Thalamus

Shepherd (2004) Chapter 8

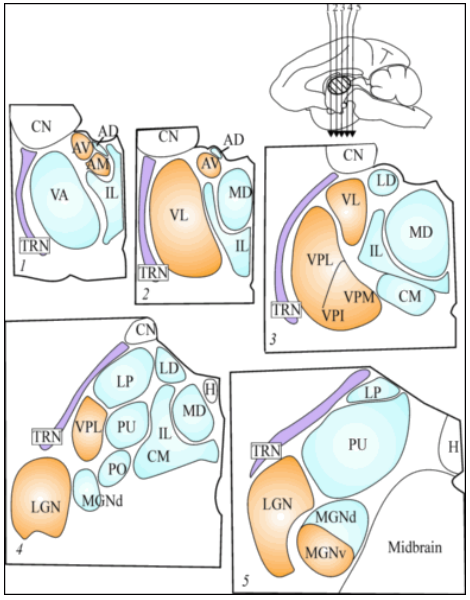
- Thalamus: S. M. Sherman and Ray W. Guillery
- Part of the figures are originally from Sherman and Guillery, *Phil. Trans. Royal Soc. B: Biol. Sci.* 357:1695–1708, 2002.

Instructor: Yoonsuck Choe; CPSC 644 Cortical Networks

The Thalamus: Introduction

- Thalamus derives from the diencephalon.
- Diencephalon consists of: Epithalamus, dorsal thalamus, ventral thalamus, subthalamus, and hypothalamus.
- Thalamus usually refers to dorsal thalamus, and thalamic reticular nucleus (TRN) to part of ventral thalamus.
- Thalamus is divided into numerous subdivisions (nuclei).
- Dorsal and ventral thalamus communicate with the cortex (both ways!) and other areas (striatum and amygdala, etc.).
- Thalamus is the major way-station to the cortex.

Major Nuclei in the Thalamus



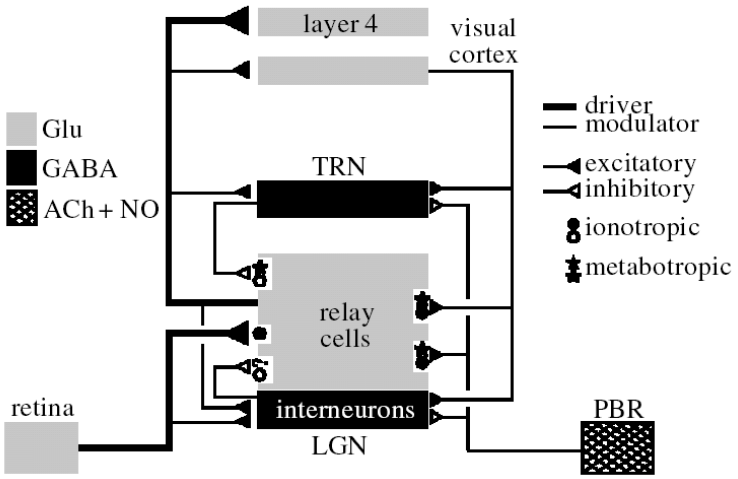
- V (ventral) M (medial) L (lateral) P (posterior) C (centre) D (dorsal) A (anterior) PO (posterior) CN (caudate nucleus)
- Orange: first-order relays
  - VA and VL: from cerebellum, to motor cortex.
  - VP: receives somatosensory signals.
  - MGN: auditory; LGN: visual.
- Others: higher-order relays – receives input (layer 5) and projects to the cortex.
  - MD: from olfactory cortex and amygdala, to frontal cortex.
  - LD: from cingulate, to cingulate.
  - PU: occipital to temporal.
  - IL: from motor cortex, to striatum and cortex.

From: http://www.scholarpedia.org/article/Thalamus.

Major Types of Afferents to Thalamic Nuclei

- Functional and morphologically distinct inputs: drivers vs. modulators.
- LGN: Only 10% input from retina and 90% from other sources. These 10% must be really strong (driver).
- Driver: define receptive field property.
- Modulator: modify the nature of transmission to the cortex.
- Feedback from cortex: layer 5 (driver), layer 6 (modulator?).

Main Connections of LGN



Parallel Pathways and Maps in the Thalamus

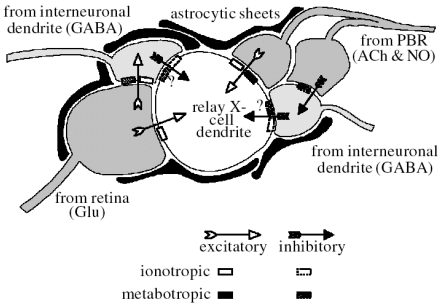
Noninteracting parallel pathways exist:

- Retinal ganglion cell to thalamus:
  - W, X, Y pathways in cat.
  - K, Parvocellular (P: stationary input, slow processing), Magnocellular (M: moving input, fast processing) in monkeys.
- Similar arrangements found in somatosensory thalamus.

Maps in the thalamic nuclei

- Afferents are arranged to form a map, and the projections to the cortex also are organized in a similar manner.

Neuronal Elements in the Thalamic Nuclei



Glomerulus (tight synapses w/o intervening astrocyte):

- Afferent inputs (Round Large).
- Relay cell (main projection to the cortex).
- Interneurons (inhibitory; Flat, F1 and F2): local interaction within the nuclei; almost nonexistent in rat and mouse.

Cortical feedback (Round Small): rarely participates in glomeruli.

Inputs and Outputs of Thalamus

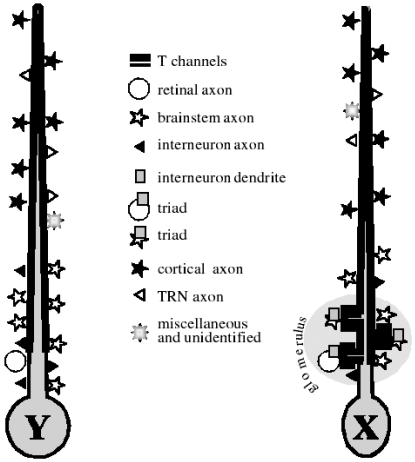
Input

- Driving afferents: from sensory areas or layer 5 of cortex.
- Cortical afferents: modulatory feedback from layer 6
- Inputs from TRN: reciprocal connections with thalamic nuclei. Inhibitory contribution.
- Brainstem afferents: from parabrachial region, etc.

Output

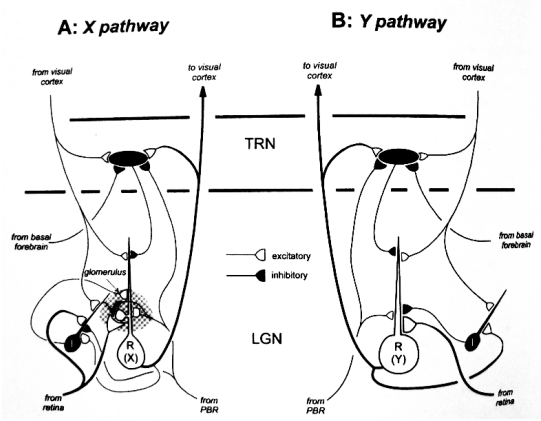
- Relay neurons: only projection outside of the thalamus, mostly to the cortex, and branchs to the TRN.
- Interneurons

Synaptic Connections



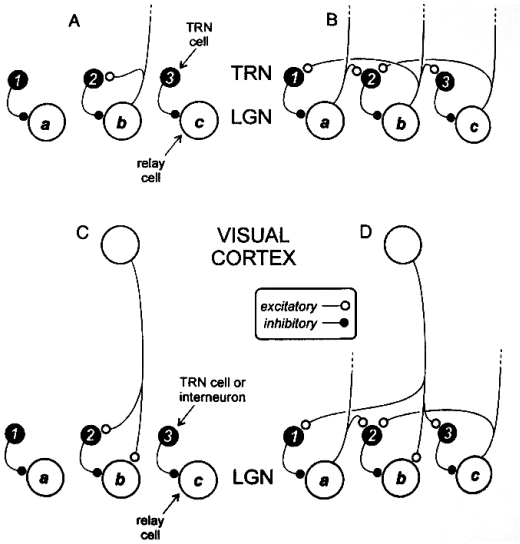
- Relay cells: 4,000–5,000 synapses.
- Location of synapse varies depending on the source.

Basic Neuronal Circuit



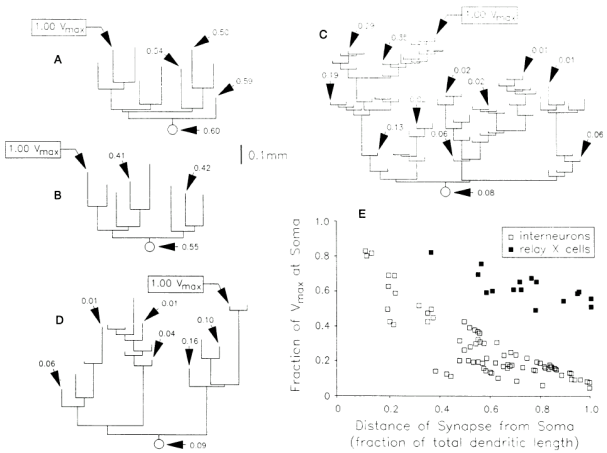
- Cat LGN: X and Y pathways.

Relay–TRN–Cortex Relations



- Several possible scenarios for cortical/reticular feedback.

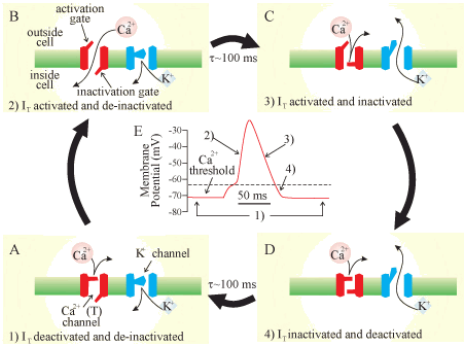
Electrical Properties



A,B: relay cell; C,D: interneuron

- Relay cells are electrotonically compact (not much attenuation en route to the soma). Thus, distal synapses can exert strong influence.

Membrane Properties



- Na^+: Fast inactivating, and persistent non-inactivating.
- Ca^{2+}: high threshold, and low threshold (I_T current generating a spike; only in dendrite and soma).

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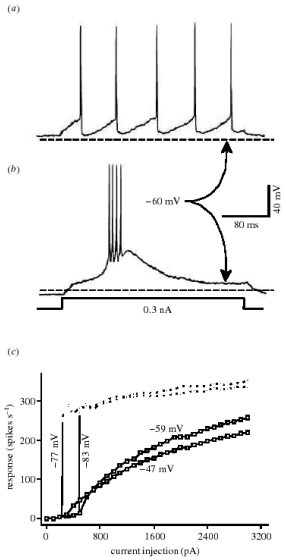
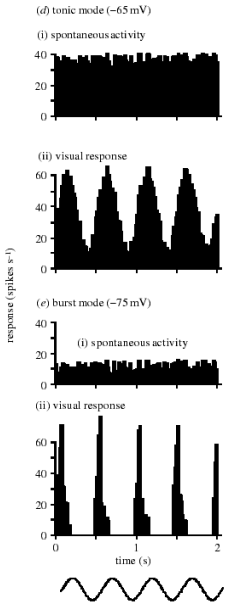
Tonic vs. Low-Threshold Burst Firing



- I_T is inactivated at relatively depolarized state: Tonic mode (regular spiking).
- I_T is de-inactivated at relatively hyperpolarized state: Burst mode (burst firing).

Gating and Transformations



- Tonic: linear
- Burst: nonlinear
- Compare spontaneous firing rate in both cases: Detectability, and signal to noise ratio.