Journal Title: Journal of comparative neurology

ISSN:0021-9967

Volume: 156
Issue: 3
Month/Year: August 1974
Pages: 337-374

Article Author: Tegner M. Stokes, Christiana M. Leonard, Fernando Nottebohm
Article Title: The telencephalon, diencephalon, and mesencephalon of the canary, Serinus canaria, in stereotaxic coordinates

Cited In:

Location: Health Serials
Call #:

CUSTOMER HAS REQUESTED:

Rush?: Regular
Delivery Method: PDF via Web
Special Instructions:

The Telencephalon, Diencephalon, and Mesencephalon of the Canary, *Serinus canaria*, in Stereotaxic Coordinates

TEGNER M. STOKES, CHRISTIANA M. LEONARD
AND FERNANDO NOTTEBOHM
The Rockefeller University, New York, New York 10021

ABSTRACT A stereotaxic atlas of the telencephalon, diencephalon and mesencephalon of the canary, *Serinus canaria*, was prepared for use in anatomical and behavioral experiments. Canaries have a complex vocal and behavioral repertoire many of whose components are under hormonal control in the male, and are therefore useful for many physiological and anatomical experiments. They are available commercially, breed easily in captivity, are quite hardy and respond well to anesthetic and surgical procedures.

The atlas consists of 30 frontal plates from the frontal pole to the level of the motor nucleus of the trigeminus. One sagittal plate is included for reference purposes. Six birds (three males and three females) with marking lesions were used to make the atlas. Their brains were embedded in albumin-gelatin media, cut at 50 and 25 μ and stained with cresyl violet for cell bodies, Weil stain for myelinated fibers and the Fink-Schneider method for unmyelinated fibers. Plates were drawn from the cresyl violet series and labeled using all three stains.

The completed atlas was tested for accuracy by making 12 small lesions in a number of predetermined discrete loci in several birds and evaluating their placement. Eleven of these lesions were found to be within the targeted structure. The results of this test, combined with the results of experiments in over 50 birds, have shown the atlas to be accurate in 80% of all cases.

In recent years there has been growing interest in the anatomy, physiology and hormonal mechanisms of birds. They are interesting from a comparative and evolutionary standpoint as well as particularly useful in the study of sensory control over learned and species-specific behaviors. Songbirds have a complex vocal repertoire, which in some species is learned and monitored through auditory feedback (reviews in Nottebohm, '70, '72; Marler and Mundinger, '72). We have been investigating the neural pathways and hormonal systems underlying the output of vocal behavior (Zigmond et al., '73, and in preparation). A system of stereotaxic coordinates was required to place small lesions that would induce deficits in song production. The atlas contained in the following pages was prepared for this purpose.

Although the original experiments in our investigation were on the European chaffinch, *Fringilla coelebs*, the present embargo on importation of foreign birds forced us to use a more available species, the canary. We have found it to be a most satisfactory experimental bird and we would recommend it to other investigators with interests in sensory systems. Canaries have highly complex vocal and behavioral repertoires which facilitate the detection of small post-operative deficits. Several pure bred strains are commercially available and canaries are easy to keep and breed in captivity; they are quite hardy and respond well to anesthetic and surgical procedures.

METHODS

Selection of plane of section and design of a headholder. The technology of preparing an atlas has grown considerably in recent years and good equipment is available from a number of companies. We chose the Kopt Small Animal Stereotaxic Instrument. The earbars used were the

non-rupturing, blunt "rat-type" supplied with the instrument. The posterior fixation point was the earbar placement in the external auditory canal of the animal.

The most complete and widely used atlas of the avian brain is that of the pigeon by Karten and Hodos ('67). They describe at length the difficulties in selecting an anterior fixation point which produces a convenient and appropriate plane of section. We used the ventral surface of the upper mandible as our anterior fixation point. In the mammal, the anterior and posterior fixation points are usually parallel to the horizontal axis of the instrument. However, because of the bird's upright posture and differing feeding habits, the brain location or cerebral axis within the skull varies in its alignment to the bill axis (Cobb, '60). As a result, the plane of section is not consistent with established mammalian anatomical relationships. Karten and Hodos used an adaptor designed by Dr. Alvin Revsin to support the anterior fixation point. This adaptor places the anterior fixation point 45° below the horizontal axis of the instrument. For our atlas, we reproduced the Revzin pigeon adaptor which is carefully described by Karten and Hodos in their book. The 45° angle of the Revzin adaptor provided an excellent perpendicular section of the forebrain laminae in the canary and made it relatively easy to demarcate forebrain structures.

Our initial headholder included a small bar to support the upper mandible. Later we discovered that this allowed considerable pivotal motion around the bar, even when the earbars were securely fastened in place. As a result, we replaced the bill bar with a bill plate which included a small clamp to attach over the upper mandible. This new bill plate with its dimensions is contained in figure 1. The placement of the head in the stereotaxic instrument, the anterior and posterior fixation points and the angle of penetration of the electrode are also depicted in figure 1.

Surgery. Adult male and female canaries, *Serinus canaria*, of the Wasserschlager breed weighing about 20 gms were used. The animals were deprived of food and water for a minimum of two hours before surgery and then injected with 0.06–0.08 cc Equithesin.

The head of the bird is placed in the stereotaxic instrument in much the same way that is used for any small mammal or rodent. The external auditory canal is quite easily located by lifting or plucking away the feathers on the side of the head. The earbars can be gently pushed in until a slight resistance is felt and then secured. The average inter-ear distance in our breed was 8 mm. After securing the earbars the bill plate can be placed between the upper and lower mandibles and fitted into the holes in the Revzin adaptor. The clamp is then fitted over the upper mandible and the screws tightened. This draws the bill plate tightly against the upper mandible. The crescent-shaped cut-out in the center of the plate was added to prevent the tongue from touching the metal and causing a choking reflex. The notches in the plate help in centering the beak and head.

With the head placed in the holder, the calvarium was removed and the brain exposed. Marking lesions were made at a number of predetermined loci in both hemispheres using 100 μ diameter stainless uninsulated electrodes in six birds.

After surgery birds were perfused through the left ventricle with 0.9% saline followed by 10% formalin in 0.9% saline. At this time the head was replaced in the stereotaxic holder and the brain blocked with a knife held by the electrode carrier in either the transverse or sagittal plane. This insured that the plane of section was exactly parallel to the penetration of the electrodes. The brain was then removed completely from the skull and fixed in 10% formalin for 6–12 days. After the initial fixation the brain was transferred to a 30% sucrose in 10% formalin solution for three days before embedding.

Histology. The embedding medium was the egg albumin and gelatin method described by Snodgrass and Dorsey ('63) and modified in our lab. The blocked surface of the brain was placed on a platform of 5% hardened gelatin about 3 mm thick in the bottom of a cardboard disposable histo-mold (Lipshaw). The albumin-gelatin solution was added and the histo-mold with its contents placed in a dish with 1/2" concentrated formalin cov-

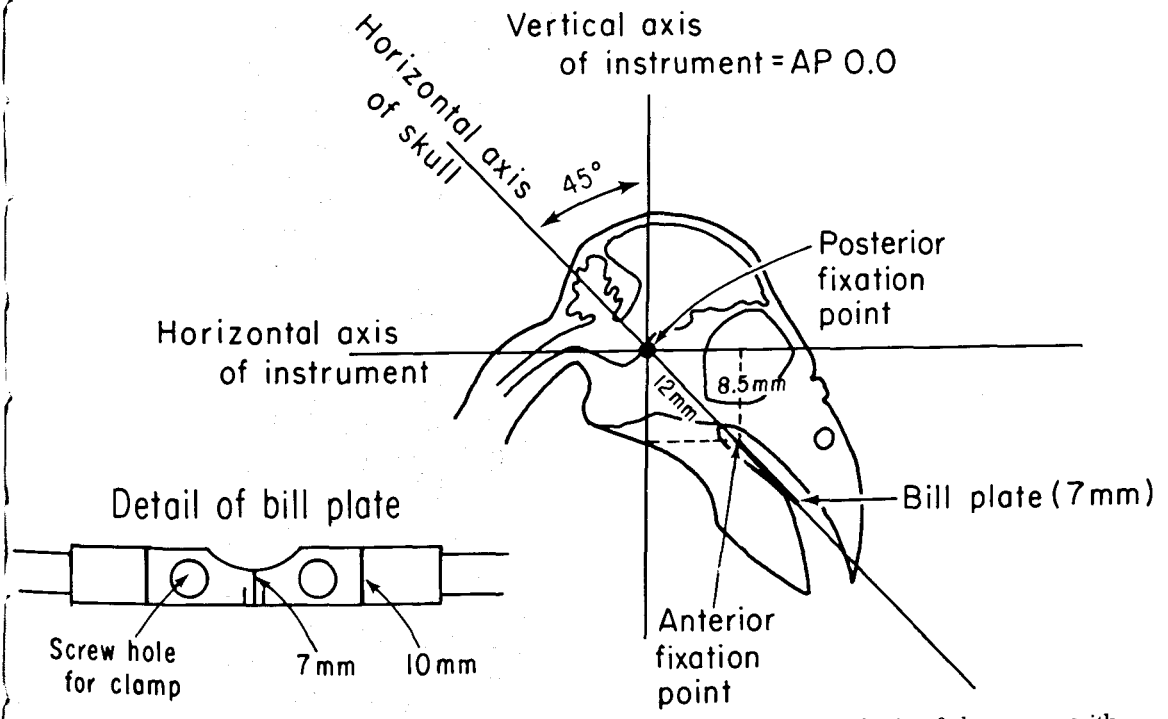


Fig. 1 A diagrammatic representation of the orientation of the skull and brain of the canary with respect to the horizontal and vertical axes of the stereotaxic instrument. If the bill was too overgrown with respect to the horizontal and vertical axes of the stereotaxic instrument. If the bill was too overgrown to permit smooth closure over the bill plate, it was clipped slightly at the tip. The Revzin adaptor, which is described completely in Karten and Hodos ('67), is not shown. A top view of the bill plate is shown in the inset. The depth coordinate for lesion placement was calculated relative to the brain surface. The zero on the vertical scale of the plates does not equal ear bar zero.

ering the bottom. The dish was then put in the refrigerator for two to four days.

After the albumin had hardened, the brain was placed on the freezing stage of an A.O. Spencer sliding microtome and sectioned at 50 μ and 25 μ. Two 25 μ sections were taken following two 50 μ sections to maintain a standard distance between stained sections. The 50 μ sections were collected sequentially into 50% ethyl alcohol and the 25 μ sections into 10% formalin.

The 50 μ sections were mounted immediately on crome-alum (chromium potassium sulfate) gelatinized slides and alternating sections later stained with the cresyl violet stain for Nissl substance and the Weil stain for myelin sheath. The 25 μ sections were kept one week under refrigeration (40°F) before staining with the Fink-Schneider technique (Schneider, '69) for unmyelinated fibers and cells.

Drawings were made from the cresyl violet stained series using a Bausch and Lomb microprojector. Major cell nuclei and fiber pathways were outlined and fine structure was filled in using the Weil and Fink-Schneider series.

To estimate the extent of shrinkage the authors compared measurements made in fresh and perfused tissue, embedded tissue, and mounted stained sections. Measurements were made by selecting a standard magnification on the Bausch and Lomb microprojector and then projecting the differently prepared tissues over one another. The numbers obtained from the projected measurements were also compared with the depths and distances of the marking electrode tracks. Less than 5% increase or decrease in size was found in the cresyl violet and Weil series when compared with the fresh or perfused unstained tissue. The Fink-Schneider series on the other hand was found to be up to 10% larger when compared with the fresh or perfused unstained tissue. Consequently these sections were never used for draw-

ing atlas plates and were adjusted when used to identify structuures.

No significant difference was found in the size of the three female and three male brains used for the atlas. We hope that the transverse sections represented here are as free as possible of distortion resulting from histological procedure. To test for the accuracy of the atlas a total of 12 lesions were made in several birds. Targets were chosen which were small and represented a full range of depths and anterior-posterior levels. Eleven of these 12 lesions were found to be within the targeted structure. The results of this test, combined with the results of experiments in over 50 birds have shown the atlas to be accurate in 80% of all cases.

COMMENTS

The issue of nomenclature has been a persistent and unresolved problem in the study of the avian brain. The terminology of Huber and Crosby in their classic paper of 1929 is probably the most widely used even though it sometimes conflicts with more recent anatomical data. Many atlas authors have discussed the difficulties in applying their nomenclature (e.g., Karten and Hodos, '67; van Tienhoven et al., '62) but none-the-less it appears to have the most popularity and thus is the most easily understood.

We used this nomenclature for our atlas whenever it did not conflict with more recent findings. In cases where structures were not identified by Huber and Crosby or their nomenclature was confusing, we used the terminology of Karten and Hodos.

Both dashed and solid lines were used to outline nuclei depending on the clarity they gave an individual drawing. Where shading lines were used to indicate fibers, the direction of the lines does not always indicate the direction in which the fibers travel. In large areas where structure was quite complex (e.g., optic tectum or archistriatum) no attempt was made to label small subdivisions. In some cases where we were unable to find any relevant information in the literature about well-defined cell groups, we outlined the structure and left it without a label. It is hoped that future anatomical and physiological work will enable us and other workers to attach names and functions to an ever increasing number of structures.

ACKNOWLEDGMENTS

We especially want to thank Dr. Harvey Karten of Massachusetts Institute of Technology for his generous help. He spent many hours consulting with us, looking over our atlas drawings and checking our identifications. He should not, however, be held responsible for our mistakes.

We also wish to thank Dr. Carl Pfaffman for his support of this project and his generous gift of lab space.

This work was supported by NIMH Grant #18343 to Dr. Fernando Nottebohm.

LITERATURE CITED

Adamo, N. J. 1967 Connections of efferent fibers from hyperstriatal areas in chicken, raven and African love-bird. J. Comp. Neur., *131:* 337–356.

Brodal, A., K. Kristiansen and J. Jansen 1950 Experimental demonstration of a pontine homologue in birds. J. Comp. Neur., *92:* 23–69.

Brown, J. L. 1971 An exploratory study of vocalization areas in the brain of the redwinged blackbird (*Aoelaius phoeniceus*). Behaviour, *39:* 91–127.

Cobb, S. 1960 Observations on the comparative anatomy of the avian brain. Perspectives Biol. Med., *3:* 383–408.

Craigie, E. H. 1928 Observations on the brain of the hummingbird. J. Comp. Neur., *45:* 377–481.

——— 1932 The cell structure of the cerebral hemisphere of the hummingbird. J. Comp. Neur., *55:* 135–168.

——— 1936 Notes on the cytoarchitectural features of the lateral cortex and related parts of the cerebral hemisphere in a series of birds and reptiles. Trans. Royal Soc. Canada, Series 3, Sec. V, *30:* 87–113.

Delius, J. 1971 Neural substrates of vocalizations in gulls and pigeons. Exp. Brain Research, *12:* 64–80.

Fox, C. A., D. Hillman, K. Siegesmind and L. Sether 1966 The primate globus pallidus and its feline and avian homologues: a Golgi and electron microscope study. In: Evolution of the Forebrain. R. Hassler and H. Stephen, eds. Thieme, Stuttgart, pp. 237–248.

Huber, G. C., and E. C. Crosby 1929 The nuclei and fiber paths of the avian diencephalon with consideration of telencephalic and certain mesencephalic centers and connections. J. Comp. Neur., *48:* 1–225.

Jones, A. W., and R. Levi-Montalcini 1958 Patterns of differentiation of the nerve centers and fiber tracts of the avian cerebral hemisphere. Arch. Italian Biol., *95:* 231–284.

Jungherr, E. 1945 Certain nuclear groups of the avian mesencephalon. J. Comp. Neur., *82:* 55–175.

Kappers, C. U. A., G. Huber and E. Crosby 1936 (Reprinted 1960). The Comparative Anatomy of the Nervous System of Vertebrates, including Man. Macmillan, New York.

Karten, H. J. 1965 Projections of the optic tectum in the pigeon. Anat. Rec., *151:* 369.

——— 1967 The organization of the ascending auditory pathway in the pigeon (*Columba livia*). I. Diencephalic projections of the inferior colliculus (Nucleus mesencephali lateralis, pars dorsalis). Brain Research, *6:* 409–427.

——— 1968 The ascending auditory pathway in the pigeon (*Columba livia*). II. Telencephalic projections of the nucleus ovoidalis thalami. Brain Research, *11:* 134–153.

Karten, H. J., and A. M. Revzin 1966 Afferent connections of the nucleus rotundus in the pigeon. Brain Research 2: 368–377.

Karten, H., and W. Hodos 1967 A Stereotaxic Atlas of the Brain of the Pigeon (*Columba livia*). Johns Hopkins Press, Baltimore, Md.

——— 1970 Telencephalic projections of the nucleus rotundus in the pigeon (*Columba livia*). J. Comp. Neur., *140:* 35–52.

Kuhlenbeck, H. 1937 The ontogenetic development of diencephalic centers in bird brain (chicken) and comparison with reptilian and mammalian diencephalon. J. Comp. Neur., *66:* 23–27.

Marler, P., and P. Mundinger 1971 Vocal learning in birds. In: Ontogeny of Vertebrate Behavior. Academic Press, Inc., New York.

Nottebohm, F. 1970 Ontogeny of bird song. Science, *167:* 950–956.

——— 1972 The origins of vocal learning. The American Naturalist, *106:* 116–140.

Revzin, A. M., and H. Karten 1967 Rostral projections of the optic tectum and the nucleus rotundus in the pigeon. Brain Research, *3:* 264–276.

Schneider, G. E. 1969 Two visual systems. Science, *163:* 895–902.

Snodgrass, A. B., and C. H. Dorsey 1963 Egg albumin embedding: A procedure compatible with neurological staining techniques. Stain Technology, *38:* 149–155.

van Tienhoven, A., and L. Juhasz 1962 The chicken telencephalon, diencephalon and mesencephalon in stereotaxic coordinates. J. Comp. Neur., *118:* 185–197.

Zeier, H. J., and H. J. Karten 1971 The archistriatum of the pigeon: Organization of afferent and efferent connections. Brain Research, *31:* 313–326.

——— 1973 Connections of the anterior commissure in the pigeon (*Columba livia*). J. Comp. Neur., *150:* 201–216.

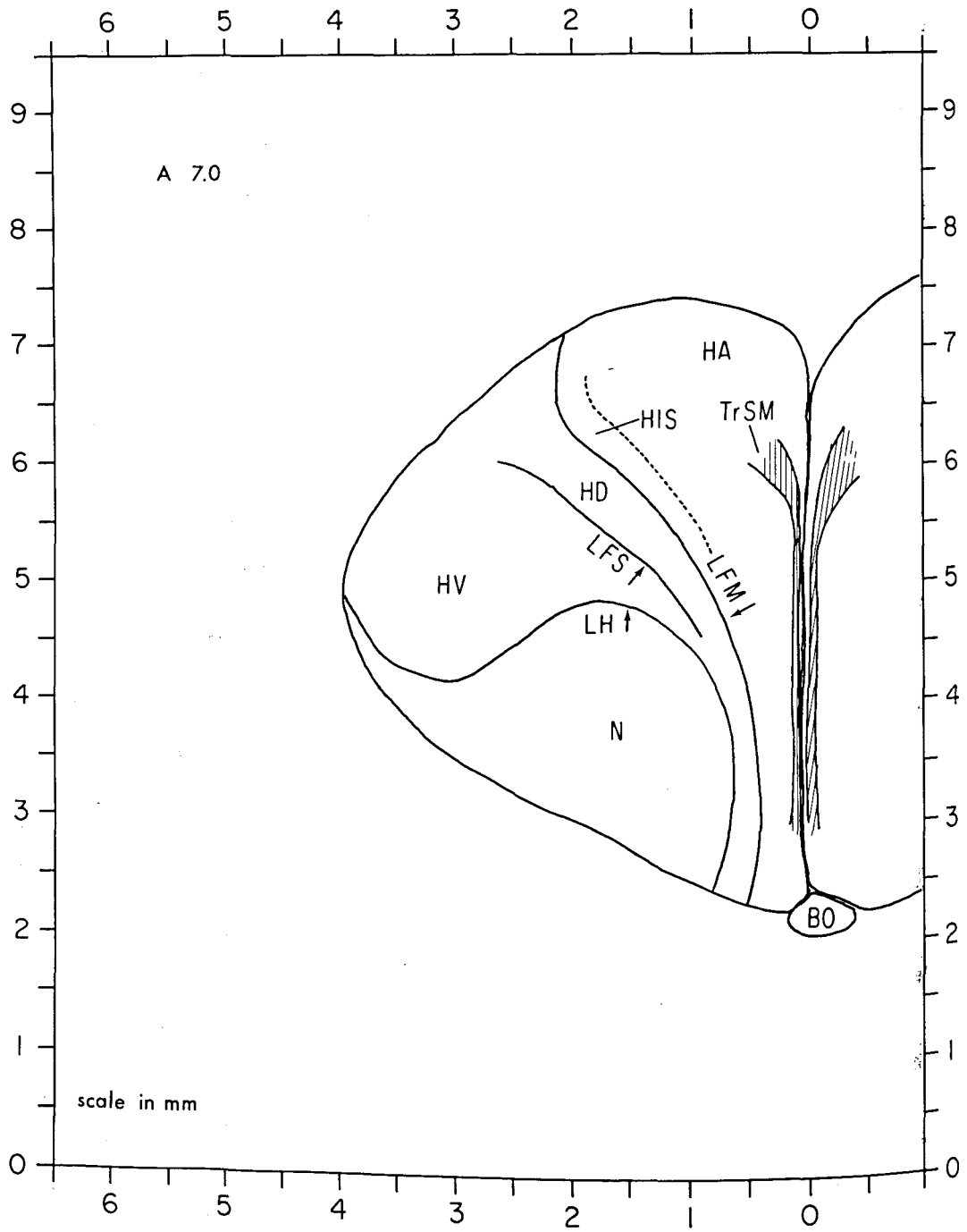
Zigmond, R., F. Nottebohm and D. Pfaff 1973 Androgen-concentrating cells in the midbrain of a songbird. Science, *179:* 1005–1007.

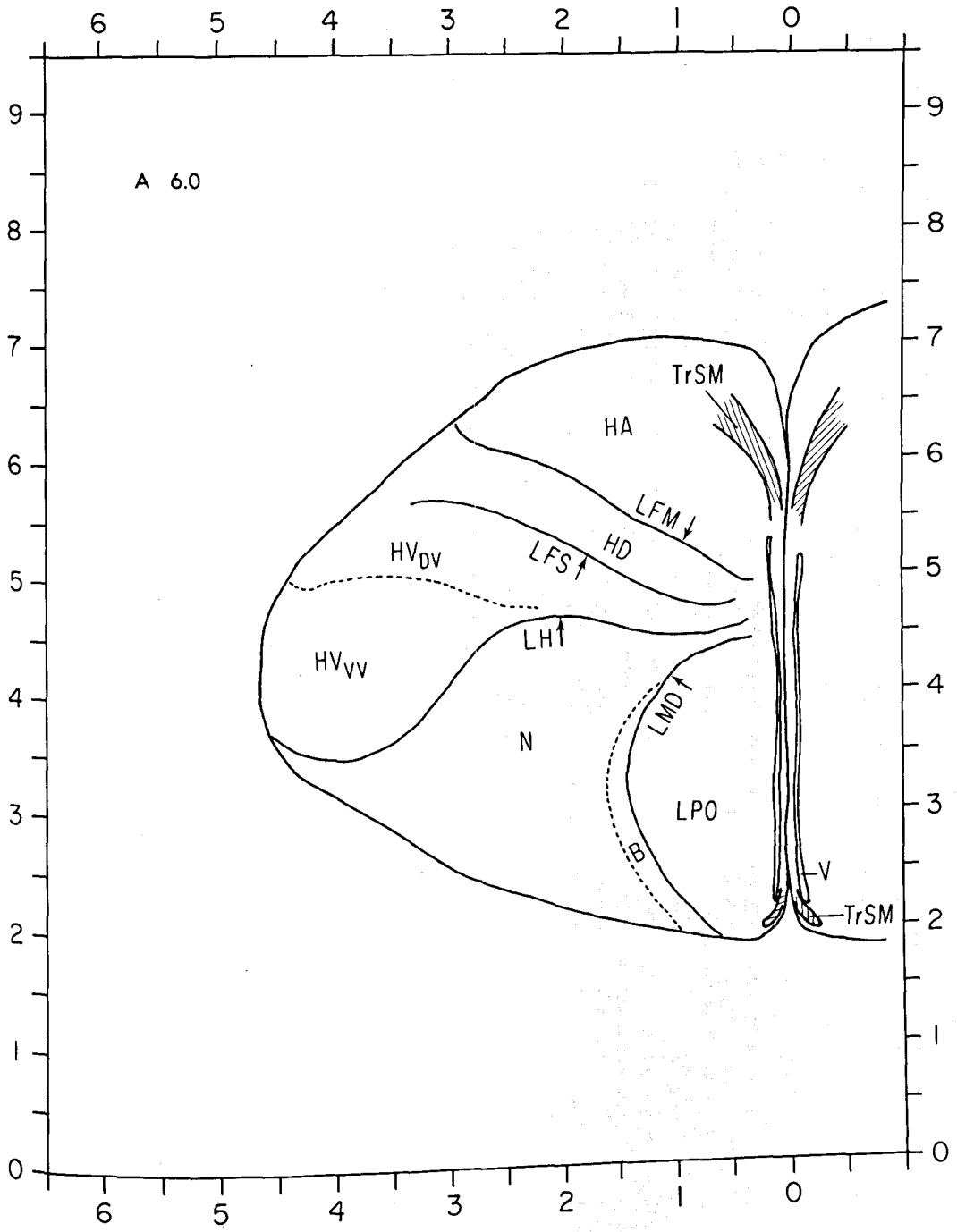
Zweers, G. A. 1971 A Stereotaxic Atlas of the Brainstem of the Mallard (*Anas. platyrhynchos* L.). Koninklijke Van Gorcum and Corp. N.V., Assen., Netherlands.

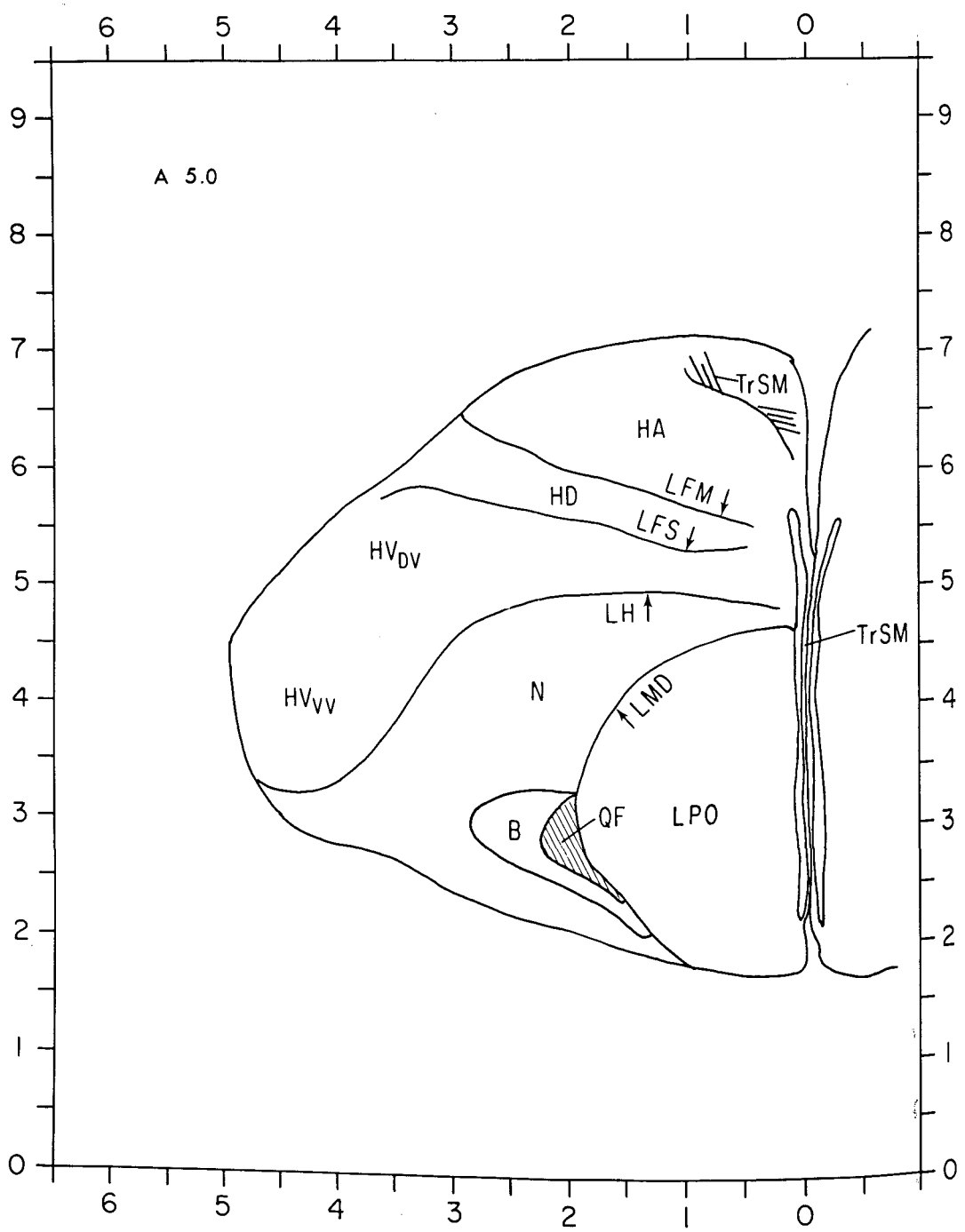
Abbreviations

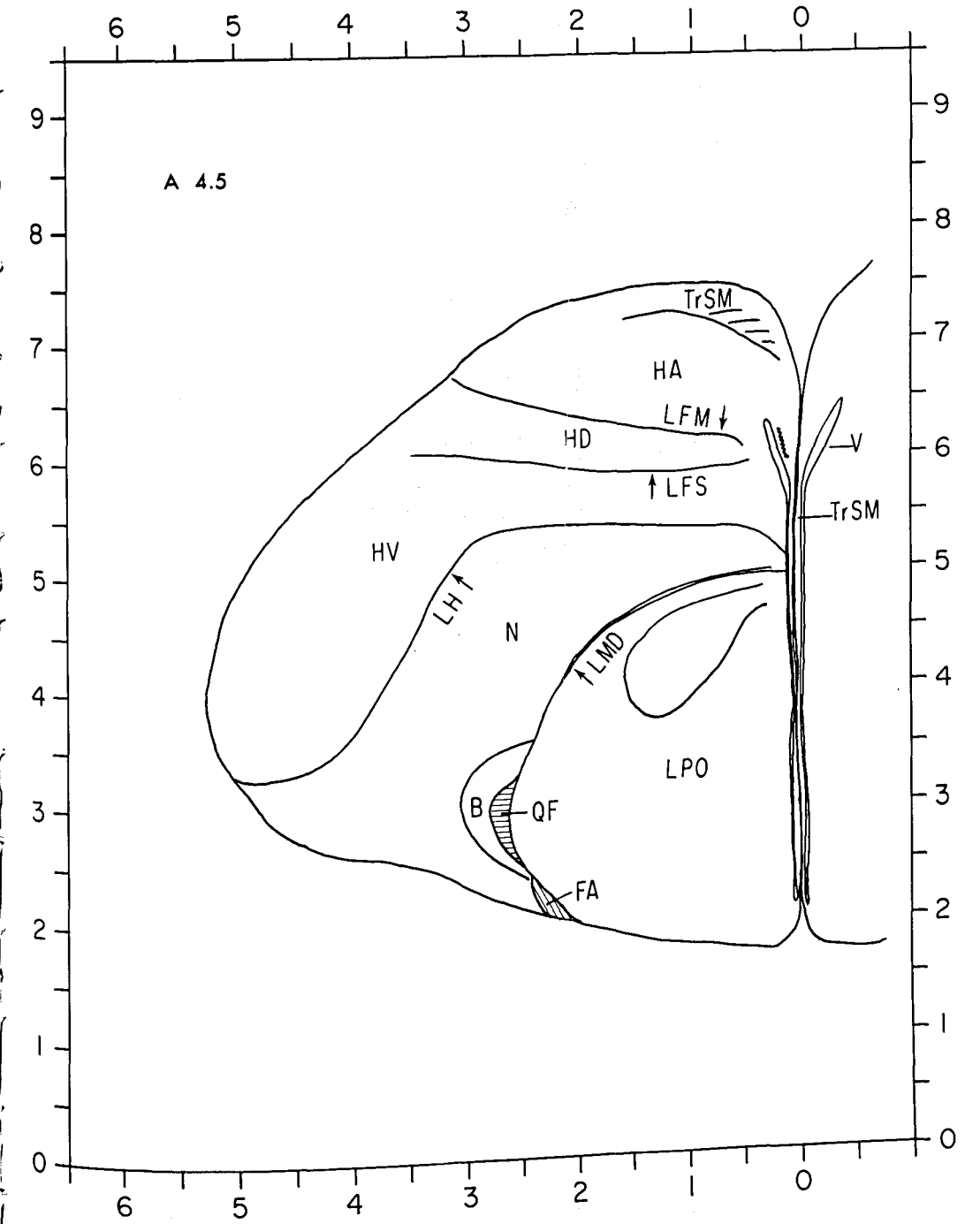
A, Archistriatum P0.2–P1.6
Ac, Nucleus accumbens A4.0
AL, Ansa lenticularis A1.8–A0.6
ANI, Nucleus annularis P1.0–P1.2
AP, Area pretectalis A0.4–P0.8
APH, Area parahippocampalis P0.6–P1.6
AQ, Aqueductus cerebri AP0.0–P0.6
AVT, Area ventralis (Tsai) A1.0–A0.6
B, Nucleus basalis A6.0–A2.8
BC, Brachium conjunctivum A0.2–P1.6
BCA, Brachium conjunctivum ascendens AP0.0–P0.2
BCD, Brachium conjunctivum descendens P0.6–P1.0
BCS, Brachium colliculi superioris A0.4–P1.2
BO, Bulbus olfactorius A7.0
Cb, Cerebellum A0.4–P1.6
CF, Campi Foreli A0.8–A0.6
CHCS, Tractus cortico-habenularis et cortico-septalis A0.8–A0.4
CO, Chiasma opticum A3.5–A2.0
CoA, Commissura anterior A1.6–A1.2
CoS, Nucleus commissuralis septi A1.6–A1.2
CP, Commissura posterior AP0.0–P0.4
CPa, Commissura pallii A1.2
CS, Nucleus centralis superior (Bechterew) P0.2
CT, Commissura tectalis P0.4–P0.8
CTz, Corpus trapezoideum P0.8–P1.6
D, Nucleus of Darkschewitch A0.2–AP0.0
DA, Tractus archistriatalis dorsalis A1.0–P1.6
DBC, Decussatio brachiorum conjunctivorum P0.2–P1.0
DIP, Nucleus dorsointermedius posterior thalami A0.6–A0.4
DIV, Decussatio nervi trochlearis P1.4
DLAmc, Nucleus dorsolateralis anterior thalami, pars magnocellularis A1.8–A1.6
DLL, Nucleus dorsolateralis anterior thalami, pars lateralis A1.4–A1.0
DLM, Nucleus dorsolateralis anterior thalami, pars medialis A0.8–A0.6
DLP, Nucleus dorsolateralis posterior thalami A0.2
DMP, Nucleus dorsomedialis posterior thalami A0.6–P0.2
DS, Decussatio supraoptica A2.8
DSD, Decussatio supraoptica dorsalis A2.6–A2.2
DSV, Decussatio supraoptica ventralis A2.4–A1.8
E, Ectostriatum A2.8–A1.0
EM, Nucleus ectomammillaris A1.0–A0.6
Ep, Regio periectostriatalis A1.6
EW, Nucleus of Edinger-Westphal P0.6–P1.0
FA, Tractus fronto-archistriatalis A4.5–P1.4
FDB, Fasciculus diagonalis Brocae A2.8–A2.6
FLM, Fasciculus longitudinalis medialis P0.6–P1.6
FPL, Fasciculus prosencephali lateralis (lateral forebrain bundle) A2.8–A0.8
FRL, Formatio reticularis lateralis mesencephali A0.6–P0.8
FRM, Formatio reticularis medialis mesencephali A0.6–P0.2
GLV, Nucleus geniculatus lateralis, pars ventralis A2.8–A1.2
GCT, Substantia grisea centralis AP0.0–P1.2
HA, Hyperstriatum accessorium A7.0–A1.0
HD, Hyperstriatum dorsale A7.0–A2.0
HIS, Hyperstriatum intercalatus superior A7.0
HL, Nucleus habenularis lateralis A0.4–AP0.0
HM, Nucleus habenularis medialis A0.4–AP0.0
HP, Hippocampus A1.8–P0.4
HV, Hyperstriatum ventrale A7.0–P1.2
HVdv, Hyperstriatum ventrale, dorsoventrale A6.0–A5.0
HVvv, Hyperstriatum ventrale, ventroventrale A6.0–A5.0
ICo, Nucleus intercollicularis AP0.0–P1.2
ICT, Nucleus intercalatus thalami A2.2–A1.8
III, Nervus oculomotorius A1.4–P0.6
IM, Nucleus isthmi, pars magnocellularis A1.2–P1.4
IN, Tractus infundibularis A1.2–A1.0
INP, Nucleus intrapeduncularis A2.0–A1.0
IO, Nucleus isthmo-opticus P1.4–P1.6
IP, Nucleus interpeduncularis A0.6–AP0.0
IPC, Nucleus isthmi, pars parvocellularis A1.0–P1.4
IPS, Nucleus interstitio pretecto-subpretectalis A1.0–A0.8
IS, Nucleus interstitialis (Cajal) A0.4–AP0.0
LA, Nucleus lateralis anterior thalami A2.6–A2.4
LAD, Lamina archistriatalis dorsalis P0.4–P1.6
LFM, Lamina frontalis suprema A7.0–A2.0
LFS, Lamina frontalis superior A7.0–A1.0
LH, Lamina hyperstriatica (tractus fronto-occipitalis) A7.0–AP0.0
LHy, Nucleus lateralis hypothalami A2.4–A1.6
LL, Lemniscus lateralis P1.2–P1.4
LLd, Nucleus lemnisci lateralis, pars dorsalis (Groebbels) P1.0–P1.2
LM, Nucleus lentiformis mesencephali A2.0–A1.8
LMD, Lamina medullaris dorsalis A6.0–A0.2
LoC, Locus ceruleus P1.4–P1.6
LPO, Lobus parolfactorius A6.0–A1.2
MLd, Nucleus mesencephalicus lateralis, pars dorsalis AP0.0–P1.0

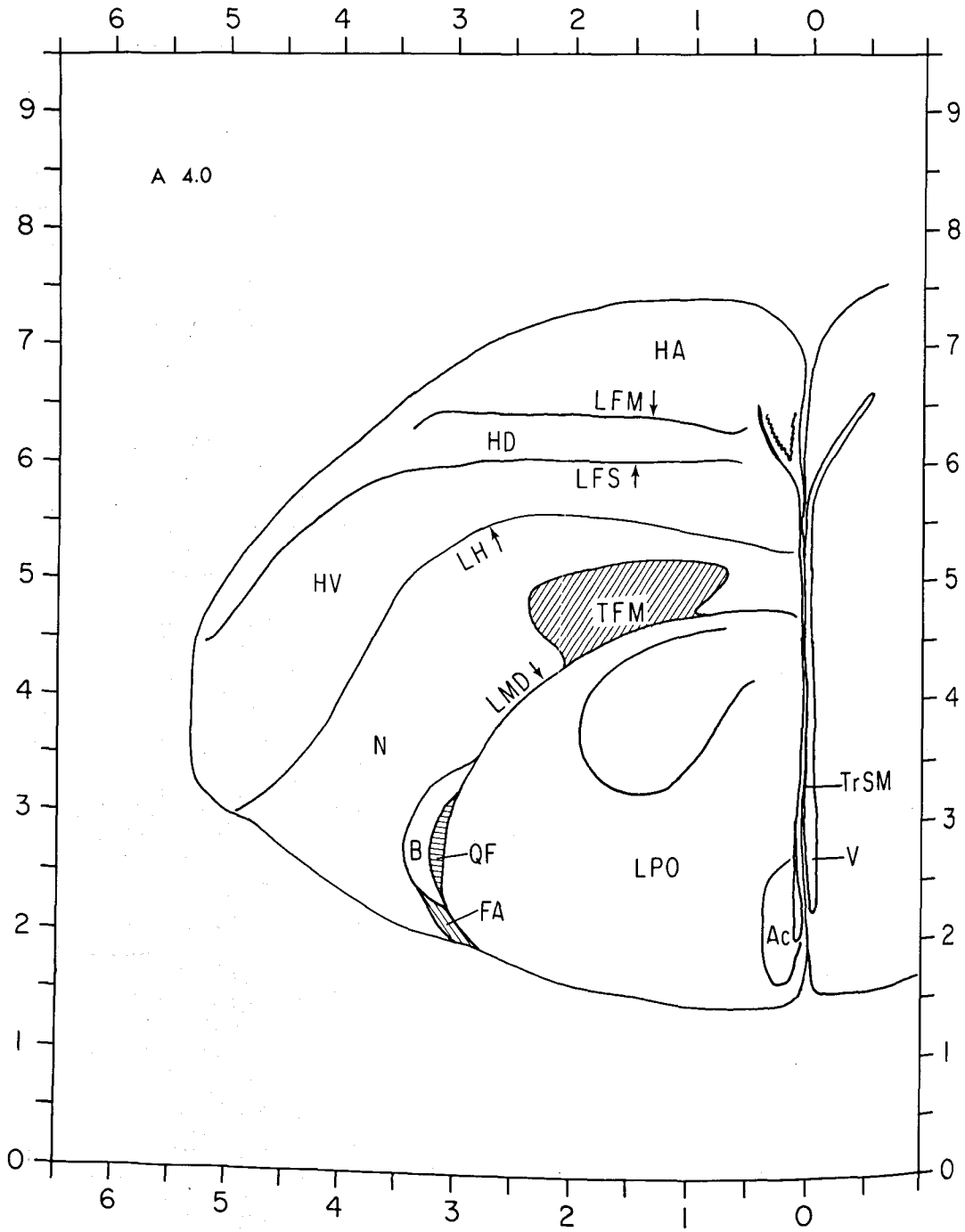
MLv, Nucleus mesencephalicus lateralis, pars ventralis A0.6–AP0.0
MNV, Nucleus mesencephalicus nervi trigemini P0.6–P1.2
MPv, Nucleus mesencephalicus profundus ventralis (Jungherr) A0.4–AP0.0
MV, Nucleus motorius nervi trigemini P1.2
N, Neostriatum A7.0–AP0.0
NC, Neostriatum caudale P0.2–P1.6
NIII, Nervus oculomotorius A1.4–P0.6
NIV, Nervus trochlearis P1.0–P1.4
nIV, Nucleus nervi trochlearis P1.2–P1.4
nSt, Nucleus striaterminalis (Karten) A1.6–A0.6
OM, Tractus occipitomesencephalicus A1.6–P1.2
OMd, Nucleus nervi oculomotorii, pars dorsalis P0.2–P0.8
OMv, Nucleus nervi oculomotorii, pars ventralis P0.2–P0.8
OV, Nucleus ovoidalis A1.6–A0.6
PA, Paleostriatum augmentatum A2.8–P0.2
pap, Nucleus papillioformis A0.2–P0.4
PD, Nucleus pretectalis diffusus A0.6
PL, Nucleus pontis lateralis P0.2–P1.0
PLH, Nucleus lateralis hypothalami posterioris A2.0–A1.8
PM, Nucleus pontis medialis P0.2–P1.4
PMH, Nucleus medialis hypothalami posterioris A2.2–A1.2
PMI, Nucleus paramedianus internis thalami A0.4
POA, Nucleus preopticus anterioris A2.8
POM, Nucleus preopticus medialis (van Tienhoven) A2.6
PP, Paleostriatum primativum A2.6–A0.2
PPC, Nucleus *principalis* precommissuralis A1.4–AP0.0
PPM, Nucleus preopticus paraventricularis magnocellularis (van Tienhoven) A2.6
PrV, Nucleus sensorius principalis nervi trigemini P1.6
PST, Tractus pretecto-subpretectalis A0.8
Pt, Nucleus pretectalis A0.8–A0.6
PV, Nucleus posteroventralis thalami (Kuhlenbeck) A1.8–A1.2
PVM, Nucleus paraventricularis magnocellularis A2.4–A1.0
QF, Tractus quintofrontalis A5.0–P0.8
R, Nucleus Raphes P1.0–P1.2
RPgc, Nucleus reticularis pontis caudalis, pars gigantocellularis P1.0–P1.6
RPO, Nucleus reticularis pontis oralis P0.4–P0.8
RSd, Nucleus reticularis superior, pars dorsalis A1.6
RSv, Nucleus reticularis superior, pars ventralis A1.6
Rt, Nucleus rotundus A2.2–A1.0
Ru, Nucleus ruber A0.6–AP0.0
RxVM, Radix mesencephalicus nervi trigemini P1.4–P1.6
S, Nucleus septalis A2.6–A0.8
SAC, Stratum album centrale P0.6–P1.6
SCE, Stratum cellulare externum A1.6–A0.8
SCI, Stratum cellulare internum A1.4–A0.8
SGC, Stratum griseum centrale P0.6–P1.4
SGF, Stratum griseum et fibrosum superficiale A0.8–A0.6
SGP, Substantia grisea et fibrosa periventricularis A1.2–A0.6
SHL, Nucleus subhabenularis lateralis A0.2–A0.6
SLu, Nucleus *semilunaris* A0.2–P1.2
SM, Nucleus septalis medialis A2.4–A1.2
SL, Nucleus septalis lateralis A2.4–A1.2
SMe, Stria medullaris A0.8–A0.6
SP, Nucleus subpretectalis A1.2–A0.8
SPC, Nucleus superficialis parvocellularis (nucleus of septomesencephalic tract) A1.0–P0.4
SpL, Nucleus *spiriformis* lateralis A1.0
SpLd, Nucleus spiriformis lateralis, pars dorsalis A0.8–A0.6
SpLv, Nucleus spiriformis lateralis, pars ventralis A0.8–A0.6
SpM, Nucleus spiriformis medialis A0.4–P0.2
SRt, Nucleus subrotundus A1.2–A1.0
TeO, Tectum opticum A2.6–P1.6
TFM, Tractus thalamo-frontalis et frontalis-thalamicus medialis A4.0–A3.5 + A2.6–A1.4
TIO, Tractus isthmo-opticus A2.4–P1.2
Tn, Nucleus taeniae P0.2–P1.4
ToS, Torus *semicircularis* A0.4–A0.2
TOV, Tractus nuclei ovoidalis A1.4–A1.0
TPc, Nucleus tegmenti pedunculopontinus, pars compacta A0.4–P0.4
TrEM, Tractus nuclei ectomamillaris (basal optic root) A1.2
TrO, Tractus opticus A2.8–P0.2
TrSM, Tractus septomesencephalicus A7.0–AP0.0
TT, Tractus tectothalamicus A2.0–A1.0
Tu, Nucleus tuberis A1.6–A1.2
TV, Nucleus tegmenti ventralis (Gudden) P1.2–P1.4
TVM, Tractus vestibulo-mesencephalicus (Papez) P0.8–P1.0
V, Ventricle
VLT, Nucleus ventrolateralis thalami A2.4–A2.0
VLV, Nucleus ventralis lemnisci lateralis P0.8–P1.0

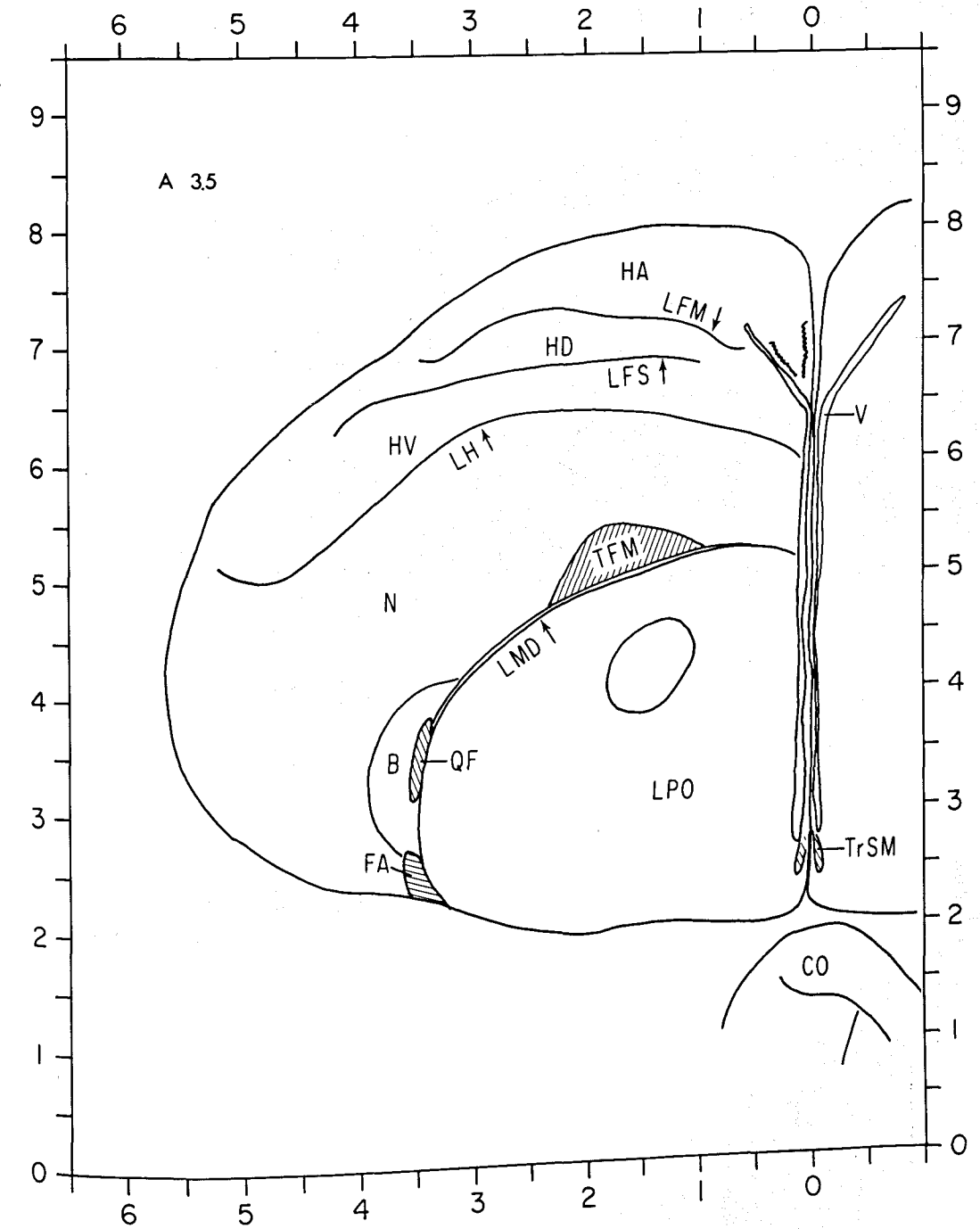

A 7.0
HA
HIS
TrSM
HD
LFS
LFM
HV
LH
N
BO
scale in mm

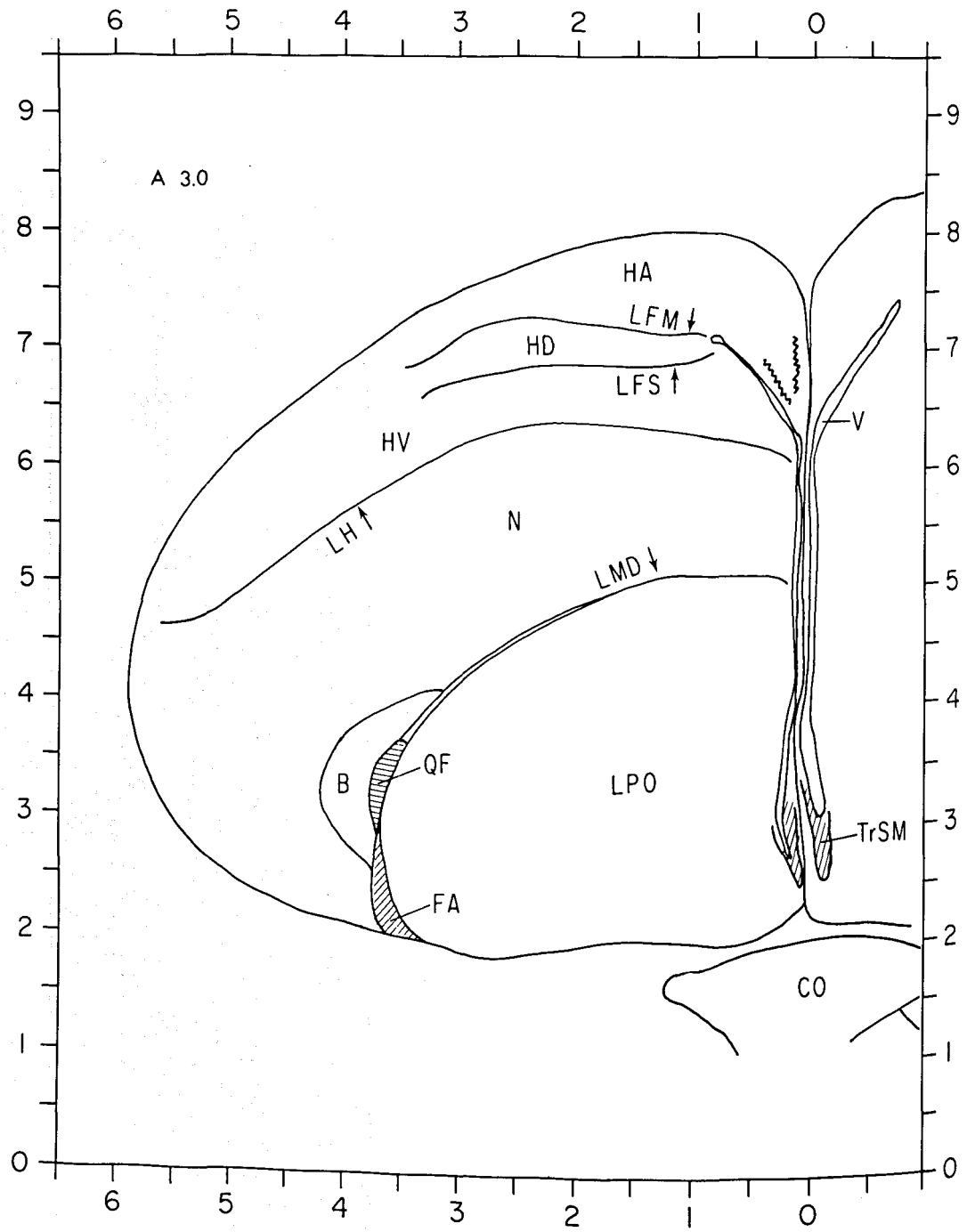

A 6.0
TrSM
HA
LFM
HD
LFS
HVDV
LH
HVVV
N
LMD
LPO
B
V
TrSM

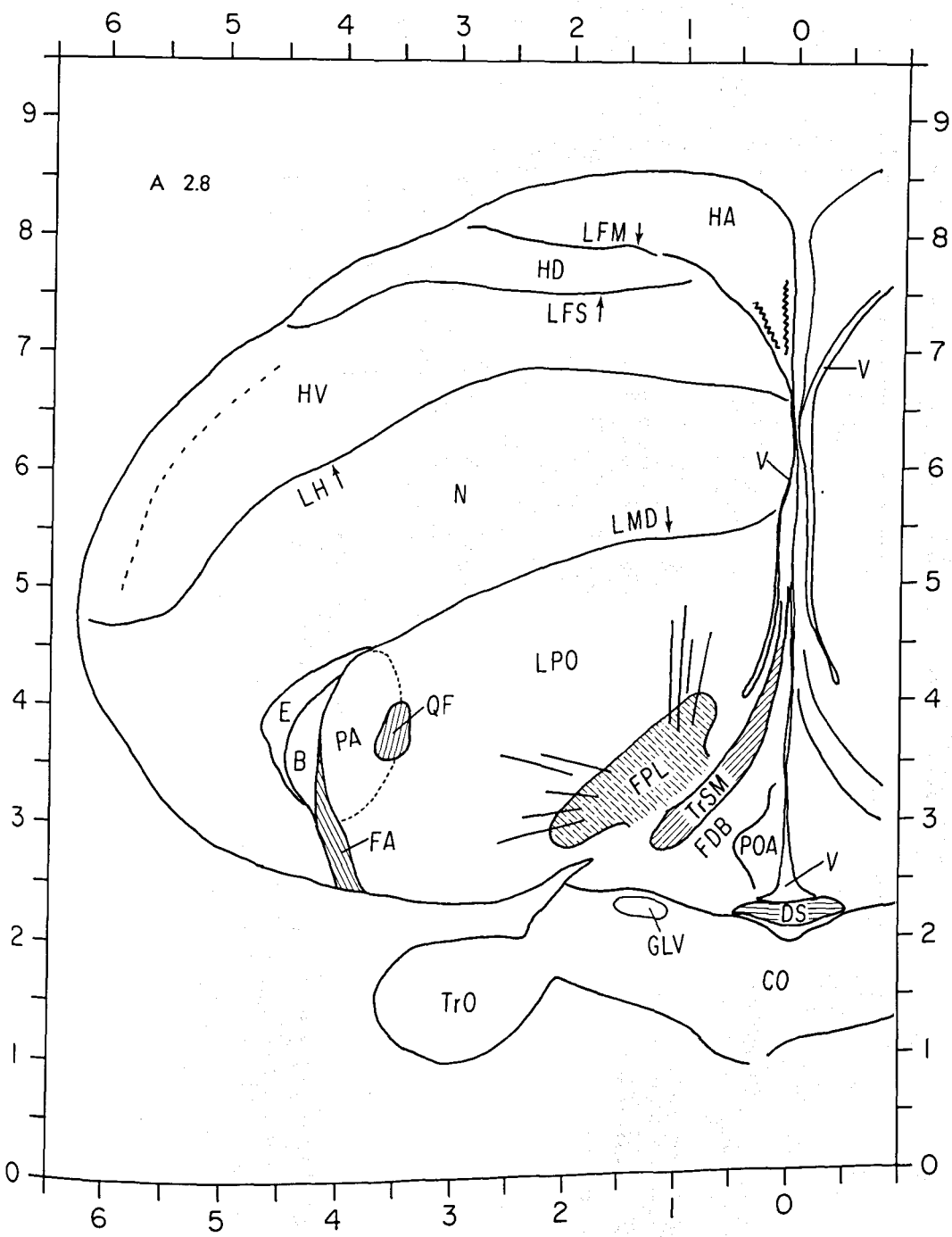

A 5.0
TrSM
HA
HD
LFM
LFS
HV$_{DV}$
LH
TrSM
HV$_{VV}$
N
LMD
B
QF
LPO

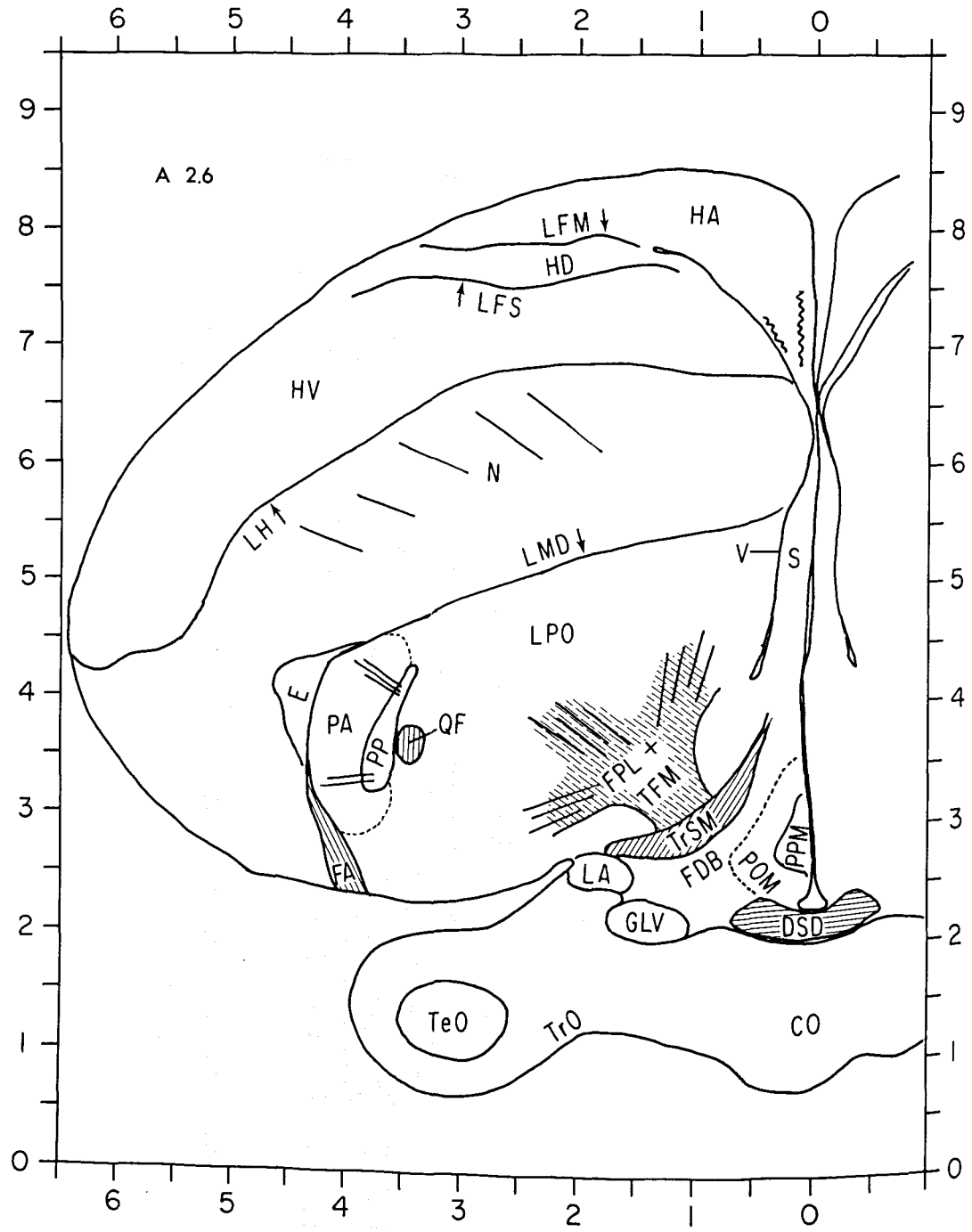

A 4.5
TrSM
HA
LFM
HD
V
LFS
TrSM
HV
LH
N
LMD
LPO
B
QF
FA

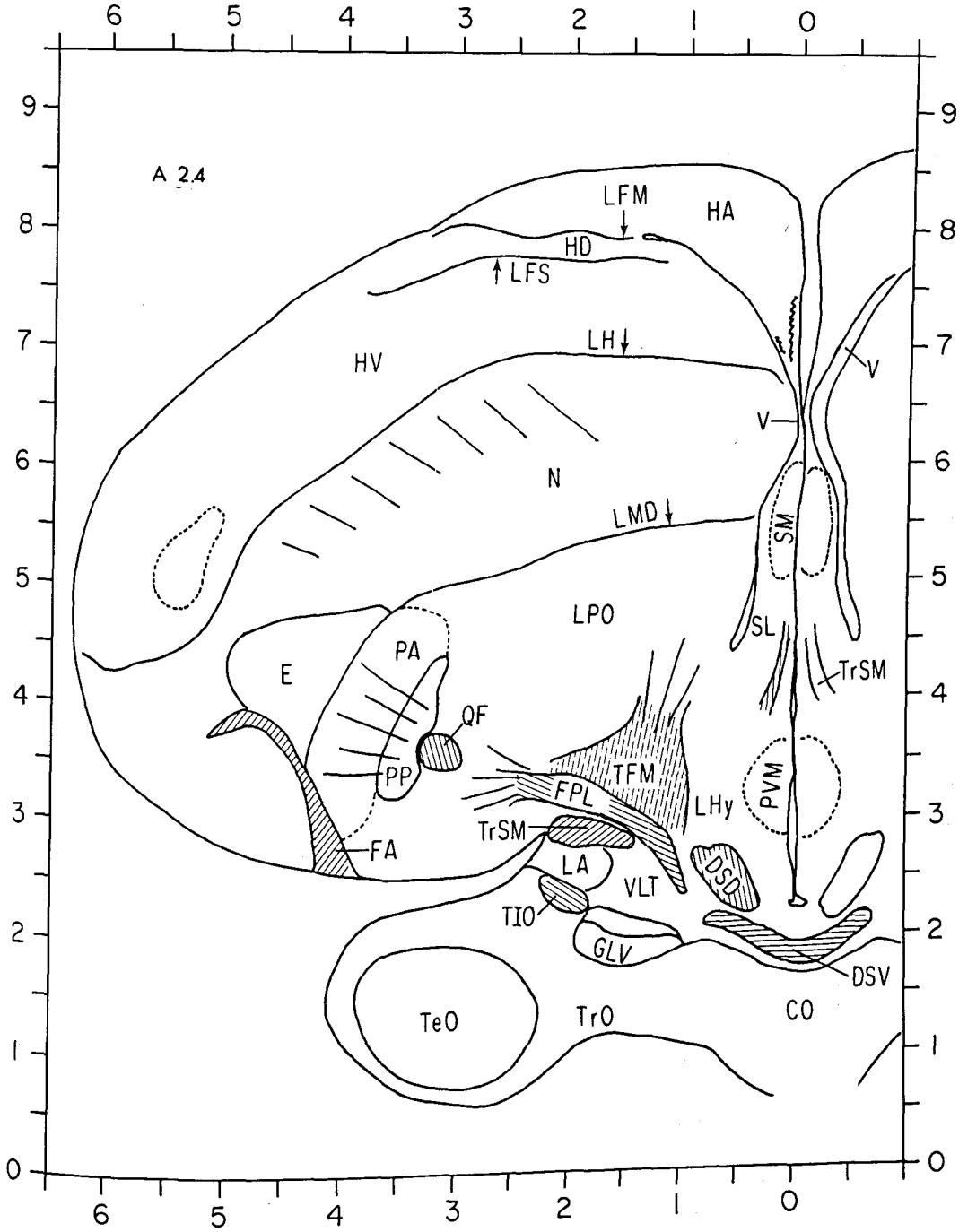

A 4.0
HA
LFM
HD
LFS
LH
HV
TFM
LMD
N
TrSM
V
B
QF
LPO
FA
Ac

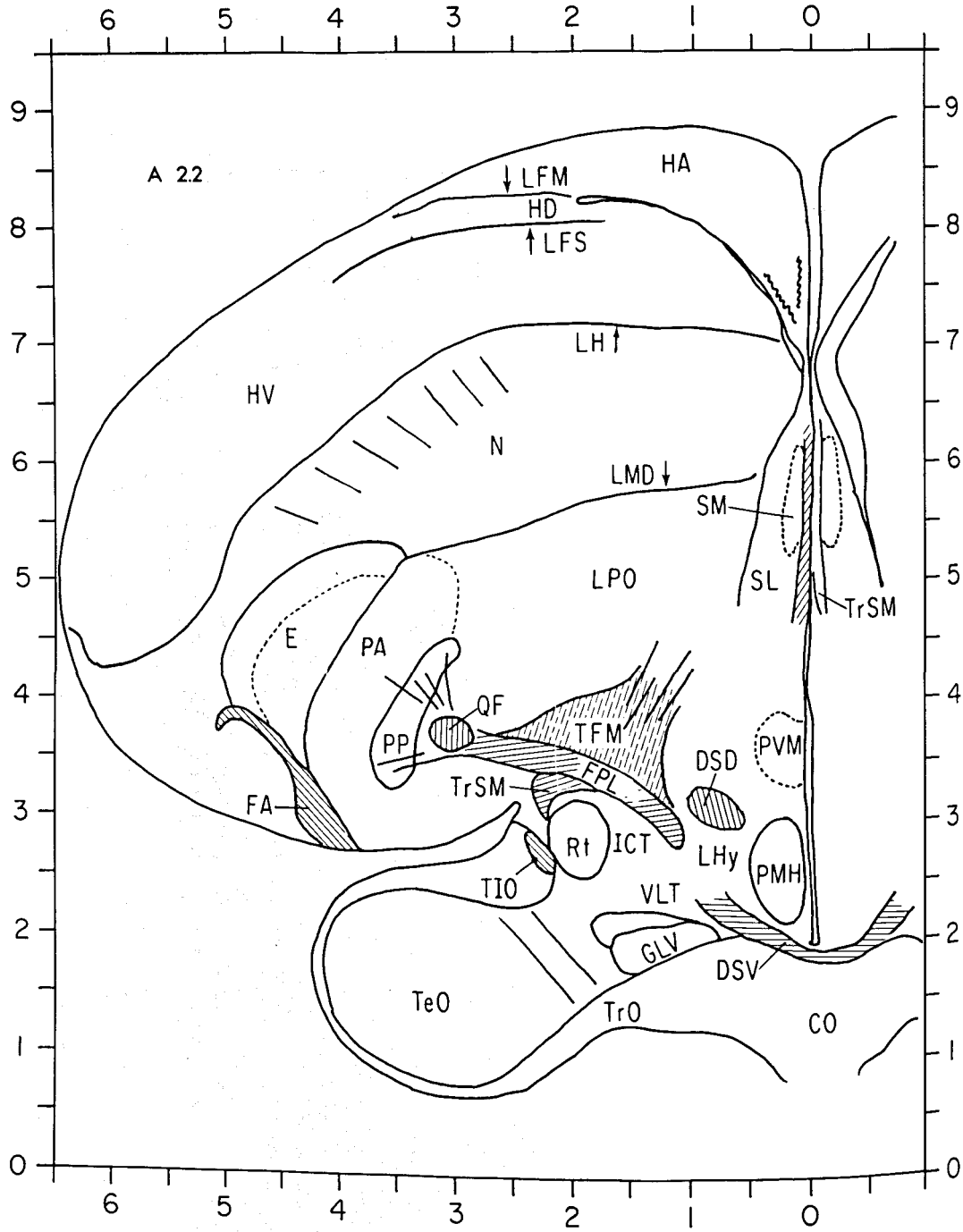

A 3.5
HA
LFM
HD
LFS
V
HV
LH
TFM
N
LMD
B
QF
LPO
TrSM
FA
CO

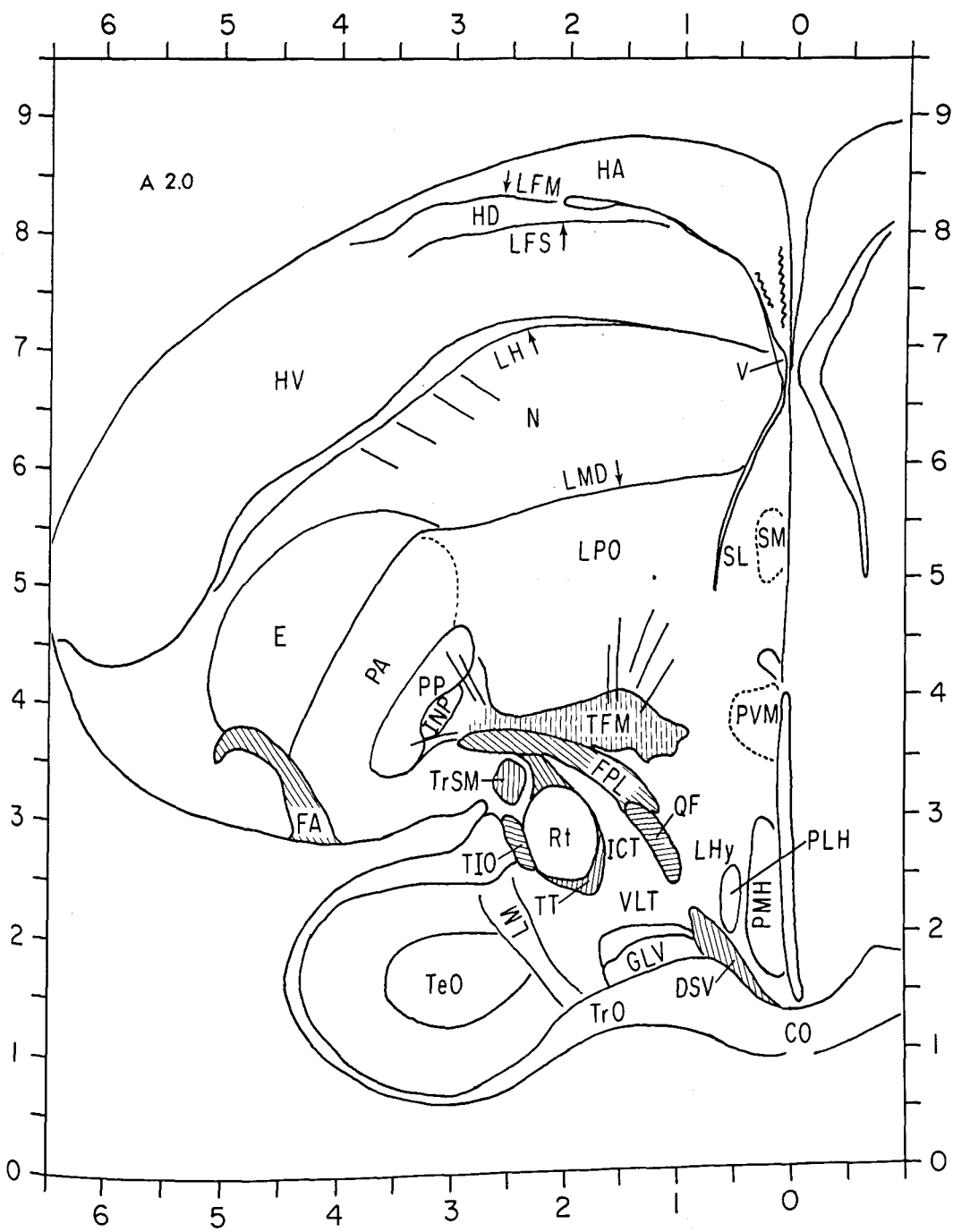

A 3.0
HA
LFM
HD
LFS
V
HV
LH
N
LMD
B
QF
LPO
TrSM
FA
CO

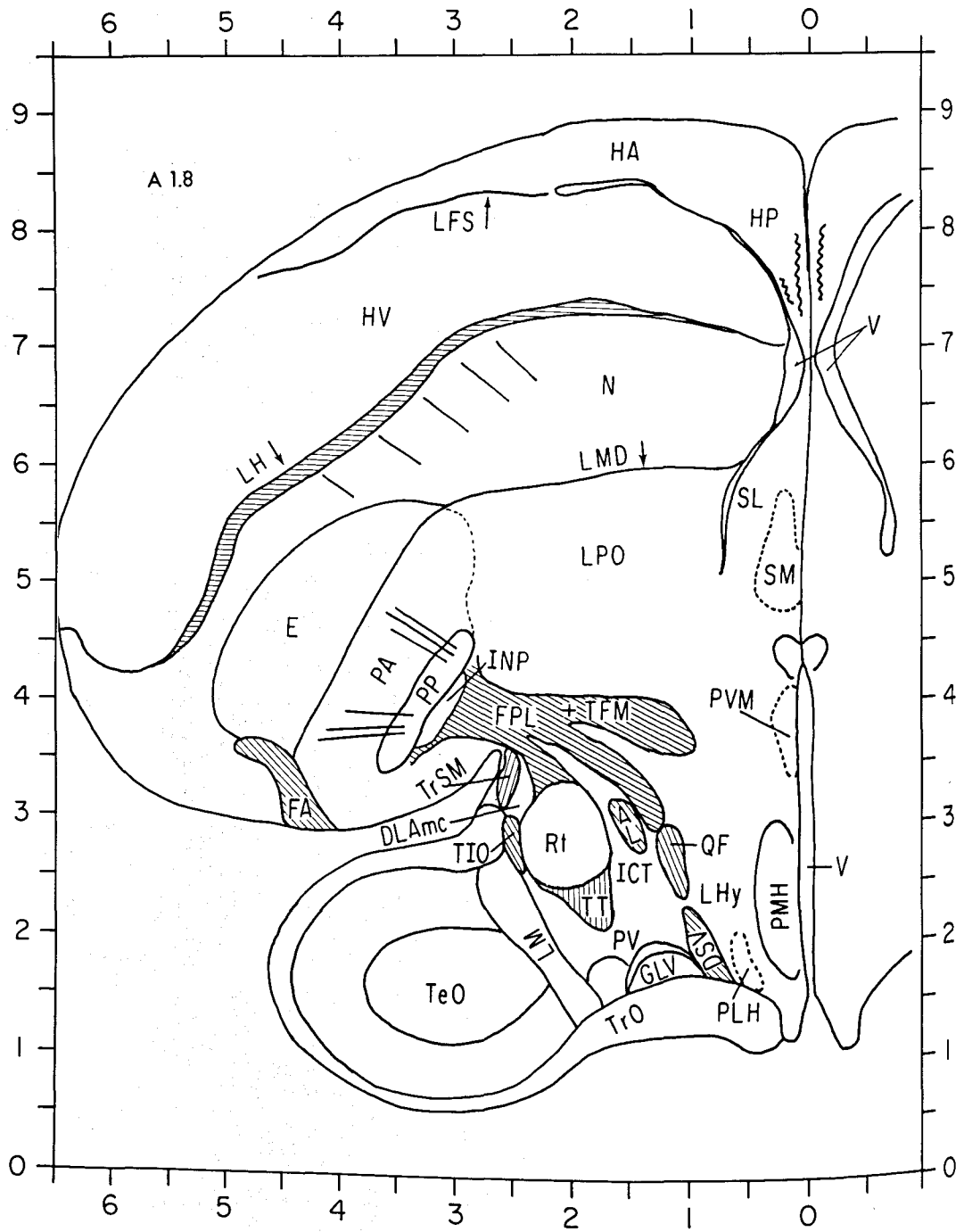

A 2.8
HA
LFM
HD
LFS
HV
V
LH
N
V
LMD
LPO
E
B
PA
QF
FA
FPL
TrSM
FDB
POA
V
DS
GLV
CO
TrO

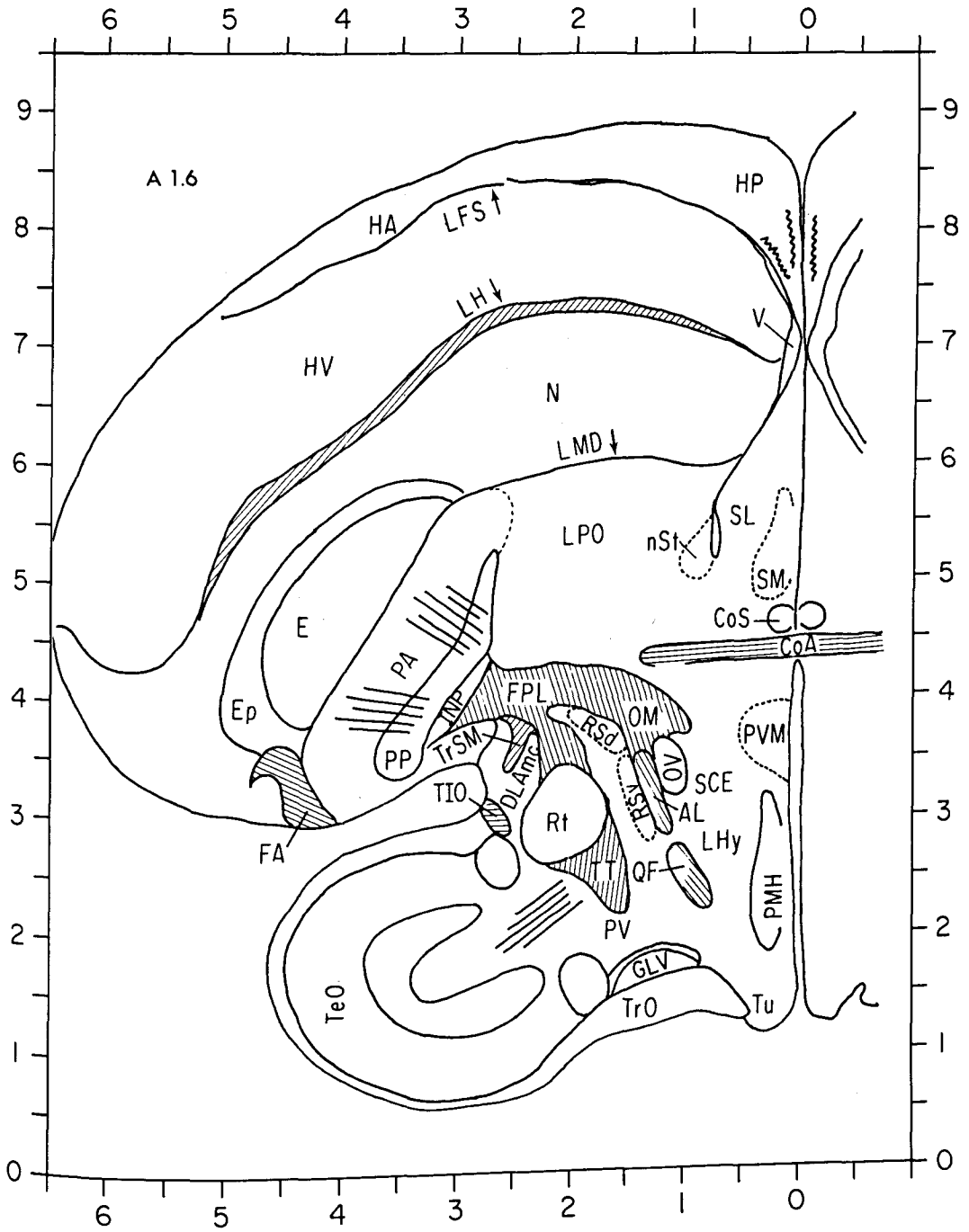

A 2.6
LFM
HA
HD
LFS
HV
N
LH
LMD
V
S
LPO
E
PA
QF
PP
FPL
TFM
TrSM
PPM
FDB
POM
FA
LA
GLV
DSD
TeO
TrO
CO

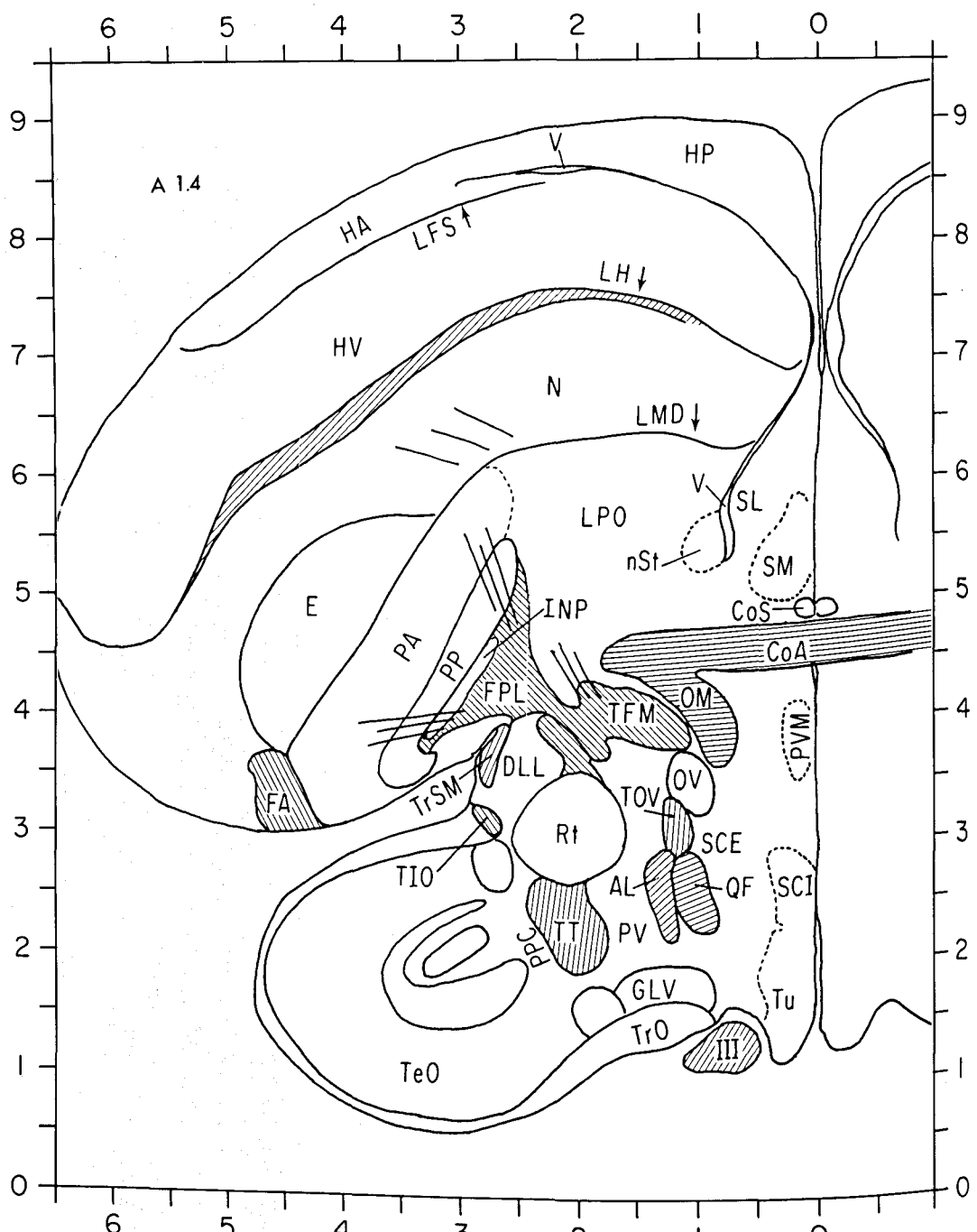

A 2.4
LFM
HA
HD
LFS
LH
HV
V
V
N
LMD
SM
LPO
SL
TrSM
PA
E
QF
PP
TFM
FPL
LHy
PVM
TrSM
FA
LA
VLT
DSD
TIO
GLV
DSV
TeO
TrO
CO

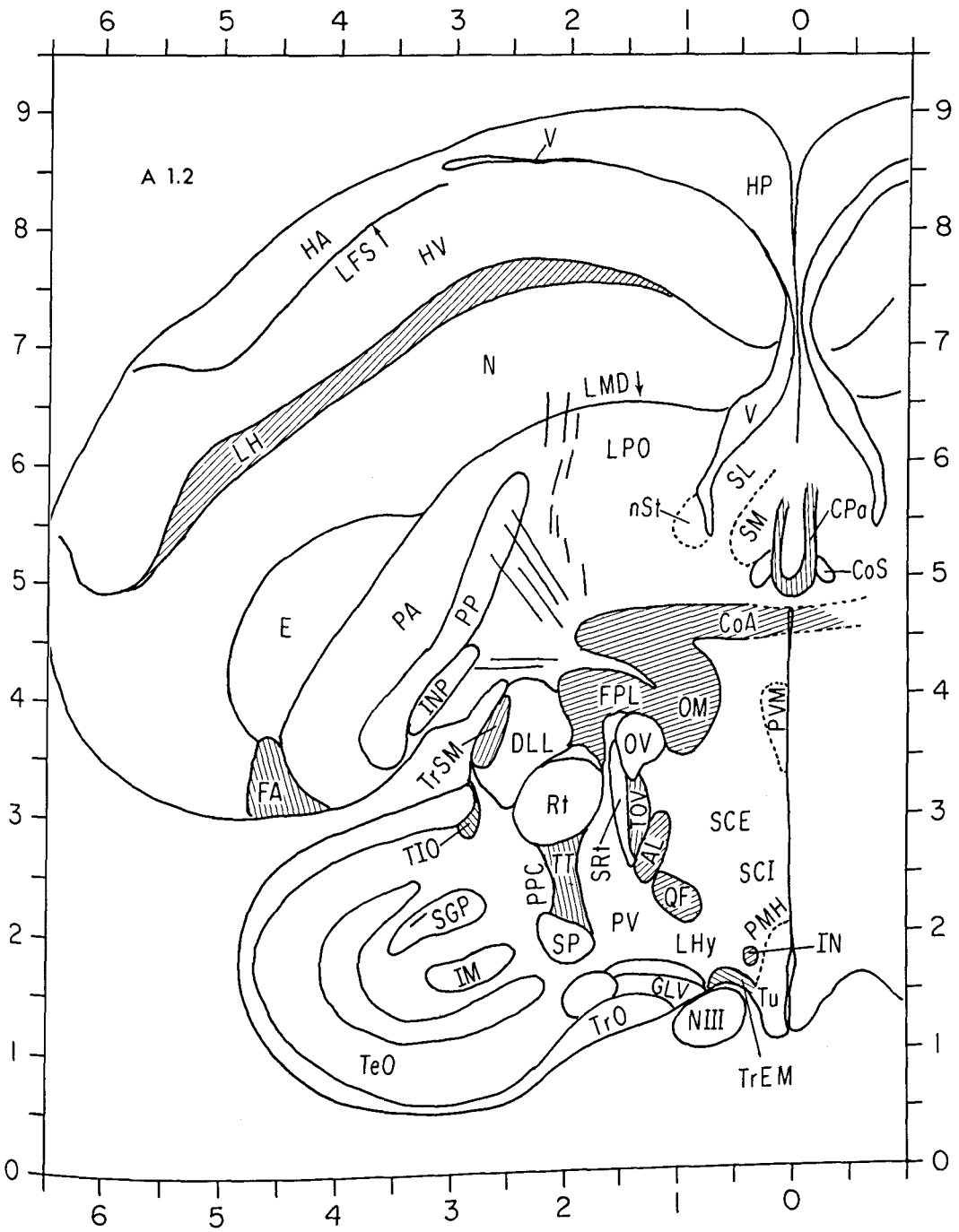

A 2.2
LFM
HD
LFS
HA
LH
HV
N
LMD
SM
LPO
SL
TrSM
E
PA
QF
PP
TFM
PVM
DSD
FPL
TrSM
FA
Rt
ICT
LHy
PMH
TIO
VLT
GLV
DSV
TeO
TrO
CO

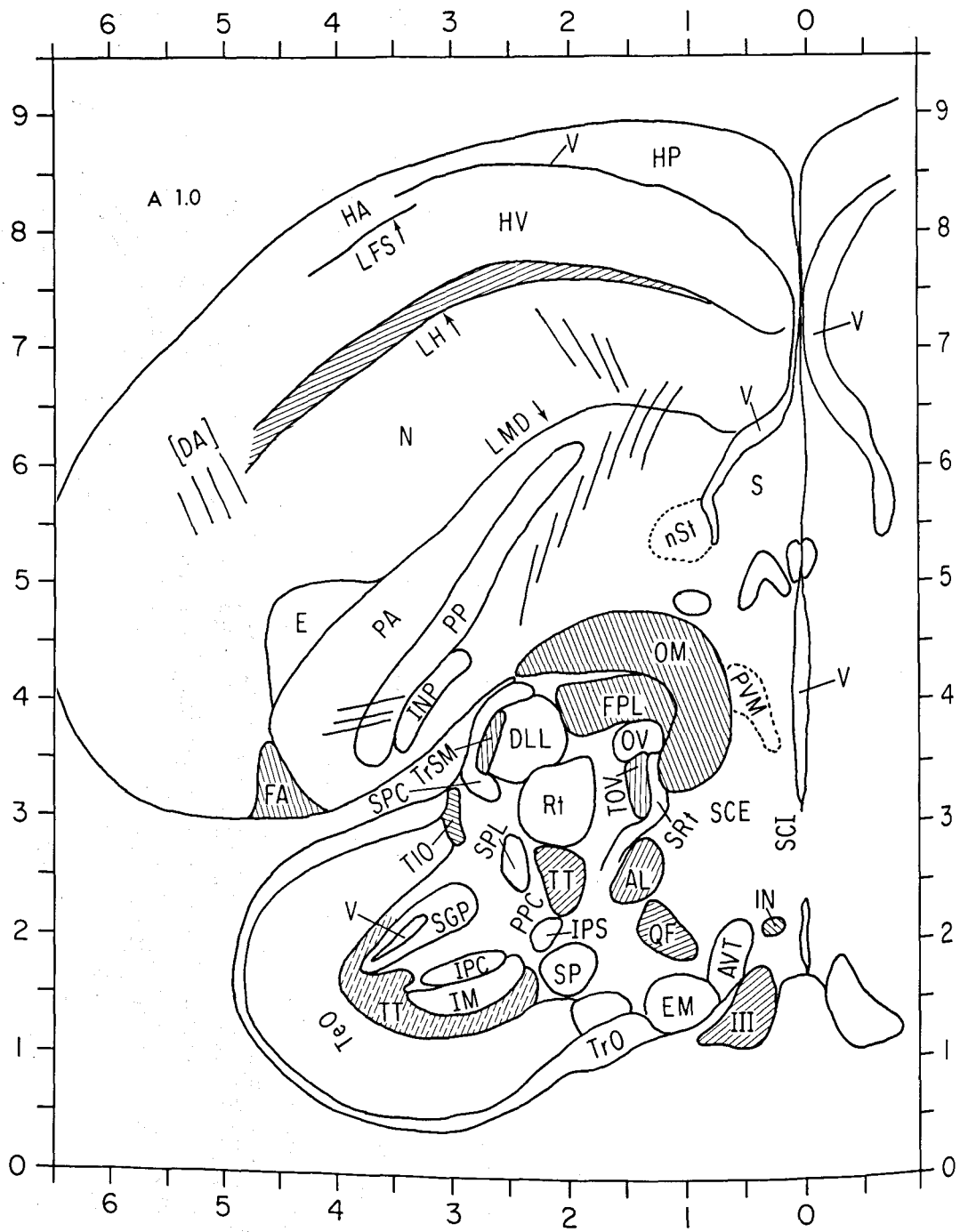

A 2.0
LFM
HA
HD
LFS
HV
LH
N
V
LMD
LPO
SL
SM
E
PA
PP
TNP
TFM
PVM
TrSM
FPL
QF
FA
Rt
ICT
LHy
PLH
TIO
TT
VLT
PMH
LM
GLV
TeO
DSV
TrO
CO

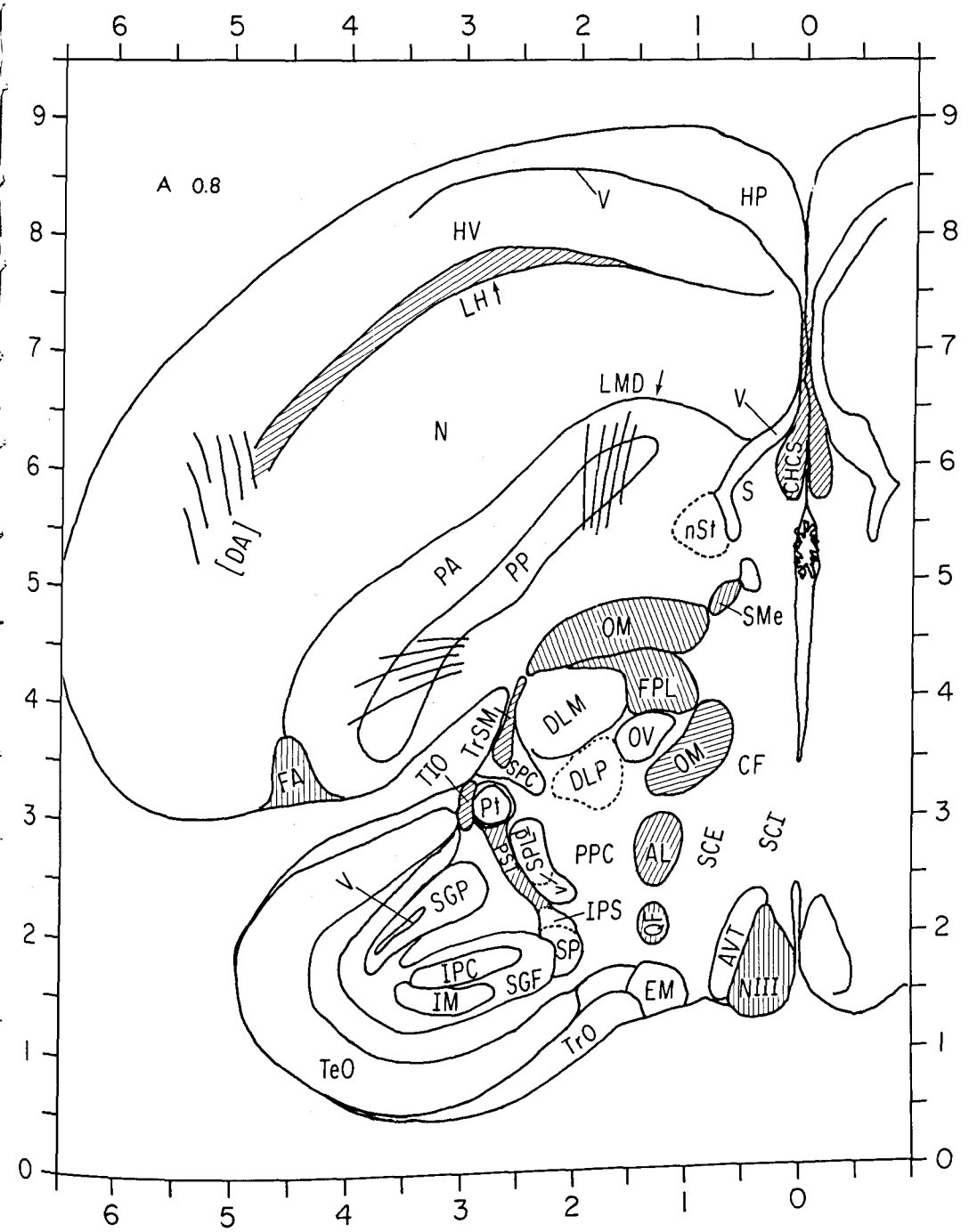

A 1.8
HA
LFS
HP
HV
N
V
LH
LMD
SL
LPO
SM
E
PA
PP
INP
FPL
TFM
PVM
TrSM
FA
DLAmc
TIO
Rt
AL
QF
ICT
LHy
PMH
TT
PV
LM
GLV
ASO
TeO
TrO
PLH

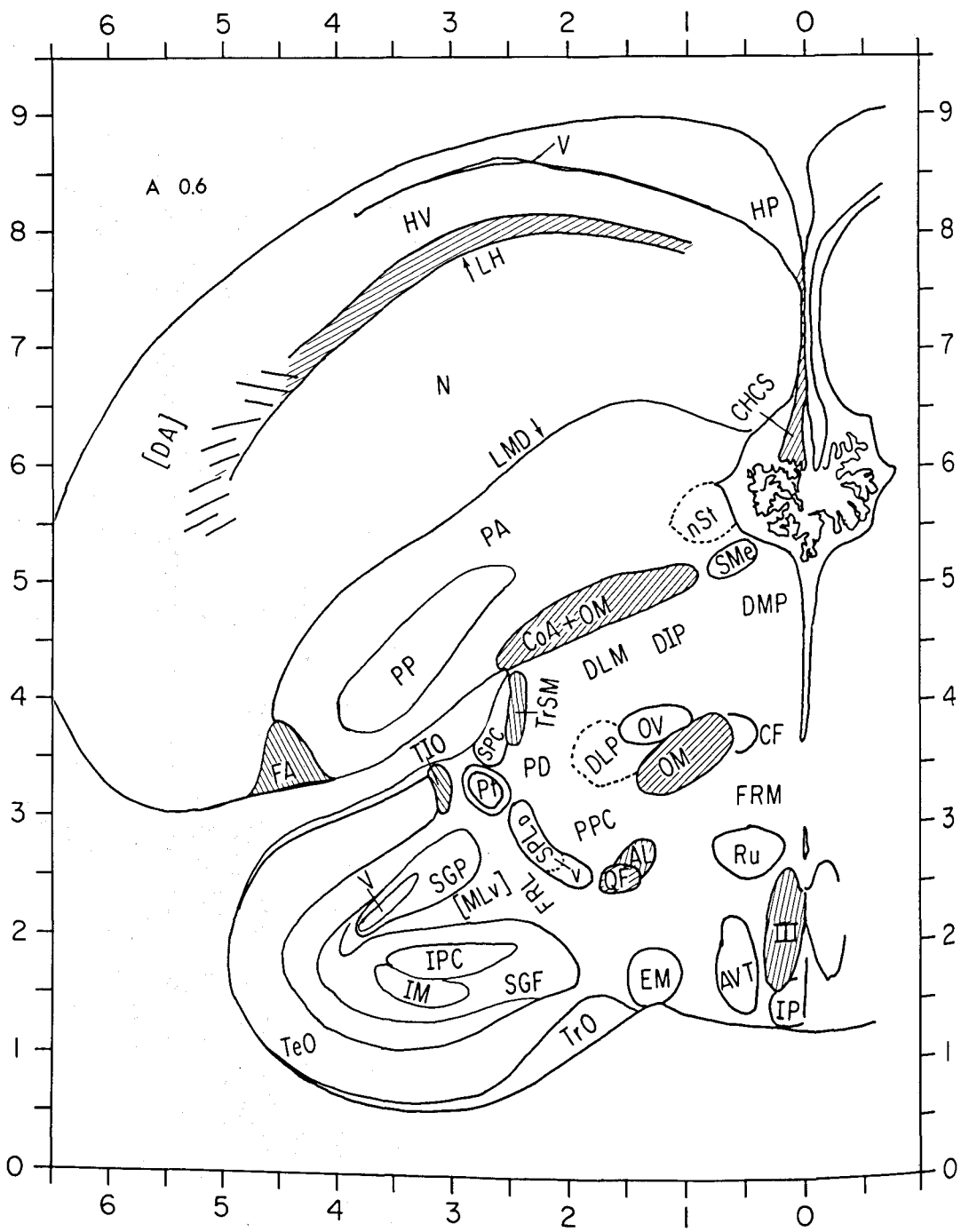

A 1.6
HA
LFS
HP
LH
V
HV
N
LMD
LPO
nSt
SL
SM
CoS
CoA
E
PA
Ep
AMP
FPL
RSd
OM
PVM
PP
TrSM
DLAmc
TIO
OV
SCE
RSv
AL
Rt
LHy
FA
TT
QF
PMH
PV
GLV
TeO
TrO
Tu

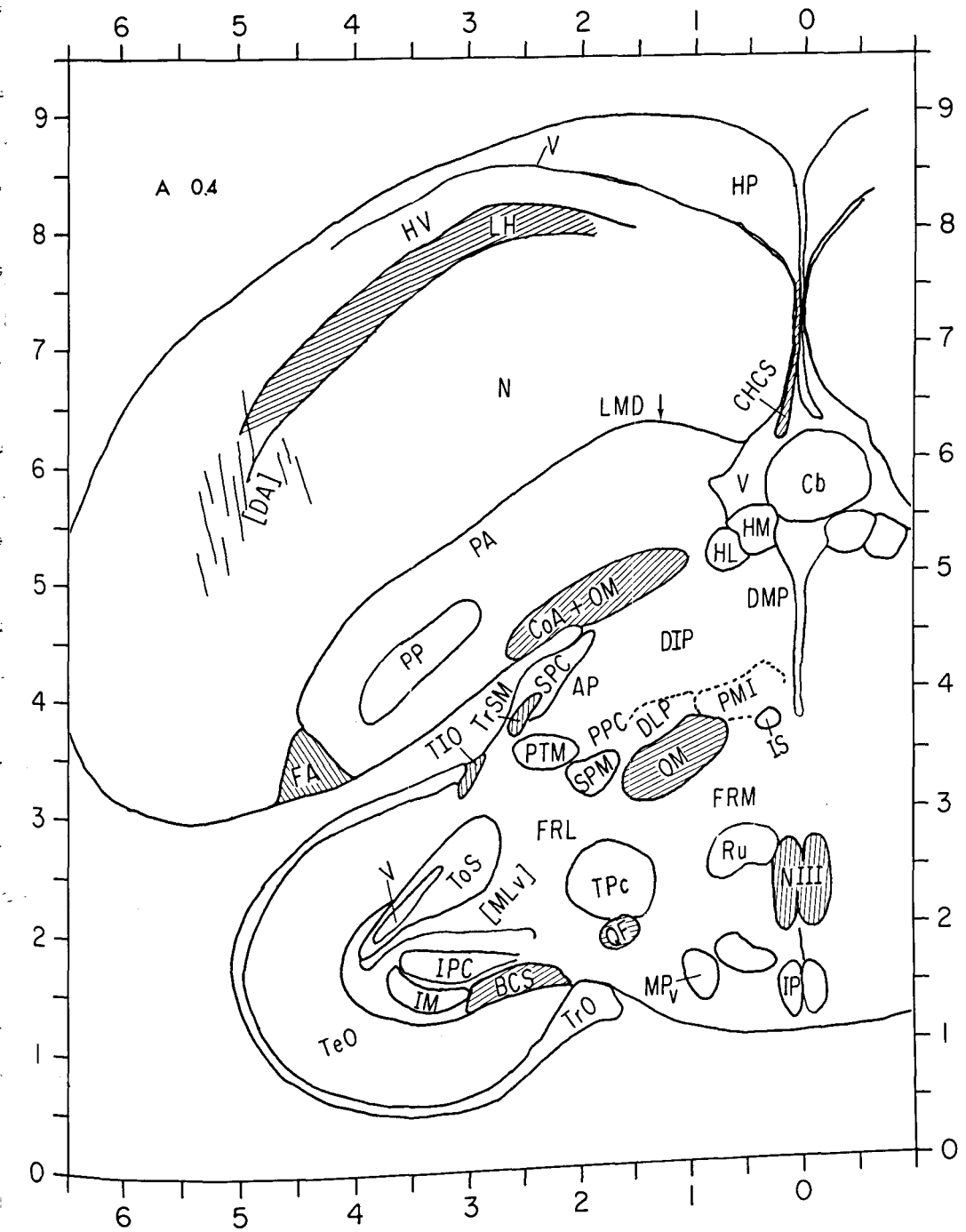

A 1.4
V
HP
HA
LFS
LH
HV
N
LMD
V
SL
LPO
nSt
SM
E
INP
CoS
PA
PP
CoA
FPL
TFM
OM
PVM
DLL
OV
FA
TrSM
TOV
Rt
SCE
TIO
AL
QF
SCI
PPC
TT
PV
GLV
Tu
TrO
III
TeO

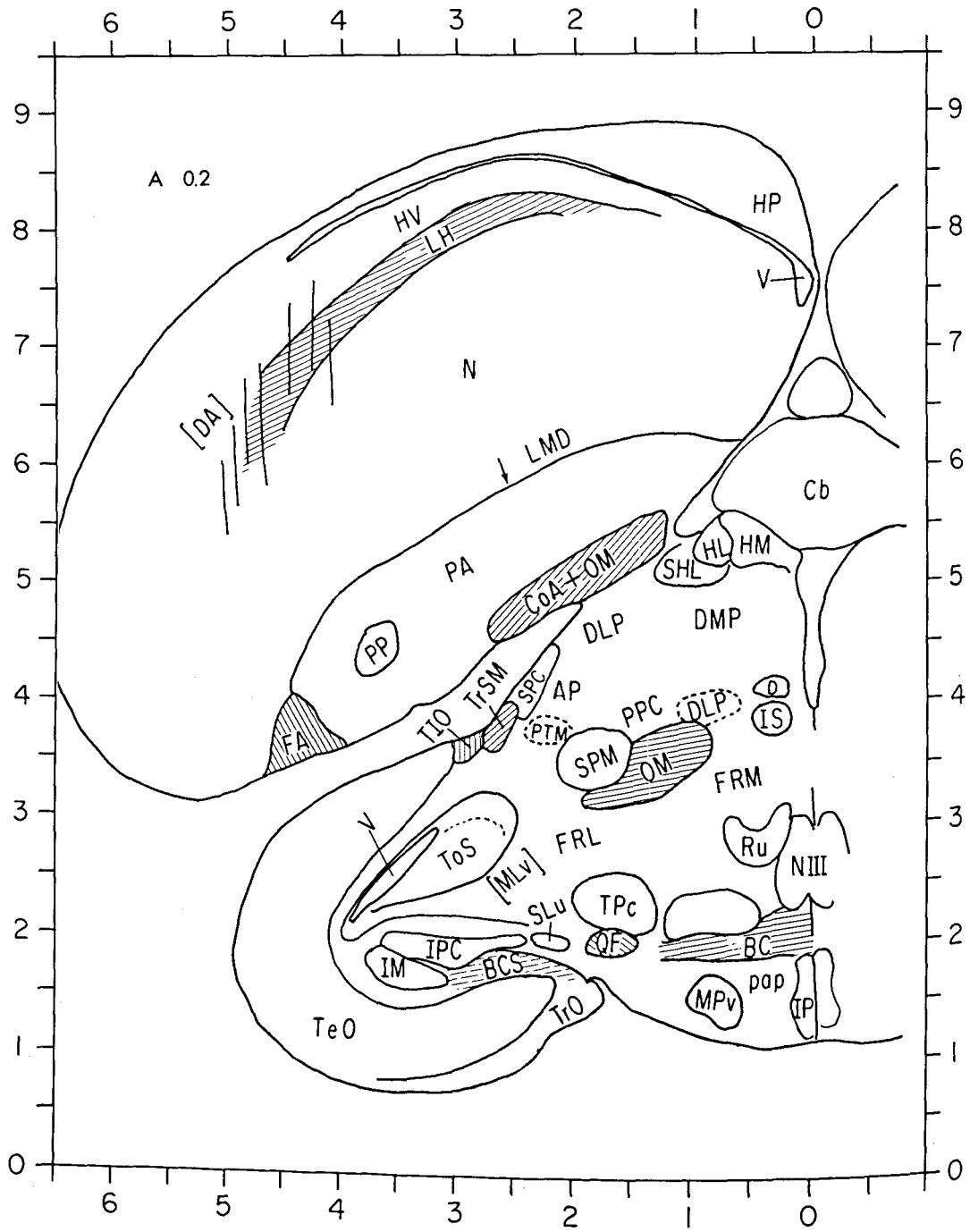

A 1.2
V
HP
HA
LFS
HV
N
LMD
LH
LPO
V
SL
nSt
SM
CPa
CoS
E
PA
PP
CoA
INP
FPL
OM
PVM
DLL
OV
TrSM
FA
Rt
TOV
SCE
TIO
PPC
TT
SRt
AL
QF
SCI
SGP
PV
PMH
IN
SP
LHy
IM
GLV
Tu
TrO
NIII
TeO
TrEM
0
1
2
3
4
5
6
7
8
9

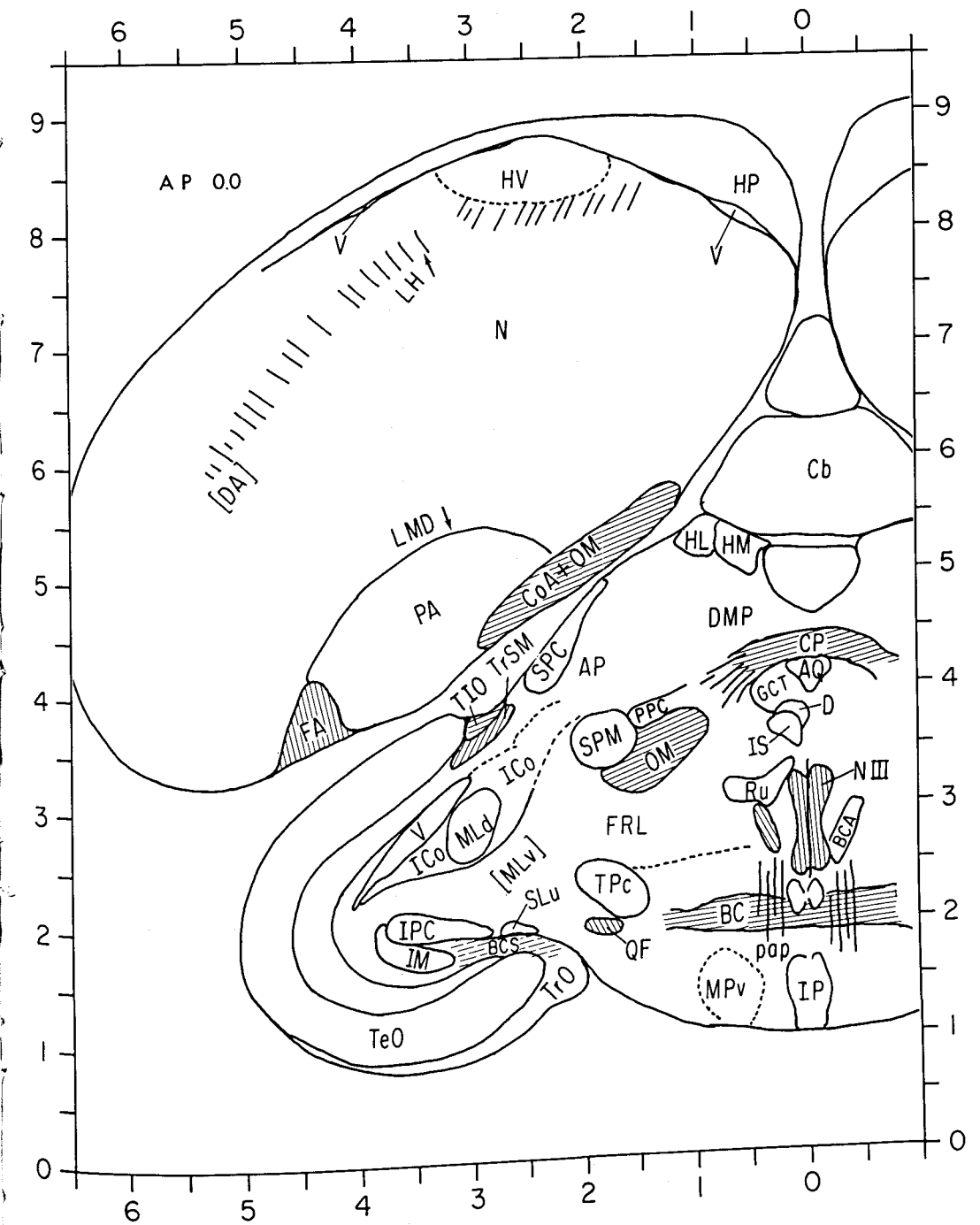

A 1.0
HP
HA
HV
LFS
LH
N
LMD
[DA]
V
S
nSt
E
PA
PP
INP
OM
PVM
FPL
DLL
OV
TrSM
SPC
FA
Rt
TOV
SRt
SCE
SCI
TIO
SPL
TT
AL
PPC
IPS
QF
IN
AVT
SGP
IPC
IM
SP
EM
III
TrO

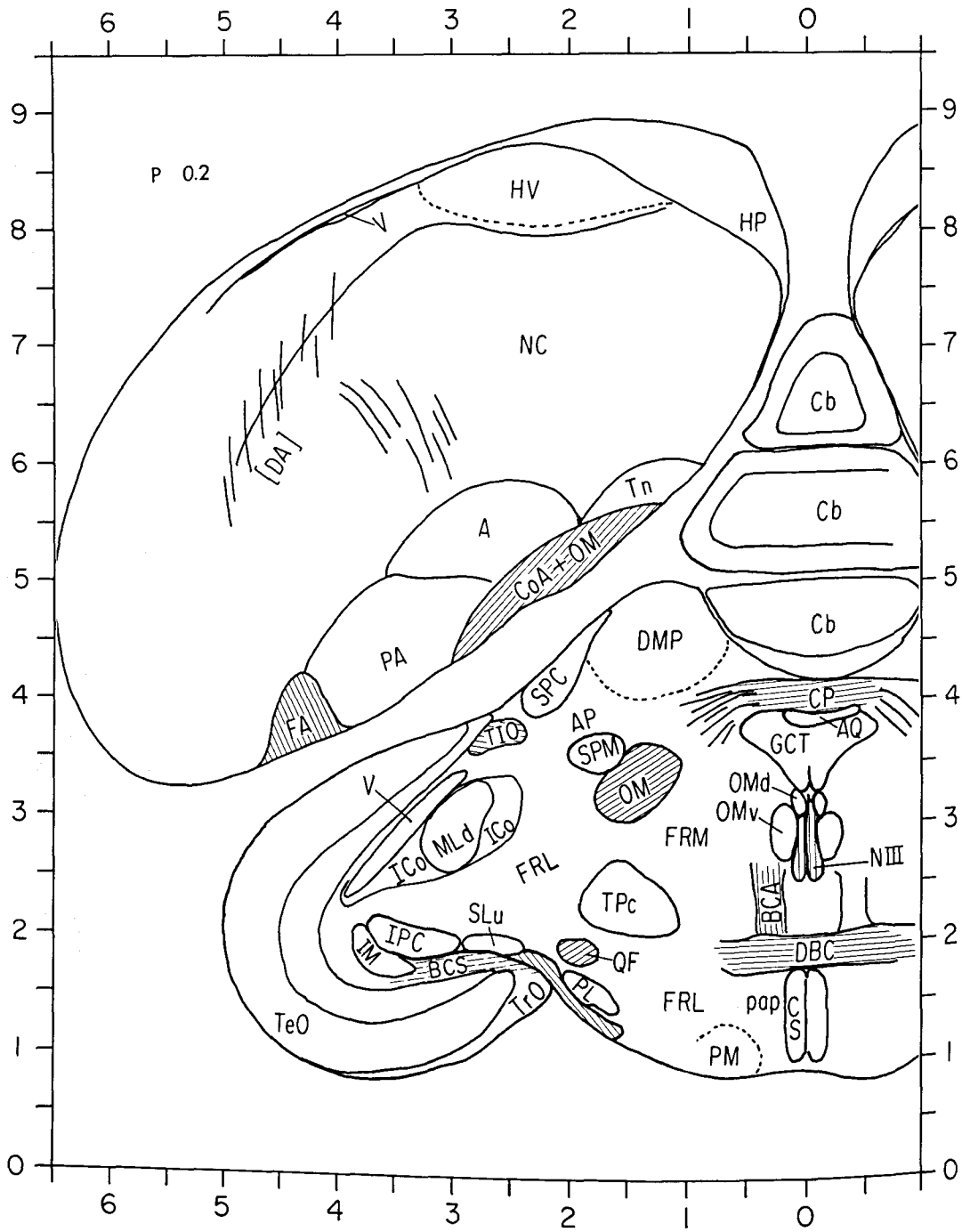

A 0.8
V
HP
HV
LH
LMD
V
N
CHCS
S
nSt
[DA]
PA
PP
SMe
OM
FPL
DLM
OV
OM
CF
DLP
FA
TrSM
TrO
SPC
Pt
PPC
AL
SCE
SCI
V
SGP
PSPL
V
IPS
SP
IPC
IM
SGF
TeO
TrO
EM
AVT
NIII

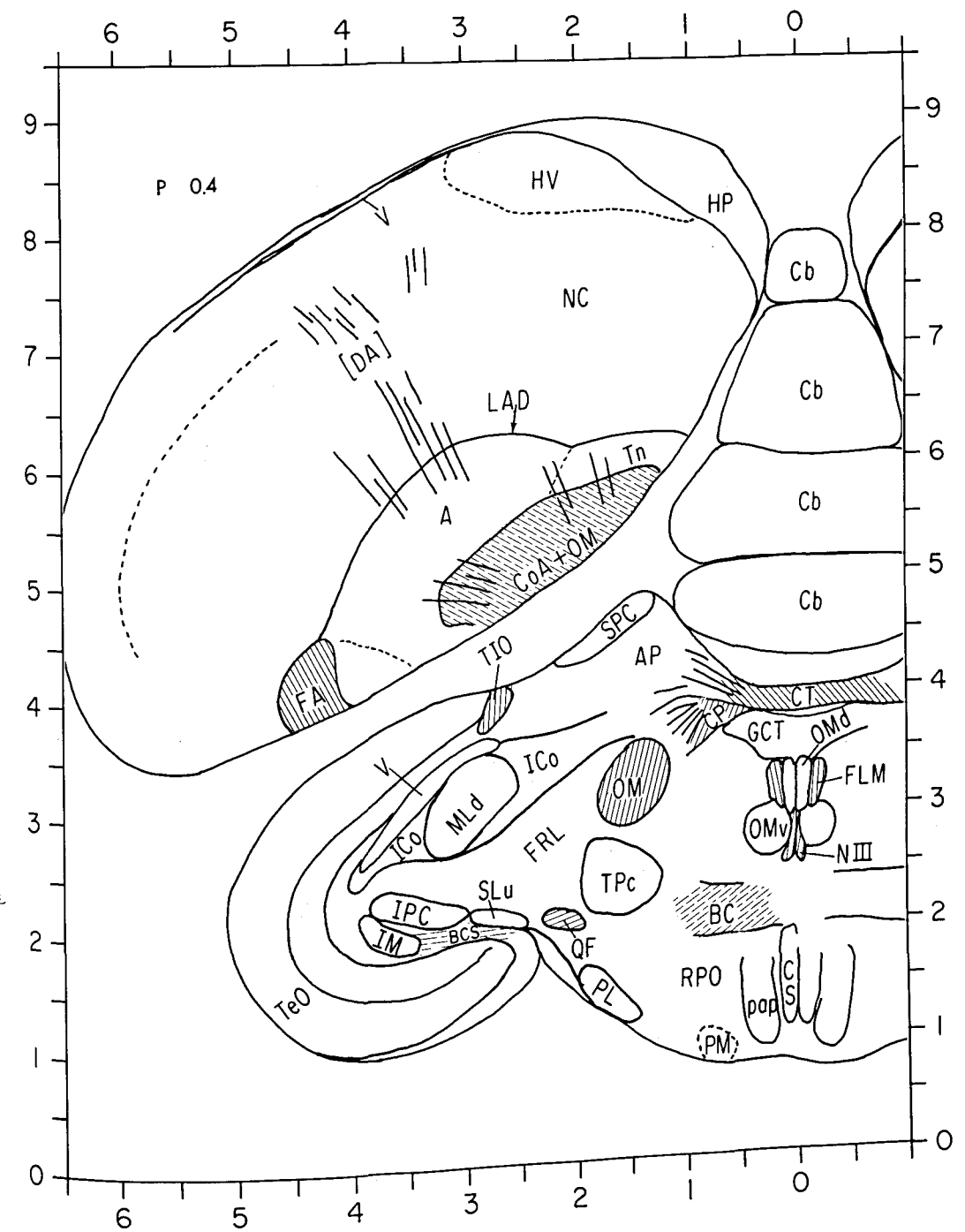

A 0.6
V
HV
HP
LH
N
[DA]
LMD
CHCS
nSt
SMe
PA
DMP
PP
CoA+OM
DLM
DIP
TrSM
SPC
TIO
FA
PT
PD
DLP
OV
OM
CF
FRM
PPC
SPL
AL
QF
Ru
SGP
[MLv]
TrF
III
IPC
IM
SGF
EM
AVT
IP
TeO
TrO

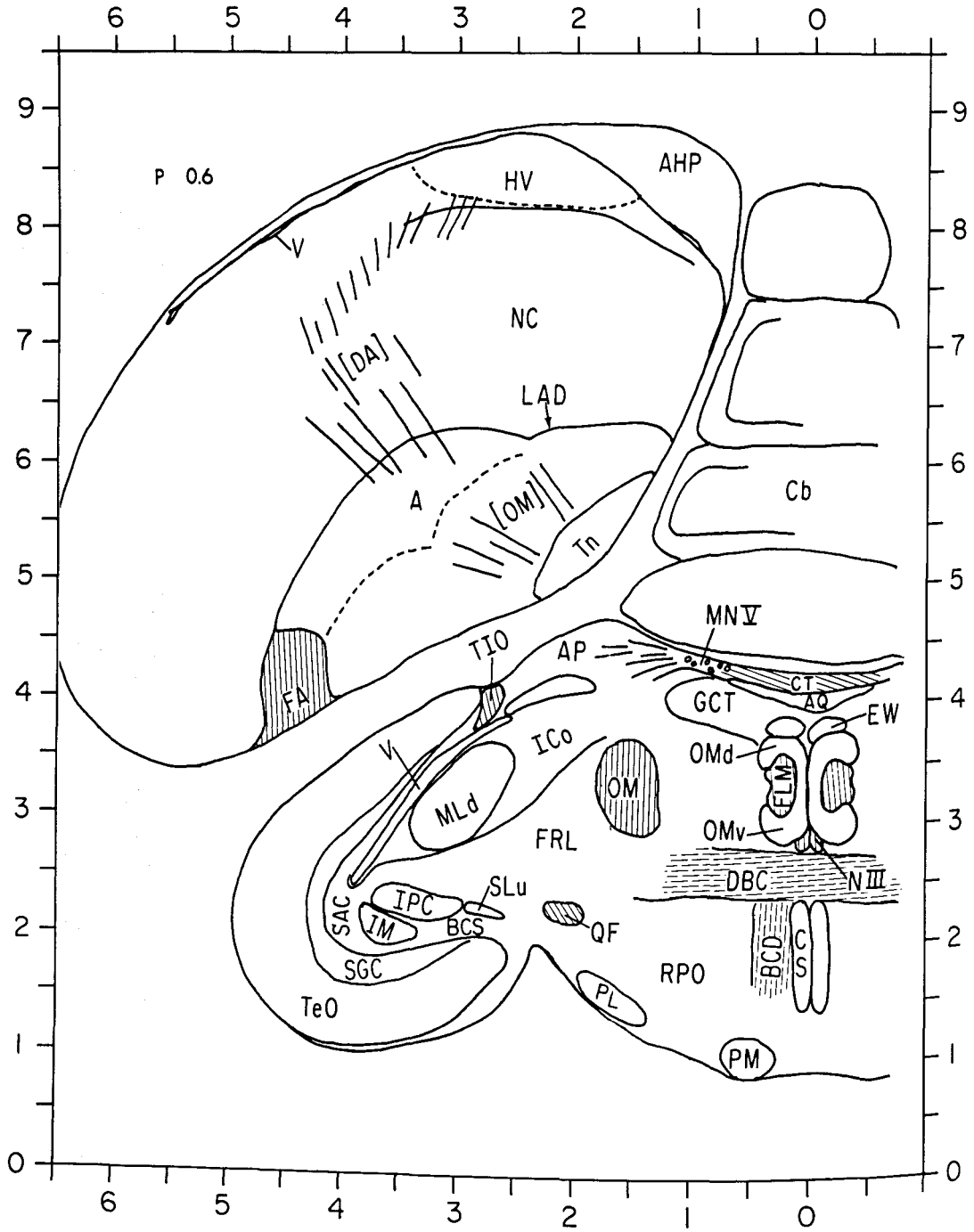

A 0.4
V
HP
HV
LH
N
LMD
CHCS
[DA]
V
Cb
HM
HL
PA
DMP
CoA+OM
PP
DIP
SPC
AP
TrSM
TIO
PPC
DLP
PMI
PTM
SPM
OM
IS
FA
FRM
FRL
Ru
NIII
V
ToS
[MLv]
TPc
QF
IPC
IM
BCS
MPv
IP
TrO
TeO

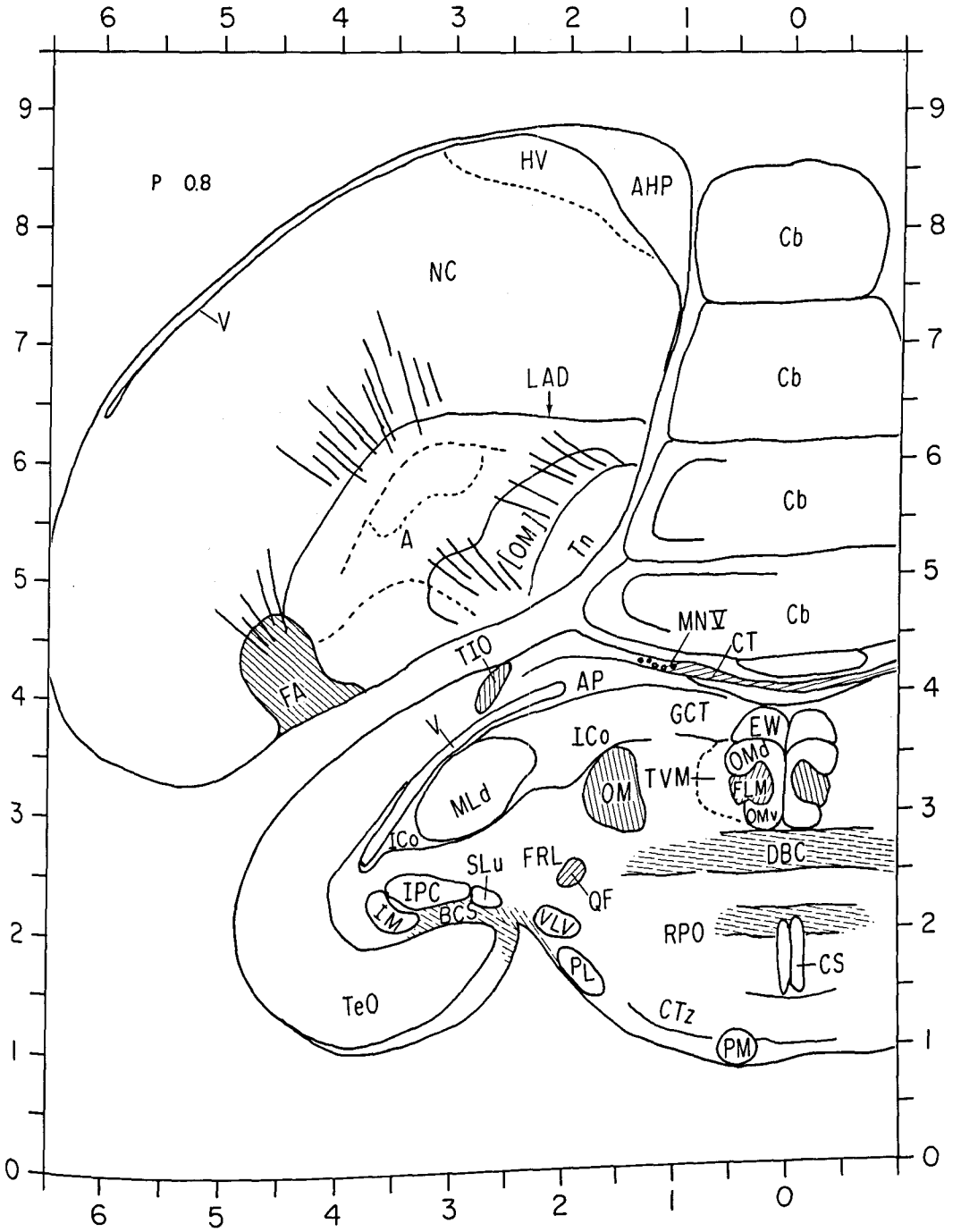

A 0.2
HV
LH
HP
V
N
[DA]
LMD
Cb
PA
CoA+OM
SHL
HL
HM
PP
DLP
DMP
TrSM
SPC
AP
PPC
DLP
D
IS
FA
TIO
PTM
SPM
OM
FRM
V
ToS
[MLv]
FRL
Ru
NIII
SLu
TPc
IPC
IM
BCS
OF
BC
pap
MPv
IP
TrO
TeO
6
5
4
3
2
1
0
9
8
7
6
5
4
3
2
1
0

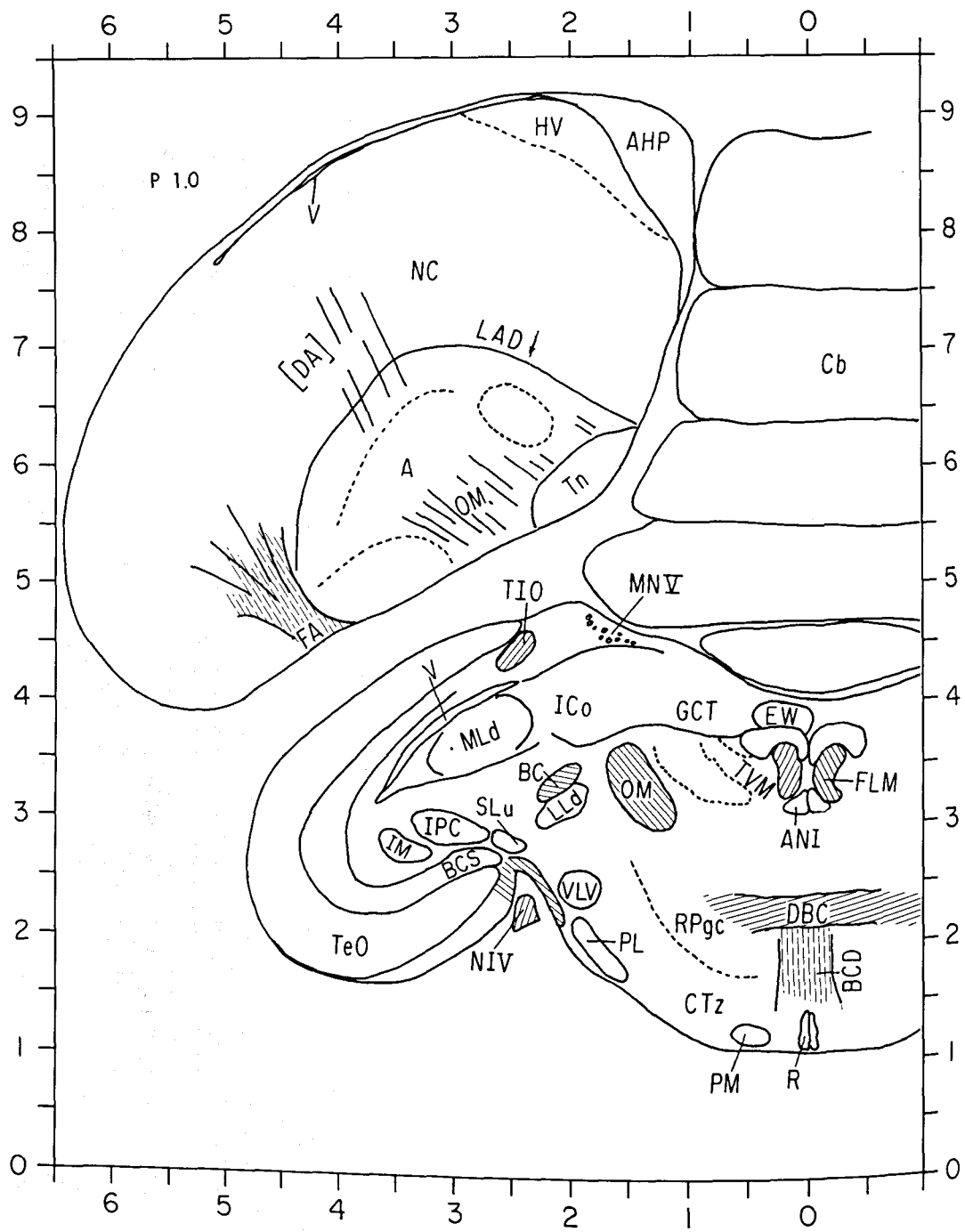

AP 0.0
HV
HP
V
LH
N
[DA]
LMD
PA
CoA+OM
Cb
HL
HM
DMP
CP
AQ
GCT
D
IS
TrSM
SPC
AP
TIO
FA
SPM
PPC
OM
NIII
Ru
ICo
MLd
FRL
BCA
[MLv]
SLu
TPc
BC
IPC
IM
BCS
QF
pap
MPv
IP
TrO
TeO

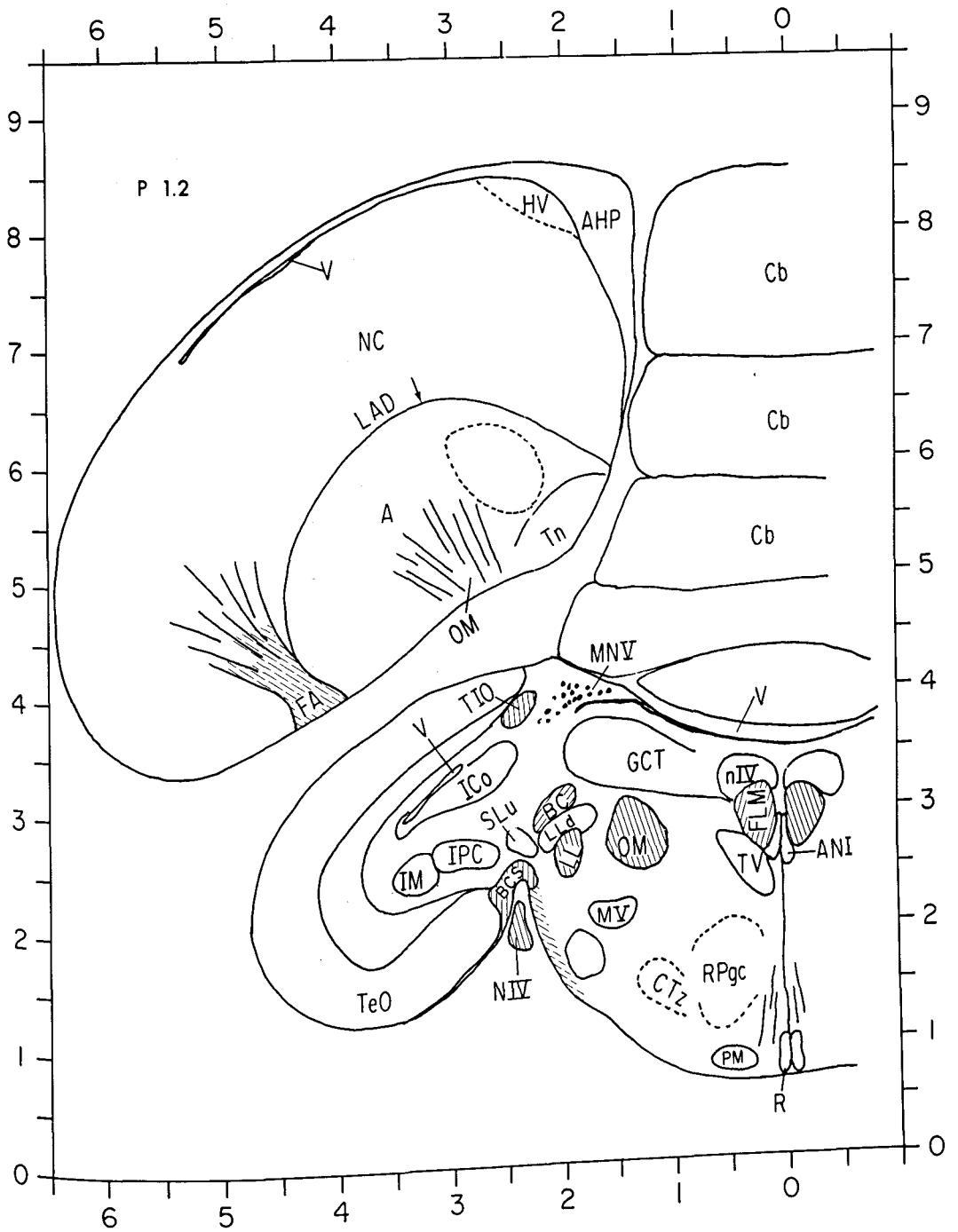

P 0.2
HV
V
HP
NC
[DA]
Cb
Cb
Cb
Tn
A
CoA+OM
PA
DMP
SPC
FA
TO
AP
SPM
OM
CP
GCT
AQ
OMd
OMv
NIII
V
ICo
MLd
ICo
FRL
FRM
TPc
SLu
IPC
IM
BCS
QF
BCA
DBC
TrO
PL
FRL
pap
CS
TeO
PM

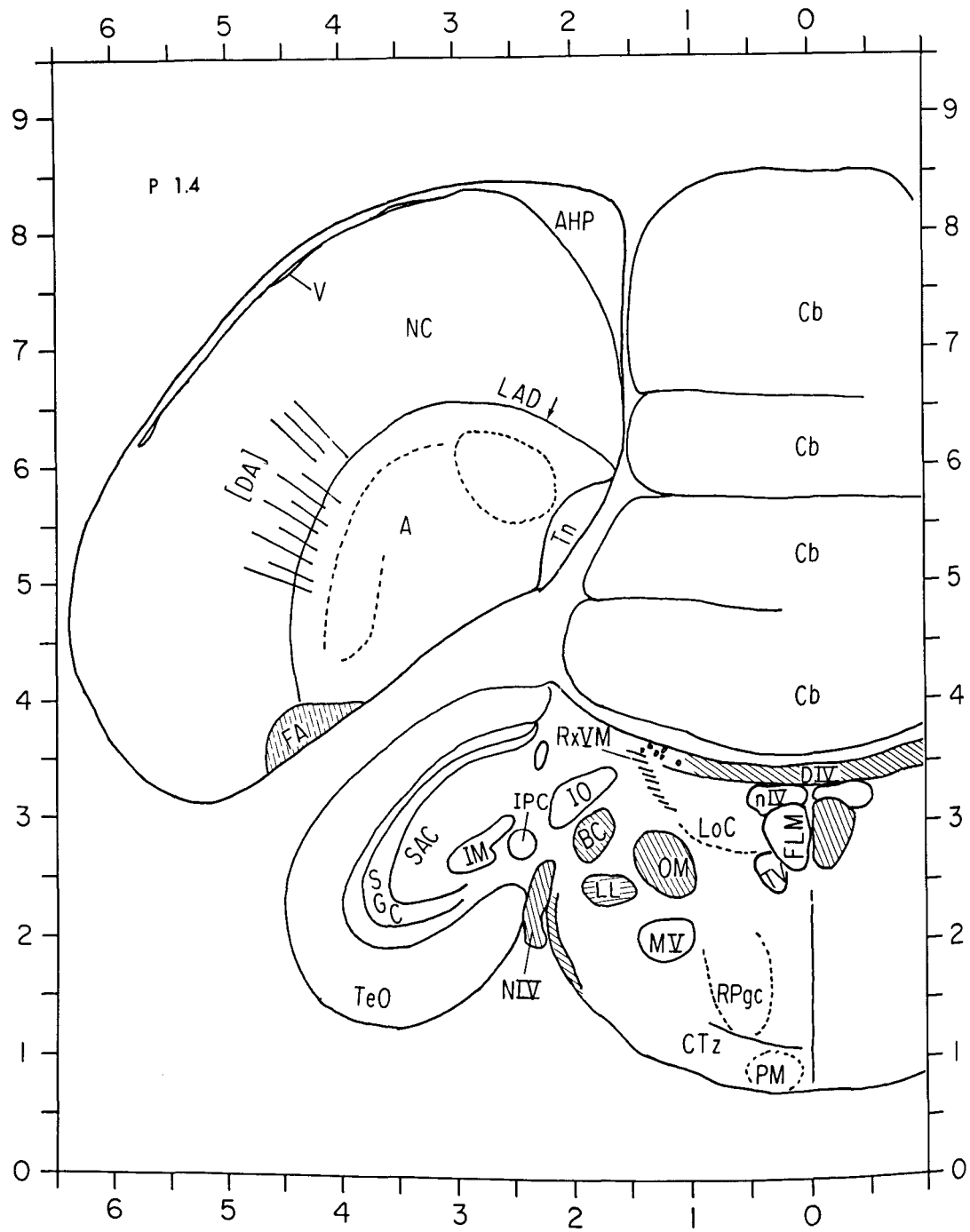

P 0.4
HV
HP
NC
Cb
Cb
Cb
Cb
[DA]
LAD
A
Tn
CoA+OM
SPC
AP
TIO
FA
CT
GCT
OMd
FLM
OMv
NIII
V
ICo
MLd
ICo
FRL
OM
TPc
SLu
IPC
IM
BCS
QF
PL
BC
RPO
pap
CS
PM
TeO

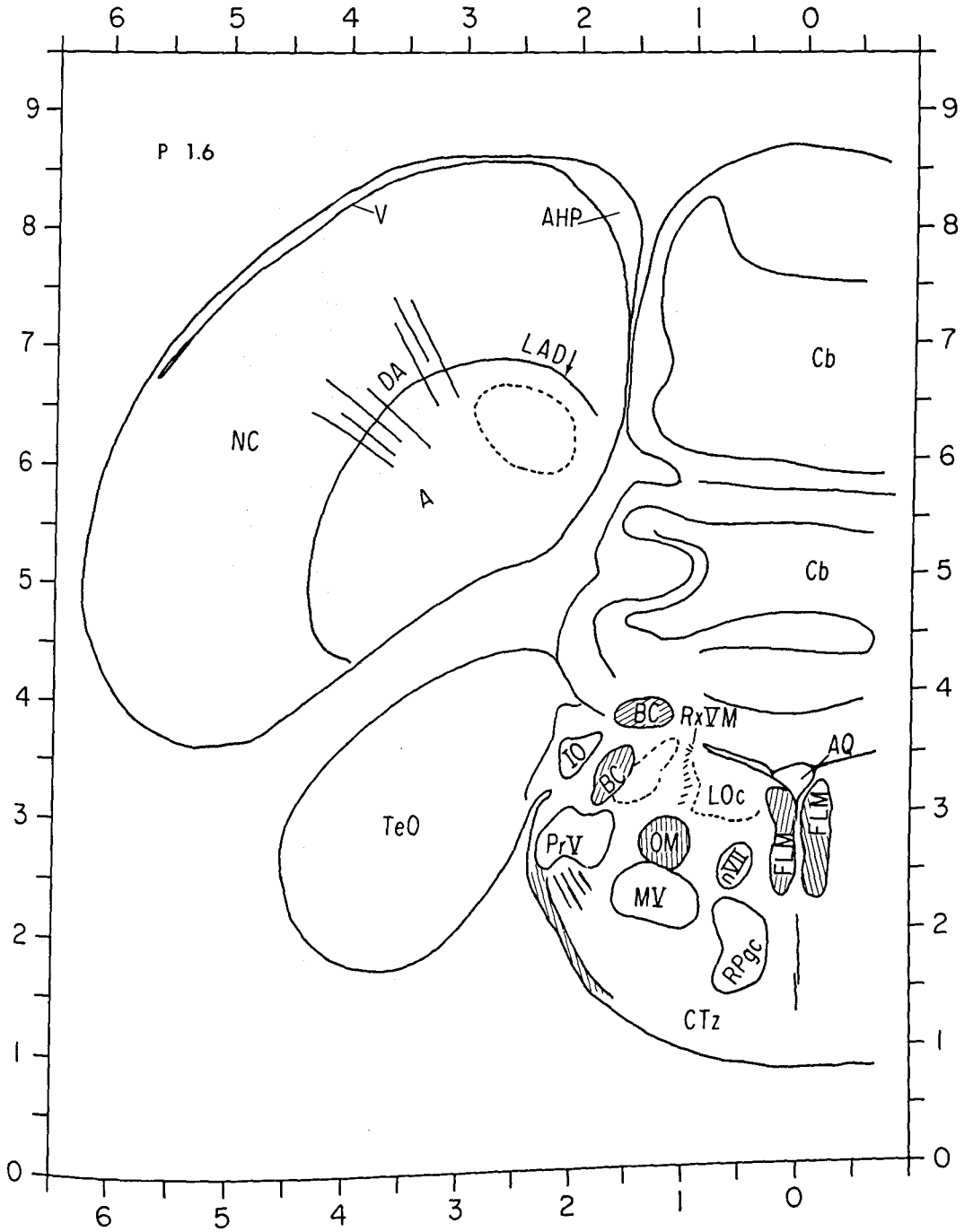

P 0.6
HV
AHP
V
NC
[DA]
LAD
A
[OM]
Tn
Cb
MN V
TIO
AP
FA
GCT
CT
AQ
EW
ICo
OMd
V
MLd
OM
FRL
ELM
OMv
DBC
N III
SLu
IPC
SAC
IM
BCS
QF
SGC
RPO
BCD
C
S
TeO
PL
PM
6
5
4
3
2
1
0
9
8
7
6
5
4
3
2
1
0

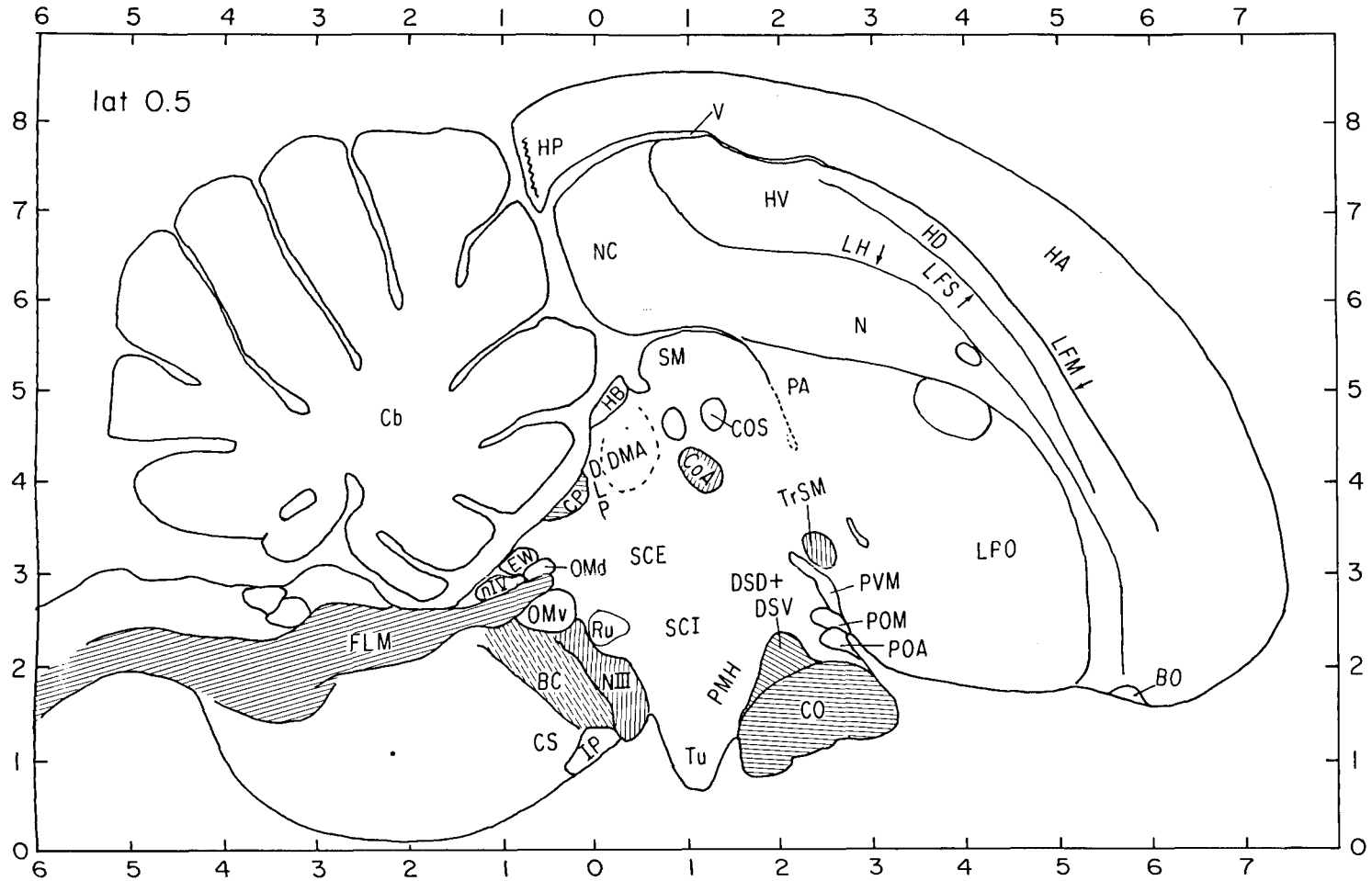

P 0.8
HV
AHP
NC
V
LAD
A
[OM]
Tn
Cb
Cb
Cb
Cb
MNV
CT
TIO
AP
FA
V
GCT
EW
ICo
OMd
TVM
FLM
OMv
OM
MLd
ICo
DBC
SLu
FRL
QF
IPC
IM
BCS
VLV
PL
RPO
CS
TeO
CTz
PM


P 1.0
HV
AHP
V
NC
[DA]
LAD
Cb
A
OM
Tn
FA
TIO
MNV
V
ICo
GCT
EW
MLd
BC
LLd
OM
IVM
FLM
SLu
IPC
IM
BCS
ANI
VLV
RPgc
DBC
TeO
NIV
PL
BCD
CTz
PM
R


P 1.2
HV
AHP
V
NC
LAD
A
Tn
OM
FA
Cb
Cb
Cb
MNV
V
TTO
V
ICo
GCT
nIV
FLM
SLu
BC
LLd
OM
TV
ANI
IPC
IM
BCS
MV
RPgc
CTz
NIV
TeO
PM
R


P 1.4
AHP
V
NC
Cb
Cb
Cb
Cb
LAD
[DA]
A
Tn
FA
RxVM
DIV
nIV
IPC
IO
BC
LoC
FLM
SAC
IM
SGC
OM
LL
MV
NIV
TeO
RPgc
CTz
PM


P 1.6
V
AHP
LADL
DA
NC
A
Cb
Cb
BC
RxVM
IO
BC
AQ
LOc
TeO
PrV
IOM
nVIII
FLM
FLM
MV
RPgc
CTz


lat 0.5
HP
V
HV
NC
LH
HD
LFS
HA
LFM
N
SM
PA
HB
Cb
COS
D
DMA
CoA
CP
LP
TrSM
LPO
SCE
EW
OMd
nIV
DSD+
PVM
DSV
POM
POA
OMv
Ru
SCI
FLM
BC
NIII
PMH
CO
BO
CS
IP
Tu
6 5 4 3 2 1 0 1 2 3 4 5 6 7
8 7 6 5 4 3 2 1 0