IV. Neural Network Learning

A Very Brief Tour of Real Neurons (and Real Brains)

The Lobes of the Cerebral Hemispheres

Left Hemisphere

Typical Neuron

Overview of Brain to Neurons

<http://www.youtube.com/watch?v=DF04XPBj5uc>
(play flash video)
Part 4B: Real Neurons

Animation of Neuron

- An animated film about nicotine addiction
- A good visualization of a single neuron
- ©2006, Hurd Studios
- Winner of NSF/AAAS Visualization Challenge
- View flash video

Grey Matter vs. White Matter

Neural Density in Cortex

- 148,000 neurons / sq. mm
- Hence, about 15 million / sq. cm

Cortical Areas

Intercortical Connections

- (1) Short arcuate bundles, (2) Superior longitudinal fasciculus, (3) External capsule, (4) Inferior occipitofrontal fasciculus, (5) Uncinate fasciculus, (6) Sagittal stratum, (7) Inferior longitudinal fasciculus
Part 4B: Real Neurons

Neural Representations

Brodman’s Areas

Macaque Visual System

Hierarchy of Macaque Visual Areas

Bat Auditory Cortex

Neurons
**Typical Neuron**

**Dendritic Trees of Some Neurons**
- A. inferior olivary nucleus
- B. granule cell of cerebellar cortex
- C. small cell of reticular formation
- D. small gelatinosa cell of spinal trigeminal nucleus
- E. ovoid cell, nucleus of tractus solitarius
- F. large cell of reticular formation
- G. spindle-shaped cell, substantia gelatinosa of spinal chord
- H. large cell of spinal trigeminal nucleus
- I. putamen of lenticular nucleus
- J. double pyramidal cell, Ammon’s horn of hippocampal cortex
- K. thalamic nucleus
- L. globus pallidus of lenticular nucleus

*(fig. from Trues & Carpenter, 1964)*

**Axonal Terminations**
*(Tectum of Turtle)*

**Axonal Net**
*(fig. from Arbib 1995)*

**Neural Connections**
*(array tomography by O’Shea at SmithLab, Stanford)*

**Minicolumn**
- Up to ~100 neurons
  - ~75–80% pyramidal
  - ~20–25% interneurons
- 20–50µ diameter
- Length: 0.8 (mouse) to 3mm (human)
- ~6×10⁵ synapses
- 75–90% synapses outside minicolumn
- Interacts with 1.2×10⁵ other minicolumns
- Mutually excitable
- Also called microcolumn
Part 4B: Real Neurons

Layers and Minicolumns

- 70% of minicolumn connections are within macrocolumn
- Basket neurons provide shunting inhibition between minicolumns
- Winner-takes-all networks
- Represent microfeatures

Macrocolumns

Intracortical Connections

- Dendrites extend 2–4 minicolumn diameters
- Axons extend 5× (or even 30–40×) minicolumn diameter
- Periodic spacing of axon terminal clusters causes entrainment
- ~2×10^7 connections to macrocolumn

Neural Networks in Visual System of Frog

Reorganization of Cortex

- Median nerve sectioned to show fluidity of cortical organization
- (C) before
- (D) immediately after
- (E) several months later
Orientation Columns

Orientation Columns

Cell Responses in V4

Cell Responses in V4

Slow Potential Neuron

Slow Potential Neuron

Variations in Spiking Behavior

Variations in Spiking Behavior

Frequency Coding

Frequency Coding
Synapses

video by Hybrid Medical Animation

Chemical Synapse

1. Action potential arrives at synapse
2. Ca ions enter cell
3. Vesicles move to membrane, release neurotransmitter
4. Transmitter crosses cleft, causes postsynaptic voltage change

Typical Receptor

Axon Hillock

Dendrite & Dendritic Branches

Dendrite & Dendritic Spine
Part 4B: Real Neurons

Neuropil

Myelinated Axon Making Synapse on Dendrite

Various Synapses

Excitatory Synapse Between Axon Terminal and Dendritic Thorn

Dendro-dendritic Synapses

Electrotonic Synapse
**Nonsynaptic Communication (“twitching neurons”)**

- When neurons fire, the axons swell slightly
- This opens channels, releasing neurotransmitters (e.g., ATP)
- A form of nonsynaptic communication between neurons and glia
- May control formation of myelin and other processes

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**Neuronal Group Selection (“Neural Darwinism”)**

- Theory developed in '70s and '80s by Gerald Edelman (Nobel Prize, 1972)
- Diversity
  - of neural responses to stimuli
  - disjunctive representations of categories
- Competitive Amplification
  - winner-take-all adaptation to stimuli
- Reentry
  - spatiotemporal continuity and coherence

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**Release of ATP from Axons Firing Action Potentials**

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**Read Flake, ch. 20**