Theoretical & computational Neuroscience:

Programming the Brain

(BM 6140)

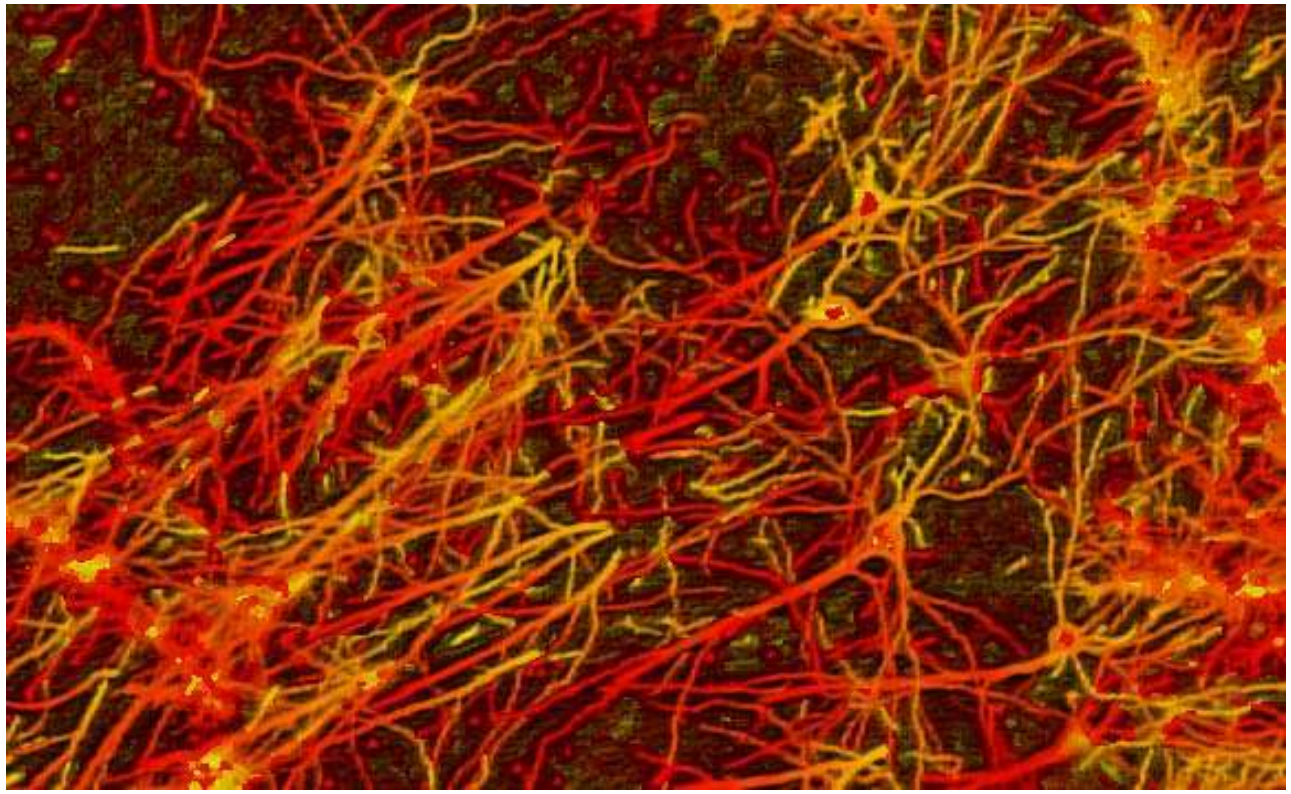
2-credit

Levels of abstraction in Neuroscience

Behaviour	Responses to stimuli, choices etc
Systems	e.g. Visual, Auditory, Motor
Areas	e.g. Frontal, Temporal lobes
Circuit	e.g. cortical column
Neurons	A Cell
Synapse	Connection between cells
Molecule	Molecules, ions entering/leaving the cell

From systems to regions to networks/ckt

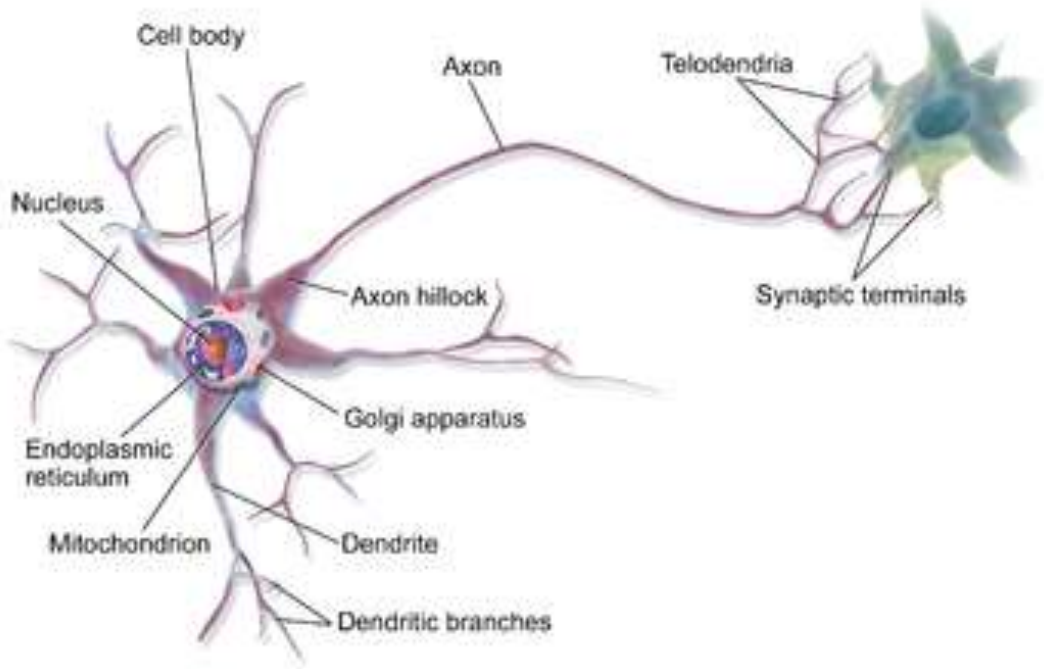
- A piece of brain tissue contains densely packed neurons connected together
- What is the connection topology ?
- How is information transmitted between neurons ?
- What is the language of neurons?



www.willamette.edu

Neuron

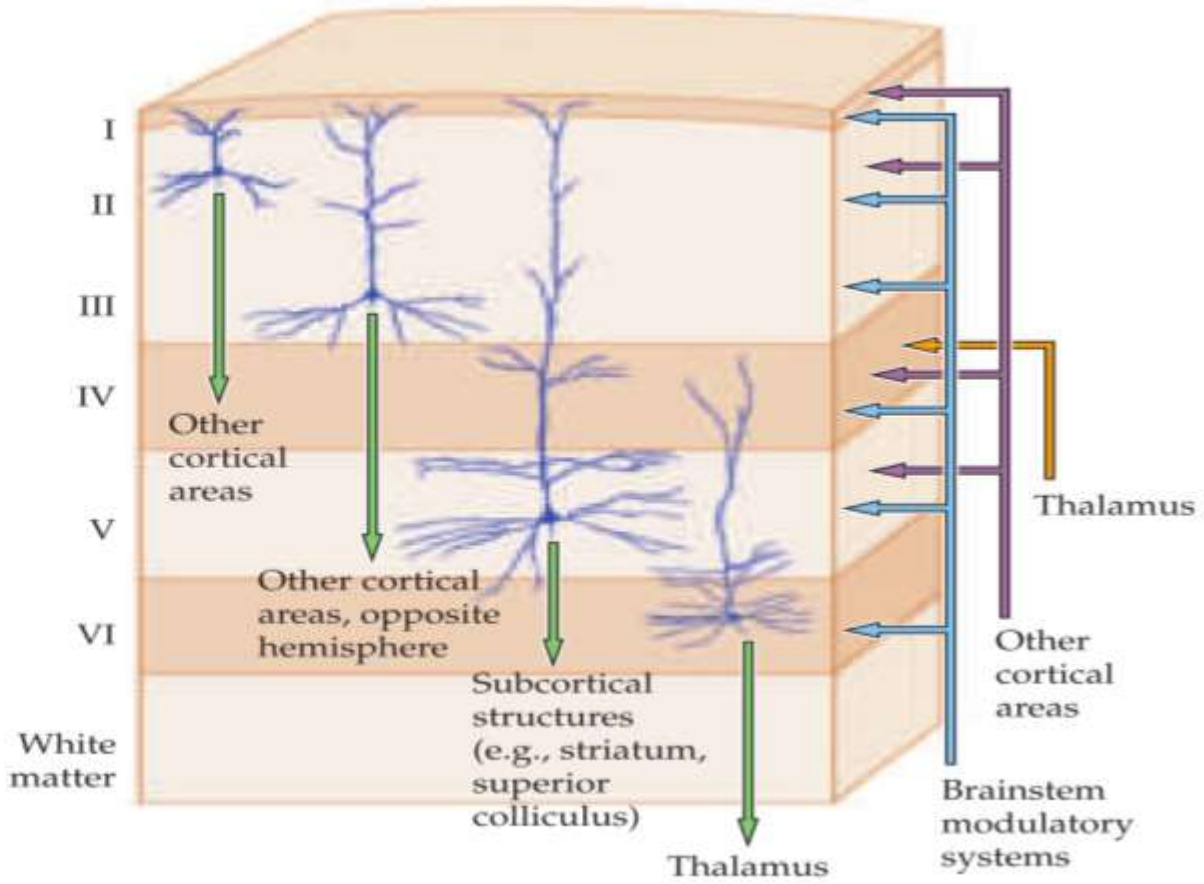
…..Synapse-Dendrite-Soma-Axon-Synapse….



http://en.wikipedia.org/wiki/Neuron

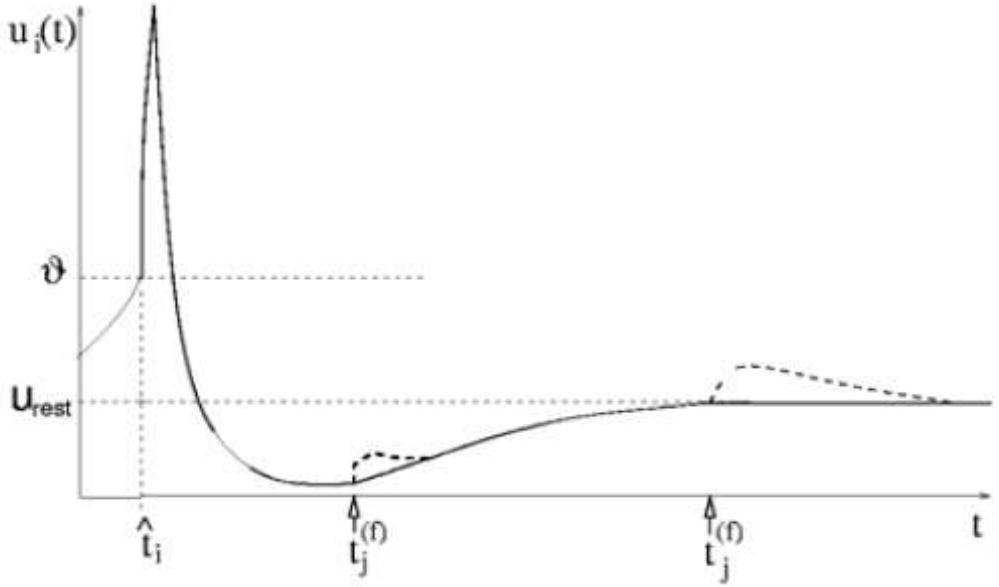
Circuitry of neocortex

Figure 25.3 Canonical neocortical circuitry. Green arrows indicate outputs to the major targets of each of the neocortical layers in humans; orange arrow indicates thalamic input (primarily to layer IV); purple arrows indicate input from other cortical areas; and blue arrows indicate input from the brainstem modulatory systems to each layer.



Action Potential

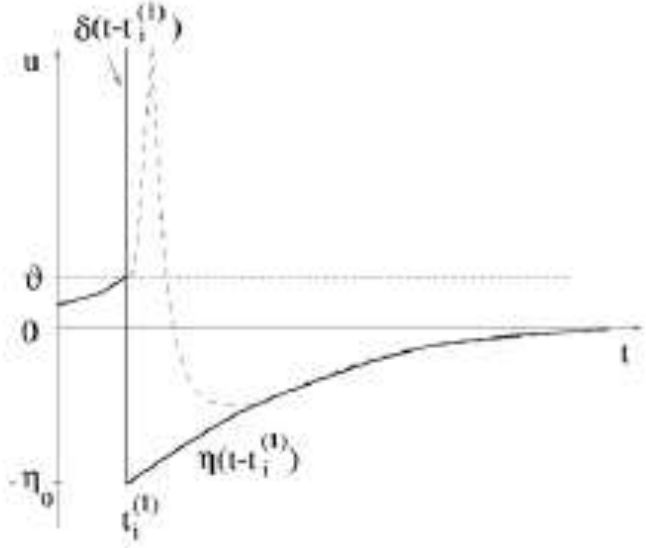
- Basic currency of signaling
- All-or none
- Voltage waveform unimportant !
- Fact that an AP occurred is important !
- AP injects current(voltage) in post synaptic neuron… this waveform matters !



Gerstner, Spiking Neuron models

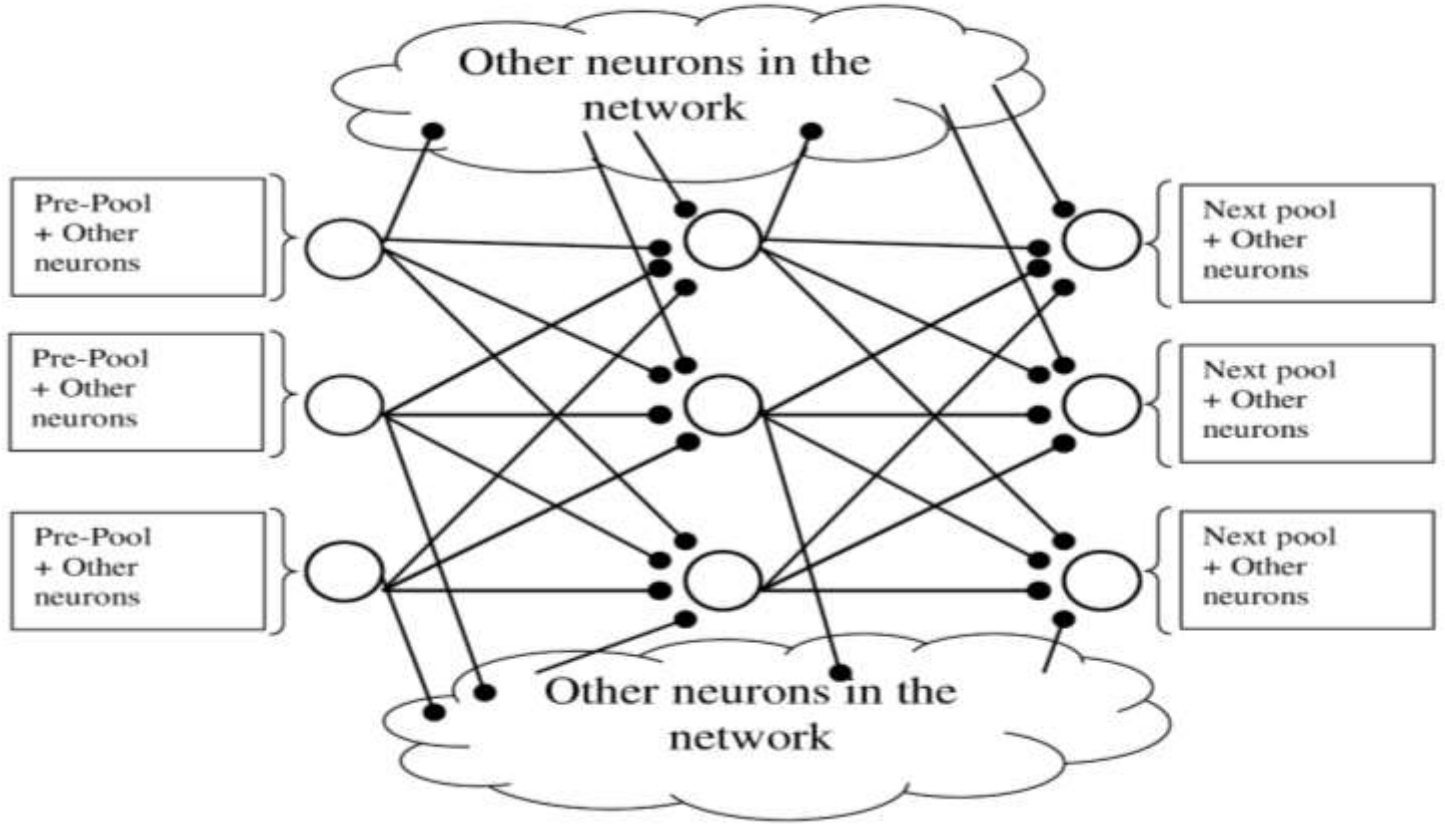
Neuron : Integrate and fire AP

- Input currents(voltages) from various synapses (connections with other neuron)
- Add inputs from all synapses
- If resultant voltage > threshold
- then FIRE!!
- Replace AP by a line



Gerstner, Spiking Neuron models

One neuron does not fire another neuron. It takes a group(pool) of neurons to do that !



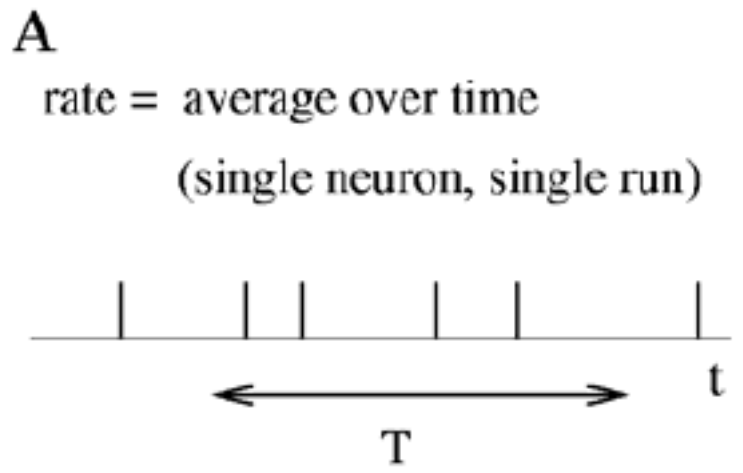
So where is the information ?

Rate code

- Adrian 1926,1928
- Nobel 1932
- APs in stretch receptor neurons proportional to force applied to muscle

Measuring rates: Spike counting / averaging

- Rate of APs
- *Spike count (# APs/ time)*
- *Spike density (average over many trials)*
- *Population average (average over many neurons)*

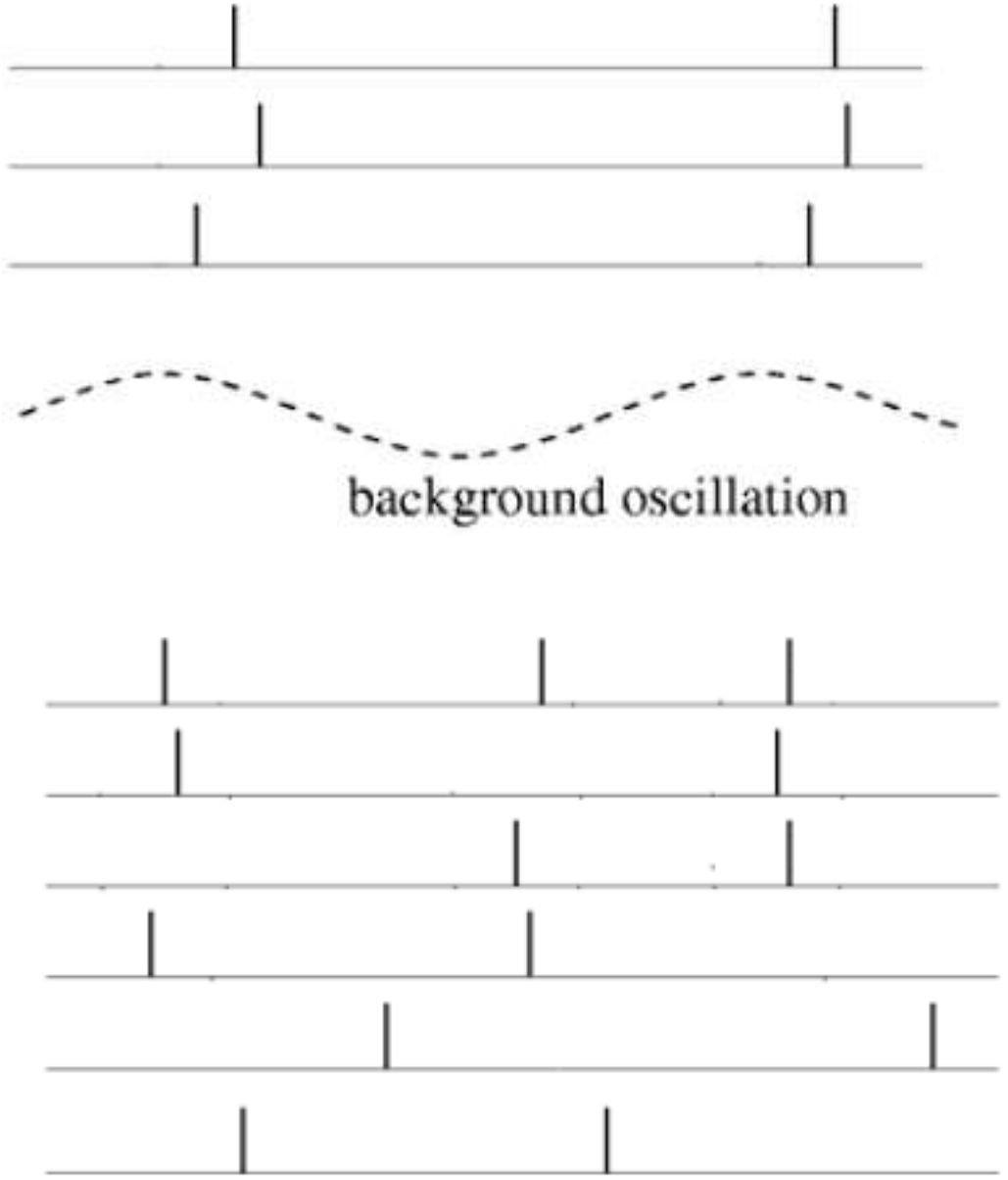


Gerstner, Spiking Neuron models

Rates can be calculated in many ways

Spike codes

- Time to first spike
- Phase w.r.t oscillation
- Correlation / synchrony



Gerstner, Spiking Neuron models

Rate and spike codes
Are they really different ?

- What happens when the bin size (over which spikes are counted) becomes small ?
- Relation between time-to-first-spike and inter spike interval in a renewal process ?