
IRON MAIDEN
Piece of Mind


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Visual System II: objects and faces

I. Local vs. distributed functions
II. Interlude—four kinds of experiments
III. Ventral and dorsal streams and the sensory hierarchy
IV. Face cells—early electrophysiology
V. fMRI and face areas
VI. Recent single unit recordings—hierarchy again

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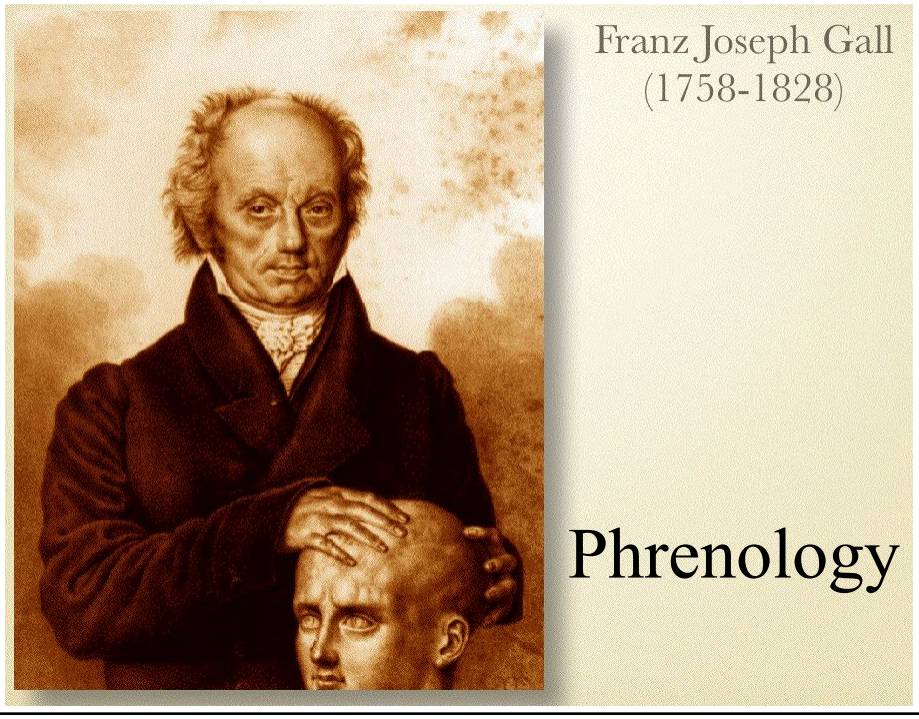
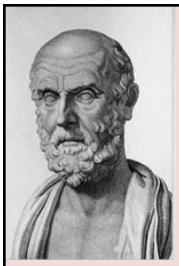


Jean Pierre Flourens
1794-1867

"Equipotential" cortex



Hippocrates

"Men ought to know that from the brain and from the brain only arise our pleasures, joys, laughter, and jests as well as our sorrows, pains, griefs and tears."

4th century B.C.

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Interlude: 4 kinds of experiments

- Block
- Measure
- Mimic

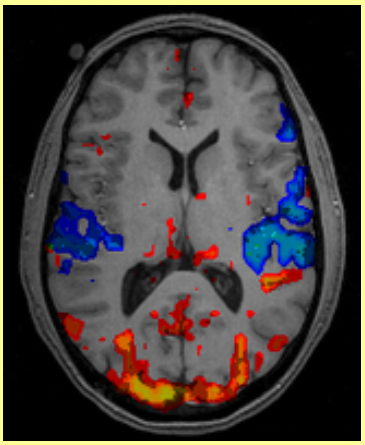
- Determine

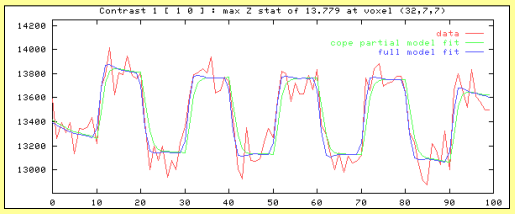
Why do we think the brain is the organ most directly related to behavior and mind?

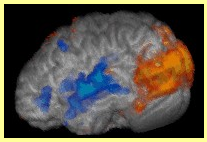
Hypothesis: the brain controls behavior

Brain lesions: block

Functional Magnetic Resonance Imaging



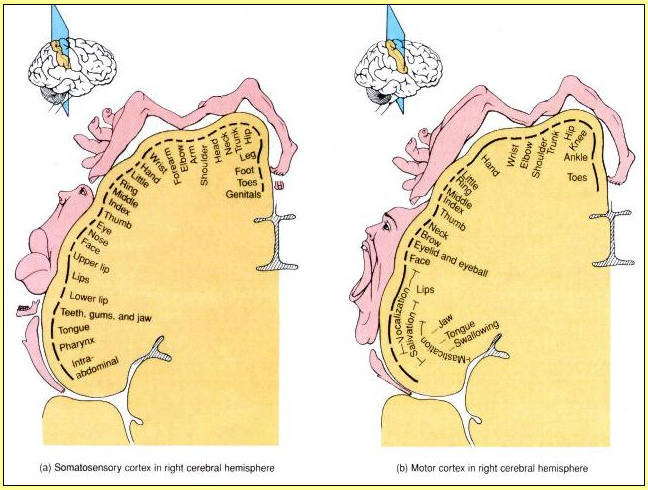




Measure

Intracranial microstimulation

Wilder Penfield
(1891-1976)



Mimic

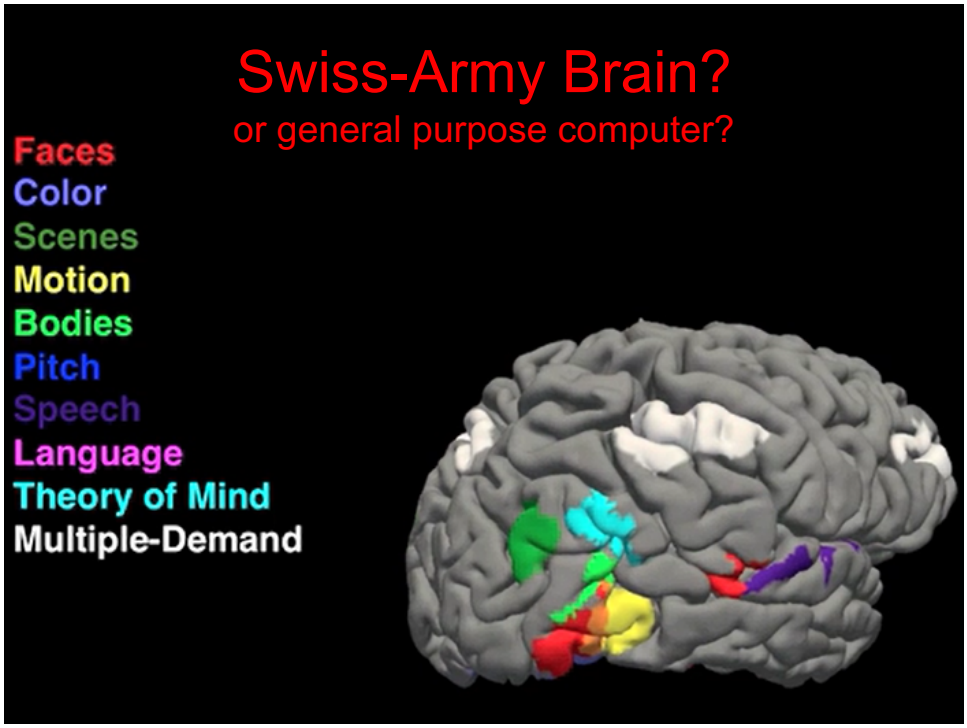
Paul Broca

Paul Broca
1824-1880

A victory for the localizationist, modular point of view

1947 Joachim Bodamer reports on three cases of "prosopagnosia": specific loss of face recognition ability

→Suggests?



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Sensory system motifs

- Topography
- Parallel processing
- **Hierarchy**

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Topographic organization:

Neighboring regions of sensory surface project to neighboring brain regions.

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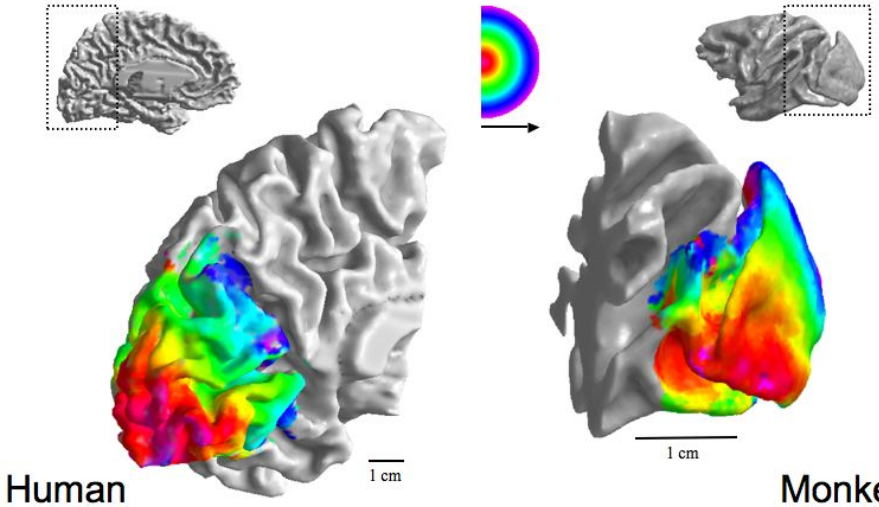
Retinotopy



Human Monkey

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Parallel processing

Relatively independent
neural pathways or modules process different
sensory features at the same time

(...which must somehow be combined to form
a coherent behavioral response
or unified perception:
The Binding Problem.)

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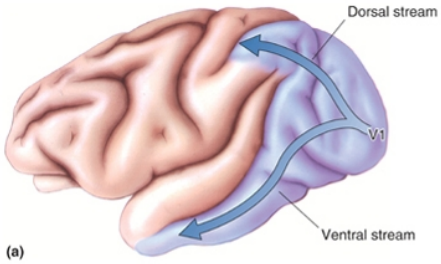
Extrastriate visual cortex

1) Ventral Stream projects to inferior temporal cortex
   - Color -- Achromatopsia
   - Faces -- Prosopagnosia
   - "What" -- conscious perception of objects

2) Dorsal Stream projects to posterior parietal cortex
   - "Where" & "How" -- manipulating objects



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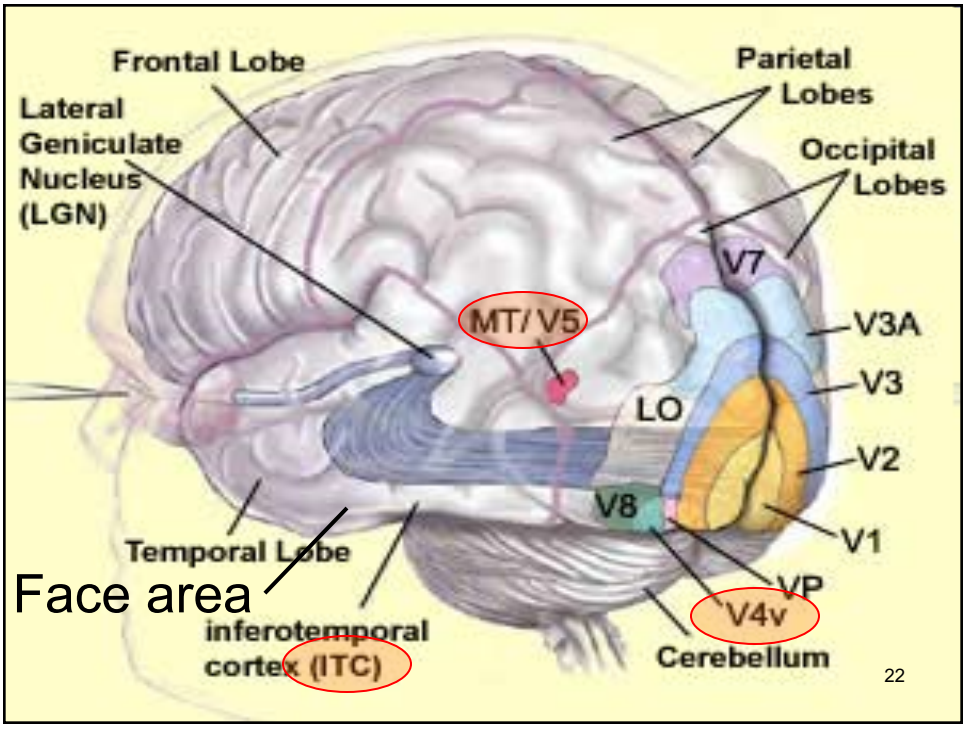

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Sensory Hierarchy

Ascending through stages into the brain, neurons represent progressively more complex sensory features

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Hierarchical organization:

- Peripheral (**lower**) levels of the sensory hierarchy respond to simple features and have relatively small receptive fields
- Central (**higher**) levels respond to more complex stimuli and have larger receptive fields

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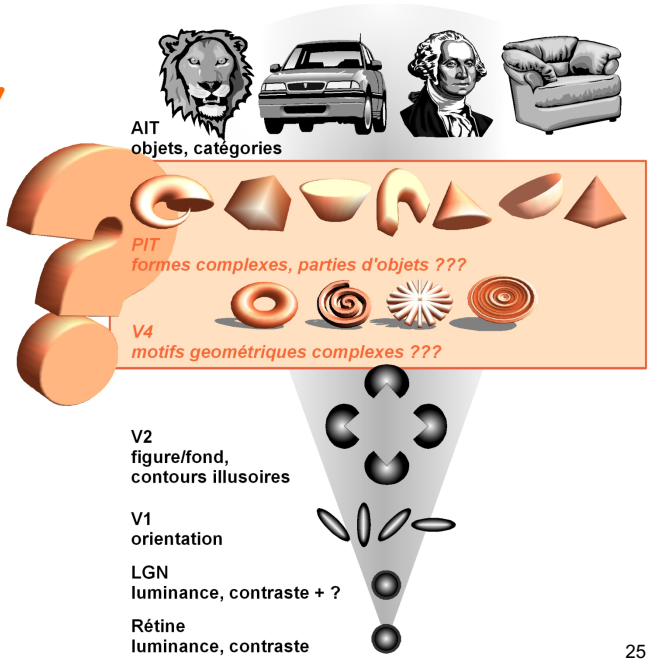
Visual Hierarchy



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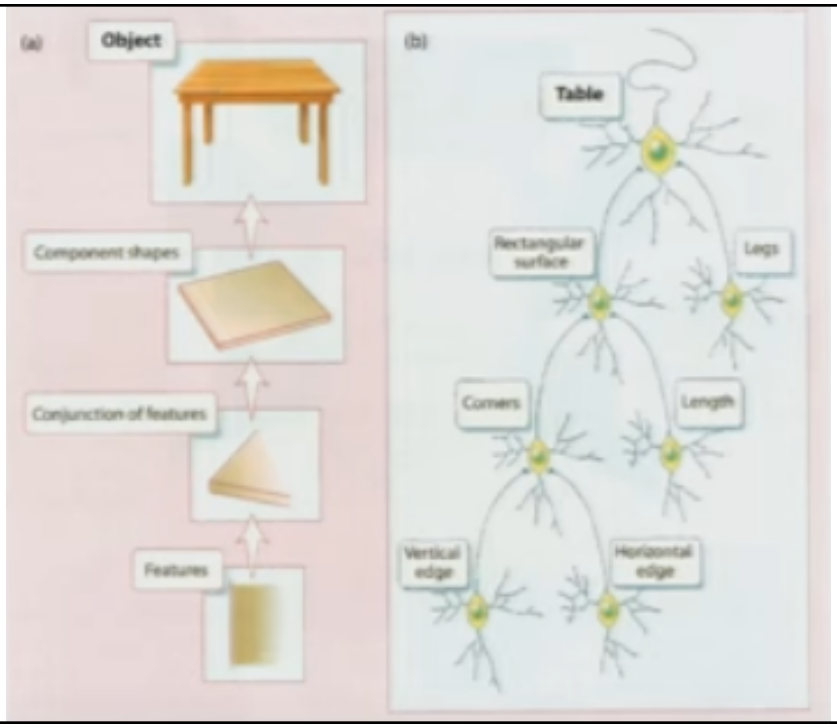
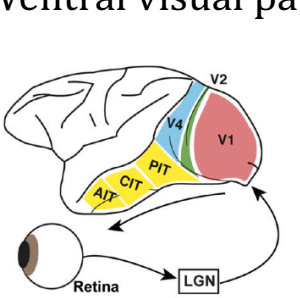
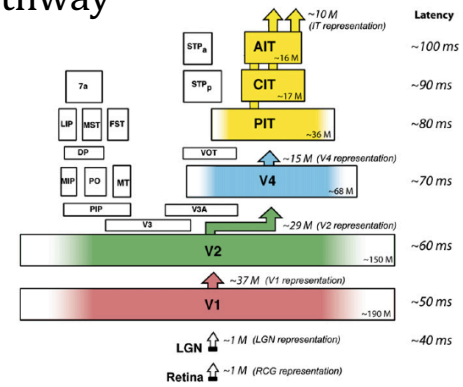


Ventral visual pathway

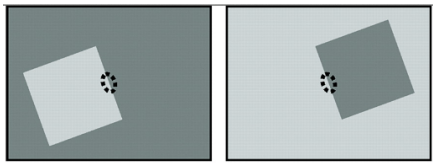




Progressing to higher areas along the ventral pathway:

- response latency increases
- receptive field size increases
- neurons become selective to more complex spatial patterns
- **neural responses become more invariant to changes in position, scale, pose, etc.**

Object boundaries in V2 and V4



Some V2 neurons respond to illusory contours

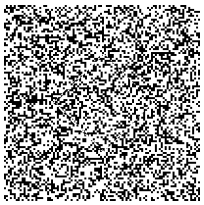
Zhou, Friedman & von der Heydt (2000)

- Border ownership distinction arises only ~ 25 ms after edge response
- Response is scale invariant

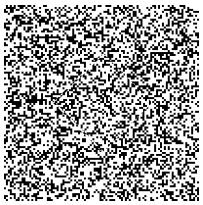
Qiu & von der Heydt (2005)

- Similar border ownership distinction for stereo edges

Others found selectivity for the orientation of stereo and motion boundaries in areas V2 and V4

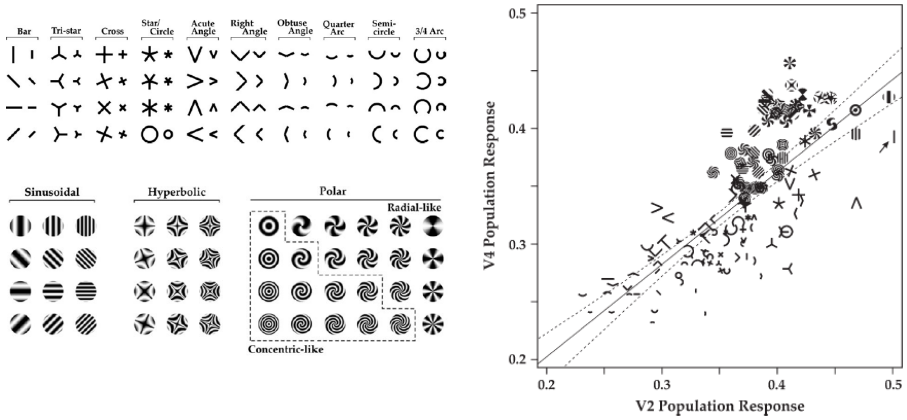


left
time 1



right
time 2

V2 and V4 responses to complex shapes



Hegde & Van Essen, 2007

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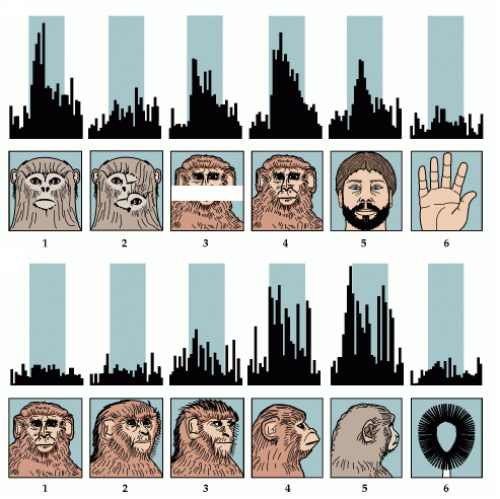
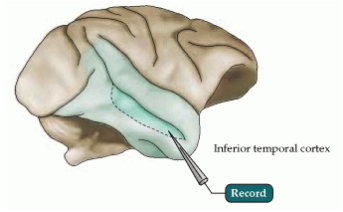
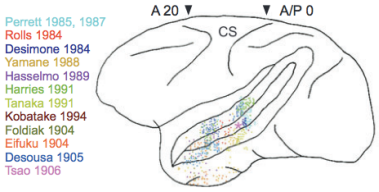
Face selective cells in IT cortex



Desimone et al., 1984



Locations of face selective cells in IT, from single cell recordings



"Grandmother Cells" or Population Feature Coding?

i.e. DISTRIBUTED

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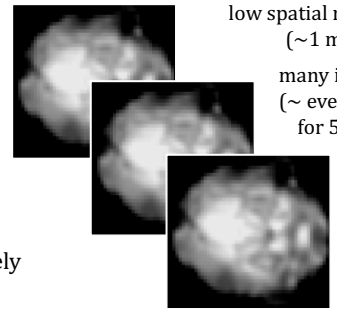
functional Magnetic Resonance Imaging (fMRI)



low spatial resolution (~1 mm)

many images (~ every 2 sec for 5 mins)

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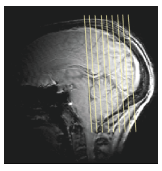
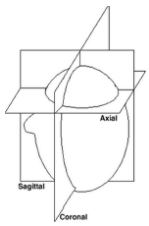
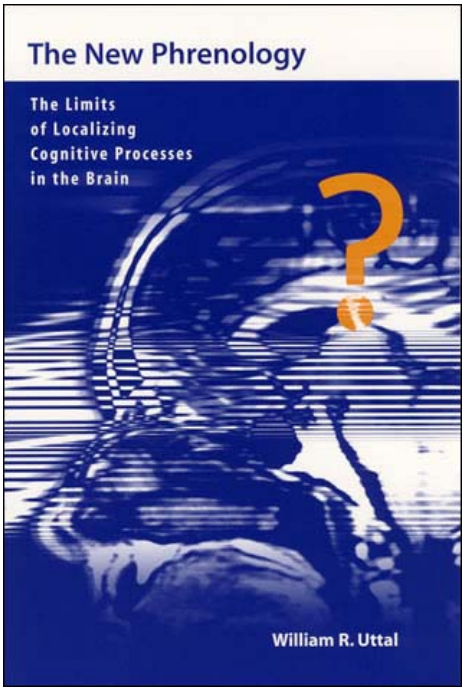
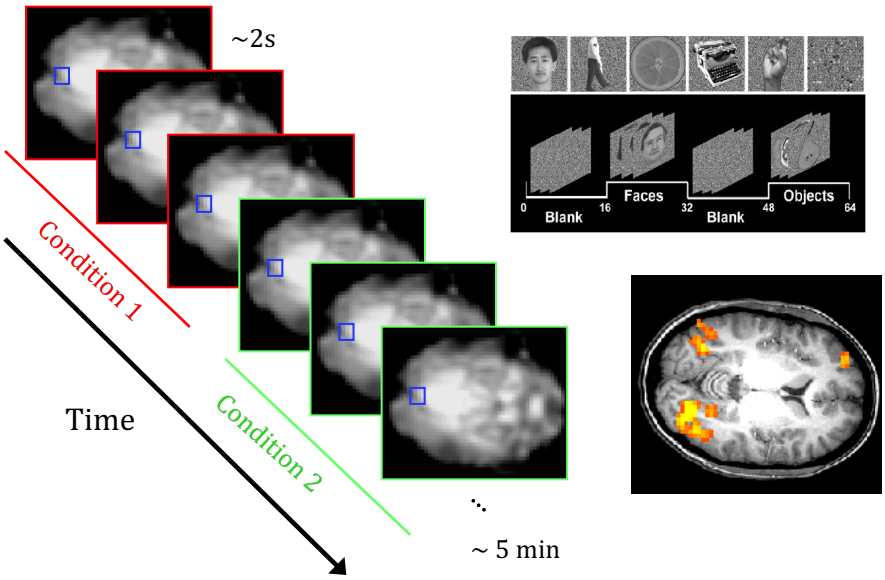




- best spatial resolution available for measuring neural activity noninvasively in the whole human brain
- increased neural activity
  → increased local blood flow
    → change in oxygenation of hemoglobin
      → increase in MRI signal
- Blood Oxygenation Level Dependent (BOLD) signal is an indirect measure of neural activity
- raw data: ~30,000 3D "voxels"
  (each voxel: hundreds of thousands of neurons)



fMRI experiment



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Fusiform Face Area (FFA) in the human brain

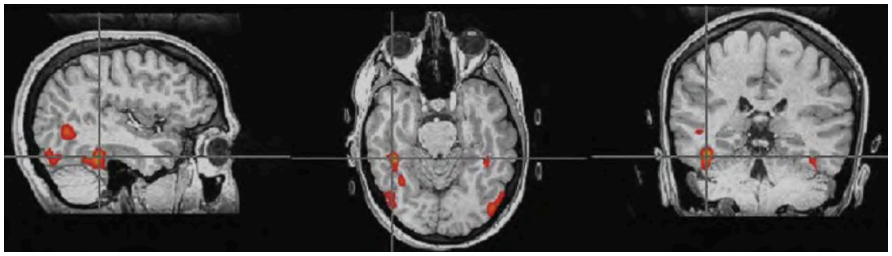
The Journal of Neuroscience, June 1, 1997, 17(11):4302–4311

The Fusiform Face Area: A Module in Human Extrastriate Cortex Specialized for Face Perception

Nancy Kanwisher,[1,2] Josh McDermott,[1,2] and Marvin M. Chun[2,3]

[1]Department of Psychology, Harvard University, Cambridge, Massachusetts 02138, [2]Massachusetts General Hospital NMR Center, Charlestown, Massachusetts 02129, and [3]Department of Psychology, Yale University, New Haven, Connecticut 06520-8205

Nancy Kanwisher



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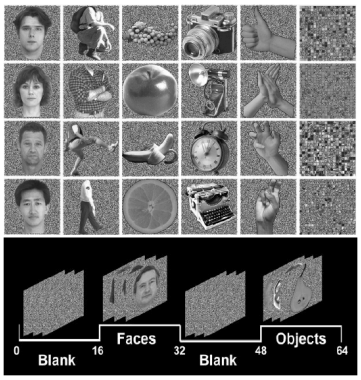
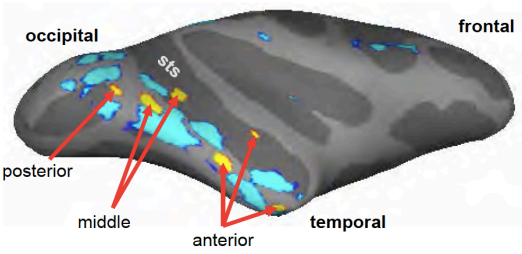
Face patches in macaque IT cortex

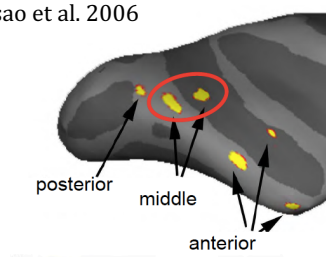


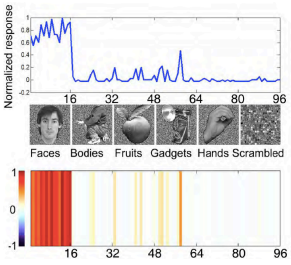


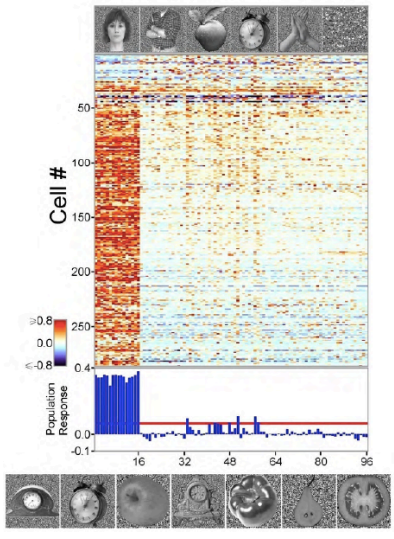
Tsao, Freiwald, Tootell, Livingstone, 2006

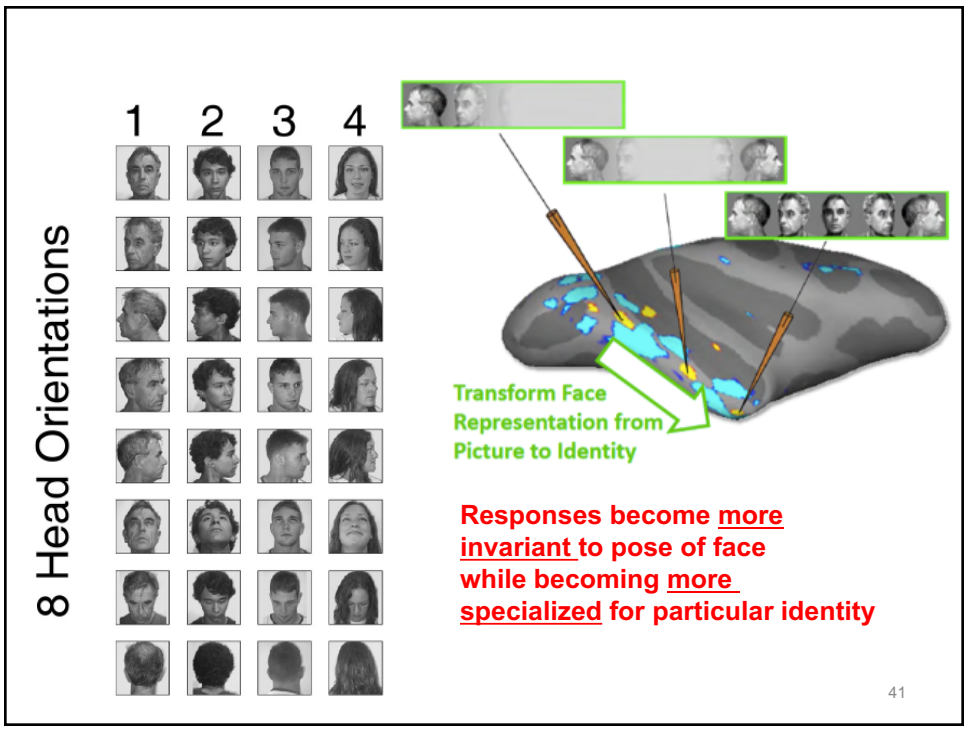
Targeting neurons in middle face patch using single cell recording

Tsao et al. 2006








1 2 3 4
8 Head Orientations
Transform Face Representation from Picture to Identity
Responses become more invariant to pose of face while becoming more specialized for particular identity
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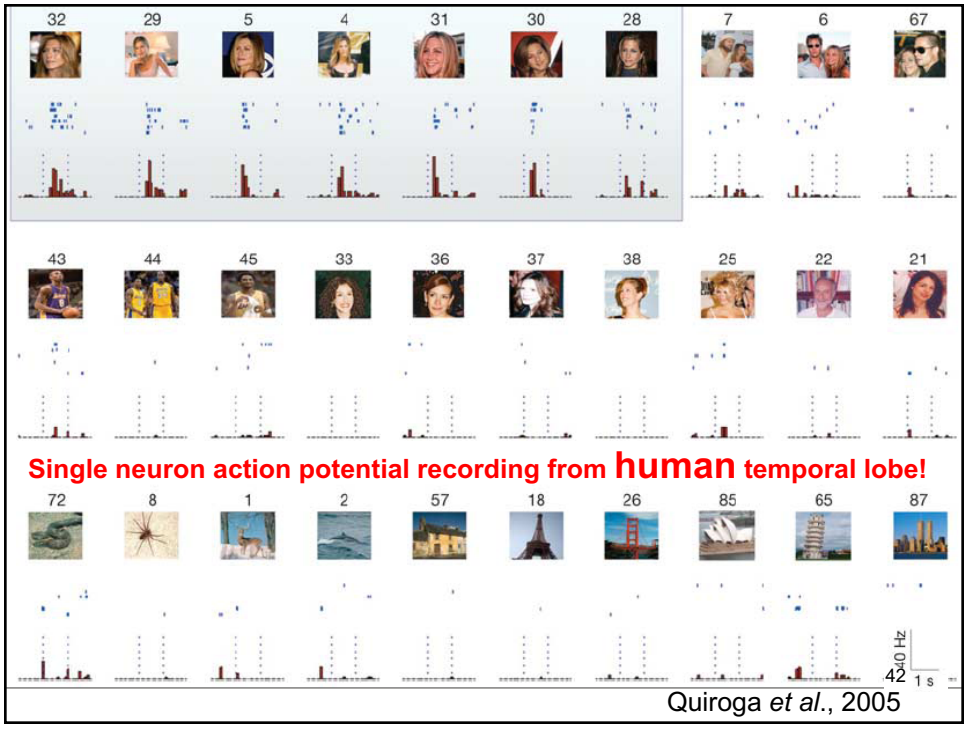
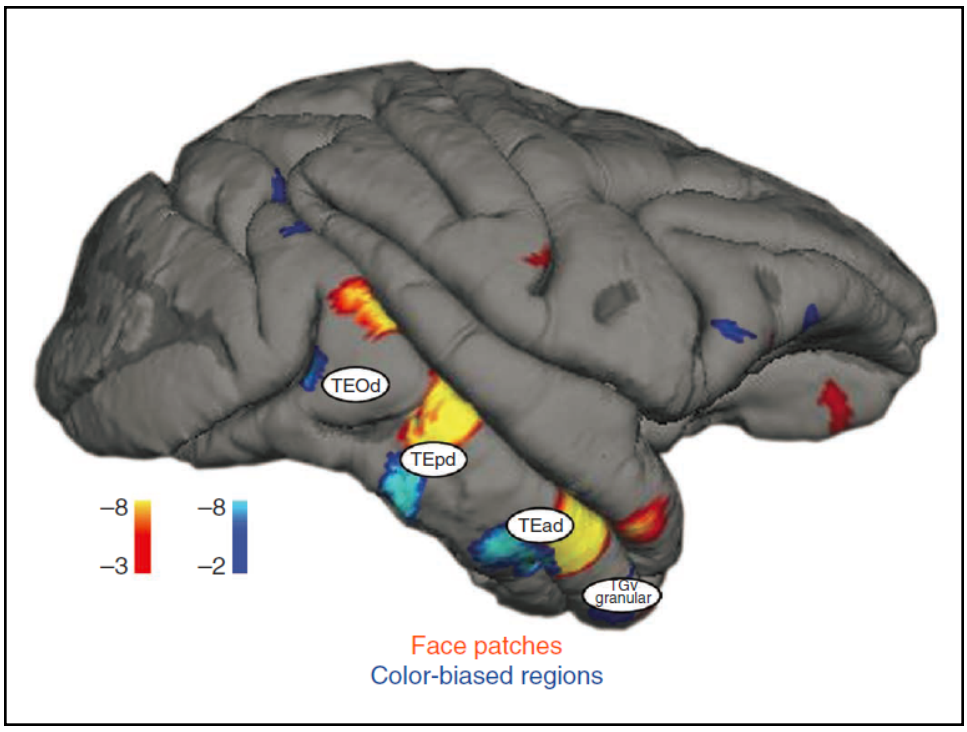
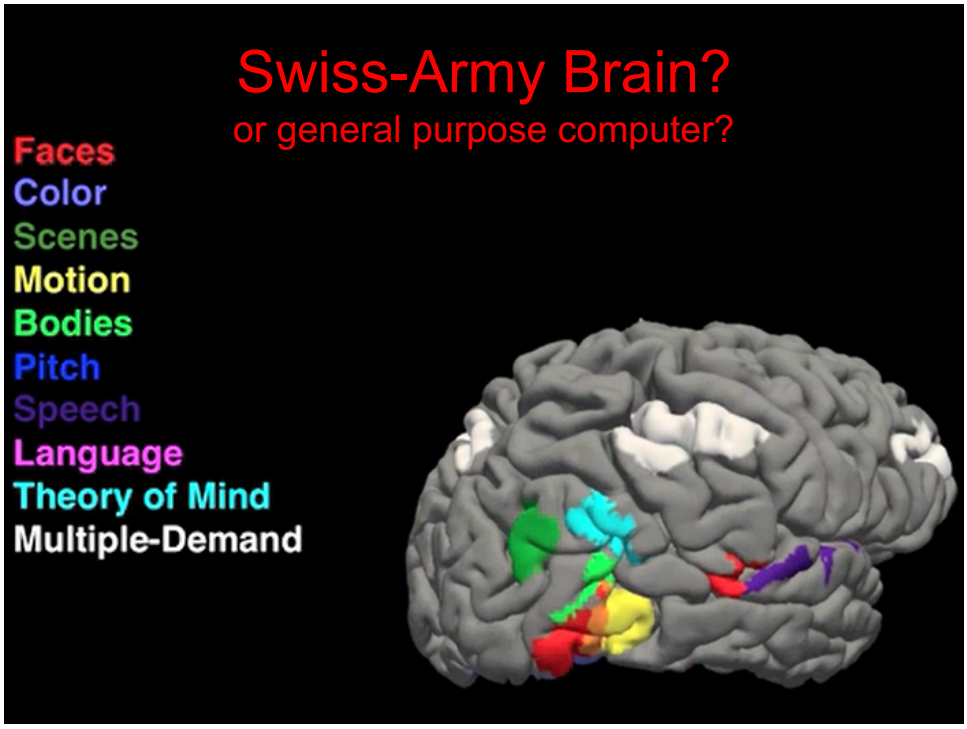

32 29 5 4 31 30 28 7 6 67
43 44 45 33 36 37 38 25 22 21
Single neuron action potential recording from human temporal lobe!
72 8 1 2 57 18 26 85 65 87
40 Hz
1 s
42
Quiroga et al., 2005

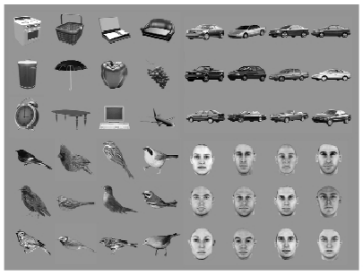

TEOd
TEpd
TEad
TGV granular
−8
−3
−8
−2
Face patches
Color-biased regions

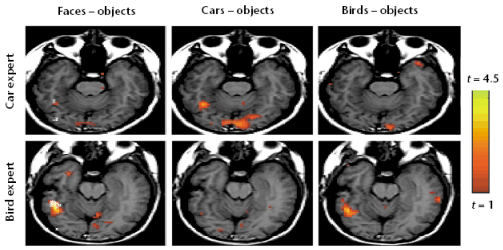

Swiss-Army Brain?
or general purpose computer?
Faces
Color
Scenes
Motion
Bodies
Pitch
Speech
Language
Theory of Mind
Multiple-Demand

Expertise for cars and birds recruits brain areas involved in face recognition

Isabel Gauthier[1,2], Pawel Skudlarski[2], John C. Gore[2] and Adam W. Anderson[2] (*Nature Neuroscience*, 2000)

[1] *Present Address: Department of Psychology, Vanderbilt University, Wilson Hall, Nashville, Tennessee 37240, USA*
[2] *Department of Diagnostic Radiology, Yale University Medical School, Fitkin Basement, 333 Cedar Street, New Haven, Connecticut 06510, USA*
Correspondence should be addressed to I.G. (isabel.gauthier@vanderbilt.edu)





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Conclusions

- Visual neurons are arranged in retinotopic "maps"
- The cortex is organized **hierarchically**: More complex and specific feature-sensitivities are constructed from lower-level features
- The cortex has parallel localized "modules" specialized for different functions, features, and objects, like speech, **faces**, color, motion…even "theory of mind"

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