Organization of the Primate Visual System

1. The problem of functional topography in the visual system: is there a general explanatory principle?

2. A specific, local solution: the V1 hypercolumn.

3. A wider scope: the retinotopic map.

4. A general application of the principle: the overall organization of the entire visual system.

Why is there any topography at all? Why not just connect the neurons correctly regardless of physical location in brain?

Instead, similar functions are physically near each other. Revealing about functionally important dimensions.

Possible reasons:

Minimizing wire length = faster communication

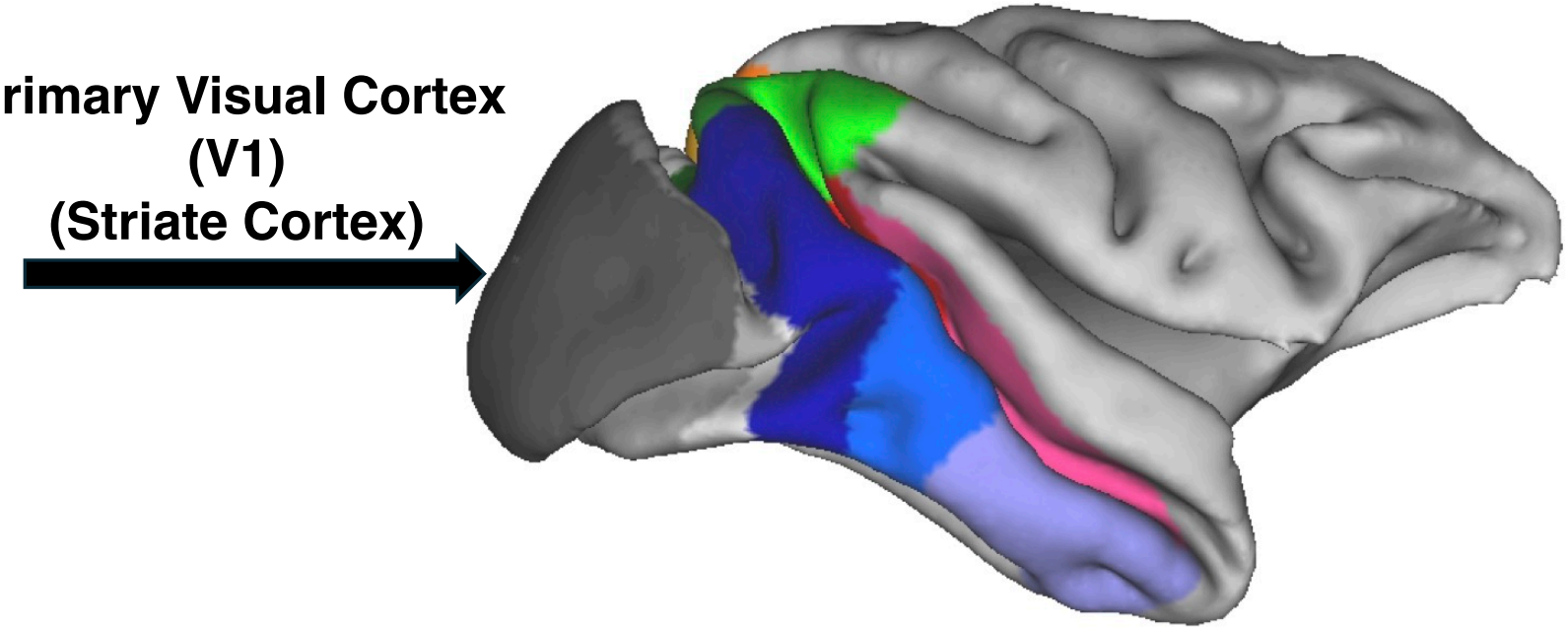
Development through chemical gradients might result in topographies

Principle of Optimal Local Smoothness.

Dimensionality Reduction.

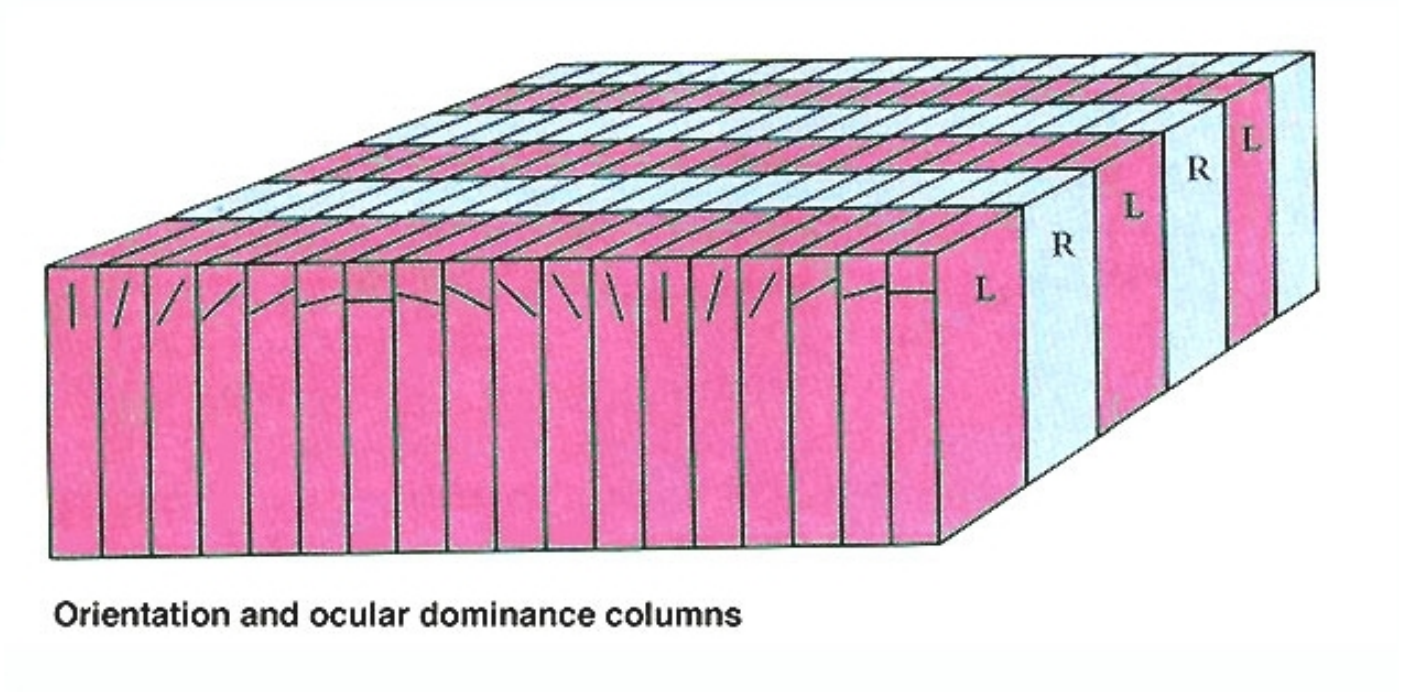
Monkey Visual System

Primary Visual Cortex
(V1)
(Striate Cortex)



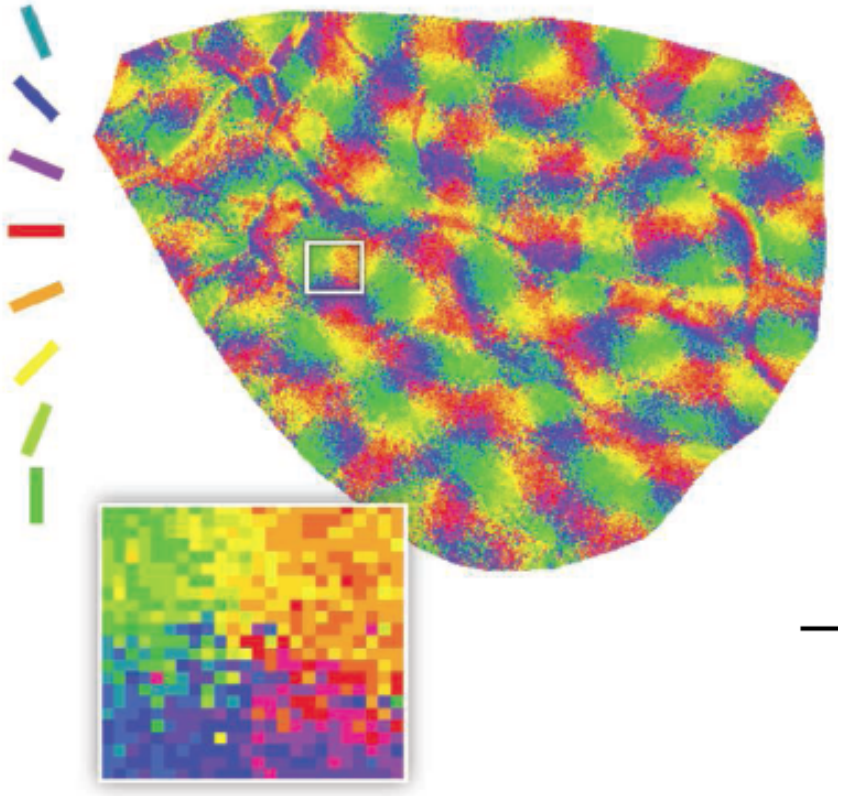
Hypercolumns in V1:
Orientation Pinwheels

Old Ice Cube Model of V1: Hubel and Weisel

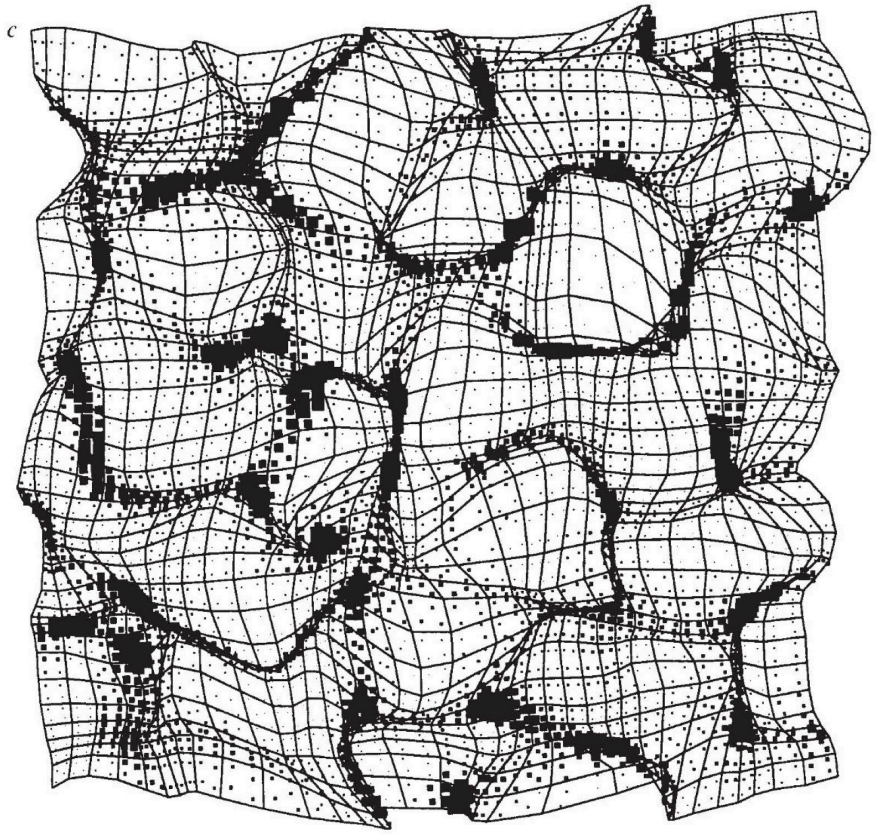


Orientation and ocular dominance columns

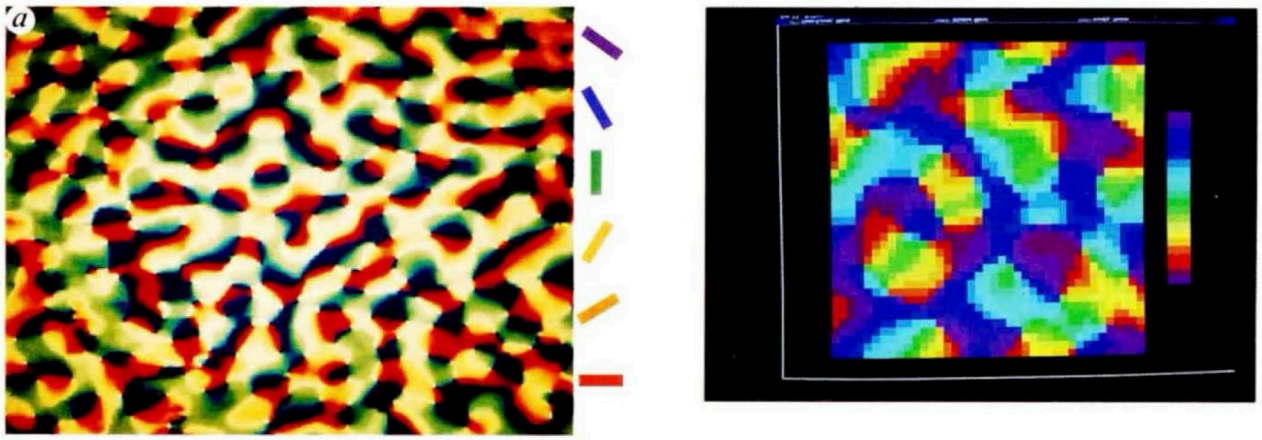
Pinwheels in V1: Hubel and Weisel



4 dimensions:
Retinal space (X,Y)
Orientation
Ocular Dominance

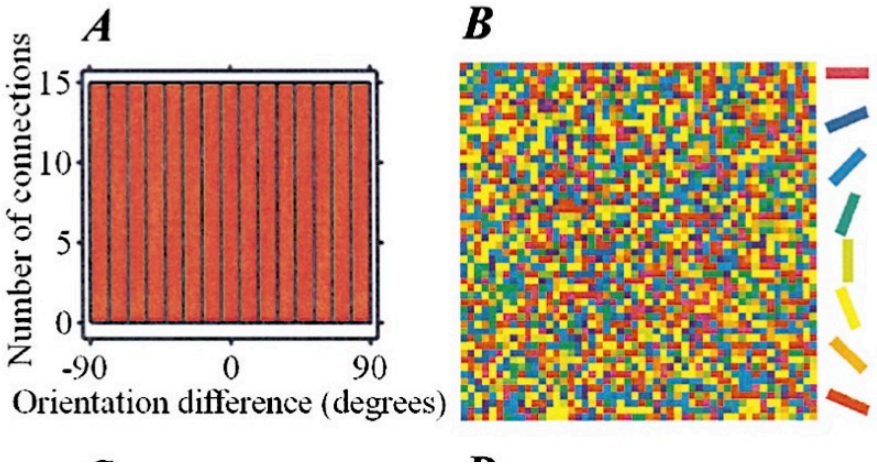


Durbin R, Mitchison G. A dimension reduction framework for understanding cortical maps. *Nature* 343: 644 – 647, 1990.



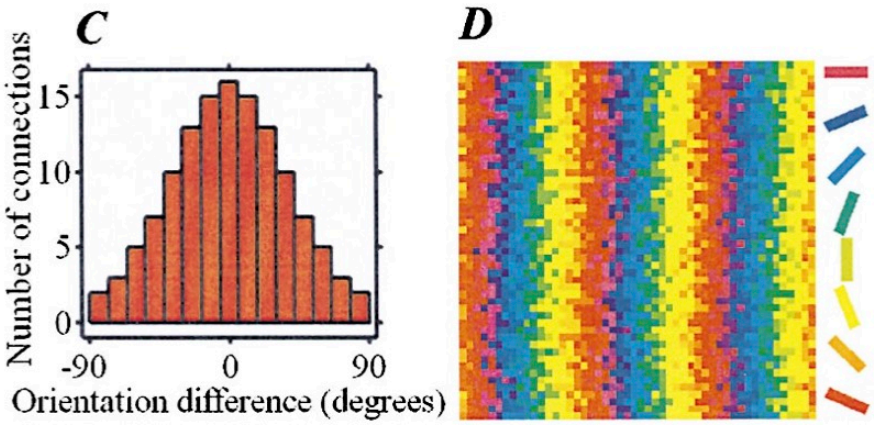
Durbin R, Mitchison G. A dimension reduction framework for understanding cortical maps. *Nature* 343: 644 – 647, 1990.

For equal connectivity, “Salt and Pepper” minimizes wire length.



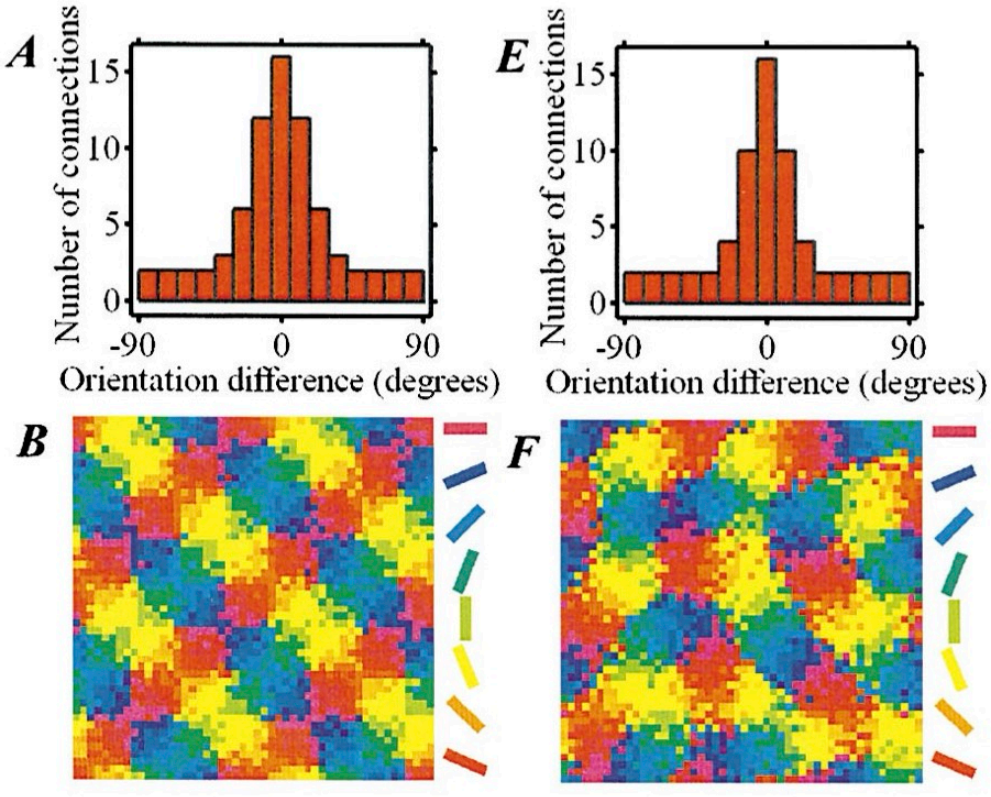
Koulakov AA, Chklovskii DB. Orientation preference patterns in mammalian visual cortex: a wire length minimization approach. *Neuron* 29: 519 –527, 2001.

For narrower connectivity, “Ice Cube” minimizes wire length.



Koulakov AA, Chklovskii DB. Orientation preference patterns in mammalian visual cortex: a wire length minimization approach. *Neuron* 29: 519 –527, 2001.

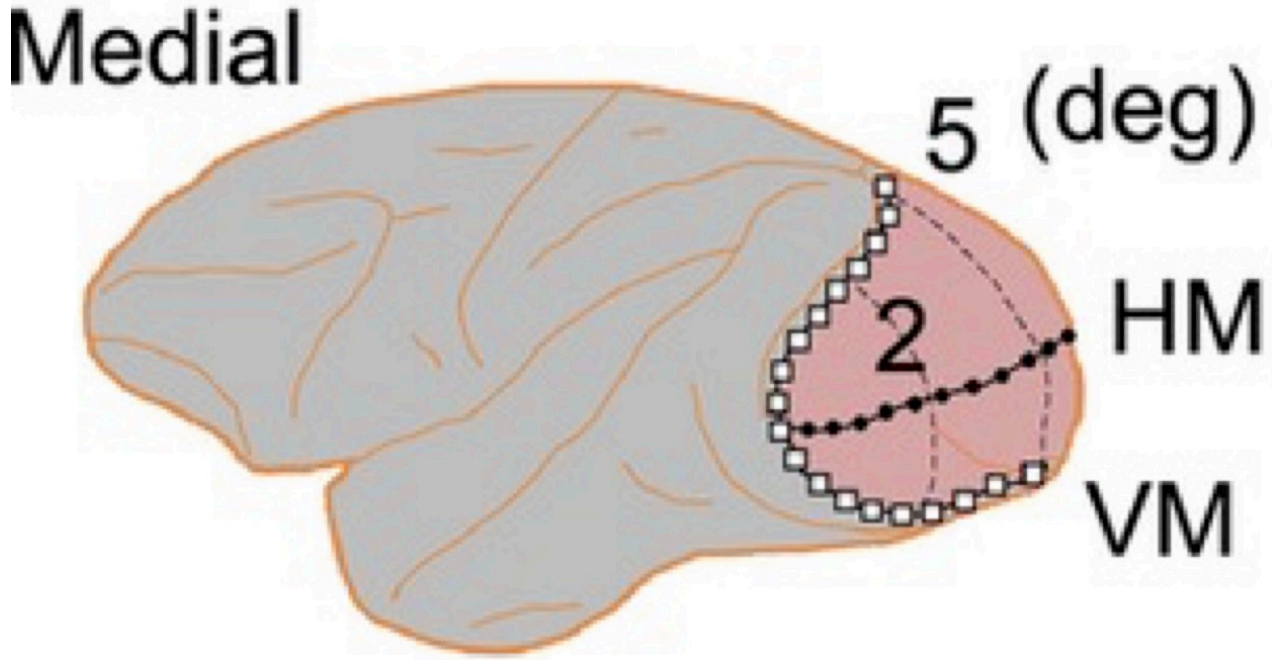
For narrowest connectivity, “pinwheel” minimizes wire length.



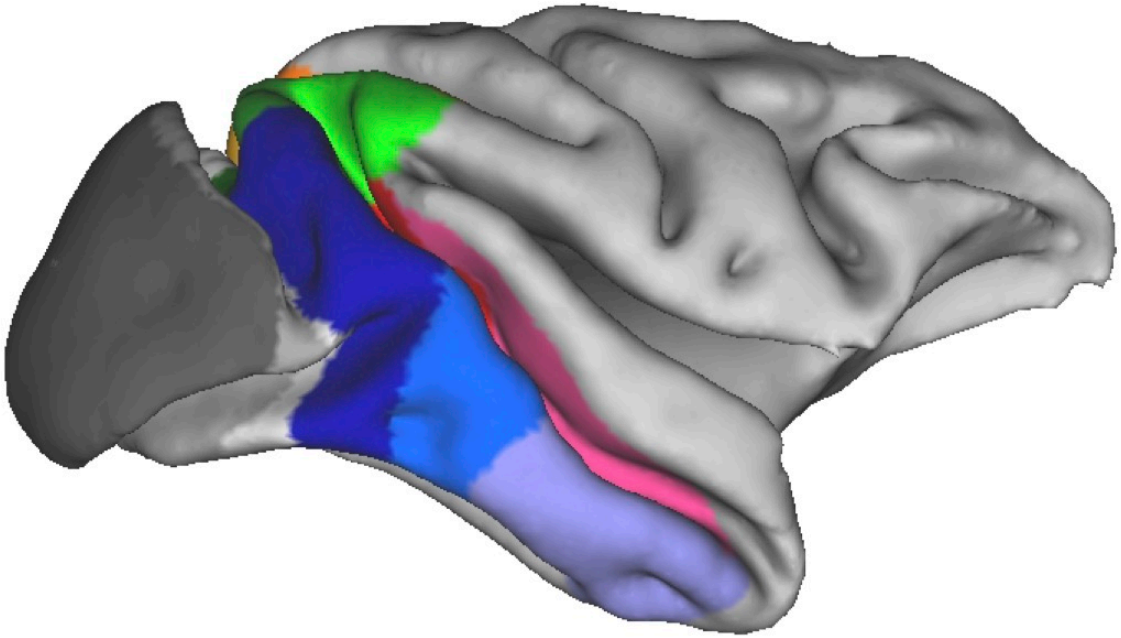
Koulakov AA, Chklovskii DB. Orientation preference patterns in mammalian visual cortex: a wire length minimization approach. *Neuron* 29: 519 –527, 2001.

Retinotopic Maps
In
V1 and Other Areas

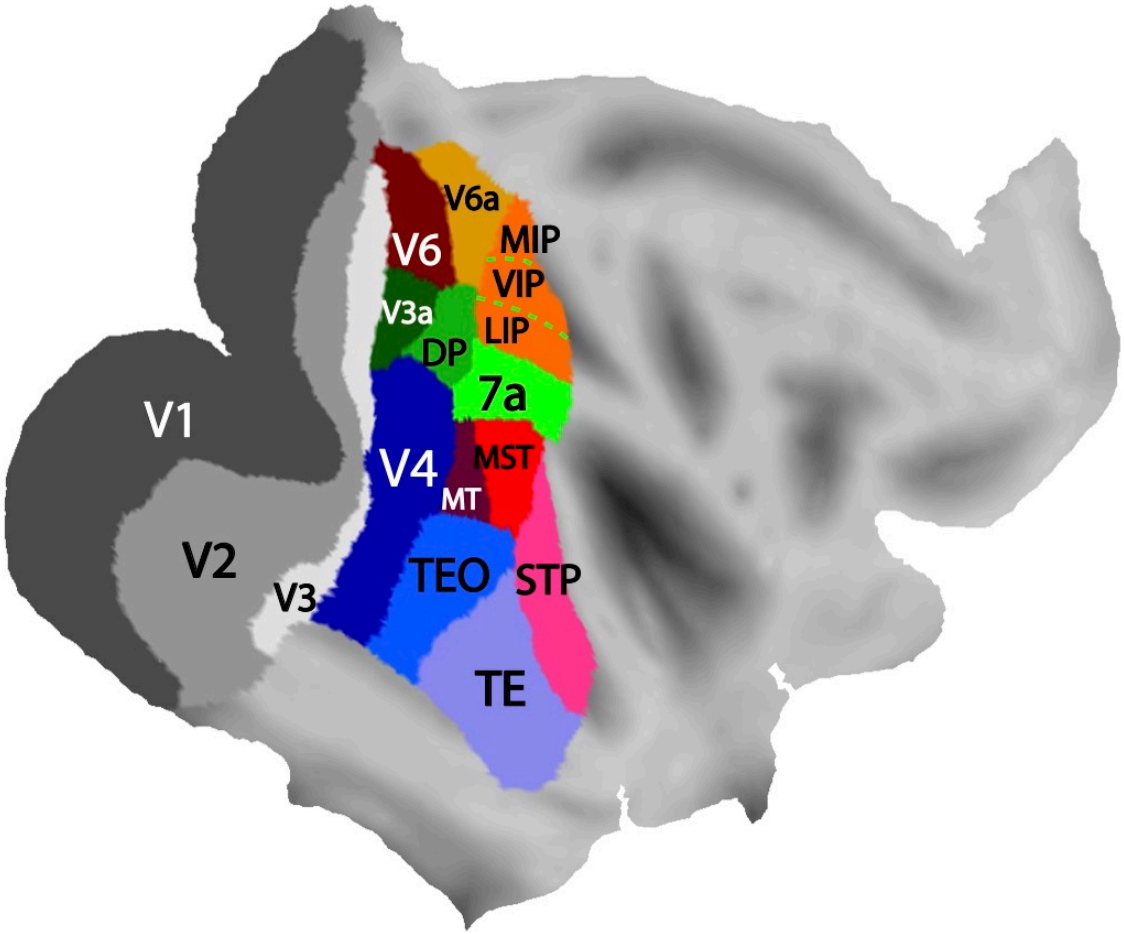
Retinotopic map in V1



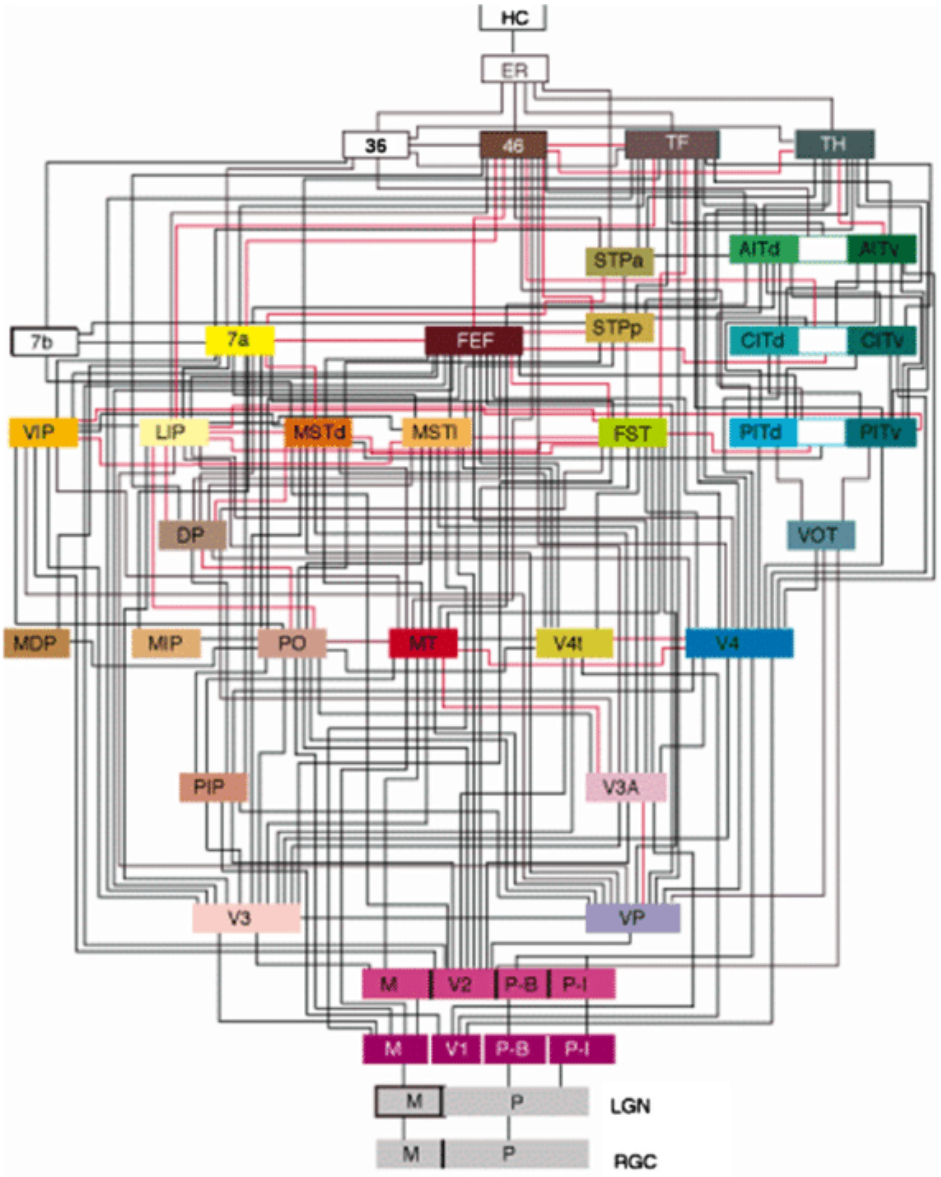
Monkey Visual System

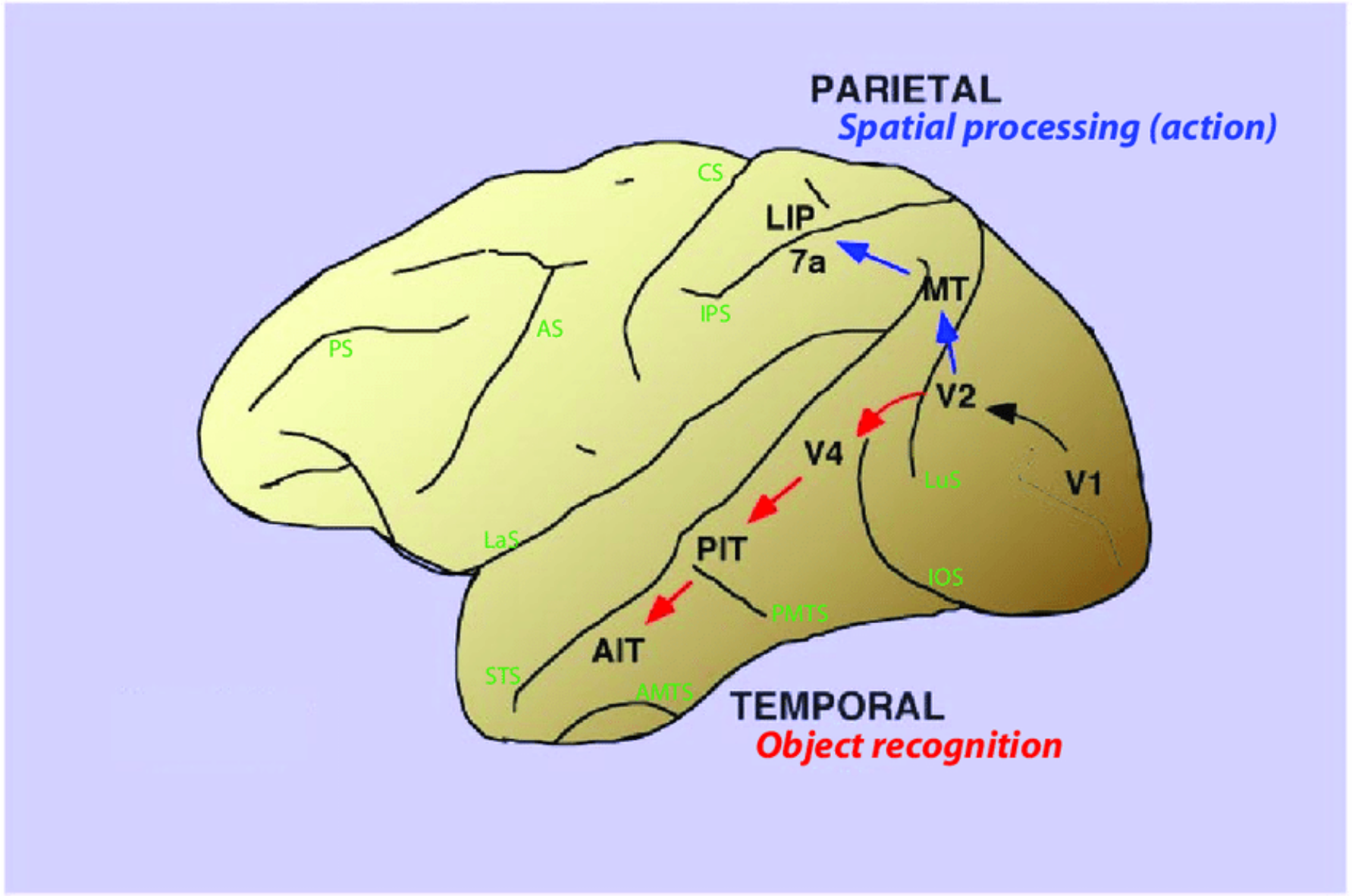


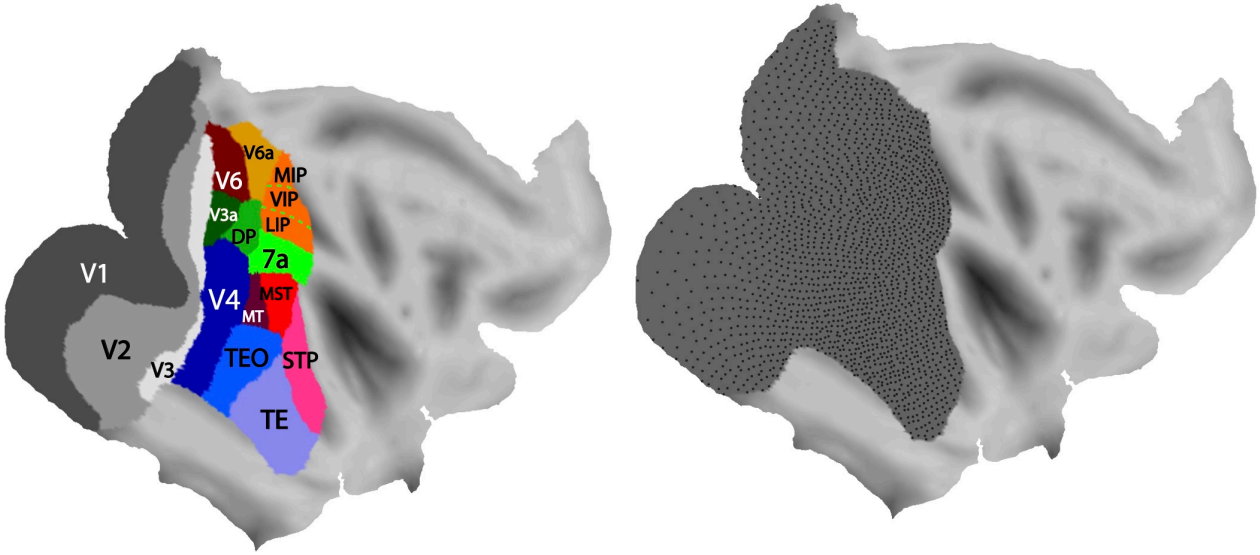
Flattened cortical map of visual system



Overall Organization of the Visual System

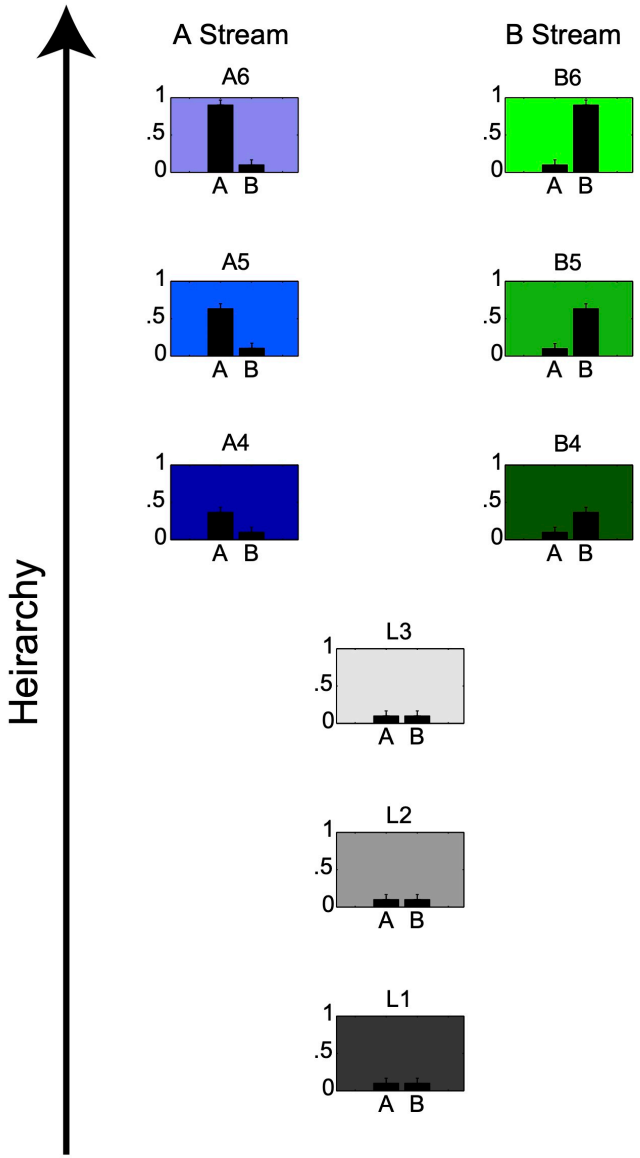

HC
ER
36
46
TF
TH
AITd
AITv
STPa
STPp
CITd
CITv
7b
7a
FEF
VIP
LIP
MSTd
MSTl
FST
PITd
PITv
DP
VOT
MDP
MIP
PO
MT
V4t
V4
PIP
V3A
V3
VP
M
V2
P-B
P-I
M
V1
P-B
P-I
M
P
LGN
M
P
RGC


PARIETAL
Spatial processing (action)
CS
LIP
7a
MT
IPS
AS
PS
V2
V4
V1
LuS
LaS
PIT
IOS
PMTS
AIT
STS
AMTS
TEMPORAL
Object recognition



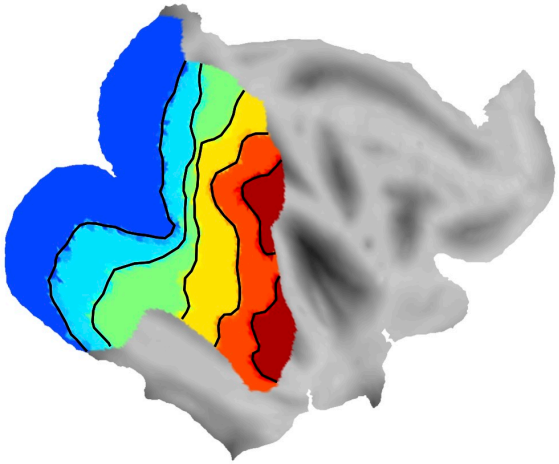
Aflalo TN and Graziano MSA (2011) The organization of the macaque extrastriate visual cortex re-examined using the principle of spatial continuity of function. Journal of Neurophysiology, 105: 305-320.

Two-Stream Model

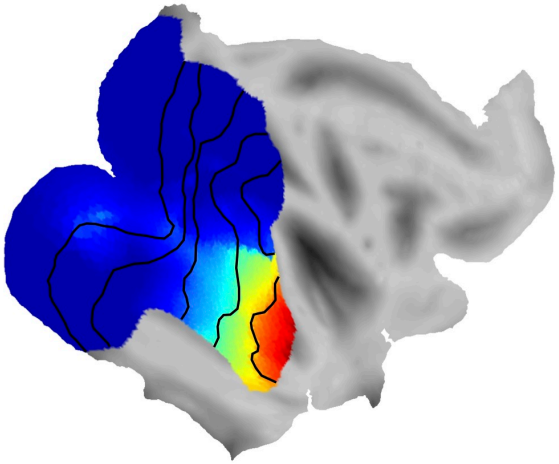


Areas Produced By 2-Stream Model

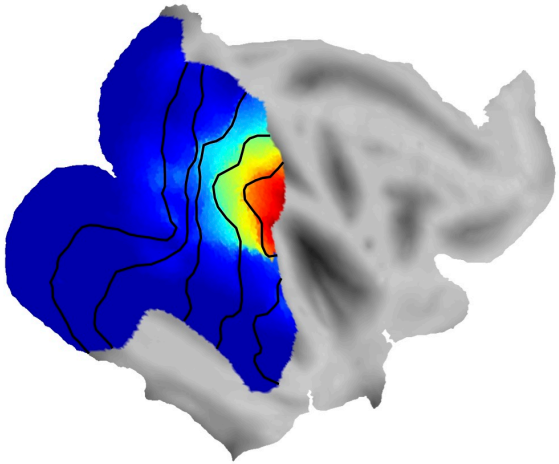
A : Heirarchy



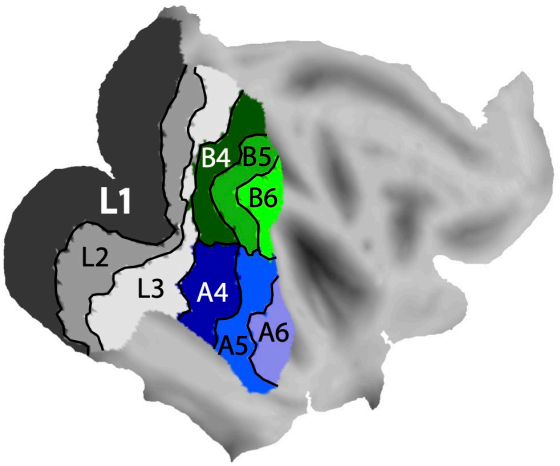
B : Magnitude of property A



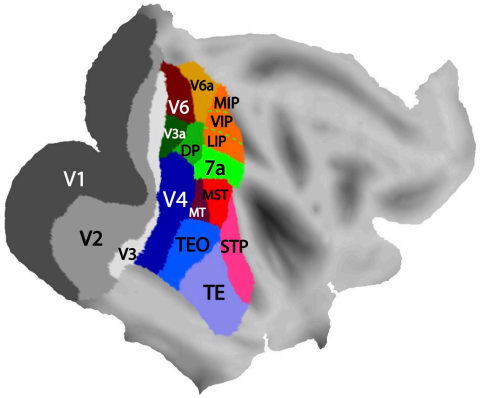
C : Magnitude of property B



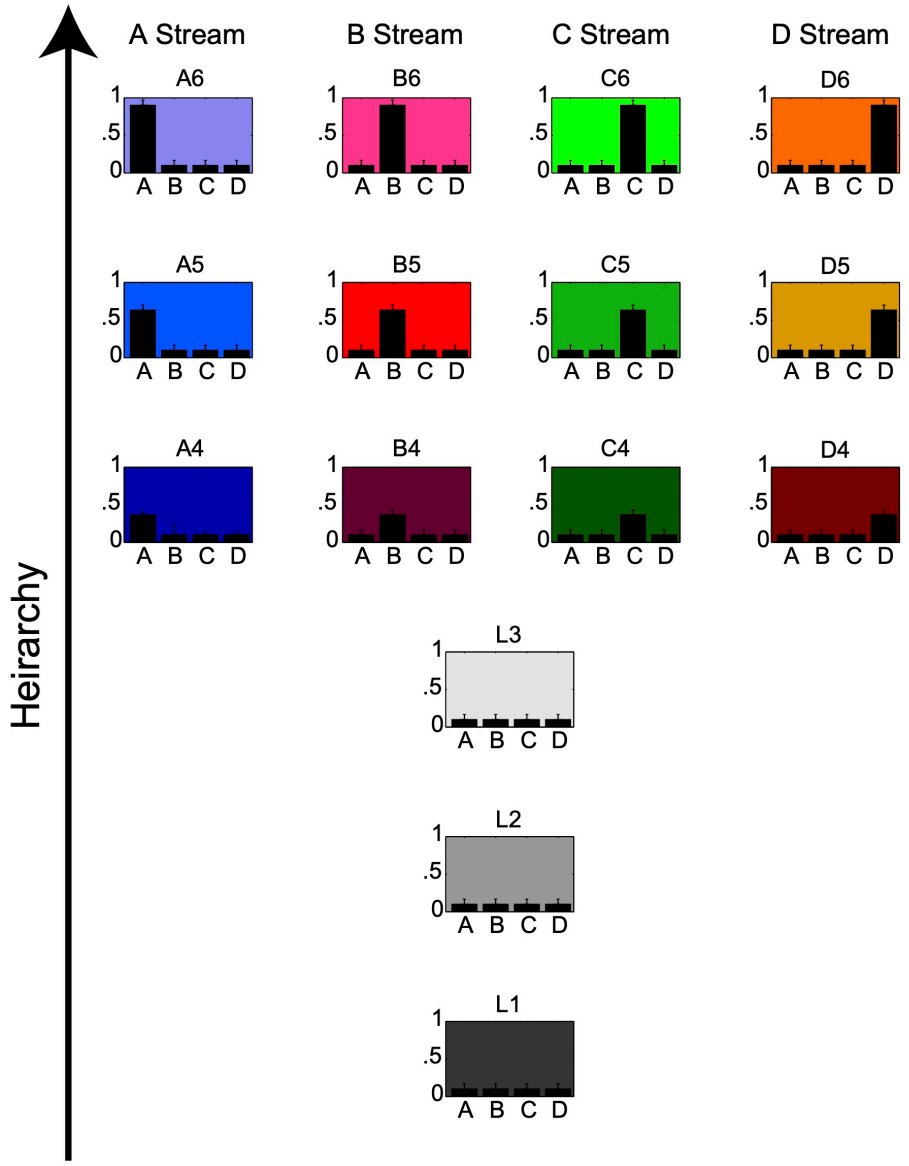
D : Areas Produced by the Two-Stream Model



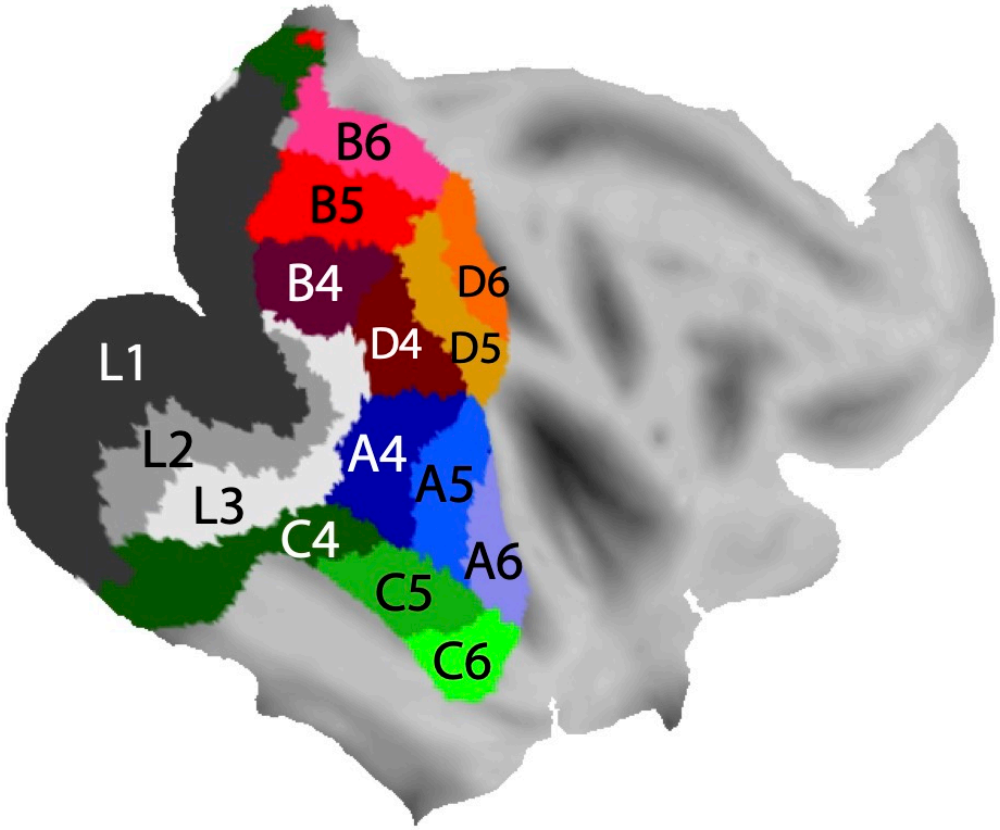
Actual Map



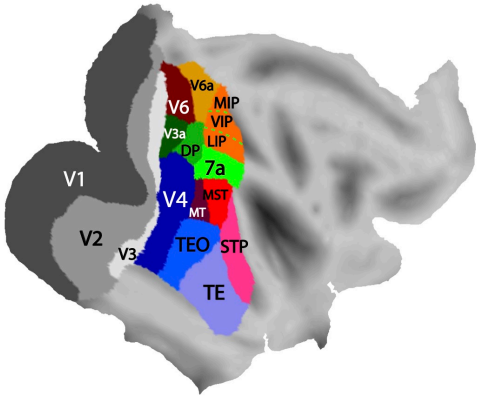
Four-Stream Model



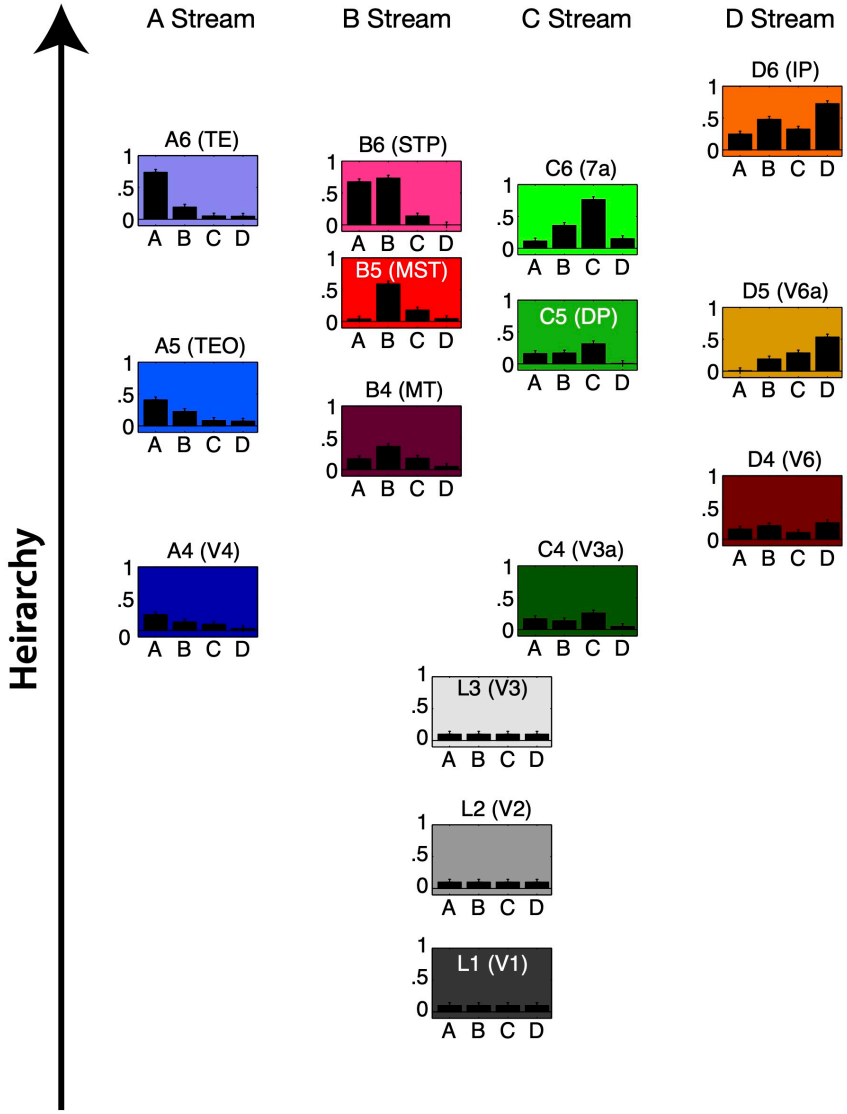
Areas Produced by the Four-Stream Model



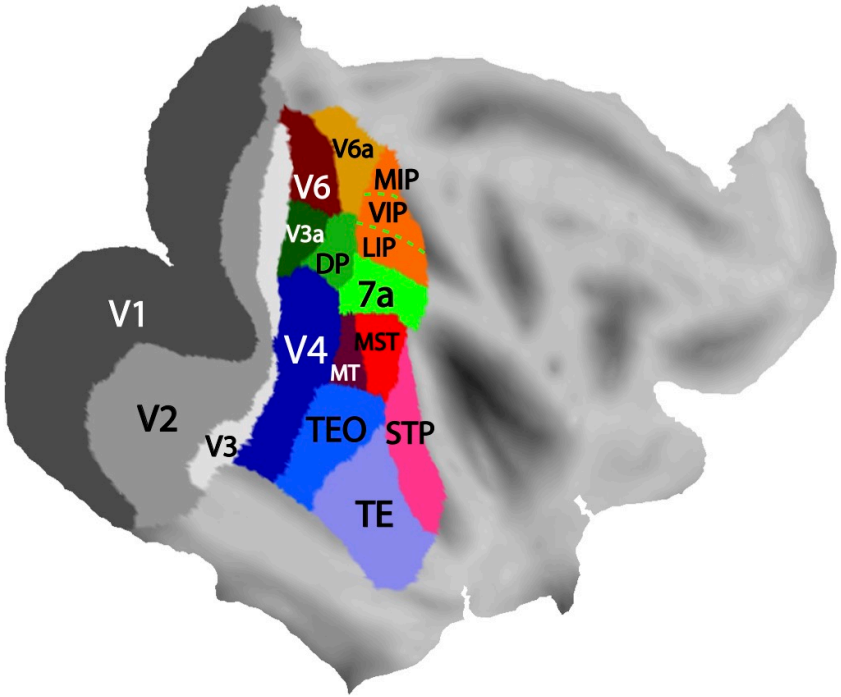
Actual Map



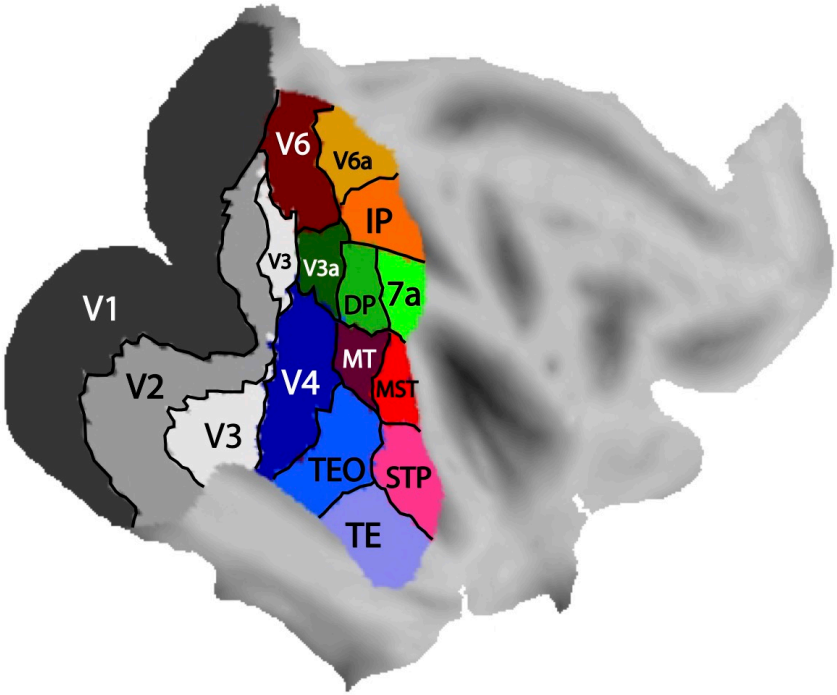
Optimizing the 4-Stream Model



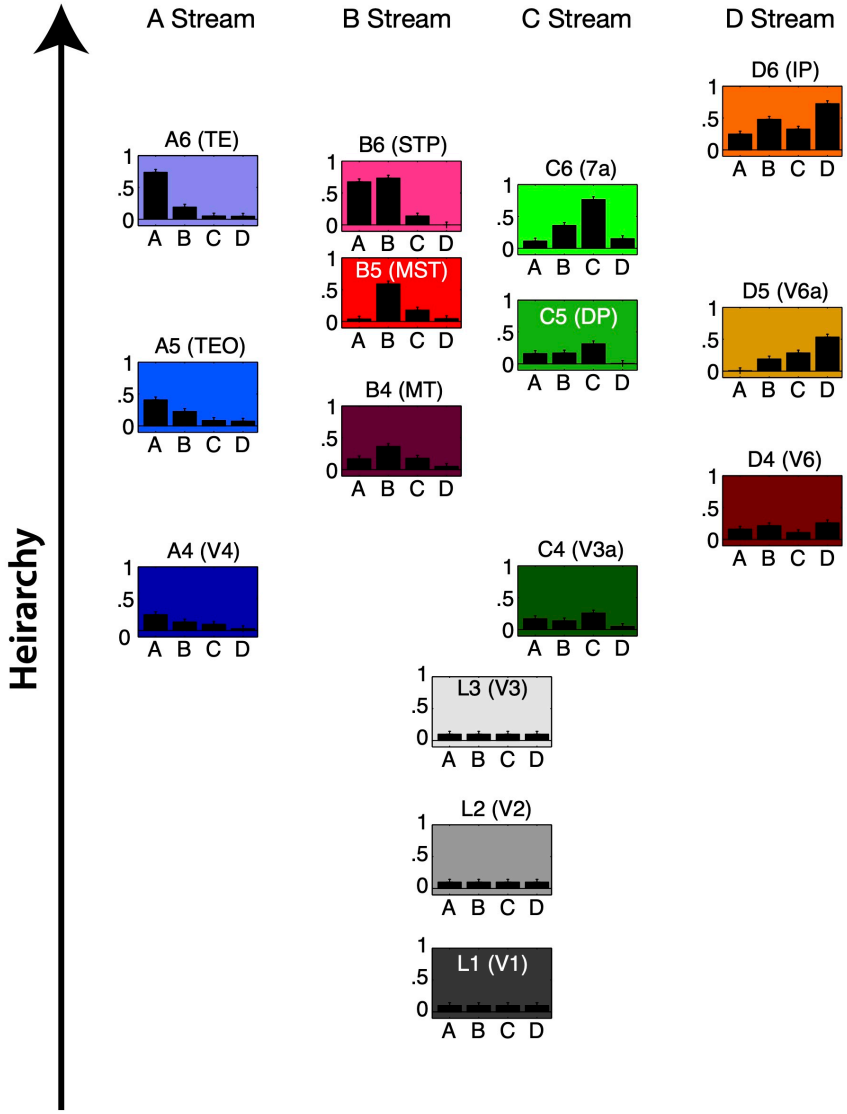
Actual Brain

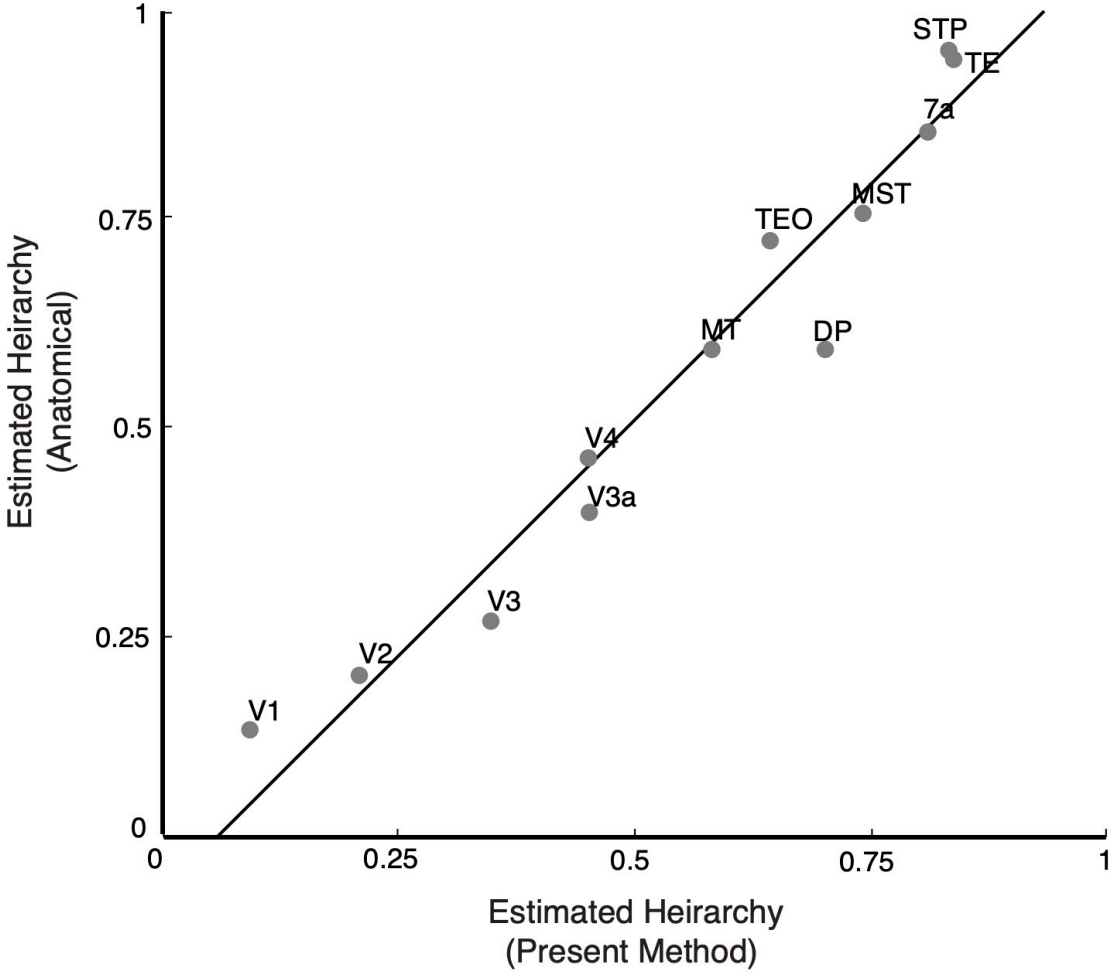


Results of Optimized 4-stream model



Optimized 4-Stream Model




1
0.75
0.5
0.25
0
0
0.25
0.5
0.75
1
Estimated Heirarchy
(Anatomical)
Estimated Heirarchy
(Present Method)
STP
TE
7a
MST
TEO
MT
DP
V4
V3a
V3
V2
V1