COGS 107B – Systems Neuroscience

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Fri 11:00-11:50 CSB 005
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(Connectome - http://thinktank.uchicago.edu/)
Slides adapted from Luisa Schuster (NYU)
Today’s Schedule

• 1. Lecture 1: Brain Potentials, Levels of Analysis
• 2. Lecture 2: Tactile Sensation
• 3. Lecture 3: Proprioception
Who postulated the neuron doctrine and the law of dynamic polarization?

SANTIAGO RAMÓN Y CAJAL
Principles of the week:

The Neuron Doctrine: the neuron is the basic structural and functional unit of the brain.

Law of Dynamic Polarization: Neural/electrical transmission proceeds in one direction.

Dendrites/Soma

↓

Axon

↓

Axon Terminal
Membrane Potential vs Equilibrium Potential
Synaptic Potentials vs Action Potential

- Continuous
- Discrete (All or None!)
Synaptic Integration

synaptic integration: temporal vs. spatial

[Diagram showing temporal and spatial summation of synaptic potentials]
Properties of Ion Channels

1) Ion Selectivity:
What types of ions pass through the channel? Na+, Ca++, K+, Cl-.

2) Gating:
What opens it?
Voltage, ligand.
Properties of Ion Channels

3) **Kinetics:** How long does it remain open?

4) **State:**
   - **Activated:** Open.
   - **Inactivated:** Closed.
   - **Deinactivated:** Primed to open
   - **Persistent:** Open or closed for a long time.

5) **Distribution:** Where is it located? Dendrites, axon hillock.
## Levels of Analysis

<table>
<thead>
<tr>
<th>Structure</th>
<th>Synapses</th>
<th>Neurons</th>
<th>Nuclei</th>
<th>Regions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1" alt="Synapse Image" /></td>
<td><img src="image2" alt="Neuron Image" /></td>
<td><img src="image3" alt="Nucleus Image" /></td>
<td><img src="image4" alt="Region Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dynamics</th>
<th>Synaptic Potentials</th>
<th>Action Potentials</th>
<th>EEG/Field Potentials</th>
<th>fMRI</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5" alt="Synaptic Potential Images" /></td>
<td><img src="image6" alt="Action Potential Image" /></td>
<td><img src="image7" alt="EEG/Field Potential Image" /></td>
<td><img src="image8" alt="fMRI Image" /></td>
<td><img src="image9" alt="fMRI Image" /></td>
</tr>
</tbody>
</table>

(Micro) -> (Macro)
Lecture 2: Tactile Sensation

Principle of the week: 

**Topographic representation:** Ordered projection of a sensory surface in the brain.

- **Barrel Cortex**
- **Homunculus**
Dorsal Root Ganglion Cell

Generator potential
= Graded Potential
Touch Receptors
attached to unmyelinated end of Dorsal Root Ganglion Cells

Meissner Corpuscles
Merkel Disks
Shallow: Merkel and Meissner Receptors

SA - Slow Adapting/Persistent
FA - Fast Adapting/Transient

Perception
- Fine details

Slip/ low frequency vibration
Merkel Disk Density & Receptive Field

Fine Texture Discrimination

low acuity

high acuity

lowest tactile acuity: on back and legs
Meissner Corpuscles
Senses low-frequency vibrations like microslips while gripping objects
Deep: Pacinian Corpuscle and hair Receptors

- Ruffini cylinder
  - Fires to continuous pressure
- Pacinian corpuscle
  - Fires to "on" and "off"

Perception
- Stretching
- Vibration
- Fine texture by moving fingers

FA- Fast Adapting/Transient
Pacinian corpuscles

Senses High Frequency Vibrations and overall textures like wood vs. velvet
dorsal root ganglion pathways to the brain

DRG → Medulla → Cuneate Nucleus (crosses-over) → Gracile Nucleus → Medial Lemniscus → Thalamus → Somatosensory Cortex (S1)
S1: Fast adapting Meissner and Pacinian information converges with slow adapting Merkel Disk information in layer 2 of the primary somatosensory cortex.

GREEN: Slow adapting (Merkel)

PURPLE Fast adapting (Meissner and Pacinian)
Different Types of Receptor Fields

- Small versus large response fields
- Inhibitory surround: complete vs. incomplete
- Whole versus patchy
S1: direction-selective surround inhibition

Black: Excitatory. More APs
White: Inhibitory. Less APs
Grey: Baseline. No change
S2 – response fields expand across digits, but maintain directional selectivity
## Touch Receptors in Skin

<table>
<thead>
<tr>
<th>Type</th>
<th>Looks like</th>
<th>RA/SA</th>
<th>Depth</th>
<th>Response field</th>
<th>Sensitivity</th>
<th>Best stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacinian Corpuscle (Onion)</td>
<td><img src="PacinianCorpuscle.png" alt="Image" /></td>
<td>RA</td>
<td>Deep</td>
<td>Very Large/Hand</td>
<td>Very high (10 nm).</td>
<td>High frequency vibration.</td>
</tr>
<tr>
<td>Meissner Corpuscle (Pancakes)</td>
<td><img src="MeissnerCorpuscle.png" alt="Image" /></td>
<td>RA</td>
<td>Shallow</td>
<td>3-5 mm</td>
<td>Micro-slips.</td>
<td>Low frequency vibration</td>
</tr>
<tr>
<td>Merkel Disk (Flowers)</td>
<td><img src="MerkelDisk.png" alt="Image" /></td>
<td>SA</td>
<td>Shallow</td>
<td>Spotty 2 - 3mm</td>
<td>Broad depth range.</td>
<td>Form, texture. Points, edges.</td>
</tr>
</tbody>
</table>
Proprioceptive System

**Proprioception:** Knowledge of where your body is relative to itself and relative to gravity.

2. Adjustment of muscle contraction/recruitment
4. Coordination of motor commands
5. Sense of self.
proprioception and touch sense: the ‘all-axon’ ganglion cell
The Knee-Jerk Reflex

2 Minute Neuro Video
The Muscle

Two types of fibers comprise the muscle:

- **Extrrafusal fibers**: Helpful for lifting.
- **Intrrafusal fibers**: They tell the brain when a muscle elongates.
The Muscle Spindle Afferent

Carries \textit{transient} info about the \textit{elongation} of a muscle.
The Muscle Spindle Afferent

1) Senses **Elongation** of muscle. (Ex: Stretch of biceps during arm extension.)
2) Contractile portions contract, stretching the non-contractile portion.
3) Deformation of unmyelinated portion of DRG cell (i.e. Muscle Spindle Afferent)
4) Generator Potential → Action Potential
The Muscle Spindle Afferent

- **Gamma motor fibers** reset the contractile portion, which relaxes the non-contractile portion, prepping it for the next elongation.
The Golgi Tendon Organ

Type of dorsal root ganglion cell that attaches on tendon (where muscle meets bone). **Muscle contraction** deforms shape of tendon.

Sustained response
## Proprioceptors: Summary

<table>
<thead>
<tr>
<th>Muscle Spindle Afferent</th>
<th>Golgi Tendon</th>
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</thead>
<tbody>
<tr>
<td>Muscle stretching.</td>
<td>Muscle contracting.</td>
</tr>
<tr>
<td>Transient response (fast adapting)</td>
<td>Sustained response (slow adapting)</td>
</tr>
</tbody>
</table>

![Diagram of muscle spindle and Golgi tendon organ](image)
Posterior Parietal Cortex (AIP region)

- AIP registers how a primate manipulates their hand to grasp a concept.
- AIP also registers the concept of how to manipulate hand to grasp an object.
The Pinocchio Effect

1) Vibration against tendon.
2) Stimulation of muscle spindle afferent tricks MSA into thinking you are elongating biceps.
3) But because your hand is on your nose...
   Hand touching nose + elongation of biceps
   
   =
4) Feels like nose is growing out.

SOMATOSENSORY + PROPRIOCEPTIVE SYSTEMS