Introduction to Neuroscience:
Systems Neuroscience - Concepts and Methods

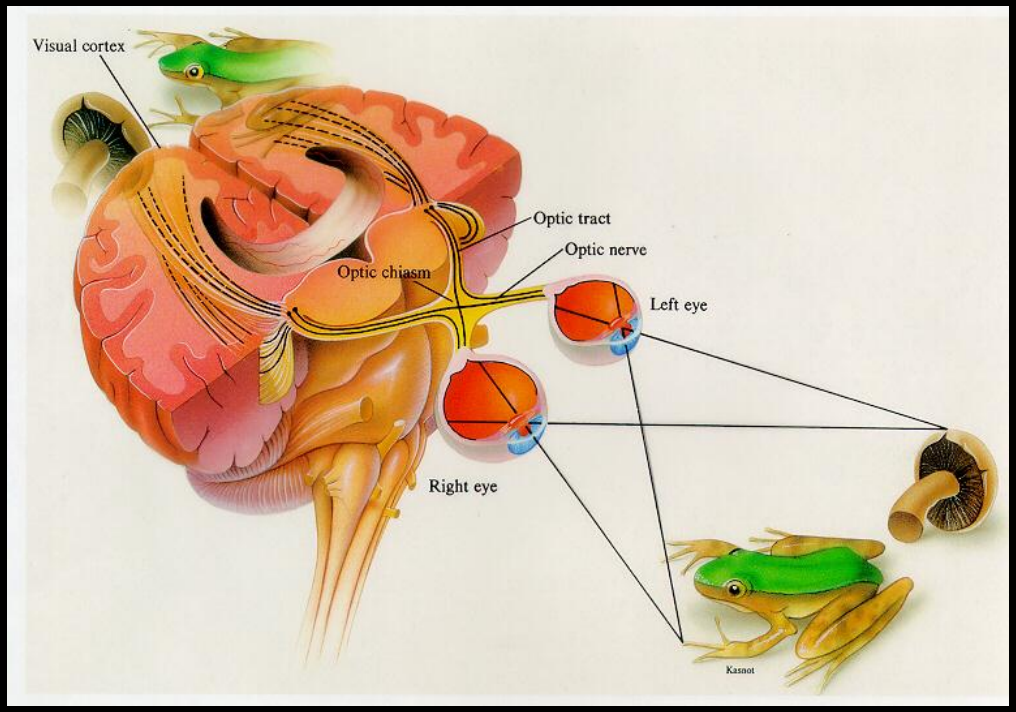
Seeing: Central visual processes

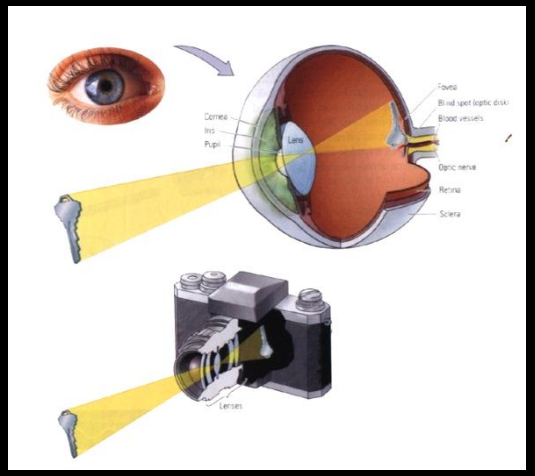
Rafi Malach

Department of Neurobiology

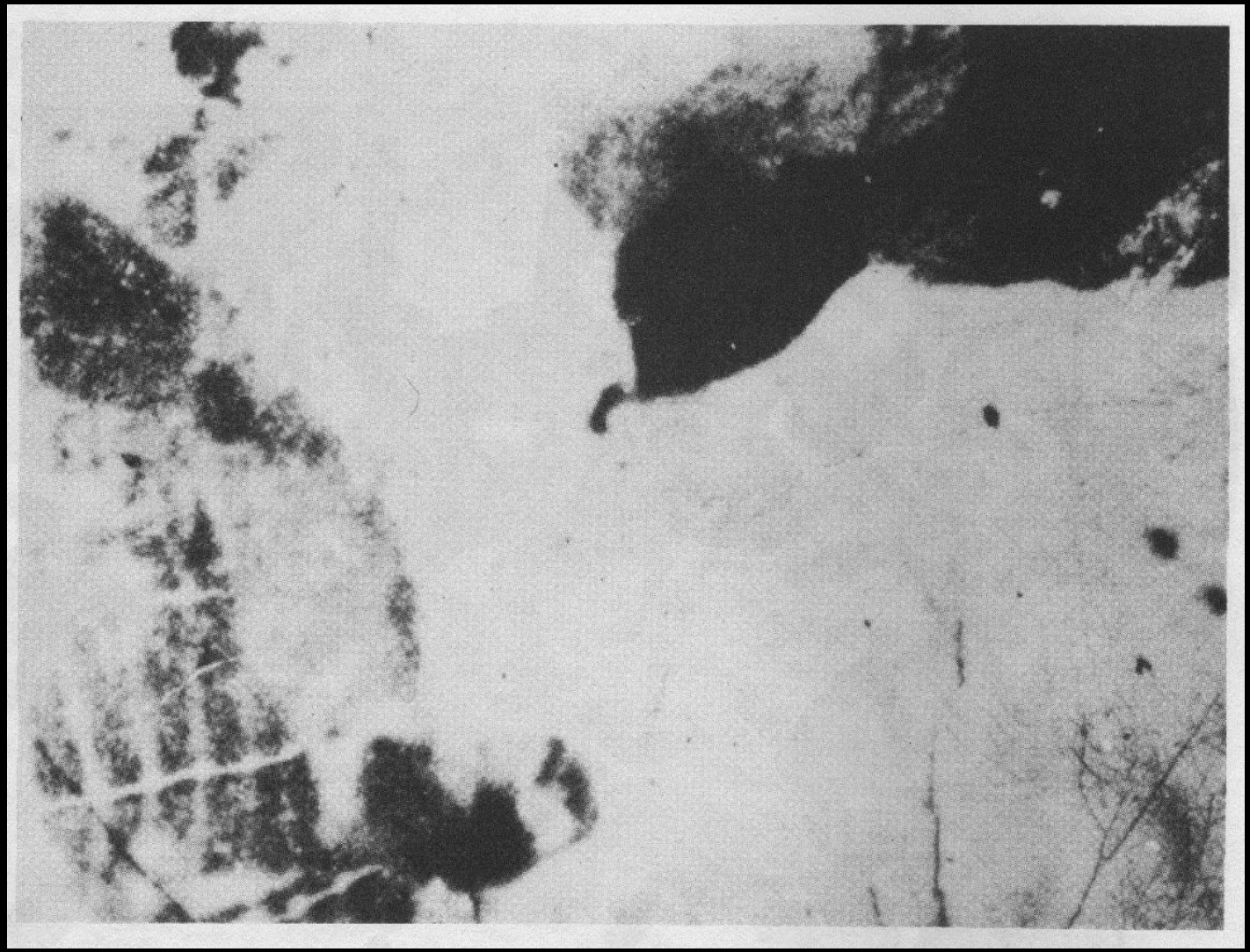
What is the function of the visual system?

"The Visual system: "detects and interprets information from visible light " (Wikipedia)"

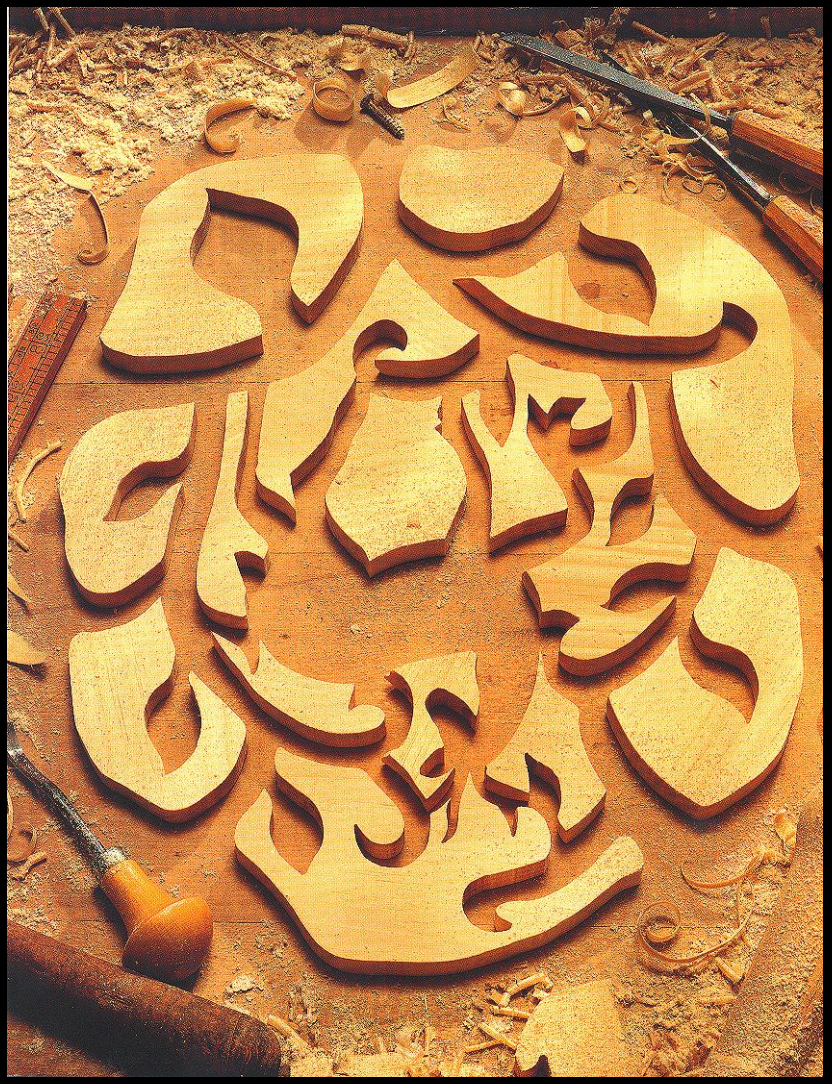




Our visual images combine incoming information with prior knowledge

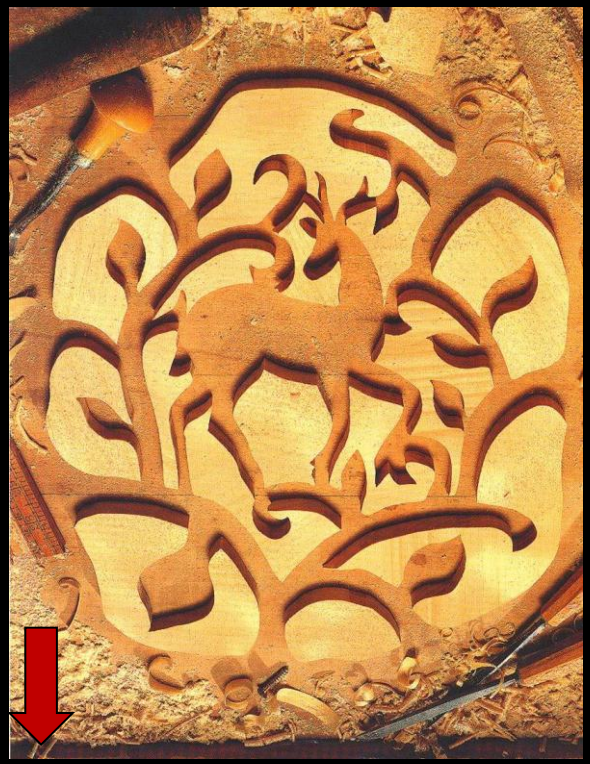


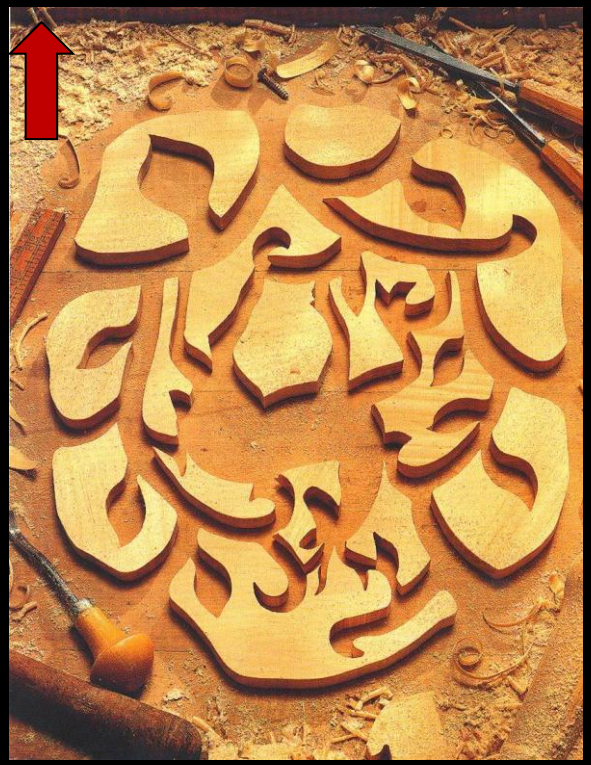
Unconscious priors in image generations



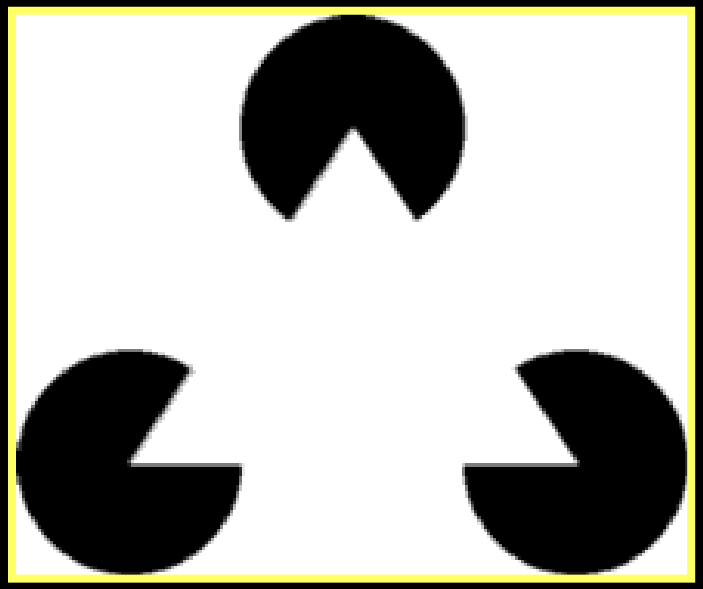
Unconscious priors in image generations

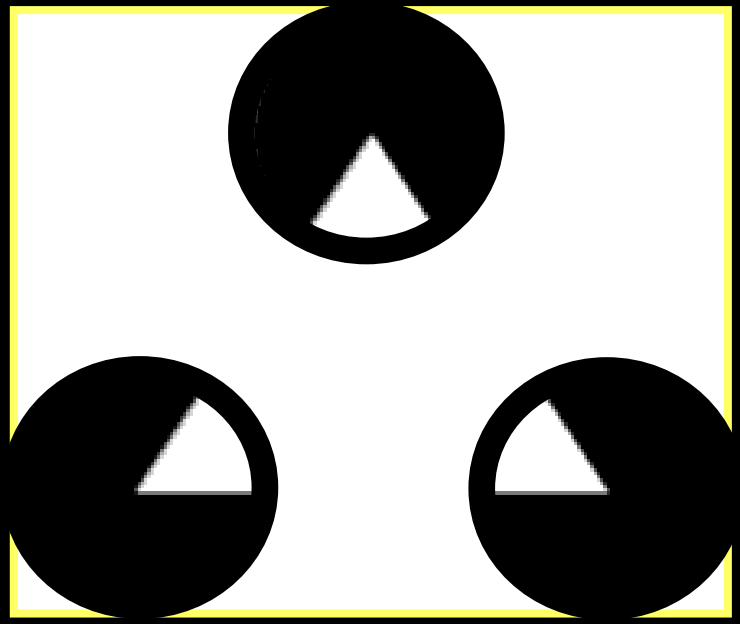
The impact of stored priors in visual perception





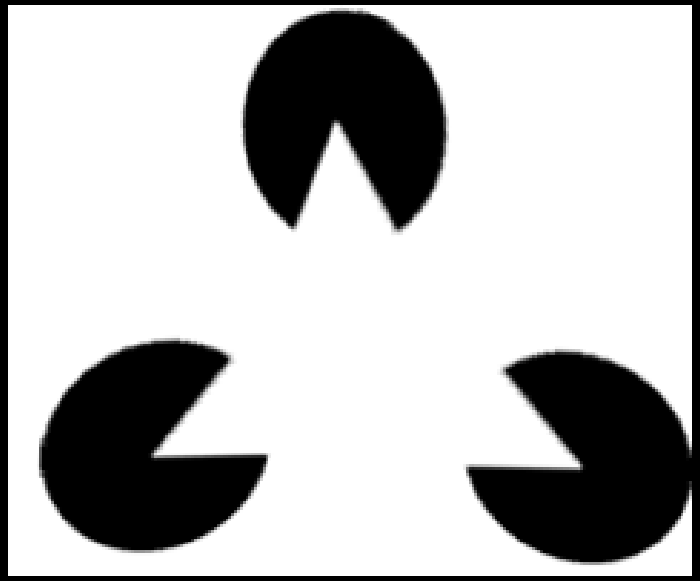
The Kanizsa Hallucination



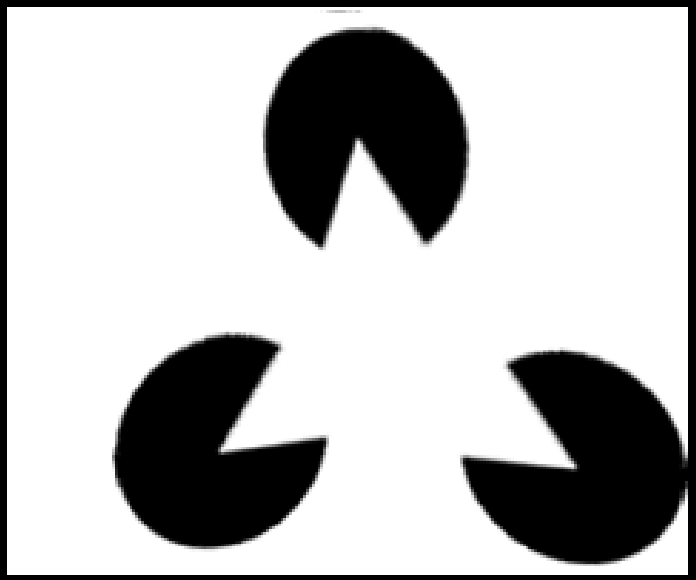


hal·lu·ci·na·tion
noun
1.an experience involving the apparent perception of something not present.

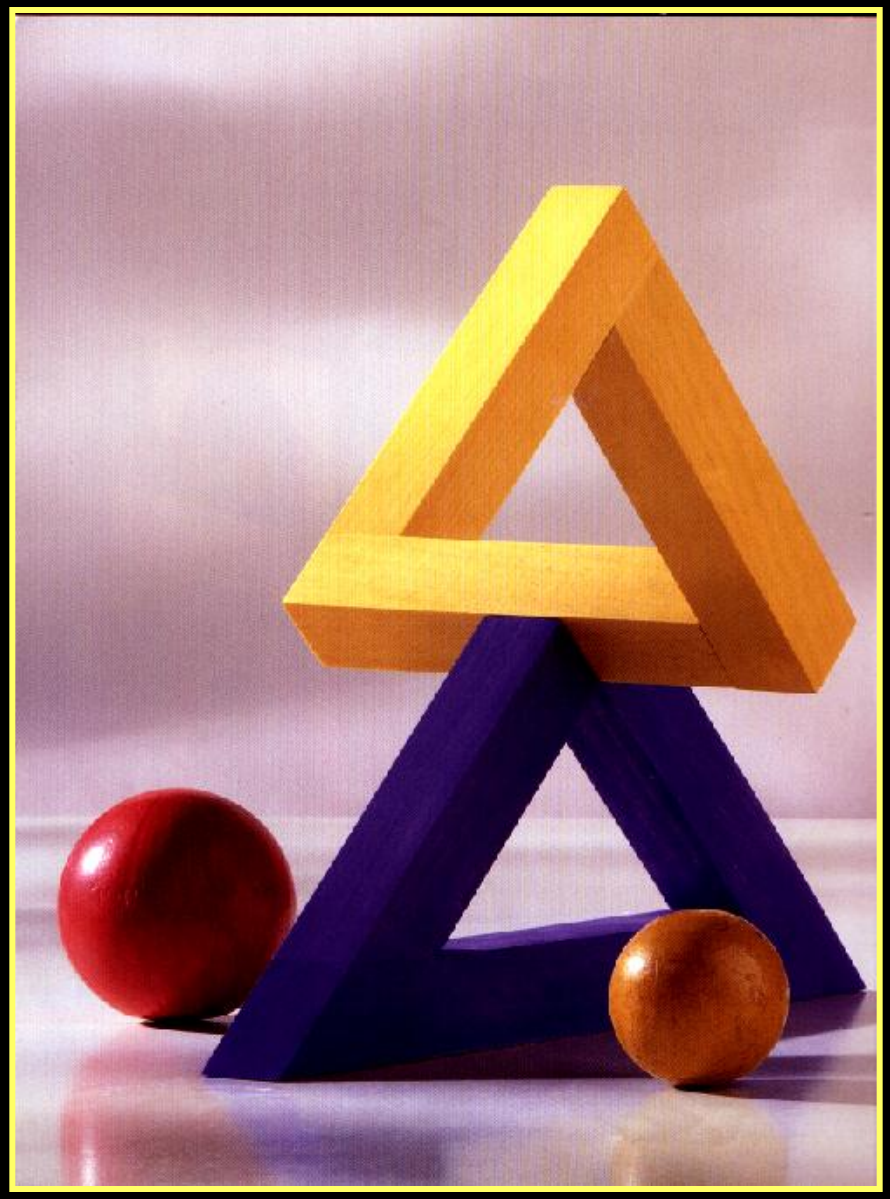
Illusory motion



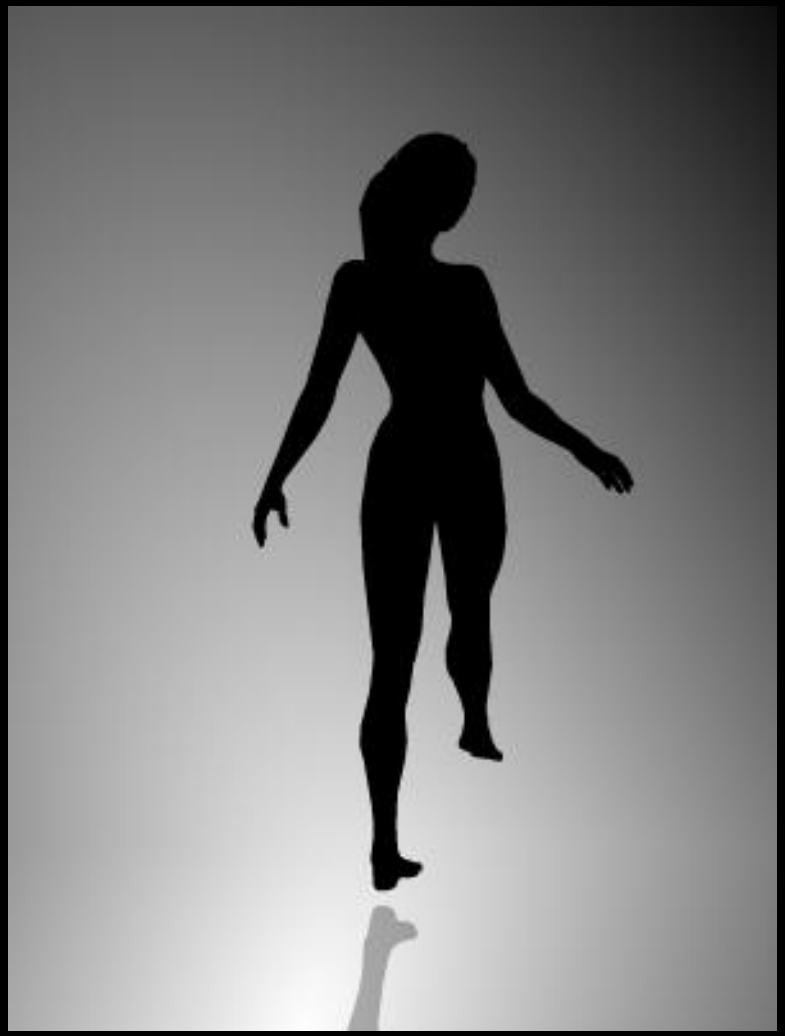
Illusory motion

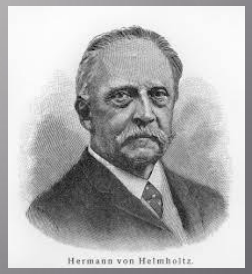


The visual system can generate percepts that can not possibly exist



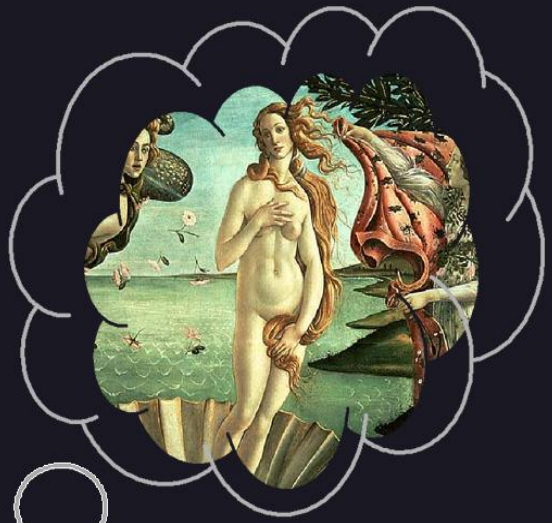
Priors are often individually-unique



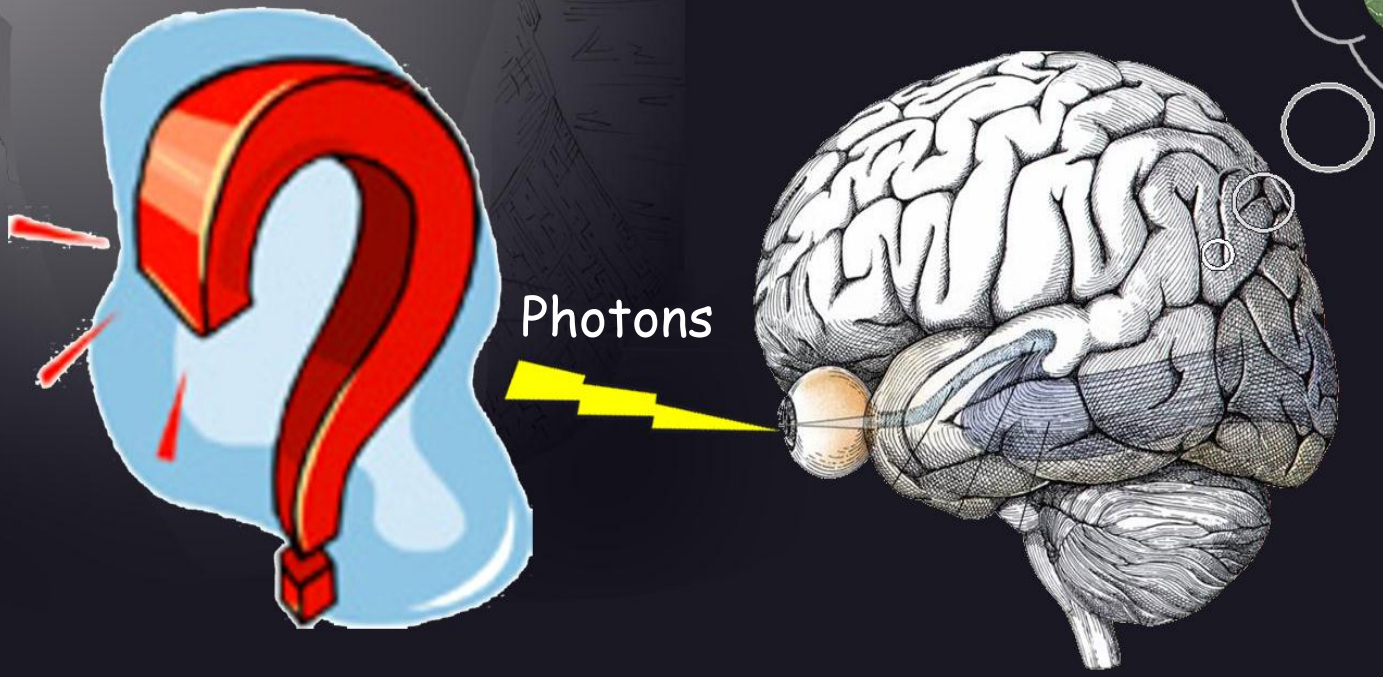


Hermann von Helmholtz

Brain stimulation



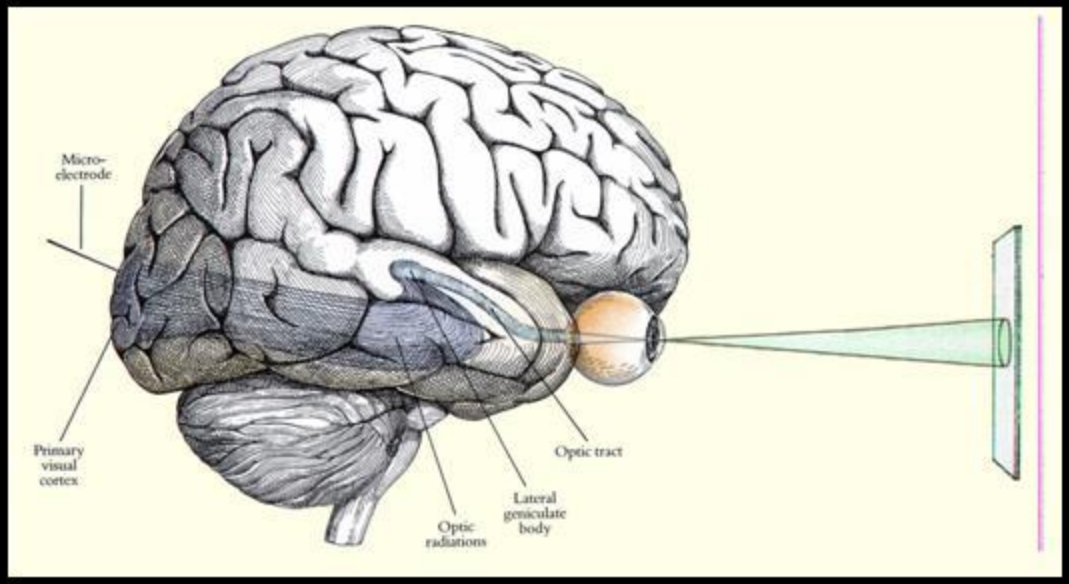
Visual images



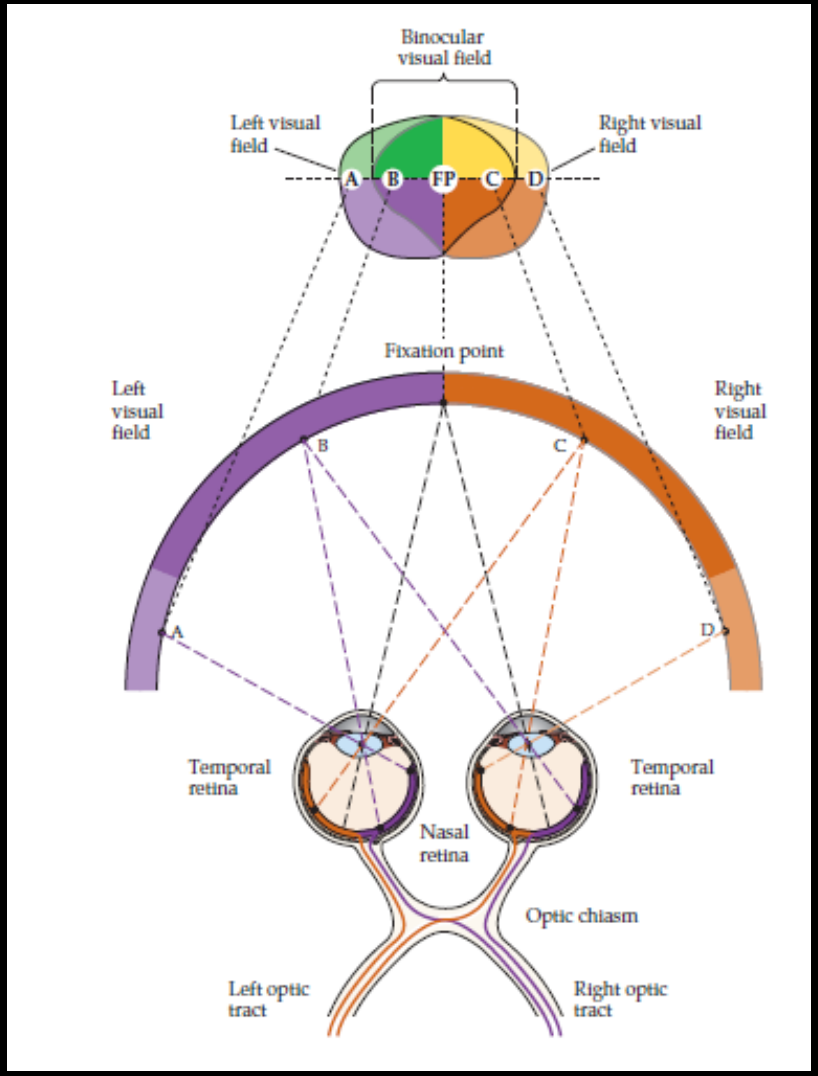
The outside world

Visual images are hypotheses generated by the visual system-not a picture of the external world

The Human Visual System



Definitions:



retinotopy, visual field, contra- ipsi, fixation point, vertical meridian
Horizontal meridian

Flow of information form the eye to the brain

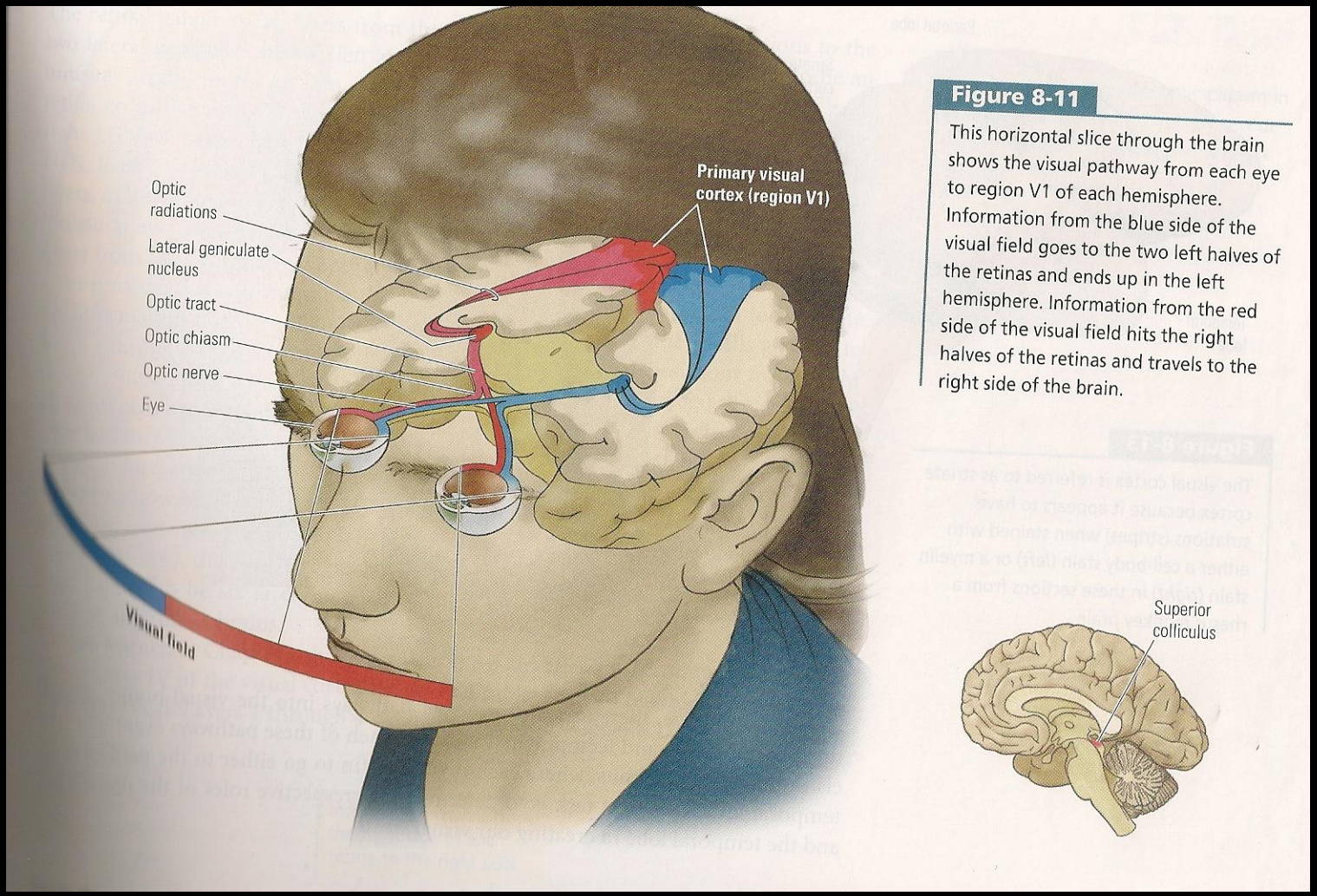
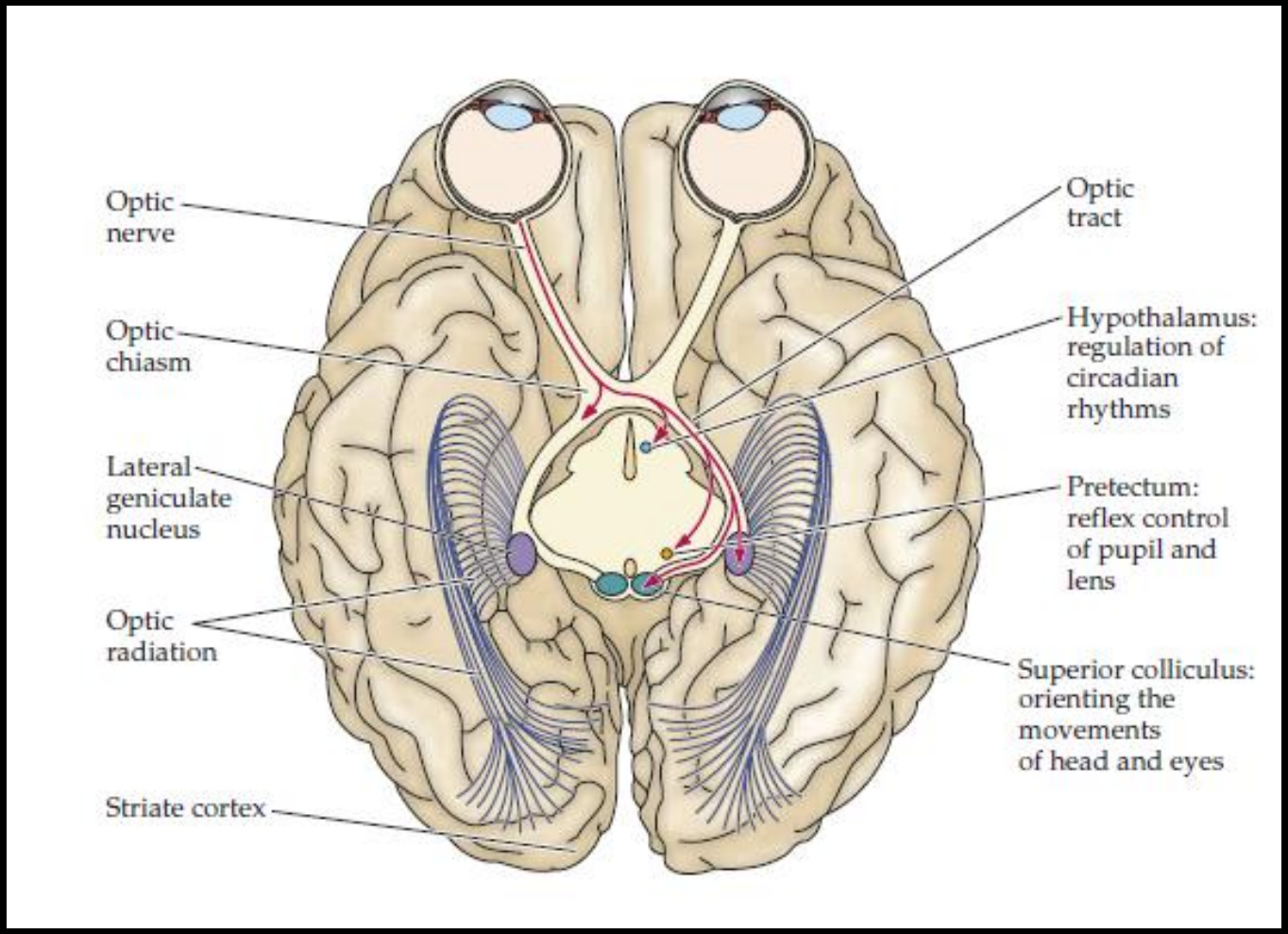


Figure 8-11

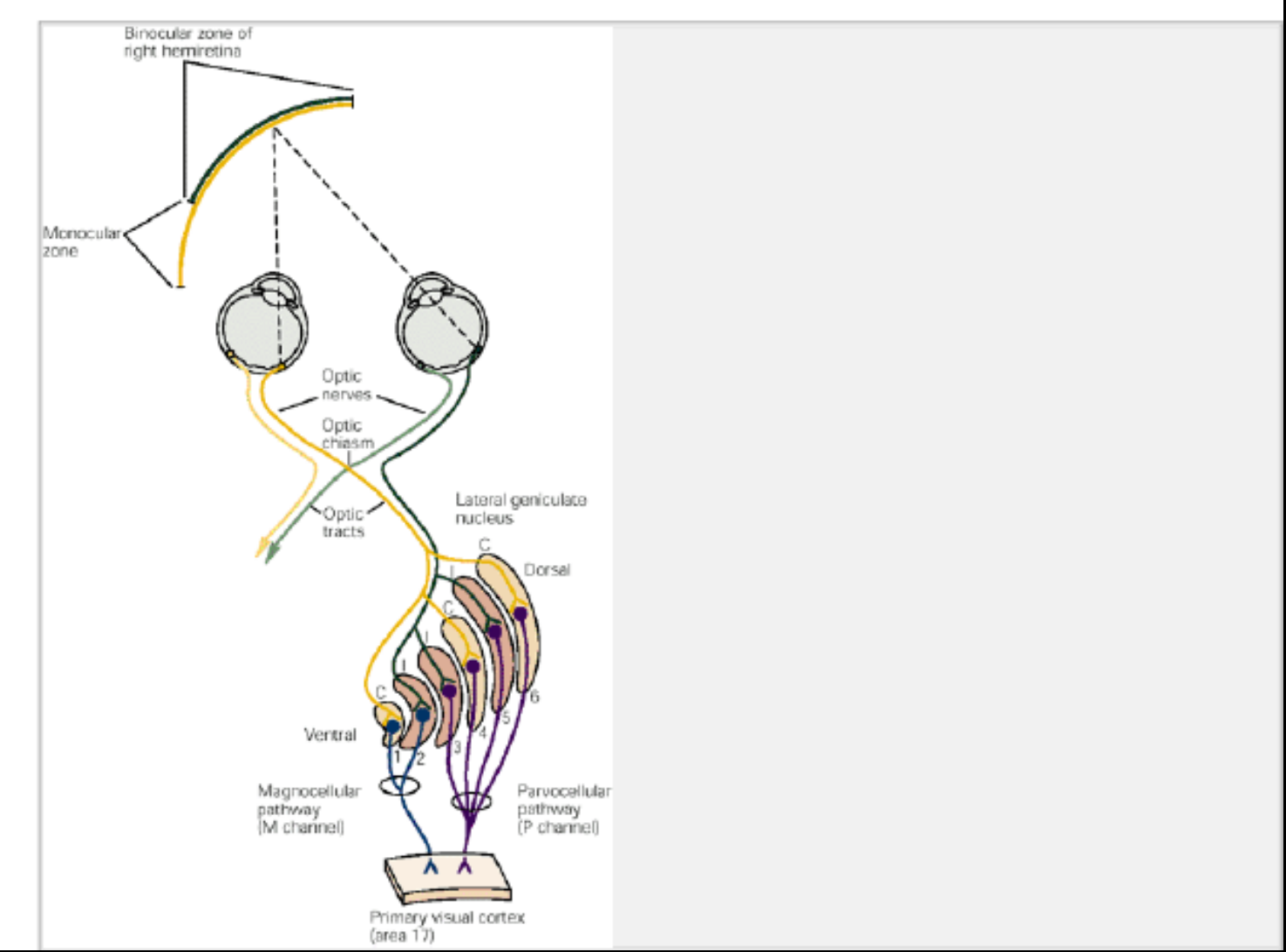
This horizontal slice through the brain shows the visual pathway from each eye to region V1 of each hemisphere. Information from the blue side of the visual field goes to the two left halves of the retinas and ends up in the left hemisphere. Information from the red side of the visual field hits the right halves of the retinas and travels to the right side of the brain.

Optic nerve, chiasm, tract and radiation

Many light related functions- not only vision

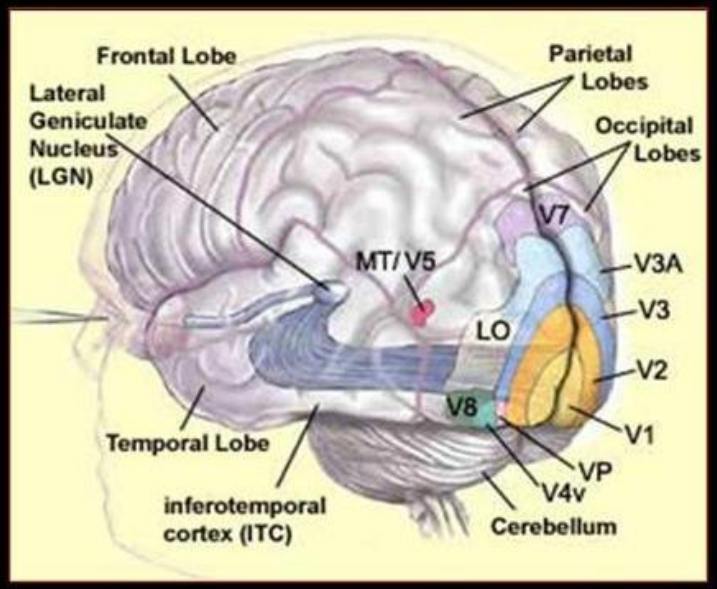


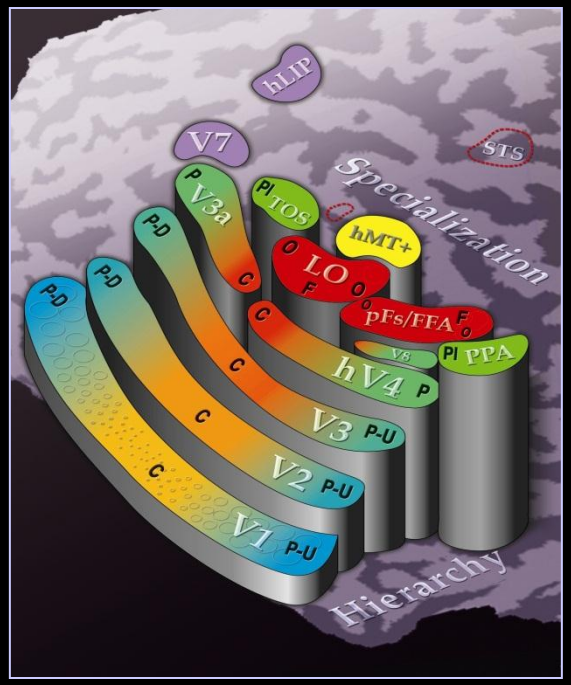
LGN- Relay and gating station



Magno (~ motion) and Parvo (~shape) pathways

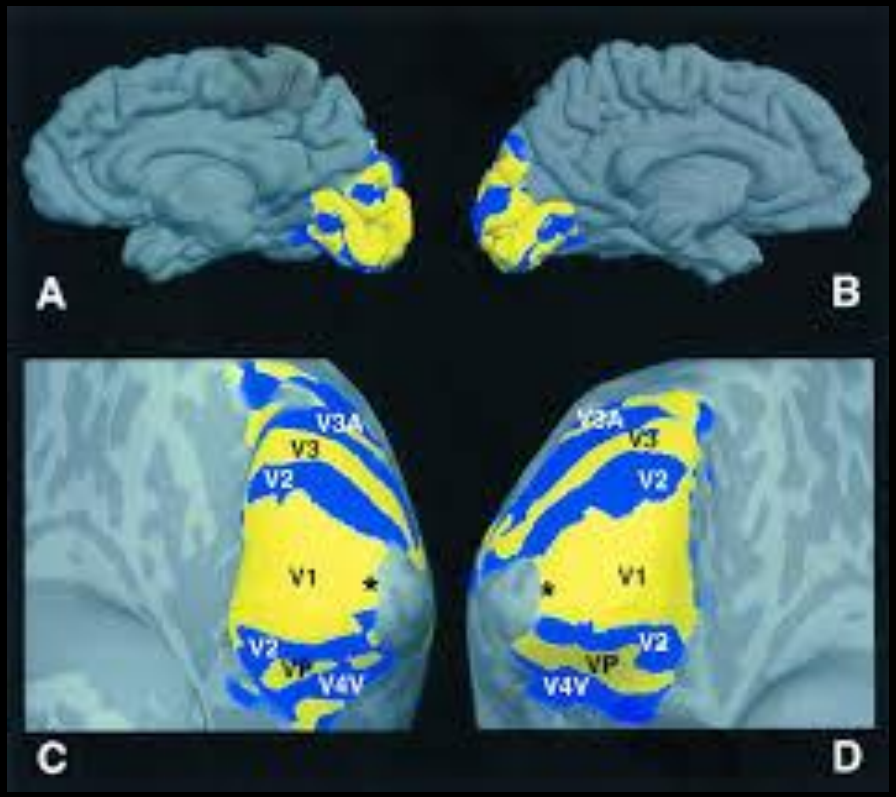
Atlas of human visual areas



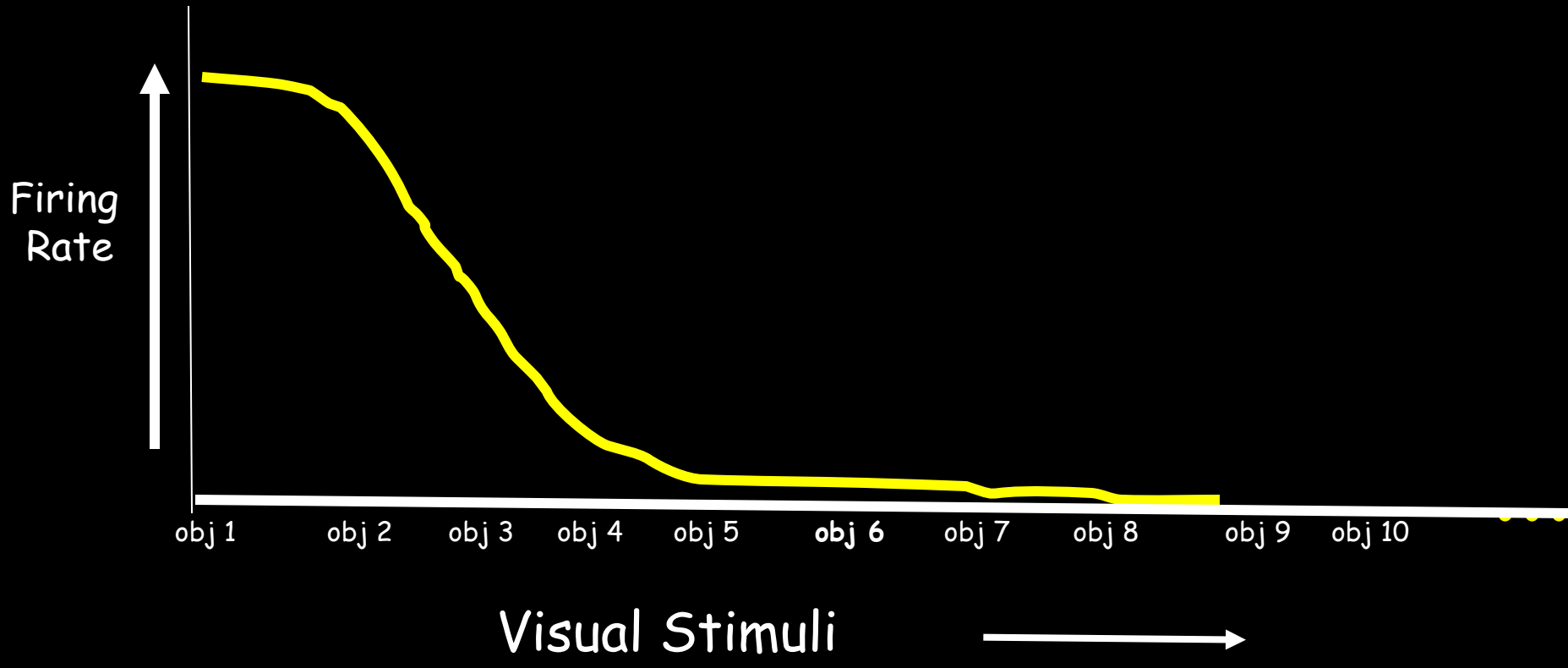


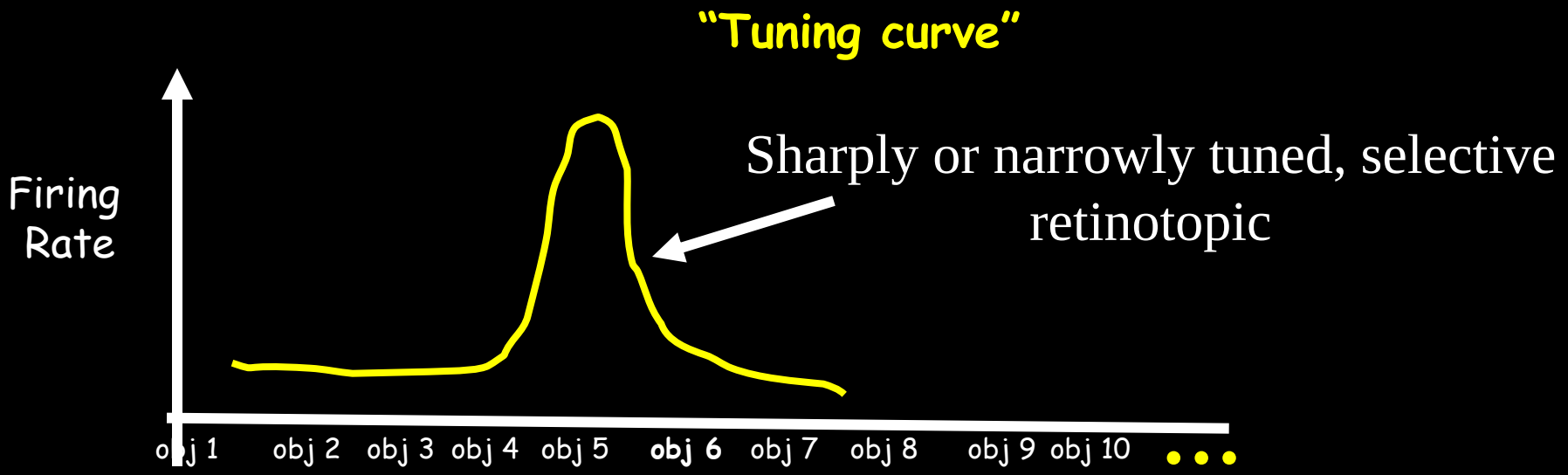
Large scale organization principles

Human primary visual cortex
Visual Area 1- V1



The Concept of a Receptive Field

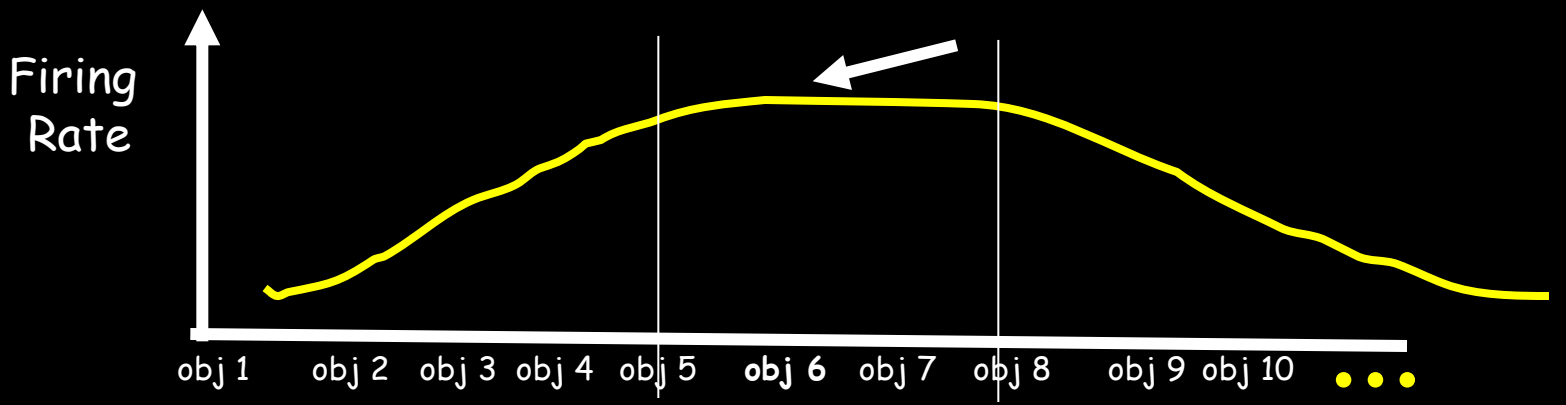




Visual Parameter
(e.g. retinal position)

Example: "Simple cells"- Tuned to orientation and position

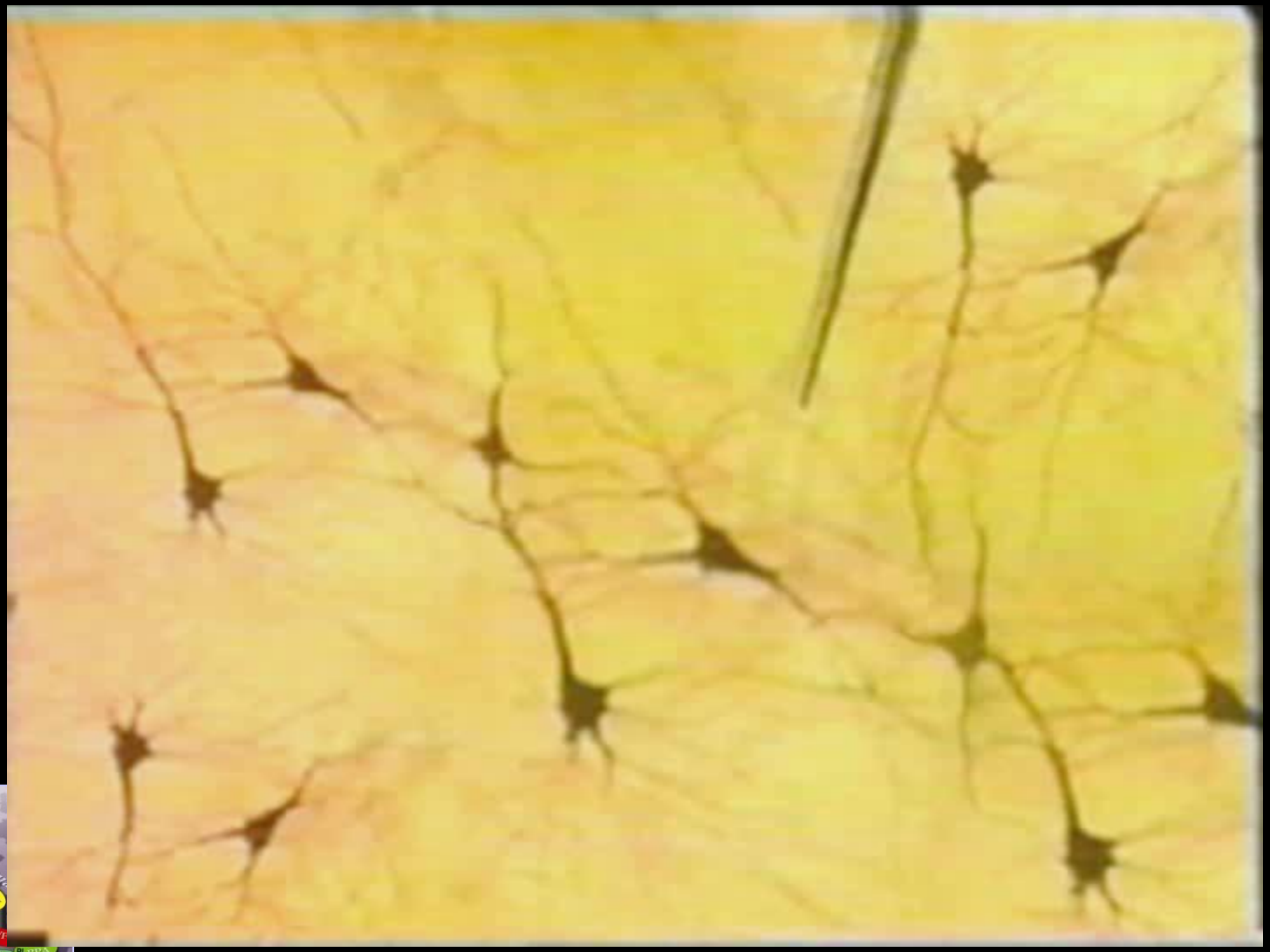
Invariance: a group of stimuli that equally activate a neuron

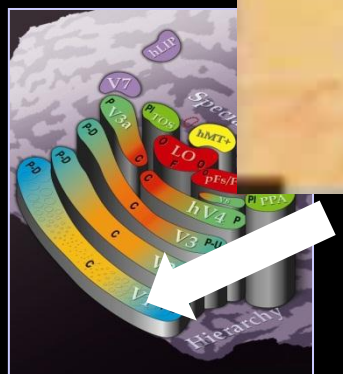


Visual Parameter
(e.g. retinal position)

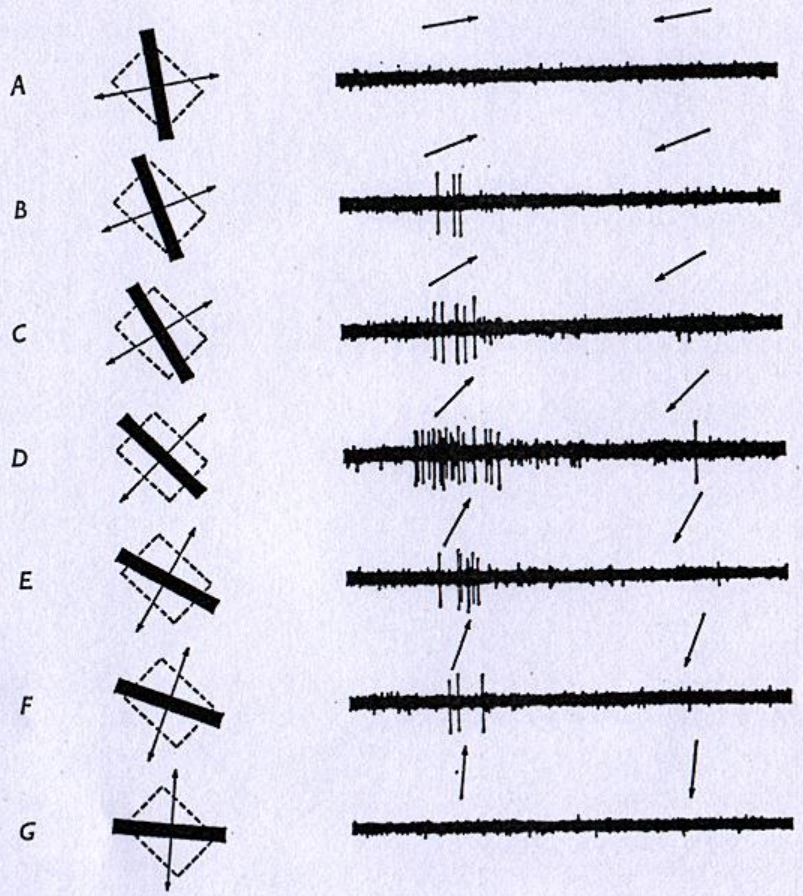
Example: position invariance
(Large retinotopic receptive field)

The properties of single neurons in area V1





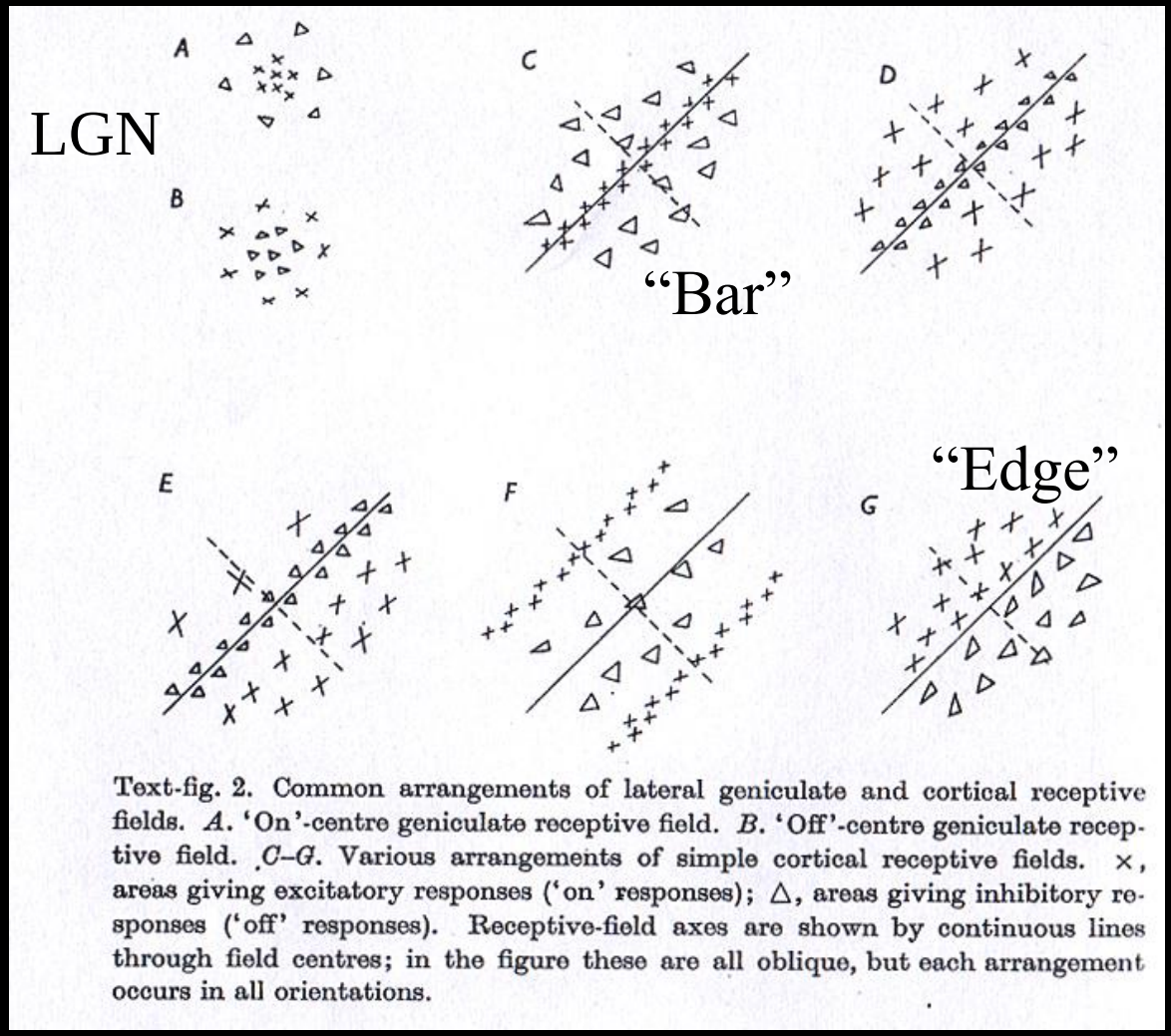
Receptive field of a visual neuron in area V1



Text-fig. 2. Responses of a complex cell in right striate cortex (layer IV A) to various orientations of a moving black bar. Receptive field in the left eye indicated by the interrupted rectangles; it was approximately $\frac{3}{8} \times \frac{3}{8}°$ in size, and was situated 4° below and to the left of the point of fixation. Ocular-dominance group 4. Duration of each record, 2 sec. Background intensity 1·3 $\log_{10}$ cd/m², dark bars 0·0 log cd/m².

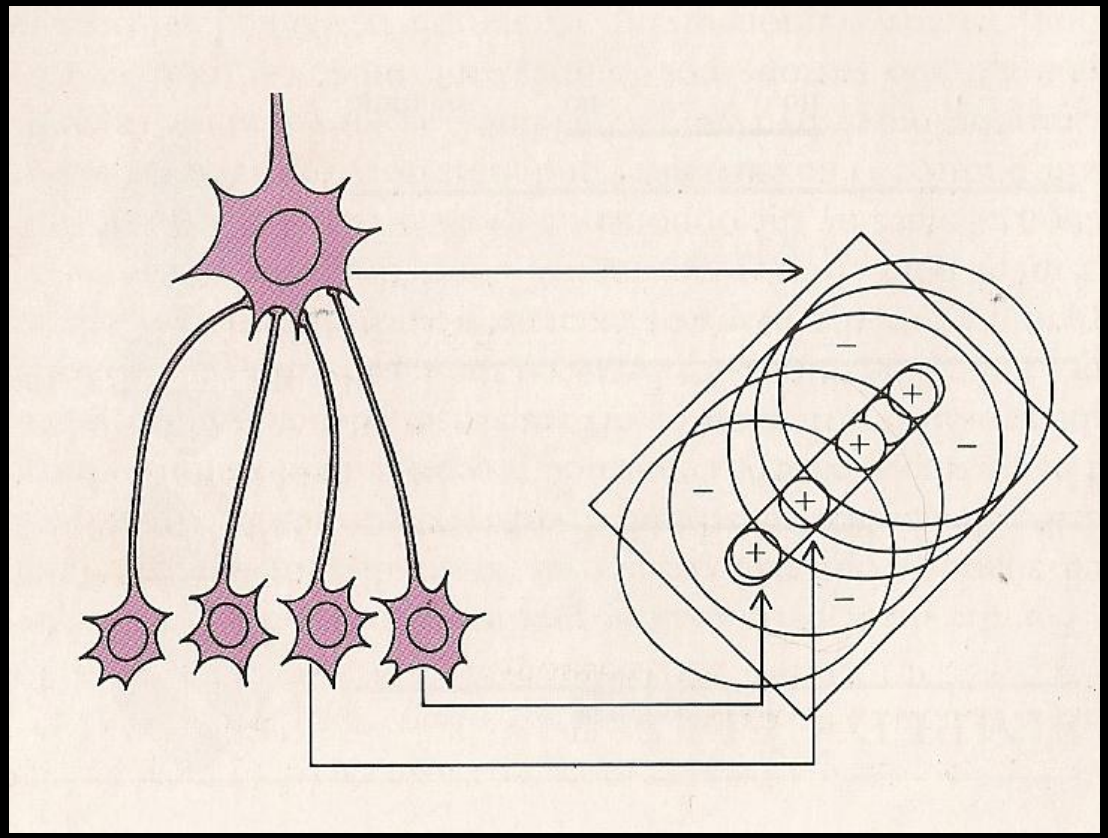
Stimulus selectivity of receptive fields

Receptive field of a "Simple" cell in area V1



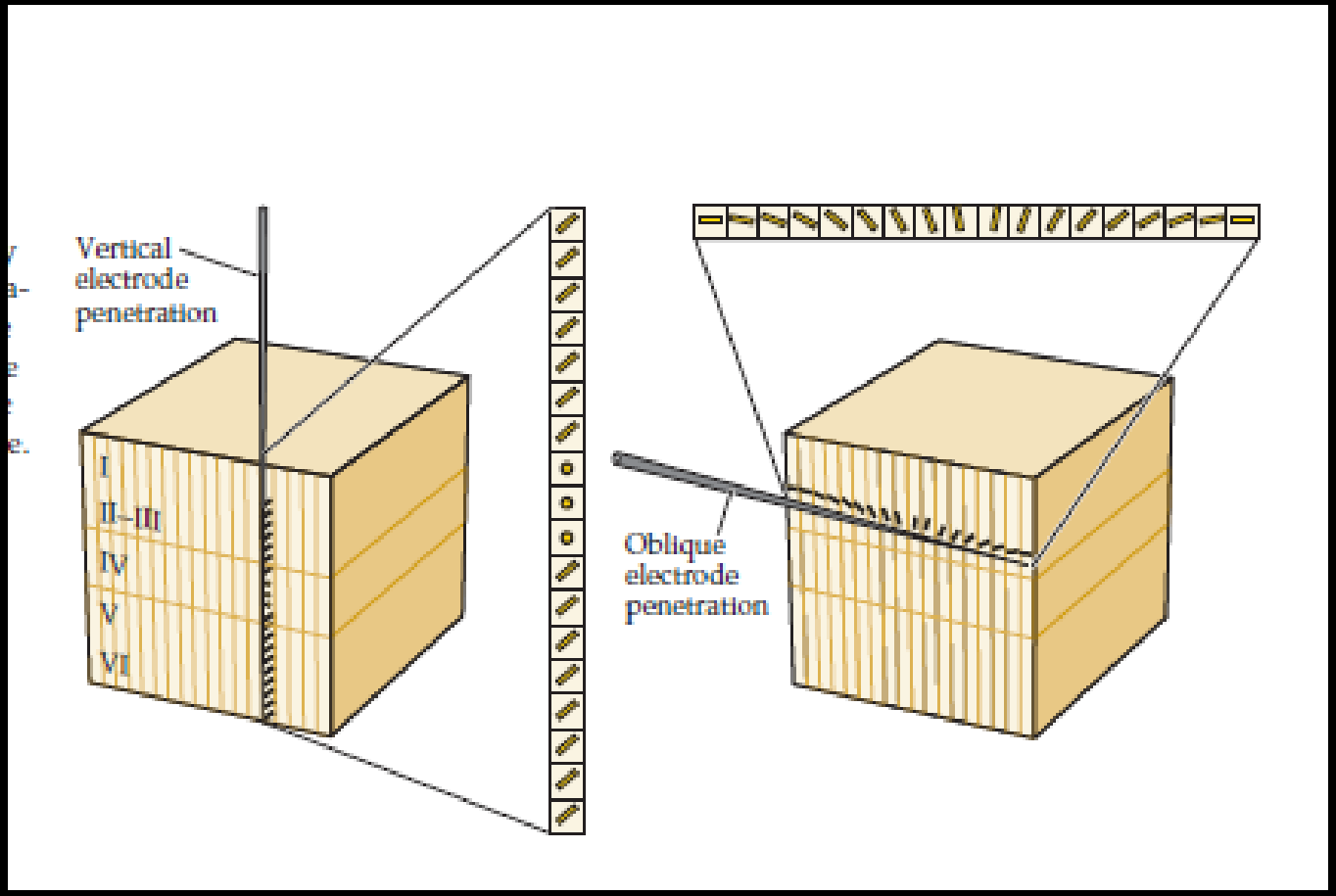
Text-fig. 2. Common arrangements of lateral geniculate and cortical receptive fields. *A*. 'On'-centre geniculate receptive field. *B*. 'Off'-centre geniculate receptive field. *C–G*. Various arrangements of simple cortical receptive fields. ×, areas giving excitatory responses ('on' responses); △, areas giving inhibitory responses ('off' responses). Receptive-field axes are shown by continuous lines through field centres; in the figure these are all oblique, but each arrangement occurs in all orientations.

The simple cell model

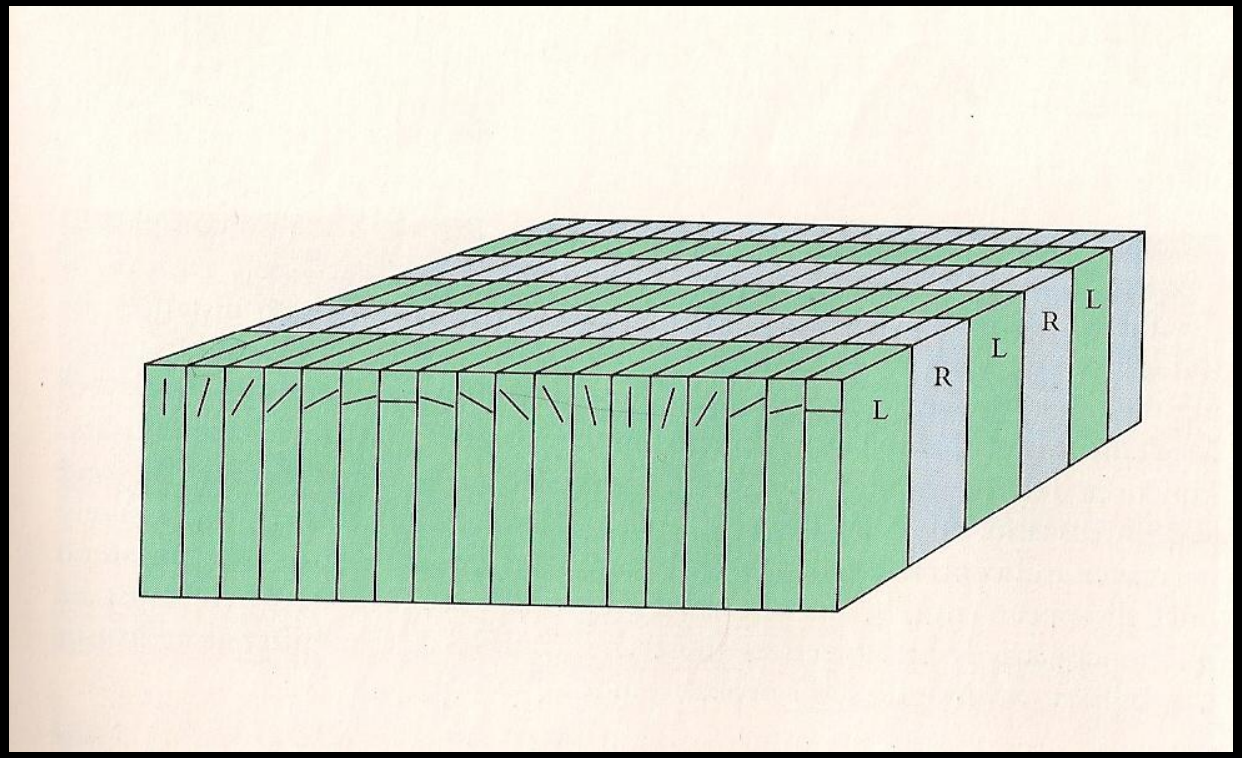


Convergence, threshold, synchrony
An "and" function

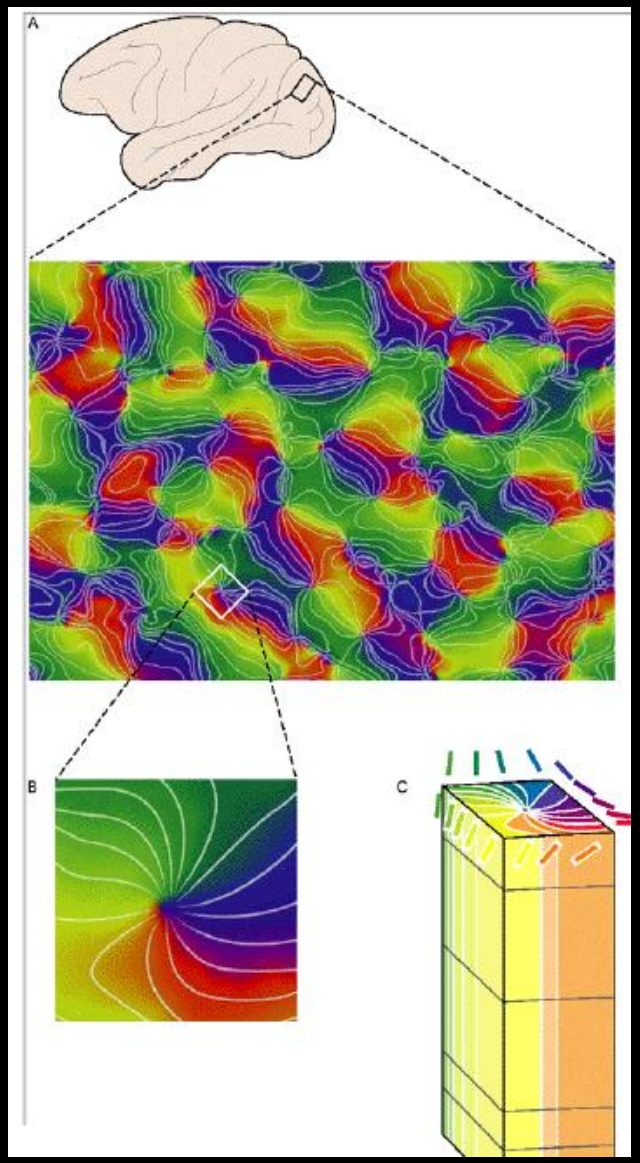
Columns: Within area subdivisions



Orientation and ocular columns- the “hyper –column”

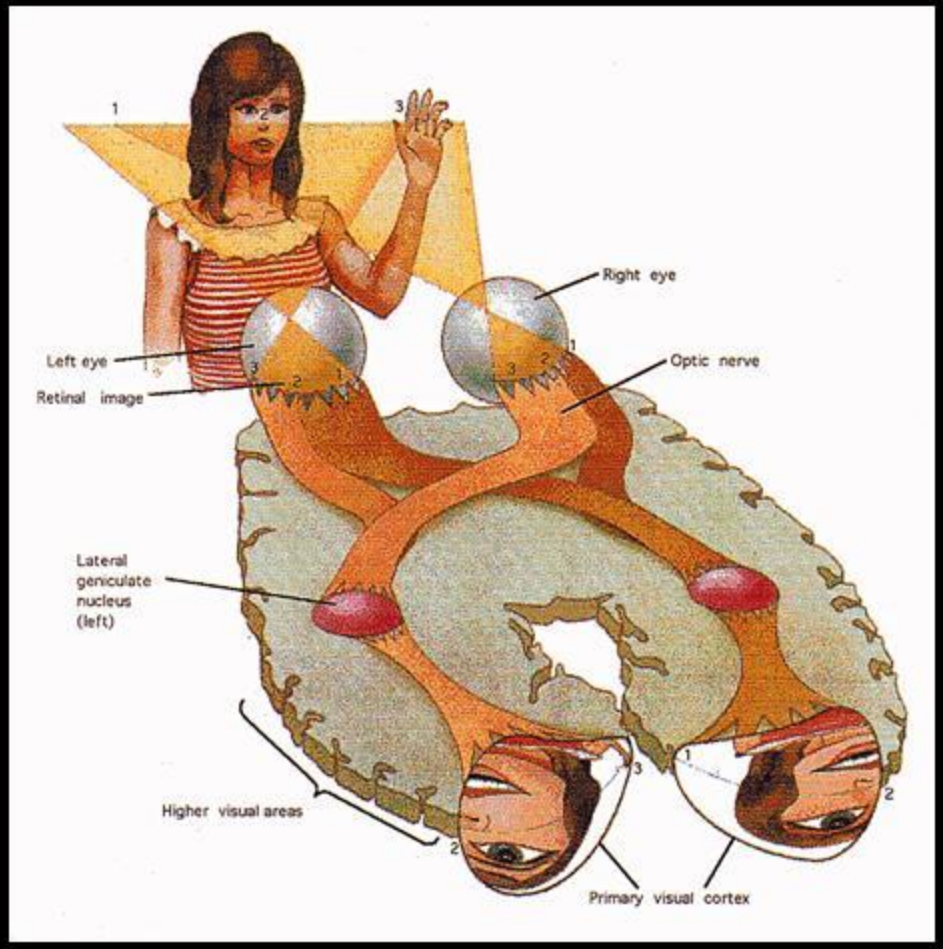


The true organization, "pinwheels"



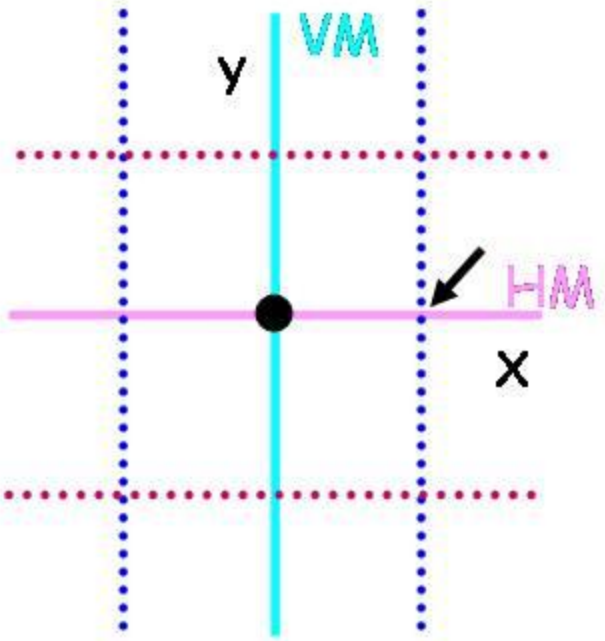
Foveal magnification in V1

Log Topographical representations in the human visual system

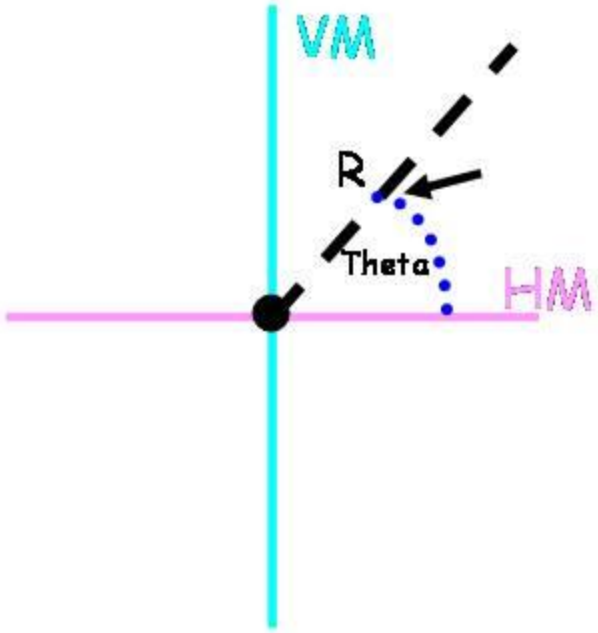


Magnification factor: how many mm cortex correspond to a mm on the retina

Coordinate frames

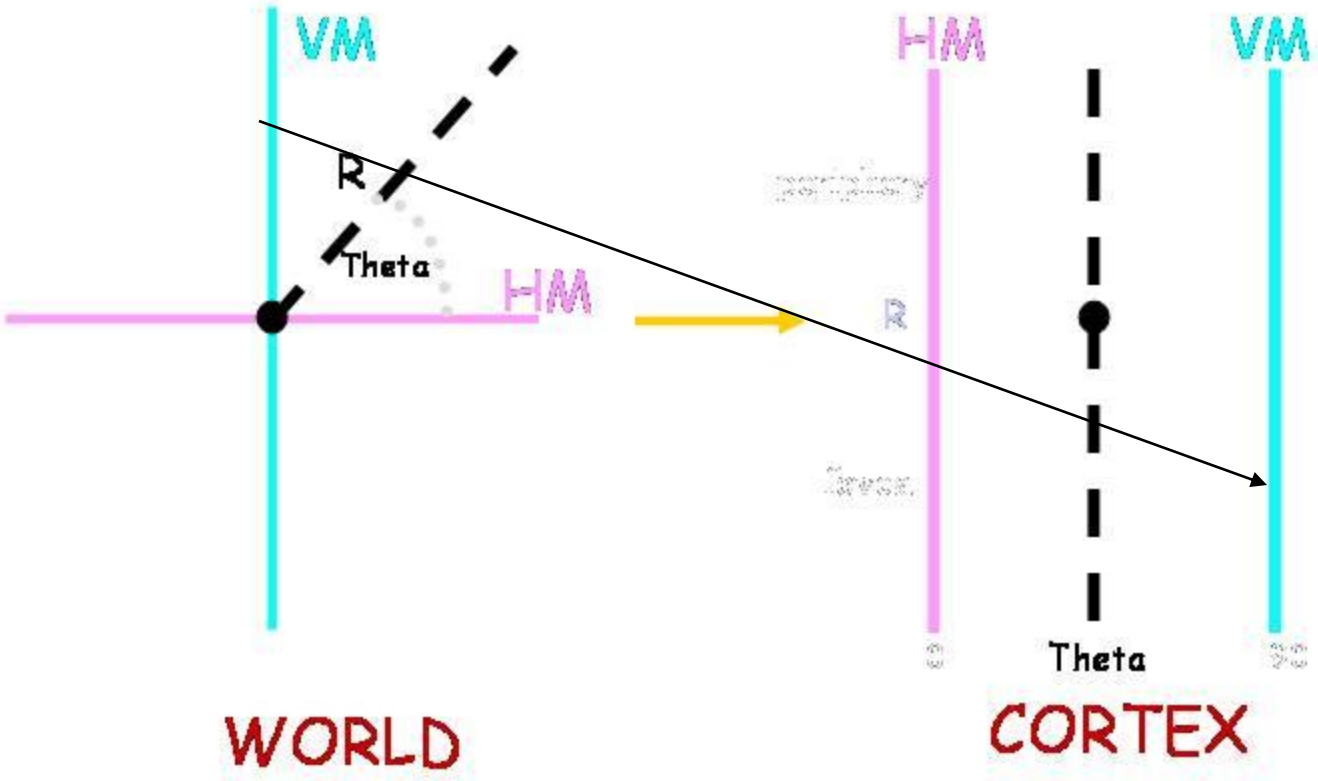


Euclidean

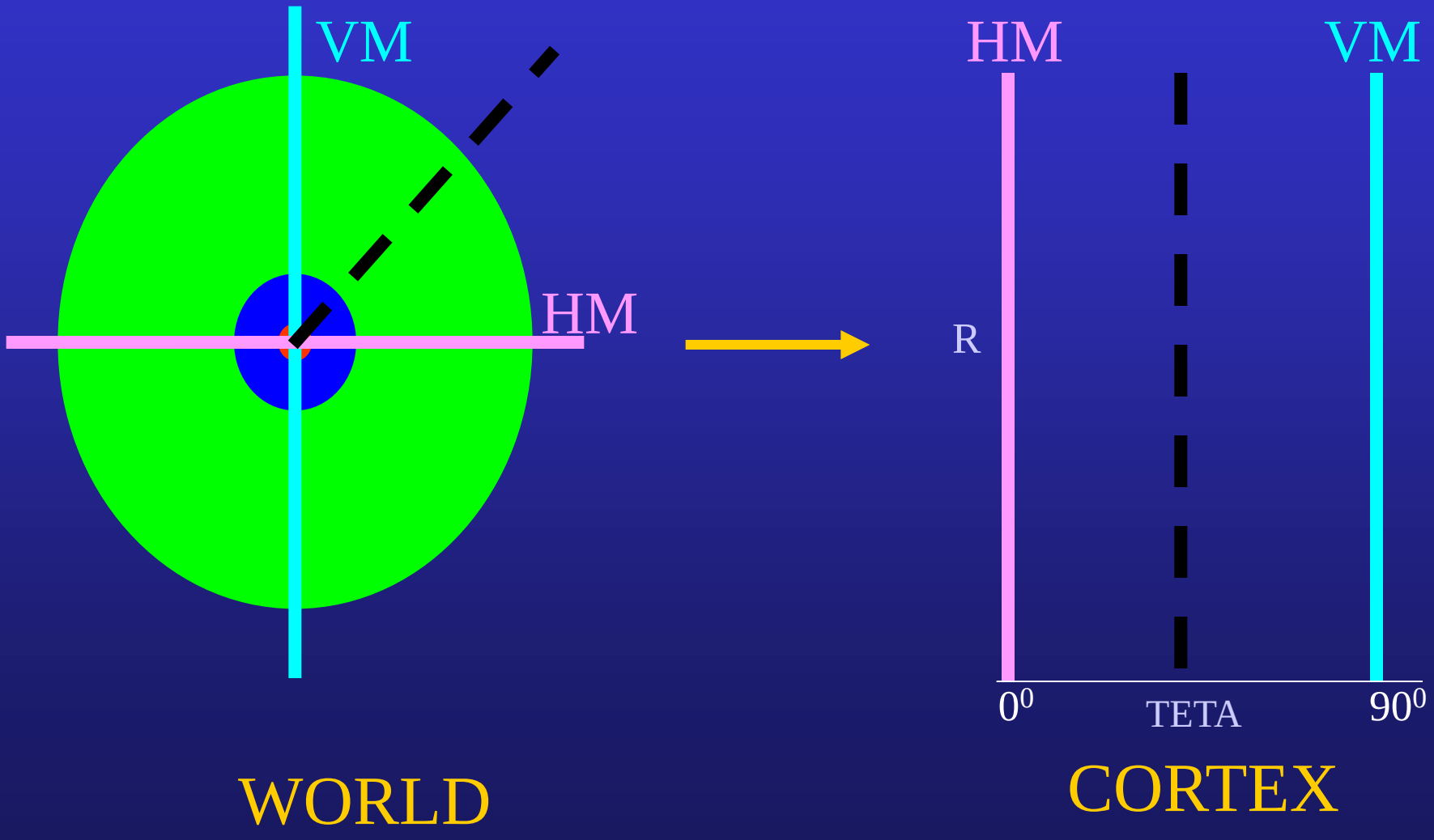


Polar

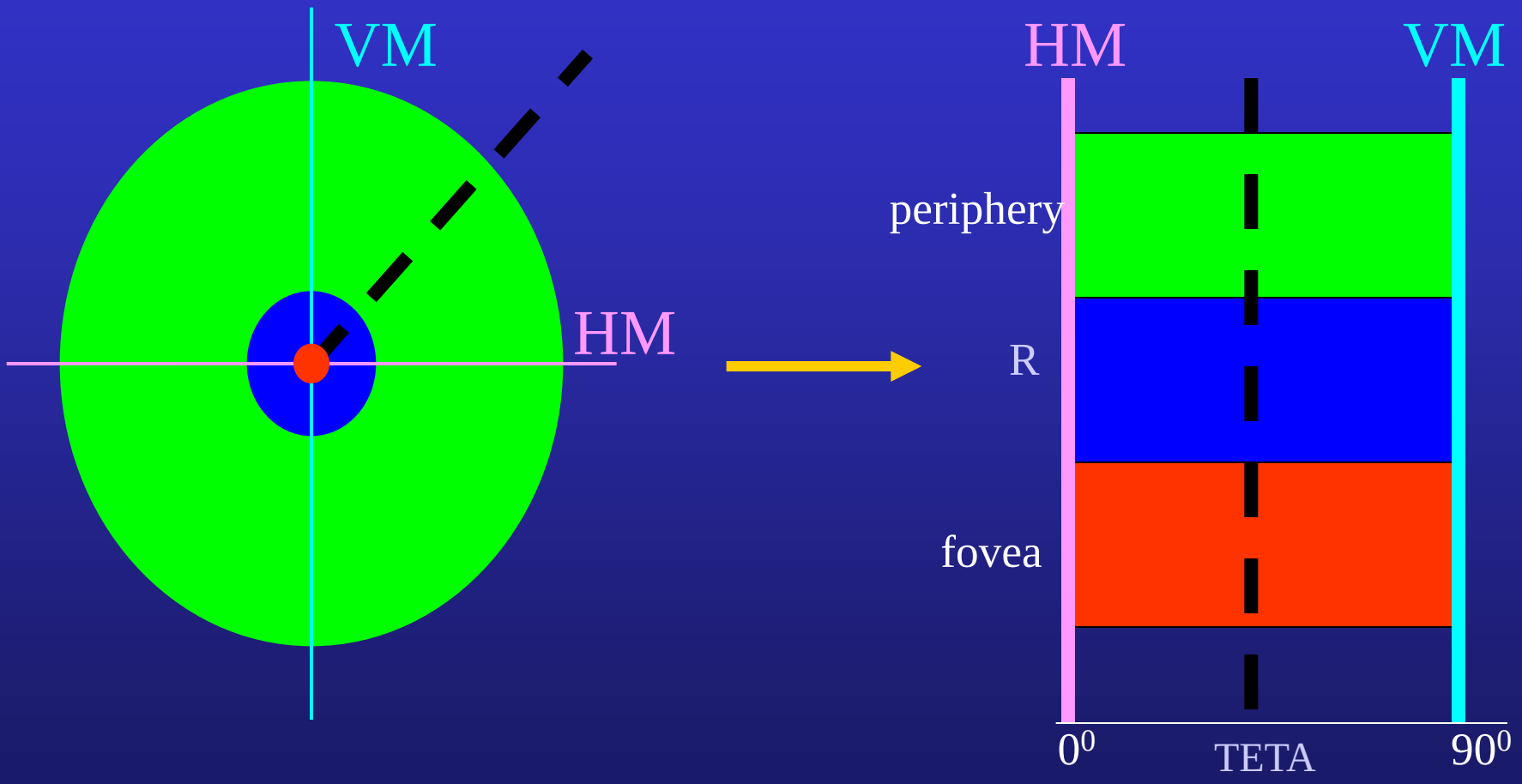
Angle Mapping - Theta



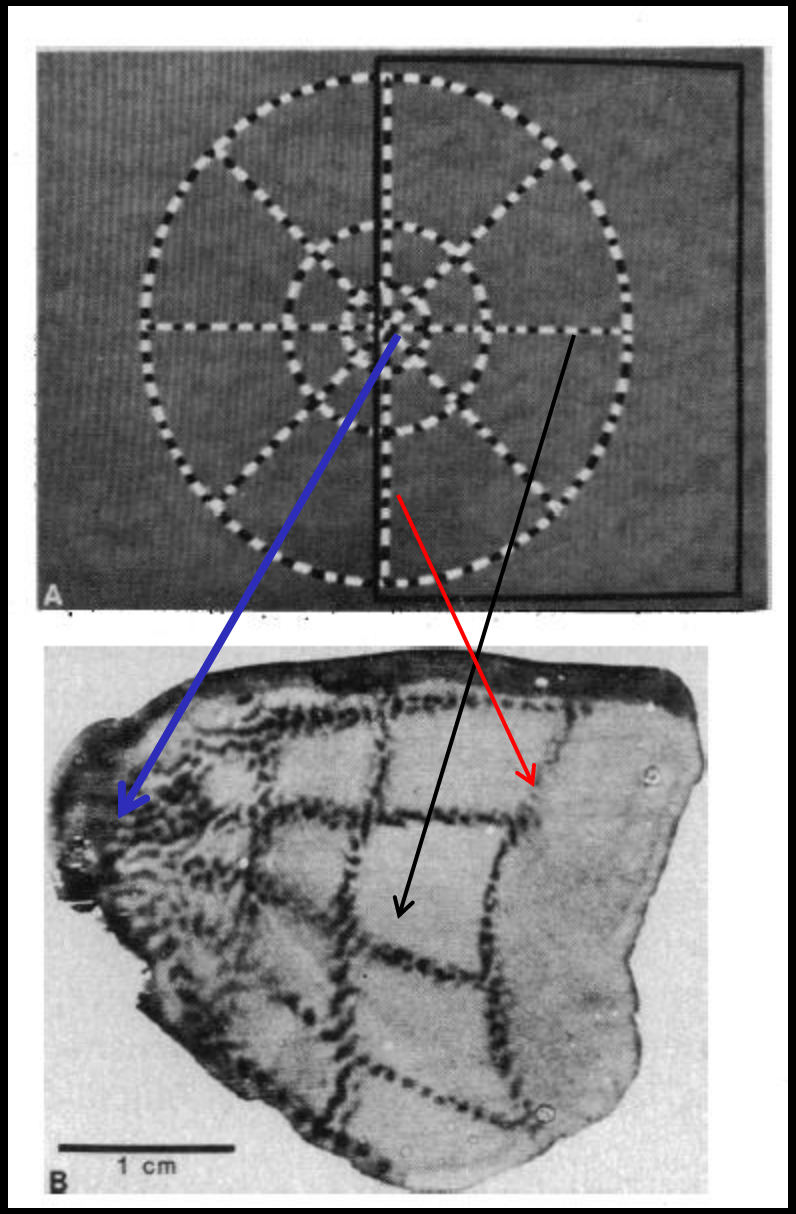
Log-Polar mapping: from world to cortex

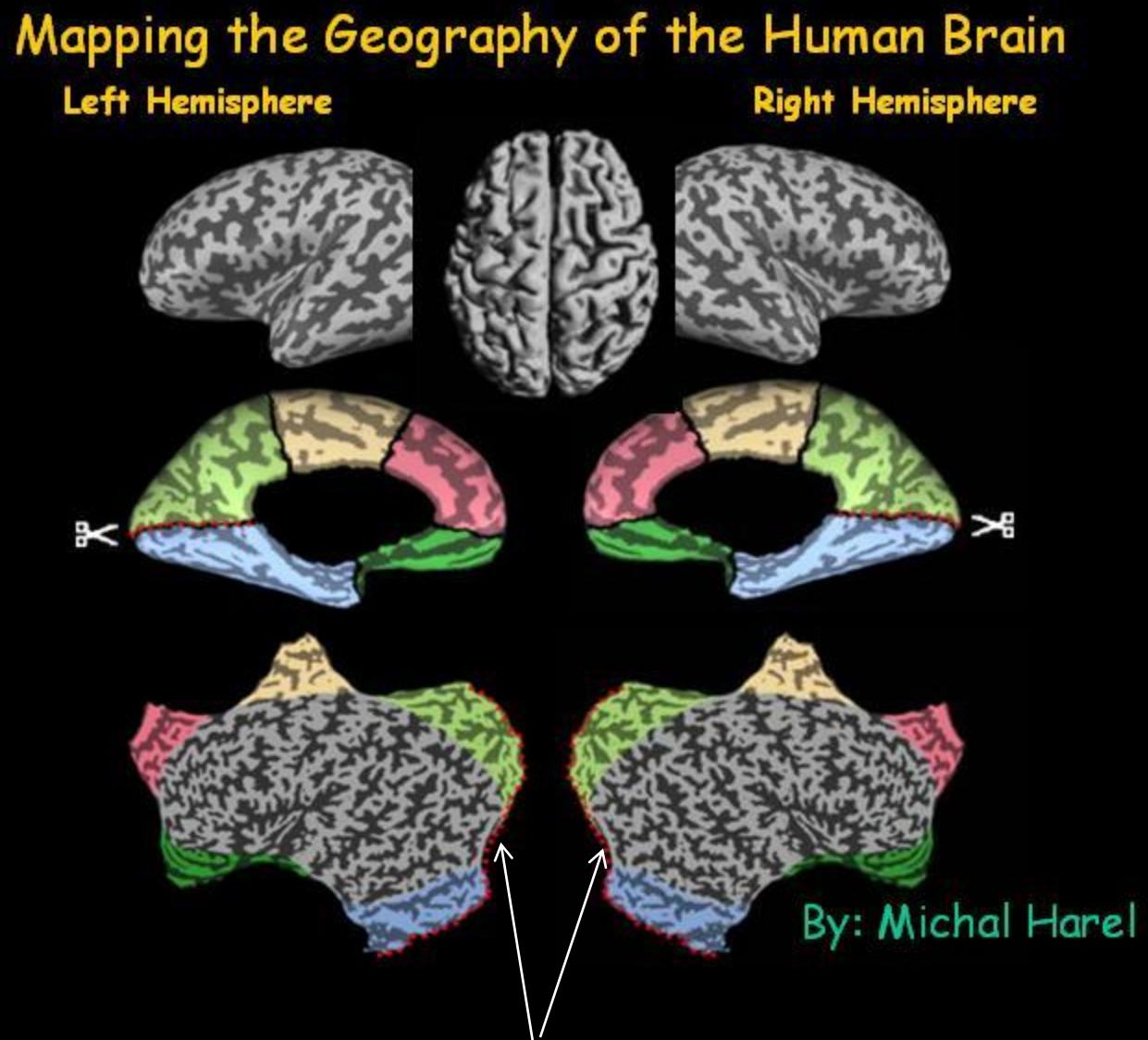


Log-Polar mapping: from world to cortex

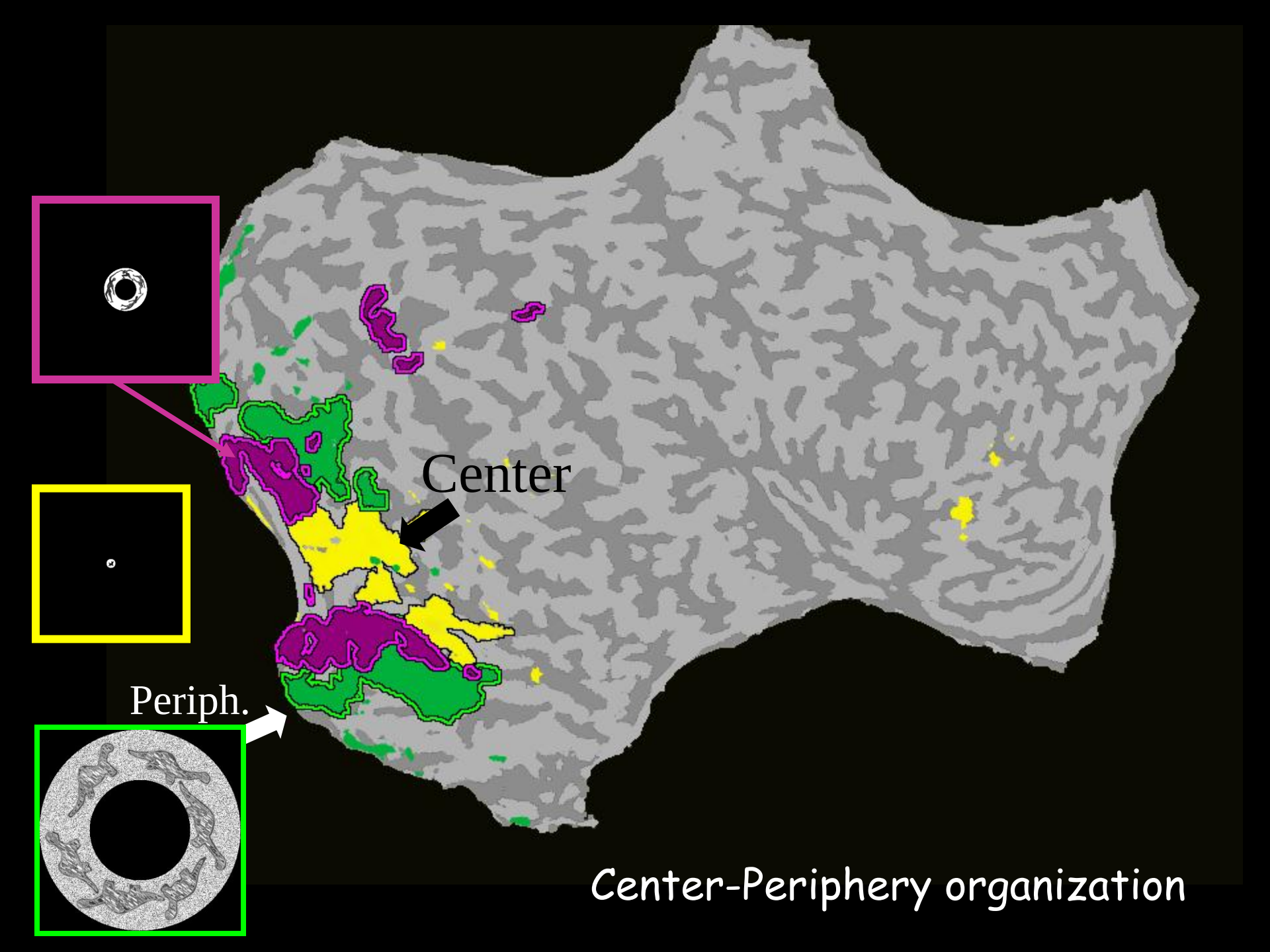


Metabolic mapping of retinotopy in V1





Cut V1 along the horizontal meridian

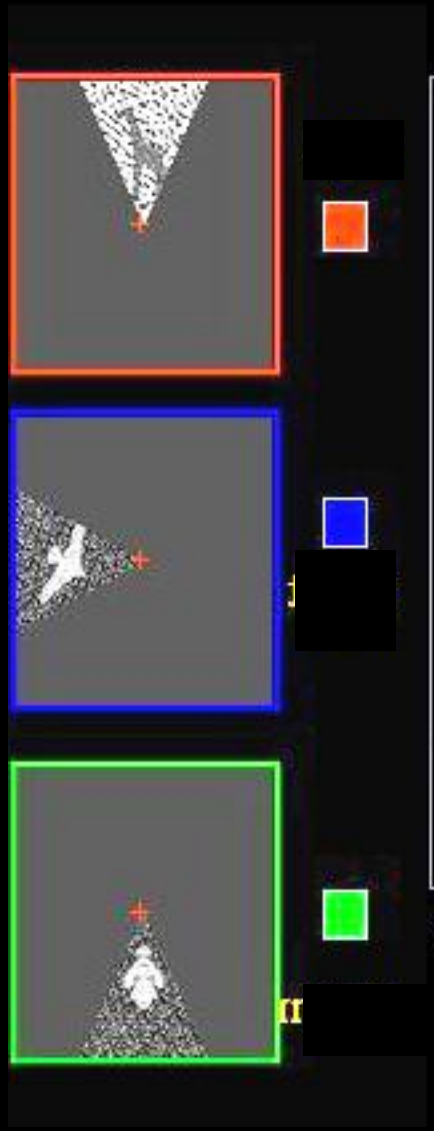

Center
Periph.
Center-Periphery organization

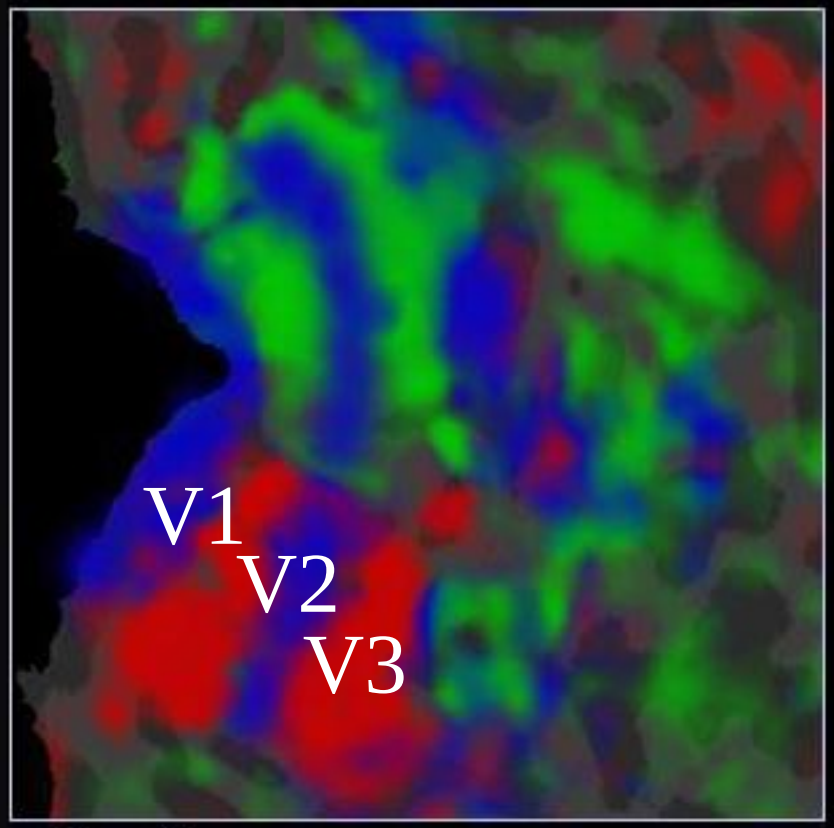
Meridians define borders of visual areas

Vertical Meridian Upper

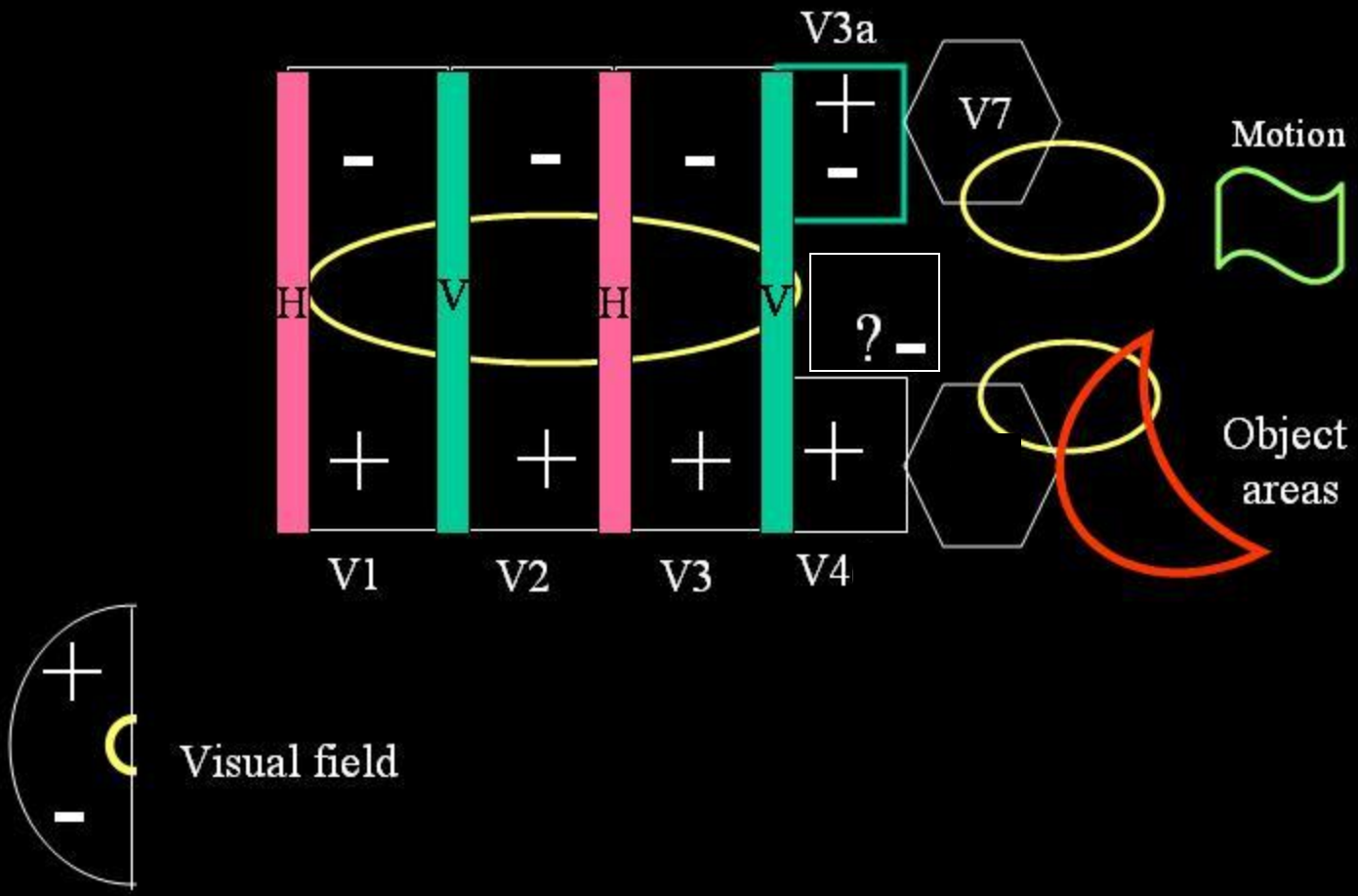
Horizontal Meridian

Vertical Meridian Lower

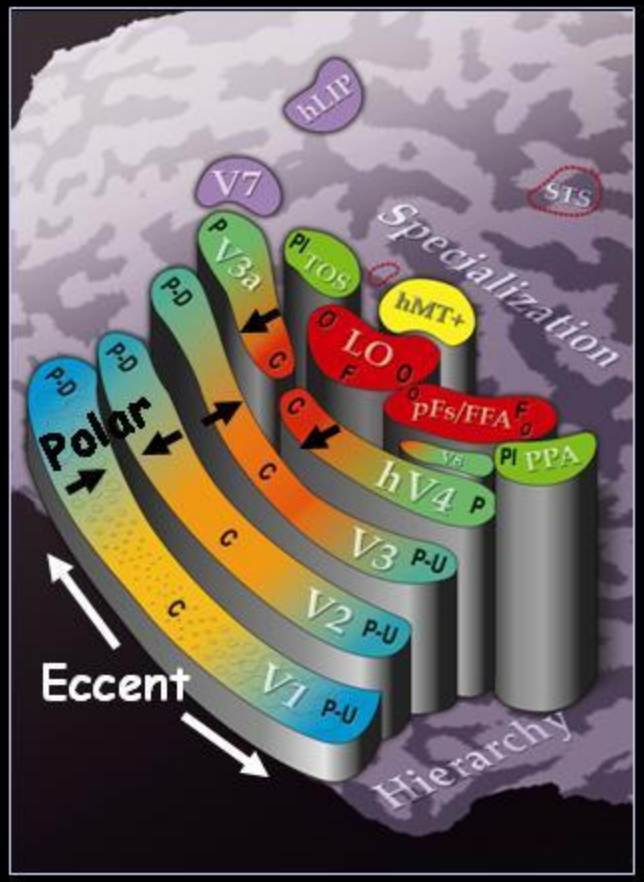


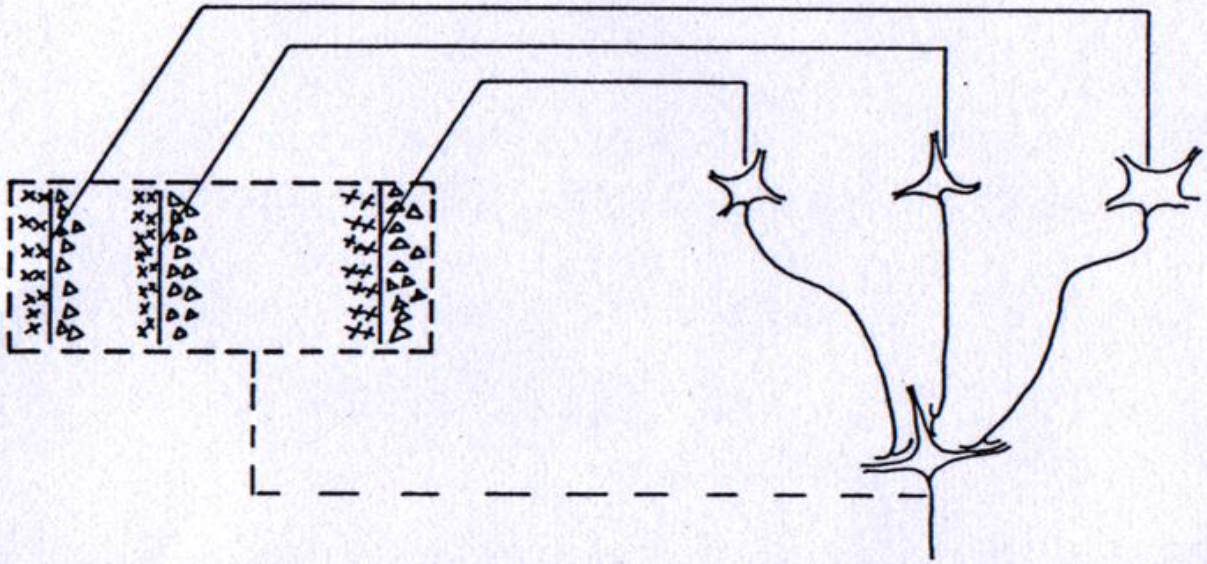


Schematic diagram of visual areas in the human right hemisphere



Multiple mirror symmetric topographic maps

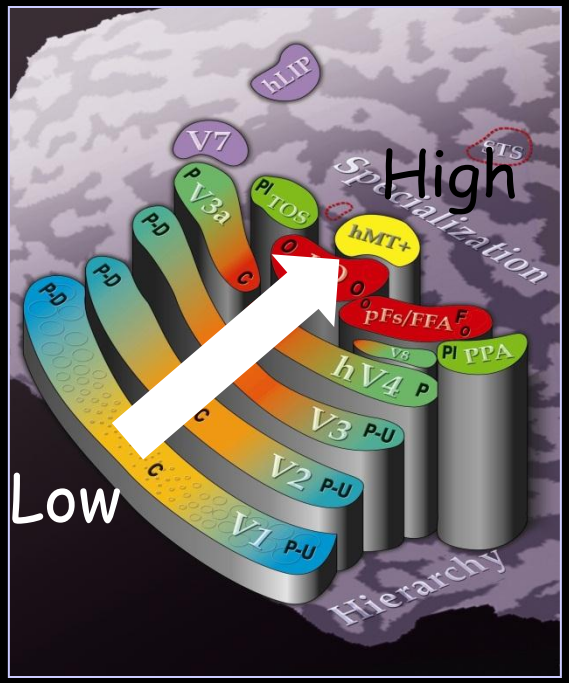


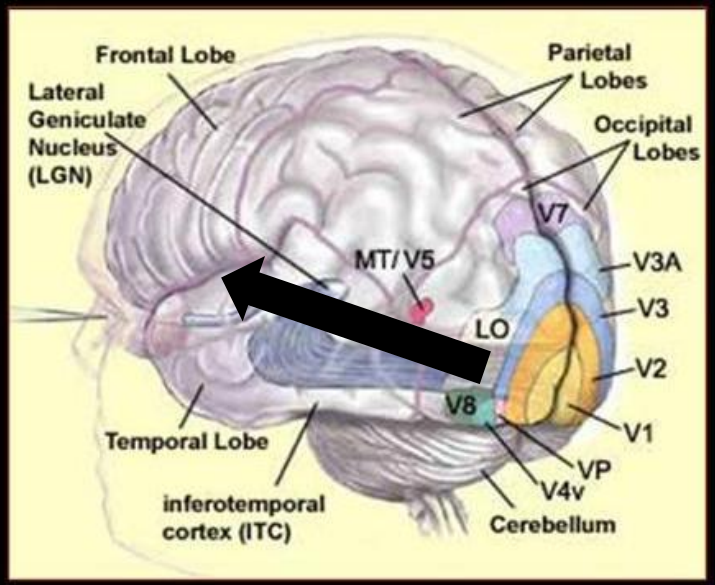


Text-fig. 20. Possible scheme for explaining the organization of complex receptive fields. A number of cells with simple fields, of which three are shown schematically, are imagined to project to a single cortical cell of higher order. Each projecting neurone has a receptive field arranged as shown to the left: an excitatory region to the left and an inhibitory region to the right of a vertical straight-line boundary. The boundaries of the fields are staggered within an area outlined by the interrupted lines. Any vertical-edge stimulus falling across this rectangle, regardless of its position, will excite some simple-field cells, leading to excitation of the higher-order cell.

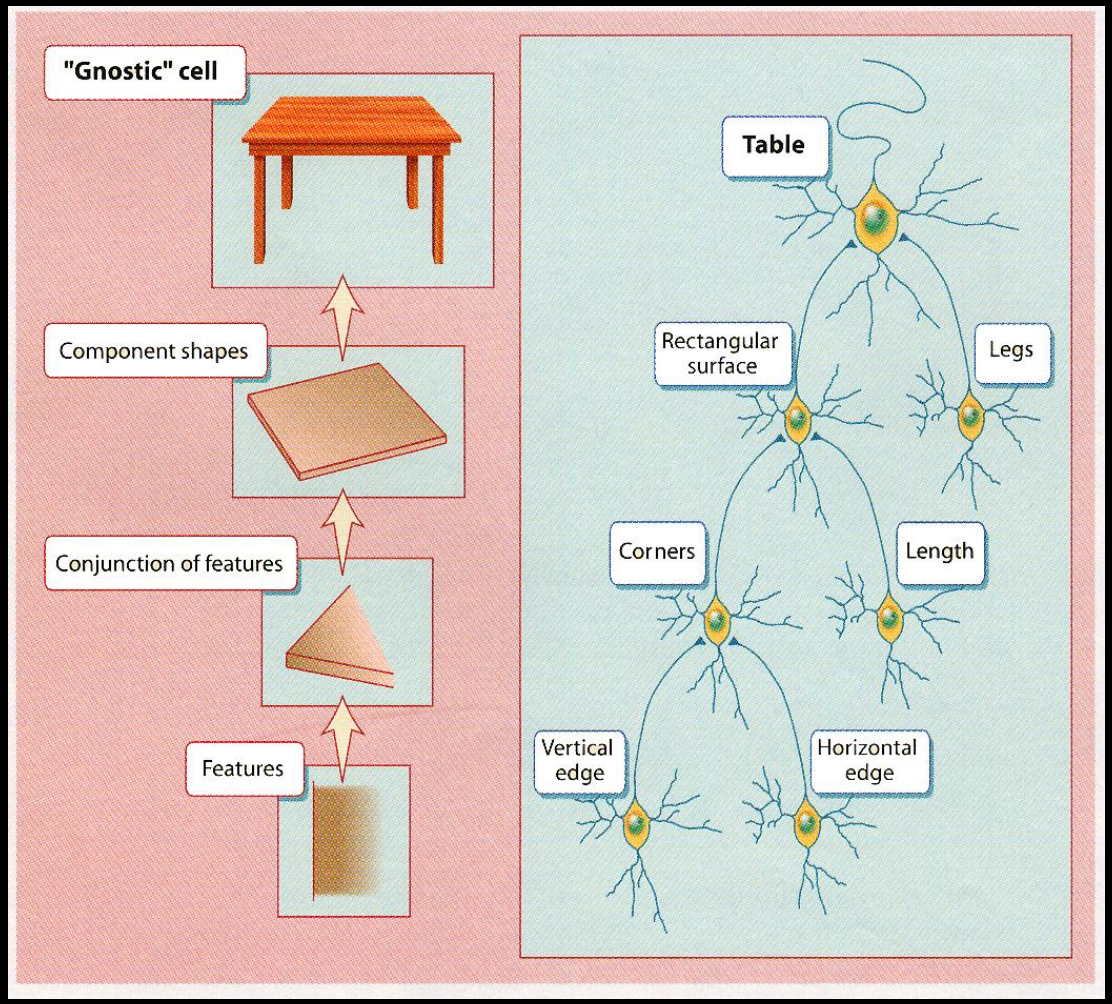
Complex cells: the first step towards position invariance
An "or" function

The Hierarchy principle



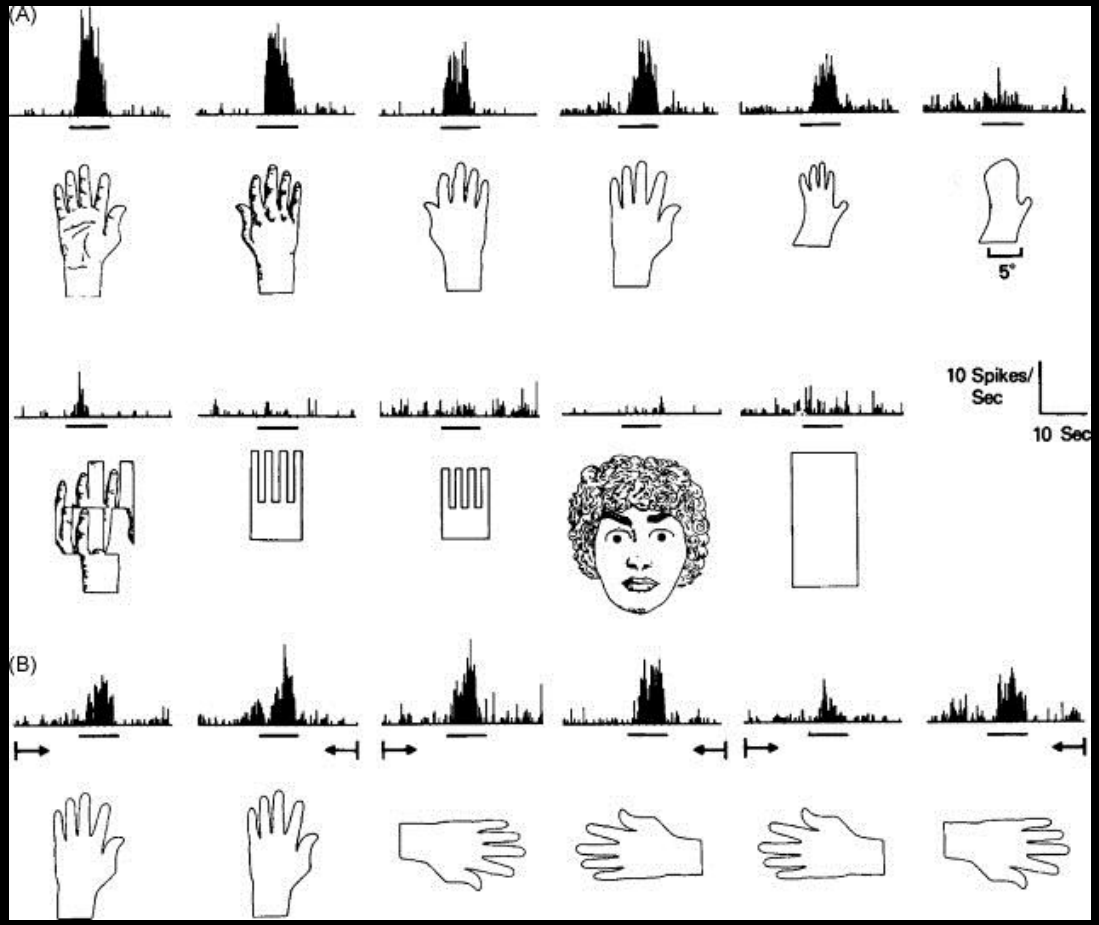


Hierarchical representation: illustration



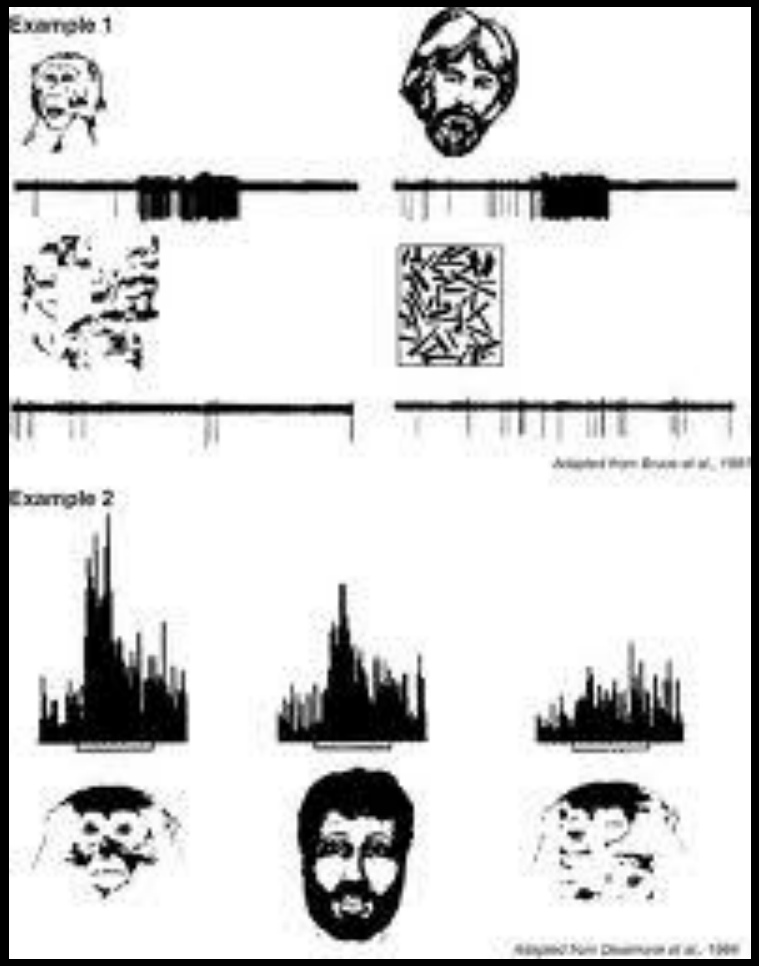
Simple, complex… “grand-mother” cells

Complex properties of neurons at the top of the hierarchy



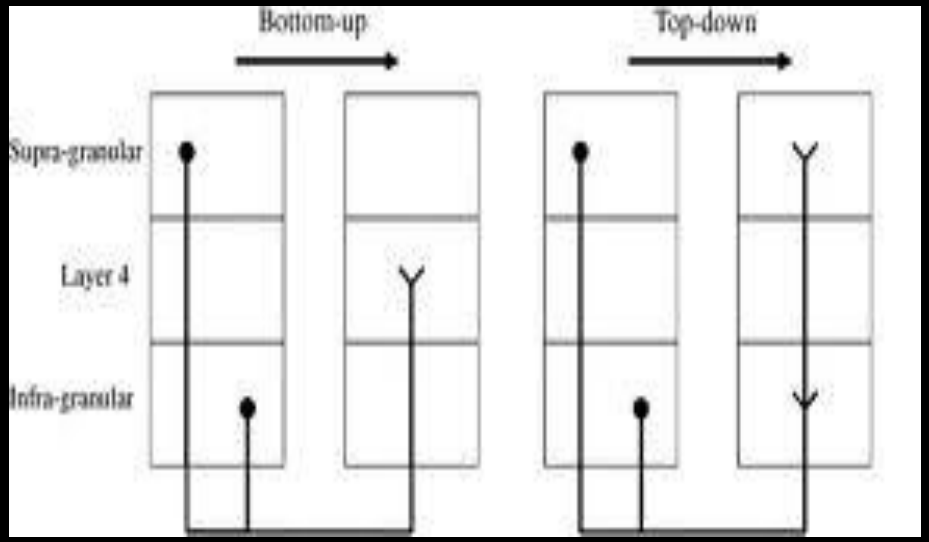
"Hand" neurons

Complex properties of neurons at the top of the hierarchy

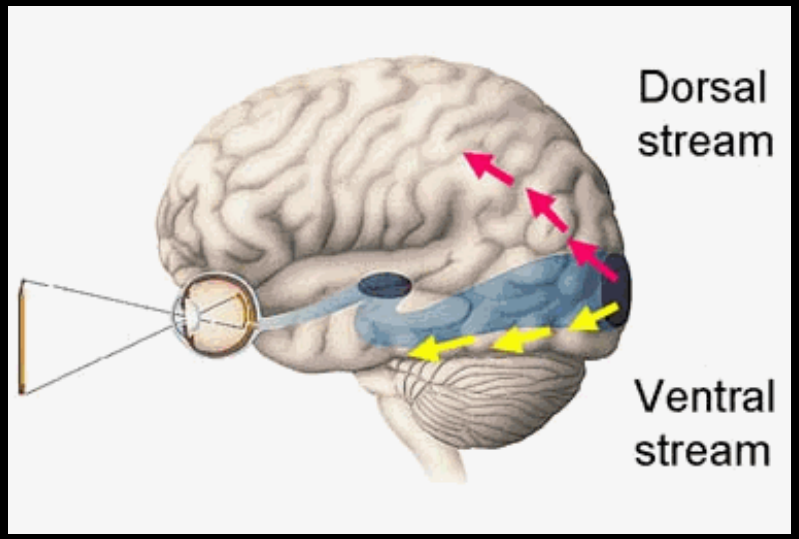


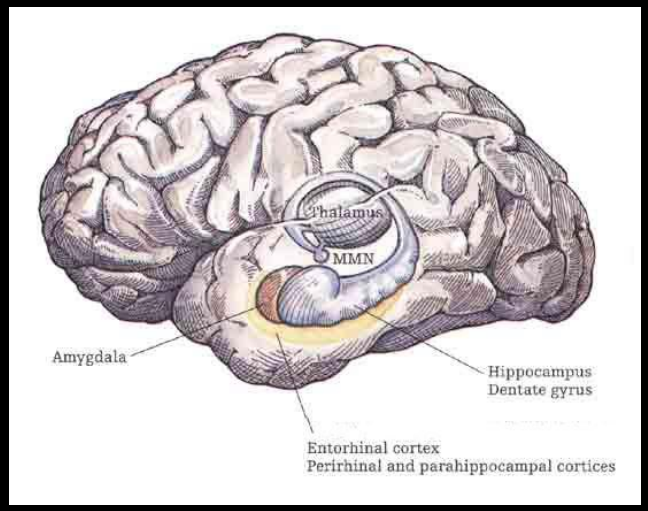
"Face" neurons

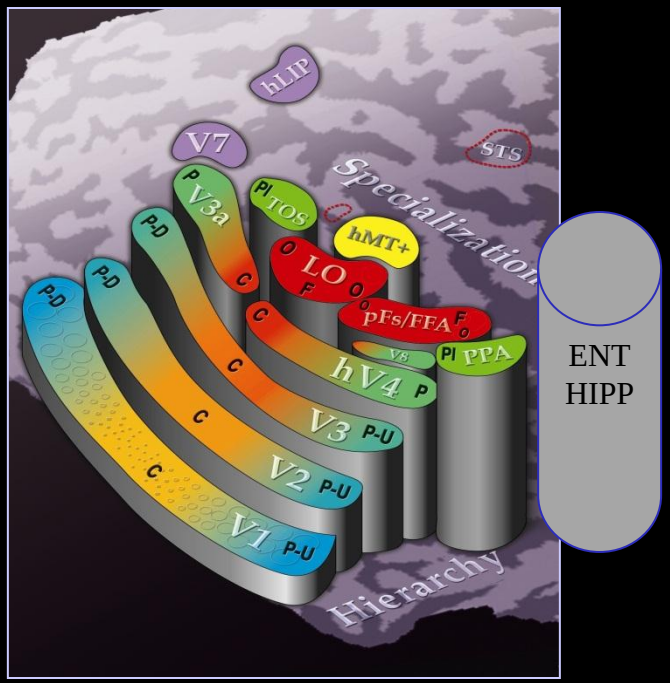
The flow of hierarchical information is directed to specific layers



Medial Temporal Lobe as the highest stage in the recognition hierarchy







Complex properties of neurons at the top of the hierarchy

Viewing Session
- 5-10 sec clips
- each clip = an episode
- famous people / landmarks
- 6-10 repeats for each clip
- interleaving blanks
- pseudo-random order
- 10-16 different clips

Intervening Task
- digit task
- short conversation

***Free* Recall Session**
- “what do you remember seeing?”
- No cue!
- 91.1% recalled

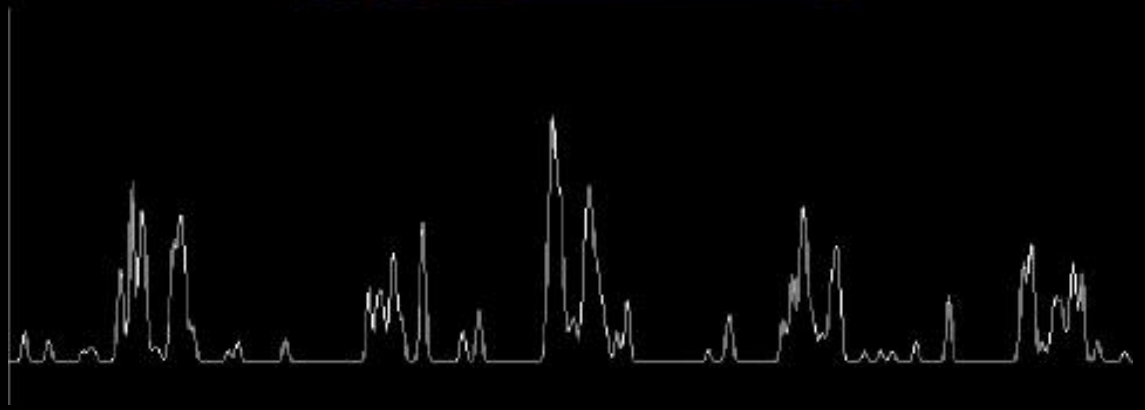
Time

10 min | **1-5 min** | **3-8 min**

הגר גלברד-שגיב, יצחק פריד

Visual responses

What the patient saw



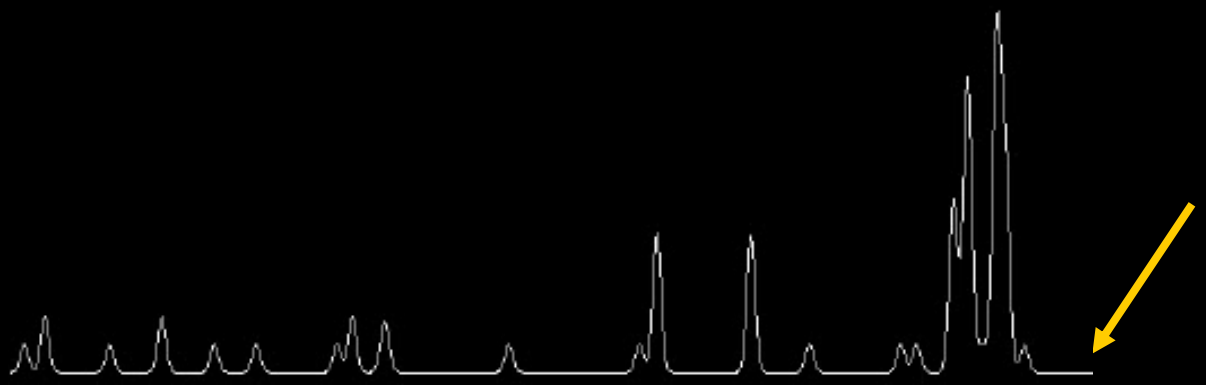
Neuronal activity

entorhinal cortex

beeps are spikes of a single human neuron

Recollection in the absence of visual stimulation

What the patient said

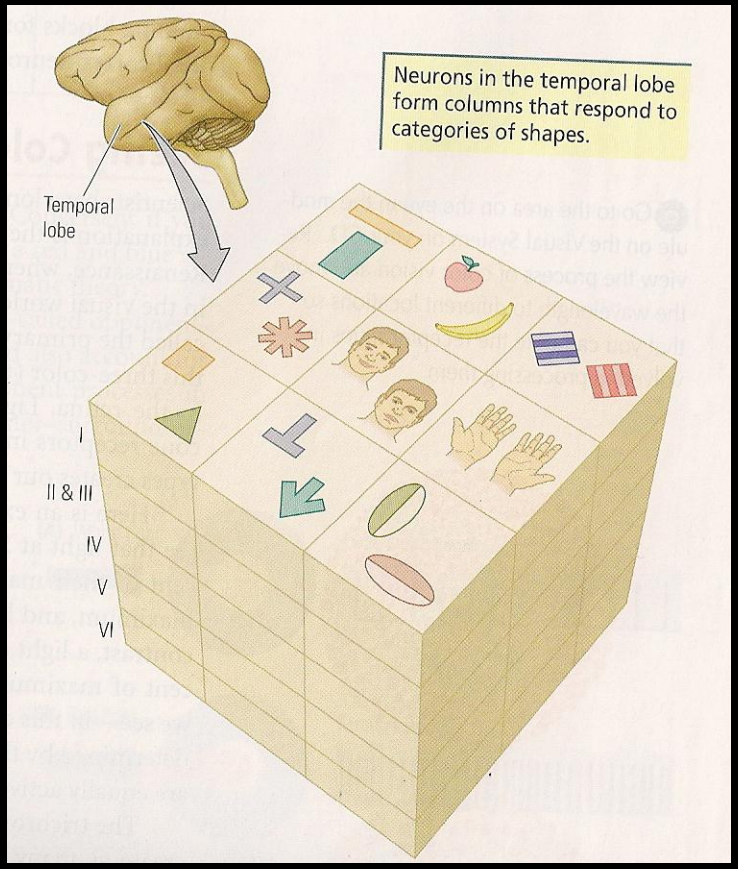


Neuronal activity

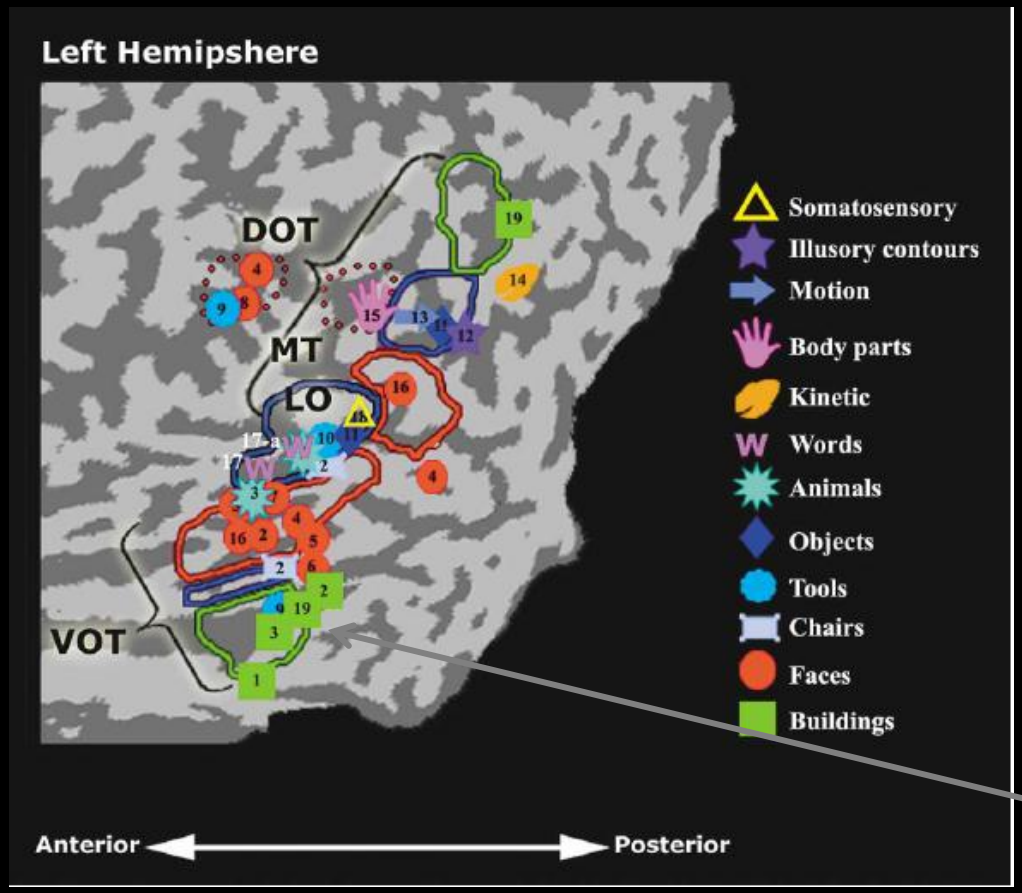
entorhinal cortex

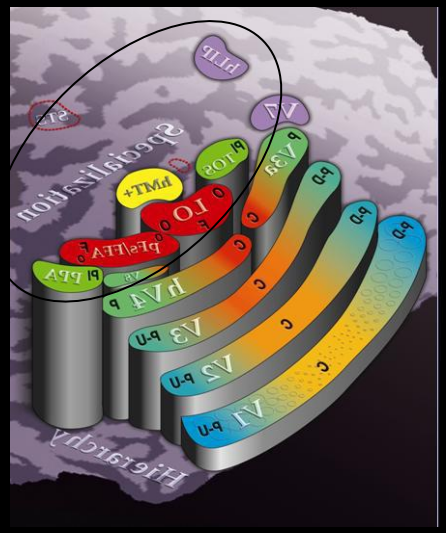
beeps are spikes of a single human neuron

Complex element representation at the top of the hierarchy



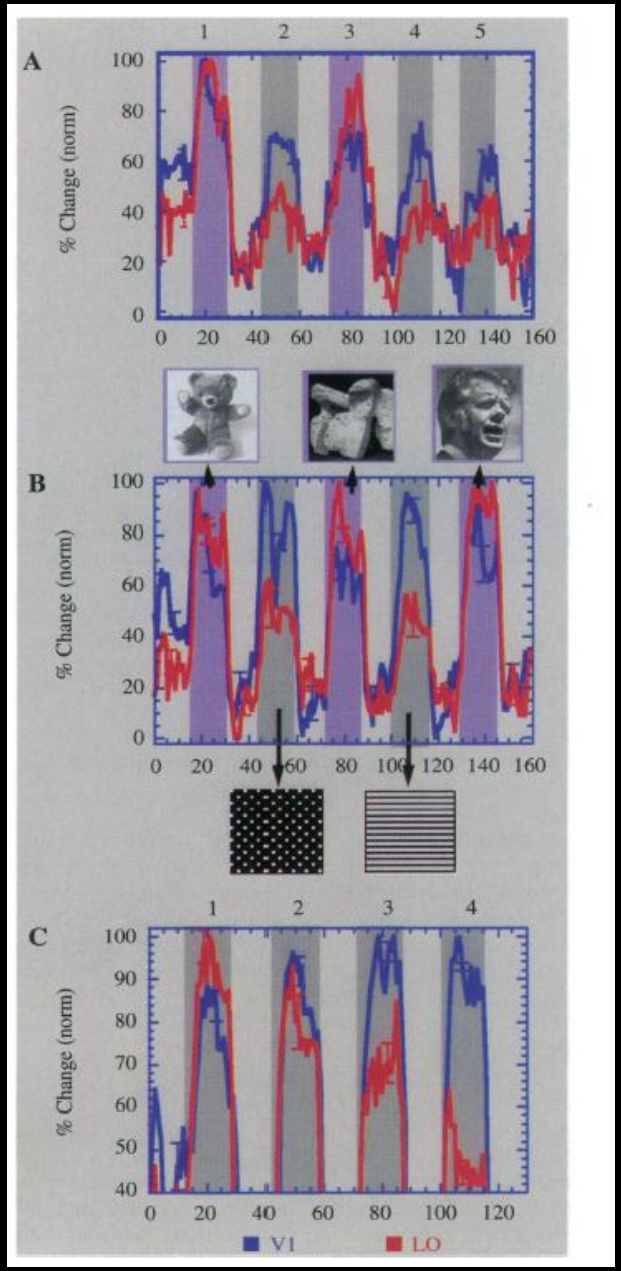
Large scale principles: Category organization





LOC

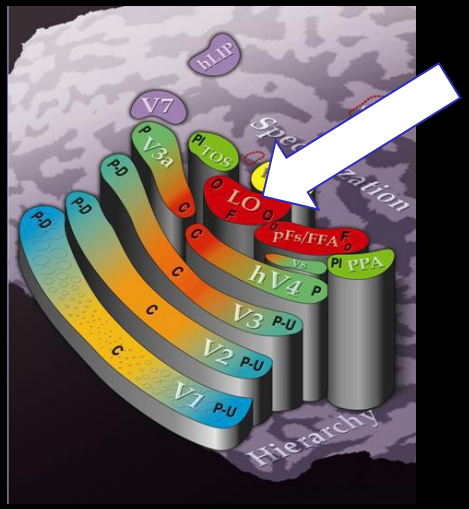
V1



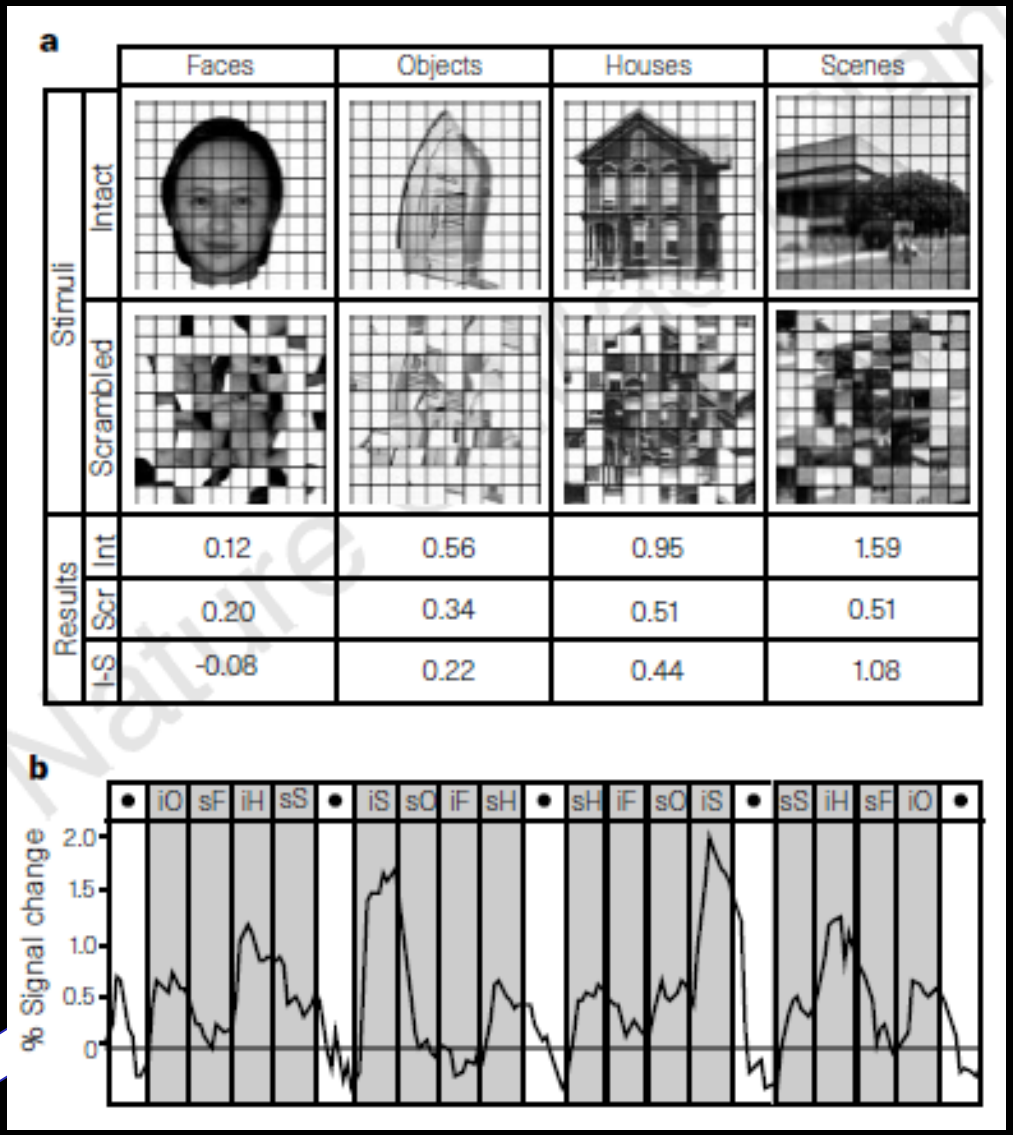
3D Obj vs. Textures

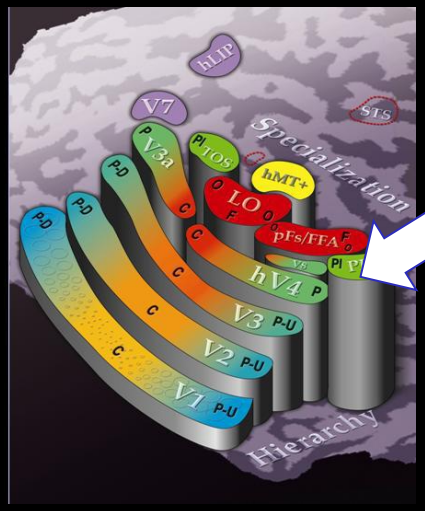
Unrelated to familiarity

Noise degradation



LOC "object" Area





Parahippocampal "Place" Area

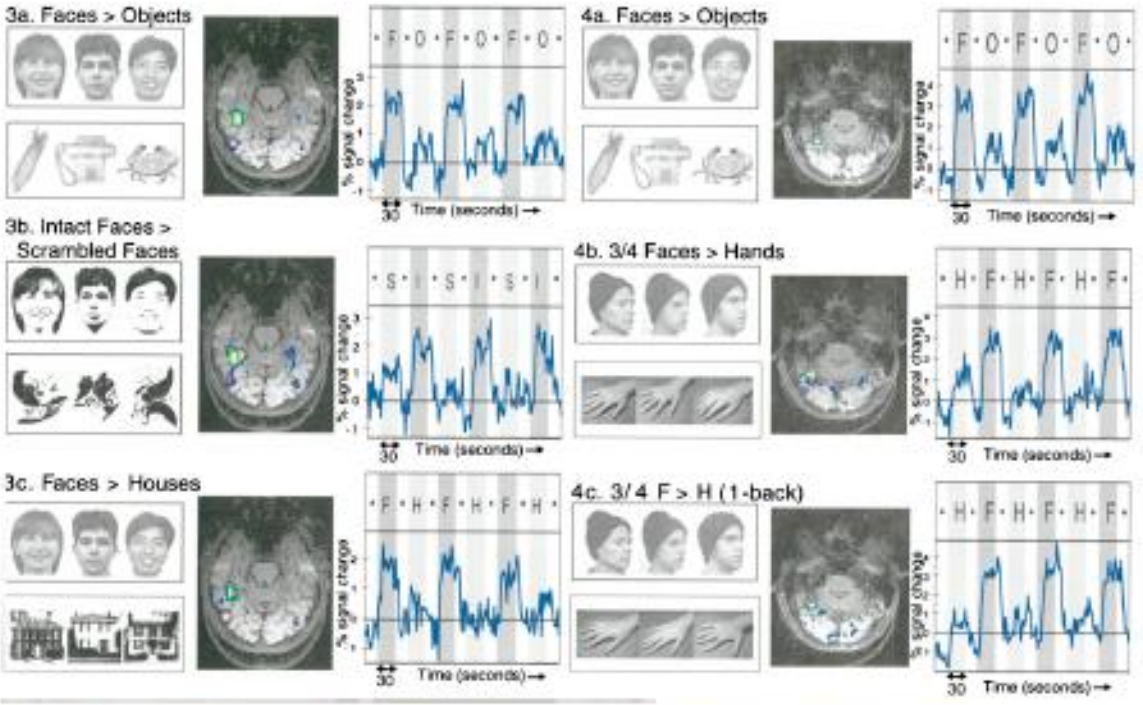
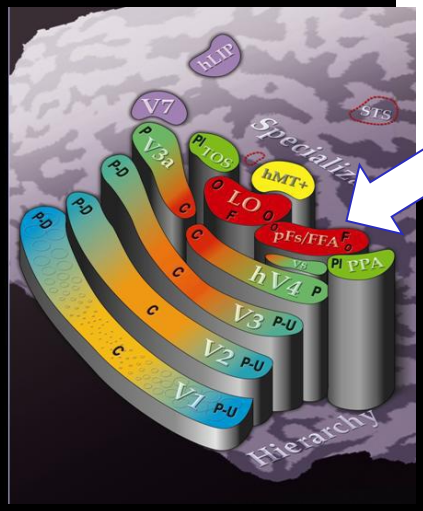
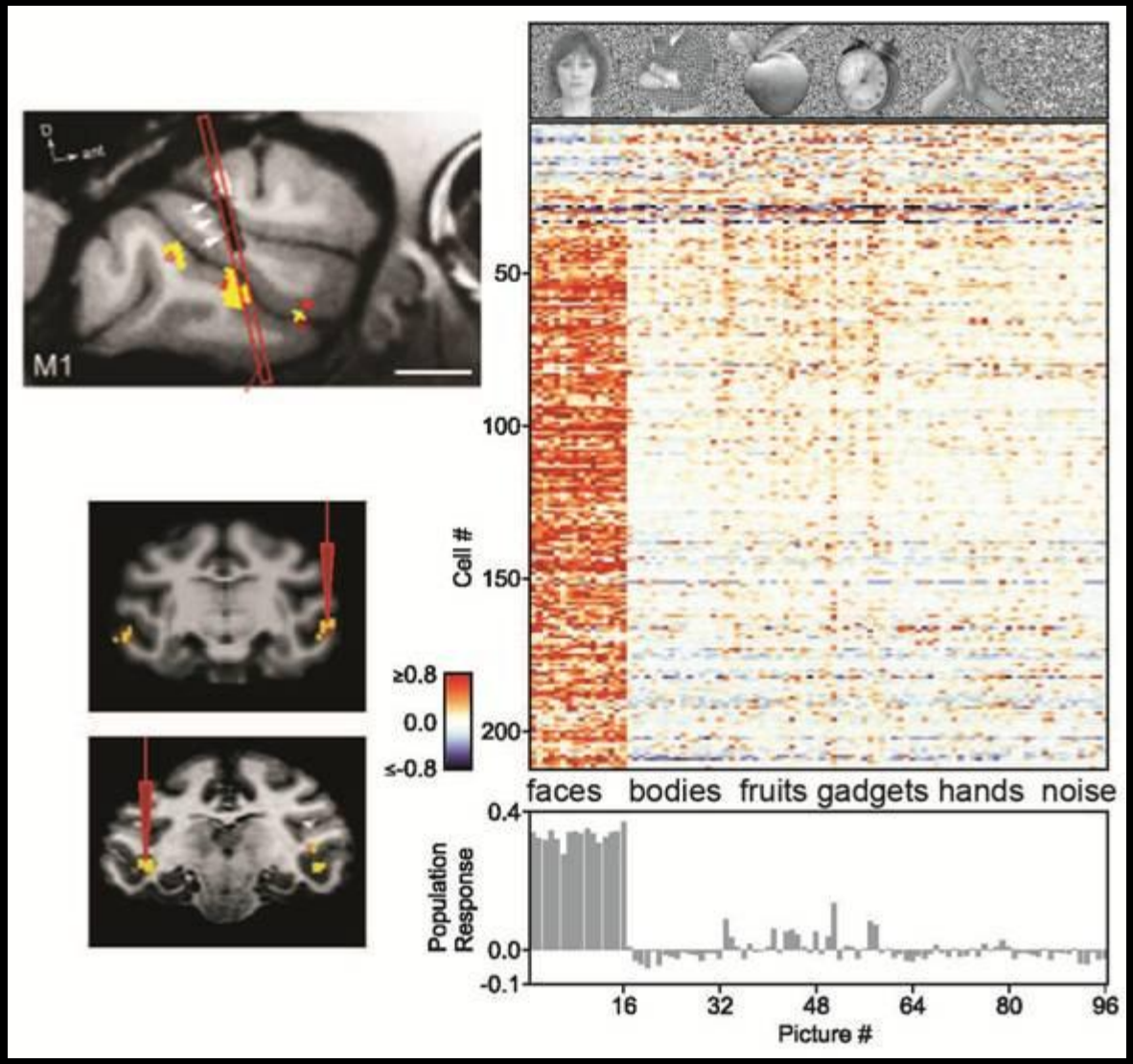


Figure 3 Results of Part II. *Left columns*, Sample stimuli used for the faces versus objects comparison as well as the two subsequent tests. *Center columns*, Areas that produced significantly greater activation for faces than control stimuli for subject S1. *a*, The faces versus objects comparison was used to define a single ROI (shown in green outline for S1), separately for each subject. The time courses in the *right columns* were produced by (1) averaging the percentage signal change across all voxels in a given subject's ROI (using the original unsmoothed data), and then (2) averaging these ROI-averages across the five subjects. *F* and *O* in *a* indicate face and object epochs; *I* and *S* in *b* indicate intact and scrambled face epochs; and *F* and *H* in *c* indicate face and hand epochs.

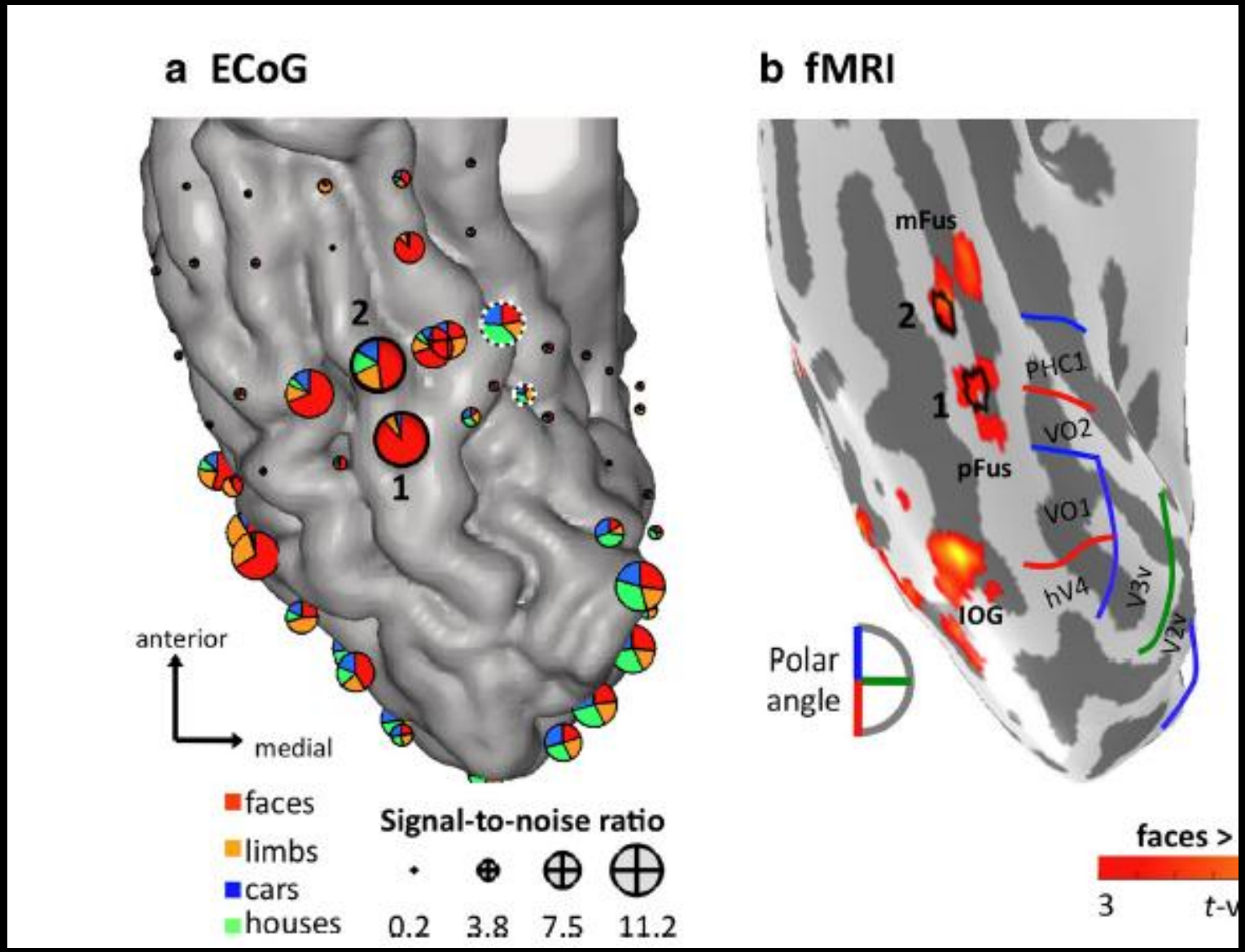
Figure 4 Results of Part III. Stimulus contrasts for each test are shown in the *left column*. *a*, Face ROIs were defined separately for each subject using the average of two face versus object scanning described for Figure 3a. The resulting brain slice with statistical overlay for one subject (S10) is shown in the *center column*, and the time course of signal intensity averaged over the five subjects' ROIs is shown at the *right*. As described for Figure 3a (Part II), the ROI specified on the basis of the faces versus objects comparison was used for the two subsequent comparisons of passive viewing of three-quarter faces versus hands (*b*), and the consecutive matching task on three-quarter faces versus hands (*c*).



Fusiform "Face" Area



Face "Patches" are built of "face-neurons"


a ECoG
b fMRI
2
1
anterior
medial
faces
limbs
cars
houses
Signal-to-noise ratio
0.2
3.8
7.5
11.2
mFus
2
1
pFus
PHC1
VO2
VO1
hV4
V3v
V2v
IOG
Polar angle
faces >
3
t-v

Electrical stimulation of the fusiform face area