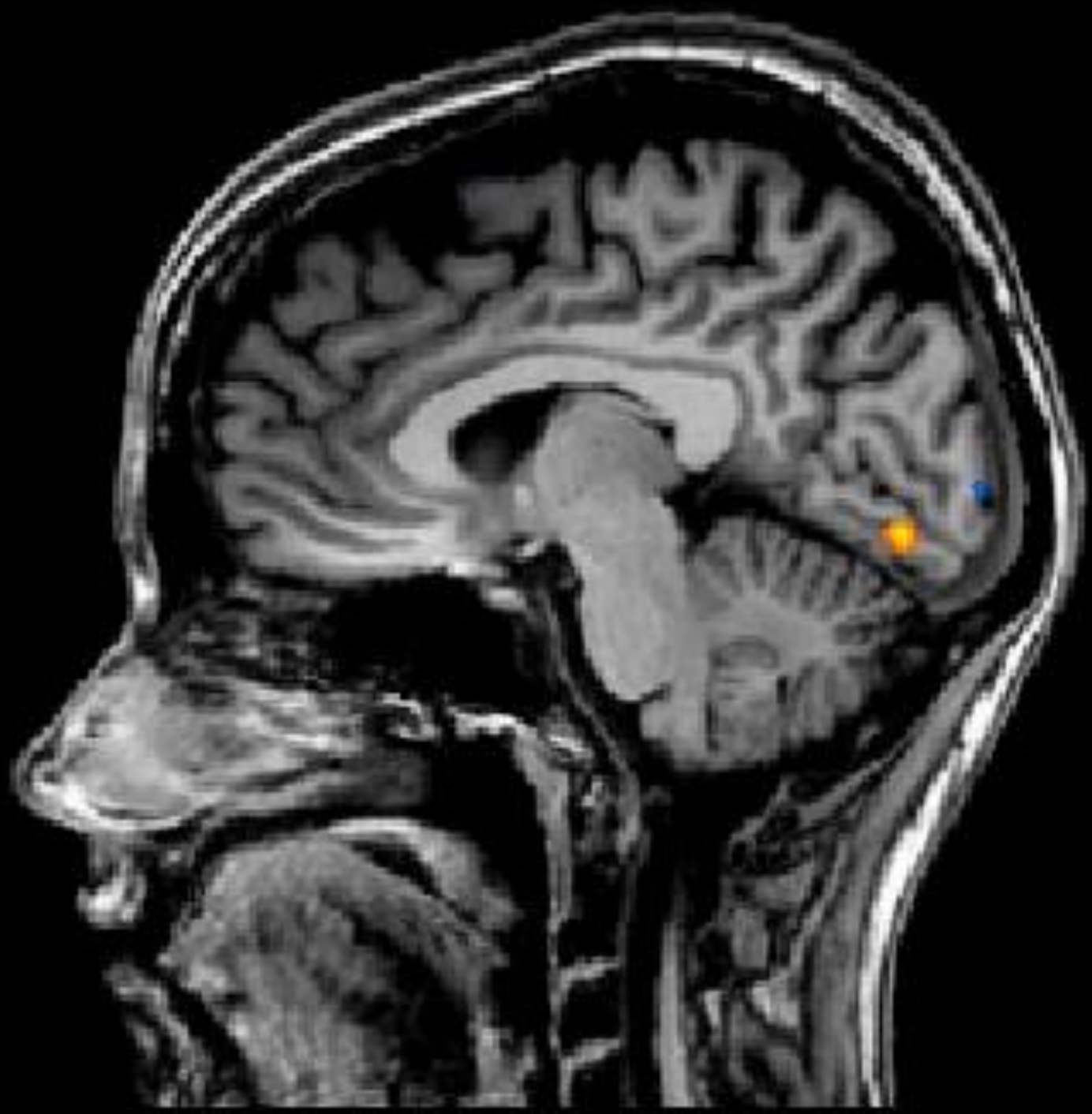
Computational neuroscience



What is the neural code?

-- techniques for recording from the brain

-- tools for discovering how the brain represents information

-- models that express our understanding of this representation

-- some methods for inferring what the brain is doing based on its activity *(week 3)*

-- using information theory to quantify neural representations *(week 4)*

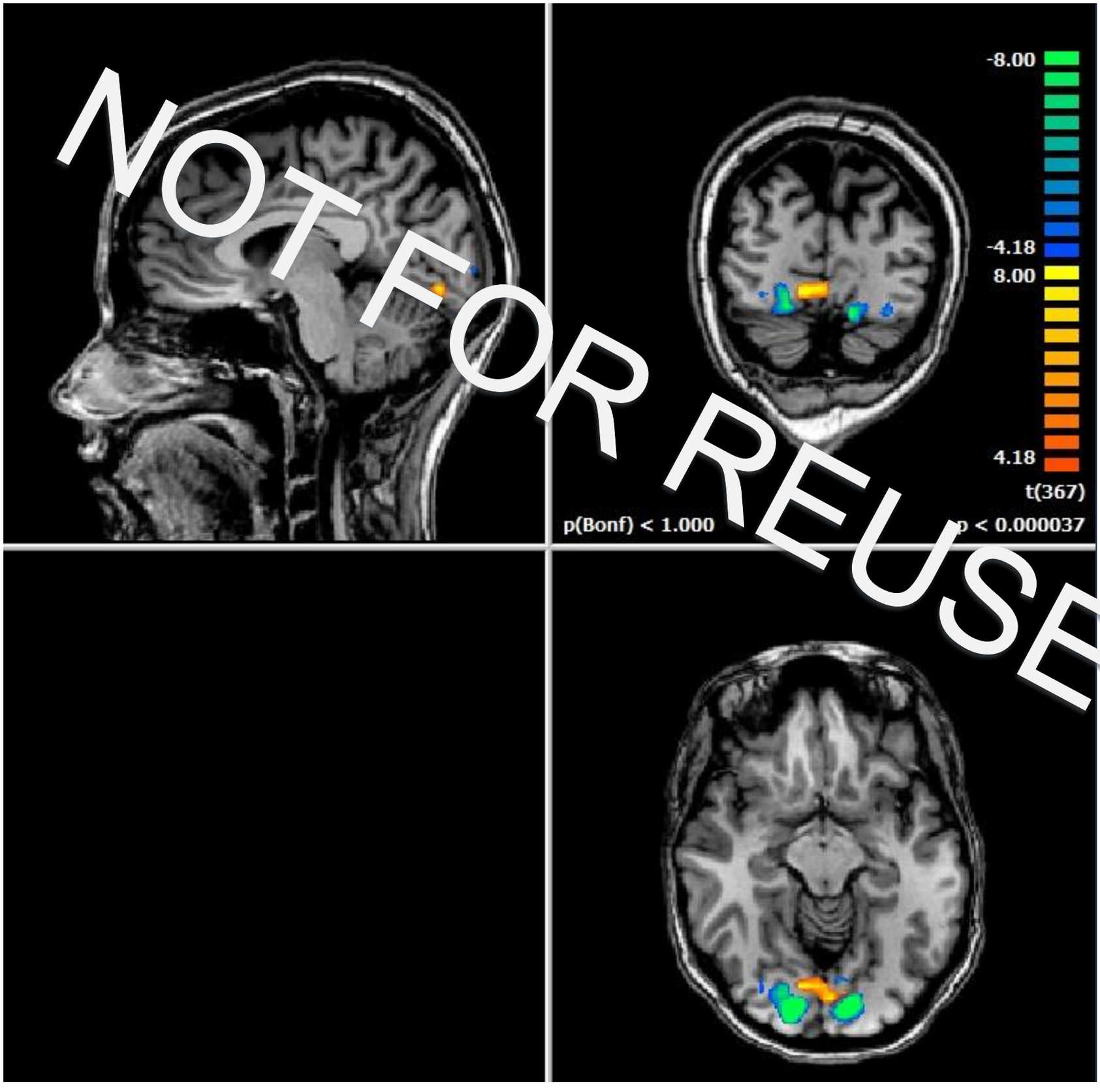
-- the biophysical basis of how the brain processes inputs and performs complex computations *(week 5)*

Recording from the brain

Recording from the brain: fMRI

Scott Murray

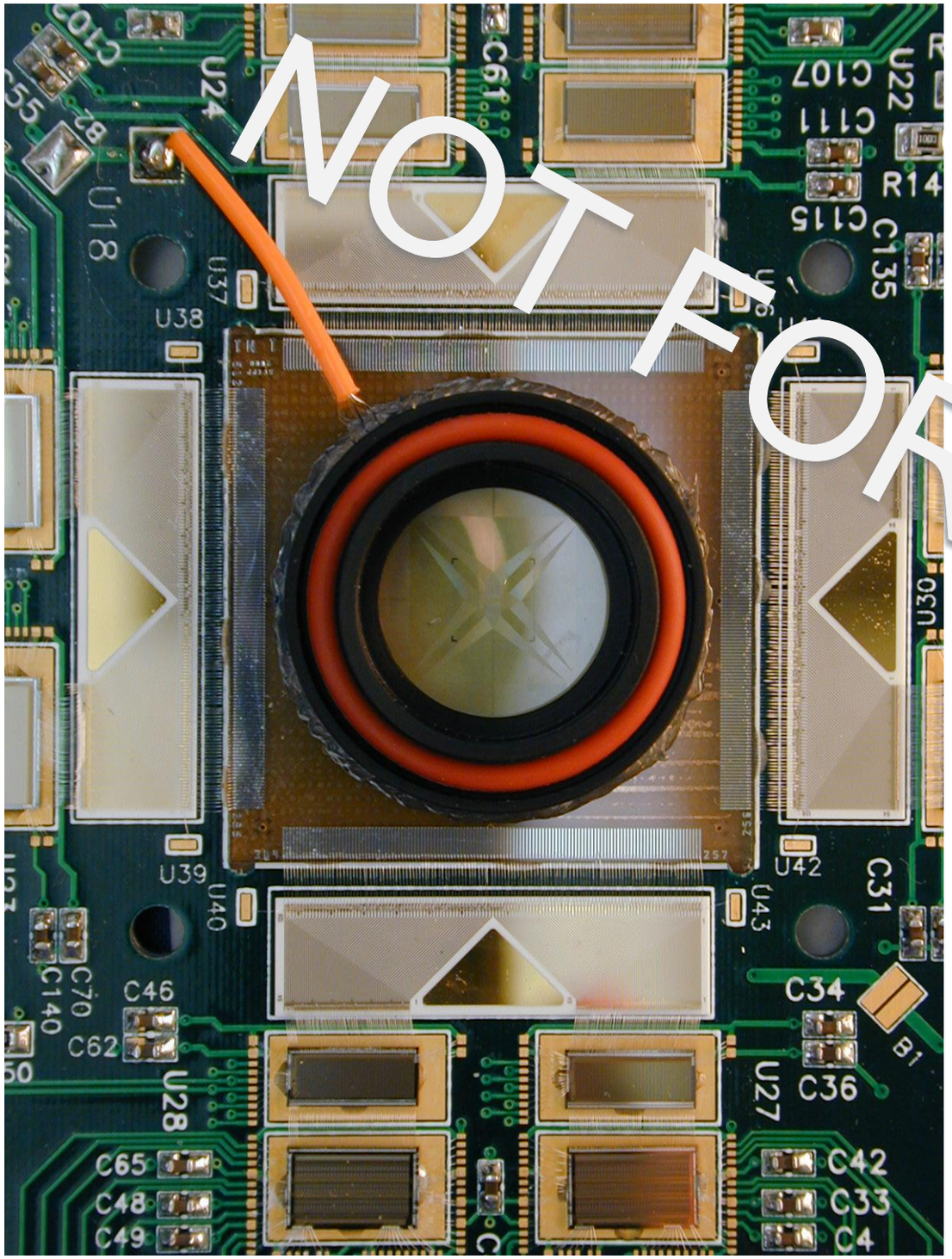
Recording from the brain: fMRI

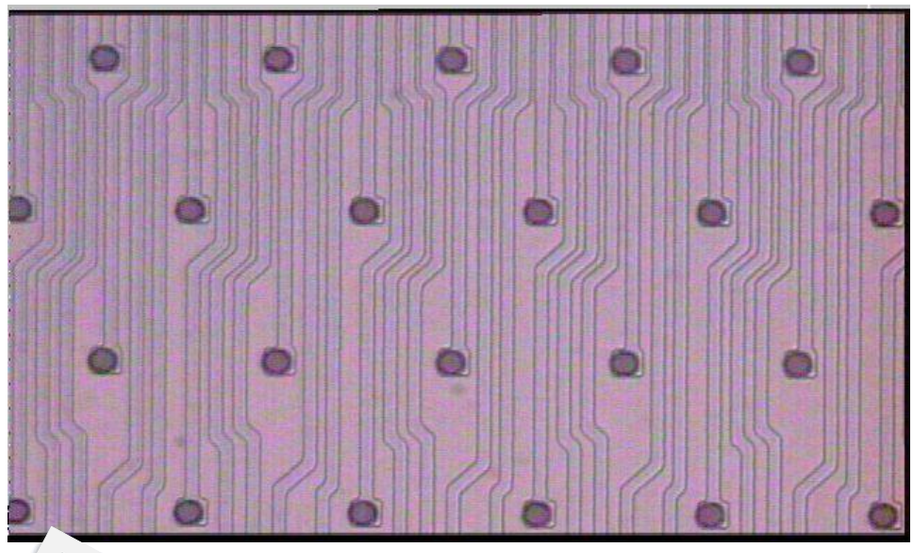


S. Murray

Recording from the brain: EEG

Reading out the neural code: electrode arrays

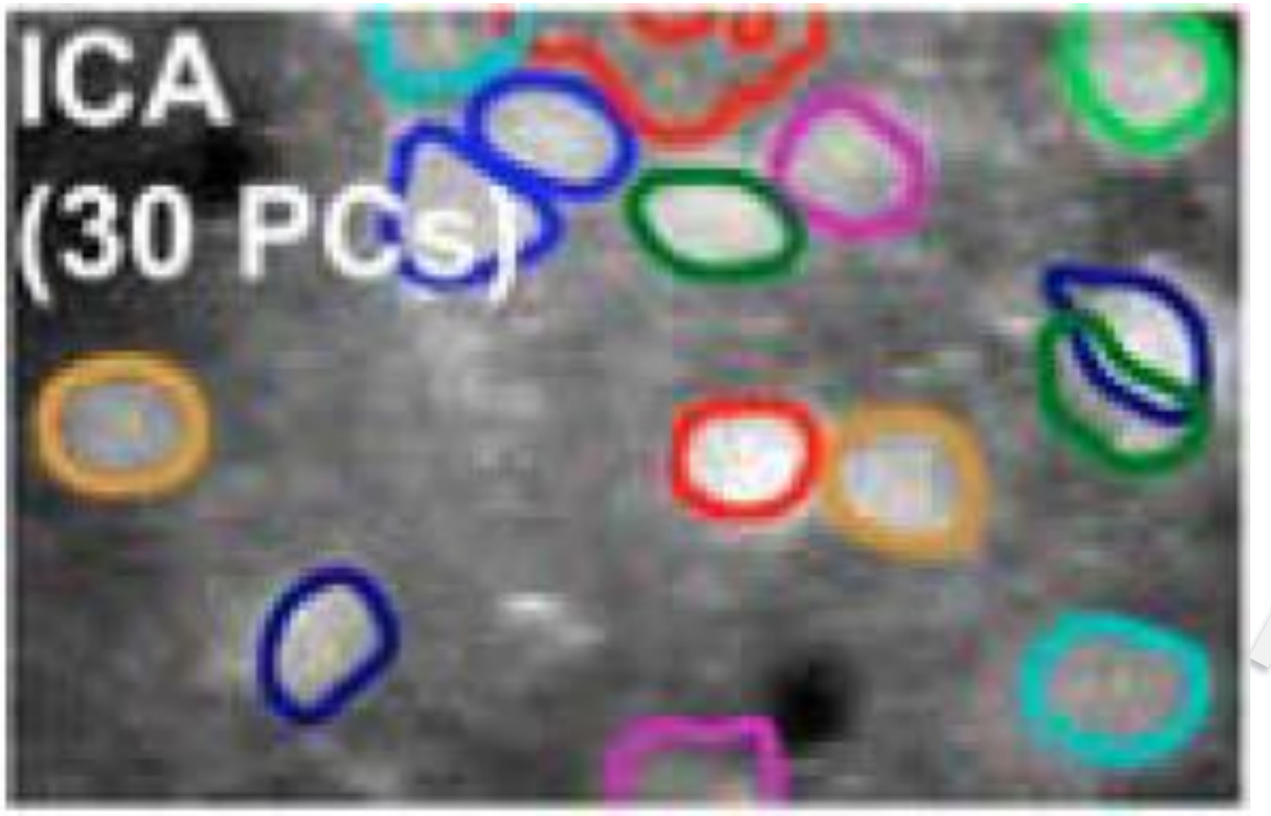


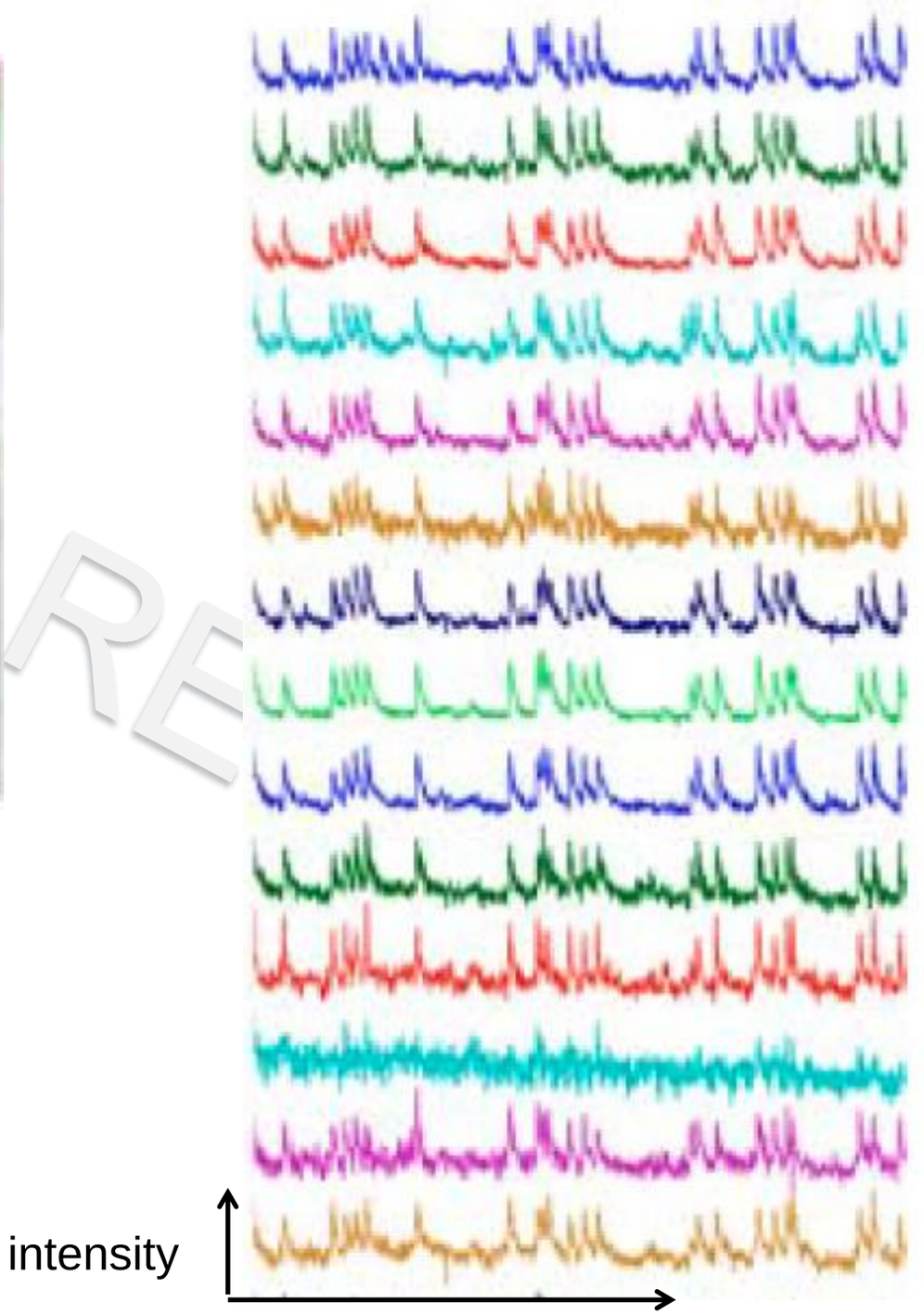


Alan Litke, UCSC

Reading out the neural code: electrode arrays

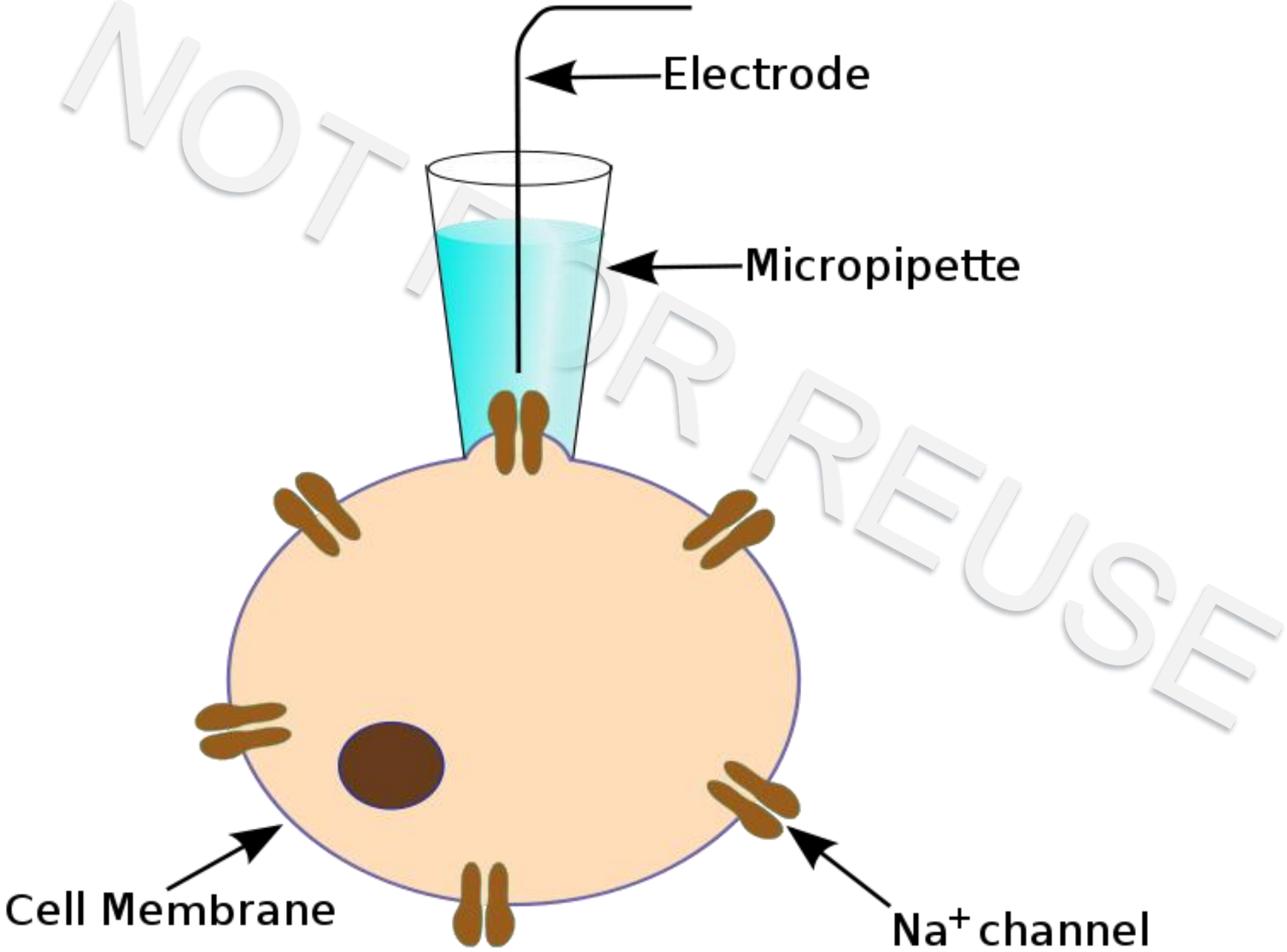
Reading out the neural code: calcium imaging





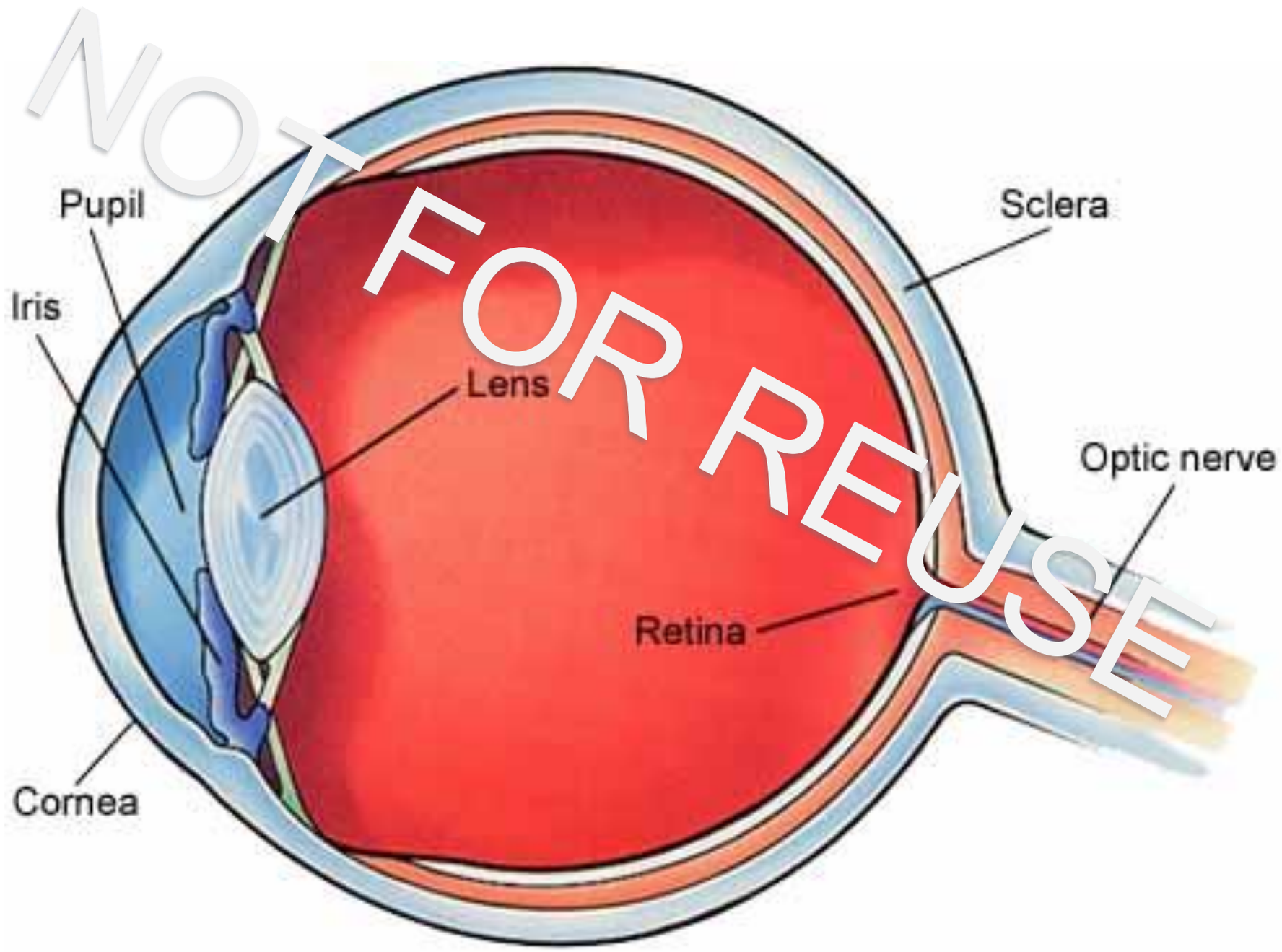
Alex Kwan

Looking inside single cells



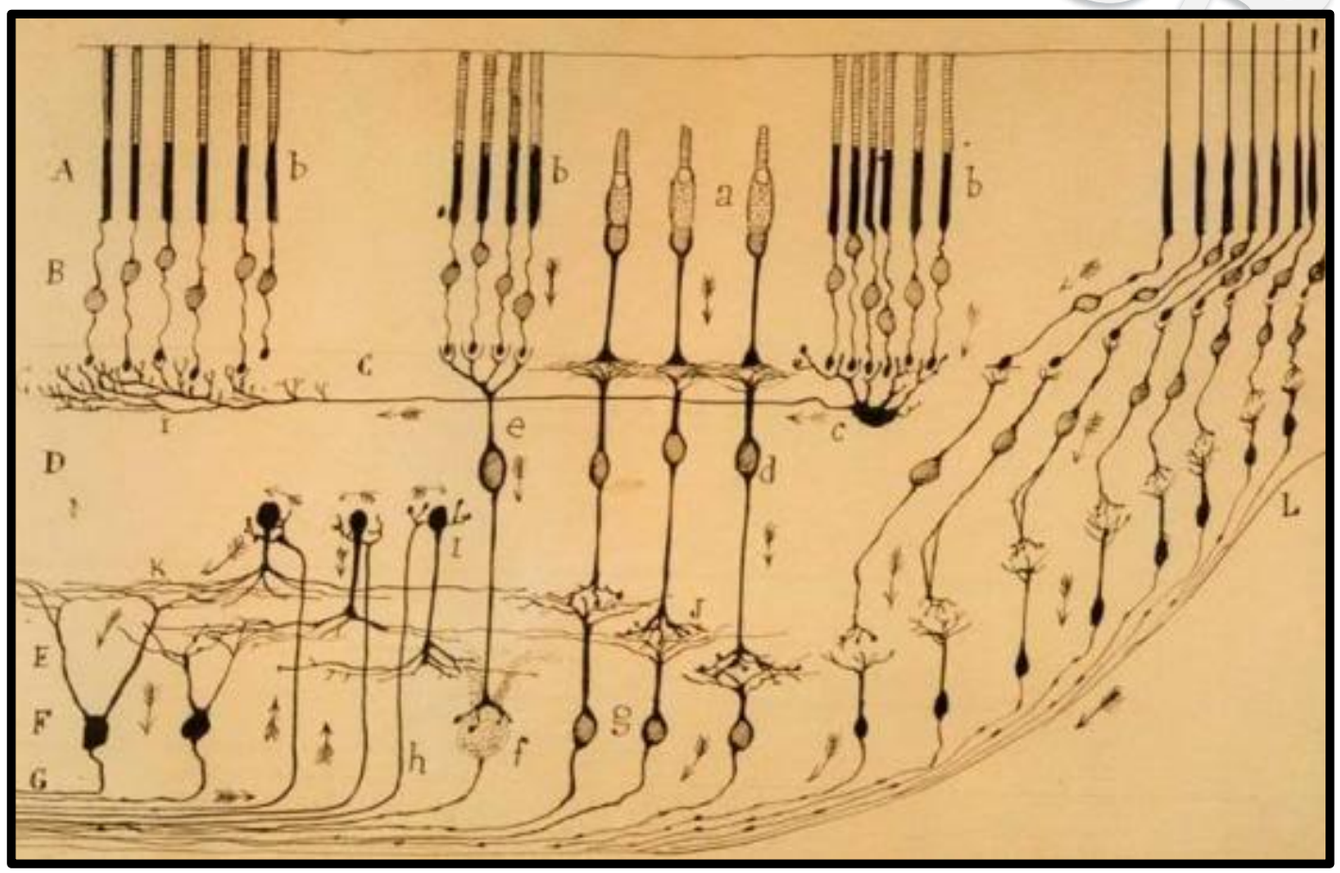
Theresa Knott, Creative Commons

What is the neural code?

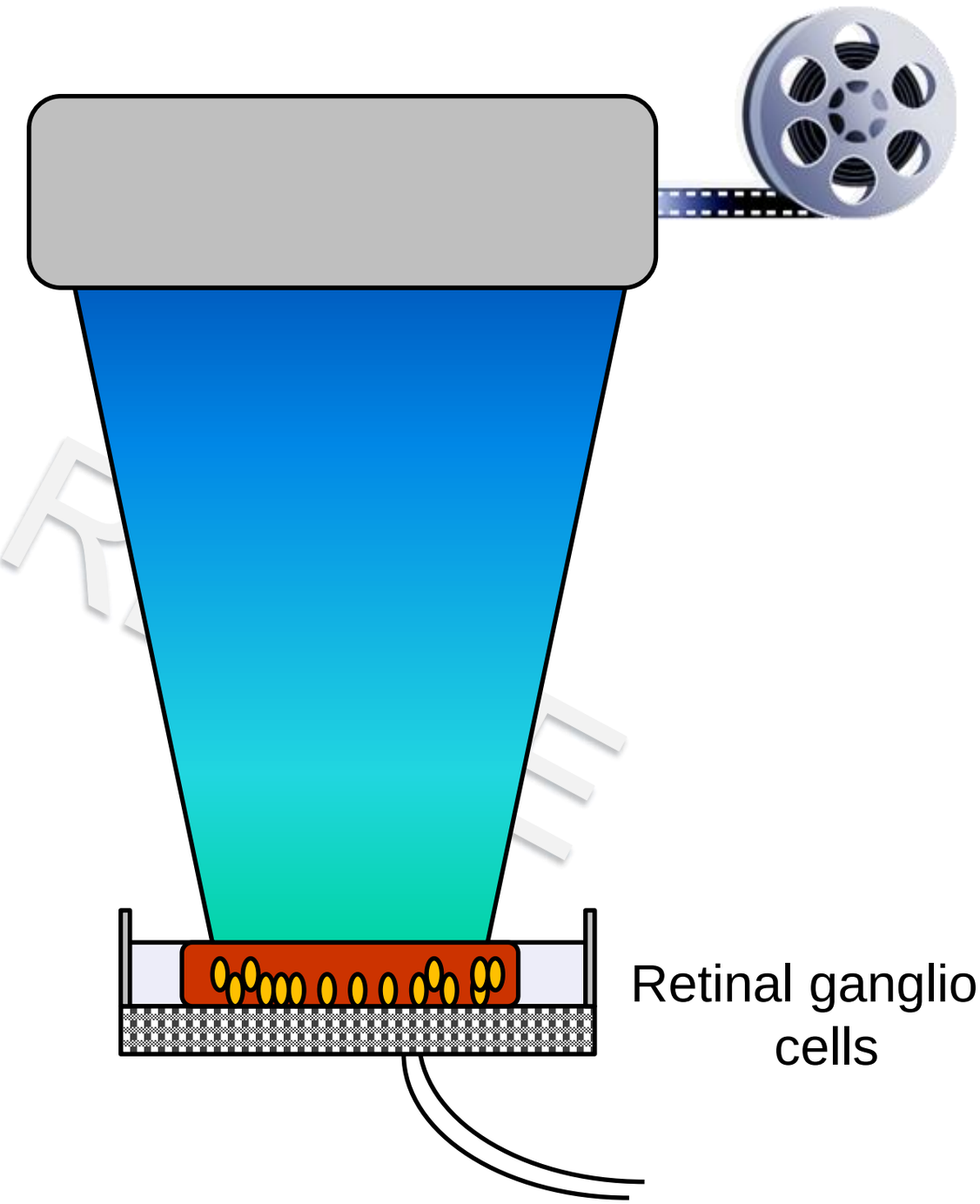


http://www.royles-opticians.co.uk

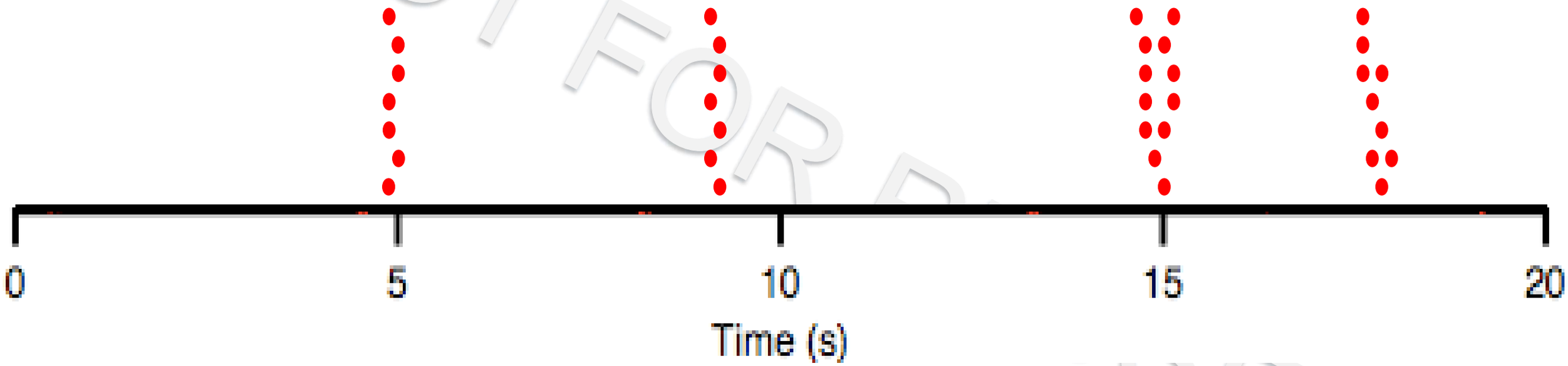
What is the neural code?



Ramon y Cajal, 1901

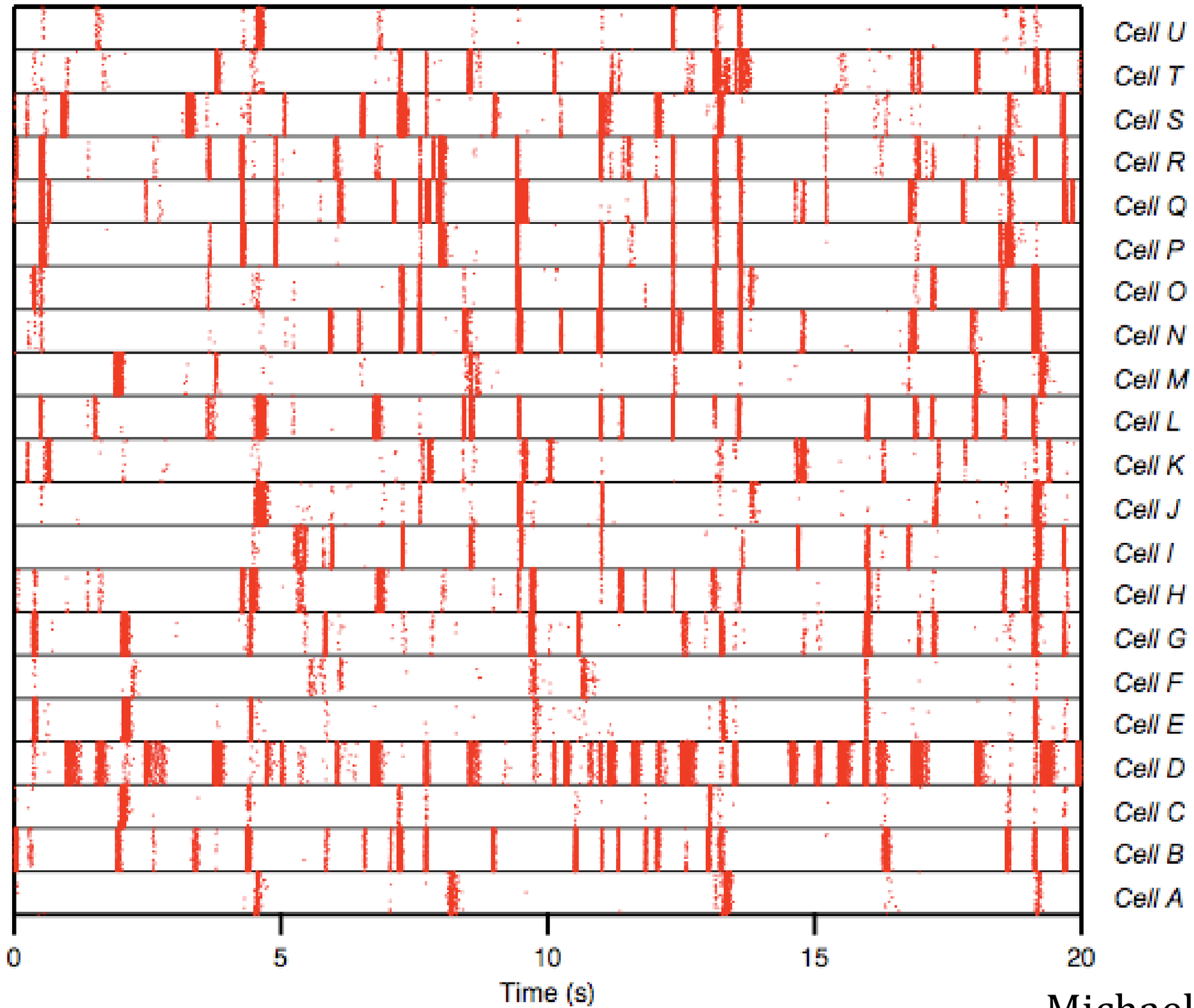


What is the neural code?



Michael J. Berry II

What is the neural code?



Michael J. Berry II

Encoding and decoding

Encoding: how does a stimulus cause a pattern of responses?

- building quasi-mechanistic models

Decoding: what do these responses tell us about the stimulus?

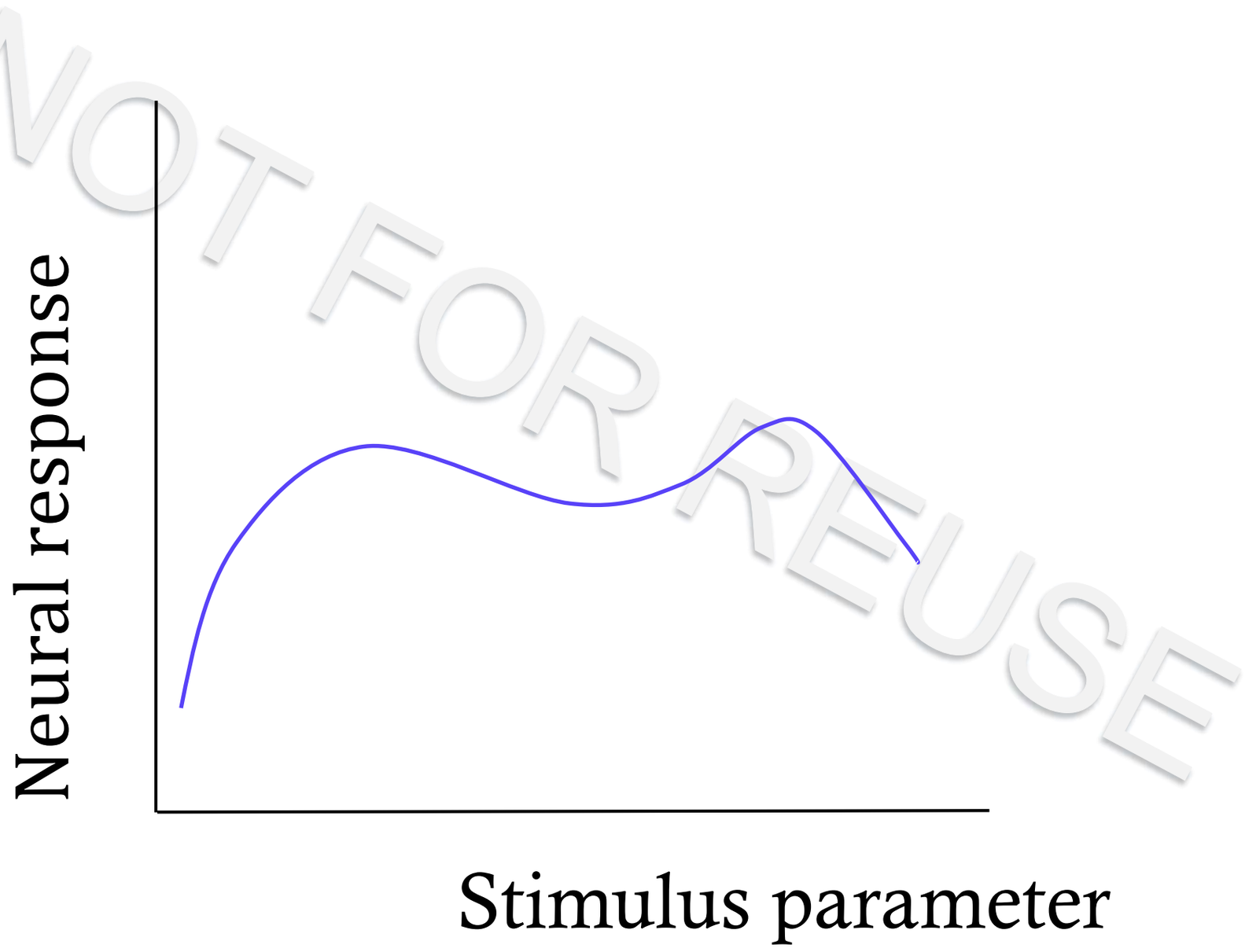
- how can we reconstruct what the brain is doing?

P(response | stimulus) *encoding*

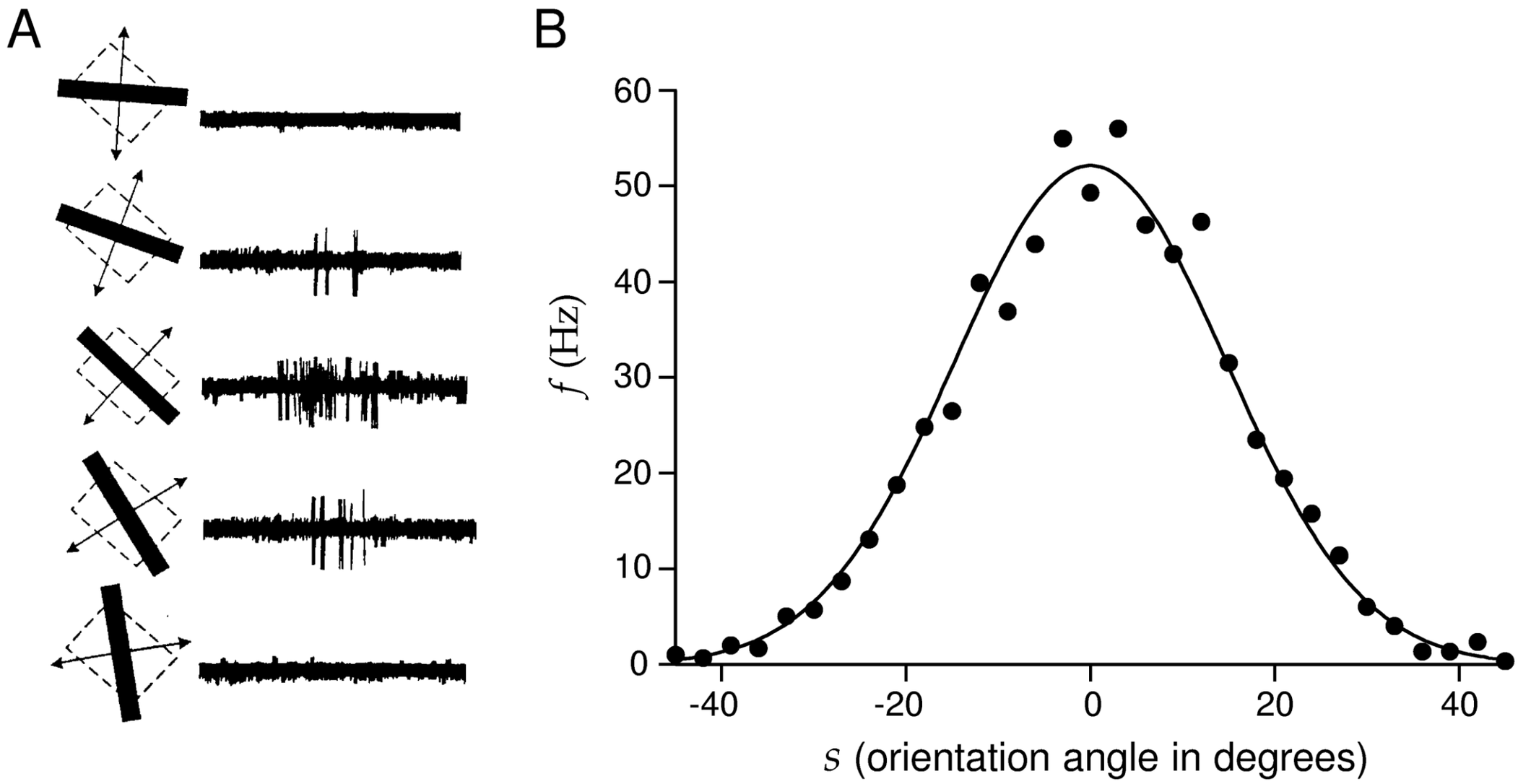
P(stimulus | response) *decoding*

What is the response? What is the stimulus?
What is the relationship between them?

Neural representation of information



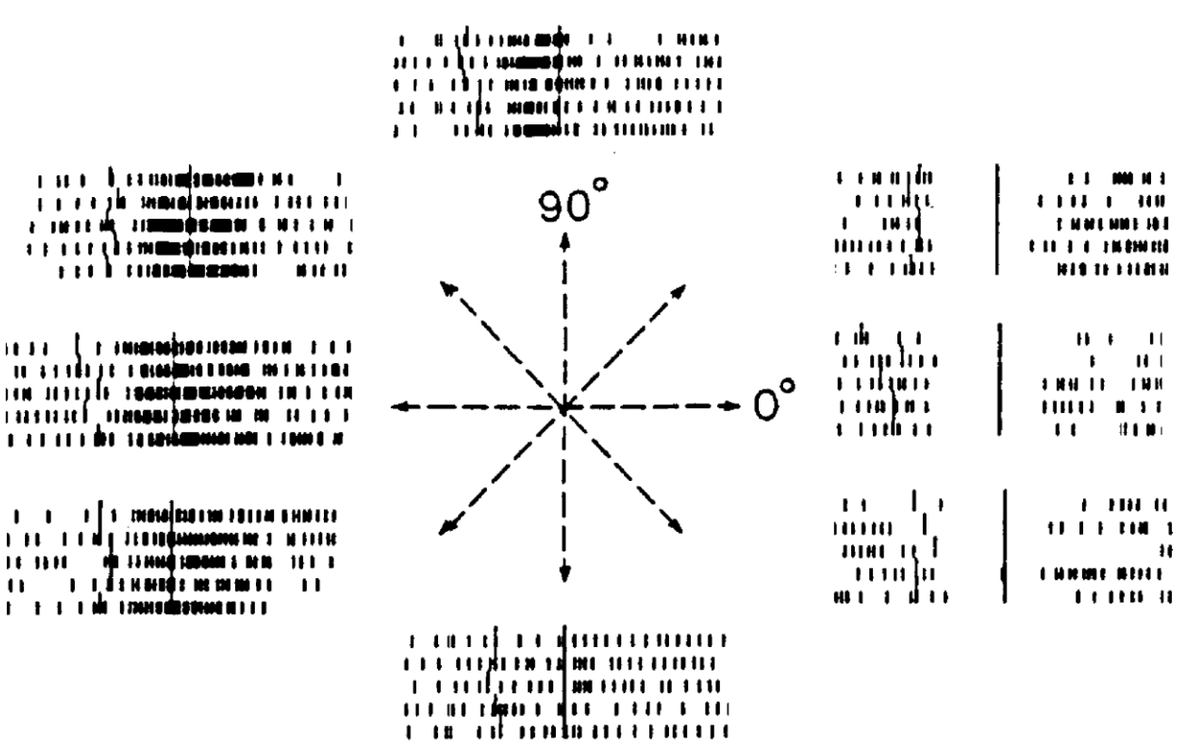
Tuning curves



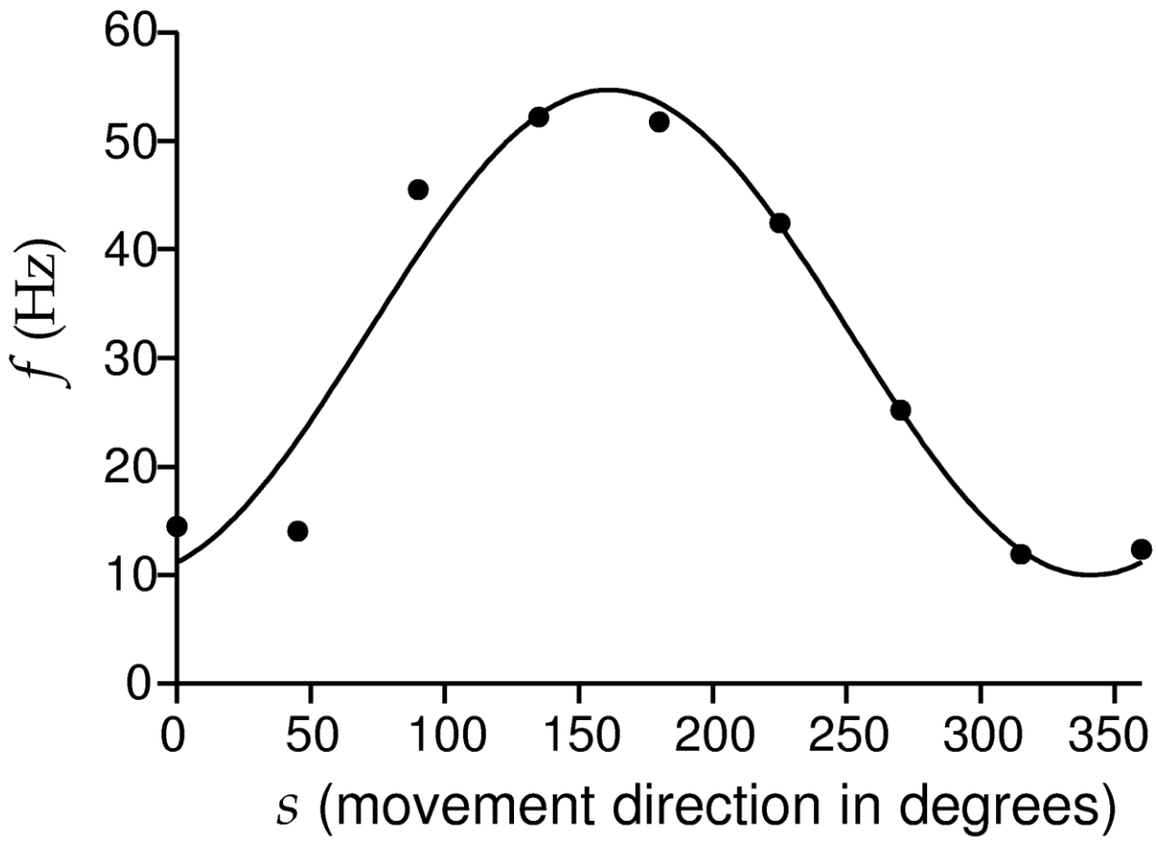
Gaussian tuning curve of a cortical (V1) neuron

from Dayan and Abbott, *Theoretical Neuroscience*:
adapted from Wandell ’95, Hubel and Wiesel ‘68; data from Henry et al., ‘74

Tuning curves



Hand reaching direction



Cosine tuning curve of a motor cortical neuron

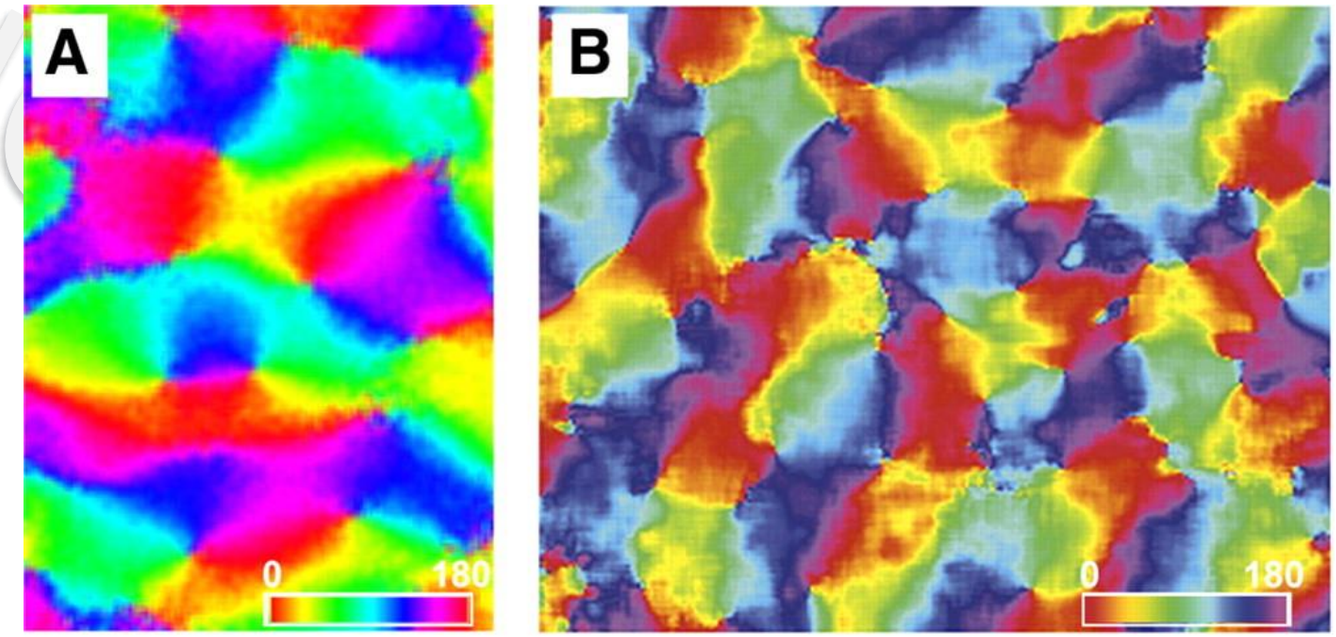
from Dayan and Abbott, *Theoretical Neuroscience*:
adapted from Georgopoulos et al. '92

Map of feature selectivity in primary visual cortex

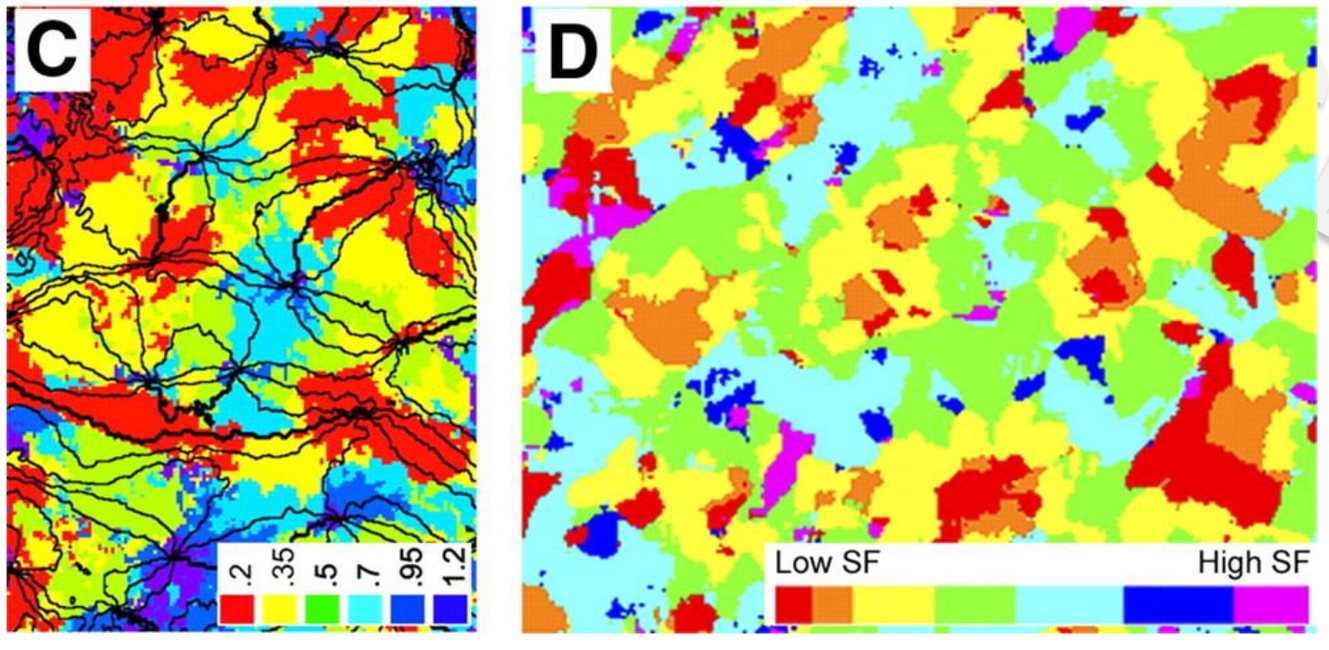
Cat

Bush baby

Orientation



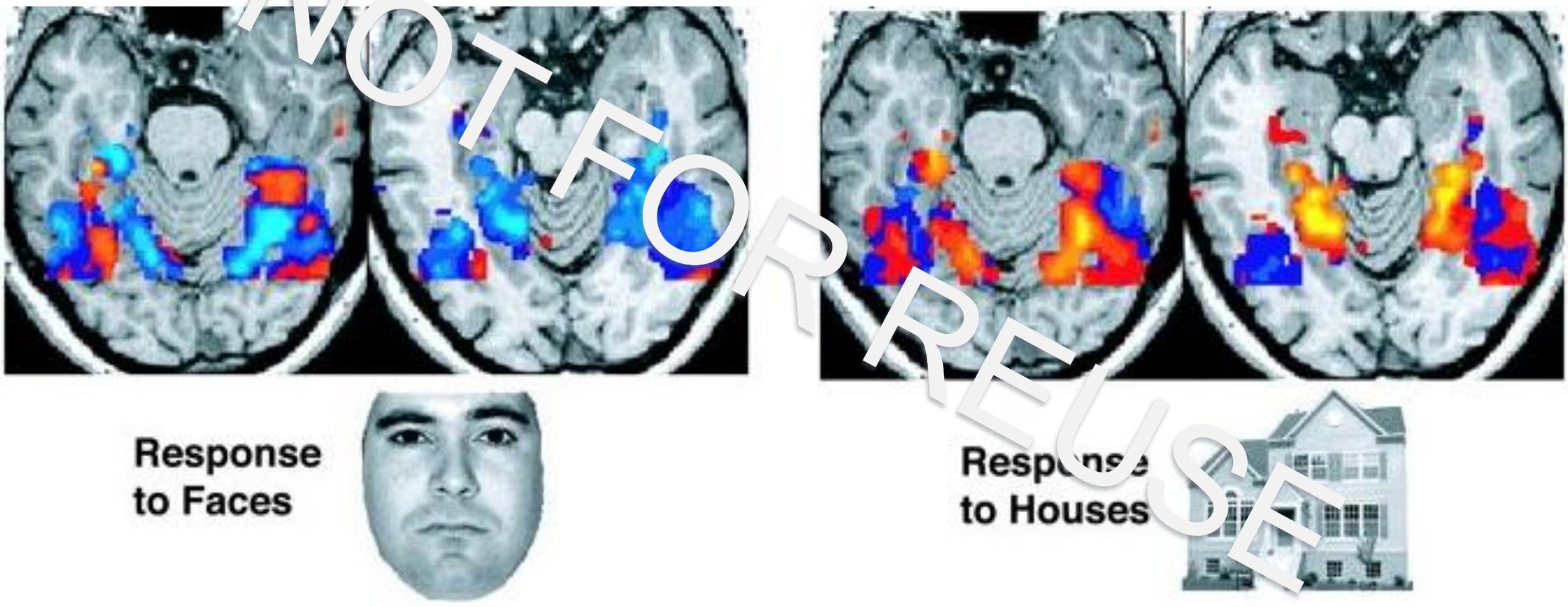
Spatial frequency



Issa N P et al. J Neurophysiol 2008;99:2745-2754

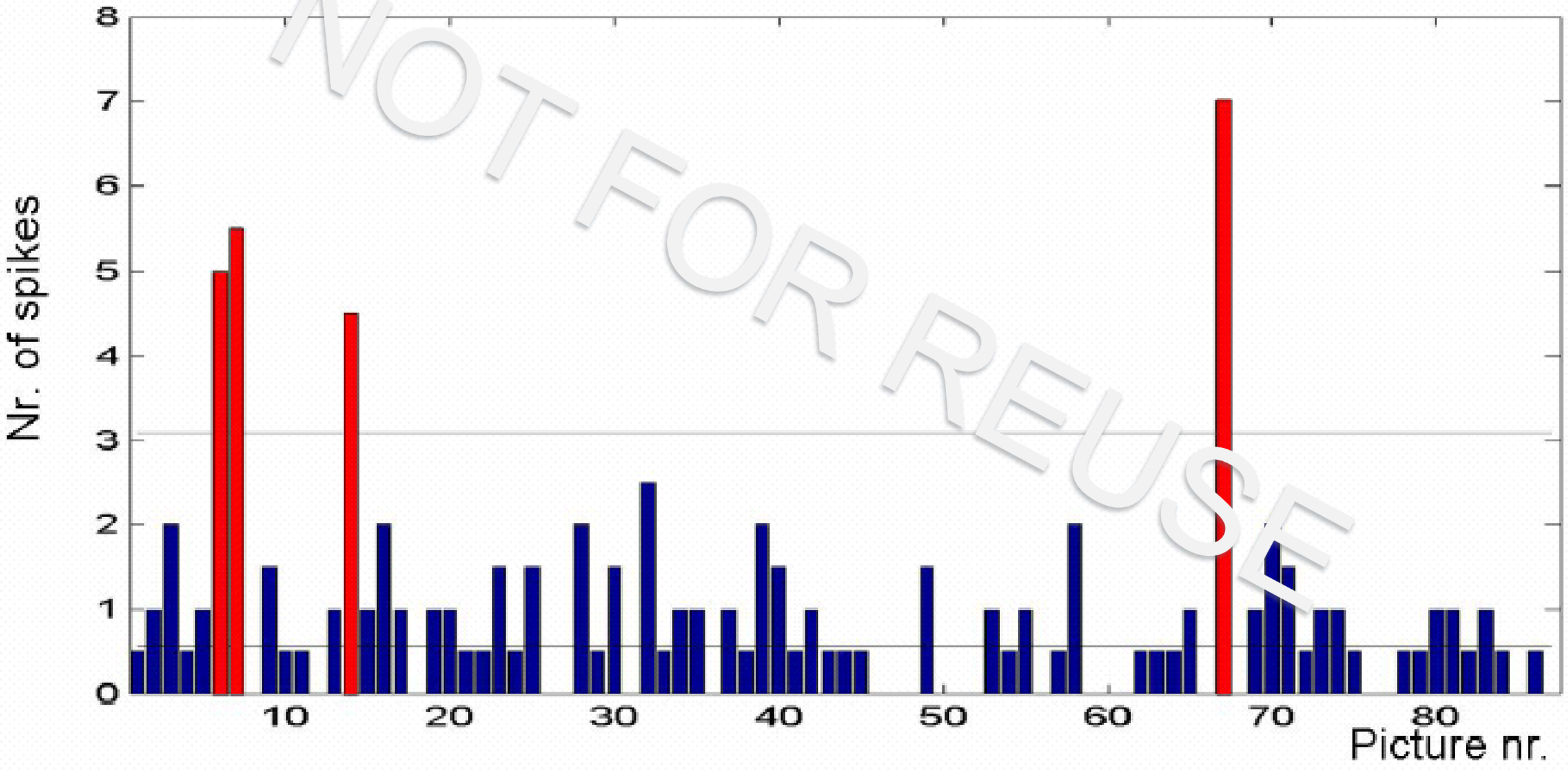
Journal of Neurophysiology

Higher order feature selectivity



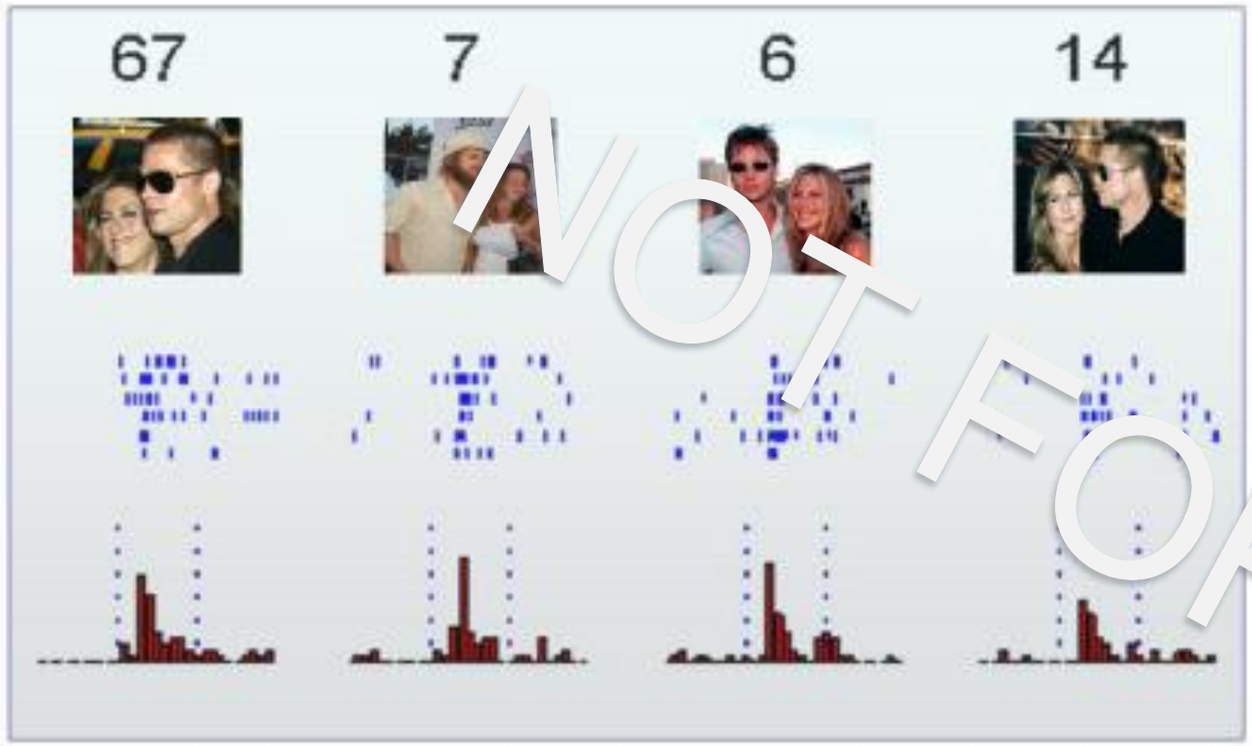
Haxby et al., *Science* (2001)

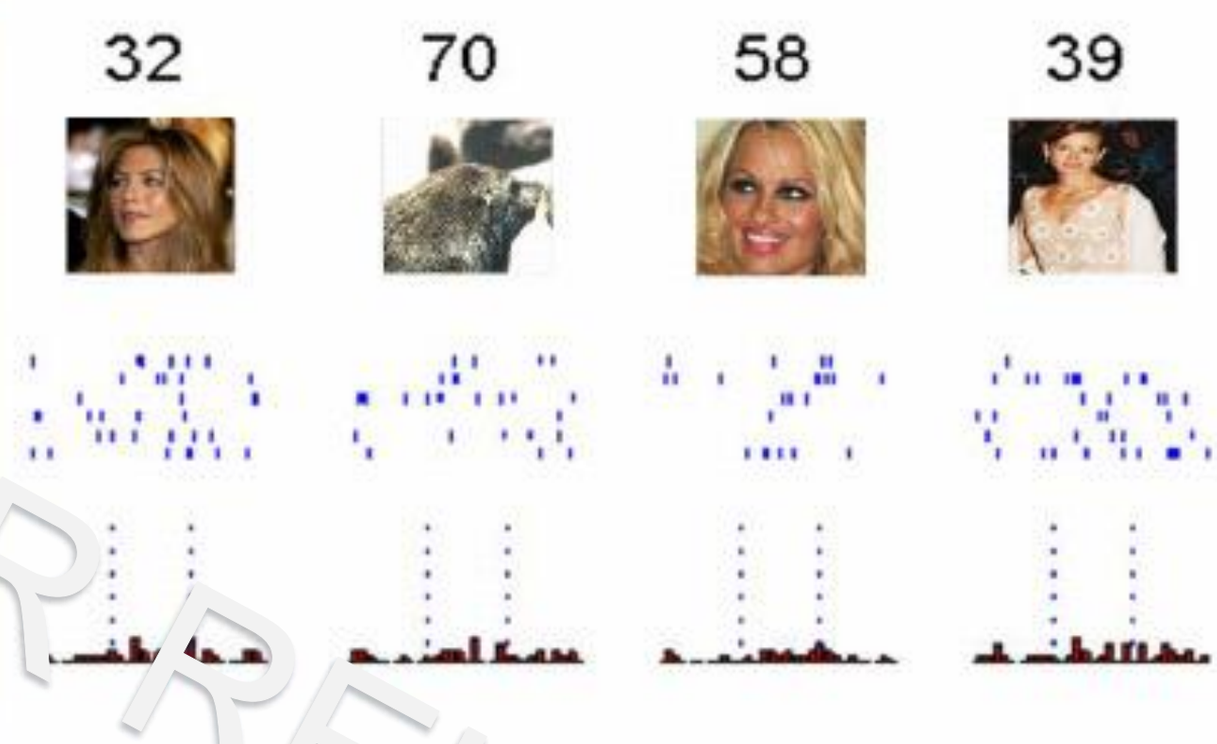
“Tuning curves”

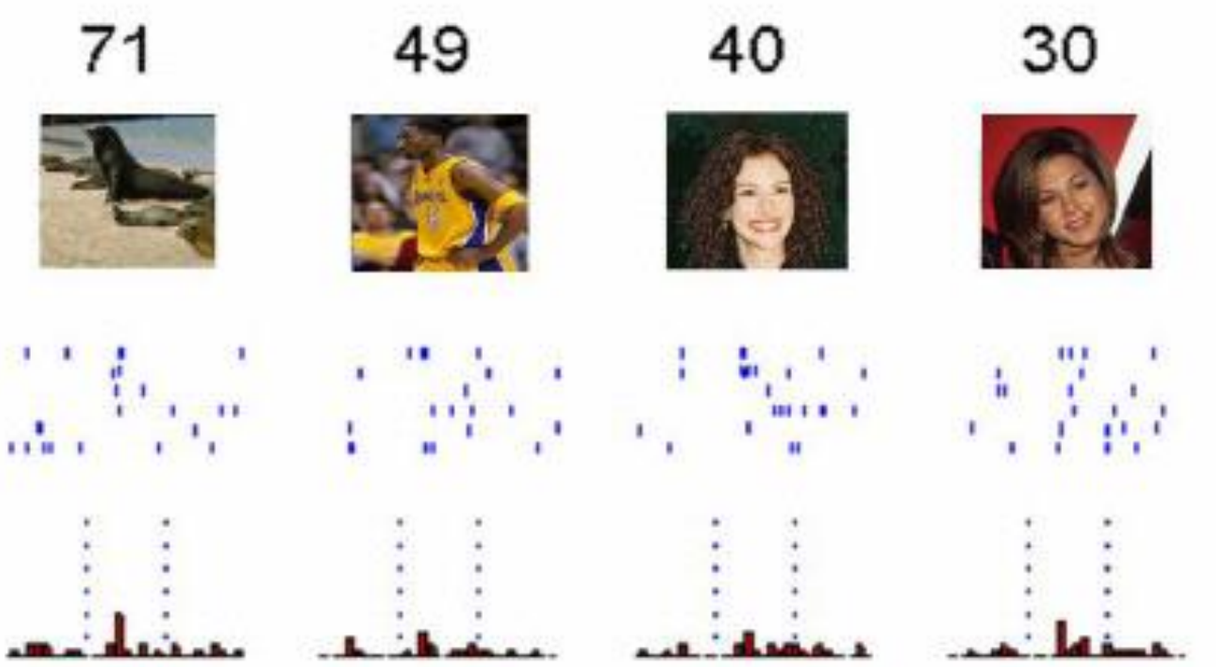


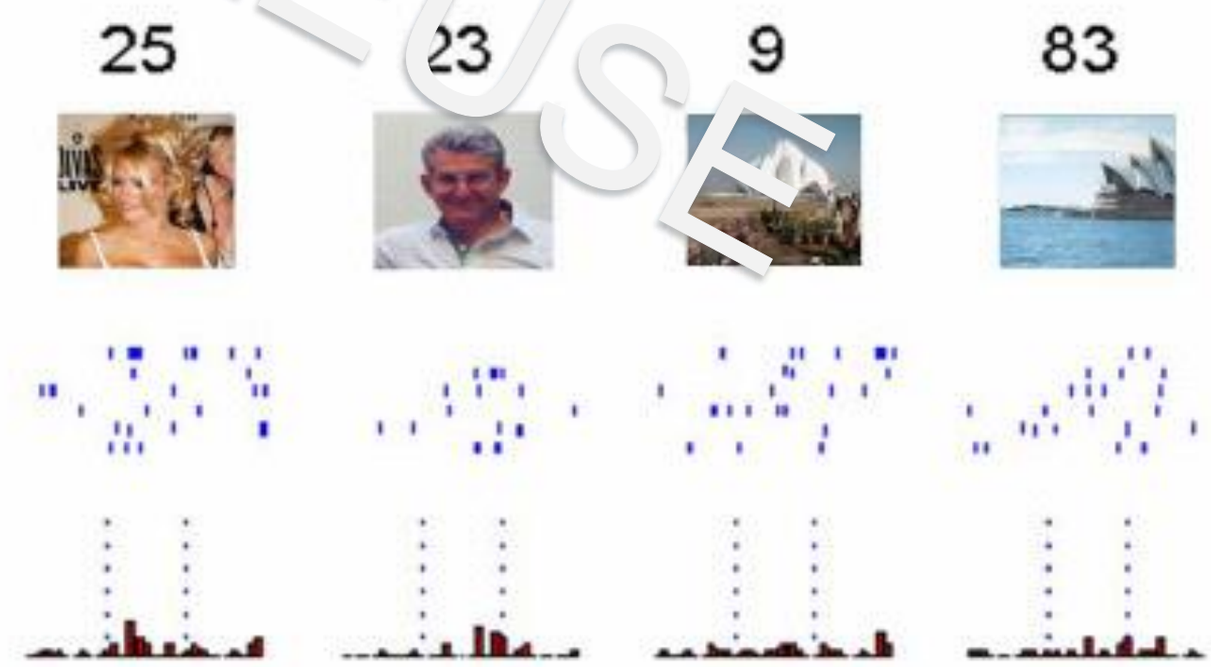
Quian Quiroga, Reddy, Kreiman, Koch and Fried, *Nature* (2005)

What is the stimulus *s*?



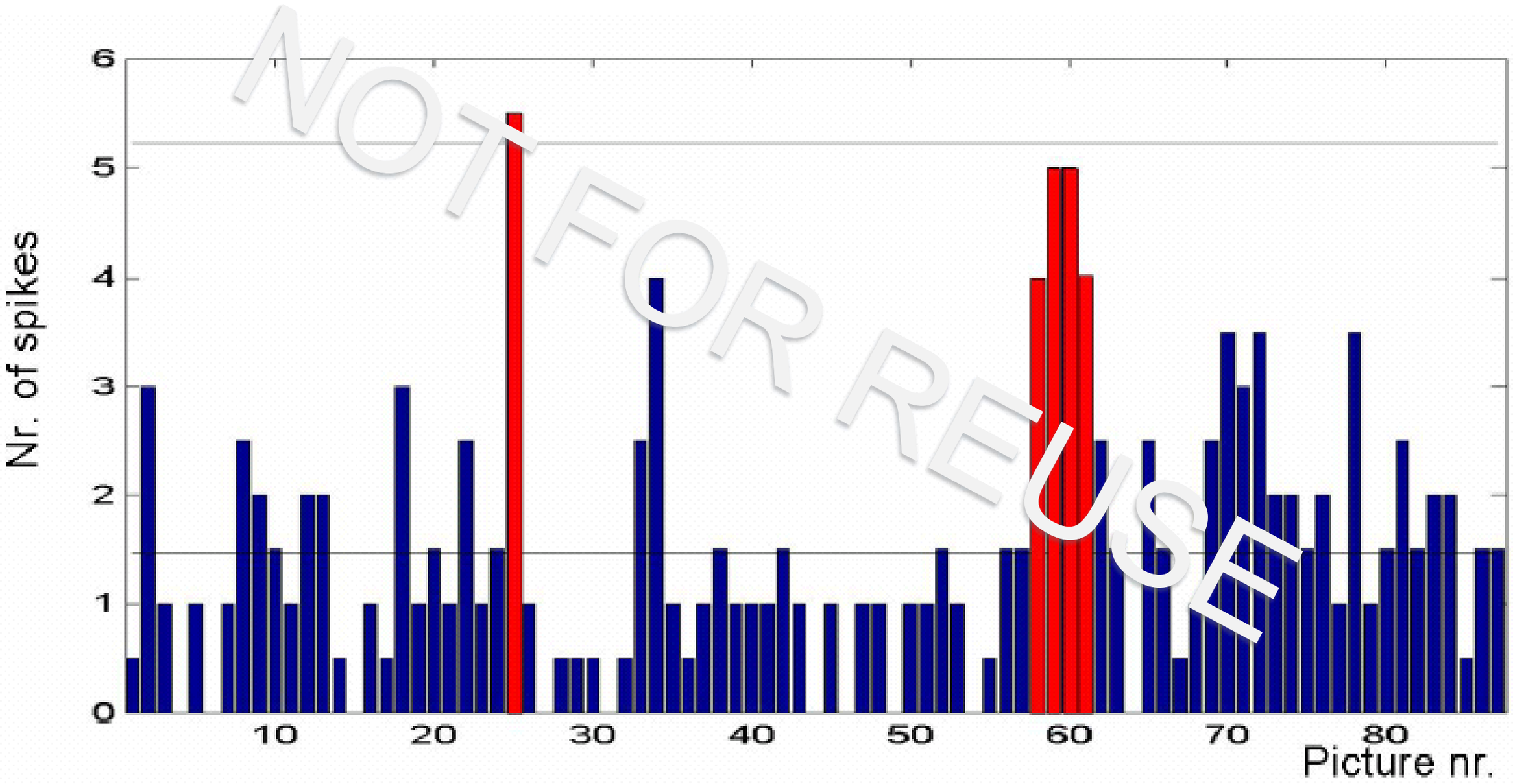






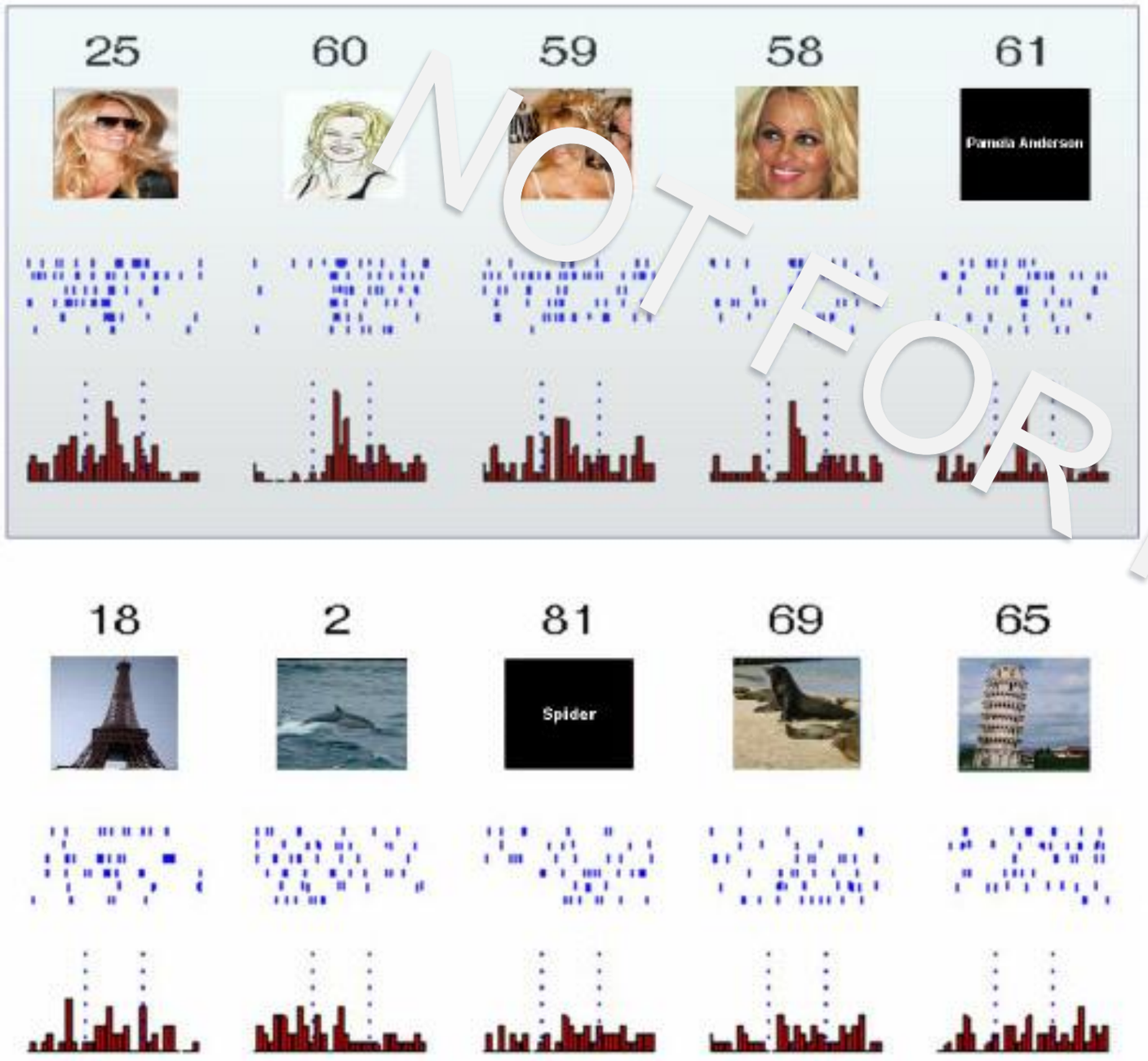
Quian Quiroga, Reddy, Kreiman, Koch and Fried, *Nature* (2005)

Tuning curves



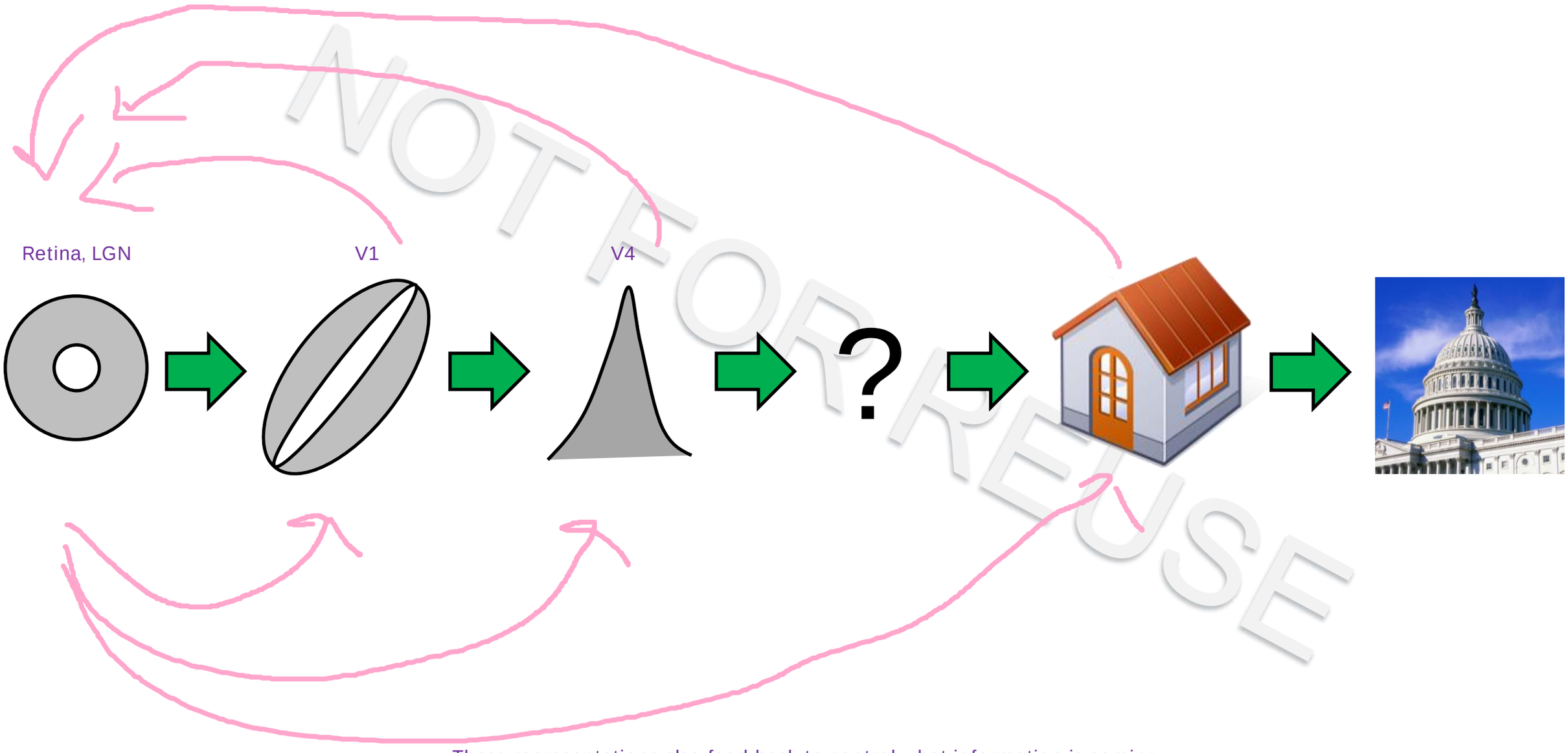
Quian Quiroga, Reddy, Kreiman, Koch and Fried, *Nature* (2005)

What is *s*?



Quian Quiroga, Reddy, Kreiman, Koch and Fried, *Nature* (2005)

Building up complex selectivity



These representations also feed back to control what information is coming through in the first place. So this is how semantics, the meaning or the value of the context of an image, can end up influencing its initial representation in V1 or V4. So here where there's a role for learning and for expectation. What you think you're looking at can shape what you actually see.

Top-down effects

Next up: constructing response models

P(response | stimulus)