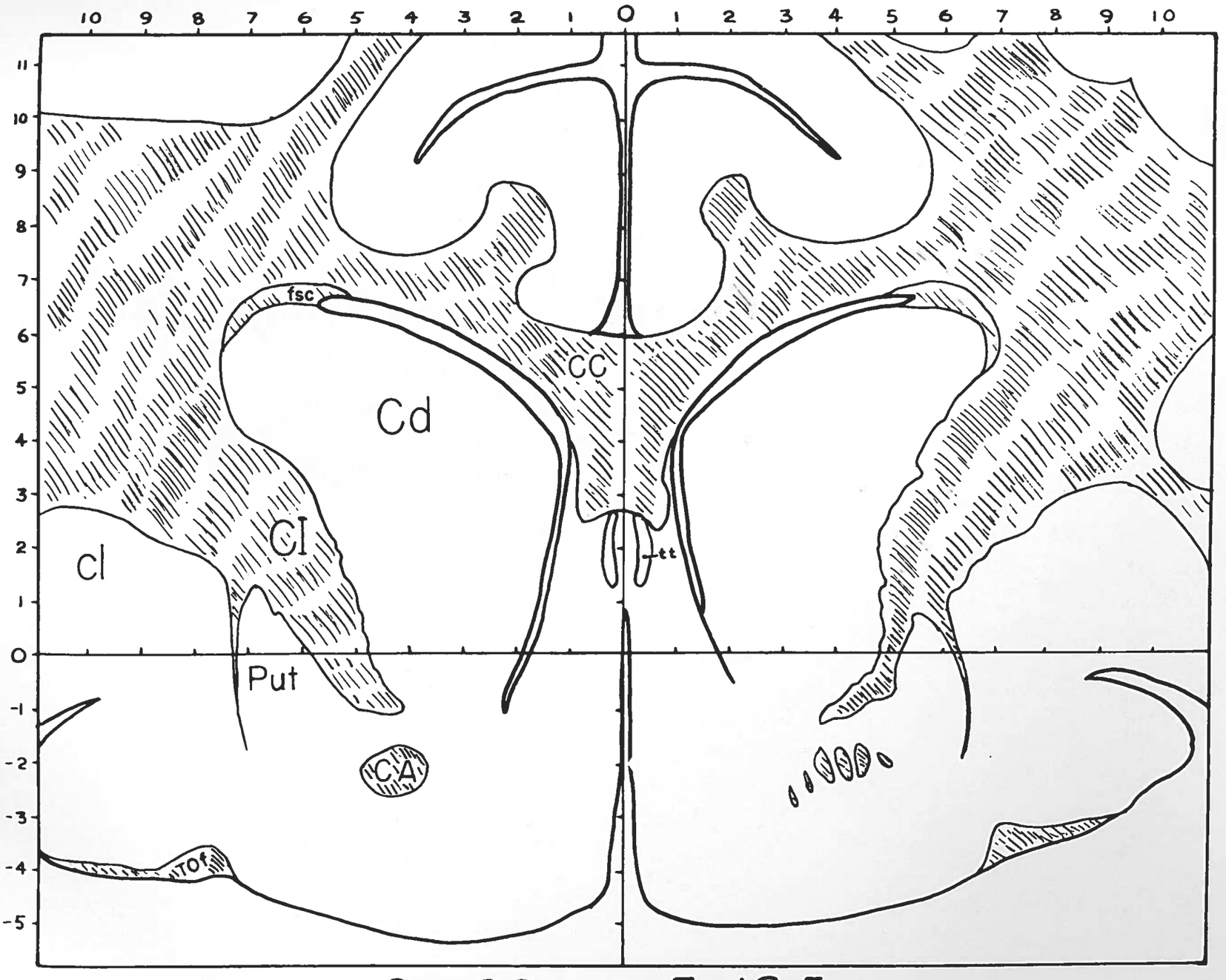
SEC. 50 FR. 17.0



Sec. 50 Fr. 17.0



SEC. 20 FR. 18.5


10 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10
11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5
fsc
CC
Cd
Cl
cl
tt
Put
CA
TOf

Sec. 20 Fr. 18.5