Network model: thalamocortical circuit

Traub, R.D. et al.. Single-column thalamocortical network model exhibiting gamma oscillations, sleep spindles, and epileptogenic bursts. Journal of Neurophysiology 93: 2194-2232, 2005. PMID 15525801.

Authors' goal: "to better understand population phenomena in thalamocortical neuronal ensembles", specifically gamma oscillations, sleep spindles, and how interactions between neocortex and thalamus could produce epileptiform activity.

What are these phenomena?

What cells and networks generate them?

What aspects of biology did the authors represent in this model, and why?

What new insights do the authors say we should have?

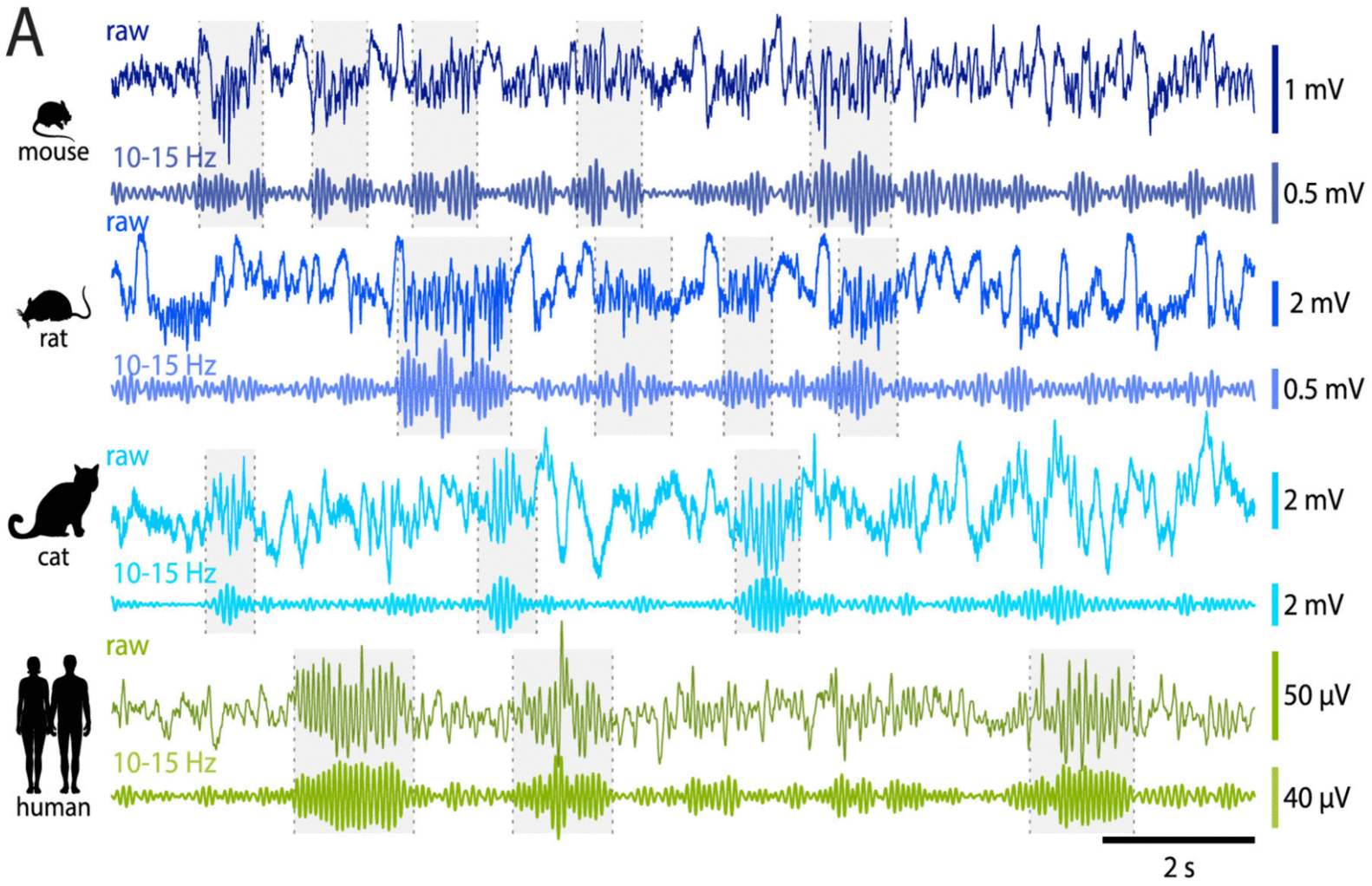
Sleep spindles

Definition (for EEG of an adult human): "train of distinct waves with frequency 11-16 Hz (most commonly 12–14 Hz) with a duration >= 0.5 s" (Iber C et al.. The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications. Westchester, IL: American Academy of Sleep Medicine, 2007).

Charateristically seen in stage 2 sleep.

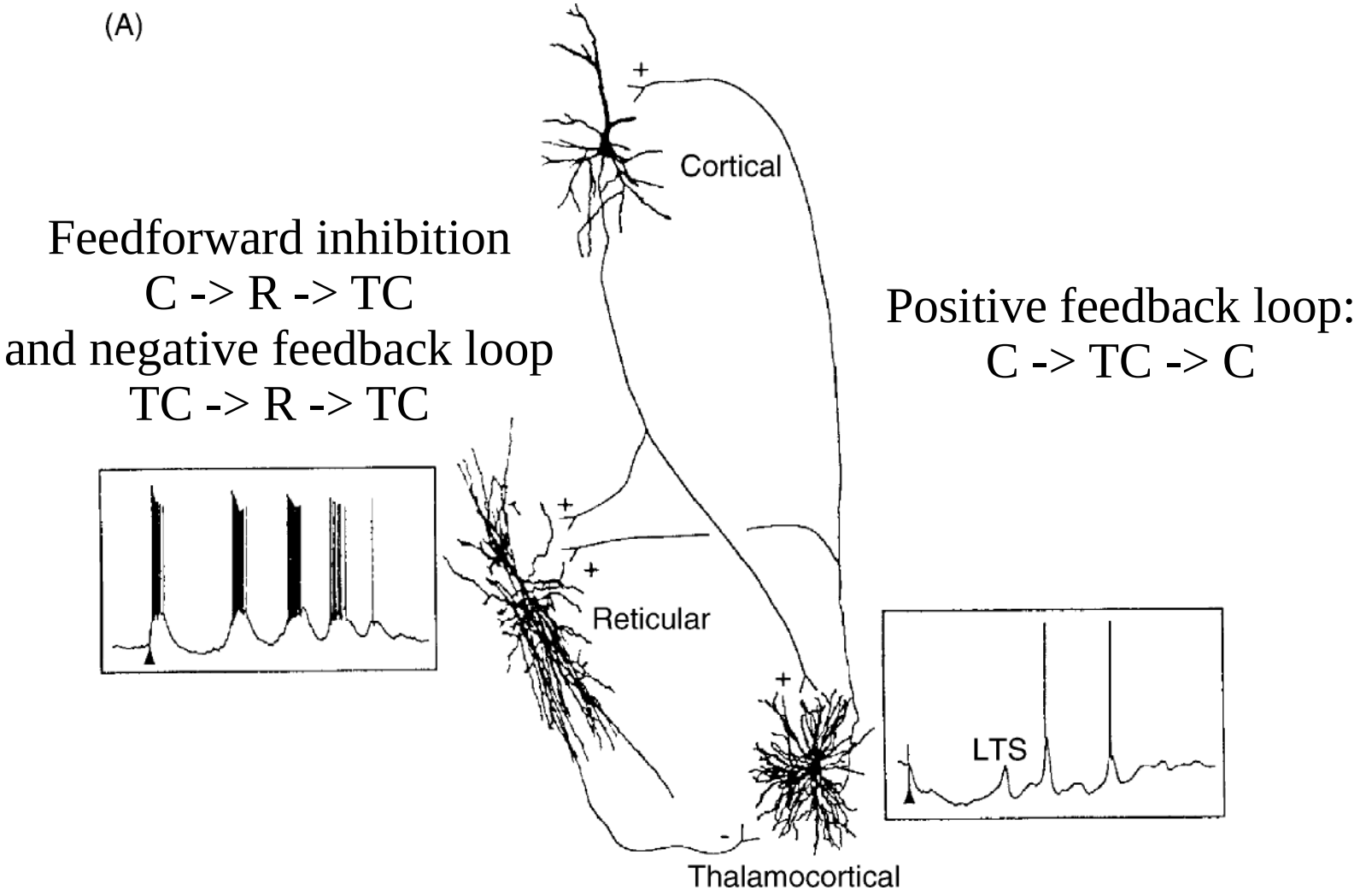
Similar phenomena reportedly observed in EEG from all mammals studied.

Sleep spindles



From Fig. 2 of Fernandez, LMJ and Lüthi, A. Sleep spindles: mechanisms and functions. Physiological Reviews 100:805-868, 2020. PMID 31804897.

Thalamocortical oscillations

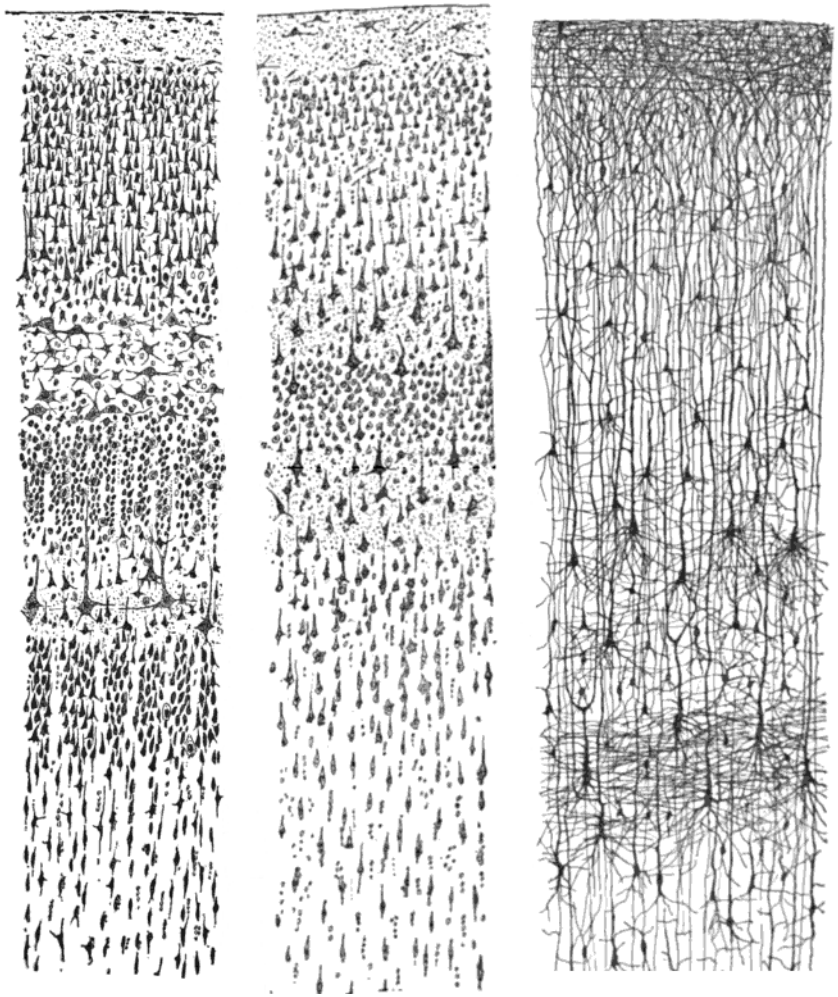


Feedforward inhibition
C -> R -> TC
and negative feedback loop
TC -> R -> TC

Positive feedback loop:
C -> TC -> C

Fig. 1A from Fuentealba, P and Steriade, M. The reticular nucleus revisited: intrinsic and network properties of a thalamic pacemaker. Progress in Neurobiology 75:125-141, 2005. PMID 15784303.

Neocortex: cells, columns, and circuits 1



Drawings from p. 314, 361, and 363 of Ramon y Cajal, S..
Comparative study of the sensory areas of the human cortex. 1899.

Neocortex: cells, columns, and circuits 2

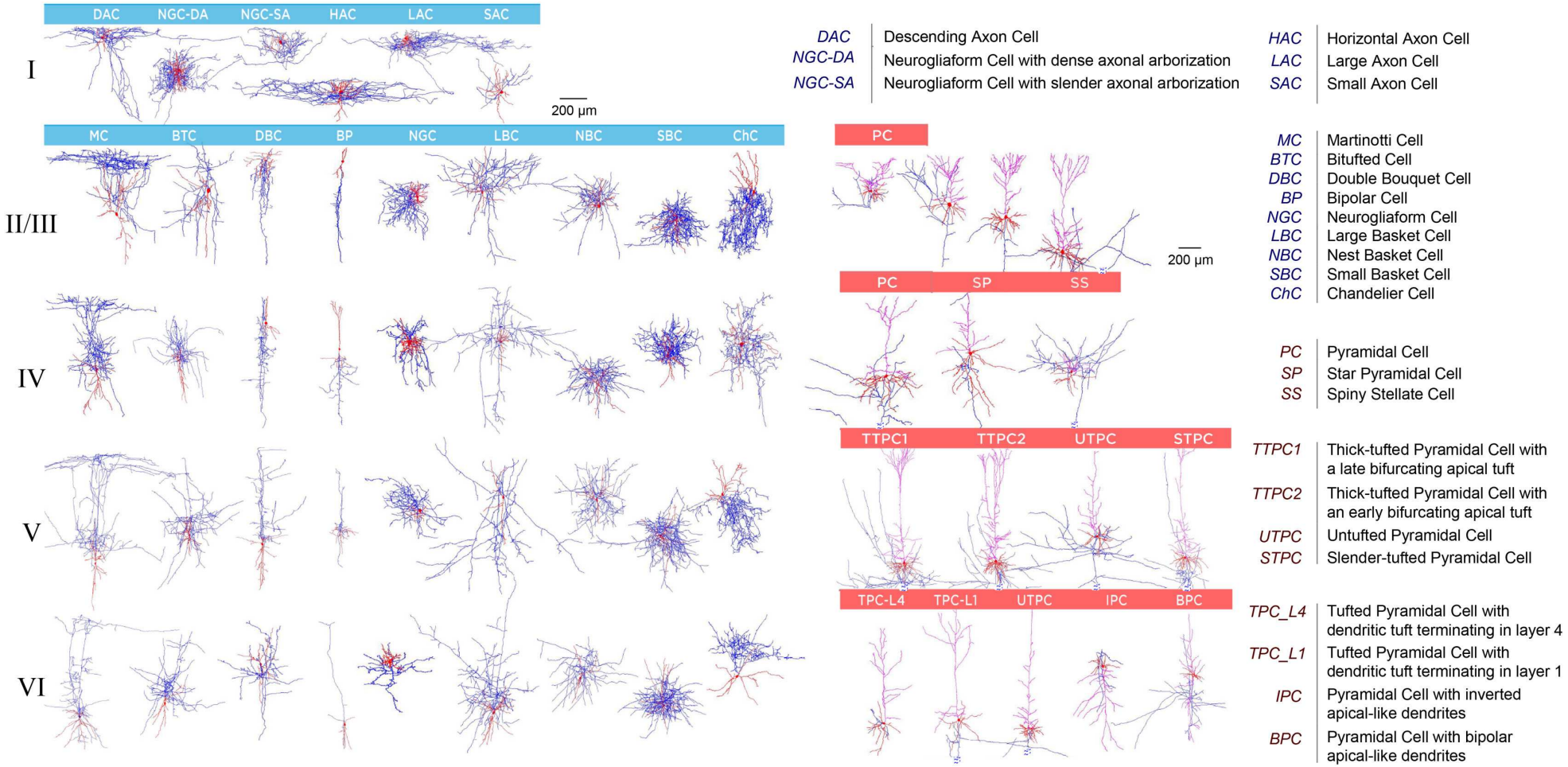


Figure 2 from Markram et al.. Reconstruction and simulation of neocortical microcircuitry. Cell 163:456--492, 2015. PMID 26451489.

Neocortex: cells, columns, and circuits 3

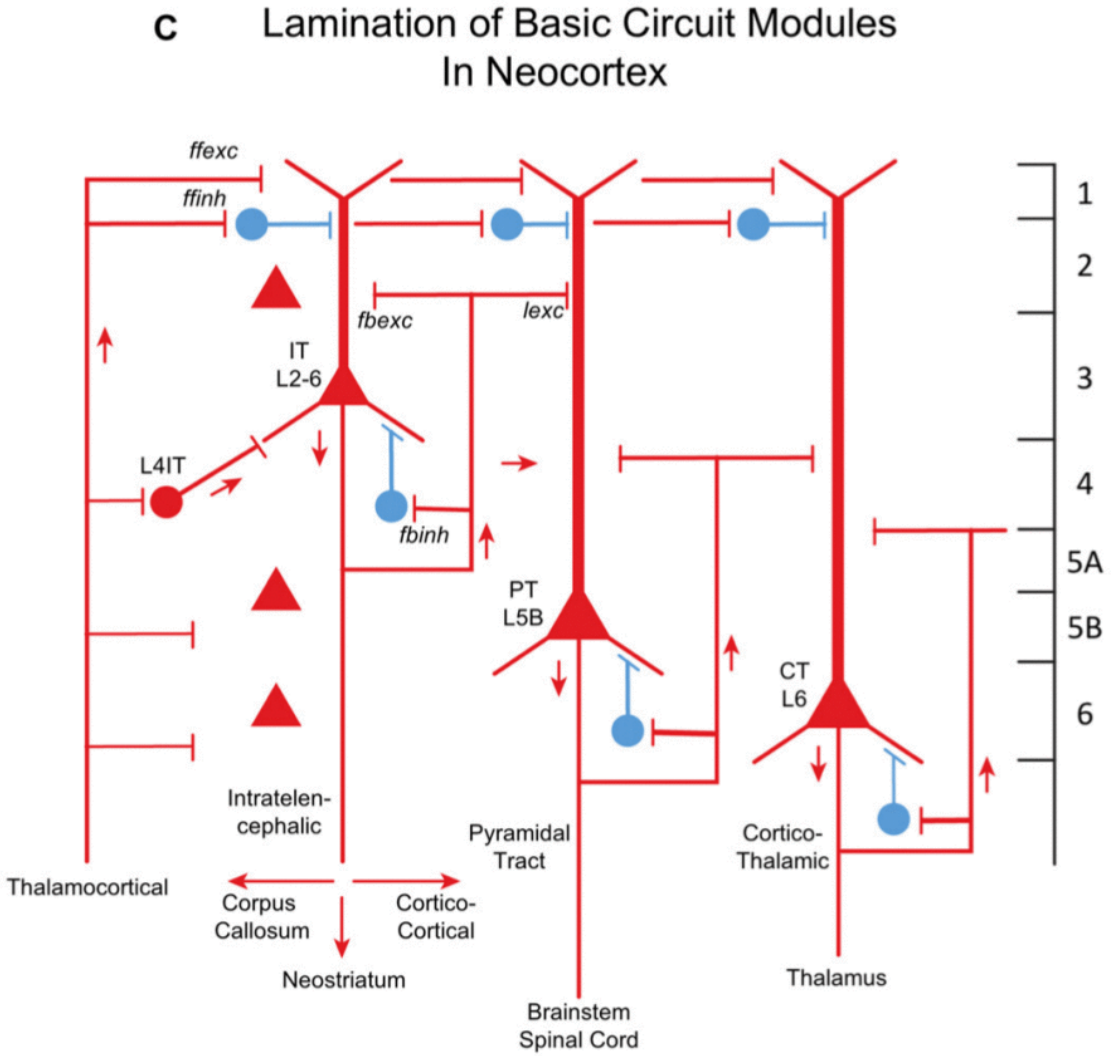
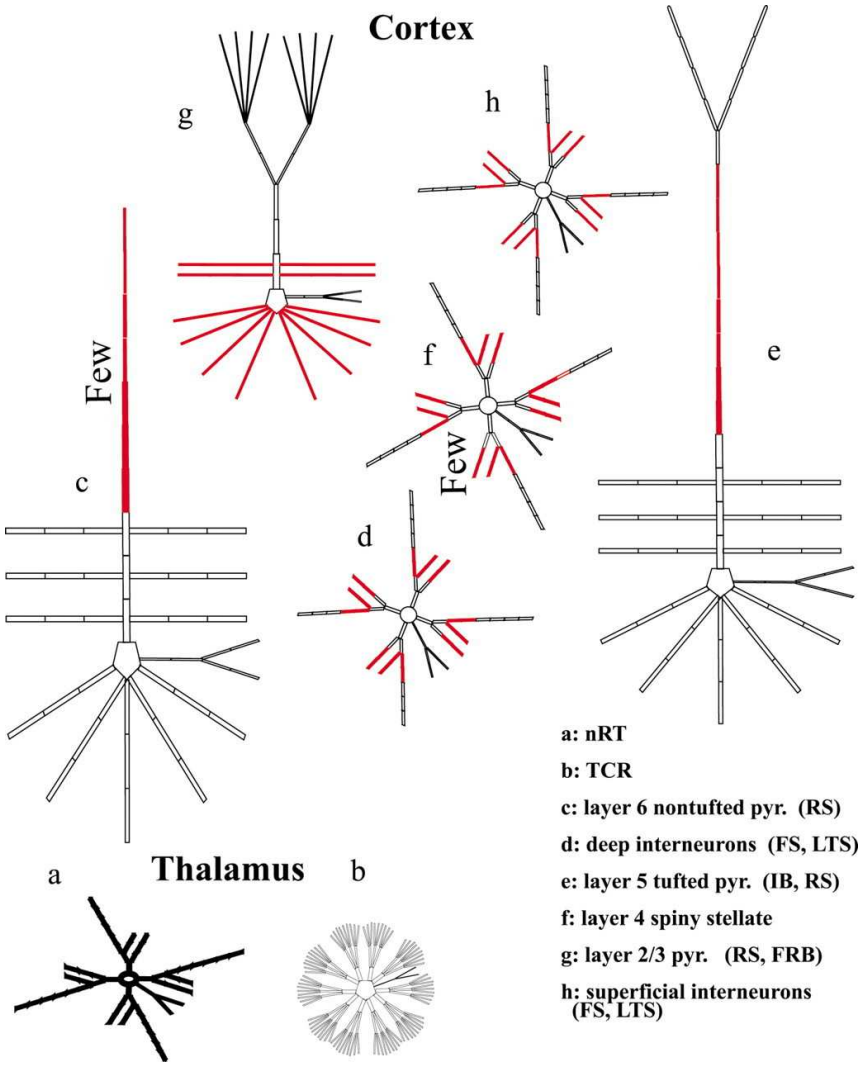


Figure 1 from Shepherd, GM and Rowe, TB.. Neocortical lamination: insights from neuron types and evolutionary precursors. Frontiers in Neuroanatomy vol 11, 2017. DOI 10.3389/fnana.2017.00100.

Traub et al. 2005 model cells



Abbreviations:
nRT reticular nucleus interneuron
TCR thalamocortical relay neuron

Excitatory (glutamatergic):
pyramidal, spiny stellate, and thalamocortical relay neurons

Inhibitory (gabaergic):
all other neurons

Figure B1 from Traub, R.D. et al.. Single-column thalamocortical network model exhibiting gamma oscillations, sleep spindles, and epileptogenic bursts. Journal of Neurophysiology 93: 2194-2232, 2005. PMID 15525801.

Connectivity matrices--see spreadsheet

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Assumptions: are stated in Introduction, Methods, and appendices.

Model validation: reproduced several experimentally observed phenomena (gamma, spindles, epileptiform bursts etc.).

New thoughts? Confirmed need for electrical coupling between axons to get persistent gamma. Indicates that epileptiform activity is affected by axonal coupling, recurrrent excitation between spiny stellate cells, and persistent firing of spiny stellate cells over multiple bursts.

Working with the model

Download the model from ModelDB, read its README,
compile its mod files, and run a simulation by doing what README says--that is, execute

nrniv init.hoc

Better: read init.hoc to see what we're getting into.
    Especially the value of tstop!

Output file perf.dat:

We're interested in the first 5 or 6 numbers in perf.dat

- # of cores (AKA hosts) used for this simulation
- # of cells in model
- ? time consumed by load balancing? (optional part of model setup)
- "use_gap" ?
- time used to set up model
- time spent doing the simulation itself