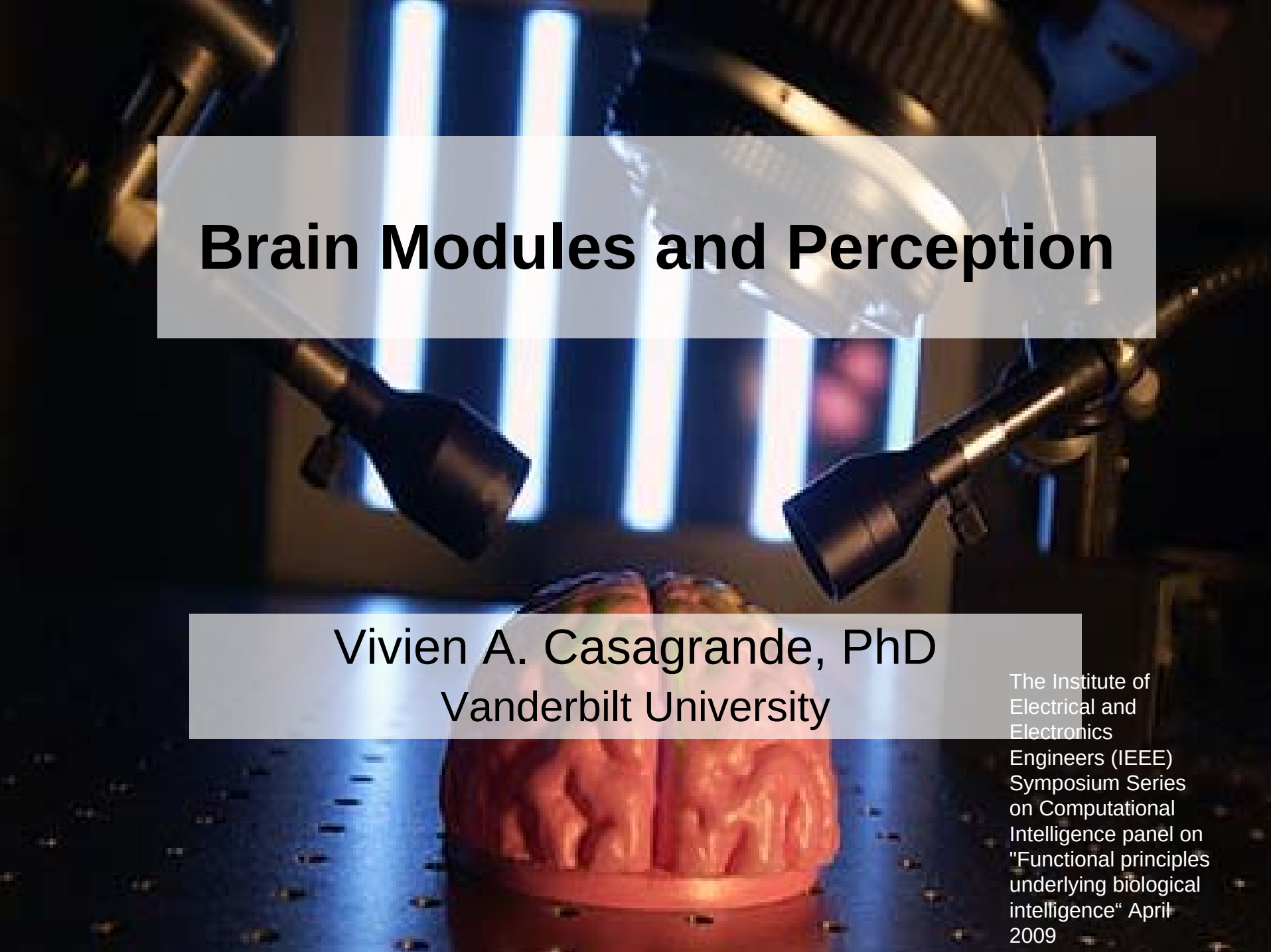
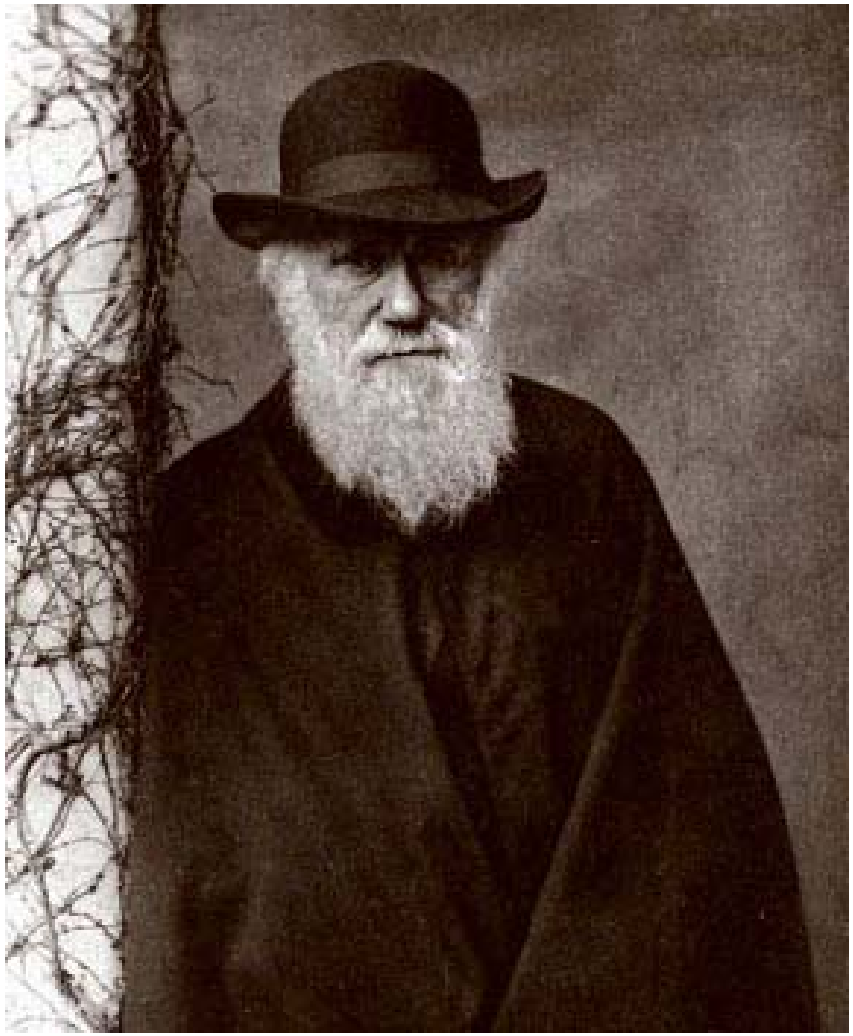


Brain Modules and Perception

Vivien A. Casagrande, PhD
Vanderbilt University

The Institute of Electrical and Electronics Engineers (IEEE) Symposium Series on Computational Intelligence panel on "Functional principles underlying biological intelligence“ April 2009

Evolutionary history and developmental rules should guide our models

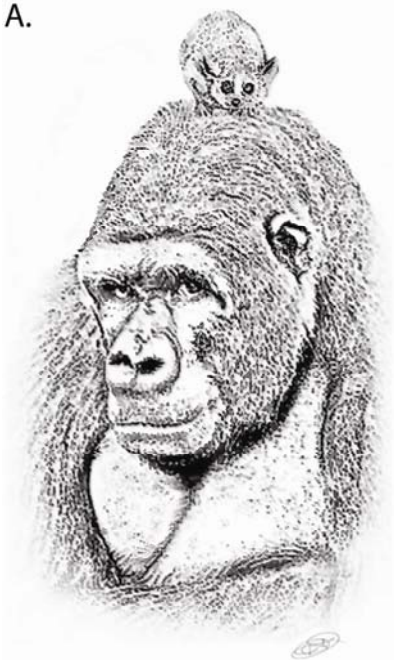


This year (2009) mark's Darwin's 200th birthday!

The Visual System (the brain) is not designed to represent "reality". You see what is important to **survival** and **reproduction**.

Comparative studies can reveal general principles

A.

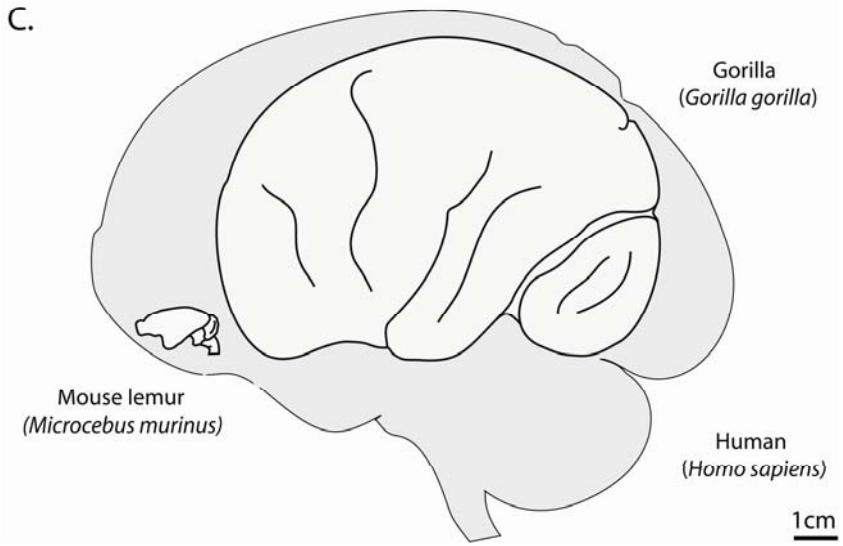


B.

Relative Body and Brain Sizes

Mouse Lemur	*body:*	*0.06kg*
(*Microcebus murinus*)	*brain:*	*1.73g*
Gorilla	*body:*	*175kg*
(*Gorilla gorilla*)	*brain:*	*535g*
Human	*body:*	*65kg*
(*Homo sapiens*)	*brain:*	*1400g*

C.

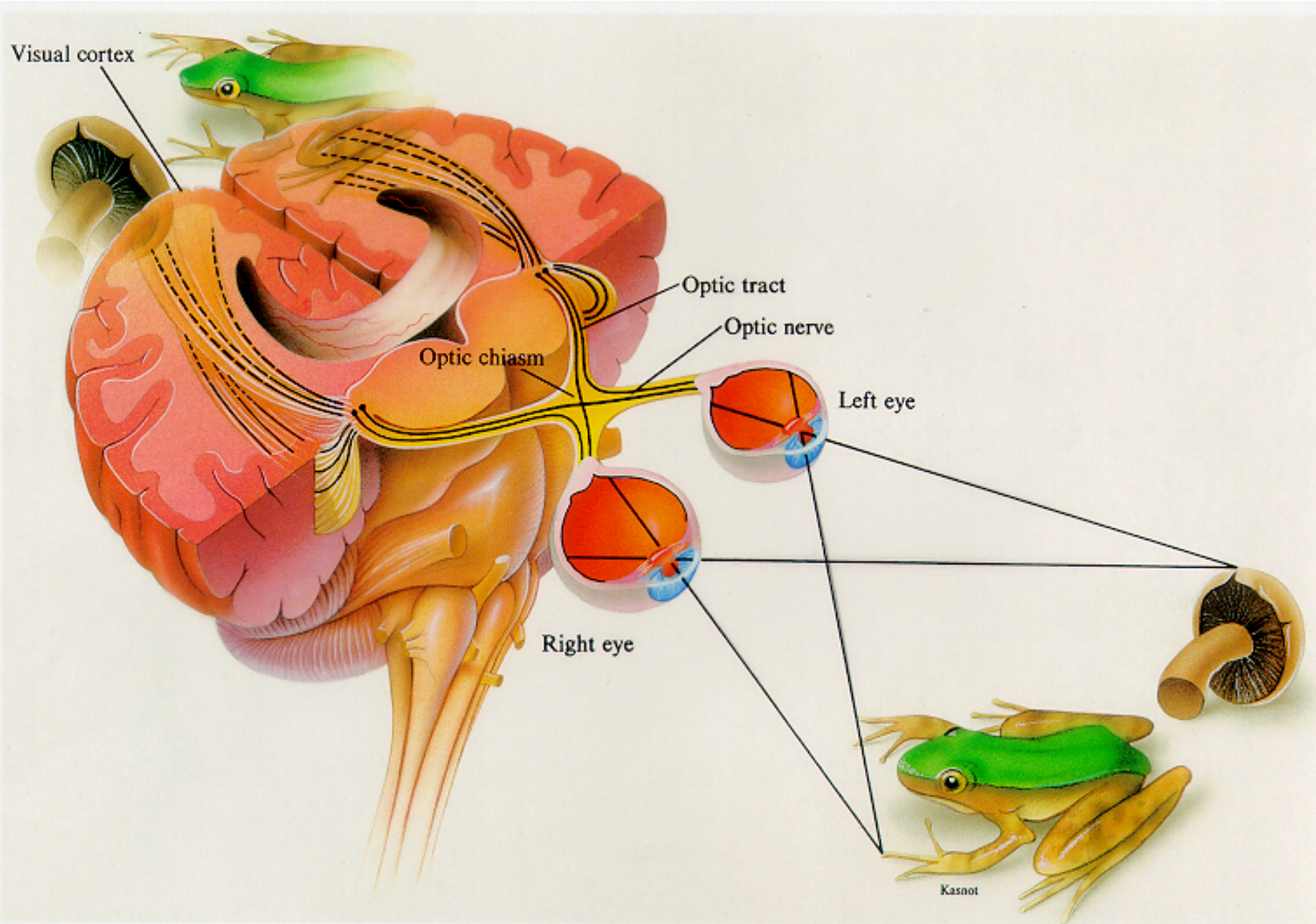


Casagrande et al. 2006

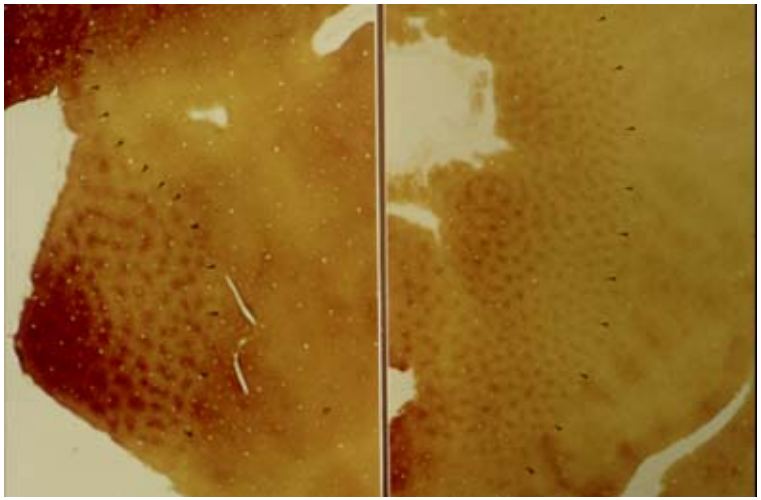
Questions

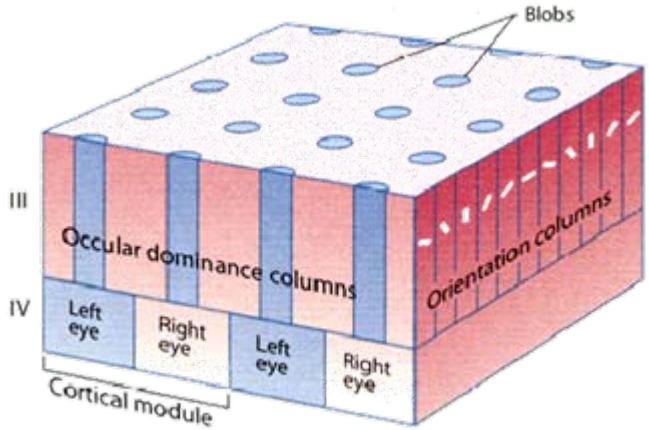
- Are there common rules that govern how stimulus attributes are mapped in visual cortex?
-
- How does the organization of functional maps relate to perception?

The Visual System keeps track of where things are in space

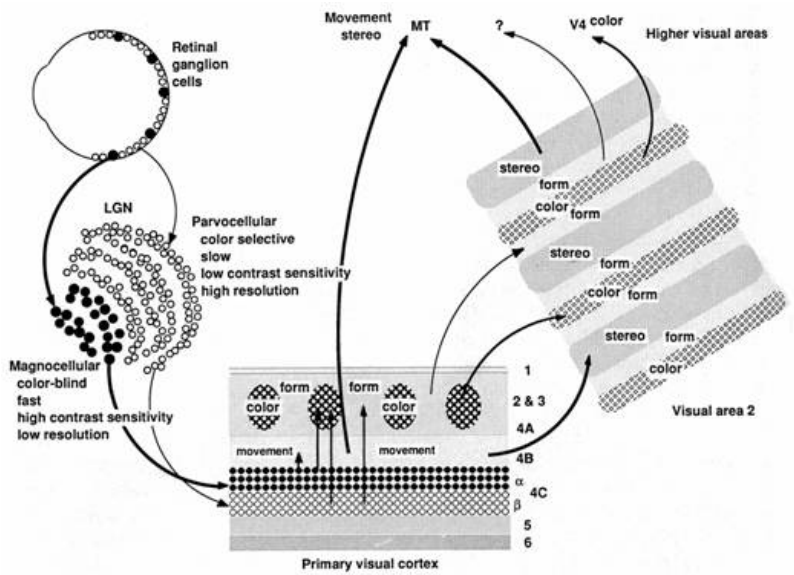


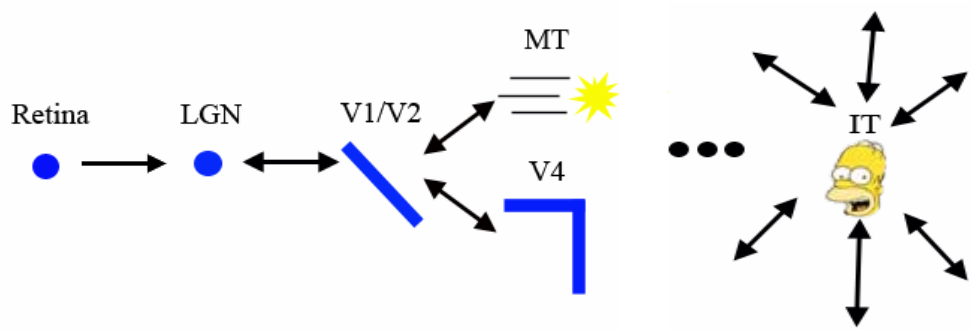
Traditional view: stimulus sorting, feed-forward, static



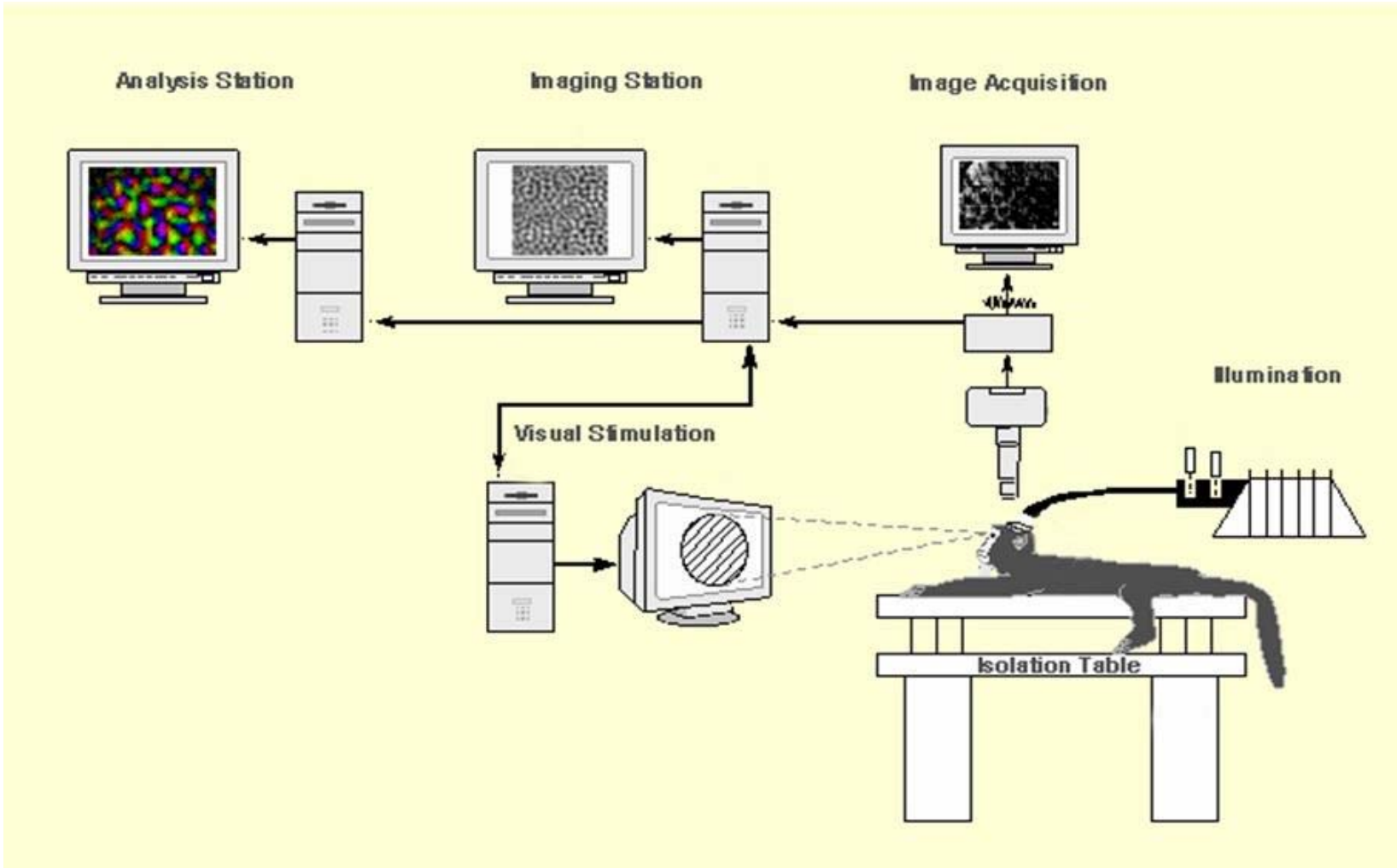


(Aus Gazzaniga et al., 1998)



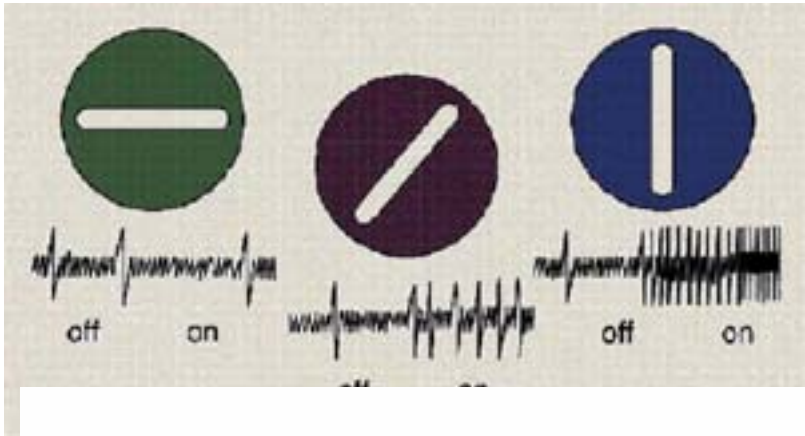


Optical Imaging

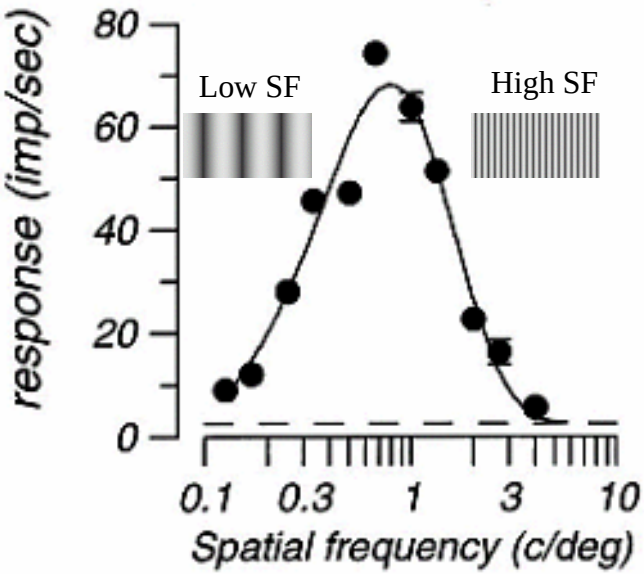


Stimuli

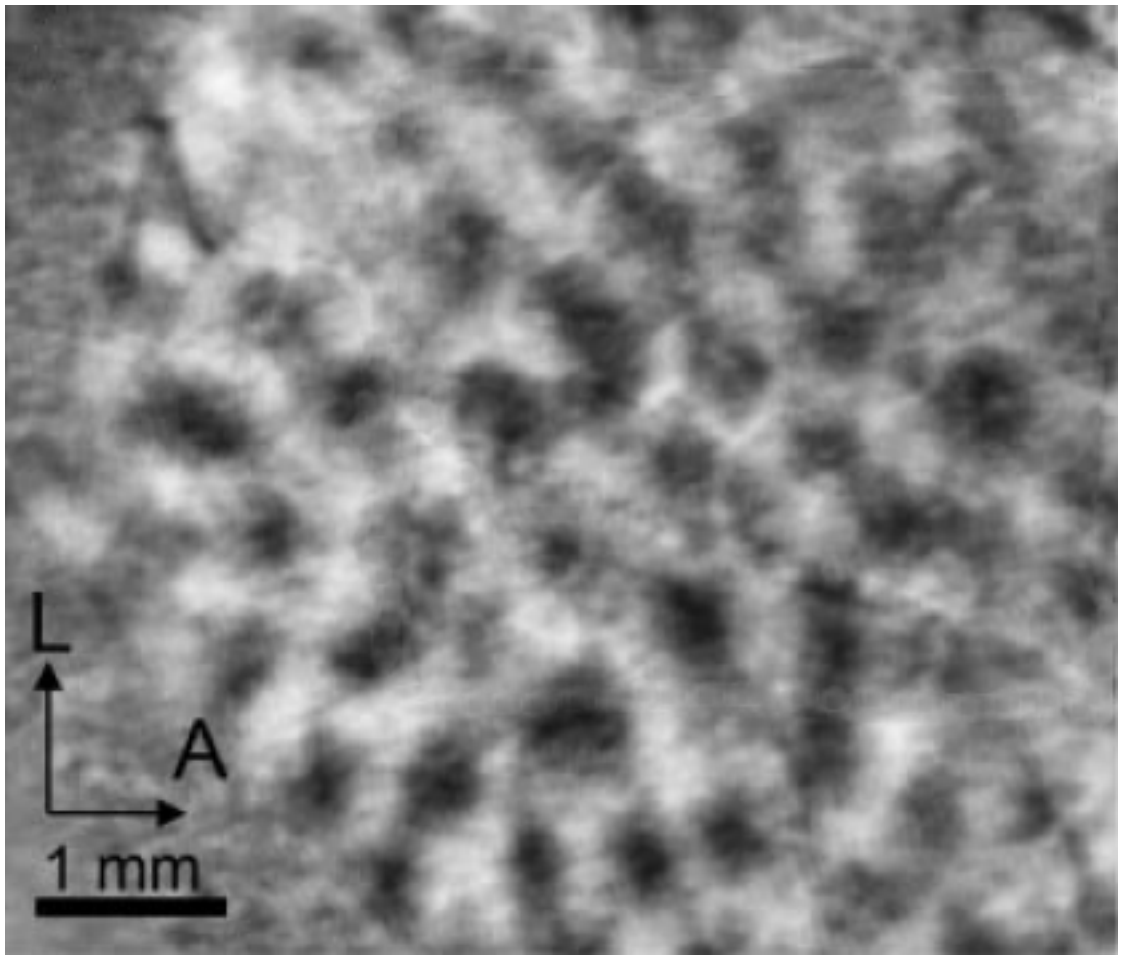
Orientation Selectivity of Visual Cortical Neuron



Spatial Frequency (SF) Selectivity



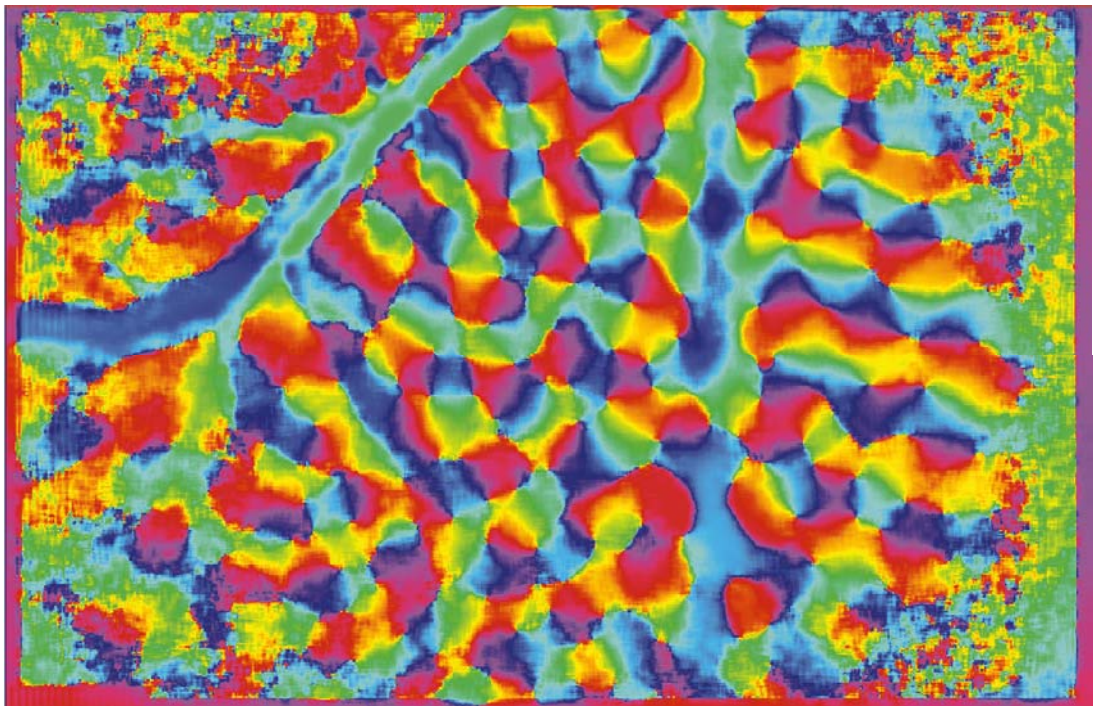
Ocular Dominance Map

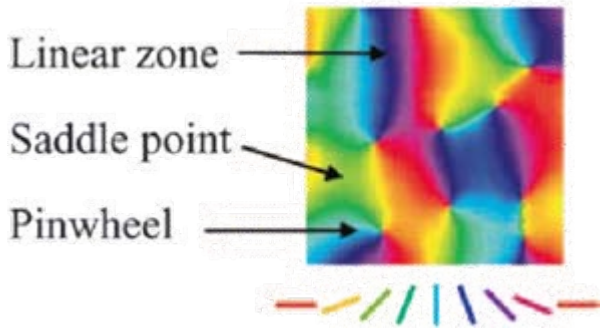


Bush baby

Xu et al., *J Neurophys 2005*

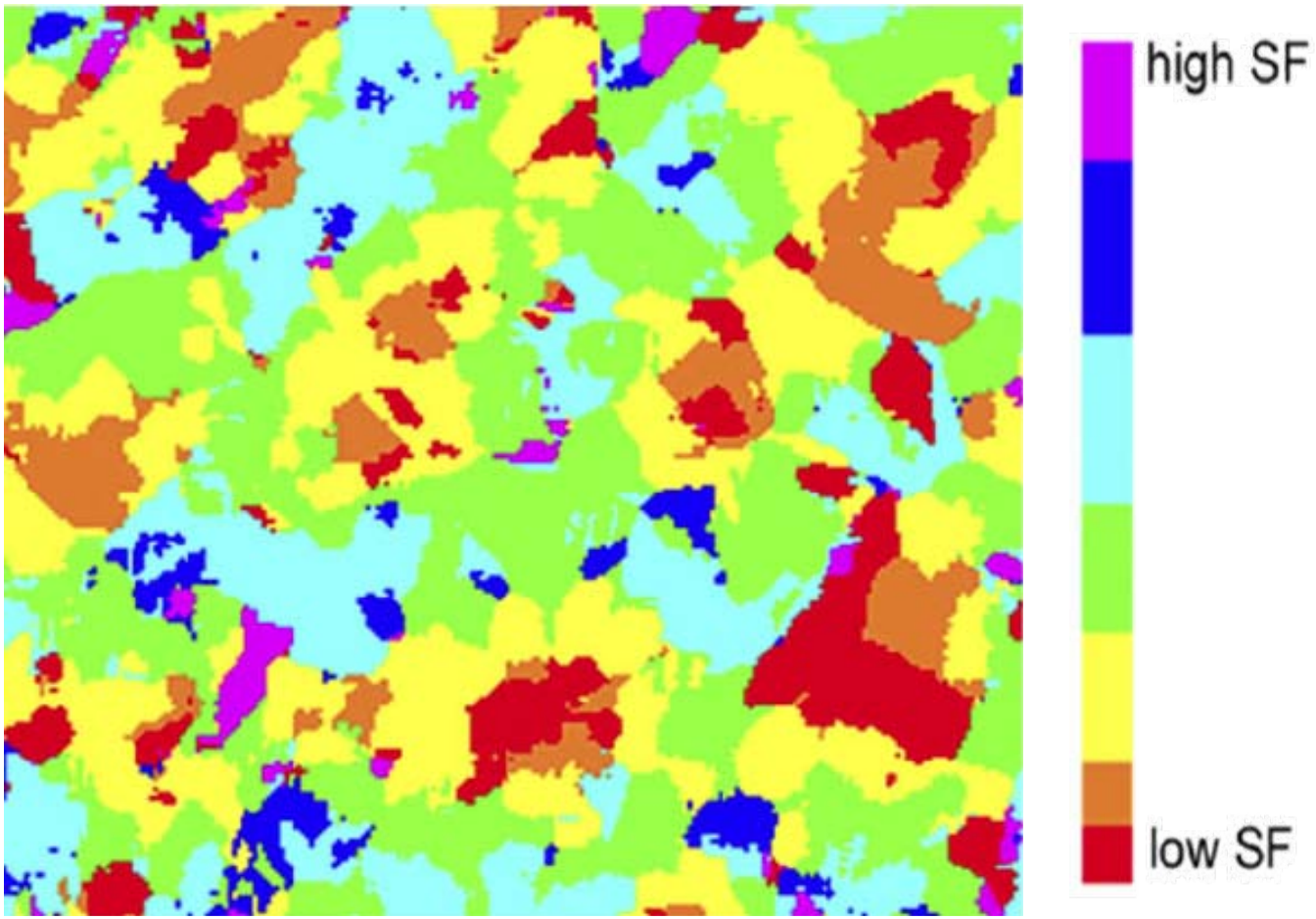
Orientation Preference Map





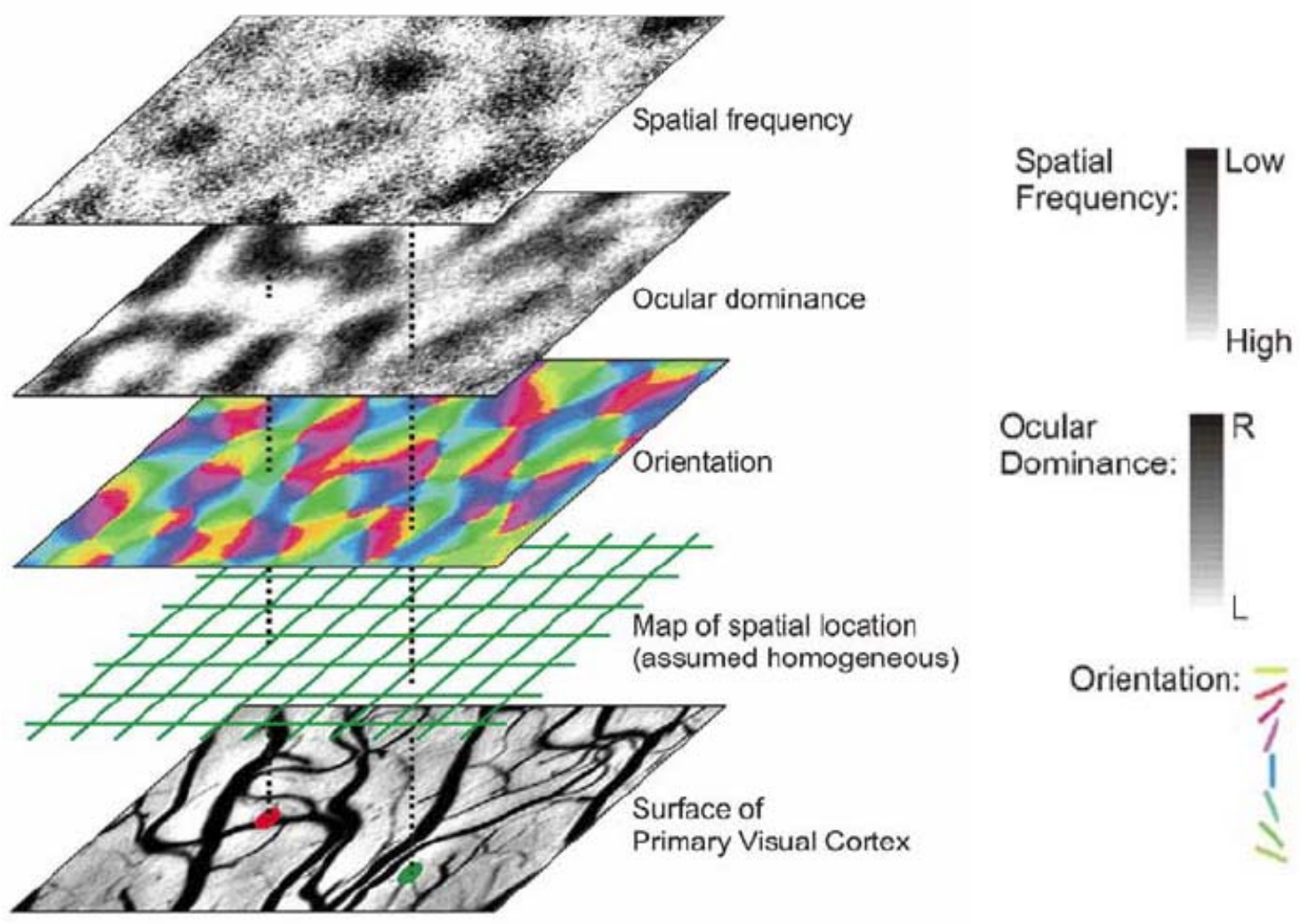
Khaytin et al *2005*
Xu et al., *J Neurophys 2007*

Spatial Frequency Map



Xu et al., *J Comp Neurol 2007*

Stacking of Maps

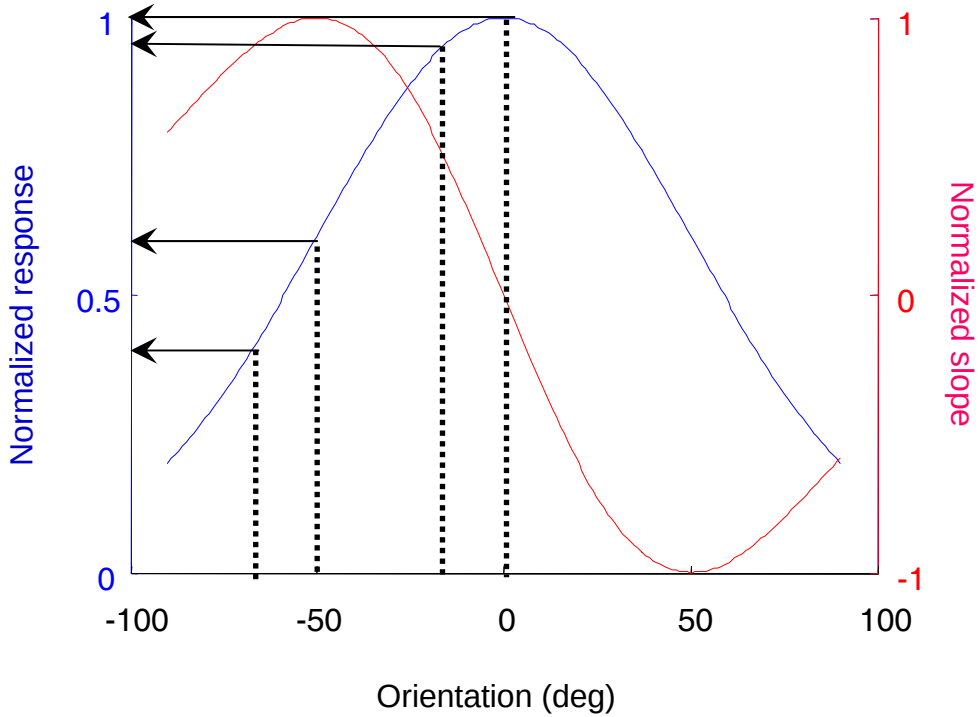


Das *Neuron 2005*

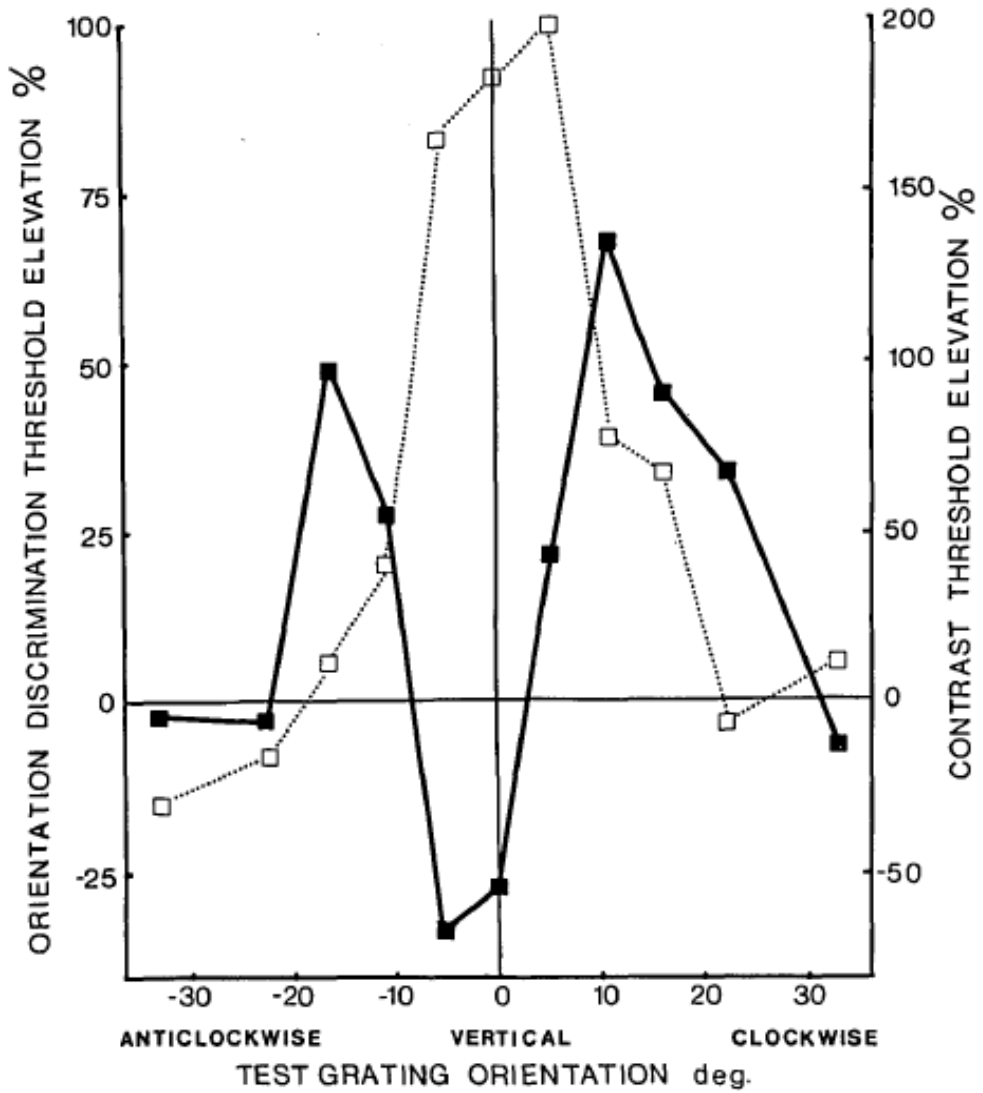
Stimulus properties

- Orientation, spatial frequency, ocular dominance are mapped into domains in visual cortex such that each point in visual space gets adequate representation.
- **BUT WHAT DOES IT MEAN FOR PERCEPTION?**
- Ocular dominance columns **don't exist** in all primates and most mammals even those with good stereopsis.
- Rodents have nicely tuned orientation selective cells with **no orientation domains in visual cortex.**
- Selectivity for orientation, spatial and temporal frequencies are **too broad to account for discrimination.**

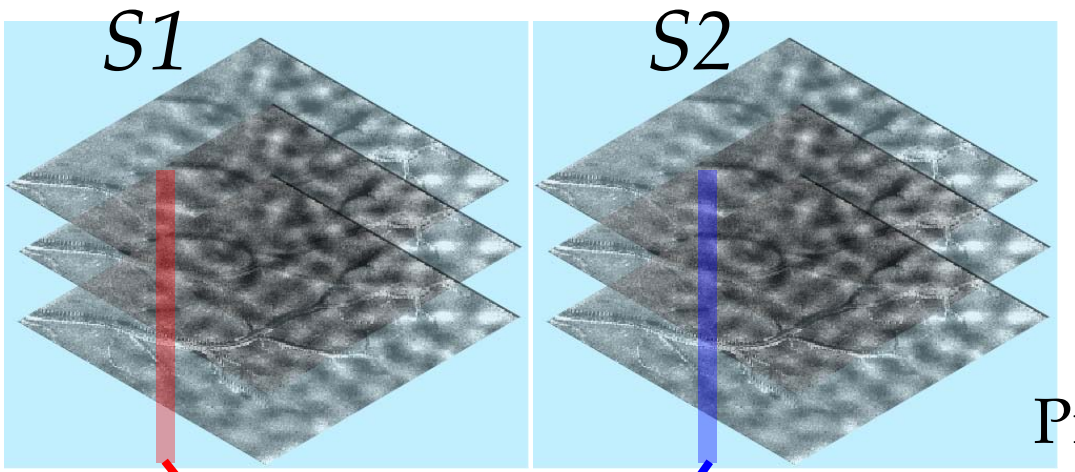
- How does the organization of functional maps relate to perception?

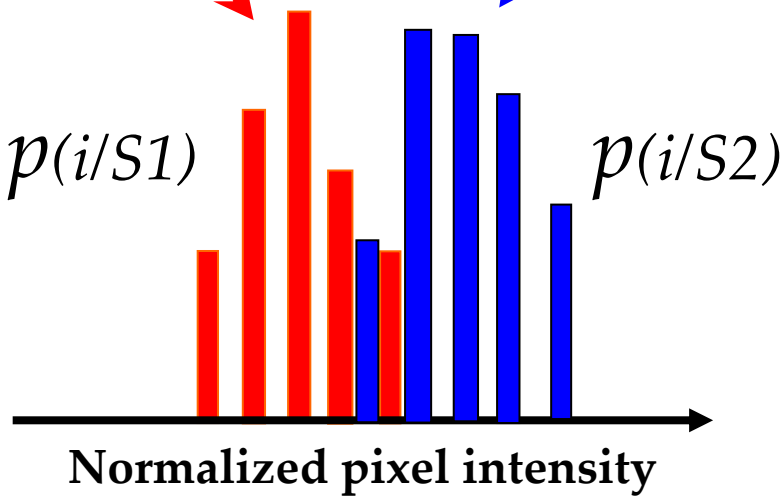

1
0.5
0
Normalized response
1
0
-1
Normalized slope
-100
-50
0
50
100
Orientation (deg)

Regan & Beverly, 1985, *JOSA*



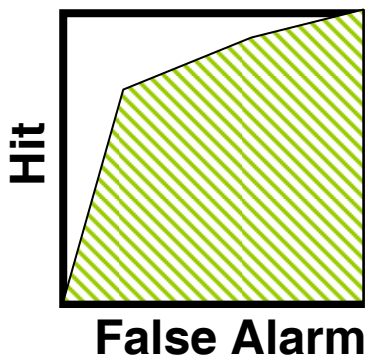
ROC analysis





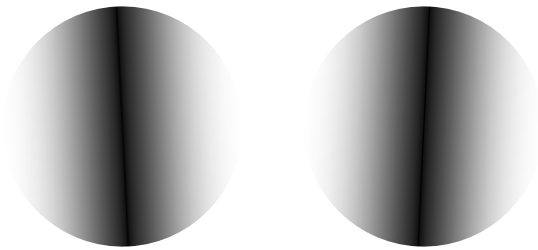
Probability of detection =

$$\int_0^{\infty} \left\{ \int_y^{\infty} p(x/S1)\, dx \right\} p(y/S2)\, dy$$

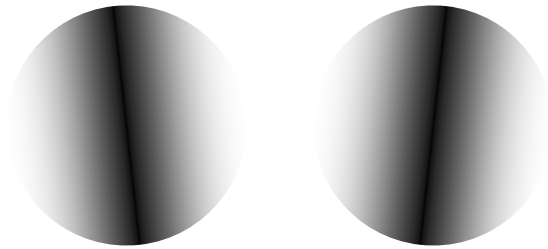


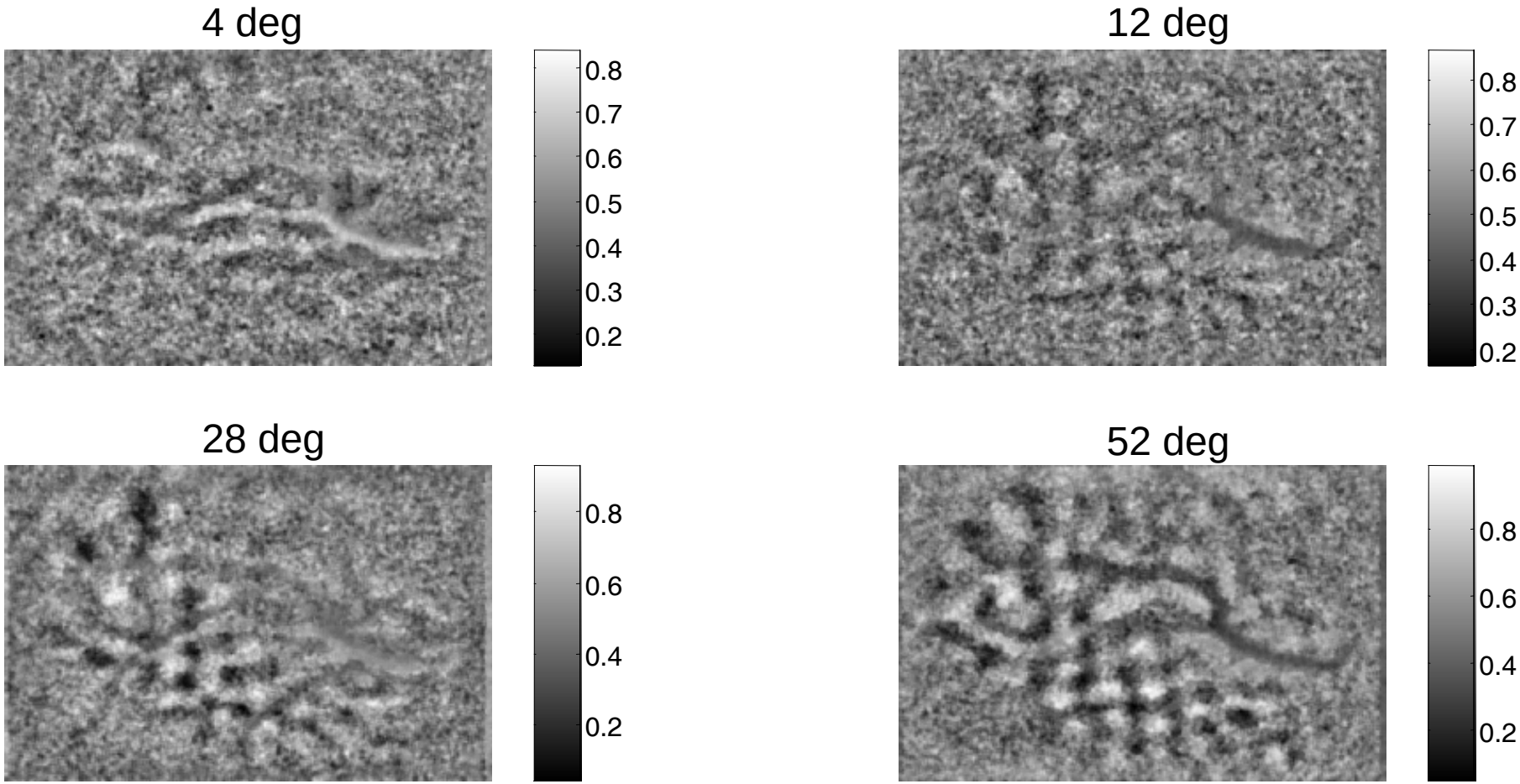
Purushothaman JN 2009

12 deg



28 deg





Discrimination domains are stable – they do not change their positions significantly as the orientation difference increases. Thus, the position of a discrimination domain is determined by the reference orientation and not by the orientation difference. This is analogous to the fact that the position of activation domains in an orientation map are determined by the orientation itself but the strength of activation is determined by contrast.

Purushothaman et al. 2008, 2009

Conclusion

- Sensory information is organized in domains across primate V1 for both detection and discrimination..
- BUT bigger question is how these pieces of sensory information used in the behaving animal?

Discussion Points

- *What is (are) your favorite principle(s) of brain function/biological Intelligence, and why do you think so?*

- Development constrains basic organization which is modular. The developing system uses synchrony to wire correctly and uses local synchrony for coding in the adult.

- Energy costs a lot so sparse coding is likely.

- To understand coding principles we need to understand what animals do (action) and see under natural conditions.

- Primary sensory areas probably do more. They detect and discriminate and are altered by reward, attention and memory through massive feedback..

Discussion Points

- *Do you think there is a single dominant operational principle of brain function and biological intelligence? Why?*

  – Evolution shapes the brain design through conservative developmental rules for survival. We are pre-wired to perform many basic tasks in a natural environment.

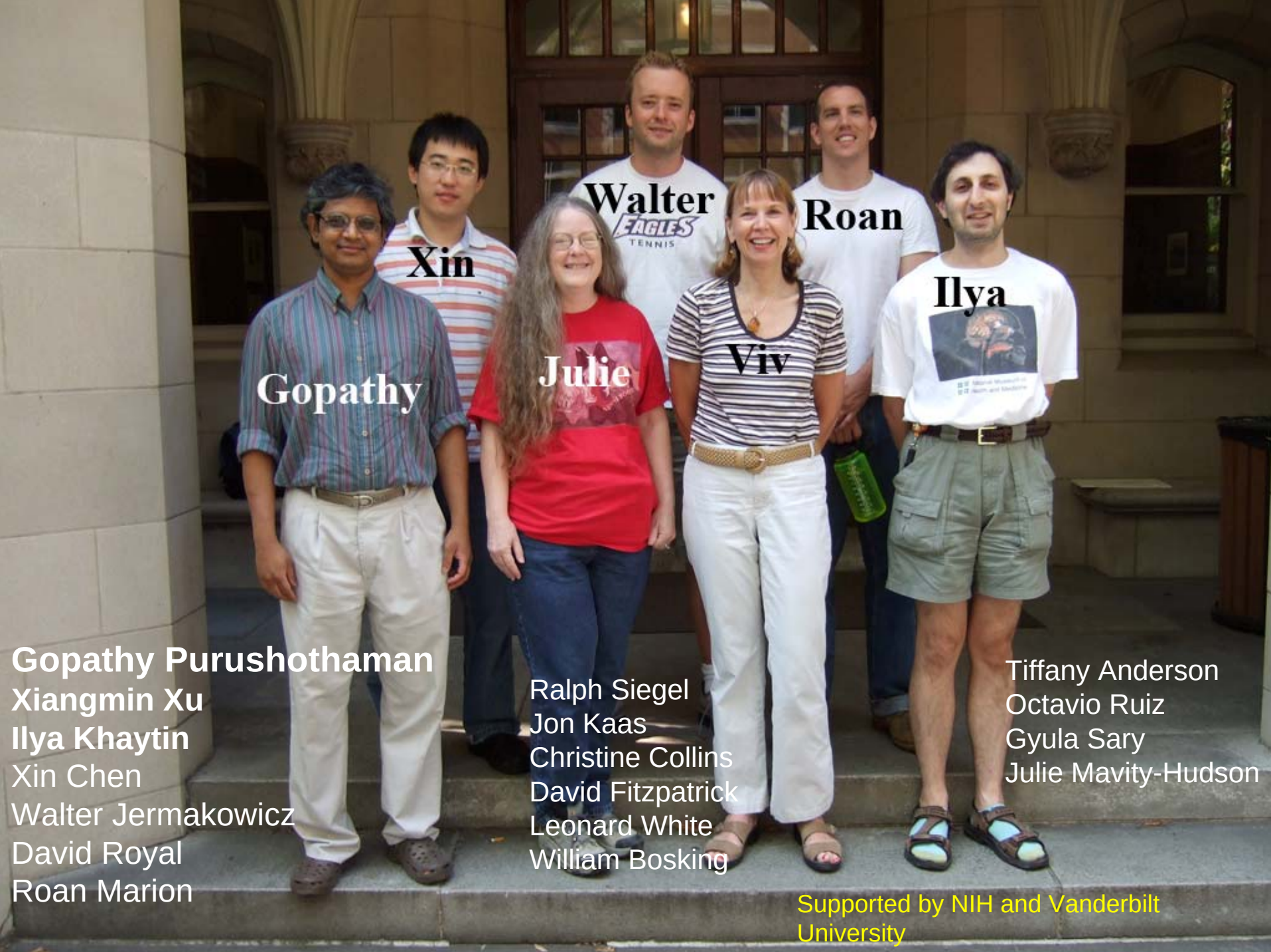
Many hoofed animals can run with the herd shortly after birth

Discussion Points

- *If you think our current ideas are lacking in any way,, what kind of breakthroughs would be needed, in which fields?*

- More comparative studies to understand common principles of wiring and coding.
-
- More studies of natural environments and tasks (action) that animals normally perform in those environments.

- Studies using a combinations of genetic manipulation, physiology and behavior to understand what is coded where and how.



Gopathy Purushothaman
Xiangmin Xu
Ilya Khaytin
Xin Chen
Walter Jermakowicz
David Royal
Roan Marion

Ralph Siegel
Jon Kaas
Christine Collins
David Fitzpatrick
Leonard White
William Bosking

Tiffany Anderson
Octavio Ruiz
Gyula Sary
Julie Mavity-Hudson

Supported by NIH and Vanderbilt University