Topics in Brain Computer Interfaces
CS295-7

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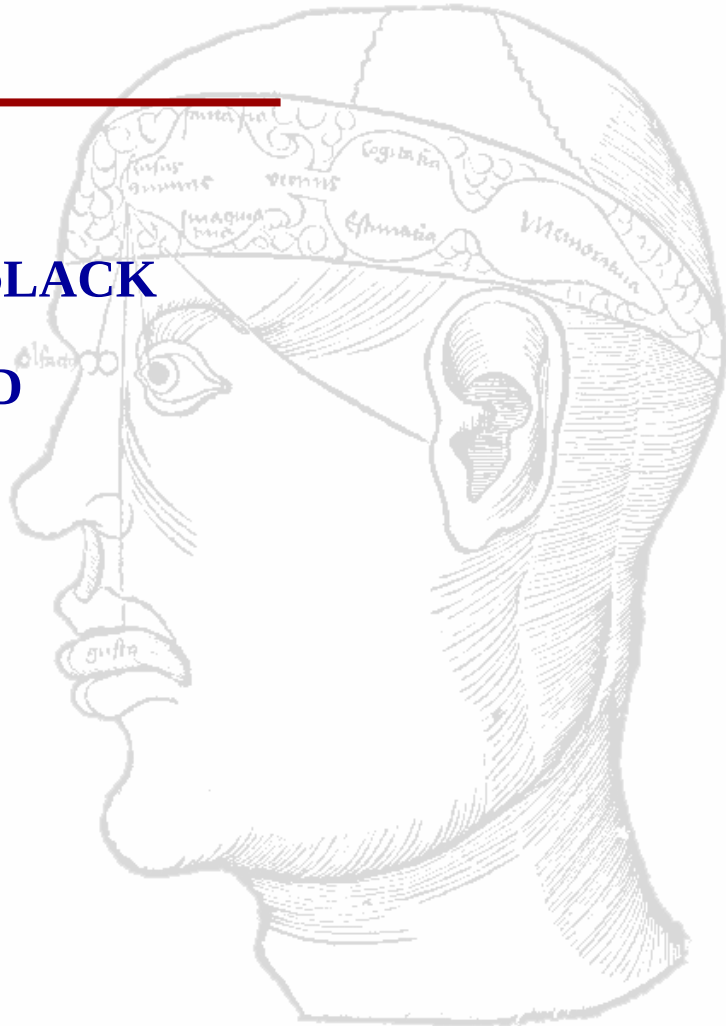
TA: **FRANK WOOD**

Spring 2005



What can we measure from the brain?

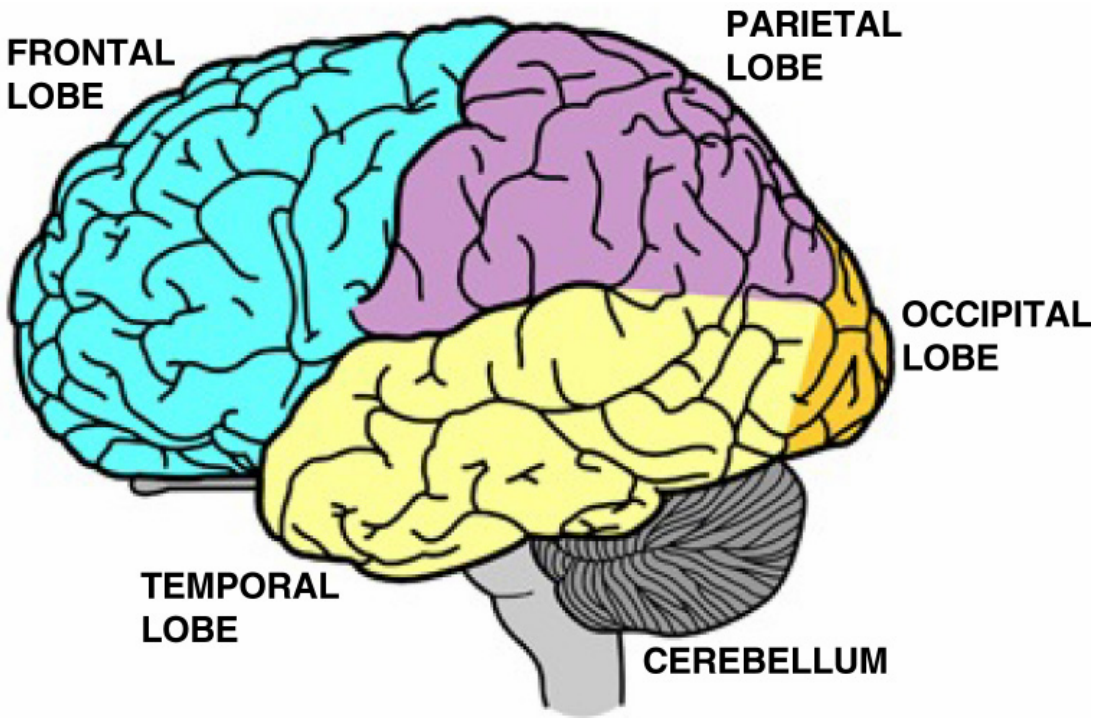
Cerebral Cortex

Frontal lobe. Planning of action and control of movement.

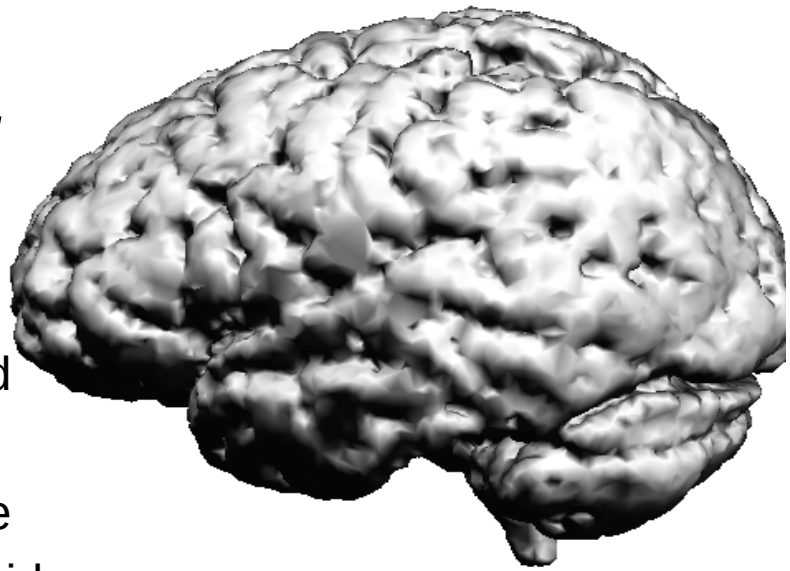
Temporal lobe. Hearing. In its deep structures lies the hippocampus, an important location for memory.

Occipital lobe. Vision.

Parietal lobe. Sense of position.

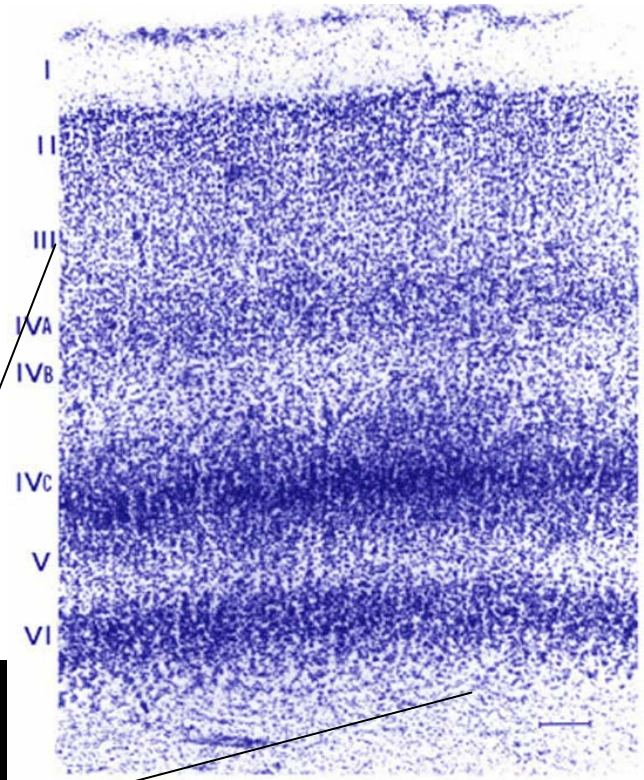


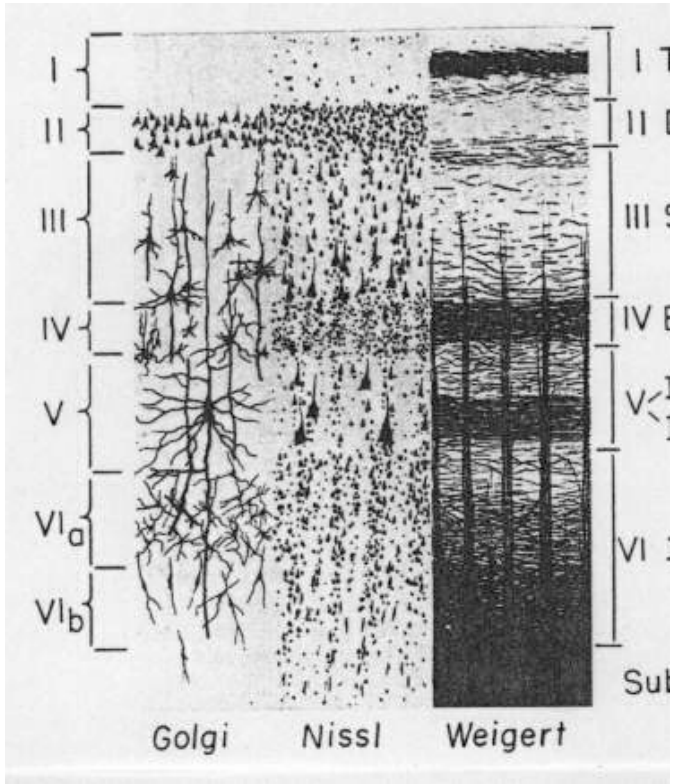
Useful Terms

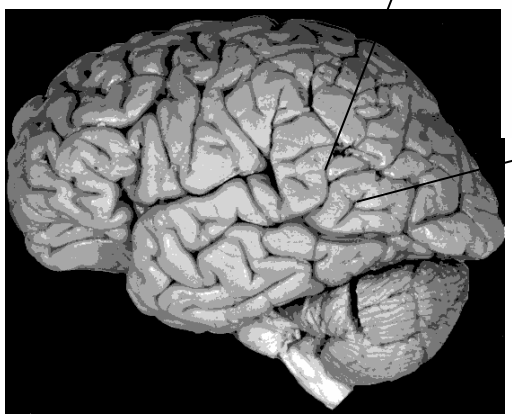


- Rostral/Anterior=head or front end
- Caudal/Posterior=tail or hind end
- Dorsal /Superior= back or top side
- Ventral/Inferior = belly or bottom side
- Medial=toward the midline of the body
- Lateral=away from the midline
- Proximal = closer
- Distal = farther away

Layered Cortex

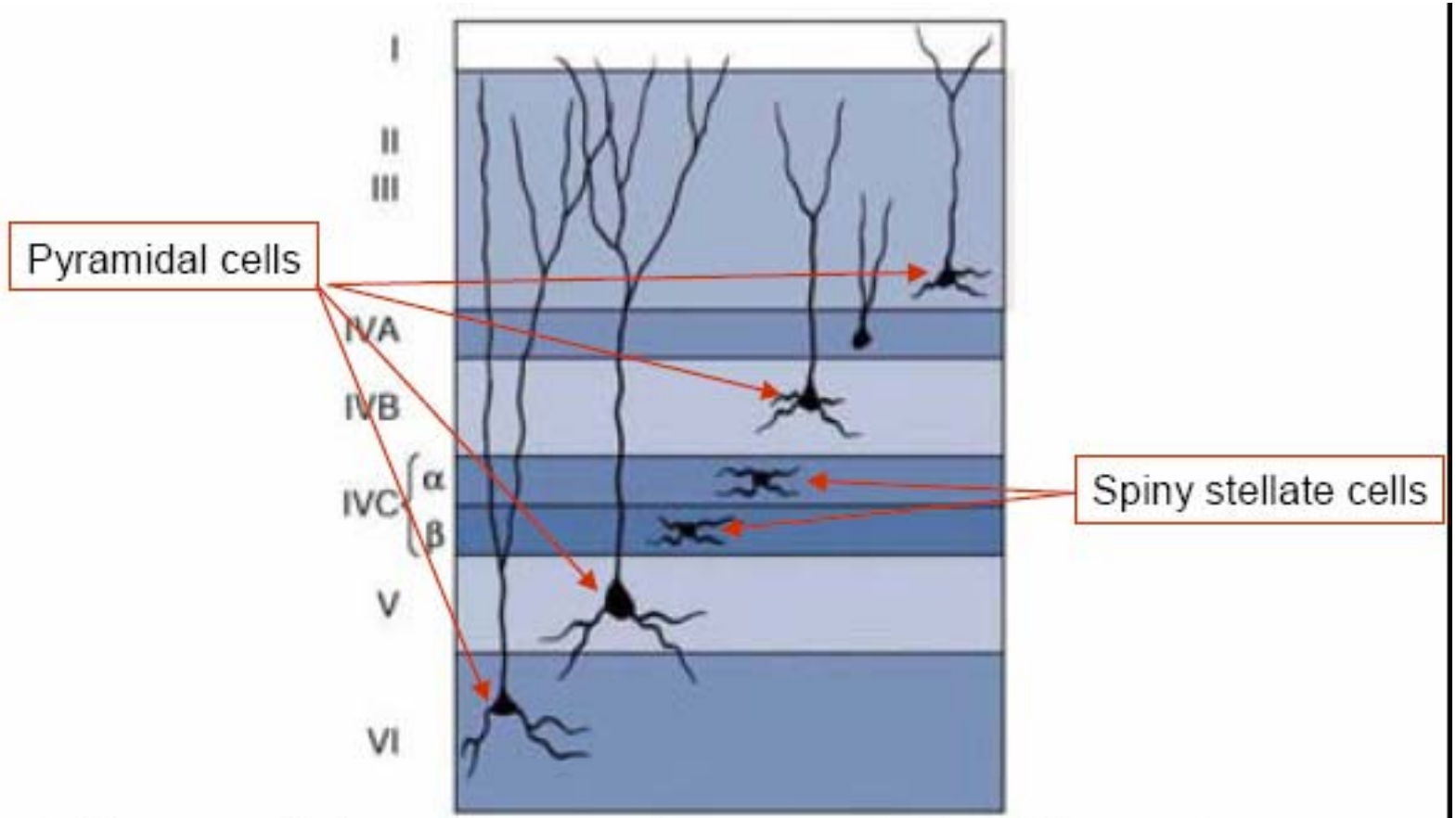






Largely "accessible".

Cortical layers



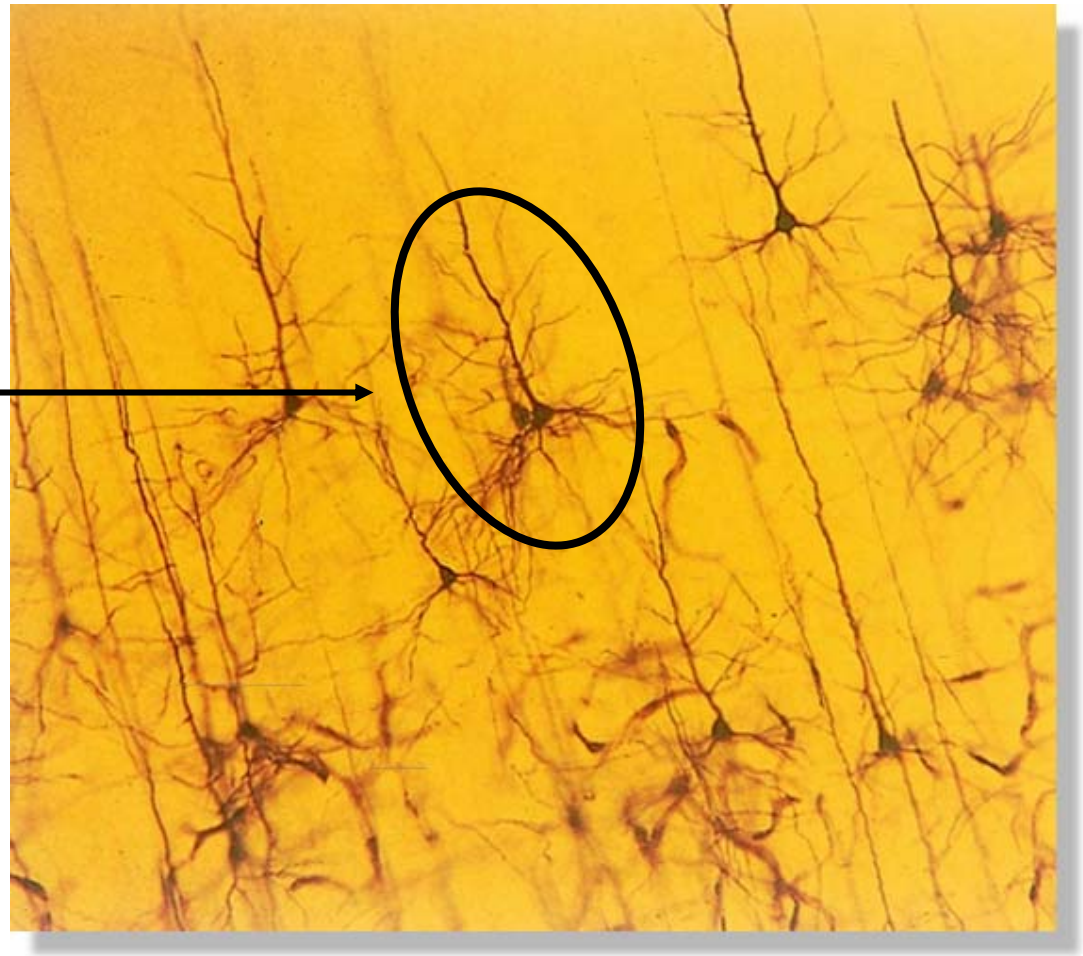
Only pyramidal neurons send axons outside of the cortex

N.B. The specific illustrations are for primary visual cortex, but the general principles apply throughout the cortex

Neurons

Single cells of the nervous system

Pyramidal cell

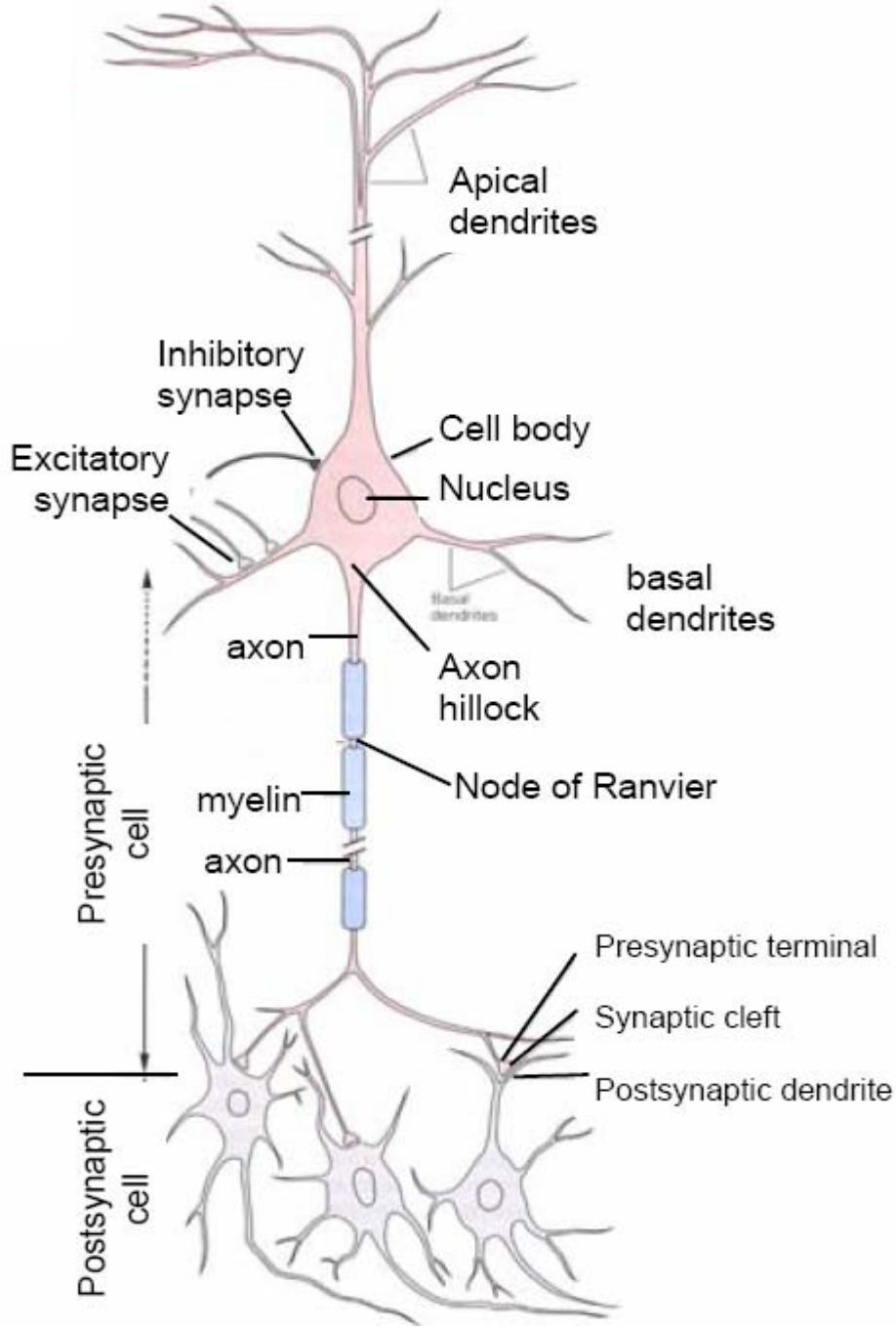


100,000,000,000 in your brain

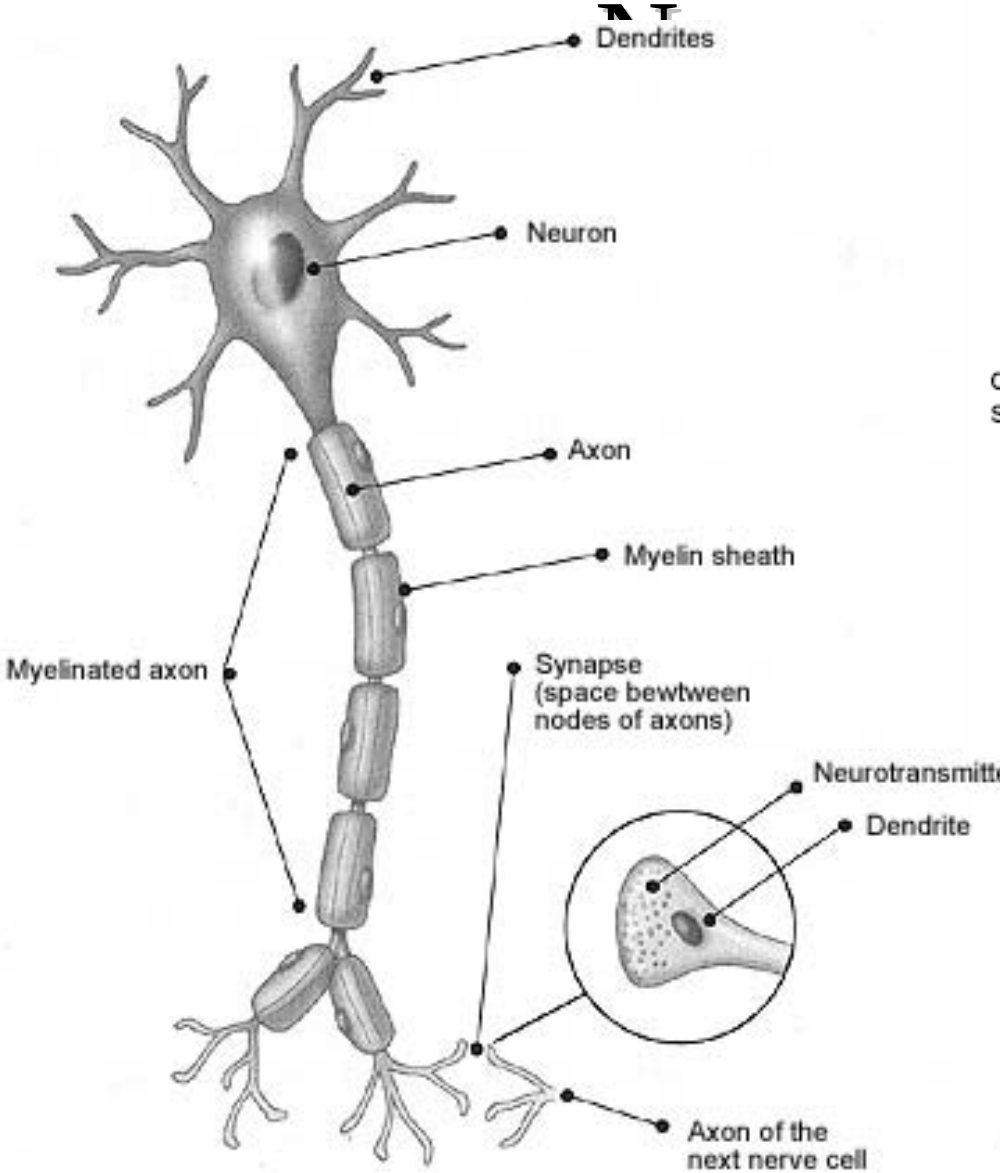
Source: Hubel

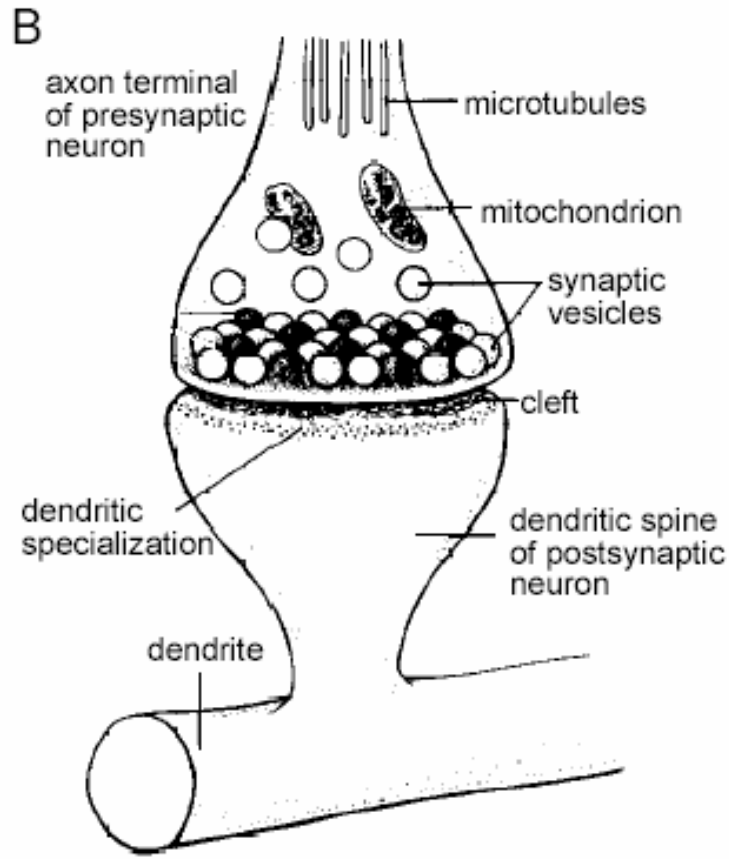
Neurons have four functional regions:

- Input component (dendrite)
- Trigger area (soma)
- Conductive component (axon)
- Output component (synapse)



Source: R. Shadmehr

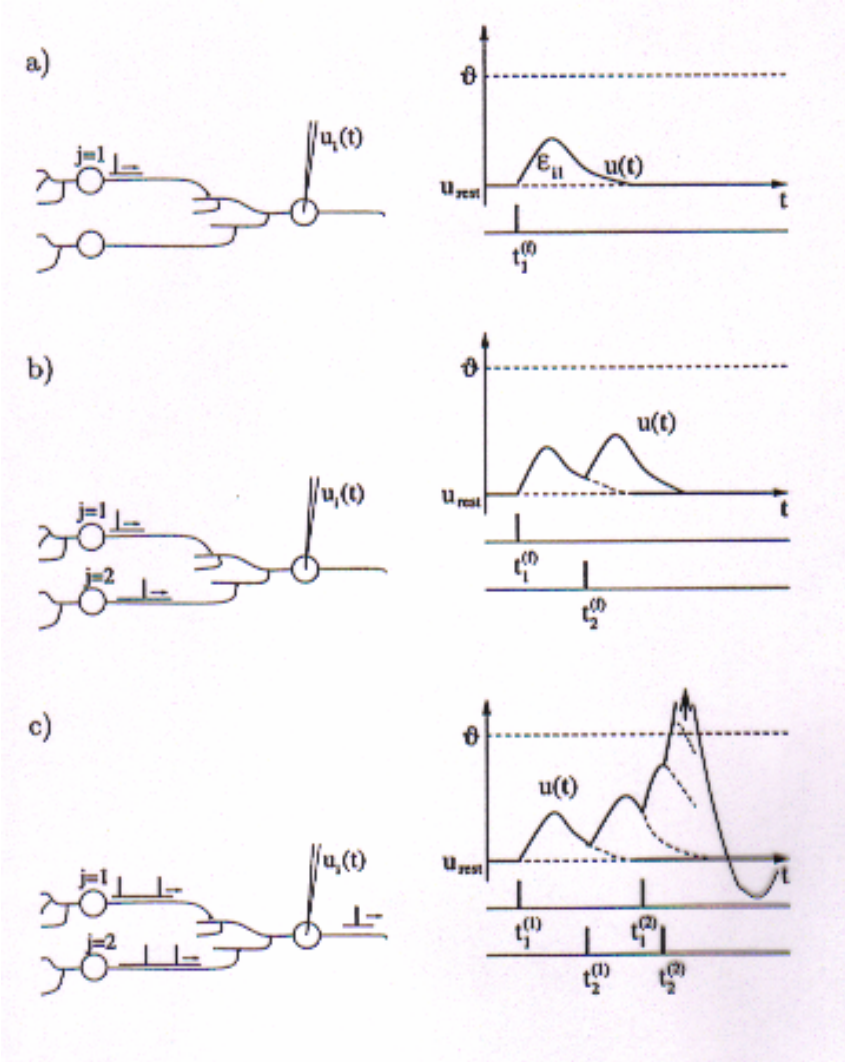




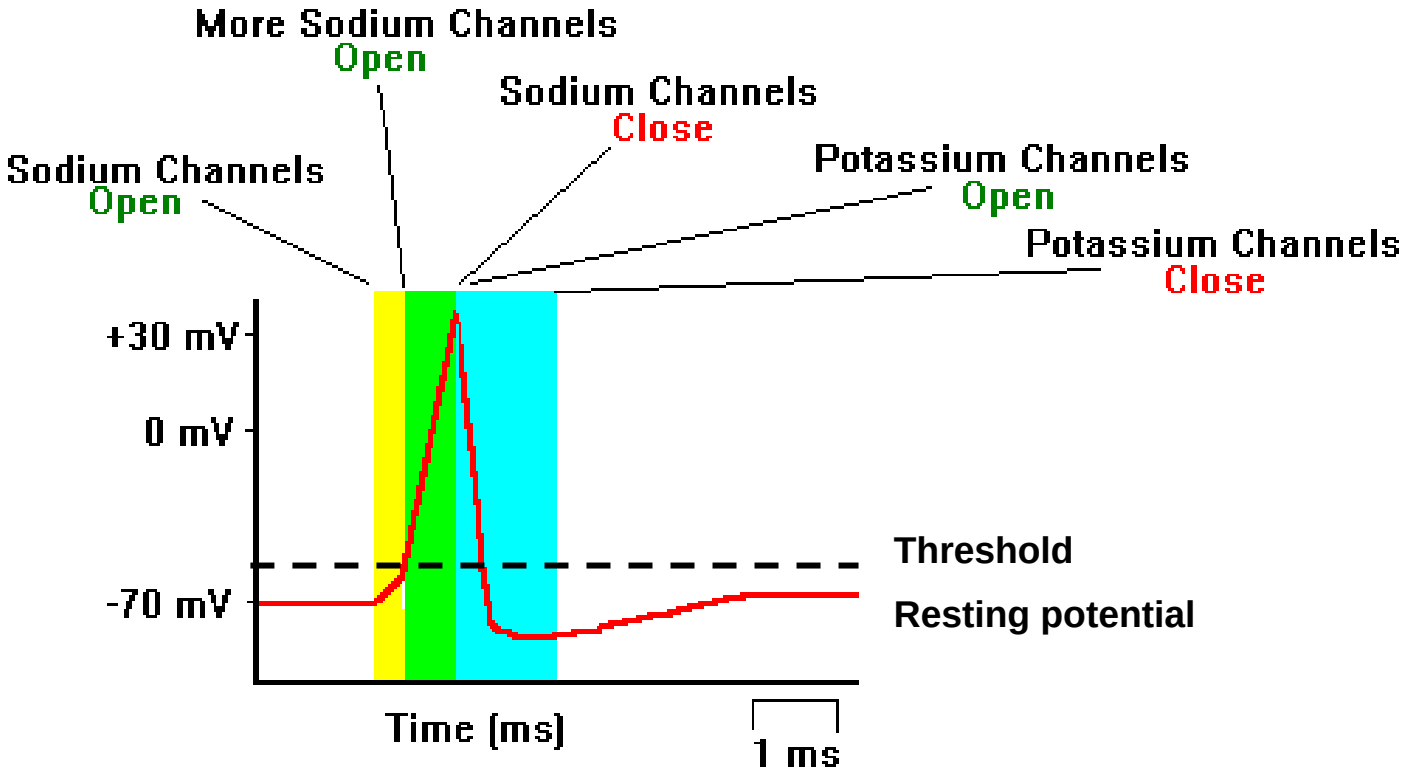
source: Health South Press

The Action Potential

0. The cell has a negative resting potential of around -65mV.
1. Excitatory synapses cause small depolarization of cell.
2. Enough of these add up until the cell's potential depolarizes to cross a voltage threshold.

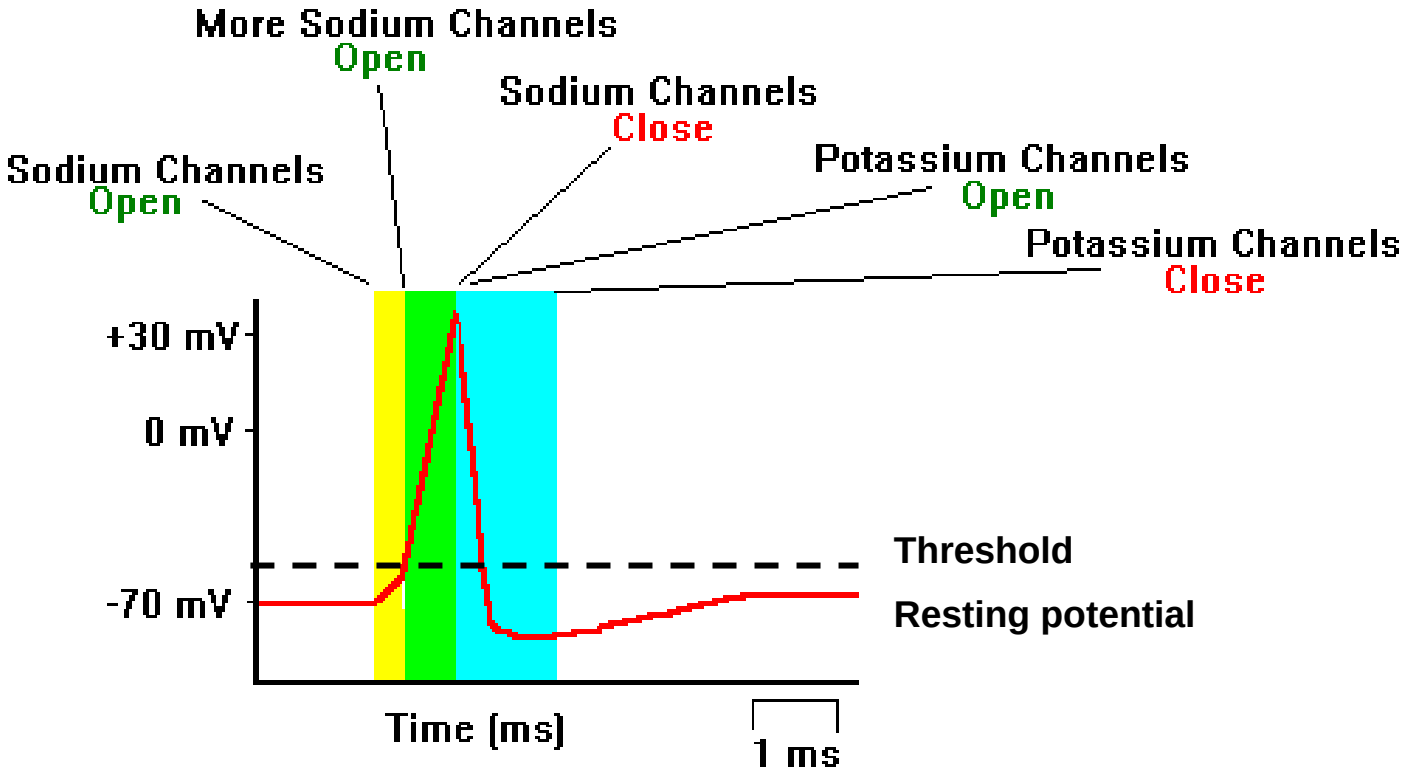


The Action Potential



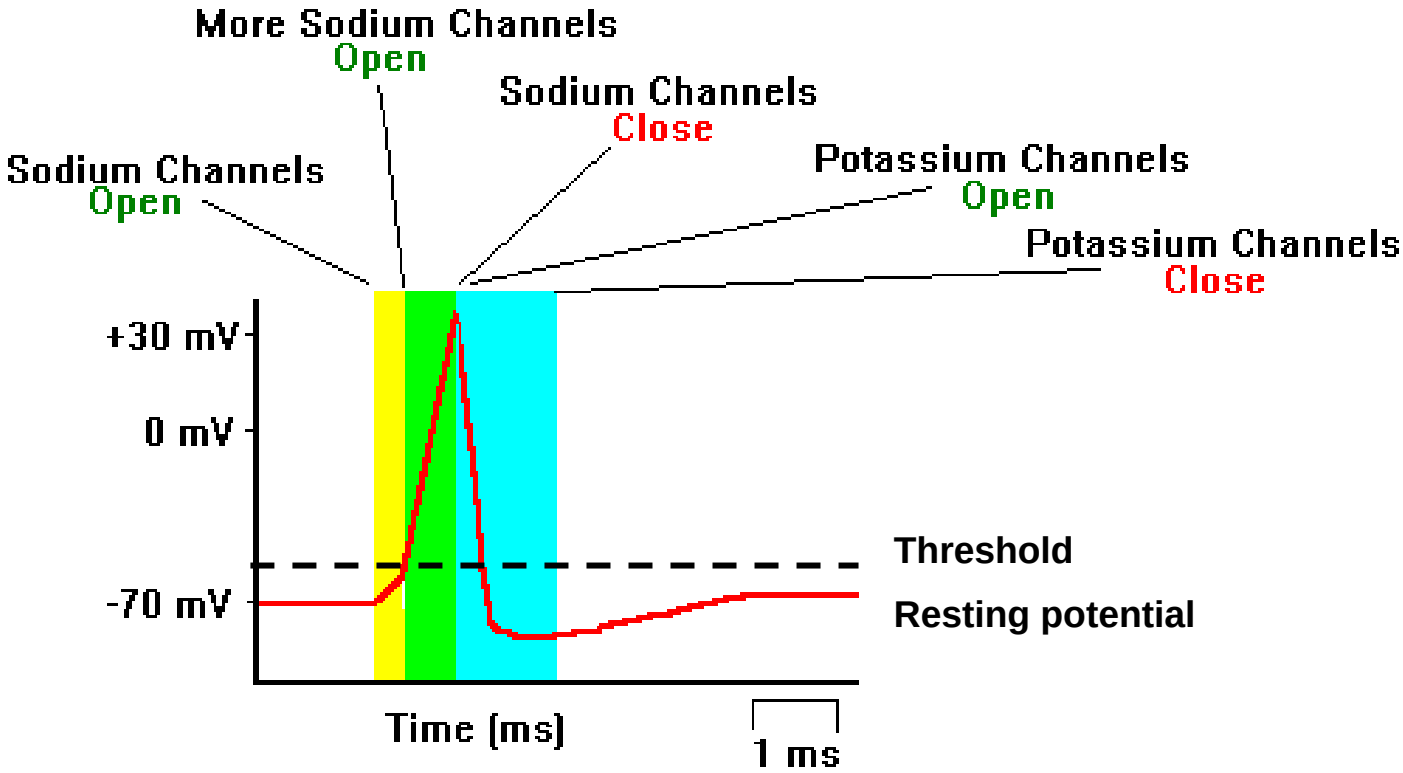
3. Rising phase. Sodium (Na+) channels open and Na+ ions rush into cell.

The Action Potential



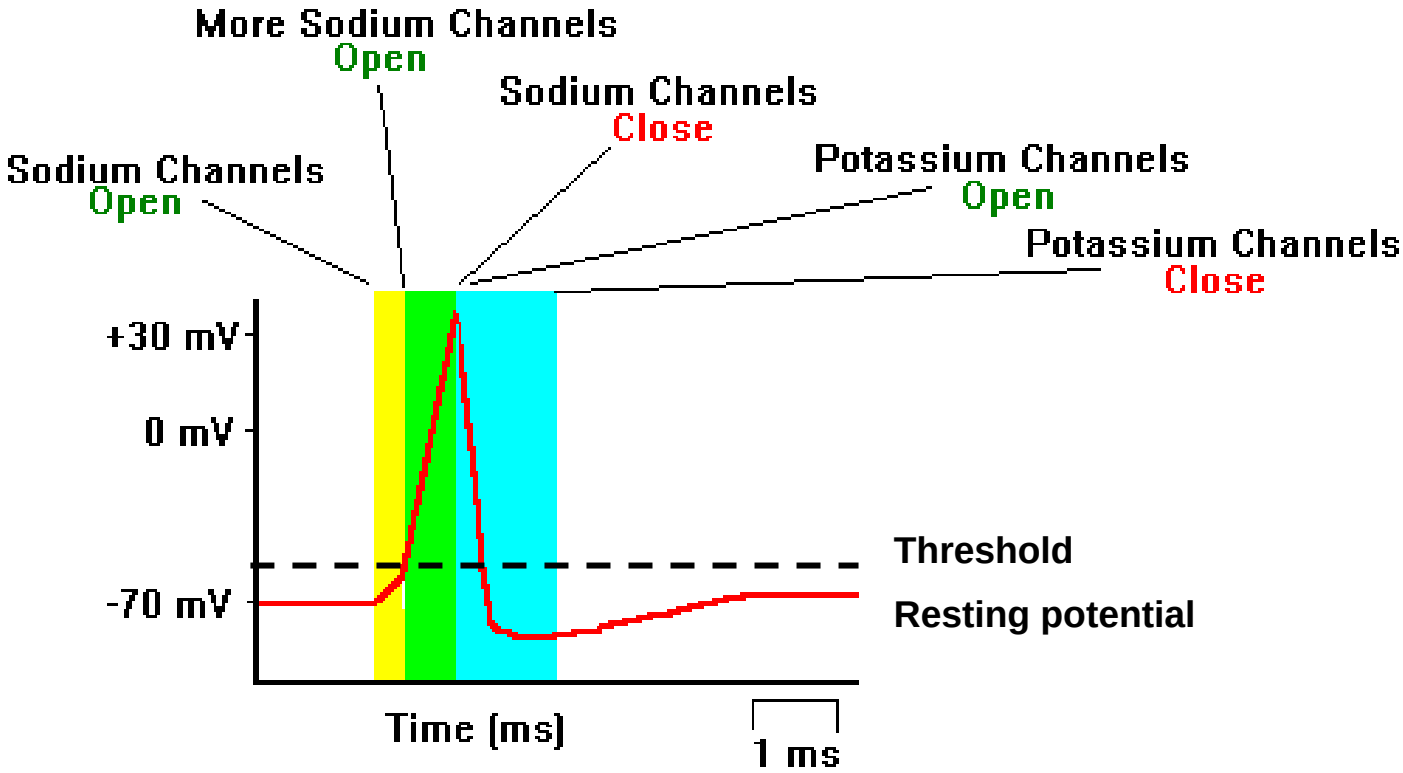
4. Falling phase. Sodium channels close and potassium (K+) channels open. K+ ions flow out.

The Action Potential



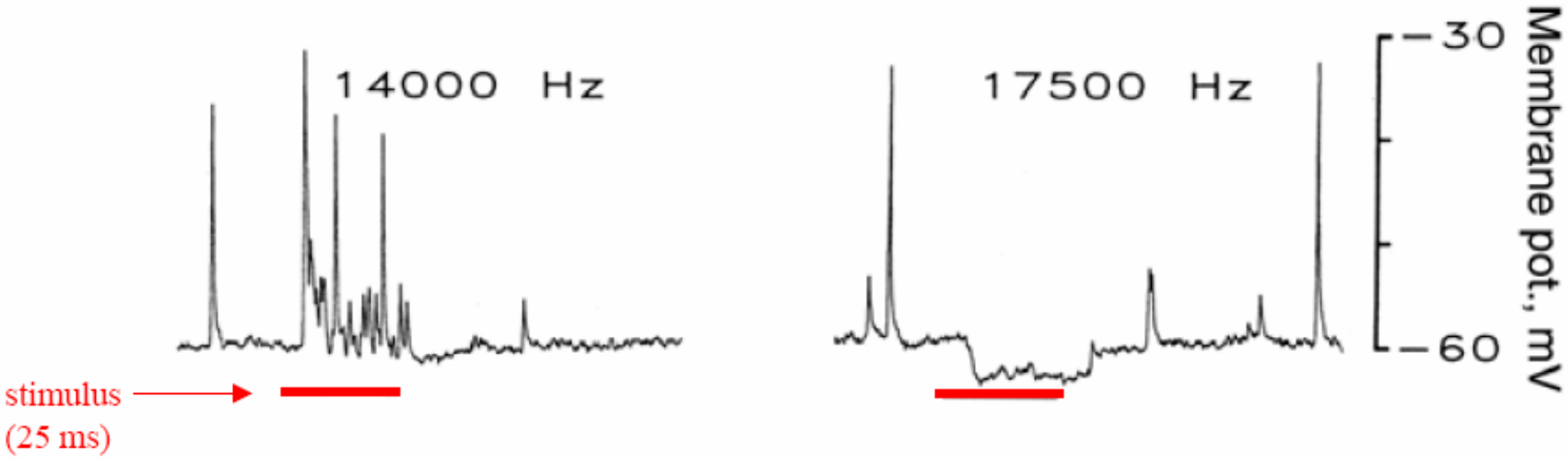
5. Absolute refractory period. Sodium channels deactivate when cell is strongly depolarized. Can't be activated again (ie no new action potential) until potential is sufficiently negative.

The Action Potential



6. Relative refractory period. Potential stays hyperpolarized until Ka+ channels close – more current required to bring cell to threshold.

Excitation and Inhibition



Excitation:

Depolarization

Excitatory post-synaptic potentials.

Increased spike rate

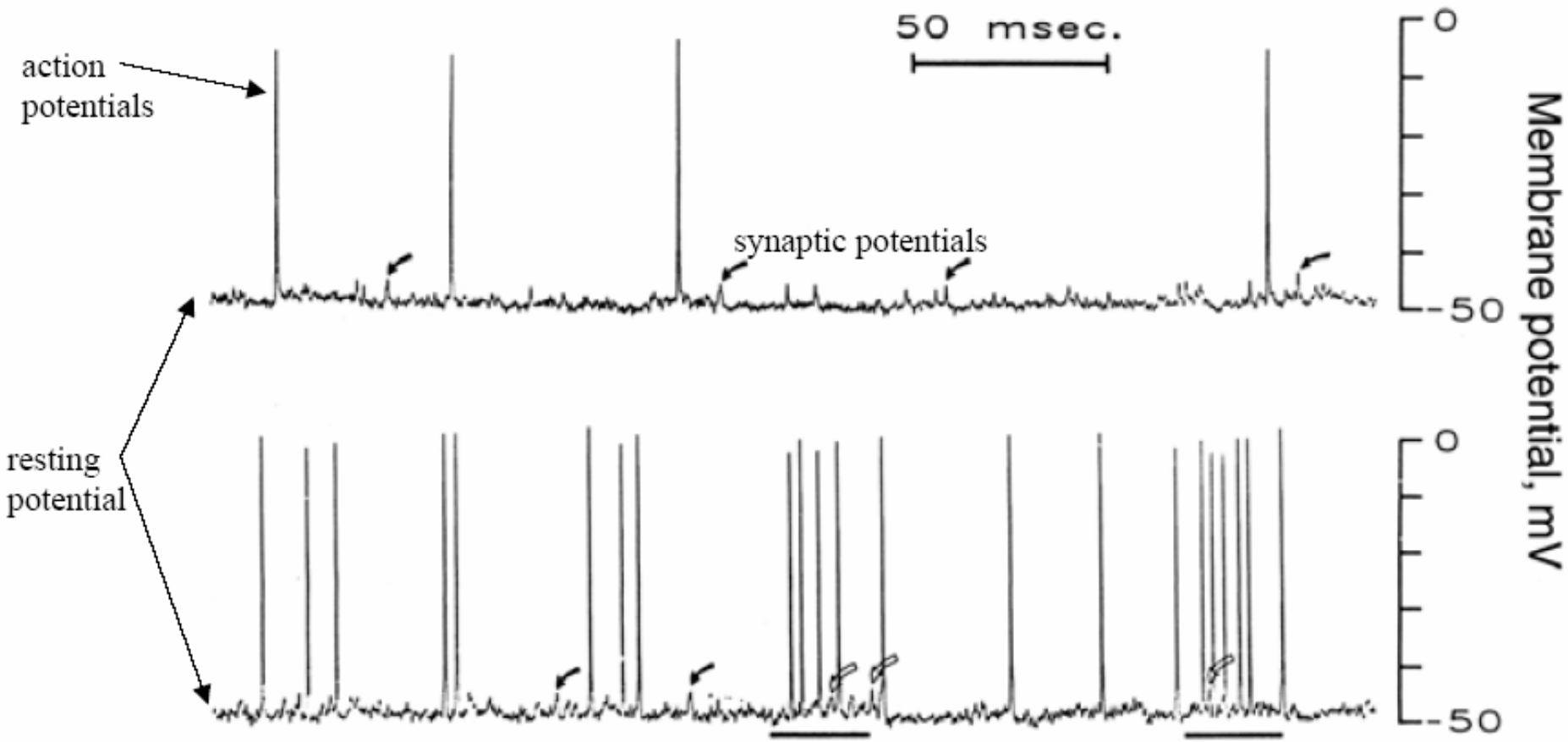
Inhibition:

Hyperpolarization

Inhibitory post-synaptic potentials.

Decreased spike rate

Intra-cellular recording

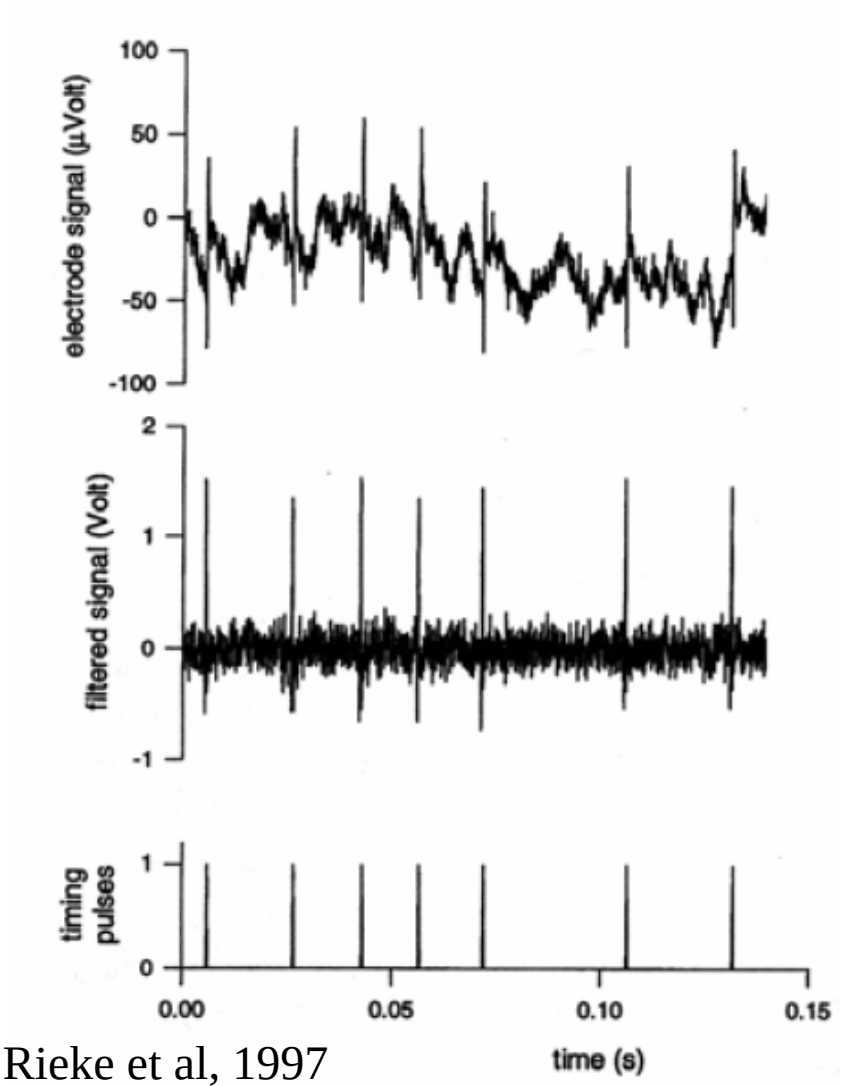


Smith and Rhode, 1987.

Extra-cellular recording

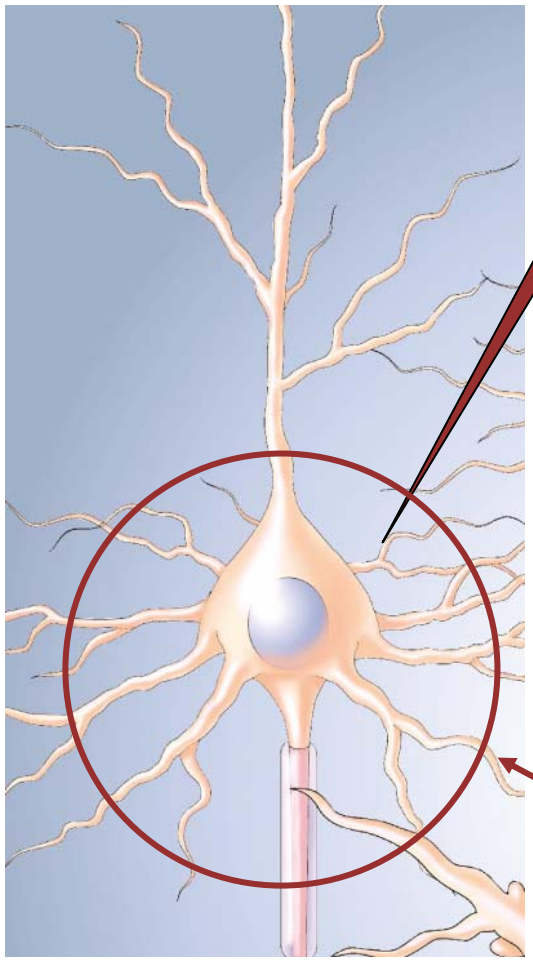
Can only observe action potentials (spikes).

Assumption: neurons convey information in their spikes.



Rieke et al, 1997

Computational Elements of the Brain



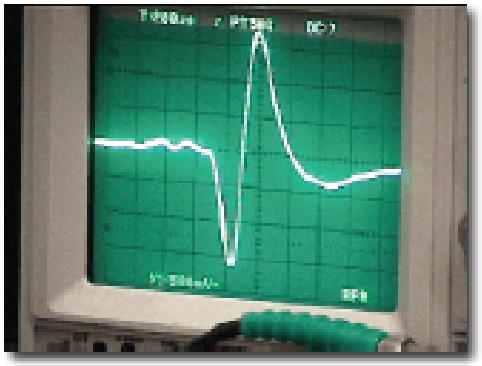
2/1000's second

1/10 mm

Source: Bear, Connors, Paradiso

Extra-cellular Recording

SIGNAL



SENSOR

Microelectrode
(insulated, tapered conductor)

Spike

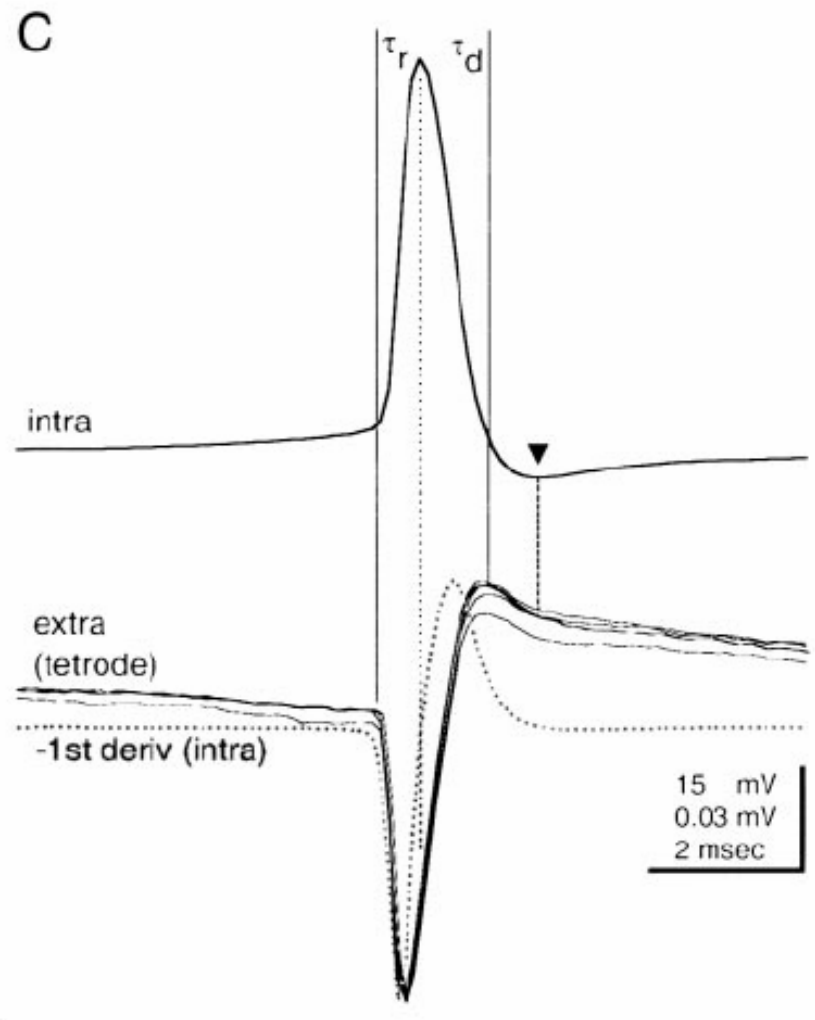
- 1/1000 of a second electrical impulse
- rates carry information

(rate = how many/time)

Recording Spikes

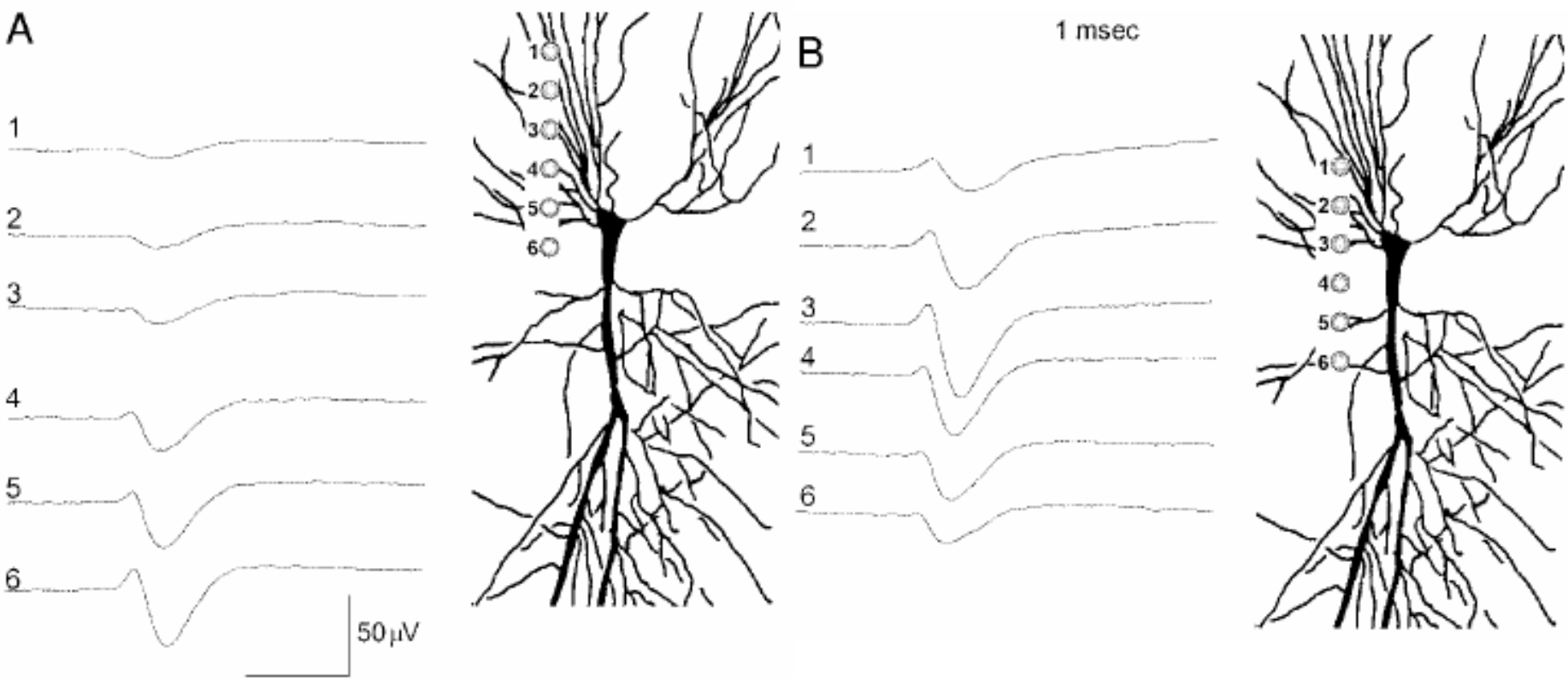
Intra-cellular recording

Extra-cellular recording

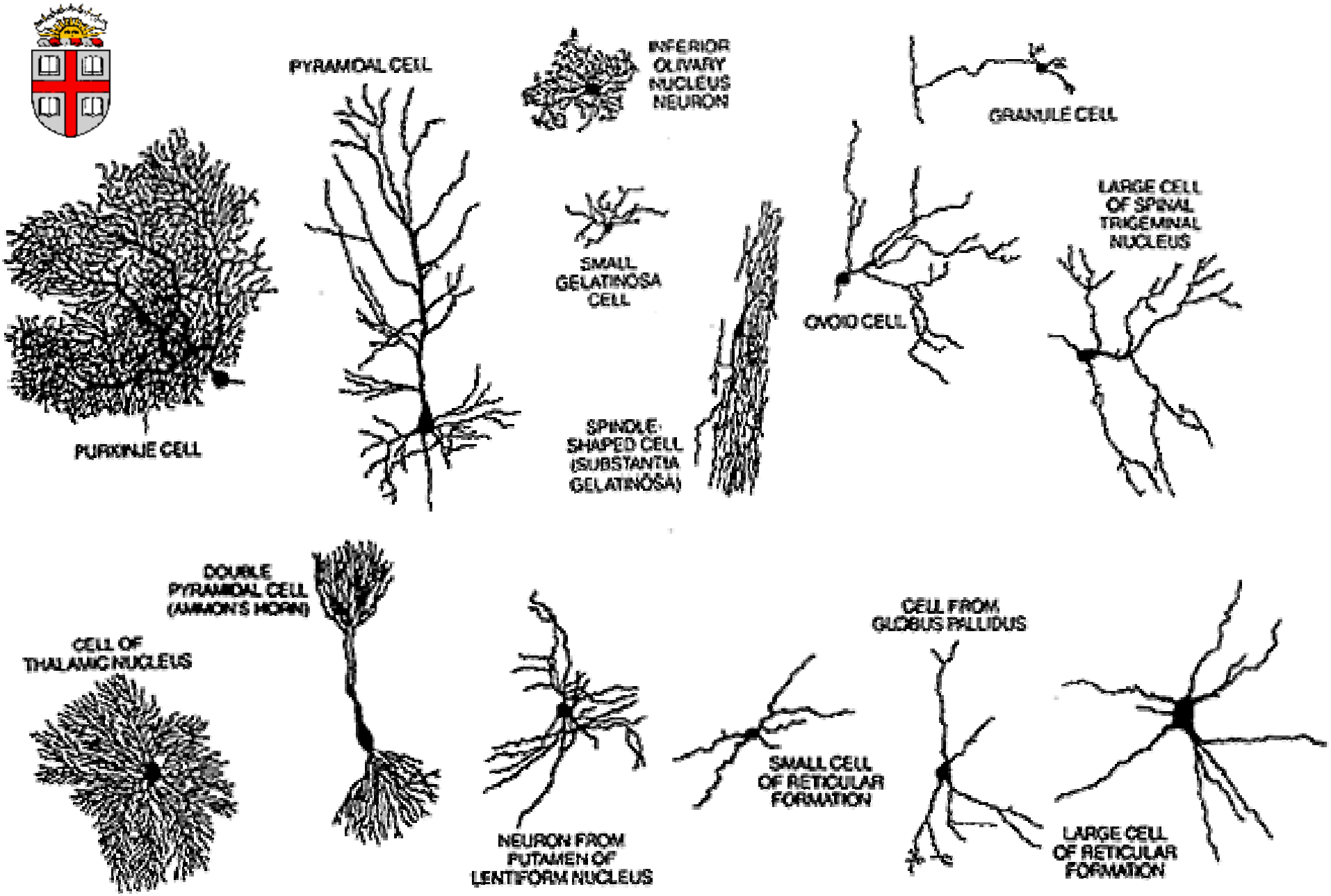


Source: Henze et al. 2000

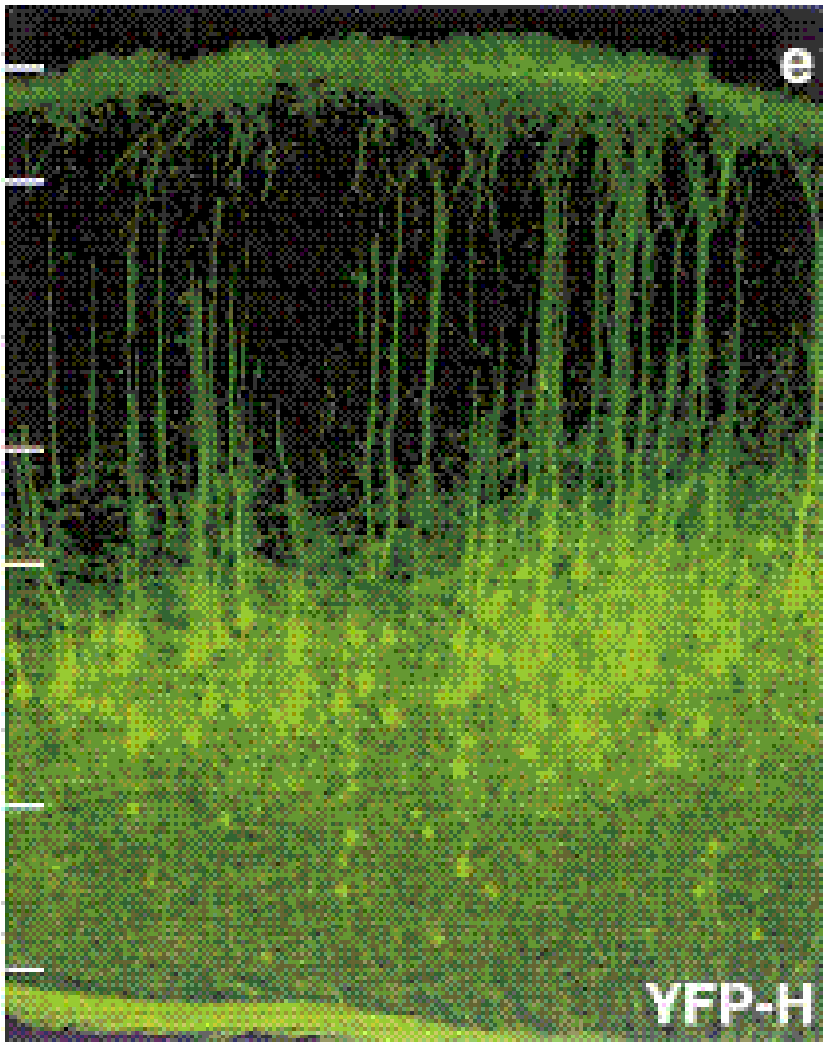
Recoding as a function of depth



Source: Henze et al. 2000 http://www.cns.nyu.edu/~siddha/SPF_papers/Henze.pdf


PYRAMIDAL CELL
INFERIOR OLIVARY NUCLEUS NEURON
GRANULE CELL
PURKINJE CELL
SMALL GELATINOSA CELL
SPINDLE-SHAPED CELL (SUBSTANTIA GELATINOSA)
OVOID CELL
LARGE CELL OF SPINAL TRIGEMINAL NUCLEUS
DOUBLE PYRAMIDAL CELL (AMMON'S HORN)
CELL OF THALAMIC NUCLEUS
NEURON FROM PUTAMEN OF LENTIFORM NUCLEUS
SMALL CELL OF RETICULAR FORMATION
CELL FROM GLOBUS PALLIDUS
LARGE CELL OF RETICULAR FORMATION

Pyramidal Cells in Cortex

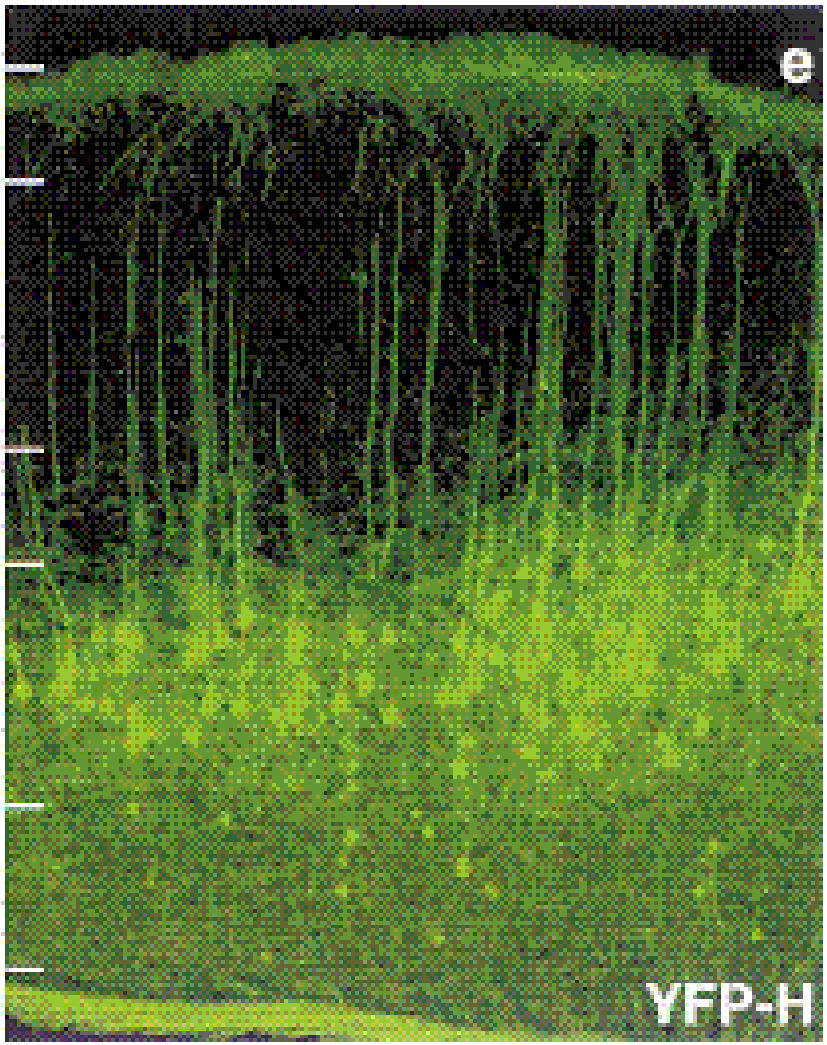


A dense population.

Pyramidal cells arranged roughly parallel to each other.

May record from multiple cells simultaneously (we'll return to this later).

Pyramidal Cells in Cortex



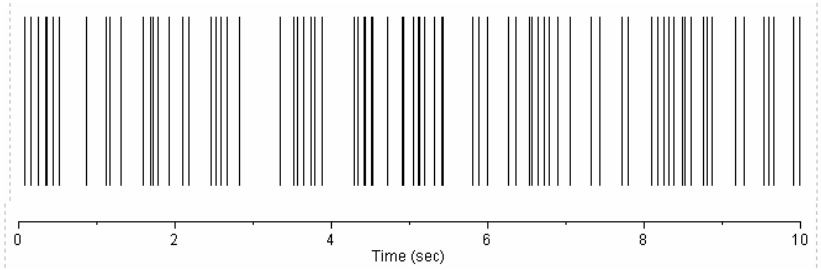
Local Field Potential (LFP) – electrical activity of all cells averaged over some spatial neighborhood.

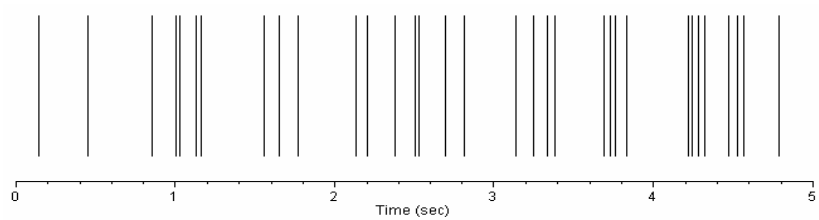
Highpass filtering in 1-2ms range gives spikes (1-2kHz).

LFP signal is lower frequency (e.g. 10-100Hz)

Spike "Sorting"

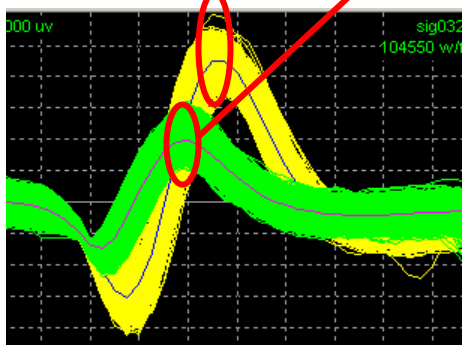
Spike Train, $\{t_i\}$, from cell j



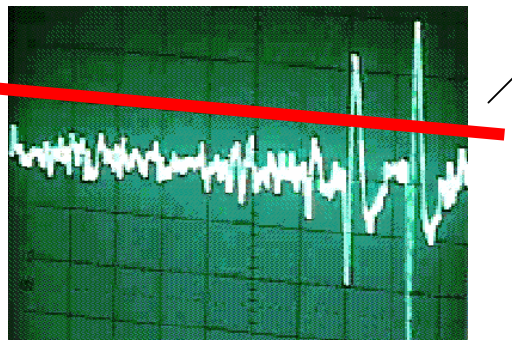


Peak Time

Classify $S_{i,j}^*(t)$

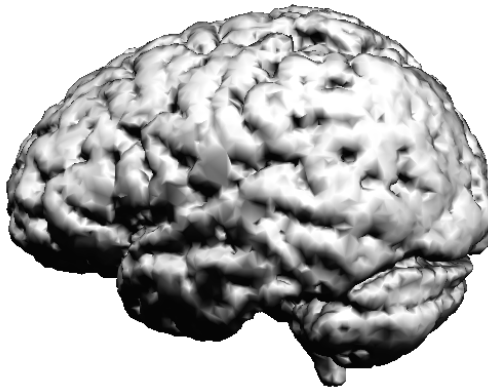


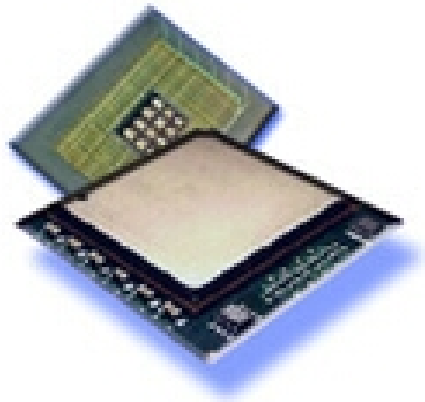
Threshold



Record S(t)

BRAIN VERSUS COMPUTER





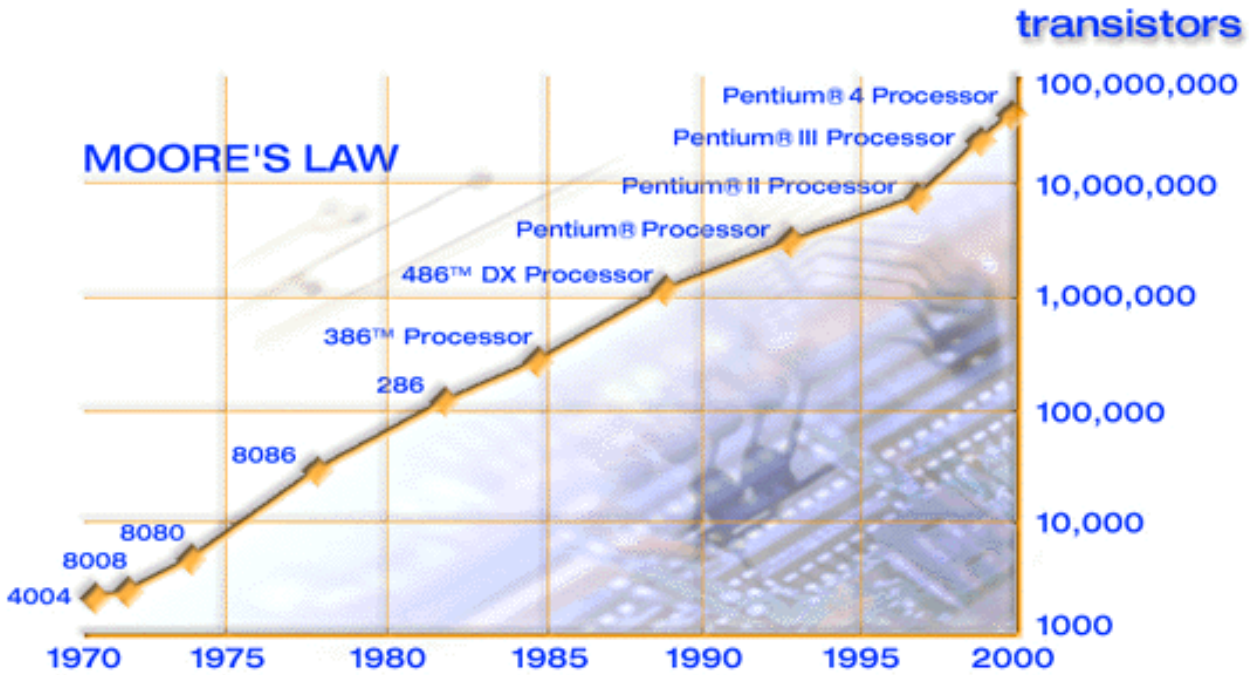
Computational Elements

100,000,000,000	100,000,000
Neurons	Transistors

Speed (operations/second/element)

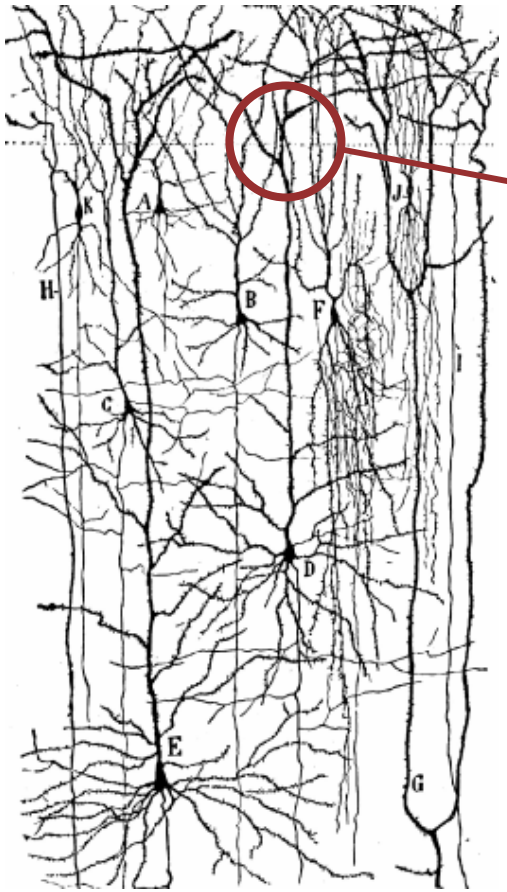
30-300	$1.5 * 10^9$

MOORE'S LAW

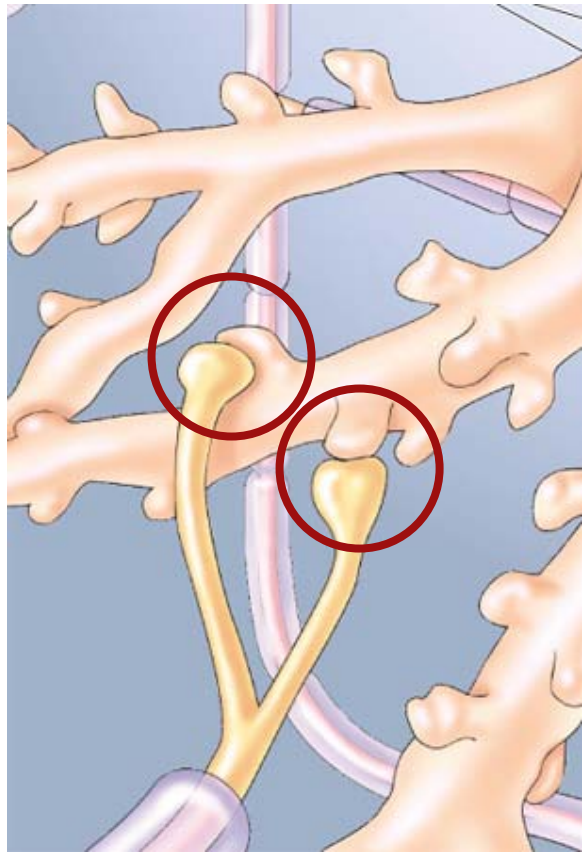


source: Intel

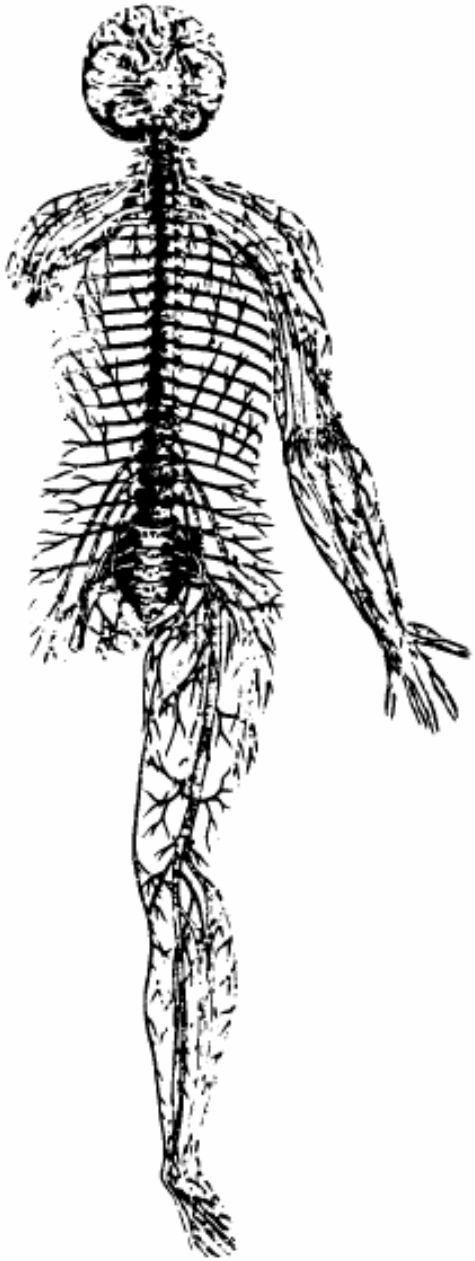
MASSIVE CONNECTIVITY



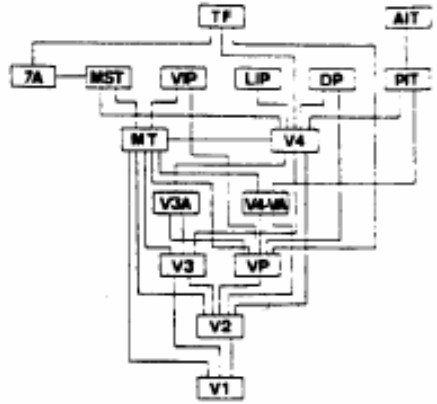
SYNAPSES

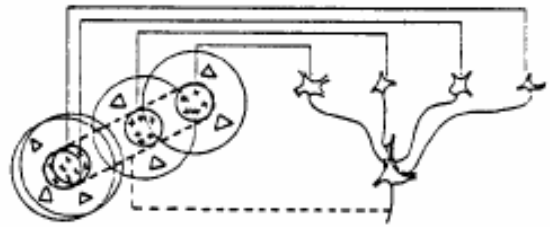


source: David Sheinberg



1 m	CNS
10 cm	Systems
1 cm	Maps
1 mm	Networks
100 μm	Neurons
1 μm	Synapses
1 Å	Molecules





From what part of the brain should we record?