Hidden neural states underlie canary song syntax

How (and why) should we study the brain (with miniscopes)?
(PhD ... It's a degree in Philosophy)

How do neurons cooperate in a massively interconnected network to generate high-level cognitive function?

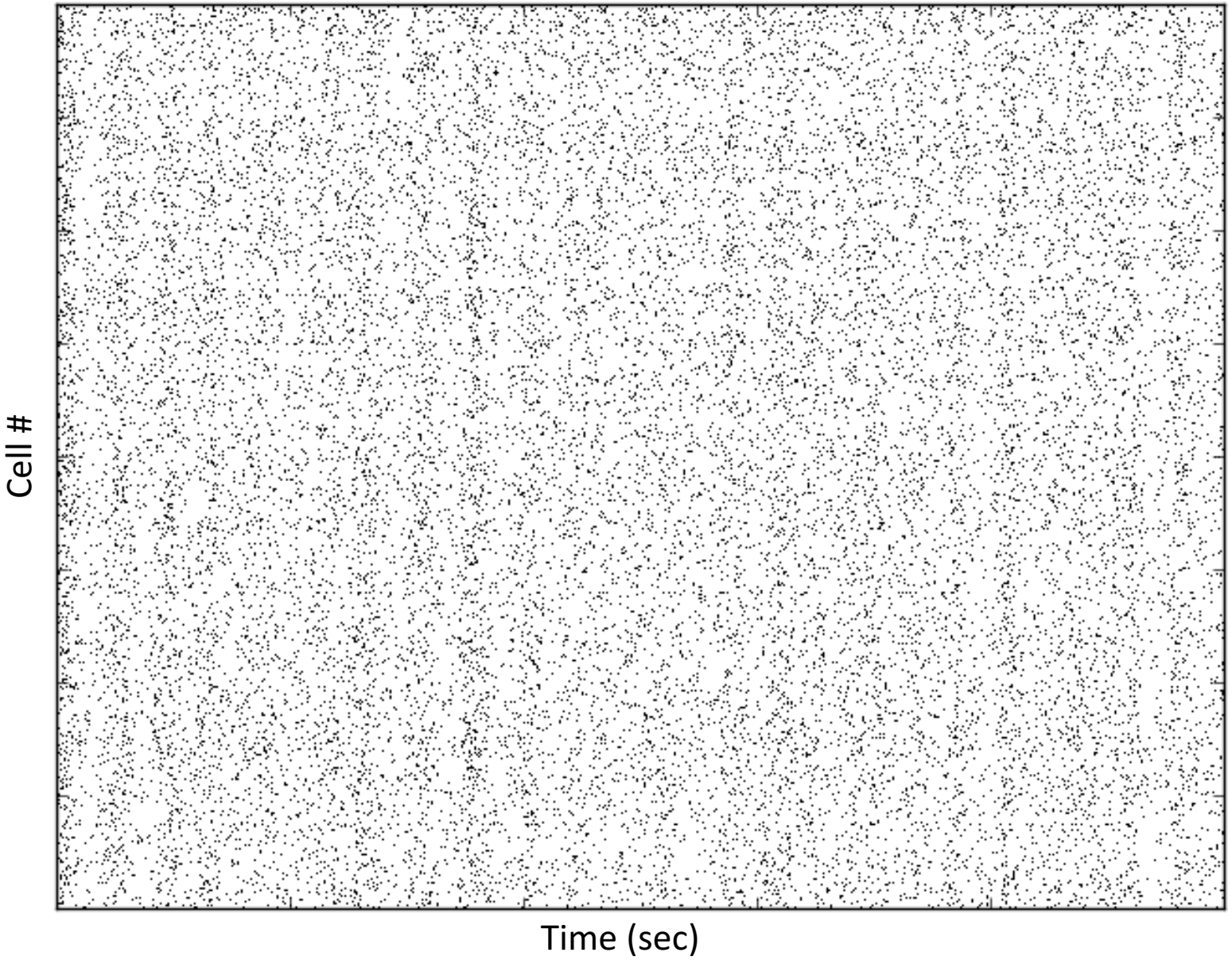
The **thing-in-itself** (German: Ding an sich) is a concept introduced by Immanuel Kant. Things-in-themselves would be objects as they are, independent of observation. (*Wikipedia*)

"You believe in a God who plays dice, and I in complete law and order in a world which objectively exists, and which I in a wildly speculative way, am trying to capture. I firmly believe, but I hope that someone will discover a more realistic way, or rather a more tangible basis than it has been my lot to find." (*A. Einstein to M. Born*)

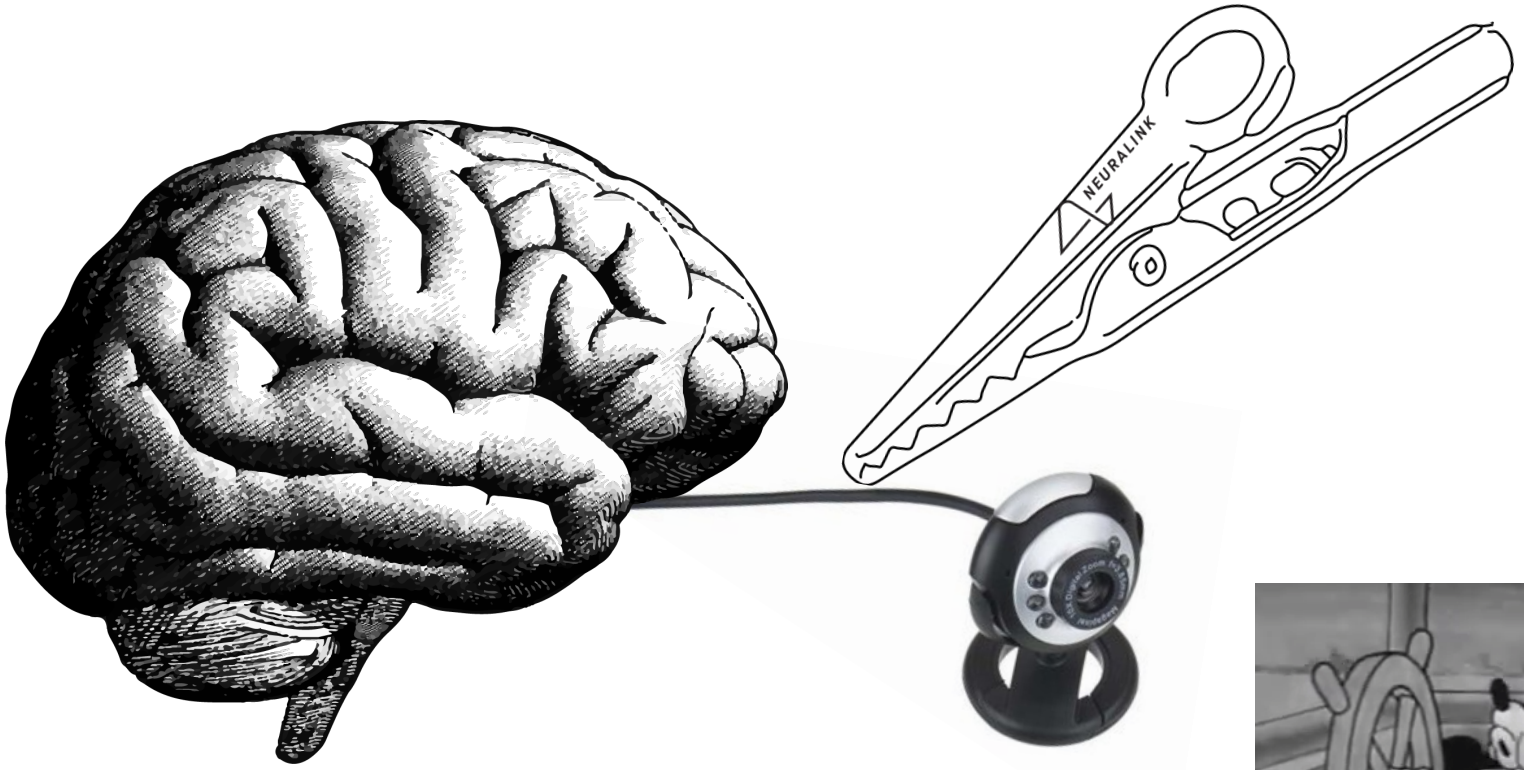
Pragmatism considers thought as an instrument or tool for prediction, problem solving and action, and rejects the idea that the function of thought is to describe, represent, or mirror reality. Pragmatists contend that most philosophical topics—such as the nature of knowledge, language, concepts, meaning, belief, and science—are all best viewed in terms of their practical uses and successes. (*Wikipedia*)

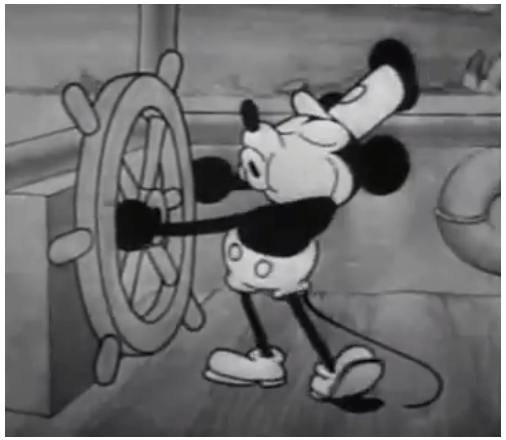
Yarden Cohen, BU Biology, Otchy lab

Massively-connected neurons cooperate in brain functions

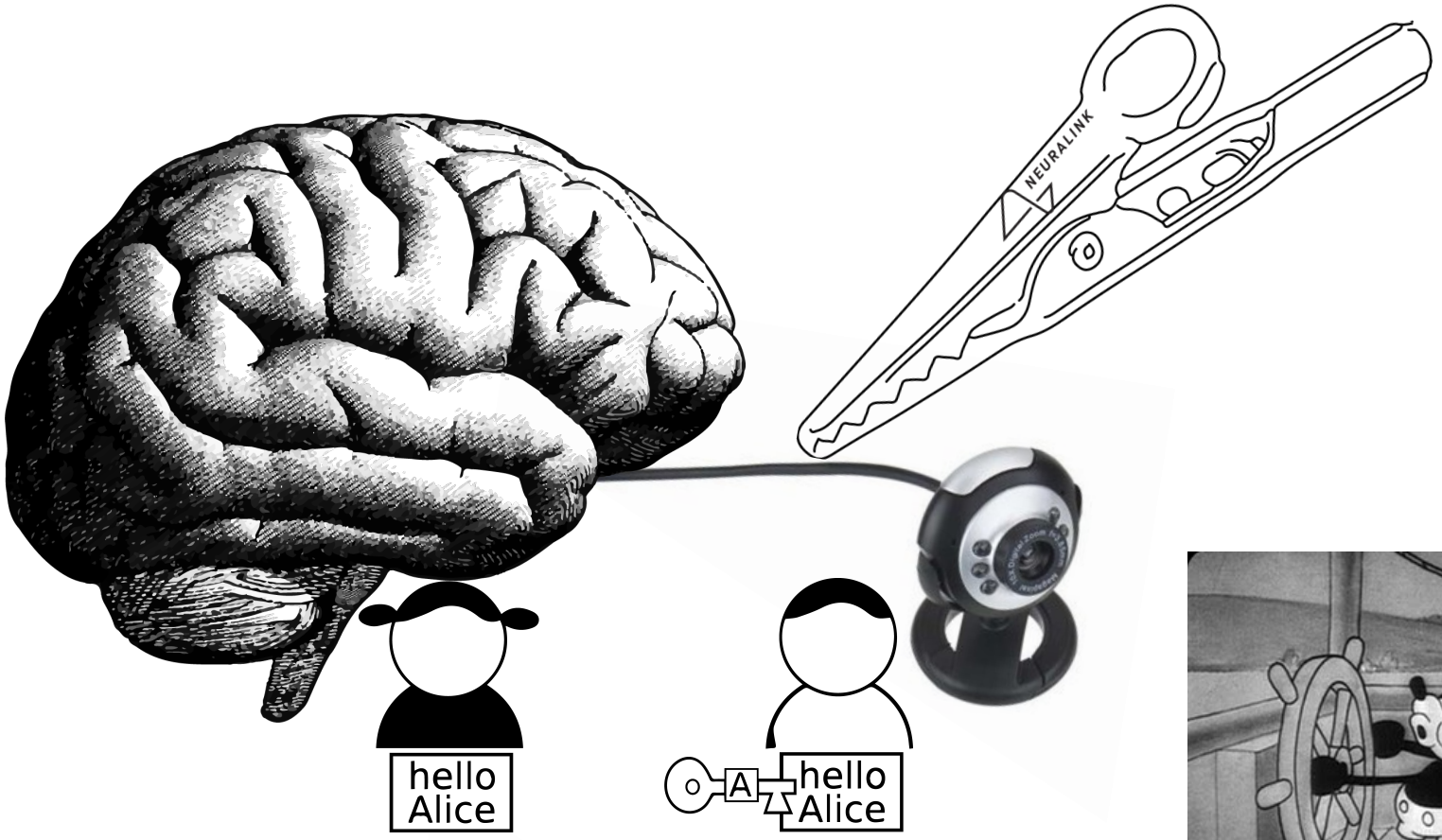


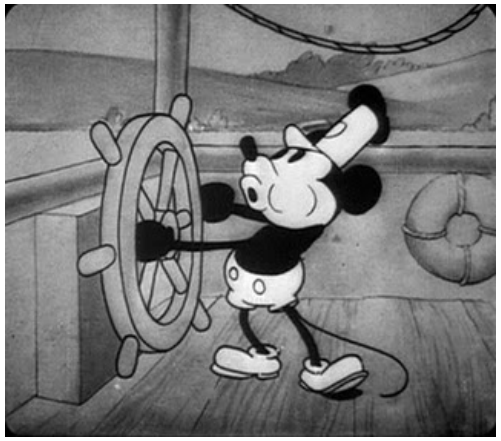
Massively-connected neurons cooperate in brain functions



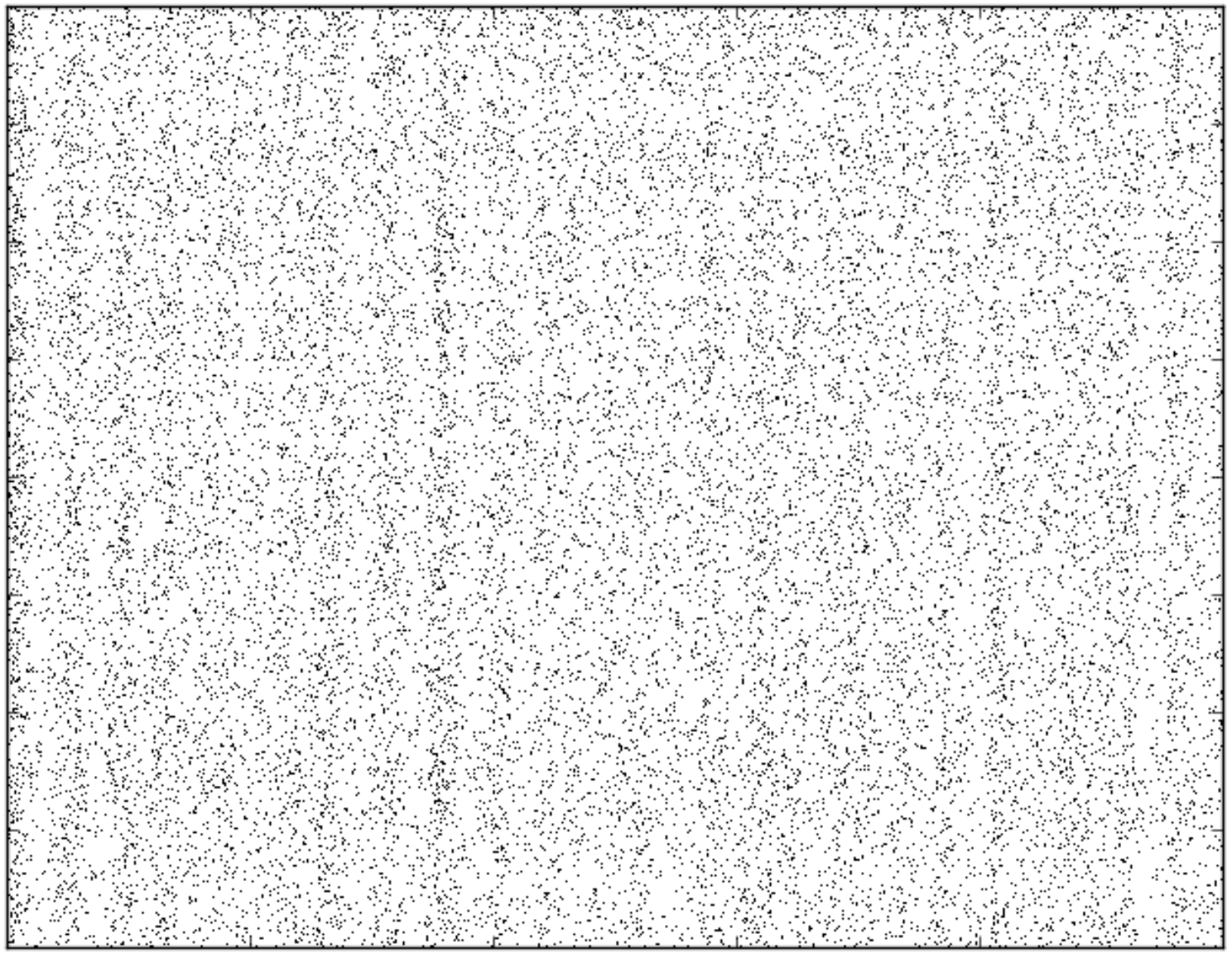


Massively-connected neurons cooperate in brain functions





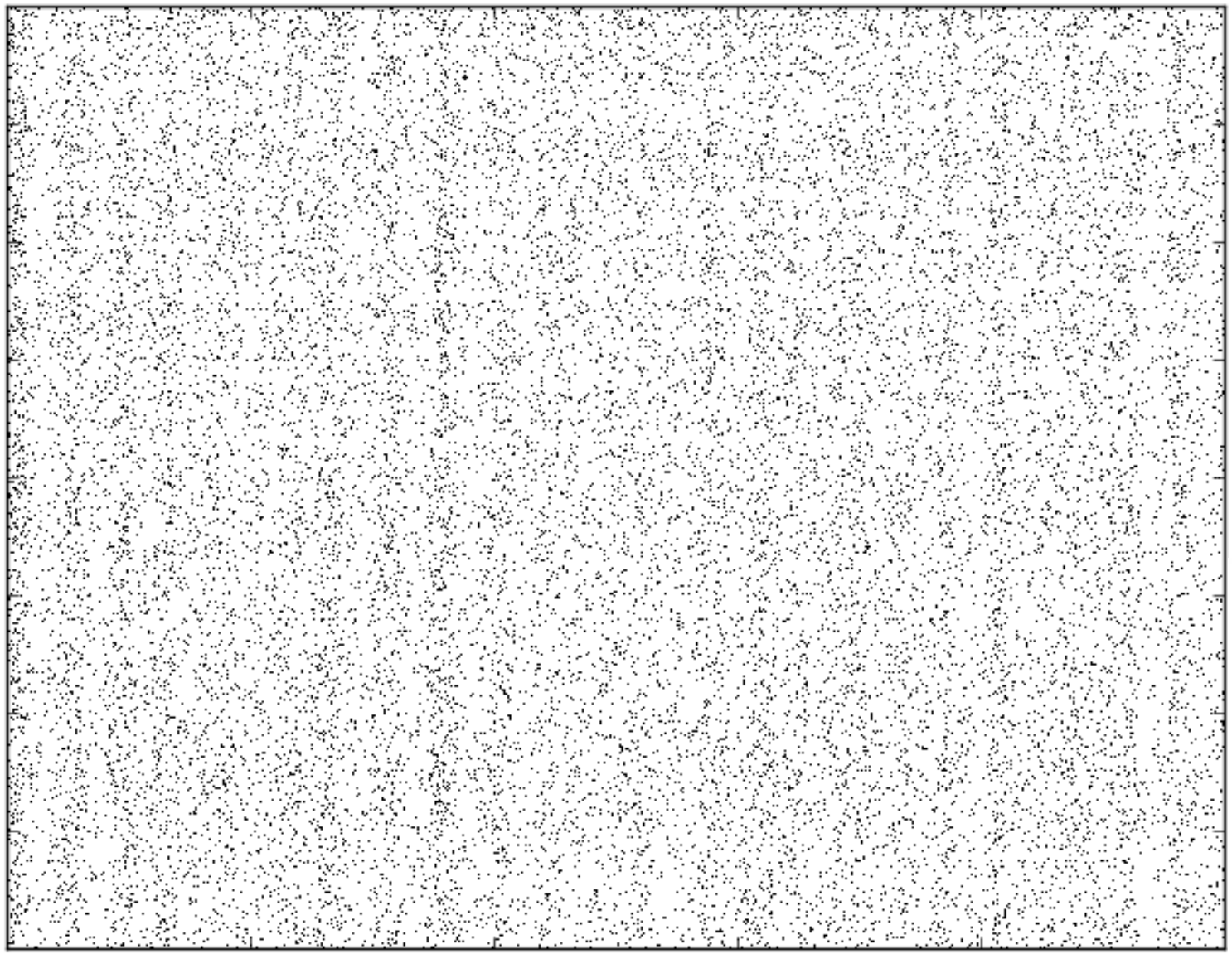
Can we identify ‘atoms’ of neural function ?



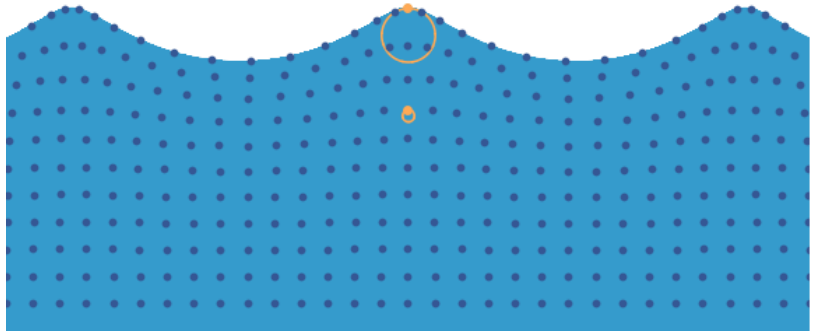
Can we?

1. Identify the heuristics used by the brain
2. Without making strong assumptions

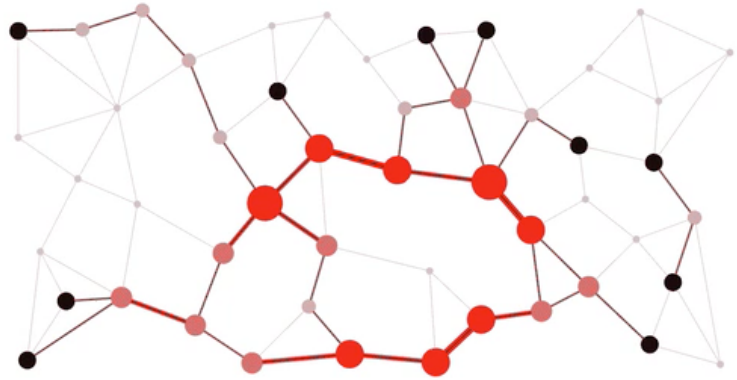
Can we identify ‘atoms’ of neural function ?



Emergent geometry



Biology is noisy



M. Abeles, D. Plenz

Structured neural activity changes when the brain is forced to adapt, learn, or counter noise

Model system with small and well-characterized variability

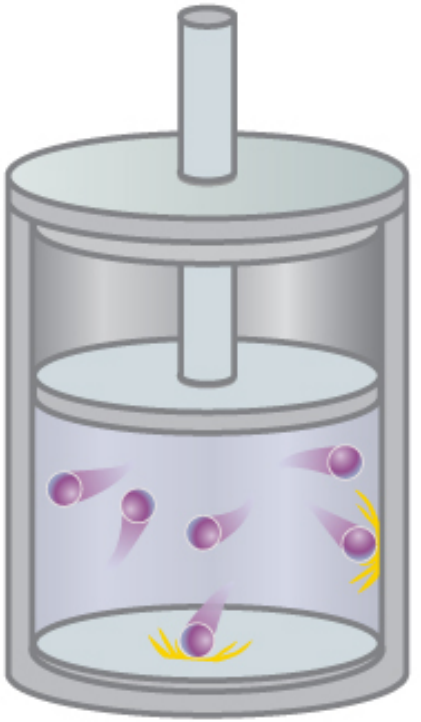
‘Good’ cover of relevant (ethological) function

Neural recording from functionally identified sources (from multiple neurons simultaneously)

Observed, estimated, and maybe emergent, neural ‘code’

Means of driving (a small) change

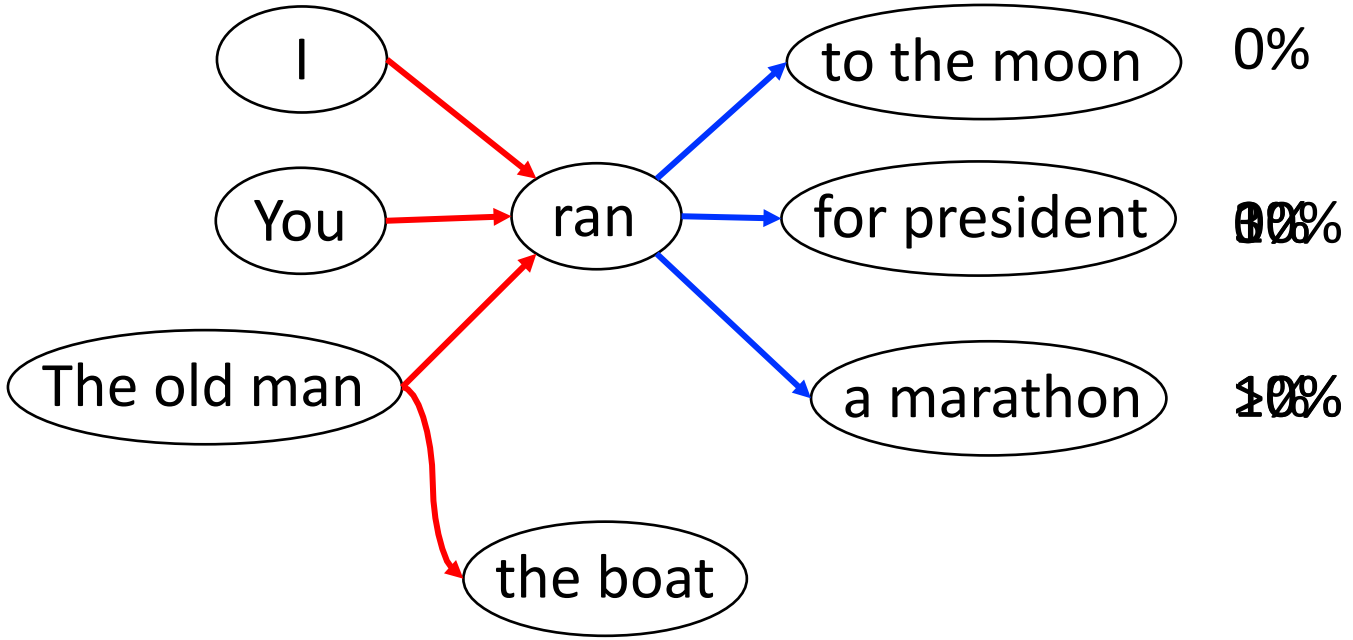
A ’good’ framework will tweak its parameters, not structure, to encompass the change

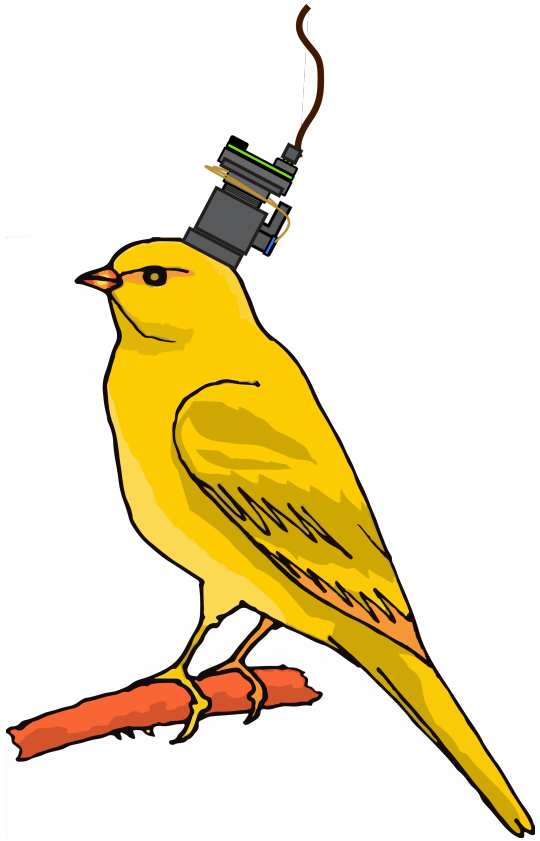


Hidden neural states underlie canary song syntax

Model system with small and well-characterized variability
'Good' cover of relevant (ethological) function

Syntax rules : transitions with long range history dependency





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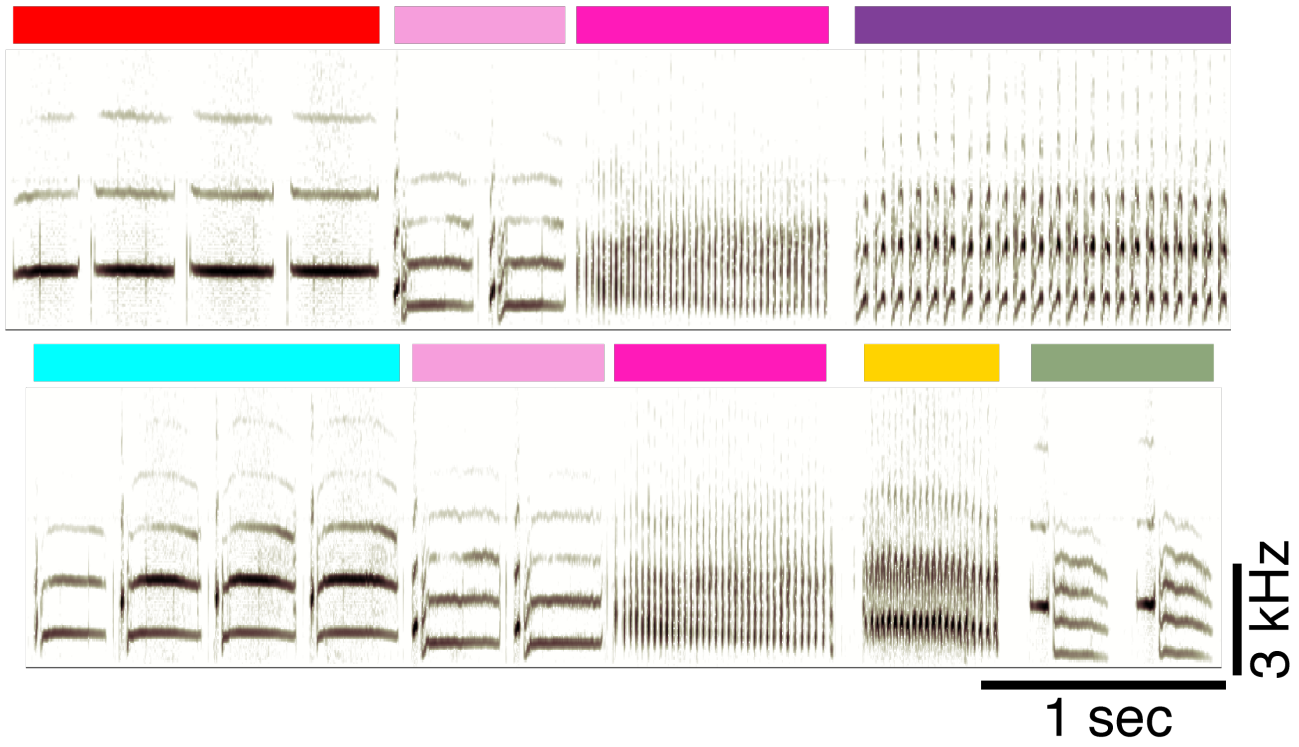
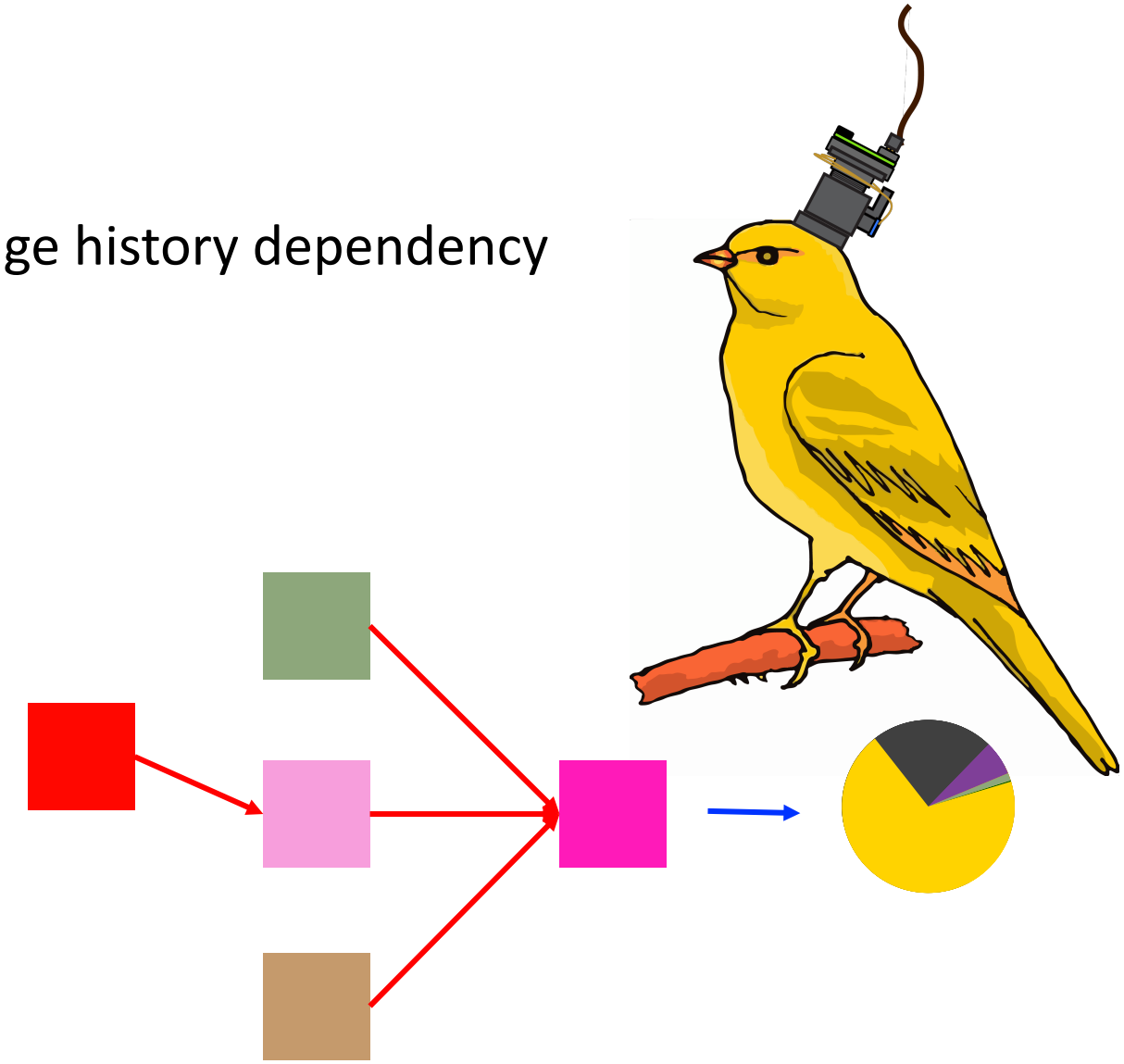
Syntax rules : transitions with long range history dependency

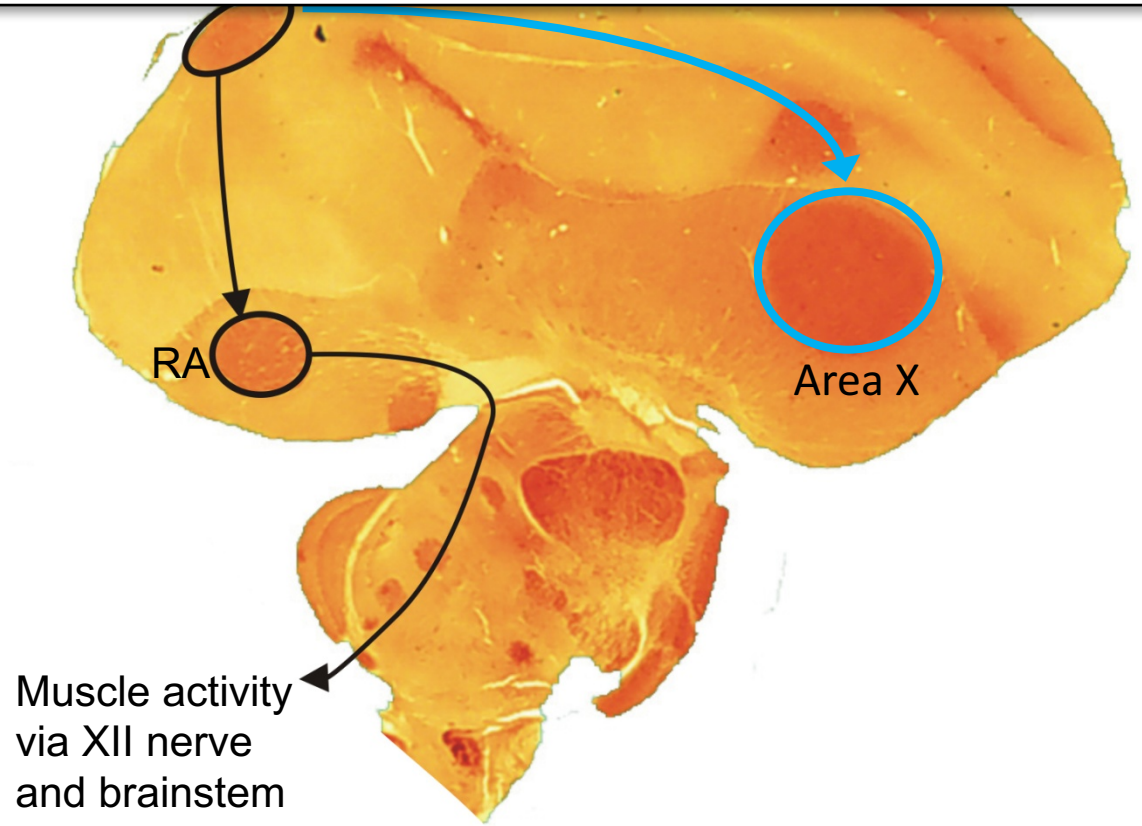




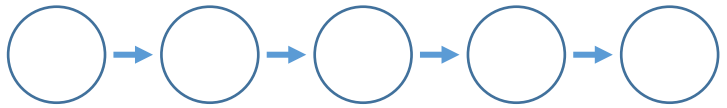
(Cohen,Gardner, in review.)

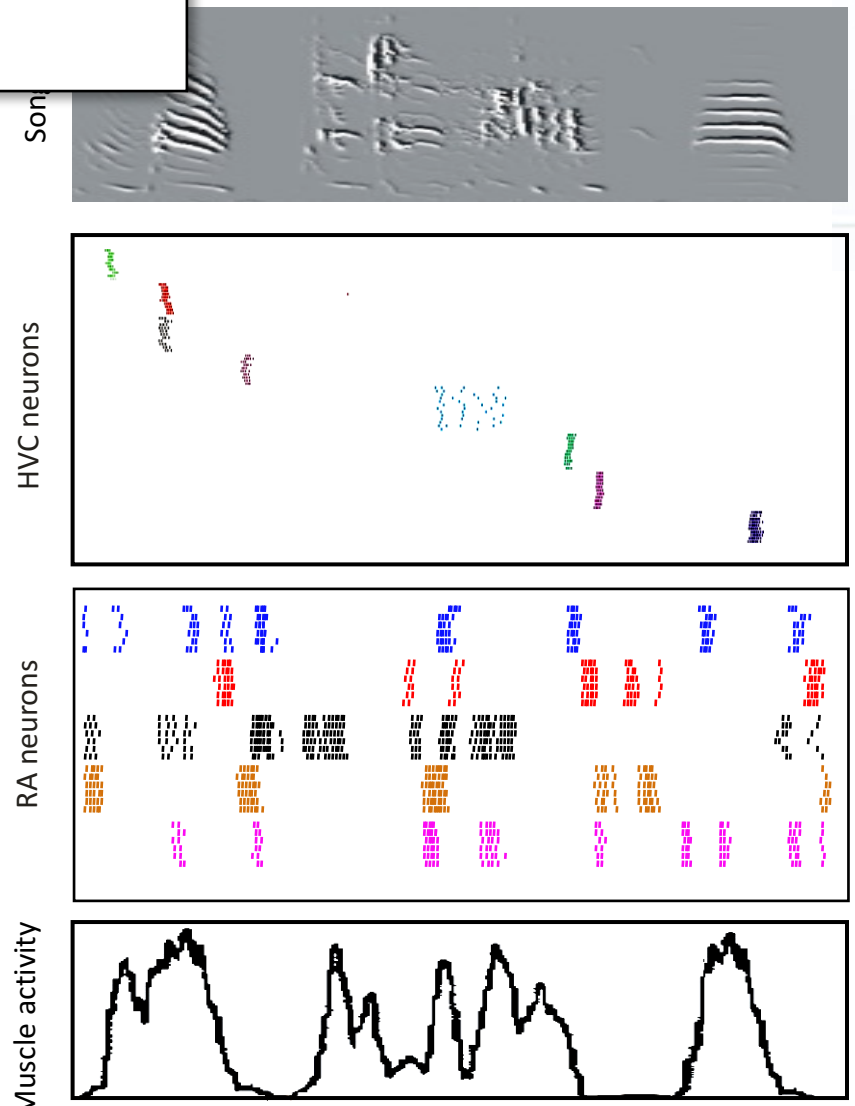
Songbirds: Identified nuclei and constrained neural variability

Neural recording from functionally identified sources
(from multiple neurons simultaneously)



Hypothesis: Chain of ‘neural attractors’

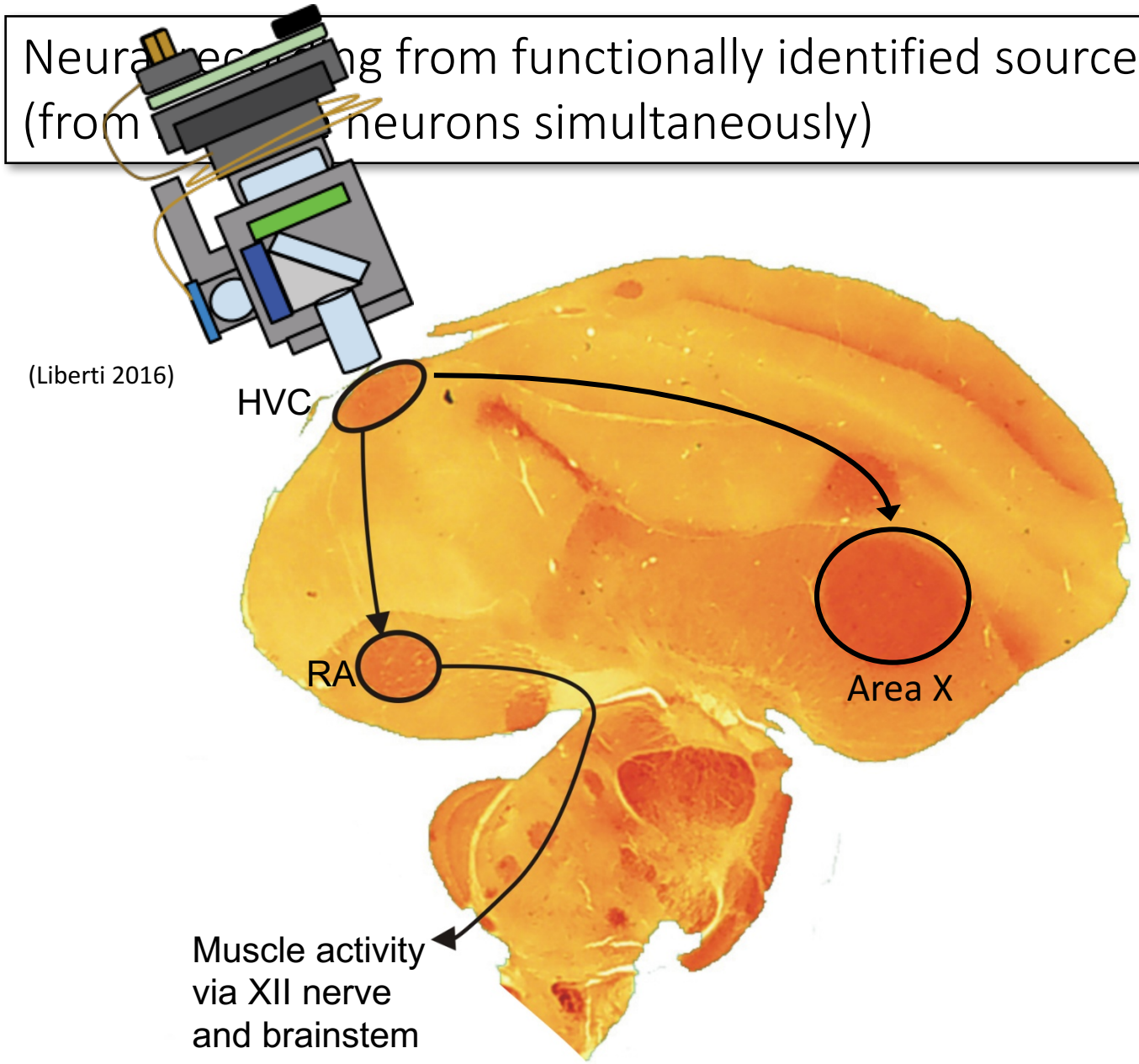




(Hahnloser et al 2002, Leonardo and Fee 2005)
(Kozhevnikov and Fee 2007)
(Fujimoto, Hasegawa, Watanabe 2011)

Songbirds: Identified nuclei and constrained neural variability

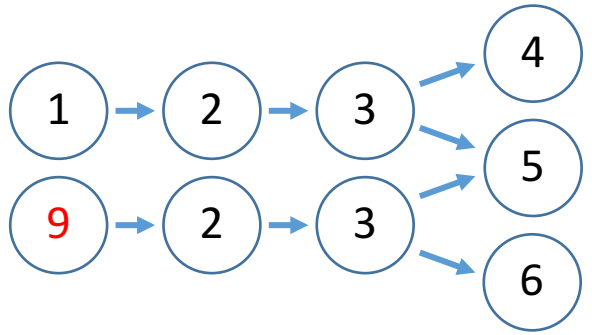
Neural recording from functionally identified sources
(from [illegible] neurons simultaneously)



HVC:

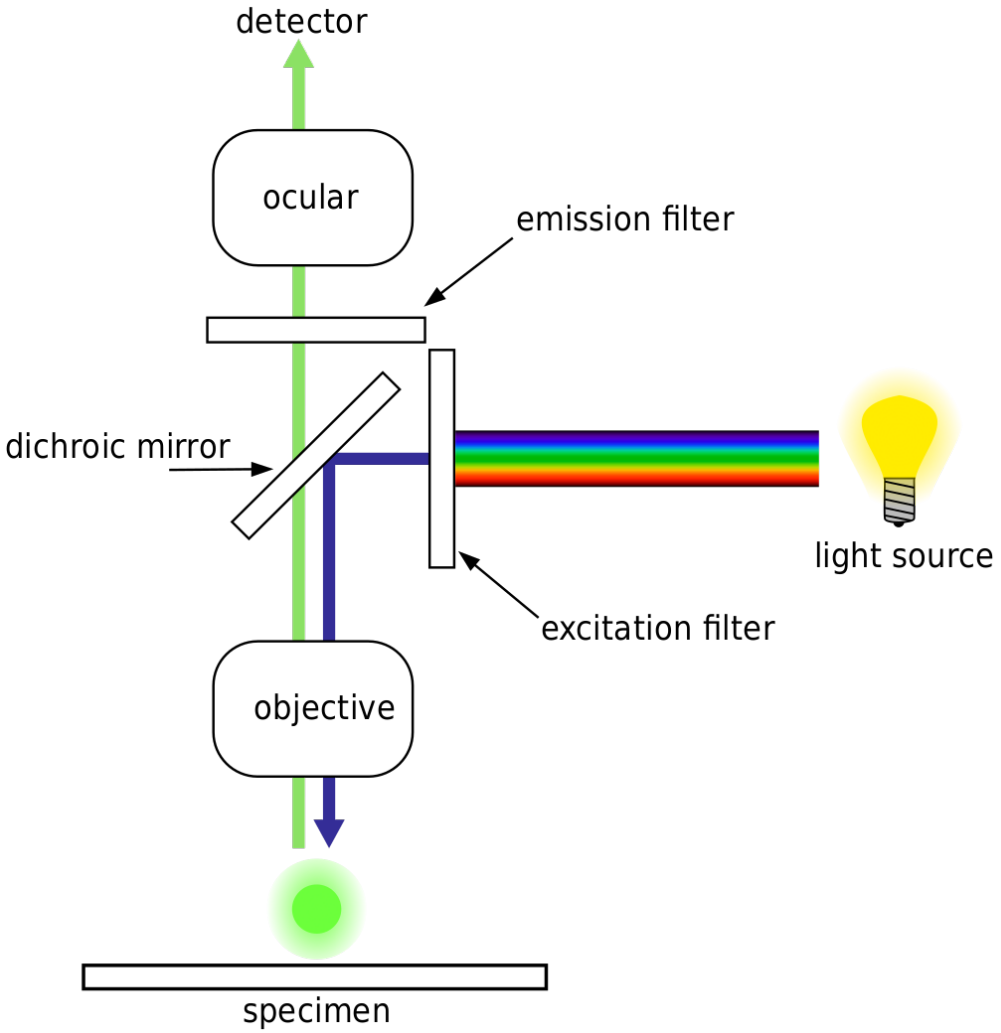
- Involves in sequencing
- PNs active in sparse bursts
- Locked to song
- Reflect current and recent syllables

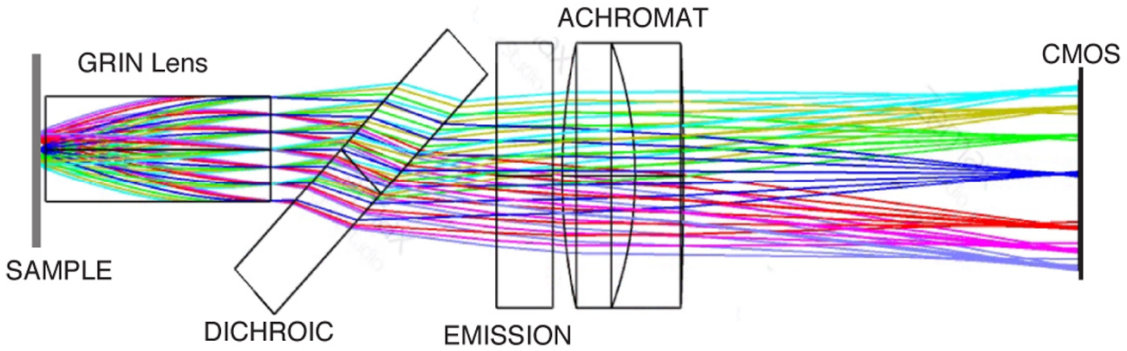
Hypothesis: Chain of 'neural attractors'

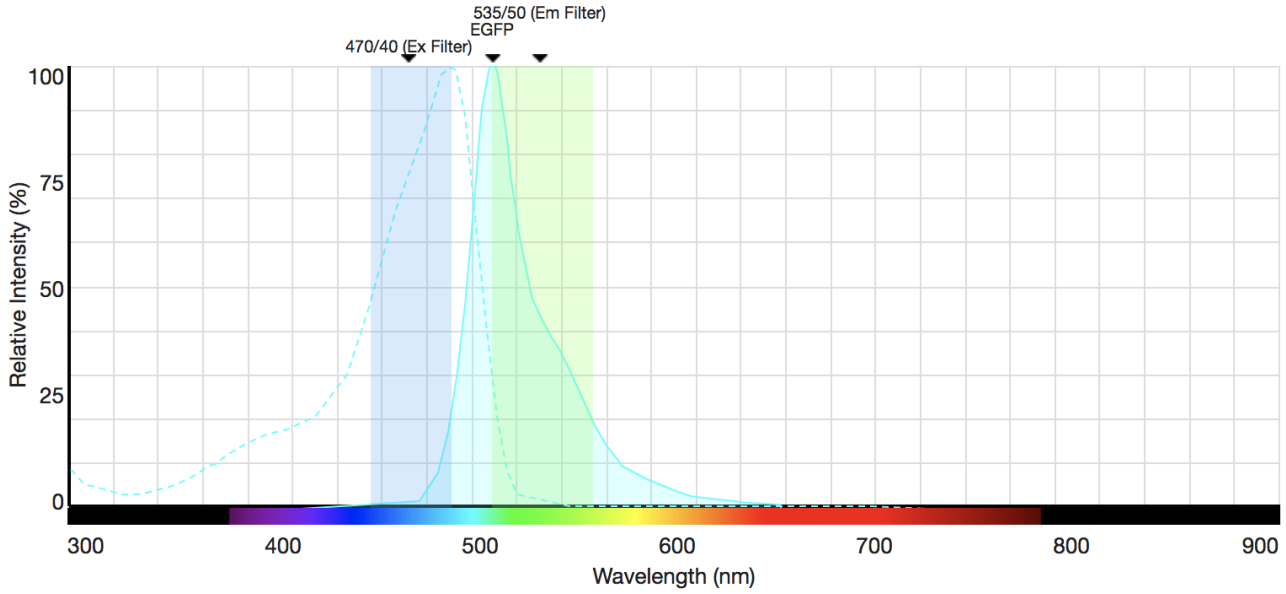


(Jin and Kozhevnikov, 2011)
(Hahnloser et al 2002, Leonardo and Fee 2005)
(Kozhevnikov and Fee 2007)
(Fujimoto, Hasegawa, Watanabe 2011)

FreedomScope: 1p miniaturized fluorescence microscope

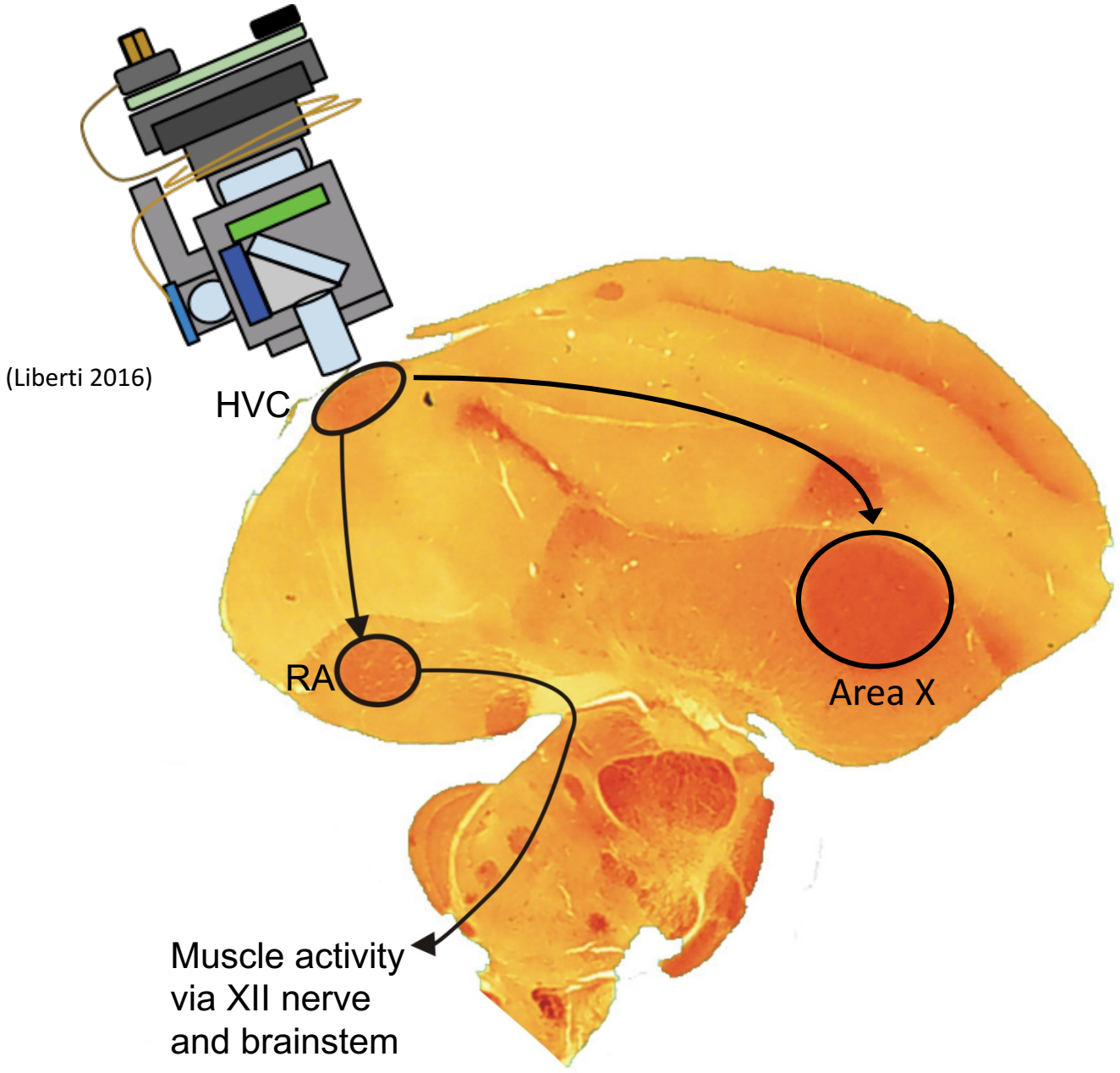


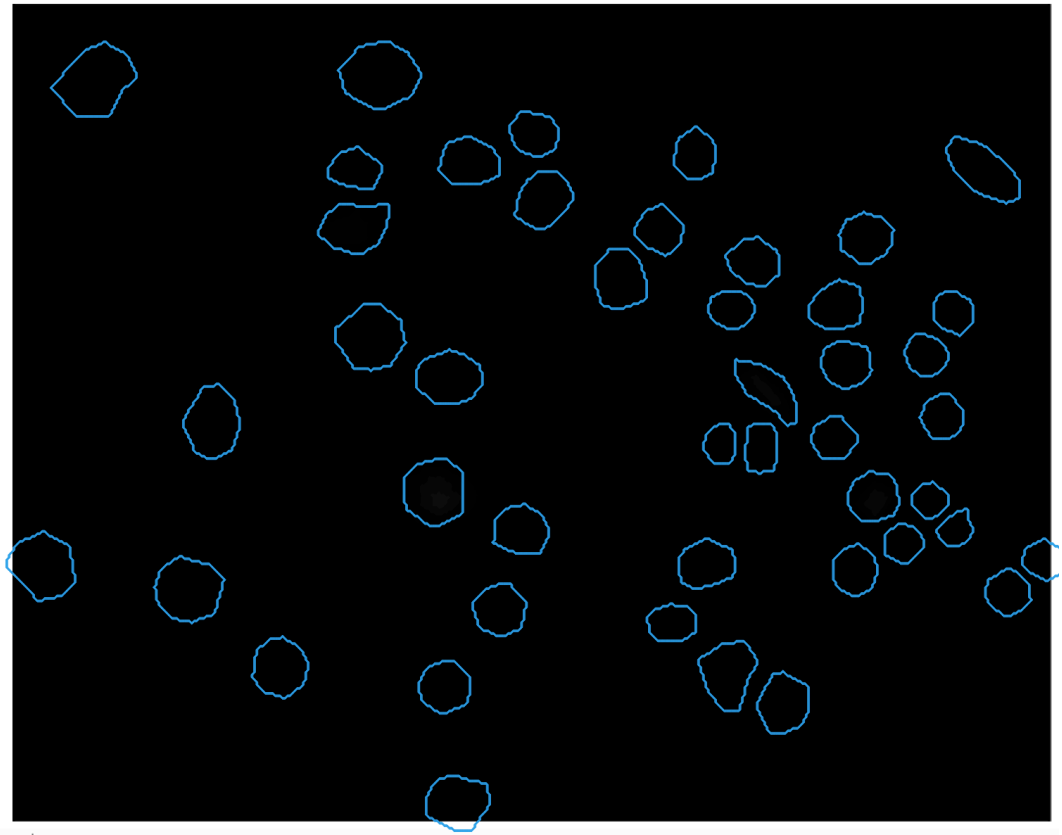


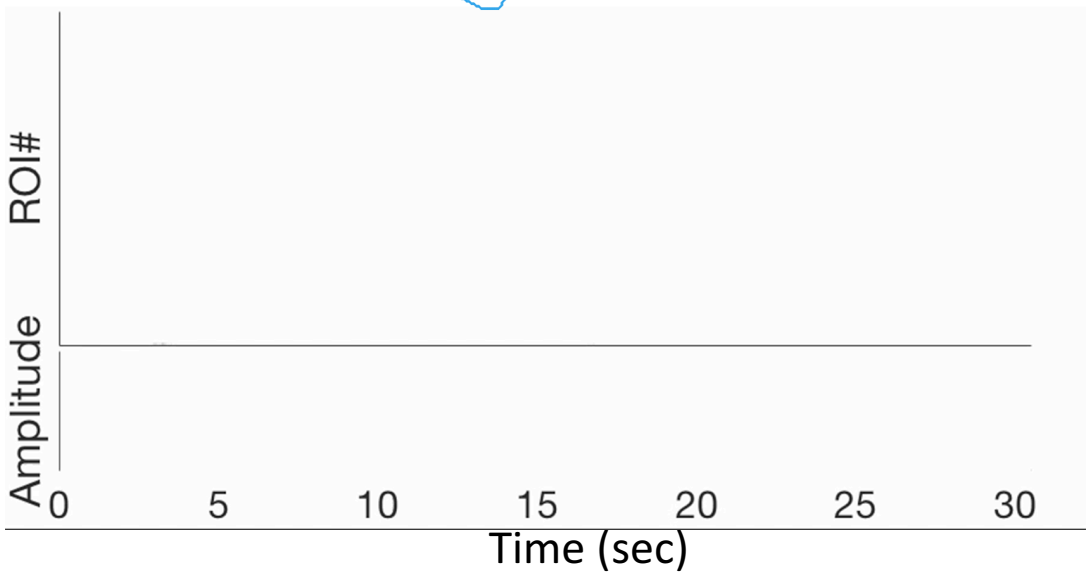


(Liberti 2018)

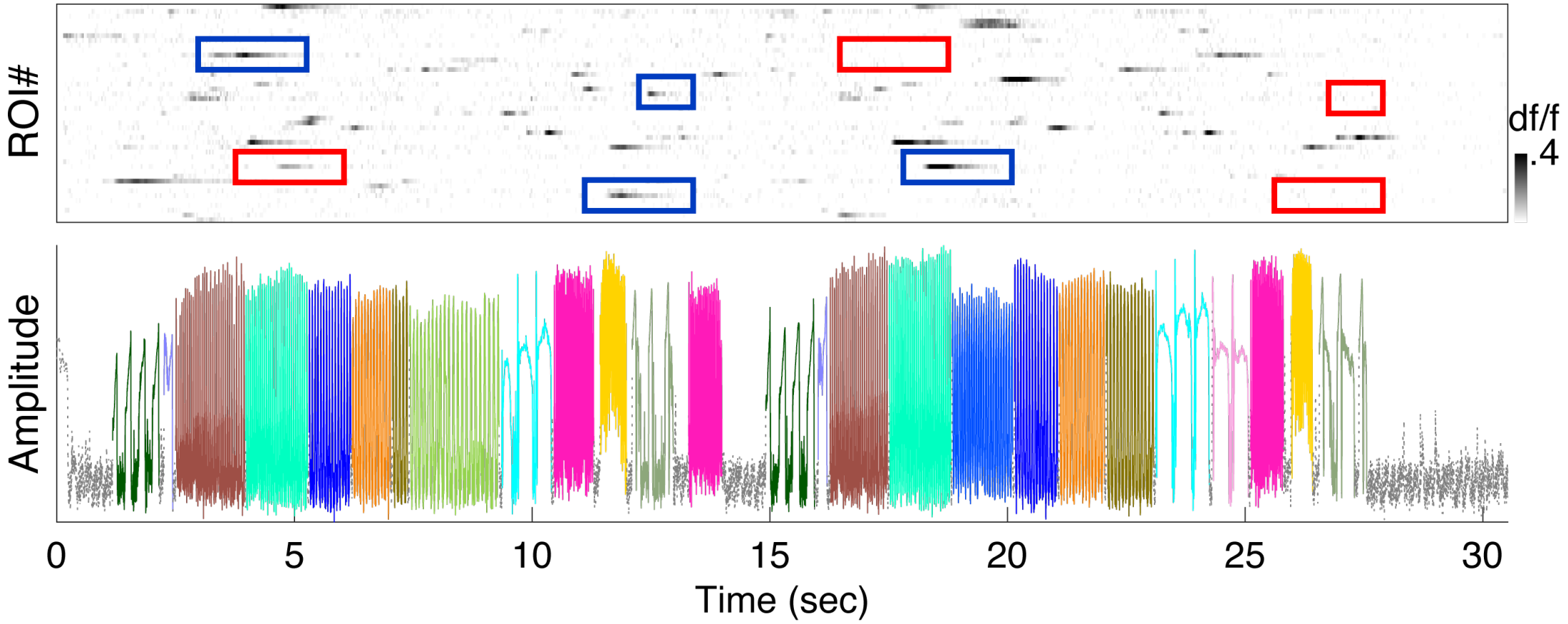
FreedomScope: Stability and Scaling



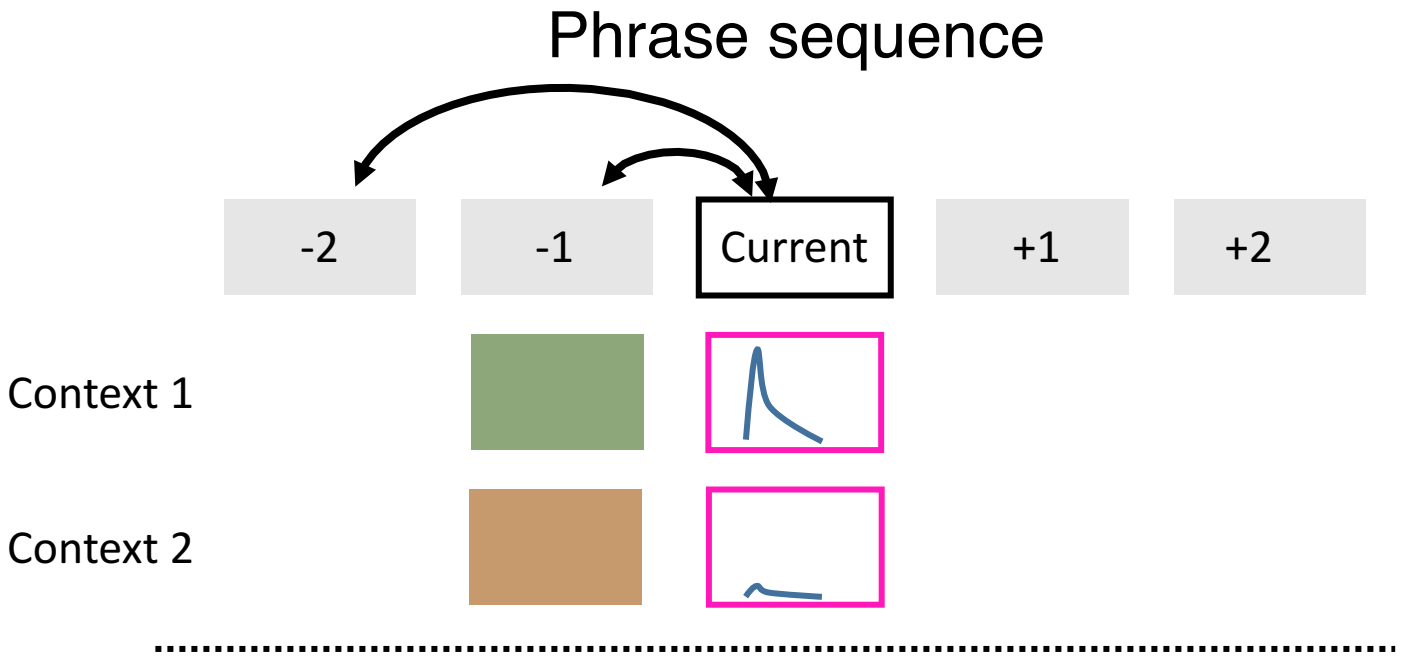


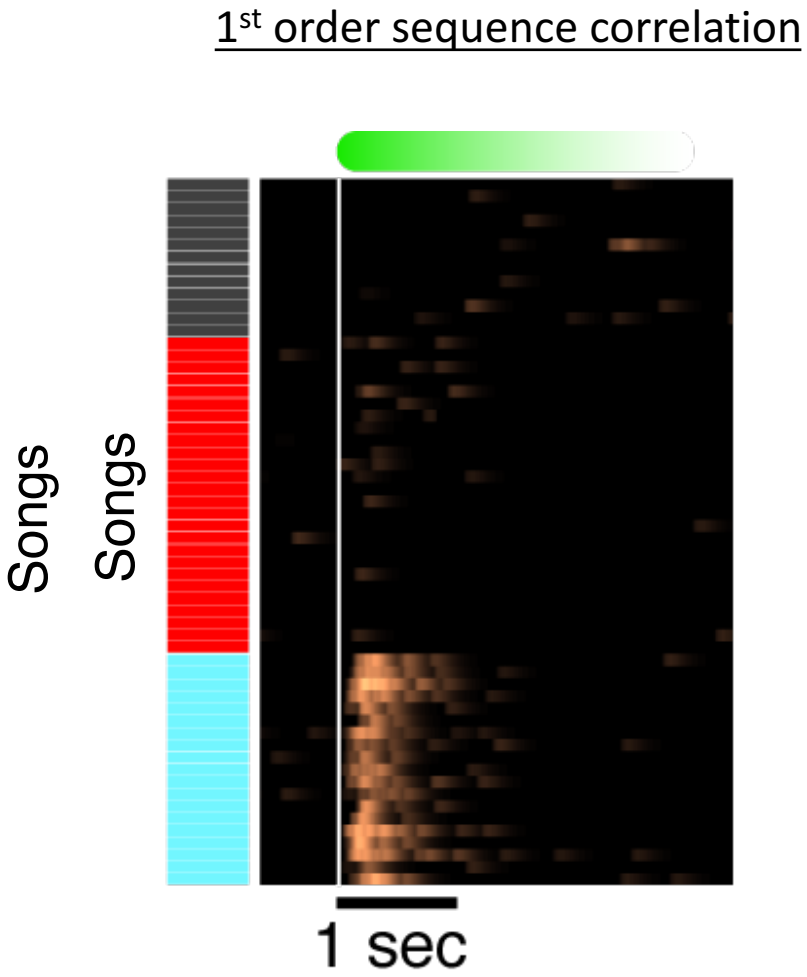


Some Ca^{2+} signals are context-dependent

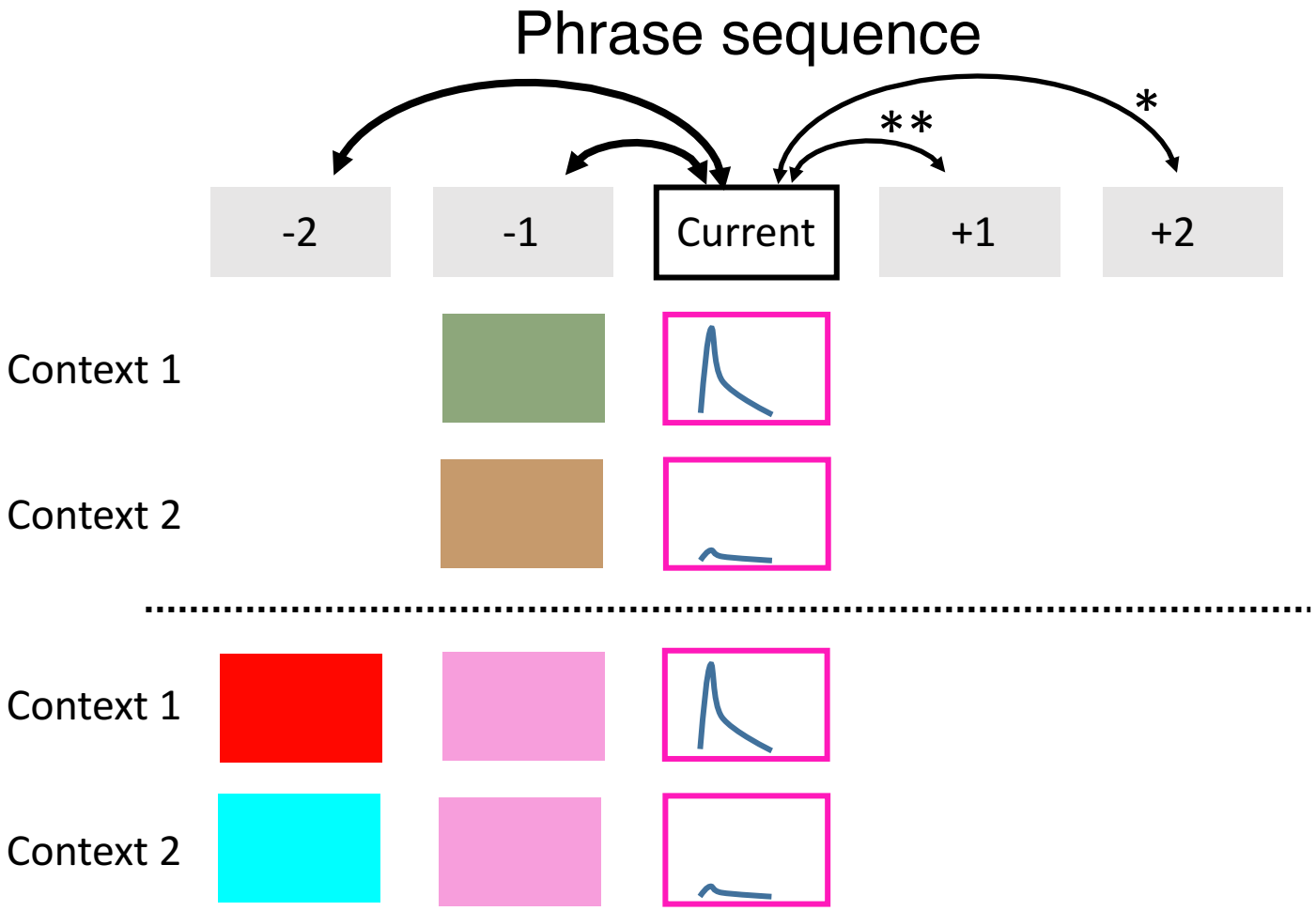


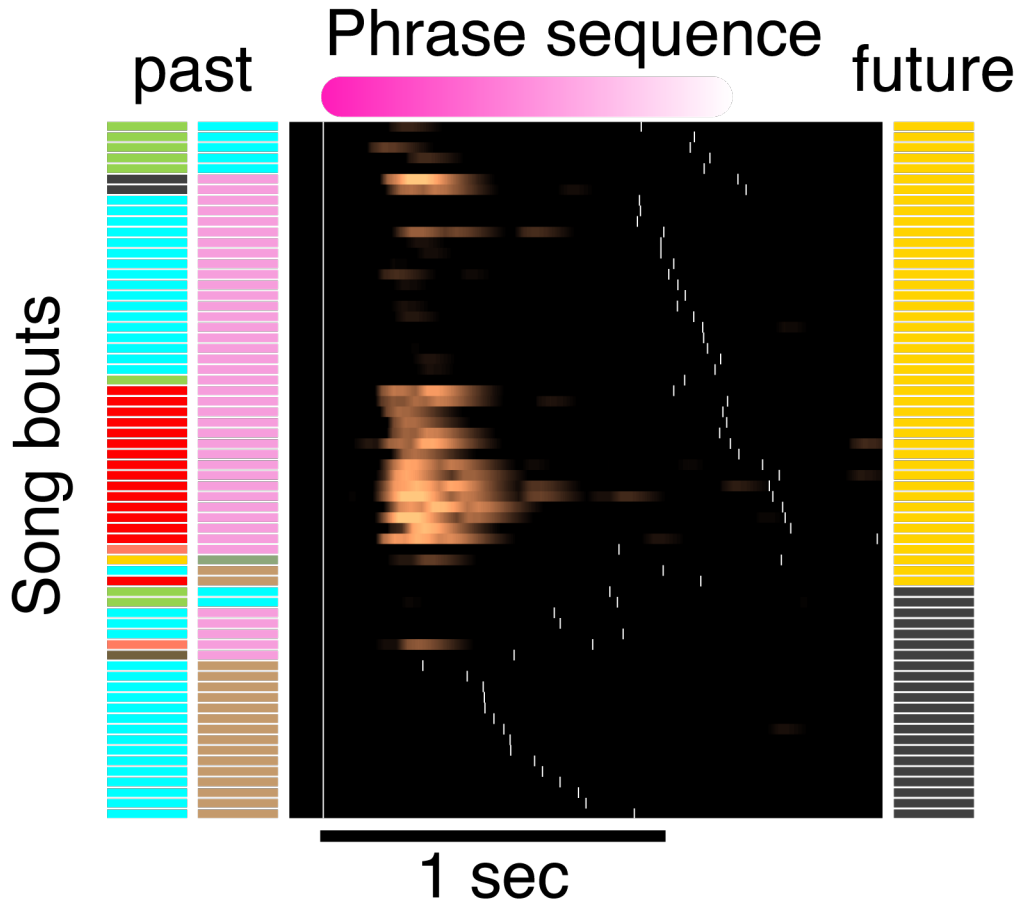
HVC neurons reflect long-range sequence information





HVC neurons reflect long-range sequence information

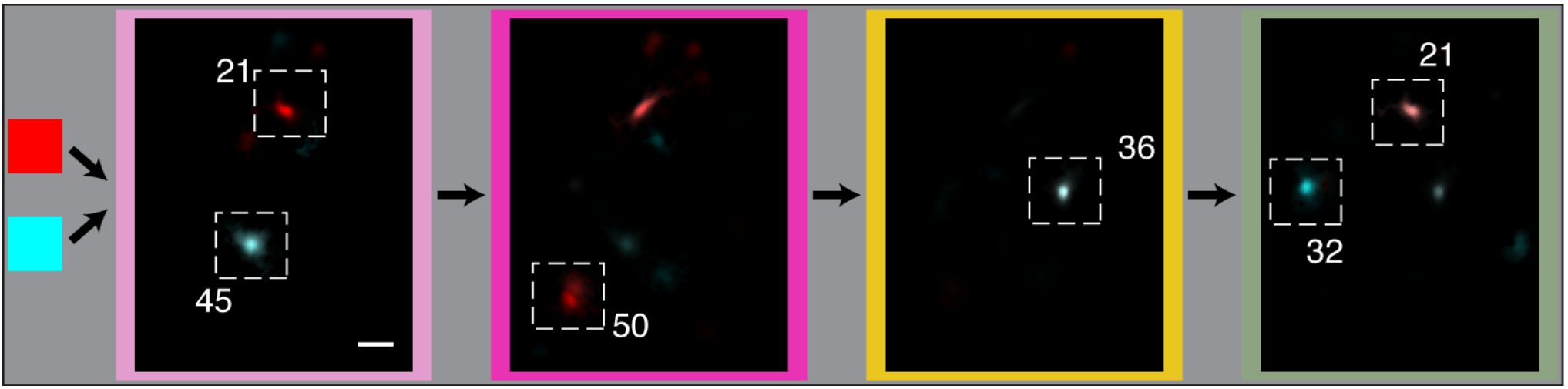


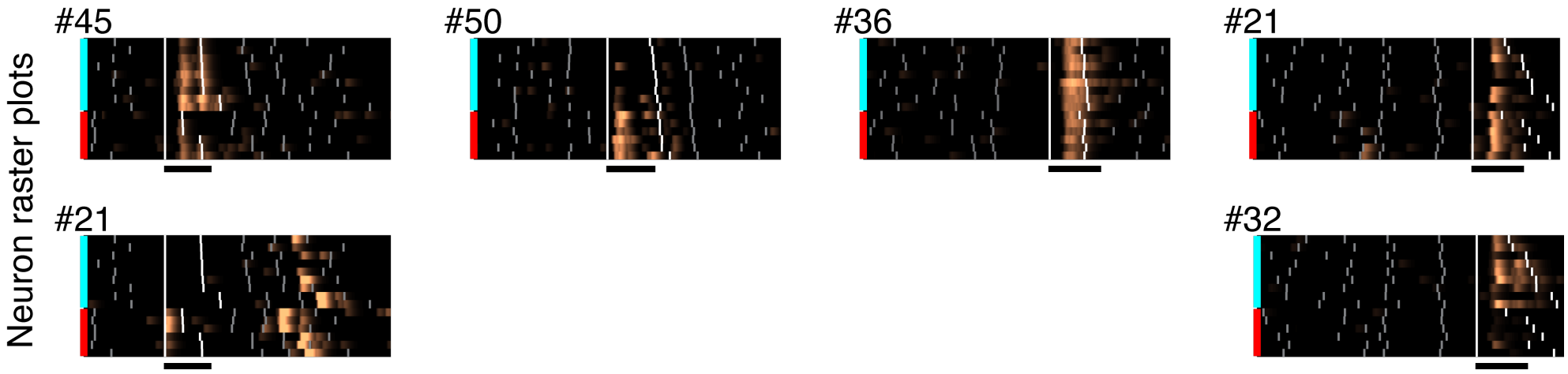


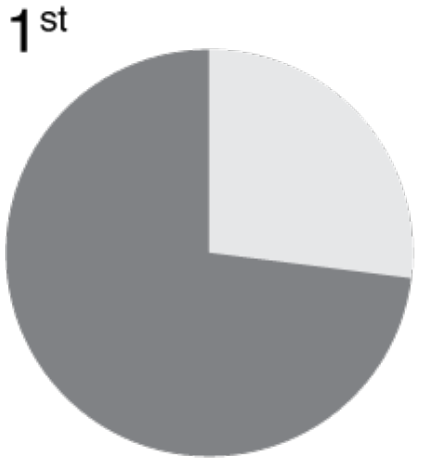
** : $p<10^{-6}$

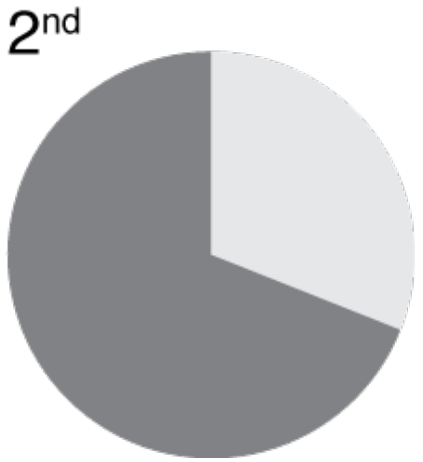
* : $p< 0.0125$

HVC neurons report long-range historic information in a repeating sequence of phrases

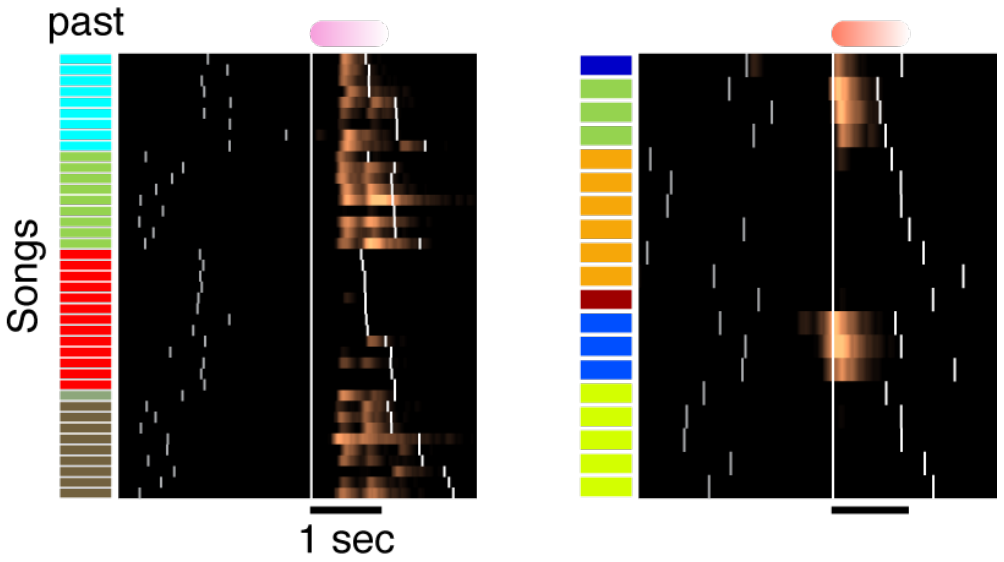


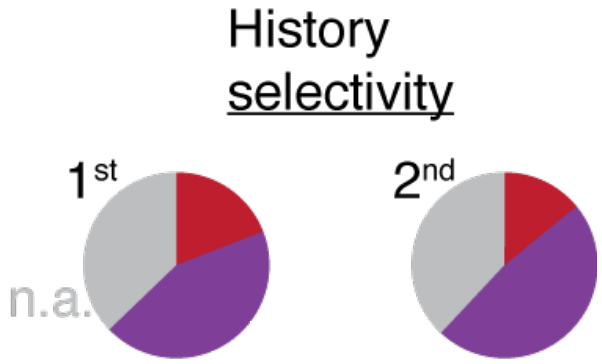






Sequence-correlated neurons vary in the number of preferred song histories

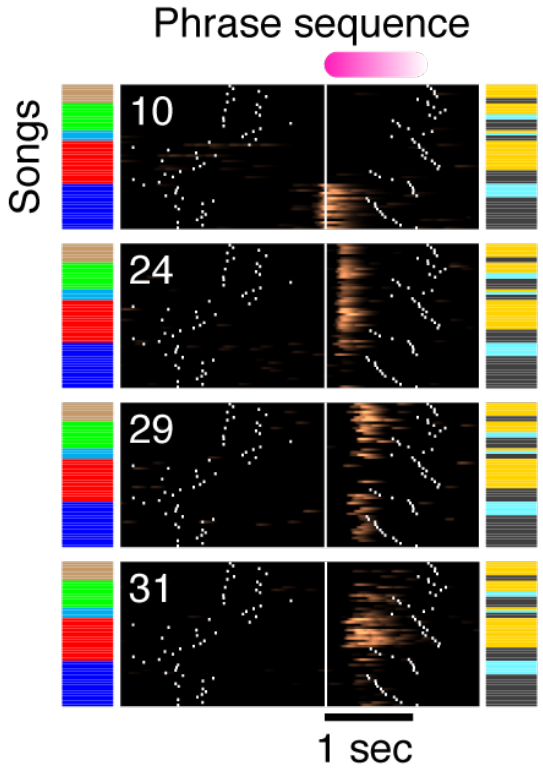


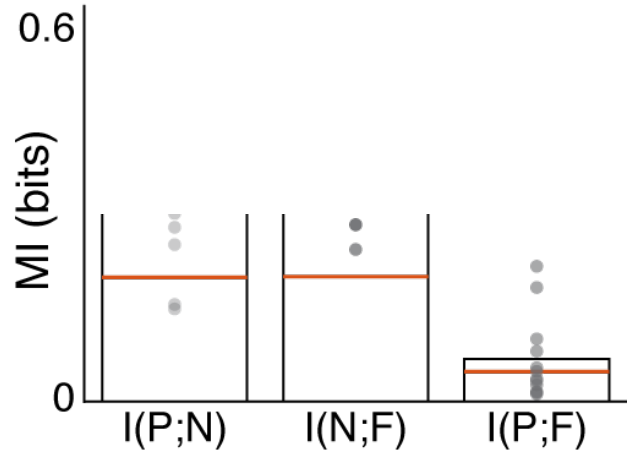


Cells selective to: 1 context

≥ 2 contexts

Jointly-recorded cells predict behavior prior to a complex transition



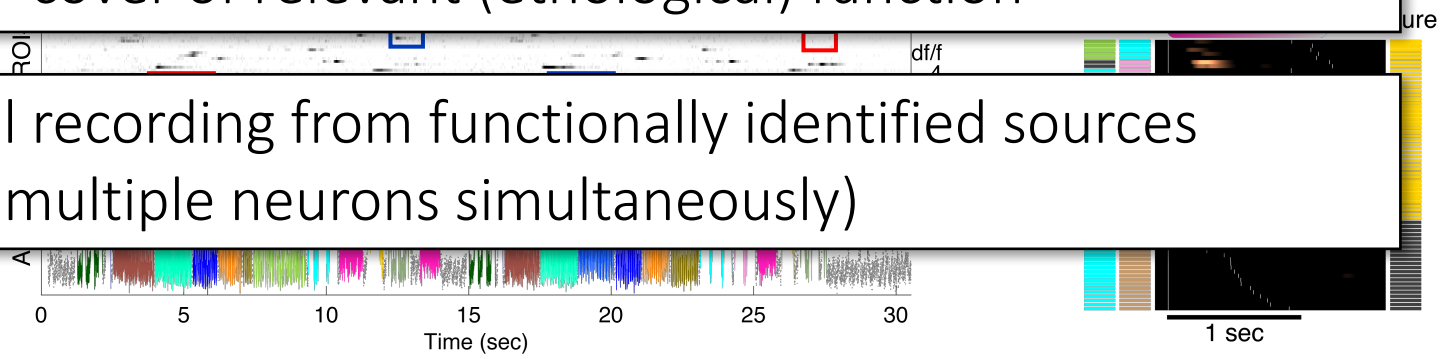


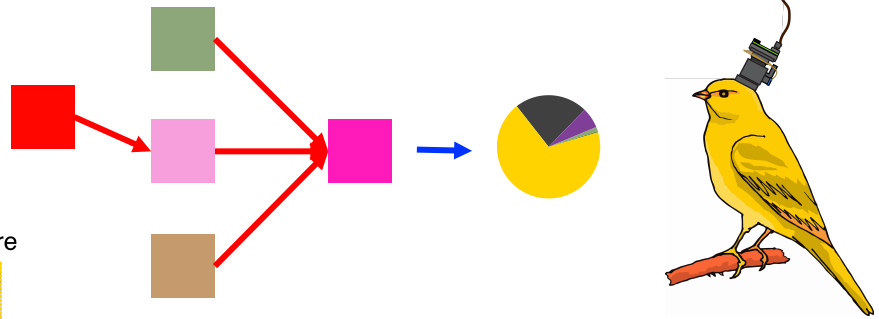
P = past, F = future, N = network

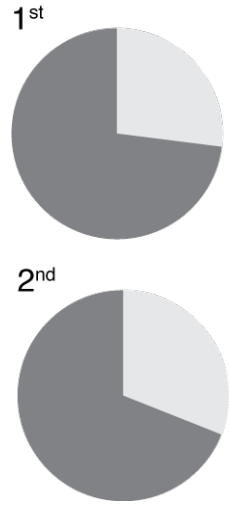
Canary song has complex transitions.

Model system with small and well-characterized variability
'Good' cover of relevant (ethological) function

Neural recording from functionally identified sources
(from multiple neurons simultaneously)

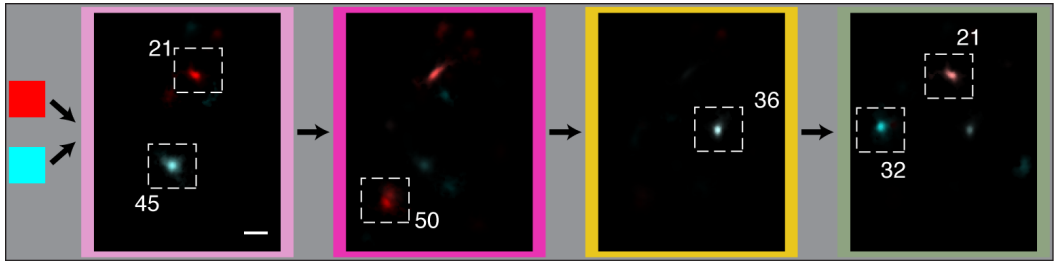




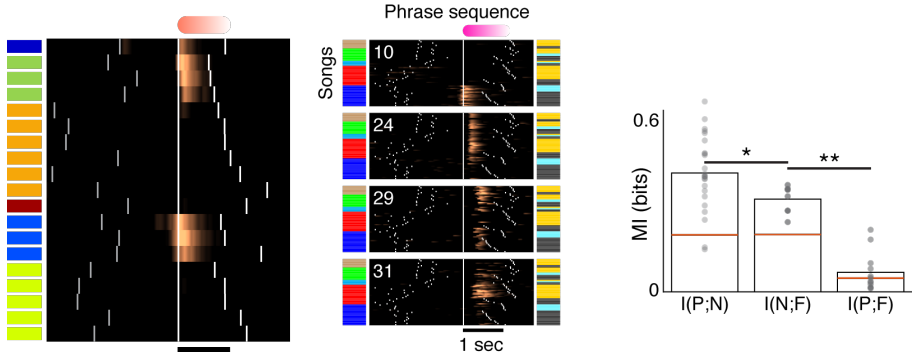


PNs reflect phrases that happened 4 steps back

Sequence correlates aggregate around complex transitions,



indicate multiple histories, and predict complex transitions



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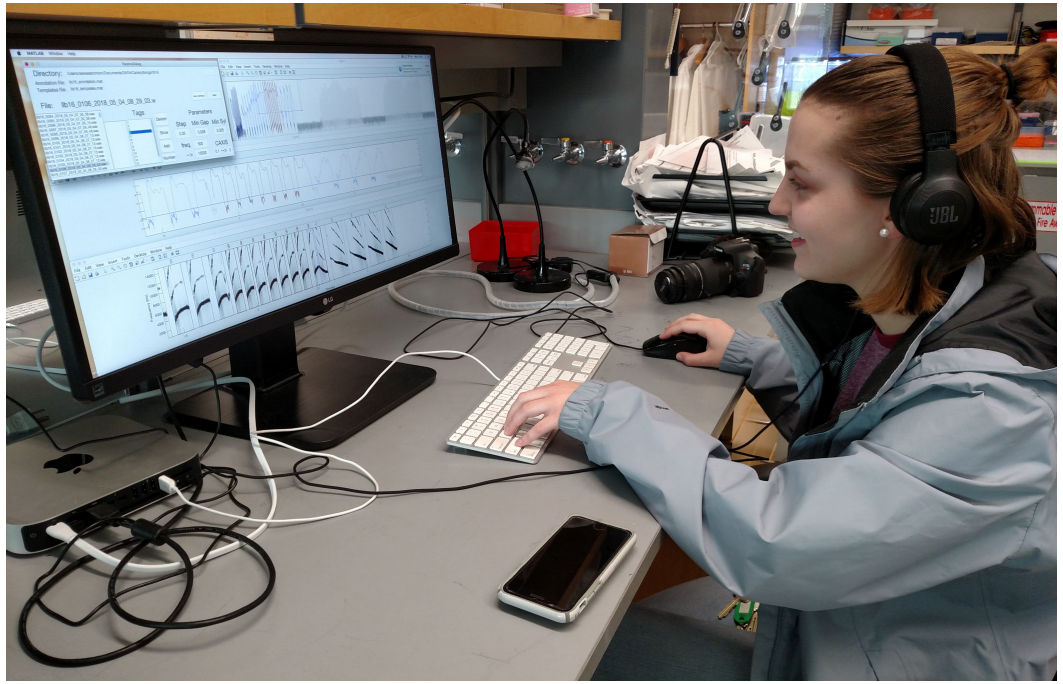
Darrell Kotton

Derek Liberti

Sober lab (Emory):

David Nicholson



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