

Neuroeconomics:

Background and Methods I

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# Neuroeconomics



# Neuroeconomics

- Very short history
  - “First” paper in 2001 (McCabe et al. *PNAS*)
- Rests on assumption that we know enough about brain to study economic behavior
  - Some areas more tractable than others
  - Methodologically diverse (not just neuroimaging)



## Some History...

- Measuring percepts and behavior in the brain
  - Encoding of information in the brain
  - Neuronal rate codes
  - Various methods

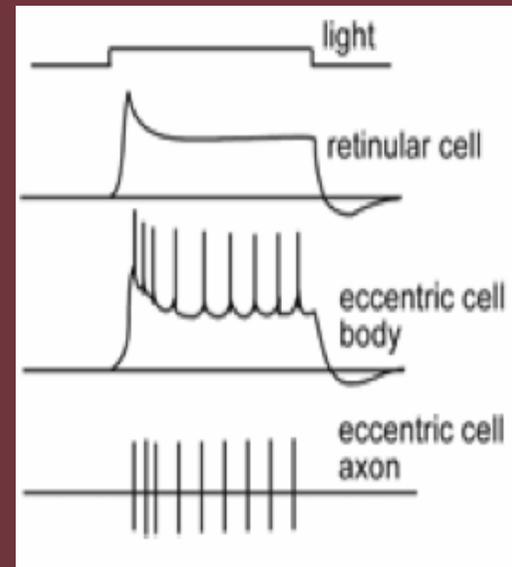
• • •  
Limulus “Crabcam”



Passaglia et al. Proc. Natl . Acad. Sci . USA 94

# Encoding of Information

- Encoded in neuron firings
  - Rate of spikes
  - Spike timing
  - Spatial variation of spikes
  - Spatial/temporal correlation of firing



# Intensity Code

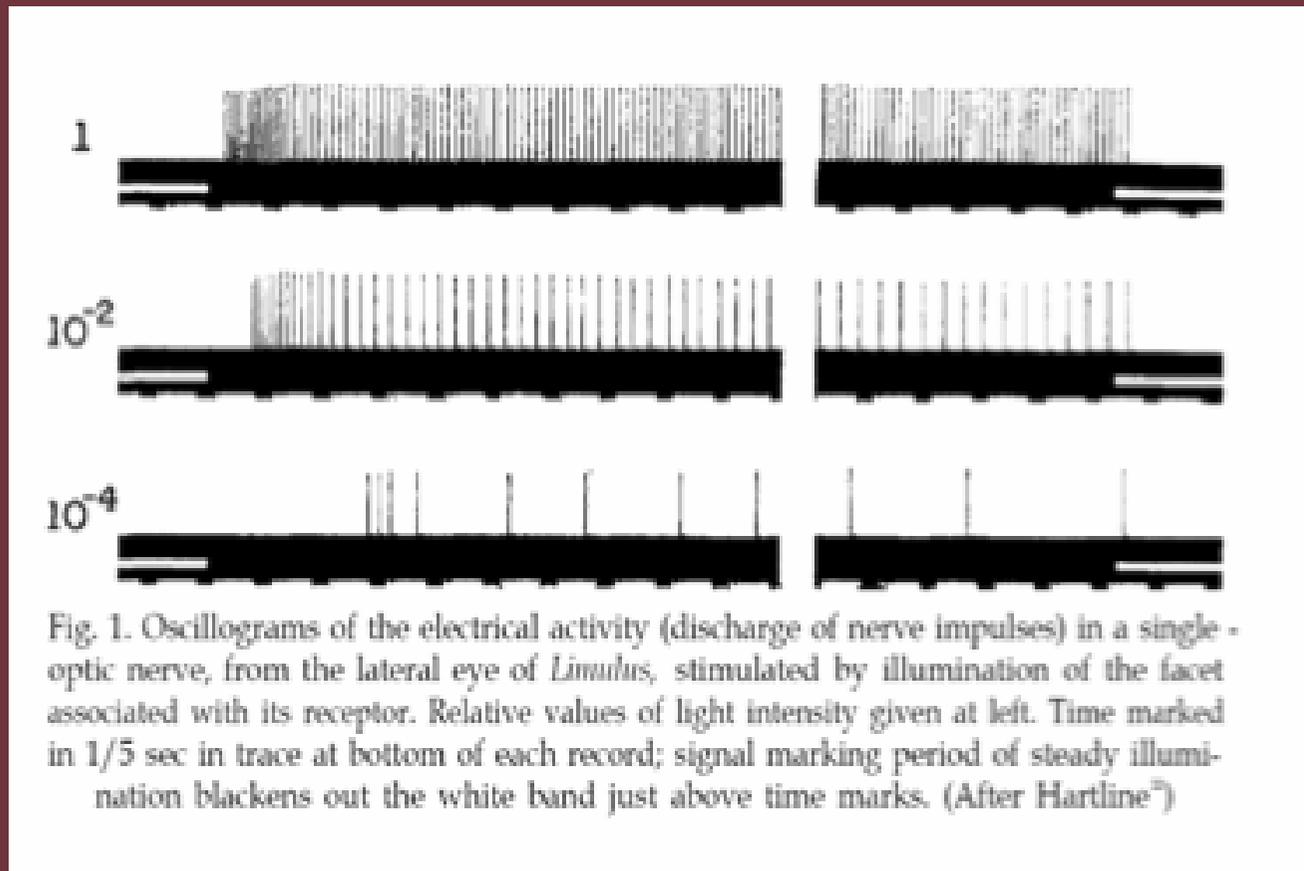
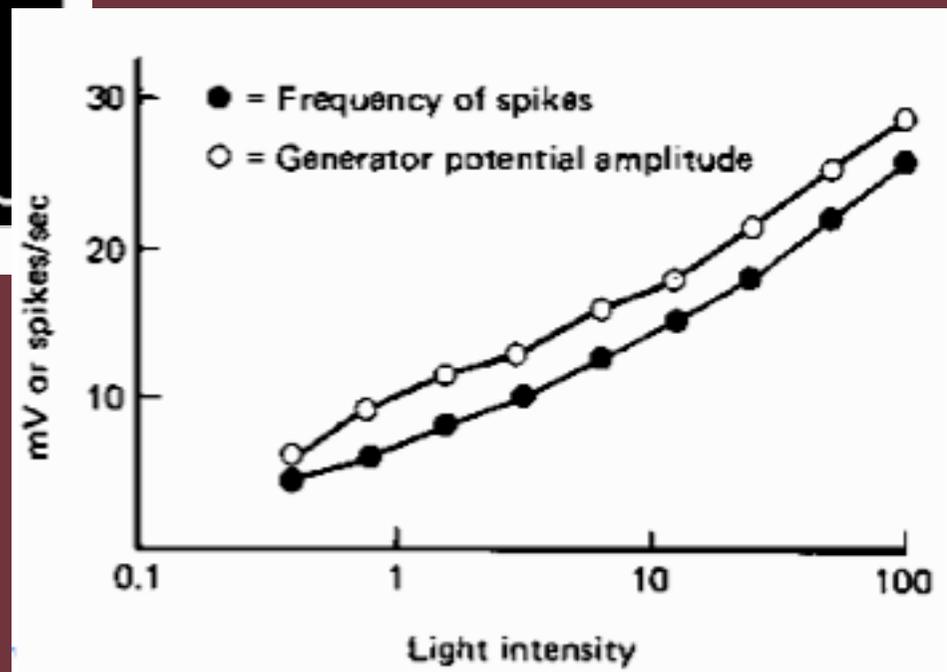
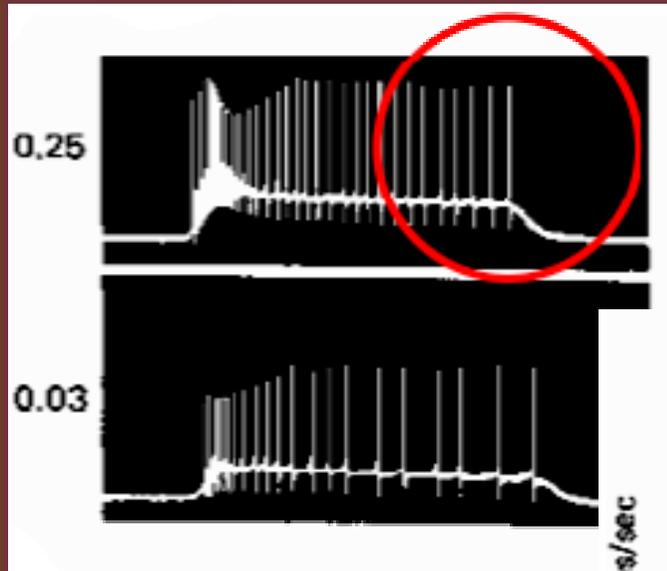
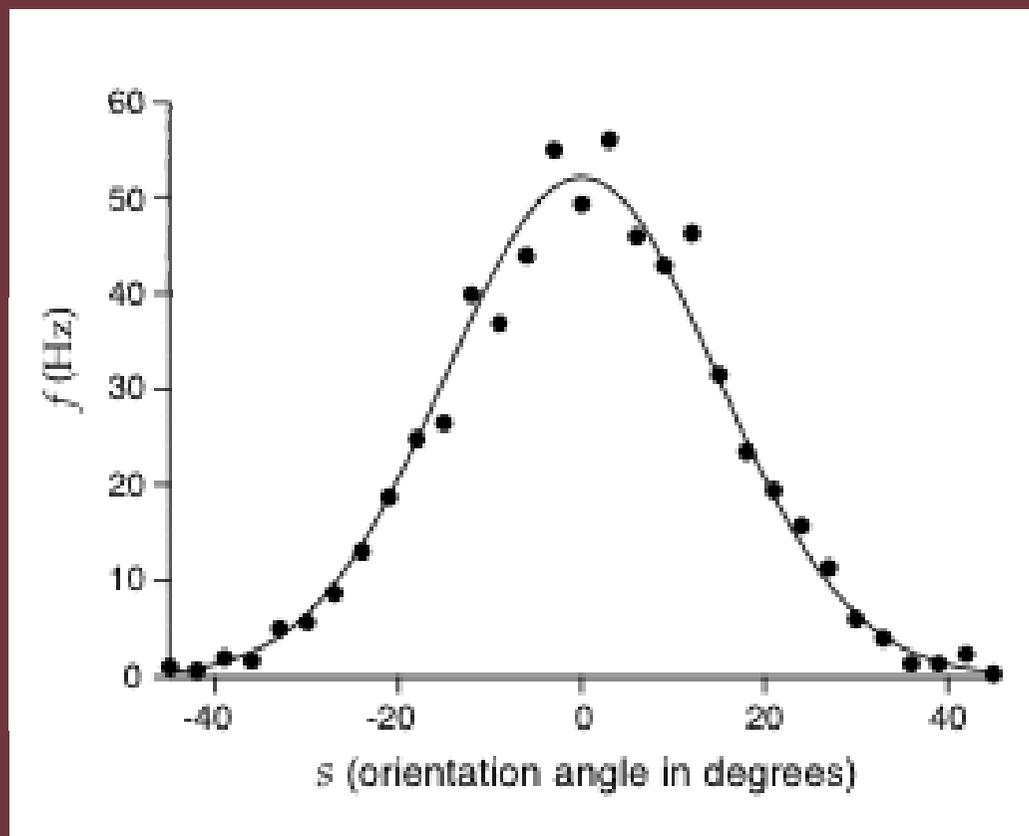


Fig. 1. Oscillograms of the electrical activity (discharge of nerve impulses) in a single optic nerve, from the lateral eye of *Limulus*, stimulated by illumination of the facet associated with its receptor. Relative values of light intensity given at left. Time marked in 1/5 sec in trace at bottom of each record; signal marking period of steady illumination blackens out the white band just above time marks. (After Hartline<sup>2</sup>)

## Sir Edgar Adrian's "Rate Code"

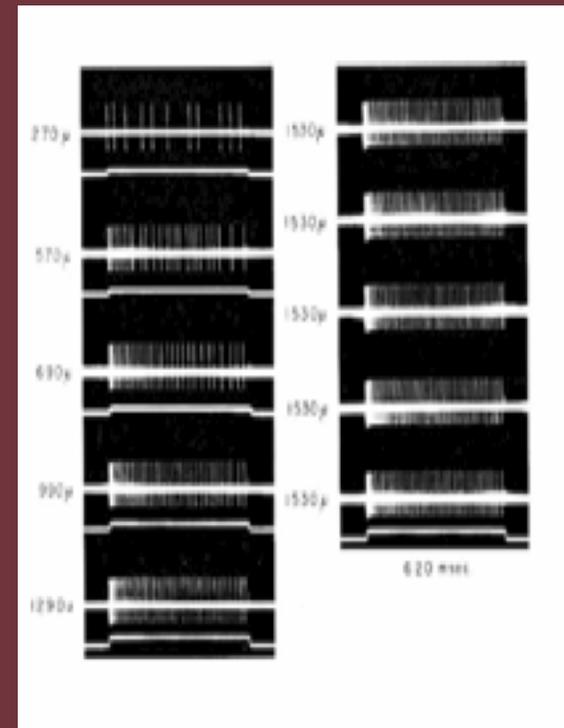


# Tuning Curves



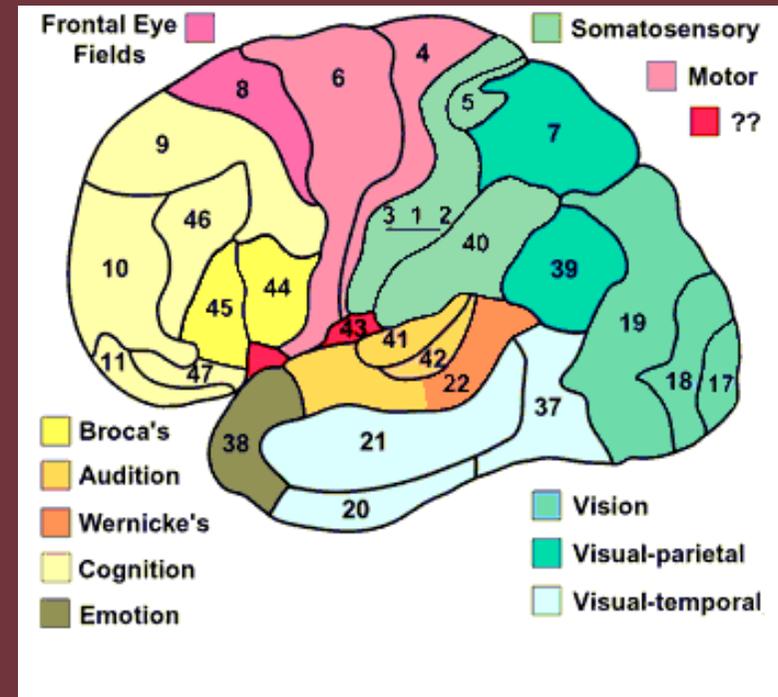
## Other Instances of Rate Codes

- Proprioception: skin receptor in primate in response to indentation.
- Olfactory receptor
- Taste
- Ampullary electroreceptor
- Hair cell of lateral line



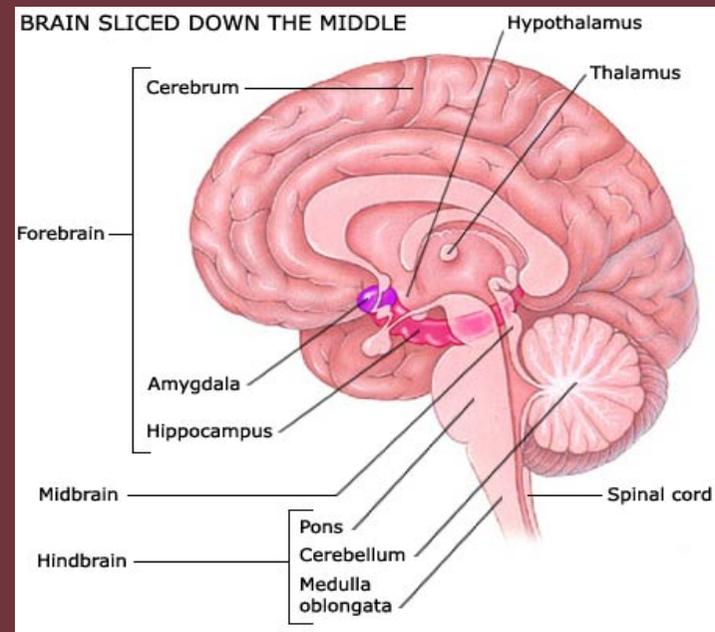
# The Brain

- Cortex is divided into 4 lobes:
  - Frontal lobe (higher intellectual functions, e.g. thinking, planning, decision-making)
  - Temporal lobe (speech, sound, complex visual perceptions)
  - Occipital lobe (vision)
  - Parietal lobe (sensory processes, attention, language)
- Various subcortical structures

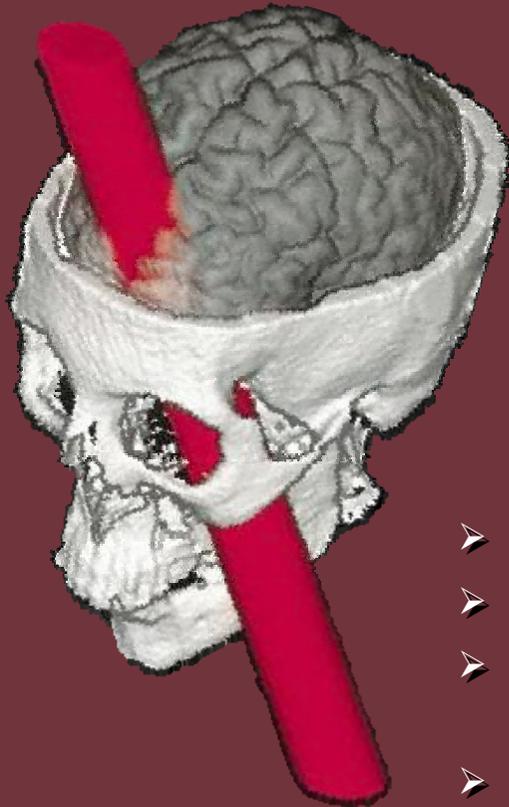


# The Brain

- The nervous system consists mainly of a particular kind of cells, neurons.
  - $\sim 10^{10}$  neurons in the brain
  - Up to 15,000 connections between neurons.
- Modularity
  - cortices, nuclei, sulci, gyri etc



# The Story of Phineas Gage



“...fitful, irreverent, indulging at times in the grossest profanity...”

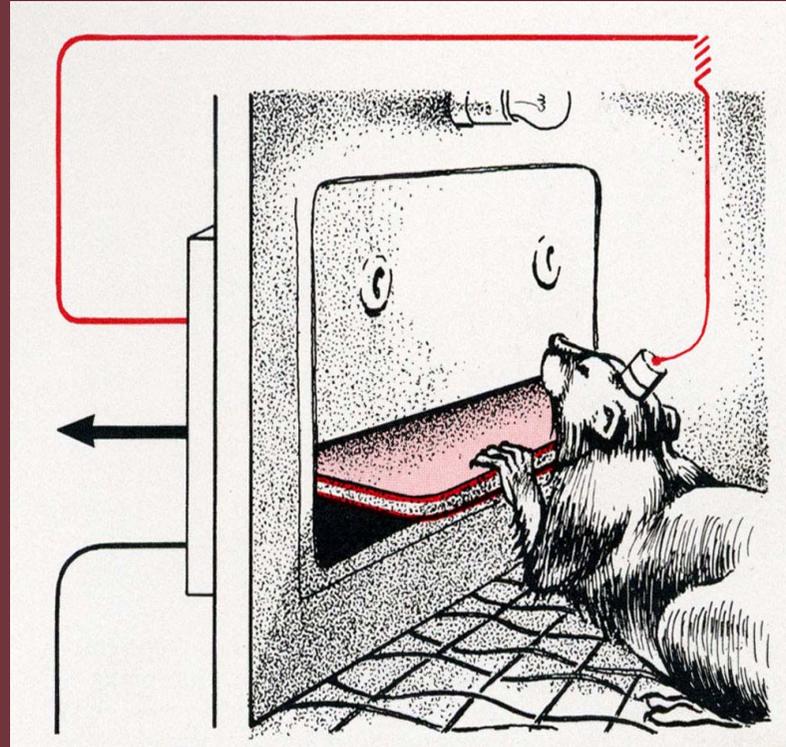
-- Gage's physician

- Impulsiveness
- Poor insight
- Impaired decision-making
- Both social and financial

Orbitofrontal Cortex

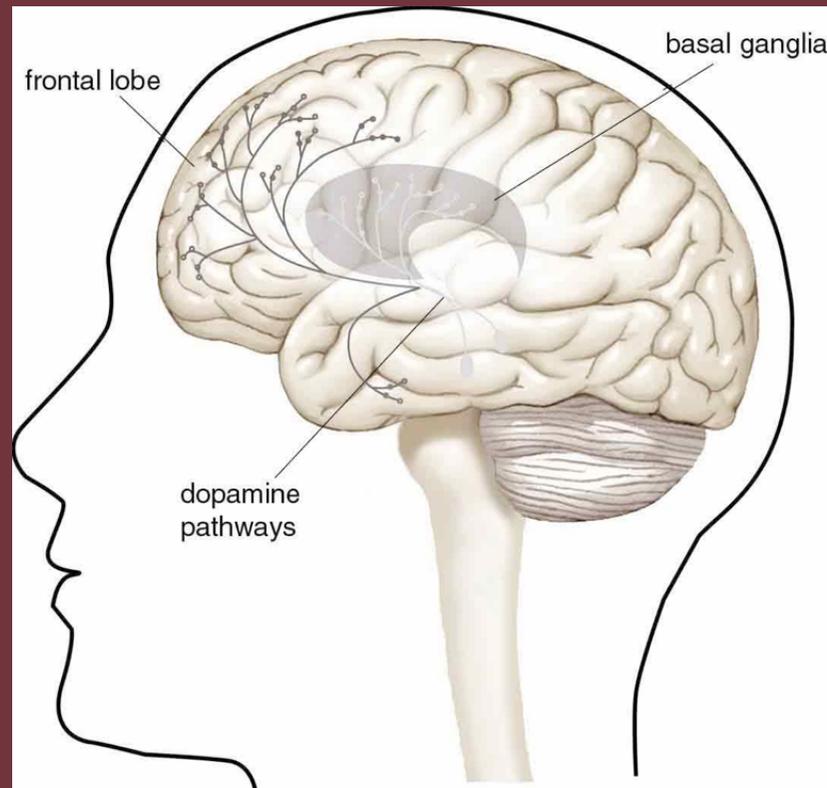


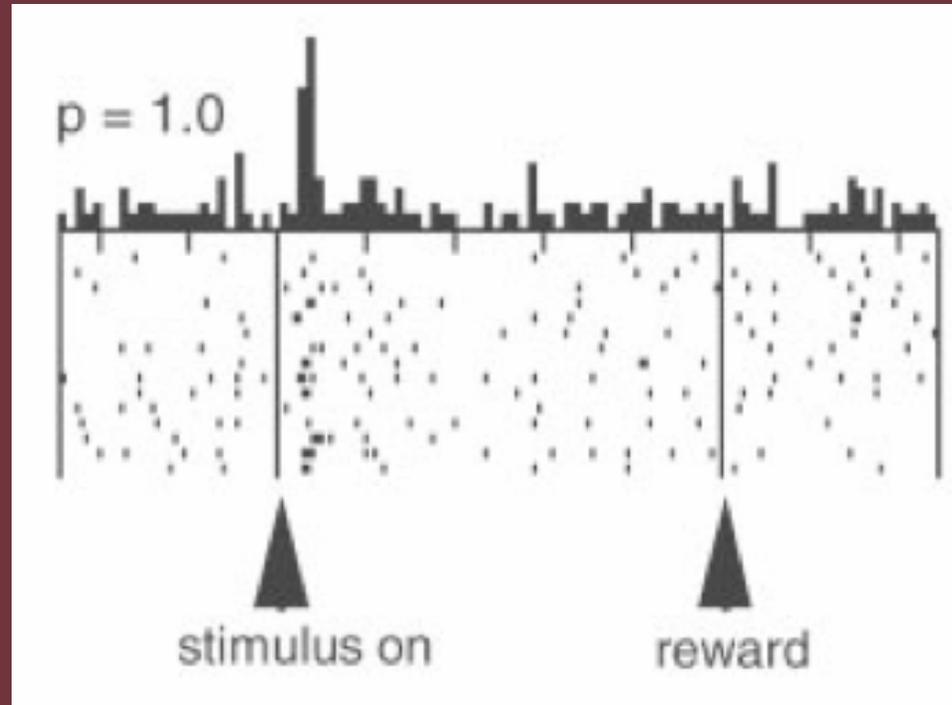
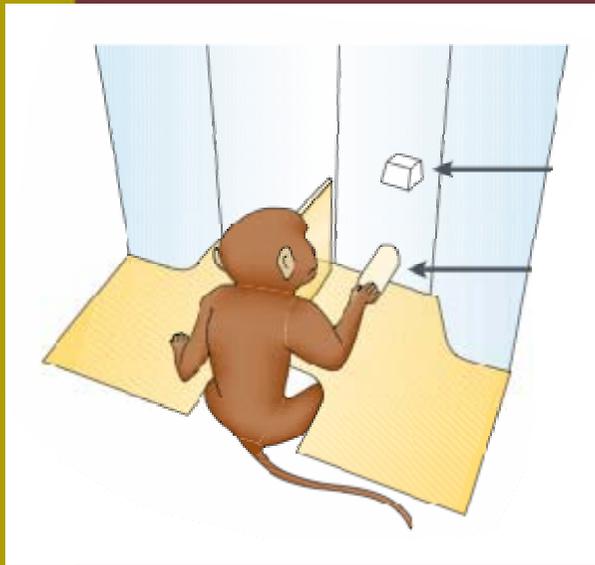
# Electrical Stimulation of Nucleus Accumbens



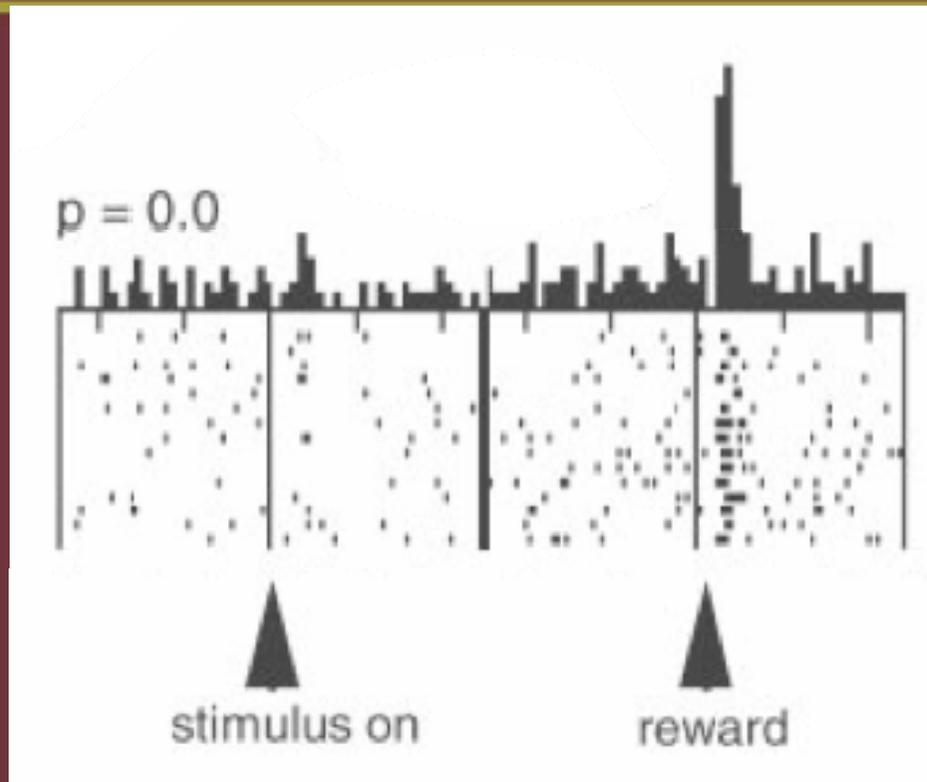
Olds and Milner, 1954

# Reward Learning and Dopamine

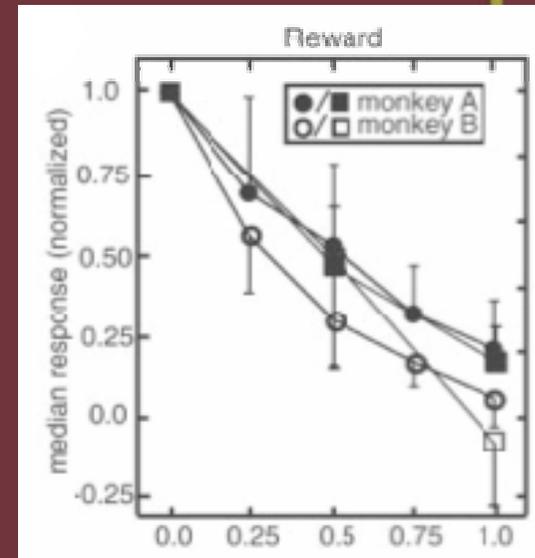
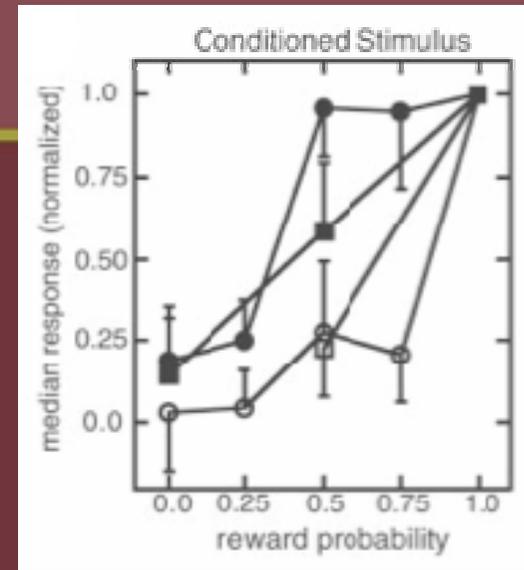
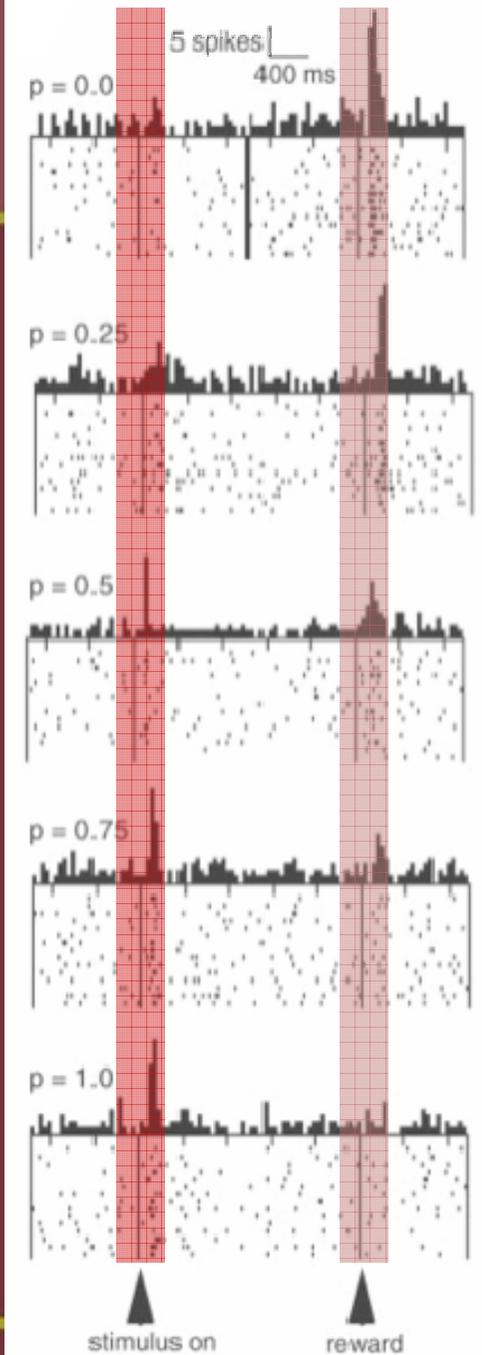




Fiorillo, Tobler, and Schultz. *Science*. (2003)



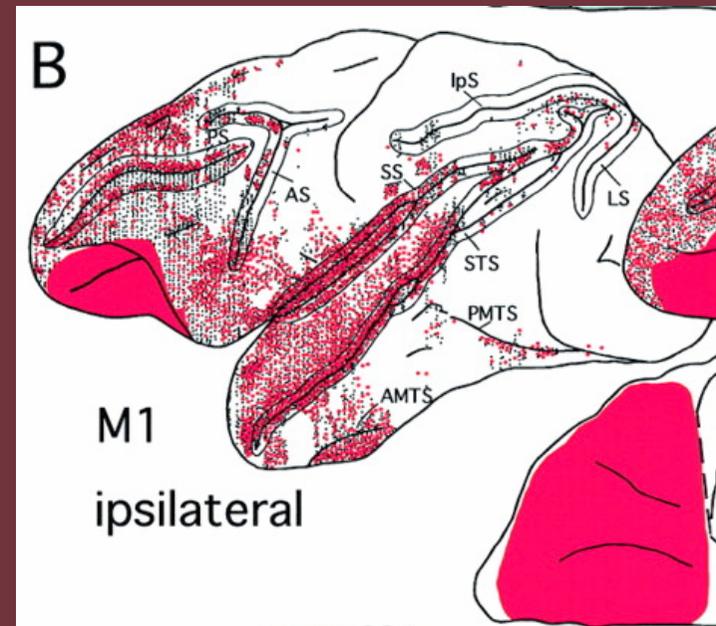
Fiorillo, Tobler, and Schultz. *Science*. (2003)



# Orbitofrontal Cortex (OFC)



Human OFC



Macaque OFC

Choice

QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

Cell response

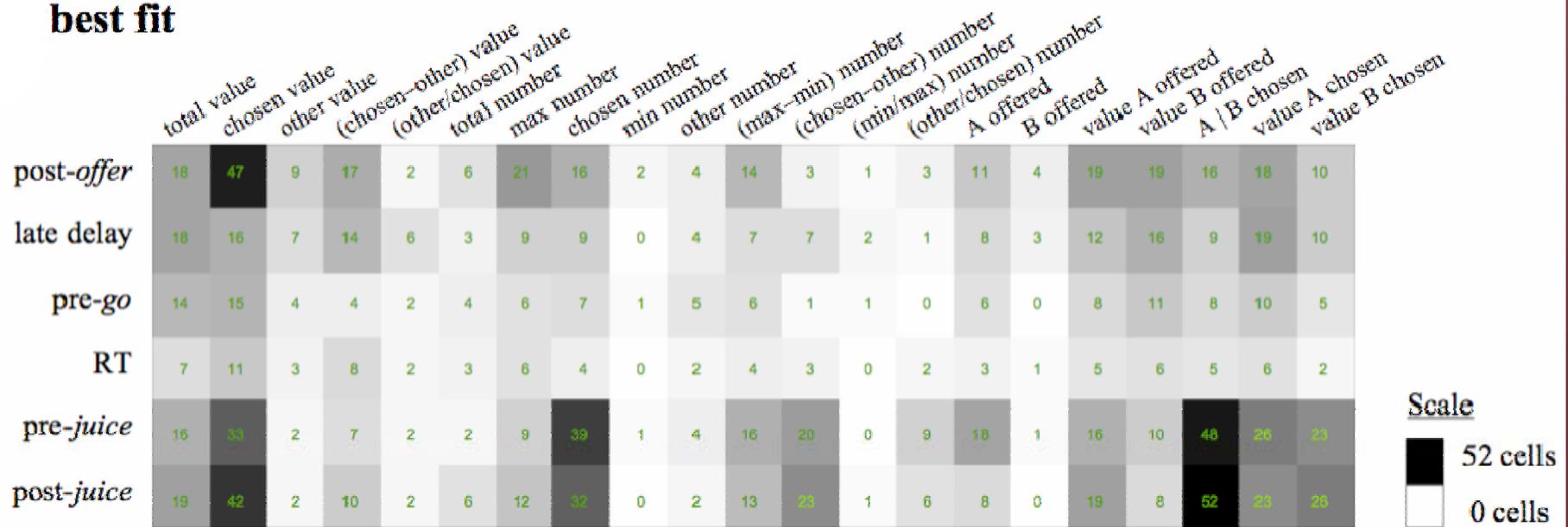
QuickTime™ and a  
TIFF (LZW) decompressor  
are needed to see this picture.

Correlate with #A

Correlate with choice

Padoa-Schiapo and Assad (Nature 2006)

## best fit



Padoa-Schiapo and Assad (Nature 2006)

# Why Do We Care As Economists?

- Because all behavior must originate in the brain.
- Known brain regions associated with specific economic variables.



## Why Do We Care As Economists?

- Things we can learn:
  - The mechanisms behind economic behavior.
  - Expand set of inputs to our models.
  - Help provide insight to existing paradoxes/models.
  - Similar to what how a scientist might study vision/olfaction.

# Why Do We Care As Economists?

- Things we can contribute:
  - Conceptual: decision theory, game theory, applied micro.
    - Without SEU, we would likely not consider ambiguity aversion a “paradox”.
  - Methodology: experimental and econometric.

# Fundamental Assumptions

- **Psychophysics (Boynton et al. 1999)**
  - Subjects' perception/choice result of neuronal responses
  - Neuron  $\Rightarrow$  Behavior
  - Same in neuroeconomics
- **Lots of tools**
  - Including fMRI

# Tools to Measure Brain Activity

## fMRI

Non-invasive  
Good spatial and temporal resolution (compared to other imaging methods, e.g. PET)  
Indirect measurement of neuronal activity

## Neurophysiology recordings

Invasive (mostly on animals)  
Directly measures firing of neurons  
High spatial and temporal resolution

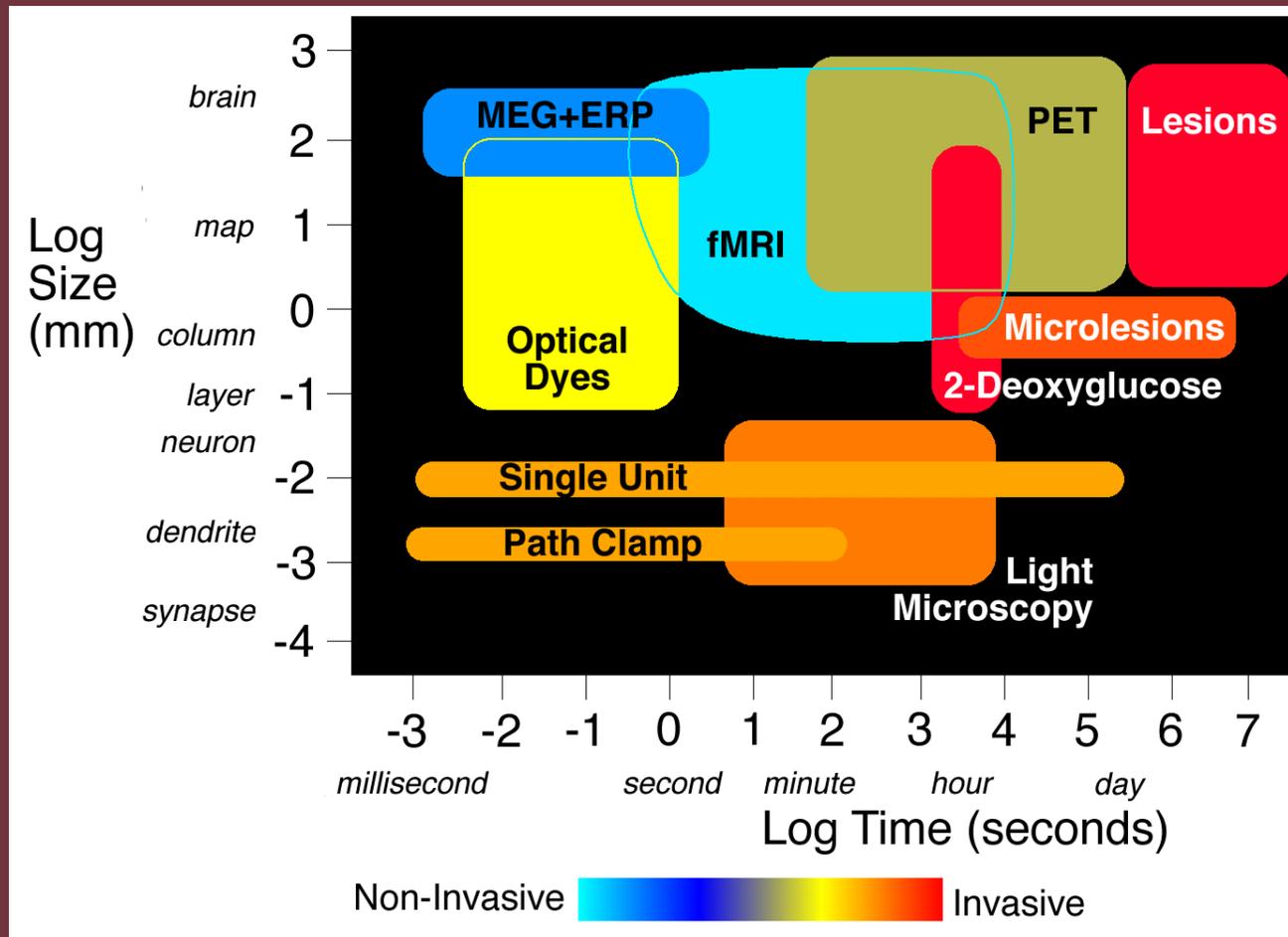
## Lesion

High-invasive!  
Limited by misfortunate events in the world  
Assess necessity of neural structure for behavior

## Drug Manipulations

Invasive  
Tough ethics standards  
Can assess sufficiency, with some caveats

# Measurements of Brain Activity

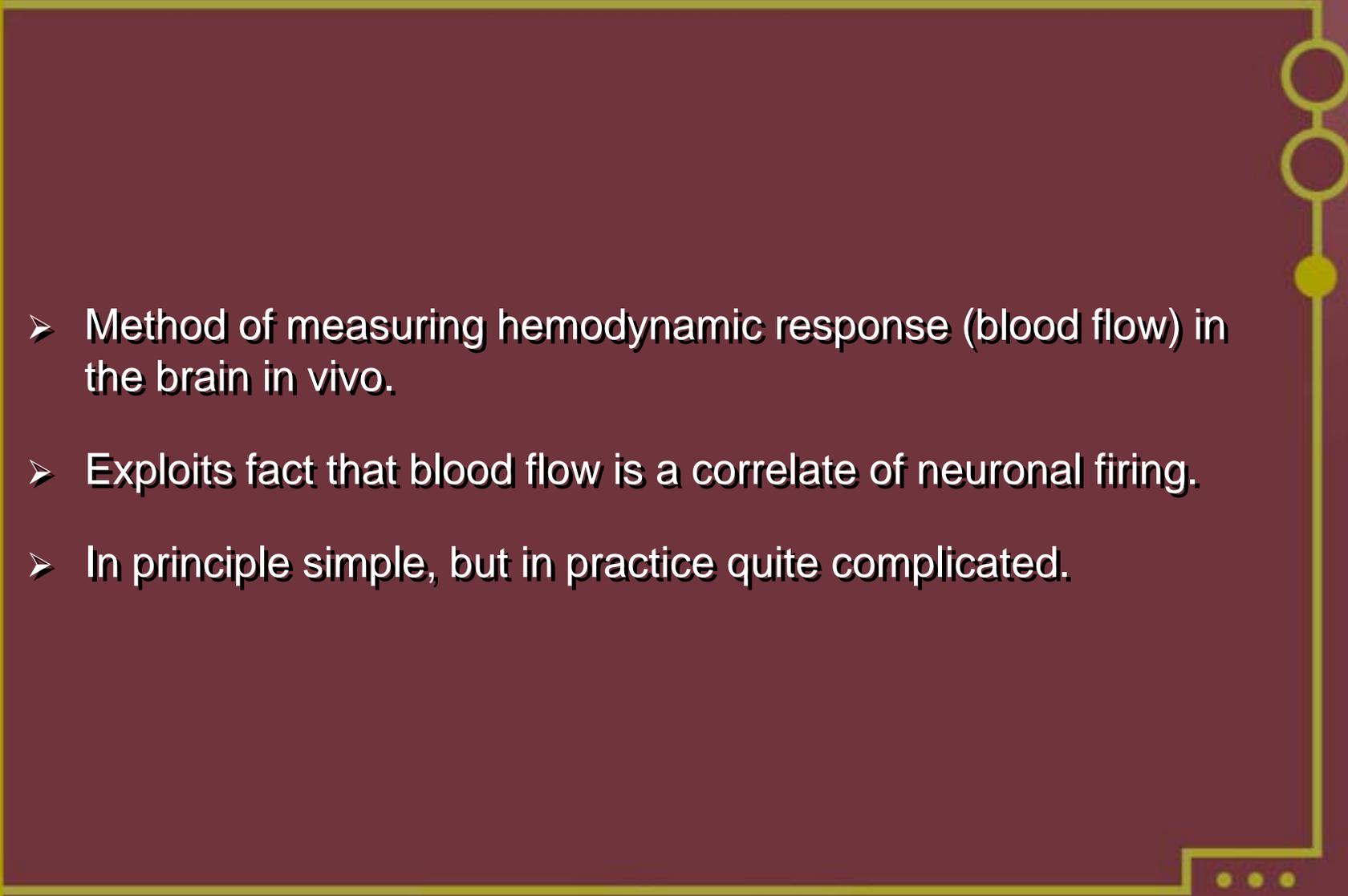


## Use of fMRI to study neural correlates of behavior

- Assumptions
  - Subjects' perception/behavior result of neuronal responses (neuron  $\Rightarrow$  behavior)
  - fMRI responses proportional to local average neuronal activity (neuron  $\Rightarrow$  BOLD)



# Functional Magnetic Resonance Imaging



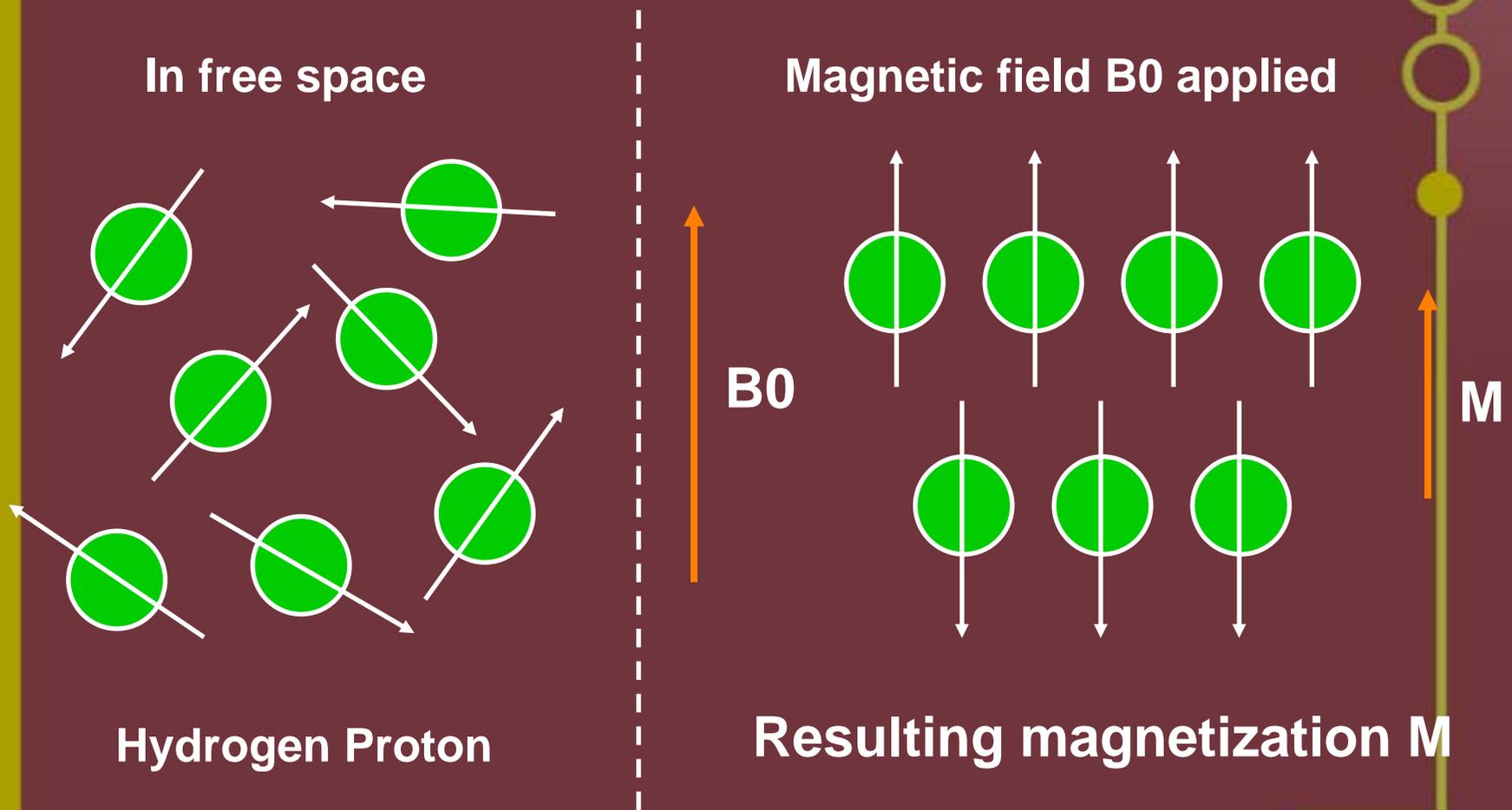
- Method of measuring hemodynamic response (blood flow) in the brain in vivo.
- Exploits fact that blood flow is a correlate of neuronal firing.
- In principle simple, but in practice quite complicated.

# fMRI Scanner

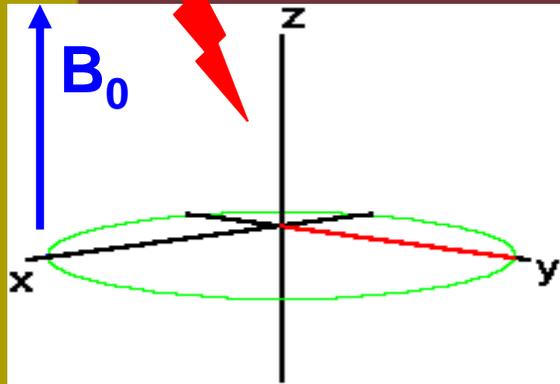


Stimulus display + image acquisition

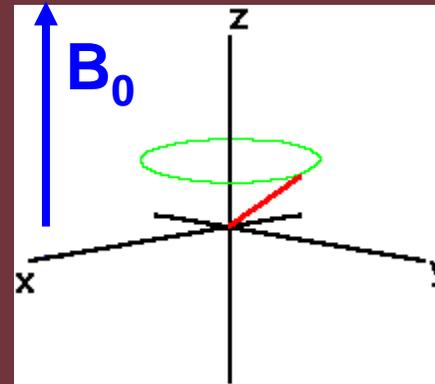
# Physics of fMRI



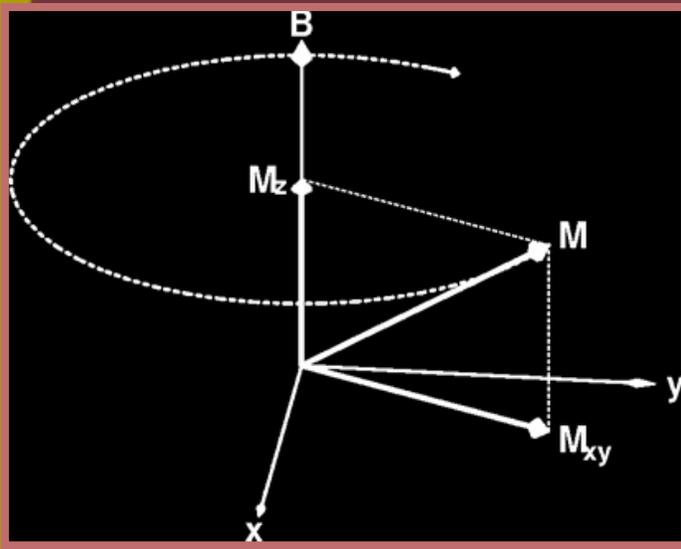
# Physics of fMRI



pulse



Spin rotates around  $B_0$  at the Larmor frequency



- Part of M parallel to  $B_0$  grows back [ $M_z$ ]  
→ longitudinal magnetization

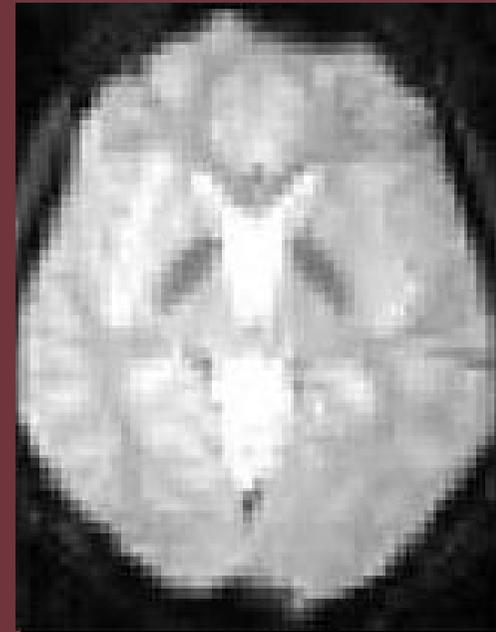
- Part of M perpendicular to  $B_0$  shrinks [ $M_{xy}$ ]  
→ transverse magnetization

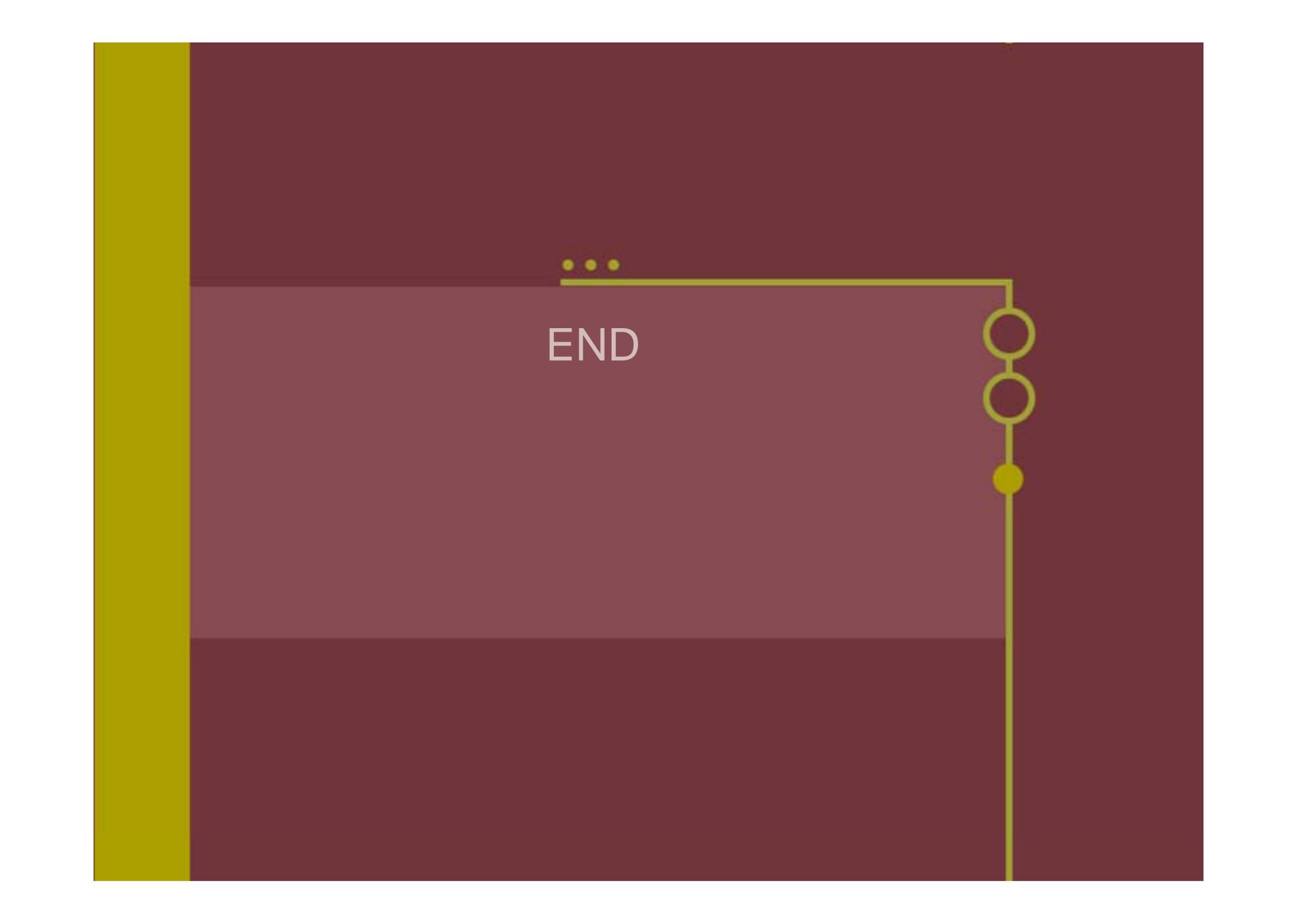
T1: relaxation of M back to alignment with  $B_0$

T2: intrinsic decay of the transverse magnetization

# Magnetic Susceptibility

- **MRI**
  - Different tissues have different T2 values:
  - hemoglobin is diamagnetic when oxygenated and paramagnetic when deoxygenated
- **Functional MRI**
  - Blood Oxygenation Level Dependent (BOLD) images
  - Changes in magnetic properties over time





END