What do you notice?
Coordinated oscillators and nested rhythms:

So far we have talked about how rhythmic activity can arise from:

1) The physiological properties of the cells
2) Interactions with inhibitory neurons

Neurons in a single brain region can flexibly participate in many rhythms by changing the way they interact with other neurons.
We have seen that individual neurons can have an intrinsic rhythm, and that small clusters of interacting neurons can produce a rhythm. During behavior and complex cognitive processes, rhythmic neurons from multiple different brain regions must communicate. How might the brain coordinate the activity of all of its (often independent) oscillators?
A single cortical region can manifest many different rhythms under different conditions:

These rhythms can be created by adding agonists such as carbachol (cholinergic agonist) or kainate (glutamatergic agonist).

The release of different neurotransmitters, and different degrees of excitation can change the local rhythms.

Rat Somatosensory Cortex

Roopun et al., Front. Neuro., 2008
Distinct oscillating populations can coordinate their activity in a larger rhythm:

- Frequency ~40 Hz, Period 25 ms
- Frequency ~25 Hz, Period 40 ms

These rhythms are locally generated.

Roopun et al., *PNAS USA*, 2006
Distinct oscillating populations can coordinate their activity in a larger rhythm:

During high excitation, distinct populations of neurons exhibit different rhythms.

During low excitation, distinct populations of neurons exhibit the same frequency.

Separation of deep and superficial layers (at layer IV) abolished the slower rhythm.

Frequency ~15 Hz
Period 65 ms

Roopun et al., *Frontiers in Cellular Neuroscience*, 2006
Distinct oscillating populations can coordinate their activity in a larger rhythm:

Intrinsically bursting cells in deep layers of cortex:

This intrinsic rhythm is dependent upon hyperpolarization activated (h-currents) that promote rebound spiking when these neurons are inhibited.

Roopun et al., *PNAS USA*, 2006
Distinct oscillating populations can coordinate their activity in a larger rhythm:

1. These neurons interact to produce a gamma

2. These neurons resonate at a fast beta

3. The interaction between these two populations creates a slow beta
Distinct oscillating populations can coordinate their activity in a larger rhythm:

1) A burst of spikes produced by intrinsically bursting (IB) cells

2) Excitation of the superficial layer basket cells, which inhibit the superficial layer pyramidal cells.

3) These superficial layer pyramidal cells rebound from the inhibition and generate spikes one gamma cycle later, activating both superficial basket cells and low-threshold spiking (LTS) interneurons.

4) The latter then inhibit the deep layer IB cell dendrites, which rebound and burst one short beta cycle later.

Kramer et al., *PLoS Computational Biology*, 2008
Distinct oscillating populations can coordinate their activity in a larger rhythm:

Kramer et al., *PLoS Computational Biology*, 2008

We have seen that individual neurons can have an intrinsic rhythm, and that small clusters of interacting neurons can produce a rhythm. During behavior and complex cognitive processes, rhythmic neurons from multiple different brain regions must communicate. How might the brain coordinate the activity of all of its (often independent) oscillators?
The golden ratio: