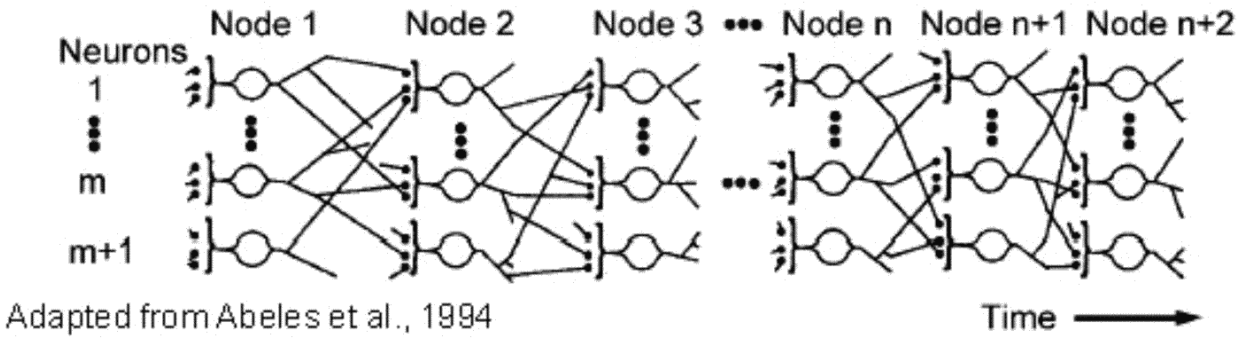
Repeating motifs of synaptic activity in neocortex

the neocortex appears composed of unreliable, depressing, weak synapses

how can information be transmitted through such a structure reliably?

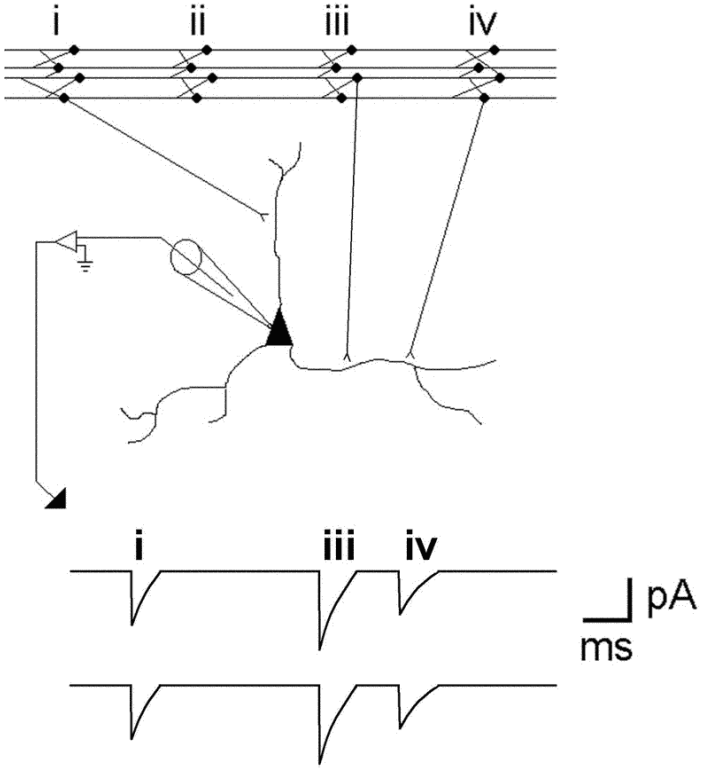
can the neocortex support precise and reliable sequences of synaptic activity?

Synfire chains



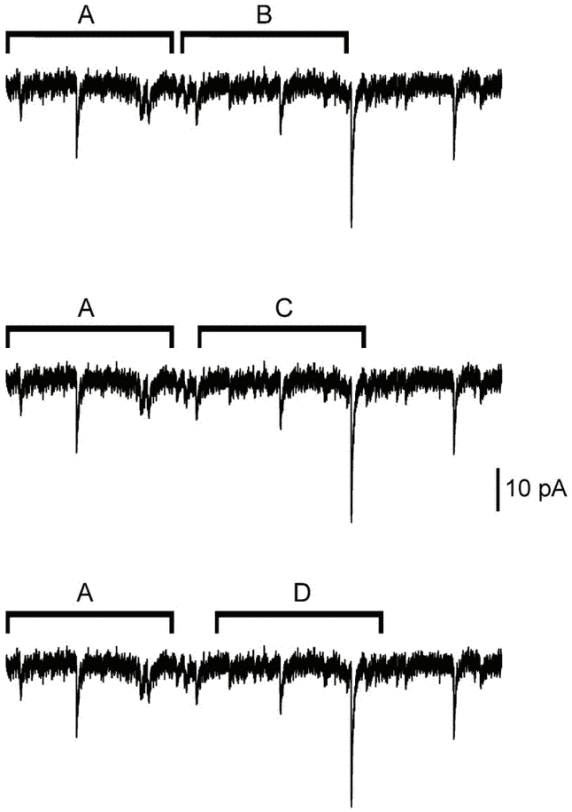
Adapted from Abeles et al., 1994

Synfire chains and repeats of activity in a single cell



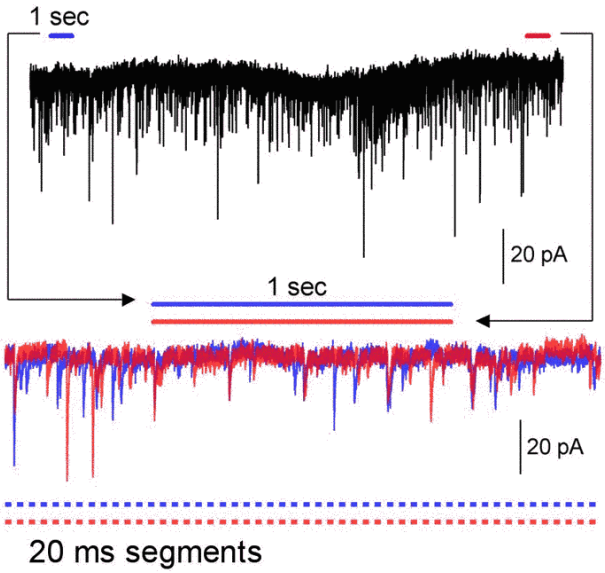
Searching for repeats of activity in a single neuronal recording

$$h(\tau) = \frac{\sum_{t=-T}^{T} (x_t - \bar{x})(y_{t+\tau} - \bar{y})}{\sqrt{\sum_{t=-T}^{T} (x_t - \bar{x})^2 \sum_{t=-T}^{T} (y_t - \bar{y})^2}}$$



Examine the covariance, $h(\tau)$, between segments:
(AxB), (AxC),...(BxC), (BxD),.....

High resolution index (HRI)

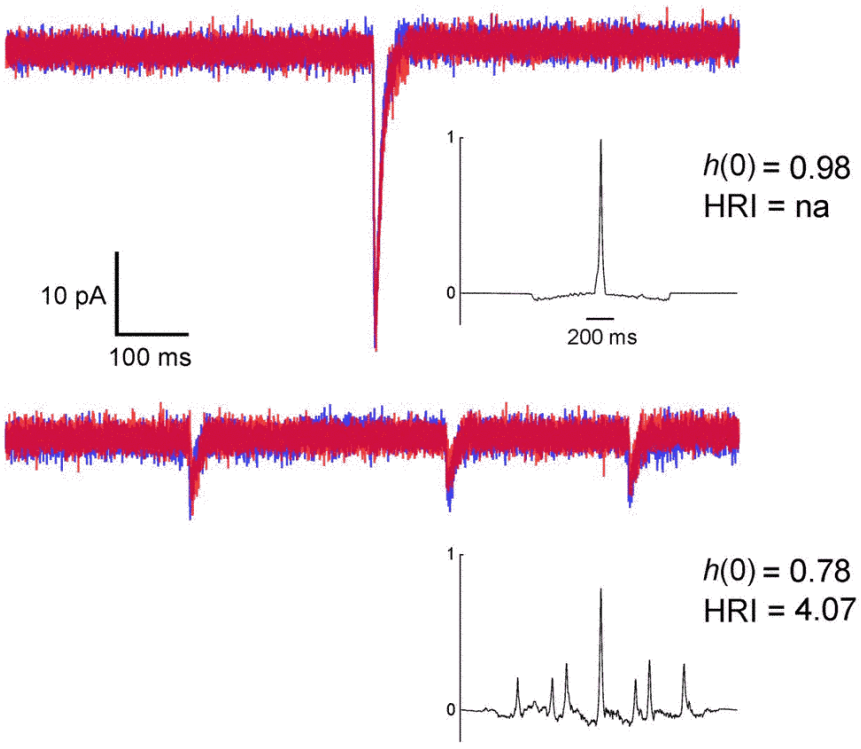


The 2 secs surrounding the 1 sec epoch found with $h(0)$ are now analyzed, but with 20 ms widths. $h(0)$ for each 20 ms increment is computed ($h_{20}(0)$) and adjusted for amplitude differences, yielding T values:

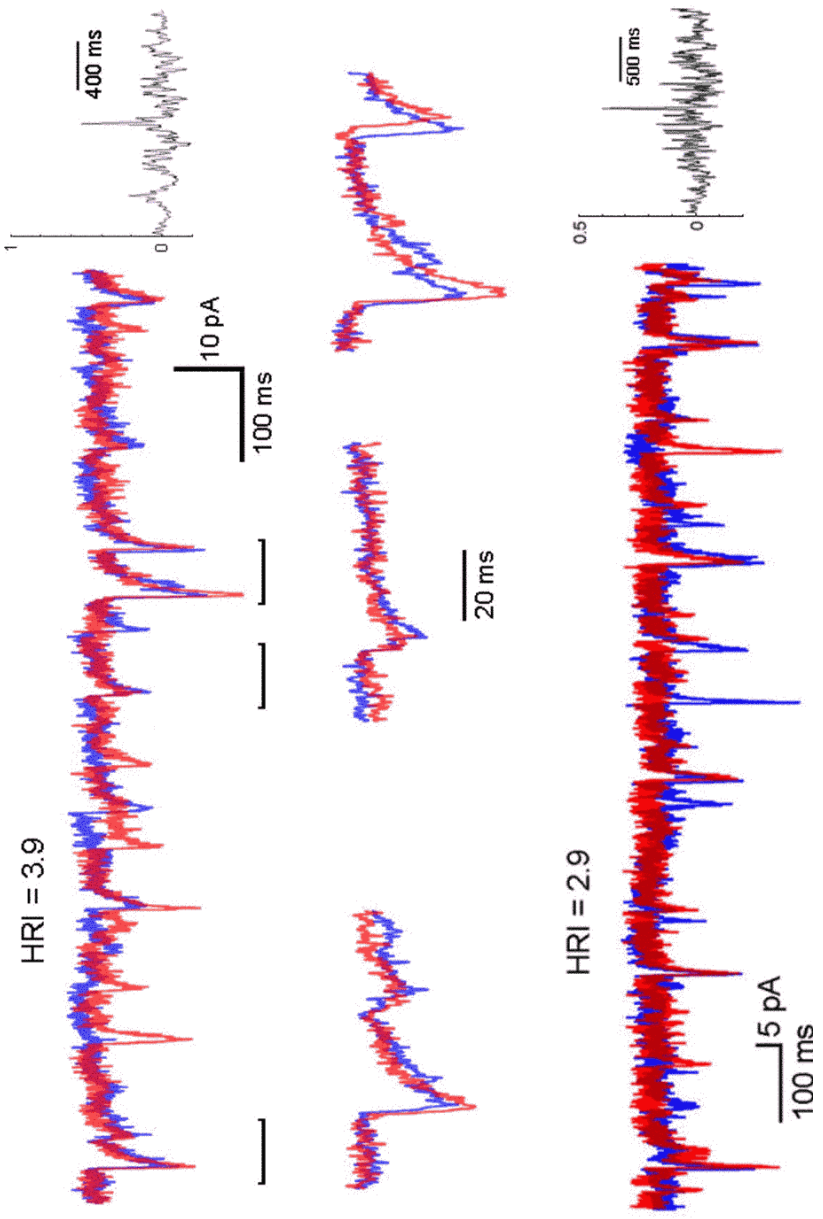
$$\mathrm{T} = h_{20}(0) \cdot \left(1 - \frac{\overline{|m - r|}}{|m| + |r|} \right)$$

$$\mathrm{HRI} = \frac{\left(\sum_{i=1}^{n} T_i \right)^2}{n} \cdot \frac{\sqrt{std(motif) \cdot std(repeat)}}{\overline{|motif - repeat|}}$$

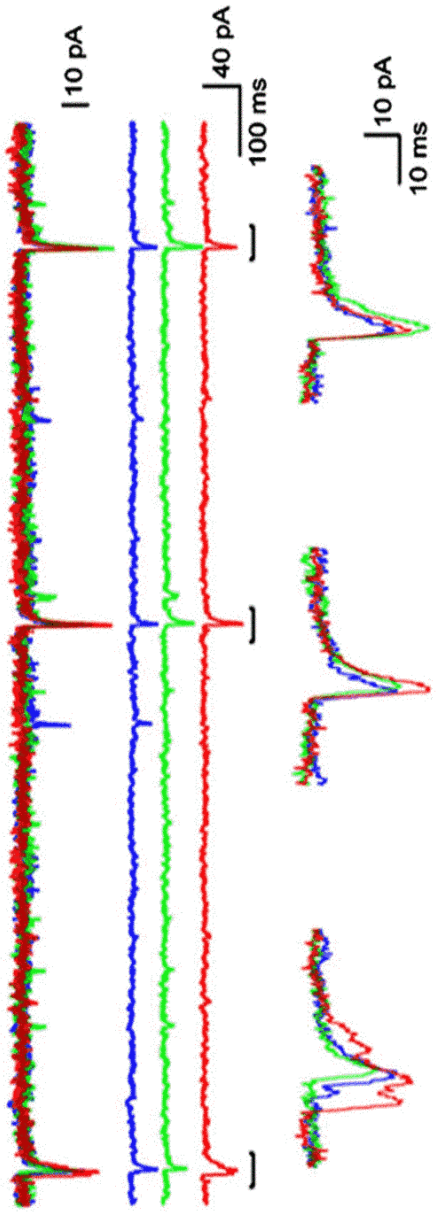
$h(0)$ vs. HRI



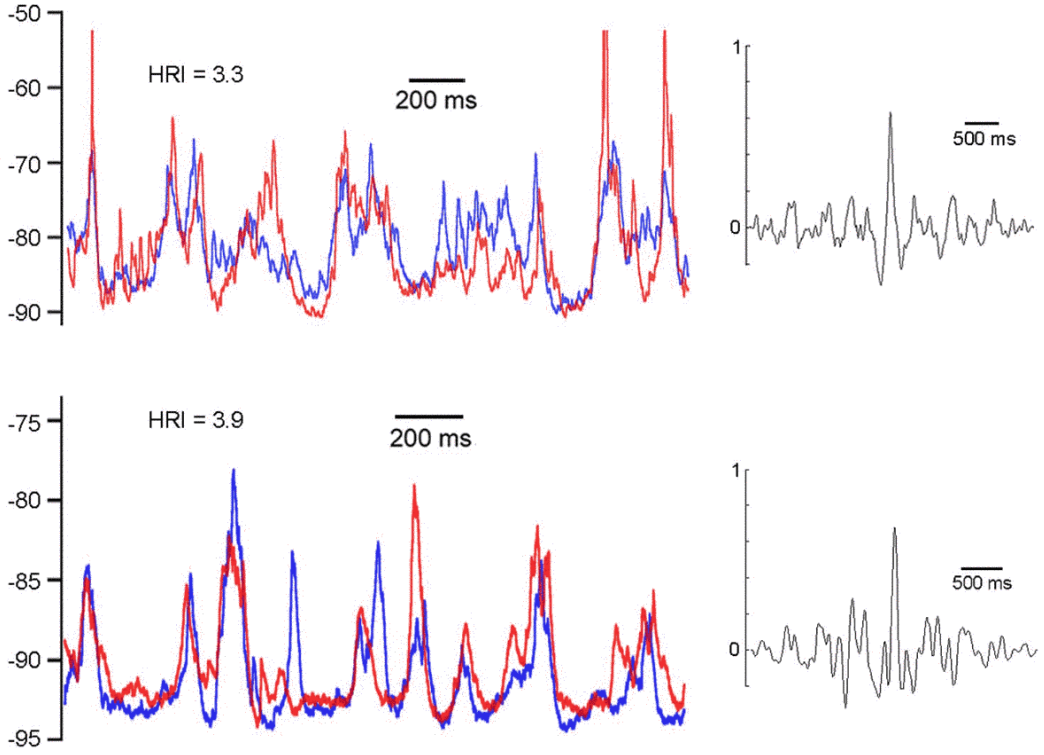
Single repeat in a voltage-clamped neuron *in vitro*



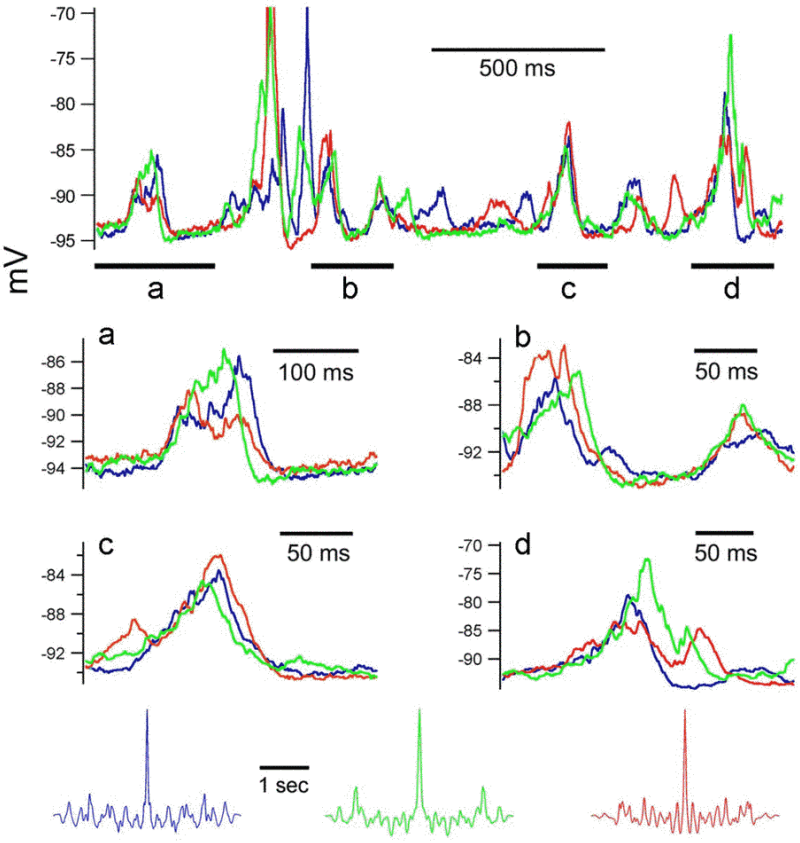
Threepeat detected in a single voltage-clamped neuron *in vitro*



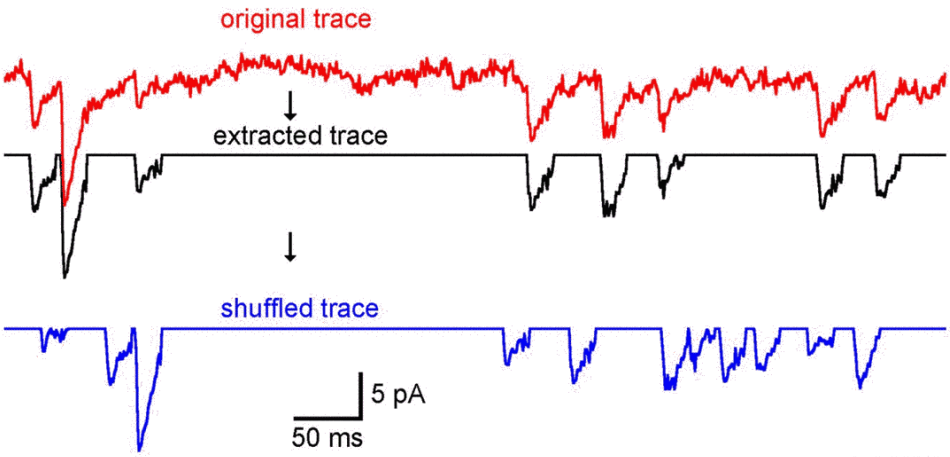
Single repeats detected in a current clamped neuron *in vivo*



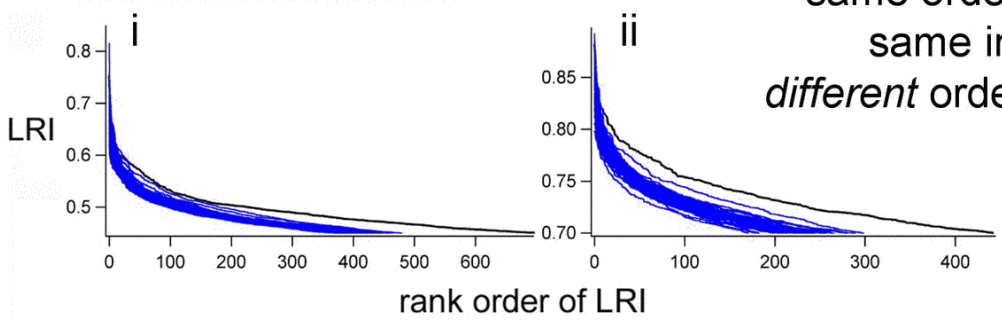
Threepeat detected in a single current clamp neuron *in vivo*



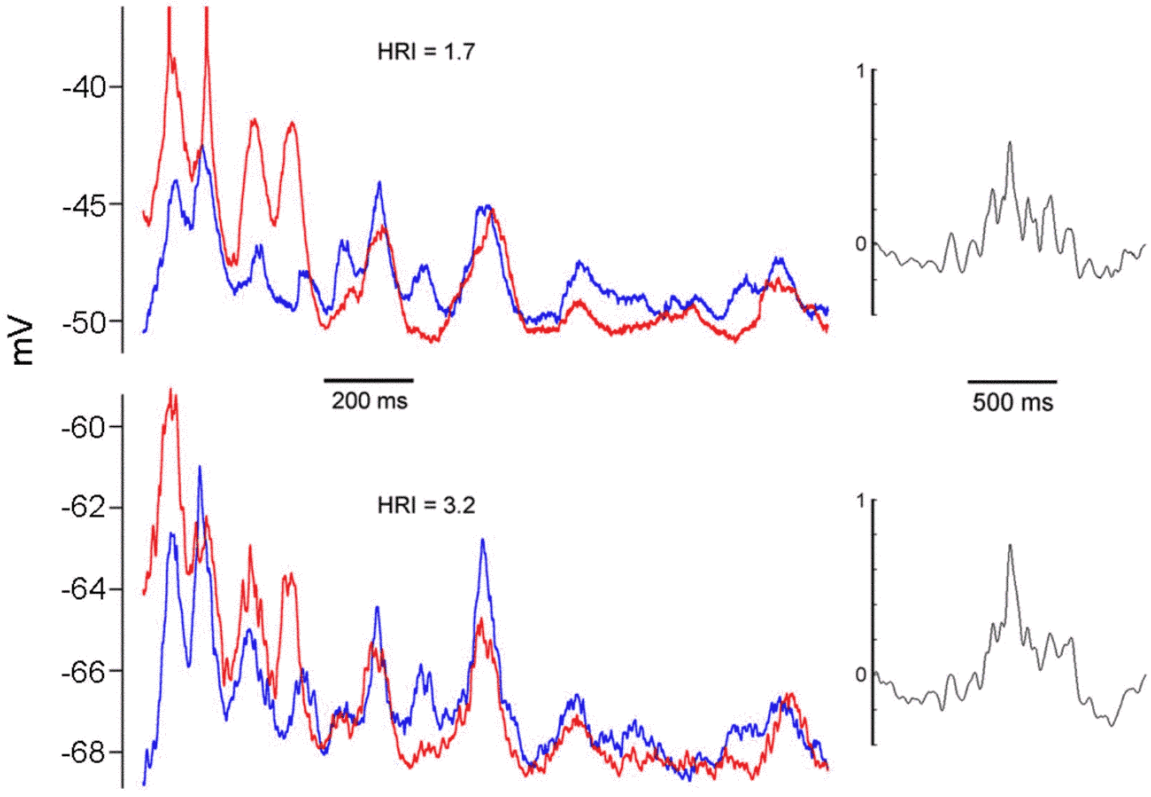
Looking for repeats in shuffled traces



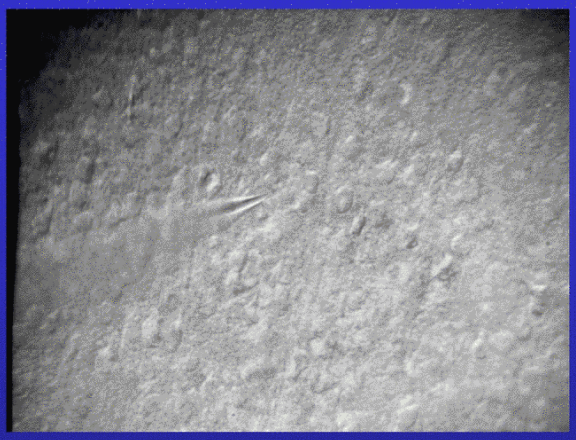
same events
same order of events
same intervals
different order of intervals

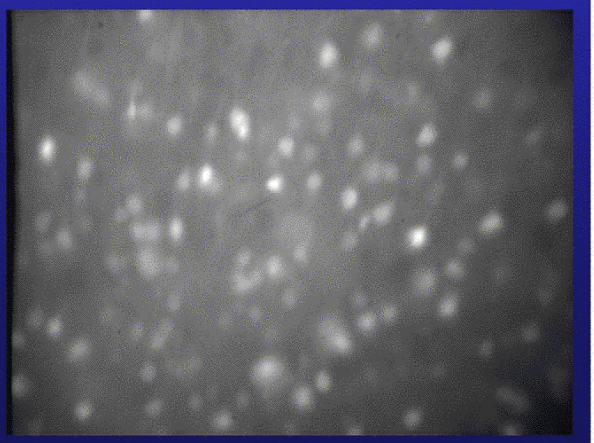


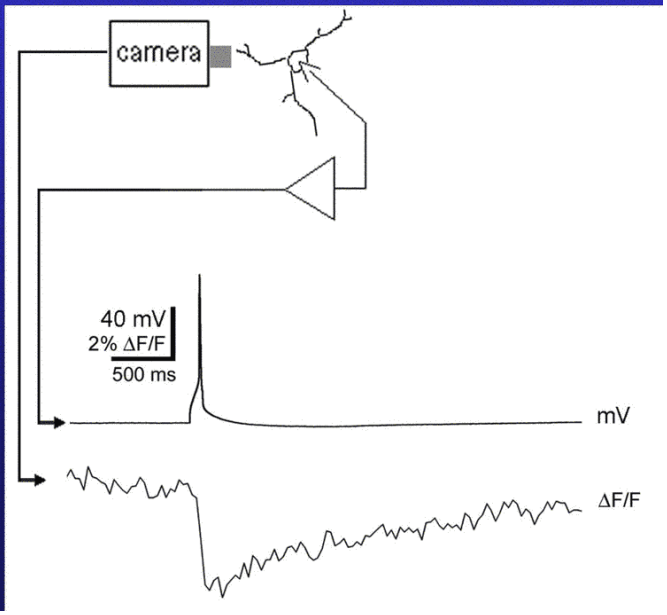
Repeats detected simultaneously in two current clamped neurons *in vivo*



Calcium imaging of neuronal activity







Nipkow spinning disk confocal

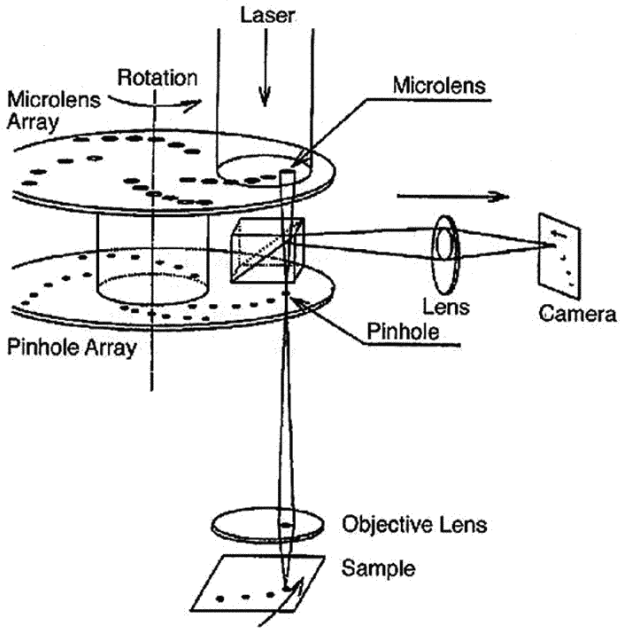
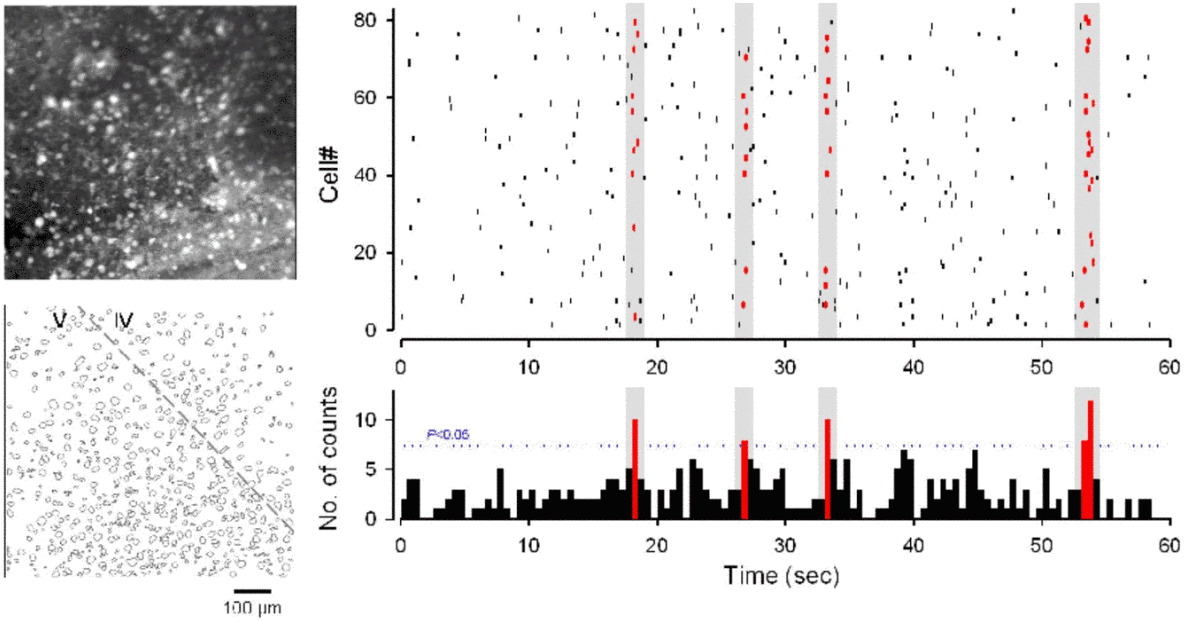


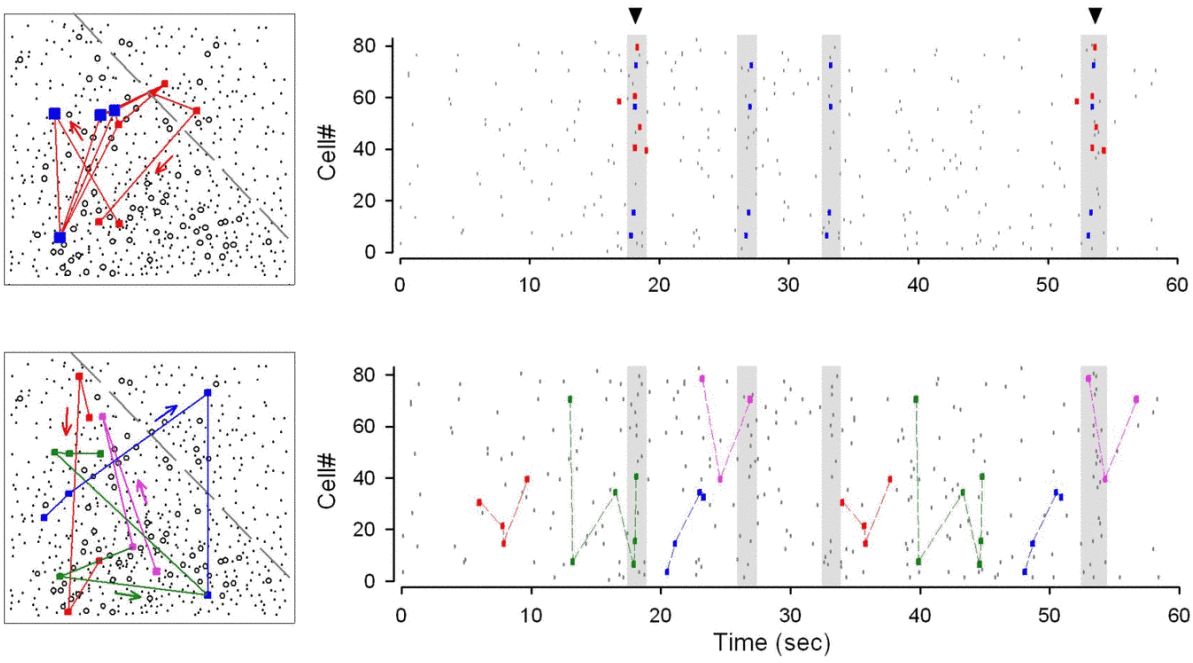
FIGURE 2-71. Yokogawa high-speed confocal system. Microlenses on a second Nipkow disk increase disk transmission to 40–60% instead of a fraction of a percent as in conventional, single-Nipkow-disk systems. The microlens and pinhole arrays are patterned to give a homogeneous field with no sign of scan lines. (From Ichihara *et al.*, 1996.)

"Video Microscopy", Inoue and Spring, 1997

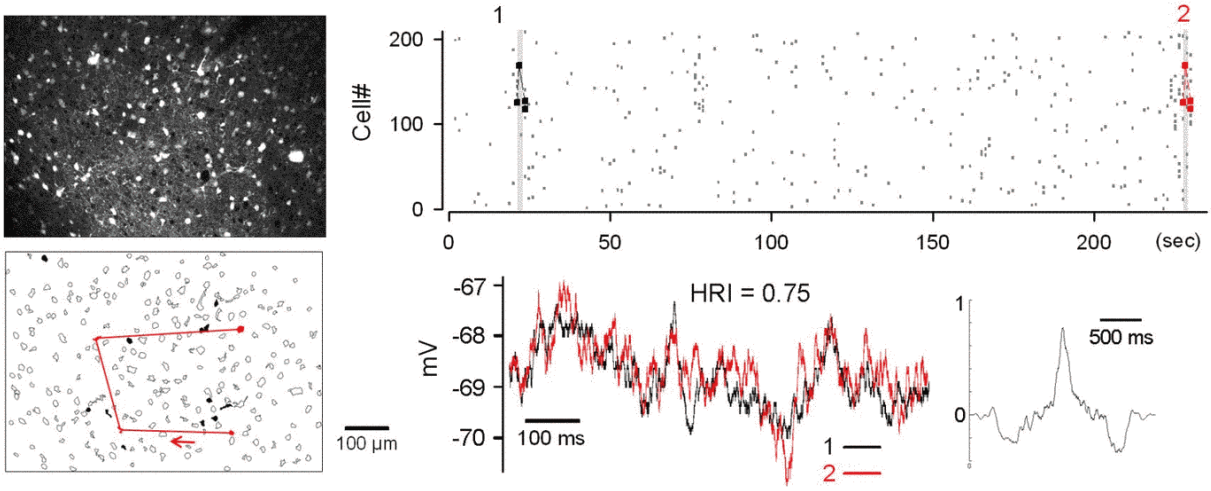
Calcium imaging of a slice: finding significant levels of synchrony



Optical detection of repeats among many neurons: can occur during synchronous discharges. Bottom panel: repeats of repeats



Simultaneous detection of a repeat in a single neuron and the network



Methodology notes:

Repeat finding with one neuron:

ADVANTAGES
- high temporal resolution (>1kHz sampling rate)
- can be done in vitro and in vivo

DISADVANTAGES
- don't know which neurons responsible for repeat
- don't know the number of neurons responsible-- might be just one

Repeat finding with calcium imaging:

ADVANTAGES:
- records many hundreds of neurons
- "shows" location of neurons and spatial patterns of network activity

DISADVANTAGES:
- lower temporal resolution (<100 Hz sampling rate)
- so far, restricted to a plane and the surface of an *in vitro* slice

Conclusions:

Precise repeats of network activity occur *in vivo* and *in vitro*

Repeats are a product of synaptic activity

The neocortex alone is sufficient for the detection of repeats

Repeats occur more often than chance, and don't occur in dissociated cultured neurons (n=4, so far...)

Repeats may be an emergent property of the neocortical architecture, and/or a reflection of functional building blocks in the construction of cortical activity

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