Synchrony

Rhythmic firing (30-80Hz, gamma) and silence (4-8Hz, theta) in basket cell (hippocampus)

Rhythmic activity is common in hippocampus and neocortex

Rhythms are nested: slower ones modulate faster ones

Basket-cell network synchronizes in the gamma band

Brain rhythms
A. Spectrum of hippocampal EEG shows peaks. B. Frequency peaks in rat cortex. [Buzsaki 04]
Basket cells in hippocampus

Basket cells make connections (circles) to other basket cells locally [Wang & Buzsaki 96]

Basket cell electrophysiology
Basket cells show frequency adaptation and rebound spikes [Buzsaki et al 95]

For gamma synchrony, we model basket cell with positive-feedback neuron plus M-current.

It's reasonable to ignore the rebound current; it requires prolonged hyperpolarization (theta inhibition).

**Synaptic physiology**

**Chemical**

Pre. BC | Post. BC
---|---

100 mV

\[ \tau = 1.5 \text{ ms} \]

100 pA

**Electrical**

10.5 nA

50 mV

20 ms

5 mV

Hippocampal BCs are chemically (GABA\(_A\)) and electrically (gap junctions) coupled [Jonas et al 02]

Post-synaptic currents rise fast (\( \tau = 0.16 \text{ ms} \)) and decay rapidly (\( \tau = 1.2 \) to 2.5 ms; slower in pyramidal cells).

Delay arises from axonal conduction (0.25 m/s) and synaptic latency (0.5 ms).

Nearby basket-cells are coupled by gap-junctions; coupling ratio is 0.1 (fraction of voltage).

We use rise-time as a surrogate for delay and ignore electrical coupling.
Interneuron network model: Unconnected

Spike rasters (256 cells) and histogram (top); individual rates (right) and distribution (green)

The interneurons receive a constant input current.

Their spike-rates have a CV (mean/SD) of 0.24.

Variability is introduced by fabrication process.
Interneuron network model: Mutual Inhibition

Interneurons synchronize in gamma band.

About half of the neurons are silenced; these are the least excitable neurons.

The rest fire once per cycle, except for a few that skip cycles or fire twice per cycle.
Quantifying synchrony: Vector strength

Each spike is assigned a vector by mapping the period onto a circle

Each spike is represented by a unit-length vector:

\[ \vec{u}_i = (\cos[\theta_i], \sin[\theta_i]) \quad \text{where} \quad \theta_i = 2\pi \left( \frac{t_i \mod T}{T} \right) \]

\( t_i \) is the spike-time; \( T \) is the rhythm's period. The normalized vector sum

\[ \vec{v} = \frac{1}{N} \sum_{i=1}^{N} \vec{u}_i \]

is computed: Its magnitude ranges from 0 (independent spiking) to 1 (coincident spiking).
Next lecture: Synaptic rise-time determines period

Period is proportional to rise-time (linear fit includes offset); purple—mean interneuron period