What is Systems-Level Neuroscience?

What is the goal?

What are you hoping to learn?

What distinguishes it from cellular/molecular neuroscience?

What, in essence, does the brain do?
Levels of Analysis

After Churchland & Sejnowski 1992
Historical Approaches

Psychology
Carefully characterize behavior and infer neural function

Neurobiology
Understand how neurons respond to stimuli, how they are organized, and how they are connected

Engineering/Computational
Build brain-like circuits that do interesting things
Some Elements of the Modern Systems Approach

• Focus on how neural circuits *process information*. What is coded and how?

• Understand how neural representations are distinct and how they are tailored for different functions

• Relate neural activity to behavior, including learning

• A working model is the ideal endpoint

• Models must respect biological implementation
What should a systems neuroscientist know?

Factual Knowledge

• The hardware: neuroanatomy and connectivity
• What the hardware elements can do: neurophysiology
• How specific systems are organized and how they work
• What tools are available: methods

Conceptual Knowledge

• Neural Coding
• Neural Representations
• How to ‘read out’ population activity
• Maps
• Correlation with Behavior vs. Causation

How to Recognize Important Issues, How to Critically Analyze Experimental Approaches
Methods and Tools

Anatomical
- Neuron morphology
- Tract tracing
- Areal boundaries (Brodmann)
- MRI

Physiological (Invasive)
- Single-unit recording
- Multiple-unit population recordings
- Optical imaging
- Electrical microstimulation
- Reversible inactivation
- Viral expression and imaging
- Optogenetics
Methods and Tools (cont.)

Physiological (Non-Invasive)

- EEG & MEG
- fMRI
  - BOLD
  - DTI
- PET

Behavioral

- Psychophysics
- Movement Analysis
- Accuracy and Reaction time

Modeling and Engineering Approaches

- Linear (and non-linear) systems analysis
- Control systems analysis
- Self-organizing networks
Methods: Spatial and Temporal Resolution

After Churchland & Sejnowski 1992
A Major Theme:

Think about the function of sensory systems from the standpoint of the organism.

The organism has no direct experience of the outside world except through the streams of sensory signals flowing in. Organism’s goal is to infer what is present in its surroundings from the available sensory signals, and use that information to plan action.

Have to think about both encoding and decoding of sensory signals. Have to understand the relationship between sensory neural signals and behavior. Have to understand how sensory information is transformed into a decision to act.