The Ever-Changing Brain

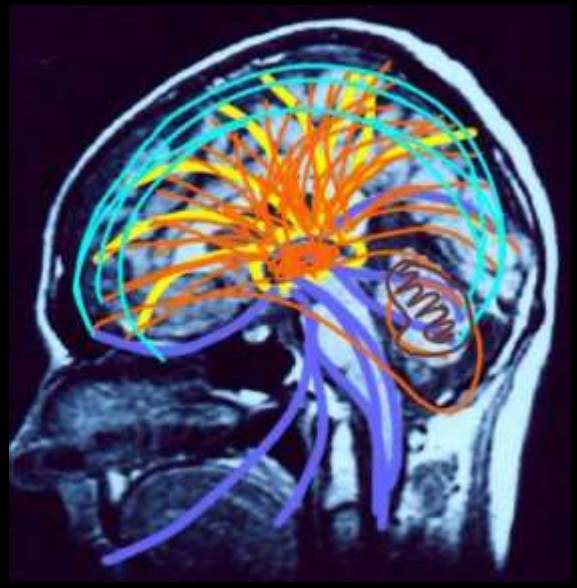
Dr. Julie Haas
Biological Sciences

Outline

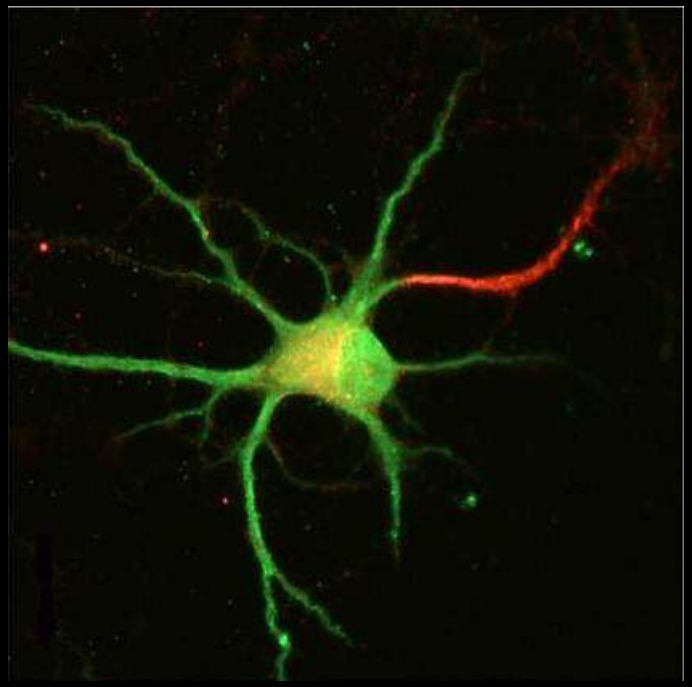
1) Synapses: excitatory, inhibitory, and gap-junctional
2) Synaptic plasticity, and Hebb’s postulate
3) Sensory maps and plasticity
4) Brain plasticity

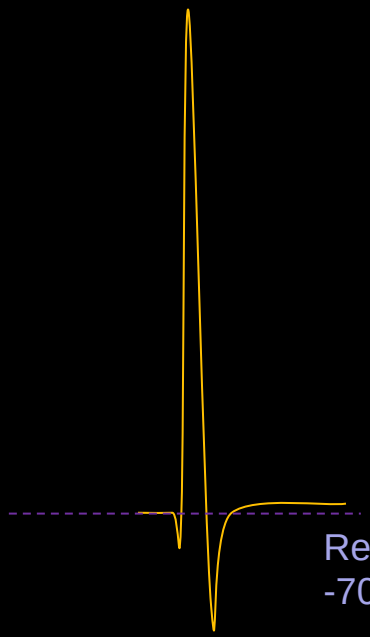
Synapses

- The human brain has ~10 billion neurons.
- Each neuron receives ~10,000 inputs from other neurons at specialized contacts known as synapses.
- The brain is organized into areas – and pathways.



Gary Osborn, “The Gate of God”



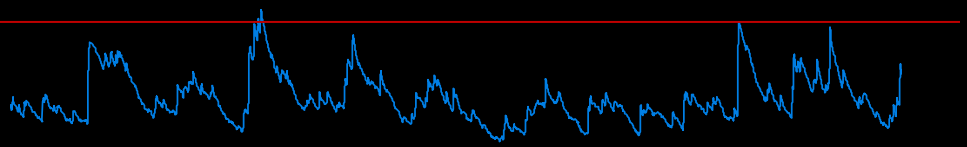


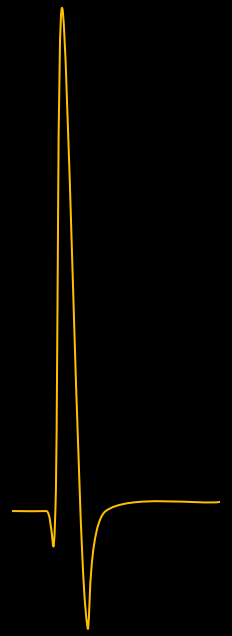
Resting membrane voltage
-70 mV

Do the synaptic responses in neuron 2 make it spike?

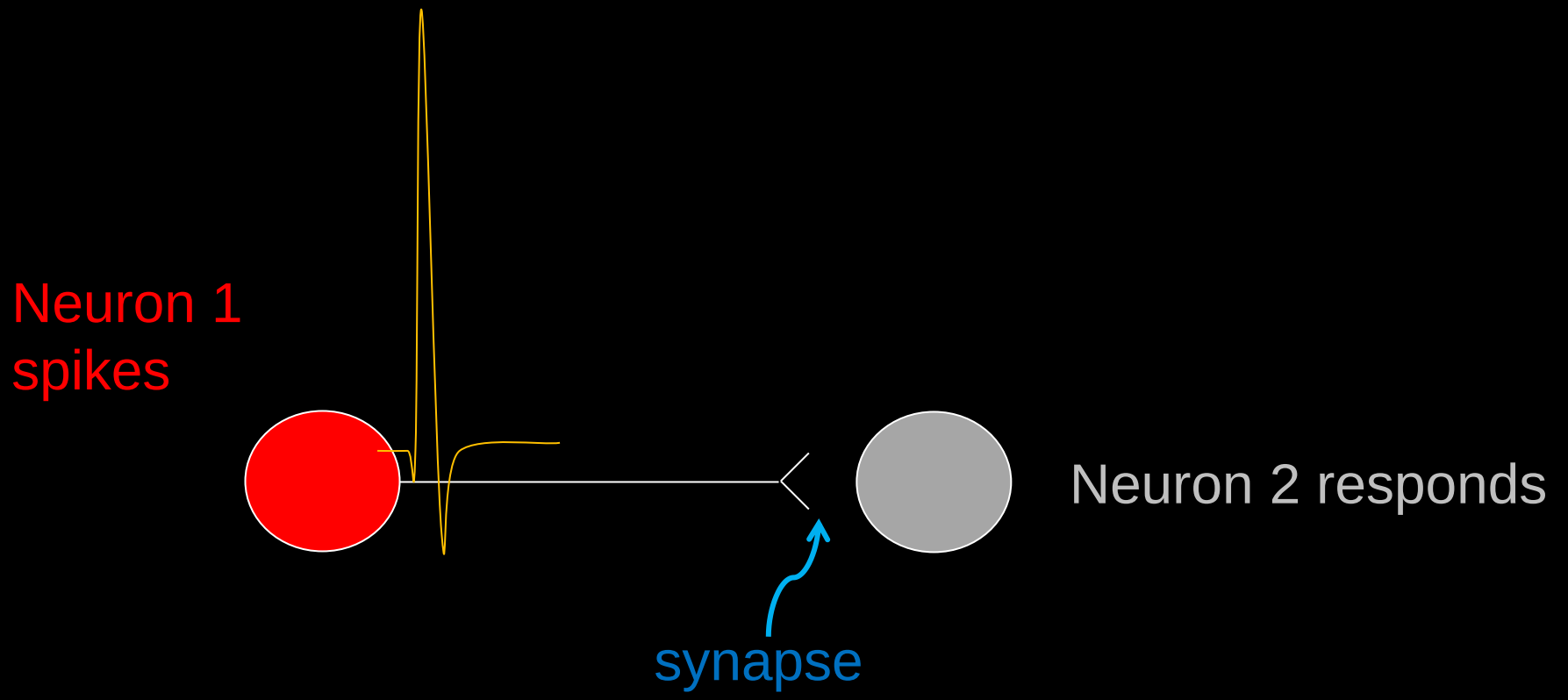
Spike threshold voltage
-40 mV

Resting membrane voltage
-70 mV





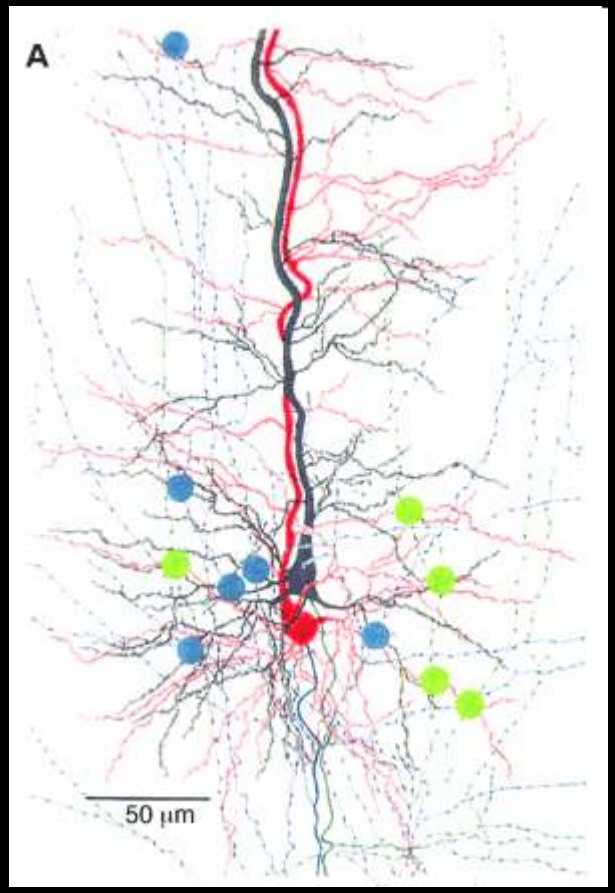
Neurons communicate with spikes at synapses:



What is a synapse?

Sir Charles Sherrington

Derived from the Greek word meaning “to clasp”, a synapse is considered *any specialized relation between two neurons in which one affects another*.



Markram et al. (1997)

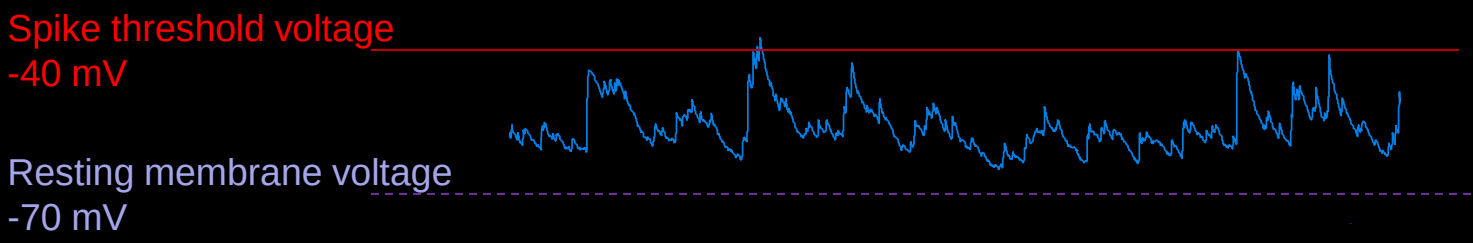
Neuron 1

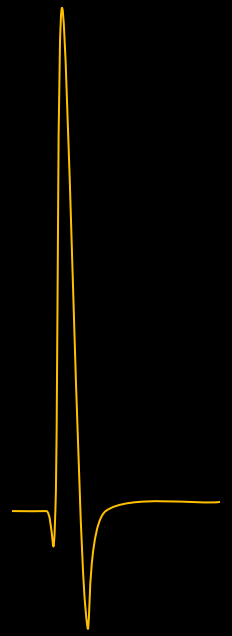
Neuron 2

Synapses from neuron 1 to neuron 2

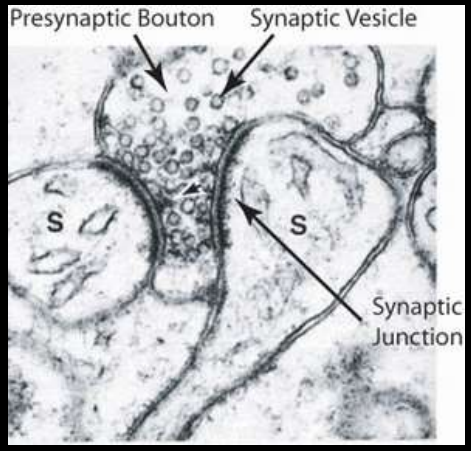
Synapses from neuron 2 to neuron 1

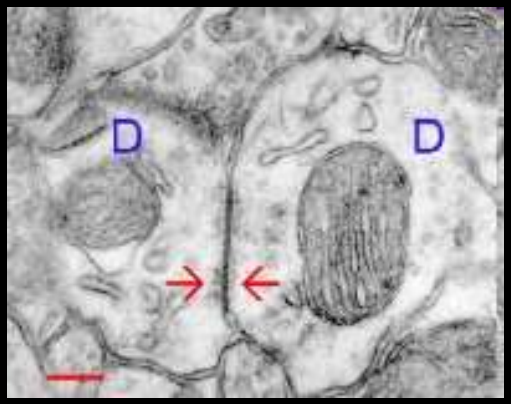
Do the synaptic responses* in neuron 2 make it spike?



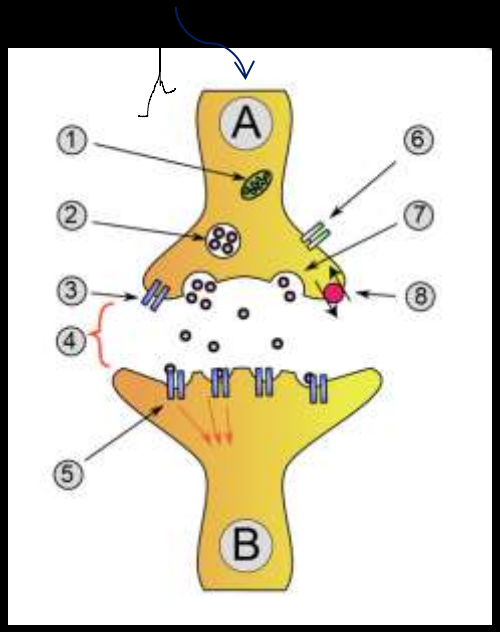


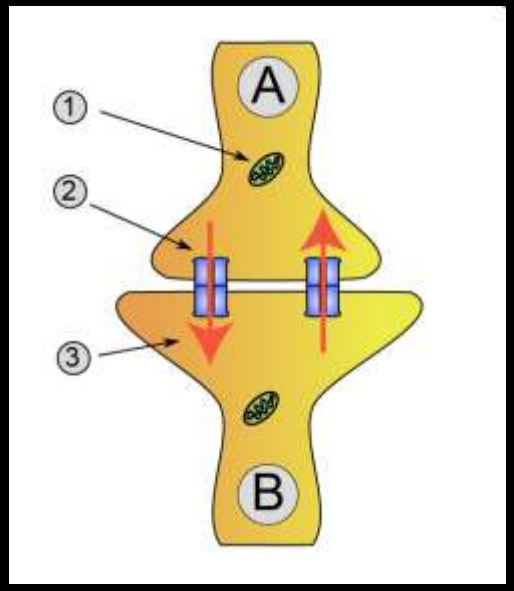
*collected from all over the neuron’s dendrites





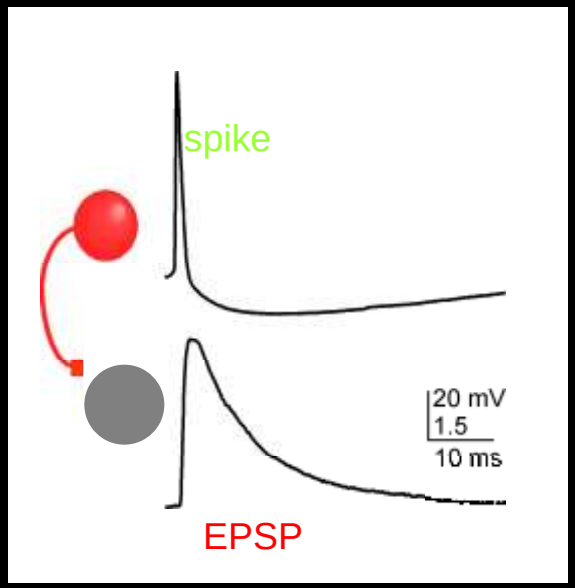
Synapses use neurotransmitter …. or not!





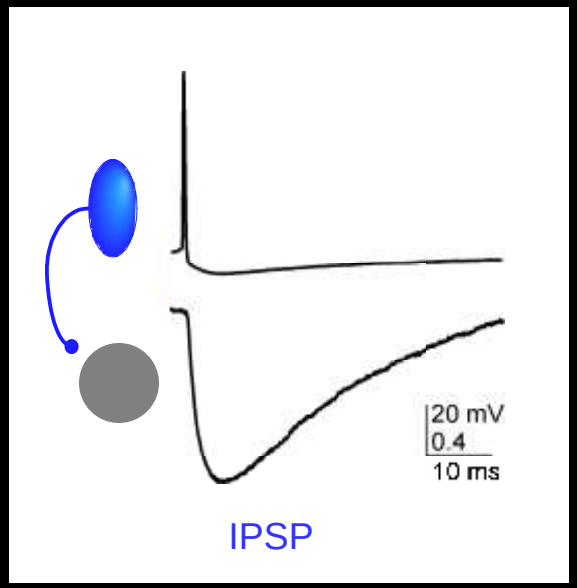
Synaptic Transmission

Excitatory

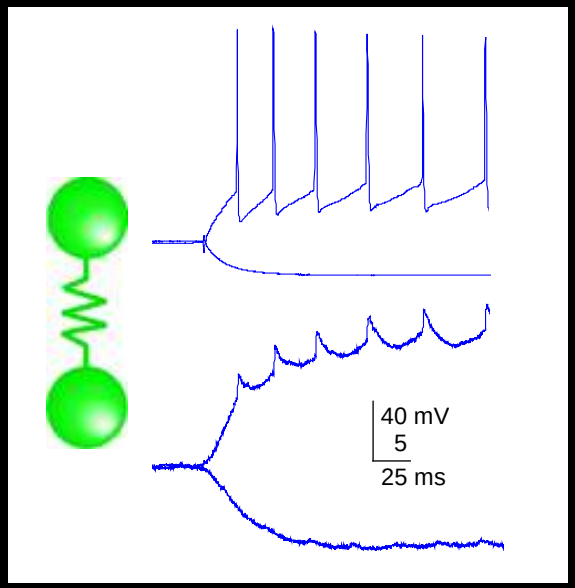


- Directional, with pre- and post-synaptic sides
- Stereotyped timecourses
- Metabolically expensive

Inhibitory

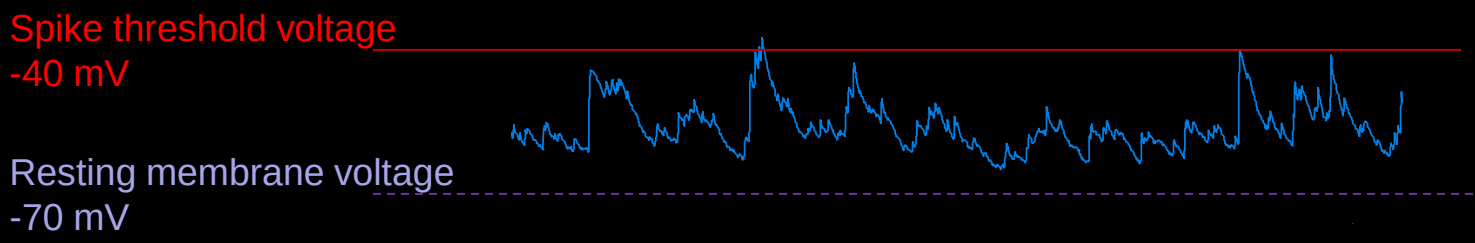


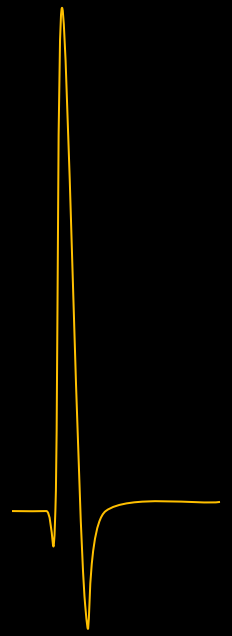
Electrical



- Bidirectional flow
- Sign-preserving response

Do the synaptic responses* in neuron 2 make it spike?





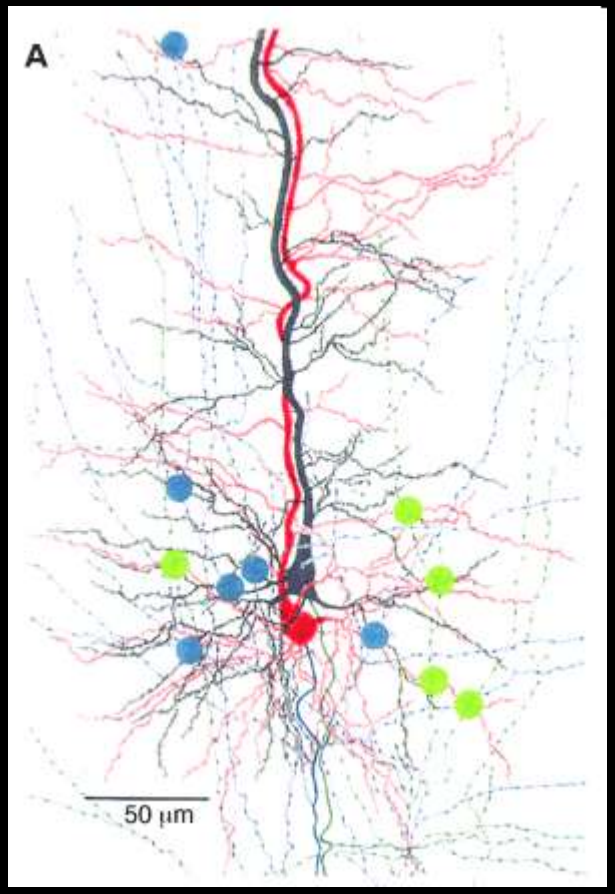
*a combination of excitatory, inhibitory and gap-junctional synaptic inputs

Outline

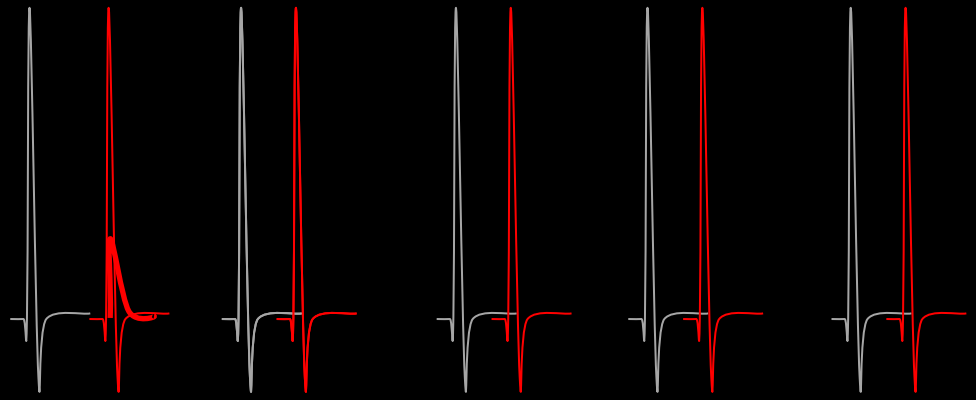
1) Synapses: excitatory, inhibitory, and gap-junctional
2) Synaptic plasticity, and Hebb’s postulate
3) Sensory maps and plasticity
4) Brain plasticity

Let us assume that the persistence or repetition of a reverberatory activity (or "trace") tends to induce lasting cellular changes that add to its stability.… When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased.

Donald Hebb, 1949

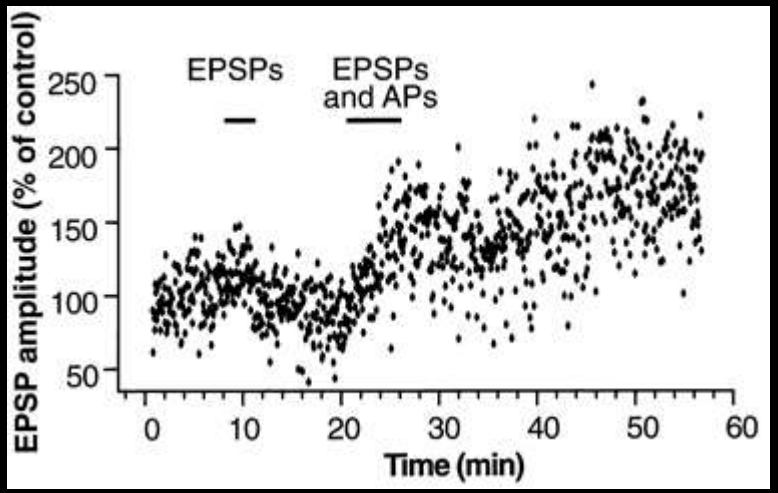


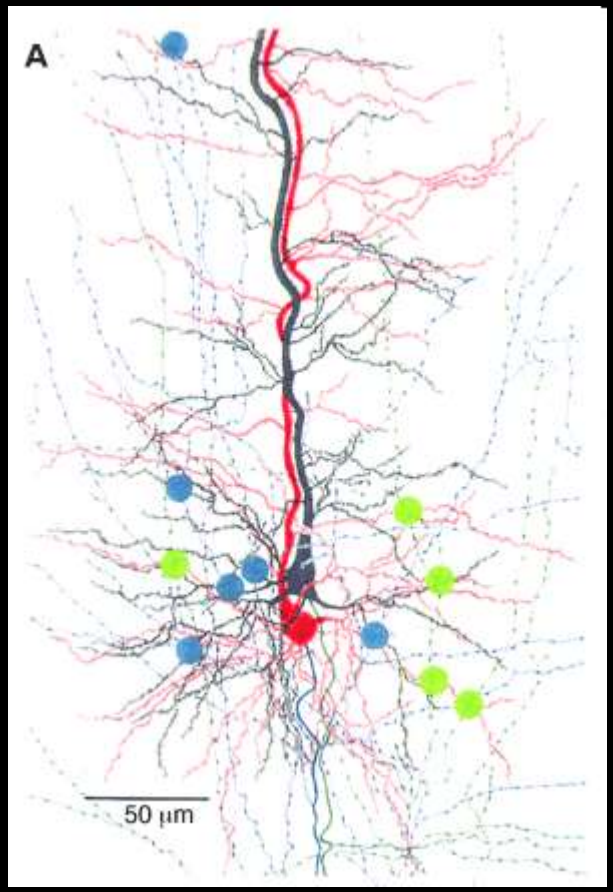
Markram et al. (1997)



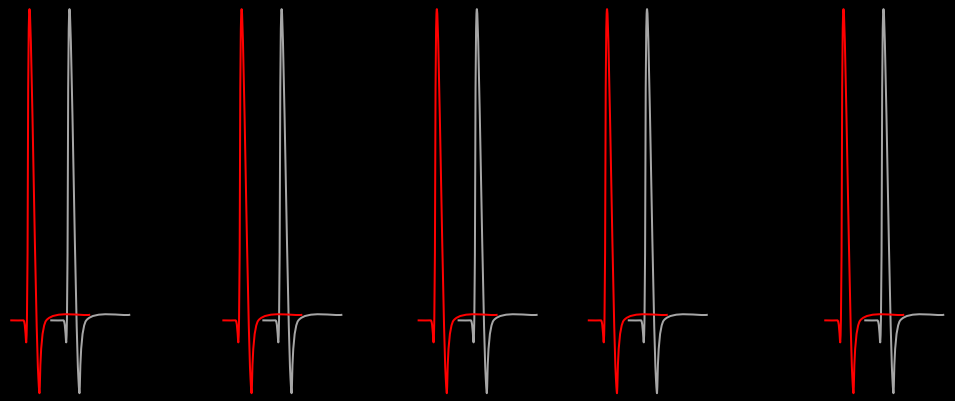
firing together ….

… and wiring together, strengthening connections

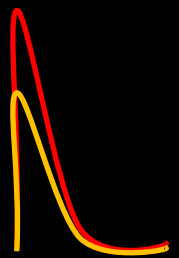




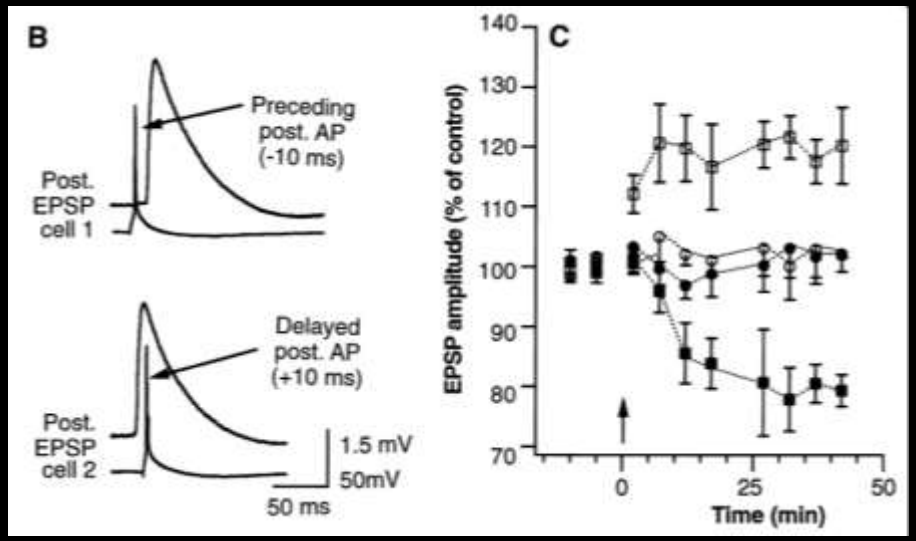
Markram et al. (1997)



for the opposite spiking order



the synaptic connection gets weaker

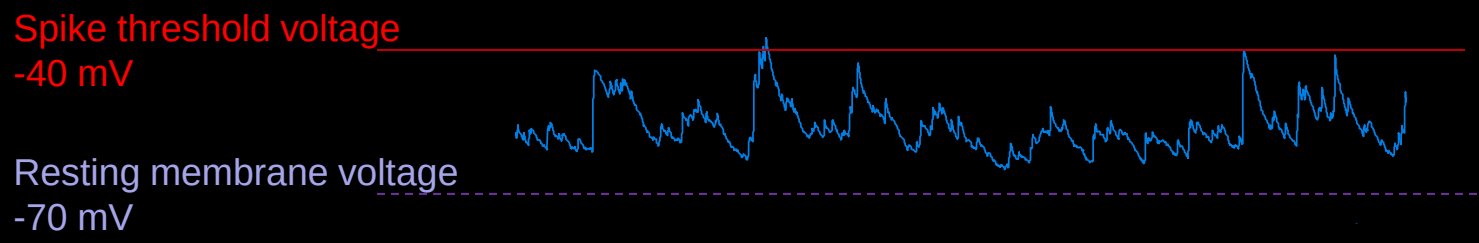


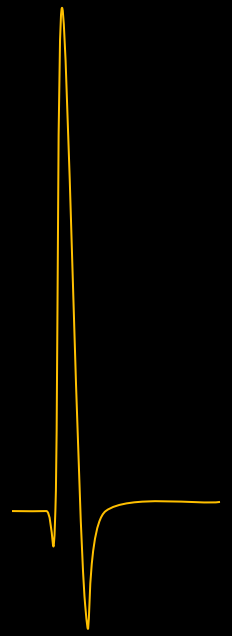
stronger

weaker

Markram et al. (1997)

Do the synaptic responses in neuron 2 make it spike?



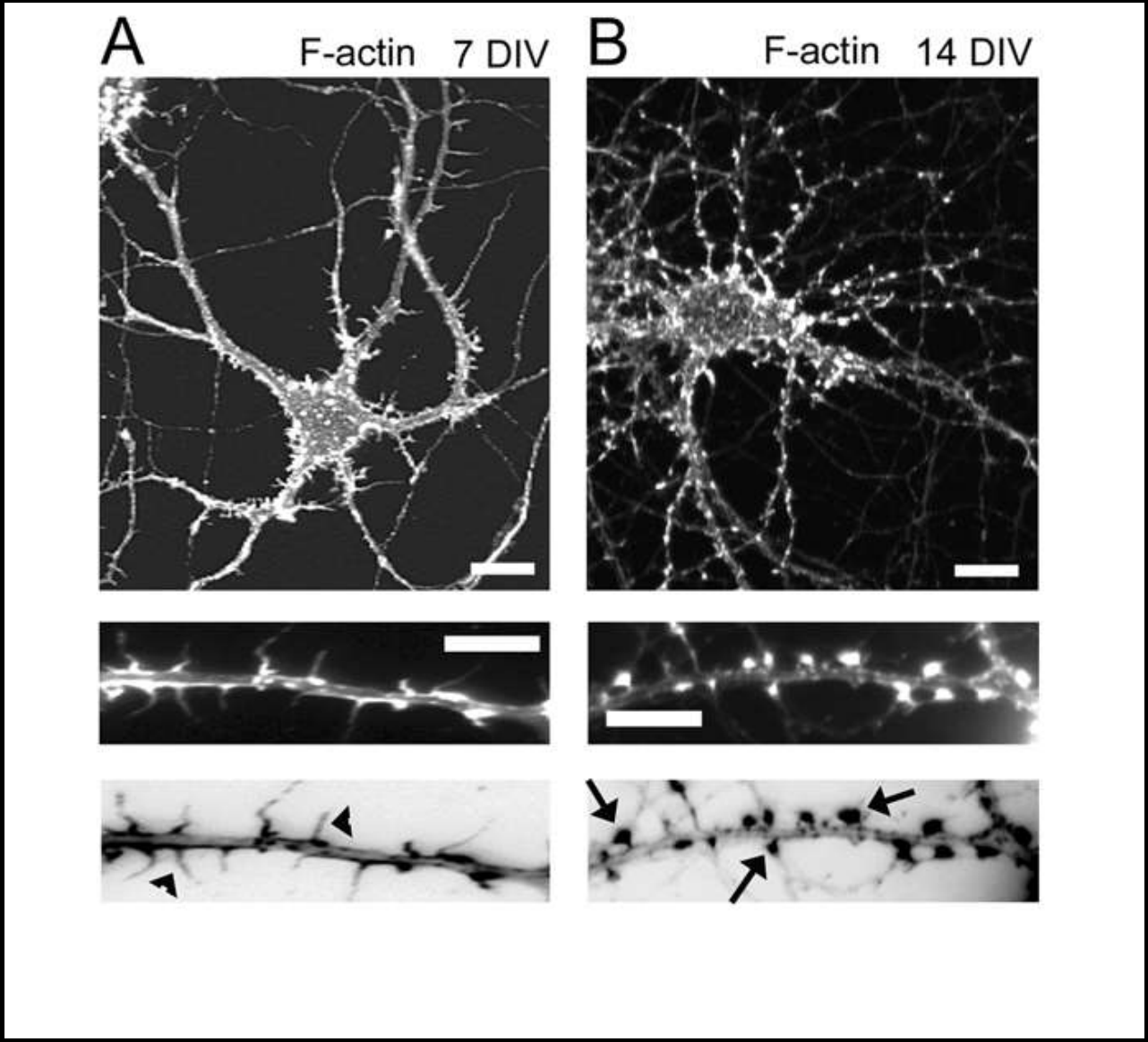


How about now?
How about now?
How about now?
How about now?

Plasticity is everywhere!

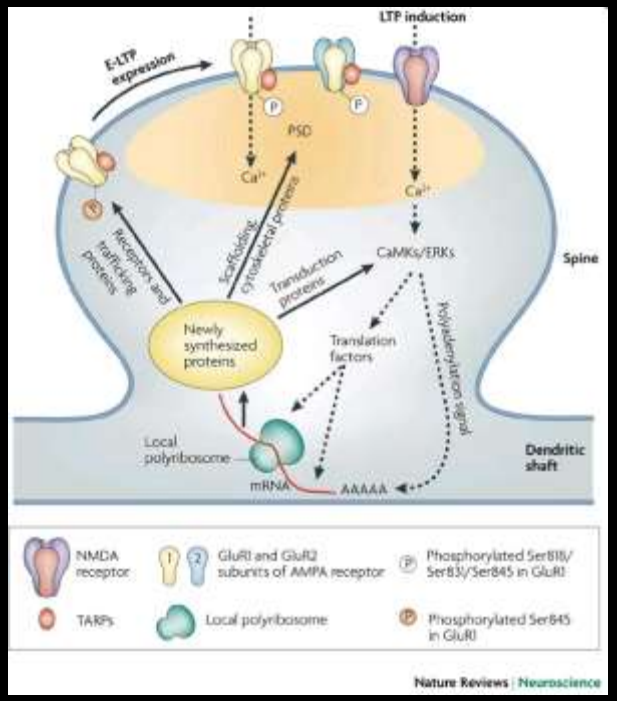
- at excitatory synapses
- at inhibitory synapses
- at gap junctional synapses
- long-term depression, long-term potentiation
- short-term depression, short-term potentiation
- Metaplasticity – changes in how plasticity is expressed.
- Structural plasticity: growth and pruning of synaptic structures
- …….the list goes on!

Structural plasticity



Shi and Ethel, 2006

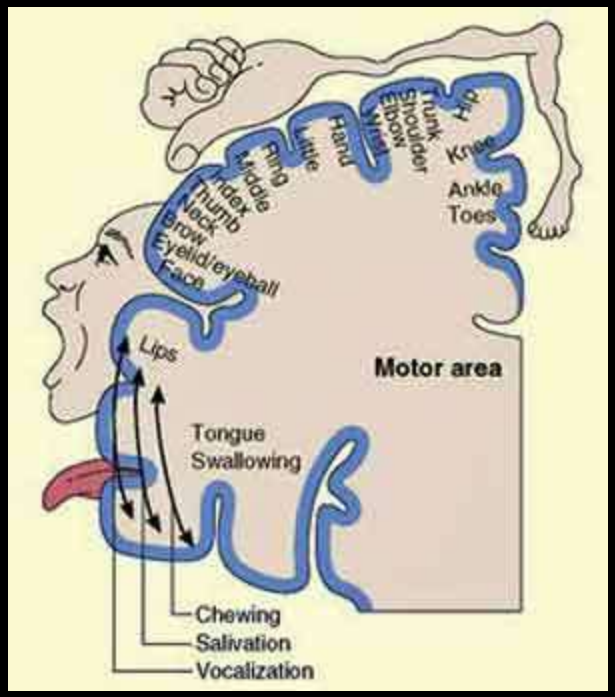
Plasticity is complex



Outline

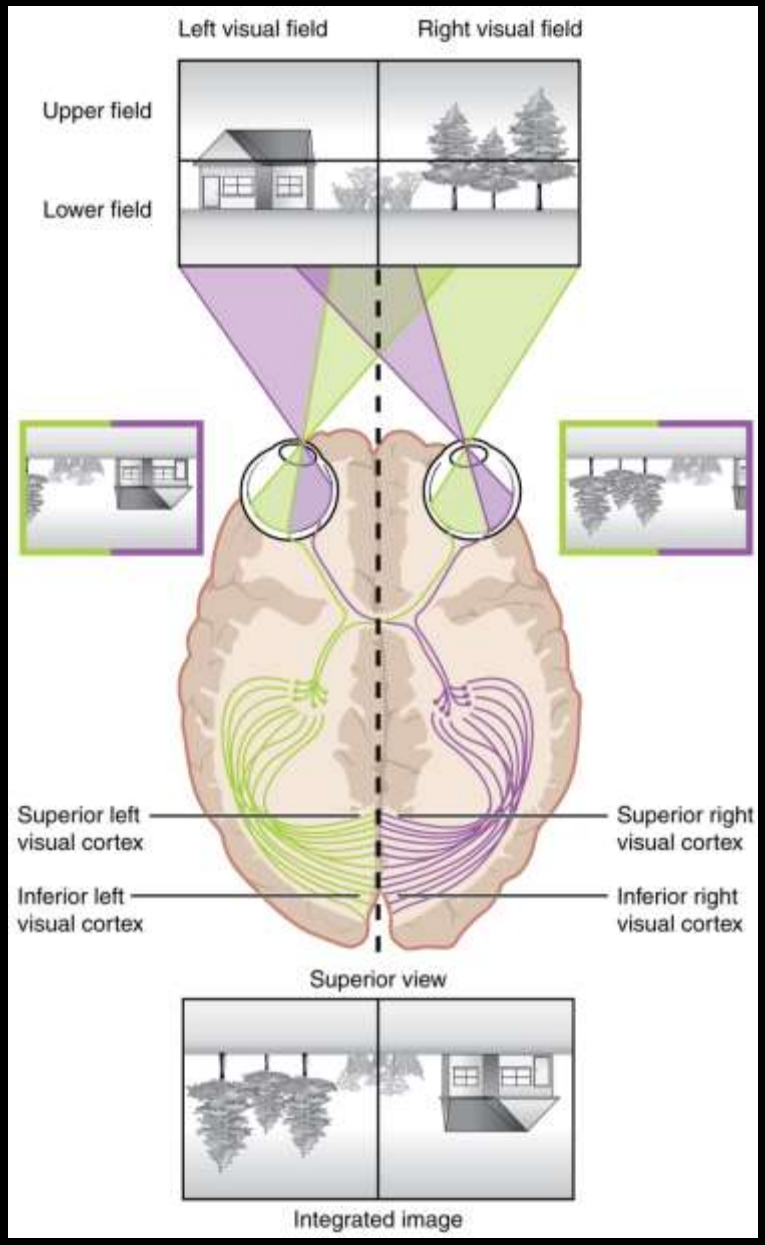
1) Synapses: excitatory, inhibitory, and gap-junctional
2) Synaptic plasticity, and Hebb’s postulate
3) Sensory maps and plasticity
4) Brain plasticity

The somatosensory homonculus:

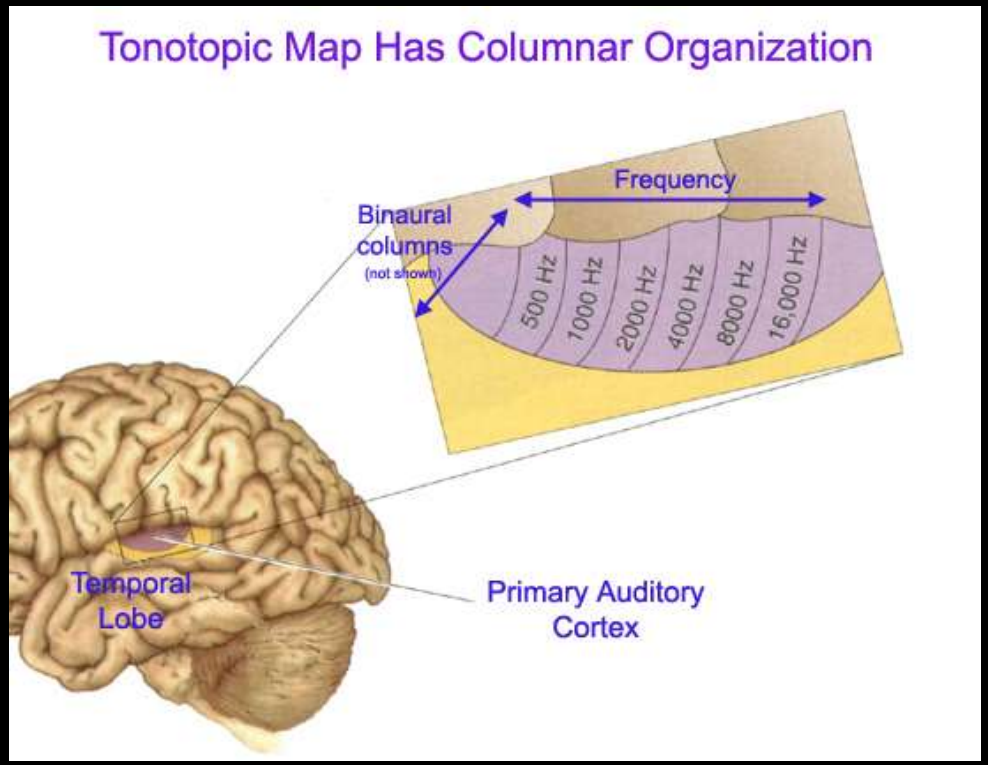


mybrainnotes.com

Visual topographic maps



cnx.org

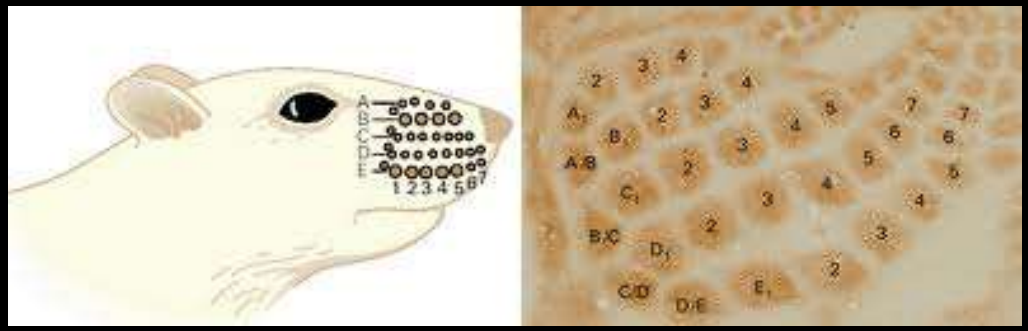


Auditory tonotopic maps

?

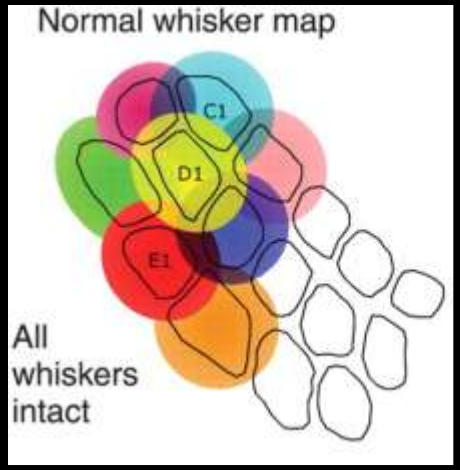
Olfactory map

Rats and the barrel cortex – a type of sensory map

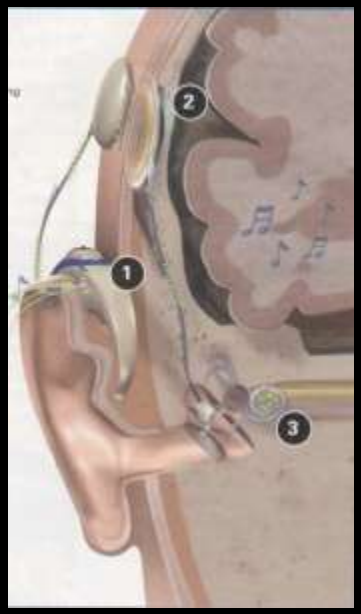


www.neurobiology.info

Sensory map can be changed by experience: Map plasticity



D. Feldman and M. Brecht, Science 2005

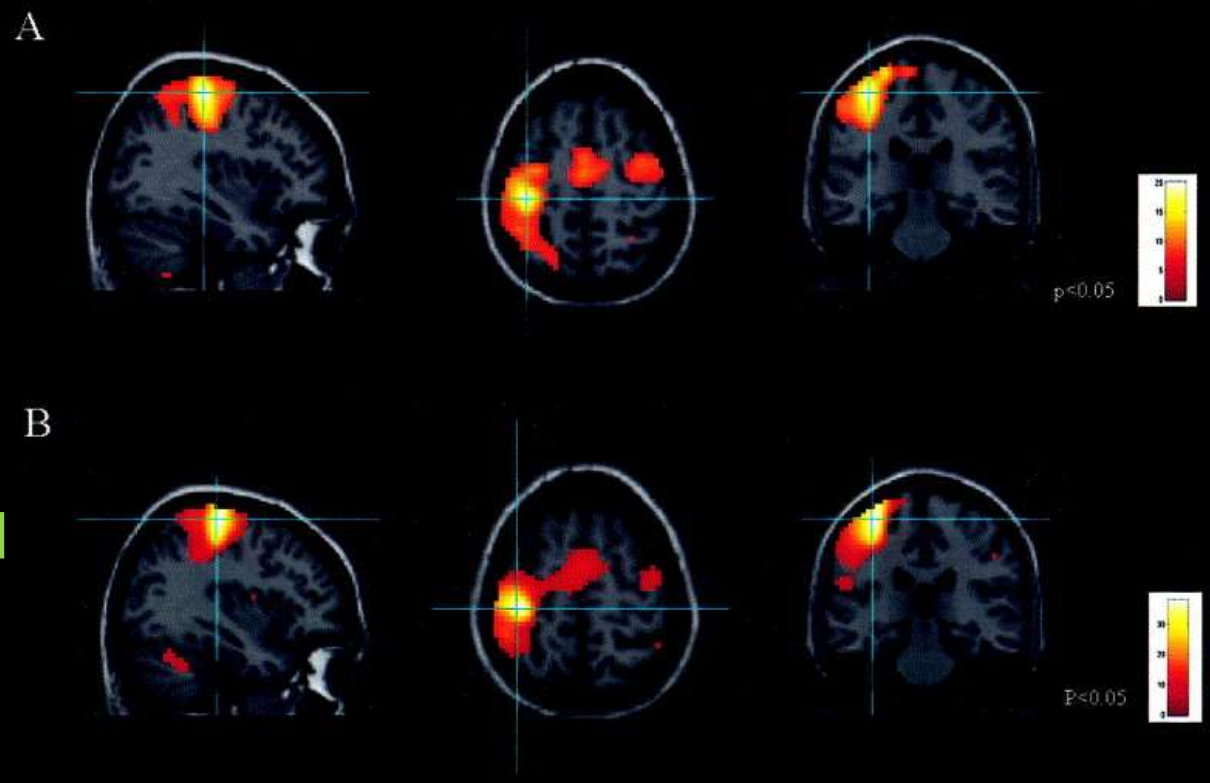


Cochlear implants: a form of map plasticity?

Outline

1) Synapses: excitatory, inhibitory, and gap-junctional
2) Synaptic plasticity, and Hebb’s postulate
3) Sensory maps and plasticity
4) Brain plasticity

Brain Plasticity: A finger tapping task



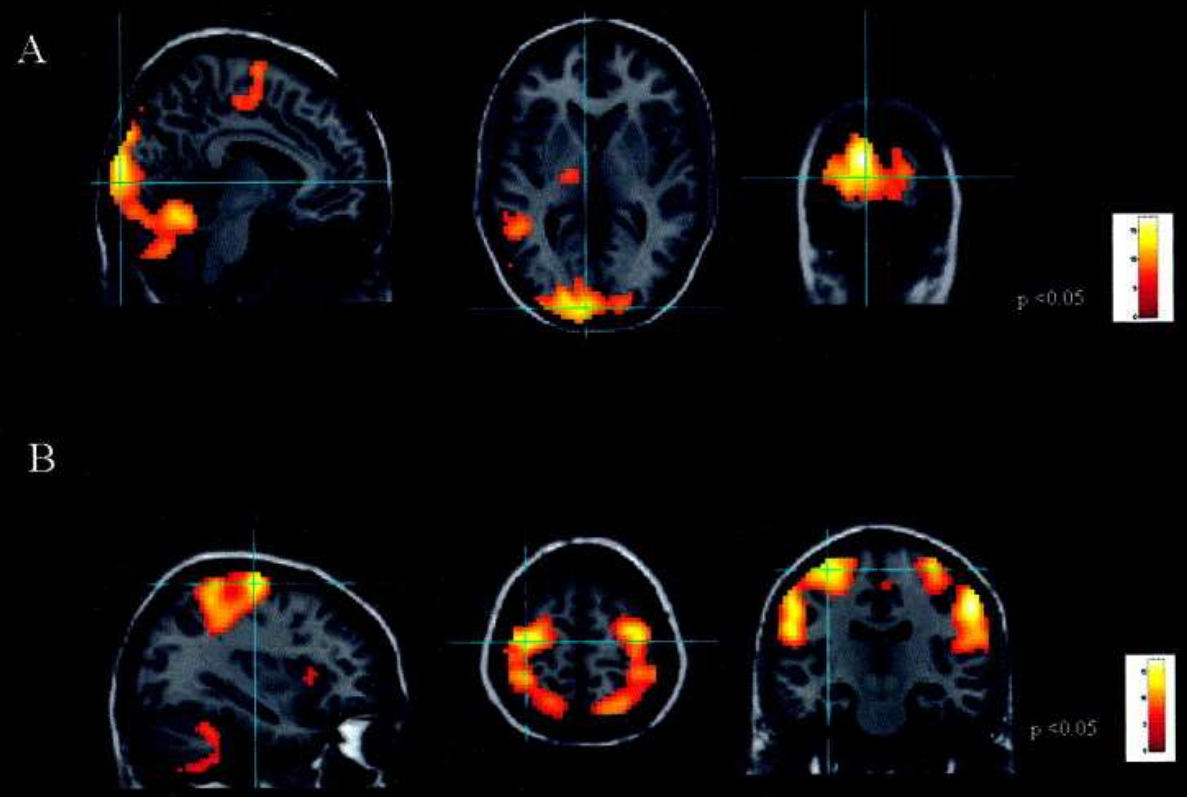
blind

sighted

Braille – a language task

blind

sighted



Brain Plasticity:

Lumosity.com