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neuroanatomy

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Preface

In this new edition of the text, I point out where new research has discarded several previous hypotheses and seeming facts. Now, by imaging with radioisotopes, magnetic resonance scans, and electrical recording, we can almost chase a thought through the circuits of the brain. Each advance in functional localization, though, places more demands on knowing the neuroanatomic basis.

As well as glimpsing exciting new vistas, the text must serve the practitioner. Therefore, I have tried to balance the intellectual neuroanatomy required to correlate neurologic function and structure against the practical neuroanatomy required to diagnose the next patient who comes to your office with numbness and tingling in a toe. In addition, more clinical applications throughout the text justify the student's devotion to learning neuroanatomy.

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Contents

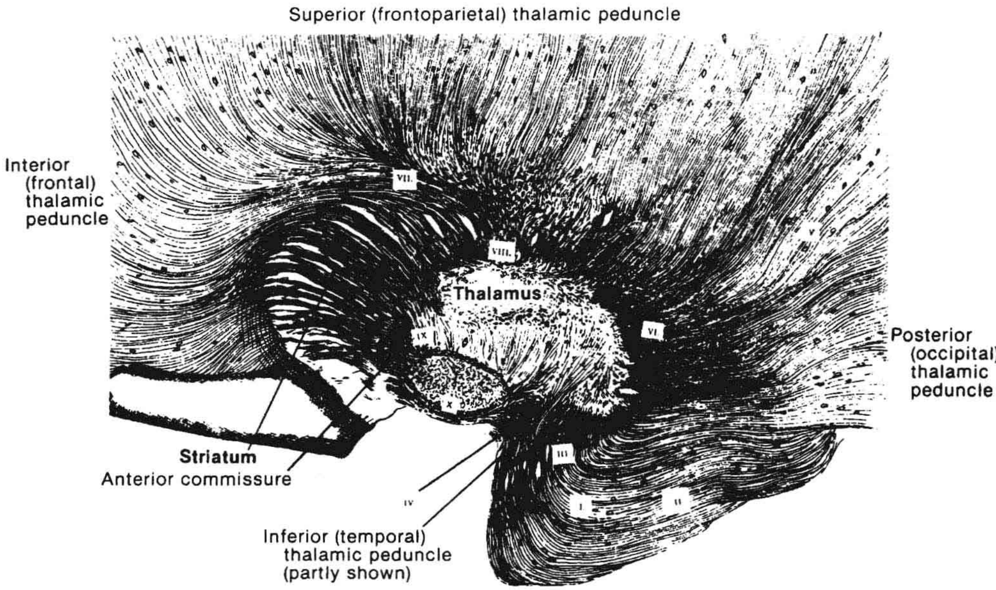

FIGURE 12-8. Drawing of a parasagittal section of a cerebral hemisphere demonstrating the fan of fibers that radiate to and from the thalamus. A continuous arc of 300 degrees, the fan is more or less arbitrarily divided into peduncles. *I, II,* and *III* = geniculocalcarine tract of the occipital peduncle (see Figure 10-11); *IV* = transversely cut auditory radiation of the inferior peduncle; *V* and *VI* = superior part of the occipital peduncle; *VII* = subcallosal fasciculus of the frontal peduncle; *VIII* = fibers of the stria terminalis; *IX* and *X* = fibers approaching and surrounding the subthalamic nucleus. (Reprinted with permission from Rosett J: A study of the cerebral fibre systems by means of a new modification of anatomical methods. The lateral wall of the thalamus and the sagittal portion of its cerebral fibre system. *Brain* 45:357–384, 1922. Labels have been added; Roman numerals are original author's.)

2. They convey axons from the longitudinal fasciculi of the cerebrum and the cingulum, connecting the insular cortex and the rest of the cerebrum (see Figures 13-25 and 13-26).
3. Transversely crossing axons interconnect the thalamus and basal ganglia with the claustrum and insula.
4. No known clinical syndrome results from lesions of the external and extreme capsules and the claustrum.

O. **Clinical syndromes resulting from lesions of the thalamus dorsalis.** Because the functions of the thalamus reflect the functions of the whole of the cerebrum, thalamic lesions may impair any of the three great categories of cerebral function: **mental**, **motor**, and **sensory**.

1. **Unilateral thalamic lesions**
   a. The functions of the left thalamus reflect the functions of the left cerebral hemisphere. Lesions of the left thalamus tend to cause deficits in language production, syntax, word production, prosody, voice volume, and interpretation and expression of words as symbols for communication (thalamic aphasia).
   b. The functions of the right thalamus reflect the functions of the right cerebral hemisphere. Lesions of the right thalamus cause difficulties with spatial relations. The patient neglects tactile, visual, and auditory stimuli from the left half of space and gets lost when going from one place to another. Language functions and mentation are preserved. Right hemisphere lesions tend to cause a defect in the recognition of emotions expressed by others and in the patient's own behavioral expression of affect.
   c. A unilateral lesion of nucleus ventralis posterior, or its projection through the internal capsule, causes contralateral loss of sensation. Because the lesion is usually an infarct, the condition is called "pure thalamic sensory stroke."

(1) Sometimes, along with the loss of sensation, the patient also experiences extreme pain in the affected extremities. This classic thalamic syndrome is called the Dejerine-Roussy syndrome of "painful anesthesia" (anesthesia dolorosa).
(2) Because the lateroventral region of the thalamus shares its blood supply with the internal capsule, the patient with thalamic sensory stroke may also exhibit some degree of hemiparesis.

2. **Bilateral thalamic lesions** impair consciousness and higher mental functions.
   a. The patient becomes demented, amnestic, emotionally labile, and loses orientation to person, time, and place.
   b. The patient may display various degrees of hypokinesia, mutism, or permanent loss of consciousness.
3. **Bilateral lesions of nucleus medialis dorsalis and its frontal connections**
   a. Destruction of nucleus medialis dorsalis, its frontal connections through the anterior thalamic peduncle, or the frontal cortex anterior to the motor region results in loss of drive and initiative, placidity, and a general indifference to stimuli, including pain.
   b. For this reason, neurosurgeons may transect the anterior thalamic peduncle (prefrontal leukotomy or lobotomy) in moribund cancer patients to reduce their reaction to pain. Although lobotomy also has helped some psychotic and severe obsessive-compulsive patients, medications have nearly obviated the operation.

TABLE 12-5. Thalamic Peduncles (Radiations), Their Components, and Their Course Through the Internal Capsule*

Thalamic Peduncle and Course	Thalamic Nucleus	Destination
Anterior thalamic peduncle (through anterior limb of the internal capsule)	N. medialis dorsalis	Frontal granular cortex (prefrontal cortex rostral to motor area)
	N. anterior	Cingulate gyrus
	N. ventralis anterior and lateralis	Areas 4 and 6 (all fibers from n. ventralis are sometimes grouped with superior peduncle)
Superior (centroparietal) thalamic peduncle (through genu and posterior limb per se of the internal capsule)	N. ventralis posterolateralis	Body and extremity area of postcentral gyrus
	N. ventralis posteromedialis	Face area of postcentral gyrus
	N. pulvinaris	Parietal, occipital, and temporal cortex, exclusive of areas served by the thalamic sensory relay nuclei
Posterior thalamic peduncle (through retrolenticular part of the internal capsule)	N. pulvinaris	Occipital cortex, exclusive of calcarine cortex
Inferior thalamic peduncle (through sublenticular part of the internal capsule)		
Anterior component (ansa peduncularis)	Rostromedial thalamic nuclei (exact origin unsettled)	Medial-basal part of temporal lobe: amygdala, piriform lobe, and orbital surface of frontal lobe
Posterior component	Medial geniculate body	Transverse temporal gyri (auditory receptive area)
	Lateral geniculate body (geniculocalcarine tract)	Calcarine cortex of occipital lobe (Area 17, visual receptive area)

N. and n. = nucleus.
*Most of the connections are thalamocortical/corticothalamic circuits.

c. The neurons of nucleus medialis degenerate in retrograde fashion after prefrontal leukotomy.

III. HYPOTHALAMUS AND PITUITARY BODY

A. Gross anatomy of the hypothalamus

1. **Definition.** The hypothalamus is the most ventral of the four longitudinal nuclear zones of the diencephalon (see Figures 12-1, 12-2, and 12-10). It comprises the floor and that portion of the wall of the third ventricle **ventral** to the hypothalamic sulcus (sulcus limitans) [see Figure 12-10].
2. **Functional significance.** Although it weighs only a few grams, the hypothalamus is essential to life because it controls the viscera, endocrine system, vegetative functions, and homeostasis (fluid balance, body temperature, appetite, and so forth). Through limbic lobe connections, it mediates the experience and expression of emotions and the control of instinctive behaviors such as mating, feeding, aggression, and fright/flight responses.
3. **Visualization** of the hypothalamus requires:
   a. A **ventral** view of the base of the brain to see its **external** aspect
   b. **Sagittal section** through the lumen of the third ventricle to see its **medial** aspect
   c. **Coronal sections** to see its **transverse** extent
4. **Ventral aspect of the hypothalamus.** Locate the following in Figure 12-9:
   a. Optic chiasm and tract
   b. Infundibular stalk (neurohypophysis is cut off)
   c. Median and lateral eminences (the tuber cinereum or tuberal region)
   d. Mammillary bodies (the postmammillary sulcus separates the hypothalamus from the midbrain basis)
5. **Medial aspect of the hypothalamus** (Figure 12-10)
   a. The **rostral boundary** of the hypothalamus is the junction of the lamina terminalis of the diencephalon with the anterior commissure of the telencephalon.

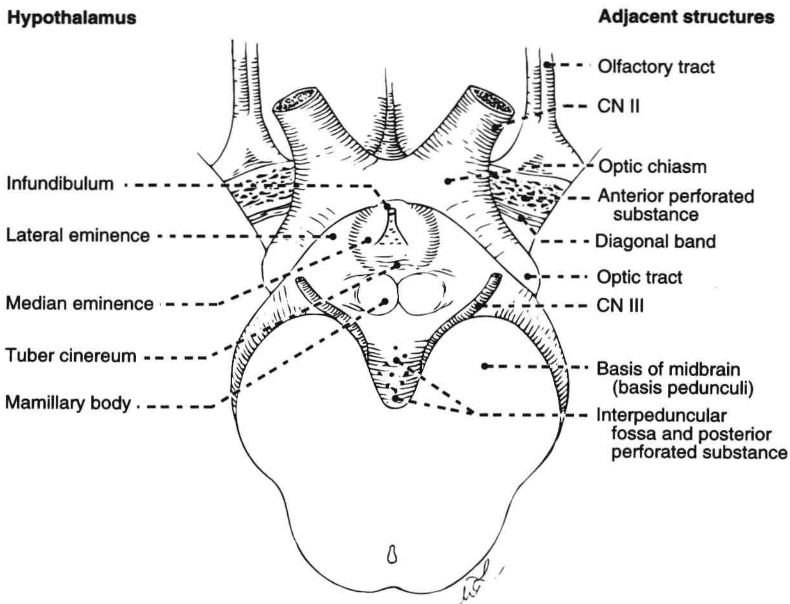

FIGURE 12-9. Gross anatomy of the ventral surface of the hypothalamus.

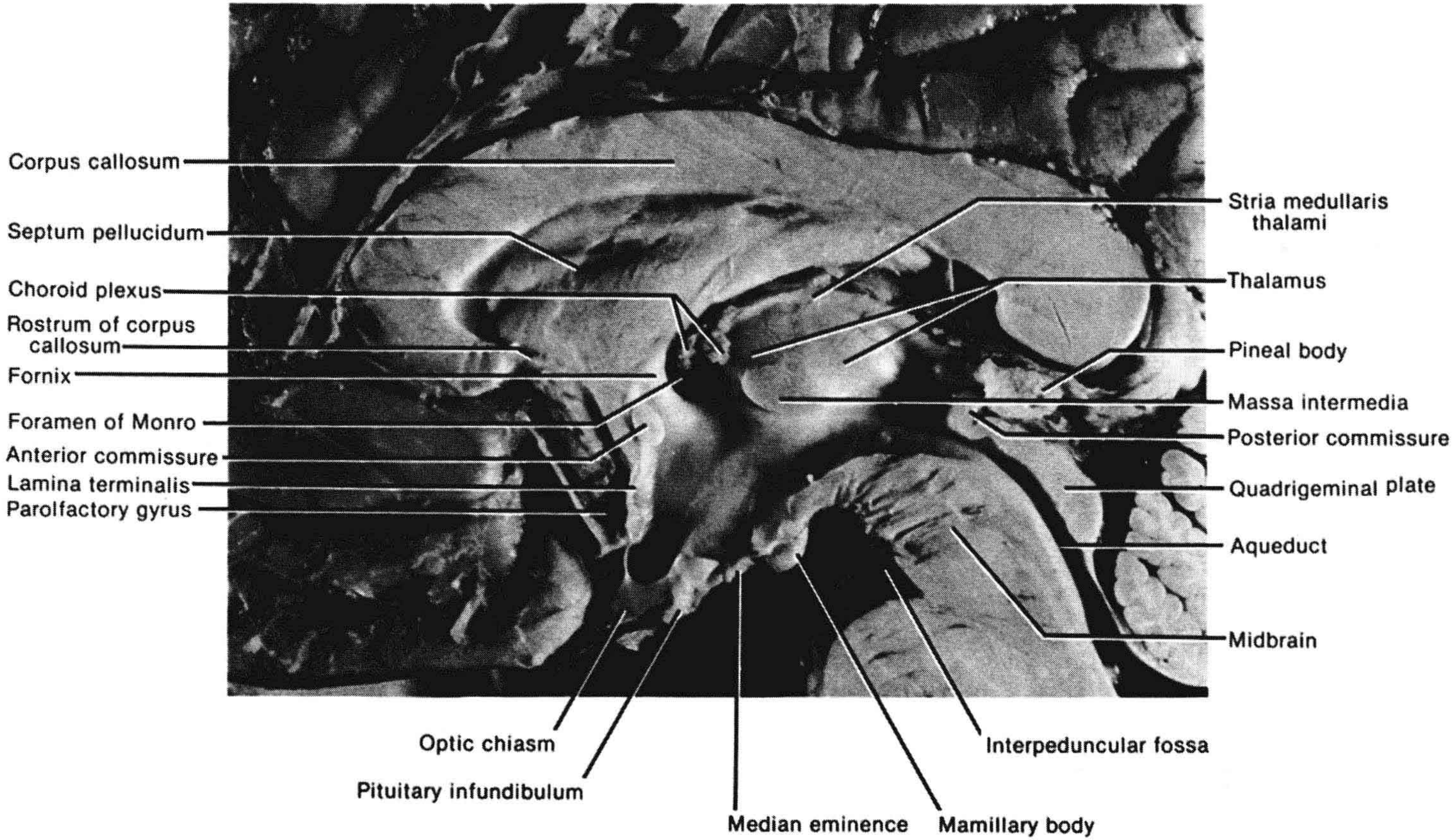

FIGURE 12-10. Sagittal section of the cerebrum.

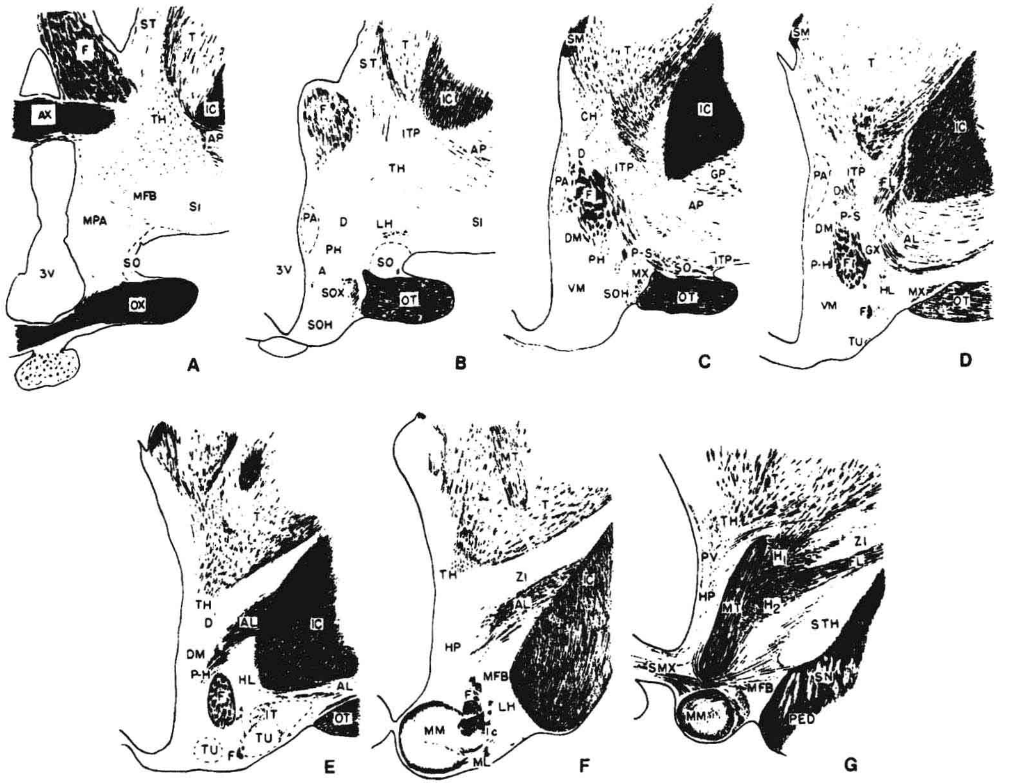

FIGURE 12-11. Myelin-stained atlas of coronal sections of the hypothalamus, anterior to posterior levels (*A–G*). *A* = anterior hypothalamic area; *AL* = ansa lenticularis; *AP* = ansa peduncularis; *AX* = anterior commissure; *CH* = corticohabenular fibers; *D* = dorsal hypothalamic area; *DM* = dorsomedial hypothalamic nucleus; *F* = fornix; *FL* = fasciculus lenticularis; *GP* = globus pallidus; *GX* = dorsal supraoptic commissure, pars dorsalis; H_1, H_2 = fields of Forel; *HL* and *LH* = lateral hypothalamic area; *HP* = posterior hypothalamic area; *IC* = internal capsule; *Ic* = nucleus intercalatus; *IT* = fibers of nucleus tuberalis; *ITP* = inferior thalamic peduncle; *MFB* = medial forebrain bundle; *ML* = lateral mammillary nucleus; *MM* = medial mammillary nucleus; *MPA* = medial preoptic area; *MT* = mammillothalamic tract; *MX* = dorsal supraoptic commissure, pars ventralis; *OT* = optic tract; *OX* = optic chiasm; *PA* = paraventricular nucleus; *PED* = cerebral peduncle; *PH* = paraventricularhypophyseal fibers; *P-H* = pallidohypothalamic fibers; *P-S* = paraventriculosupraoptic fibers; *PV* = periventricular system; *SI* = substantia innominata; *SM* = stria medullaris; *SMX* = supramammillary commissure; *SN* = substantia nigra; *SO* = supraoptic nucleus; *SOH* = supraopticohypophyseal tract; *SOX* = supraoptic commissures; *ST* = stria terminalis; *STH* = subthalamic nucleus; *T* = thalamus; *TH* = thalamohypothalamic fibers; *TU* = nucleus tuberis laterale; *VM* = ventromedial hypothalamic nucleus; *ZI* = zona incerta; *3V* = third ventricle. (Reprinted with permission from Raven Press, NY. Originally from Ingram WR: Nuclear organization and chief connections of the primate hypothalamus. In *Proceedings of the Association for Research in Nervous and Mental Disease,* 1939.)

b. The **dorsal boundary** of the hypothalamus is the plane of the hypothalamic sulcus, running longitudinally in the wall of the third ventricle.

c. The **caudal boundary** of the hypothalamus is the plane of a line drawn from the postmammillary sulcus to the lip of the posterior commissure.

d. In Figure 12-10, locate the anterior commissure. Then trace the hypothalamus ventrally and caudally through the lamina terminalis, the optic chiasm, median eminence, and mammillary body region to its midbrain junction.

6. Lateral boundary of the hypothalamus in transverse sections (Figure 12-11)

a. At **rostral** levels, Figure 12-11 shows that the hypothalamus is bounded laterally by the:

(1) Ventromedial edge of the internal capsule

(2) Medial tip of the globus pallidus and the ansa peduncularis

(3) Substantia innominata of the anterior perforated substance and the diagonal band, which belong to the telencephalon (see Figure 12-9)

b. At **caudal** levels, the ventromedial edge of the internal capsule marks the lateral hypothalamic boundary, as the capsular fibers descend into the midbrain basis.

7. Giving the hypothalamus a name and formal boundaries may obscure a more important fact—its anatomical and functional continuity as a link or center in the circuitry that controls visceration and affect.
   a. At its **caudal** end, the hypothalamus extends the periaqueductal gray matter and RF into the diencephalon.
   b. At its **rostral** end, the hypothalamus merges with basal rhinencephalic structures of the telencephalon, namely the anterior perforated substance, substantia innominata (just ventral to the caudate nucleus), and septal region.

B. Nuclei and regions of the hypothalamus

1. The hypothalamus displays some well-delineated nuclei and others with obscure boundaries, referred to as groups or areas (Figure 12-12 and Table 12-6).
2. **Anterior group of hypothalamic nuclei**
   a. The **preoptic** area is dorsal to the optic chiasm at the level of the lamina terminalis, where the hypothalamus meets the telencephalon.
   b. The **supraoptic** and **paraventricular** nuclei have fairly large neurons and sharp boundaries (see Figure 12-11A–D).
      (1) The **supraoptic** nuclei drape over the optic tract.
      (2) The **paraventricular** nuclei form a plate of neurons in the subependymal zone of the wall of the third ventricle (see Figure 12-11B–D).
3. **Middle group of hypothalamic nuclei.** A parasagittal plane through the fornix splits the hypothalamus into **medial** and **lateral** nuclear areas (see Figure 12-11C–E).
   a. The **medial** hypothalamic region contains two large nuclei, the **ventromedial** and **dorsomedial**, at the midhypothalamic level. A small **arcuate** nucleus (infundibular nucleus) is located in the periventricular zone, just dorsal to the median eminence.

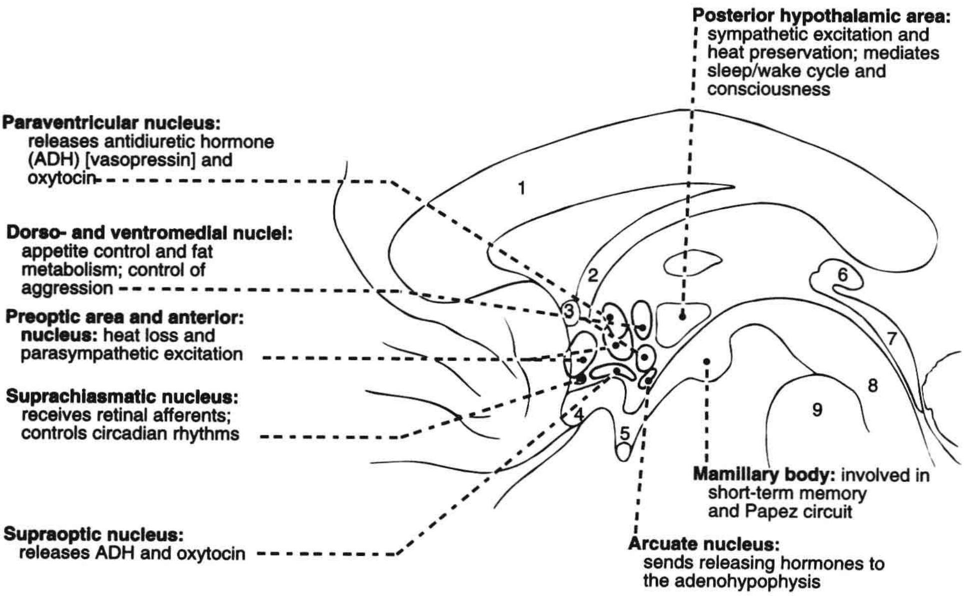

FIGURE 12-12. Nuclear regions of the hypothalamus as superimposed on a sagittal section of the cerebrum (compare with Figure 12-10). *1* = corpus callosum; *2* = fornix; *3* = anterior commissure; *4* = optic chiasm; *5* = infundibulum; *6* = pineal body; *7* = quadrigeminal plane; *8* = midbrain; *9* = pons.

TABLE 12-6. Hypothalamic Nuclei*

Dorsal group
N. subthalamicus
N. globus pallidus
Anterior group
Preoptic area
N. paraventricularis
N. supraopticus (n. tangentialis of Cajal)
N. praeopticus lateralis (interstitial n. of the medial forebrain bundle)
N. hypothalamicus anterior
N. suprachiasmaticus
Middle group
N. hypothalamicus lateralis
N. hypothalamicus ventromedialis
N. hypothalamicus dorsomedialis
N. tuberis and arcuatus of the infundibulum
Posterior group
N. hypothalamicus posterior
N. mammillaris medialis, pars medialis and pars lateralis
N. mammillaris lateralis (n. intercalatus of Le Gros Clark)

N. and n = nucleus.
*Partial listing.

b. The **lateral** hypothalamic area extends from the midhypothalamus into the posterior hypothalamus zone. It also includes the tuberal nuclei along the ventral, surface border of the hypothalamus.

4. Posterior group of hypothalamic nuclei (see Figure 12-11F)

a. The **mammillary nucleus**, the largest and most conspicuous of the hypothalamic nuclei (see Figure 12-10), has **medial** and **lateral** parts.

(1) The **lateral** part receives the fornix.

(2) The **medial** part sends mammillary efferents to the thalamus and brain stem tegmentum.

b. The posterior hypothalamic nuclei merge with similar neurons of the posterior part of the lateral nucleus. The entire lateral zone of the hypothalamus can be thought of as a continuum from the lateral preoptic zone caudally through the posterior hypothalamic zone, to where it merges with the midbrain tegmentum.

C. Connections of the hypothalamus

1. Preview

a. Highlighting its role in the rhinencephalic, limbic, autonomic, and endocrine systems, the strongest afferent and efferent connections of the hypothalamus are with basal rhinencephalic structures of the telencephalon, including the:

(1) Amygdala and adjacent basal frontal and temporal lobe cortex

(2) Hippocampal formation and pyriform cortex [paleocortex and archicortex (see Figure 13-31)]

(3) Limbic nuclei and midline nuclei of the thalamus

(4) RF and periaqueductal gray matter of the brain stem

(5) Retina (via optic nerve and chiasm to suprachiasmatic nucleus)

b. To focus on the sources of hypothalamic afferents, note where they do not come from or come from in only small numbers:

(1) Striatum

(2) Lemniscal systems (medial, lateral, spinal, and trigeminal)

(3) Cerebellum

(4) Thalamus (other than midline and intralaminar nuclei and nucleus medialis)

(5) Neocortex (projections established in lower animals, but questionable in humans)

c. In general, the hypothalamus will return efferents to its afferent sources, either directly or by feedback circuits.

d. The hypothalamus has numerous short, multisynaptic connections within itself and with neighboring structures, as well as several conspicuous, named fiber systems.

2. Fiber systems of the hypothalamus

a. Medial forebrain bundle

(1) The medial forebrain bundle runs longitudinally from the medial basal rhinencephalic structures of the substantia innominata, through the lateral part of the hypothalamus, and into the brain stem tegmentum and periaqueductal gray matter [see Figure 12-11 A and F (the bundle is present in sections B–E, but not labeled)].

(2) The bundle conveys afferent and efferent fibers, receiving and paying them out along its course. It is laden with interstitial neurons, forming numerous short, polysynaptic pathways.

(3) Edinger named it the **medial forebrain bundle** to contrast it with the **lateral forebrain bundle**, which is composed of the internal capsule and the pallidal efferents.

(a) The lateral forebrain bundle, consisting mainly of myelinated fibers, is the highway for somatic motor and sensory events and willed movements, as related to external space.

(b) The medial forebrain bundle, consisting mainly of unmyelinated fibers, is the highway for automatic visceral control, as related to internal space.

b. Three arching systems of fibers related to the hypothalamus

(1) Three arching fiber systems distribute axons in the depths of the cerebrum: the **stria terminalis**, **stria medullaris**, and **fornix** (Figures 12-13 and 12-14).

(2) These bundles interchange axons in complicated pathways. They connect the amygdala, rhinencephalon, and hippocampus of the telencephalon with the hypothalamus, thalamus, and epithalamus (habenula) of the diencephalon.

3. The **stria terminalis** arises in the amygdala and follows the tail of the caudate nucleus around the roof of the inferior horn of the lateral ventricle to occupy the thalamostriate seam in the floor of the body of the lateral ventricle (see Figure 12-3). The stria terminalis decussates in part at the anterior commissure. At this site, the fibers distribute to the:

a. Opposite stria terminalis and amygdala

b. Preoptic area and anterior hypothalamus

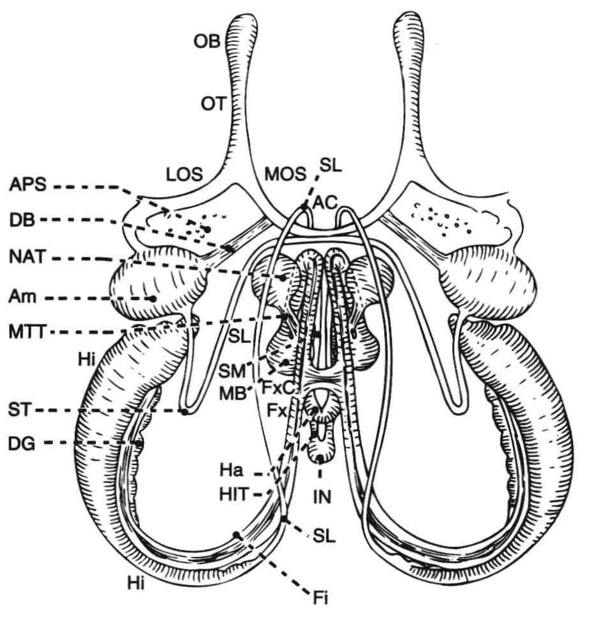

FIGURE 12-13. Dorsal stereoscopic view of the arching fiber systems related to the hypothalamus. *AC* = anterior commissure; *AM* = amygdala; *APS* = anterior perforated substance; *DB* = diagonal band; *DG* = dentate gyrus; *Fx* = fornix; *FxC* = fornix commissure; *Ha* = habenula; *Hi* = hippocampus; *HIT* = habenulointerpeduncular tract; *IN* = interpeduncular nucleus; *LOS* = lateral olfactory stria; *MB* = mammillary body; *MTT* = mammillothalamic tract; *NAT* = nucleus anterior of the thalamus; *OB* = olfactory bulb; *OT* = olfactory tract; *SL* = stria lancisii; *SM* = stria medullaris; *ST* = stria terminalis.