Functional Anatomy of Thalamus

The **thalamus** is the largest component of the diencephalon and acts as the major **relay and integration centre** between the cerebral cortex and subcortical structures. Almost all sensory information, except **olfaction**, reaches the cerebral cortex through the thalamus.

1. Situation and gross anatomy

- The thalamus is a paired, ovoid mass of **gray matter** situated on either side of the **third ventricle**.
- It forms much of the **lateral wall of the third ventricle**.
- It lies between the **hypothalamus inferiorly** and the **internal capsule laterally**.
- The two thalami may be connected by the **interthalamic adhesion (massa intermedia)**.
- Major nuclear groups are separated by the **internal medullary lamina**, a Y-shaped sheet of white matter.

2. Functional nuclear groups

Nuclear group	Important nuclei	Major connections/functions
Anterior group	Anterior nucleus	Limbic system; memory and emotion
Medial group	Mediodorsal nucleus	Prefrontal cortex; emotion, motivation, cognition
Lateral group	Ventral anterior (VA)	Motor planning; basal ganglia → cortex
	Ventral lateral (VL)	Motor control; cerebellum/basal ganglia → motor cortex
	VPL	Somatic sensation from body
	VPM	Somatic sensation from face + taste
	Lateral geniculate body (LGB)	Visual relay
	Medial geniculate body (MGB)	Auditory relay
Intralaminar nuclei	Centromedian, parafascicular	Arousal, attention, pain, motor integration
Reticular nucleus	Thalamic reticular nucleus	Regulates activity of other thalamic nuclei and cortical rhythms

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3. Major connections

A. Sensory connections

Ventral posterolateral nucleus — VPL

Receives:

- **Medial lemniscus** → fine touch, vibration, proprioception from body
- **Spinothalamic tract** → pain, temperature and crude touch

Projects mainly to the **primary somatosensory cortex** through the internal capsule.

Body → VPL → sensory cortex

Ventral posteromedial nucleus — VPM

Receives:

- **Trigeminal sensory pathways** from the face
- **Solitary tract** carrying taste

Projects to the face and taste areas of the cerebral cortex.

Face → VPM → sensory cortex

B. Visual pathway

Retina → optic tract → lateral geniculate body → optic radiation → primary visual cortex

The **lateral geniculate body (LGB)** is therefore the principal thalamic relay for vision.

C. Auditory pathway

Inferior colliculus → medial geniculate body → auditory radiation → primary auditory cortex

The **medial geniculate body (MGB)** is the thalamic relay for hearing.

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4. Motor connections

The thalamus participates in the control and coordination of voluntary movement.

Ventral anterior (VA) nucleus

Receives mainly from:

- Basal ganglia

Projects to:

- Premotor and supplementary motor areas

Function: motor planning and initiation.

Ventral lateral (VL) nucleus

Receives from:

- Cerebellum
- Basal ganglia

Projects to:

- Primary motor and premotor cortex

Function: coordination and regulation of voluntary movement.

Thus:

Cerebellum/basal ganglia → VA/VL thalamus → motor cortex

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5. Limbic connections

Anterior nucleus

Receives fibres from the **mammillary bodies** through the mammillothalamic tract and projects to the **cingulate gyrus**.

It forms part of the **Papez circuit**:

Hippocampus → fornix → mammillary body → anterior thalamic nucleus → cingulate gyrus → hippocampus

Functions:

- Memory
- Learning
- Emotional behaviour

Mediodorsal nucleus

Has reciprocal connections with:

- Prefrontal cortex
- Amygdala
- Hypothalamus
- Other limbic structures

Functions:

- Motivation
- Emotion
- Memory
- Executive and cognitive functions

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6. Thalamocortical and corticothalamic connections

Most thalamic nuclei have **reciprocal connections with the cerebral cortex**.

Thus, information does not simply pass through the thalamus as a passive relay. The thalamus **filters, modifies and integrates information** before transmitting it to the cortex.

The **thalamic reticular nucleus** receives corticothalamic and thalamocortical collaterals and helps regulate thalamic activity.

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7. Functions of thalamus

1. Sensory relay

It relays and processes:

- Pain
- Temperature
- Touch
- Pressure
- Vibration
- Proprioception
- Vision
- Hearing

- Taste

Olfaction is the major sensory modality that reaches the cortex without a primary thalamic relay.

2. Sensory integration and modulation

The thalamus:

- Selects relevant sensory information
- Modulates sensory signals
- Participates in attention and awareness

3. Motor function

Through connections with:

- Basal ganglia
- Cerebellum
- Motor cortex

it participates in:

- Initiation of movement
- Motor planning
- Coordination
- Regulation of muscle activity

4. Consciousness and arousal

Intralaminar and other thalamic nuclei participate in the **ascending arousal system** and maintenance of consciousness.

5. Emotion and behaviour

Through limbic connections, the thalamus participates in:

- Emotional behaviour
- Motivation
- Memory

6. Cognition

Connections with the prefrontal cortex contribute to:

- Attention
- Learning
- Memory
- Executive functions

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8. Clinical abnormalities of thalamus

A. Thalamic syndrome

A lesion of the **posterolateral thalamus**, particularly involving VPL/VPM, can produce **contralateral hemisensory loss**.

Features include:

- Loss or impairment of pain and temperature
- Loss of touch
- Impaired proprioception and vibration
- Sensory ataxia
- Later development of **thalamic pain**

Thalamic pain syndrome — Dejerine–Roussy syndrome

After an initial sensory deficit, the patient may develop:

- Severe, persistent burning or aching pain
- Hyperalgesia
- Allodynia
- Exaggerated response to normally non-painful stimuli

The pain is typically **contralateral to the thalamic lesion**.

B. VPL/VPM lesions

Produce **contralateral sensory deficits** involving the body or face respectively.

- **VPL lesion → contralateral body sensory loss**
- **VPM lesion → contralateral facial sensory loss**, with possible taste disturbance.

C. Lateral geniculate body lesion

Produces a **contralateral homonymous visual field defect**, depending on the extent and location of the lesion.

D. Medial geniculate body lesion

Because auditory pathways have substantial bilateral representation above the brainstem, an isolated MGB lesion usually does **not** cause complete unilateral deafness but may affect auditory processing/localization.

E. Thalamic involvement in consciousness

Bilateral damage involving important **intralaminar thalamic nuclei** can cause:

- Reduced alertness
- Impaired attention
- Altered consciousness
- In severe cases, coma

F. Thalamic lesions and movement

Damage to motor-related thalamic nuclei or their connections with basal ganglia/cerebellum can produce:

- Tremor
- Ataxia
- Abnormal involuntary movements
- Problems with motor control

G. Memory and cognitive abnormalities

Lesions involving the **anterior or mediodorsal nuclei** may cause:

- Memory impairment
- Confusion
- Impaired learning
- Behavioural and cognitive changes

High-yield summary

Thalamus = major relay + integration centre

Body sensation → VPL → sensory cortex

Face/taste → VPM → sensory cortex

Vision → LGB → visual cortex

Hearing → MGB → auditory cortex

Basal ganglia/cerebellum → VA/VL → motor cortex

Mammillary body → anterior nucleus → cingulate cortex → memory/emotion

Mediodorsal nucleus → prefrontal cortex → cognition/emotion

Clinical correlation

Thalamic lesion → contralateral sensory loss ± thalamic pain, movement abnormalities, cognitive/behavioural changes and, when strategically located or bilateral, impaired consciousness.