

Computational Neuroscience and Learning



Artificial and robotic vision

visual system: why?

“eyes” evolved for different reasons, not necessarily to take mega-pixel pictures...

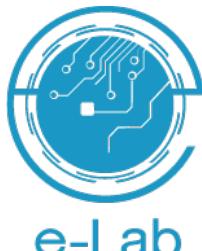
Eyes: sensory structures capable of spatial vision, i.e. imaging the environment, no matter how crude the image is

(Land and Nilsson, Animal Eyes)

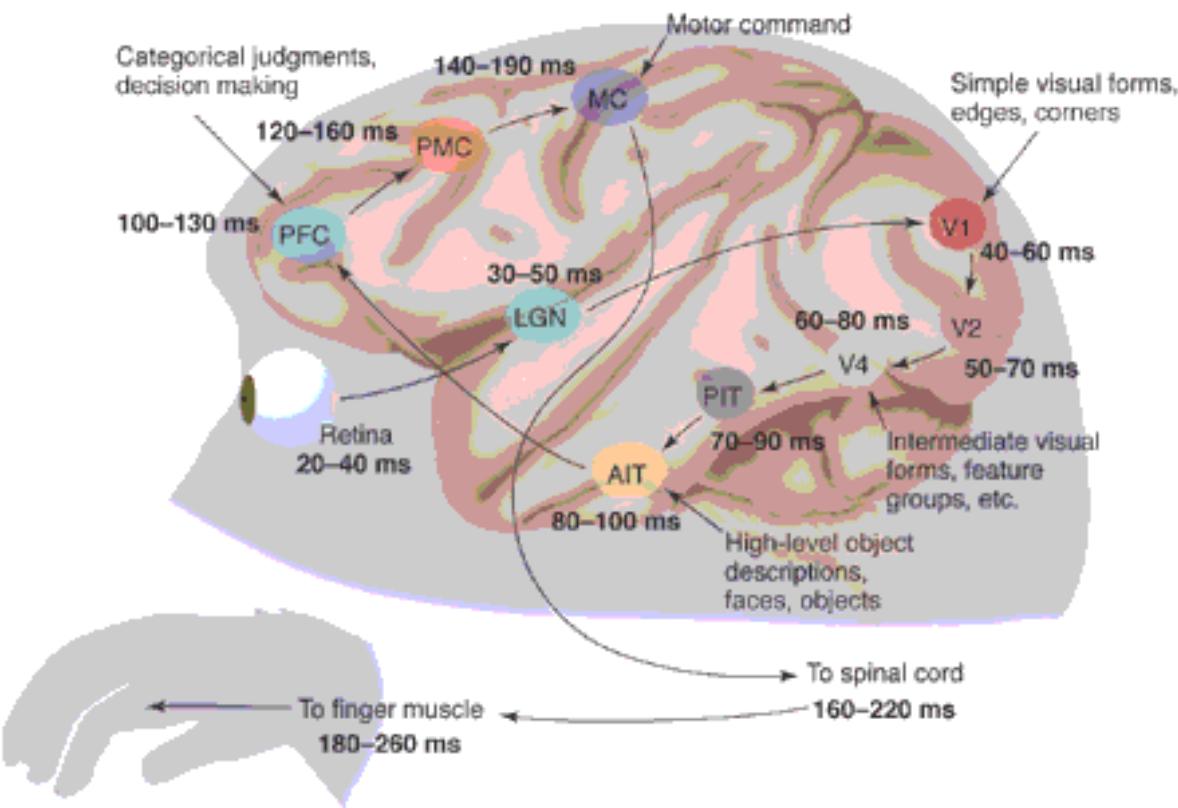
- Is there something interesting in the environment ?
 - in a specific class of objects
- Where is it ?
- What is it ?

often it is about a few bits in the right place at the right time

Andreas Andreou, ~2003



human visual system



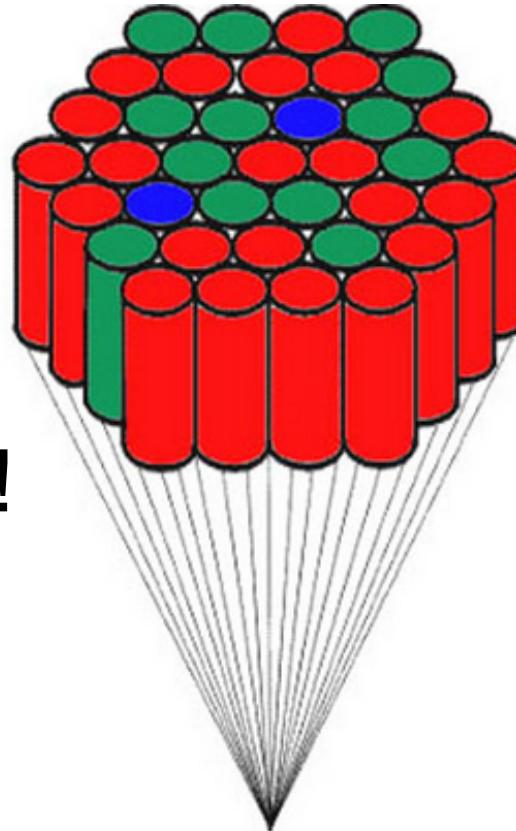
- eyes
- lateral geniculate nucleus
- V1,V2,V4,IT
- pre-frontal cortex
- motor command
- muscles

before a tool...

receptive fields

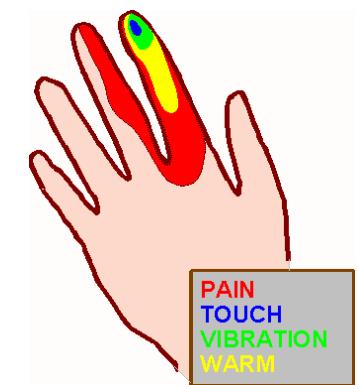
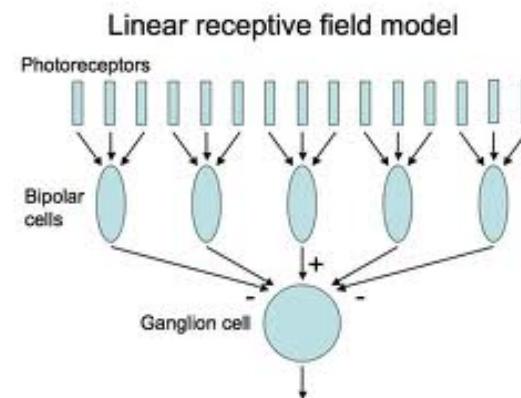
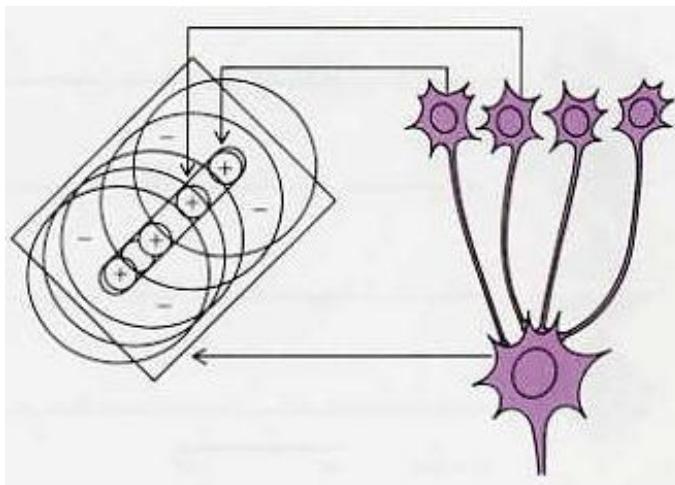
receptive fields

aggregate information!



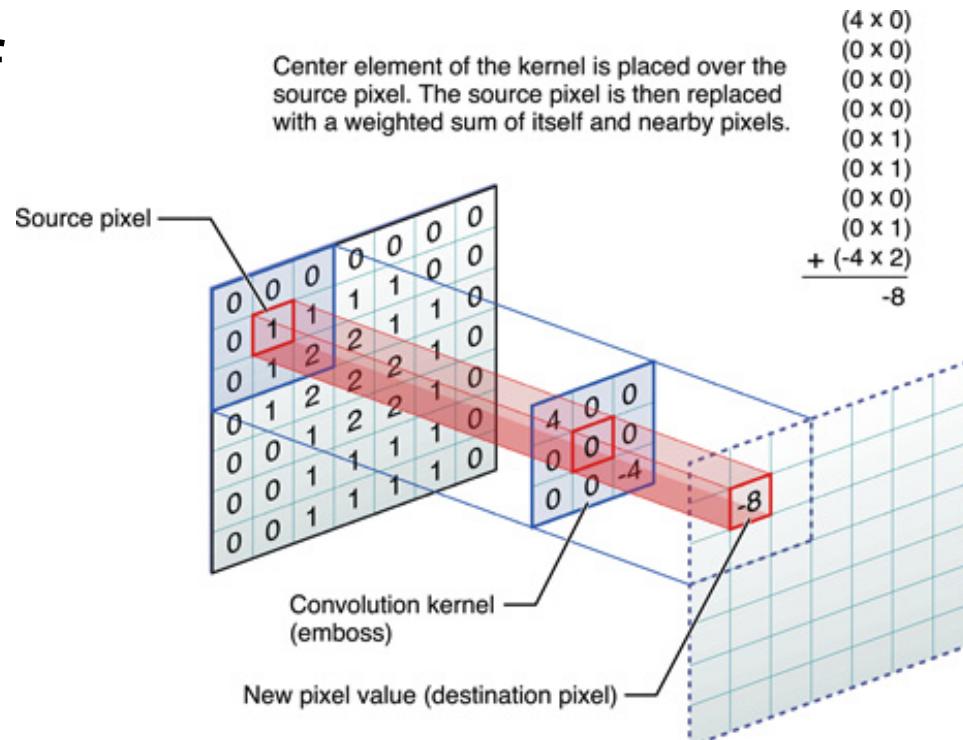
neighborhood operation

local vote sampling



artificial receptive fields

an
ensemble of
neurons



one output

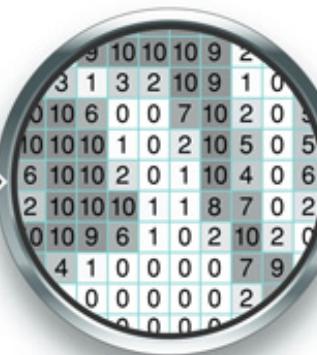
a voting
scheme



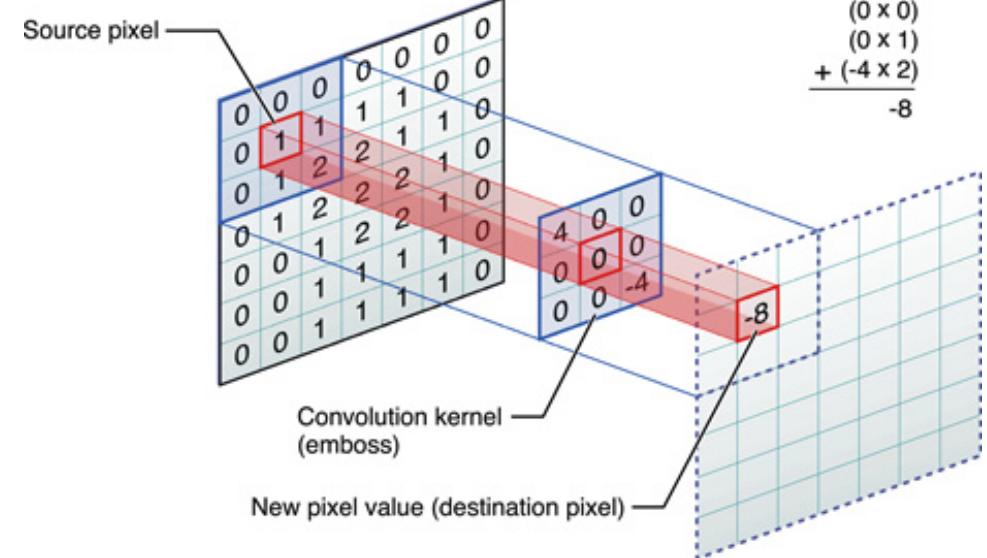
convolutions as receptive fields



Pixels depicted by a grid of numbers representing intensity



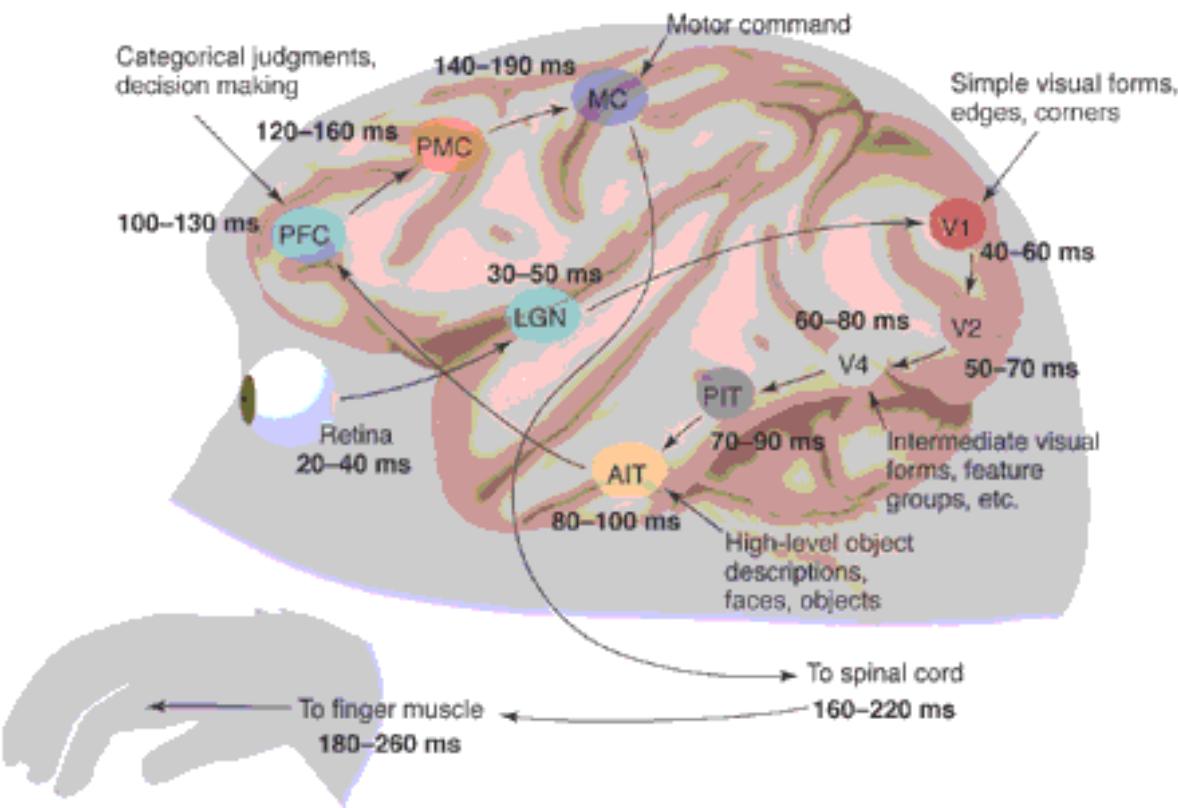
Center element of the kernel is placed over the source pixel. The source pixel is then replaced with a weighted sum of itself and nearby pixels.



<https://developer.apple.com/library/mac/documentation/performance/Conceptual/vImage/ConvolutionOperations/ConvolutionOperations.html>

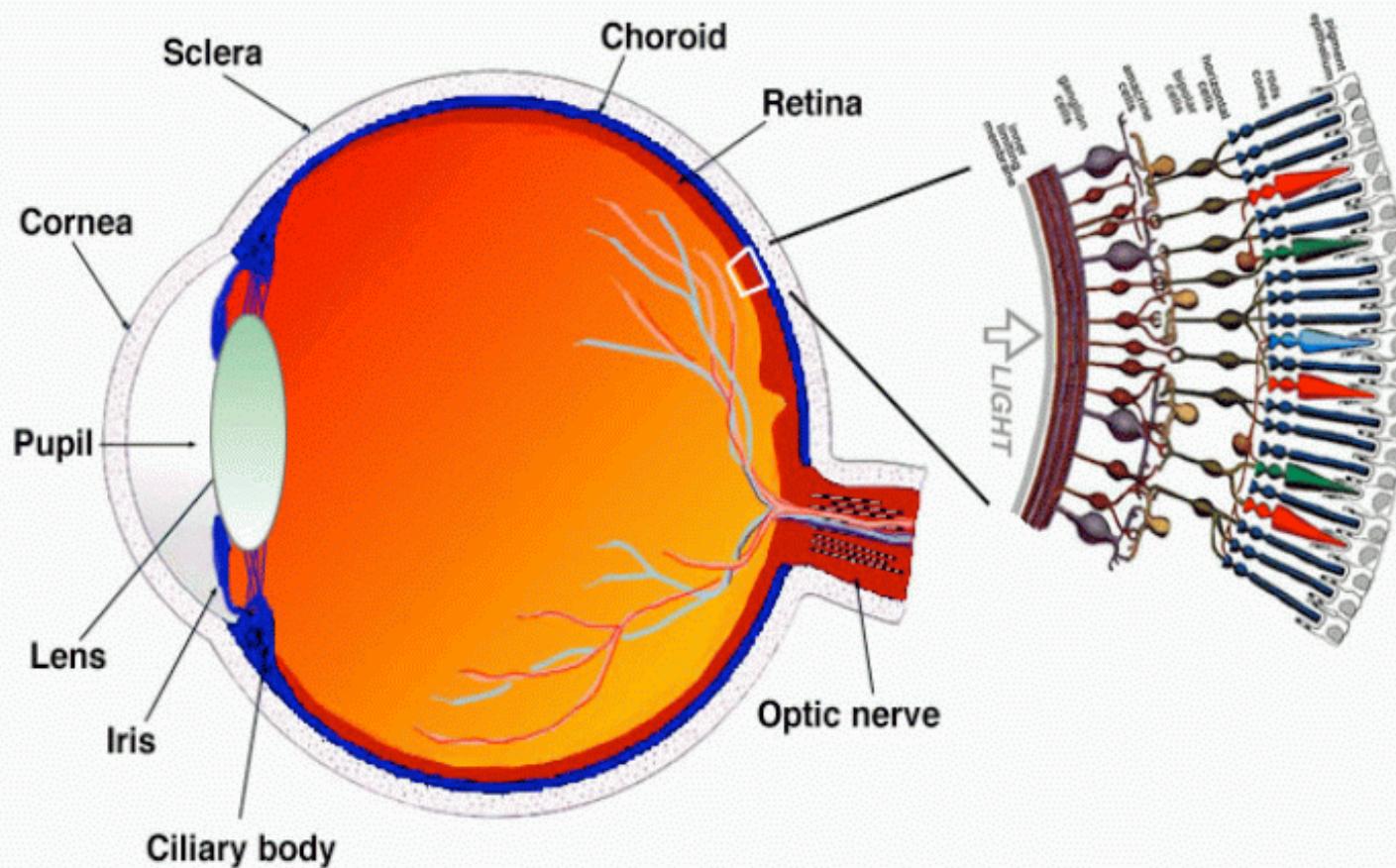
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human visual system



- eyes
- lateral geniculate nucleus
- V1,V2,V4,IT
- pre-frontal cortex
- motor command
- muscles

eyes



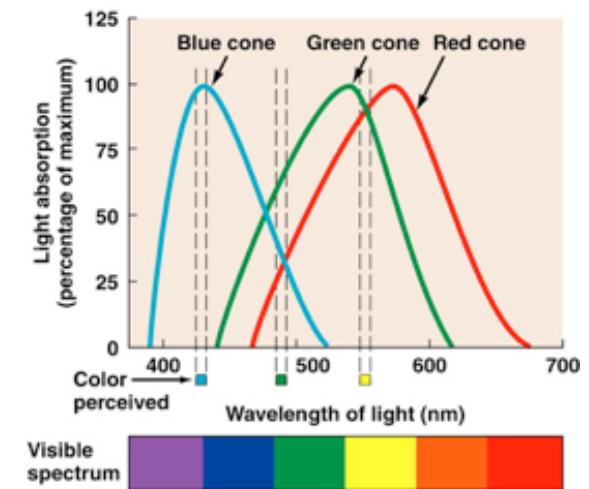
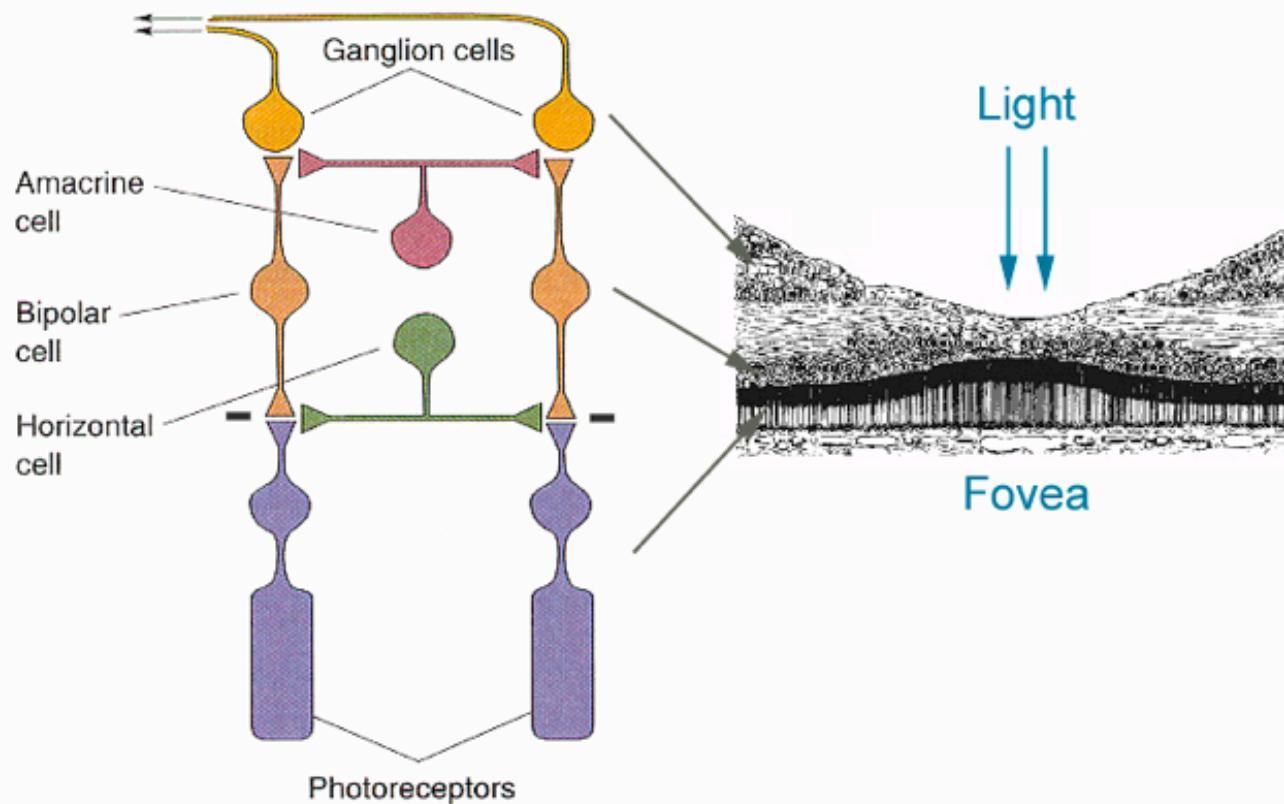
lens

retina

optic nerve

simple retina

Ganglion cell axons
projecting to forebrain



extract contours

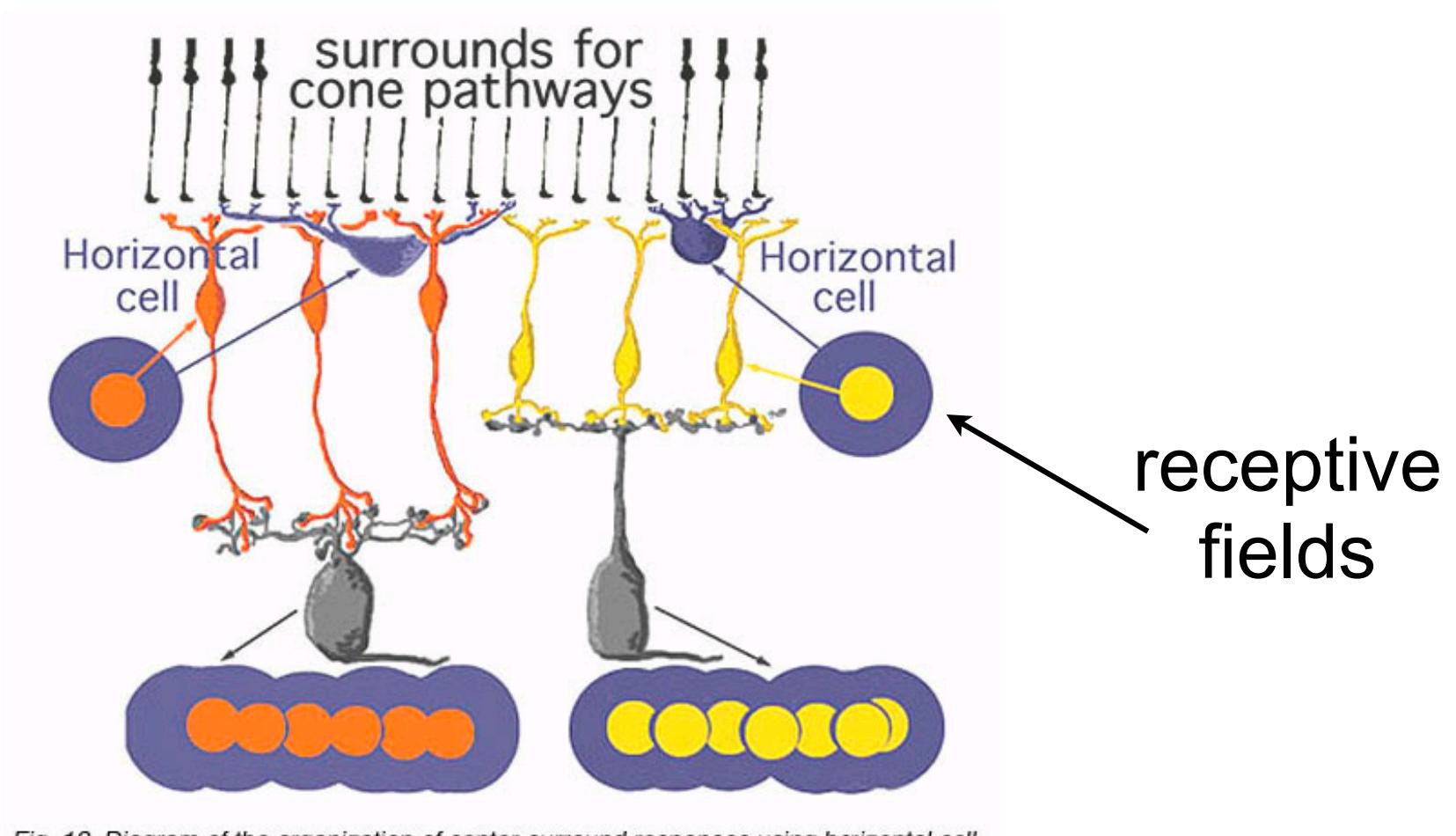
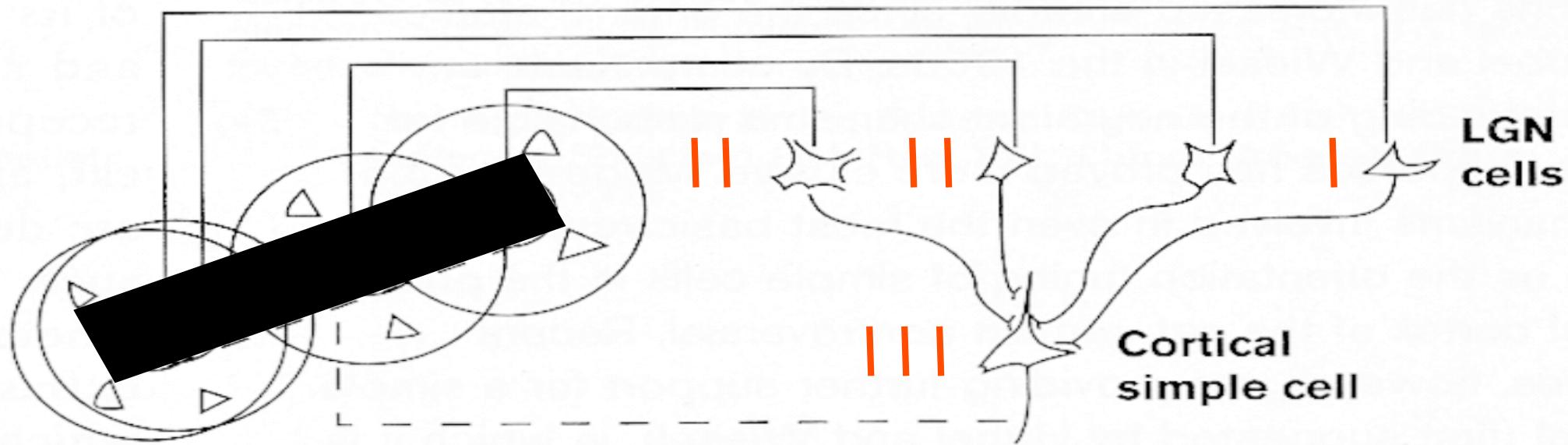
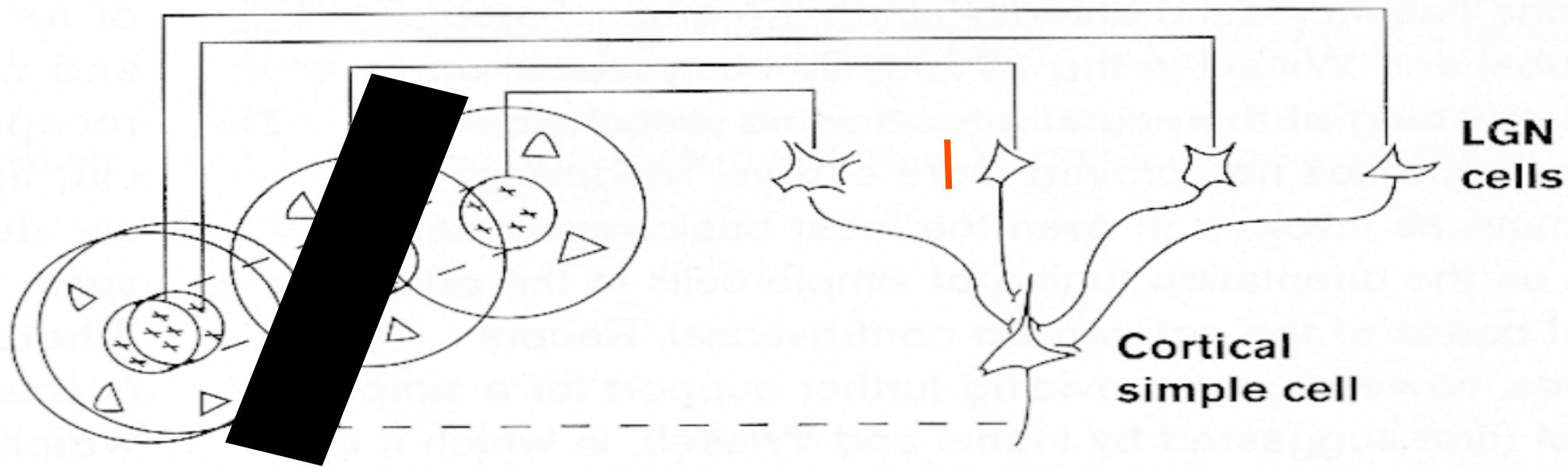


Fig. 12. Diagram of the organization of center-surround responses using horizontal cell circuitry to provide the antagonistic surround.

extract contours



extract contours



retinal processing “motion” and “contours”

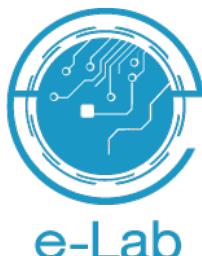
movies of our eyes



By Frank Werblin and Botond Roska

[http://mcb.berkeley.edu/labs/
werblin/multiple.html](http://mcb.berkeley.edu/labs/werblin/multiple.html)

local contrast normalization



and yes, the retina is more than just these simple operations...

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and yes, the retina is more than just these simple operations...

for your benefit READ MORE:

<http://en.wikipedia.org/wiki/Retina>

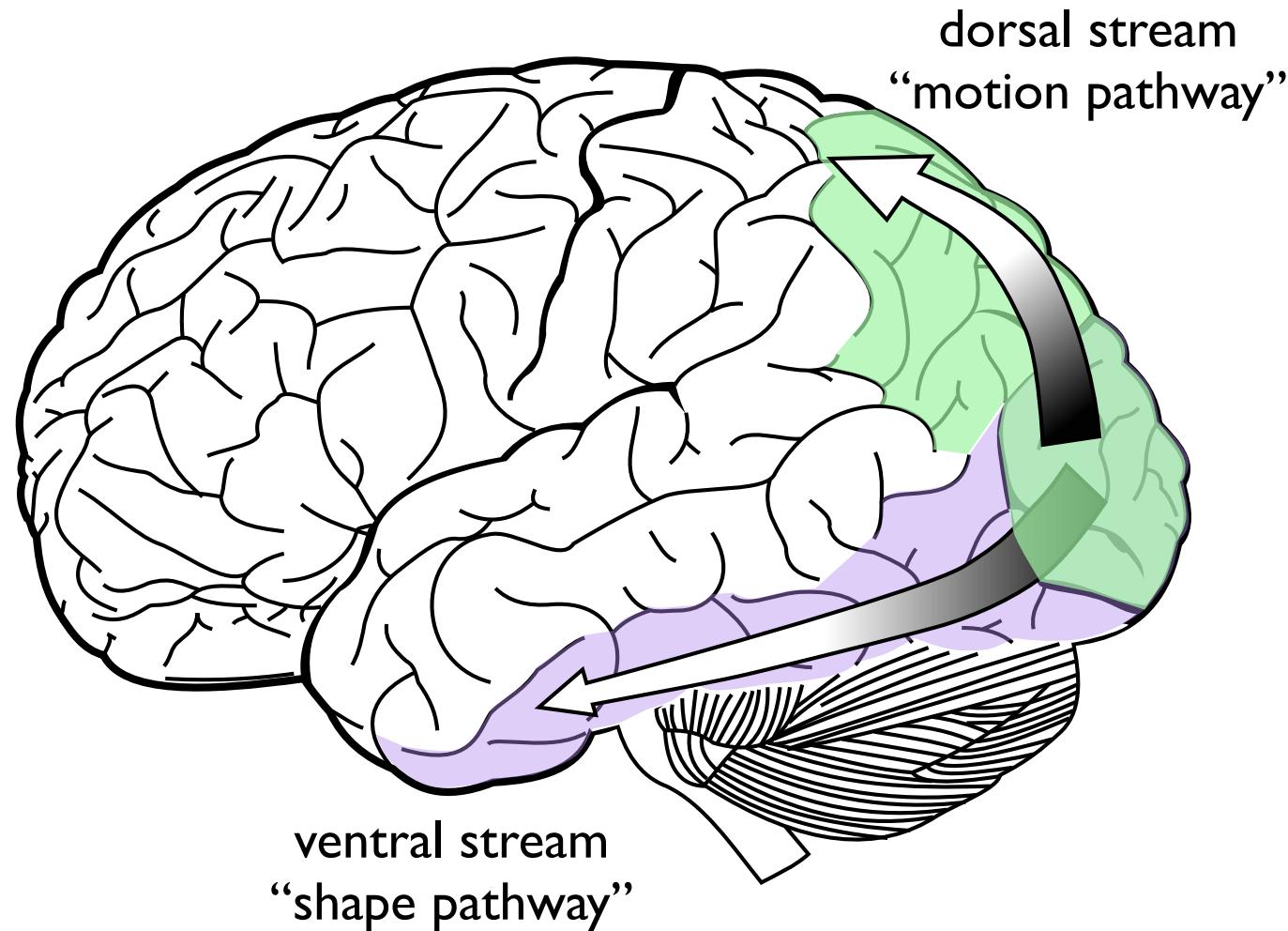
<http://mcb.berkeley.edu/labs/werblin/multiple.html>

neuroscience books

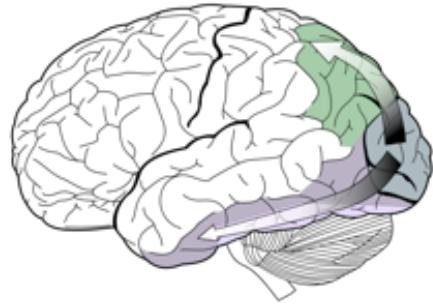
...



visual cortex



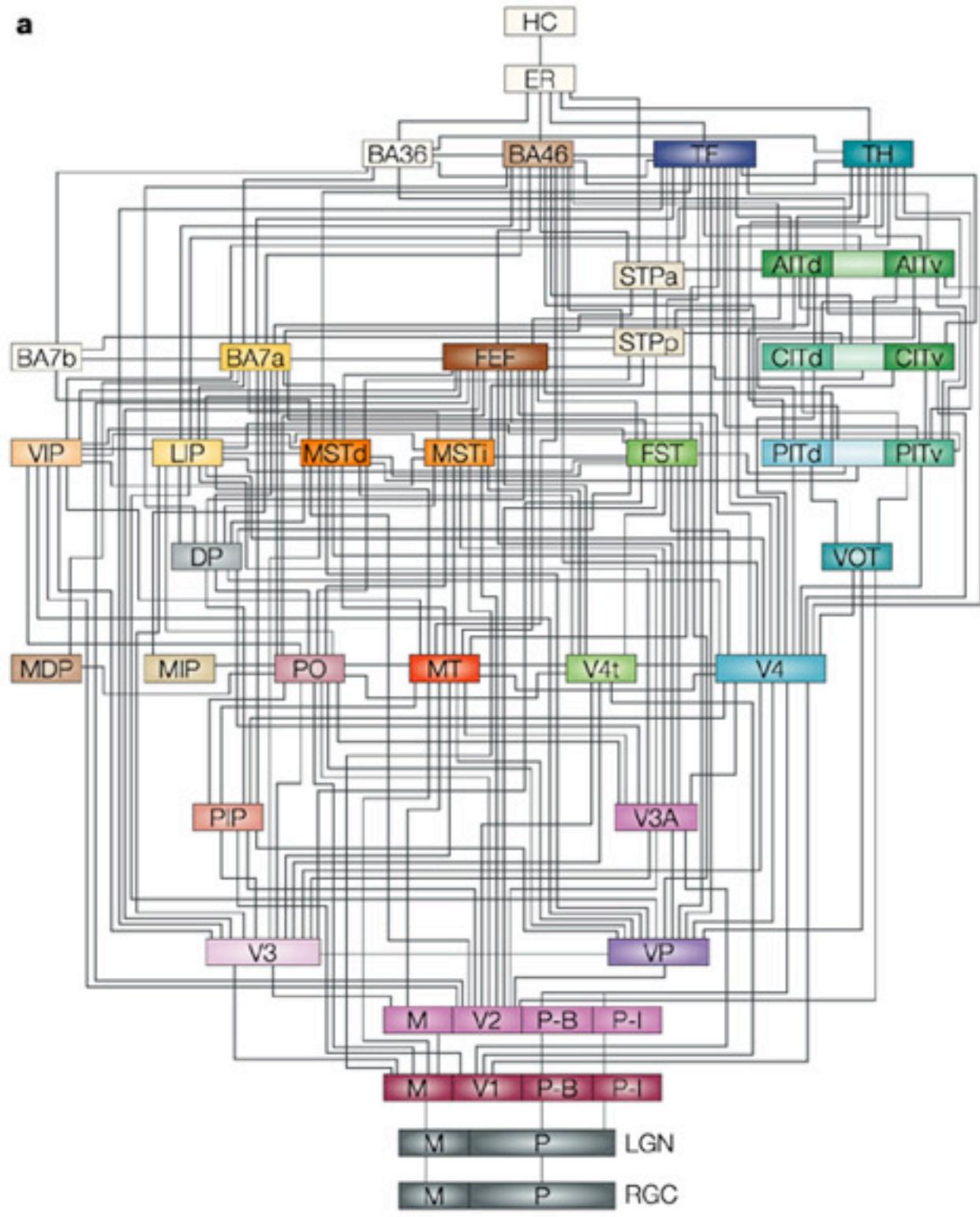
in this course we mostly work on the...

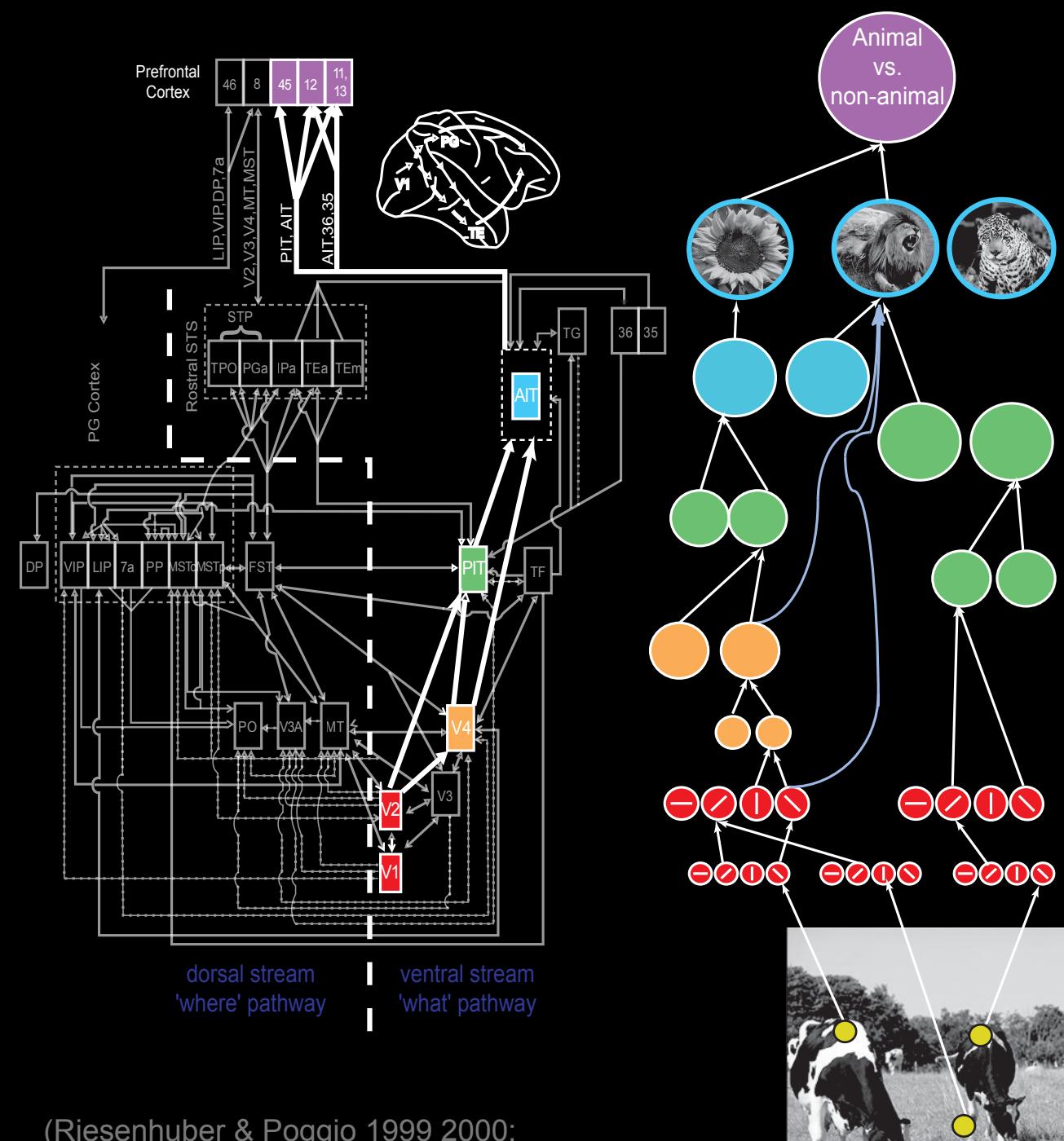


ventral pathway

The visual cortex: A hierarchy of about 30 visual areas

Felleman & van Essen 1991





(Riesenhuber & Poggio 1999 2000;
Serre Kouh Cadieu Knoblich Kreiman & Poggio 2005;
Serre Oliva & Poggio 2007)

◆ V1:

- Simple and complex cells tuning properties (Schiller et al 1976; Hubel & Wiesel 1965; Devalois et al 1982)
- MAX operation in subset of complex cells (Lampl et al 2004)

◆ V4:

- Tuning for two-bar stimuli (Reynolds Chelazzi & Desimone 1999)
- MAX operation (Gawne et al 2002)
- Two-spot interaction (Freiwald et al 2005)
- Tuning for boundary conformation (Pasupathy & Connor 2001)
- Tuning for Cartesian and non-Cartesian gratings (Gallant et al 1996)

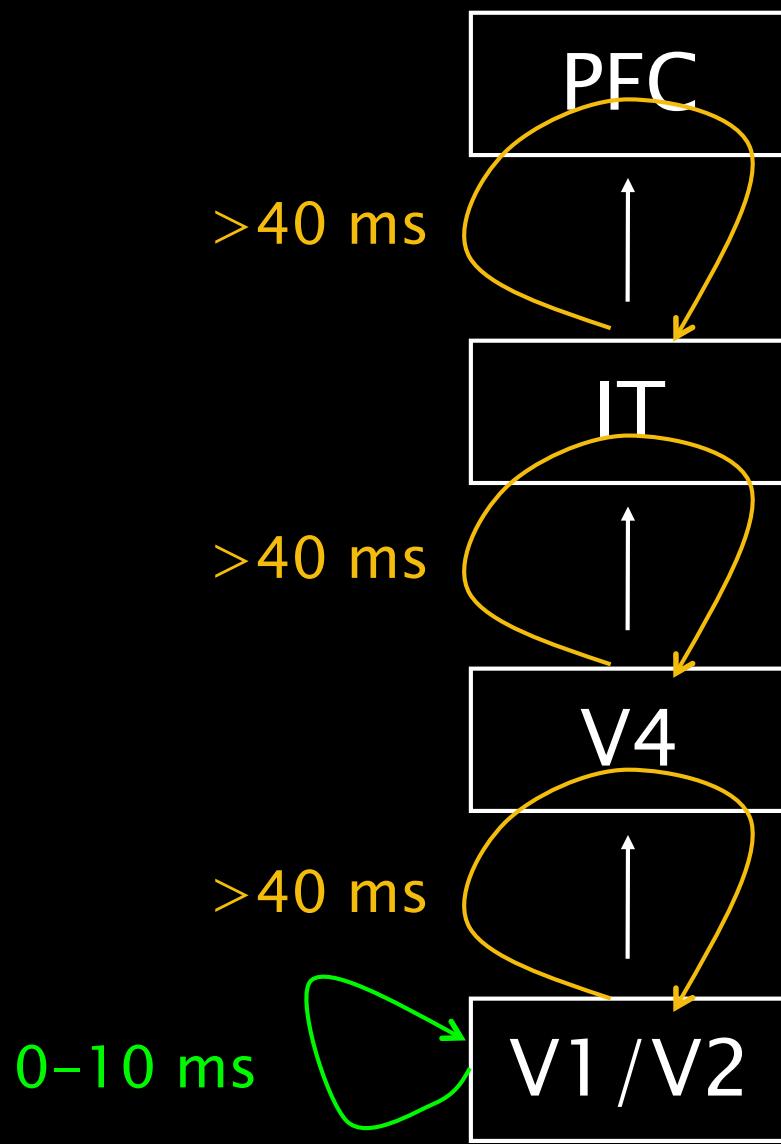
◆ IT:

- Tuning and invariance properties (Logothetis et al 1995)
- Differential role of IT and PFC in categorization (Freedman et al 2001 2002 2003)
- Read out data (Hung Kreiman Poggio & DiCarlo 2005)
- Average effect in IT (Zoccolan Cox & DiCarlo 2005; Zoccolan Kouh Poggio & DiCarlo in press)

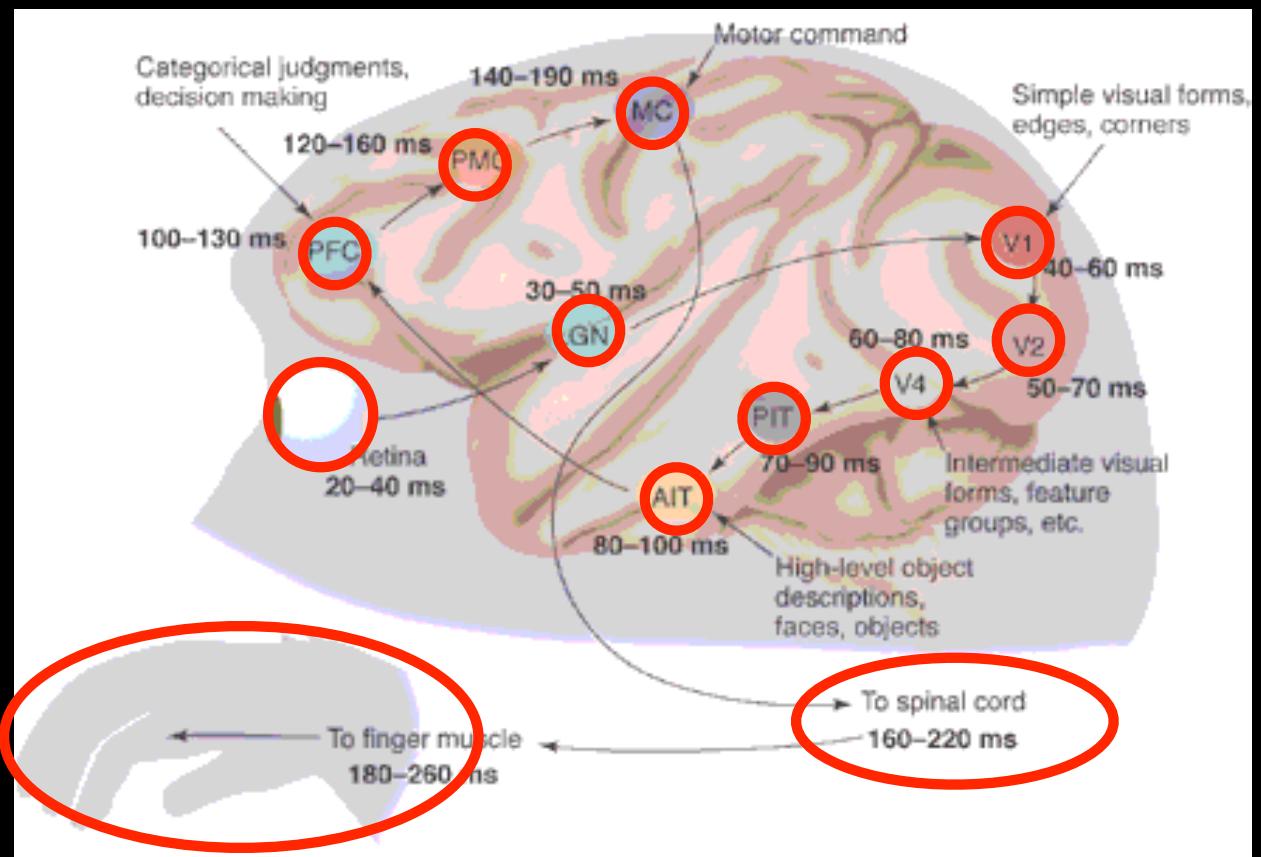
◆ Human behavior:

- Rapid animal categorization (Serre Oliva Poggio 2007)

The two “modes” of vision

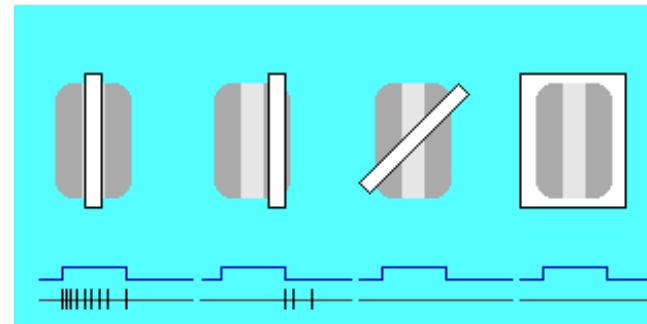


Feedforward processing

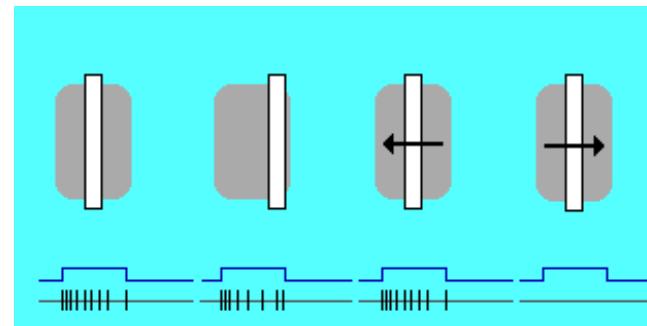


V1 area

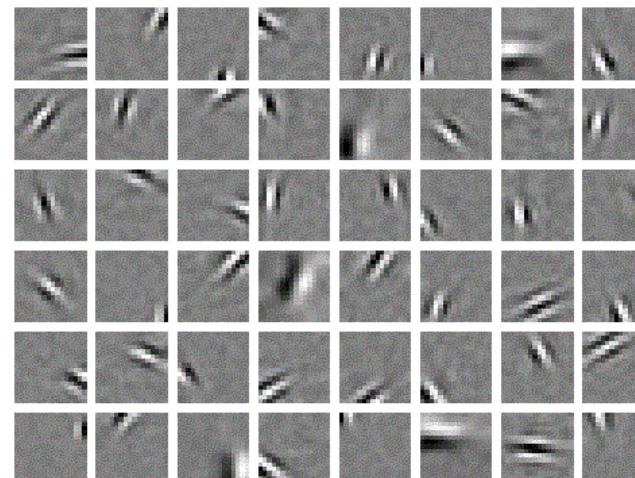
complex cells



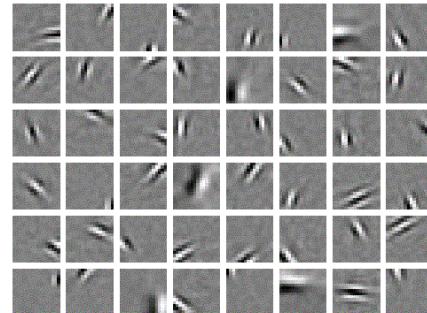
simple cells



receptive fields
[filters]

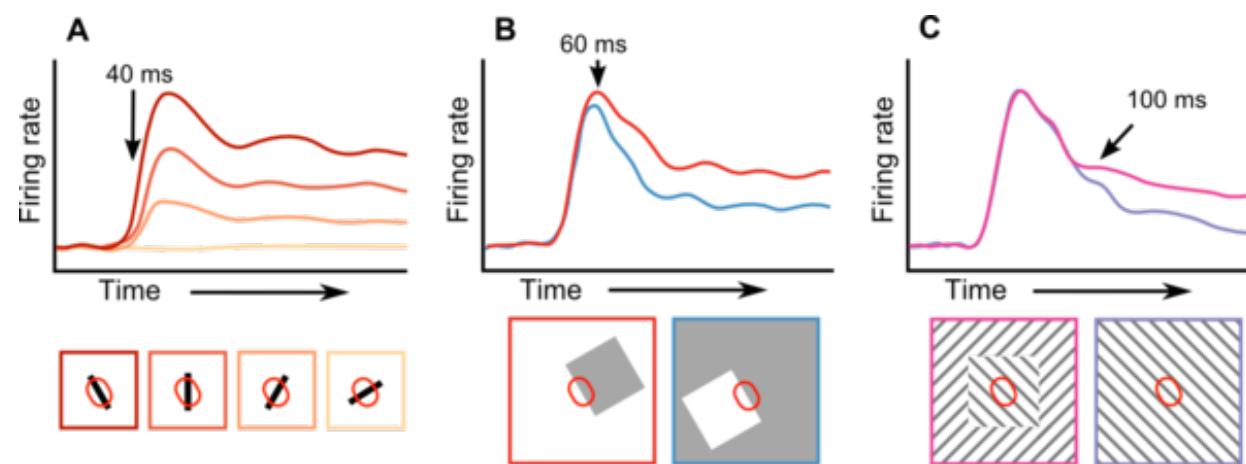


V2 area



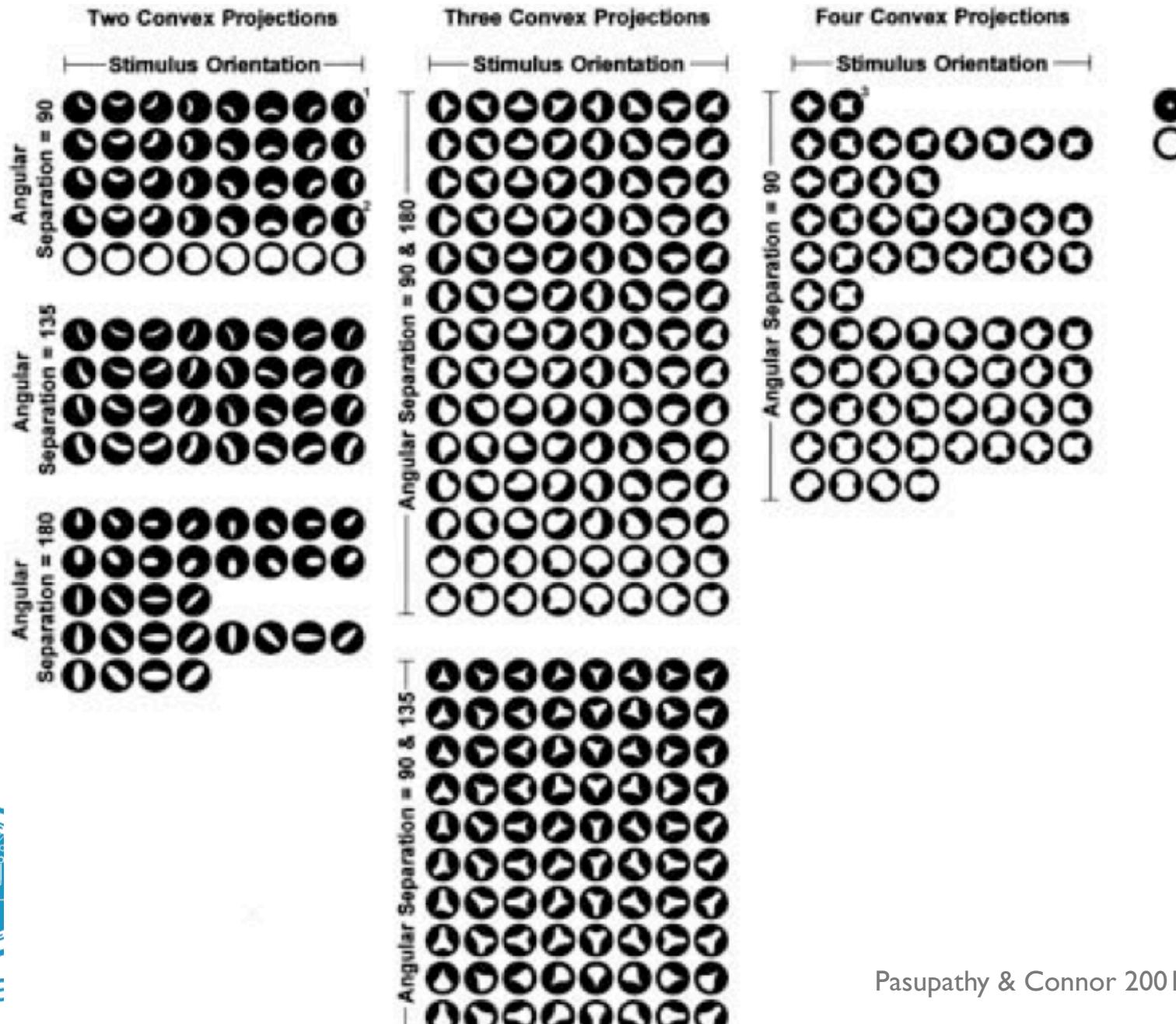
some cells like V1

some cells: border ownership, proto-objects:



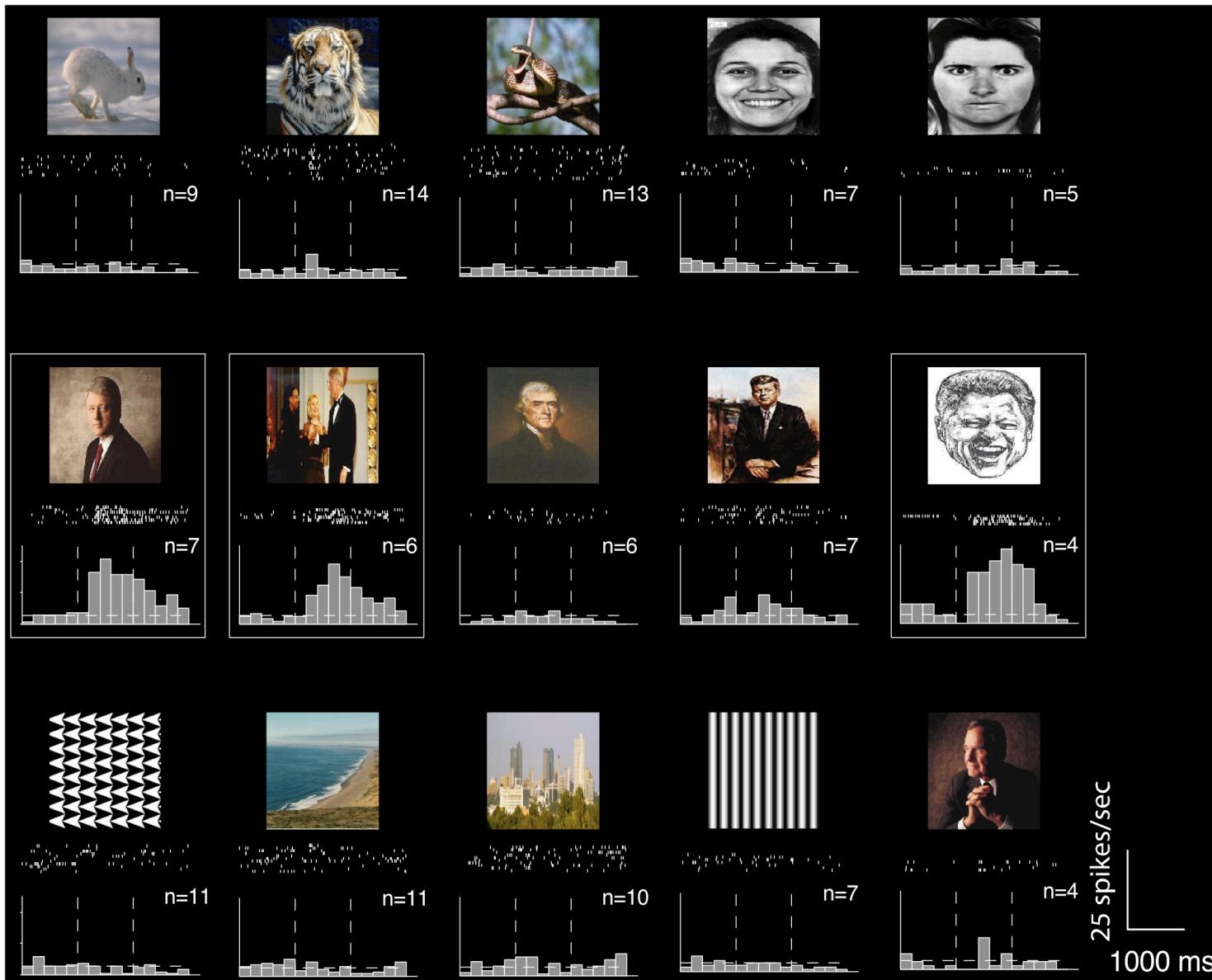
V4 area

V4 is tuned for object features of intermediate complexity



IT area

tuned for complex object features



Kreiman Koch & Fried 2002; Quiroga et al 2005

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and yes, the visual cortex is more than just these slides...

for your benefit READ MORE:

DiCarlo JJ, Zoccolan D, Rust NC. "How does the brain solve visual object recognition?" Neuron. 2012;73(3):415-34.

http://www.scholarpedia.org/article/Models_of_visual_cortex

http://en.wikipedia.org/wiki/Visual_cortex

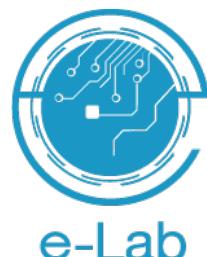
http://www.scholarpedia.org/article/Area_V1

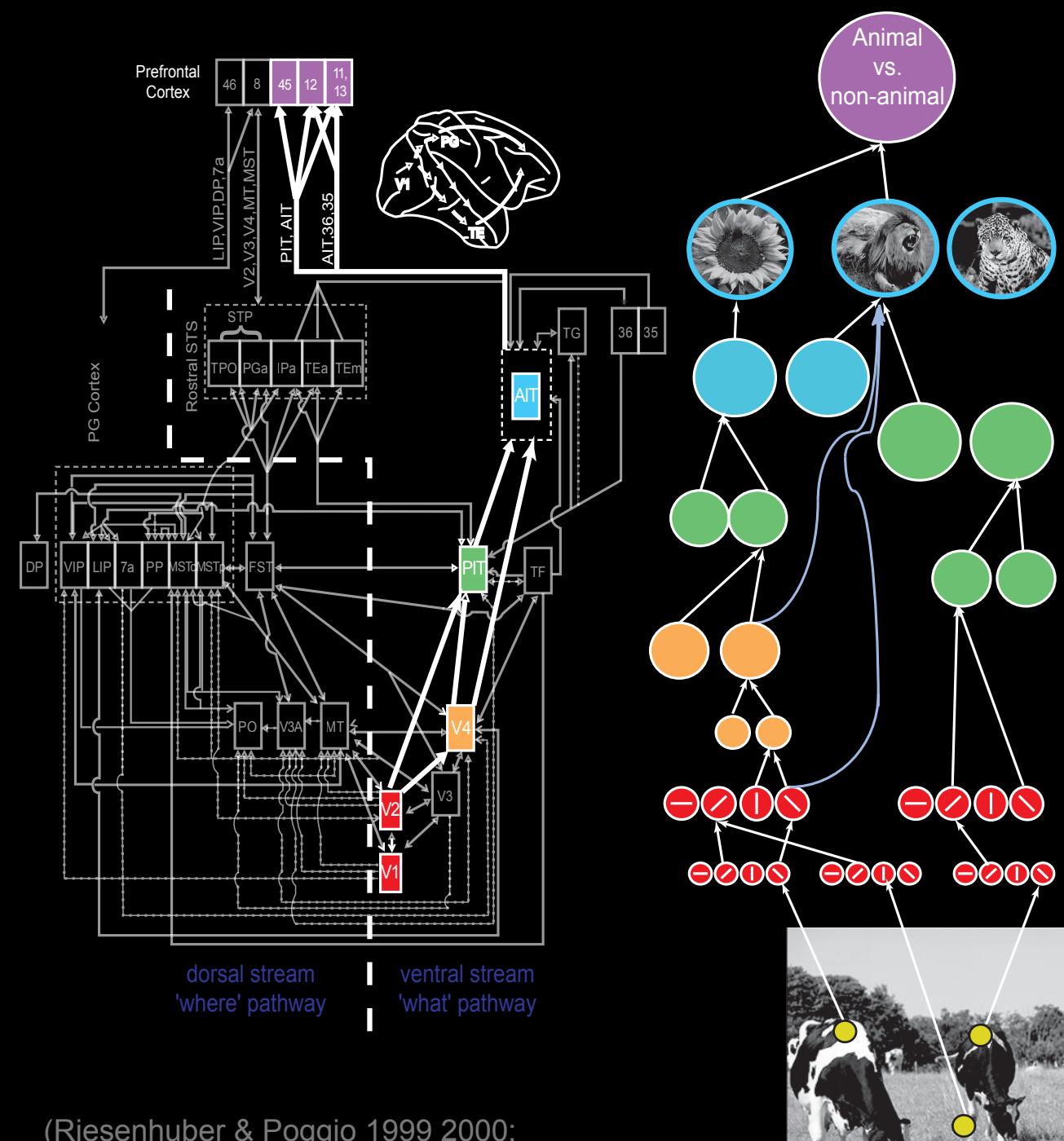
ALL REFERENCES TO THESE ARTICLES!!!!

neuroscience books

...

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for your benefit READ MORE:

LABs and People to keep an eye on
and read everything they have
listen to online talks...

James DiCarlo, MIT
Tomaso Poggio, MIT
Thomas Serre, Brown

...

