The Ever-Changing Brain

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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.
Resting membrane voltage
-70 mV
Do the synaptic responses in neuron 2 make it spike?

<table>
<thead>
<tr>
<th>Voltage Description</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Spike threshold voltage</td>
<td>-40 mV</td>
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</tbody>
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Neurons communicate with spikes at synapses:
What is a synapse?

Derived from the Greek word meaning “to clasp”, a synapse is considered *any specialized relation between two neurons in which one affects another.*
Synapses from neuron 1 to neuron 2
Synapses from neuron 2 to neuron 1

Markram et al. (1997)
Do the synaptic responses* in neuron 2 make it spike?

*Spike threshold voltage
-40 mV

*Resting membrane voltage
-70 mV

*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**
- Bidirectional flow
- Sign-preserving response
Do the synaptic responses* in neuron 2 make it spike?

Spike threshold voltage
-40 mV

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*a combination of excitatory, inhibitory and gap-junctional synaptic inputs
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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
... and wiring together, strengthening connections
for the opposite spiking order

the synaptic connection gets weaker

Markram et al. (1997)
Markram et al. (1997)

- stronger
- weaker
Do the synaptic responses in neuron 2 make it spike?

Spike threshold voltage
-40 mV

Resting membrane voltage
-70 mV

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
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The somatosensory homunculus:
Visual topographic maps
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?
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Brain Plasticity: A finger tapping task

blind

sighted
Braille – a language task

blind

sighted
Brain Plasticity:

Lumosity.com