

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

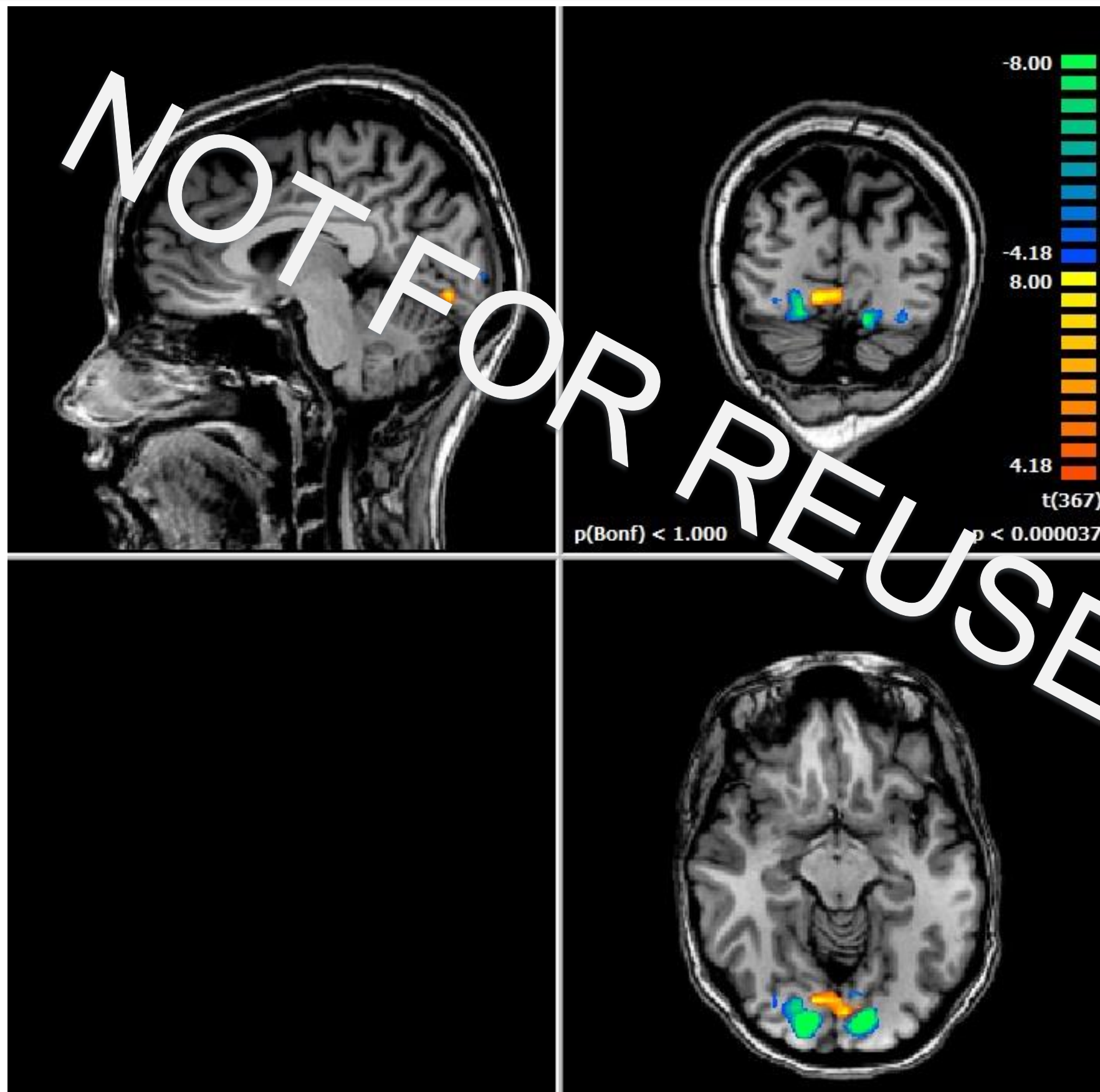
NOT FOR REUSE

Recording from the brain: fMRI



Scott Murray

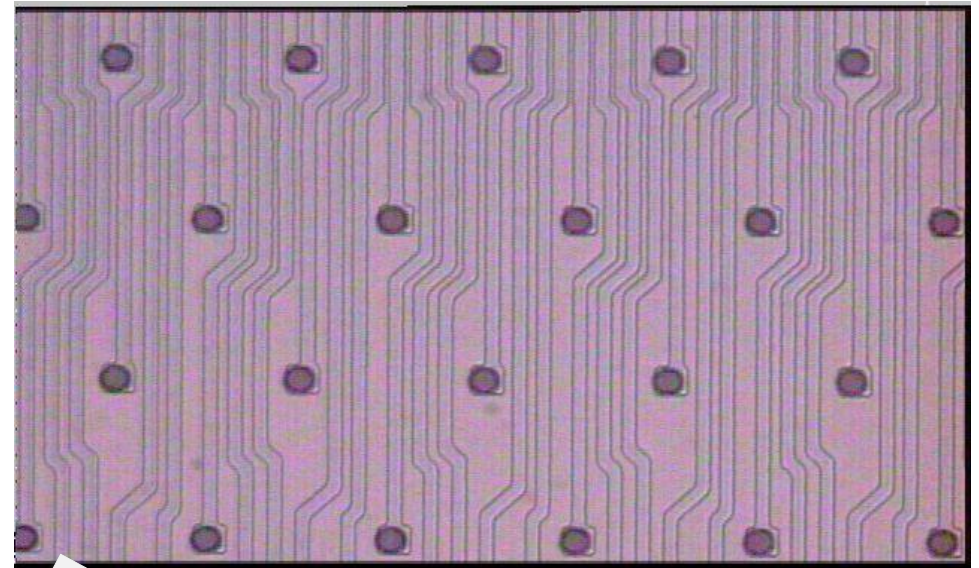
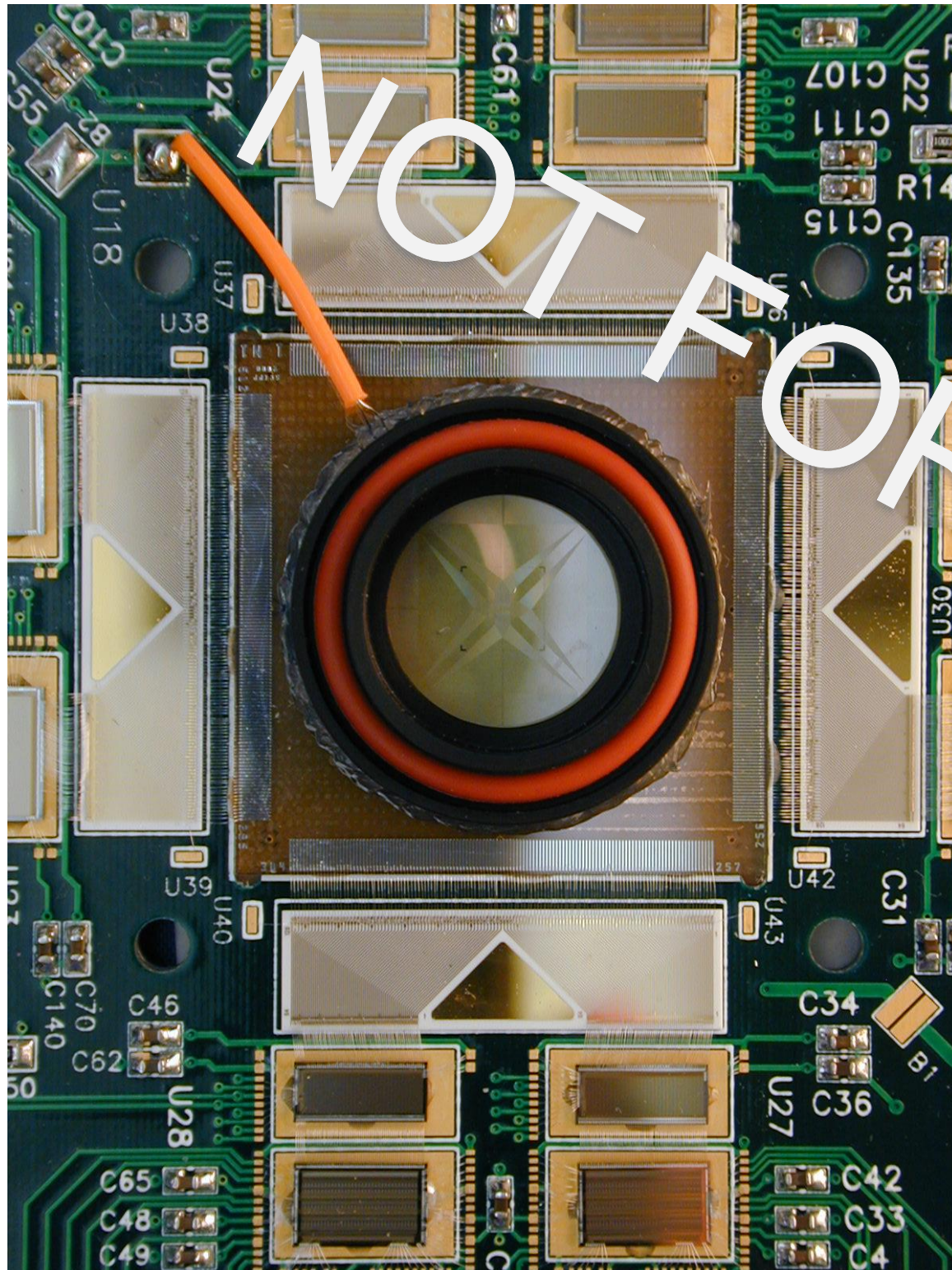
Recording from the brain: fMRI



Recording from the brain: EEG



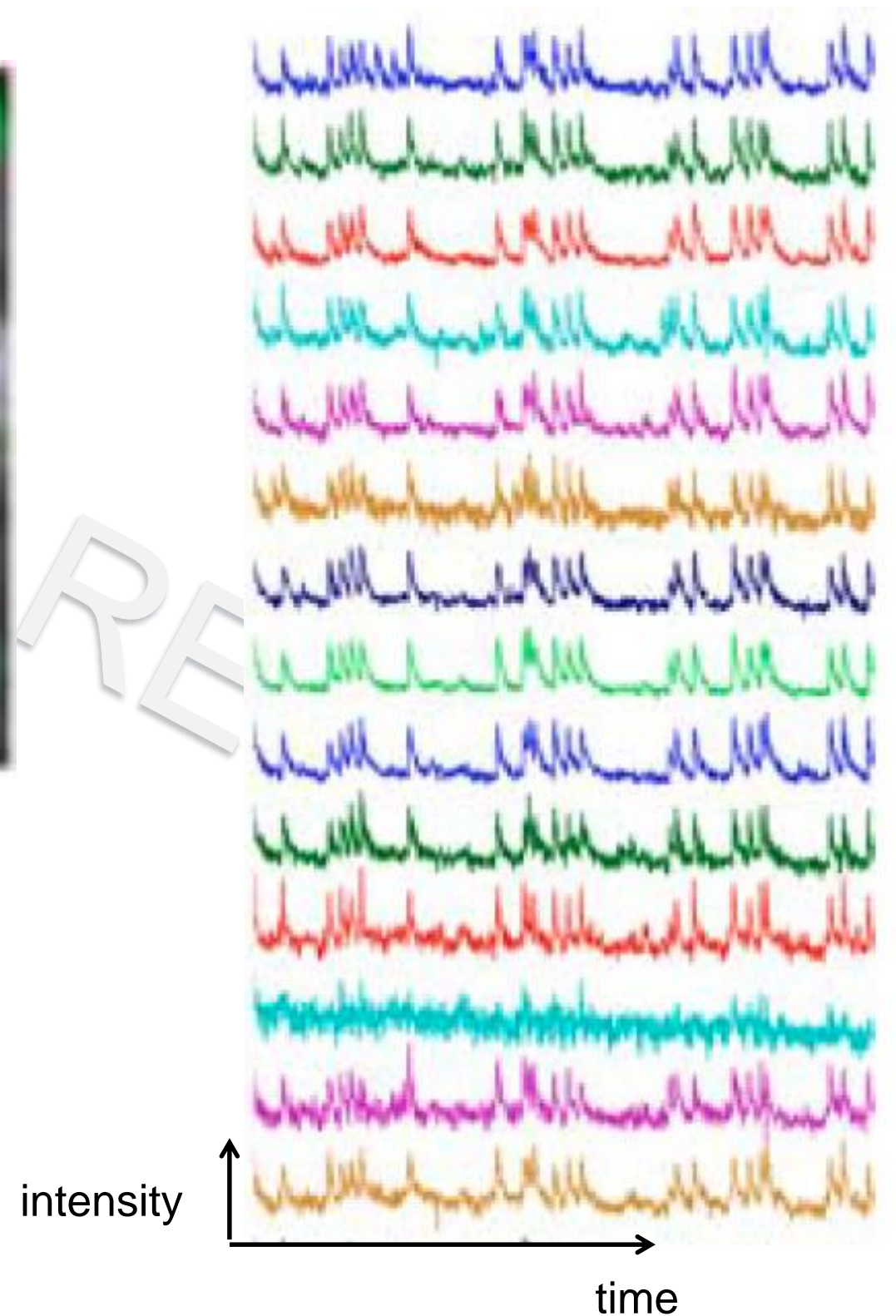
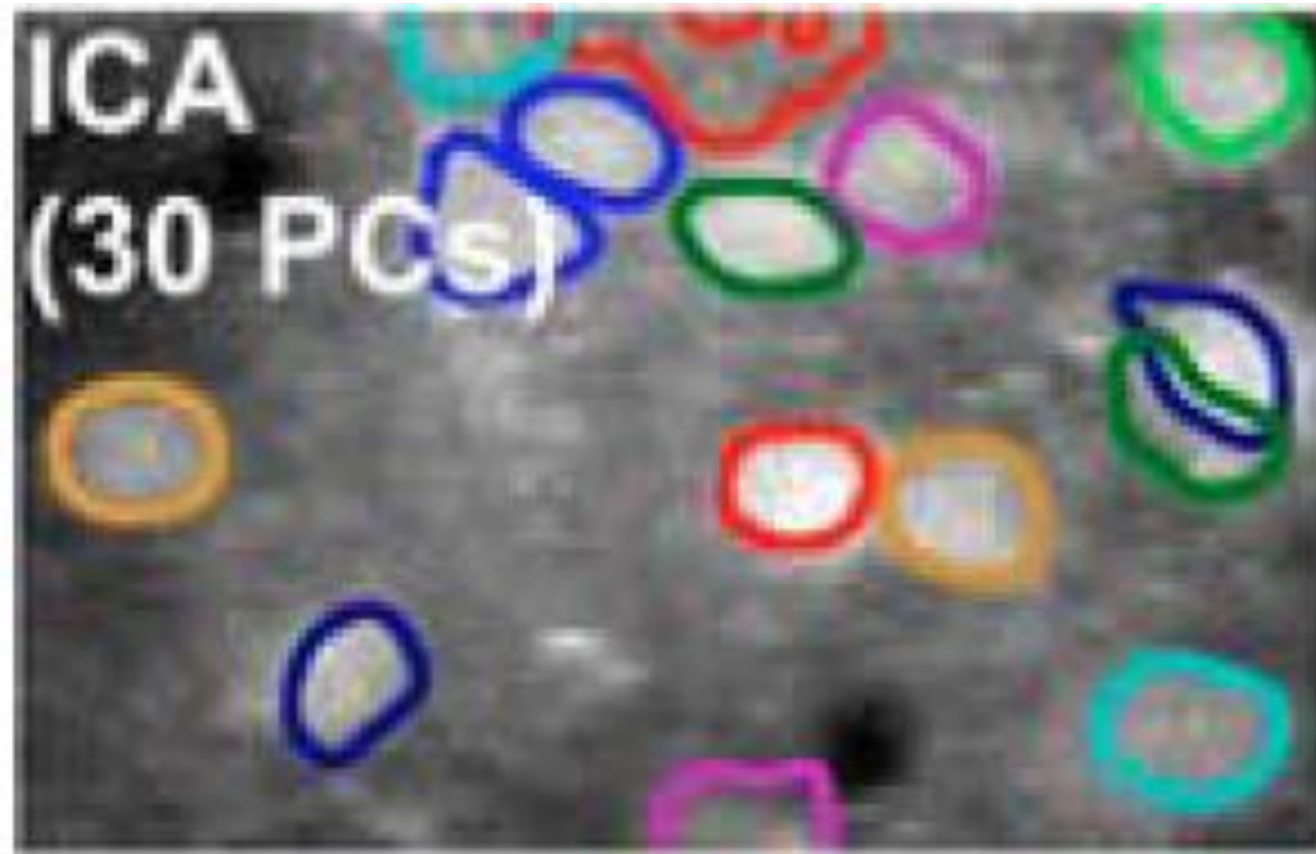
Reading out the neural code: electrode arrays



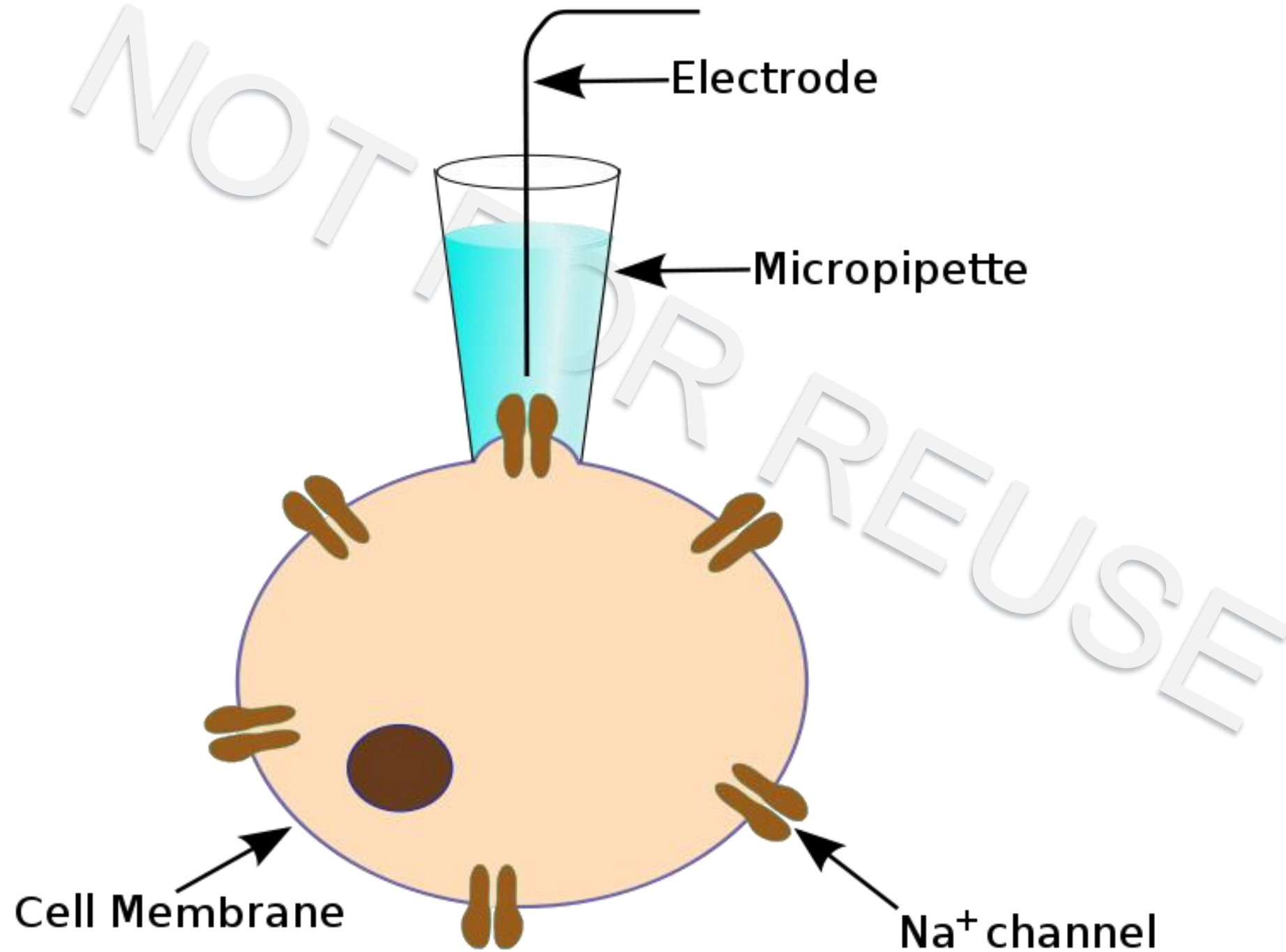
Reading out the neural code: electrode arrays



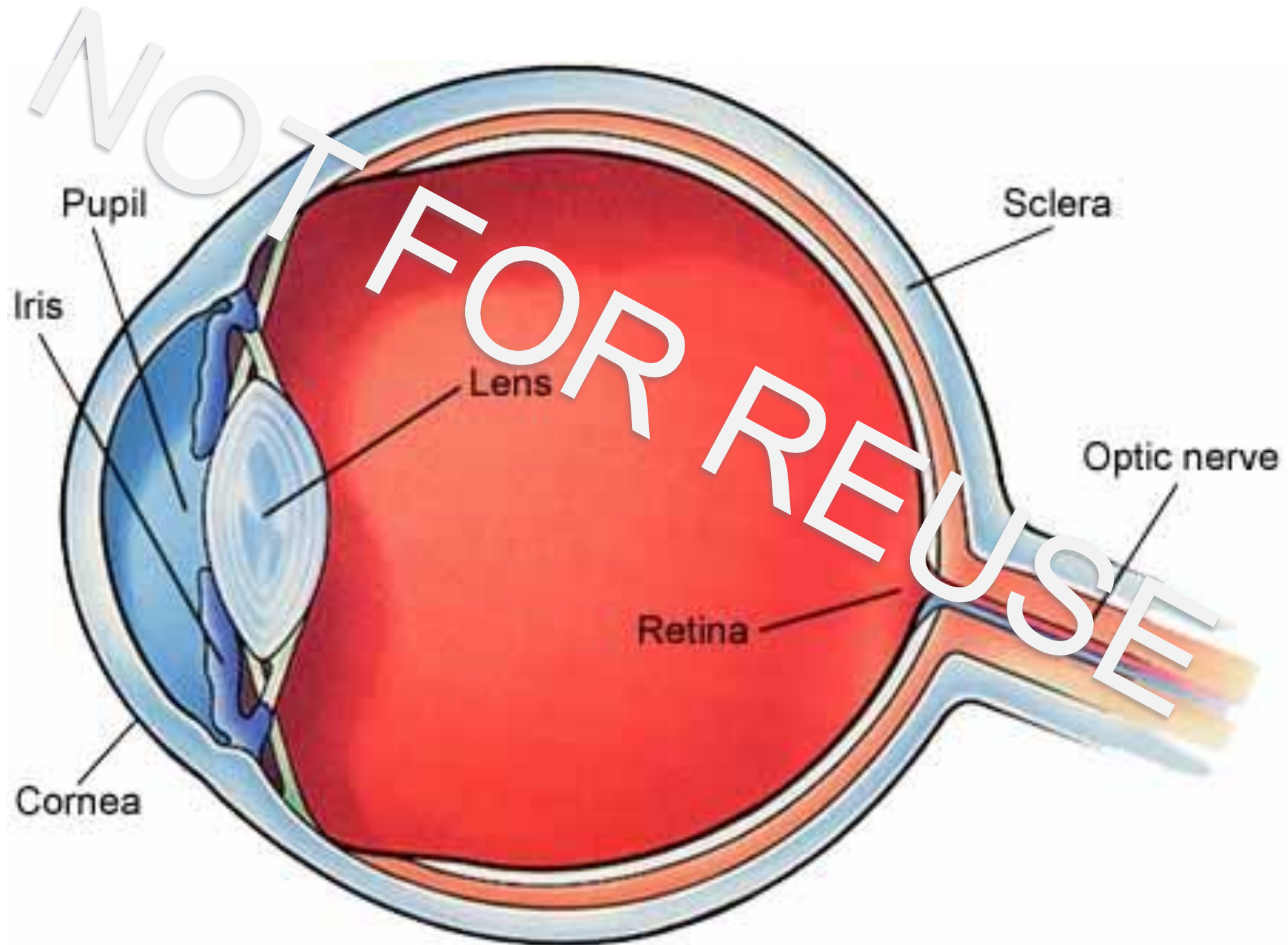
Reading out the neural code: calcium imaging



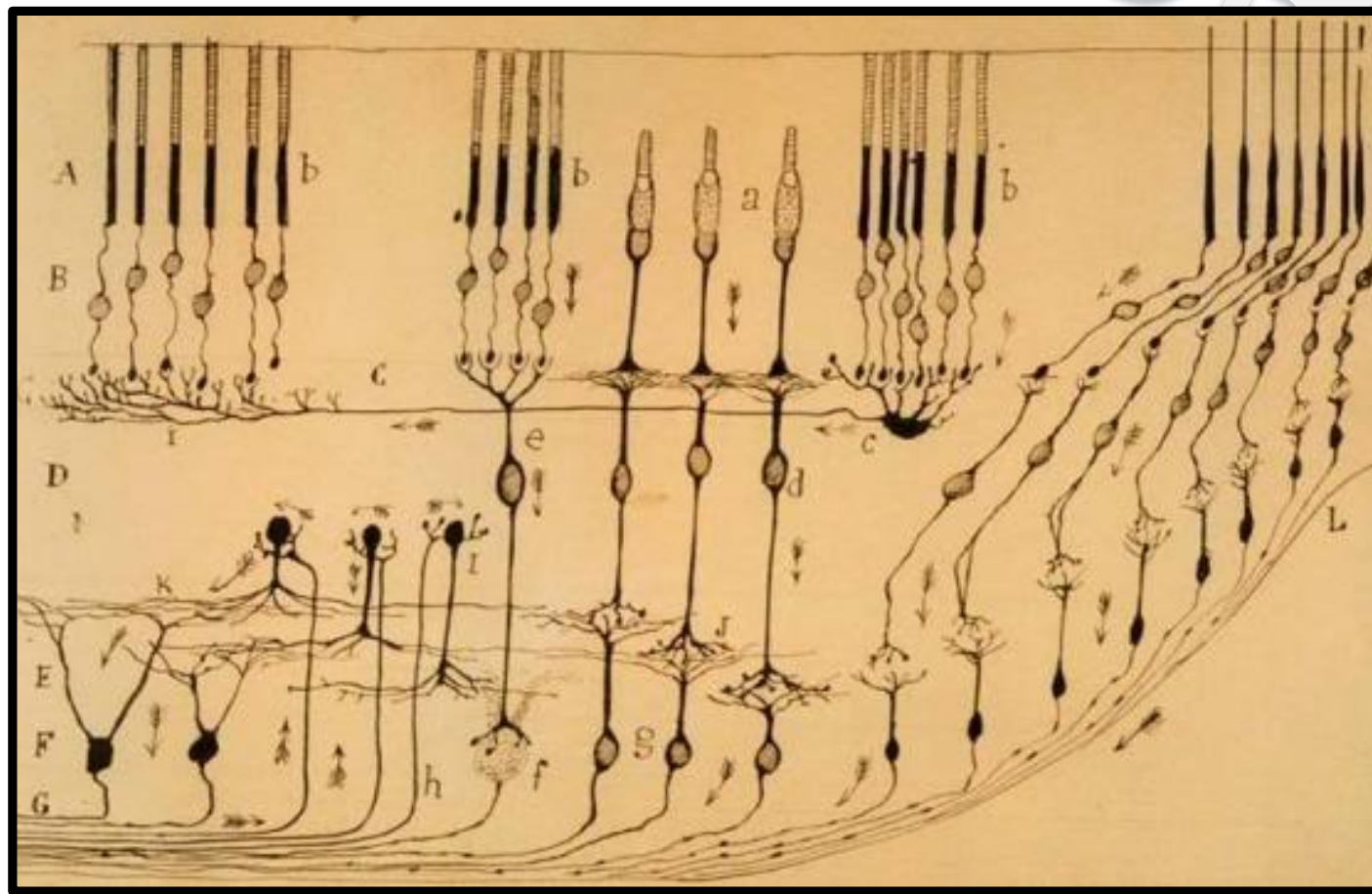
Looking inside single cells



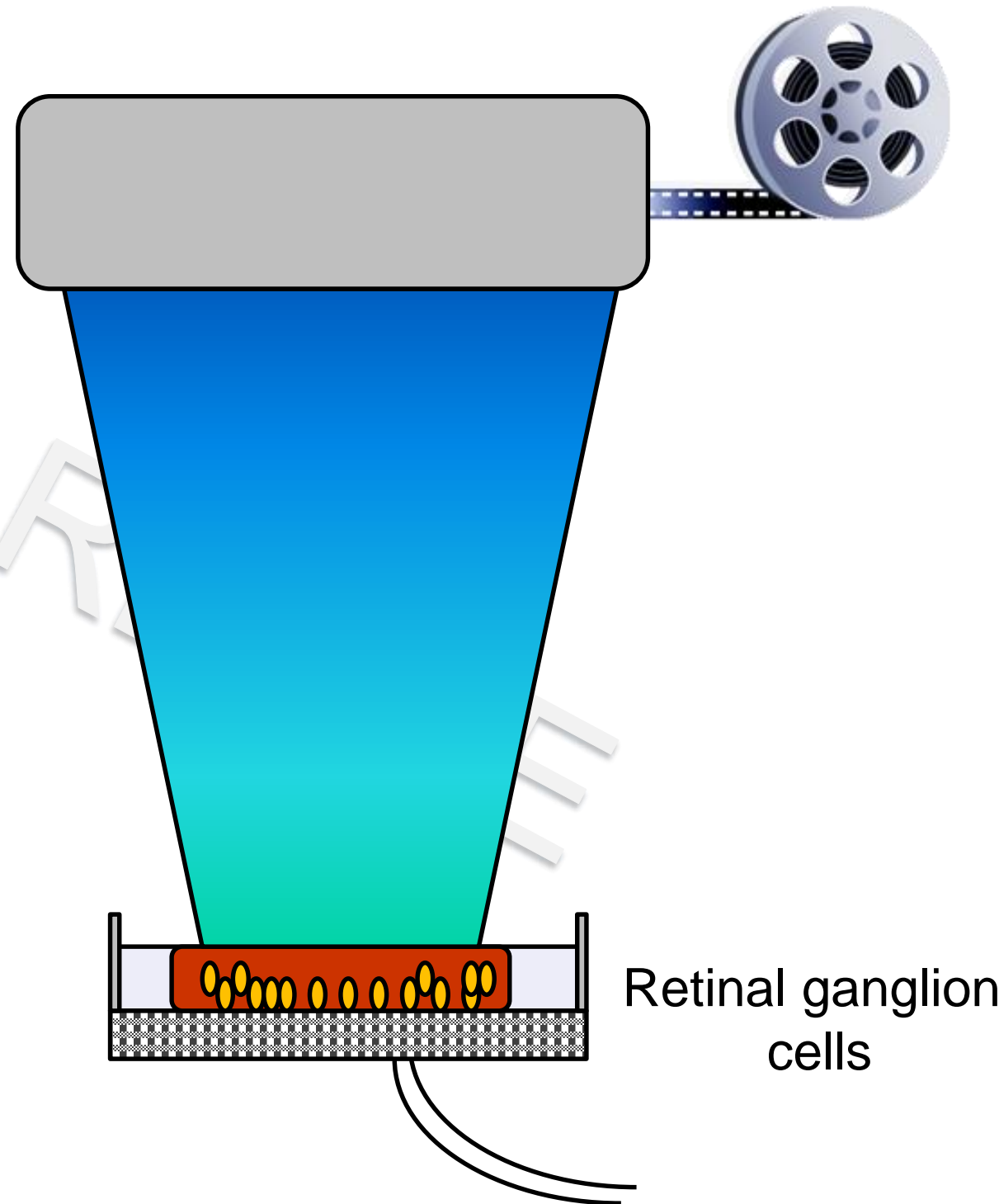
What is the neural code?



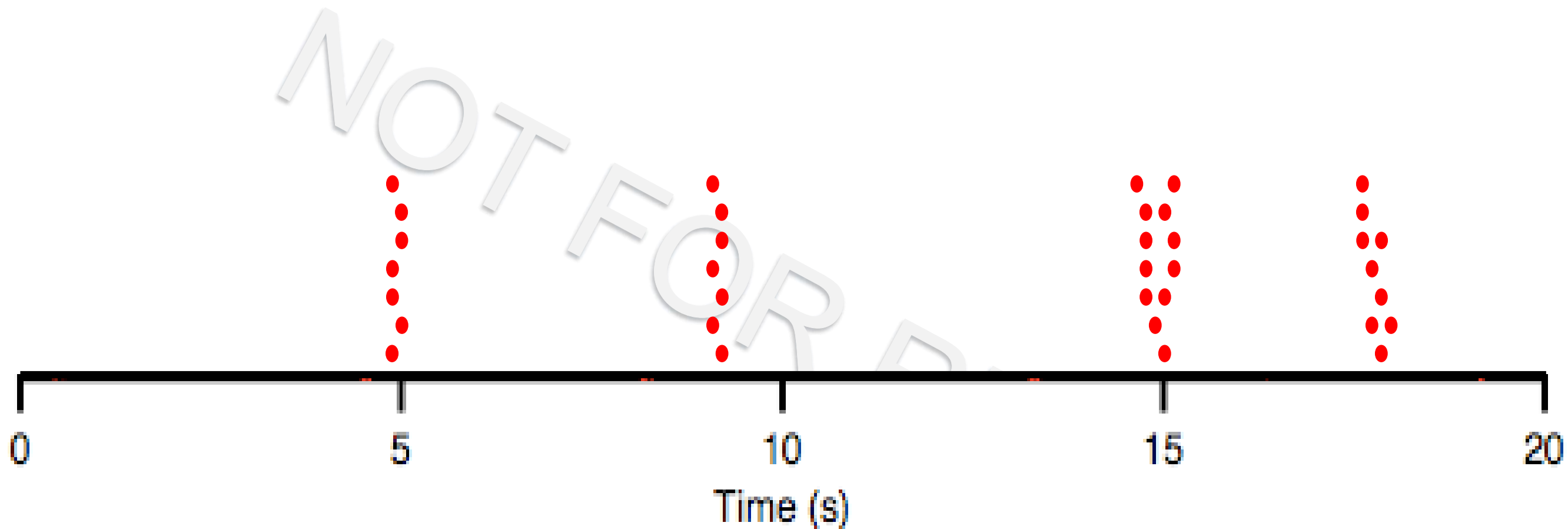
What is the neural code?



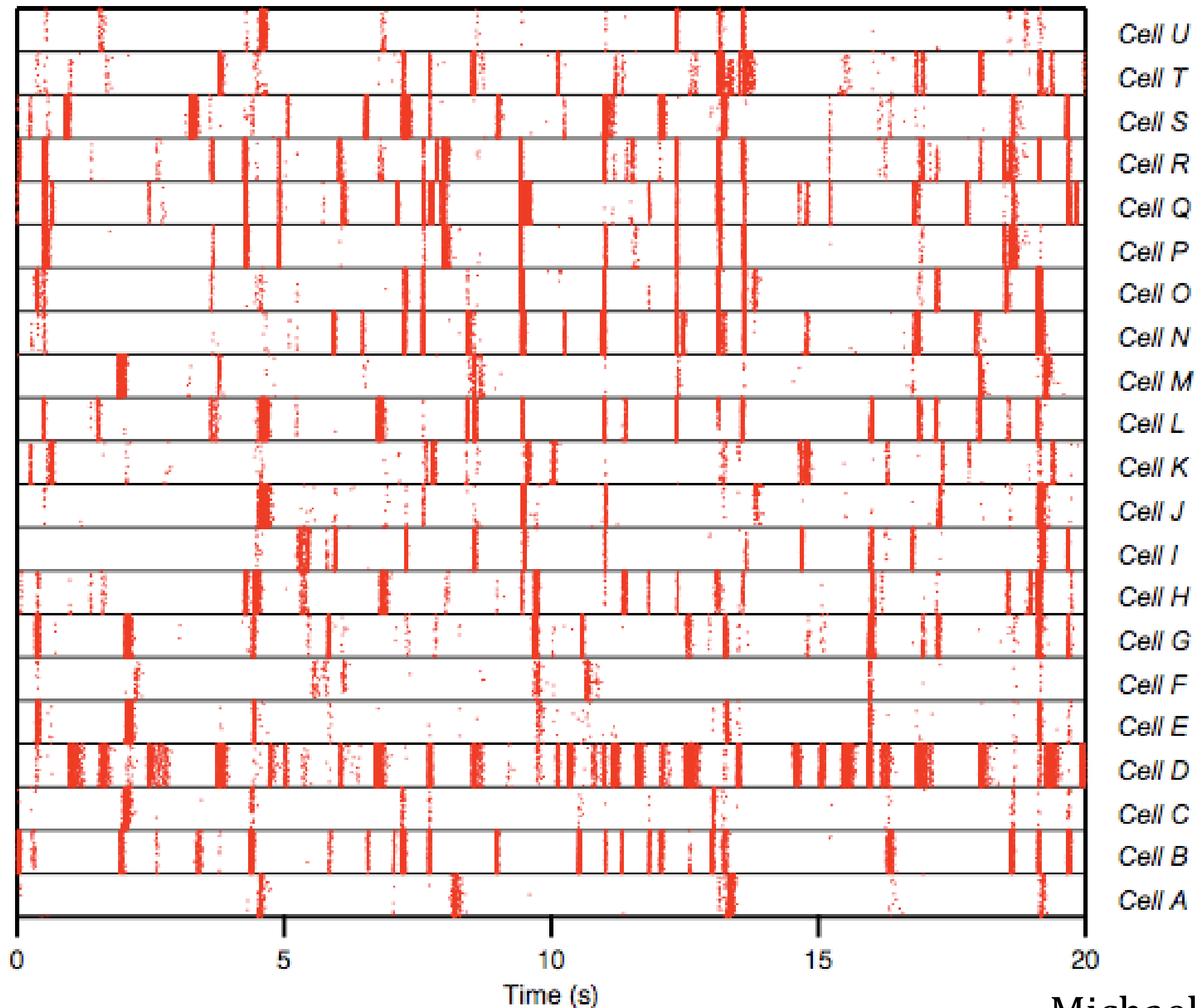
Ramon y Cajal, 1901



What is the neural code?



What is the neural code?



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?

$P(\text{response} \mid \text{stimulus})$

encoding

$P(\text{stimulus} \mid \text{response})$

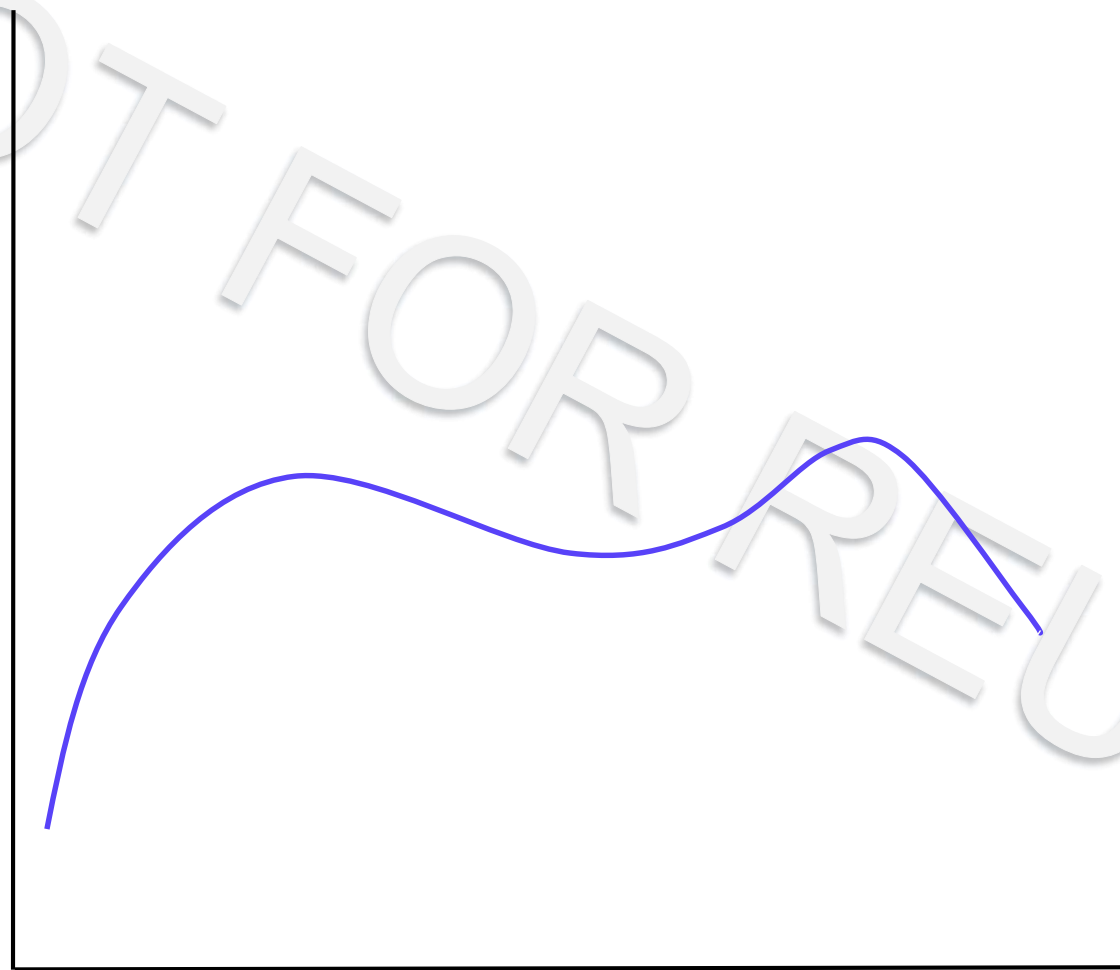
decoding

What is the response? What is the stimulus?

What is the relationship between them?

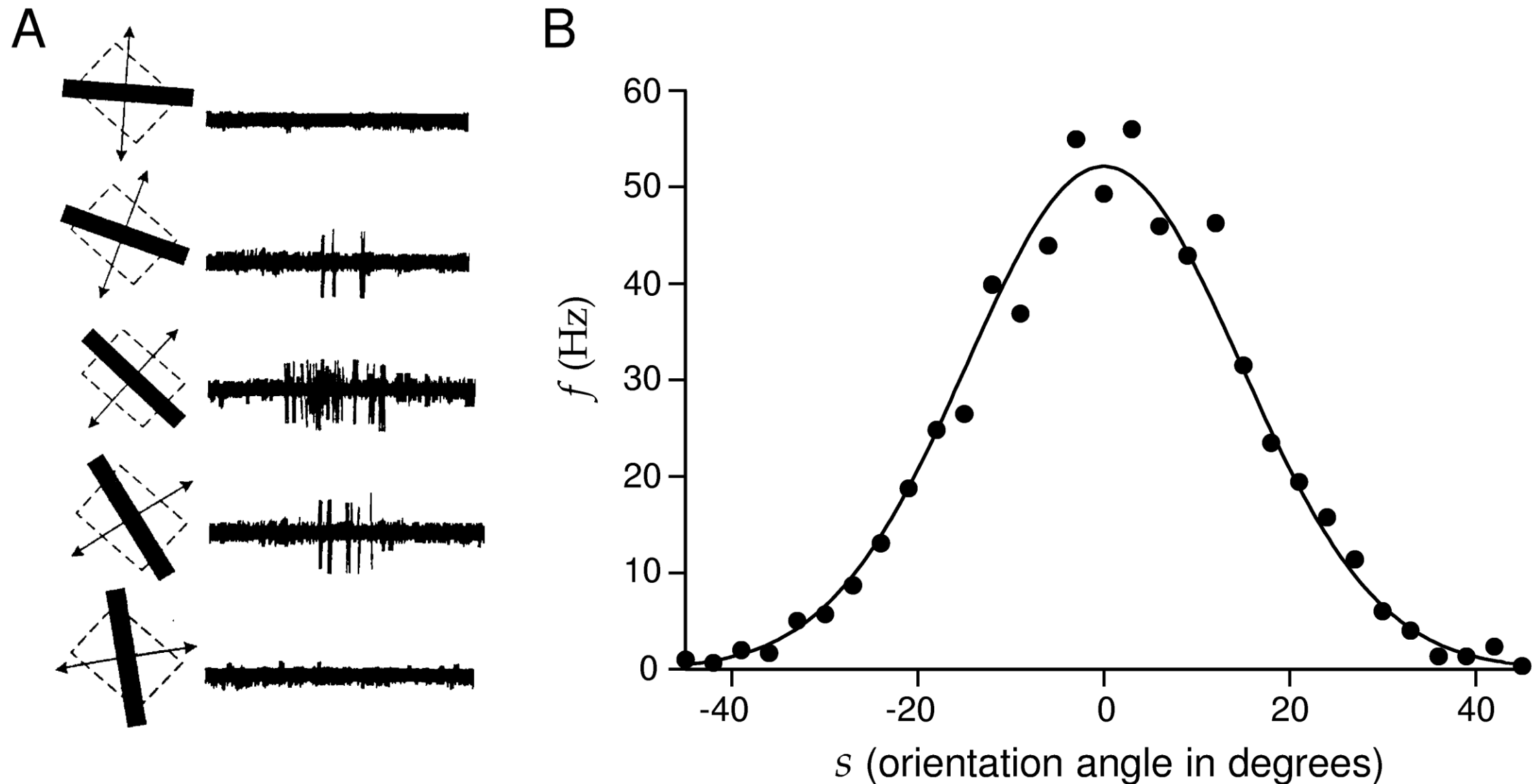
Neural representation of information

Neural response



Stimulus parameter

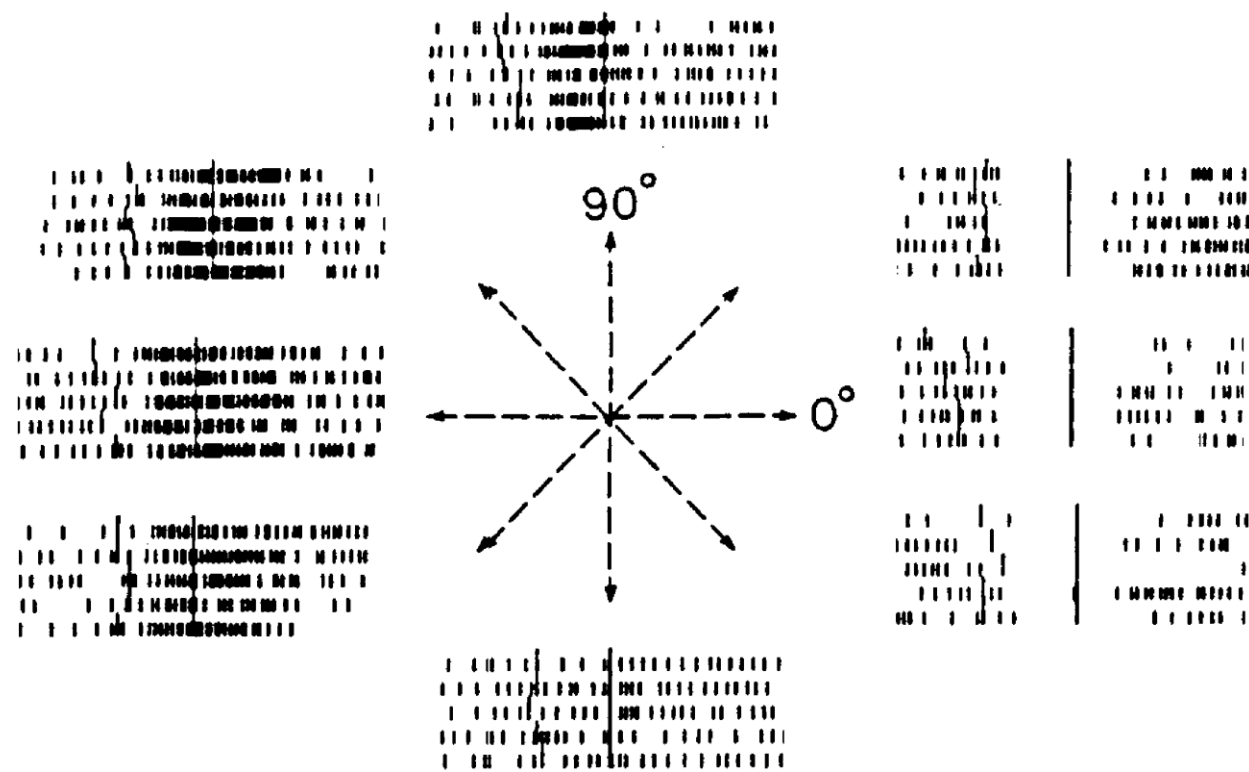
Tuning curves



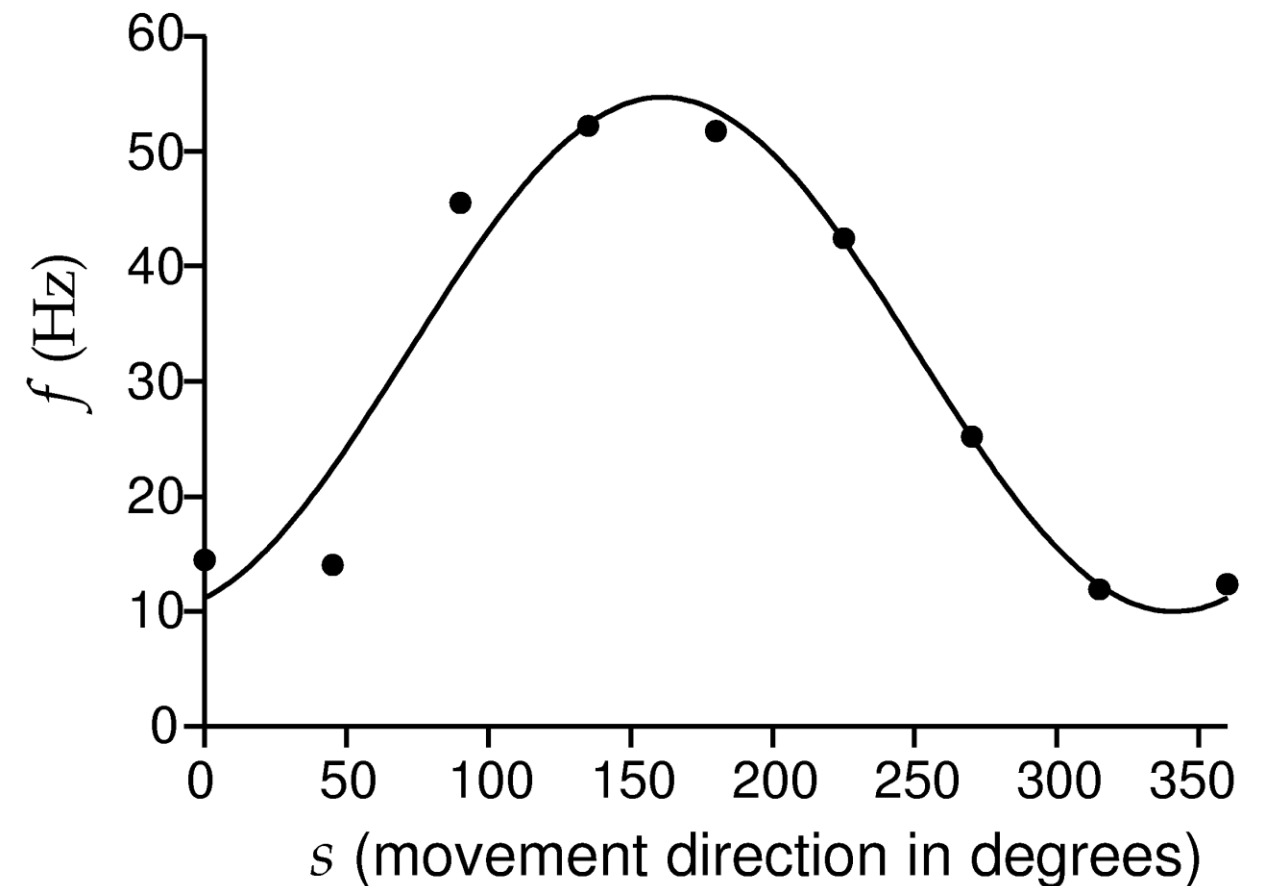
Gaussian tuning curve of a cortical (V1) neuron

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

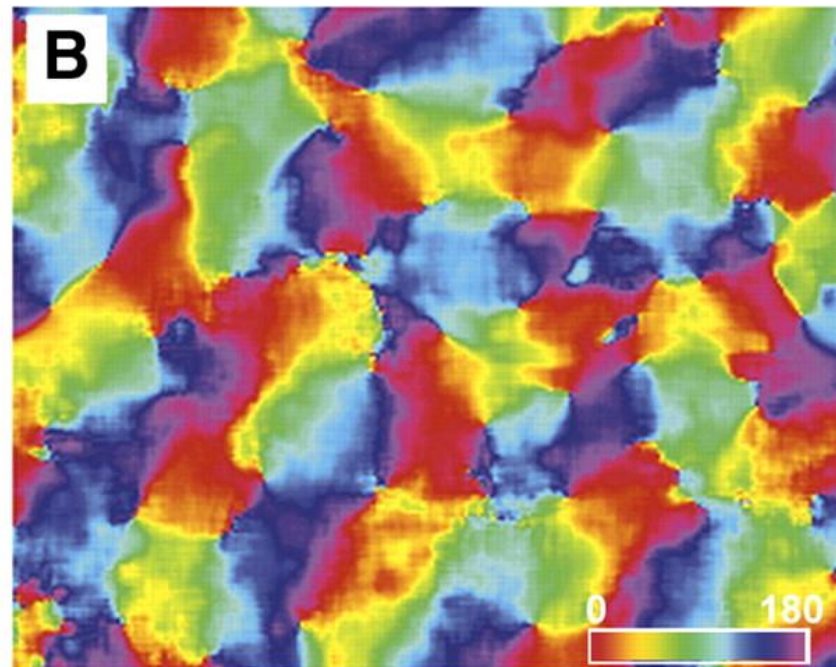
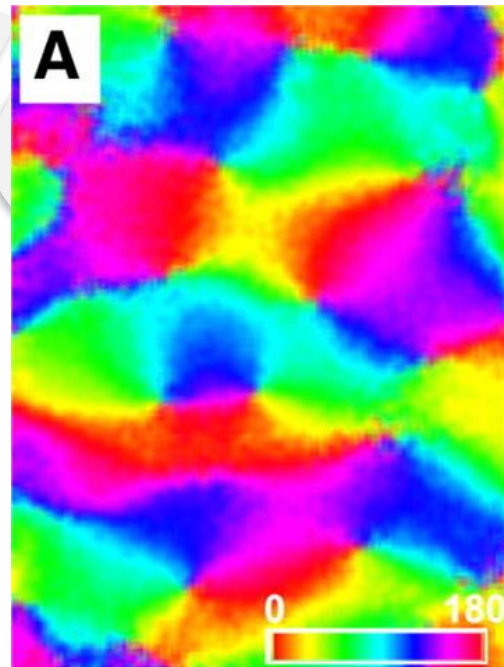
from Dayan and Abbott, *Theoretical Neuroscience*:
adapted from Georgopoulos et al. '92

Map of feature selectivity in primary visual cortex

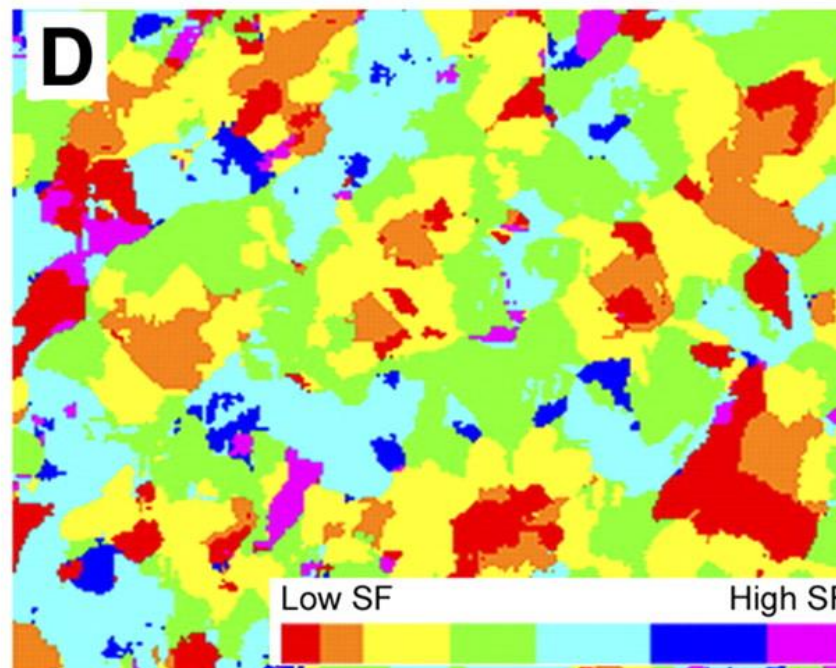
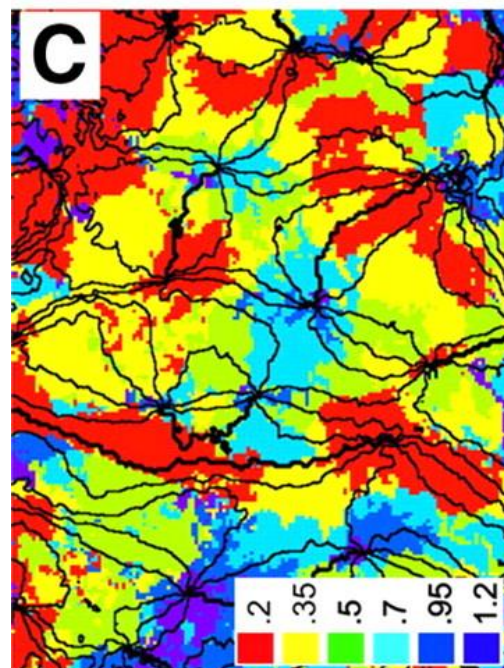
Cat

Bush baby

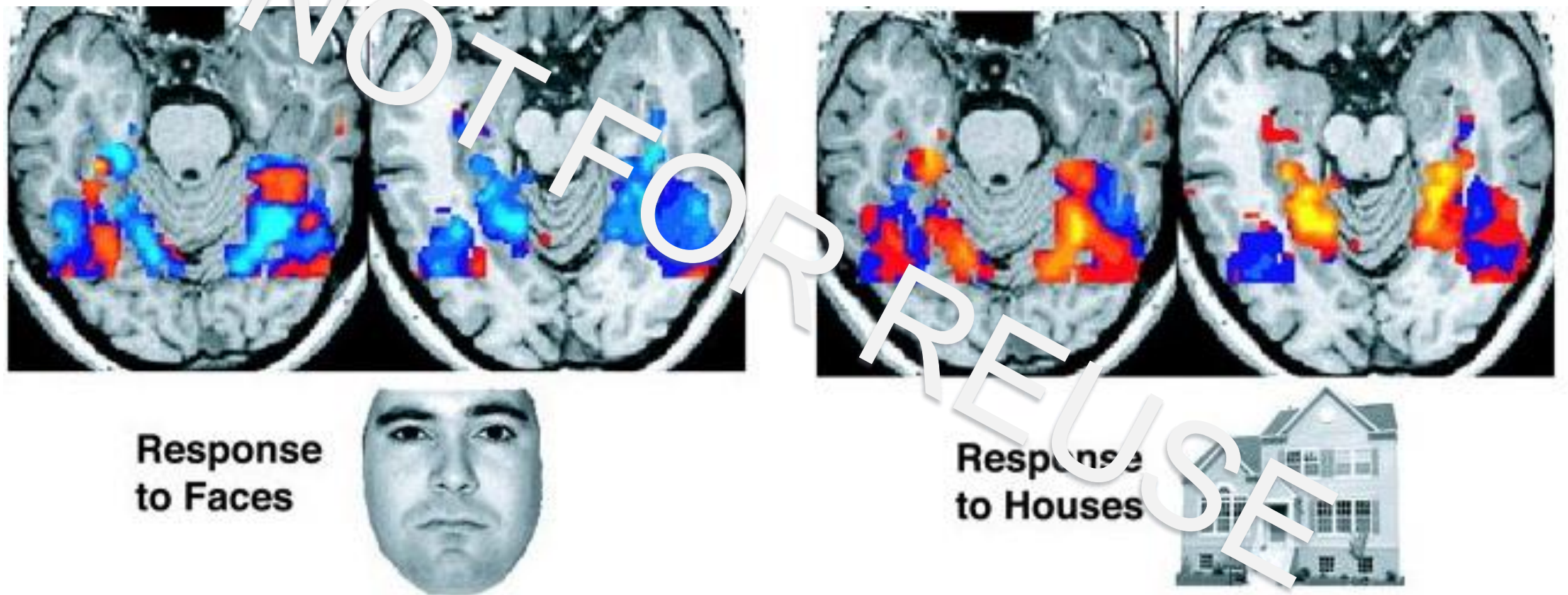
Orientation



Spatial frequency

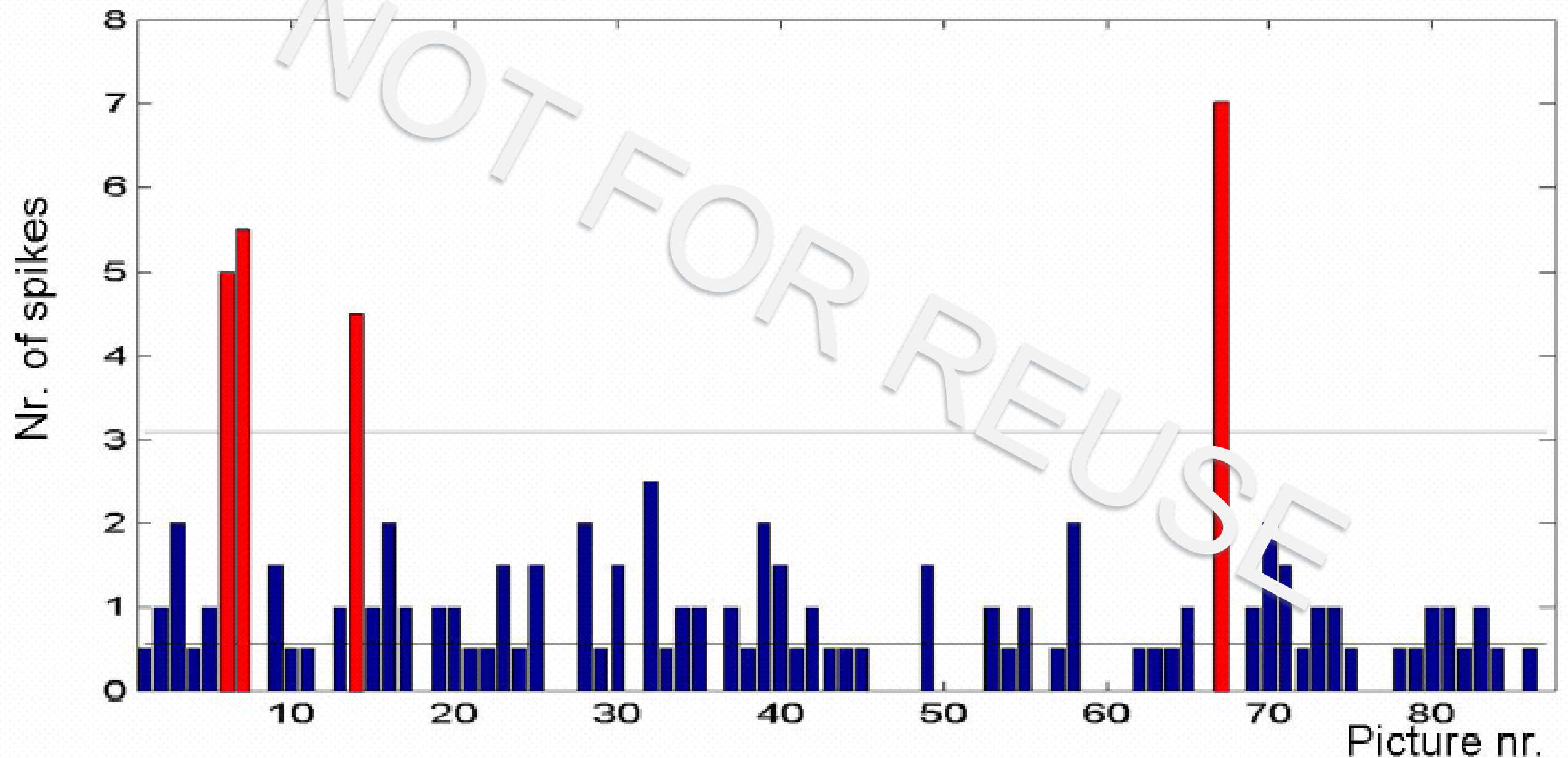


Higher order feature selectivity



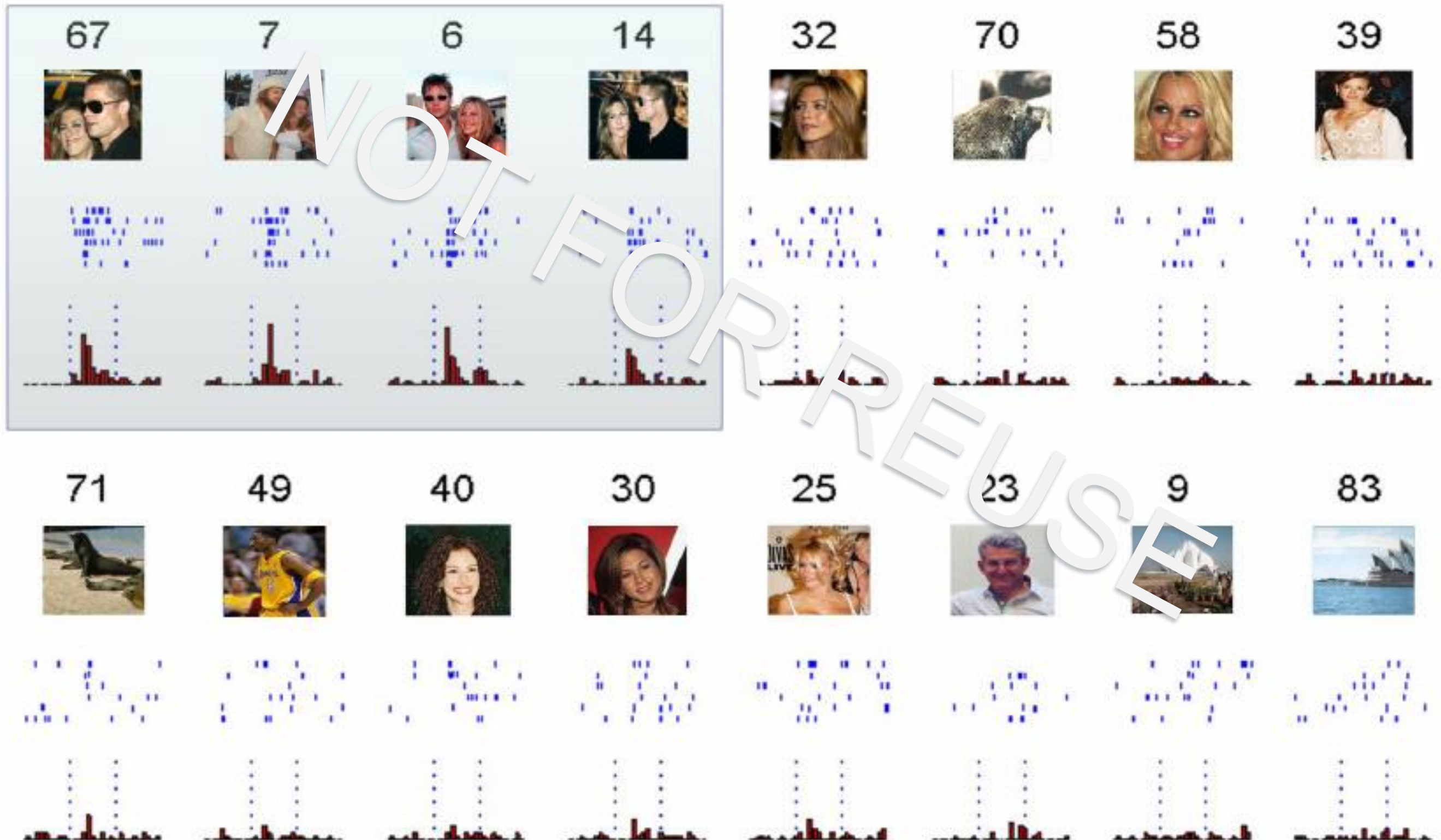
Haxby et al., *Science* (2001)

“Tuning curves”



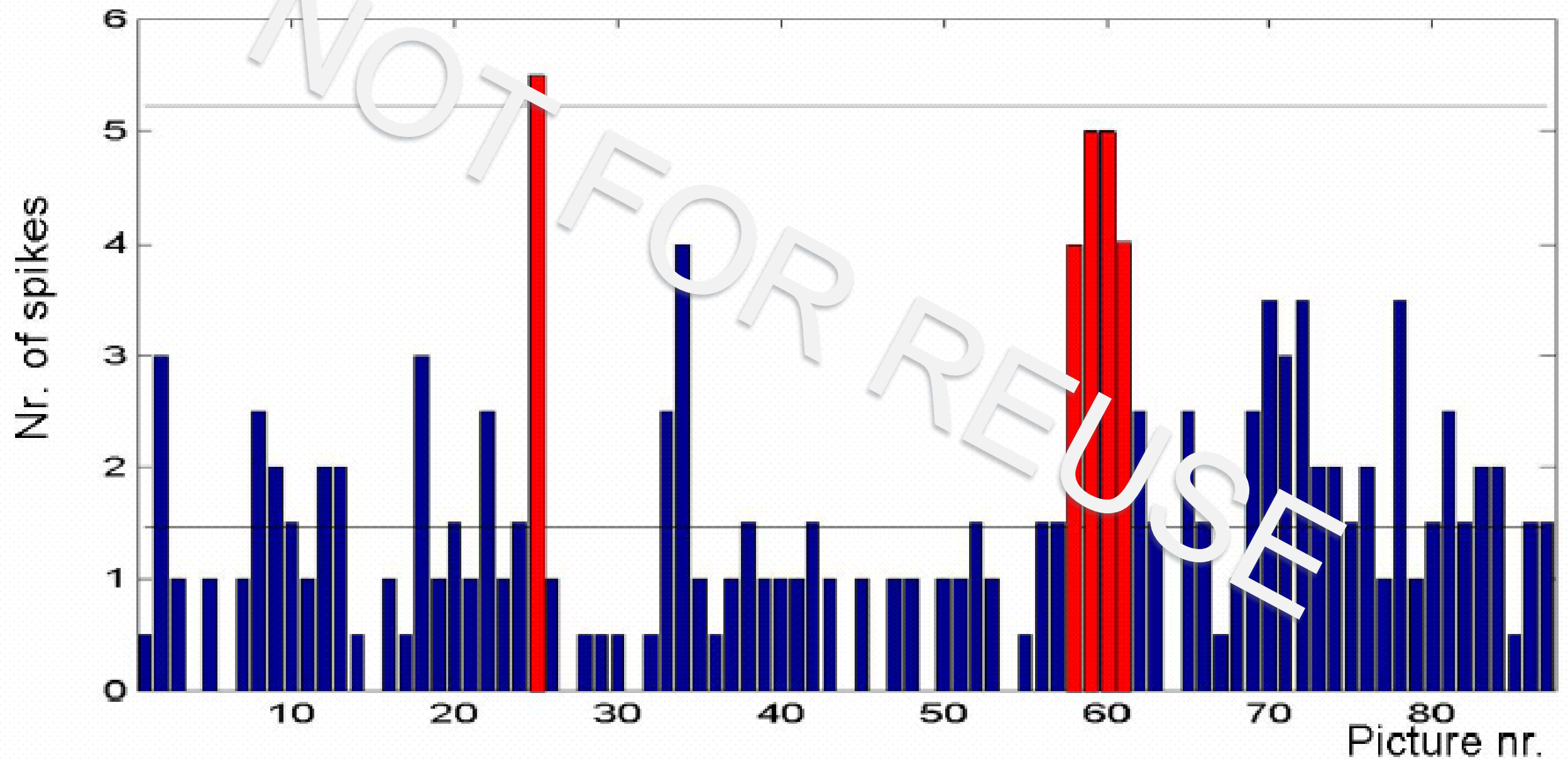
Quian Quiroga, Reddy, Kreiman, Koch and Fried, *Nature* (2005)

What is the stimulus s ?



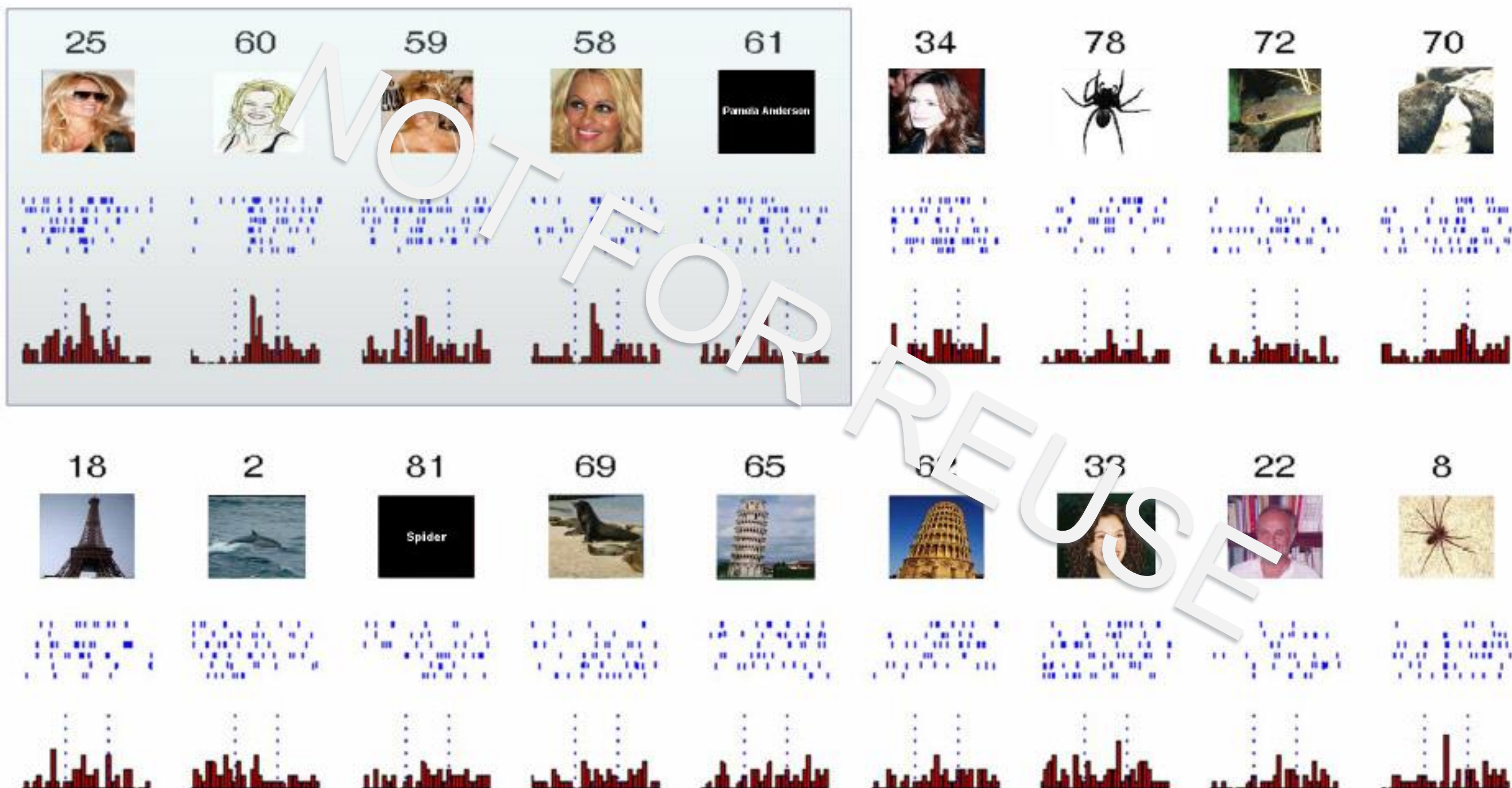
Quian Quiroga, Reddy, Kreiman, Koch and Fried, *Nature* (2005)

Tuning curves



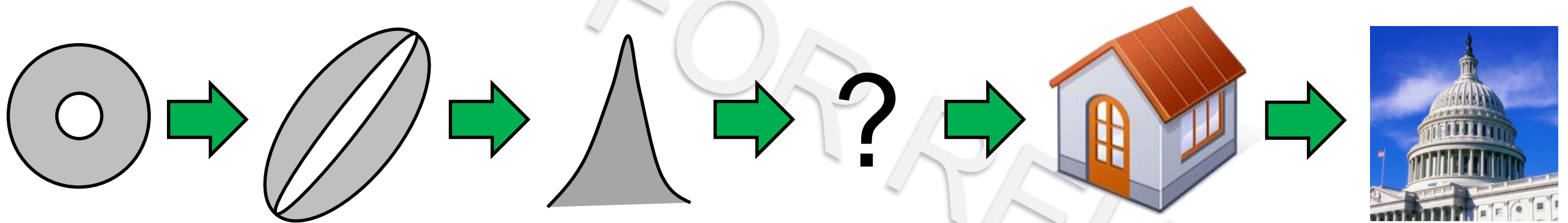
Quian Quiroga, Reddy, Kreiman, Koch and Fried, *Nature* (2005)

What is s ?



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

Building up complex selectivity



Top-down effects



Next up: constructing response models

$P(\text{response} \mid \text{stimulus})$