Week 1 Lecture Notes

Points of clarification and fun facts re: video lectures

L2: Computational Neuroscience: Descriptive Models

- Slide: An Example: Models of "Receptive Fields"
  - If you want to see more examples of Hubel and Wiesel's experiments, check out: http://www.youtube.com/watch?v=Cw5PKV9Rj3o
  - Converting the electrical activity of neurons to an audio signal is a common practice in experimental neuroscience, as it allows researchers to easily and immediately tell when a neuron is active. In a typical setup, each "pop" in the signal is an action potential—when neurons fire many action potentials per second, the sound resembles loud static.
- Slide: Descriptive Model of Receptive Fields
  - When we talk about center-on, surround-off, or center-off, surround-on cells, remember that we're not talking about the center and "surround" of the entire retina, but rather only the small portion of it associated with that cell, i.e., each cell generally cares only about what's going on in a very small region of the visual field, and these regions tend to be on the order of a degree or two (though the size of the RF depends on its location). As a rough approximation, you can think of many cells' RFs "tiling" the visual scene (in reality, there is quite a bit of overlap, and different cells may have different color-tuning properties, etc.). Smaller RFs near the center of the visual field (the fovea) lead to "higher resolution" there during the daytime.

L3: Computational Neuroscience: Mechanistic and Interpretive Models

- Slide: III. Interpretive Model of Receptive Fields (oriented bars)
  - Again, remember that these oriented bars do not span the entire retina, but only a small portion of it (if they spanned the entire retina, you'd only be able to make asterisk-like images). Because of this, you can linearly combine them to make an enormous variety of images. For example, can you think of the combination of RFs needed to make a square? A polygon? A duck?
- Slide: III. Interpretive Model of Receptive Fields (RFs from natural images)
  - It's worth emphasizing that the RFs on this slide are learned only from the set of natural images and do not depend at all on any experimental data. The algorithm that learns them simply chooses the ideal set of RFs for natural images subject to two constraints (1. Efficient representation (sparse coding)—representing images using as few components as possible, 2. Faithful representation—accurate representation of important image features). The fact

that the RFs found by the algorithm match the RFs observed experimentally is very cool, suggesting that perhaps efficient and faithful representation were also the optimization criteria “used” during the evolution of V1.

L 4: The Electrical Personality of Neurons

- Slide: The Idealized Neuron
    - In the initial EPSP plots, the x-axis is time, and the y-axis is electrical potential (voltage).
    - It is important to note that an action potential is not just the sum of several EPSP’s, but is rather an active signal generated by the sum of the EPSP’s crossing a threshold. Usually this threshold is around 30mV above the neuron’s resting potential.
- Slide: The Electrical Personality of a Neuron (ion channels)
    - While pumps and other components are indeed needed to model the cell as a complete circuit that obeys Kirchoff’s laws, etc., for our purposes, we can just think of pumps as having the sole purpose of maintaining the steady-state intra- and extracellular ion concentrations. Channels, on the other hand are just gates that, when opened, allow ions to flow down their concentration gradients.
    - It’s worth noting that the properties of an action potential can’t be derived from a simple application of Ohm’s law. This is because current, voltage, and membrane conductance all change as a function of time. Instead, an action potential is described by a set of differential equations that model how these variables change with time. Hodgkin and Huxley were the first to formulate and present a solution to this set of equations, as will be discussed in later lectures.
- Slide: Active Wiring: Myelination of Axons
    - Lossless signal propagation is very important, as some action potentials have to travel very long distances (think of the axons that reach down to your toes, for example). If signal propagation were based on passive changes in membrane potential, then signals would dissipate much too fast for information to be conveyed over long distances.

L 5: Making Connections: Synapses

- Slide: Long Term Depression (LTD)
    - Depending on the specific situation, sometimes it can be useful to have LTP, and sometimes it can be useful to have LTD. For example, LTP can be used to strengthen connections between circuits that fire synchronously so as to increase their chance of firing synchronously in the future. LTD on the other hand, could be used to separate circuits that normally operate independently. Another type of synaptic depression occurs in homeostatic

plasticity, in which networks of neurons change their synaptic strengths over long time scales—it has been hypothesized that this occurs to control the average firing rate of a network. The mechanisms and computations related to synaptic plasticity is an active area of study.