

Dynamics in a preconfigured brain

("We use 10 percent of our brain". Do we?)

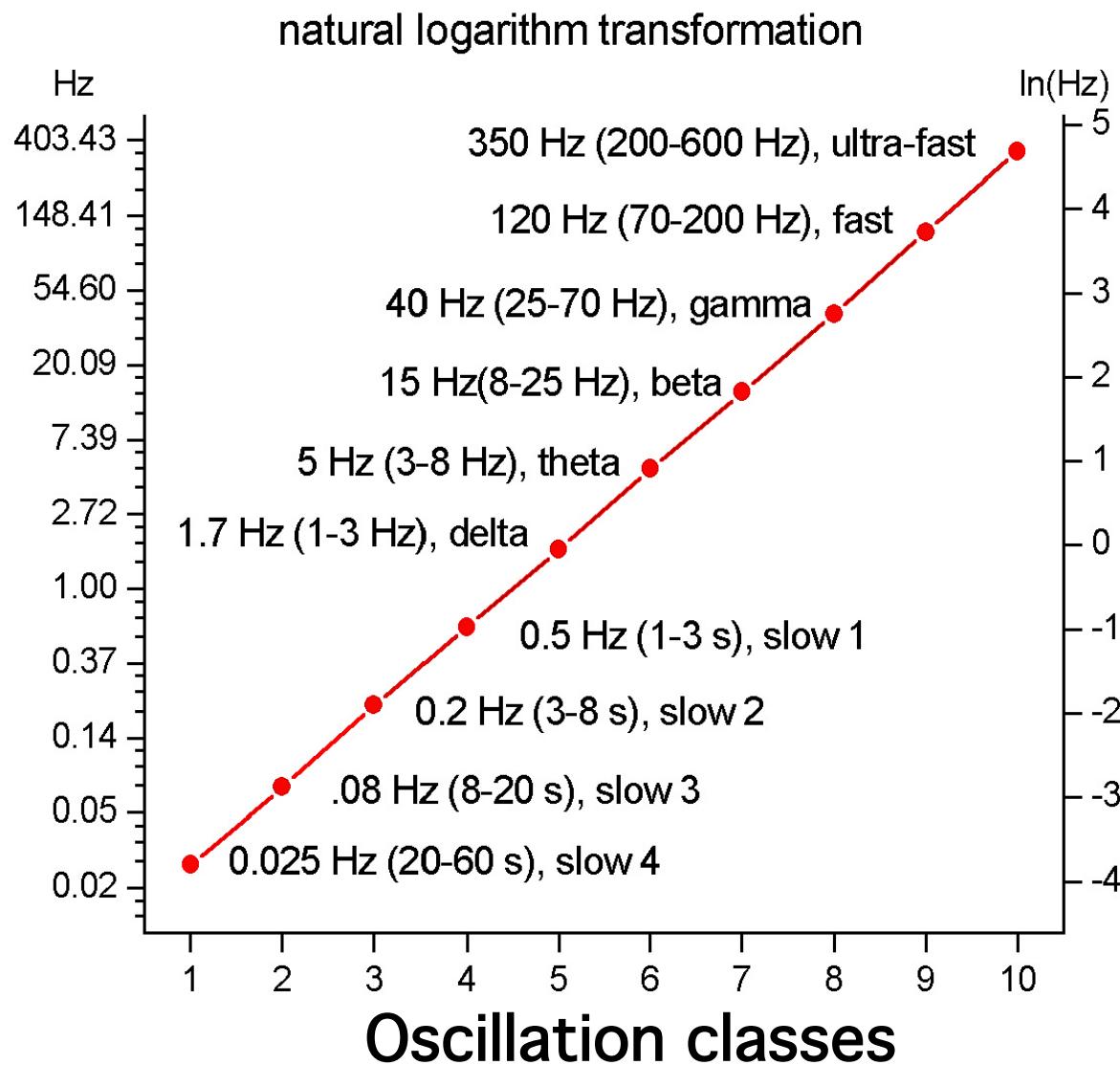
Canonical log brain rules

- A fundamental rule of psychophysics, the Weber-Fechner (log) 'law', describes subjective perception as proportional to the *logarithm* of the stimulus intensity

Canonical log brain rules

- A fundamental rule of psychophysics, the Weber-Fechner (log) 'law', describes subjective perception as proportional to the *logarithm* of the stimulus intensity
- Wide dynamic range of synaptic weights, firing rates and population synchrony (*lognormal* distribution)
- These dynamics occur on an anatomical substrate wherein the morphological connectivity within the network also displays *lognormal* distributions.

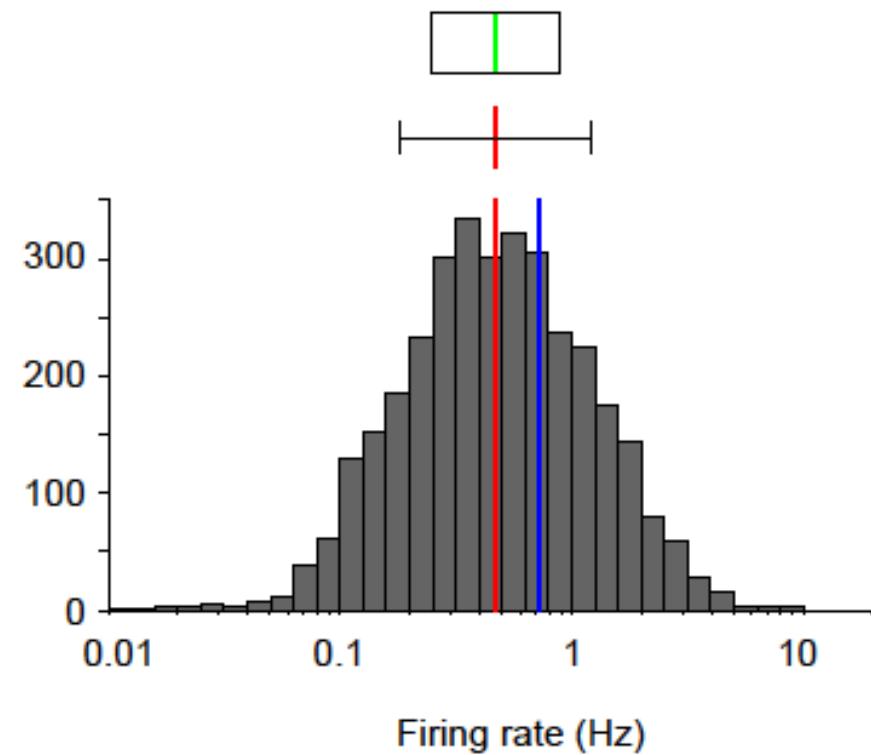
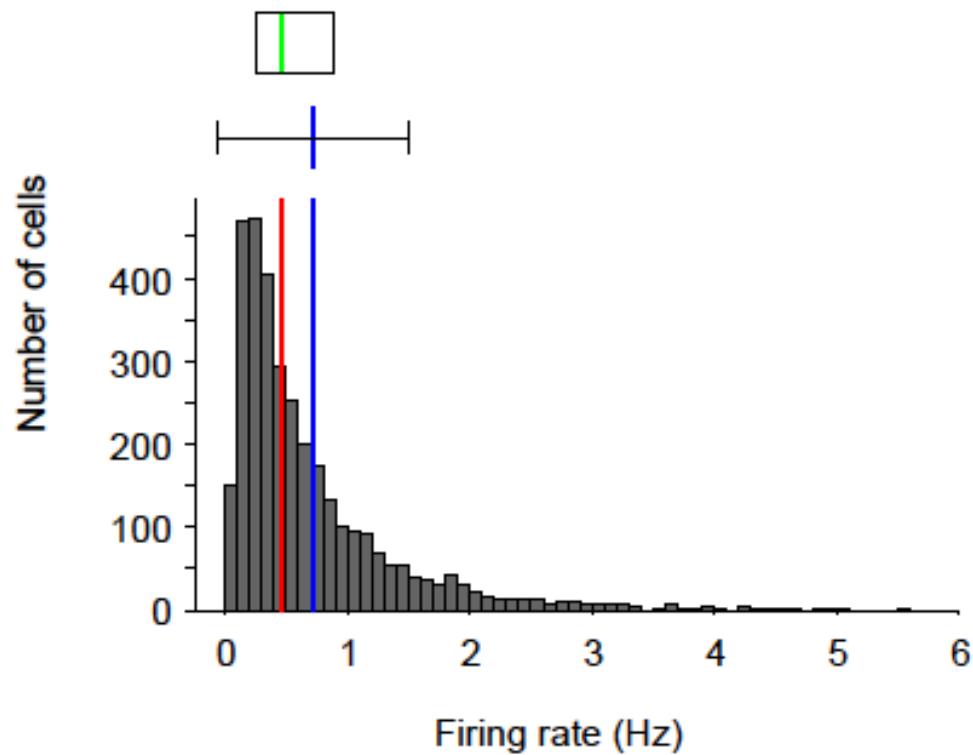
Hierarchies of oscillators (In rule) allow brain operations at multiple temporal scales



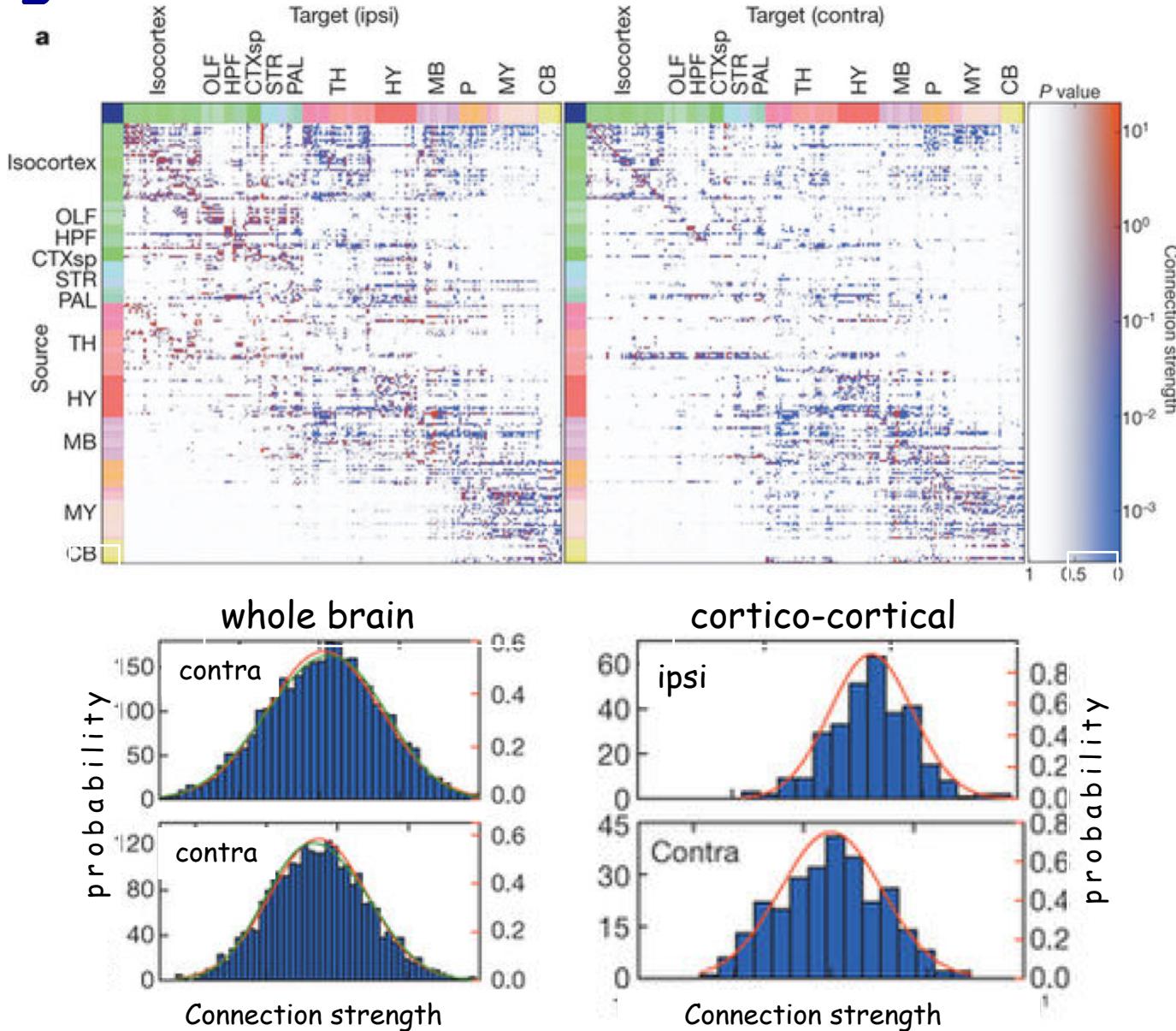
Multiple interacting rhythms are at work in the brain

Lognormal distribution of firing rates (CA1 pyramidal cells)

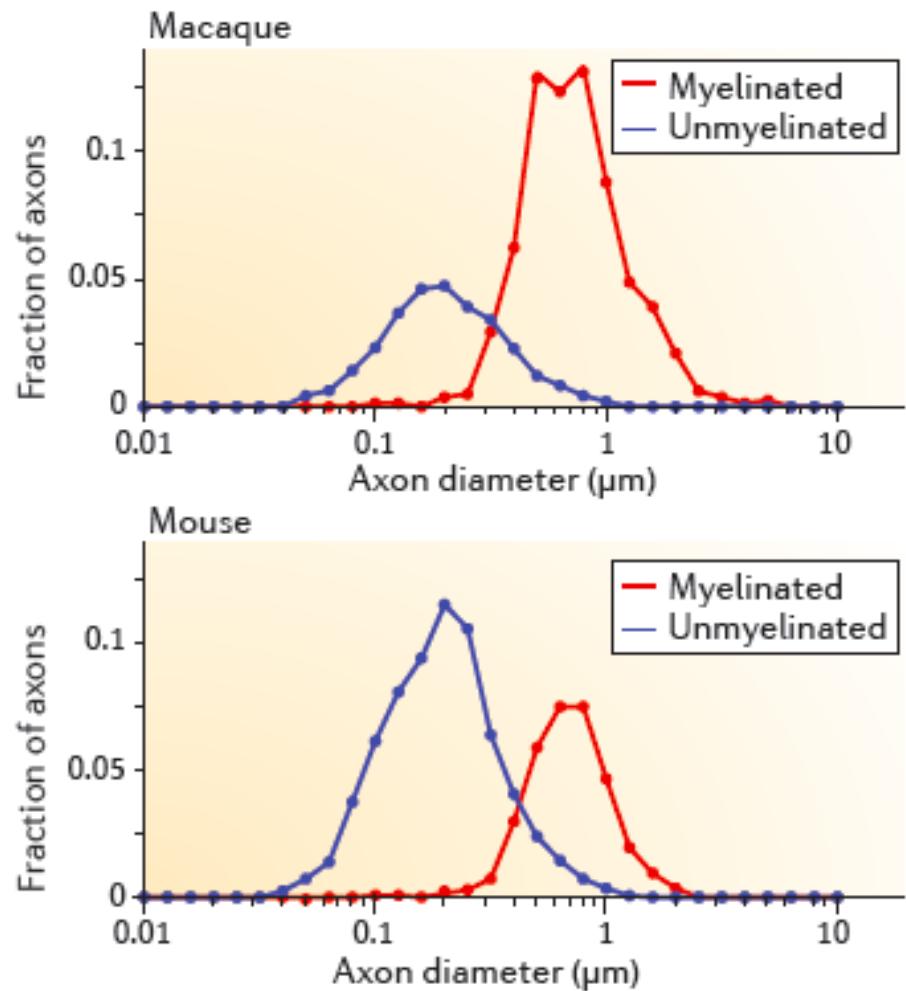
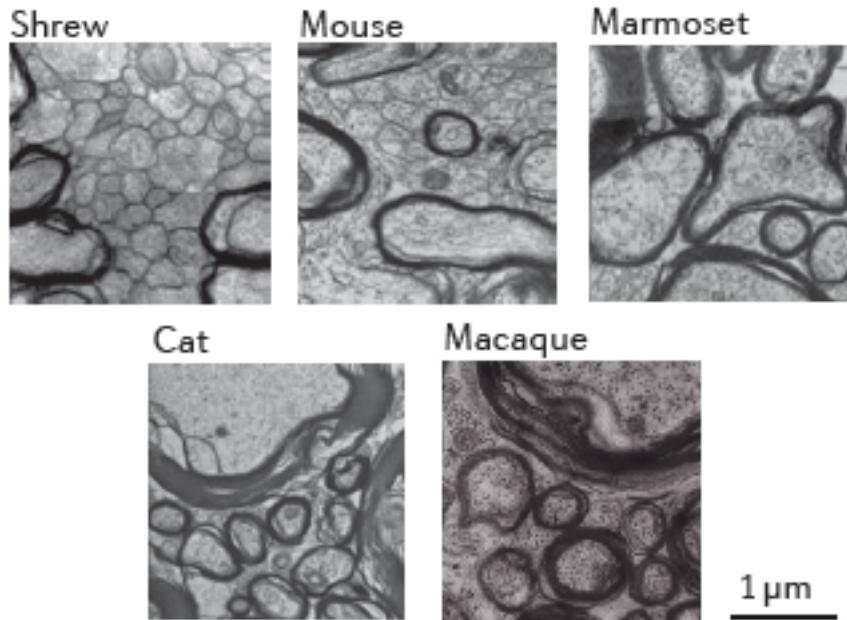
multiply/divide random numbers



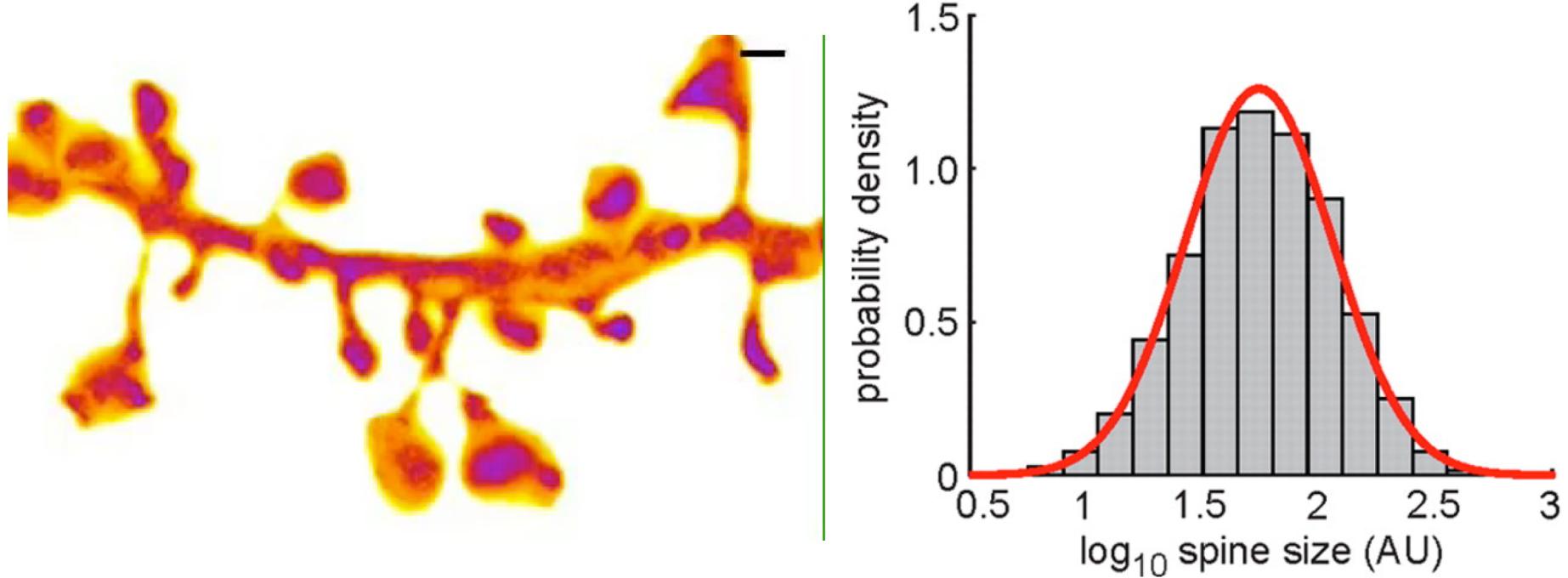
Lognormal distribution of brain connectivity



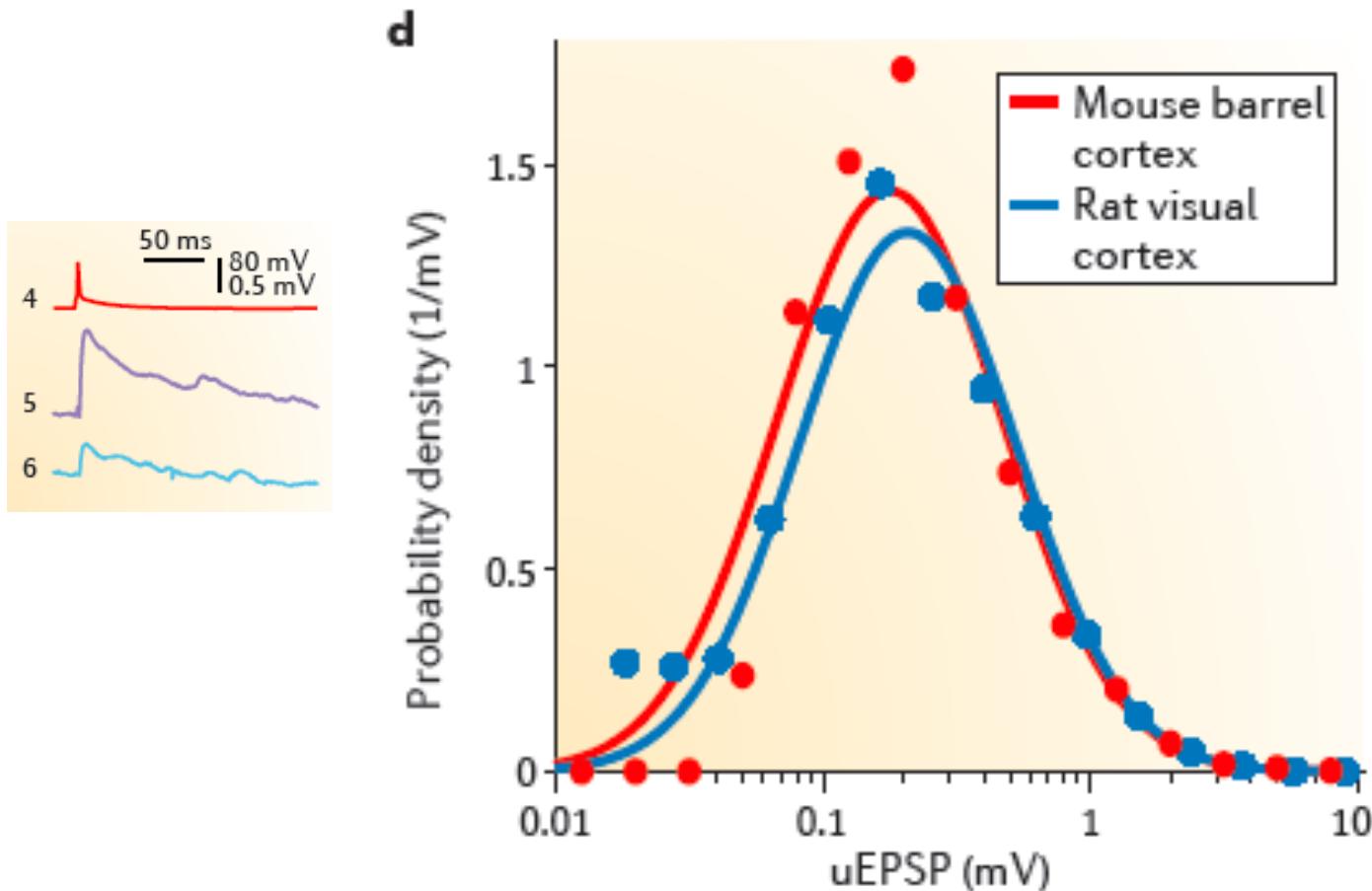
Log-normal distribution of axon diameters



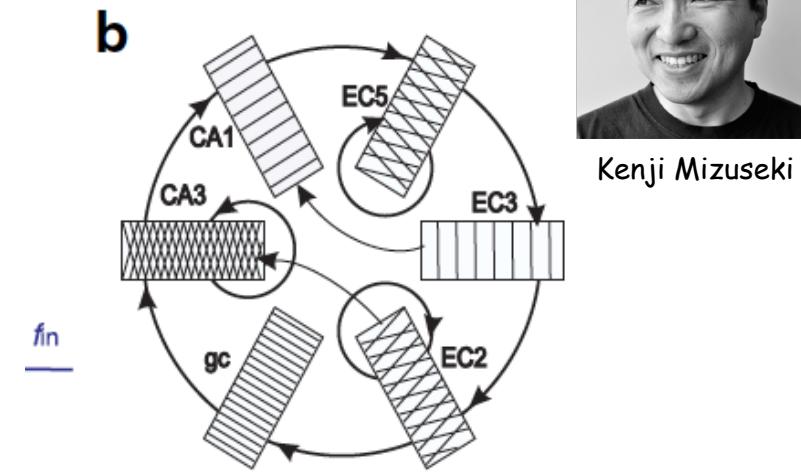
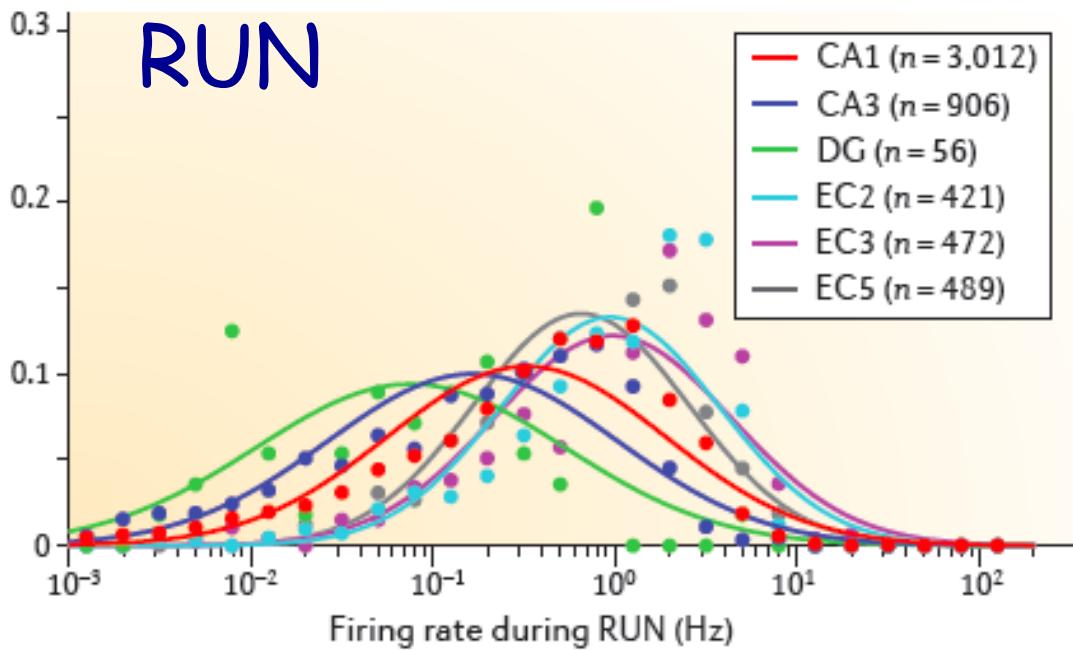
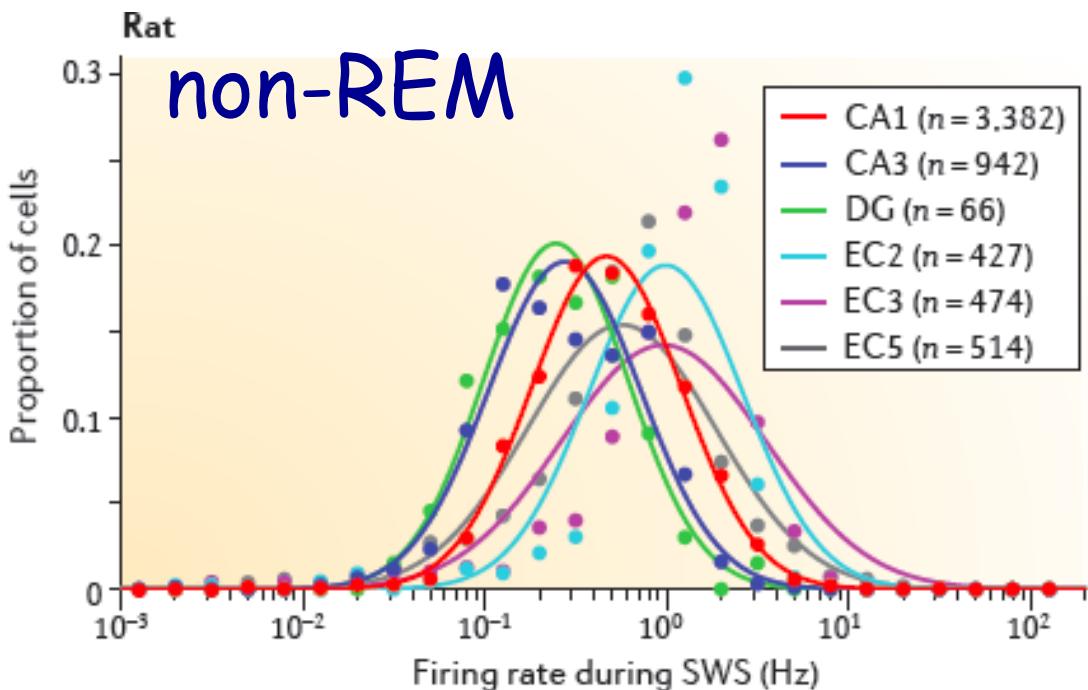
Distribution of spine sizes shows log-normal distribution



Distribution of synaptic strengths shows log-normal distribution (in vitro)



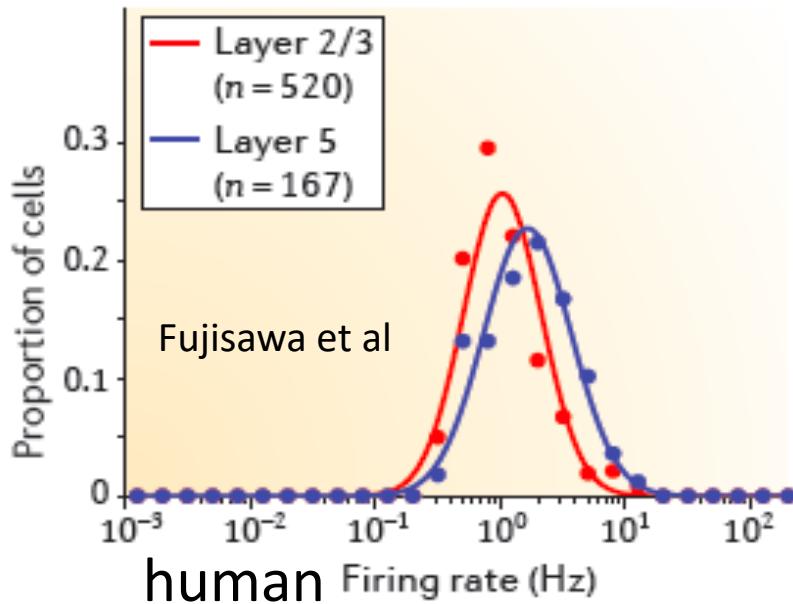
Larger synapses and multiple synapses are stronger



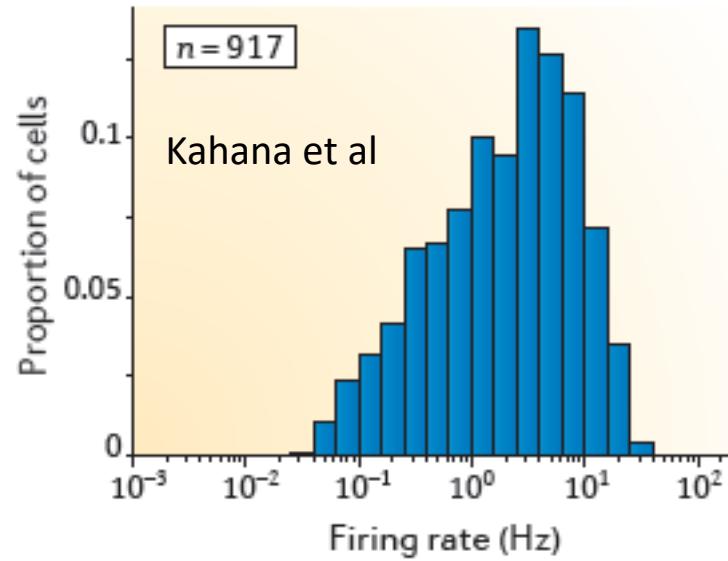
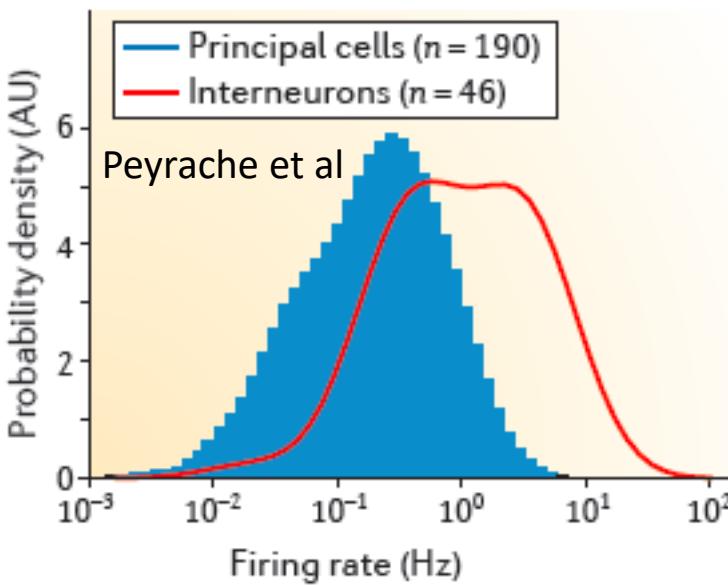
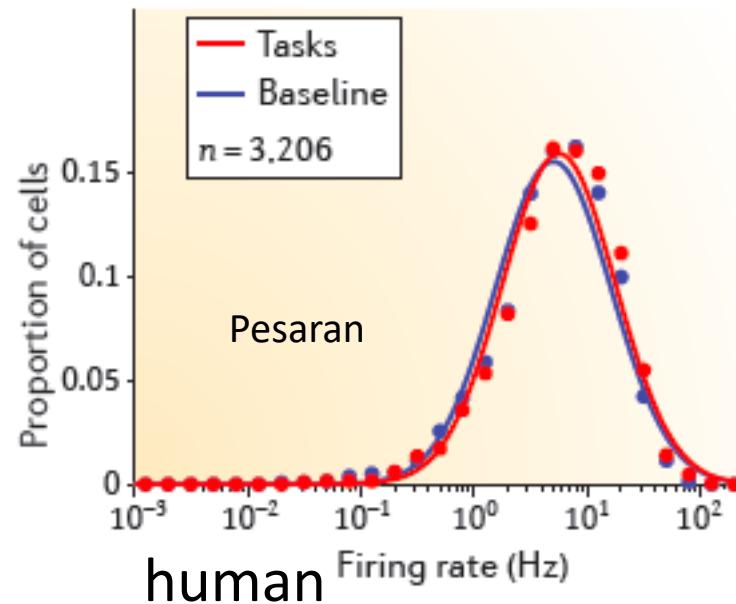
Log-normal rate distribution in each layer and region of the EC-hippocampus and brain state

Rate distributions in neocortex

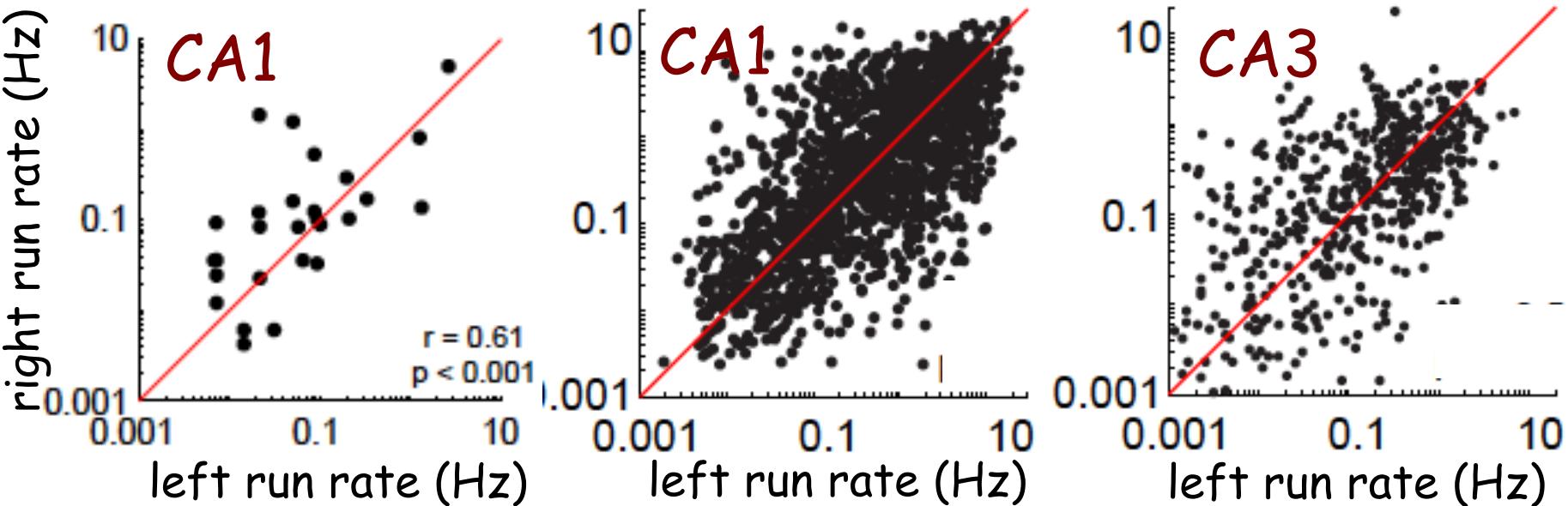
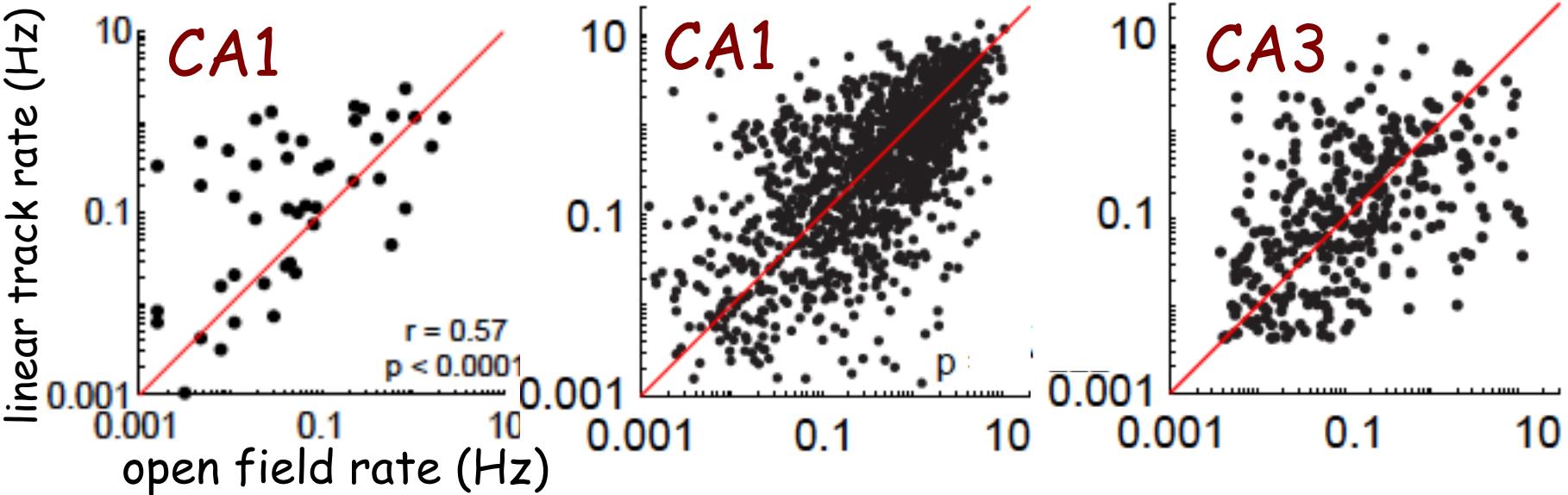
rat



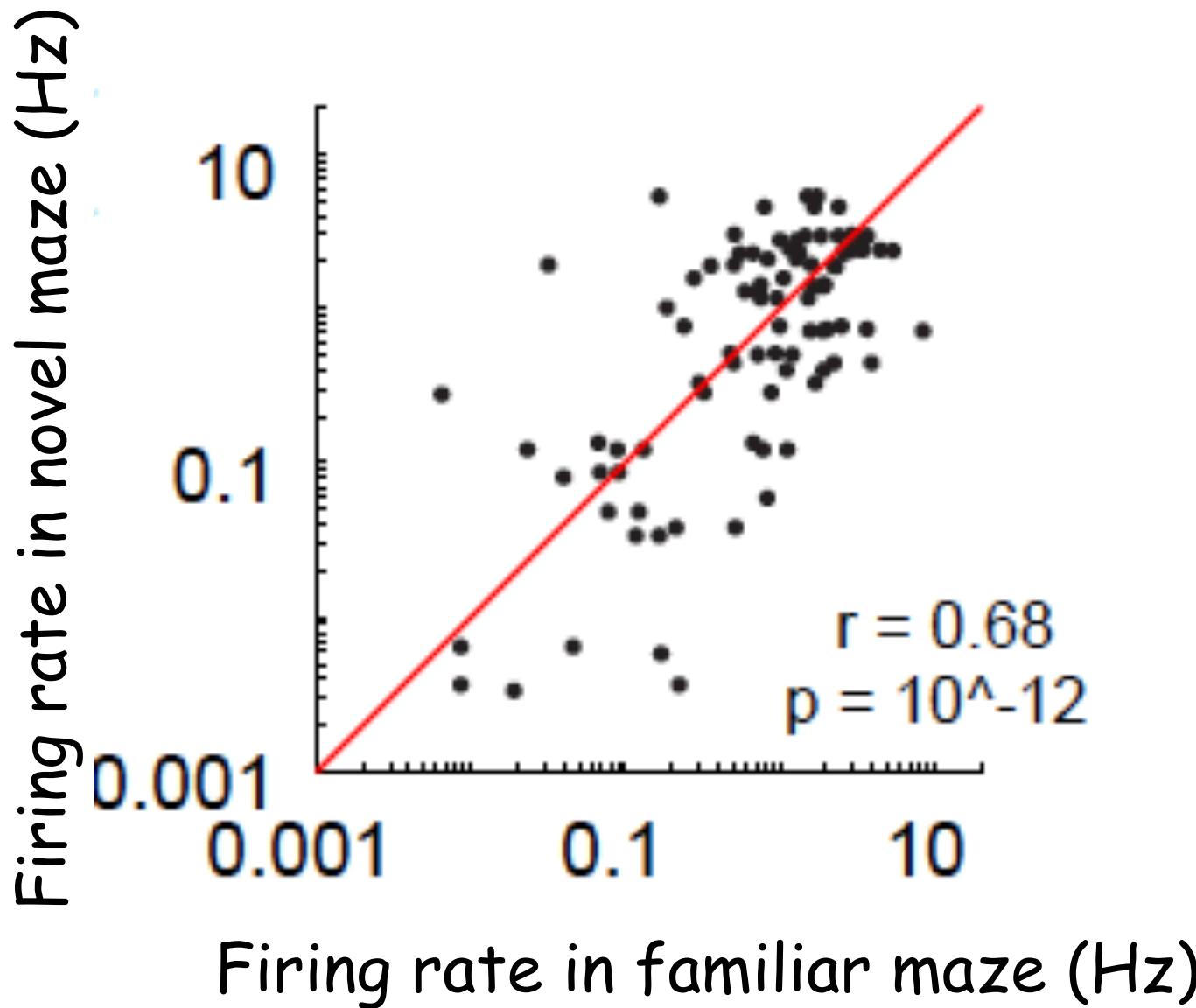
monkey



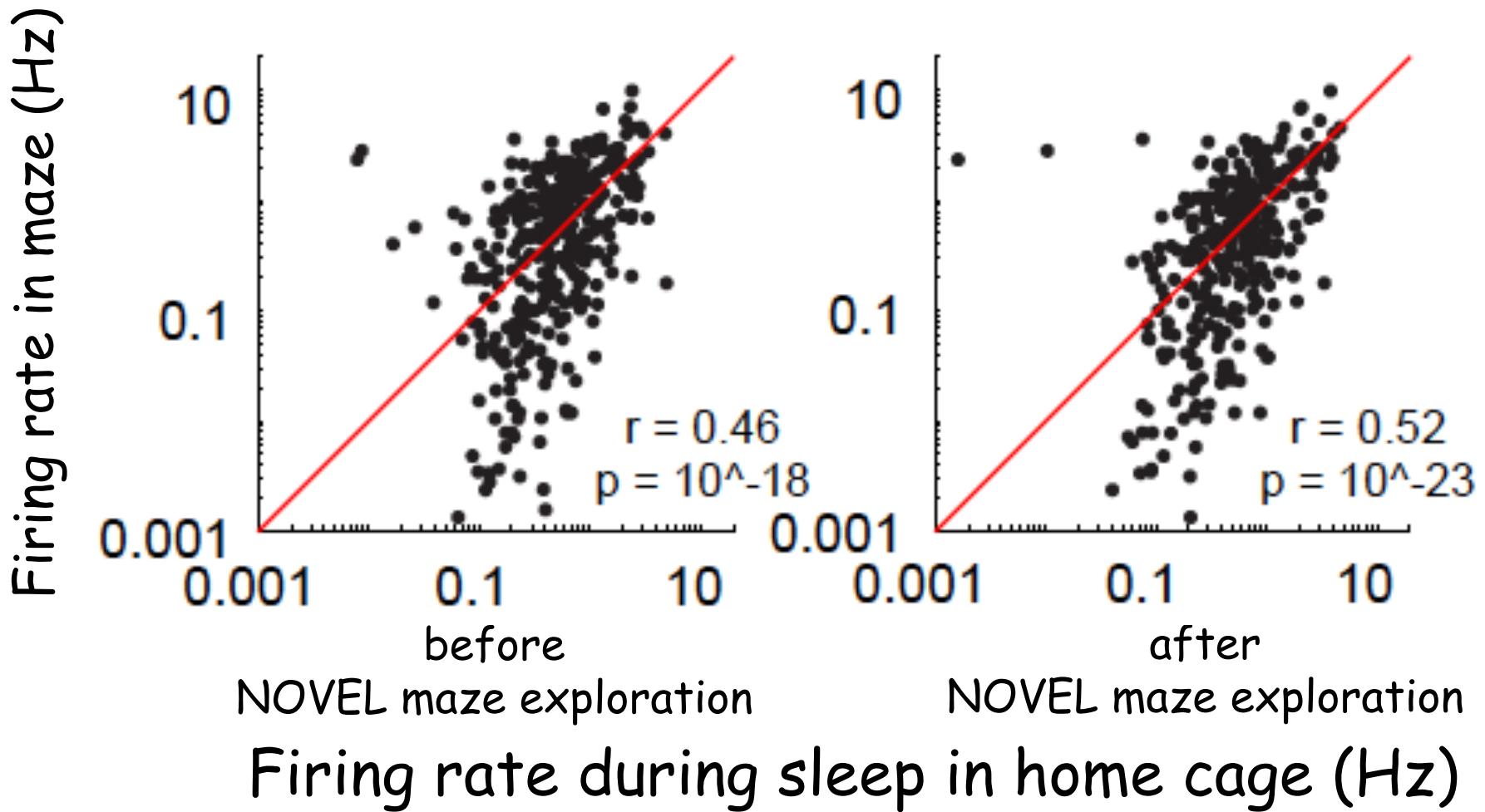
Log firing rate correlations across 're-mapping'



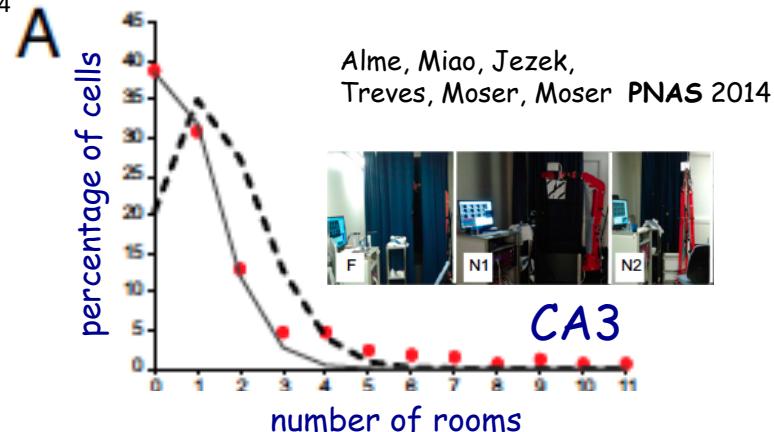
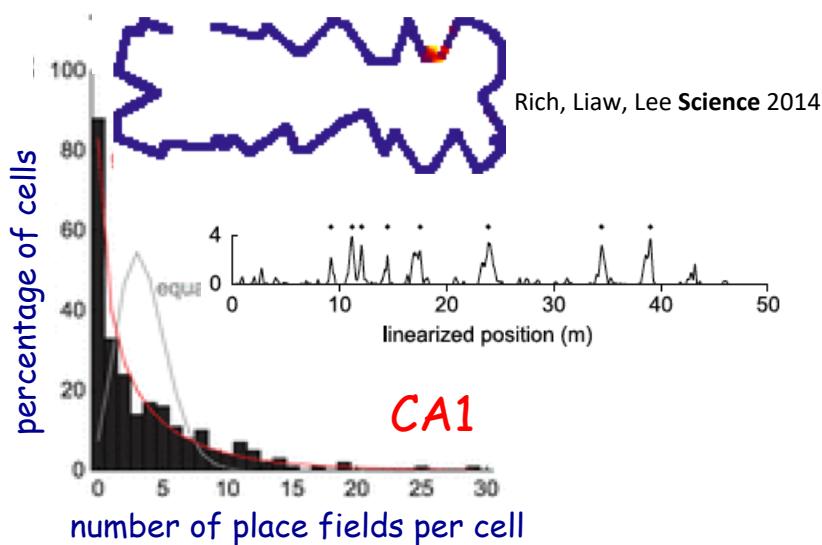
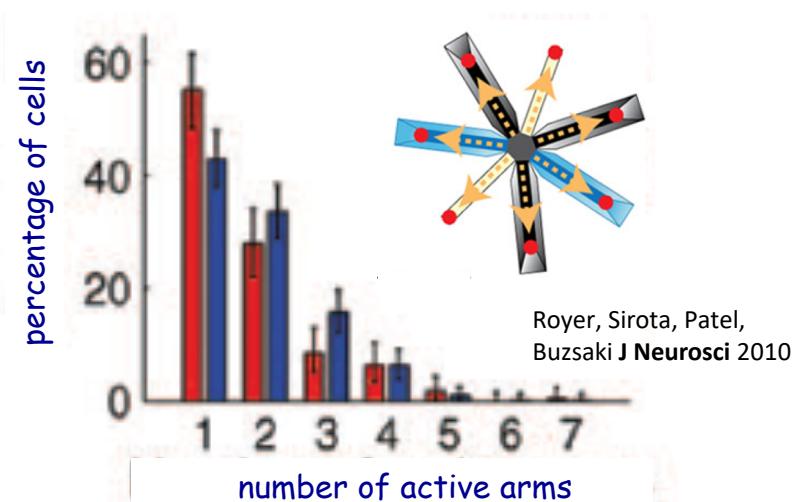
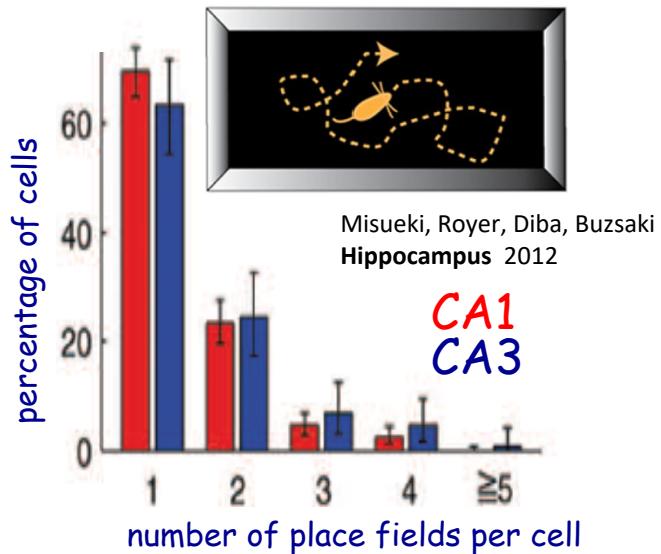
Firing rate correlations between familiar and novel environments



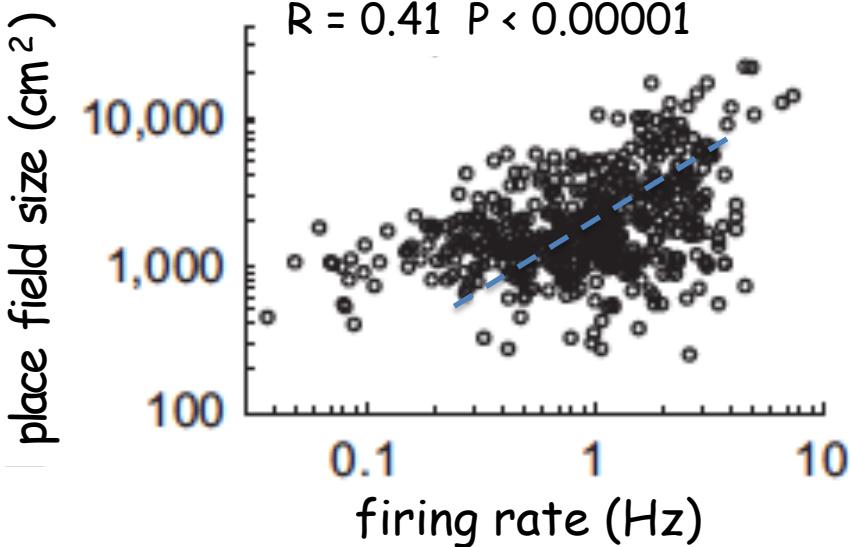
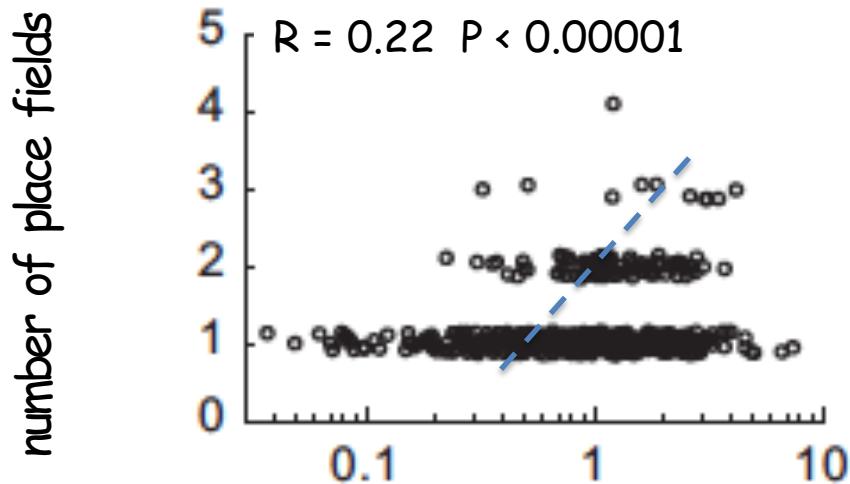
Firing rate correlations between novel environment and sleep



Log representation of environments



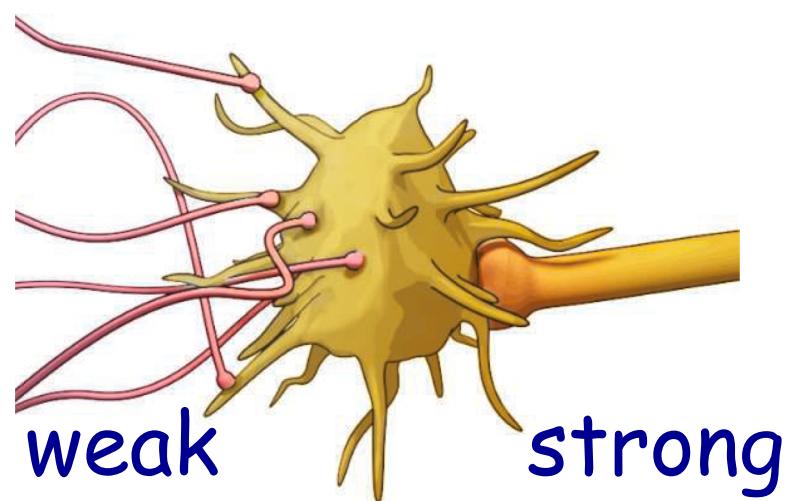
Firing rates and behavioral expressions are correlated



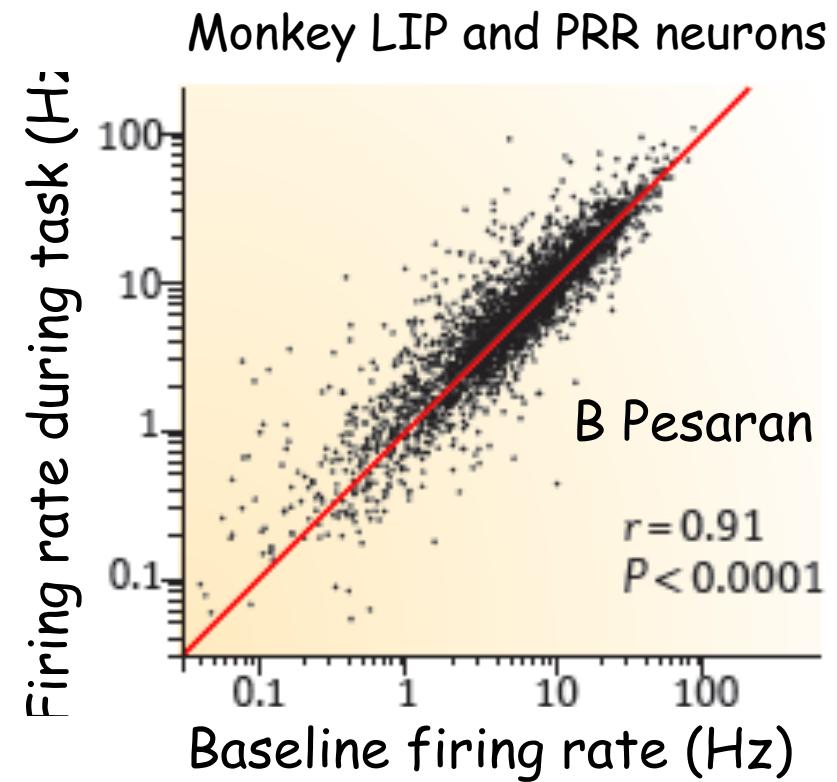
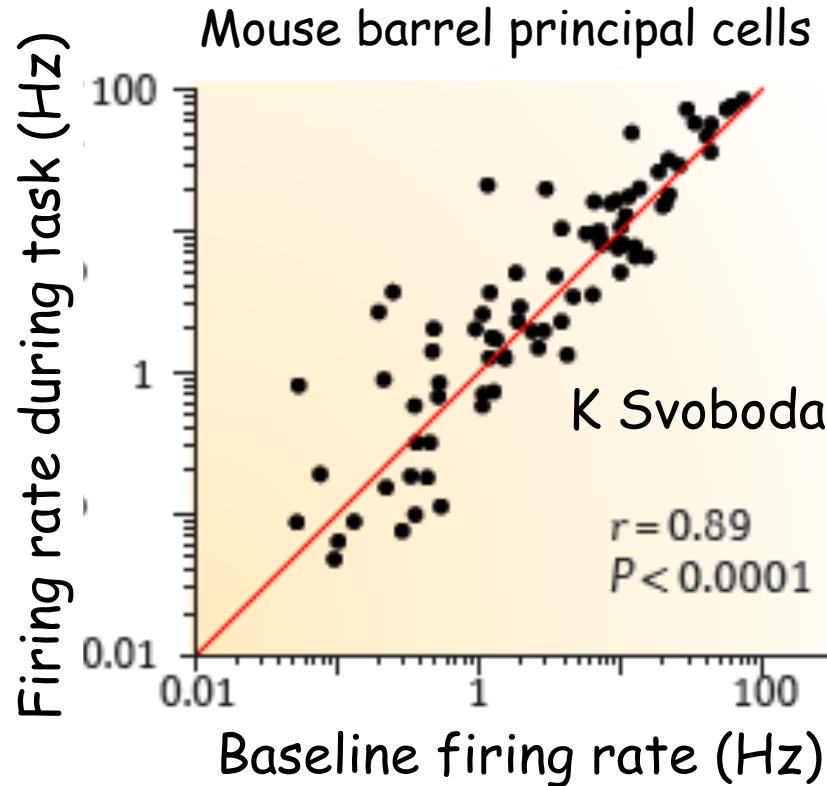
How do downstream 'readers' interpret messages sent by skewed populations?

novel?

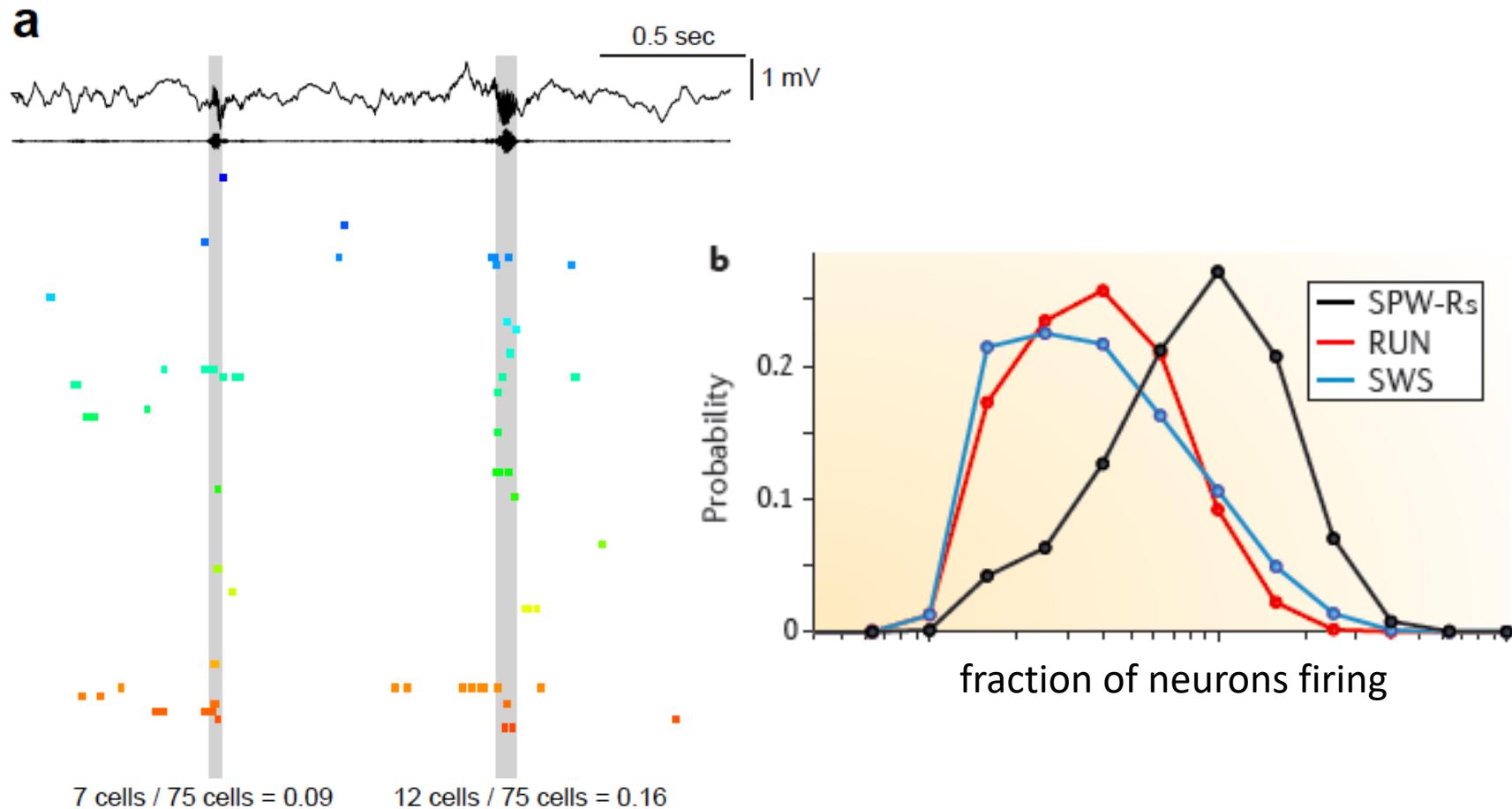
familiar?



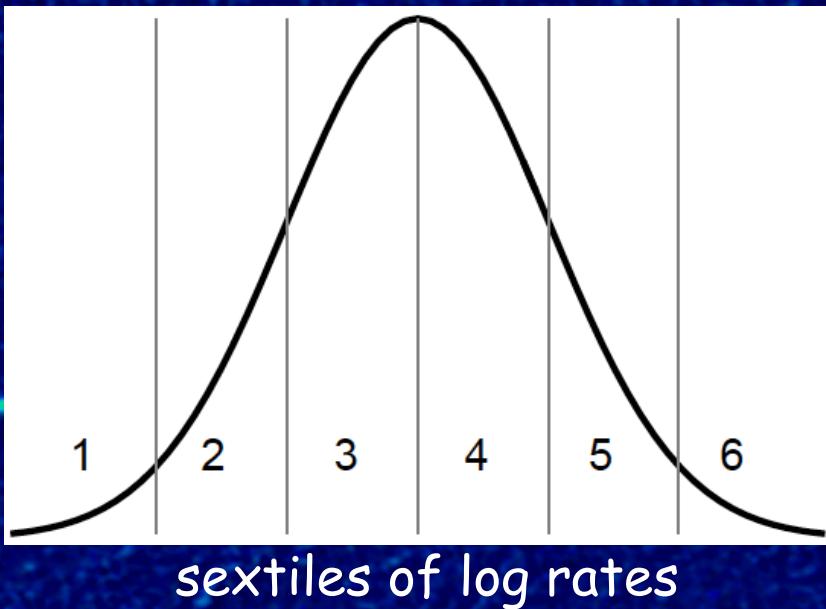
Log correlations between spontaneous and induced firing rates



Population level: magnitude of neuronal synchrony follows lognormal statistics

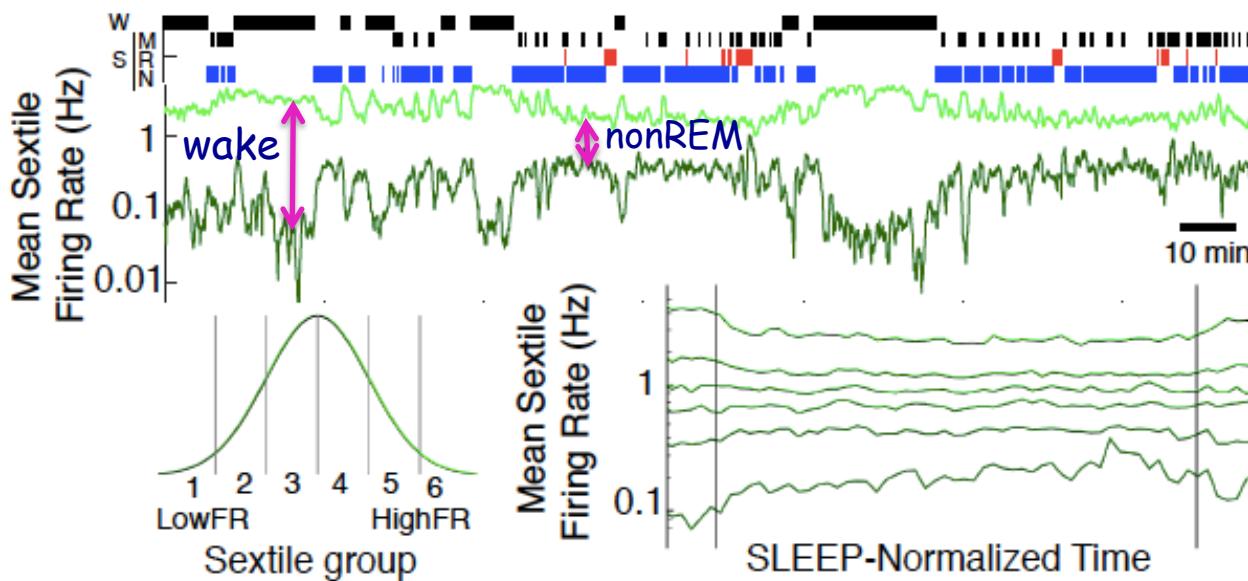


- These observations are not just statistical curiosities
- The brain's attempt to reconcile conflicting demands among wide dynamic range, stability, robustness and plasticity, redundancy, resilience, degeneracy, homeostasis



- How are log distributions of firing rates brought about ?
- How stable are rate distributions?
- How are log distributions maintained ?
- How are log distributions exploited for function ?

Slow and fast firing neurons are differentially regulated

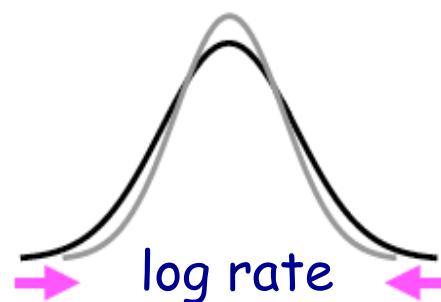


Brendon Watson



Dan Levenstein

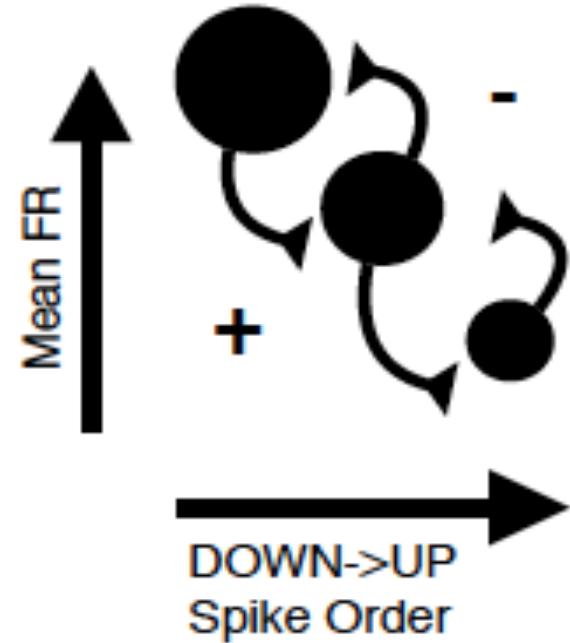
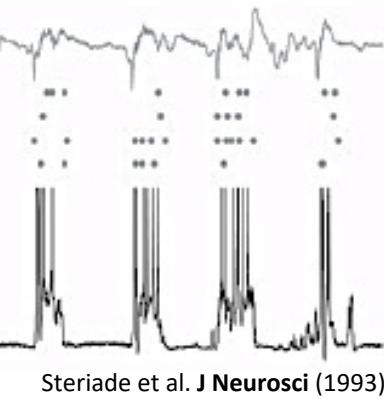
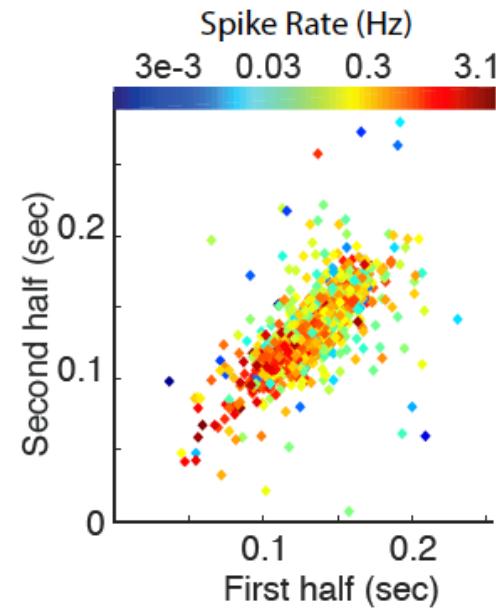
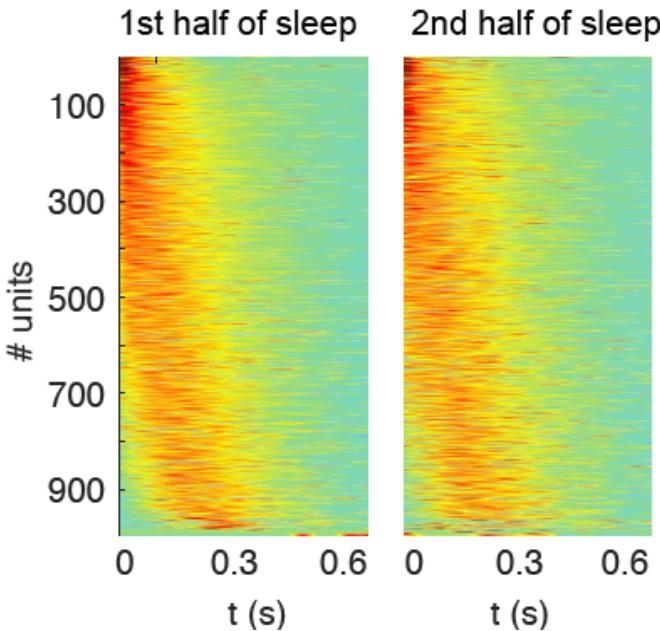
During nonREM SLEEP the coefficient of firing rate variation is decreased



Members of the slow and fast tails of the firing rate distribution are segregated in time during sleep

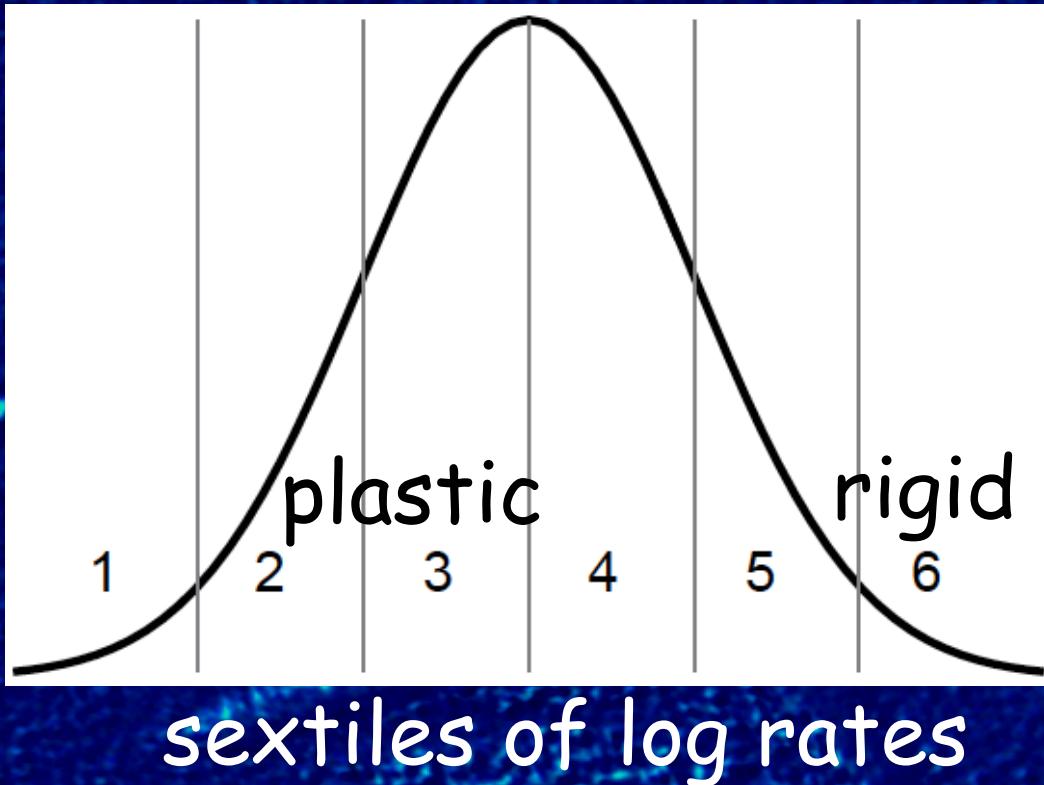
Hypothesis: slow and fast firing neurons are differentially affected by STDP

Sorted by latency



Sleep Plasticity

- Fast and slow firing neurons synchronize differently - STDP - segregation
- The two tails of the distribution are regulated by different mechanisms



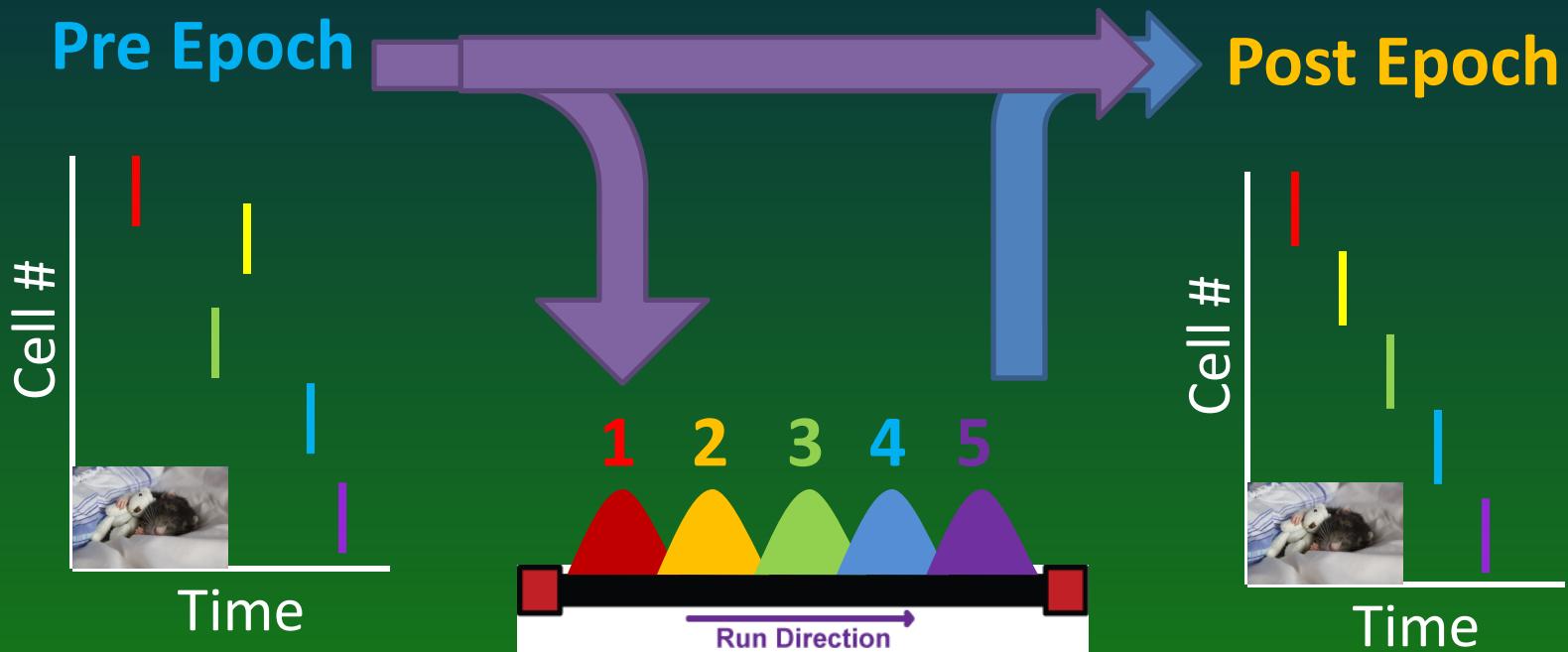
Functions for
skewed distributions

Firing rates correlate with learning-induced changes



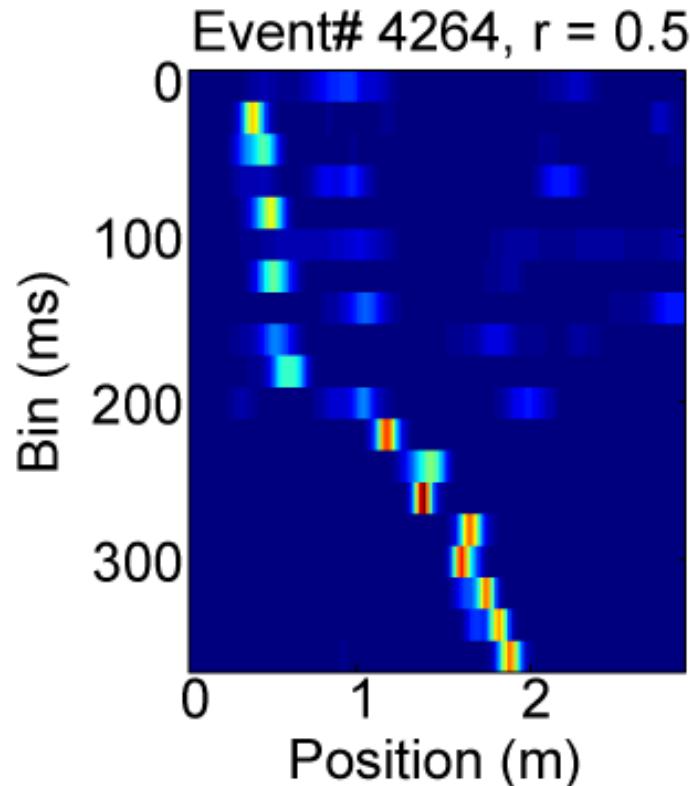
Andres Grosmark

Wilson, McNaughton, *Science* 1994
Dragoi, Tonegawa, *Science* 2011

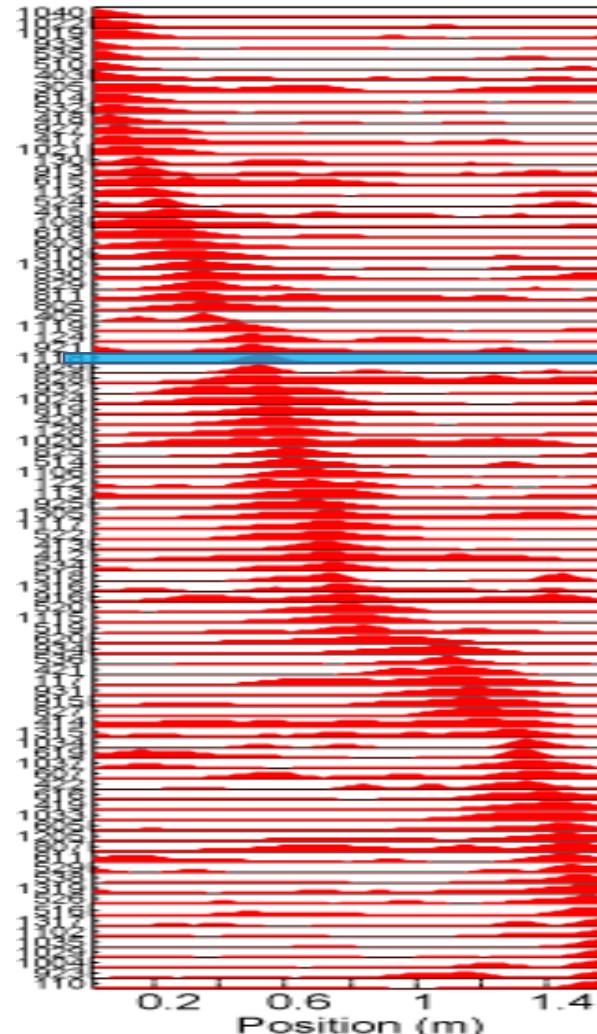


Per cell contribution (PCC) index

Bayesian decoding of position
(sequence score for each neuron)

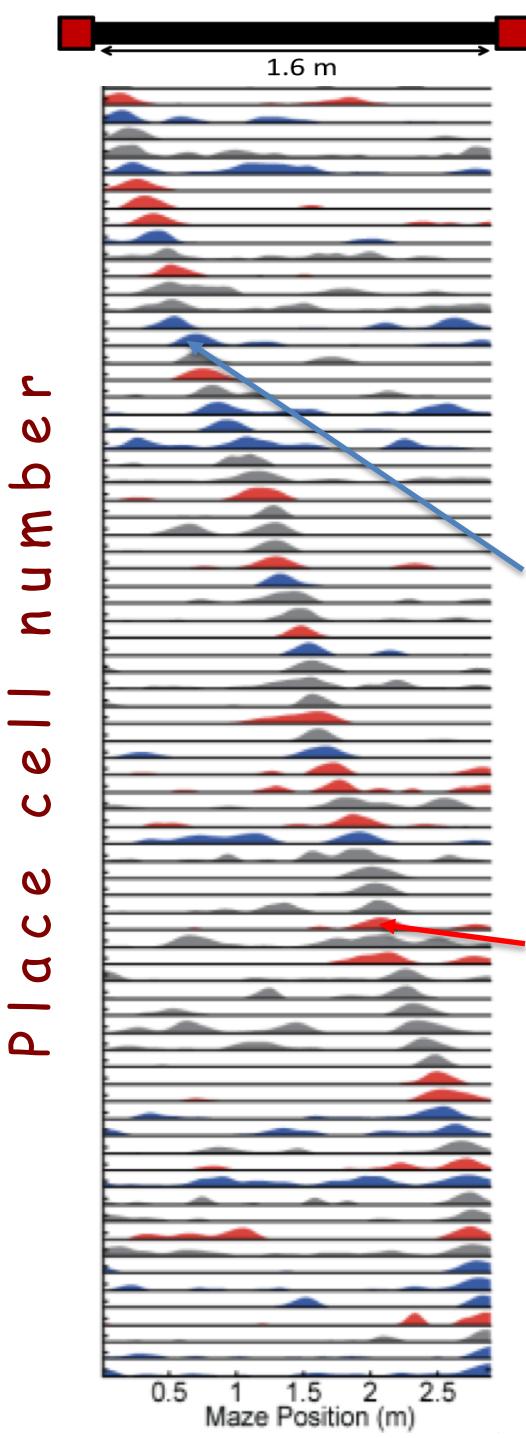


Linear Maze:

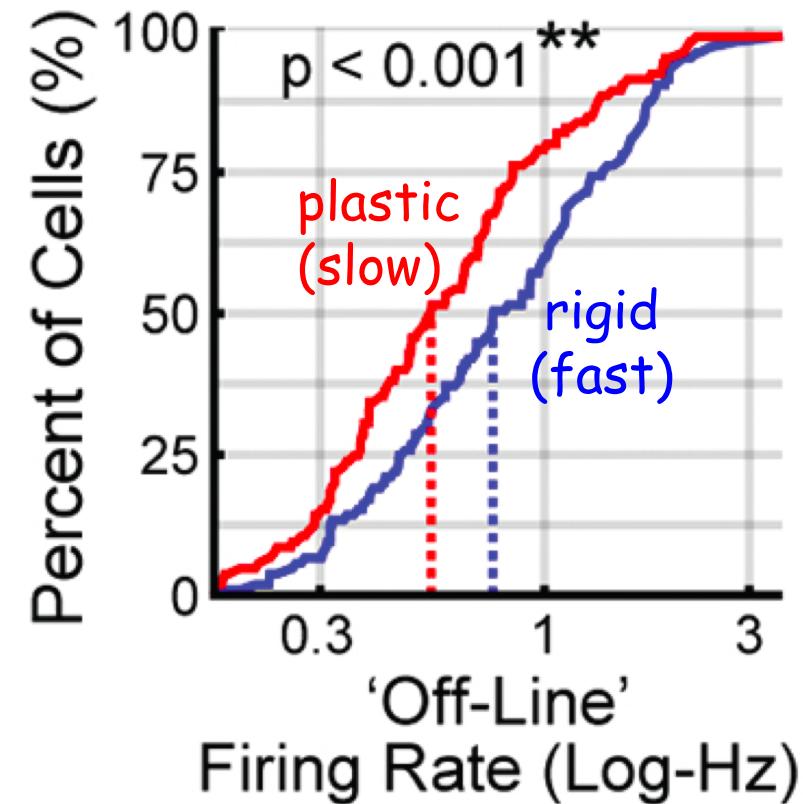


For each cell participating in each event:

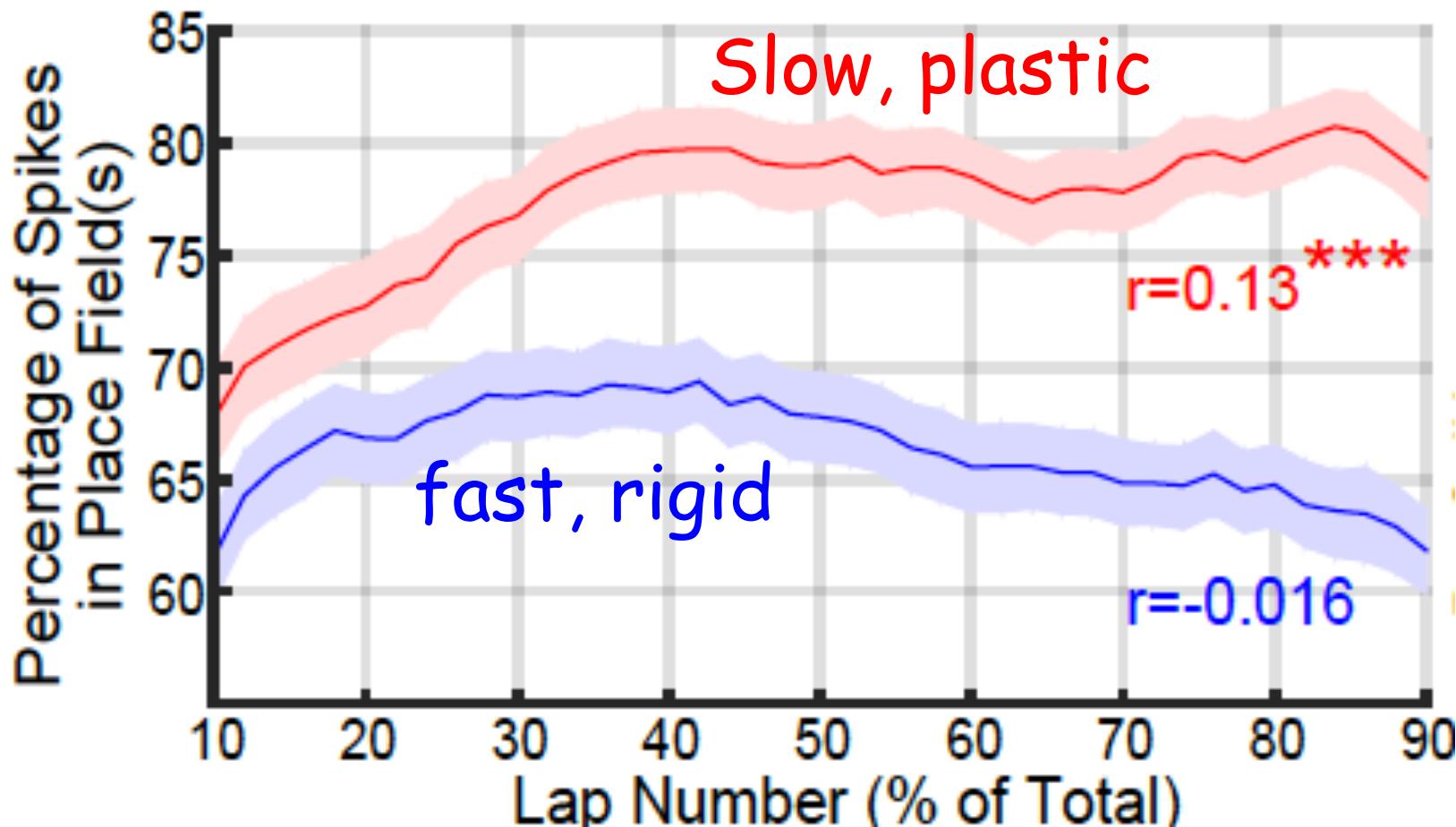
$$\text{P.C.C.} = [rZ(\text{observed}) - rZ(\text{cell shuffle})] \times N\text{Cells}$$



New place cells are added onto a backbone of pre-existing place cell sequence



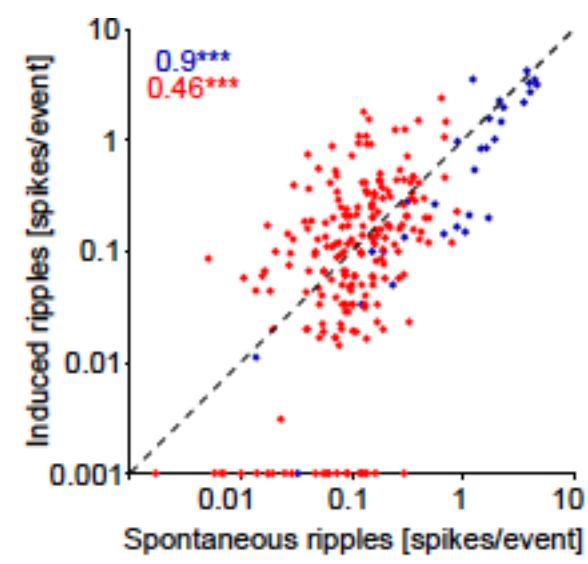
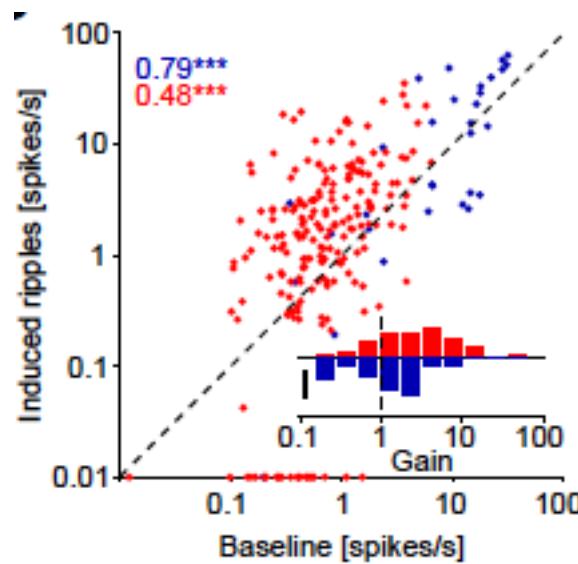
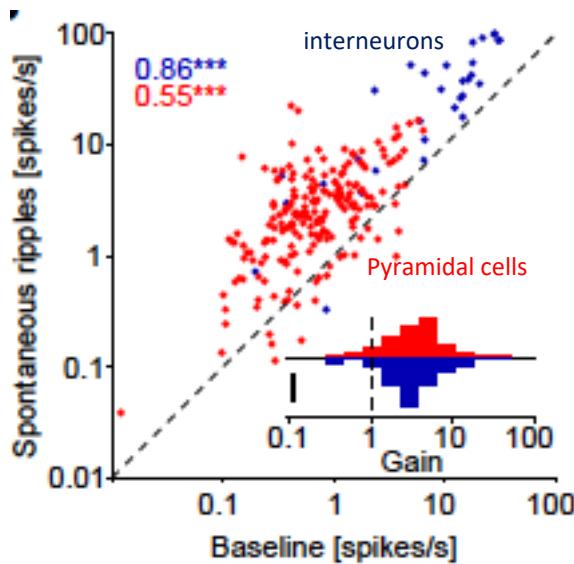
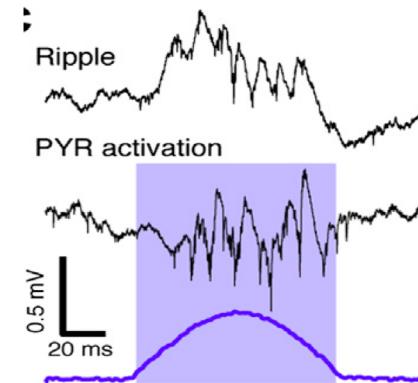
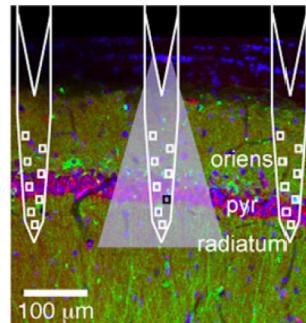
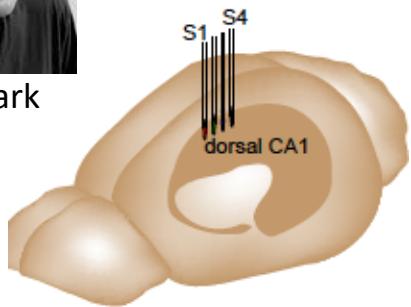
Slow firing place cells increase their spatial specificity over trials in a novel environment



Local circuit and intrinsic properties affect firing patterns



Eran Stark



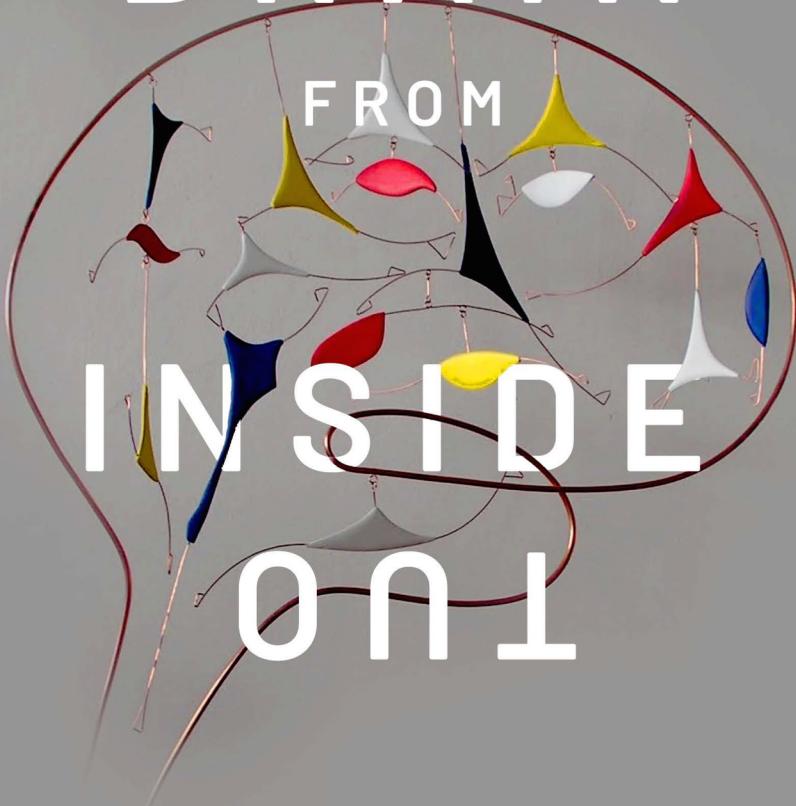
Simplicity is the ultimate
form of sophistication



- Leo Da Vinci

- Every ready, "good enough brain" for most situations versus "careful, detail-oriented brain"
- Fast decision versus slow precision
- Rigid minority versus plastic majority
- Generalizers versus specialists

THE
BRAIN
FROM
INSIDE
OUT

An abstract mobile sculpture by Alexander Calder, featuring various colored shapes (yellow, red, blue, white, black) suspended from a circular frame, set against a dark background.

GYÖRGY BUZSÁKI

Author of the seminal Rhythms of the Brain

Oxford Univ Press
2019

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Only low firing rate neurons are affected by learning

