COGS 107B Section

Wednesday 1-2PM  (Office hours Wednesday 2-3PM)
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Introductory Matters

- Sections will consist of summary slides
  - Section will skip the summary of the lecture from the day before (Tuesday)
  - I will try to get these online through Nitz
  - Section structure subject to change, e.g. based on learning needs

- Go to class!
  - Drawings-based questions
  - You might want to find someone to exchange notes with, just in case

- “Exploratory” questions
  - I will do my best to answer questions that extend beyond class material, but I may need to check other sources, or they might be better answered by Prof. Nitz or a grad student TA

- Class website (dnitz.com) > “Teaching” tab > “Cogs 107B” link
Muscle spindle afferent in the leg muscle sends signal through ventral horn of spinal cord

Activates quadriceps muscle that will make the leg kick

Simultaneously, it is activating an inhibitory interneuron that stops the hamstring muscle
  - Prevents injury
Brain is electrical device responsible for all your thoughts, actions, etc.  
- **BRAIN = MIND; “dualism will not be tolerated”**

**Principles**
- Neuron doctrine by Ramon y Cajal: neurons are individual cells, basic unit
- Law of dynamic polarization (also Ramon y Cajal): generally, neurons relay information in one direction – dendritic areas --> axon --> axon terminals

**Levels of analysis**
- **Structure**
  - (Micro) synapses --> neurons --> nuclei --> regions (macro)
- **Dynamics**
  - (Micro) synaptic and action potentials --> field potentials/ EEG --> fMRI (macro)
Lecture 1 – Brain Basics (Cont.)

- Nuclei are groups of neurons that connect in a specific way for function
  - Collective activity measured with local field potentials (patterns matter!)
  - For our purposes, think of it as an EEG recording of a small region

[Diagram showing brain anatomy with labels EC, DG, CA1, CA3, Sub, SR, SP, SO, and voltage traces labeled 'theta rhythm' and 'sharp wave ripples']
Equilibrium potentials
- The membrane potential at which the net flux of ions across the membrane is 0 given the overall concentrations on either side of the membrane
- Nernst equation for calculating equilibrium potential

Membrane potential
- The voltage difference between the intracellular space of a neuron and the surrounding extracellular space (including resting, synaptic, and action potentials)

Synaptic potentials
- Excitatory and inhibitory inputs from one neuron (at its axon terminal) onto another neuron (at its dendrite or soma); temporally or spatially summated

Action potentials
- All-or-none electrical events which reflect the spatial and temporal integration of synaptic potentials
Lecture 1 – Properties of Ion Channels

- **Ion selectivity**
  - Channels are selective towards particular ions, such as Na+, Ca++, K+, Cl-.

- **Gating**
  - Channels can open/close based on: voltage change, particular ligands (NT)

- **Kinetics**
  - Channels have different amounts of time for which they will be open

- **State**
  - The state a channel is in; e.g., activated, inactivated, deinactivated, persistent

- **Distribution**
  - Where the channels are distributed; e.g., in dendrites, at axon hillock
Lecture 1 – Neurotransmitters

- Mediate information exchange between neurons through generation of synaptic potentials
- Three basic types of neurotransmitter
  - Excitatory
  - Inhibitory
  - Neuromodulatory
Lecture 2 – Relevant Concepts

- Principle: topographic representation
  - The “space” of something physical is represented in a spatially ordered way within the brain
  - Examples of systems: visual (retina), auditory, vestibular

- Filtering
  - Sensory systems cannot veridically represent information in the brain; it must be translated
  - As part of the process, only some information is coded; other information is “filtered out”
    - E.g. humans “filter out” UV light, but bees don’t, because it is relevant to them

- Dimensionality reduction
  - Break down complicated system into usable pieces of information

- Temporal dimension
  - Brain encodes how information changes across time
“All-axon” cell, located outside of spinal cord

One part of axon will reach the skin, in this case

End portion is not myelinated
  - Think of it as the dendrite, because it’s the input side

It is also like the dendrite because of its generator potential
  - Ending has a special type of sodium channel that is sensitive to shape of membrane (whether it’s bent), which is like a sensor
  - Can be bent a little or a lot, which relates to depolarization time (a lot = longer time)
  - Generator potentials (true of all synaptic potentials) vary continuously
    - Durations and amplitudes can take on multiple values
Lecture 2 – DRG

- Action potential (at myelinated axon portion) = series of membrane potential changes that corresponds to series of ion channels opening and closing
  - All or none - discrete
  - Bigger than synaptic potentials
  - Like a code, like set of 0's and 1's in computer
  - Transform input to brain signals
- Depolarization phase = Na+ channel
- Hyperpolarization = K+ channel
Within the somatosensory system, the DRG cell will end in several different ways:

- Meissner’s corpuscle
- Merkel disk receptor
- Hair receptor
  - Wrapped around base of hair to deform membrane when hair moves
- Pacinian corpuscle
- Ruffini ending
Response fields = how neuron responds as stimuli is moved across a field
- Make map where neuron responding more, less, or same as baseline

Ex: Put an electrode in skin (e.g. index finger), and place the tip very close to DRG cell such that electrical potentials are registered
- At any given time, how many action potentials per second?
- There is a baseline firing rate, not zero
- Move probe around skin, see if it is responding
Lecture 2 – Response Field Types

- Forms of response fields
  - Small vs large
  - Inhibitory surround
    - Complete vs incomplete
  - Whole vs patchy
- Combination of neurons register stimuli to give complete picture
  - Distribute information across cells to form a pattern
  - E.g., two response fields respond differently to same stimulus
Lecture 2 – Adaptation of Mechanoreceptors

- Transient vs sustained adaptation of mechanoreceptors
  - Aka rapidly adapting vs slowly adapting
  - Aka transient change vs persistent [adaptation]
- Slowly adapting
  - Merkel disks
  - Respond as long as stimulus is there
- Rapidly adapting
  - Meissner corpuscles, Pacinian corpuscles
  - Only respond to the change
    - I.e. when it comes “on” and when it comes “off”
Lecture 2 – Meissner Corpuscle

- Shallow placement
- Small response field (3-5 mm)
- Responsive to light touch
- Rapidly-adapting
- Highly sensitive to low-frequency vibrations between 10-50 Hz
  - Sensitivity to slip = grip control
- Stack of skin cells (like stack of pancakes), and DRG unmyelinated end winds through
  - When MC is smashed down, the membrane of DRG will be deformed, activate Na ion channels
  - Causes a generator potential (but only responds to initial)
Lecture 2 – Pacinian Corpuscle

- Deep-placement
- Large response field
- Sensitive to vibration and pressure
- Rapidly-adapting
- Sensitive to pressure and high frequency vibration (~250Hz)
- May help to detect texture
- Unmyelinated portion of the DRG cell is wrapped with multiple layers of skin cells (like layers of a 2D onion); tip is in the middle
  - Deformation is different
Researcher locates part of skin that is the excitatory response field for DRG cell
  - Press down vibrating stimulus
  - Varies how hard they have to press (i.e., how deeply to deform) to get excitatory response

Graph on left: detection threshold
  - Need less pressure to detect at really high frequencies

Graph on right: human detection threshold curve matches mechanoreceptor detection curves
Lecture 2 – Merkel Disk

- Single DRG cell contacts multiple Merkel cells embedded in the skin (split end)
- Shallow-placement
- Small, spotty response field (0.5 mm)
- Slowly-adapting (sustained)
- Sensitive to form, texture, points, edges
- Helps us know what is the form
  - Eg cylindrical chalk vs hexagonal pencil
Two point discrimination (stimulus) test = Merkel disk density
- Prongs separated by different distances
- Better discrimination is when the smallest distance between the points to register as two different points is really small

- Lowest tactile acuity: on back and legs
- Small Merkel disk receptive field = fine texture discrimination
  - Ex: spatial distribution of action potentials mirrors actual Braille
  - General principle: More neurons needed for better representation (more patterns)
Lecture 2 – DRG Pathways to the Brain

- Dorsal root ganglion pathways to the brain
- DRG travels up spinal cord
- First synapse is on medulla, on either gracile or cuneate nucleus
  - Around here, switch L-R and R-L
  - This is a processing point, not just transition point
    - Active sensing modulates how info about touch is relayed through system
    - Involved in expectation of stimuli based on movements
- Axons → ventral posterolateral nucleus (VPN) of thalamus
  - Also a processing point
    - For almost any region of thalamus, inputs from the cortex outnumber the sensory inputs
- To somatosensory cortex (S1)
Lecture 2 – S1

- Somatosensory cortex (S1)
- Postcentral gyrus + posterior bank of central sulcus
- Topographic map
  - Homunculus
  - Topographic representation of skin “on” brain
Primary somatosensory cortex: within-region (column) processing

Coming out of thalamus, the thalamic neurons that respond to Pacinian corpuscles inputs are different from thalamic neurons that respond to Merkel type DRG cells

Segregation of information that persists through thalamus is finally mixed at S1 (cortex)

Thalamic cells that respond to Pacinian stimulation and Meissner stimulation will send their axons into layer 4 of cortical column in somatosensory columns

Merkel disks will project into layers 2-3

To a large extent, the pathway of activity processing within a cortical column is from layer 4 to layer 2-3 to layer 5 and 6 (output)

Because of the way information comes in, we can identify layers 2-3 as area of somatosensory cortex where the form information (originally from Merkel disks) is finally integrated w change info

- What has changed + what is consistently there

- Finally, all information is put together
  - The cortex, where it’s all integrated, is responsible for our ultimate perception/ qualia
Lecture 2 - Direction-Selective Surround Inhibition

- **S1**
- Graphs of patterns of action potentials based on direction of stimulus to inhibitory surround response field
  - Can be complete or incomplete inhibitory surround - causes different patterns
    - Incomplete gives more discrimination concerning direction
  - [Don’t worry about S2 area]