Overview of Neuronal Dynamics

Basic Features of Nervous System Organization
C. elegans
302 neurons (32 chemosensory)
7000 synaptic connections

10^{11} neurons
10^{15} synapses
extracellular action potential

Intracellular Recording

\[ V_m = V_i - V_e \]

(trans)membrane = intracellular – extracellular

action potentials

resting potential

\((-30\) to \(-90\) mV)
Fast Spiking Interneuron - Response to Current Injection

Brain Slice Intracellular Recording
encoding: mean firing rate

\[ f(t) = \frac{1}{\Delta T} \int_{t}^{t+\Delta T} \sum_{i=1}^{n_i} \delta(t' - t_i) \, dt' \]
Thalamocortical Neurons Have Two Firing Modes
Neuronal Dynamics: electrical and chemical signals

- biophysics of single neurons
- interactions between neurons

Encoding: how are sensory stimuli, motor control commands, memory, reward represented in these signals

Neural Computation: coding + dynamics

Eye Fixation During Spontaneous Horizontal Eye Movements
Area 1 
(velocity-to-position neural integrator)
persistent neural activity
(memory of eye position)

On/off
burst
input

Head Direction Cells
Neural Dynamics During Integration (ring network)

persistent pattern of activity that “rotates” to new position with integration of vestibular head velocity signals
Eye Fixation

Head Direction Cells

Neural Signal: action potential

Encoding: mean firing rate encodes motor command (eye position) or “computed” head direction in laboratory frame of reference

Dynamics: Persistent Neural Activity

A New Form of Neural Dynamics During Acoustic Sequence Production

zebrafinch
Neurons In RA Show Complex Burst Patterns During Acoustic Sequences

Bursts Reproducible Under Linear Time Warp
Bird Song Production

Neural signal: action potential

Encoding: bursts of action potentials signify articulator positions

Dynamics: burst sequence with synchronized transitions
Tritonia escape response

Intrinsically bursting neuron
Central Pattern Generators

Olfactory Systems

Neural Signal: action potential/ sub-threshold membrane potential

Encoding: CPGs: muscle tension for rhythmic contractions, olfaction?

Dynamics: Oscillation (.7 Hz -100 Hz)
noise, fluctuation