COGS 107B
Week 1

Hyun Ji
Friday 4:00-4:50pm
Before We Begin...

- Hyun Ji
  - 4th year
  - Cognitive Behavioral Neuroscience

- Email: hji@ucsd.edu
  - In subject, always add [COGS107B]

- Office hours: Wednesdays, 3-4pm in CSB 114 or by appointment
Lecture 1: Brain Potentials, Levels of Analysis

Systems Neuroscience

- Systems neuroscience is the constant interplay between the structure of the brain and the dynamics of the brain
- **Structure**
  - (Micro) Synapses $\rightarrow$ Neurons $\rightarrow$ Nuclei $\rightarrow$ Neurons (Macro)
- **Dynamics**
  - (Micro) Synaptic and action potentials $\rightarrow$ Field potentials/EEG $\rightarrow$ fMRI (Macro)
  - Split into two categories
    - Electrical
    - Chemical
- **Key point: Levels of Analysis!**
Neurons Vary in Shapes and Sizes

- **Purkinje Cell**
  - In cerebellar cortex
  - Elaborate, dendritic tree
  - Granule cell axons go through them

- **Pyramidal Cell**
  - In cerebral cortex
  - Big, long dendrites

- **Depolarization from different branches meet at the thicker part of the dendrite**
  - Less resistance
  - Individually, small effect, but collectively, create larger effect
The Fundamental Difference Between Rats and Humans

- Looked at pyramidal cells in the cortex of rats and humans
- In humans, pyramidal cells much larger and longer
- Found reduced ion channel densities in humans despite larger and longer dendrites
- Injected currents into dendrites and recorded differences between humans and rats
  - In human, input slowly decreases over time
  - In rat, input stays strong along dendrite
  - In humans, need coordination of MULTIPLE inputs to get strong responses
- **This is the FUNDAMENTAL DIFFERENCE between rats and humans in the brain**
Neuron Doctrine and Law of Dynamic Polarization

- **Santiago Ramon y Cajal**
- 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
  - Dendrite/soma -> Axon -> Axon terminal
- **Golgi**
  - Did stains of brain structures and also drew many different structures the way he saw them
Electrical Potentials Reflect the Dynamics of Ion Concentration at the Membrane Surface

- Ions flow DOWN concentration gradient (More concentrated -> Less Concentrated)
- Na concentrated more outside of cell than inside
- K concentrated more inside of cell than outside
Equilibrium Potential

- When both the concentration and voltage are balanced
- Nernst Equation used to determine equilibrium potential
  - Relates ion concentration gradients to electrical charge (defines how they balance each other)
Properties of Ion Channels

- Ion selectivity – e.g., Na+, Ca++, K+, Cl-
- Gating – e.g., by voltage, ligand
- Kinetics – e.g., open-time
- State – e.g., activated, inactivated, deinactivated, persistent
- Distribution – e.g., in dendrites, at axon hillock
Synaptic Integration: Temporal vs Spatial
Lecture 2: Tactile Sensation (Touch Mechanoreception)

Principle: Topographic Representation
Important Concepts

- Transient vs Sustained (aka Rapidly adapting vs Slowly adapting)
- Topographic representation
- Response fields
- Cortical column - segregation/integration
- **Questions on test are analogies**
Topographic Representation

- Generally, neurons in the brain are anatomically (spatially arranged)
  - Neurons responding to similar features of a single sensory modality are grouped into the same space in the brain
- Sensory inputs topographically represented in the space of the brain may reflect actual space on sensory surface
- Sensory homunculus
- “Rat”-unculus
  - Whisker barrel cortex
The “All-Axon” Ganglion Cell

- The key to somatosensory and proprioceptive systems of the brain
- All along vertebrae, at each vertebral junction
- Tip transitions from dendrite to axon
  - Unmyelinated
  - Special kind of ion channel
  - Mechano-gated
  - Bend or crumple = opens sodium ion channels
  - More bend = more depolarized
  - Generator potential - continuous distribution
- Axon goes up spinal cord and into medulla
Touch Receptors in Skin

- Each receptor is a different way of how a dendritic portion of a dorsal root ganglion cell is stimulated
- Pacinian corpuscle
  - Dendrite of dorsal root ganglion cell is wrapped around with different skin cells, like an onion
  - Very deep under skin
- Hair receptor
  - Dendrite wraps around hair follicle, if hair is moved, creates generator potential
- Meissner corpuscle
  - Closer to surface of skin
  - Dendrite winds through layers
  - Pushing sets off generator potentials
Touch Receptors in Skin (Cont.)

- Merkel disk
  - Dendrite branches off into different disks
- Ruffini ending
Response Fields

- Can record dorsal root ganglion (DRG) cell activity
- Make rough approximation of where that neuron’s receptor is located on the skin
- Excitatory = causes neurons to fire more AP
- Inhibitory = causes neurons to fire less AP
- No change = no difference in firing of AP
- Different types of response fields
  - Small vs Large
  - Inhibitory surround (Complete vs incomplete)
  - Whole vs patchy
Sustained vs. Transient Responses

- **Top = Slowly Adapting (SA or Sustained)**
  - Merkel Disks
  - Burst of activity at beginning of stimulus
  - Persistent activity throughout stimulus, but weaker
- **Middle = Rapidly Adapting (RA or Transient)**
  - Meissner corpuscles, Pacinian corpuscles
  - Burst of activity at beginning of stimulus, then dies down
  - Another burst when stimulus stops
# Mechanoreceptors

- **Know this table!!**
  - Except SA2

<table>
<thead>
<tr>
<th>type</th>
<th>RA / SA</th>
<th>depth</th>
<th>response field</th>
<th>sensitivity</th>
<th>info. processed/best stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacinian</td>
<td>RA</td>
<td>deep</td>
<td>very large (hand)</td>
<td>very high (10 nm)</td>
<td>high-freq. vibration</td>
</tr>
<tr>
<td>Meissner</td>
<td>RA</td>
<td>shallow</td>
<td>3-5 mm</td>
<td></td>
<td>slip / low-freq. vibration</td>
</tr>
<tr>
<td>Merkl</td>
<td>SA</td>
<td>shallow</td>
<td>spotty 2-3 mm (0.5 mm)</td>
<td>broad depth range</td>
<td>form, texture / points, edges</td>
</tr>
<tr>
<td>SA2</td>
<td>SA</td>
<td>deep</td>
<td>12-25 mm</td>
<td></td>
<td>hand shape / stretch</td>
</tr>
<tr>
<td>hair</td>
<td>RA</td>
<td>deep</td>
<td>10 mm</td>
<td>1 micron</td>
<td>hair displacement</td>
</tr>
</tbody>
</table>
Two-Point Discrimination

- Take two-prong device and touch the skin of subject at two points
- Graph shows: How far apart the two points must be in order for the person to perceive them as two points (instead of one)
  - Results?
  - Is the graph negatively or positively correlated with the density of Merkel disk receptors?
Pacinian Corpuscles

- Frequency-dependent sensitivity to vibration
  - Cutting hand with scalpel example
- Graph shows vibration frequency on x axis, degree to which skin has been indented on y axis
- For each frequency of stimulation how much the skin must be pressed to get response
  - Low frequency = need to press in more
  - Higher frequency = need to press less
Sensing with Tools Extends Somatosensory Processing Beyond the Body

- Person tested for being able to tell, while holding a wand, different contact points on the wand
  - Need to tell WHERE on the wand the contact point is without seeing

- **Findings:**
  - We can build simulated models of dorsal root ganglions and how they should respond in different situations
  - Tools we use and what they touch are incorporated into our senses using the same topographic representation of skin space

- **If you use tools like a pincher, your brain “extends” itself and firing corresponds to that pincher as if it was your own hand**
Meissner Corpuscles

- Low frequency vibration sensitivity
- Sensitivity to slip = grip control
- Micro-slip events
  - Objects slowly slip from our fingers
  - Senses to react to that and brain adjusts, maintaining grip
Different Types of Stains

- **Golgi Stain**
  - Lets you see the whole cell
  - Only stains some neurons, but stains all types of neurons

- **Nissl Stain**
  - Stain cell bodies of all cells

- **Weigert Stain**
  - Stain myelin and axons
Primary Sensory Cortex: Within Region (Column) Processing

- Layer 2 - lots of connections going left to right
- Typical pattern of cortical columns:
  - 4 -> 2,3
  - 2 => 4
- Layers 2,3 = integration zone for these inputs
  - Can also think of them as merging different types of info
  - RA & SA, dynamic into static, low-res to high-res
S1: Direction-Selective Surround Inhibition

- Move stylus across skin in different directions
- Pattern differs for different directions of travel
- History of where stylus was before movement determines response field
- Information about the direction of travel of something across the receptive field is also given in the dynamics of cell spiking
S2: Response Fields Expand Across Digits, But Maintain Directional Selectivity

- Neurons of S1 that respond to different positions on the hand may converge down to a single cell in S2
- Record from single neuron, get strong response when you touch different places
- **Orientation matters!!!
  - Use small bar, orient it in different ways
  - **For all response fields, the response is stronger for that neuron when the bar is vertical