Introduction to Neuroscience:
Systems Neuroscience - Concepts and Methods

Seeing: Central visual processes

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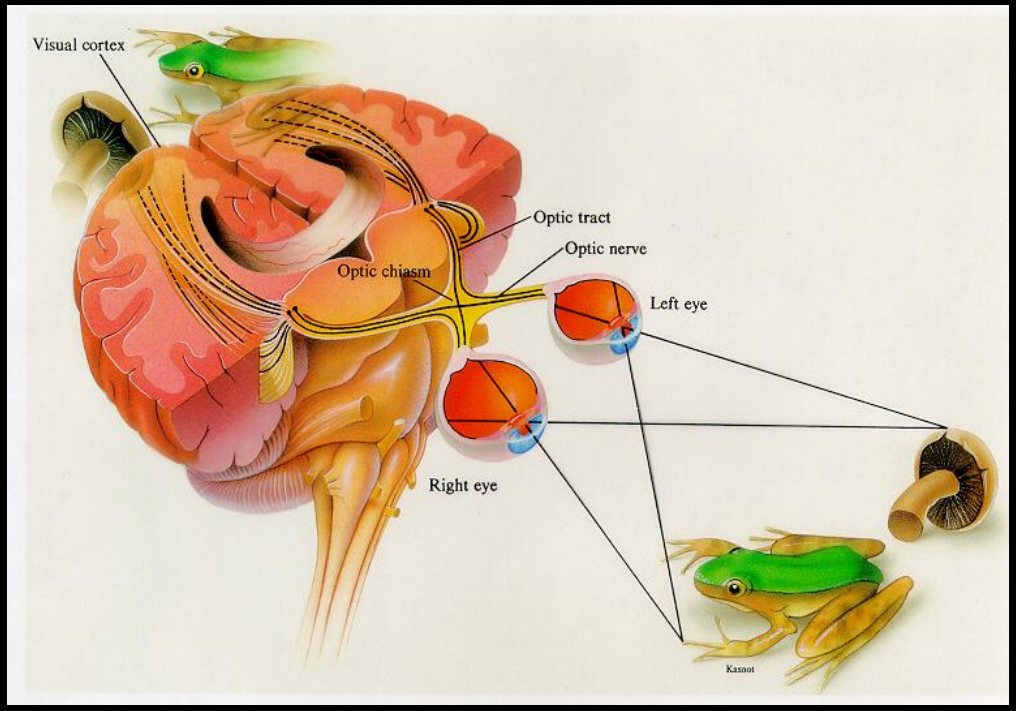
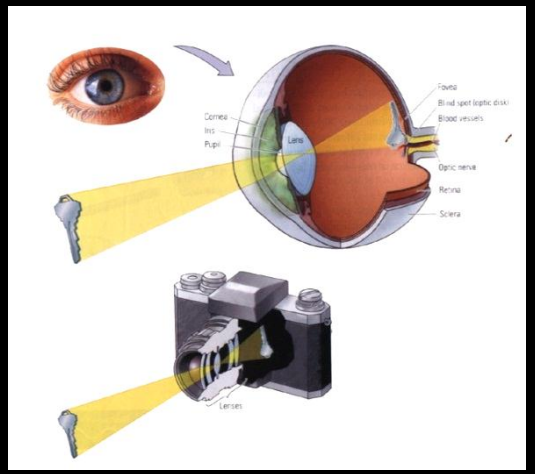
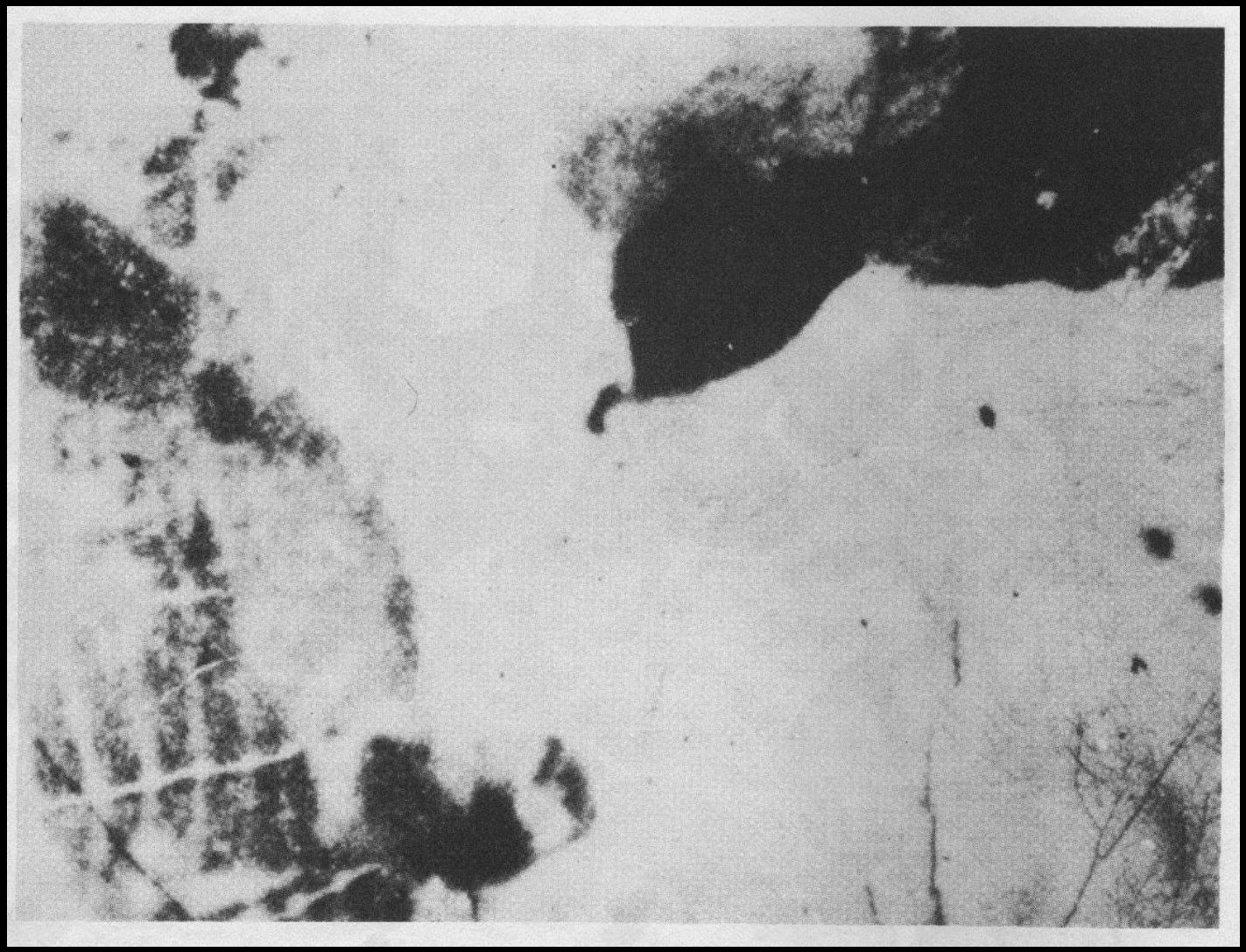
Is Vision a result of information processing of the incoming optical signals?





Our visual images combine incoming information with prior knowledge



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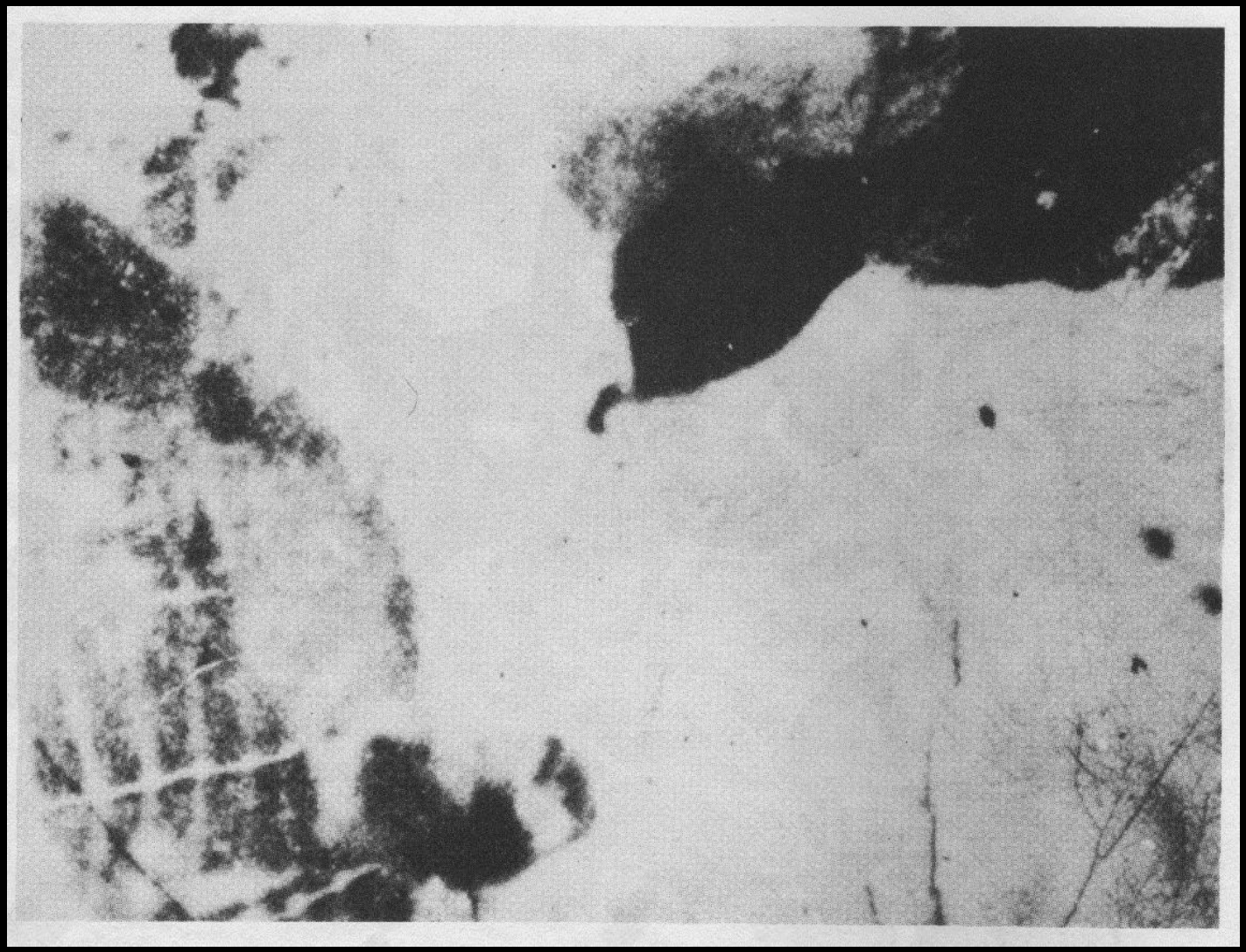
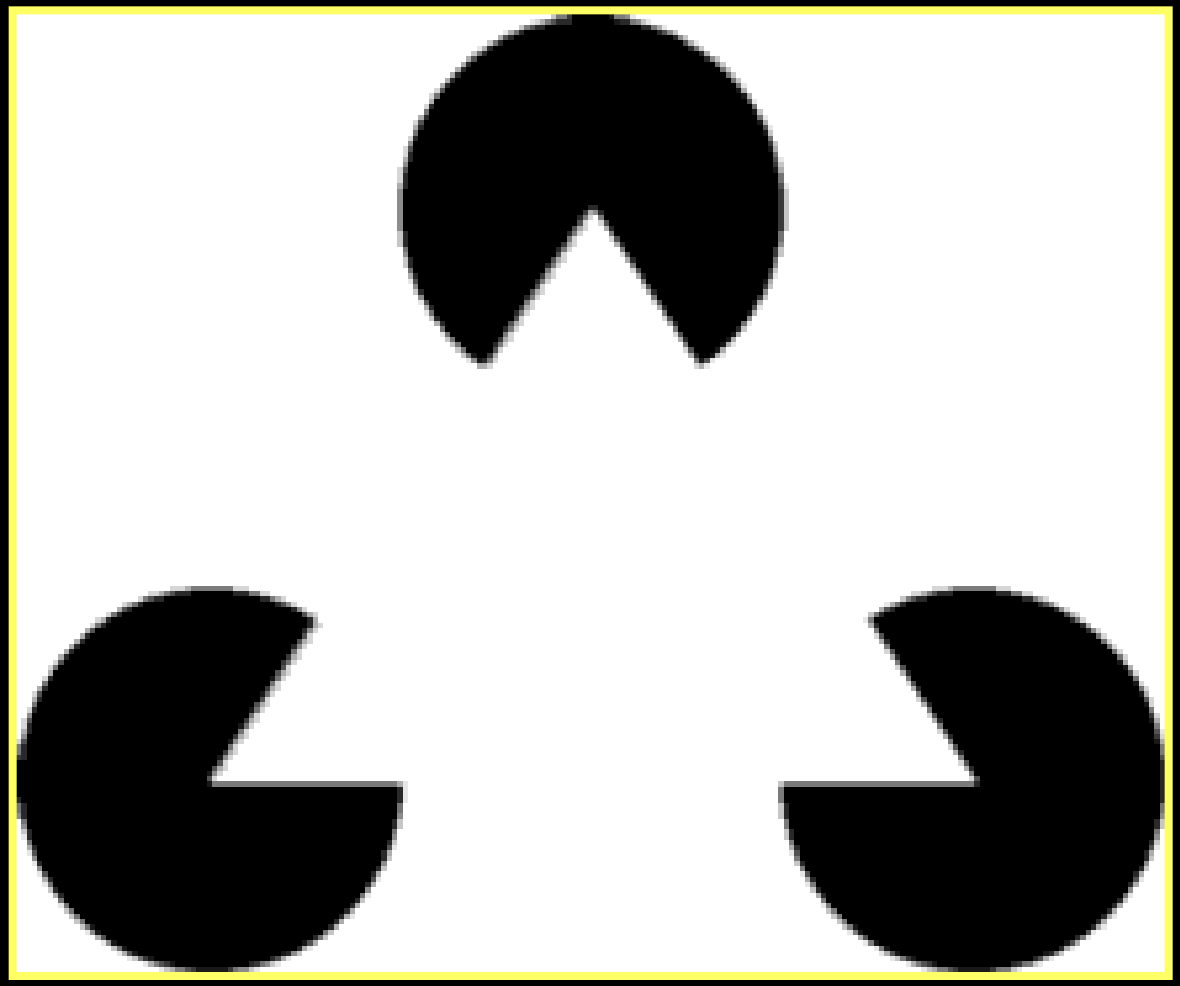
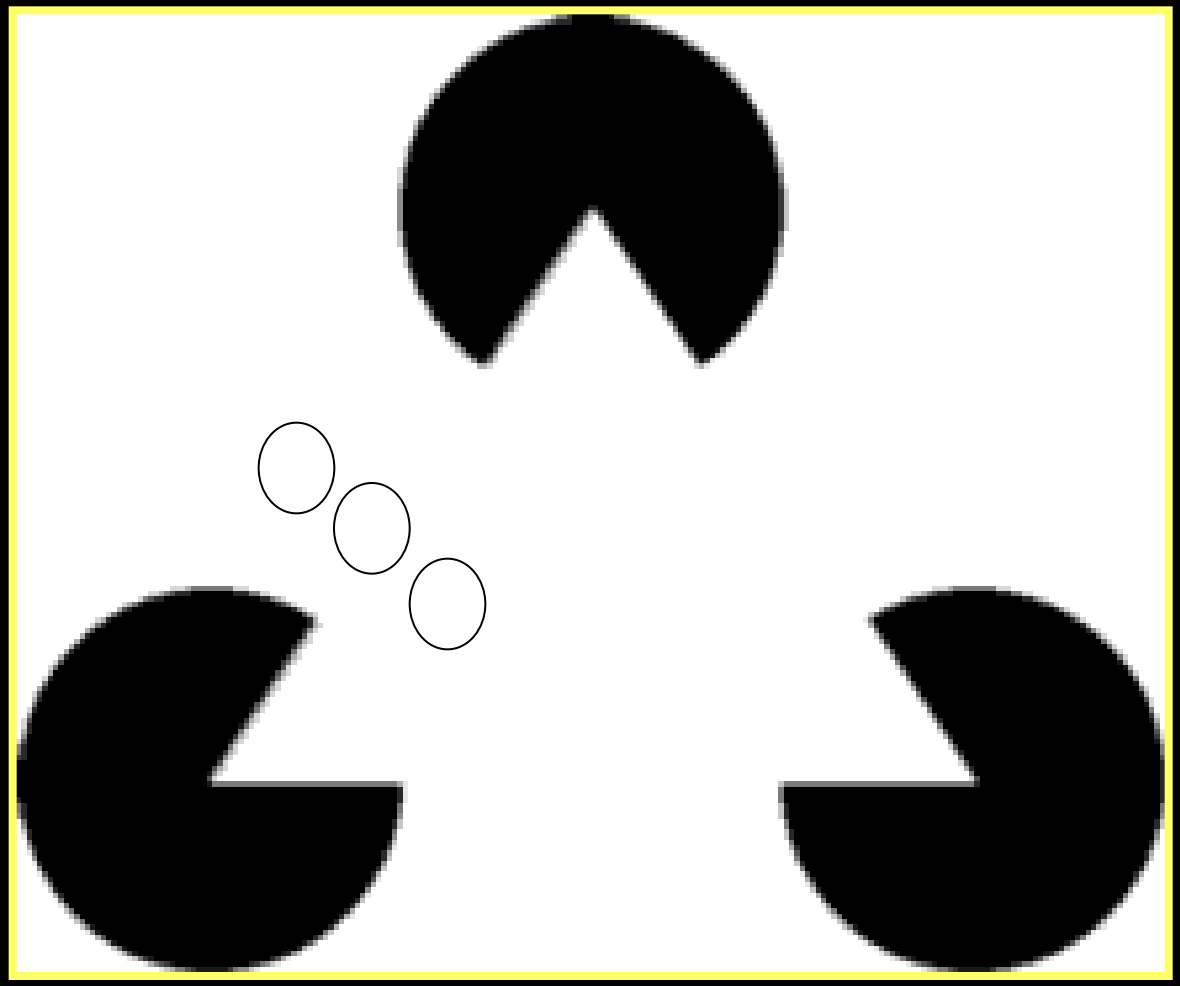


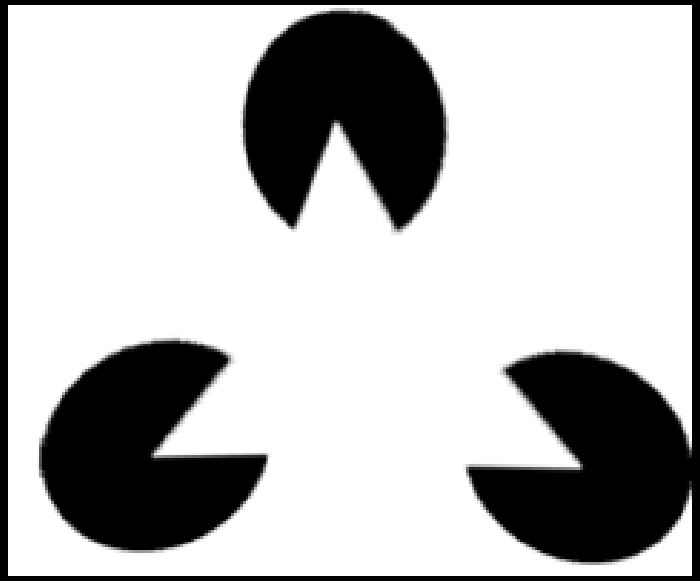
Prior knowledge often dominates over incoming optical signals



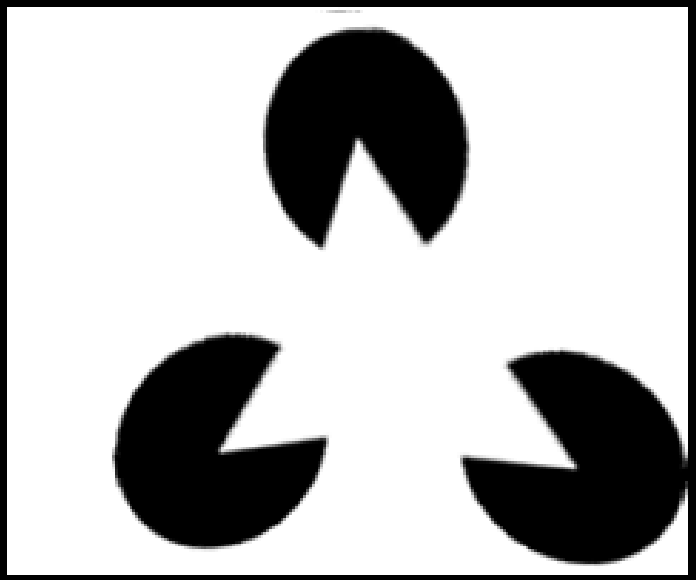
The triangle we see is a result of an internal reconstructive process



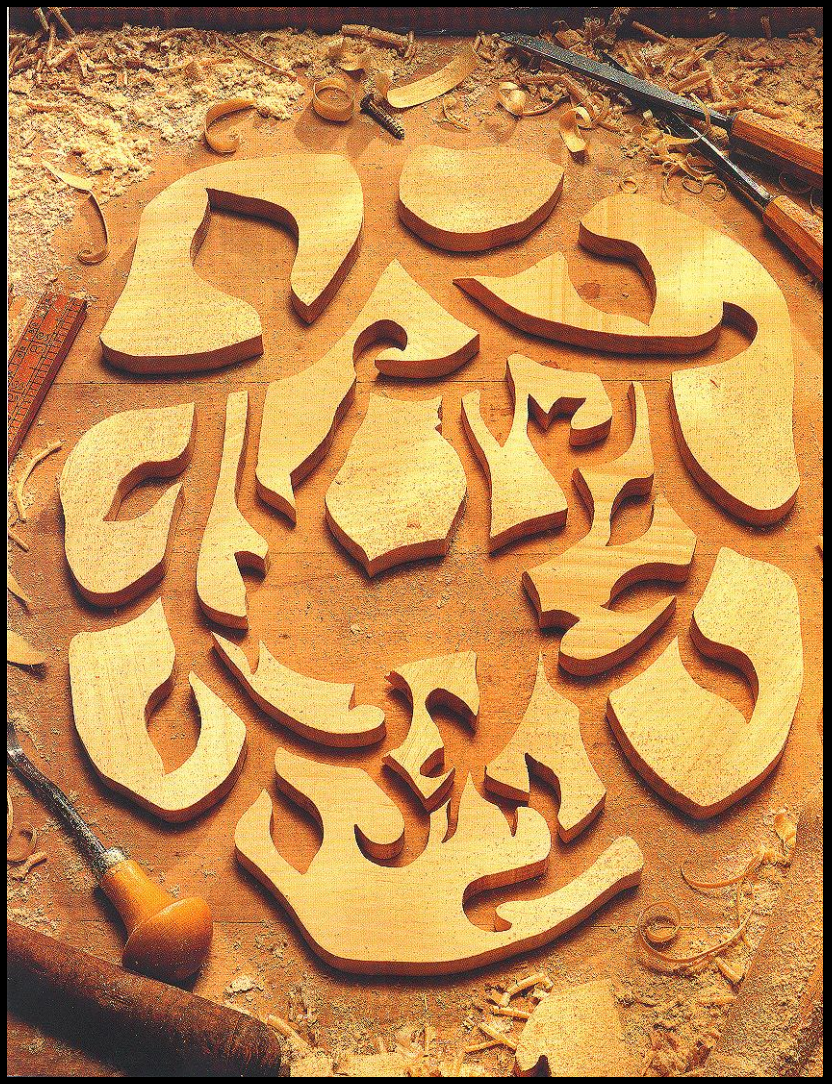
Illusory motion



Illusory motion

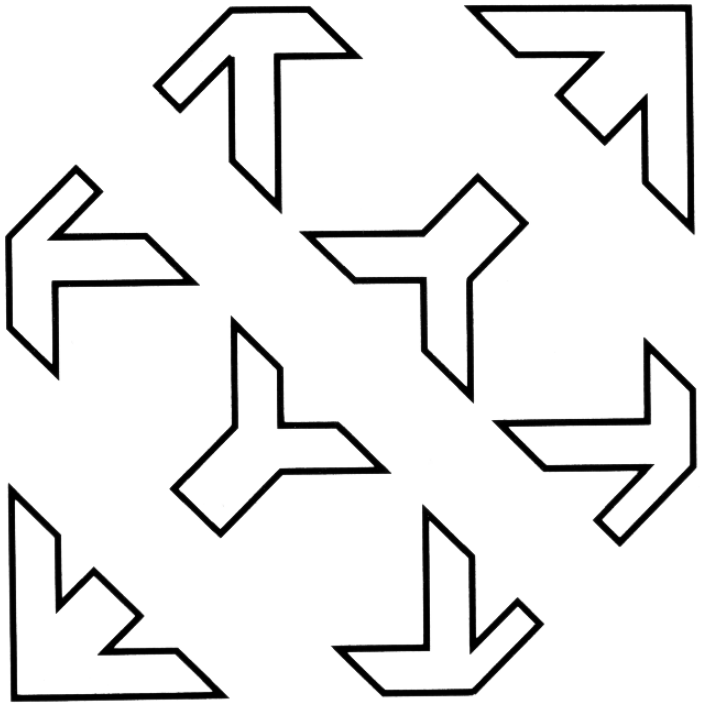


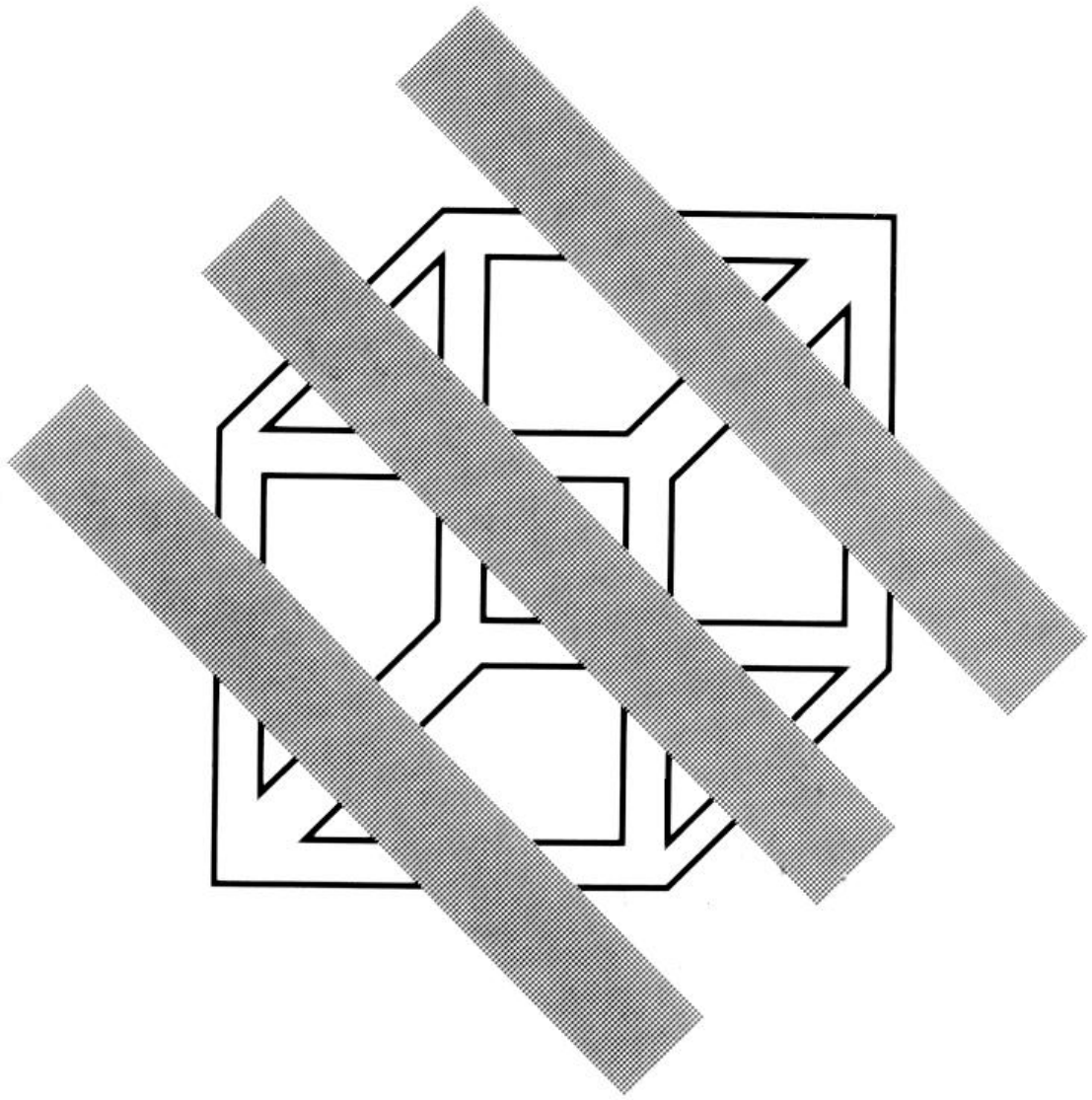
Unconscious priors in image generations



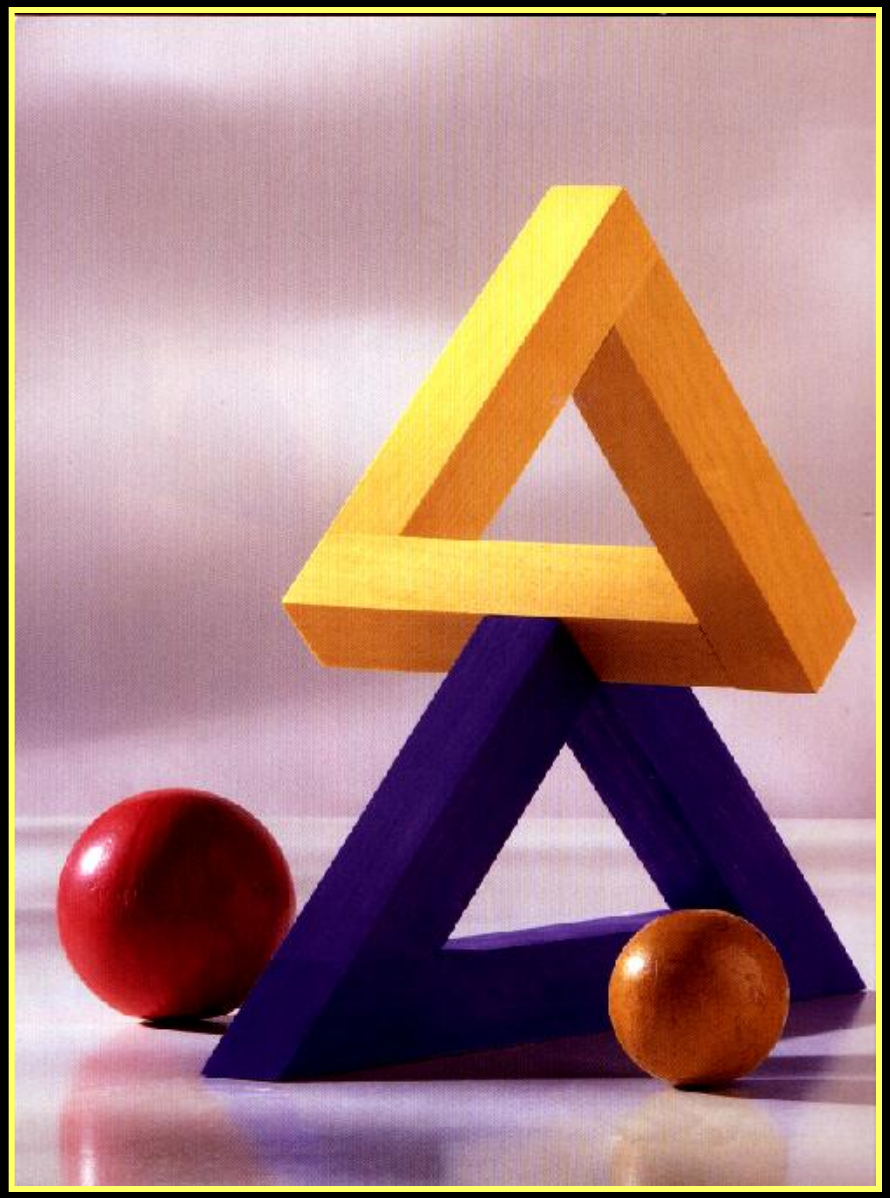
Unconscious priors in image generations

Image generation is highly non-linear

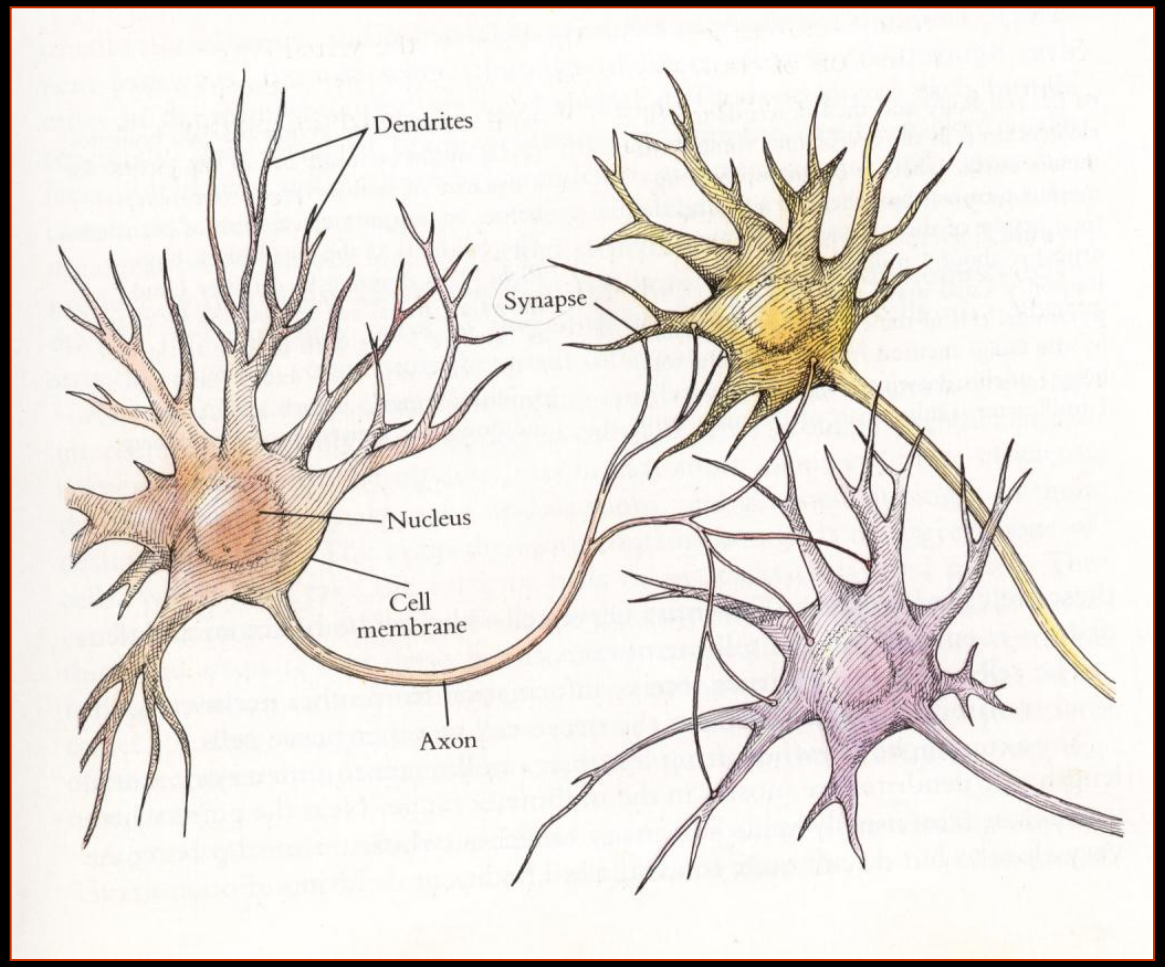




Heuristic aspects in image processing

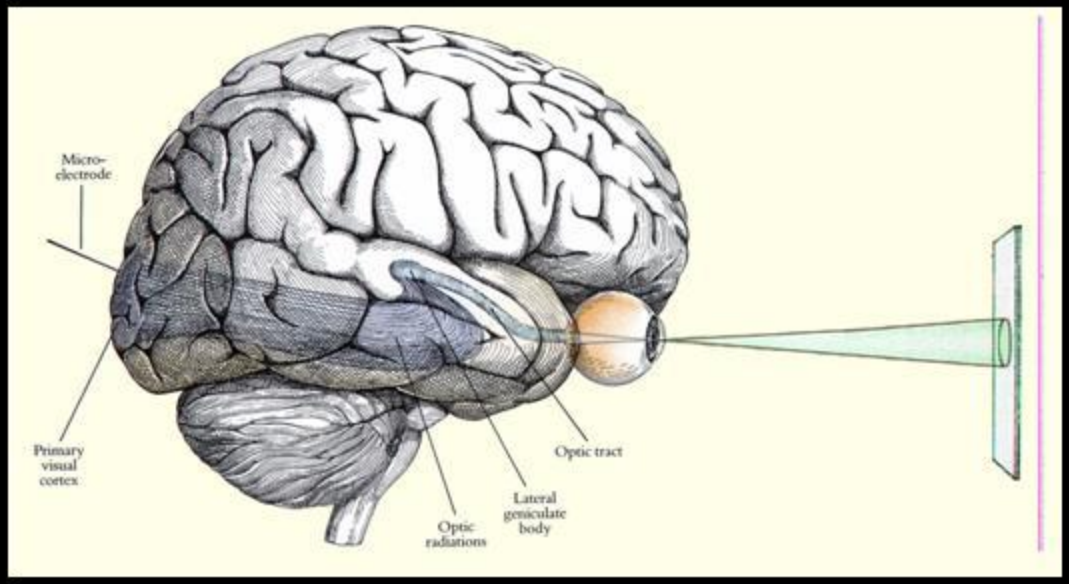


Vision is a process by which pre-existing information is integrated with optic information to build an adaptive visual interpretation

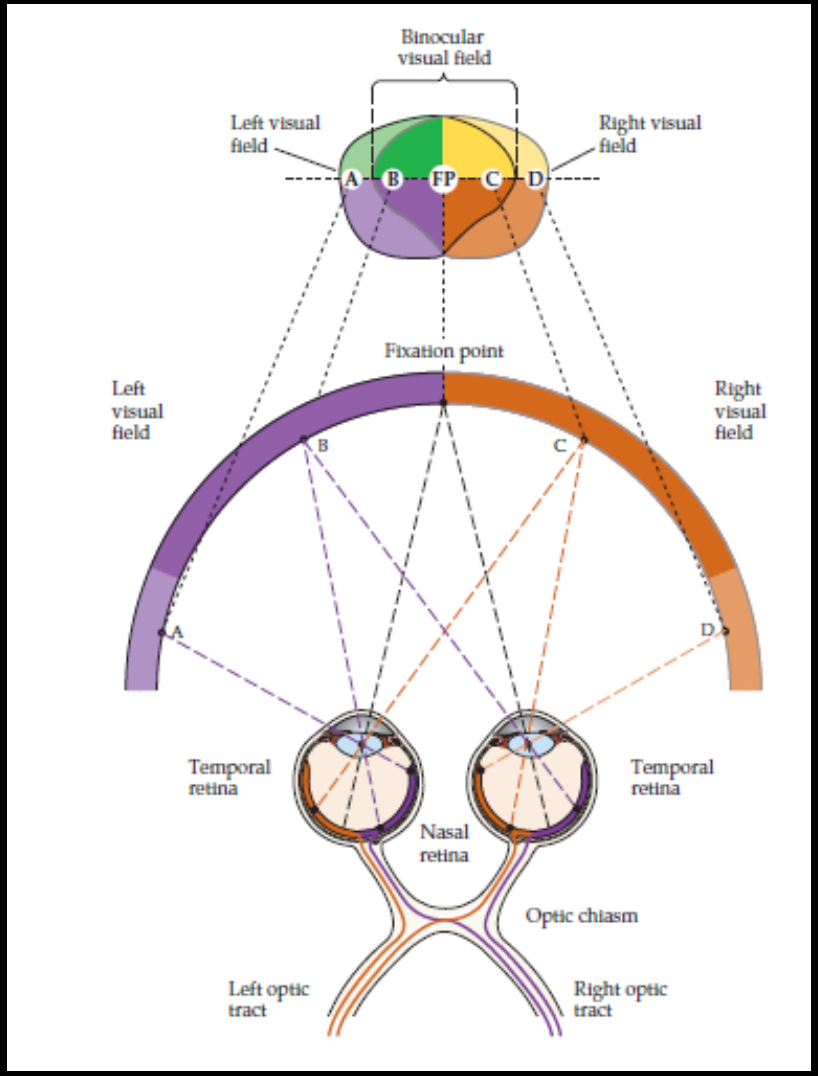


How is this process implemented by neuronal circuits?

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

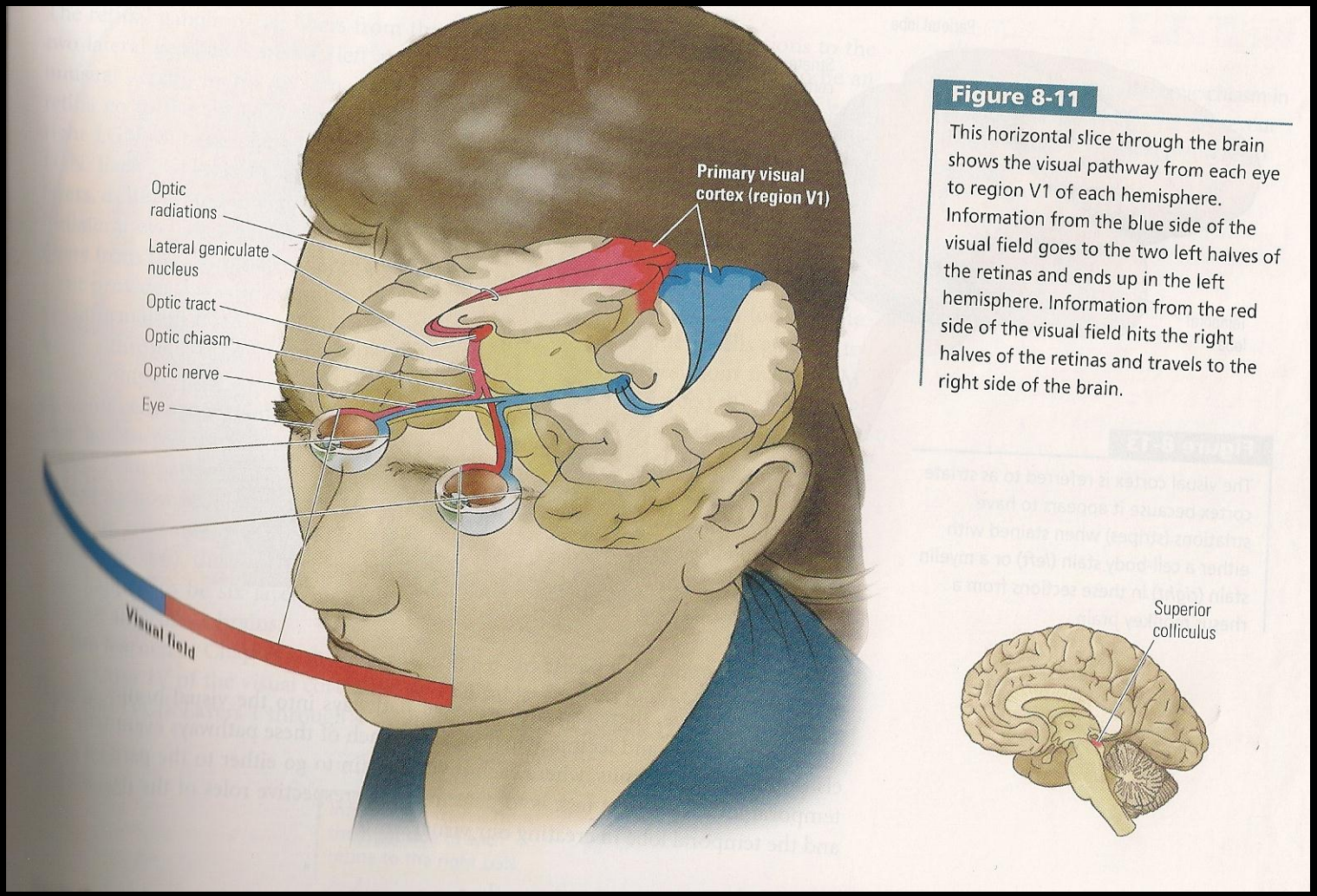
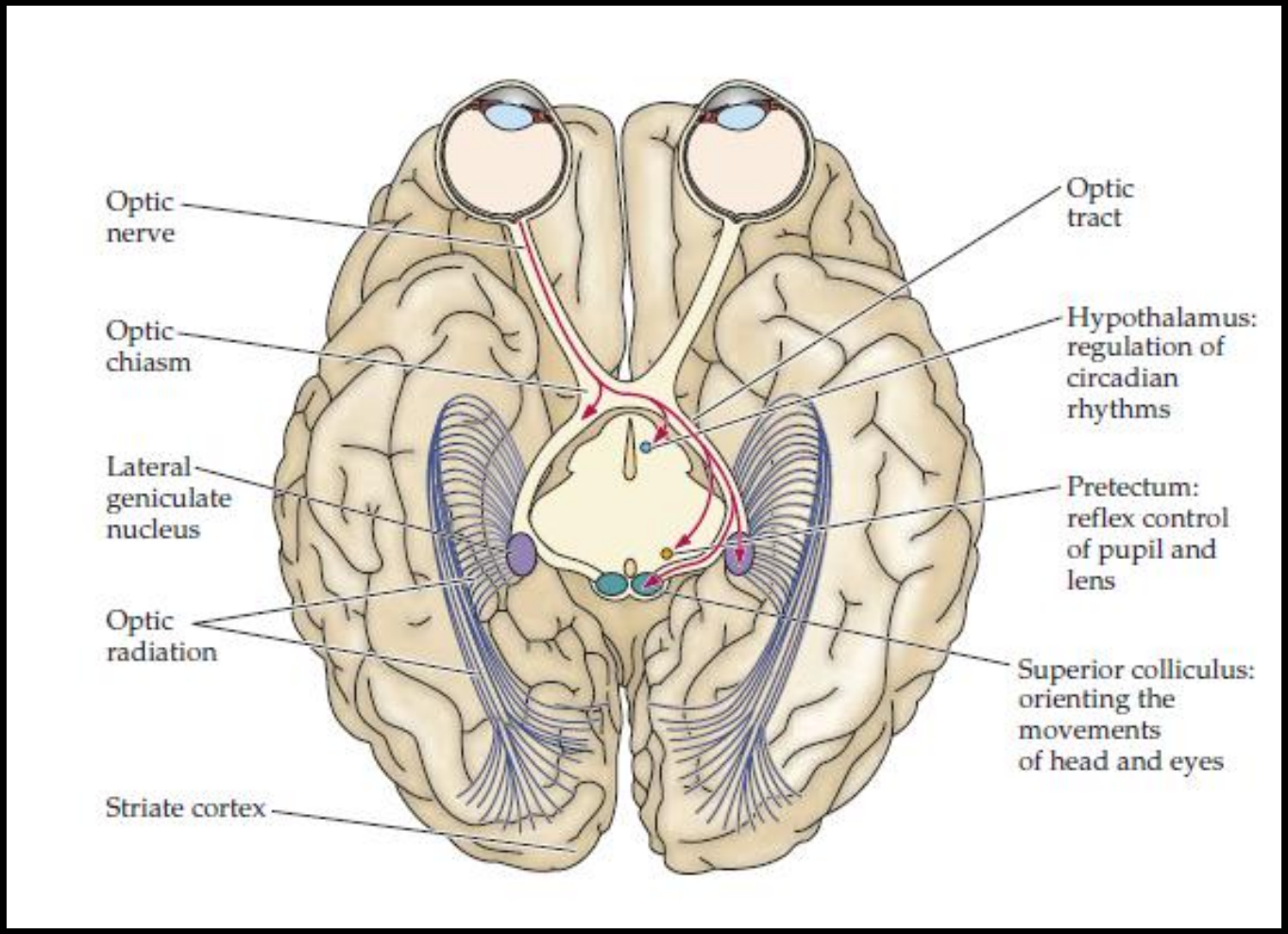


Figure 8-11

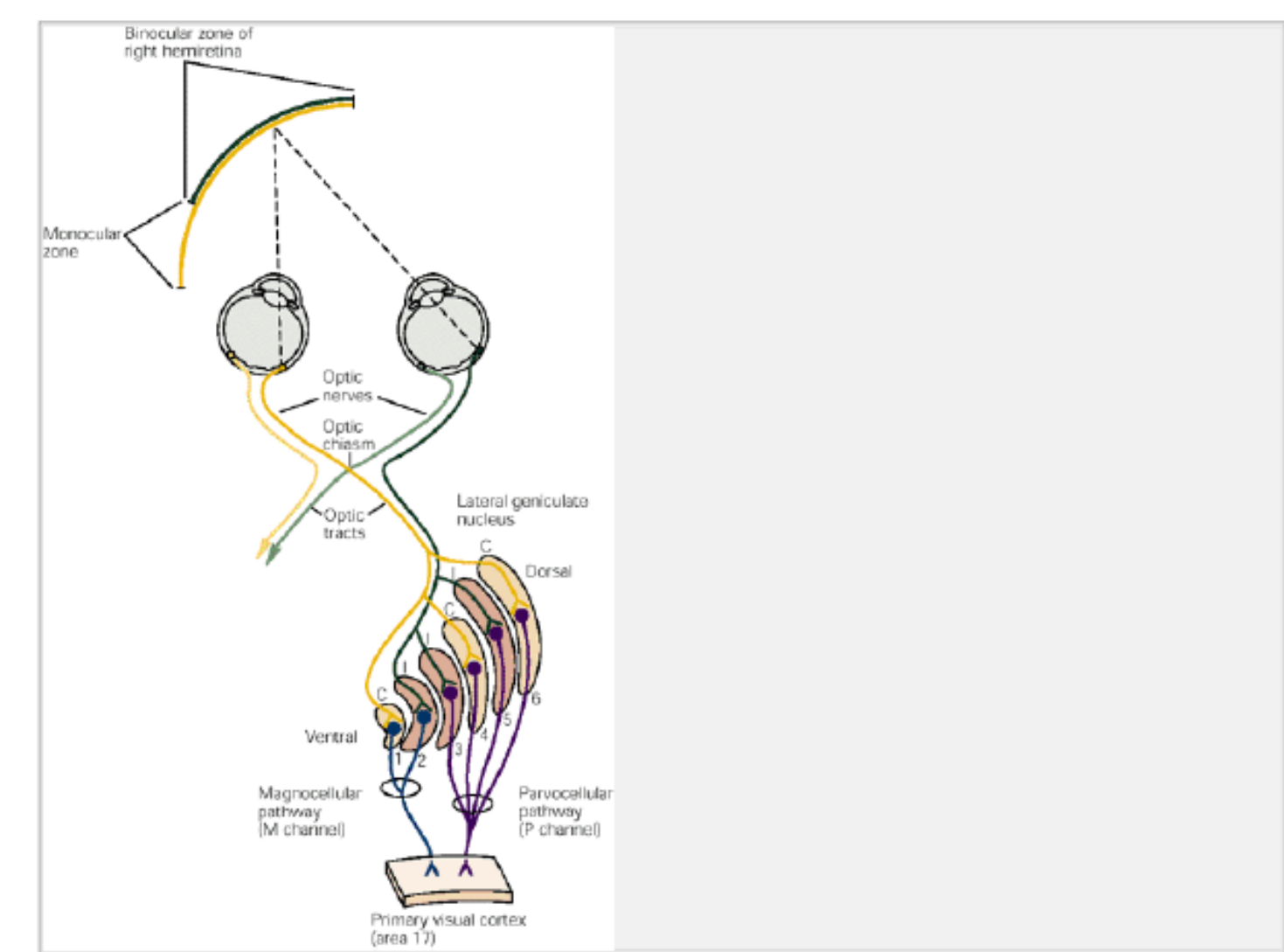
This horizontal slice through the brain shows the visual pathway from each eye to region V1 of each hemisphere. Information from the blue side of the visual field goes to the two left halves of the retinas and ends up in the left hemisphere. Information from the red side of the visual field hits the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

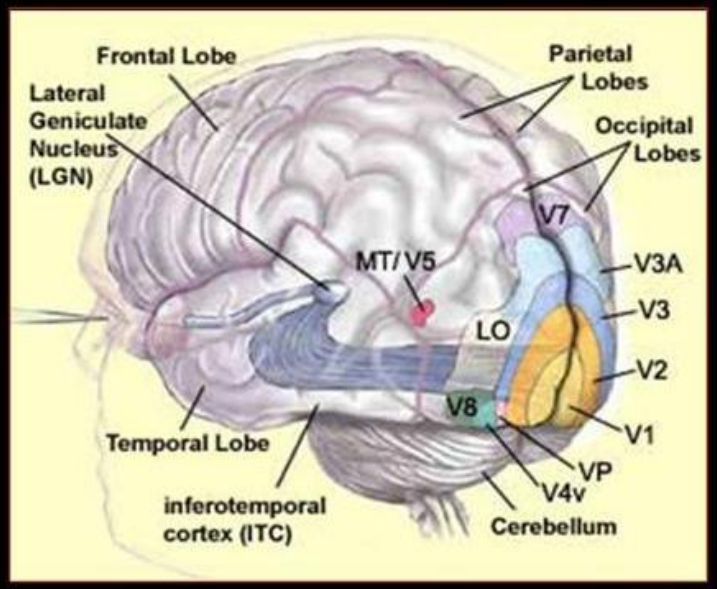


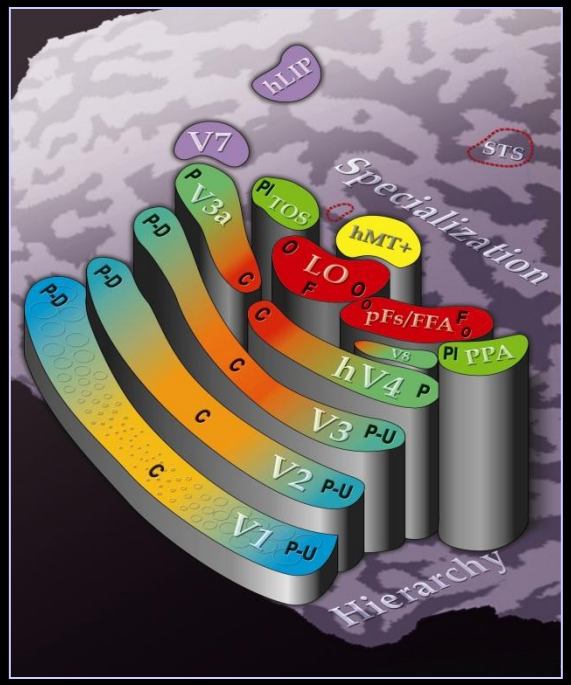
LGN- Relay and gating station



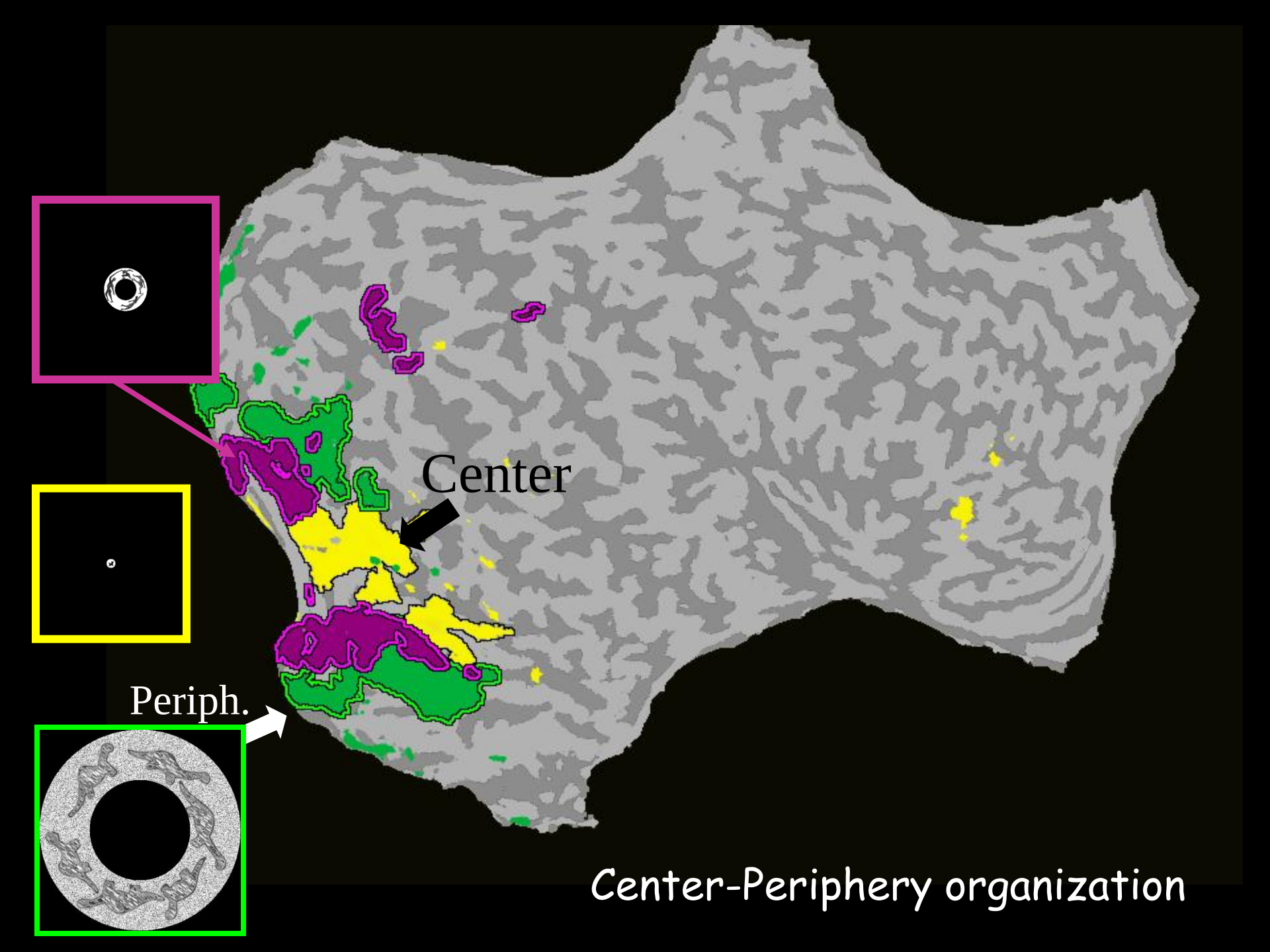
Magno (~ motion) and Parvo (~shape) pathways

Atlas of human visual areas



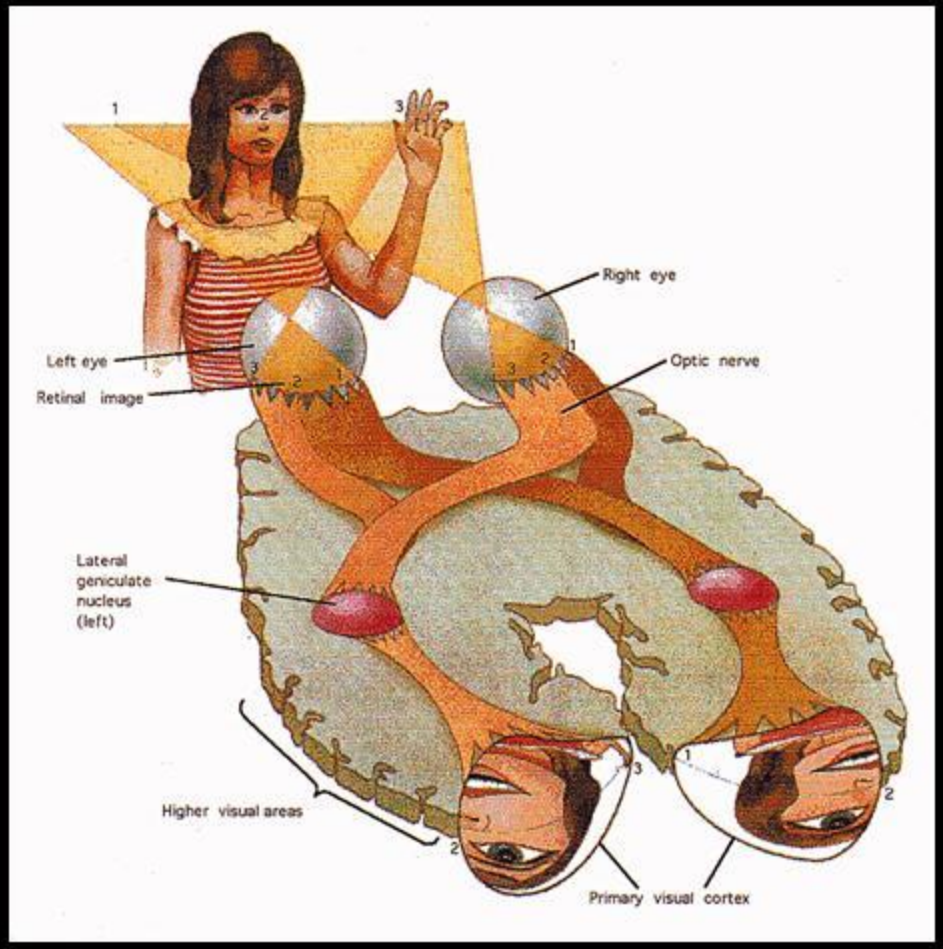


Large scale organization principles


Center
Periph.
Center-Periphery organization

Foveal magnification in V1

Log Topographical representations in the human visual system



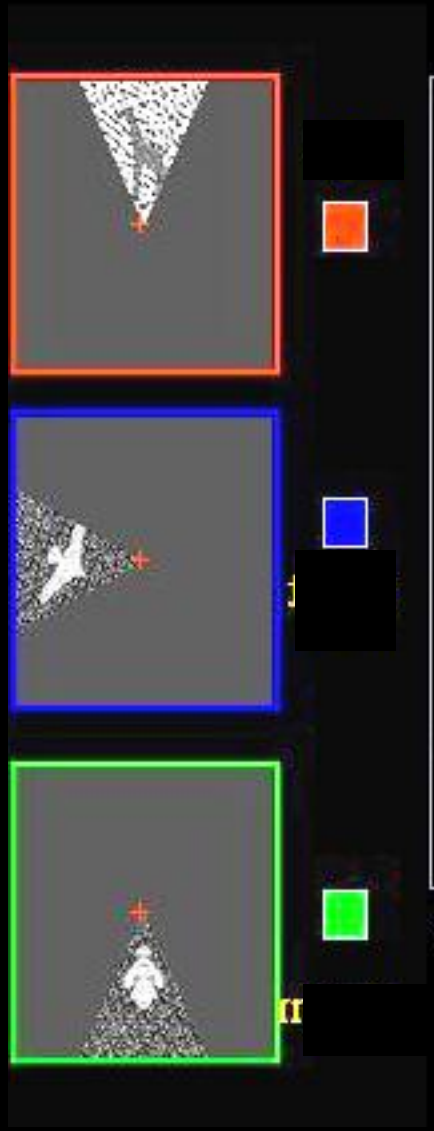
Magnification factor: how many mm cortex correspond to a mm on the retina

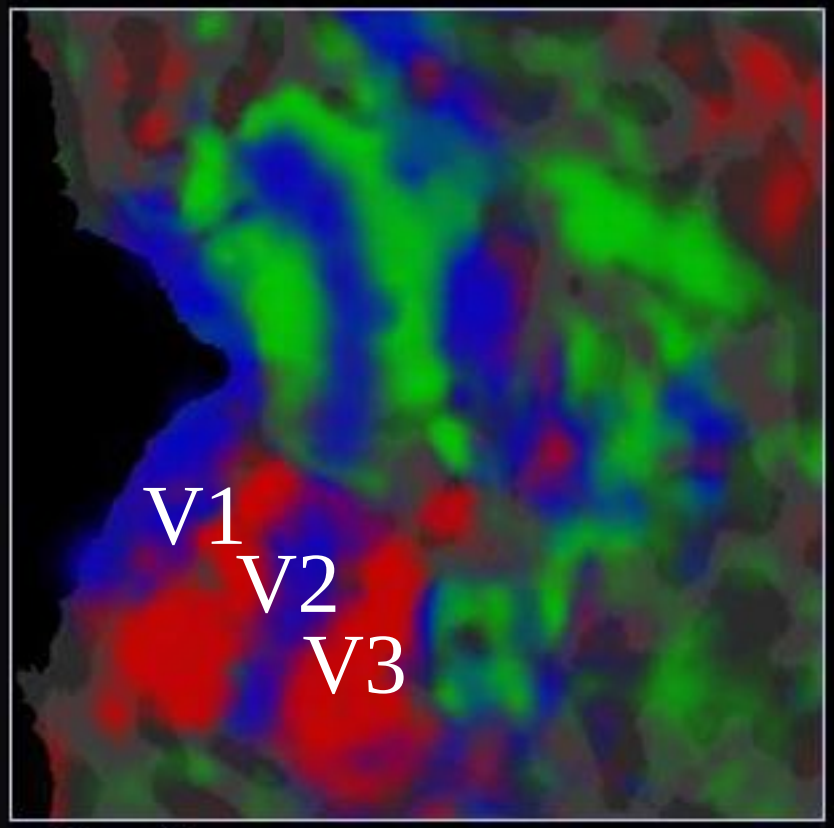
Meridians define borders of visual areas

Vertical Meridian Upper

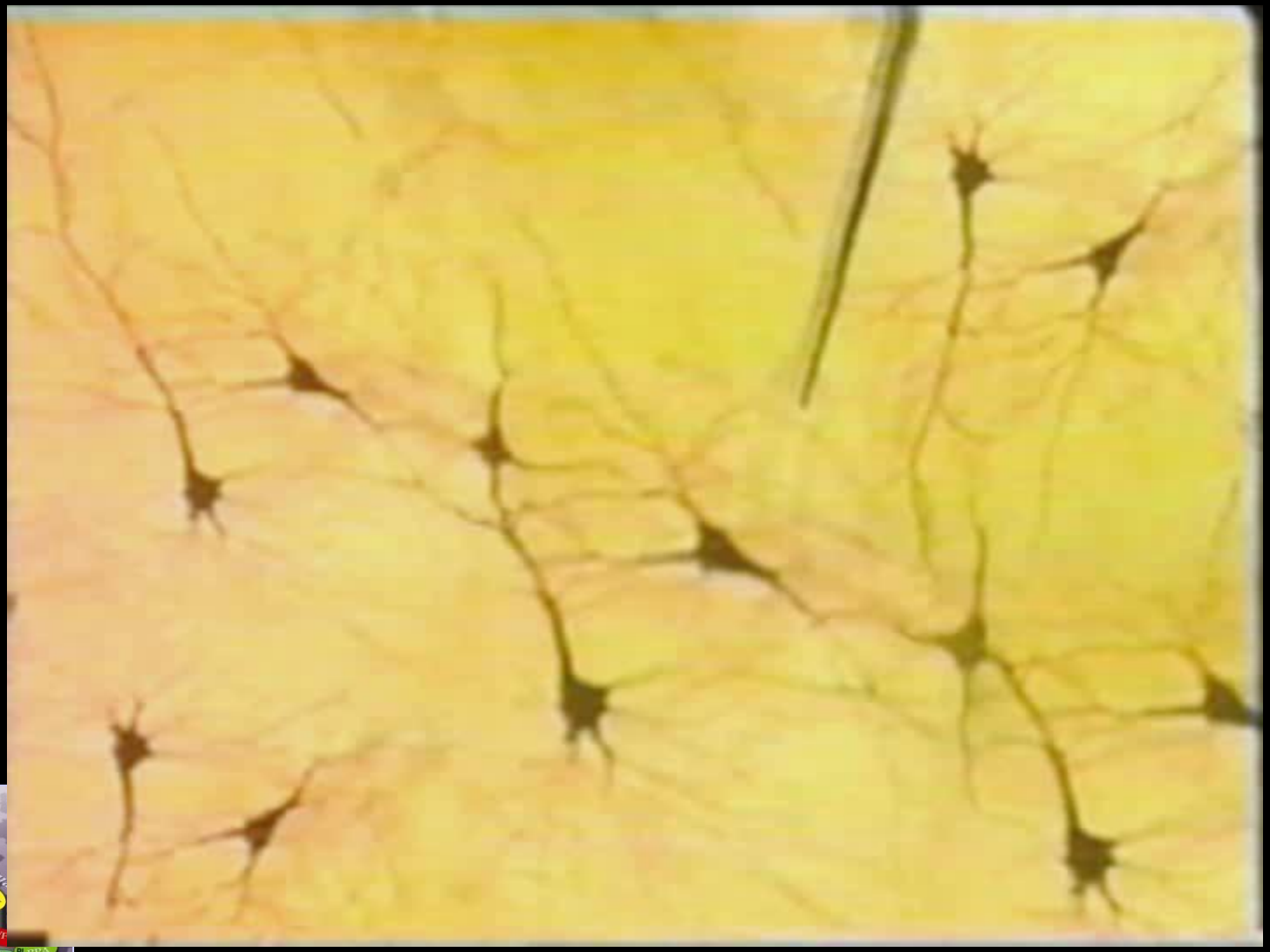
Horizontal Meridian

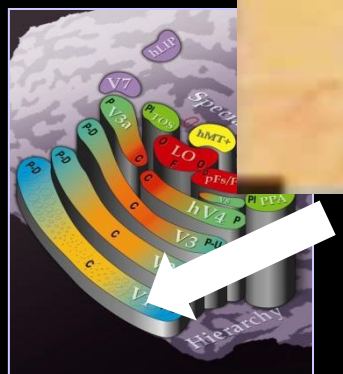
Vertical Meridian Lower



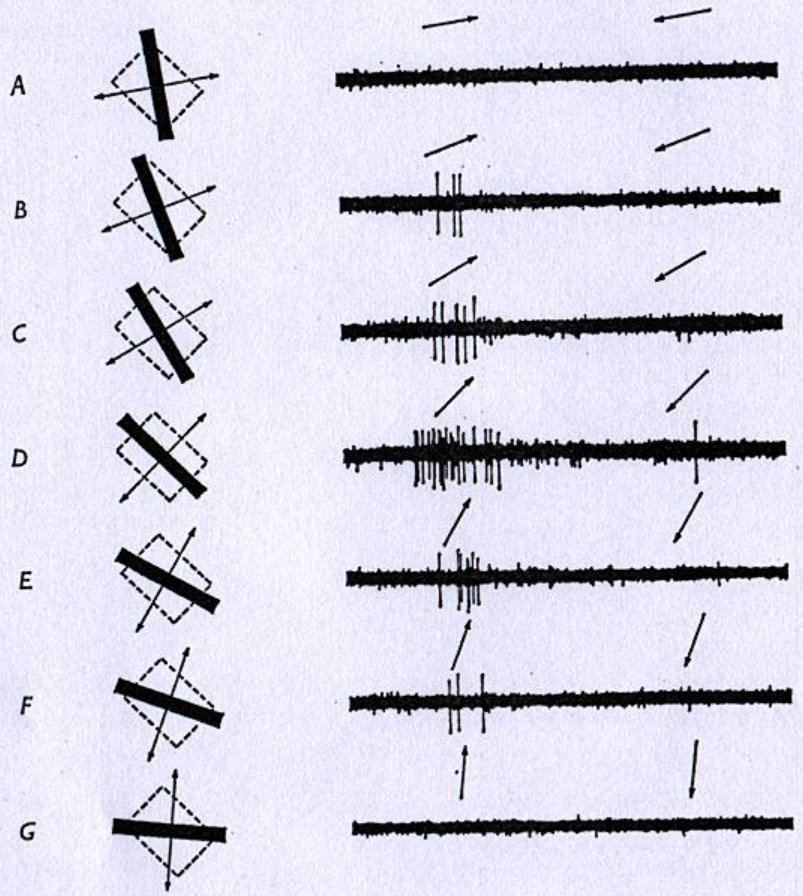


The properties of single neurons in area V1



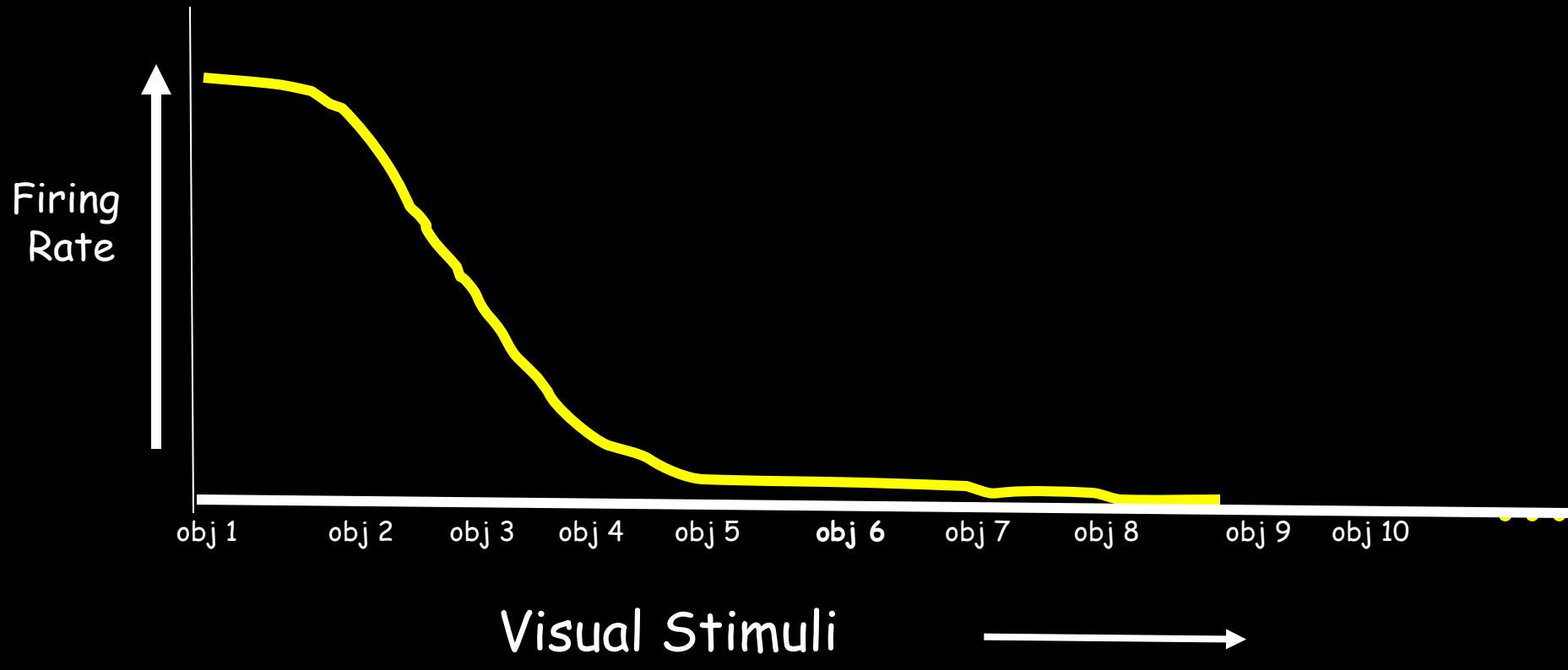


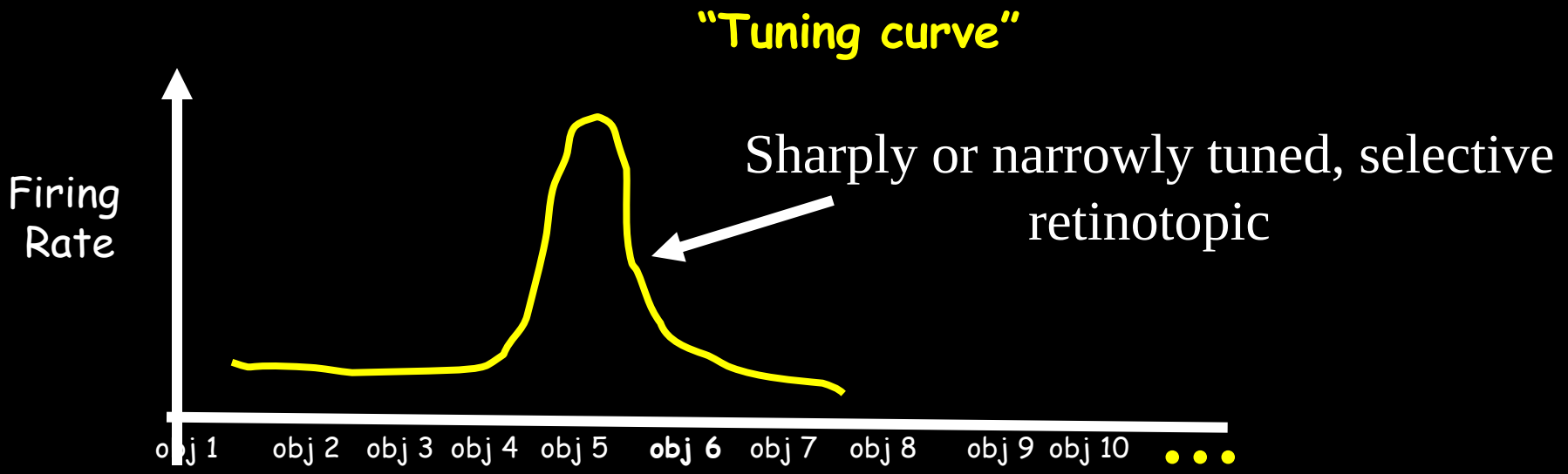
Receptive field of a visual neuron in area V1



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.

The Concept of a Receptive Field

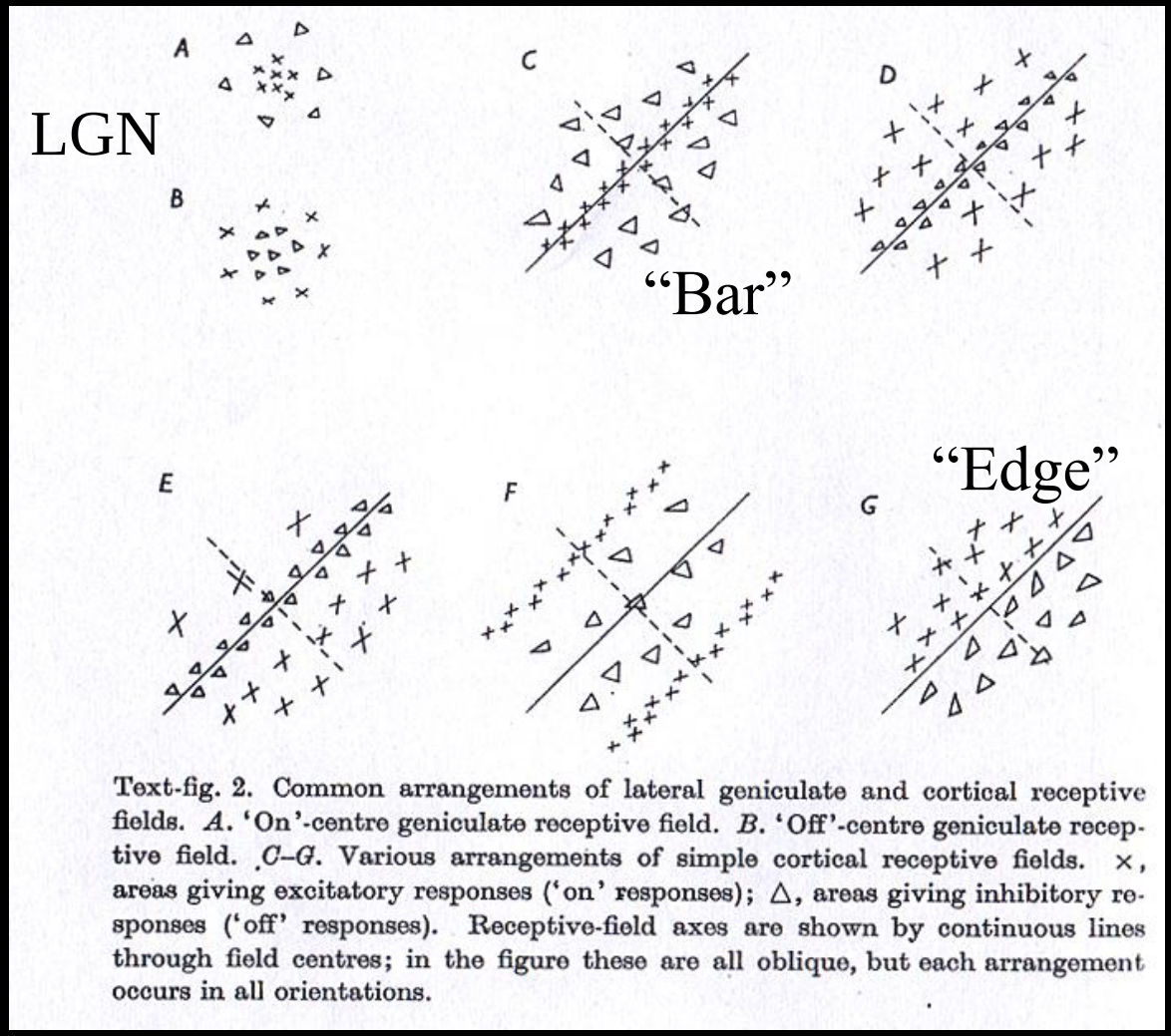




Example: "Simple cells"- Tuned to orientation and position

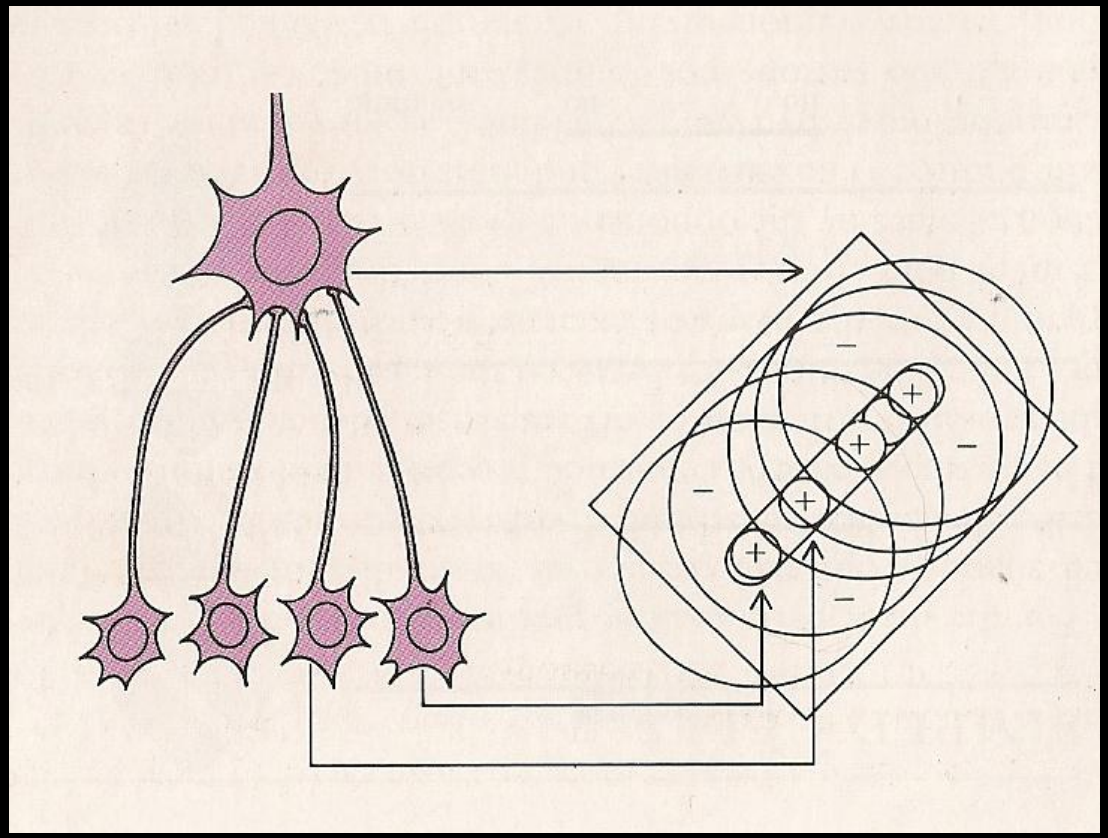
Stimulus selectivity of receptive fields

Receptive field of a "Simple" cell in area V1



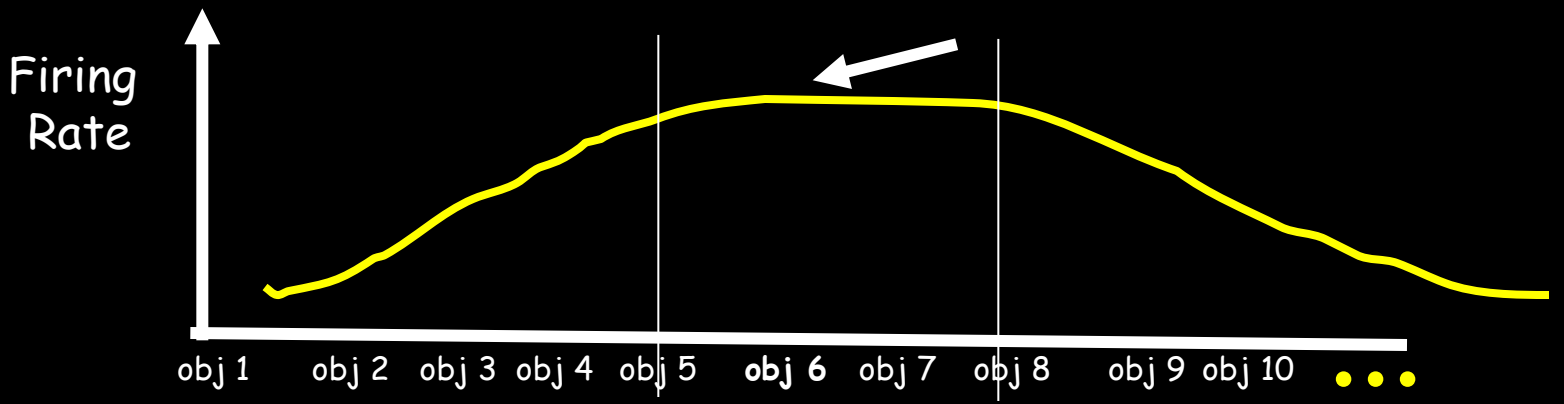
Text-fig. 2. Common arrangements of lateral geniculate and cortical receptive fields. *A*. 'On'-centre geniculate receptive field. *B*. 'Off'-centre geniculate receptive field. *C–G*. Various arrangements of simple cortical receptive fields. ×, areas giving excitatory responses ('on' responses); △, areas 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



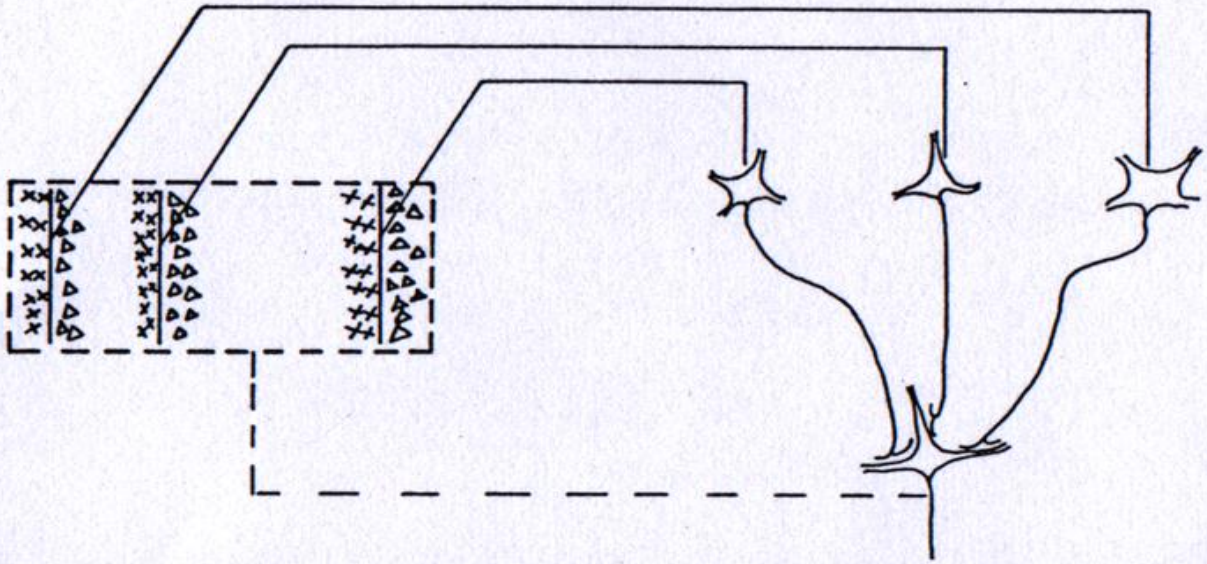
Convergence, threshold, synchrony
An "and" function

Invariance: a group of stimuli that equally activate a neuron



Visual Parameter
(e.g. retinal position)

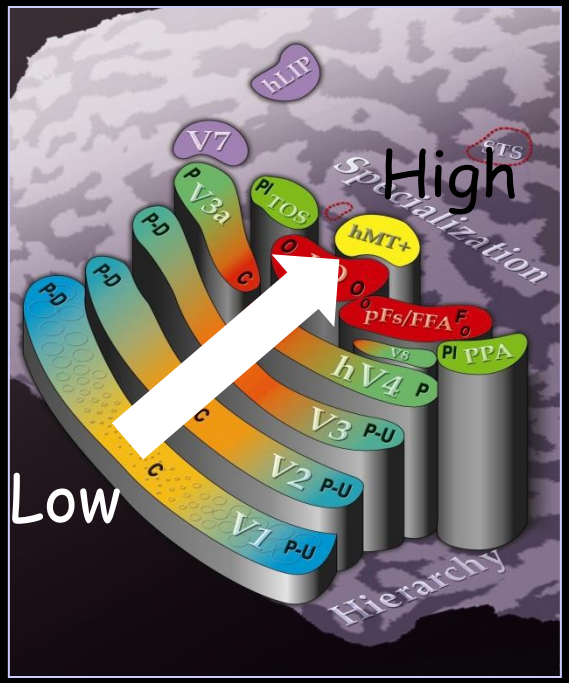
Example: position invariance
(Large retinotopic receptive field)

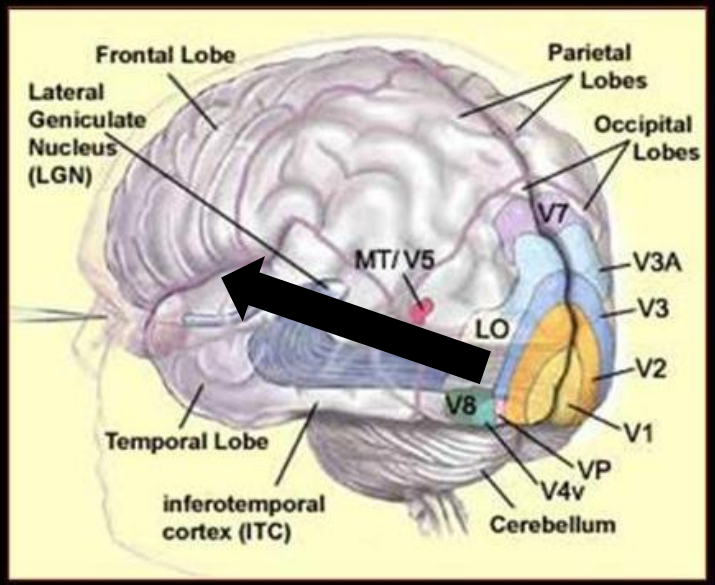


Text-fig. 20. Possible scheme for explaining the organization of complex receptive fields. A number of cells with simple fields, of which three are shown schematically, are imagined to project to a single cortical cell of higher order. Each projecting neurone has a receptive field arranged as shown to 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.

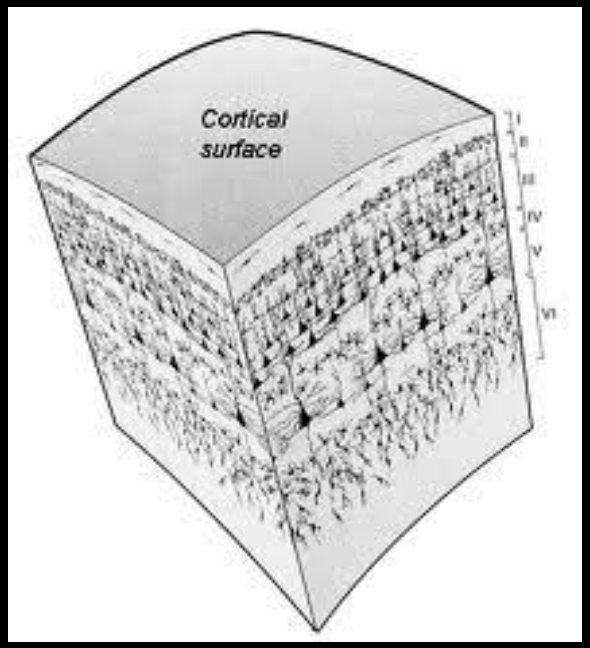
Complex cells: the first step towards position invariance
An "or" function

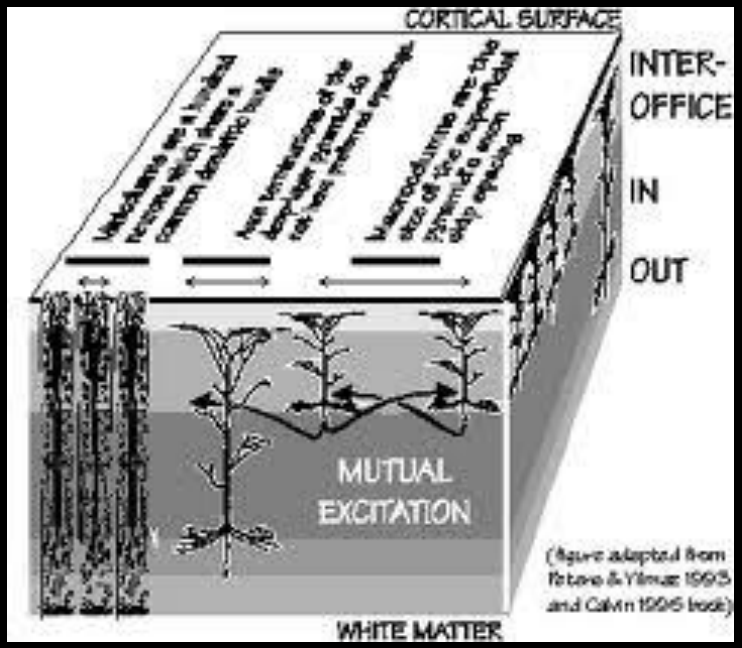
The Hierarchy principle



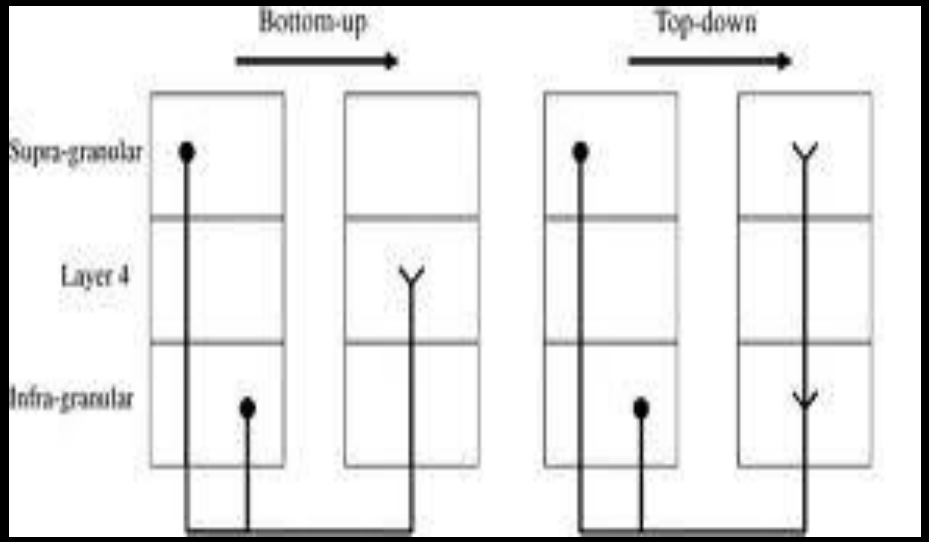


The cortex is organized in layers

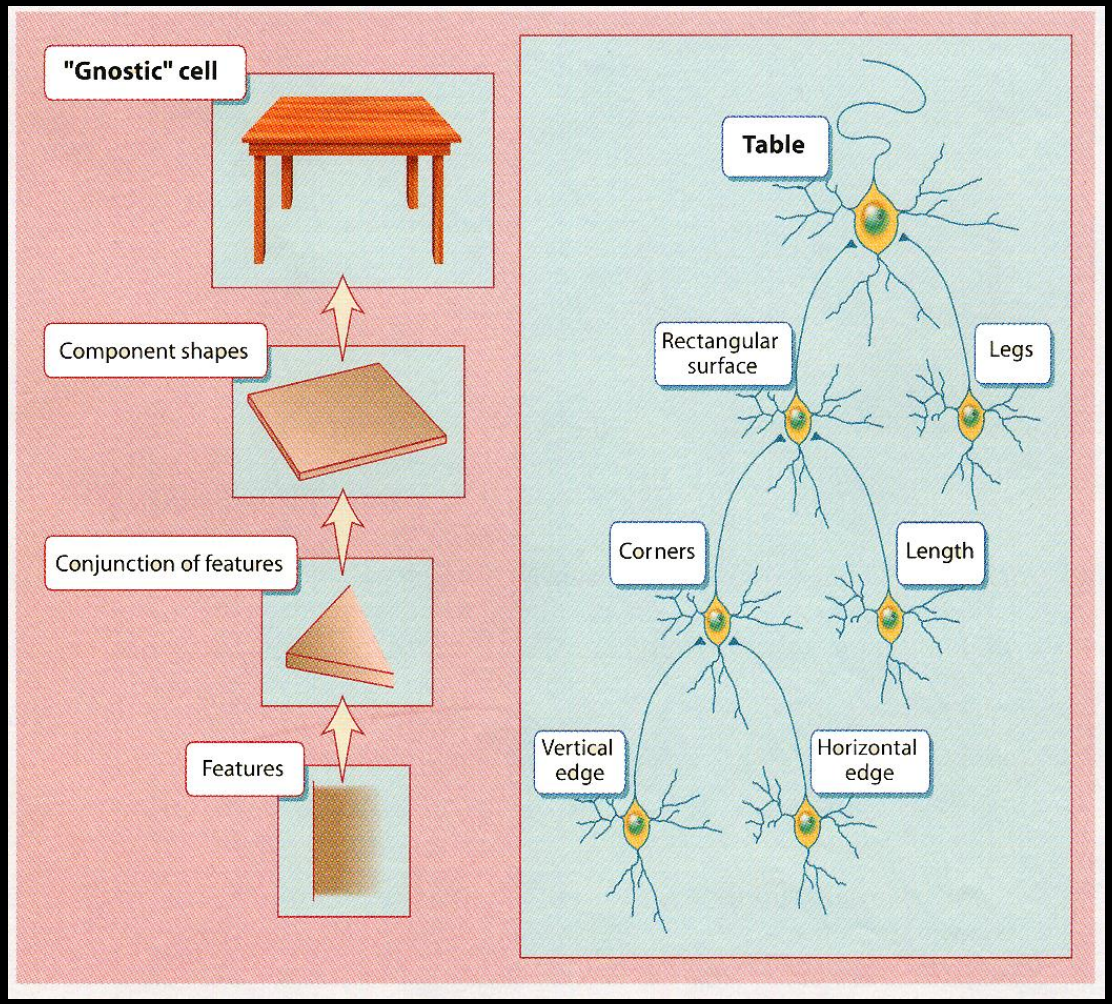




The flow of hierarchical information is directed to specific layers

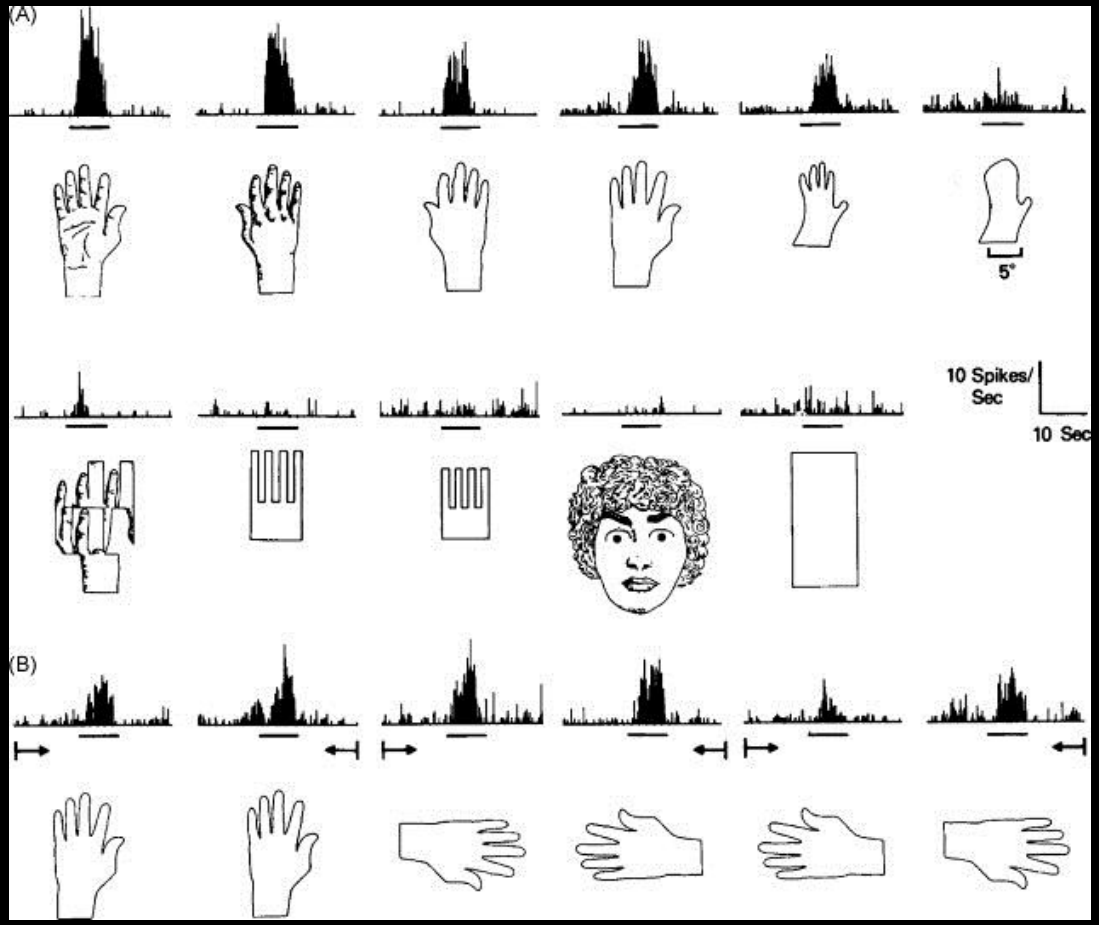


Hierarchical representation: illustration



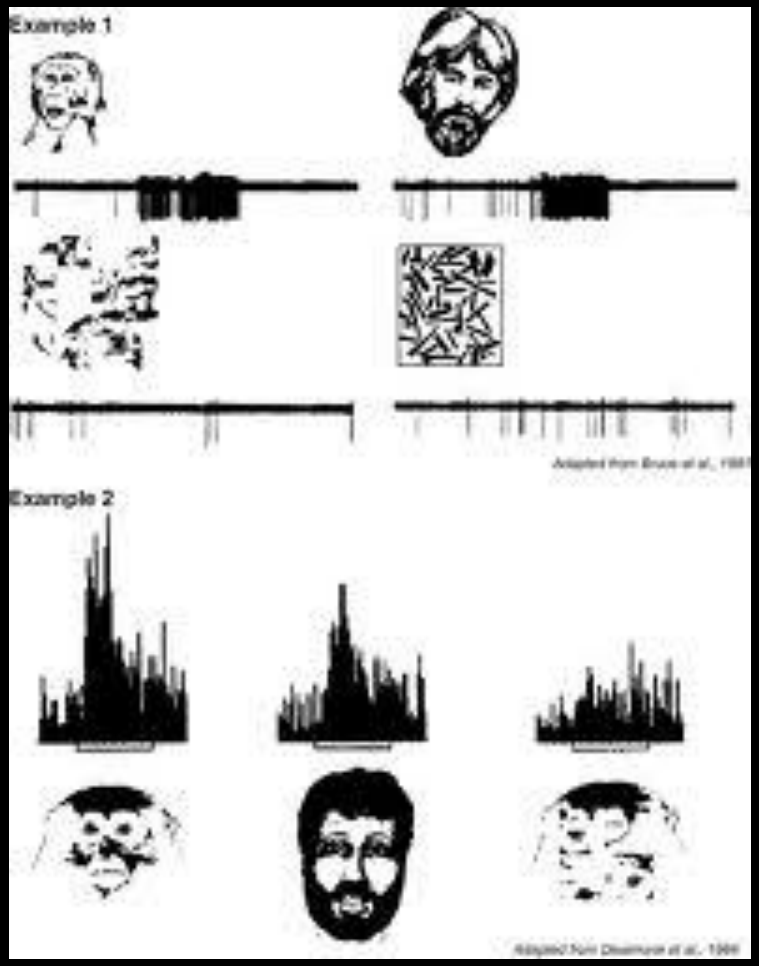
Simple, complex… “grand-mother” cells

Complex properties of neurons at the top of the hierarchy



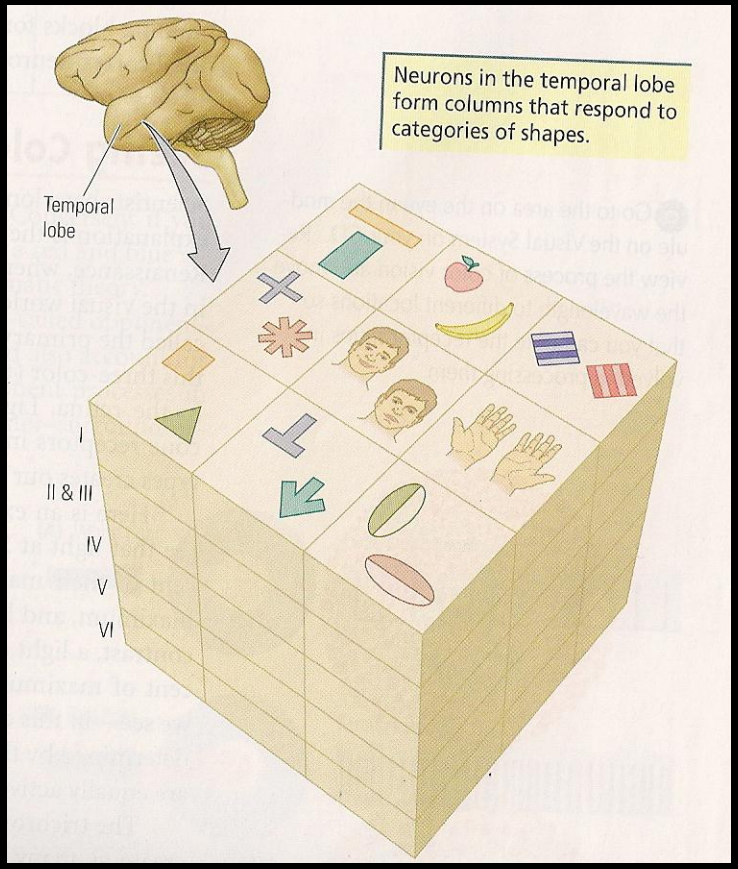
"Hand" neurons

Complex properties of neurons at the top of the hierarchy

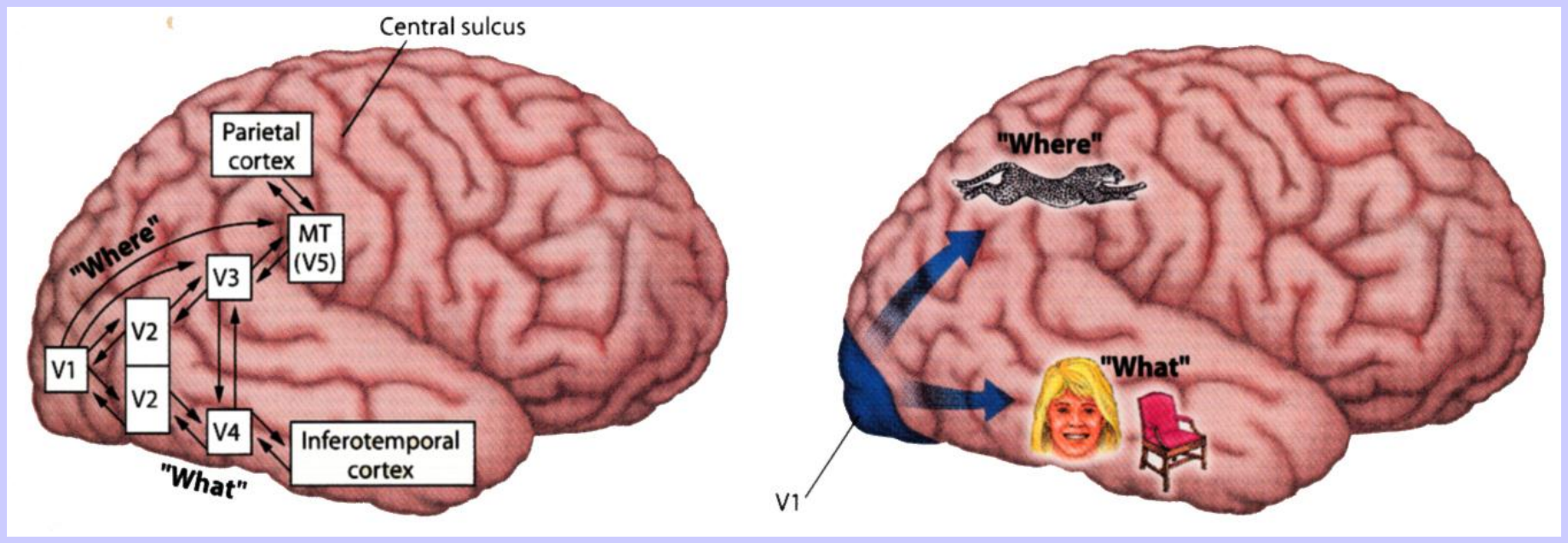


"Face" neurons

Complex element representation at the top of the hierarchy

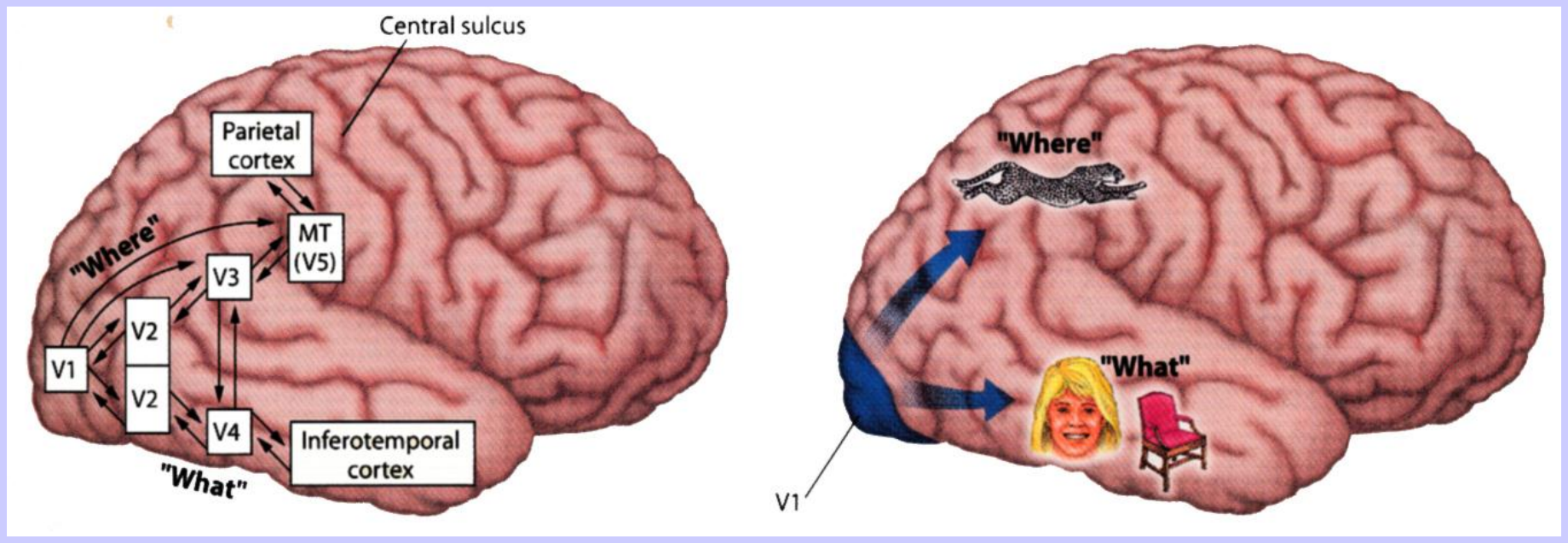


"Stream" specialization in the human brain

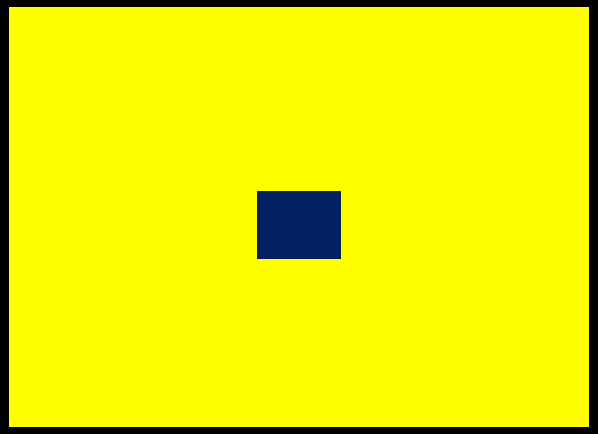


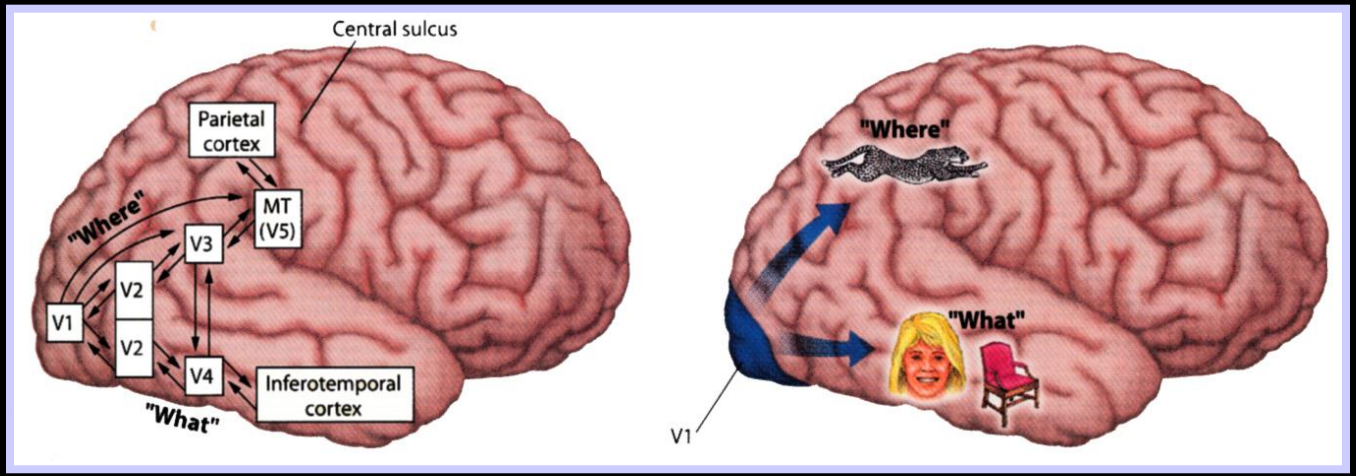
Two streams: dorsal- action, where, Ventral- what

Computations and neuronal properties



Action Pathway: Eye-hand coordination
Necessary computation- topographic map transformation
The problem of eye movements
Efferent copy





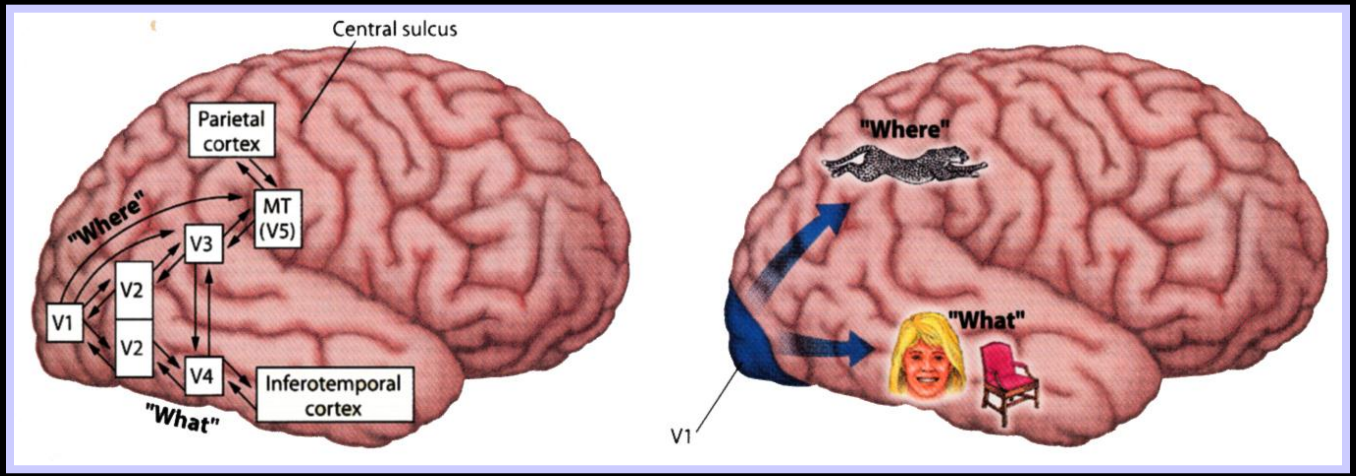
Dorsal stream- "action"- neurons

Invariant to identity

Sensitive to position

Selective to "action items"

Linked to the motor system



Dorsal stream- "action"- neurons

Invariant to identity

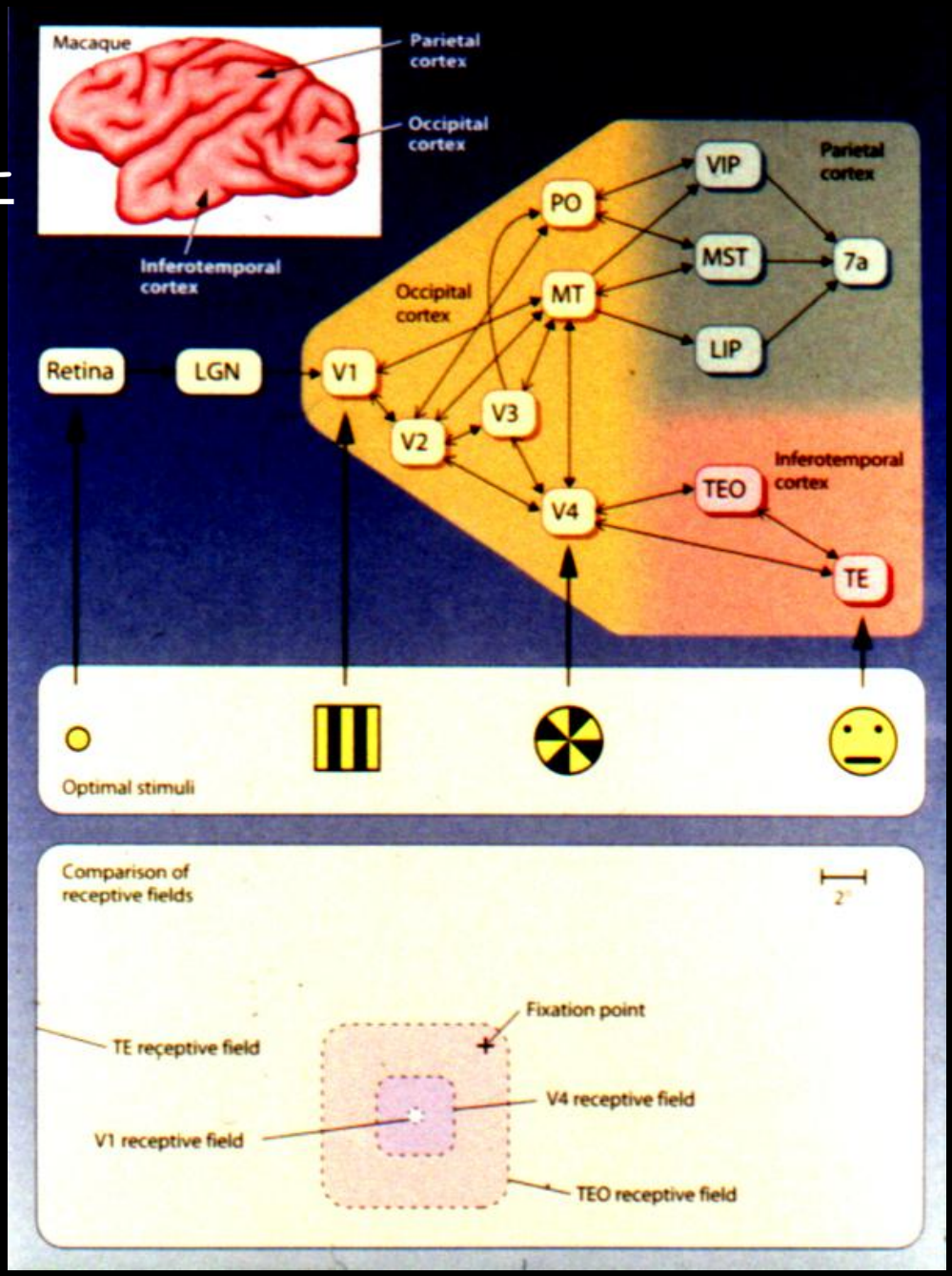
Sensitive to position

Selective to "action items"

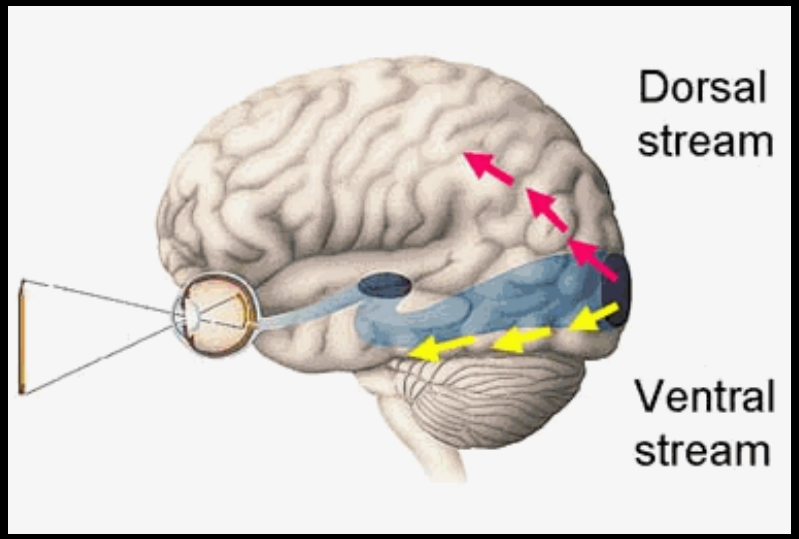
Linked to the motor system

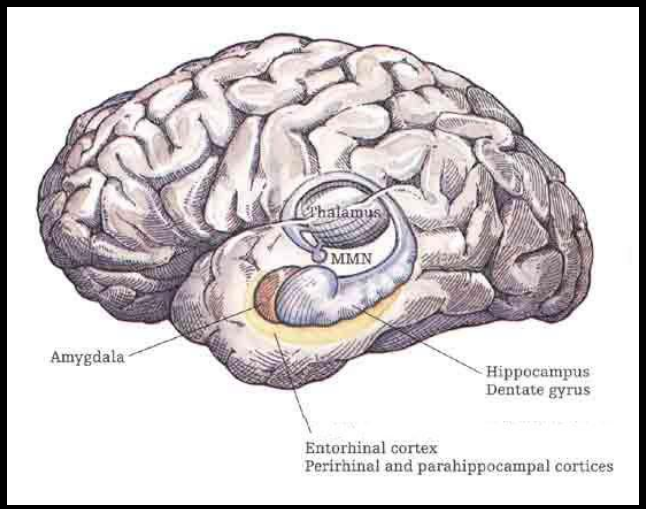
Ventral stream- "Recognition"-neurons

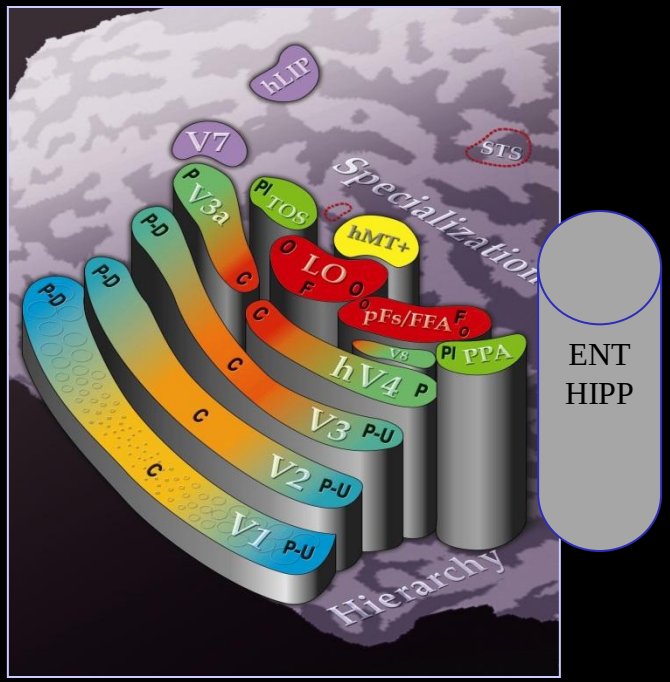
Sensitive to identity
Increased invariance to position
Tight link to memory systems



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

10 min

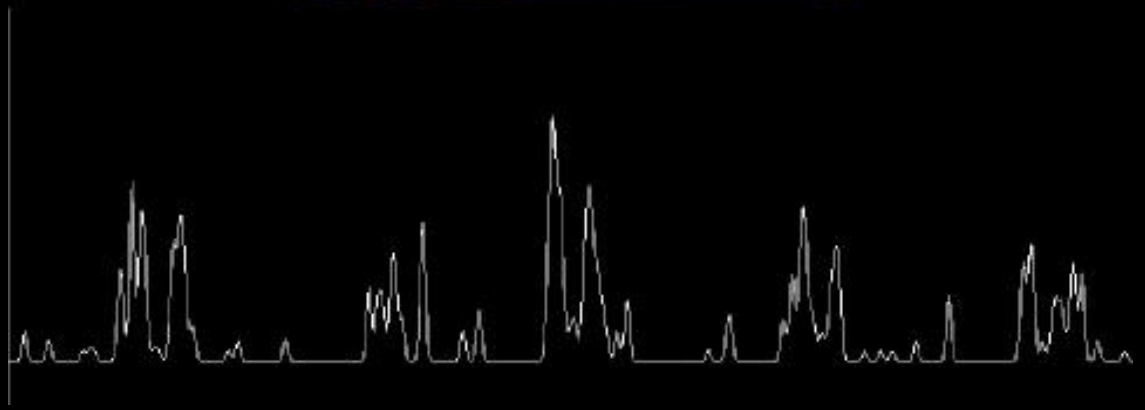
1-5 min

3-8 min

הצג מלבדך-שניקן,יצחק פריד

Visual responses

What the patient saw



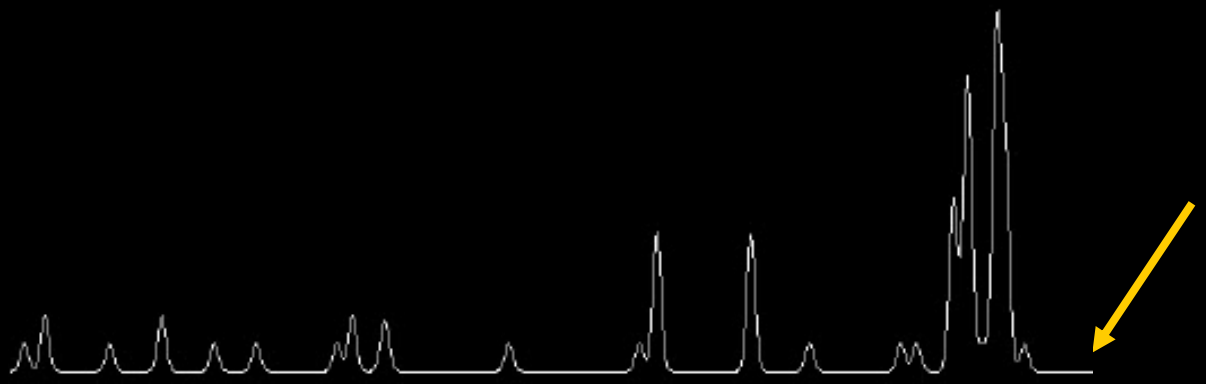
Neuronal activity

entorhinal cortex

beeps are spikes of a single human neuron

Recollection in the absence of visual stimulation

What the patient said

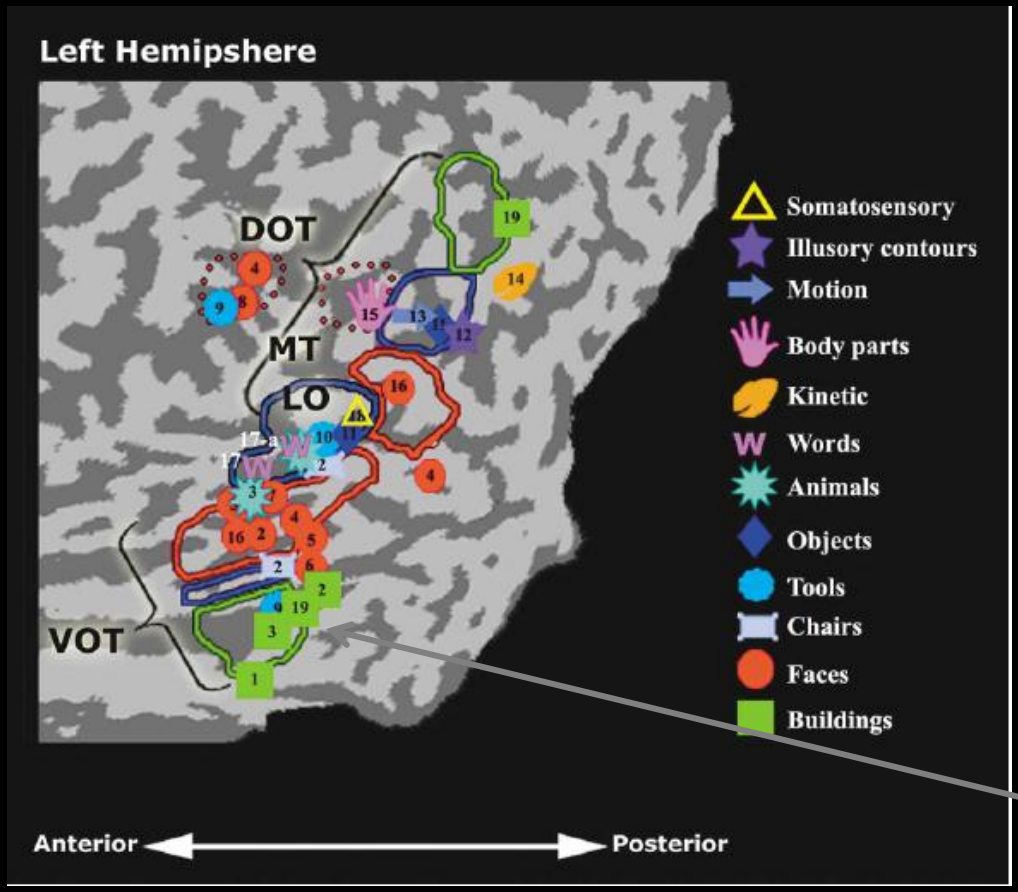


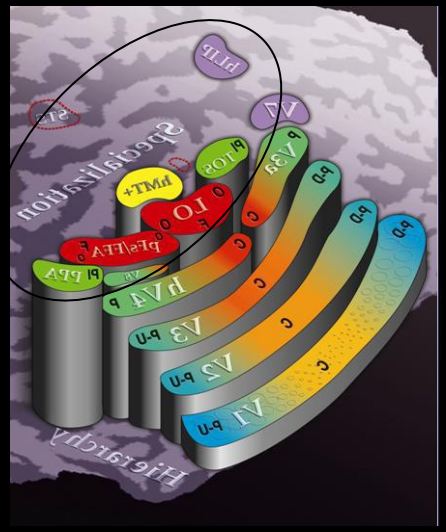
Neuronal activity

entorhinal cortex

beeps are spikes of a single human neuron

Large scale principles: Category organization





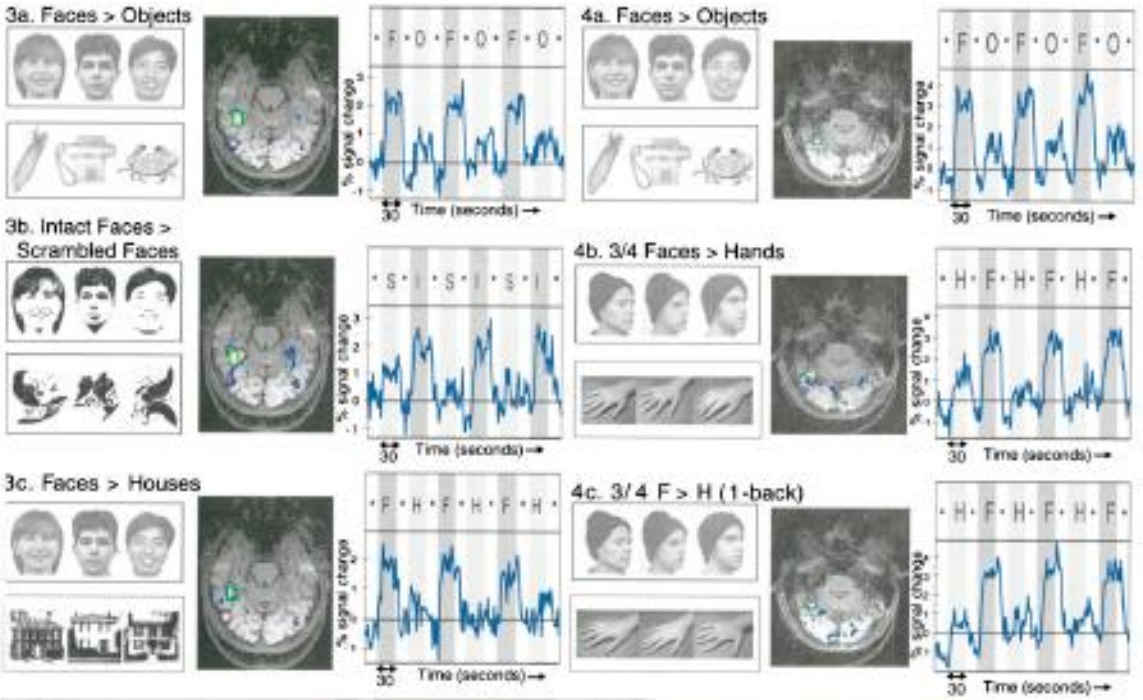
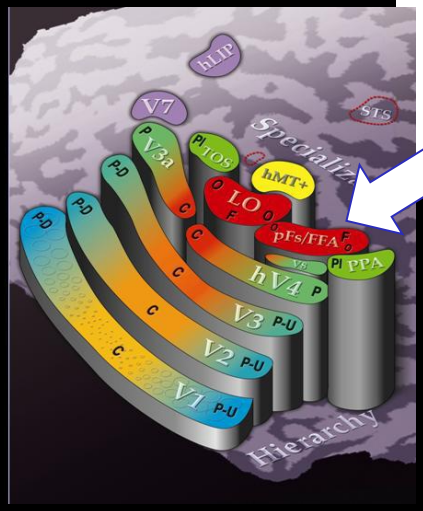
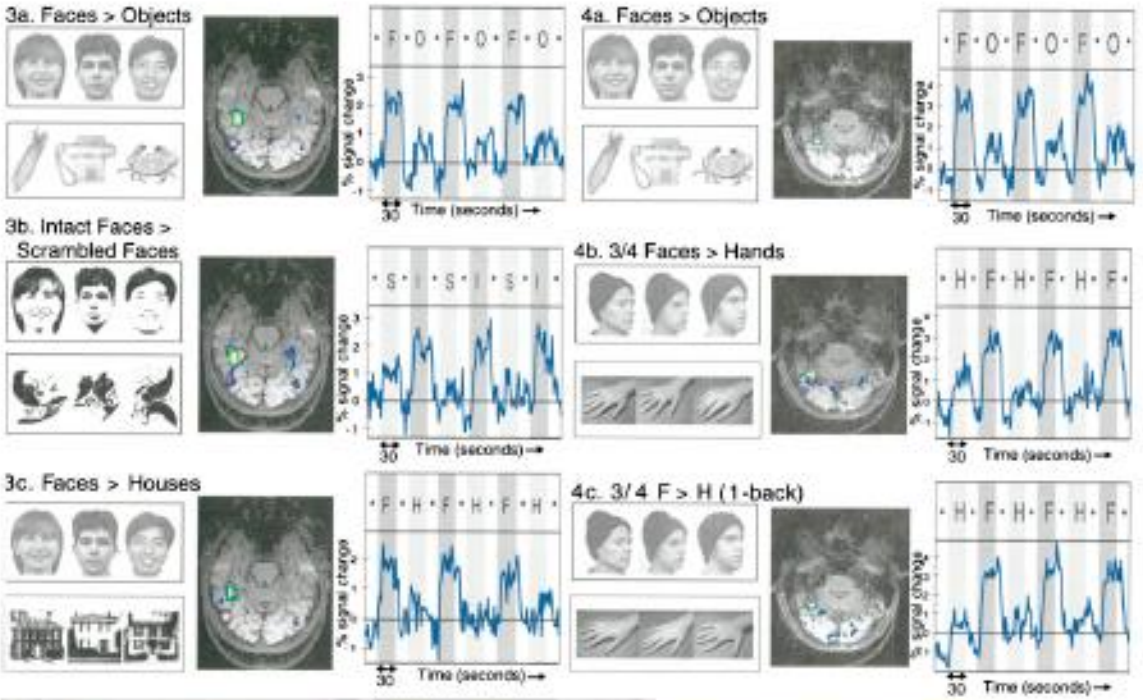


Figure 3 Results of Part II. *Left columns*, Sample stimuli used for the faces versus objects comparison as well as the two subsequent tests. *Center columns*, Areas that produced significantly greater activation for faces than control stimuli for subject S1. *a*, The faces versus objects comparison 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 scans as 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



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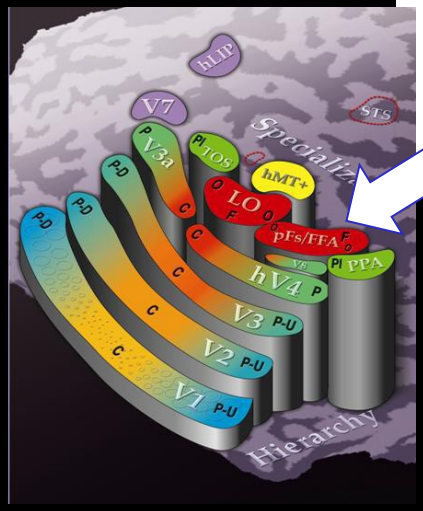
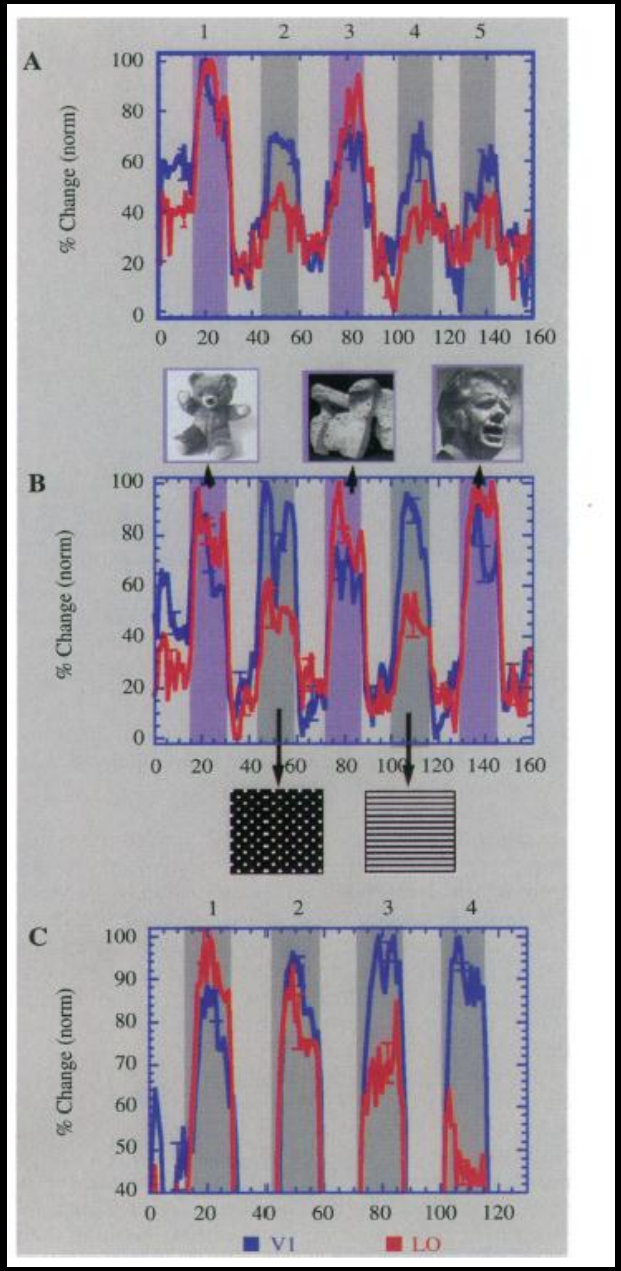


Fusiform "Face" Area

LOC

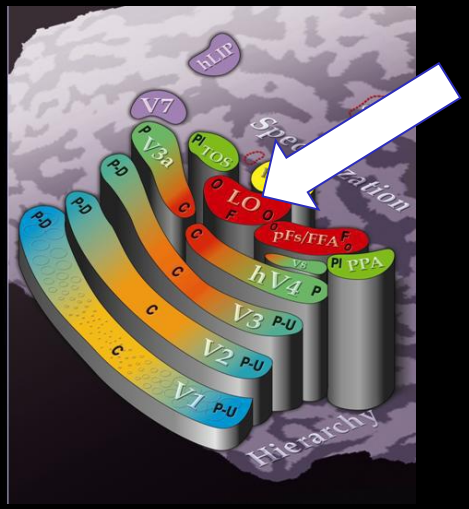
V1



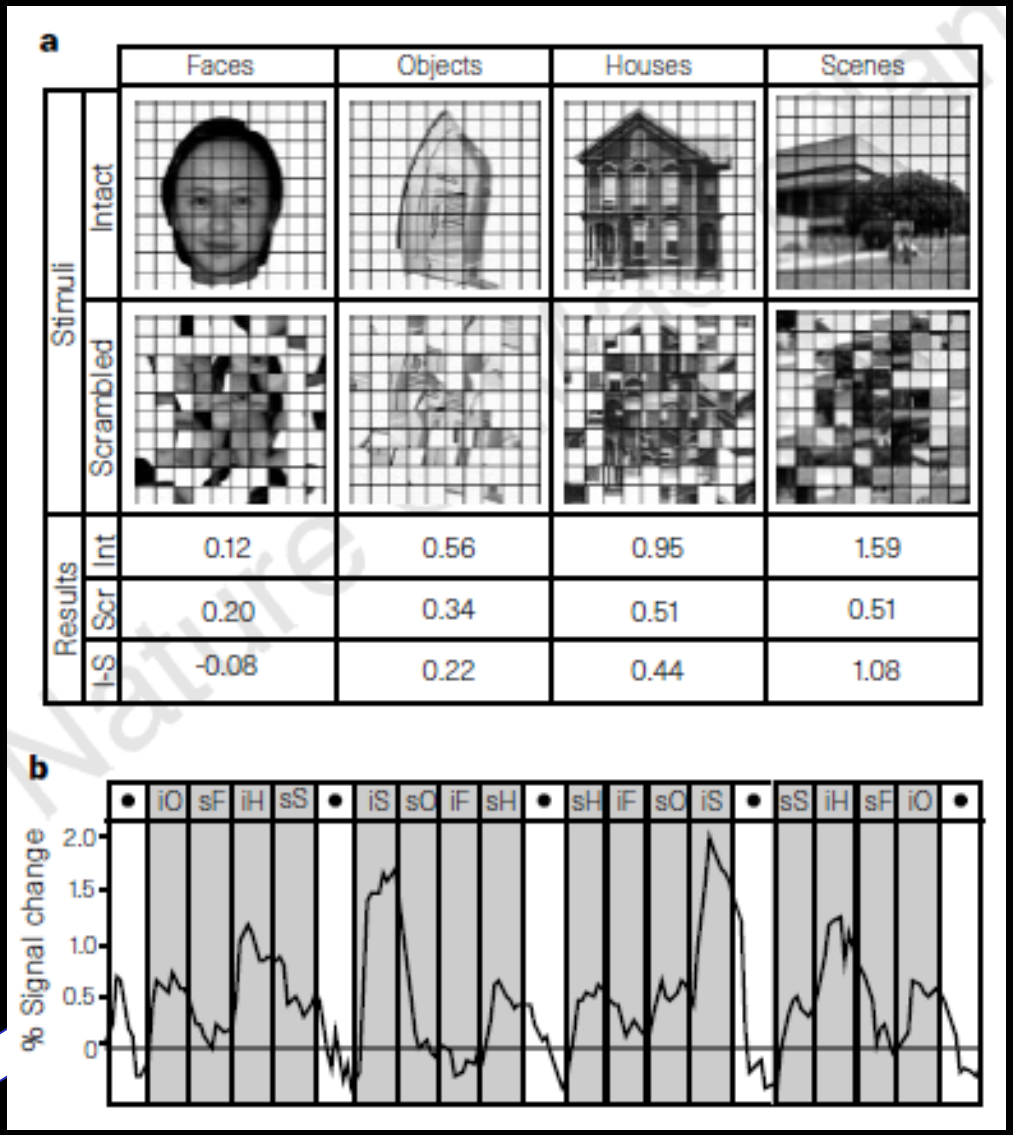
3D Obj vs Textures

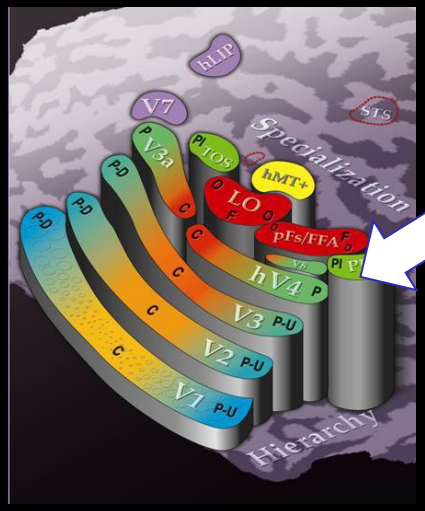
Unrelated to familiarity

Noise degradation

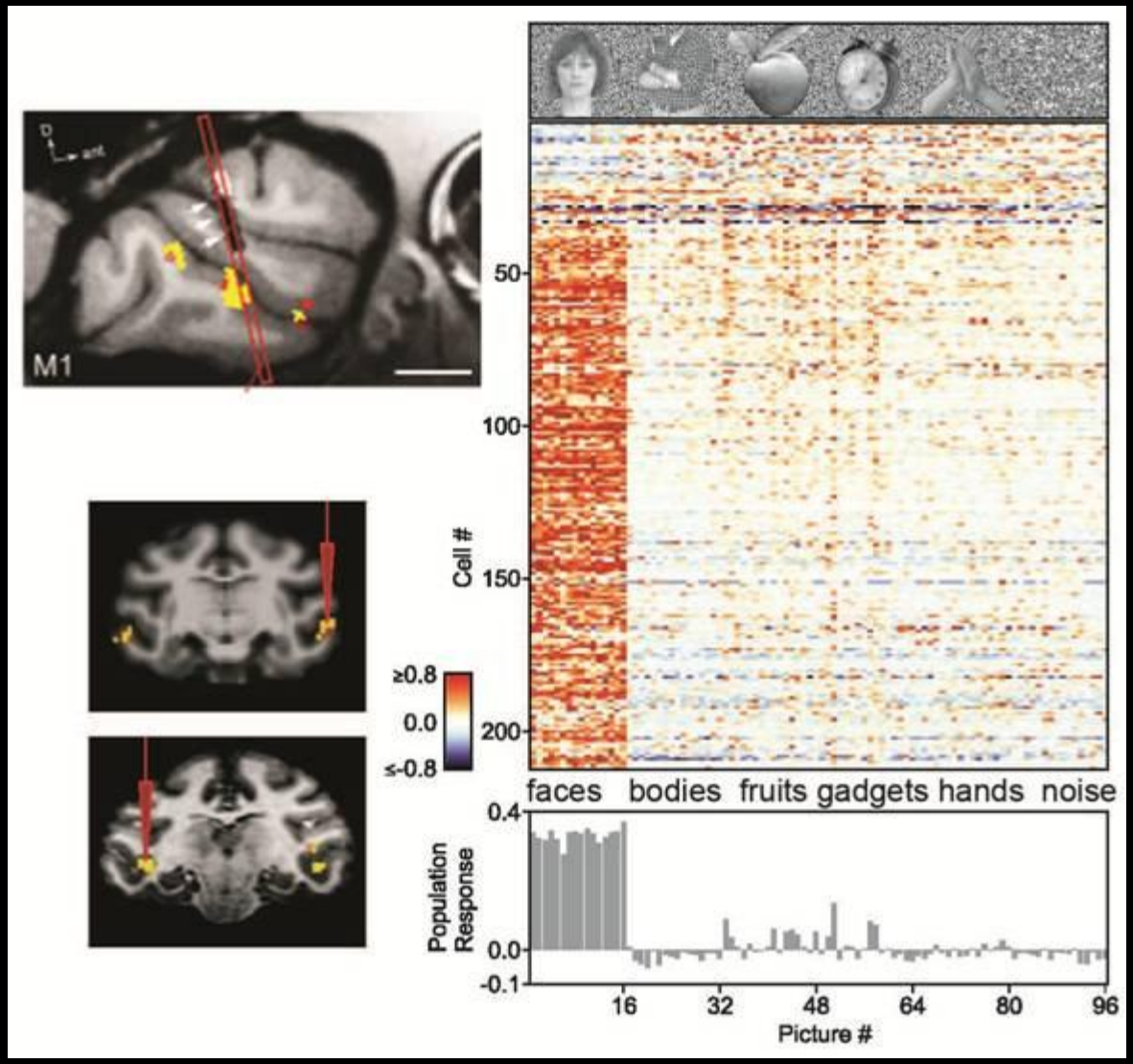


LOC "object" Area



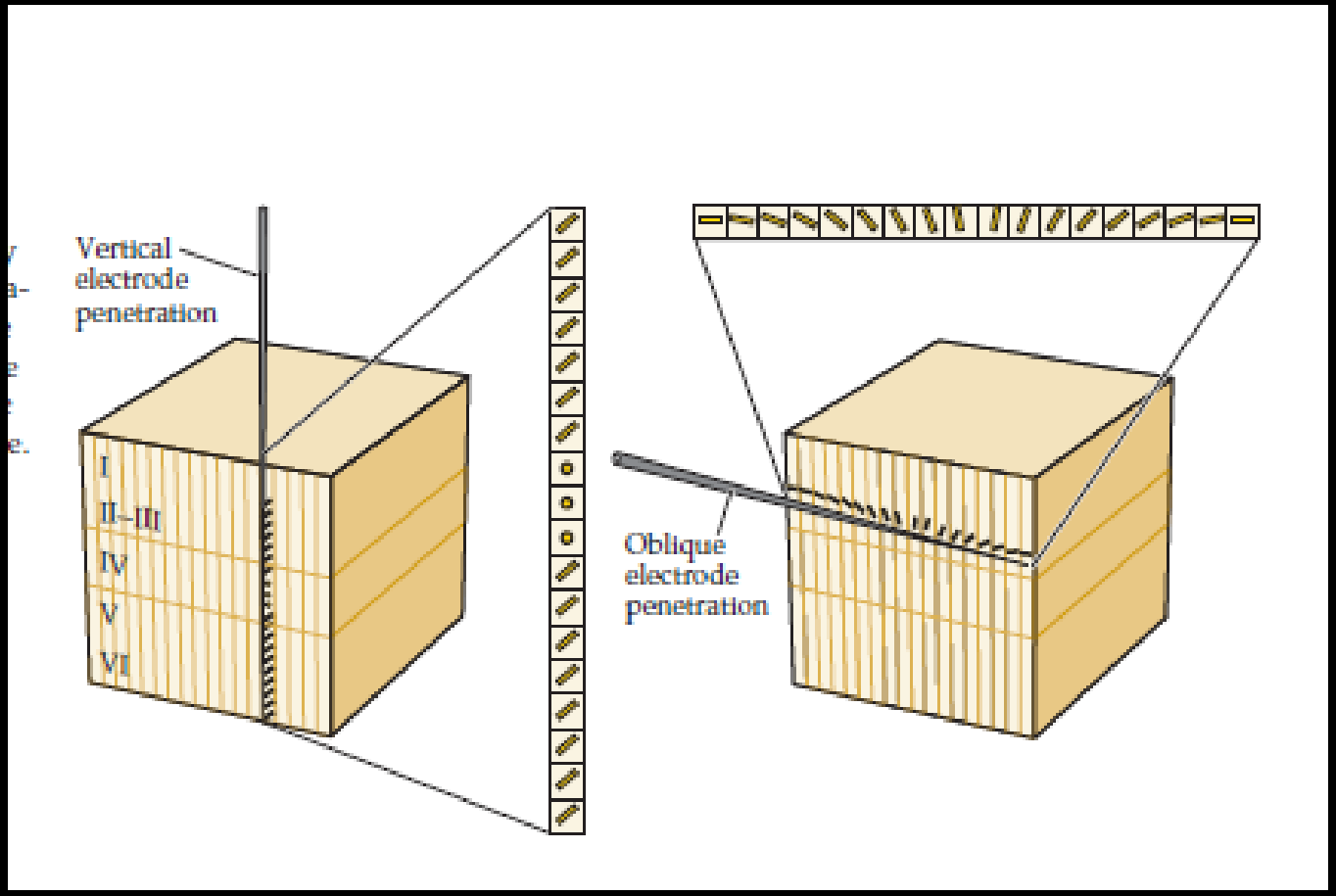


Parahippocampal "Place" Area

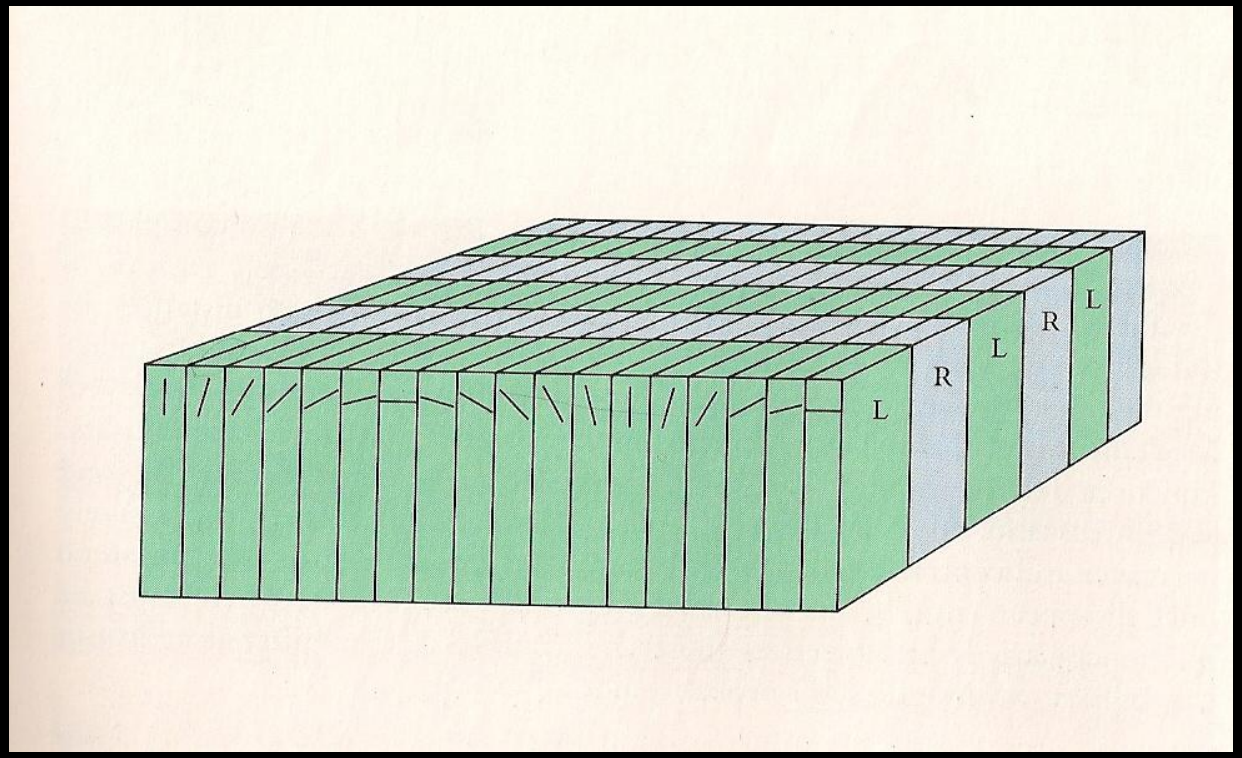


Face "Patches" are built of "face-neurons"

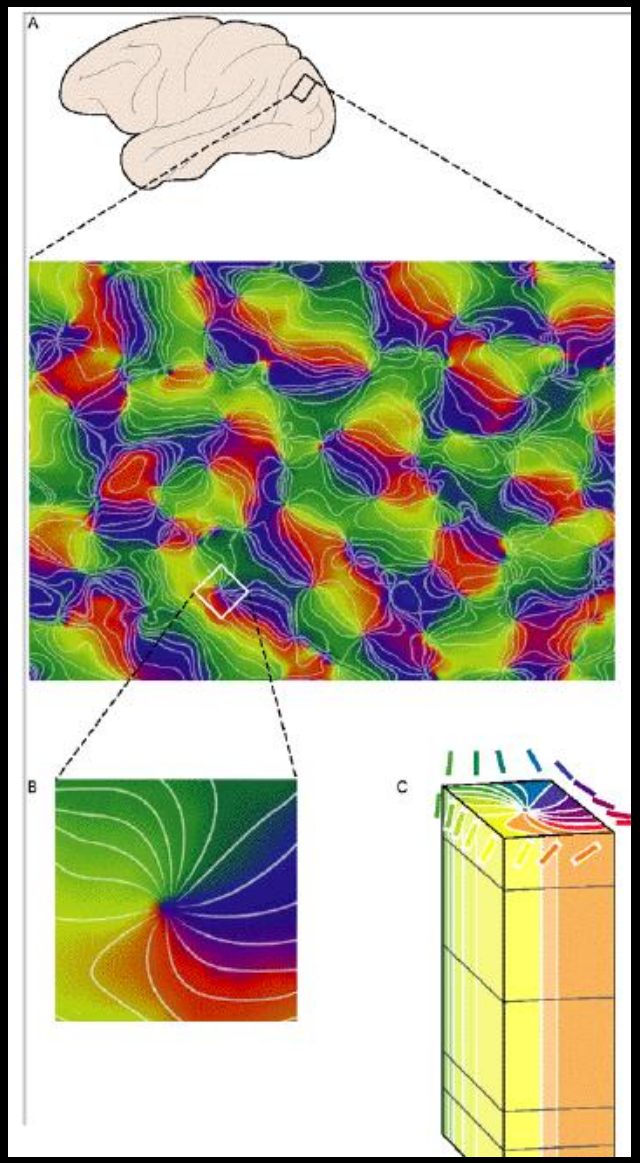
Columns: Within area subdivisions



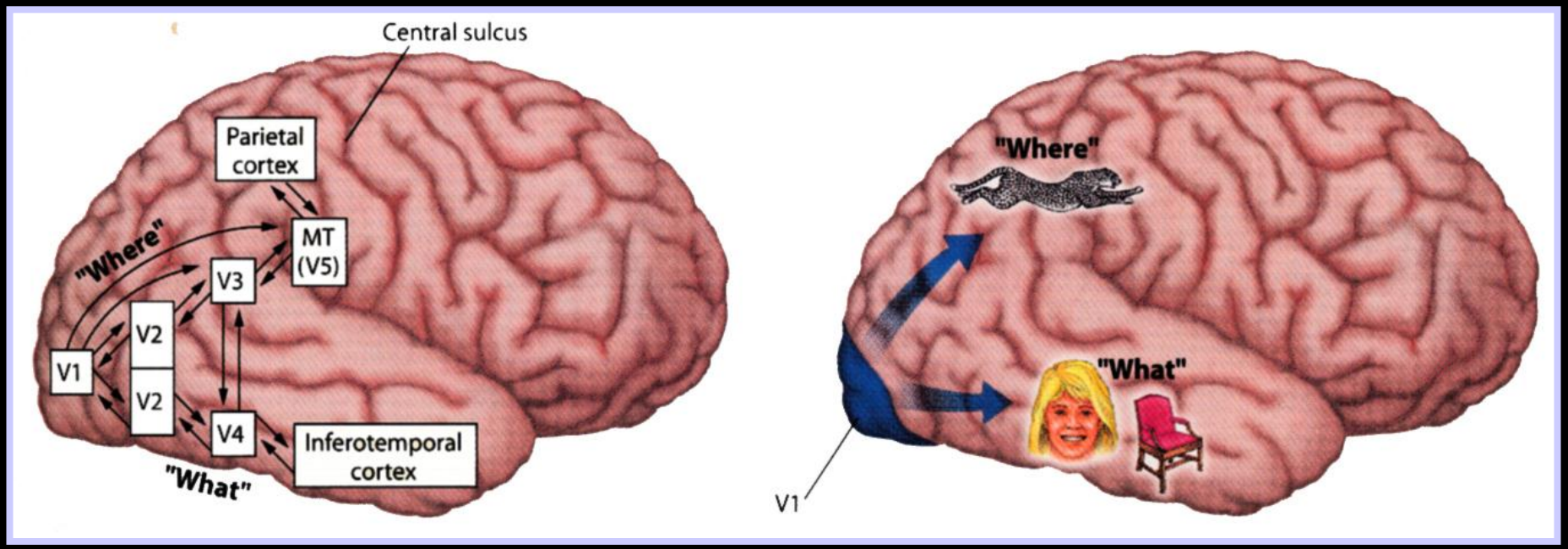
Orientation and ocular columns- the “hyper –column”

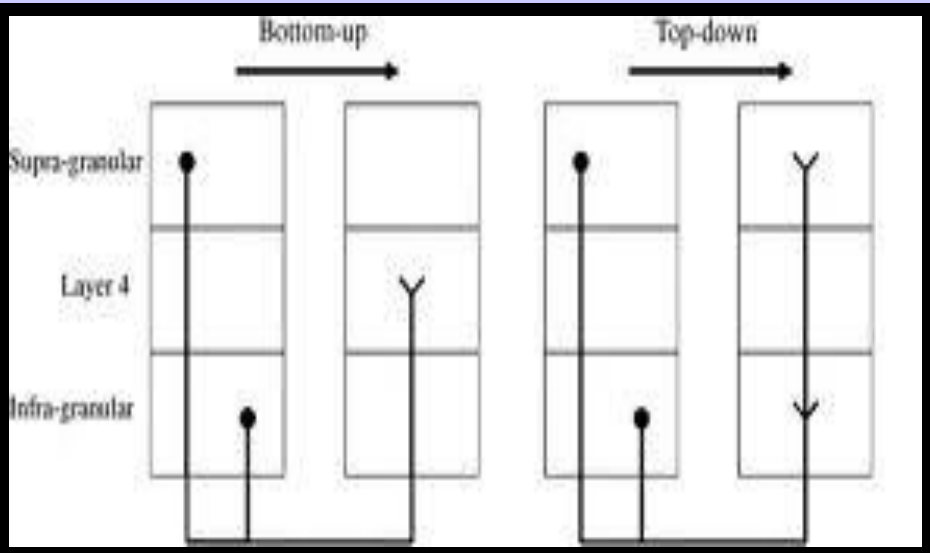


The true organization, "pinwheels"



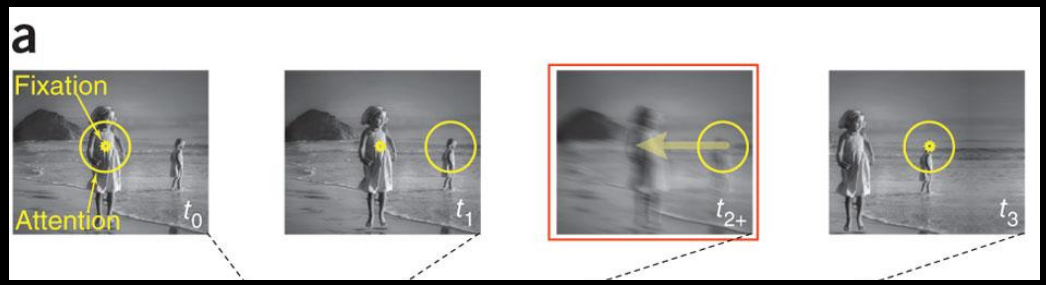
Top down information flow

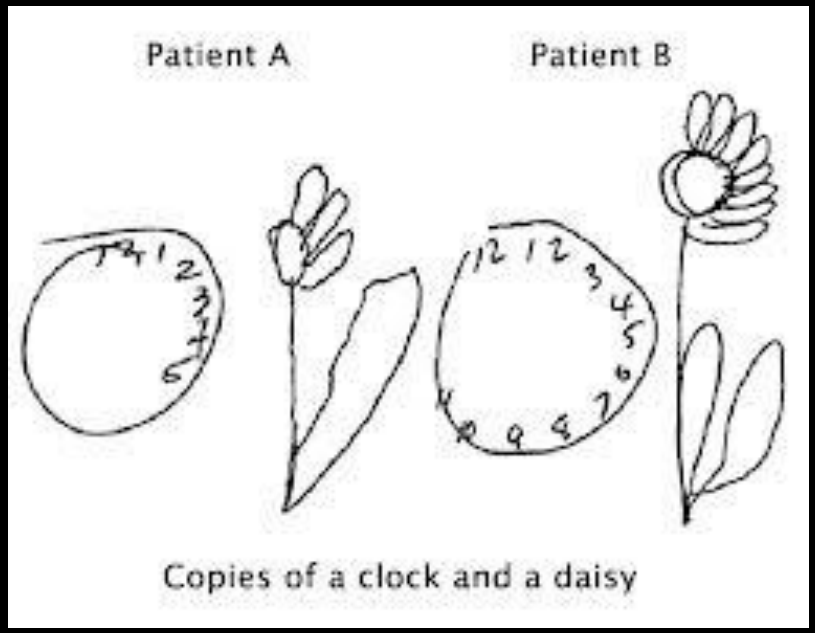





S

Two main kinds of visual attention:
a. Spatial attention





Copies of a clock and a daisy

Two main kinds of visual attention:
b. Feature-based attention