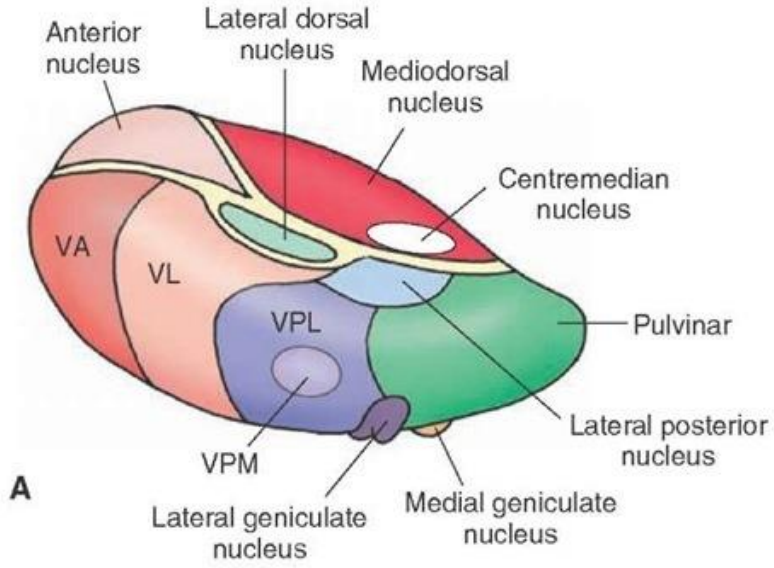
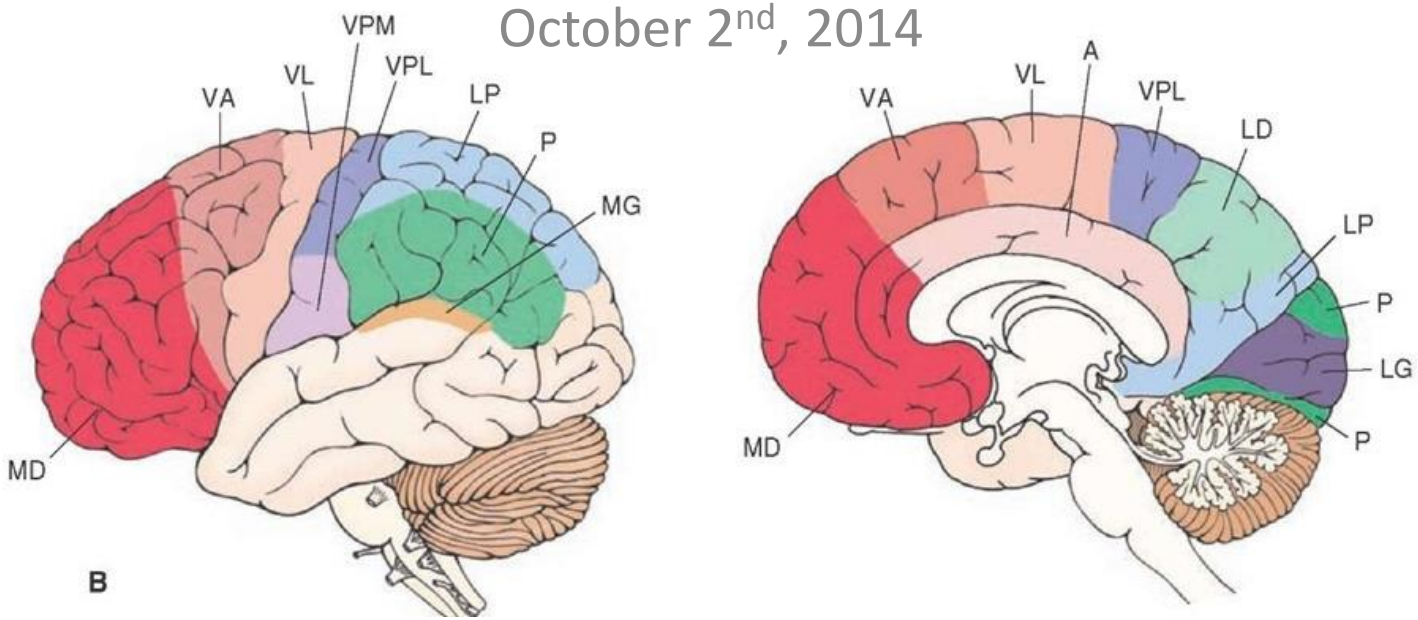


Thalamocortical Pathways

Virtual Neuroanatomy

October 2nd, 2014



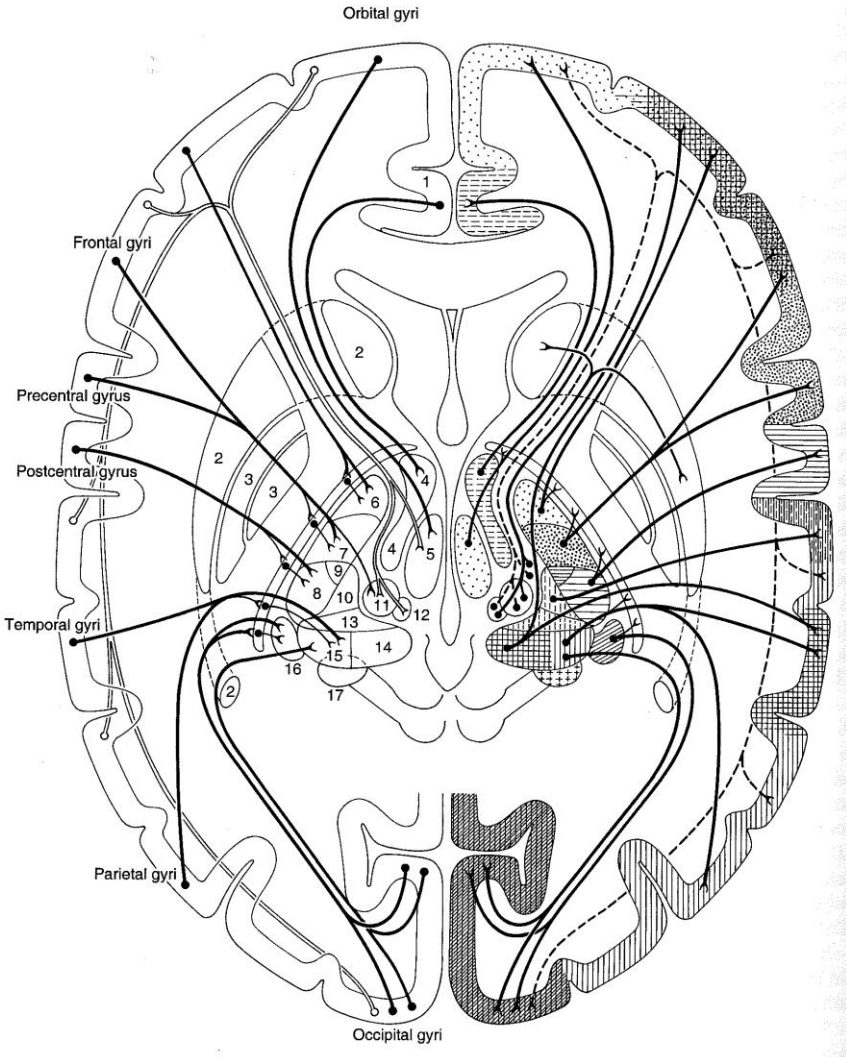
Outline

1. Overview
2. Afferents & Efferents
3. Neurophysiology
4. Neurochemical Systems
5. Physiological Correlates
6. Behavioral Correlates
7. Clinical Pathologies

Overview

Thalamocortical Pathways

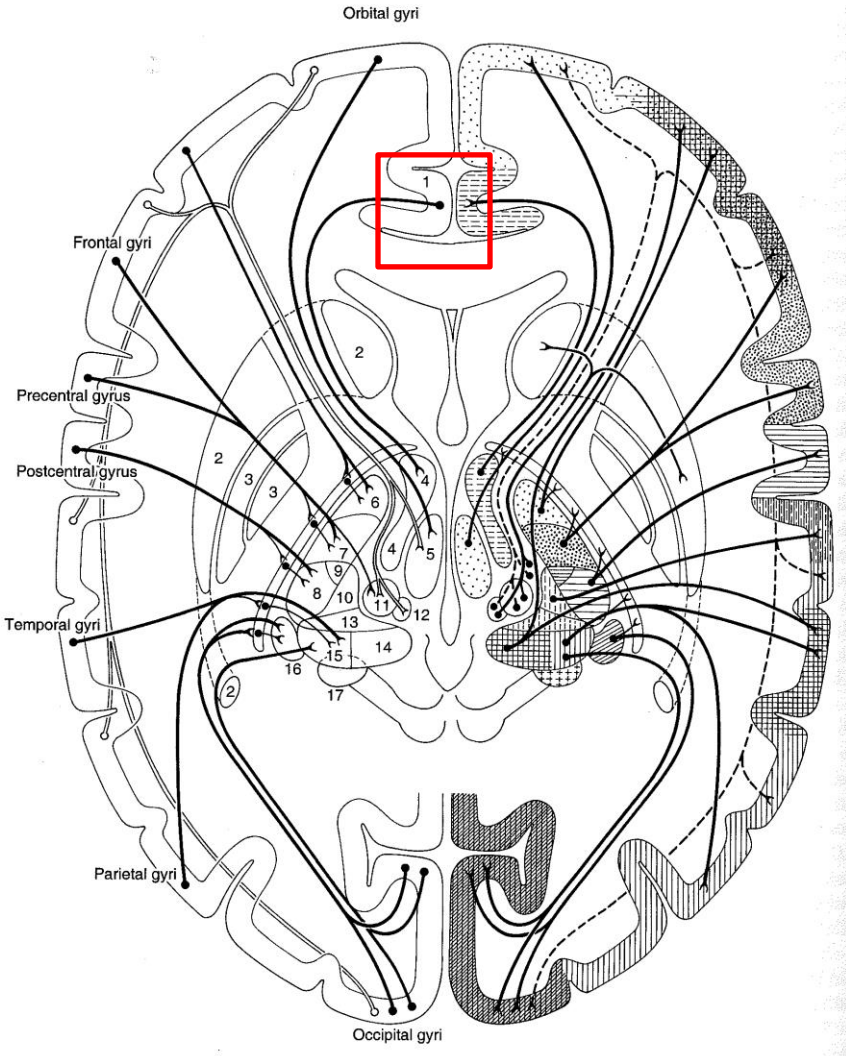
- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex



Niewenhuys et al. (2008). The Human Central Nervous System, 4th Ed.

Thalamocortical Pathways

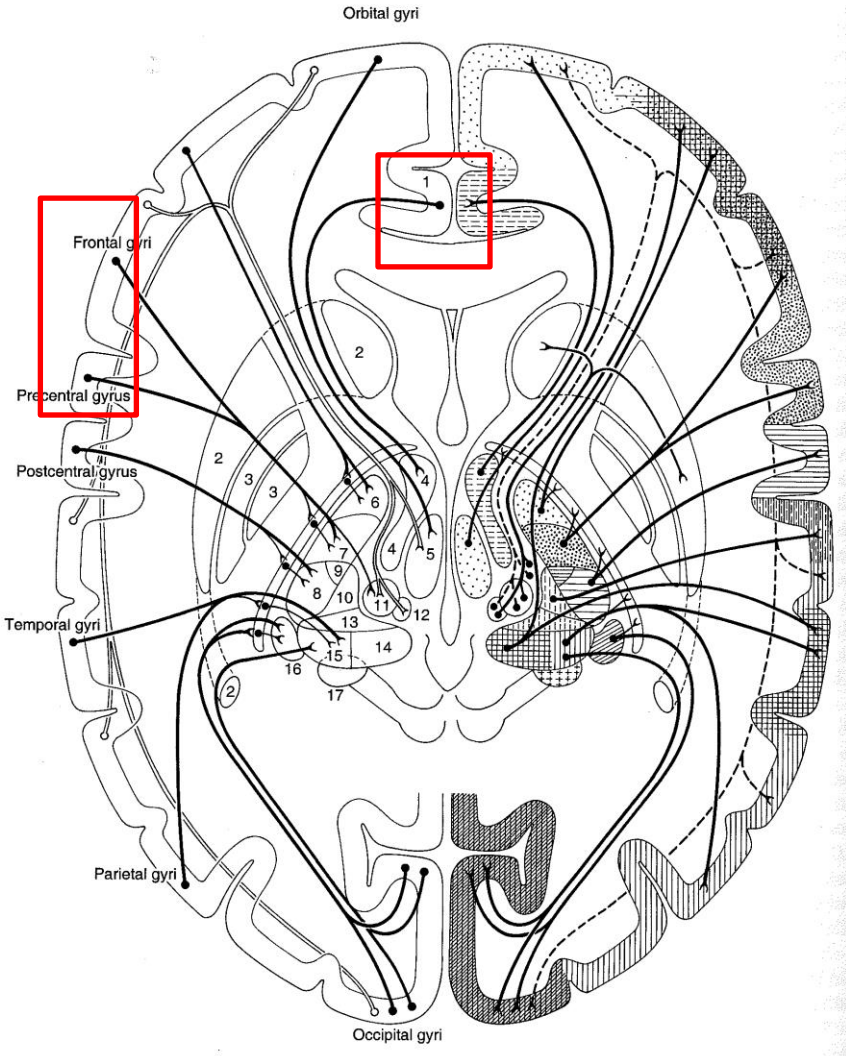
- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex
  - Emotion



Niewenhuys et al. (2008). The Human Central Nervous System, 4th Ed.

Thalamocortical Pathways

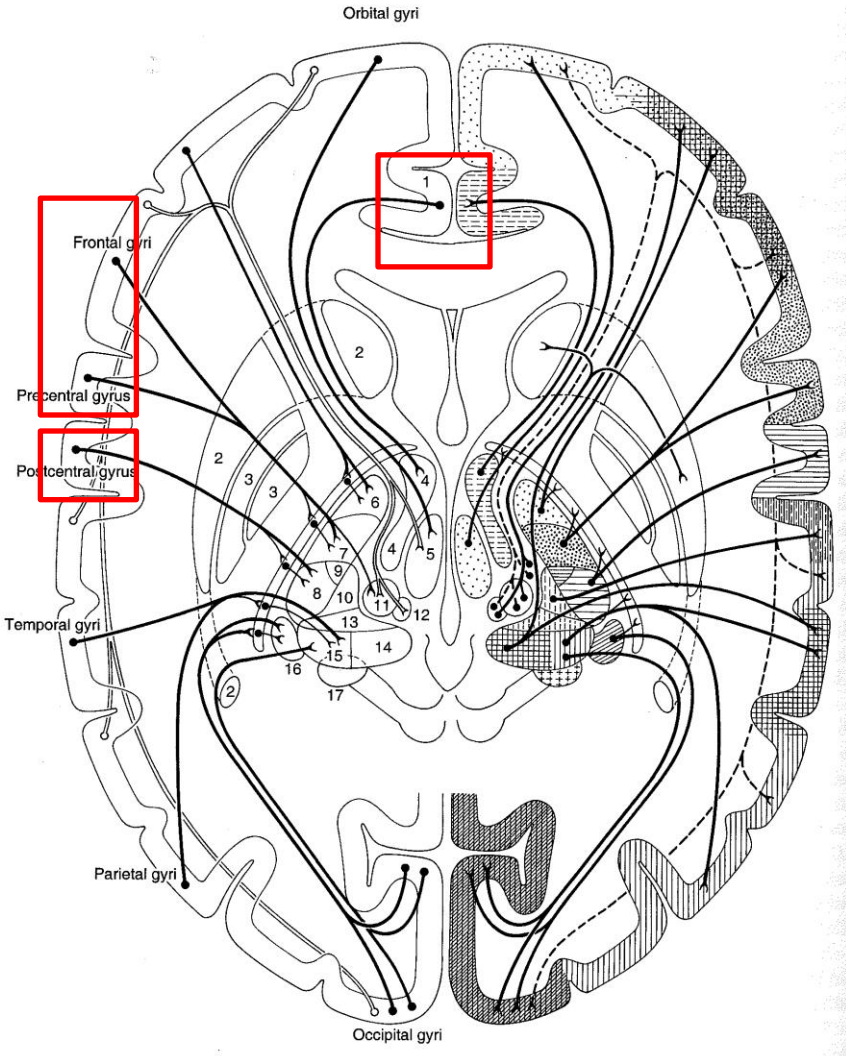
- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex
  - Emotion
  - Motor



Niewenhuys et al. (2008). The Human Central Nervous System, 4th Ed.

Thalamocortical Pathways

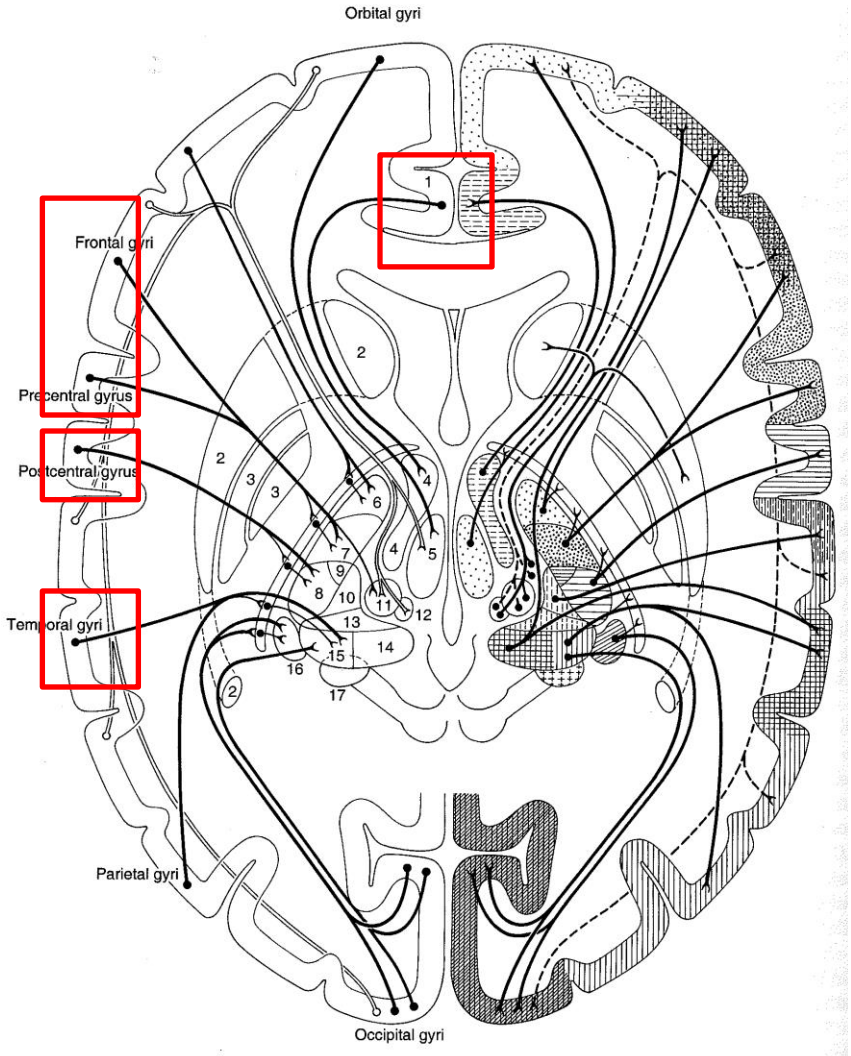
- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex
  - Emotion
  - Motor
  - Somatosensory



Niewenhuys et al. (2008). The Human Central Nervous System, 4th Ed.

Thalamocortical Pathways

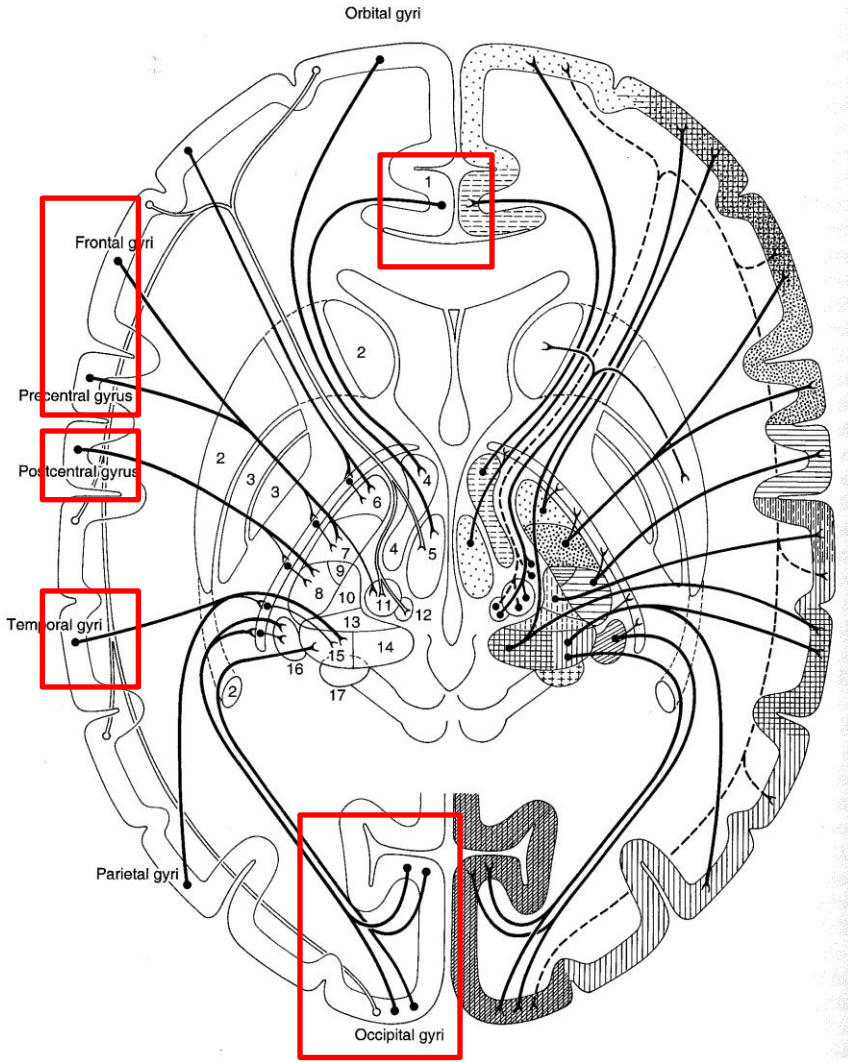
- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex
  - Emotion
  - Motor
  - Somatosensory
  - Auditory



Niewenhuys et al. (2008). The Human Central Nervous System, 4th Ed.

Thalamocortical Pathways

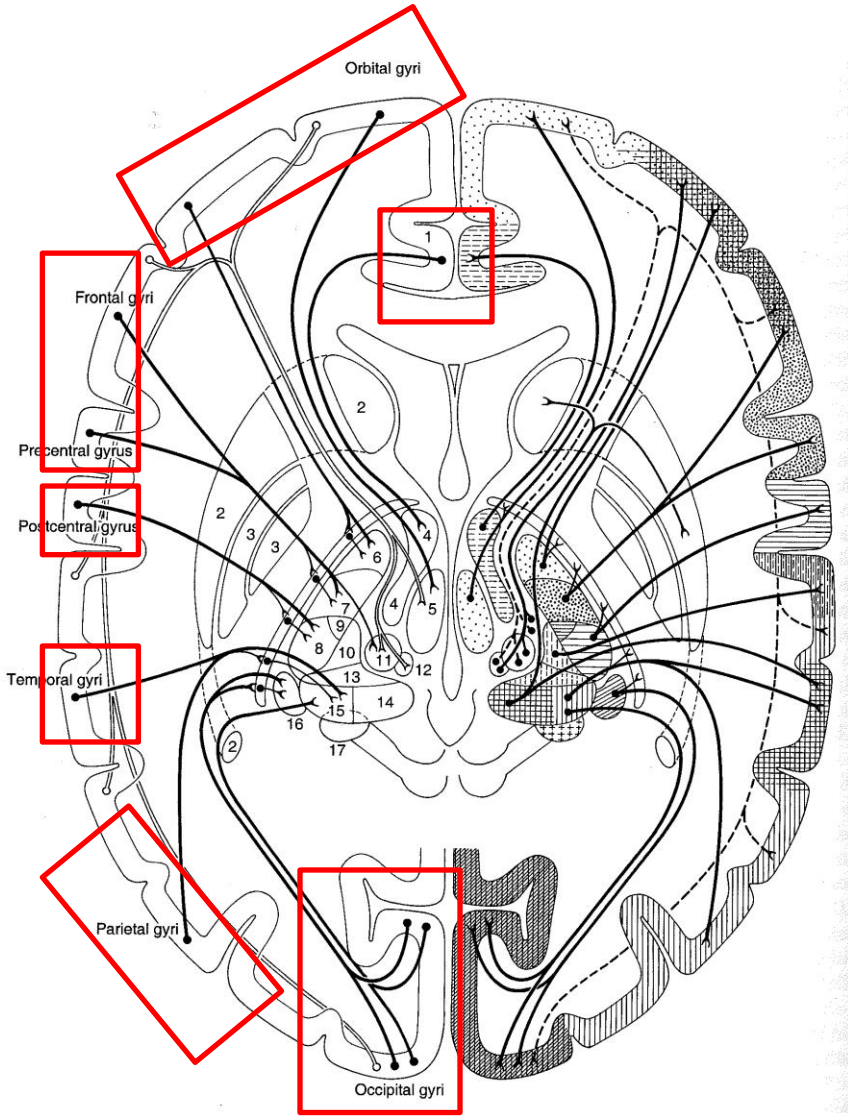
- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex
  - Emotion
  - Motor
  - Somatosensory
  - Auditory
  - Visual



Niewenhuys et al. (2008). The Human Central Nervous System, 4th Ed.

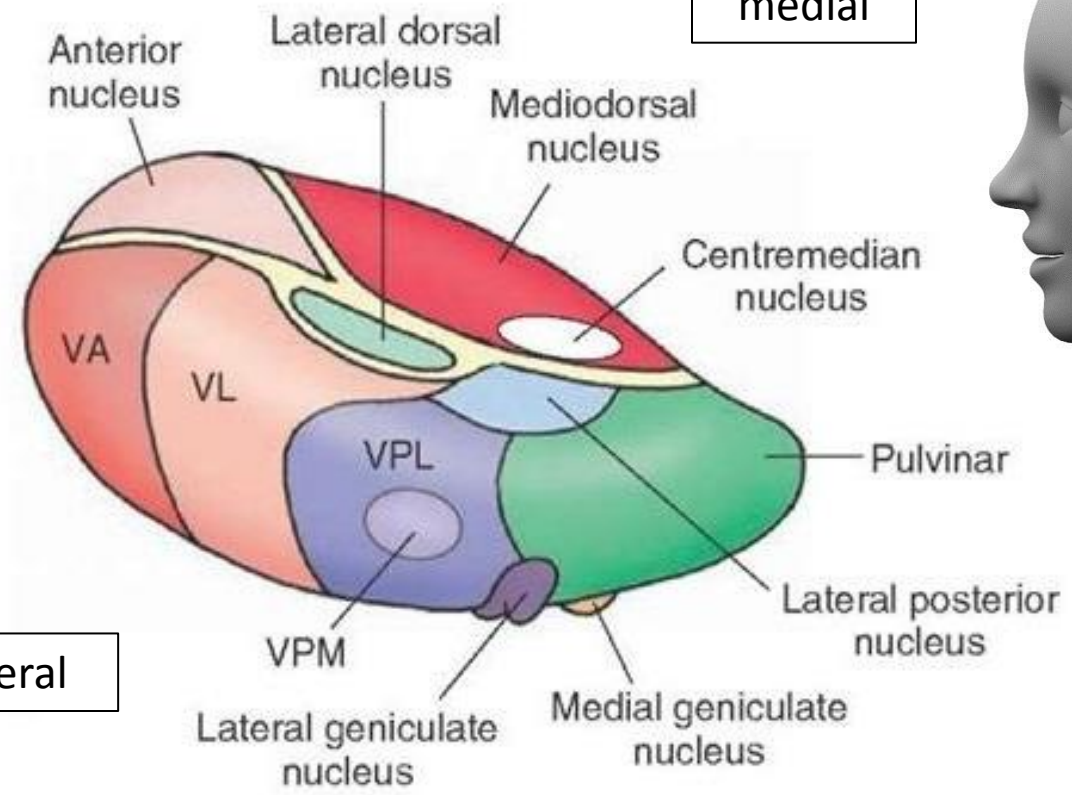
Thalamocortical Pathways

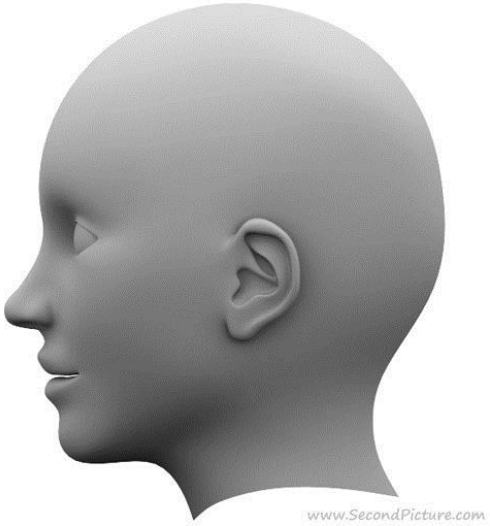
- Relay sensory information to cortex
- Integrate information from different sensory modalities
- Projects throughout cortex
  - Emotion
  - Motor
  - Somatosensory
  - Auditory
  - Visual
  - Association



Niewenhuys et al. (2008). The Human Central Nervous System, 4th Ed.

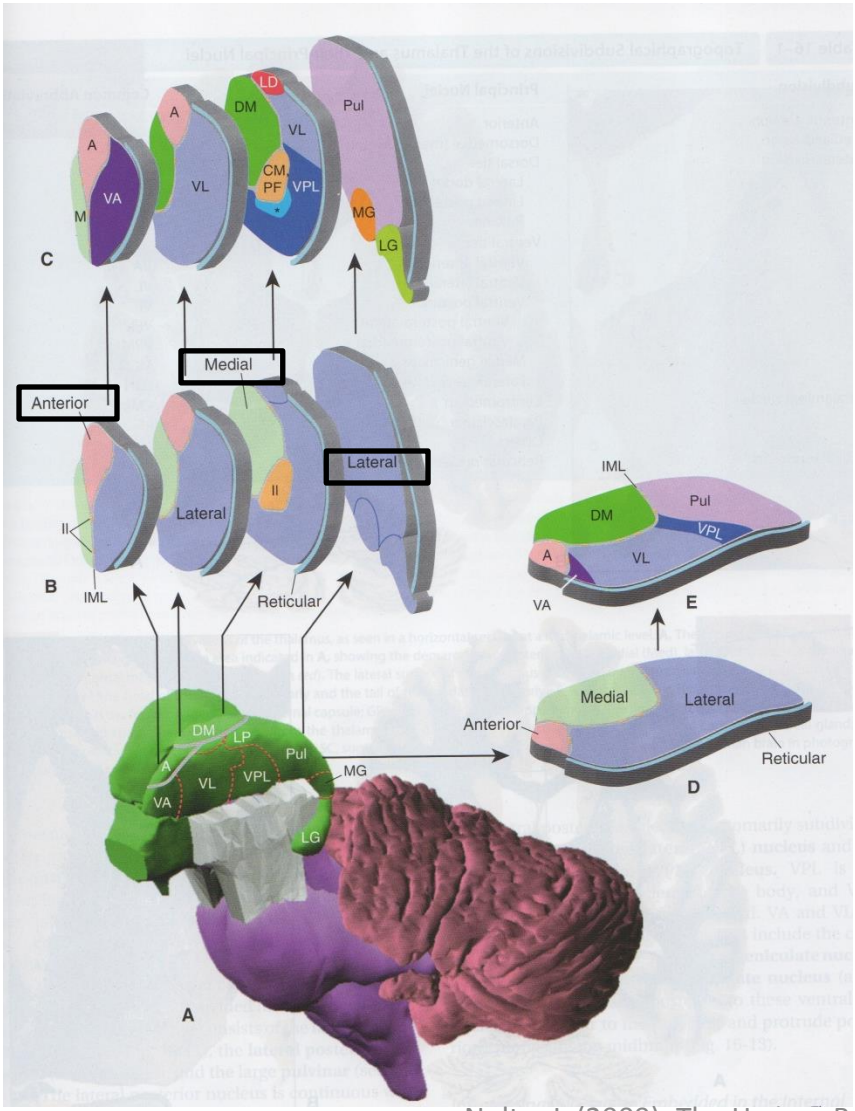
Thalamic Nuclei

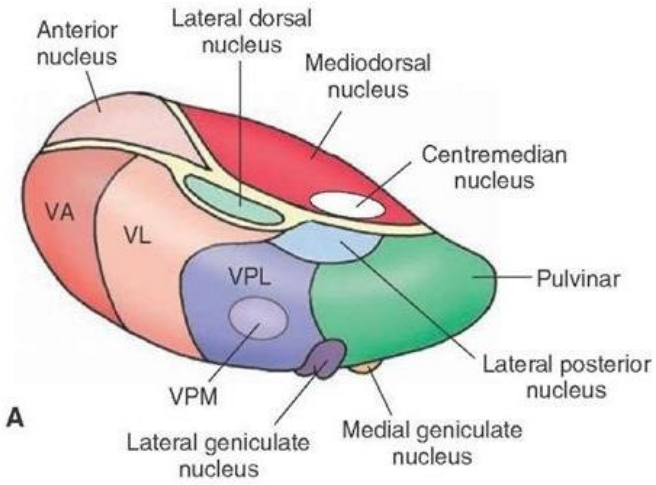




http://what-when-how.com/neuroscience/the-thalamus-and-cerebral-cortex-integrative-systems-part-2/

Thalamic Nuclei

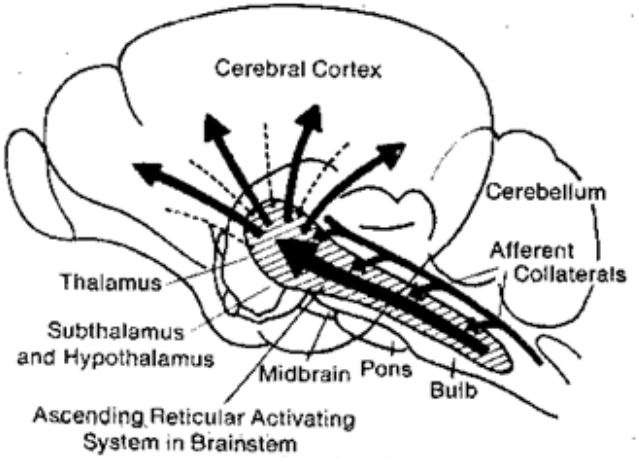


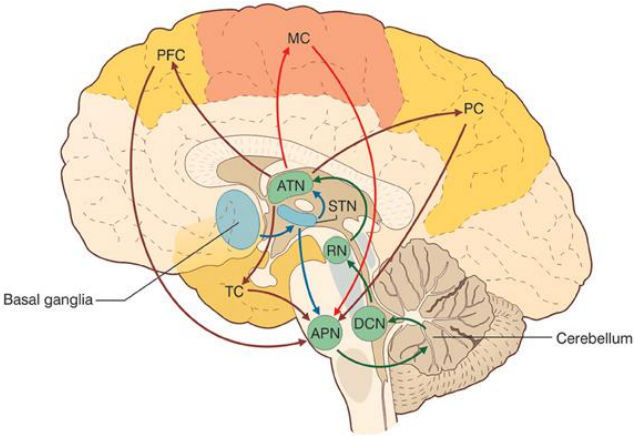


Nolte, J. (2009). The Human Brain: An Introduction to its Functional Neuroanatomy, 6th Ed.
http://what-when-how.com/neuroscience/the-thalamus-and-cerebral-cortex-integrative-systems-part-2/

Categories of Thalamic Nuclei

- Relay Nuclei
  - Project sensory info to distinct sensorimotor cortical areas
- Association Nuclei
  - Cortico-thalamic-cortical connections, project to association regions of cortex
- Nonspecific Nuclei
  - Project to wide range of cortical regions without topographical organization
  - Also project to specific thalamic nuclei





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Afferents & Efferents

Thalamic Inputs

- Relay Nuclei
  - Limbic Structures
  - Basal Ganglia
  - Cerebellum
  - Brain Stem Nuclei
- Association Nuclei
  - Cortical Association Areas

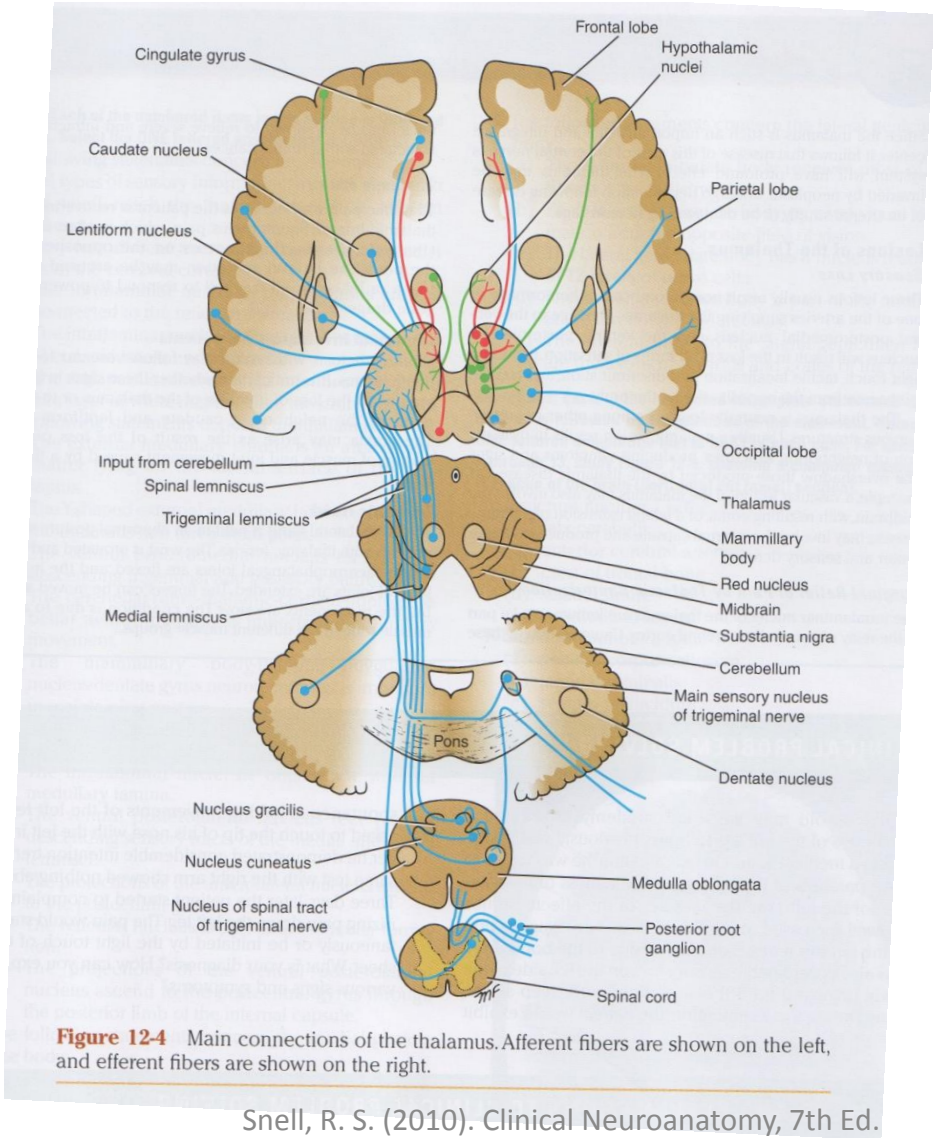
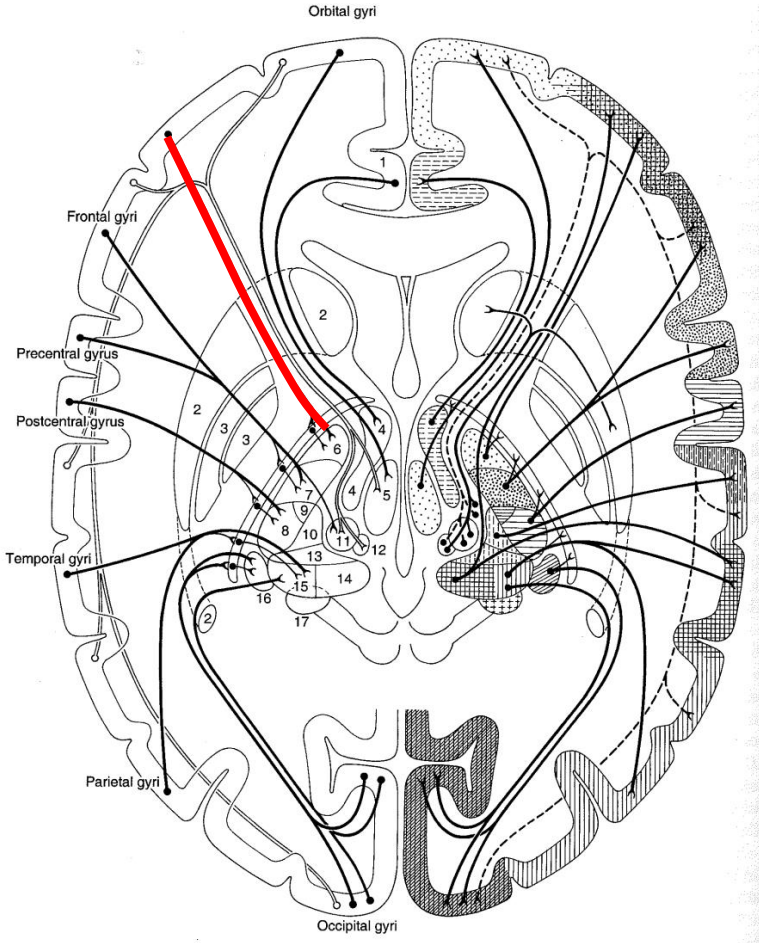


Figure 12-4 Main connections of the thalamus. Afferent fibers are shown on the left, and efferent fibers are shown on the right.

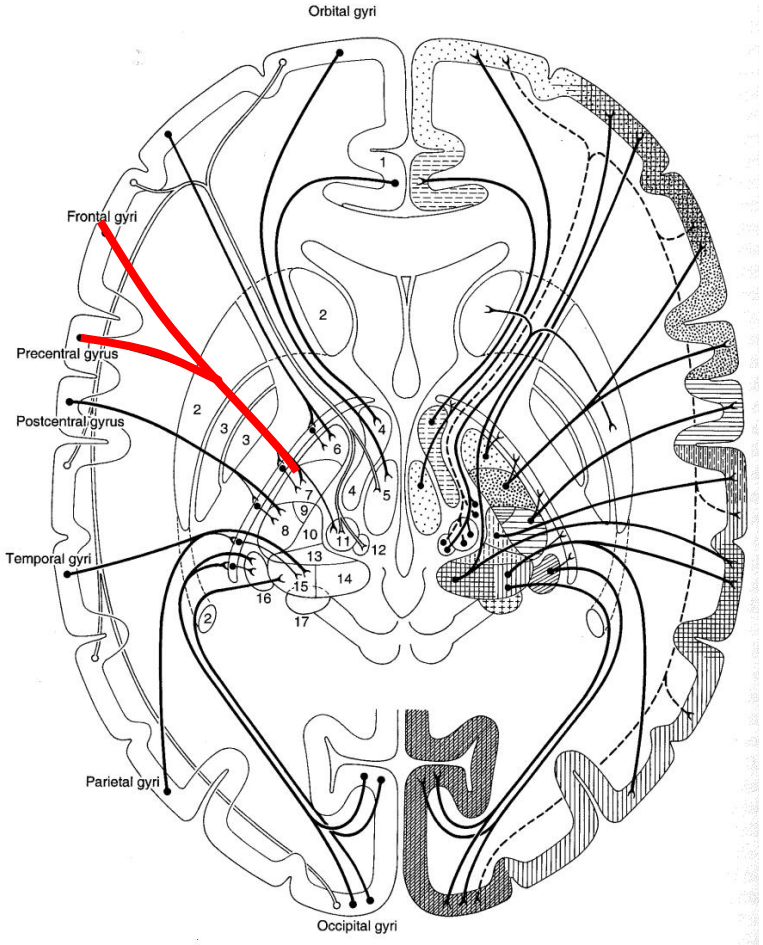
Snell, R. S. (2010). Clinical Neuroanatomy, 7th Ed.

Premotor Pathway



Basal Ganglia → VA → PMC

Motor Pathway

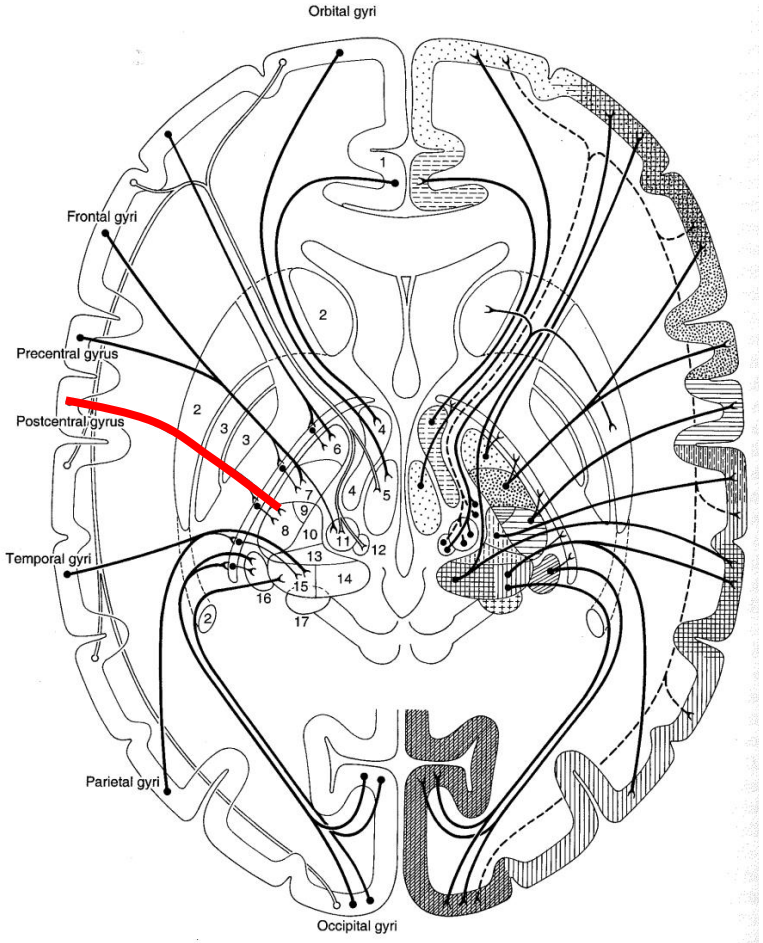


Cerebellum
Basal Ganglia

VL

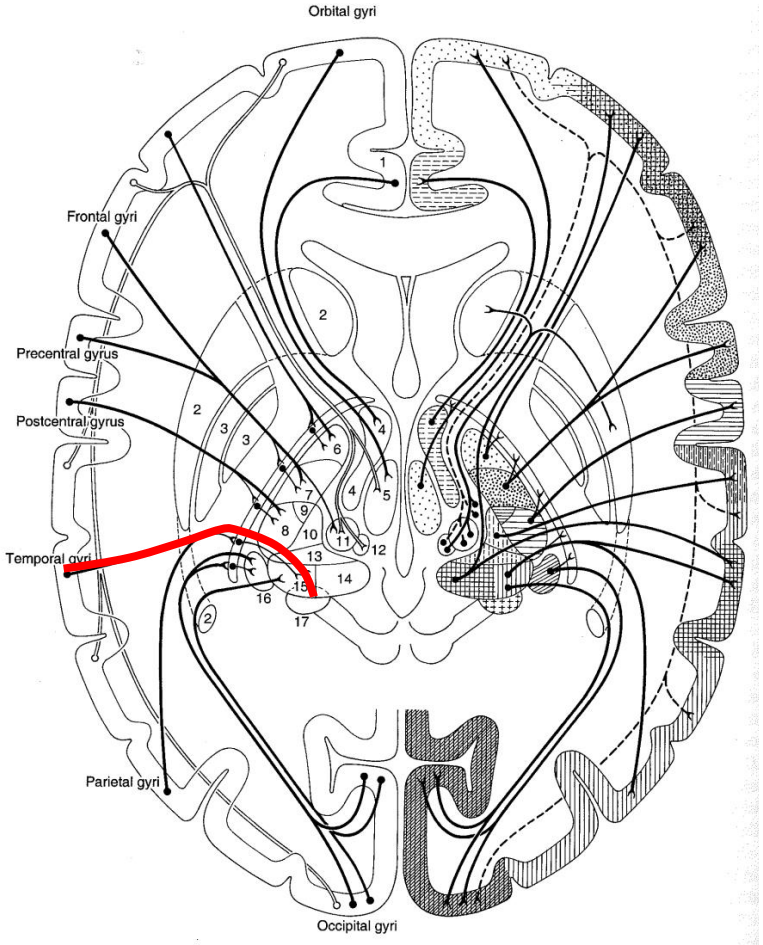
M1

Somatosensory Pathway



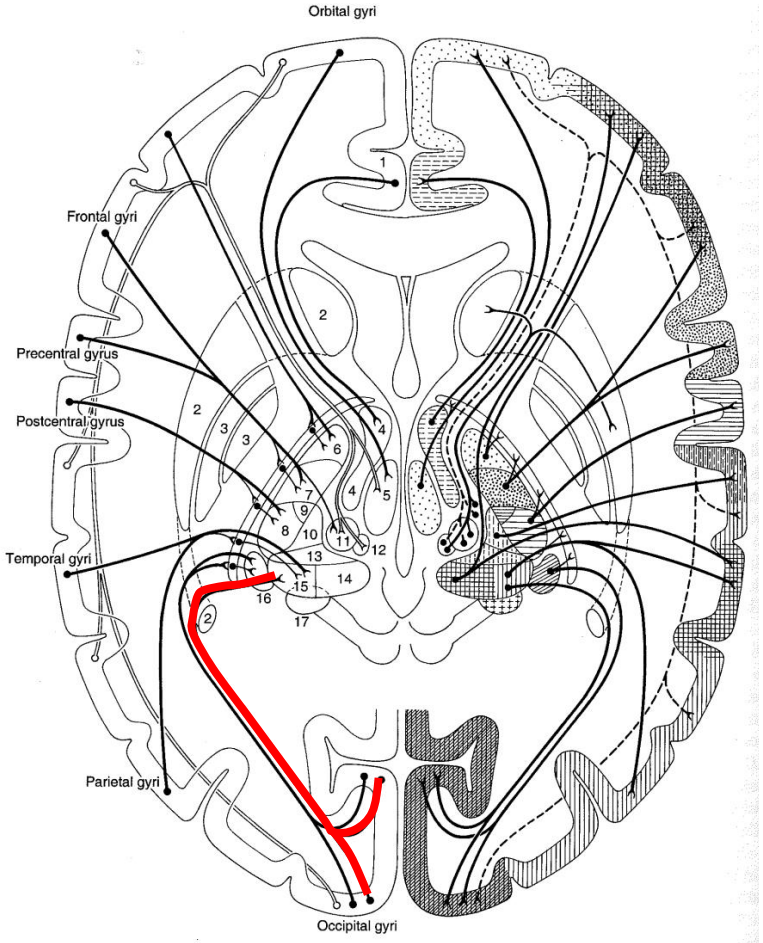
Brainstem → VP → Postcentral Gyrus

Auditory Pathway



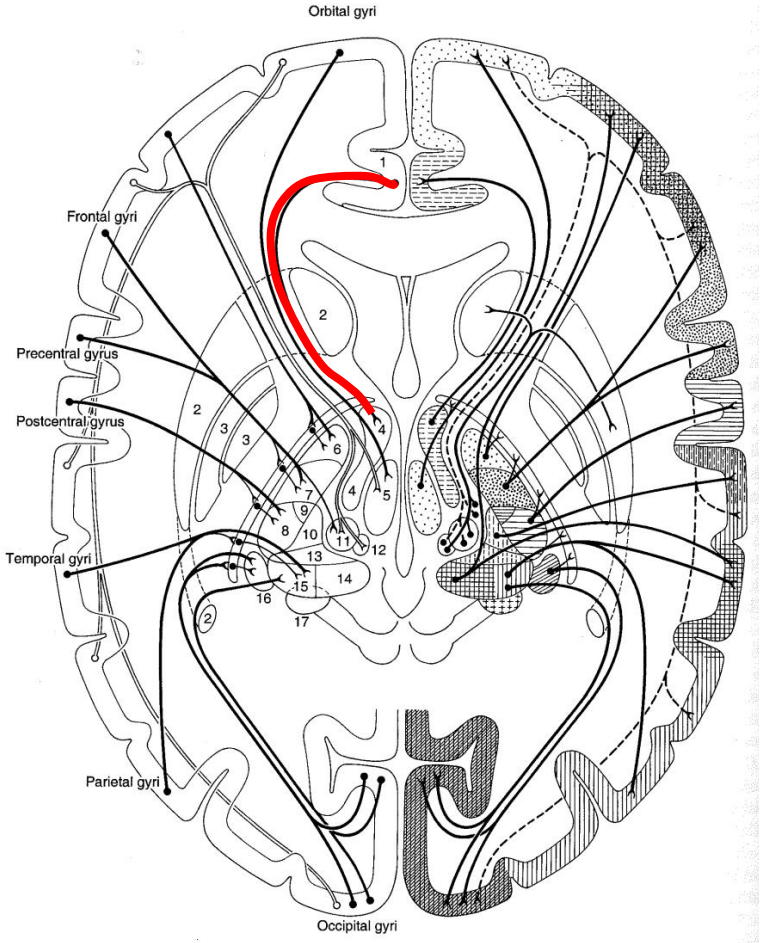
Inferior Colliculus → MGN → Auditory Cortex

Visual Pathway



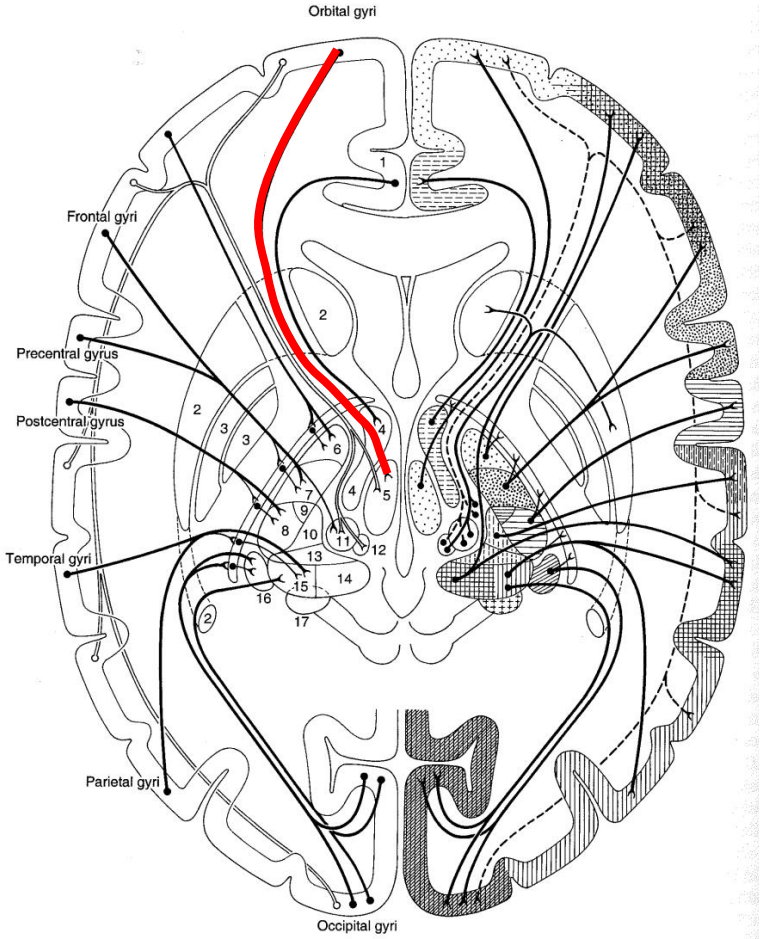
Optic Tract ⇨ LGN ⇨ Visual Cortex

Limbic Pathway



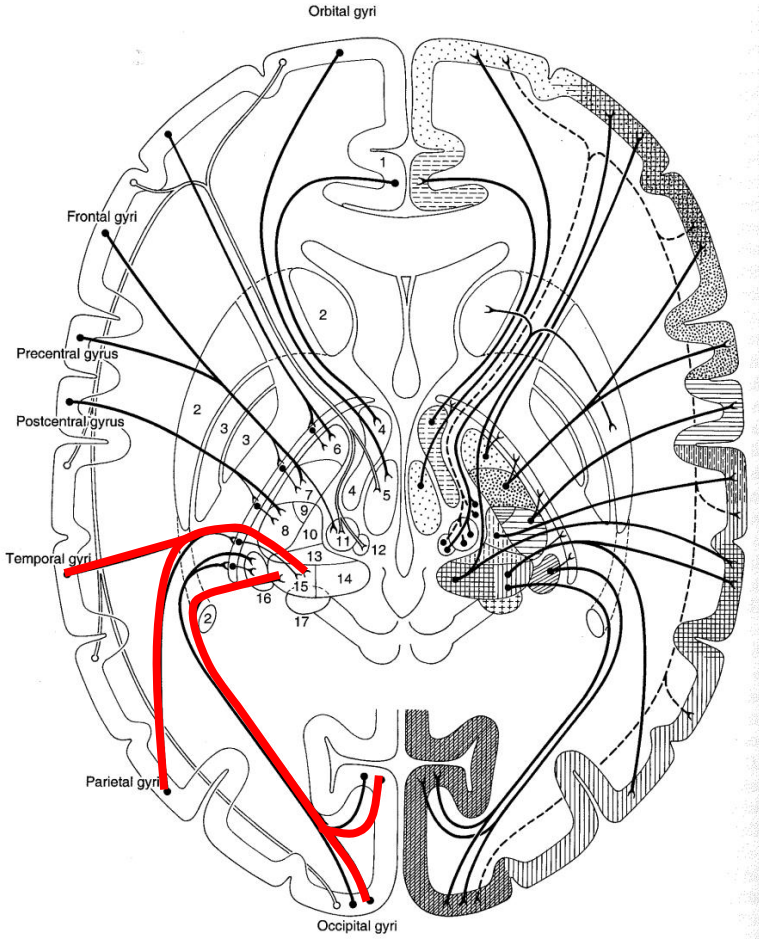
Mammillothalamic Tract → AN → Cingulate Cortex

Prefrontal Association Pathway



PFC → DM → PFC

Parietal-Occ-Temp Assoc. Pathway



Association Cortices
Superior Colliculus

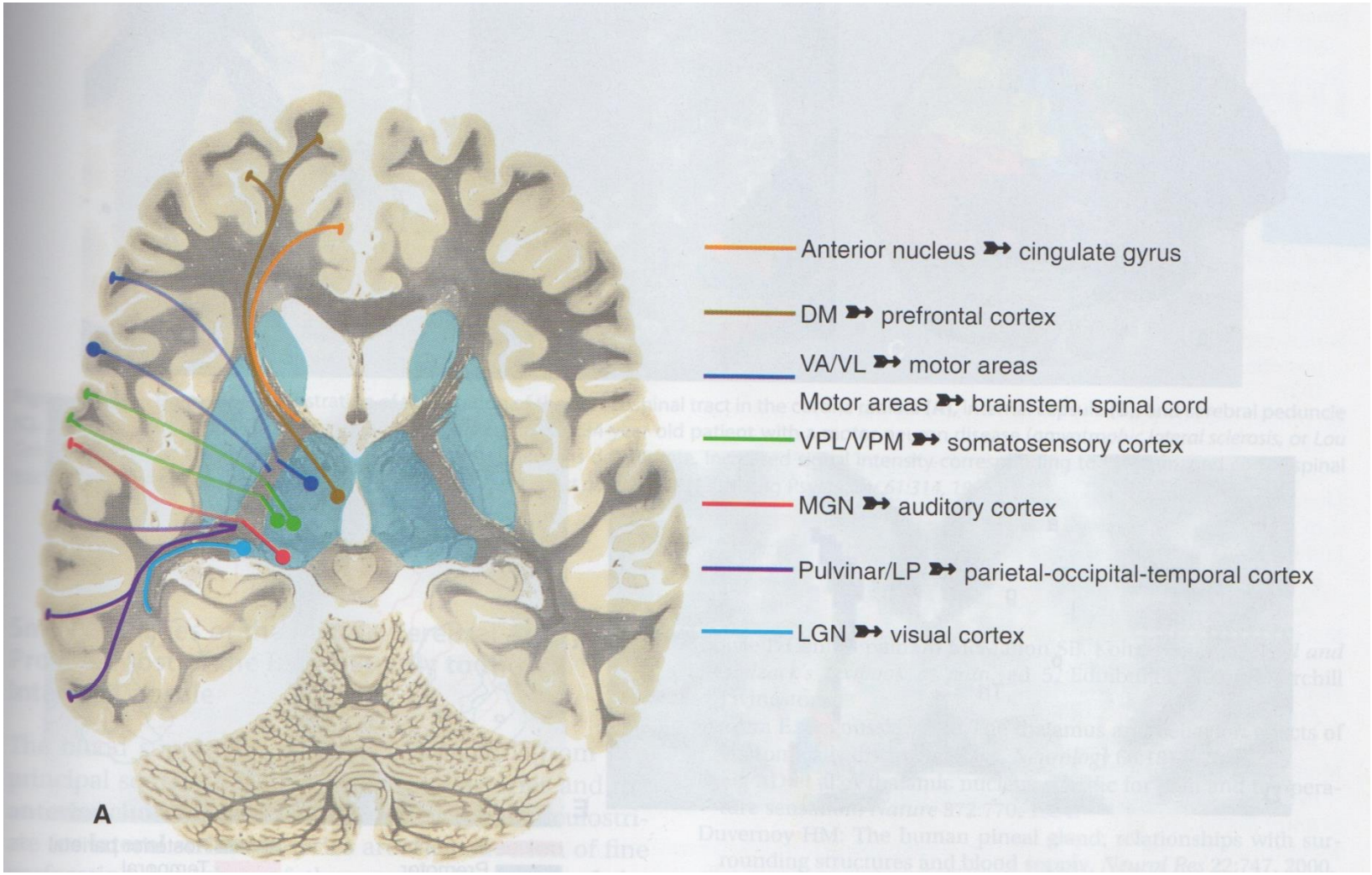
→

Pulvinar/LP

→

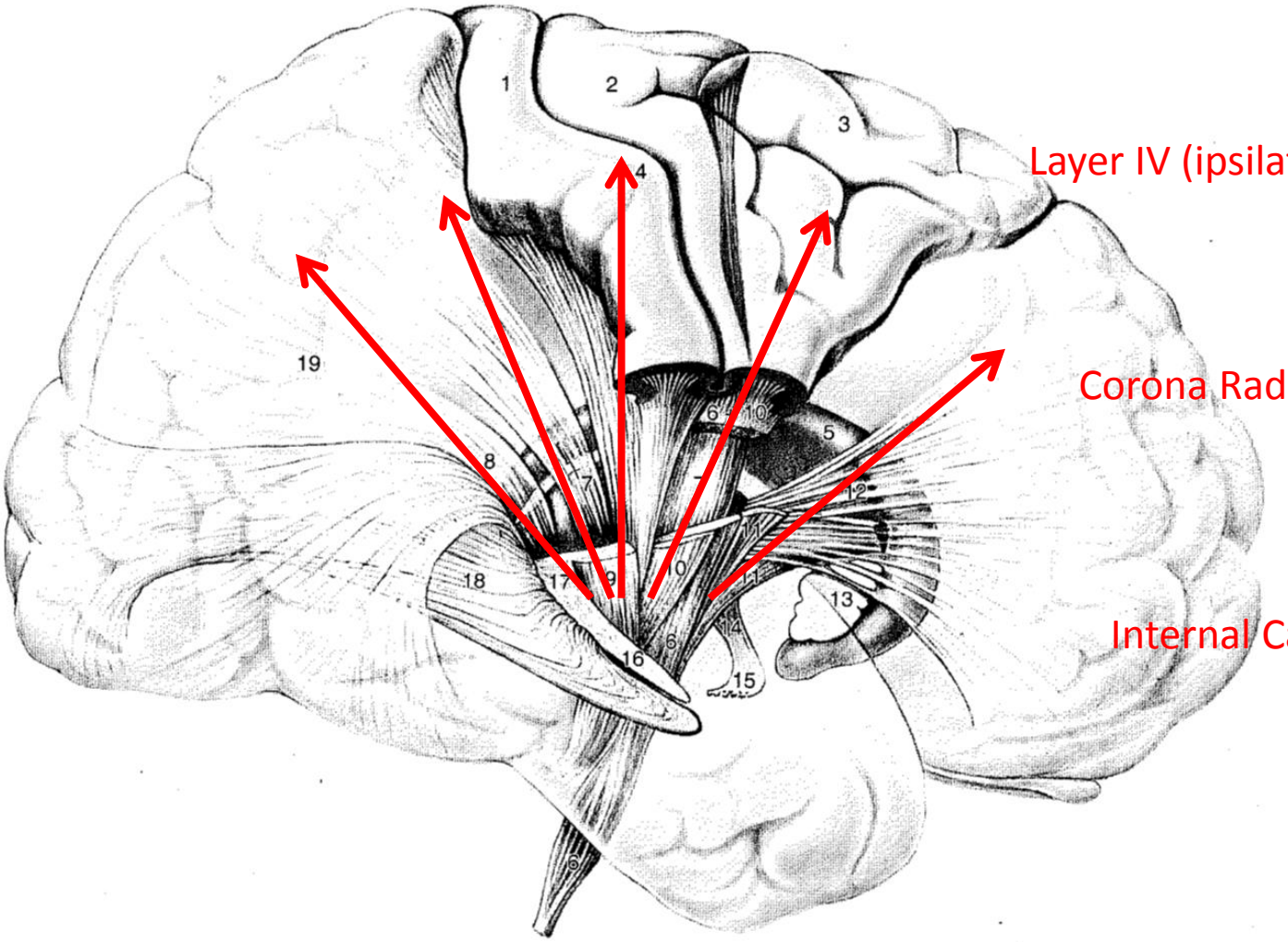
Parietal-Occipital-Temporal Association Cortex

Anterior-Posterior Topography



Nolte, J. (2009). The Human Brain: An Introduction to its Functional Neuroanatomy, 6th Ed.

Path

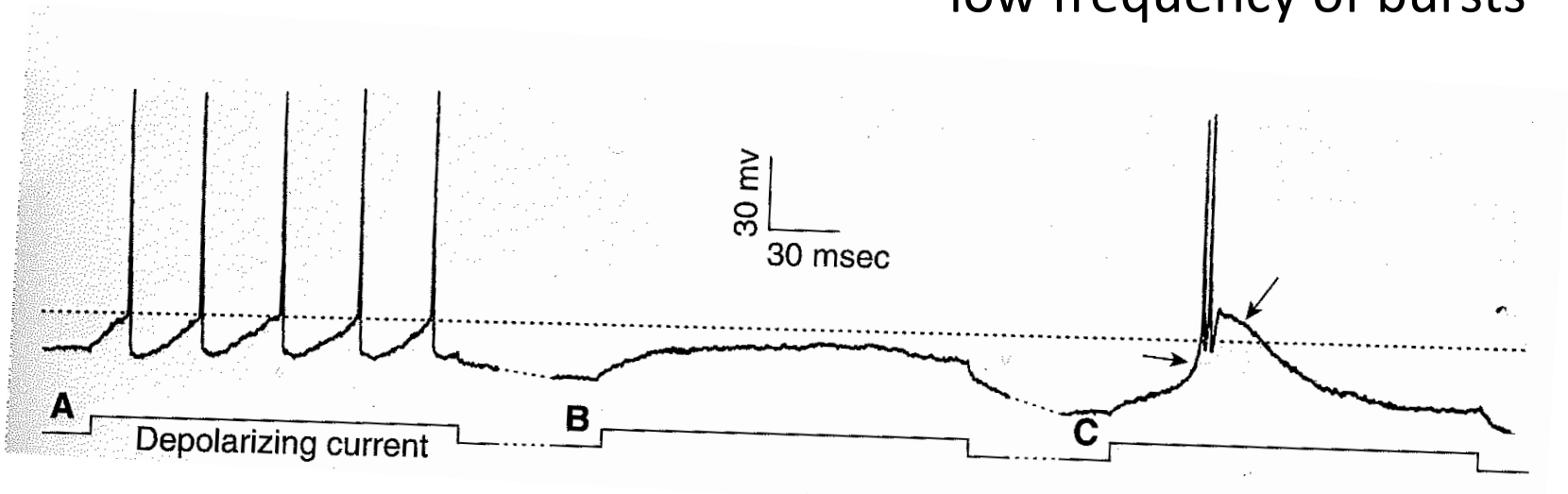


Niewenhuys et al. (2008). The Human Central Nervous System, 4th Ed.

Neurophysiology

Two Physiological States

- Tonic Mode
  - Slightly depolarized
  - Accurately transmits info
  - Focuing attention on stimulus, thought or task
- Burst Mode
  - “lookout function”
  - Very sensitive to input
  - Can’t accurately convey input info because of low frequency of bursts

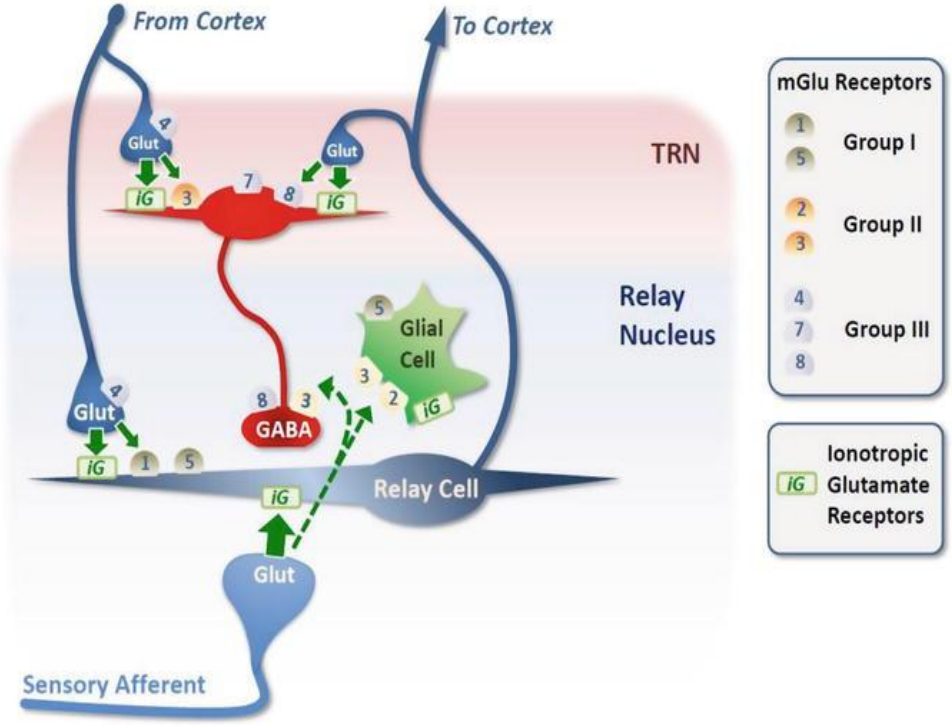


Nolte, J. (2009). The Human Brain: An Introduction to its Functional Neuroanatomy, 6th Ed.

Neurochemical Systems

Neurochemical Systems

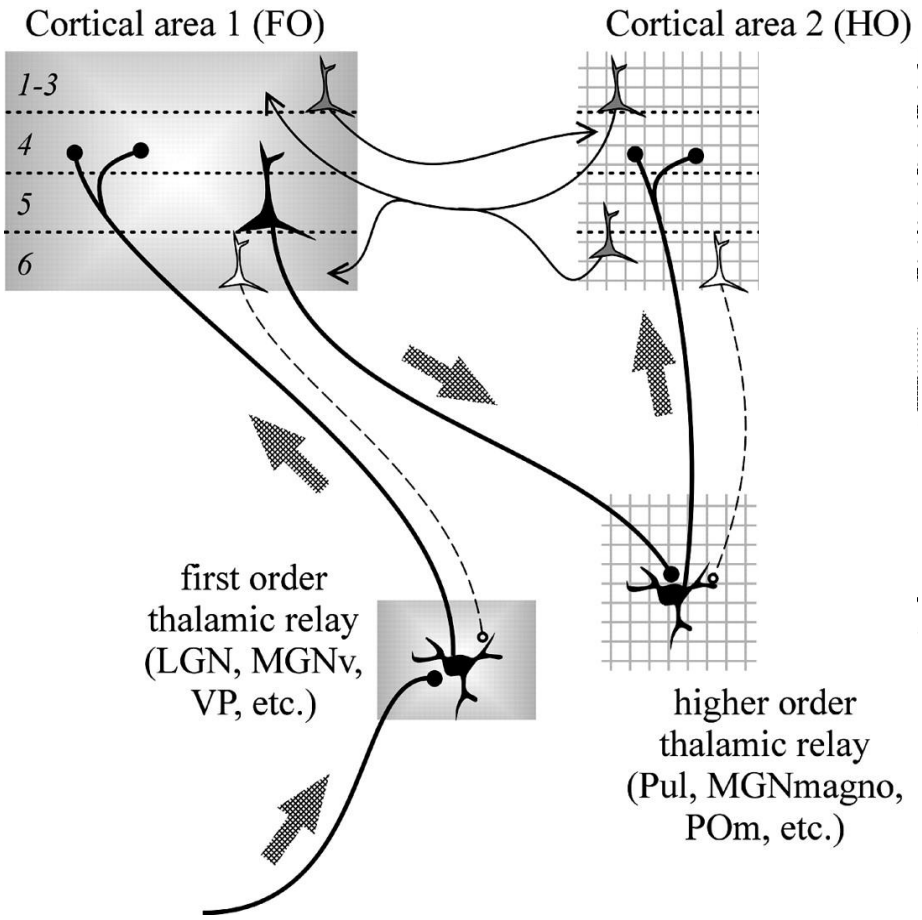
- Most thalamic relay neurons are glutamatergic
- More sensory input → faster firing to cortex



Salt, T.E. (2013). Metabotropic Glutamate Receptors in the Thalamus. Encyclopedia of Pain, 1837-42.

Corticothalamic Regulation

- Thin type-1 fibers
  - Modulatory feedback onto sensory relays
- Course type-2 fibers
  - Feedforward mechanism in cortico-thalamo-cortical circuits

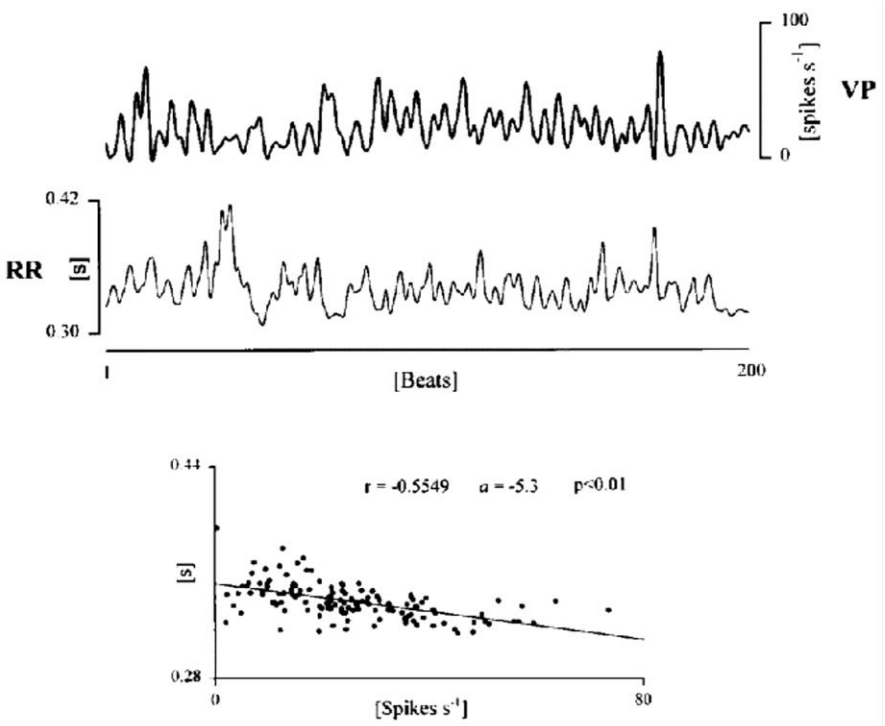


Reichova & Sherman (2004). J Neurophys. 92, 2185-2197.

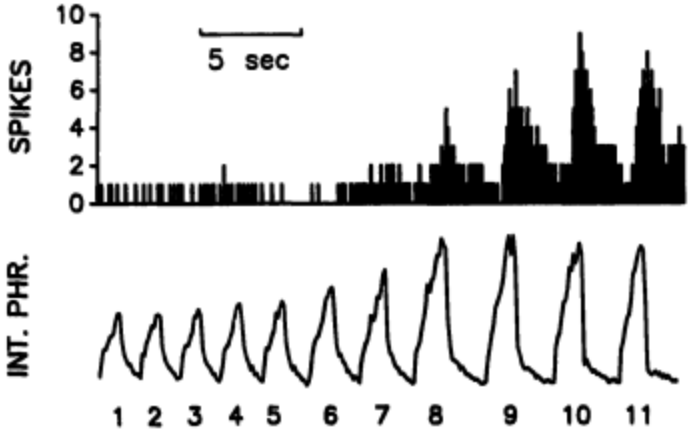
Physiological Correlates

Heart Rate & Respiration

- Negative correlation between VP firing and heart rate intervals in cat.



- Thalamic neurons carry information about the magnitude of respiratory activity

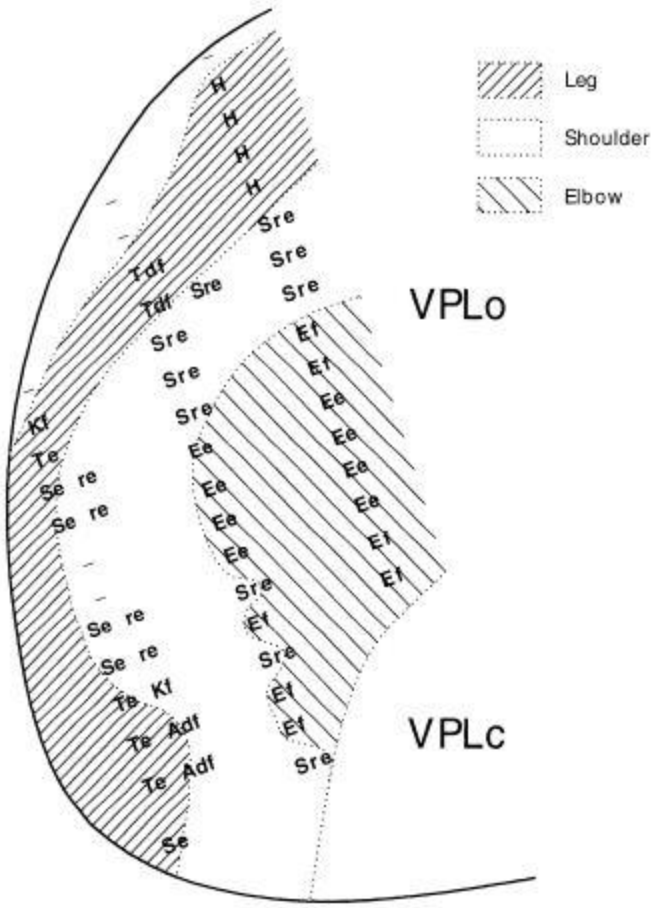


Chen et al. (1992). Resp Phys. 90, 91-113
Massimini, M. et al. (2000). J Physiol. 526, 387-396

Behavioral Correlates

Motor Movements

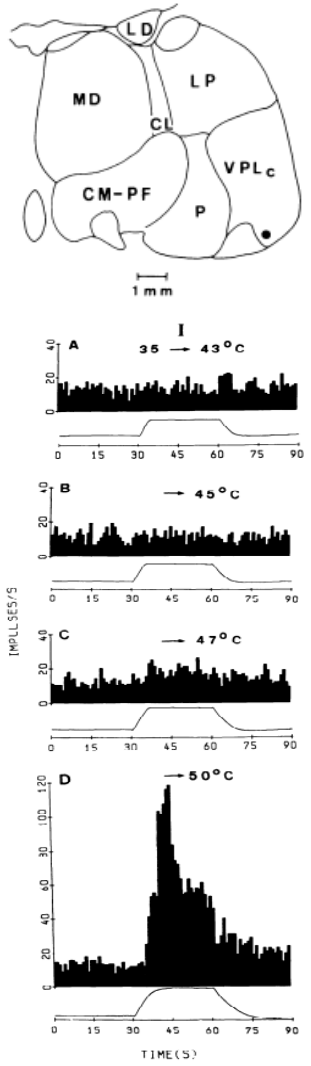
- Somatotopic arrangement of motor movements induced by microstimulation of motor thalamus in primate



Vitek et al. (1996). Journal of Neurophysiology, 72, 2486-95.

Pain Perception

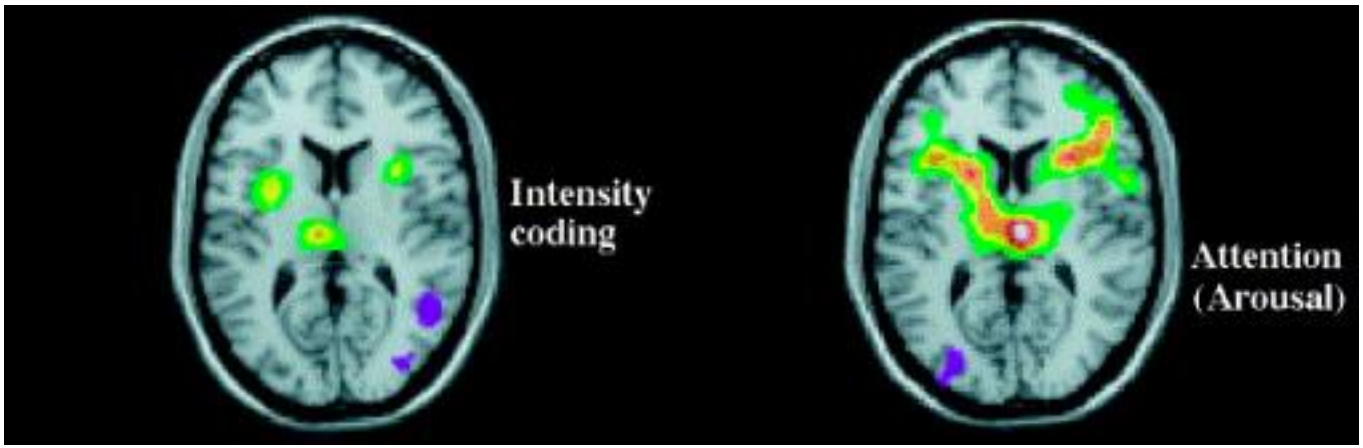
- VPL cells show large response to noxious heat stimulation

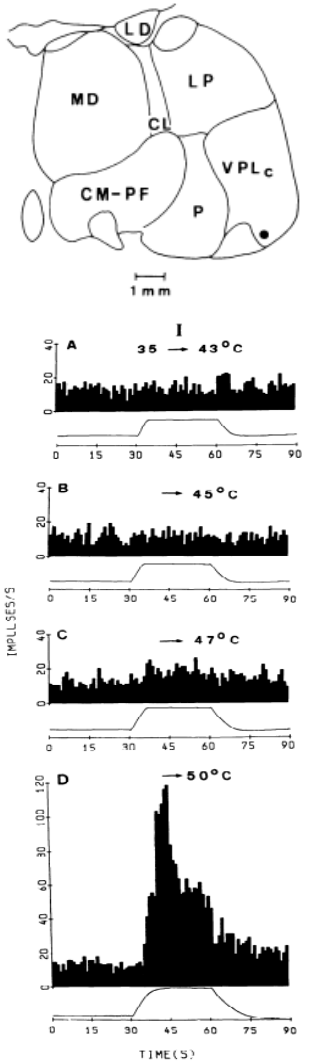


Peyron et al. (2000). Clin Neurophys. 30, 263-288.
Kenshalo et al. (1980). J Neurophys. 43, 1594-1614.

Pain Perception

- VPL cells show large response to noxious heat stimulation
- Implicated in attention/arousal to pain stimuli in humans





Peyron et al. (2000). Clin Neurophys. 30, 263-288.
Kenshalo et al. (1980). J Neurophys. 43, 1594-1614.

Auditory Perception

- MGN essential for auditory avoidance conditioning

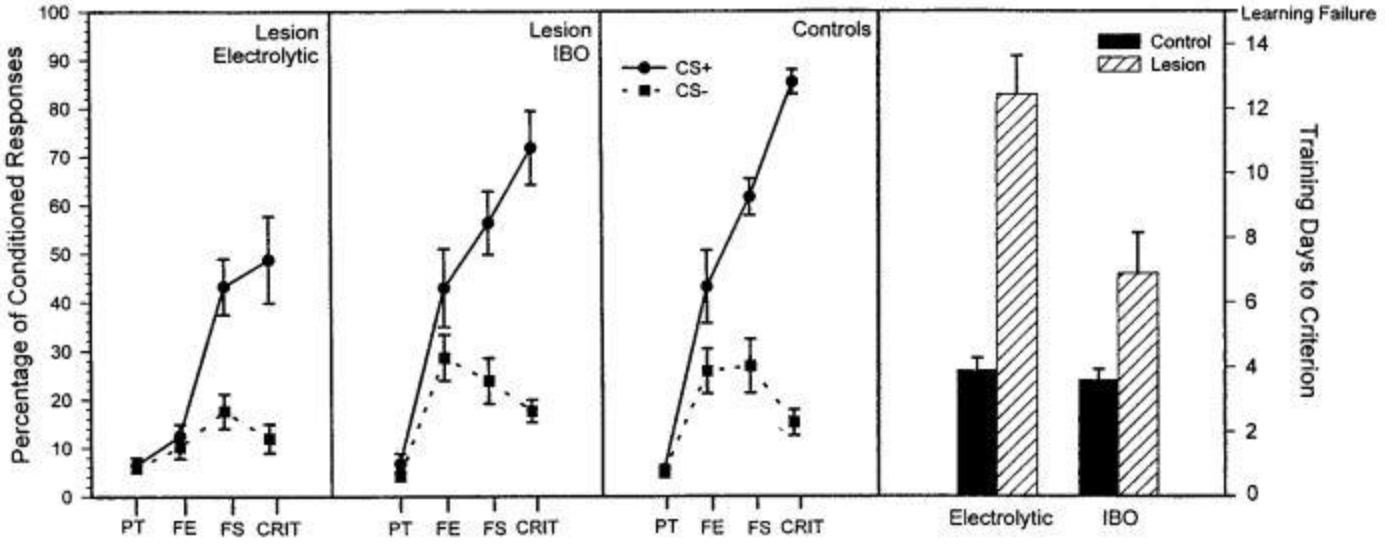
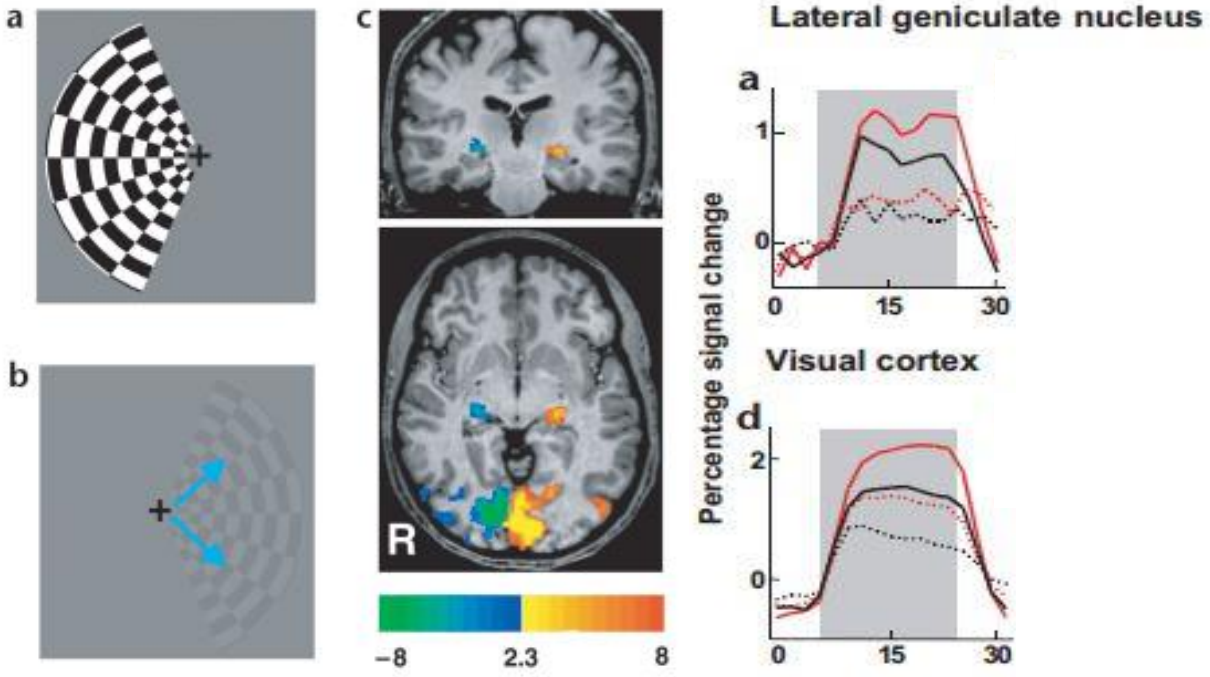


Figure 3. Percentage of conditioned avoidance responses (*left y* axis) performed in response to the CS+ and CS− is plotted for the electrolytic lesion group (*left panel*), the ibotenic acid lesion group (*second panel* from *left*), and the control group (*third panel* from *left*). The *right panel* shows the number of training sessions (days) required for attainment of the criterion of behavioral acquisiiton. The plotted values in the *right panel* refer to the *right* y-axis. *Filled bars* represent the control groups, and *hatched bars* represent electrolytic and Ibotenic acid lesion groups. *PT*, Pretraining; *FE*, session of the first exposure to paired CS+ and US training trials; *FS*, session in which the first significant behavioral discrimination occurred; *CRIT*, session in which the criterion was attained.

Poremba & Gabriel (1997). J Neurosci, 17, 8645-55

Visual Attention

- Attention to visual stimuli associated with increased BOLD activation in LGN and visual cortex in human

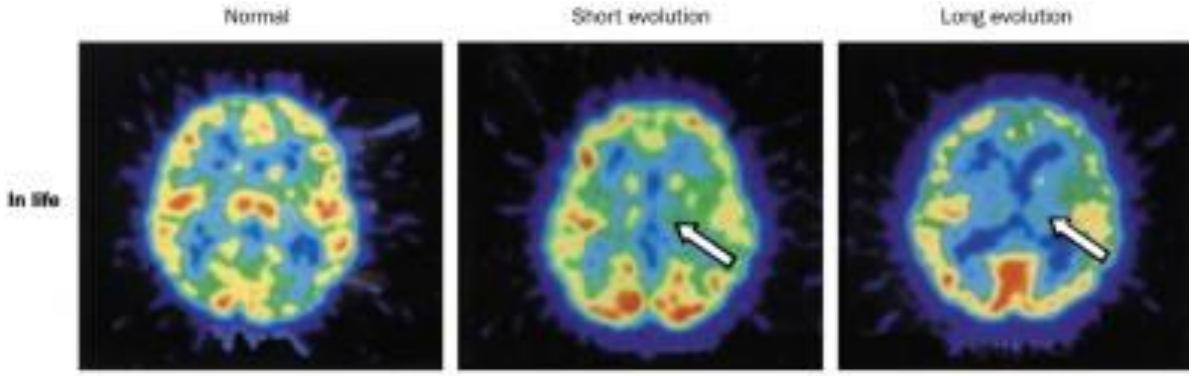


O'Connor et al. (2002). Nature Neuroscience, 5, 1203-1209.

Clinical Pathologies

Fatal Insomnia

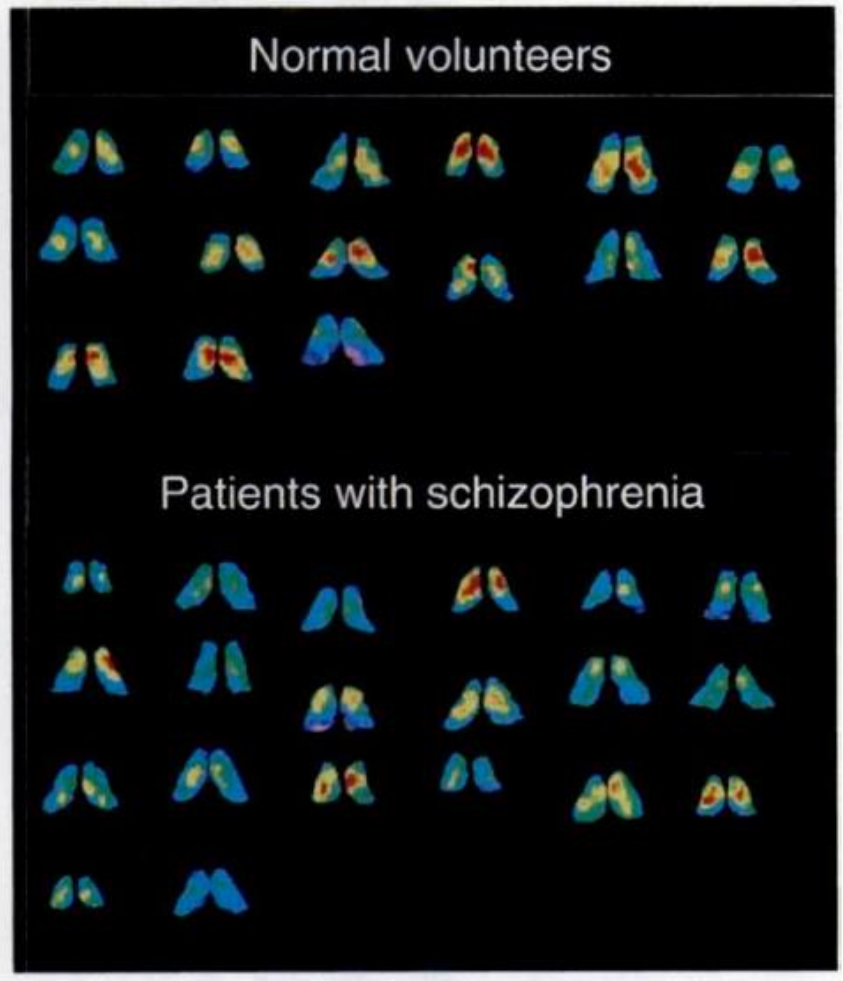
- Accumulation of prion proteins in mediodorsal and anterior thalamic nuclei
  - Disrupted sleep
  - Autonomic hyperactivity
  - Cognitive deficits
  - Motor abnormalities
    - Sudden motor contractions
    - Ataxia (lack of motor coordination)
    - Dysphagia (Difficulty swallowing)



Montagna et al. (2003). Lancet Neurology, 2, 167-176.

Schizophrenia

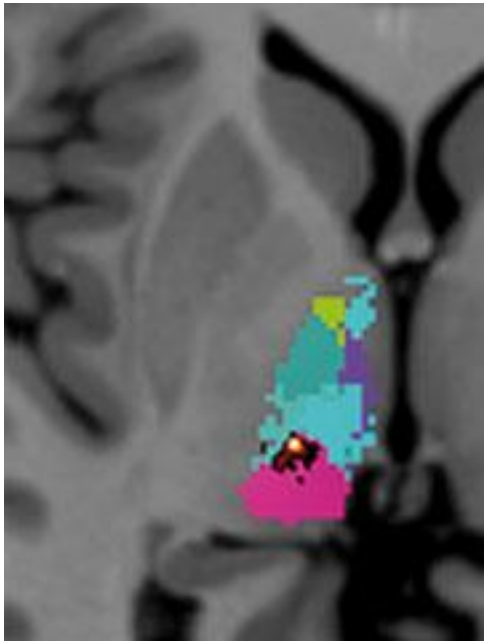
- Reduced volume and neuronal density of MD
- Greater mean diffusivity
  - Correlated with working memory performance
- Reduced FA of thalamocortical tracks in chronic patients
- Implicates degeneration of thalamic nuclei in pathophysiology of schizophrenia



Buchsbaum et al. (1996). Am J Psychiatry, 153, 191-199.
Catani et al. (2012). Atlas of Human Brain Connections

Thalamic Pain Syndrome

- VPL/VPM lesions causing damage to spinothalamic fibers
- Thalamic pain: Intense pain triggered by somatosensory stimuli
- Hemianesthesia: Loss of somatic sensation in contralateral head or body
- Sensory ataxia: loss of coordination (due to loss of proprioception)



Bible (2012). Nat Rev Neurology, 8, 412.

Symptoms of Thalamic Injury

Pathway	Thalamic groups	Principal nuclei	Function	Symptoms
Limbic	Anterior thalamic group	Anterodorsal (AD) Anteroventral (AV) Anteromedial (AM)	Limbic functions such as memory and learning, emotion, drive and motivation	Amnesia, language difficulties (reduced spontaneous speech, anomia)
Prefrontal Association	Medio-dorsal nucleus (MD) and Midline (Mid) group		Drive, motivation, emotion, executive functions, working memory, attention, autonomic and sleep-wake cycle regulation.	Apathy, abulia, disinhibition, working memory deficits, sleep dysregulation
Premotor	Ventral group	Anterior (VA)	Complex behaviour, motor programming	Dystonia, language impairment (reduced fluency, perseveration, stuttering), behavioural problems
Motor		Lateral – anterior (VLa) – medial (VLm) – posterior (VLp)	Motor, language, and memory	Ataxia, mild motor weakness, language, memory difficulties
Somatosensory		Posterior – lateral (VPl) – medial (VPm) – inferior (VPi)	Somatosensory (body and limb) Somatosensory (head and neck), gustatory Vestibular	Dejerine-Roussy disease (thalamic pain syndrome); contralateral hemianesthesia (typically for all sensory modalities) of body and limbs (VPl) or head and neck (VPm)
Par-Occ-Temp Association	Lateral group	Dorsal (LD) Posterior (LP) Pulvinar (Pul)	Visual-sensory-motor integration and visual salience (discriminating relevant from irrelevant visual stimuli)	Impaired visual discrimination, hemispatial neglect, language deficits, psychosis
Visual	Metathalamus	Lateral geniculate nucleus (LGN)	Visual perception	Contralateral homonymous hemianopia (loss of vision in the same visual field on both eyes)
Auditory		Medial geniculate nucleus (MGN)	Auditory perception	Central deafness

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