

Surgical Anatomy of the Hypothalamus*

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Summary

Described are the borderlines of the hypothalamus, its nuclei and fiber connections and its functions. The vascular supply of the hypothalamic area is included. Furthermore measurements of the IIIrd ventricle and distances between surface areas of the brain and skull as well as different landmarks near the hypothalamus are presented. For example the distance between the frontal pole and the lamina terminalis in our material measures 59.3 (52–65) mm.

Distances for the different approaches to the hypophyseal region (transsphenoidal, pterional, supra- and infratentorial, transcallosal and transventricular) are also given.

Keywords: Hypothalamus; nuclei and fibers; IIIrd ventricle and approaches.

Hypothalamus, Definition

At the base and the front of the brain, the lamina terminalis, the tuber cinereum (which is demonstrable not only behind, but also in front of the optic chiasm) and the corpora mamillaria as well as the hypophyseal stalk make up the hypothalamic area. On a median sagittal section of the third ventricle, there is no sharp demarcation between the hypothalamus and the thalamus ventralis et dorsalis, since the sulcus limitans between the basal and the alar plate runs immediately rostral to the mesencephalon forwards and is no longer visible. Occasionally a sulcus hypothalamicus can be seen running from the aqueductus cerebri to the foramen interventriculare. It then divides the diencephalon into a dorsal part consisting of the dorsal thalamus, the metathalamus and the epithalamus as well as into the hypothalamus and ventral thalamus (Fig. 1). During phylogenetic and ontogenetic develop-

ment, there is marked growth of the midbrain and less growth of the diencephalon, so that these parts of the brain do not form a progression but become convoluted so as to lie within each other. At first the diencephalon forms a marked basal protrusion, later the base of the diencephalon is separated from the skull so that a hypophyseal stalk 9 mm long is formed. Initially there were longitudinal zones in the diencephalon where the upper thalamic parts continued into the tectum mesencephali while the subthalamic zones extended into the tegmentum mesencephali. In the three-month-old embryo the expansion of other centres leads to changes in the longitudinal construction. Parts that developed early are displaced by those expanding later. For this reason the ventral thalamus is pushed in a lateral direction so that it comes to lie beside a narrow zone, known as the nucleus reticularis lateral to the dorsal section of the thalamus. The original regio preoptica is pushed upwards above the chiasm to the supraoptic region. The chiasma opticum at first lies almost directly on the base of the skull. In the adult it moves in a dorsocaudal direction. The commissura rostralis (anterior) also lies more rostral in the embryo than in the adult. Diepen (1962) emphasizes the caudal shift of the infundibulum and points out that other basal parts of the cerebrum may exert a pull so that basal parts of the diencephalon are shifted in a caudal direction. The hypothalamus of the human brain cannot readily be compared to that of the lower mammals. On the whole the hypothalamic area of man is significantly shorter than that of the lower mammals, probably due to the kinking of the brain. The infundibulum of man is less hollowed out, the nucleus mamillaris medialis including the tractus mamillothalamicus is more pronounced, while the nucleus mamillaris lateralis is less well developed (Clark 1938). According to this author, the

* This work is dedicated to my dear friend Professor Dr. Dr. h. c. Kurt Schürmann, head of Department of Neurosurgery, University of Mainz, to his 65th birthday.

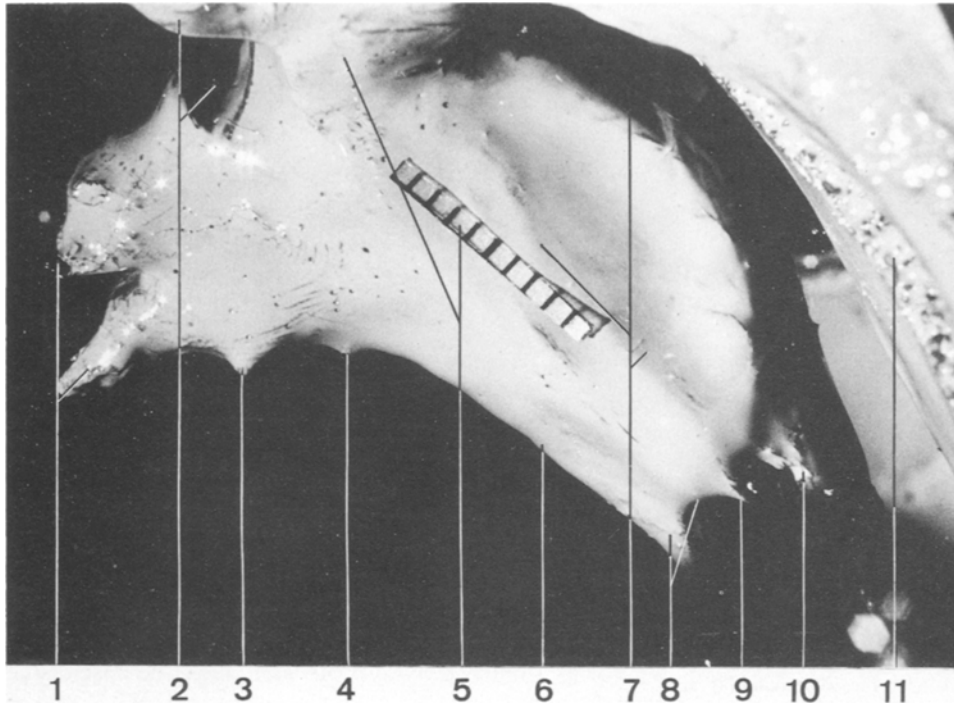


Fig. 1. Third ventricle from the lateral view (corrosion specimen by Professor Tajiri, Würzburg 1983). 1 recessus opticus and recessus infundibuli, 2 foramen interventriculare, transition to lateral ventricle, 3 recessus pre-mamillaris, 4 recessus retro-mamillaris, 5 foramen interventriculare and mm paper, 6 third ventricle, section of the posterior floor, 7 third ventricle, roof and sulcus hypothalamicus, 8 passage in the aqueduct and impression of the commissura epithalamica (caudalis), 9 recessus pinealis, 10 recessus supra-pinealis, 11 pars centralis ventr. lateralis, impression of plexus

nuclei tuberales of the human brain cannot be clearly delineated, since the nucleus paraventricularis possesses a relatively large area (Pick 1970).

Hypophysis, Development

In 2 to 3.5 mm long (approx. 22 days old) embryos an invagination develops immediately rostral to the membrana stomatopharyngealis and extends upwards to the area infundibularis of the diencephalon. In 4 to 6 mm long (approx. 28 days old) embryos, the basal membranes of the gemma neurohypophysialis of the diencephalon comes in contact with the saccus hypophysialis of the stomodeal depression (O'Rahilly 1973). In 5 to 7 mm long (approx. 32 days old) embryos the hypophysis elongates, blood vessels sprout between the basal membranes of this pouch and the brain. In 11 to 14 mm long (approx. 41 days old) embryos the juxtacerebral wall of the craniopharyngeal pouch becomes thickened, the lobi laterales (in future the partes infundibulares-tuberales) and the anterior section may be clearly recognized. The recessus infundibularis from which the neurohypophysis develops, now shows a wrinkled wall. In 16 to 19 mm long (approx. 48 days old) embryos, the lumen of the saccus hypophysialis disappears in the lower sections and changes to an epithelial strand. About the same time the pars intermedia develops out of the adenohypophysial epithelium in the vicinity of the neurohypophysis.

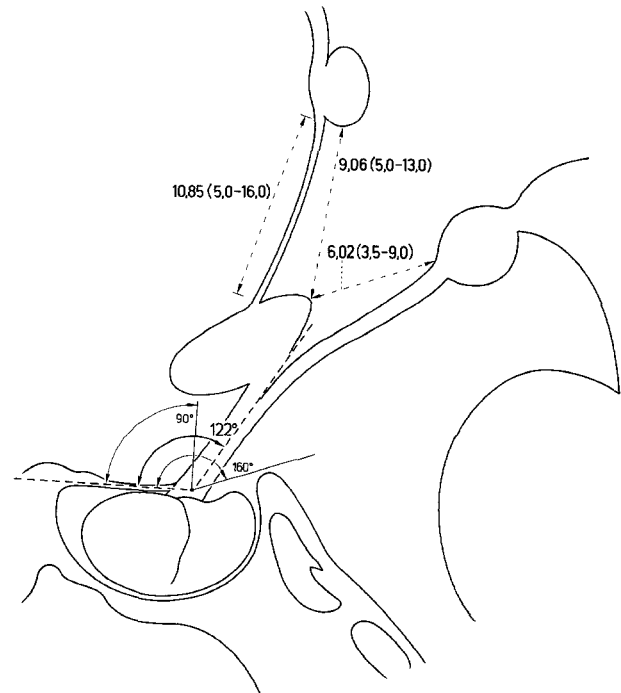


Fig. 2. Hypophyseal stalk, position in relation to the planum sphenoidale in degrees, length of the lamina terminalis, distance from commissura rostralis to the chiasm and distance between chiasm and corpus mamillare in mm (borderline values)

In the 22 to 24 mm long (approx. 52 days old) embryos, the epithelial strand of the saccus hypophysialis separates. O'Rahilly (1983) emphasizes that the

adenohypophysis and the neurohypophysis develop in close proximity and do not grow towards each other. The functional activity of the endocrine glands begins at the time the organ develops with the exception of the diencephalon. The hypophysis and the diencephalon show endocrine functions about the middle of prenatal life (O'Rahilly 1983).

Initially the hypophysis occupies a submamillary position which becomes premamillary in the second half of fetal development. Here it should be emphasized that the adults in our case material were found to have an angle of 122° between the hypophyseal stalk and the planum sphenoidale, but angles ranging from 90° – 160° were also found (Fig. 2).

Hypothalamus, Nuclei

In the hypothalamic area the isomorph grisea with uniform cell types is clearly demarcated from heteromorph parts with various cell shapes. The isomorph areas include the nuclei supraopticus, suprachiasmatis, infundibularis, tuberis lateralis et mamillaris lateralis, while the area dorsalis and the area dorsocaudalis, as well as the area lateralis of the hypothalamus belong to the heteromorph group.

Poorly myelinated and richly myelinated hypothalamus:

Poor myelination is regarded as a primitive characteristic. The poorly myelinated hypothalamus is the vegetative hypothalamus in a narrow sense. Richly

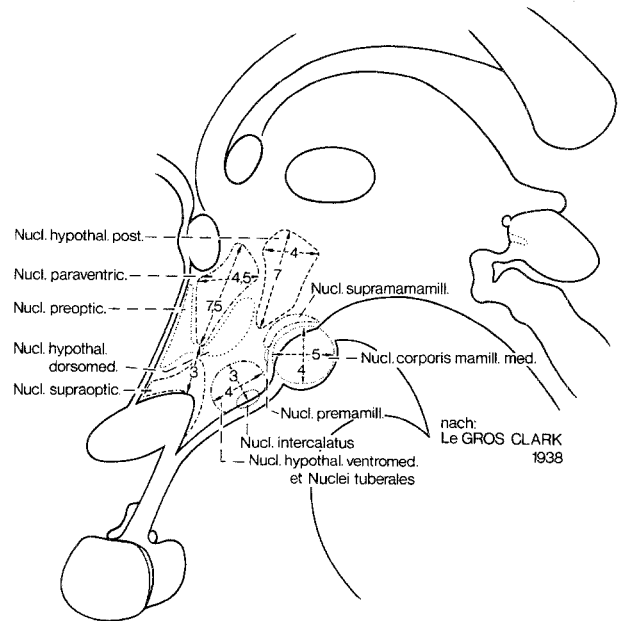
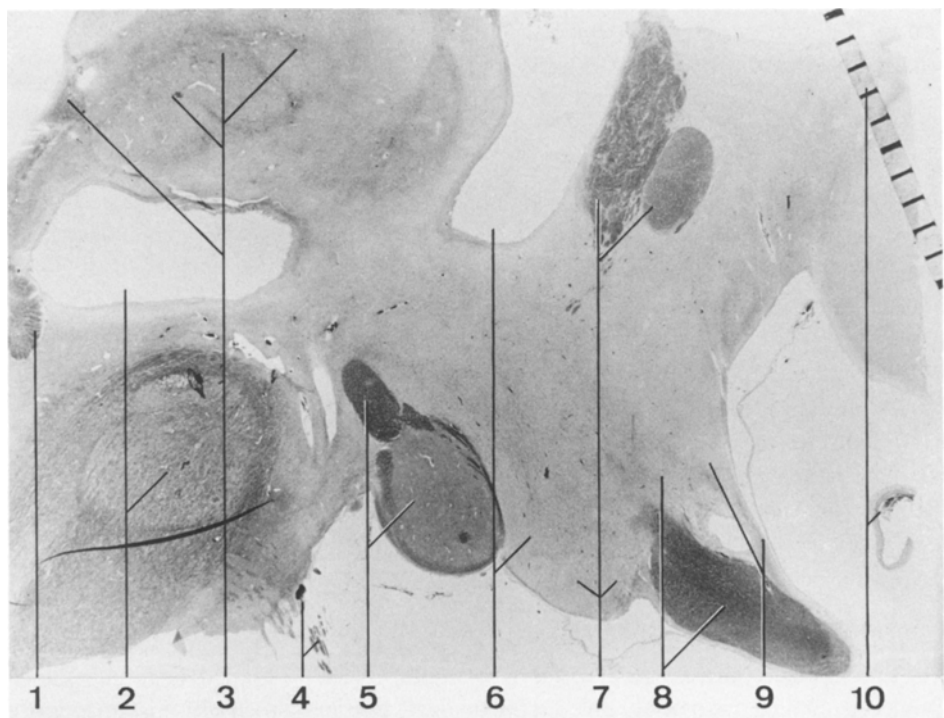


Fig. 3. Hypothalamic nuclei, size in mm (according to Clark 1938) inscribed into the lateral wall of a third ventricle of medium size (according to our measurements in 300 specimens, Lang *et al.* 1983)

myelinated hypothalamic areas are the corpus mamillare for example. Clark (1938), Rich *et al.* (1940), Brockhaus (1942), Krieg (1948), Kuhlenbeck (1954) and Feremutsch (1955) described different classifications of the hypothalamic area.

Hypothalamus, cell groups from rostral toward caudal (Figs. 3 and 4).

Fig. 4. Diencephalon, paramedian sagittal section. 1 commissura epithalamica (caudalis), 2 section of the third ventricle and the nucleus ruber, 3 thalamus nuclei and stria medullaris thalami, 4 third cranial nerve, fibres, 5 mamillothalamic tract, 6 distance and corpus mamillare, 7 third ventricle, section and nucleus pre-mamillaris, 8 fornix, commissura rostralis anterior and nuclei tuberales, 9 nucleus supraopticus and optic chiasm, 10 nucleus pre-opticus, lamina terminalis (zone), 10 millimeter paper and A. cerebri anterior



1. Regio hypothalamica anterior (preoptic cell groups, prothalamus, prethalamus, regio supraoptica).

(a) *Nuclei preoptici medialis et lateralis*

The nucleus preopticus medialis is the largest nucleus in this area. Its delineation is indistinct, particularly dorsolateral from the nucleus interstitialis of the stria terminalis, but also to the nucleus pericommissuralis in the vicinity of the commissura rostralis (anterior). The nucleus extends as far as the ependymal lining of the recessus opticus. An unpaired group of nuclei at the front wall of the recessus opticus was named nucleus preopticus medianus. In front of it at about the middle of the lamina terminalis, the organon laminae terminalis is located. Lateral to the nucleus preopticus medialis run medullated fibres interspersed with larger cells. These fibres belong to the basal anterior commissure, while the nerve cells belong to the nucleus preopticus lateralis.

(b) *Nucleus suprachiasmatis*

According to Diepen (1962) the nucleus suprachiasmatis is separated from the nucleus supraopticus by the nucleus hypothalamicus. The nucleus suprachiasmatis does not reach as far as the level of the commissura supraoptica. According to Knoche (1956 and 1957) delicate fibres run from the retina over the lamina terminalis into this area and reach the tuber cinereum without interruption and the neurohypophysis. In the English literature, this nucleus is known as the nucleus ovoideus. It corresponds to the nucleus infundibularis caudalis as well as the nucleus prothalamicus preventricularis ventralis inferior.

(c) *Nucleus hypothalamicus anterior*

This nucleus does not represent the most anterior nuclei in mammals. It lies between the nucleus paraventricularis dorsomedial and the nucleus supraopticus lateral.

(d) *Nucleus supraopticus* (see Figs. 4 and 5)

The nucleus supraopticus belongs to the large-celled nuclei and is found lateral to the base of the diencephalon. In man its major portion is located immediately in front of the chiasm, while the rest lies behind the chiasm at the medial side of the tractus opticus. As a rule, the nucleus consists of smaller islands, especially around the capillaries.

(e) *Nucleus paraventricularis* (see Figs. 4 and 5)

The nucleus paraventricularis is also made up of large cells, which are densely layered particularly in the

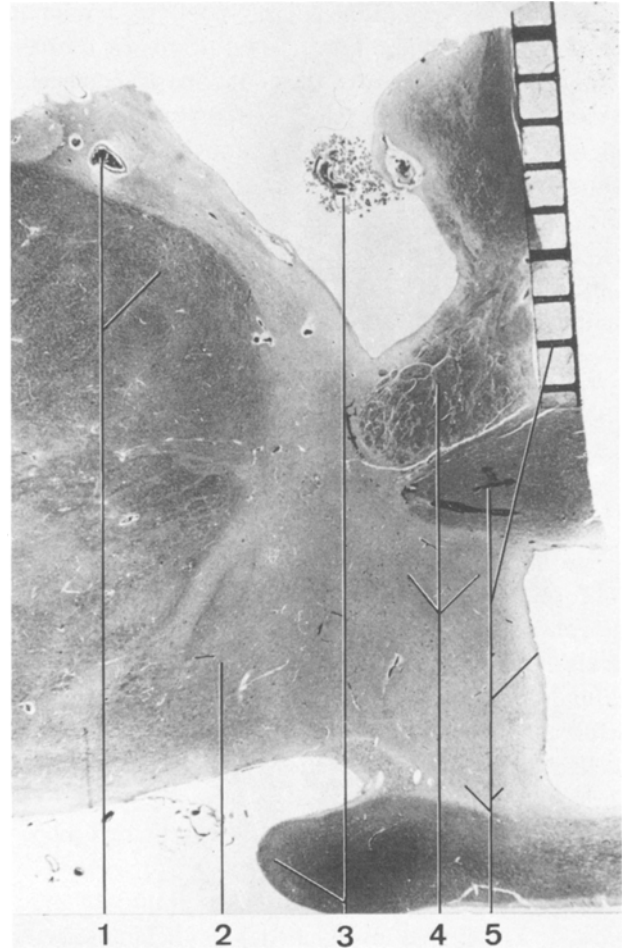


Fig. 5. Frontal section through the diencephalon at the foramen interventriculare and third ventricle. 1 V. thalamostriata and nucleus ant. thalami, 2 anterior hypothalamus, 3 plexus choroideus at the foramen interventriculare and tractus opticus, 4 fornix and nucleus paraventricularis, 5 commissura rostralis (ant.), millimeter paper and third ventricle, lateral wall as well as nucleus supraopticus

dorsal sections. The dorsocaudal pole of this nucleus usually extends as far as the area hypothalamica posterior with single scattered cells. In the medial area smaller nerve cells are found which have led to a demarcation of the nucleus paraventricularis parvocellularis.

2. Area hypothalamica intermedia (small-celled hypophyseal cell groups of the poorly myelinated hypothalamus = origin of the tuberohypophyseal system, medial field of the tuber cinereum).

(a) *Nucleus infundibularis (nucleus arcuatus)*

This nucleus surrounds the infundibulum in ring-shaped fashion. When then the hypophyseal stalk is torn off, this nucleus is also often no longer visible. The

subependymal layer of glia fibres is not present in the nuclear area. However, strong processes extend from the ependymal cells in the direction of the adeno-neurohypophysary contact surface. The nerve cells of this nucleus are small, the nuclei themselves are round to oval.

(b) *Nucleus hypothalamicus ventromedialis* (Figs. 3 and 4)

The ventromedial nucleus is the largest of the tuber cinereum and was called the nucleus principalis tuberis by Cajal (1911). Dorsolateral to this nucleus runs the fornix, occasionally separated from it by the nucleus perifornicalis. The nerve cells are medium to small, but larger than those of the nucleus infundibularis.

(c) *Nucleus hypothalamicus dorsomedialis*

This nucleus lies dorsal to the nucleus ventromedialis and is smaller. Furthermore it possesses a lower cell density. The lateral delineation of this nucleus is not distinct. In a dorsolateral direction it extends as far as the zona incerta. Its cells are smaller than those of the nucleus ventromedialis.

(d) *Nucleus periventricularis posterior*

A group of smaller nerve cells lies in the ventrocaudal section of the third ventricle. The caudal part of the nucleus is located around the recessus inframamillaris and corresponds to the nucleus periventricularis inframamillaris which is mentioned by various authors.

(e) *Nucleus premamillaris* (see Fig. 4)

This nucleus, which is not mentioned in the present nomenclature, consists of a small group of cells in the ventrocaudal hypothalamus which is poorly myelinated. It lies between the caudal pole of the nucleus ventromedialis and the corpus mamillare with whom there are no fibre connections.

(f) *Nuclei tuberales* (see Fig. 4)

Behind the last mentioned nucleus, one finds the nucleus lateralis tuberis and the nucleus tuberomamillaris in man. These contain large ganglion cells and consist of two or three more or less continuous columns. Because they are usually three spheric ganglia they are described as nuclei tuberis laterales. Diepen classifies them with the cell groups of the lateral field of the tuber cinereum.

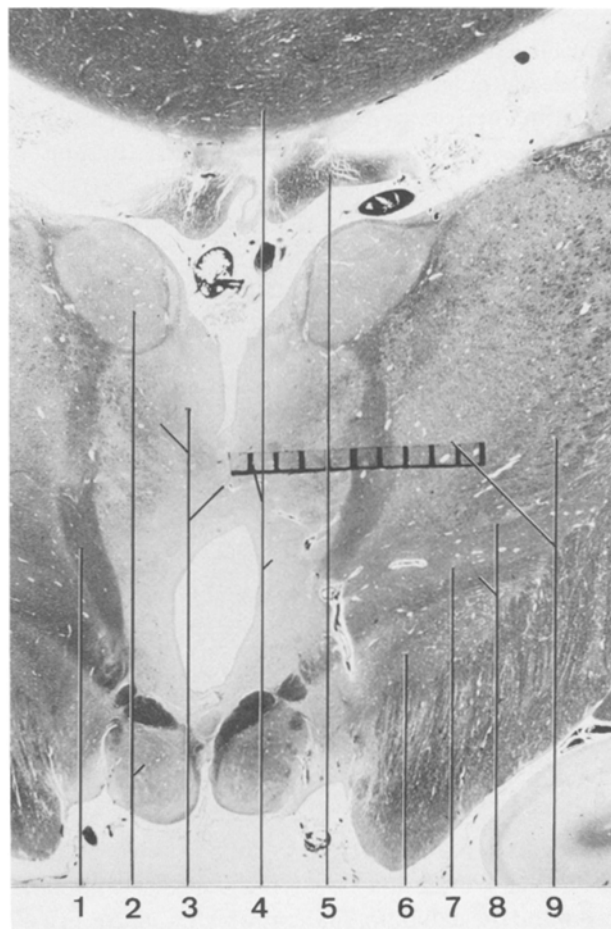


Fig. 6. Frontal section through the diencephalon at the level of the interthalamic adhesion. 1 tractus mamillothalamicus, 2 nucleus ant. ventralis, 3 nucleus med. dors. and adhesio interthalamica, 4 corpus callosum, millimeter paper and nucleus hypothalamicus posterior, 5 fornix, 6 nucleus subthalamicus, 7 zona incerta, 8 Forel fields H₁ and H₂, 9 nucleus ventralis ant. (medial) and nucleus ventralis lateralis

(g) *Nucleus tuberomamillaris*

This nucleus is not mentioned in the Nomina Anatomica. According to Diepen, it is the most markedly developed nucleus between tuber and corpus mamillare. It is not uniformly gray and overlaps the corpus mamillare.

3. Regio hypothalamica posterior. (The nuclei mamilares and the nucleus hypothalamicus posterior are ascribed to this region.)

The nucleus hypothalamicus posterior is approximately 7 mm high and 4 mm long at the most from front to back. It lies behind and above the nuclei ventromedialis, dorsomedialis and paraventricularis and in front of the lower part of the tractus mamillothalamicus. It represents a center through which the

effluent impulses of the hypothalamus are sent to the lower levels of the brain and to the spinal cord.

Medial to lateral nuclear areas (Fig. 6).

In the periventricular zone lies part of the nucleus preopticus, the nucleus suprachiasmatis, the nucleus paraventricularis (which can bulge out the ependymal lining), the nucleus infundibularis and the nucleus posterior of the hypothalamus.

Parts of the nucleus preopticus, the nucleus anterior, the nucleus dorsomedialis, the nucleus ventromedialis as well as the nuclei premamillares are all located in an intermediate zone.

In a lateral location are the nucleus supraopticus, part of the nucleus preopticus, the nucleus lateralis, the nucleus tuberomammillaris and the nuclei laterales tuberis.

Hypothalamus, Fibrous Tracts

Among the fibre tracts of the hypothalamus which include the temporohypothalamic, the thalamohypothalamic, and the pallidosubthalamic fibres, special mention should be made of the ansa lenticularis.

(a) Ansa lenticularis

According to Monakow (1895) the ansa lenticularis serves as a connection between the nucleus subthalamicus and the pallidum, findings which were confirmed by Dejerine (1901) and Sachs (1909). Vogt and Vogt (1919) were of the opinion that fibres from the thalamus to the pallidum also run in this tract. According to Muskens (1922) fibres from the nucleus interstitialis (Cajal) and from the nucleus of the posterior commissure also run in this tract, while Glees (1944) assumed that these fibres run by way of the commissura supraoptica. Bucher and Bürgi (1952) examined the ascending fibres to the ansa lenticularis in 70 cats, medium and thin fibres run from the area immediately in front of the oculomotorius nuclei (and nucleus Darkschewitsch) to the floor area of the central gray matter of the aqueduct at the level of the tractus habenuleduncularis, then continue in a lateral and ventral direction through or in front of the tractus habenuleduncularis and immediately rostral the nucleus ruber. Several fibres run to the substantia nigra, most of them to the nucleus subthalamicus others in a rostromedial direction and partly through the pes pedunculi, while another part runs to the medial edge of the nucleus entopeduncularis. All in all very variable fibre degeneration paths were observed. According to the authors a pars ascendens mesencephali runs also to the ansa.

(b) Medial forebrain bundle (basal olfactory bundle, tractus olfactomesencephalicus)

In mammals and man there is also a medial forebrain bundle between the olfactory system and the hypothalamic area. The thinly myelinated fibres run loosely from the primary and secondary olfactory system lateral to the regio hypothalamica anterior into the so-called poorly myelinated hypothalamus. One part of the fibres reaches the tegmentum mesencephali after partial crossing. Probably fibres from the corpus amygdaloideum and the basal forebrain also join here. The fibres reach the nuclei tuberis, the nucleus paraventricularis, the corpus mamillare and the nuclear areas of the tegmentum mesencephali. The caudorostral fibres are also thought to run in this tract, which is ascribed to the limbic system.

(c) Hypothalamus and autonomic nervous system

Saper (1979) has pointed out that numerous researchers had studied the connections between the hypothalamus and the sympathetic nervous system according to Karplus and Kreidl (1909). By electrophysiological methods the connections between the hypothalamus and the preganglionic sympathetic cells in the spinal cord were demonstrated. The same could be achieved with axonal degeneration studies. Other researchers (Nauta and Haymaker 1969) were of the opposite opinion, namely that the fibres from the hypothalamic area go no further than to the midbrain, instead one or several relay stations must exist in the reticular formation. Using modern transport methods, Kuypers and Maisky (1975) demonstrated that fibres of the hypothalamus reach the spinal cord, more specifically the area of the nucleus tractus solitarii and the dorsal motor vagus nucleus (Saper *et al.* 1976). Most of these neurons originate in the nucleus paraventricularis, others in the zona incerta, the areas hypothalamica lateralis et posterior. Several cells of the nucleus Westphal-Edinger also send axons in this region. The fibres run within large areas of the midbrain and pons, continue in a caudal direction at the ventrolateral edge of the medulla, from which a group of fibres passes in a dorsomedial direction to the nucleus ambiguus, the nucleus motorius dorsalis and the nucleus tractus solitarii. The other fibre tract runs in the funiculus lateralis of the spinal cord downwards and reaches the nucleus intermediolateralis of the thoracic spinal cord on both sides (studies in rats, cats and monkeys). Saper (1979) has pointed out that it was formerly assumed that nearly all oxytocin or ADH containing cells projected chiefly to the posterior

pituitary lobe. At least a part of the hypothalamoautonomous axons are collaterals of the axons to the neurohypophysis in his opinion and contain oxytocin as the transmitter.

(d) *Hypothalamus, visceral afferences*

According to Saper (1979) several fibres of the commissural section of the nucleus tractus solitarii run to the thalamus and to the lateral hypothalamic area and to the nucleus paraventricularis (Ricardo and Koh 1978—studies on rats) and Loewy and Burton (1978—studies on cats). Since polysynaptic connections are possible, it seems probable that other hypothalamic regions are not reached by these fibre bundles.

(e) *Tractus retinohypothalamicus*

From the dorsal edge of the chiasm (Greving 1925/26) fibres run from the retina through the nucleus supraopticus and branch off inside this nucleus. Returning fibres from the retina are also thought to originate in the hypothalamic area.

(f) *Fibrae intrahypothalamicae*

Many, if not all, hypothalamic nuclei are probably connected by way of fibres or fibre tracts. In man such a connection has been demonstrated between the nucleus supraopticus and the tuberal nuclei (Greving 1928).

(g) *Fibrae interdiencephalicae*

According to Laursen (1955) who performed investigations on monkeys, fibres run from the basal ganglia (globus pallidus) in the ansa lenticularis lateral to the fasciculus lenticularis. They end immediately rostral and medial to the corpora mamillaria. Probably there are also fibres of the putamen in the ansa.

(h) *Fasciculus lenticularis*

In the fasciculus lenticularis, which extends through the internal capsule and then between the nucleus subthalamicus and the zona incerta (see above), fibres probably run to the dorsomedial section of the nucleus ruber. Others reach the zona incerta. These fibres originate from the dorsal part of the globus pallidus.

(i) *Fasciculus subthalamicus*

Between the striatum and the nucleus subthalamicus fibres run chiefly in the fasciculus subthalamicus to the lateral area of this nucleus which contains large cells.

(k) *Commissures of the hypothalamus*

In the area of the nucleus paraventricularis, a commissura supraoptica dorsalis (Ganser) is demonstrated in 2%. This also contains the pericaria of the nucleus paraventricularis.

Greving also described the decussatio supraoptica dorsalis. The fibres of this supraoptic decussation surround the columna fornicis according to his Fig. 5 and continues to the other side in the floor of the third ventricle. Further fibre connections are still being discussed today. The commissura supraoptica ventralis (Meynert and Gudden) consists of fibres which connects the two optic tracts with each other and extends as far as the entopeduncular midbrain nuclei. They are said to contain a tectopetal and a tectofugal fibre system and extend in part as far as the corpus geniculatum, while other parts reach the colliculus cranialis and the regio pretectalis.

The commissura supramamillaris (hypothalamica posterior, subthalamica posterior, retroinfundibularis) connects the nucleus subthalamicus, the zona incerta and the globus pallidus with each other and with cellular areas of the contralateral tegmentum, as well as possibly with the nucleus mamillaris lateralis.

Nonmyelinated commissural fibres are thought to connect nuclear regions of the anterior hypothalamic region and its neighboring structures (septum and diagonal band of Broca) in the dorsal sections of the lamina terminalis. In the chiasmatic section the fibres run between the contralateral nuclei suprachiasmatici and the tuber cinereum. Horizontal fibres running in the ventral wall of the infundibulum were ascribed to the commissura supraoptica dorsalis (in the cat) by Fleischhauer (1960). Immediately in front of the corpus mamillare poorly myelinated fibres pass through the area of the tuber in man, probably to the nucleus tuberomamillaris as a commissure.

Hypothalamus, Functions

On the basis of physiological studies, Hess (1947 and 1949) divided the diencephalon into two different sectors: an ergotropic and trophotropic functions. Sano *et al.* (1970) are of the opinion that there are two functional self-regulating cycles interconnected with these two sectors in the prosencephalon: a prosencephalic ergotropic cycle and a prosencephalic trophotropic cycle for which the hypothalamus is the most important synaptic center. They emphasize that the hypothalamus steers not only the ergotropic and the

trophotropic cycles, but also autonomic and endocrine activities as well as expression and emotions.

Hartwig and Fetzer (1978) report that more recent studies with cytochemical and electrophysiological examinations indicate that the various hypothalamic functions can be ascribed to the classical hypothalamic nuclei only to a limited extent.

Hypothalamus, Neurosecretion (Figs. 7 and 8)

During neurosecretion, the pericaria of the hypothalamic nuclei form certain peptide hormones, which are directed to the hypophysis by way of a portal circulation where they activate hormone release. For this reason they are called releasing hormones. The corresponding neurons are located in the hypothalamus and form: vasopressin, oxytocin, somatostatin, growth hormone —, and ACTH — releasing factor, gonadotropin releasing hormone, thyrotropin releasing hormone, prolactin inhibitor factor. In the year 1980 alone, a total of 18 peptide agents were found in the brain, all of which were formed in the hypothalamus and exert an effect on the hypophysis or outside the nervous system. Greving (1926) points out that he first described the tractus supraopticohypophysialis in 1922. It extends from this nucleus to the posterior lobe of the hypophysis.

According to Burford *et al.* (1974) the nucleus paraventricularis is responsible to the oxytocin synthesis, while the nucleus supraopticus steers the production of vasopressin. On the basis of different studies they assume that oxytocin is chiefly synthesized in the nucleus paraventricularis and vasopressin in the nucleus supraopticus. However, both nuclei contribute to the synthesis of both hormones. Weindl *et al.* (1980) emphasize that vasopressin, oxytocin and their peptides (neurophysine) are produced in the magnocellular neurons of the nucleus supraopticus and the nucleus paraventricularis and transported through the inner zone of the infundibulum to the posterior lobe. There the hormones are stored and passed on to the blood circulation by way of permeable capillaries. Vasopressin and neurophysine fibres end in the outer zone of the infundibulum at permeable nuclei of the hypothalamohypophyseal circulation.

LRH and gonadotropine releasing hormone are produced in the neurones of the preoptic area and transported by way of the axons to the portal capillaries in the outer zone of the infundibulum. There they influence the capillaries of the organum vasculosum of the lamina terminalis.

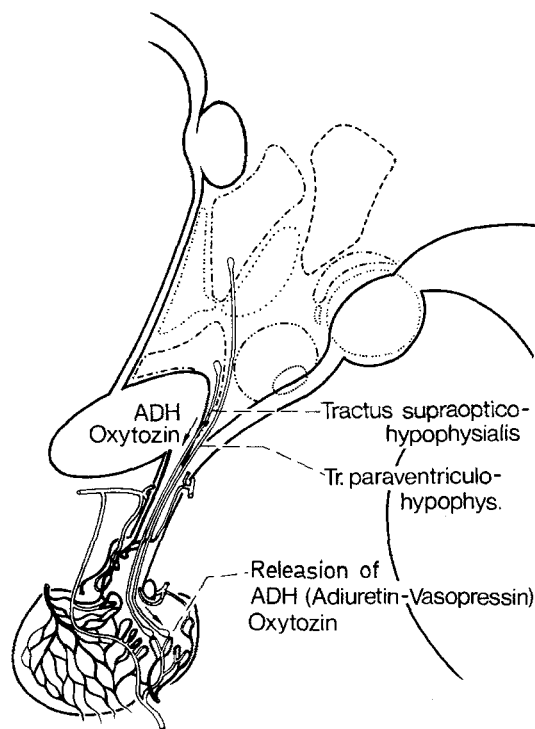


Fig. 7. Tractus supraoptico-hypophysialis and tractus paraventriculo-hypophysialis, diagram of the tracts

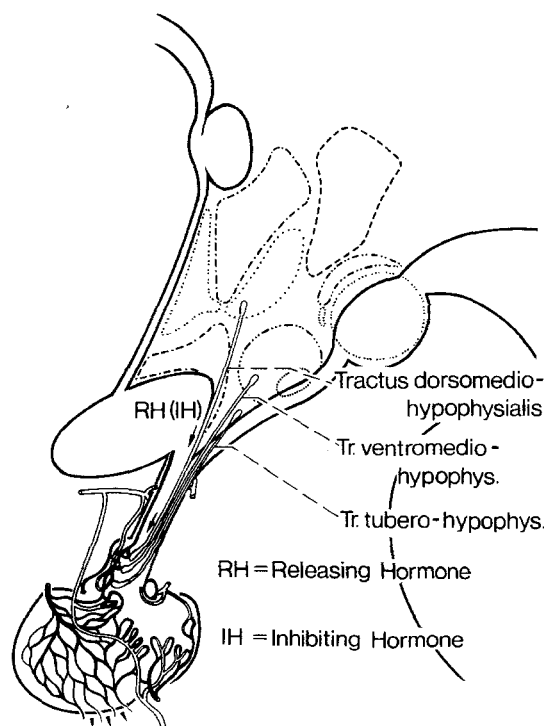


Fig. 8. Tracts and vessels to the anterior lobe of the pituitary gland

Hypothalamus, Temperature and Other Centres

Foley *et al.* (1942) examined the brain of a patient who had died due to a suddenly following an en-

cephalitis. At the anterior edge of the nucleus paraventricularis and neighboring areas of the area hypothalamica anterior, there were fresh hemorrhages increased tortuosity of the vessels and localized dilations to be seen. In the substantia nigra a bilateral loss of nerve cells and a depigmentation of the nerve cells was evident. Furthermore, there was a diffuse fibrosis of the vessel walls and fibrillary glia.

In the hypothalamic vessels of the anterior part of the nucleus paraventricularis, hyaline degeneration, an increase in the number of endothelial cells, proliferation of the fibroblastic elements and connective adventitia were seen. This was particularly evident in the vessels with perivascular hemorrhages, but also in those without bloody extravasation. The authors point out that no cerebrovascular alterations could be seen within the medulla oblongata of the pons, the cerebellum and the cortex.

From the temperature centres of the hypothalamus, thermoregulating fibres probably cross to the opposite side by way of the decussatio pyramidalis and extends as far as the nucleus intermediolateralis of the spinal cord. The efferent fibres of these nuclei proceed through the ventral radices and the rami communicantes to the where they synapse with the postganglionic fibres of the cholinergic type. By way of the rami communicantes grisei they again join the spinal nerves and reach the sweat glands with these or with the blood vessels. The sweat fibres for face and neck synapse in the ganglion cervicale superius and then proceed to the glands with the trigeminal nerve, possibly also with the facial nerve. The limits of the sympathetic dermatomes are often asymmetrical and irregular. In addition to physiological sweating (perspiratio insensibilis) which amount to 800 ml per day and can increase to 3–4 l per day in the tropics (maximum quantity 10 l), there is cortical emotional sweating with vasoconstriction during psychological stimulation, exhaustion, fear, and terror among others. Furthermore there is gustatory bulbar sweating elicited by taste sensations, spinal sensory sweating in cases of paraplegics, sweating caused by drugs and pathological hyperhidrosis. In addition to hyperhidrosis generalisata, localized hyperhidrosis is rarely observed (Böll 1978). According to Jankinson, Gewen *et al.* (1978) the fibrocyte covering of the sweat glands in man is about 1.4 µm in diameter, the capillaries of the sweat glands are about 3.7 µm and the demyelinated nerve fibres are at a distance of 1.5 µm from the basal lamina of the myoepithelium. In 10 µm sweat gland tissue, the number of capillaries in different animals range from 9–

19. In man about 25% non-myelinated fibre tracts are found within the fibrocyte sheath and the sweat glands.

Schartner (1980) pointed out that electrical stimulation of the posterior hypothalamus in animals leads to increase in arterial pressure, while a stimulation of the anterior hypothalamus leads to a lowering of the arterial blood pressure.

According to Eisert (1983) a transection caudal to the hypothalamus leads to a marked decrease in the spontaneous release of catecholamines, dopamine, noradrenaline and adrenaline in the area hypothalamica posterior. From this it may be concluded that these substances are transported from the cells of the brain stem to the hypothalamus. A decrease of low significance is evident in the three catecholamines at the anterior hypothalamus. Probably fibre tracts other than the brain stem transits influence the hypothalamic region. The author is of the opinion that an increase or decrease in the level of the arterial blood pressure leads to an activation of the anterior hypothalamus. He emphasized that the up-to-date findings about the activities of the catecholamine synthesizing enzymes and releasing rates cannot be correlated with each other. Possibly these are not cause but rather a sequel of hypertension. On the other hand, increased or decreased catecholamine concentrations in brain areas need not agree with the amount of neurotransmitters.

Sexual Centres

According to Bauer (1959) who studied 60 autopsy cases, a decrease in the function of the gonads is found chiefly with lesions in the lower and anterior hypothalamic areas. Pubertas praecox is often combined with a lesion of the posterior hypothalamus and the corpora mamillaria.

According to Heath (1964) electrical stimulation of the regio septi led to erection of the penis in three patients and chemical stimulation of this area resulted in an orgasm in a woman. In contrast Meyers 1963; cited by Walker and Blumer, 1975 described loss of potency in cases of lesions of the regio septo-fornico-hypothalamica.

Poeck and Pilleri (1965) reported on marked hypersexuality in a young woman who had had encephalitis lethargica. At autopsy lesions of the mesodiencephalic transition area were found.

Hypersexuality has been described in cases of deeplying frontotemporal tumors as well as in diseases of the limbic system.

Hypothalamus and Pubertas praecox

Pubertas praecox has been observed in cases of tumors of the adrenal glands, of the testes, of the pineal body and of the hypothalamus. Brouwer emphasizes, that Marburg's concept of an inhibiting influence of the corpus pineale on the development of the sexual organs, cannot be confirmed by physiological experiments. On the other hand a macrogenitosomia has been observed in many cases of hypothalamic lesions (e.g. hyperplastic tuber cinereum). In one case described by Brouwer the growth of a beard and hair in the pubic region occurred at age 7, a year later the sexual organs were markedly hypertrophied for this age and adipositas was also present: circumscribed malformation of the tuber cinereum and hypoplastic corpora mamillaria. In another case typical signs of pubertas praecox were seen in a 10-year-old with homosexual tendencies. At autopsy he had an astrocytoma in the hypothalamus and partly in the medial section of the right neothalamus. The corpora mamillaria were intact. In both cases there was no tumor of the epiphysis, no tumors of the adrenals or the testis—the hypothalamic type of pubertas praecox.

Hypothalamus and Hyperglycemia

Hyperglycemia and glycosuria occurred following needling of the tuber region as well as destruction of the nuclei paraventriculares. In 1940 Long already pointed out that such changes do not lead to permanent disturbances. Although it is well-known today that glycosuria is often seen in acromegaly due to excessive secretion of diabetogenic hormones, Brouwer (1950) pointed out the following: in one of his cases there was intermittent glycosuria in a case of congenital malformation of the infundibulum and the tuber cinereum, which consisted only of neuroglia. The nuclei paraventriculares were also smaller. On the other hand distinct changes of the nuclei paraventriculares were demonstrated without glycosuria. In one case Brouwer saw diabetes mellitus in a case of brain tumor which had destroyed the regio hypothalamica.

Hypothalamus and Obesity

A regulatory center for the intake of food and water is also postulated for the hypothalamic area. A loss of the medial zone of the hypothalamus leads to hyperphagia, while a loss of the lateral zone results in hypophagia to aphagia.

Brouwer (1950) pointed out that excessive obesity is less often a dysfunction of the hypophysis than of the hypothalamic regions: dystrophia adiposogenitalis—

Babinski-Fröhlich. Twice he observed sexual disturbances without obesity or genital atrophy. In one case there was extreme leanness. Various hypothalamic nuclei were degenerated: dorsomedial and ventromedial nuclei of the nucleus ventrolateralis and the anterior part of the nucleus hypothalamicus posterior. In his opinion degeneration of the gray substance around the infundibulum can cause obesity, genital atrophy or both.

Celesia *et al.* (1981) demonstrated marked hyperphagia and subsequent obesity in a 28-year-old with a neoplasm in the medial hypothalamus. They emphasize that hyperphagia is stimulated in the medial hypothalamus, anorexia with marked slenderness is caused by the lateral hypothalamus. At autopsy their patient was found to have numerous tumor cells at the level of the chiasm and the commissura rostralis (anterior) as well as in the putamen, globus pallidus and anterior part of the internal capsule. The corpus mamillare, the pedunculus cerebri and the substantia nigra were also damaged.

Posterior Hypothalamus in Man—Stimulation and Destruction

Sano *et al.* (1970) performed electrical stimulations in the posterior hypothalamus of 51 patients with pathological aggressive behavior. This stimulation led to a rise in blood pressure, tachycardia and maximum pupillary dilatation if the electrodes were localized in the posteromedial hypothalamus (1–5 mm lateral to the wall of the third ventricle and at the middle of the intercommissural line at the rostral end of the aqueduct and the anterior edge of the corpora mamillaria: the ergotropic triangle). After bilateral destruction changes occurred in the sympathetic nervous system; a calming effect in the course of the next two years in 95%. Furthermore a tendency to a decrease in the sympathetic tonus and the development of a parasympathetic. The authors emphasize that Bard *et al.* (1928 to 1937) had already pointed to a so-called rage center in the caudal hypothalamus which stands under cortical control. This caudal hypothalamus largely corresponds with the ergotropic triangle of Sano *et al.* The innermost zone of this area seems to be responsible for parasympathetic steering centers, the medial area (an area 1 to 5 mm lateral to the lateral wall of the third ventricle) for sympathetic and the lateral one again for parasympathetic steering centers. This trizonal construction in the anterior hypothalamus of man has not been confirmed as yet. Possibly this area corresponds to the fasciculus longitudinalis (Schütz) or to the posterior

section of the nucleus hypothalamicus posterior which the descending and ascending fibres of this bundle enter and leave. The fasciculus longitudinalis dorsalis is the most important tract relating the sympathetic zone of the hypothalamus with other autonomic centres of the brain and spinal cord. Therefore there is a possibility that the destruction of this tract may result in a loss of sympathetic tone.

Hypothalamus—Further Functions

According to various researchers the movements of the urinary bladder and the bowel are influenced by the hypothalamus. Brouwer also observed involuntary urinary discharge in cases of hypothalamic lesions and chronic encephalitis. The central regulation of body temperature is also said to be steered by the hypothalamus. Descending paths pass through the tegmentum. In a patient with hyperthermia on the left side of the body a higher degree of destruction was seen in the right hypothalamic area. According to Hess (1948) there is an area in the hypothalamus for the coordination between the somatic and the vegetative system. In one patient Brouwer found a typical facial nerve tic on the left and later involuntary muscle movements in the arm and neck (the right hypothalamus was more severely destroyed than the left).

Pilomotor Centre

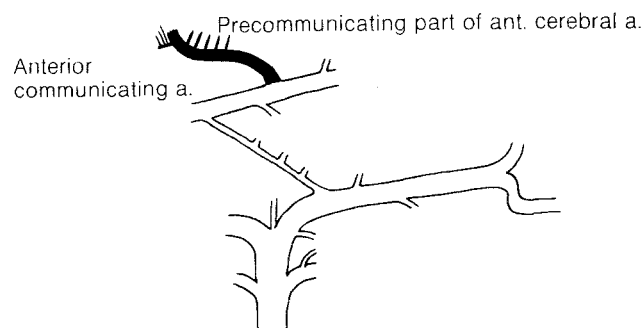
In a 53-year-old patient with a glioblastoma multiforme infiltrating the hypothalamus and the basal ganglia, Brody *et al.* (1966) observed attacks of piloerection. They emphasize that Penfield had never been able to induce piloerection by stimulation of the cortex. According to their data Ward had seen piloerection in apes following the stimulation of the cingulate gyrus and in cats following stimulation of the amygdaloid body by other researchers.

The *circadian rhythms* for body temperature, plasma components, number of eosinophilic cells, adrenocortical secretory activity, renal secretion mechanisms, sleep and waking centres such as emotions and affections are intimately connected with an intact hypothalamus. Recently a circadian rhythm has also been described for histamine (Dorsche 1983).

Hypothalamus—Blood Vessels

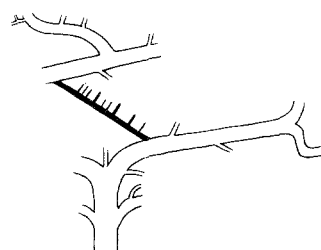
The diencephalic vessels consist of the rami *diencephalici anteriores inferiores*, which are differently developed and which supply especially the telencephalic

section of the diencephalon and occasionally the anterior upper thalamic areas. These originate from the distal sections of the pars precommunicalis of the A. cerebri anterior and the A. communicans anterior (Fig. 9).



| Zone of origin | Number (average) | Mean diameter (mm) |
|------------------------------|------------------|--------------------|
| a, Anterior cerebral a. | 1–12 (5.4) | 0.15 |
| b, Anterior communicating a. | 2–8 (4.26) | 0.18 |

Fig. 9. Anterior inferior diencephalic branches (anteromedial central branches)



| Entry zone | Number (average) | Mean diameter (mm) |
|--|------------------|--------------------|
| Tuber cinereum, dorsal to optic tract | 1–10 (4.11) | 0.17 |
| 1–3 (1.27) | 0.33 | |
| Between optic tract and cerebral peduncle | 1–4 (1.95) | 0.36 |
| Between cerebral peduncle and mamillary body | 1–3 (1.43) | 0.36 |
| To mamillary body | 1–3 (1.48) | 0.16 |

Fig. 10. Inferior diencephalic branches

In addition to the nuclei preoptici medialis et lateralis, the anterior hypothalamic area also contains the nuclei paraventriculares and the nucleus hypothalamicus anterior. Vascular alterations with a resulting destruction of these nuclear areas can lead to functional disturbances of the pituitary gland and thus influence the hormone, water and electrolyte balance as well as the unequivocally demonstrated centers for temperature sensation and regulation. Since fibres from

the nucleus paraventricularis also pass to the spinal nuclei of the sympathetic nervous system and reach it again on returning, this nucleus participates in the regulation of vasodilatation, and sweat gland secretion among others.

A further group of vessels is called the *rami diencephalici inferiores* (Fig. 10). These vessels originate especially from the A. communicans posterior and also from the A. carotis interna itself. These rami diencephalici inferiores also participate in the supply of the anterior as well as of the intermediate sections of the hypothalamus and thalamus. In the hypothalamus, the nuclei arcuatus et tuberales are classified to this region. It should be emphasized at this point that ablation of the medial sections of the hypothalamus leads to hyperphagia and the ablation of the lateral areas to hypophagia to aphagia with subsequent leanness. The circadian rhythms for body temperature, plasma components, number of eosinophilic cells, adrenocortical activity, renal secretion mechanisms, sleep and wake centers, as well as emotions and affections are related to an intact hypothalamus. An indication for a decussation of the hypothalamo-efferent fibres is the fact that a patient with hyperthermia on the left side of the body was found to have marked destruction of the right hypothalamic area.

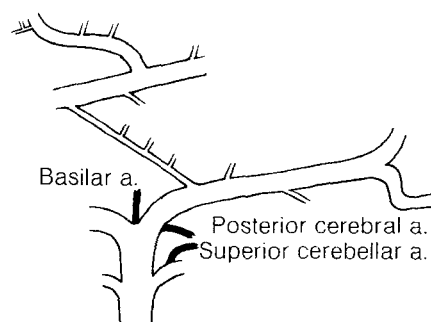
Rami diencephalici inferiores posteriores (Figs. 11 and 12)

The posterior lower hypothalamic and thalamic areas of the diencephalon are supplied by branches of the pars precommunicalis of the A. cerebri posterior, the A. basilaris and the A. cerebelli superior. These enter the substantia perforata interpeduncularis posterior of the midbrain and participate in the perfusion of the most important midbrain nuclei as well. In the posterior hypothalamic area stimulation and destruction (in man as well) leads to changes in blood pressure, heart beat sequence, pupillary dilatation as well as movements of the neck and eyes. If the area of the posterior hypothalamus is perfused with noradrenalin, dopamine, apomorphine among others, then a stimulation-dependent rise in bloodpressure can be observed. Therefore it must be assumed that neural paths from the posterior hypothalamic areas also reach the spinal sympathetic centers.

Rami diencephalici inferiores laterales (Fig. 13)

Originating chiefly from the A. choroidea anterior, less often from the A. cerebri media, arterial branches

penetrate the optic tract and lateral and medial to it into the brain substance. These rami diencephalici inferiores laterales supply not only the fibres of the tractus opticus, but also the medial sections of the globus



| Zone of origin | Number (average) | Mean diameter (mm) |
|---------------------------|------------------|--------------------|
| a. Posterior cerebral a. | 0-9 (3.04) | 0.44 |
| b. Basilar a. | 1-5 (2.3) | 0.32 |
| c. Superior cerebellar a. | 1-4 (1.6) | 0.26 |

Fig. 11. Posterior inferior diencephalic branches

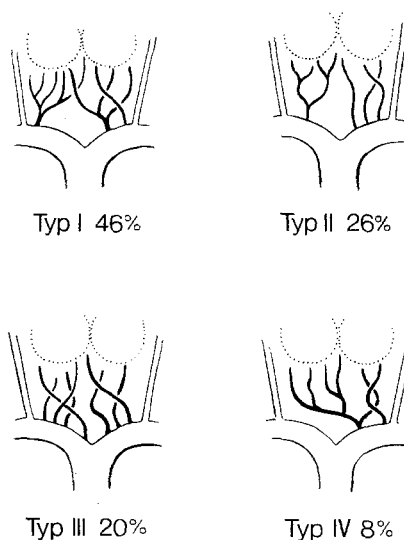
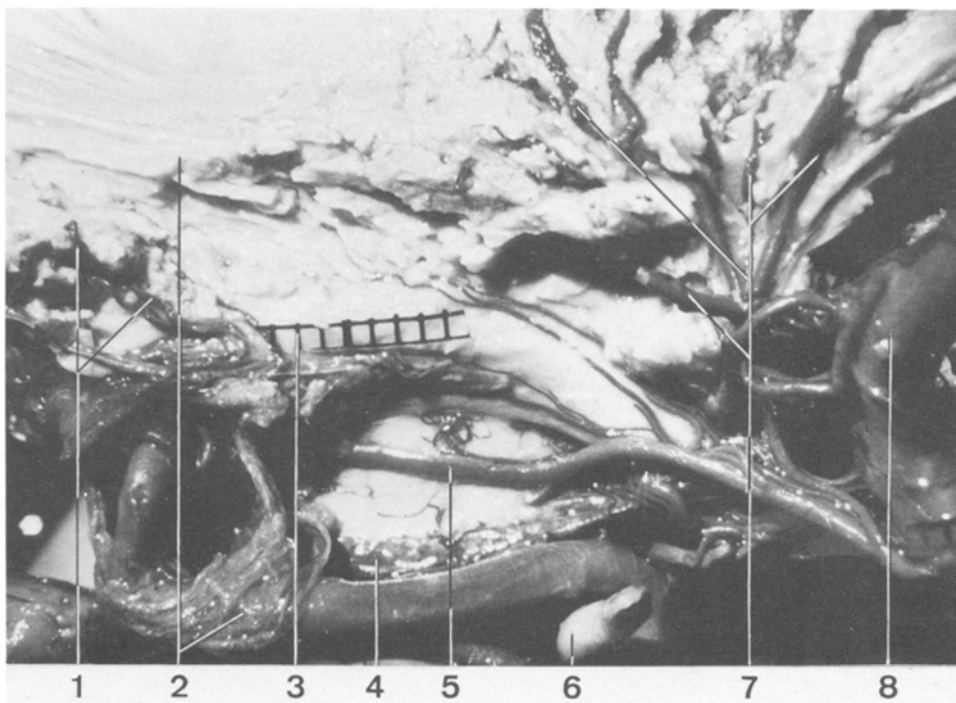


Fig. 12. Rami diencephalici inferiores posteriores

pallidus (whose supply is also provided by branches of the A. cerebri media occasionally) and proximal sections of the acoustic and visual pathways in the capsula interna. The corpus geniculatum laterale receives a blood supply from the A. choroidea anterior and from the A. cerebri posterior. Its function is particularly safeguarded by blood flow from two sides.

Fig. 13. A. choroidea anterior and Rr. centrales from a lateral view. 1 Branches to the radiatio optica from the A. chor. ant., 2 Capsula interna and A. cerebri posterior, 3 Tractus opticus, millimeter paper, 4 V. basalis (basilaris), 5 A. choroidea anterior on the cerebral peduncle, 6 N. oculomotorius, 7 Rr. centrales of the A. cerebri media, 8 A. cerebri media



Rami diencephalici posteriores (Fig. 14)

On the dorsal surface of the diencephalon (and in the lateral sections of the mesencephalon) branches from various blood vessels are seen. These originate from the ramus choroideus posteromedialis, the ramus choroideus posterior lateralis as well as the A. cerebri posterior itself. For example we were able to show that 5 such rami thalamogeniculati on the average (1–9) originate from the A. cerebri posterior. From the ramus choroideus posterior lateralis branches run to the corpus geniculatum laterale in 66% and to the pulvinar thalami in 62%, more rarely to the corpus geniculatum mediale. The ramus choroideus posterior medialis (which is double in 24%, triple in 6.2% and quadrupled in about 1%) supplies especially the corpus geniculatum mediale and its environment, more rarely, however, the pulvinar thalami.

Rami diencephalici superiores

The upper areas of the thalamus are supplied by the A. choroidea anterior as well as by the rami choroidei posteriores mediales et laterales. Only the upper anterior section of the diencephalon may also receive branches from the Aa. cerebri anterior et communicans anterior = Rr. diencephalici inferiores anteriores.

It should be pointed out here that the vessels from the rami diencephalici stem are of variable diameter and therefore the rami diencephalici themselves are also

of variable diameter, so that the intracerebral length varies and thus the area of perfusion varies as well. Since it is part of the diencephalon, the pineal body is also supplied by the rami diencephalici, particularly by the ramus choroideus posterior medialis as well as its connection with the artery for the roof of the midbrain.

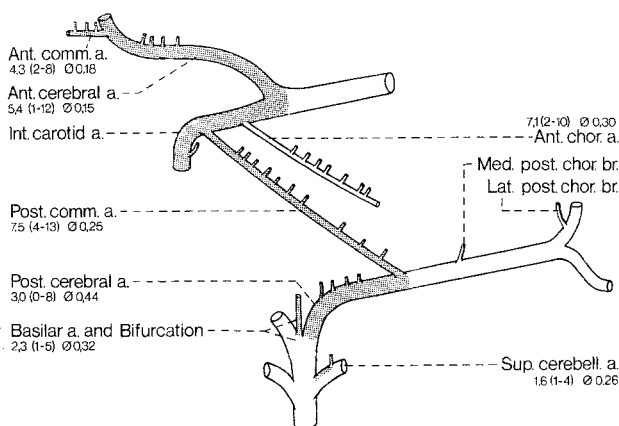


Fig. 14. Rami diencephalici, different origins. Number (borderline values in brackets) and average diameter

Hypothalamus and Third Ventricle—Approaches (Fig. 15)

The distance between the front edge of the brain and the lamina terminalis is of interest for the transfrontal approach to the hypothalamus and the third ventricle. In our study material, this distance ranged from 52–

65 mm, with an average of 59.3 mm (Fig. 19). Aside from the falx cerebri and the superior sagittal sinus which is usually developed in this area (1 cm above the

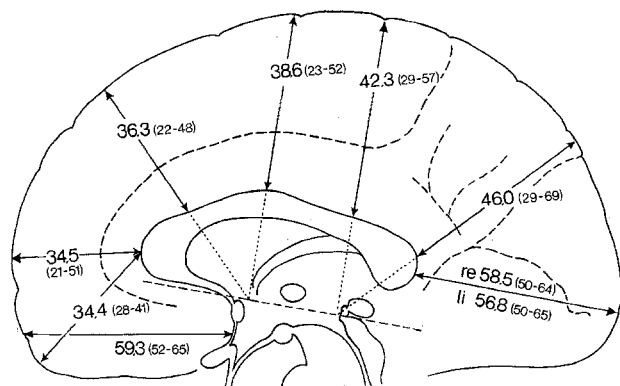


Fig. 15. Third ventricle and corpus callosum, distances to various brain areas in mm (borderline values)

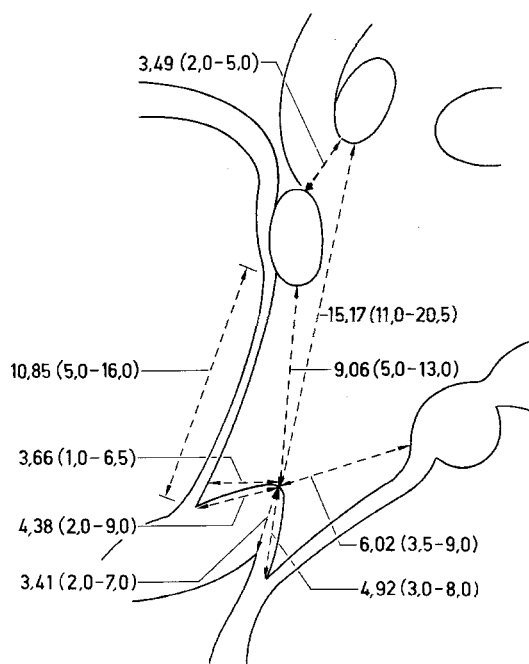


Fig. 16. Entrance and depth of the recessus opticus et infundibuli, length of the ventricle bordering the chiasm, and its distance to the corpus mamillare, length of the lamina terminalis, distance between commissura rostralis and chiasm. Distance between commissura rostralis and foramen interventriculare as well as between foramen interventriculare and chiasm. Measurements in mm (borderline values)

base of the skull), the veins flowing into this area can also be ligated. Furthermore care must be taken to avoid the ramus frontopolaris of the A. cerebri anterior, this artery itself in its pre- and postcommunica-

lateral. The distance of the A. cerebri anterior, pars postcommunica-lis to the lamina terminalis measures 2–9 mm in our examination material. For the approach to the hypophysis, the A. hypophysialis superior which supplies the underside of the N. opticus and the optic chiasm must also be looked out for.

The lamina terminalis between the upper edge of the optic chiasm and the lower edge of the commissura rostralis (anterior) is 10.85 (5.0–16.0) mm long in our case material. Behind the lamina lies the entrance to the recessus opticus, which is 3.66 (1.0–6.5) mm long and the entrance to the recessus infundibuli, which has a length of 6.02 (3.5–9.0) mm. Further measurements and distances are depicted in Fig. 16.

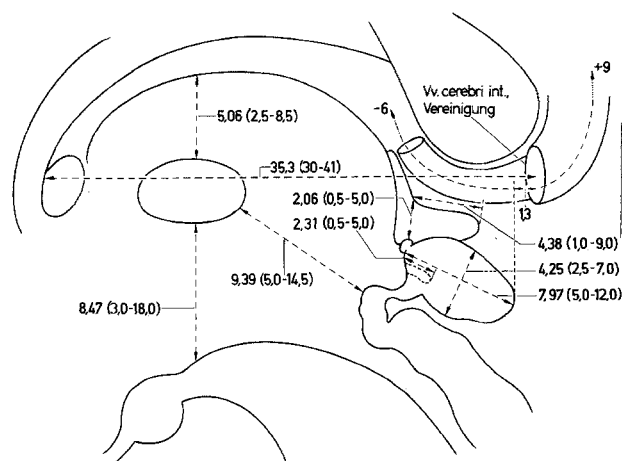


Fig. 17. Distance measurements from the adhesio interthalamica to the different brain structures, the convergence of the Vv. cerebri internae to the anterior edge of the foramen interventriculare. Measurements of the recessus suprapinealis et pinealis as well as the corpus pineale in mm (borderline values)

Transcallosal approaches to the third ventricle

In Fig. 16 the distance between the genu corporis callosi and the front edge of the brain (34.5 mm on the average) as well as the distances diagonally towards the front and upwards at various levels as well as upwards and backwards is given in millimeters. For the transcallosal approaches from above, attention must be paid to the branches of the A. cerebri anterior, from which occasional fine arteries branch out to the falx cerebri as well as to bridging veins to the sinuses sagittalis superior and inferior. After transecting the corpus callosum and the septum pellucidum the two venae cerebri internae are seen to lie close beside each other in the cisterna fissurae transversae. The rami choroidei posteriores mediales, which supply the upper diencephalic sections can also lie exactly in the midline. After pushing the vessels in the midline aside, the

approach is possible through the roof of the third ventricle which may possibly be opened during preparation. The fornix should be preserved since damage to this structure leads to disturbances in memory. (Measurements of the posterior part of the third ventricle and the V. cerebri int.—see Fig. 17.)

Supra- and infratentorial approaches

The third ventricle can be reached from dorsal by way of the supratentorial or the infratentorial approach. At this point it should be emphasized that the angle of the tentorial ridge varies greatly in the material examined.

Bridging veins can come from above and from below and flow into the tentorium cerebelli, possibly forming a sinus tentorii which runs to the sinus rectus or lateral to the sinus transversus. In the region of the splenium corporis callosi the two venae cerebri internae converge as a rule to form the V. cerebri magna. In this vein or in the V. cerebri internae empties the V. basalis (Rosenthal) and the internal occipital, the posterior pericallosal and from behind the superior vein of the vermis cerebelli. The third ventricle can also be approached by way of the recessus suprapinealis which is 4.38 (1.0–9.0) mm on the average.

The *transcortical approach* to the third ventricle is to be recommended especially in cases of dilated lateral ventricles and is achieved through the gyrus frontalis medius. The thalamostriate vein should be preserved during this approach through the foramen interven-
triculare. Interestingly, the traditional textbook course of these veins through the foramen interven-
triculare was found in only 53% of our case material. In 39% a

dorsal curve of this vein behind the foramen interven-
triculare in a medial direction was detected. In 20% other variations are seen, as demonstrated in Fig. 19.

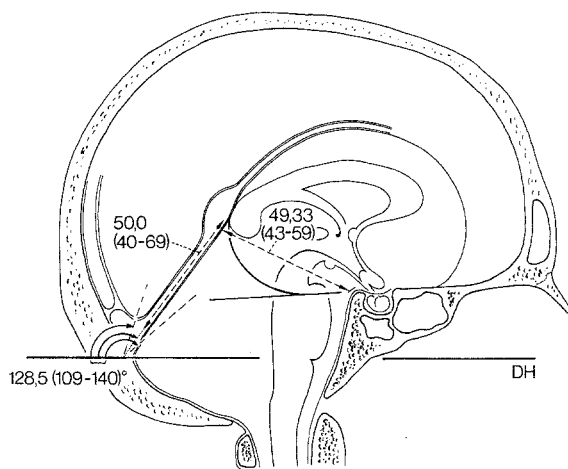


Fig. 18. Position of the sinus rectus (and thus of the fastigium tentorii) to the Deutsche Horizontalebene (German horizontal level) in degrees (borderline values) as well as the direct length of the incisura tentorii in mm (borderline values)

When the approach to the third ventricle between the fornix and the plexus choroideus is used, care should be taken to preserve the branches of the rami choroidei posteriores mediales and the A. choroidea posterior lateralis flowing to the upper diencephalic areas.

Pterional approach

In order to reach the frontal section of the hypophyseal region, the pterional approach can be used. We (Lang 1984) determined the distance between the gyrus frontalis inferior and the lateral edge of the optic nerve

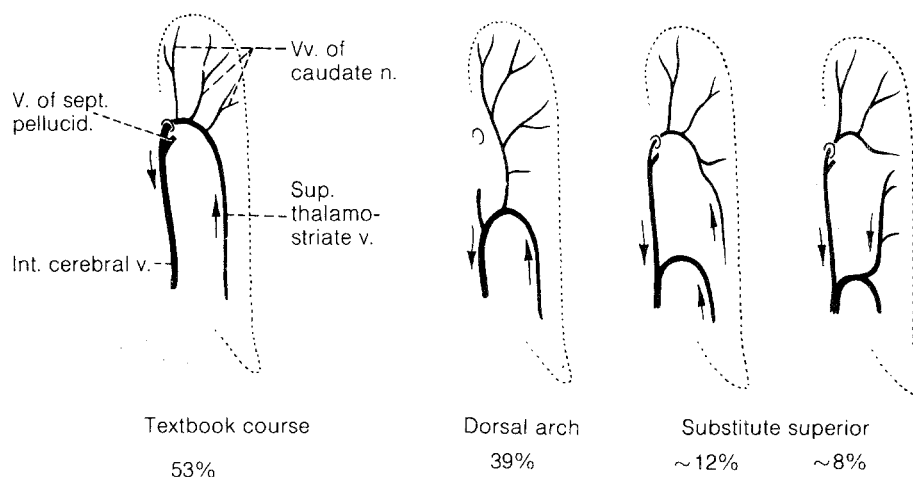


Fig. 19. Superior thalamostriate veins and veins of the caudate nucleus

at the entrance to the optic canal (Fig. 20). This approach is performed immediately in front of the substantia perforata rostralis anterior into which the rami centrales of the A. cerebri media and A. cerebri anterior as well as the A. centralis longa enter the brain substance directly. These as well as the bridging vein to the sinus sphenoparietalis and to the sinus cavernosus should be preserved (Fig. 21).

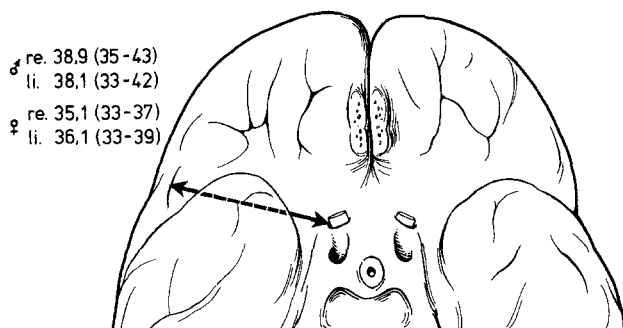


Fig. 20. Fovea endofrontalis lateralis (gyrus frontalis inferior) in the pterional region—distance to the lateral edge of the optic nerve at the entrance to the optic canals in mm (borderline values)

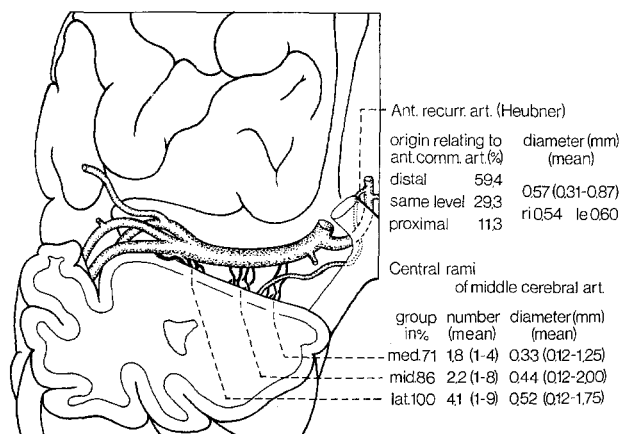


Fig. 21. Rami centrales of the Aa. cerebri anterior et media to the substantia perforata anterior. Origins, groups, number and diameter

Procedure through the Fissura Sylvii

When the hypophyseal region is approached by way of the valleculla, then the gyrus temporal superior is displaced downwards and the frontal gyri which overlap the fissura lateralis cerebri from above is displaced upwards. Care is taken to preserve branches of the A. cerebri media, the Vv. cerebri mediae superficialis et profunda as well as the bridging veins to the sinus sphenoparietalis and to the floor of the middle cerebral fossa and to the sinus cavernosus.

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