A brief Introduction to Neuroscience Terminology

Lesson I: Introduction
module 05

University of Idaho
Cognitive neuroscience - the basics

- The nervous system as the basis for cognitive operations
  - Wet cognition

- Neuronal structure and processes
  - Neurons, axons, synapses, neuro-transmitters

- Important structures in the human brain
  - Forebrain, midbrain, hindbrain

- Cerebral cortex and localization of function
  - Frontal, parietal, temporal, and occipital lobes
  - The two hemispheres
Parts of the nervous system that have been seen as crucial for human cognition ...

- The ventricles (pressure model of the mind)
- The pineal gland as the junction between rational soul and body (Descartes, 1649)
- The neuron (Nobel prize for Golgi and Cajal, 1906)

Localization of function

- Holistic processing device vs. “grandmother” cells
- Field dynamics vs. neural signaling
- Speech production (Paul Broca, 1861)
- Speech understanding (Carl Wernicke, 1874)
History

- **Trepanage**
  - The brain has long been implicated in headaches and abnormal behavior
Neurons everywhere....

- **Approximate number of neurons**
  - 100(?) billion, cerebral cortex 10 - 20 billion

- **Approximate average number of synapses**
  - 1,000 - 10,000; up to 200,000

- **Approximate transmission speed**
  - 1 - 100 m / s (unmyelinated / myelinated)

- **Transmission distance**
  - Max >1m (e.g., motor neurons from spine to toe)

- **Complex chemical communication channels**
  - Multiple neurotransmitters

For a list of impressive numbers check [http://faculty.washington.edu/chudler/facts.html](http://faculty.washington.edu/chudler/facts.html)
The basic building block: the neuron

- Dendrites
- Soma
- Axon
- Myelin sheath
- Terminal buttons
- Synapses
- Dendrites of other neurons
Synaptic "communication" via neurotransmitter

- Presynaptic membrane
- Microtubules
- Synaptic vesicles
- Synaptic cleft
- Neurotransmitters
- Postsynaptic membrane
- Dendritic spine
- Receptor sites
Action potential: schematic visualization

-30 mV

0 mV

-70 mV

Sodium channels open

Sodium channels close

Potassium channels open

Potassium channels closed

Hyperpolarization

time [ms]
Neurons are spontaneously and randomly active.

Activity increases systematically (more action potentials per time interval) when neuron is activated (e.g., by an external stimulus).
Neurotransmitters

Role of neurotransmitters
- Most neurons communicate with each other via specific neurotransmitters
- Neurotransmitter can activate or inhibit the depolarization of another neuron

Research focus
- Specific areas in the brain use specific neurotransmitters
- Manipulation of neurotransmitters can selectively block or enhance processing in functional systems

Diseases
- Some diseases (e.g., Parkinson [dopamine]) might be caused by deficits in a particular neurotransmitter
Gross Anatomy

- **Forebrain**
  - Youngest part of the brain
  - Includes *cerebral cortex*, basal ganglia, limbic system (amygdala, septum, and *hippocampus*), *thalamus*, and hypothalamus

- **Midbrain**
  - Superior and inferior colliculi
  - Reticular activating system (RAS)
  - Substantia nigra

- **Hindbrain**
  - *Cerebellum*, Pons, Medulla oblongata
Where is that brain? MRI image
The cerebral cortex

- Frontal Lobe
- Central Sulcus
- Parietal Lobe
- Occipital Lobe
- Temporal Lobe

Anterior and posterior directions are indicated.
Cerebral cortex

- Has a large surface (approx. title page of the UI argonaut, 3mm thick)
- Is folded numerous times into a number of gyri (bulges) and sulci (grooves between them)
- Comprises about 80% of the human brain
- Consists of two interconnected hemispheres (The hemispheres are connected via corpus callosum)
- The hemispheres are not mirror images of each other (hemispheric specialization)
- Some important parts of the cerebral cortex are folded out of sight and can’t easily be depicted
- Exact location of gyri and sulci differs among people
**Post-mortem analysis of the brain of patient “Tan”**
- Lesion in a specific region in the left frontal lobe (now known as Broca’s area)
- Patient was unable to produce speech
Localization of function
(retinotopic organization: Tootell, 1988 - striate cortex)
What & where? Functional organization

- Executive control, attention, motor planning
- Primary motor cortex
- Primary sensory cortex
- Spatial layout
- Speech production
- Visual memories
- Auditory memories
- Visual processing
Hemispheric specialization

- **Left hemisphere**
  - Speech production (Paul Broca, 1861)
  - Speech understanding (Carl Wernicke, 1874)
  - Skilled movement / grammar

- **Right hemisphere**
  - Visuo-spatial tasks
  - Semantic understanding / knowledge

- **Localization of function**
  - Split brain studies (Roger Sperry)
  - Local lesion studies (Carl Lashley)
Lateralization of function
- Sensory and motor control generally resides in the contralateral hemisphere

Split-Brain
- The corpus callosum provides the most important communication pathway between the two sides
- Patients with a severed corpus callosum (split brain patients) show interesting deficits
  - Unable to name objects in left visual field
  - Unable to haptically identify objects with contralateral hand
Specific methods ...

- **Post-mortem studies**
  - often after obvious lesions during life

- **Experimental lesion studies (animals)**

- **Electrical recordings**
  - Invasive: single cell, matrix recordings
  - Non-invasive: Electroencephalogram (EEG)

- **Electrical stimulation and TMS**

- **Static imaging**
  - CT scans, MRI, dyes

- **Metabolic / event related imaging**
  - PET, fMRI, dyes
Specific scientific methods ...