Neuroanatomy 7: Diencephalon

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The diencephalon is the smaller caudal part of the prosencephalon (forebrain). The diencephalon forms the mass of gray matter (nuclei) lateral to the third ventricle. The 3rd ventricle – in turn- is the midline cavity of the diencephalon.

Location & divisions:

The diencephalon is situated just superior to the midbrain, occupying the region where the cerebrum joins the brainstem. The diencephalon is divided into 4 divisions on each side, arranged as follows:

- The epithalamus: most superiorly & dorsally,
- The thalamus: in the middle,
- The hypothalamus: infero-anteriorly,
- The subthalamus: infero-postero-laterally.

Those 4 divisions have different distinct functions, & are extensively connected to the other regions of the CNS.

Thalamus

The thalamus is an ovoid nuclear mass, approximately 4 cm long, with a narrow anterior end & a dilated posterior end. The narrow anterior pole lies close to the midline and forms the posterior boundary of the interventricular foramen. The posterior end (the pulvinar) extends beyond the third ventricle to overhang the superior colliculus, it has 2 small elevations: the medial & lateral geniculate bodies. The lateral & medial geniculate bodies are connected to the superior & inferior colliculi of the midbrain via the brachium of the superior colliculus & the brachium of the inferior colliculus, respectively.

Relations:

The superior surface of the thalamus forms the floor of the body of the lateral ventricle,

The medial surface of the thalamus forms the upper part of the lateral wall of the 3rd ventricle,

The medial surface of the thalamus contains a rounded medial bulge, the interthalamic adhesion, that contacts its contralateral fellow,

The lateral surface of the thalamus is related to the posterior limb of the internal capsule,

The inferior surface of the thalamus is related to the hypothalamus anteriorly, the subthalamus laterally, & the midbrain tegmentum posteriorly.

Divisions:

The thalamus is a mass of gray matter, consisting of many groups of nuclei, each has its distinct connections & function. In general, the thalamic nuclei are "relay stations" connecting various parts of the CNS with the cerebral cortex. Internally, the thalamus contains a vertical Y-shaped sheet of white matter (with its 2 arms anteriorly), the **internal medullary lamina**. This lamina divides the thalamus into **anterior** (between the arms)**, medial** (medial to the lamina) and **lateral** (lateral to the lamina) nuclear groups.

- This lamina -itself- contains small *intralaminar nuclei* embedded within it.
- *Midline nuclei* lie adjacent to, and to some extent within, the interthalamic adhesion.
- *Reticular nuclei* lie lateral to the main nuclear mass, separated from it by the external medullary lamina.

For the details of individual thalamic nuclei, please refer to the table in page2.

Hypothalamus

The hypothalamus contains the integrative systems that, via the autonomic and endocrine effector systems, control fluid and electrolyte balance, food ingestion and energy balance, reproduction, thermoregulation and immune and many emotional responses.

The hypothalamus extends from the lamina terminalis to a vertical plane posterior to the mammillary bodies, and from the thalamus to the base of the brain beneath the third ventricle. It lies beneath the thalamus and anterior to the subthalamus and the midbrain tegmentum. Laterally, it is bordered by the anterior part of the subthalamus, internal capsule and optic tract. The hypothalamus forms the antero-inferior part of the lateral wall of the 3rd ventricle, being separated from the thalamus by the hypothalamic sulcus (a shallow curved sulcus running anterosuperiorly from the opening of the cerebral aqueduct to the interventricular foramen). Structures in the floor of the third ventricle (from anterior to posterior) are: the optic chiasma, tuber cinereum (to which the infundibulum is attached), mammillary bodies and posterior perforated substance.

Nuclear Group		Subgroup	Afferent tracts	Efferent tracts	Function
Anterior		Anteroventral (AV)	Mammillary body via mammillothalamic tract Hippocampal formation via fornix	To the cingulate gyrus	Expression of emotions Learning, memory
		Anteromedial (AM)			
		Anterodorsal (AD)			
Medial		Dorsomedial (mediodorsal)	Prefrontal cortex Amygdaloid complex Olfactory cortex	Prefrontal cortex	Integration of sensory information Expression of emotions
		Midline	Hippocampus, limbic cortex	Hippocampus, limbic cortex	Modulation of cortical excitability
Lateral	**Dorsal tier**	Lateral dorsal (LD)	Mammillary body via mammillothalamic tract	Cingulate gyrus Parahippocampal gyrus	Expression of emotions
		Lateral posterior (LP)	Superior parietal lobule Precuneus	Superior parietal lobule Precuneus	Sensory integration
		Pulvinar (P)	Association areas of parietal, temporal, and occipital lobes	Association areas of parietal, temporal, and occipital lobes	Integration of visual, auditory, and somatosensory information
	Ventral tier	Ventral anterior (VA)	Globus pallidus Substantia nigra	Frontal eye field Premotor cortex Supplementary motor area	Control of eye, face, head & limb movements
		Ventral lateral (VL)	Substantia nigra Globus pallidus Dentate nucleus of cerebellum (via dentatothalamic tract)	Primary motor cortex	Control of movement
		Ventral posterior medial (VPM)	trigeminothalamic tracts & taste pathway	Primary somatosensory cortex in postcentral gyrus	Processes touch, pressure, pain, and temperature sensation, and proprioception Taste
		Ventral posterior lateral (VPL)	Lateral spinothalamic tract Medial lemniscus Anterior spinothalamic tract	Primary somatosensory cortex in postcentral gyrus	Processes all types of general sensation from the body
		Medial geniculate nucleus	Inferior colliculus Lateral lemniscus	Auditory radiation to the primary auditory cortex	Hearing
		Lateral geniculate nucleus	Retina via optic tract Primary visual cortex	Optic radiation to the primary visual cortex	Vision
Others		Intralaminar nuclei	Motor cortex & basal nuclei Ascending sensory systems	Widespread areas of the cerebral cortex	Sensorimotor integration
		Reticular nuclei	Collaterals from the afferent & efferent fibers of the thalamic nuclei	Other thalamic nuclei Reticular formation	Integrates and controls thalamic activity

Hypothalamic nuclei: position & functions

Zone	Anterior region		Middle region	Posterior region
	Preoptic region	Supraoptic (chiasmatic) region	Infundibular (tuberal) region	Mammillary region
Periventricular	Preoptic nucleus	Suprachiasmatic nucleus	Arcuate nucleus	
	Periventricular nuclei	Periventricular nuclei		
Medial	Medial preoptic nucleus	Anterior hypothalamic nucleus	Dorsomedial nucleus	Mammillary nuclei
		Paraventricular nucleus	Ventromedial nucleus	Posterior hypothalamic nuclei
		Supraoptic nucleus		
Lateral	Lateral preoptic nucleus	Lateral hypothalamic nucleus	Lateral tuberal nuclei	Lateral hypothalamic nucleus
			Lateral hypothalamic nucleus	

Nucleus	Function(s)
Preoptic	Controls the release of reproductive hormones (FSH, LH) from the adenohypophysis
Suprachiasmatic	Regulates circadian rhythms; "master clock"
Arcuate	Produces hypothalamic releasing and inhibiting hormones
Periventricular	Produces hypothalamic releasing and inhibiting hormones
Medial preoptic	Regulates the release of reproductive hormones (FSH, LH) from the adenohypophysis
Anterior	Regulates parasympathetic nervous system activity
Dorsomedial	Stimulation of this nucleus causes savage behavior in animals
Ventromedial	Involved in eating behavior; "satiety center". Destruction results in obesity & savage behavior
Mammillary	Processes information related to emotional expression
Posterior	Regulates sympathetic nervous system activity Regulates body temperature Involved in heat conservation and heat production; "thermostat"
Lateral preoptic	Unknown
Lateral	Regulates sympathetic nervous system Involved in eating behavior; "feeding center": stimulation induces eating, destruction results in starvation
Paraventricular	Produces ADH and oxytocin Projects to autonomic nuclei of brainstem & spinal cord
Supraoptic	Produces ADH and oxytocin

Afferent pathways of the hypothalamus

Tract/Pathway	Origin	Termination	Function
Thalamohypothalamic tract	Medial dorsal and midline nuclei of the thalamus	Lateral preoptic area of the hypothalamus	
Fornix (Hippocampohypothalamic tract)	Hippocampal formation	Preoptic and anterior areas of the hypothalamus, Mammillary body	
Retinosuprachiasmatic tract	Retina	Suprachiasmatic nucleus	Control of circadian rhythms
Tegmental tract (mammillary peduncle)	Dorsal and ventral tegmental nuclei	Mammilary body	Relays sensory input from sensory pathways
Stria terminalis (amygdalohypothalamic tract)	Amygdaloid complex	Preoptic and anterior areas of the hypothalamus	Olfactory information, which influences reproductive behavior
Spinohypothalamic tract	Spinal cord	Autonomic control centers of the hypothalamus	Neuroendocrine and cardiovascular responses
Corticohypothalamic fibers	Frontal lobe of cerebral cortex, Olfactory cortex	Hypothalamic nuclei	

Efferent pathways of the hypothalamus

Tract/Pathway	Origin	Termination	Function
Mammillothalamic tract	Mammillary body	Anterior nucleus of the thalamus	
Mammillotegmental tract	Mammillary body	Dorsal and ventral tegmental nuclei	
Hypothalamohypophyseal tract	Supraoptic and paraventricular nuclei	Posterior lobe of the pituitary gland (neurohypophysis)	Releases hormones (oxytocin & ADH)
Tuberohypophyseal tract	Arcuate and periventricular nuclei	Infundibular stalk	Regulates the synthesis and release of anterior pituitary hormones
Descending fibers to brainstem and spinal cord	Preoptic, anterior, posterior, and lateral nuclei of hypothalamus	Brainstem, Spinal cord lateral cell column, Sympathetic and parasympathetic (sacral) nuclei	Influences ANS activity

Divisions:

The hypothalamus can be divided anteroposteriorly into 3 regions: **anterior** (preoptic & supraoptic), **middle** (infundibulo-tuberal) and **posterior** (mammillary) regions, and mediolaterally into **periventricular**, **medial** and **lateral** zones. Between the medial and lateral zones is a paramedian plane that contains the prominent myelinated fibres of the column of the fornix & the mammillothalamic tract.

For the details of individual hypothalamic nuclei & their connections, please refer to the tables in page 3.

Pituitary Gland

The pituitary gland, or hypophysis cerebri, is a reddish grey ovoid body approximately 12 mm in transverse diameter and 8 mm in anteroposterior diameter. It is continuous with the infundibulum, a hollow, conical inferior process from the tuber cinereum of the hypothalamus. It lies within the pituitary fossa of the sphenoid bone, where it is covered superiorly by a circular diaphragma sellae of dura mater.

The pituitary has two major parts—neurohypophysis and adenohypophysis— which differ in their origin, structure and function. The neurohypophysis is a diencephalic downgrowth connected with the hypothalamus. The adenohypophysis is an ectodermal derivative of the stomatodeum (ie: not a part of the diencephalon). The neurohypophysis includes:

1. the median eminence,
2. infundibular stem (stalk), } infundibulum
3. posterior lobe (pars nervosa).

Subthalamus

The subthalamus is a complex region of nuclear groups and fiber tracts that lies inferolateral to the thalamus. The main nuclear group is the subthalamic nucleus, which lies very close to the rostral end of the midbrain.

The main subthalamic tracts are the upper parts of the medial, spinal and trigeminal lemnisci and the solitario-thalamic tract, passing through the subthalamus in their way to the thalamic nuclei. The subthalamic nucleus is closely related to the basal nuclei, & its connections will be discussed with them.

Epithalamus

The epithalamus is the dorsal segment of the diencephalon. The epithalamus consists of the medial and lateral habenular nuclei, stria medullaris thalami, posterior commissure and pineal body (gland).

- The habenular commissure connects the habenular nuclei on both sides,
- The habenular nuclei lie posteriorly at the dorsomedial corner of the thalamus, immediately deep to the ependyma of the third ventricle,
- Stria medullaris thalami is a band of nerve fibers connecting the habenular nuclei with the limbic system. The stria passes over the superomedial aspect of the thalamus. Some of its fibers cross the midline to reach the contralateral habenular nuclei, forming the "habenular commissure".
- Pineal gland: a small piriform structure located in relation to the posterior wall of the third ventricle. It is an endocrine gland of considerable significance and is made up of cells called pinealocytes, which secrete melatonin in response to darkness. The pineal gland also secretes a number of hormones that have important regulatory influence on many endocrine organs including the pituitary, thyroid, parathyroids, adrenals and gonads. Hormones of the pineal gland reach the pituitary gland through the blood stream and the cerebrospinal fluid (CSF). As humans age, the pineal glands become calcified and form what are known as corpora arenacea or brain sand.

The function of the epithalamus is to connect the limbic system to other parts of the brain. Some functions of its components include the secretion of melatonin and secretion of hormones from pituitary gland by the pineal gland circadian rhythms, and regulation of motor pathways and emotions.

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