COGS 101A: Sensation and Perception

Virginia R. de Sa

Department of Cognitive Science

UCSD

Lecture 1:

Introduction, Administration, Motivation, Chapter 1

Course Information

- Class web page: http://cogsci.ucsd.edu/~desa/101a/index.html
- Professor: Virginia de Sa
  - ⋆ I'm usually in Chemistry Research Building (CRB) 214 (also office in CSB 164)
  - ⋆ Office Hours: to be determined
  - ⋆ email: desa at ucsd
  - ⋆ Research: Perception and Learning in Humans and Machines

At your Assistance

TAS:

- Jelena Jovanovic
- Katherine DeLong

IAS:

- Jennifer Becker
- Lydia Wood

We will discuss office hours at the next class

Course Goals

- To appreciate the difficulty of sensory perception
- To learn about sensory perception at several levels of analysis
- To see similarities across the sensory modalities
- To become more attuned to multi-sensory interactions

Grading Information

- 25% each for 2 midterms
- 32% comprehensive final
- 3% each for 6 lab reports - due at the end of the lab
- Bonus for participating in a psych or cogsci experiment AND writing a paragraph description of the study

You are responsible for knowing the lecture material and the assigned readings. Read the readings before class and ask questions in class.

Academic Dishonesty

The University policy is linked off the course web page.

You will all have to sign a form in section

For this class:

- Labs are done in small groups but writeups must be in your own words
- There is no collaboration on midterms and final exam

Proposed Schedule

is on the webpage

Introduction to/Review of the Visual System: Outline

- Show you different techniques to studying the visual system (at different levels of analysis)
- Anatomy and Physiology of the visual system
- Show you evidence of top-down processing
- Echo concepts from Chapter 1

Which is harder for us to do?

Program a computer to play chess at the Grand Master level

or

Program a computer to have vision as good as a 2 year old

Which is harder for us to do?

Program a computer to play chess at the Grand Master level

or

Program a computer to have vision as good as a 2 year old

- Vision is hard
- Vision is much more than the eye.

Newly-sighted adults "see but don't see" – Vision is more than the eye

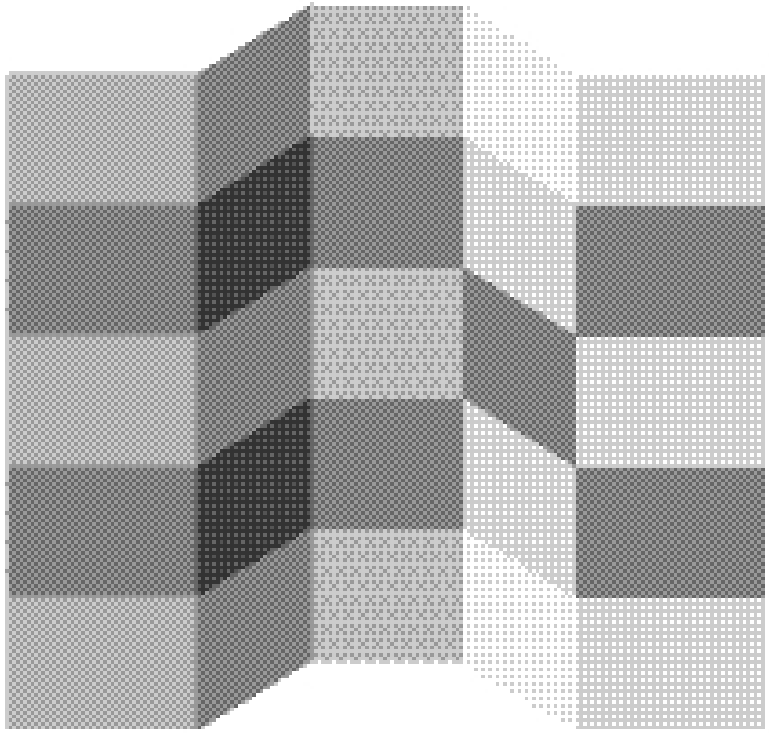
"Having often forgot which was the Cat, and which the Dog, he was asham'd to ask; but catching the Cat (which he knew by feeling) he was observ'd to look at her steadfastly and then setting her down, said, So Puss! I shall know you another Time'." [Cheselden, 1728]

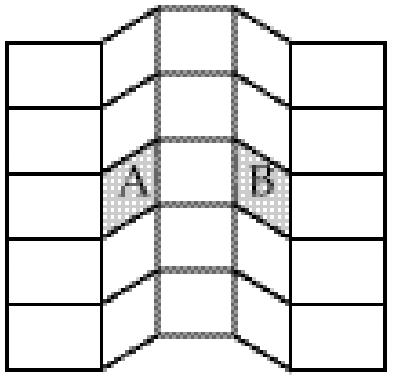
"When ... the experiment was made of giving her a silver pencil case and a large key to examine with her hands; she discriminated and knew each distinctly; but when they were placed on the table, side by side, through she distinguished each with her eye, yet she could not tell which was the pencil case and which was the key." [Wardrop 1827]

"Thus, for patient TG, telling a circle from a square, or either from a triangle was very difficult; he had to stare at the angles, one at a time, engaging in what we have called "scanning", to do it." [Valvo 1971]

Why is vision hard

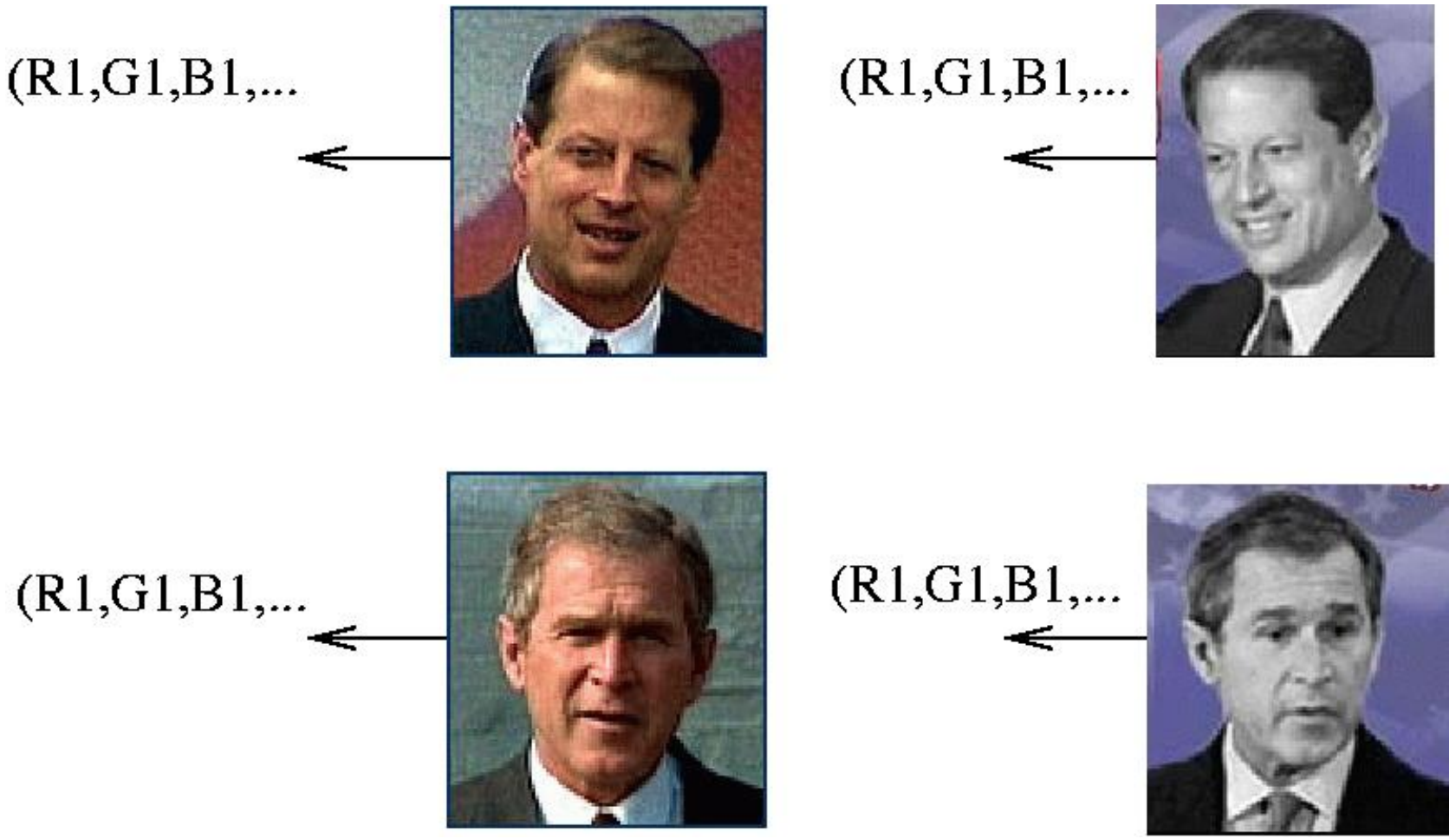
Vision is hard because there are an infinite number of 3D scenes that could give rise to a particular 2D image





from http://aris.ss.uci.edu/cogsci/personnel/hoffman/adelson-illusion.html
devised by Ted Adelson (see http://web.mit.edu/persci/gaz/)

Why is object recognition hard?



The Eye

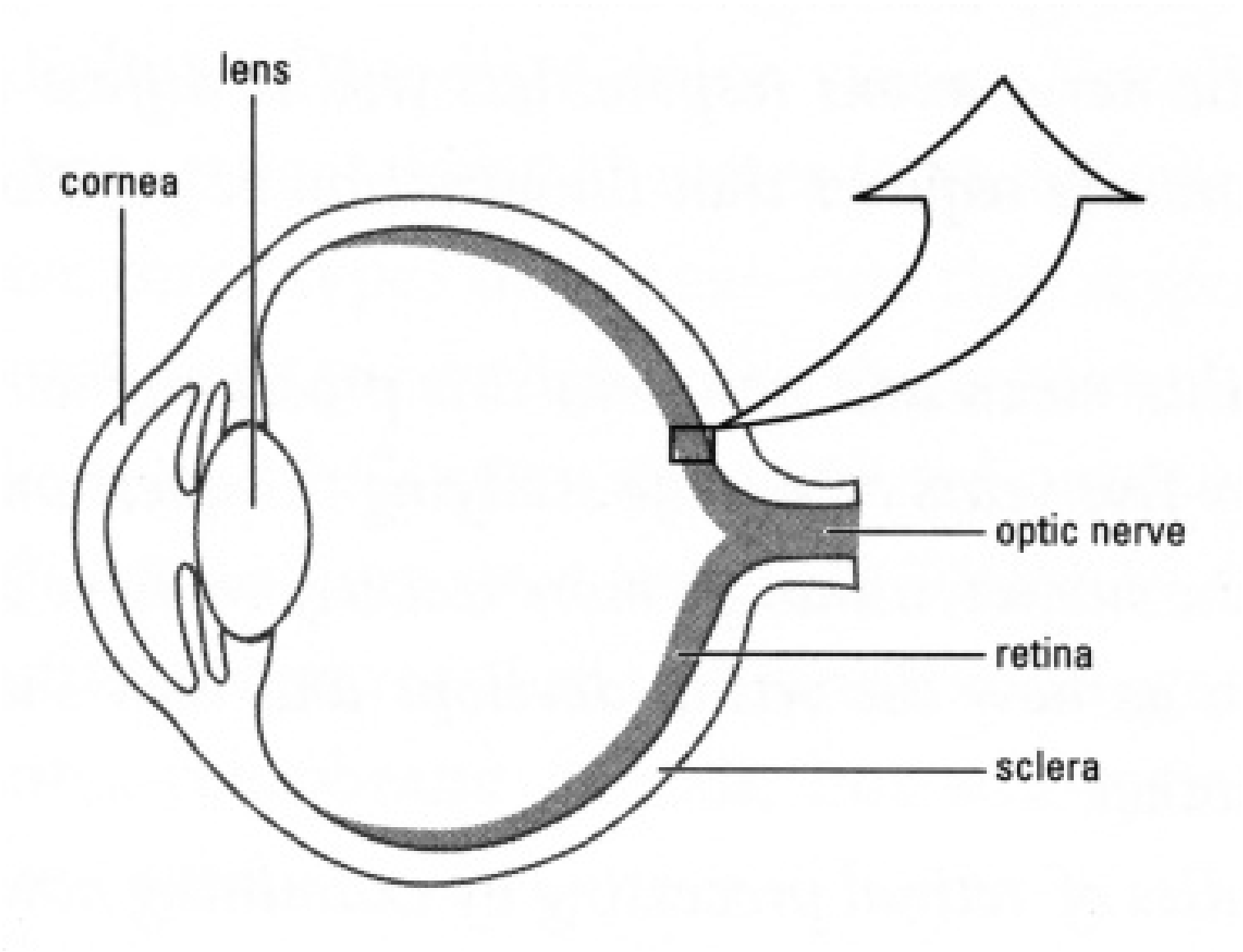


Figure from the web (lost ref)

The Eye

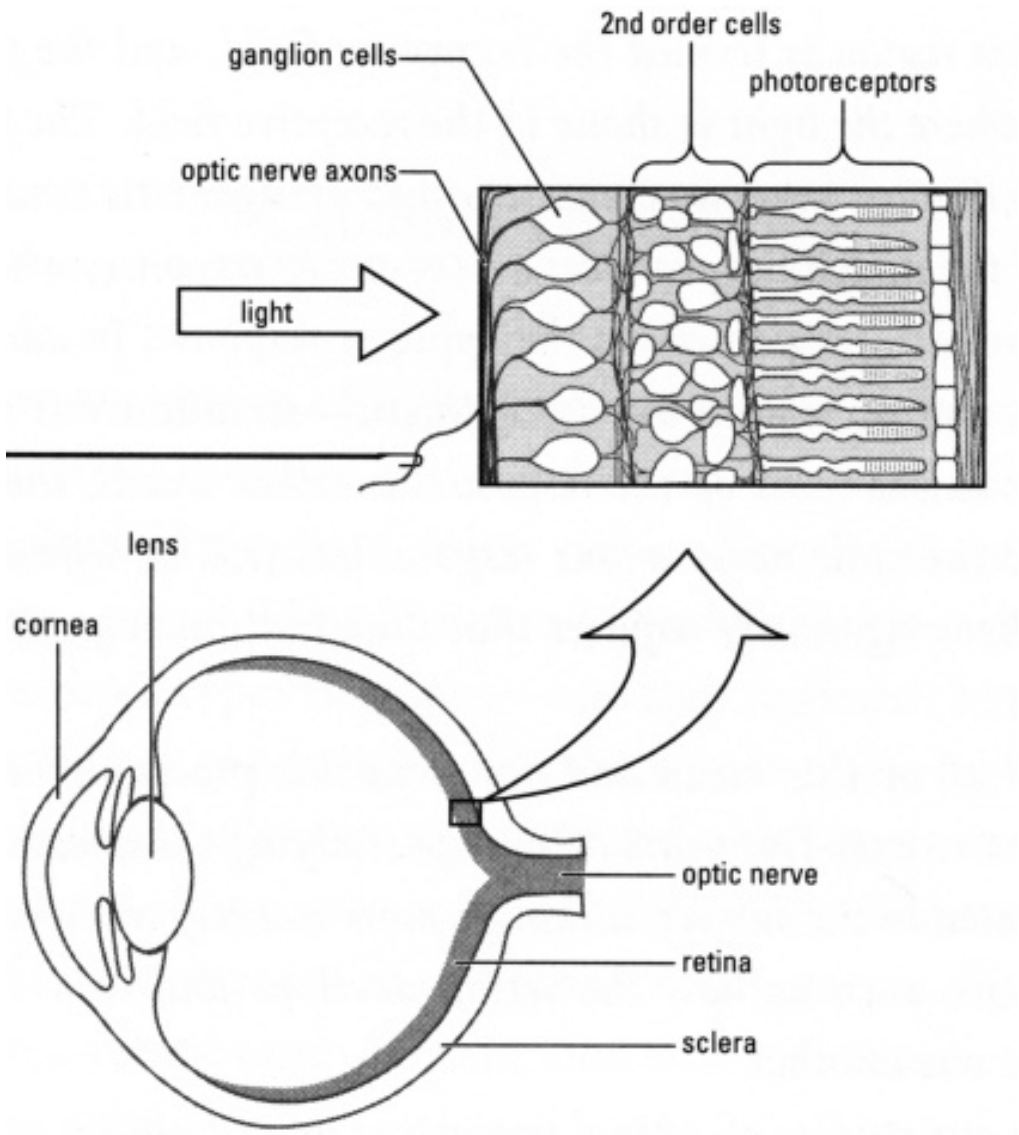


Figure from the web (lost ref)

The Eye

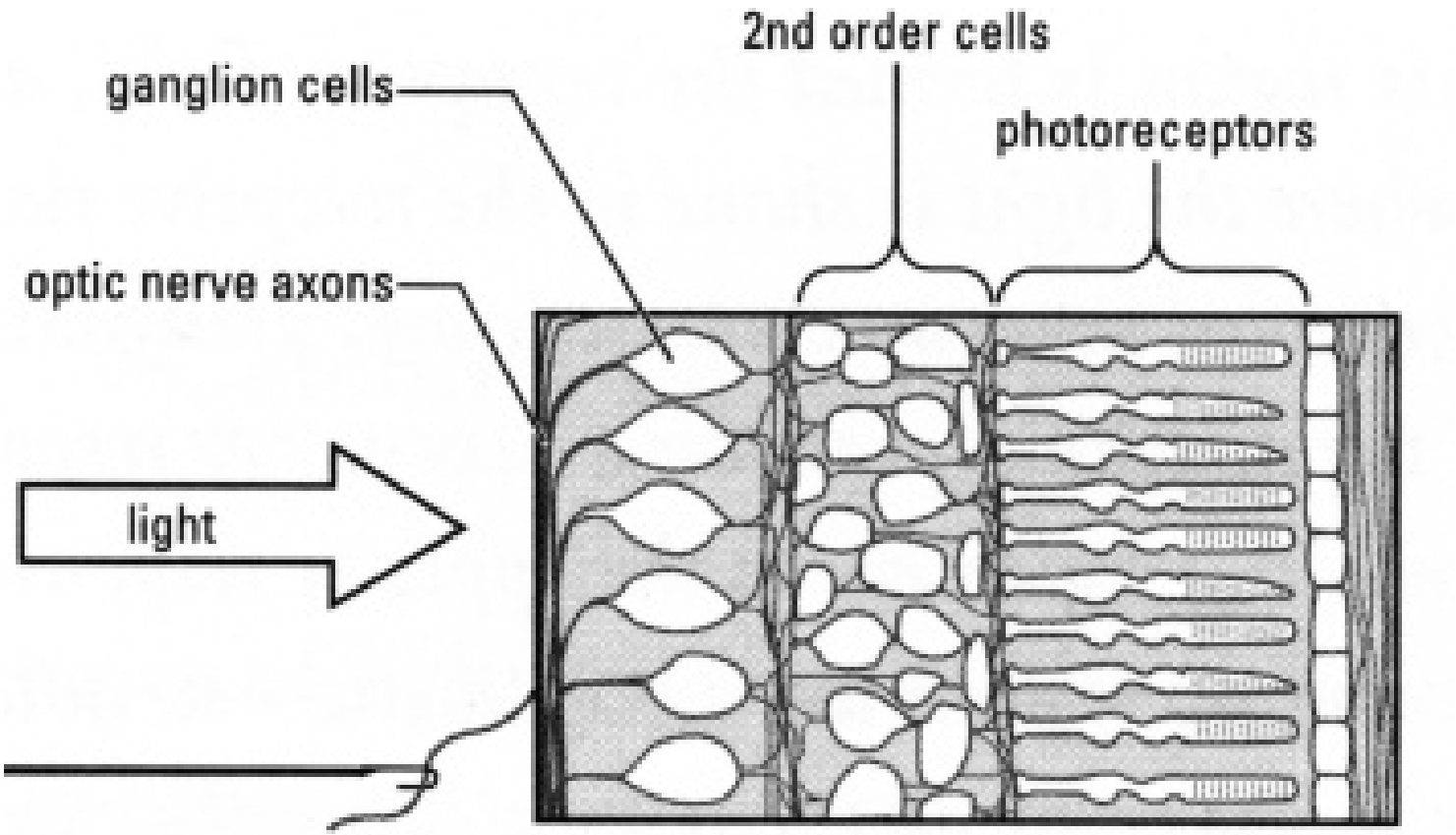


Figure from the web (lost ref)

Transduction : the transformation of one form of energy to another the photoreceptors transduce light to electrical signals (voltage changes)

Ganglion cell responses

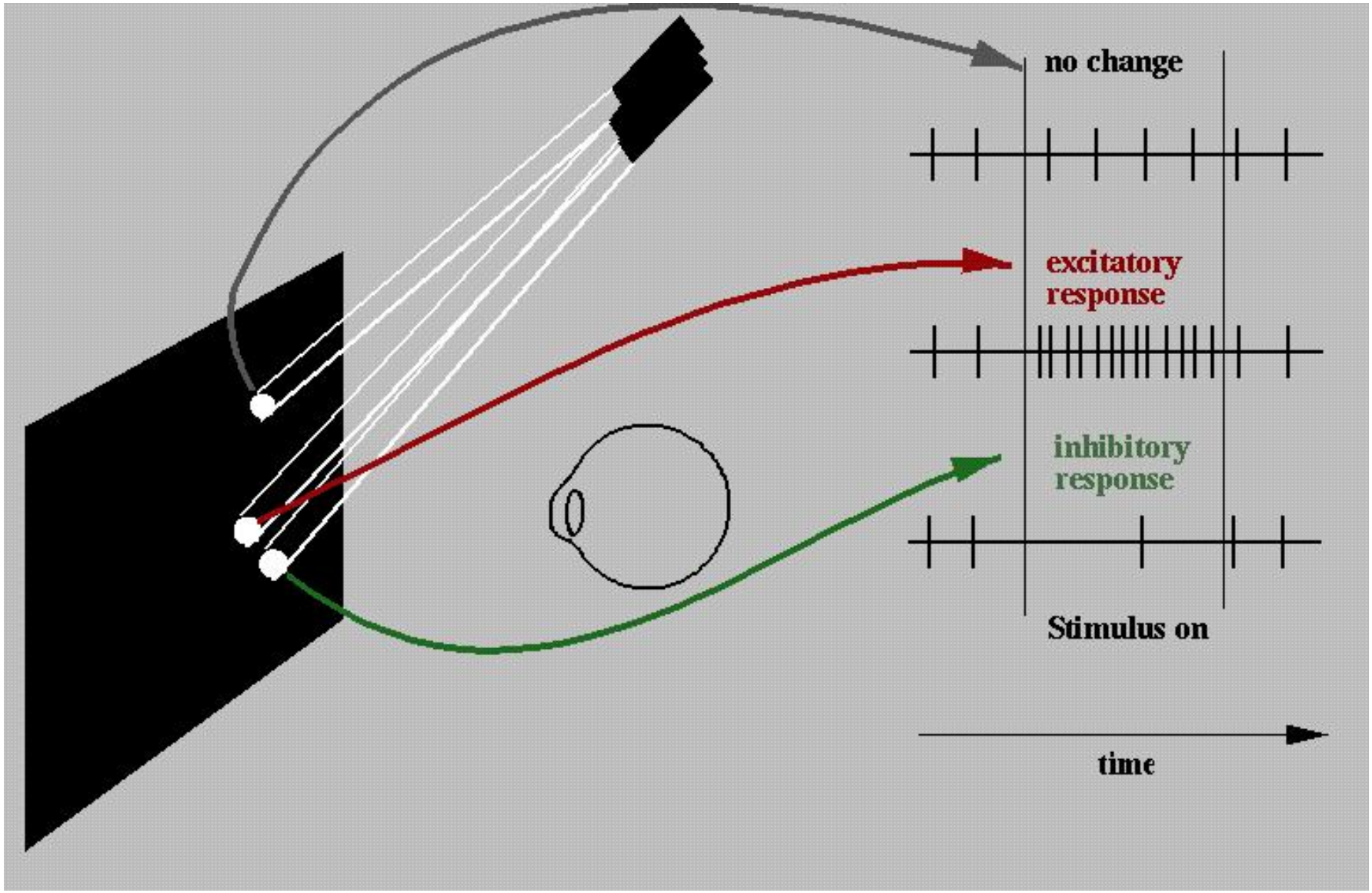
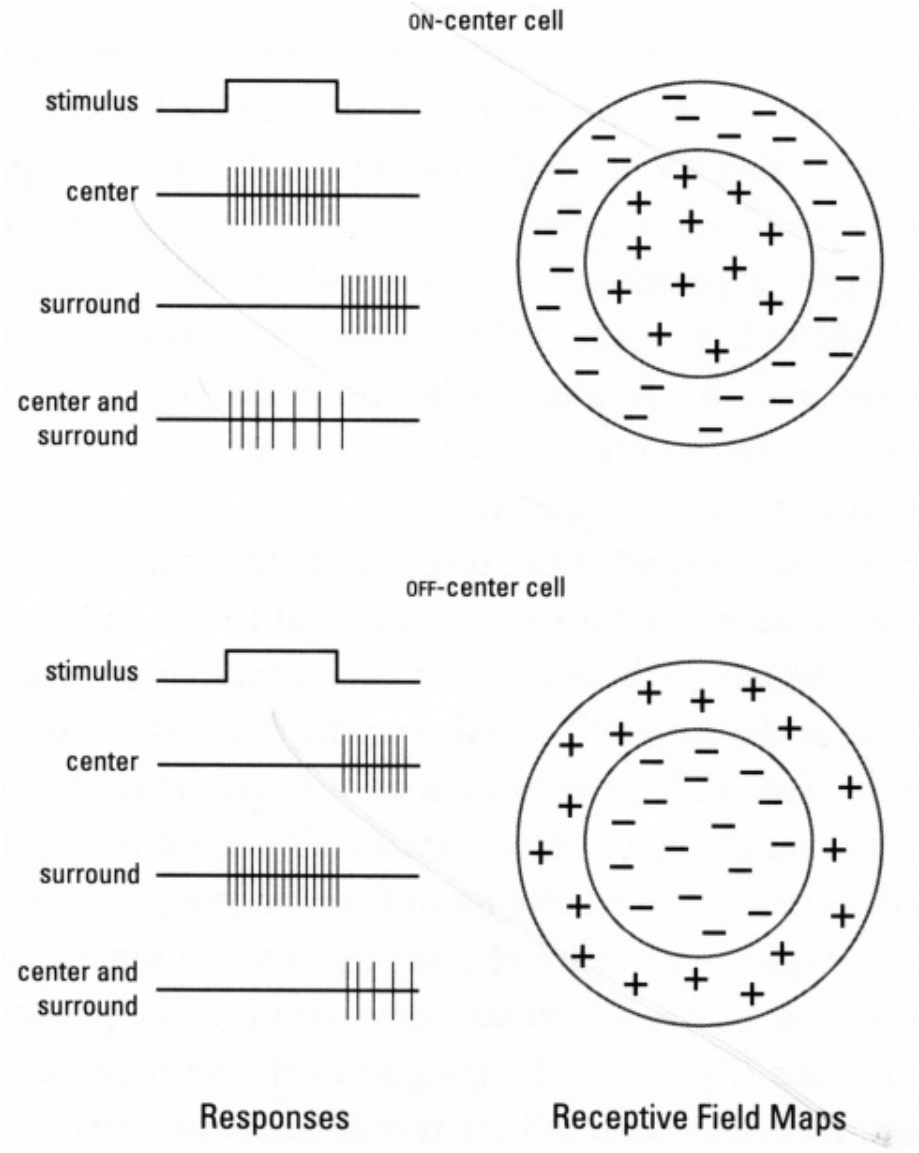


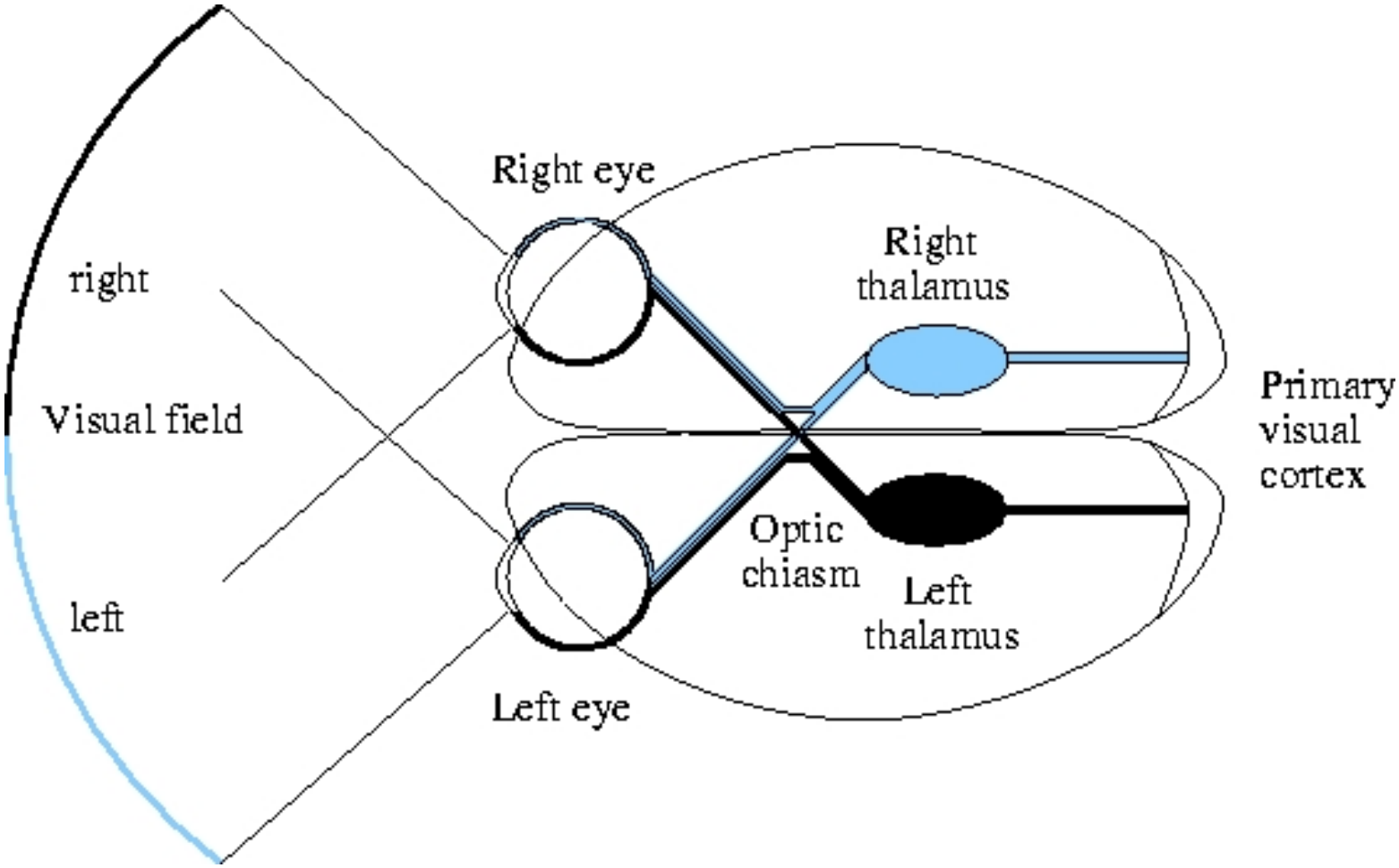
Figure from the web

Ganglion cell responses



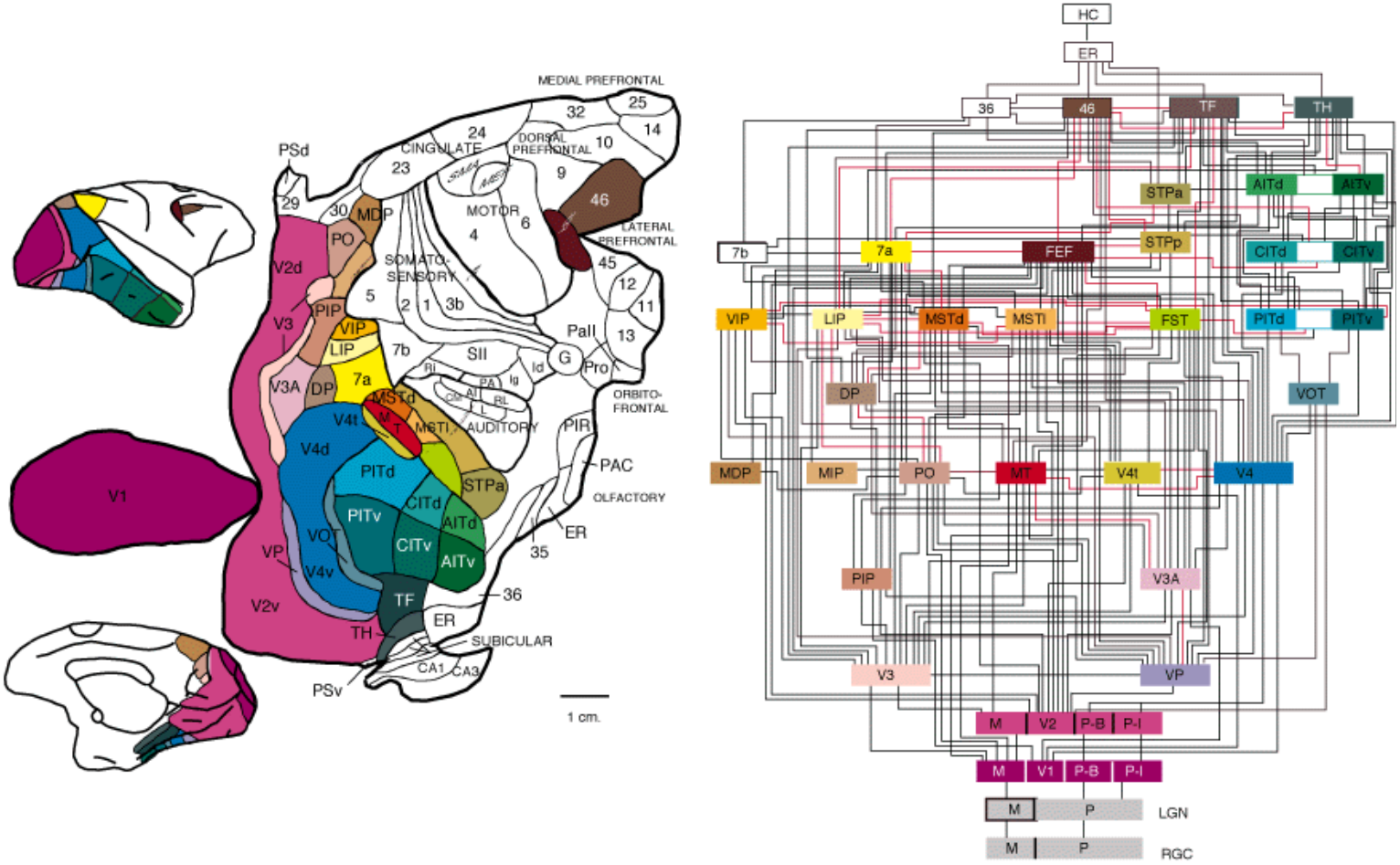
http://zeus.rutgers.edu/~ikovacs/SandP/prepI_3_1.html

Pathway to Cortex



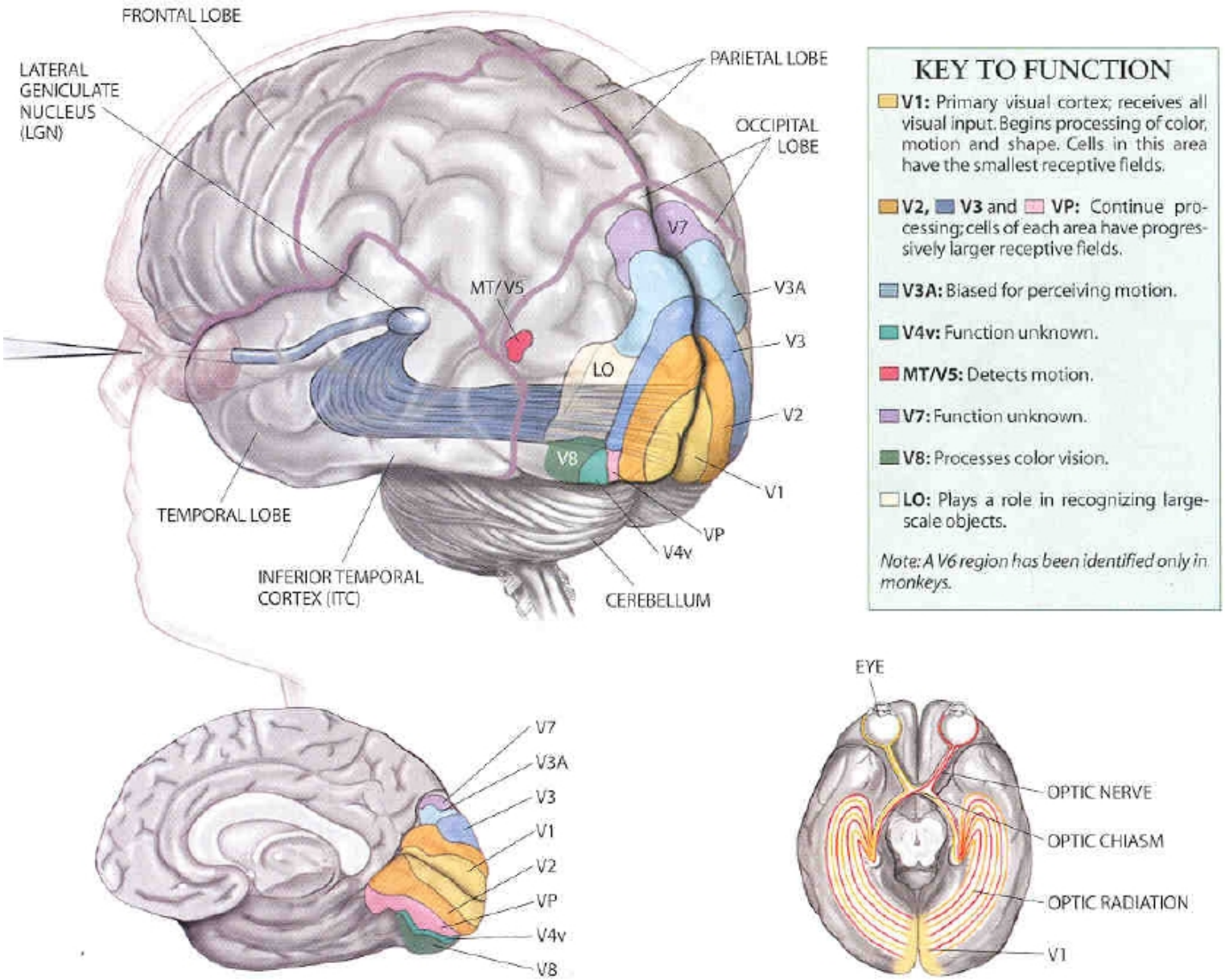
(http://www.cs.utexas.edu/users/jbednar/papers/bednar.thesis/node6.html)

Visual Cortical Areas



from Felleman, D.J. and Van Essen, D.C. (1991) *Cerebral Cortex* 1:1-47.

Visual Cortical Areas – Human

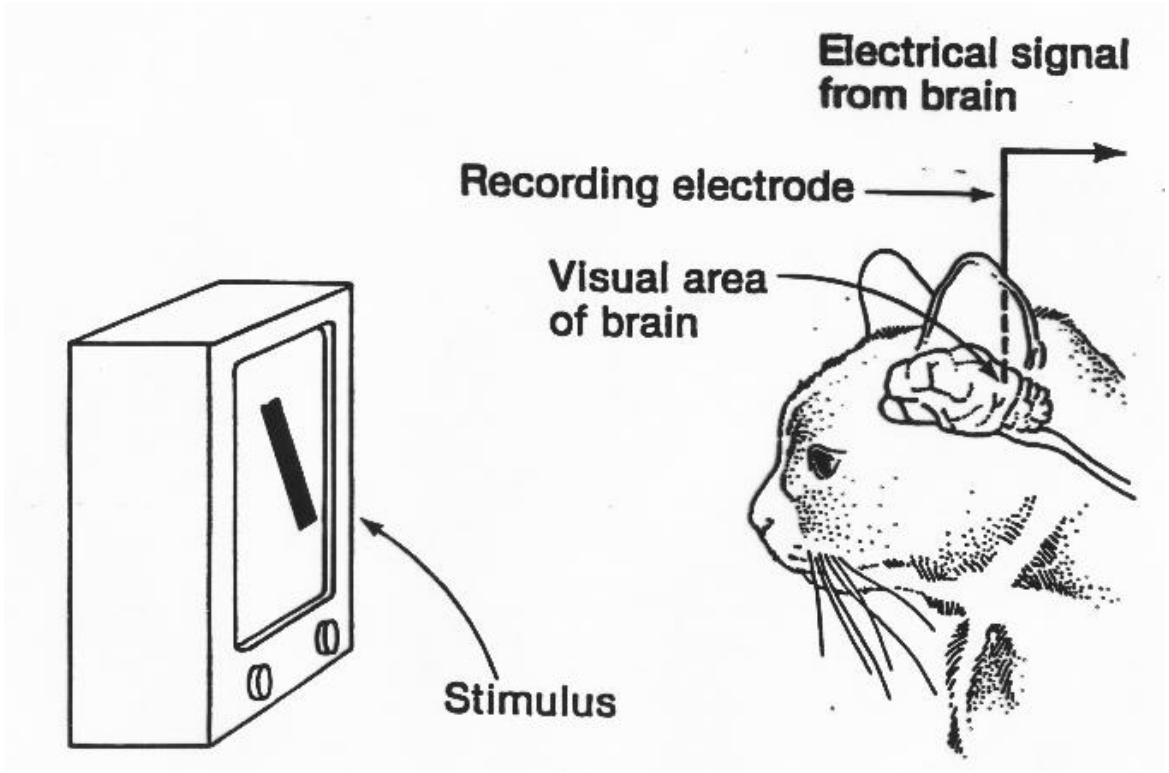


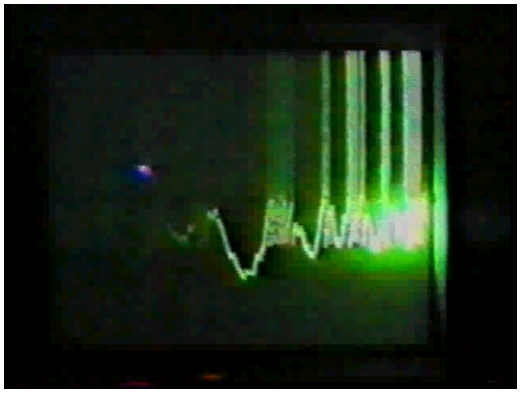
Scientific American, November 1999 (Vision: A Window on Consciousness)

How do we study Perceptual Systems?

- Physiology
  - ⋆ Single Cell Electrophysiology – what do neurons respond to?

responses of V1 neurons





movie from

`http://info.med.yale.edu/neurobio/mccormick/qt_movie.html`

Responses of V1 neurons

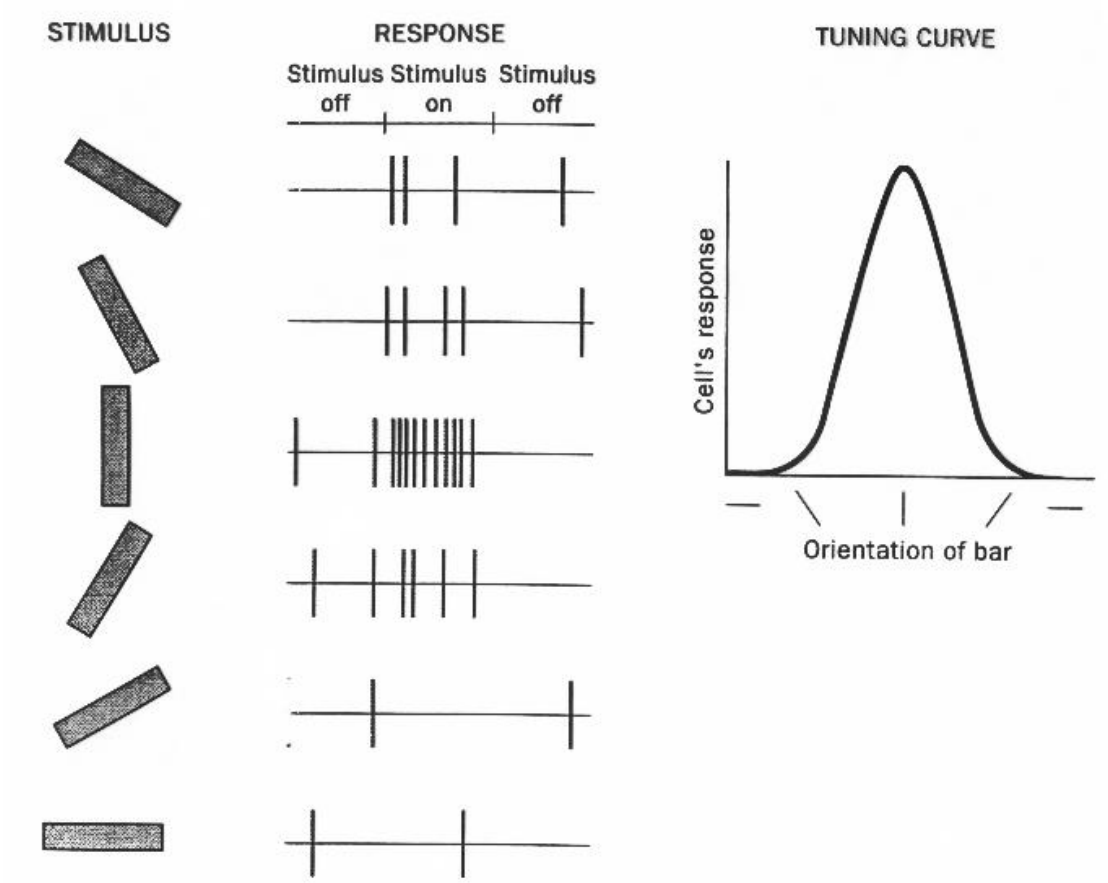
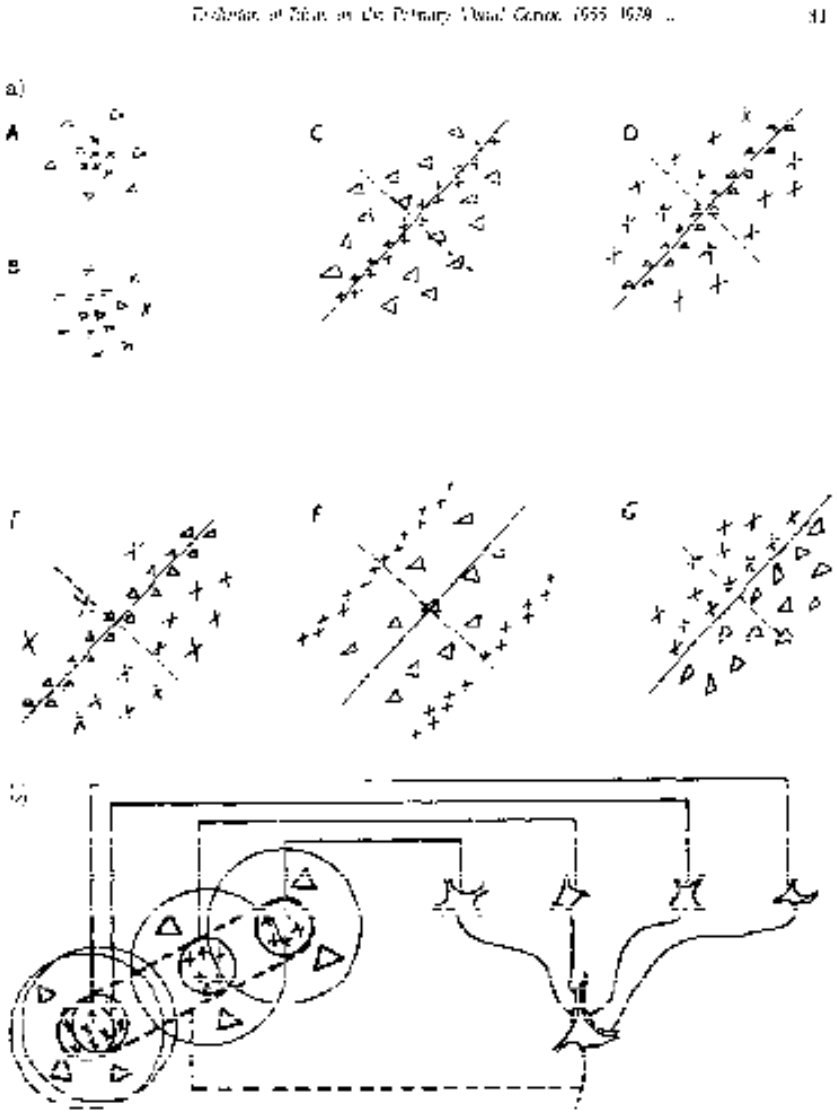


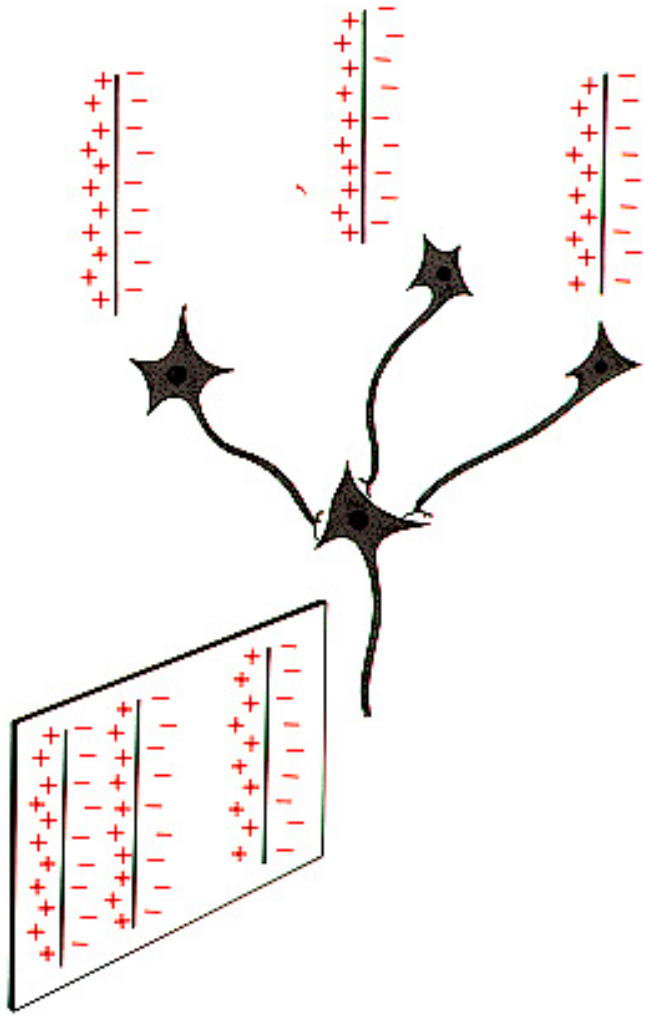
FIGURE 4.8 Response of a single cortical cell to bars presented at various orientations.

http://zeus.rutgers.edu/~ikovacs/SandP/prepI_3_1.html

Simple cells in V1

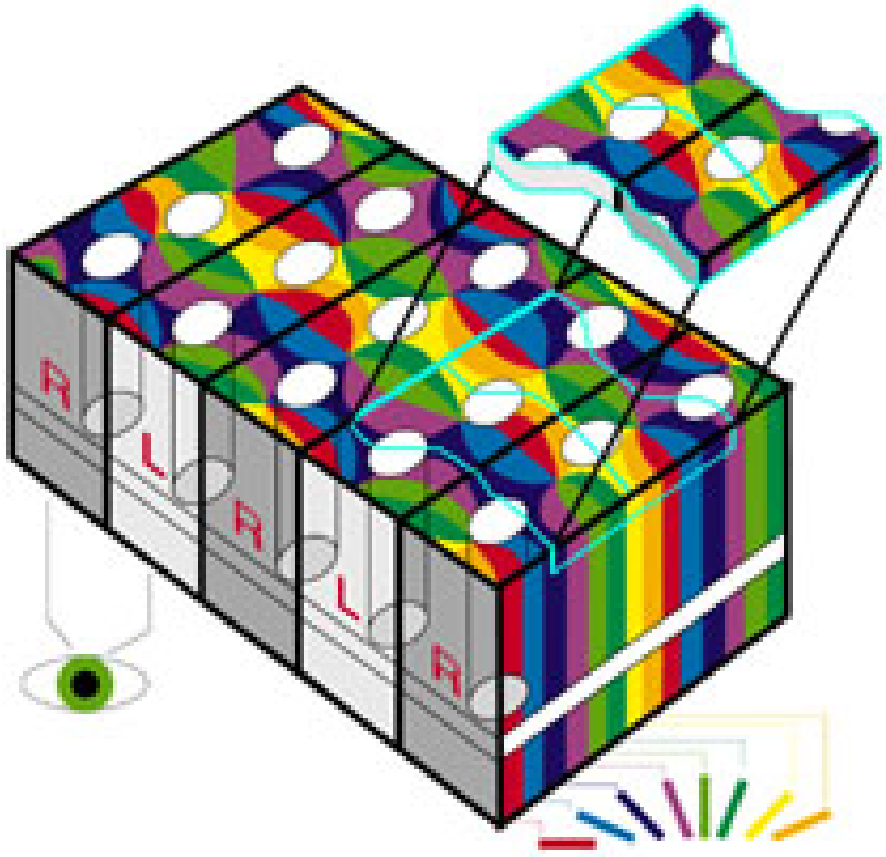


Complex cells in V1



from Mark McCourt's Psy 486 web page

Ocular dominance and orientation columns

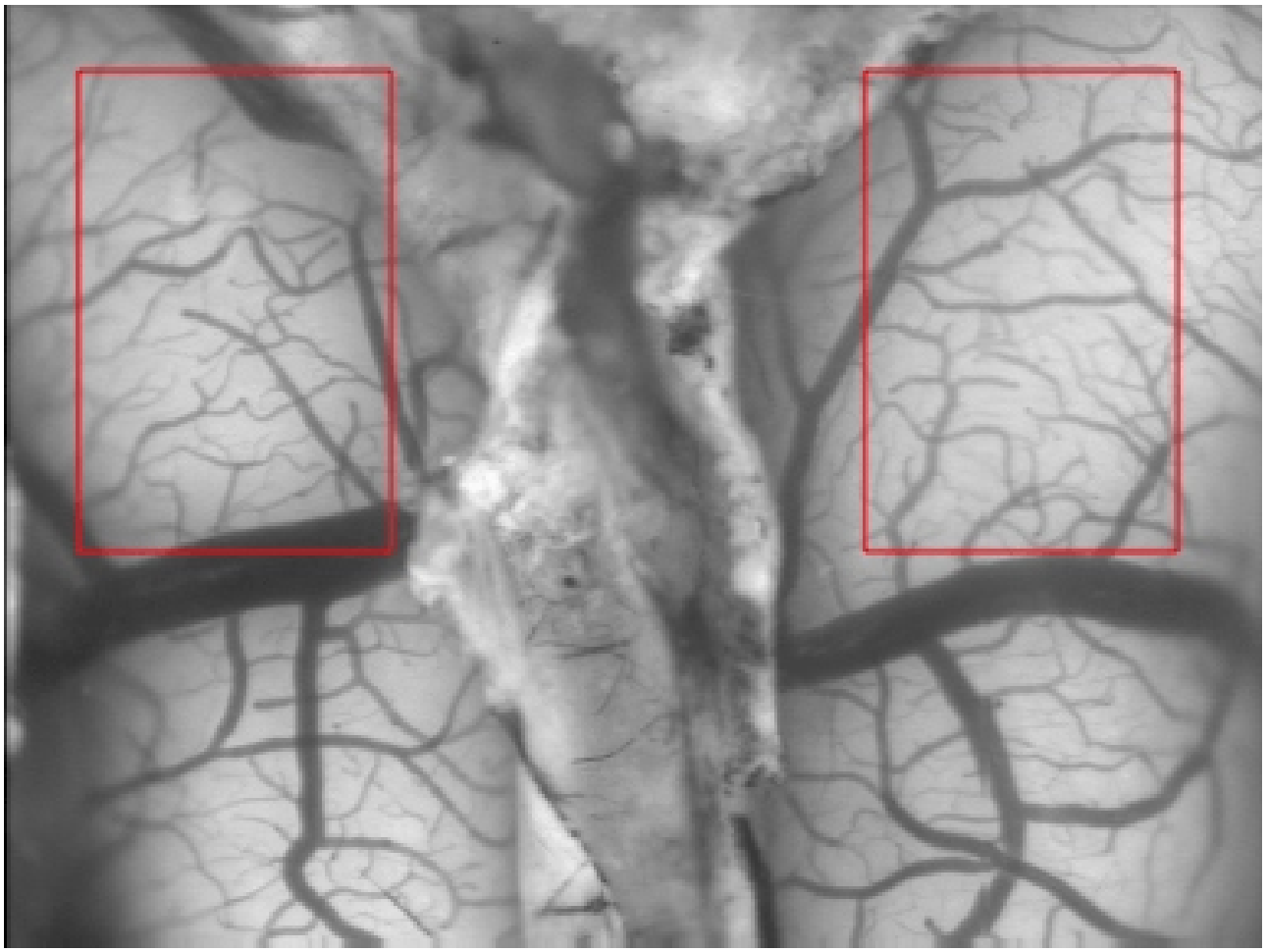


http://www.weizmann.ac.il/brain/images/icecubens.jpg

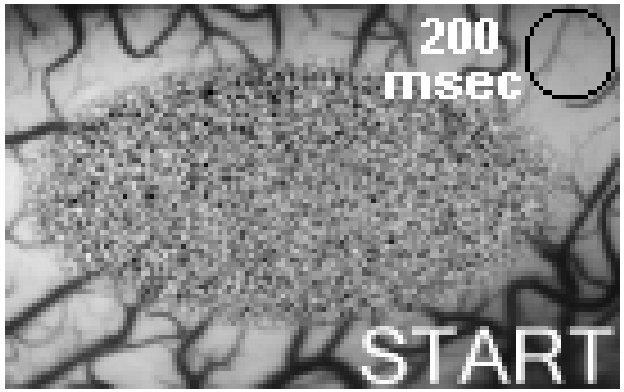
How do we study Perceptual Systems?

- Physiology
  - ⋆ Single Cell Electrophysiology – what do neurons respond to?
  - ⋆ Optical Imaging – what are groups of neurons responding to?

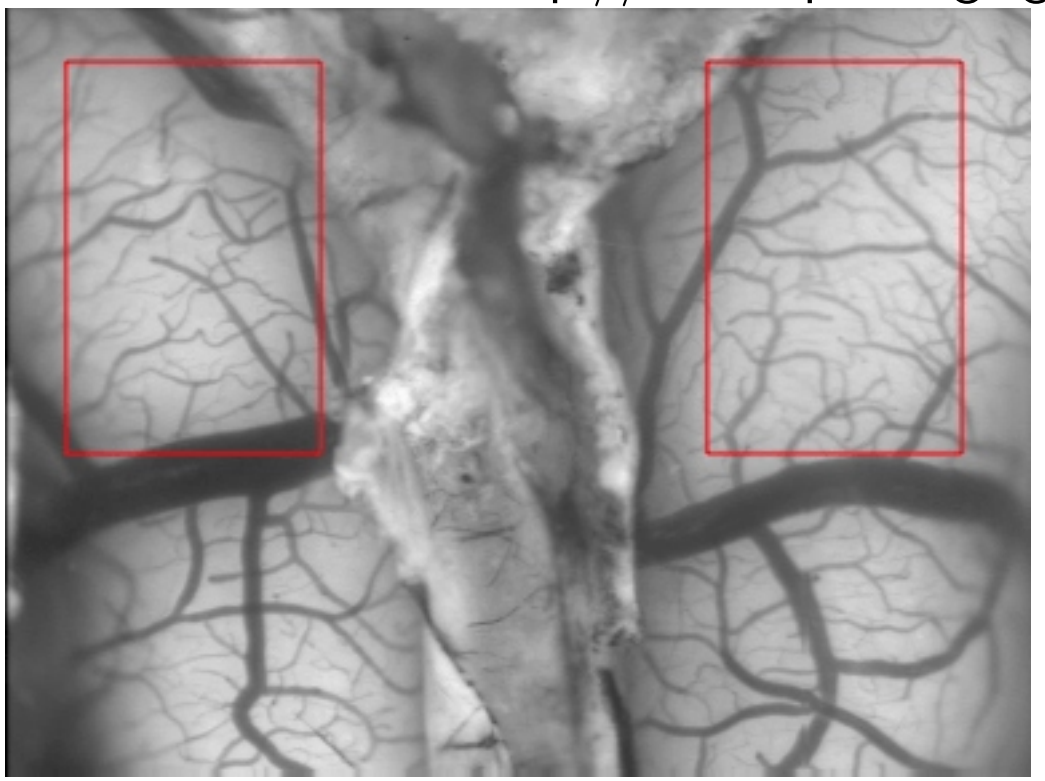
Optical Imaging reveals Orientation/Ocular dominance map



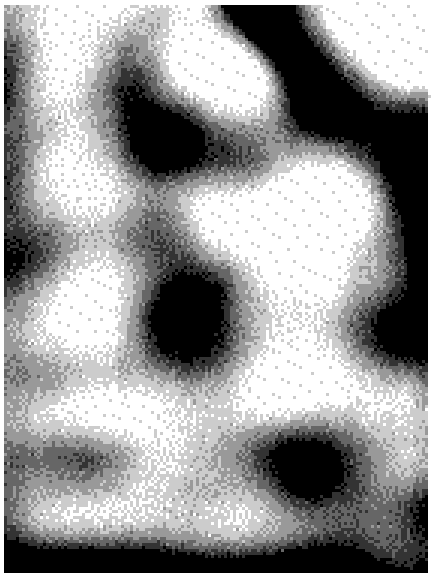
Optical Imaging reveals Orientation/Ocular dominance map

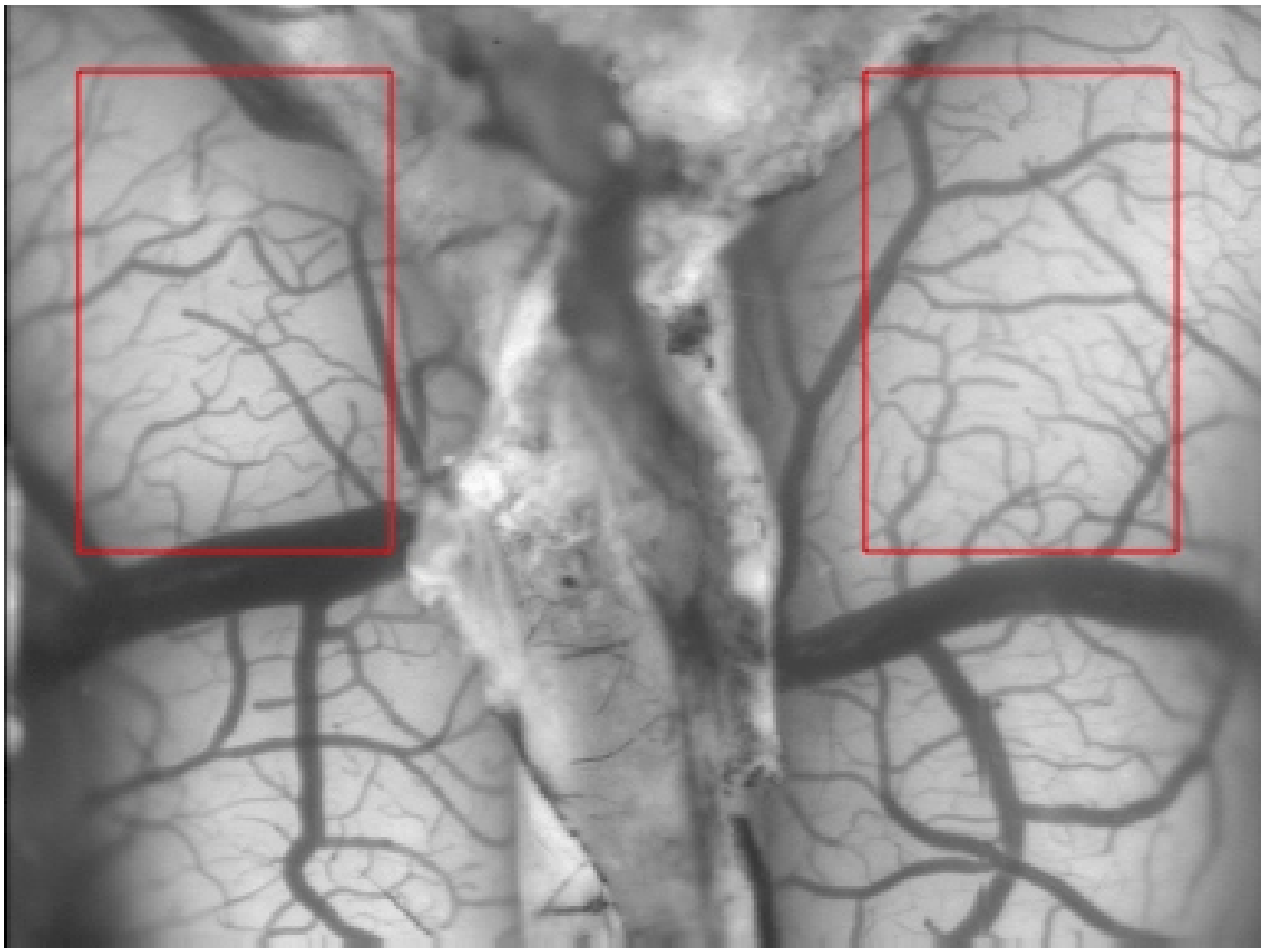


http://www.opt-imaging.com/

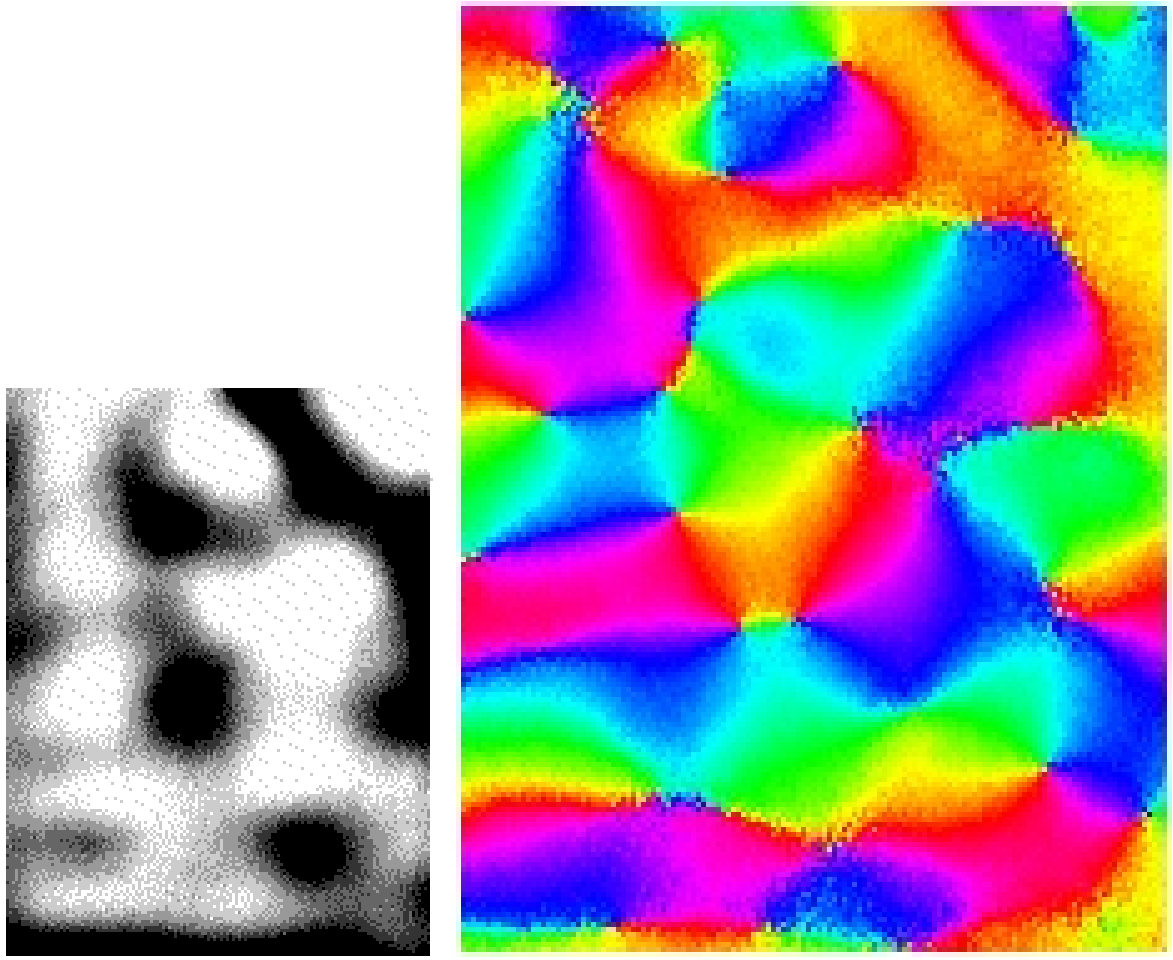


Optical Imaging reveals Orientation/Ocular dominance map



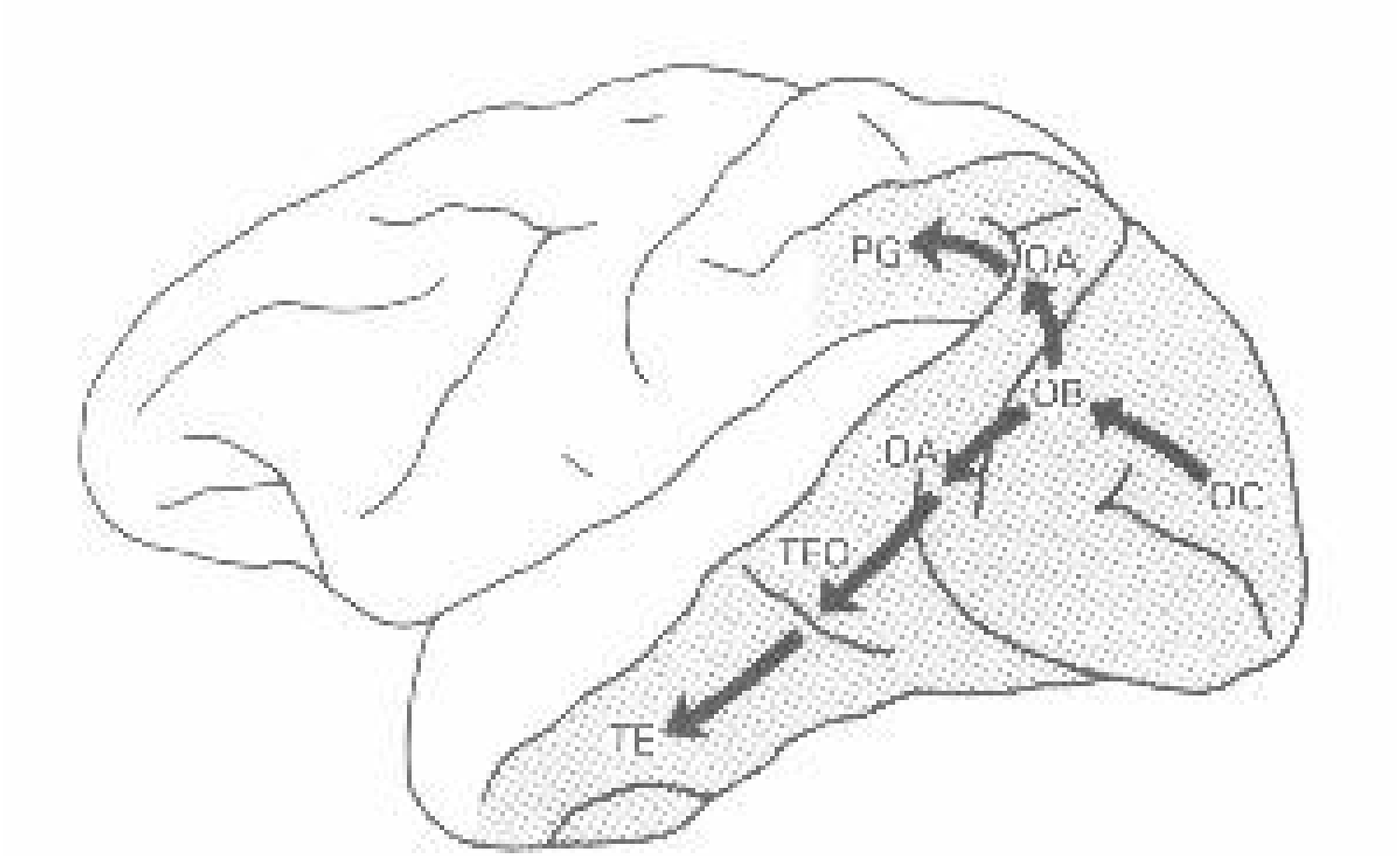


Optical Imaging reveals Orientation/Ocular dominance map



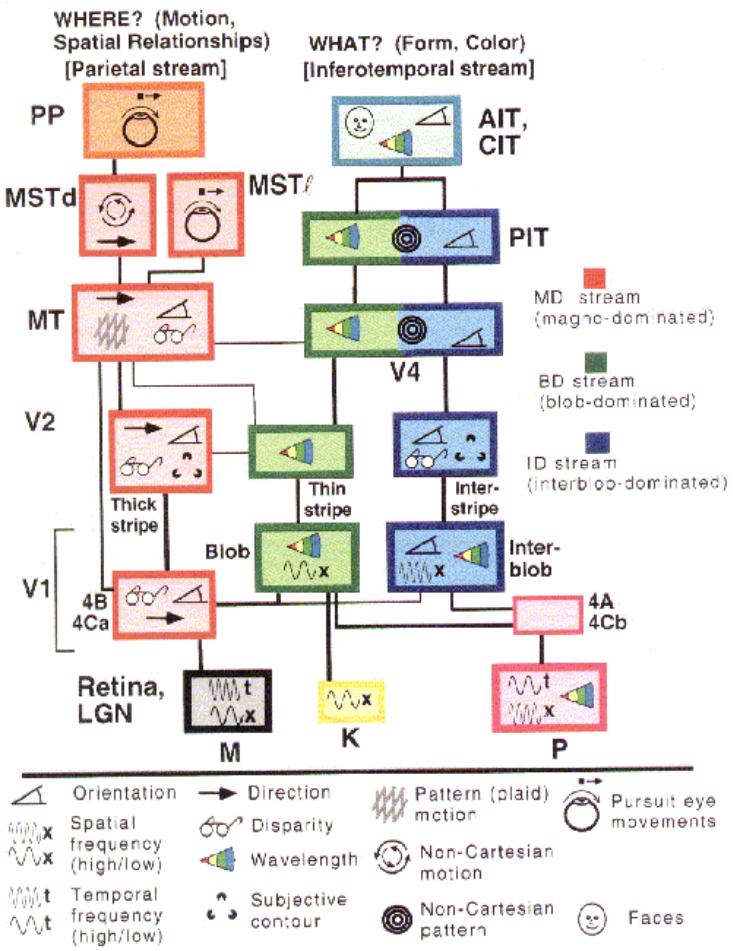
from Josh Trachtenberg
(http://phy.ucsf.edu/~joshua/postdoctoral.html)

Parallel Pathways in Visual Cortex



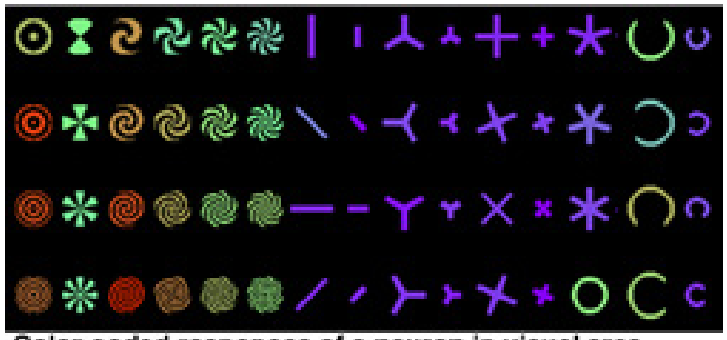
[Mishkin & Ungerleider 1982]

Parallel Pathways in Visual Cortex



[Van Essen & Gallant 1994]

higher-level neurons require more complex stimuli



Color-coded responses of a neuron in visual area V2 to different geometric stimuli.

"optimal patterns" for IT neurons (from Keiji Tanaka) are even more complex but require much less spatial precision

Neurons near the end of the Temporal pathway respond to very complex stimuli

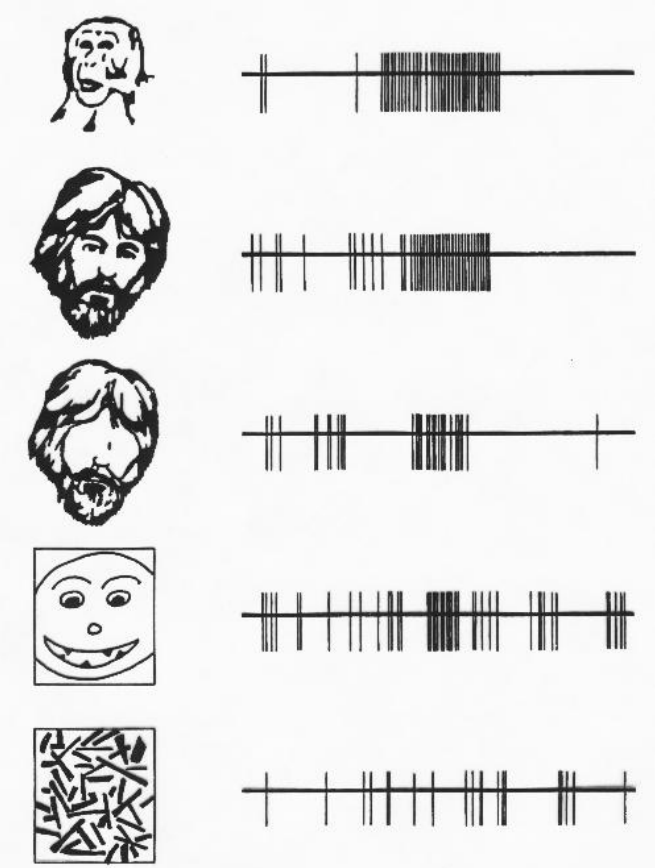


Figure 3.24
Responses of a neuron in a monkey's area IT to various

http://zeus.rutgers.edu/~ikovacs/SandP/prepI_3_1.html

Determining Function

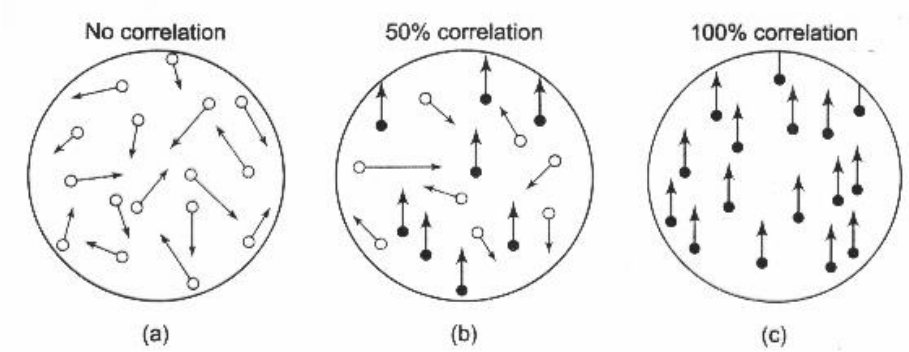
So we know that neurons in a particular area respond well to a particular kind of stimulation.

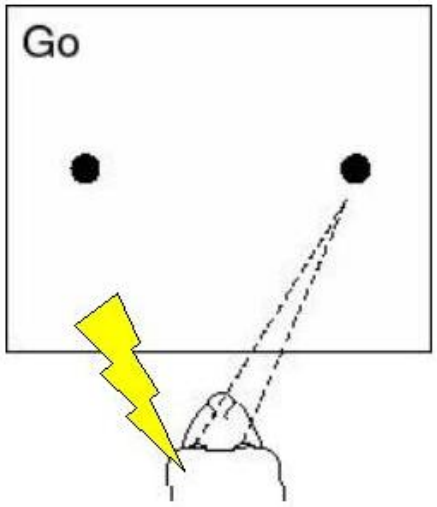
Does that tell us that these neurons are telling the animal about these stimuli?

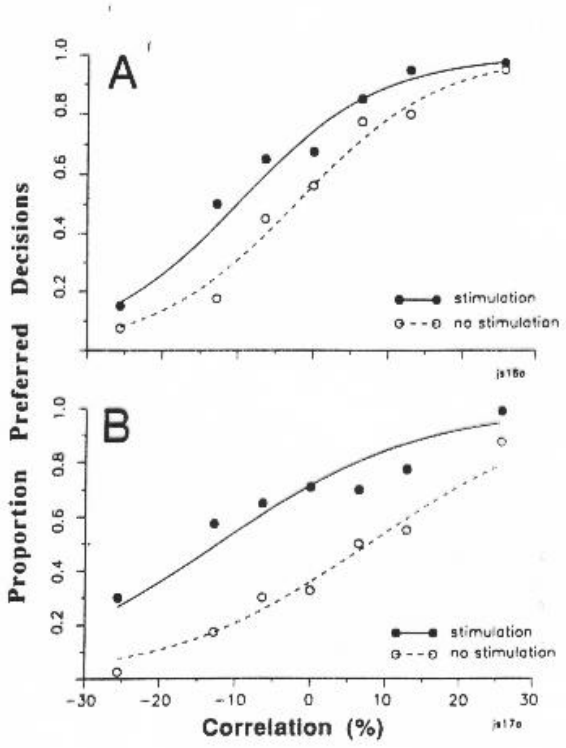
How do we study Perceptual Systems?

- Physiology
  - ⋆ Single Cell Electrophysiology – what do neurons respond to?
  - ⋆ Optical Imaging – what are groups of neurons responding to?
  - ⋆ microstimulation – how does the animal respond when we stimulate?

Microstimulation in MT influences monkey's decision

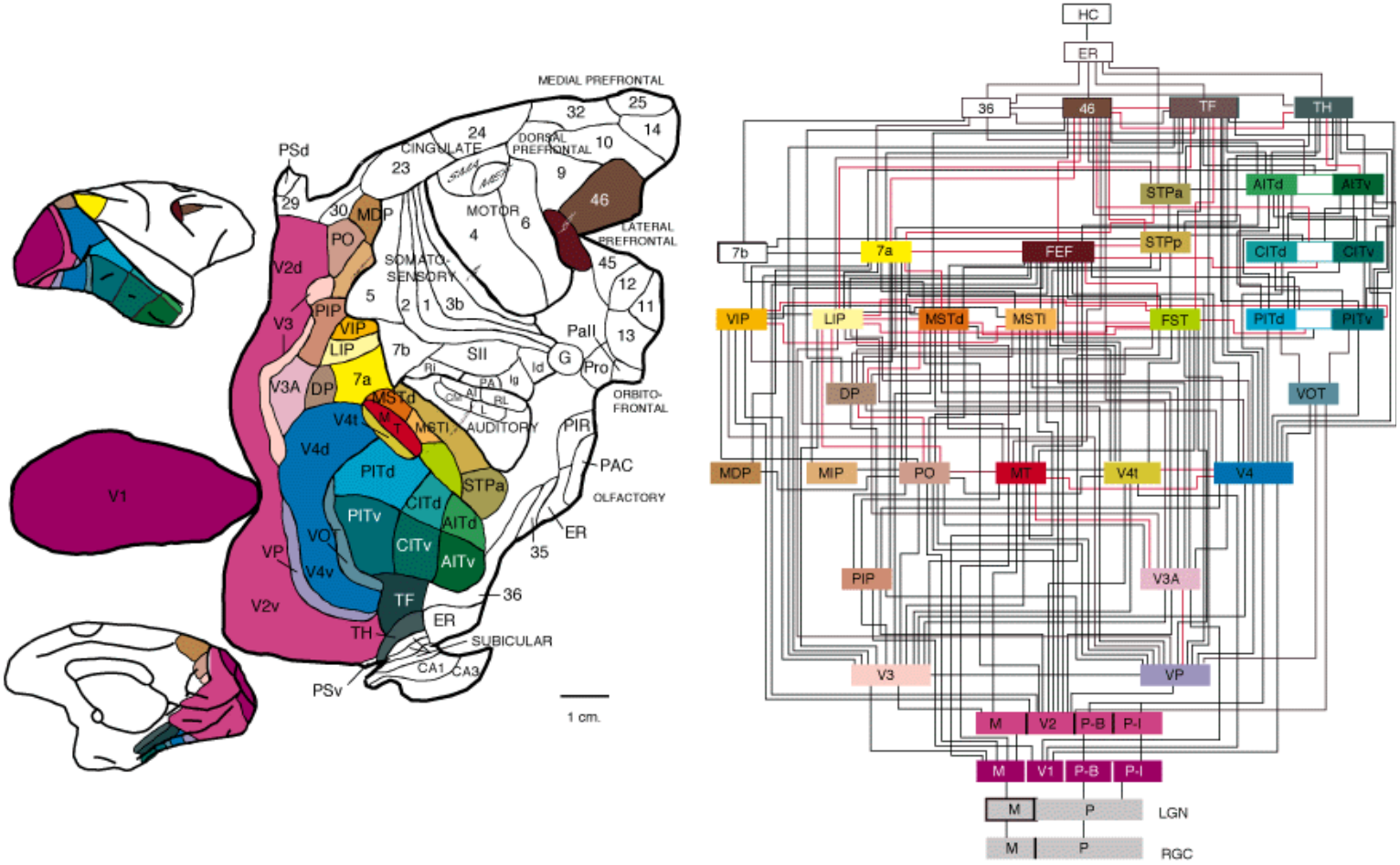






from Mike Shadlen and http://zeus.rutgers.edu/~ikovacs/SandP/prepl_3_1.html

Visual Cortical Areas



from Felleman, D.J. and Van Essen, D.C. (1991) *Cerebral Cortex* 1:1-47.

Feedback and Perception

"Feedforward and feedback connections are linked together by reciprocal connections. Much of the understanding of higher order vision rest on understanding the interactions between feedforward and feedback loops and the horizontal connections" [J Bullier, Trieste 2000]

Feedback connections are the substrate for top-down effects

The Visual System is not a fixed feed-forward system

It is influenced by

- prior experience

Influences from past experience

The original image was created by R.C. James. This image was taken from Andy Wilson's home page which was scanned from David Marr's book Vision.

Influences from past experience

This image is from Beverly Doolittle

The Visual System is not a fixed feed-forward system

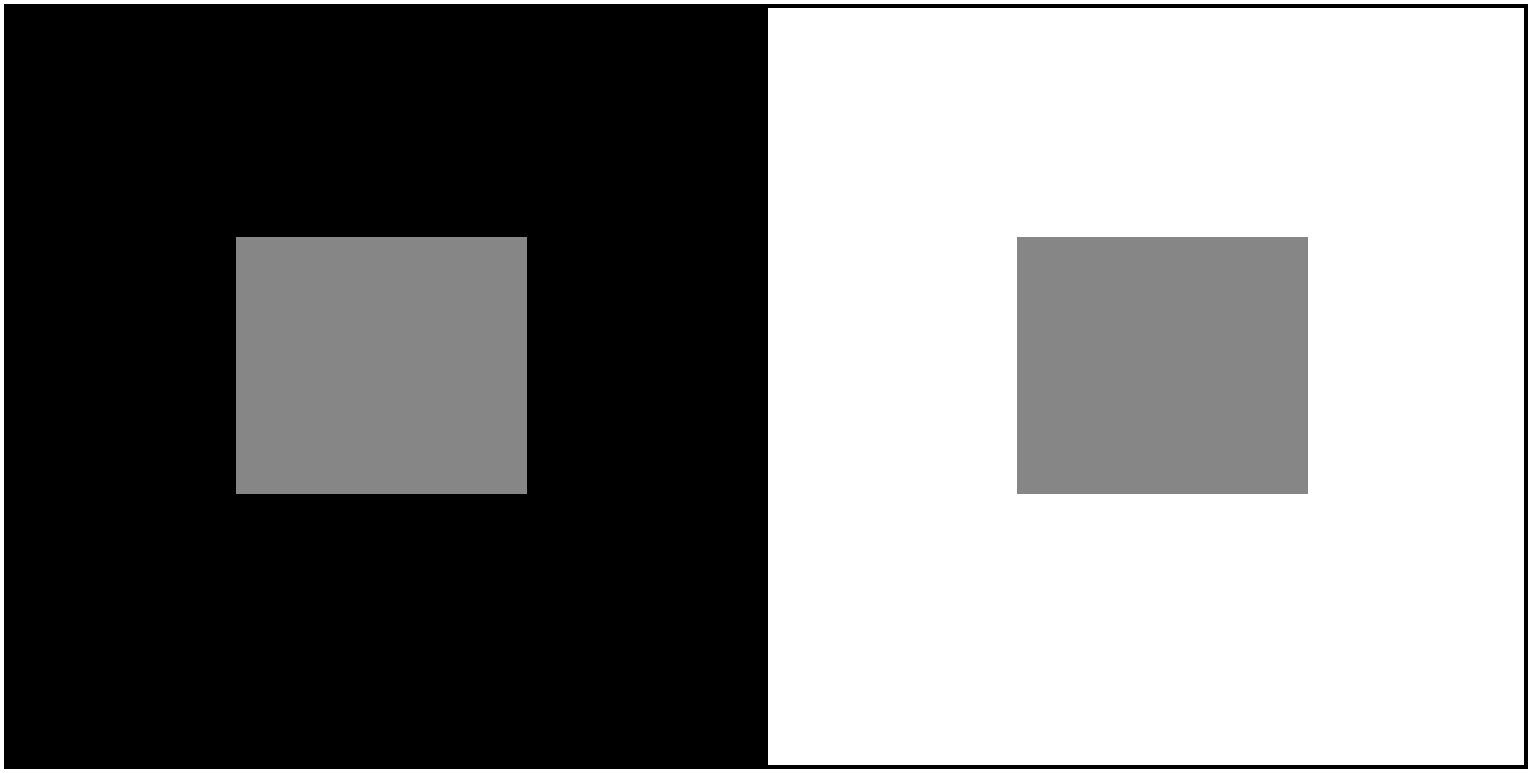
It is influenced by

- prior experience
- surrounding visual scene (and not just immediate)

Simple influences from surrounding scene

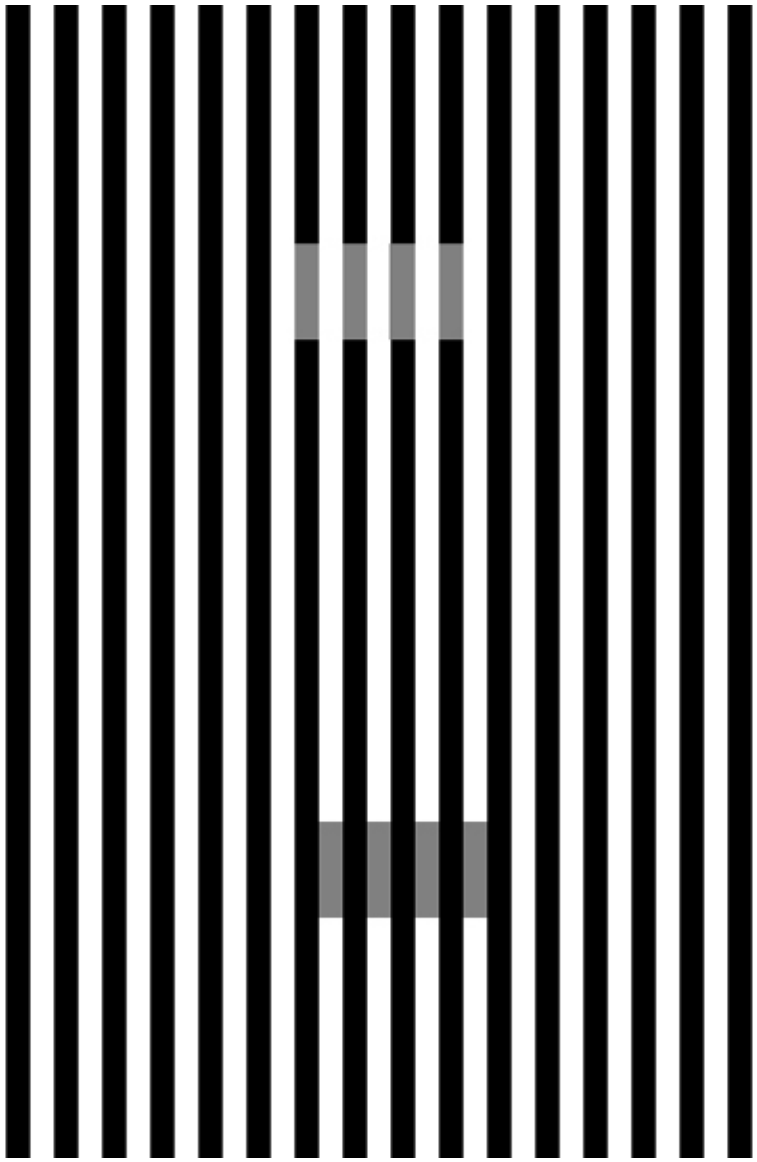
What can we learn from visual illusions?

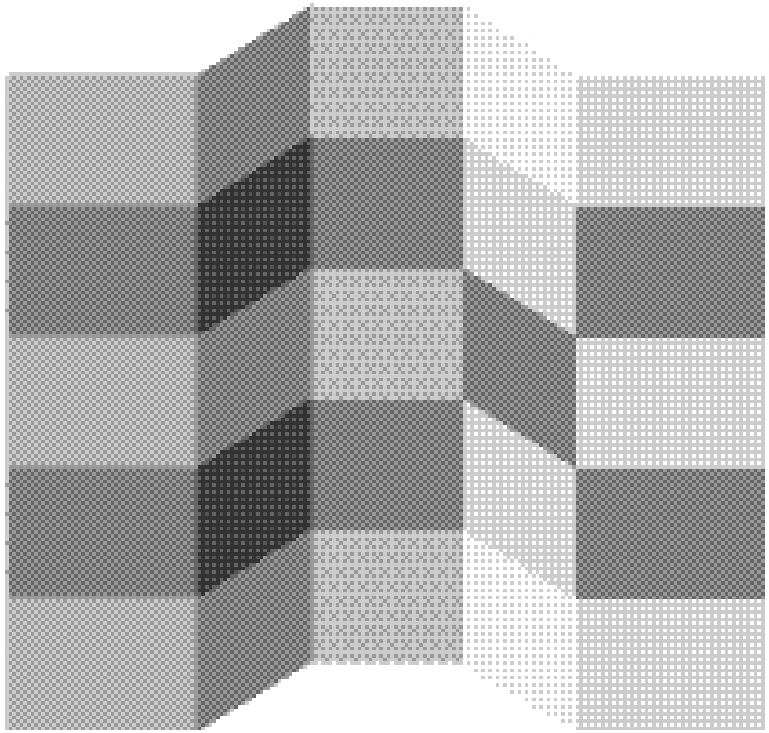
- Visual illusions occur when the brain makes an assumption that is not true.
- The assumption does not reflect a "flaw" in the visual system but represents adaptation to the the way things usually are.
- The brain must make assumptions, in order for you to perceive a 3D world from the 2D images on your retinas.
- By examining illusions and our responses, we can try to "reverse engineer" the visual system to discover the assumptions it makes in order to "see".

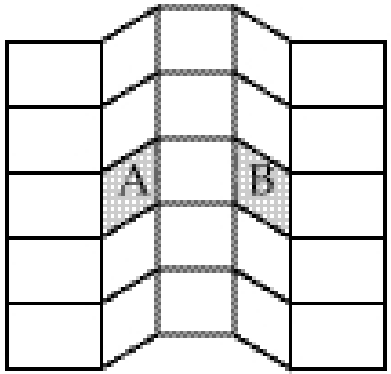


Start Applet

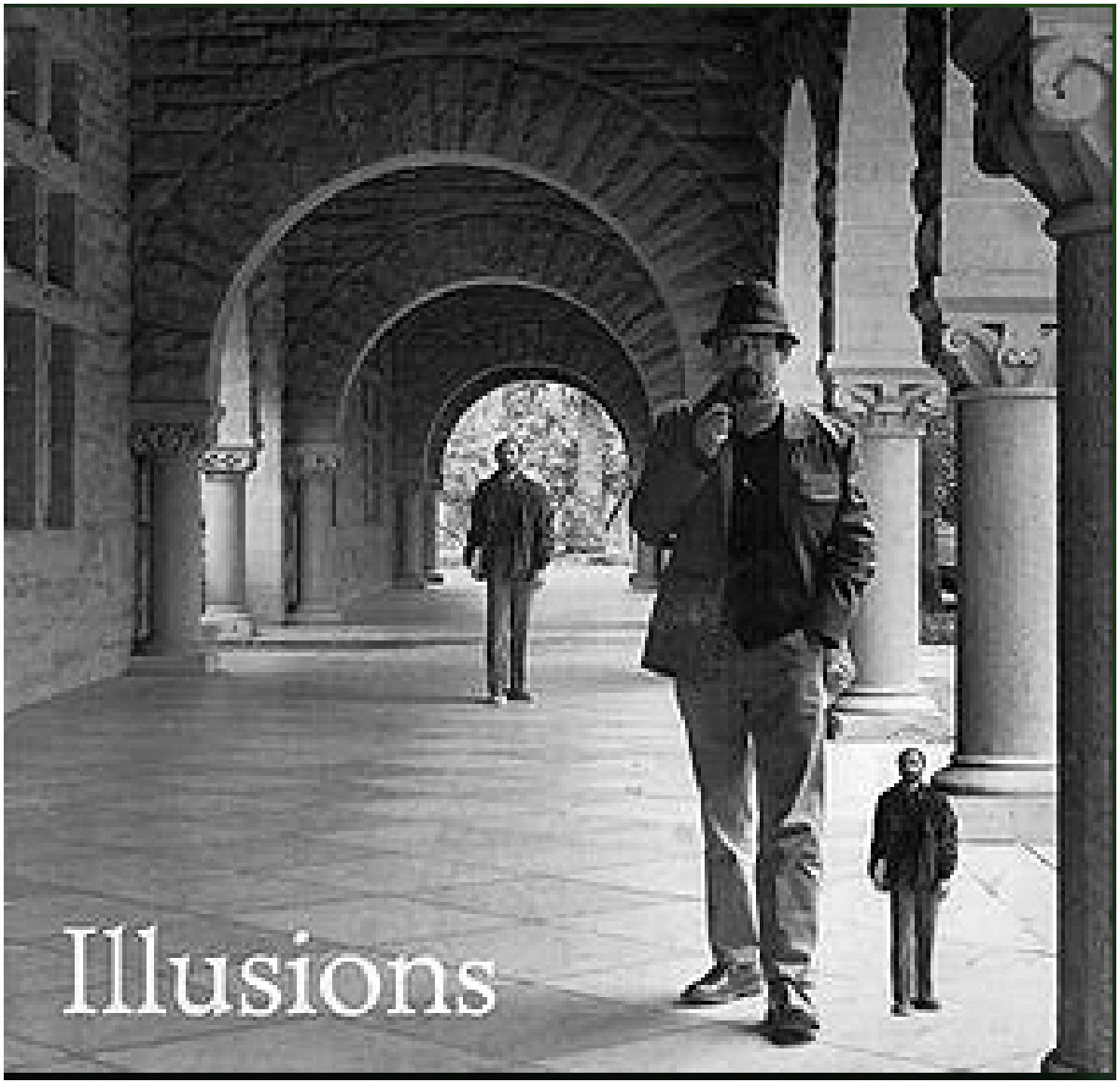
Simple influences from surrounding scene





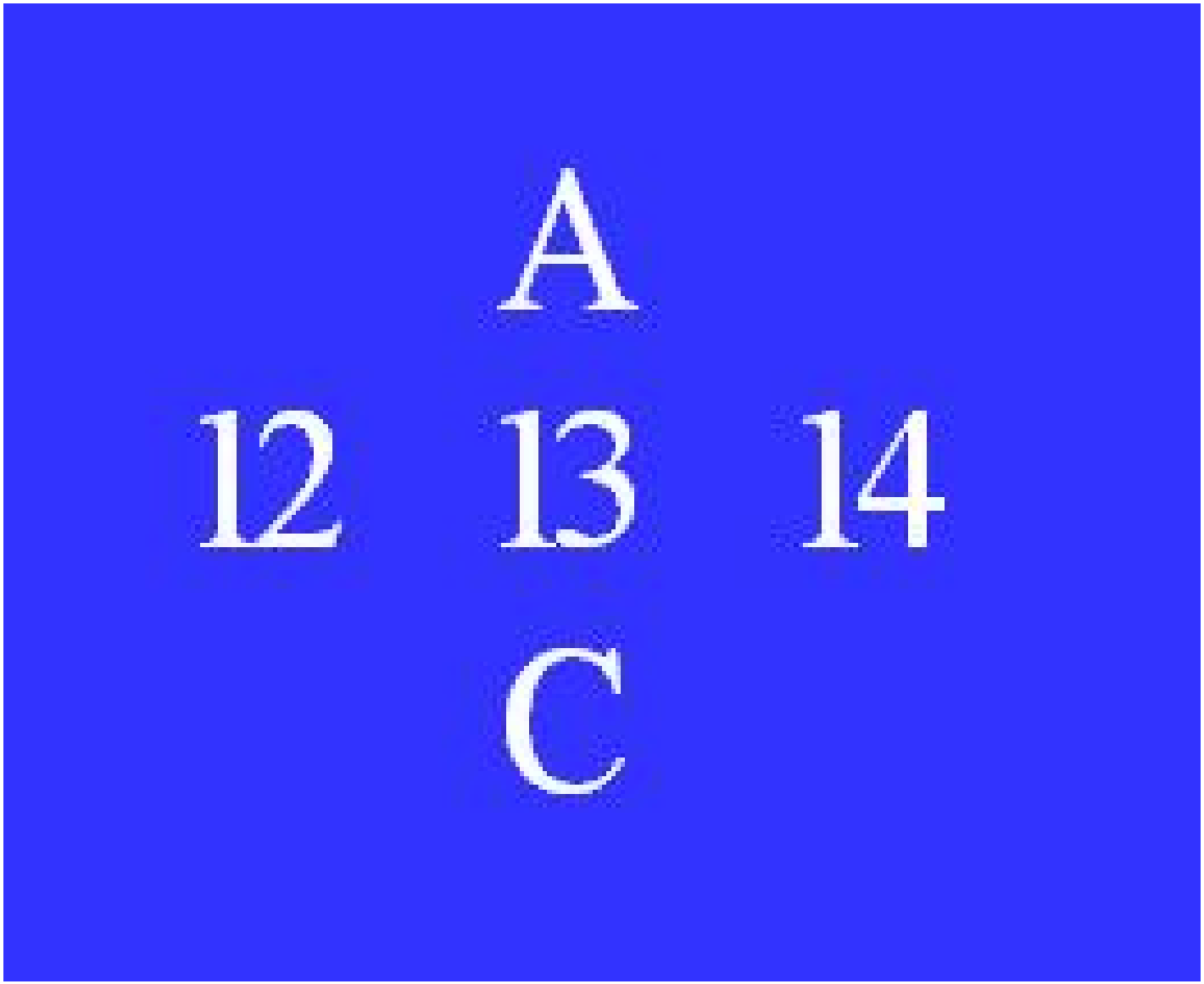

A
B

More involved influences from surrounding scene



http://www.olemiss.edu/courses/psy214/Readings/Illusions/ImageSizeAdjustmentTheo

More involved influences from surrounding scene



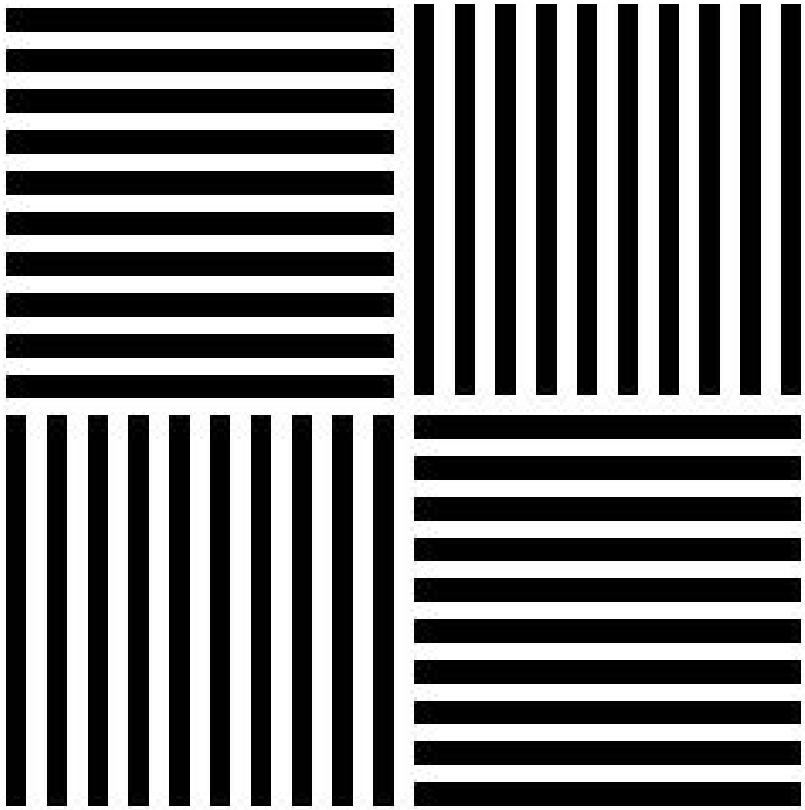
http://www1.cs.columbia.edu/~paley/spring03/assignments/HWtmp/sz184/pattern.ht

The Visual System is not a fixed feed-forward system

It is influenced by

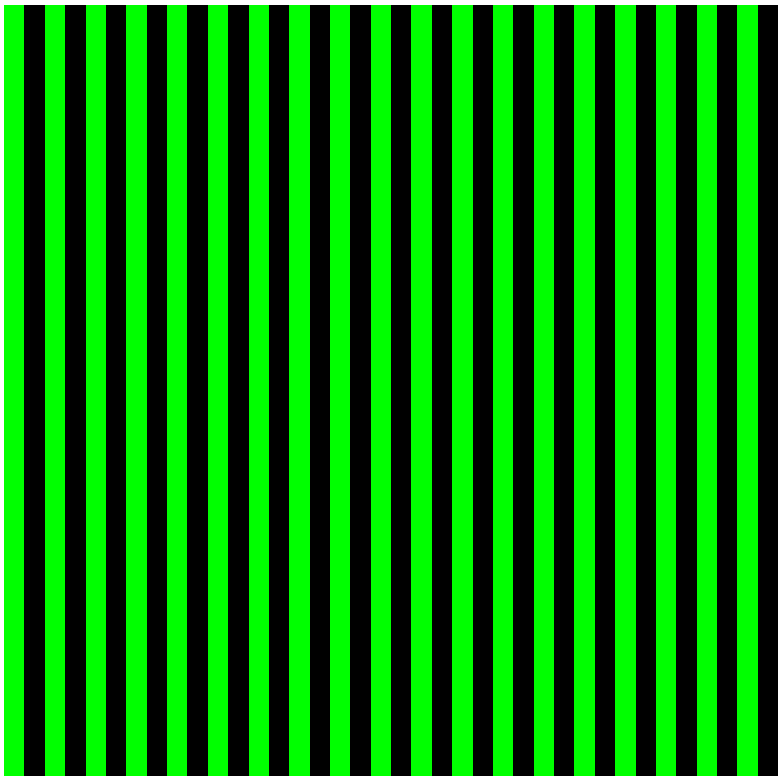
- prior experience
- surrounding visual scene (and not just immediate)
- recent prior exposure

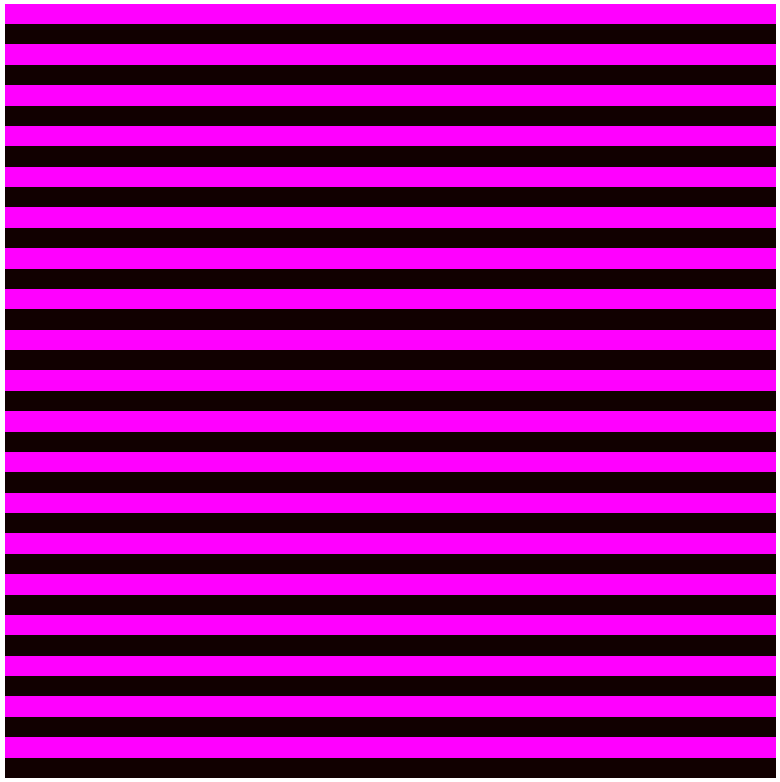
The McCollough Effect – short term changes in perception



taken from http://cm.bell-labs.com/who/ches/me/

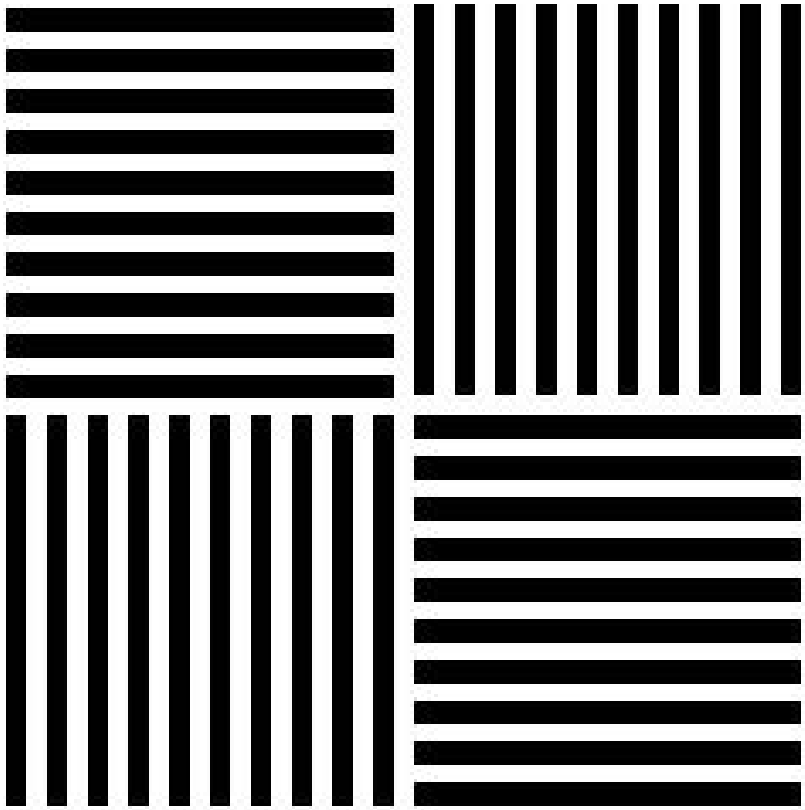
The McCollough Effect





taken from http://cm.bell-labs.com/who/ches/me/

The McCollough Effect



taken from http://cm.bell-labs.com/who/ches/me/

The Visual System is not a fixed feed-forward system

It is influenced by

- prior experience
- surrounding visual scene (and not just immediate)
- recent prior exposure
- learned familiarity with special objects

The Thatcher Illusion – influence from learned experience with (upright) faces

[Thompson 1980,Perception 9 483-484]

The Thatcher Illusion – influence from learned experience with (upright) faces

[Thompson 1980,Perception 9 483-484]

This illusion was first described by Thompson in 1980. I got this from http://www.essex.ac.uk/psychology/visual/thatcher.html

Influence from learned experience

http://www.princeton.edu/~ftong/

Influence from learned experience

http://www.princeton.edu/~ftong/

Influence from learned experience

http://www.princeton.edu/~ftong/

Influence from learned experience is specific

[Sinha and Poggio Nature 1996, 384 p 404]

Influence from learned experience is specific

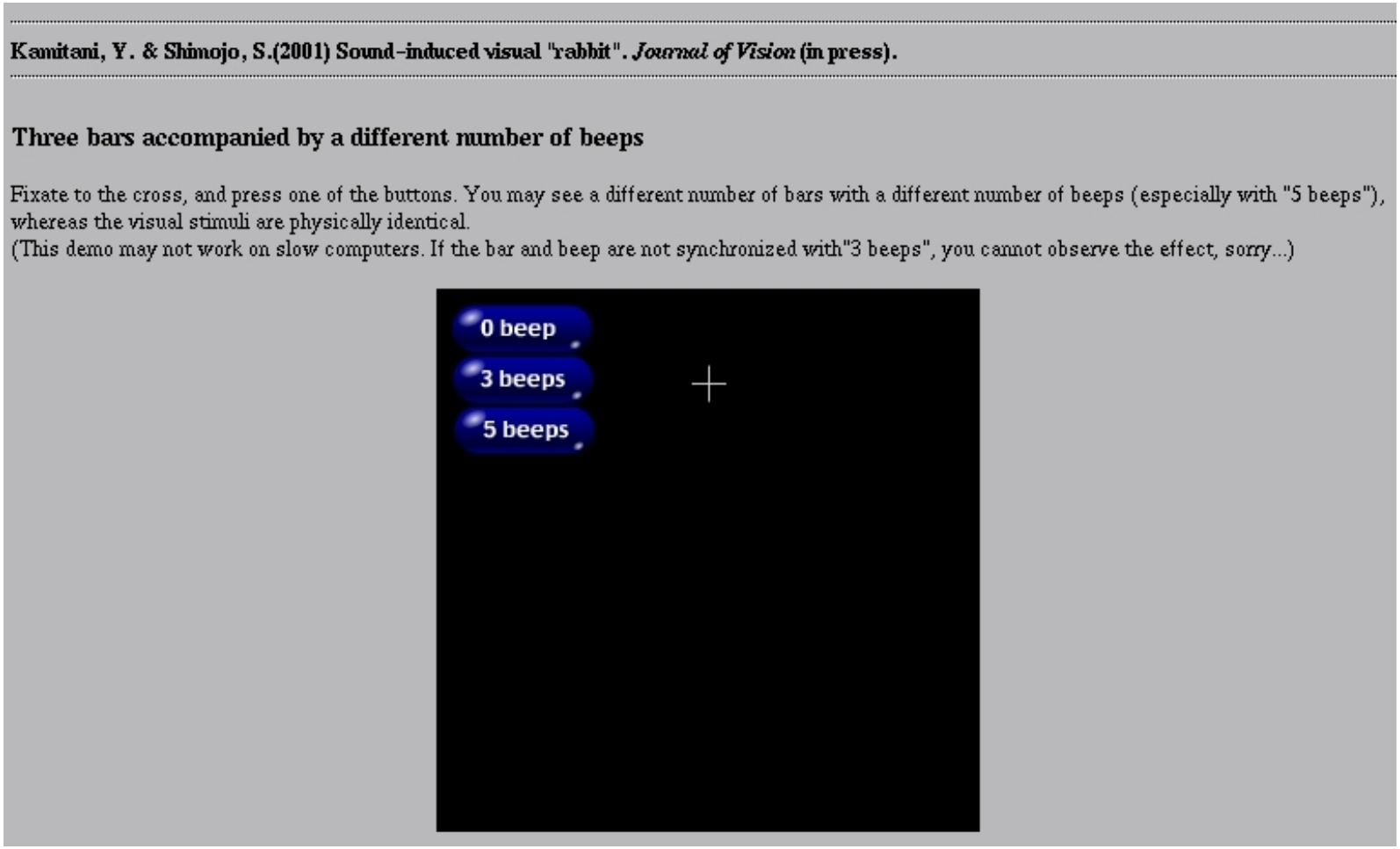
[Sinha and Poggio Perception 2002, 31(1)]
http://perceptionweb.com/perc0102/sinha.html

The Visual System is not a fixed feed-forward system

It is influenced by

- prior experience
- surrounding visual scene (and not just immediate)
- recent prior exposure
- learned familiarity with special objects
- concurrent input in other sensory modalities (where the relationship has been well learned)

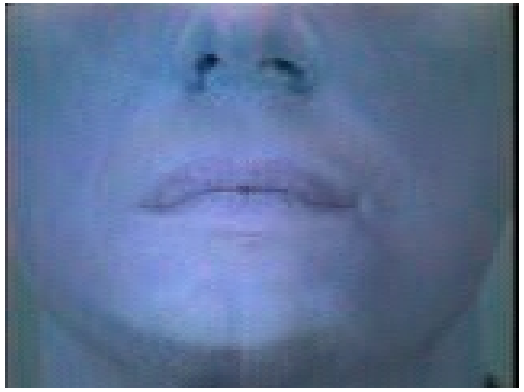
Auditory input can influence Visual Perception



Kamitani, Y. & Shimojo, S.(2001) Sound-induced visual "rabbit". Journal of Vision

available at http://neuro.caltech.edu/~kamitani/audiovisualRabbit

Visual input can influence Auditory perception – McGurk Demo

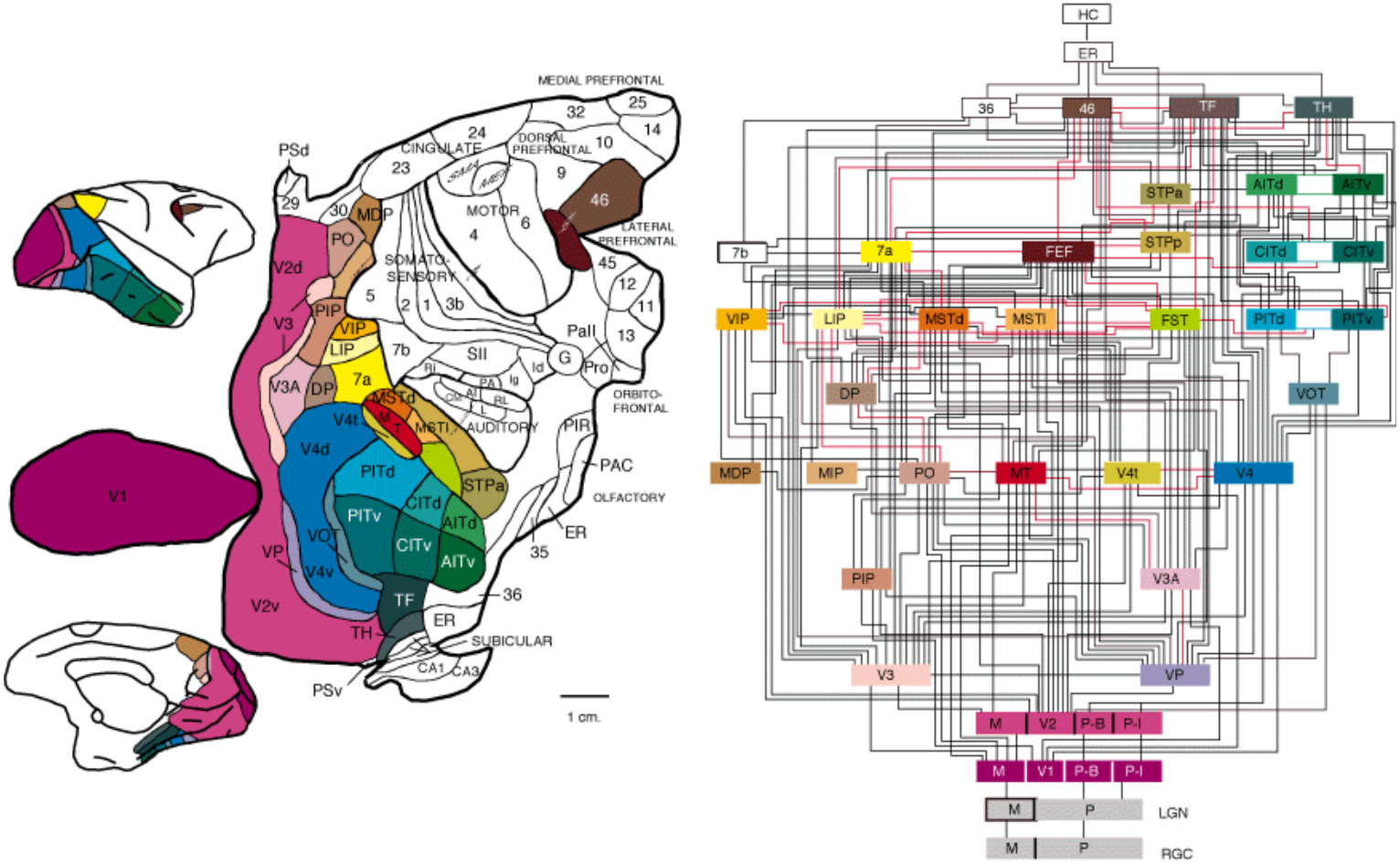


The McGurk Effect was discovered by McGurk and MacDonald in 1976. This demo is courtesy of Dr. Lawrence Rosenblum of University of California, Riverside.

How do we study Perceptual Systems?

- Physiology
  - ⋆ Single Cell Electrophysiology – what do neurons respond to?
  - ⋆ Optical Imaging – what are groups of neurons responding to?
  - ⋆ microstimulation – how does the animal respond when we stimulate?
- Psychophysics
  - ⋆ observe and analyze visual illusions

Visual Cortical Areas



from Felleman, D.J. and Van Essen, D.C. (1991) *Cerebral Cortex* 1:1-47.

How do we study Perceptual Systems?

- Physiology
  - ⋆ Single Cell Electrophysiology – what do neurons respond to?
  - ⋆ Optical Imaging – what are groups of neurons responding to?
  - ⋆ microstimulation – how does the animal respond when we stimulate?
- Psychophysics
  - ⋆ observe and analyze visual illusions
  - ⋆ observe and analyze people with brain damage

How do we study Perceptual Systems?

- Physiology
  - ⋆ Single Cell Electrophysiology – what do neurons respond to?
  - ⋆ Optical Imaging – what are groups of neurons responding to?
  - ⋆ microstimulation – how does the animal respond when we stimulate?
- Psychophysics
  - ⋆ observe and analyze visual illusions
  - ⋆ observe and analyze people with brain damage
  - ⋆ threshold detection

Fechner's Classical Psychophysical Techniques

Absolute threshold: Smallest amount of stimulus energy needed to detect a stimulus

- Method of Adjustment
- Method of Limits
- Method of Constant Stimuli

Method of Limits

Stimulus Intensity	A	D	A	D	A	D	A	D
9		Y						
8		Y				Y		Y
7		Y		Y		Y		Y
6		Y		Y		Y		Y
5		Y		Y		Y		Y
4	Y	Y		Y		Y		Y
3	N	Y	Y	Y	Y	Y		Y
2	N	N	N	Y	N	N	Y	Y
1	N	N	N	N	N		N	N
0	N		N		N		N	
-1	N		N		N		N	
-2	N		N		N		N	
-3	N		N		N		N	
-4	N		N		N		N	
-5	N		N				N	
-6	N						N	
Transition Points	3.5	2.5	2.5	1.5	2.5	2.5	1.5	1.5

Mean Threshold = 2.25

Figure 11. Threshold determination using the method of limits. A = Ascending limits, D = Descending limits, Y = Yes, the stimulus is seen and N = No, the stimulus cannot be seen.

from http://webvision.med.utah.edu/Psych1.html

Staircase method (variation of method of limits)

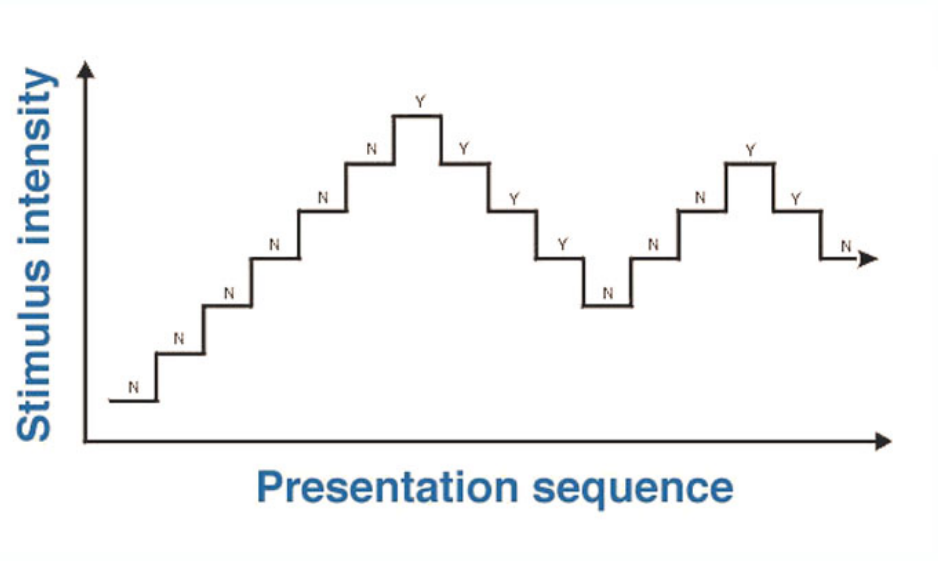


Figure 12. Staircase method. Y = Yes, the stimulus can be seen and N = No, the stimulus cannot be seen.

from http://webvision.med.utah.edu/Psych1.html

Method of Constant Stimuli

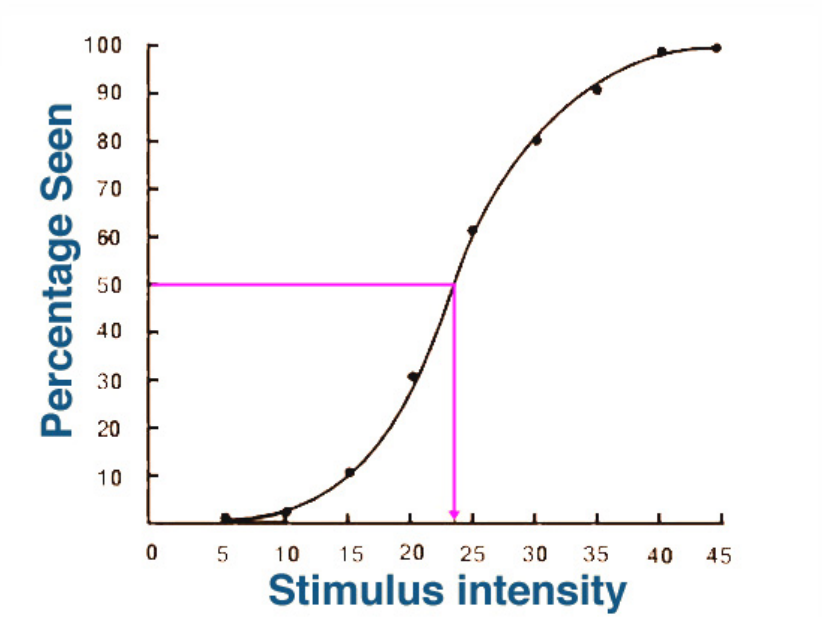


Figure 13. Psychometric function for a YES-NO paradigm.

from http://webvision.med.utah.edu/Psych1.html

curve is called a **psychometric** function (measuring mind/brain)

Difference Threshold (DL Differenze Limin)

Now commonly called **Just Noticeable Difference (JND)** : smallest detectable increase or decrease in stimulus energy

Weber's Law: $\frac{DL}{S} = K$

true for most sensations as long as significantly above threshold

Why does it not hold at threshold?

Summary

Vision is hard.

Our visual system excels because it has learned rules about our world.

We can learn about these rules by examining illusions and aftereffects which reflect the brains processing when the rules don't hold.