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?

Spike threshold voltage: -40 mV

Resting membrane voltage: -70 mV
Neurons communicate with spikes at synapses:

Neuron 1 spikes

Neuron 2 responds

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

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
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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
firing together ....
... and wiring together, strengthening connections
for the **opposite** spiking order

the synaptic connection gets weaker
Markram et al. (1997)

B

C

Preceding post. AP
(-10 ms)

Delayed post. AP
(+10 ms)

stronger

weaker

Post. EPSP cell 1

Post. EPSP cell 2

1.5 mV

50 mV

50 ms

EPSP amplitude (% of control)

Time (min)
Do the synaptic responses in neuron 2 make it spike?

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

Spike threshold voltage
-40 mV

Resting membrane voltage
-70 mV
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

A  F-actin  7 DIV

B  F-actin  14 DIV

Shi and Ethel, 2006
Plasticity is complex
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The somatosensory homonculus:
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
Brain Plasticity:
Lumosity.com