Thalamus

■ INTRODUCTION

Thalamus is a large ovoid mass of gray matter, situated bilaterally in **diencephalon.** Both thalami form 80% of diencephalon. Thalami on both sides are connected in their rostral portions by means of an **intermediate mass.** Caudal portions are more widely separated by corpora quadrigemina.

■ THALAMIC NUCLEI

Thalamic nuclei are classified by two methods:

A. Anatomical classification
B. Physiological classification.

■ ANATOMICAL CLASSIFICATION

Thalamus on each side is divided into five main nuclear groups by 'Y'-shaped internal medullary lamina.

1. Midline nuclei
2. Intralaminar nuclei
3. Medial mass of nuclei
4. Lateral mass of nuclei
5. Posterior group of nuclei.

1. *Midline Nuclei*

Midline nuclei are a group of small nuclei, situated on the medial surface of thalamus near the midline (Fig. 147.1).

2. *Intralaminar Nuclei*

Intralaminar nuclei are smaller nuclei present in the medullary septum of thalamus.

3. *Medial Mass of Nuclei*

Medial mass of nuclei are situated medial to septum and it comprises two nuclei:

i. Anterior nucleus
ii. Dorsomedial nucleus.

4. *Lateral Mass of Nuclei*

This group of nuclei are situated lateral to septum. Lateral mass of nuclei are again divided into two subgroups:

i. Dorsal group of lateral mass with two nuclei:
   a. Dorsolateral nucleus
   b. Posterolateral nucleus
ii. Ventral group of lateral mass with three nuclei:
   a. Ventral anterior nucleus
   b. Ventral lateral nucleus
   c. Ventral posterior nucleus. It consists of two parts:
      - Ventral posterolateral nucleus
      - Ventral posteromedial nucleus.

5. *Posterior Group of Nuclei*

Posterior group of nuclei are the continuation of lateral mass of nuclei. It has two subgroups:

i. Pulvinar
ii. Metathalamus which consists of two structures:
   a. Medial geniculate body
   b. Lateral geniculate body.

Thalamic reticular nucleus

Thalamus also includes thalamic reticular nucleus, which is a thin layer of neurons covering the lateral aspect of thalamus. It is separated from thalamus by external medullary lamina. It receives information from reticular formation, cerebral cortex and other thalamic and sends inhibitory signals to other thalamic nuclei.

■ PHYSIOLOGICAL CLASSIFICATION

On the basis of functions and their projections, thalamic nuclei are classified into five groups. This type of classification is also called **Bondok classification**. Five groups of thalamic nuclei are:

1. Specific sensory relay nuclei
2. Specific motor nuclei
3. Association or less specific nuclei
4. Non-specific nuclei
5. Limbic system nuclei.

Nuclei and their functions of each group are given in Table 147.1.

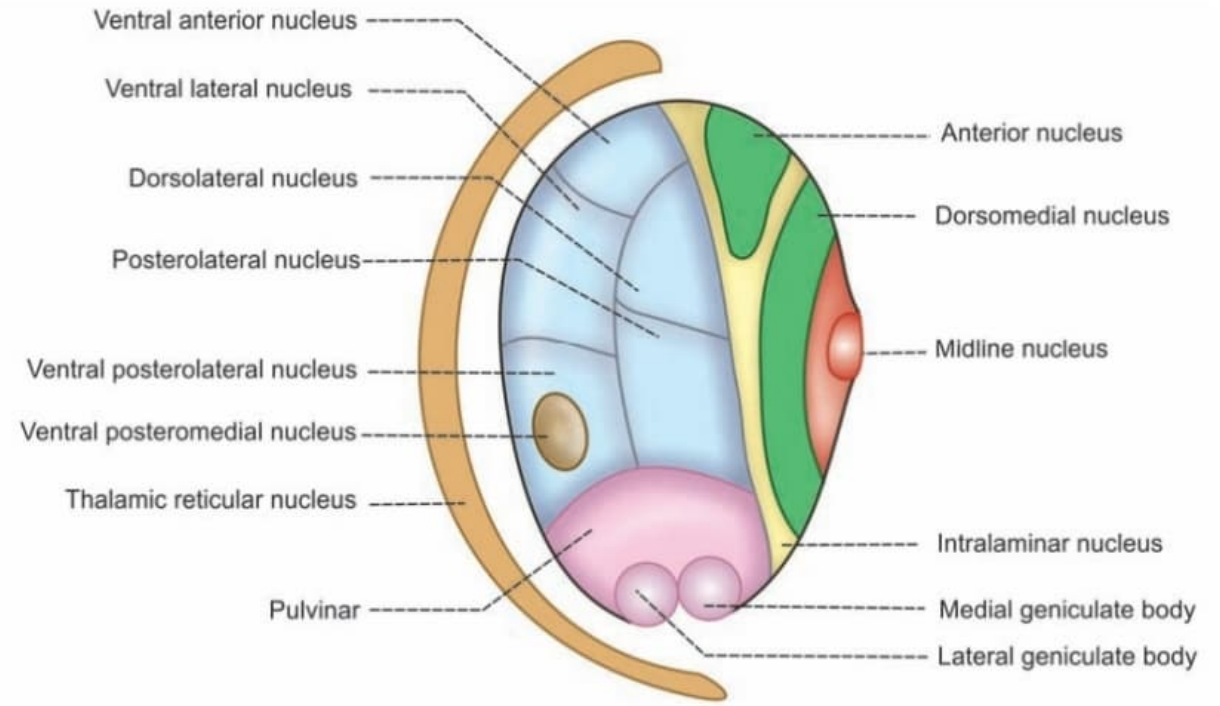

FIGURE 147.1: Thalamic nucleus. Red = Midline nucleus, Yellow = Intralaminar nuclei, Green = Medial mass of nuclei, Blue = Lateral mass of nuclei, Pink = Posterior group of nuclei.

TABLE 147.1: Bondok classification of thalamic nuclei

Group	Nuclei	Functions
1. Specific sensory relay nuclei	i. Ventral posterior nucleus ii. Medical geniculate body iii. Lateral geniculate body	Project sensory signals to distinct (specific) areas of cerebral cortex
2. Specific nuclei	i. Ventral anterior nucleus ii. Ventral lateral nucleus	Receive signals controlling motor activities from cerebellum and corpus striatum and send these signals to motor areas in the cerebral cortex to complete the feedback system of motor control mechanism
3. Association or less specific nuclei	i. Dorsolateral nucleus ii. Posterolateral nucleus iii. Pulvinar	Send information to association areas of cerebral cortex
4. Non-specific nuclei	i. Midline nuclei ii. Intralaminar nuclei iii. Reticular nucleus	Project signals to diffused areas of cerebral cortex
5. Limbic system nuclei	i. Anterior nucleus ii. Dorsolateral nucleus	Project into limbic cortex

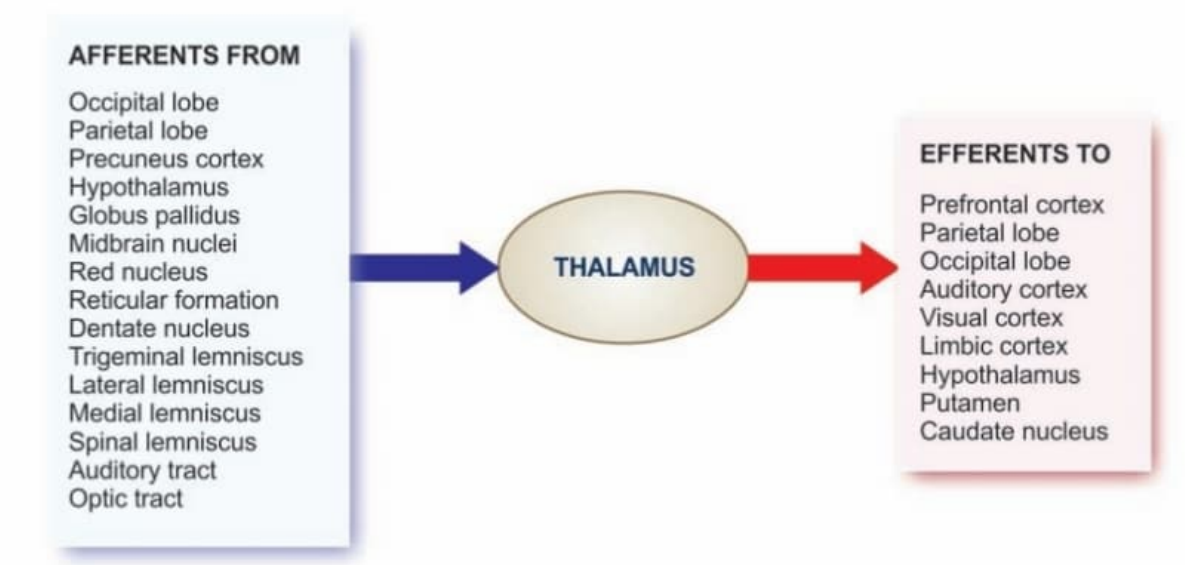

FIGURE 147.2: Connections of thalamus

■ CONNECTIONS OF THALAMIC NUCLEI

Connections of different groups of nuclei are given in Table 147.2 and Figure 147.2.

■ THALAMIC RADIATIONS

Thalamic radiation is the collection of nerve fibers connecting thalamus and cerebral cortex. It contains both thalamocortical and corticothalamic fibers. All these fibers between thalamus and cerebral cortex pass through internal capsule.

Fibers of thalamic radiation are divided into four groups, which are called **thalamic peduncles** or **thalamic stalks.** Thalamic peduncles are:

1. Anterior (frontal) thalamic peduncle or radiation
2. Superior (centroparietal) thalamic peduncle or radiation
3. Posterior (occipital) thalamic peduncle or radiation
4. Inferior (temporal) thalamic peduncle or radiation.

TABLE 147.2: Connections of different nuclear groups of thalamus

Nuclei		Afferent fibers from	Efferent fibers to
1. Midline nuclei		Globus pallidus Hypothalamus Cerebral cortex Midbrain nuclei Reticular formation	Different areas of cerebral cortex
2. Intralaminar nuclei		Reticular formation Trigeminal lemniscus Lateral lemniscus	Cerebral cortex Putamen Caudate nucleus Other thalamic nuclei
3. Medial mass	Anterior nucleus	Mamillary body	Limbic cortex
	Dorsomedial nucleus	Hypothalamus	Limbic cortex Putamen Caudate nucleus Hypothalamus
4. Lateral mass	Dorsolateral nucleus	Precuneus cortex	Precuneus cortex
	Posterolateral nucleus	Parietal lobe	Parietal lobe
	Ventral anterior nucleus	Globus pallidus	Putamen Caudate nucleus Premotor cortex
	Ventral lateral nucleus	Globus pallidus Dentate nucleus Red nucleus	Putamen Caudate nucleus Precentral cortex
	Posterior ventral nucleus	Trigeminal lemniscus Medial lemniscus Spinal lemniscus	Hypothalamus Cerebral cortex – areas 3, 1, 2, 5, 7
5. Posterior group	Pulvinar	Inferior parietal lobe Occipital lobe – areas 18, 19	Inferior parietal lobe Occipital lobe – areas 18, 19
	Medial geniculate body	Auditory tract	Auditory cortex
	Lateral geniculate body	Optic tract	Visual cortex

■ ANTERIOR (FRONTAL) THALAMIC PEDUNCLE OR RADIATION

Anterior thalamic peduncle connects the frontal lobe of cerebral cortex with medial and lateral thalamic nuclei. It contains mostly motor nerve fibers.

■ SUPERIOR (CENTROPARIETAL) THALAMIC PEDUNCLE OR RADIATION

Fibers of this peduncle connect postcentral gyrus (somesthetic area) of parietal lobe and adjacent area in frontal cortex with lateral mass of thalamic nuclei. It contains mainly the sensory fibers.

■ POSTERIOR (OCCIPITAL) THALAMIC PEDUNCLE OR RADIATION

Posterior thalamic peduncle connects occipital lobe of cerebral cortex with pulvinar and lateral geniculate body. It contains the nerve fibers concerned with vision.

■ INFERIOR (TEMPORAL) THALAMIC PEDUNCLE OR RADIATION

Fibers of this peduncle connect temporal lobe and insula with pulvinar and medial geniculate body. This peduncle contains the nerve fibers concerned with hearing.

FUNCTIONS OF THALAMUS

Thalamus is primarily concerned with **somatic functions** and it plays little role in the visceral functions. Following are the various functions of thalamus:

1. RELAY CENTER

Thalamus forms the relay center for the sensations. Impulses of almost all the sensations reach the thalamic nuclei, particularly in the ventral posterolateral nucleus. After being processed in the thalamus, the impulses are carried to cerebral cortex through thalamocortical fibers.

2. CENTER FOR PROCESSING OF SENSORY INFORMATION

Thalamus forms the major center for processing the sensory information. All the peripheral sensory impulses reaching thalamus are integrated and modified before being sent to specific areas of cerebral cortex. This function of thalamus is usually called the processing of sensory information.

Functional Gateway for Cerebral Cortex

Almost all the sensations are processed in thalamus before reaching cerebral cortex. Very little information of somatosensory function is sent directly to cerebral cortex without being processed by the thalamic nuclei. Because of this function, thalamus is usually called 'functional gateway' for cerebral cortex.

3. CENTER FOR DETERMINING QUALITY OF SENSATIONS

Thalamus is also the center for determining the quality of sensations, i.e. to determine the affective nature of sensations. Usually the sensations have two qualities:

i. Discriminative nature
ii. Affective nature.

i. *Discriminative Nature*

Discriminative nature is the ability to recognize the type, location and other details of the sensations and it is the function of cerebral cortex.

ii. *Affective Nature*

Affective nature is the capacity to determine whether a sensation is pleasant or unpleasant and agreeable or disagreeable. Determining the affective nature of sensations is the function of thalamus.

4. CENTER FOR SEXUAL SENSATIONS

Thalamus forms the center for perception of sexual sensations.

5. ROLE IN AROUSAL AND ALERTNESS REACTIONS

Because of its connections with nuclei of reticular formation, thalamus plays an important role in arousal and alertness reactions.

6. CENTER FOR REFLEX ACTIVITY

Since the sensory fibers relay here, thalamus forms the center for many reflex activities.

7. CENTER FOR INTEGRATION OF MOTOR ACTIVITY

Through the connections with cerebellum and basal ganglia, thalamus serves as a center for integration of motor functions.

APPLIED PHYSIOLOGY

THALAMIC LESION

Thalamic lesion occurs mainly because of blockage (due to thrombosis) in thalamogeniculate branch of posterior cerebral artery. Mostly, posteroventral nuclei of thalamus are affected because the thalamogeniculate branch of posterior cerebral artery supplies this part of thalamus. Lesion of thalamus leads to a condition called thalamic syndrome.

THALAMIC SYNDROME

Thalamic syndrome is the neurological disease caused by infarction of posteroventral part of thalamus. It is a rare disease and it has many names. Synonyms of thalamic syndrome are listed in Box 147.1.

BOX 147.1: Synonyms of thalamic syndrome

1. Dejerine-Roussy syndrome
2. Thalamic hyperesthetic anesthesia
3. Thalamic pain syndrome
4. Central pain syndrome
5. Central poststroke pain syndrome
6. Posterior thalamic syndrome
7. Retrolenticular syndrome

In thalamic syndrome, whole body becomes hypersensitive to pain. Effects of thalamic lesion occur in the contralateral (opposite) side.

Following are the symptoms of thalamic syndrome:

1. *Loss of Sensations*

Loss of all sensations **(anesthesia)** occurs as the sensory relay system in thalamus is affected.

2. *Astereognosis*

Astereognosis is the loss of ability to recognize a known object by touch with closed eyes. It is due to the loss of tactile and kinesthetic sensations in thalamic syndrome.

3. *Ataxia*

Ataxia refers to incoordination of voluntary movements. It occurs due to loss of kinesthetic sensation. This type of ataxia due to loss of sensation is called **sensory ataxia.** It is very common in thalamic syndrome.

4. *Thalamic Phantom Limb*

The patient is unable to locate the position of a limb with closed eyes. The patient may search for the limb in air or may have the illusion that the limb is lost. This is called thalamic phantom limb.

5. *Anosognosia*

Anosognosia is the lack of awareness or denial of existance of a neurological defect or general illness or any disability.

6. *Spontaneous Pain and Thalamic Over-reaction*

Spontaneous pain occurs often. Pain stimulus is felt more acutely than in normal conditions **(hyperalgesia).** Pain may be so intense, that it even resists the action of powerful sedatives like morphine. Threshold for pain is very much reduced. Even the light touch may be unpleasant. Sometimes, the patient feels pain even in the absence of pain stimulus. It becomes worst in conditions such as emotional disturbance and exposure to cold or heat. Pain is due to over activity of medial mass of nuclei of thalamus, which escape the lesion.

Abnormal reaction to various stimuli is called thalamic over-reaction.

7. *Involuntary Movements*

Thalamic syndrome is always associated with some involuntary motor movements.

Athetosis

Athetosis means slow writhing and twisting movements.

Chorea

Chorea means quick, jerky, involuntary movements.

Intention tremor

Tremor is defined as rapid alternate rhythmic and involuntary movement of flexion and extension in the joints of fingers and wrist or elbow. Intention tremor is the tremor that develops while attempting to do any voluntary act. Intention tremor is the common feature of thalamic syndrome.

8. *Thalamic Hand or Athetoid Hand*

Athetoid hand is the abnormal attitude of hand in thalamic lesion. It is characterized by moderate flexion at wrist and hyperextension of all fingers.