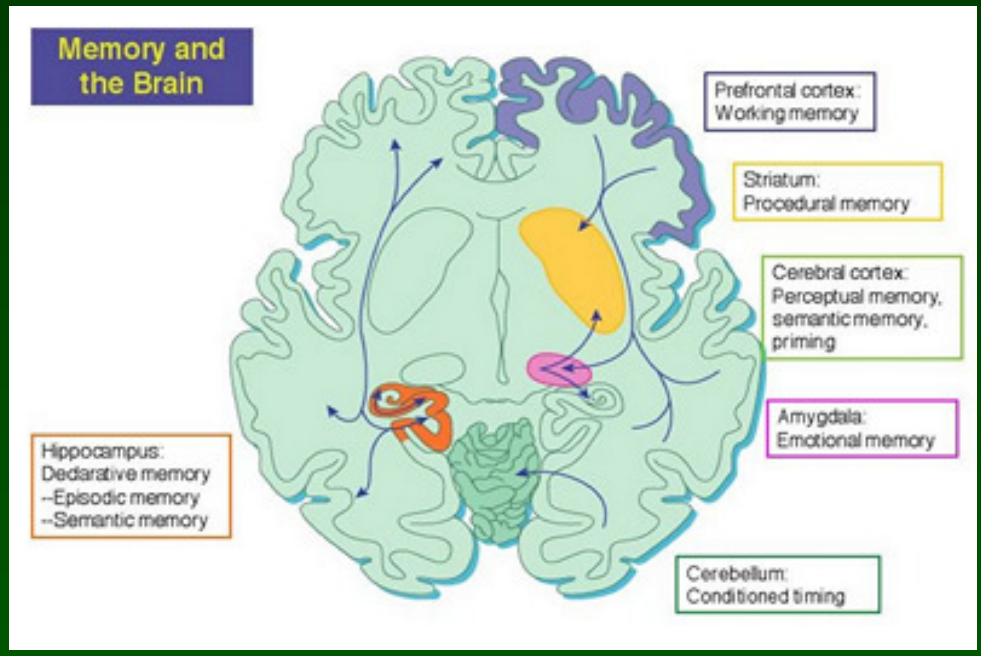
Selected topics in cognitive neuroscience and biomodeling

L10: Vision



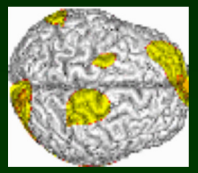
Włodzisław Duch

Neurocognitive Laboratory & Dept. of Informatics

Nicolaus Copernicus University, Poland

Google: Wlodek Duch

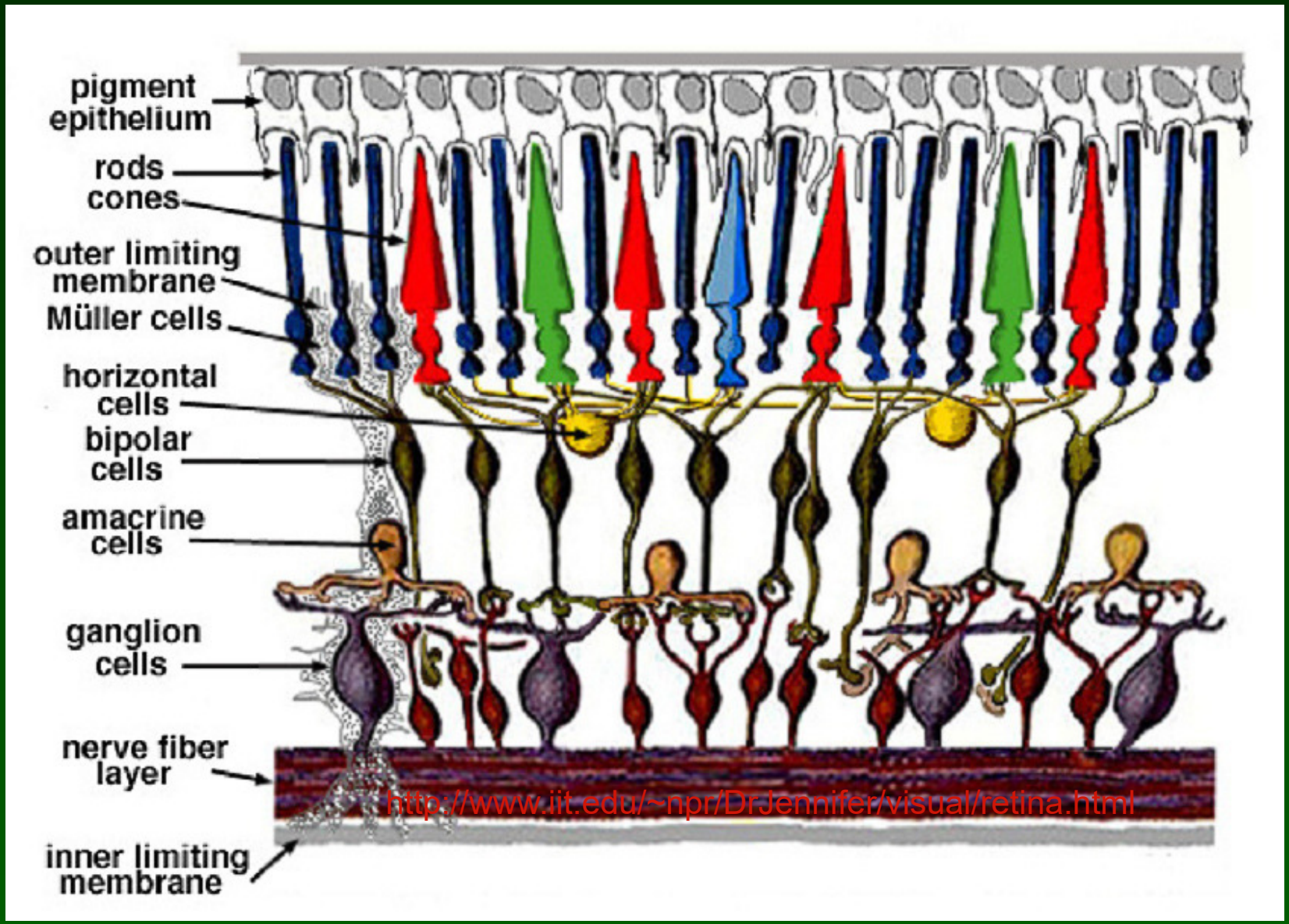
What it will be about



1. Visual perception
2. Functional organization of early visual cortex
3. Visual pathways
4. Visual illusions

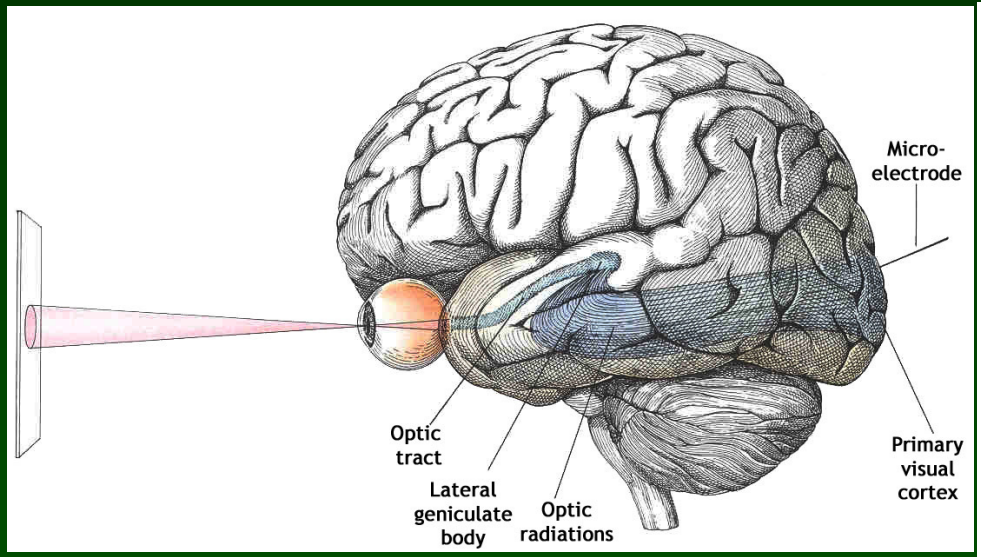
Visual perception

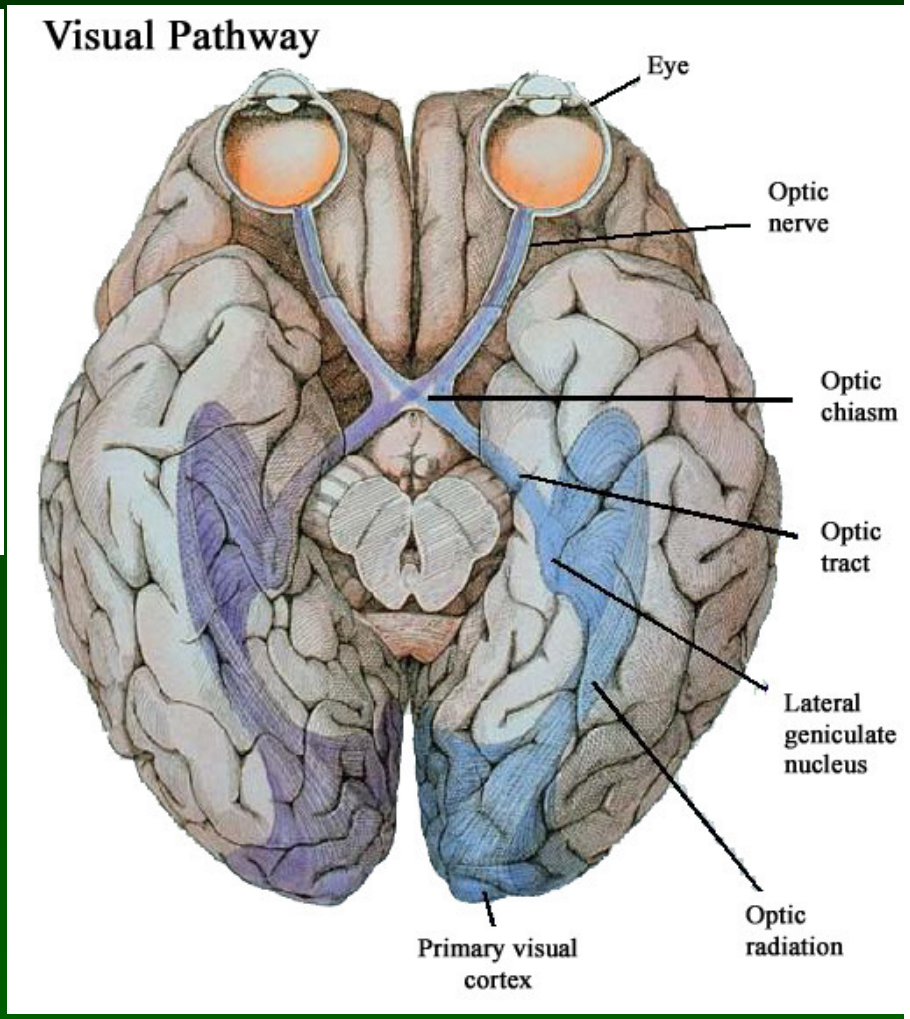
- Studies of human visual perception and neuroscience research have revealed many levels of perception.
- The human brain appears to process basic visual features, such as color, orientation, motion, texture and stereoscopic depth.
- **Knowing what and knowing where**: perceiving features, groups and objects in specific location, recognizing and acting.
- The activity of each neuron represents only a small part of the visual field. Neurons are highly tuned to specific features like a line at particular angle, specific color or direction of motion.
- Binding problem: how is the brain able to combine all types of information distributed across many cortical areas?
- The brain is able to organize basic feature elements into organized perceptual groups. Psychologists proposed the Gestalt laws of perceptual grouping, such as the laws of similarity, proximity, good continuation, common fate, etc.



Retina has quite complex structure, 6 mln cones, 120 mln rods. Signals from photoreceptors are processed by ~50 types of bipolar, horizontal and amacrine cells, before they reach the ganglion cells and are sent to LGN.

Visual pathways: back and forth



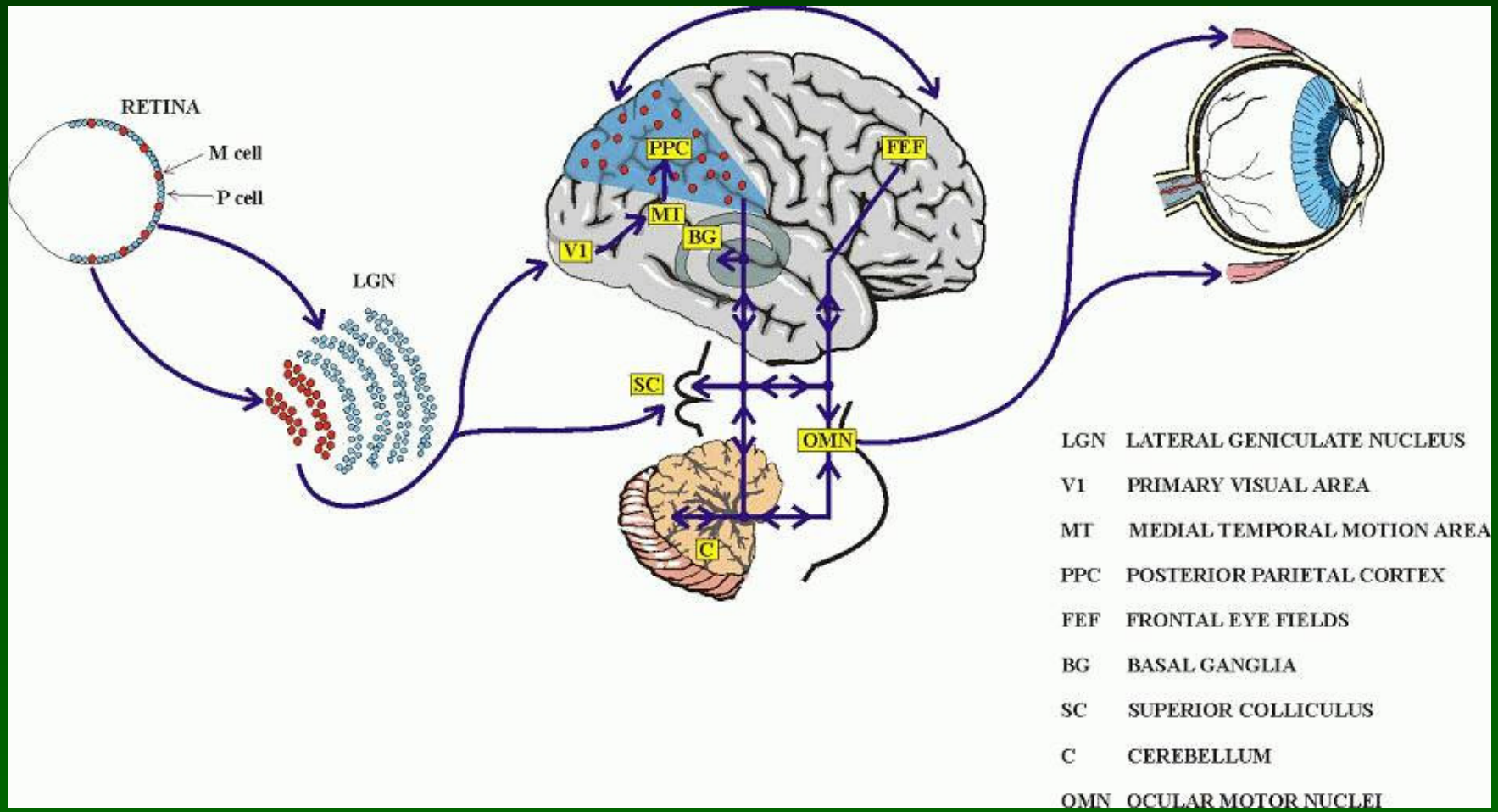


Retina => lateral geniculate nucleus (LGN)
of the thalamus (sensory relay),
=> area of the primary cortex V1,
=> higher levels of the visual system V2-V7
=> associative and multimodal areas
in parietal and temporal cortex,

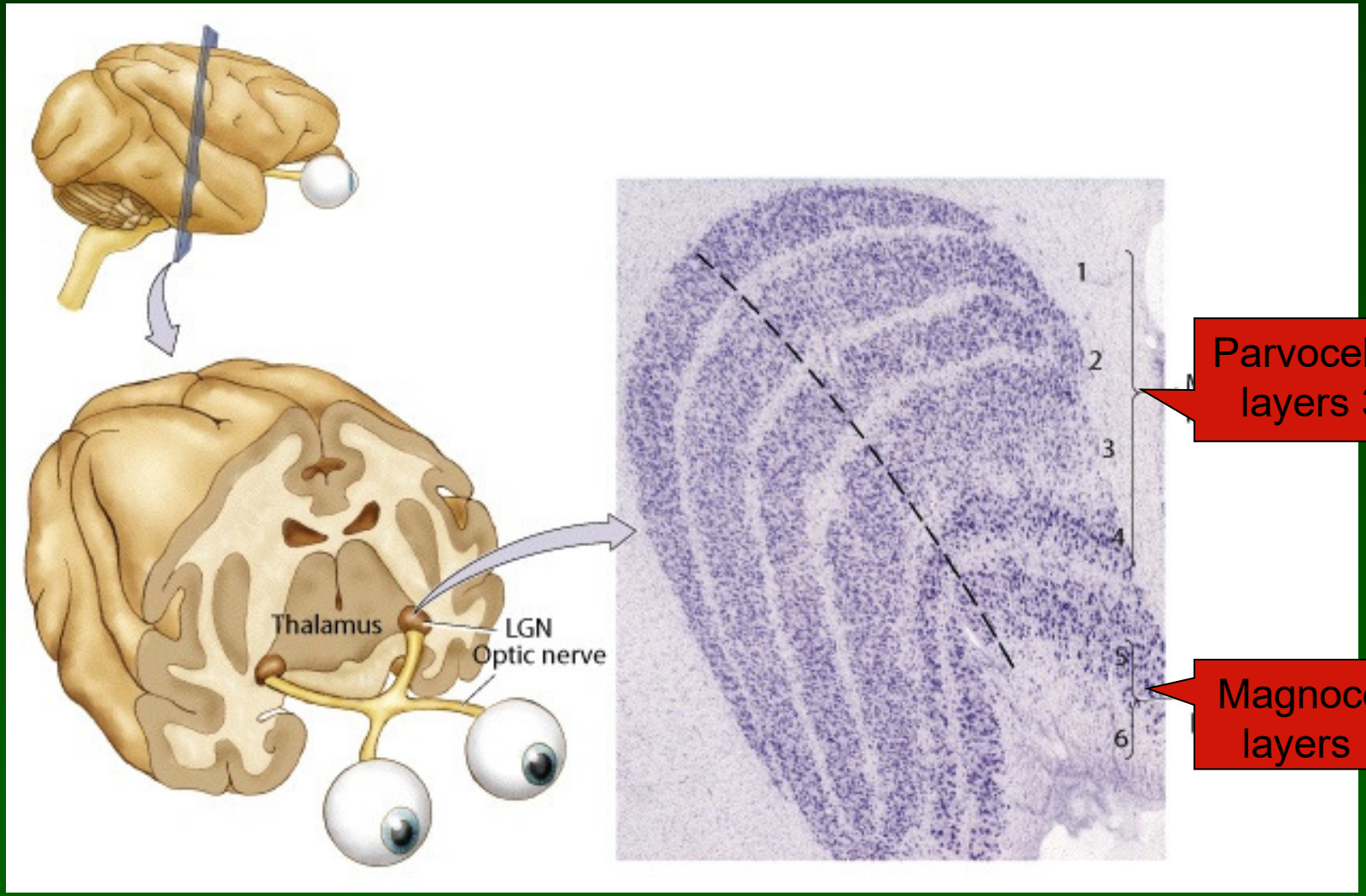
=> frontal motor and prefrontal cortex.

Functional organization

The hierarchical organization begins in the retina, passes through the lateral geniculate nucleus (LGN - part of the thalamus), reaching the primary visual cortex V1, from where it's distributed further.



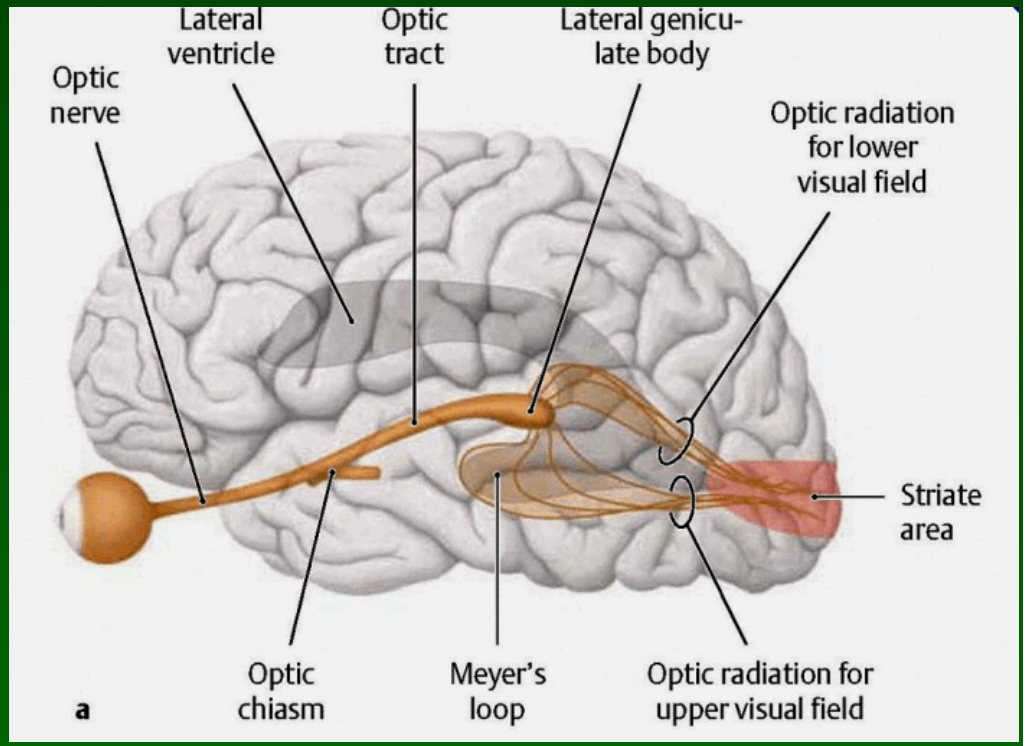
LGN of the Thalamus



Lateral geniculate nucleus

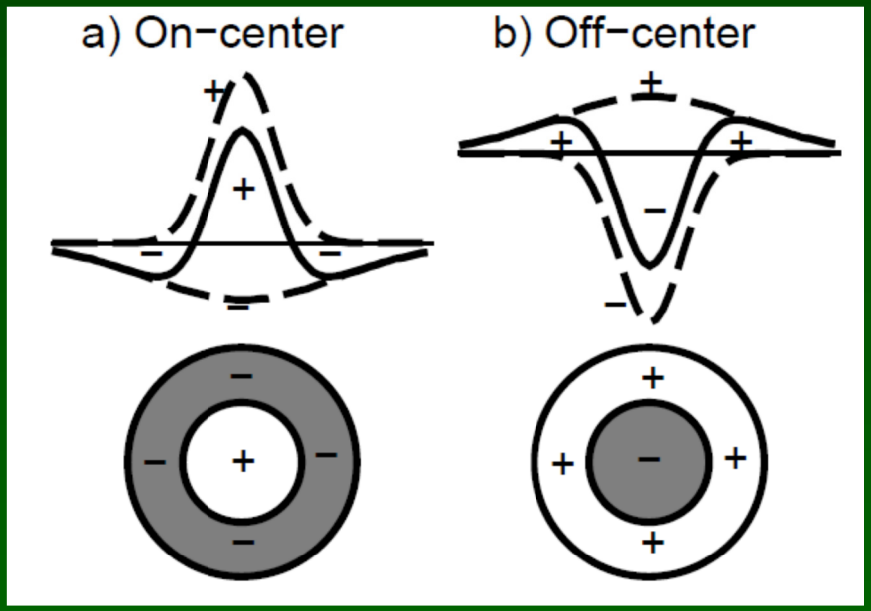
- Signal compression – partly already done by local processing in the retina.
- Different types of information is passed to different LGN layers.
- LGN is a part of intermediate relay station – all sensory signals (except olfactory) pass through different nuclei of the thalamus.
- Thalamus enables dynamic processing of information: steering attention and fast large-celled pathway reacting to motion.
- Retroactive projections V1=>LGN are an order of magnitude more numerous than LGN=>V1 (role - prediction).

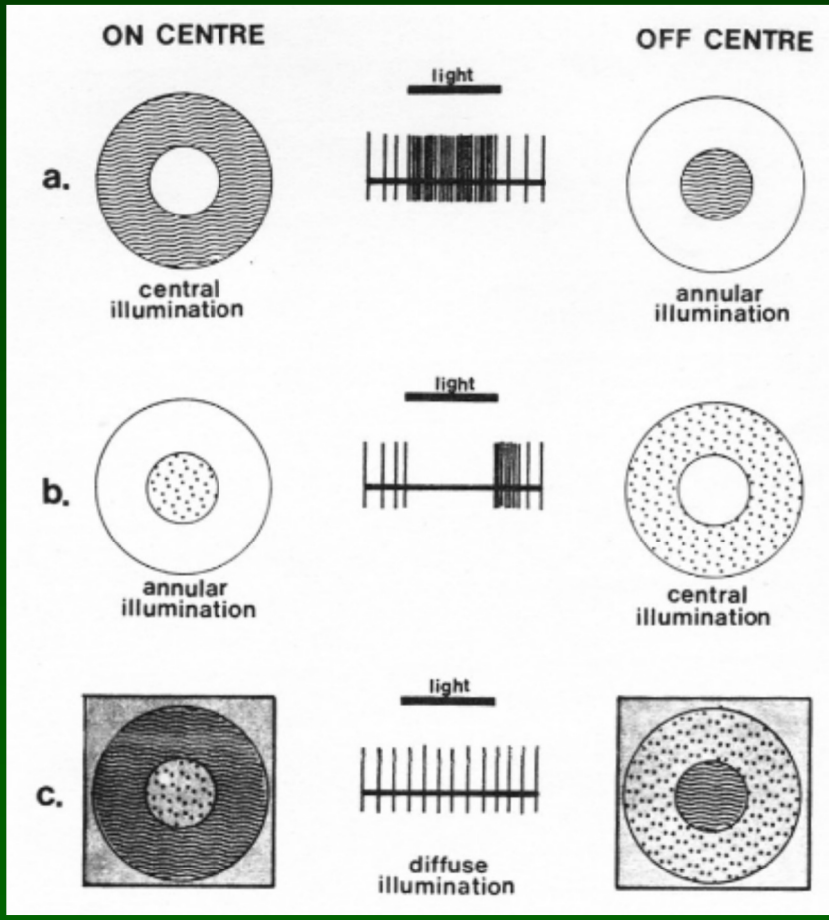
The competitive dynamic selects signals from the visual field, especially involving motion.



On/off-center surround cells

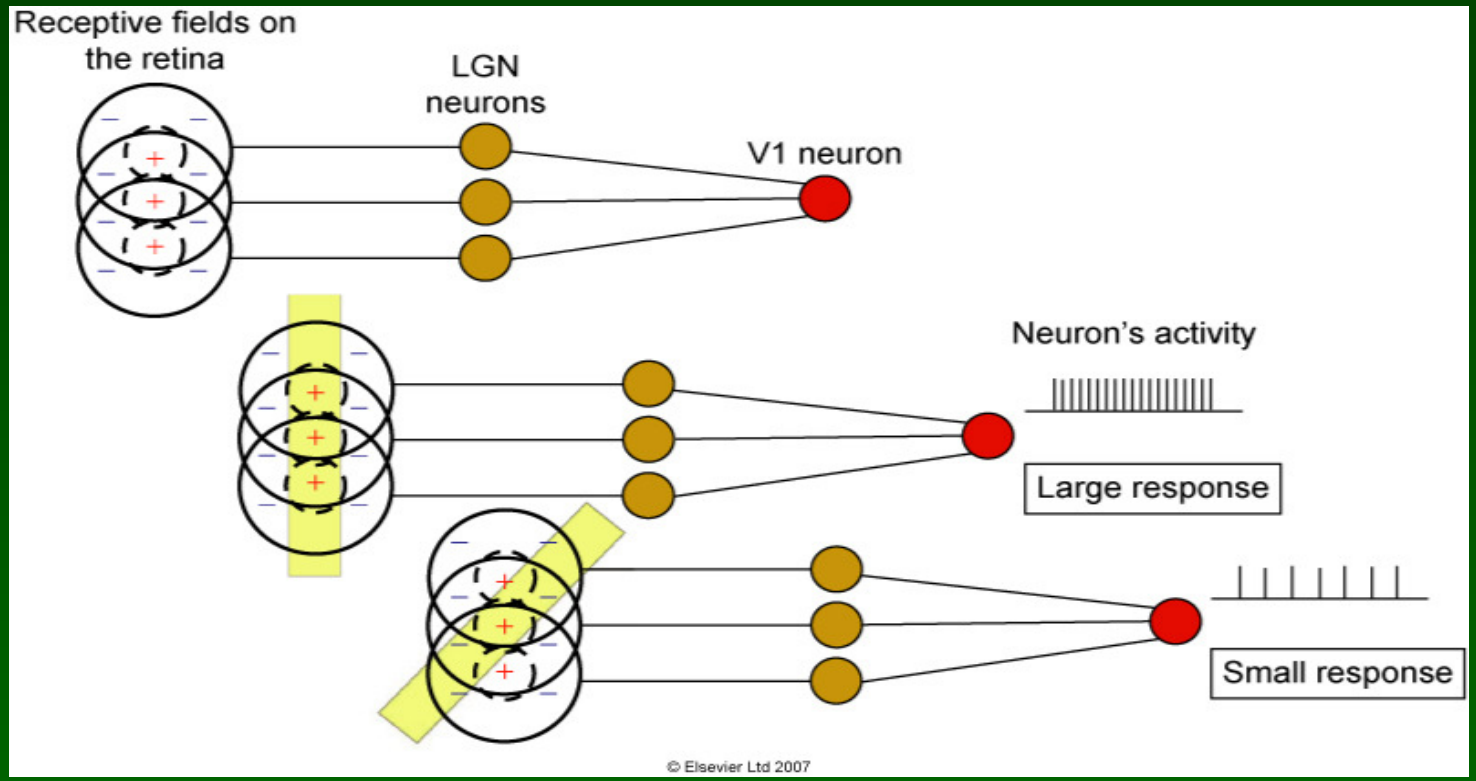
- No stimuli: both fire at slow base rate
- Stimuli in center:
  - ON-center-OFF-surround fires rapidly
  - OFF-center-ON-surround doesn't fire
- Stimuli in both regions: both fire slowly
- Stimuli in surround:
  - OFF-center-ON-surround fires rapidly
  - ON-center-OFF-surround doesn't fire





Primary visual cortex V1

- Neurons in V1 are sensitive to orientation, color differences, binocular disparities and direction of motion.
- **Orientation** helps to detect edges and contours, binocular disparities to perceive distance, color to identify objects in complex environment, and direction of motion is important to coordinate our movements.

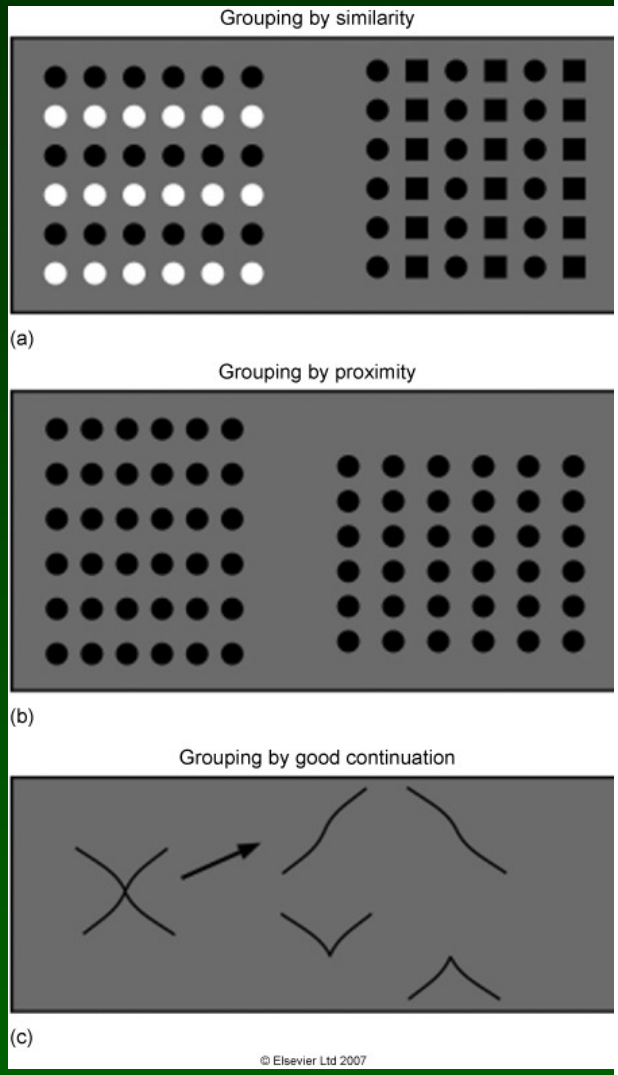


Perceptual grouping

- Grouping by similarity:
  White dots grouped with white dots, squares with squares.

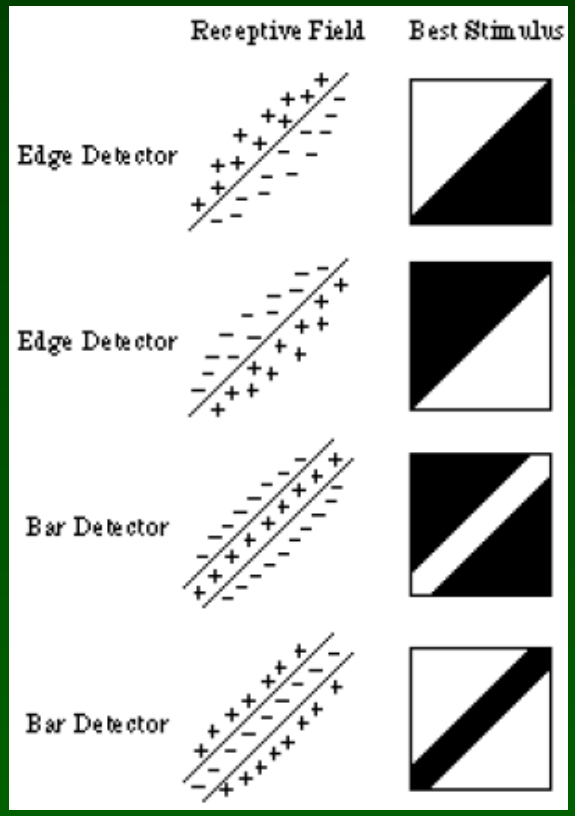
- Grouping by proximity:
  Here we perceive two separate groups of dots that are near each other.

- Grouping by good continuation:
  On the left we perceive a single object. When the same lines are separated we do not.

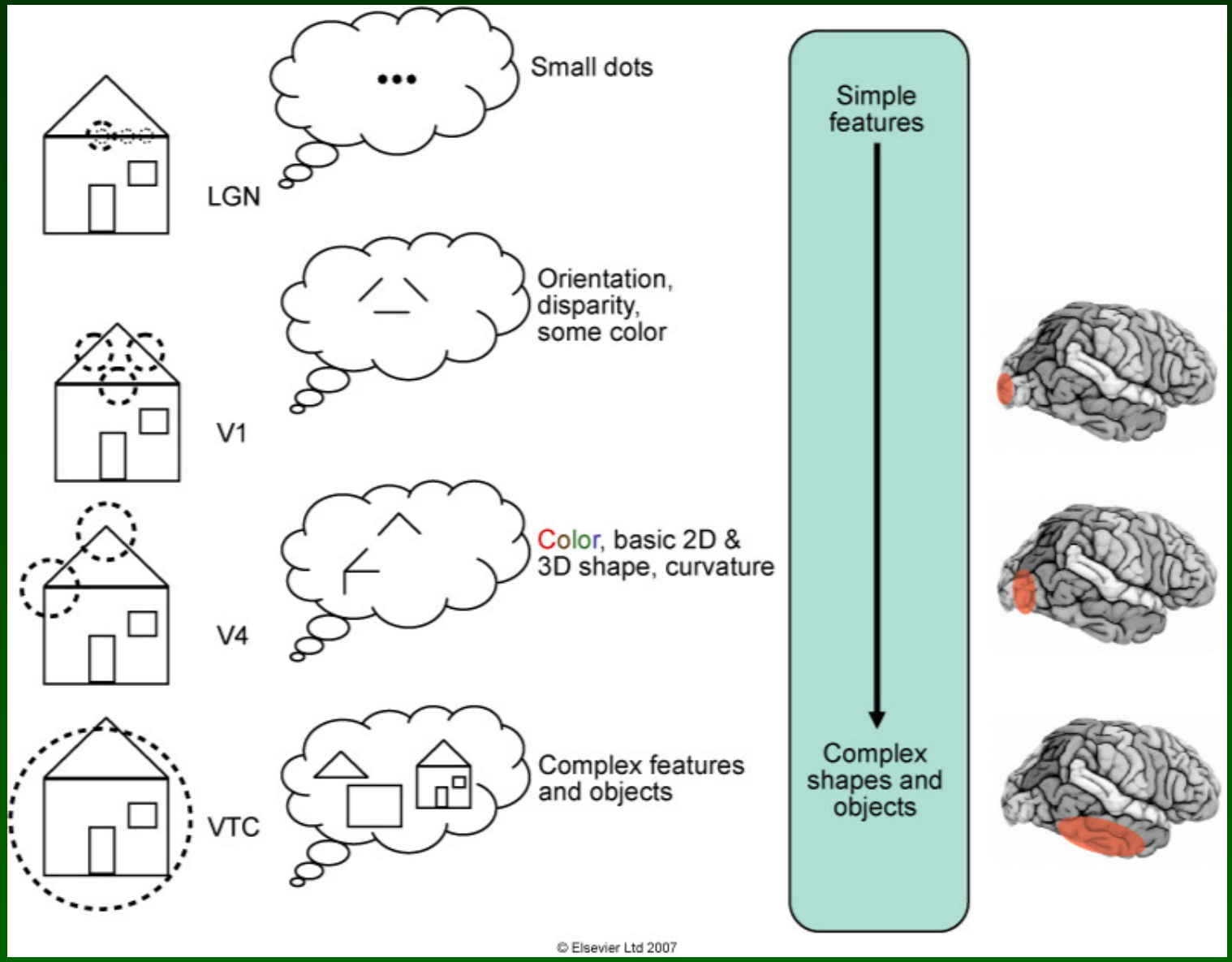


V1 edge representation

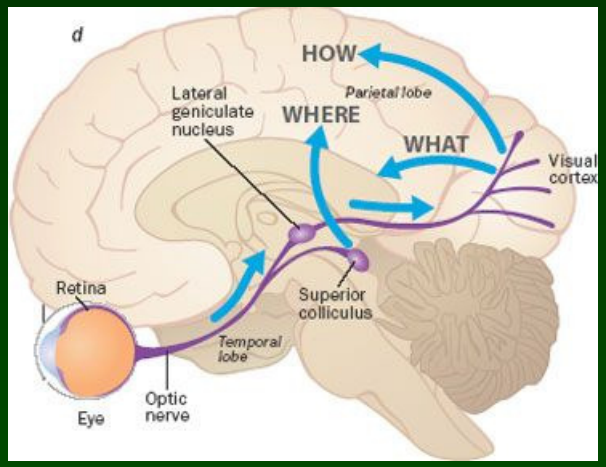
Oriented edge detectors in visual cortex are created by correlational Hebbian learning based on natural scenes.
What happens with information about color, texture, motion?



Hierarchy of visual processing



Two streams: where?/what?

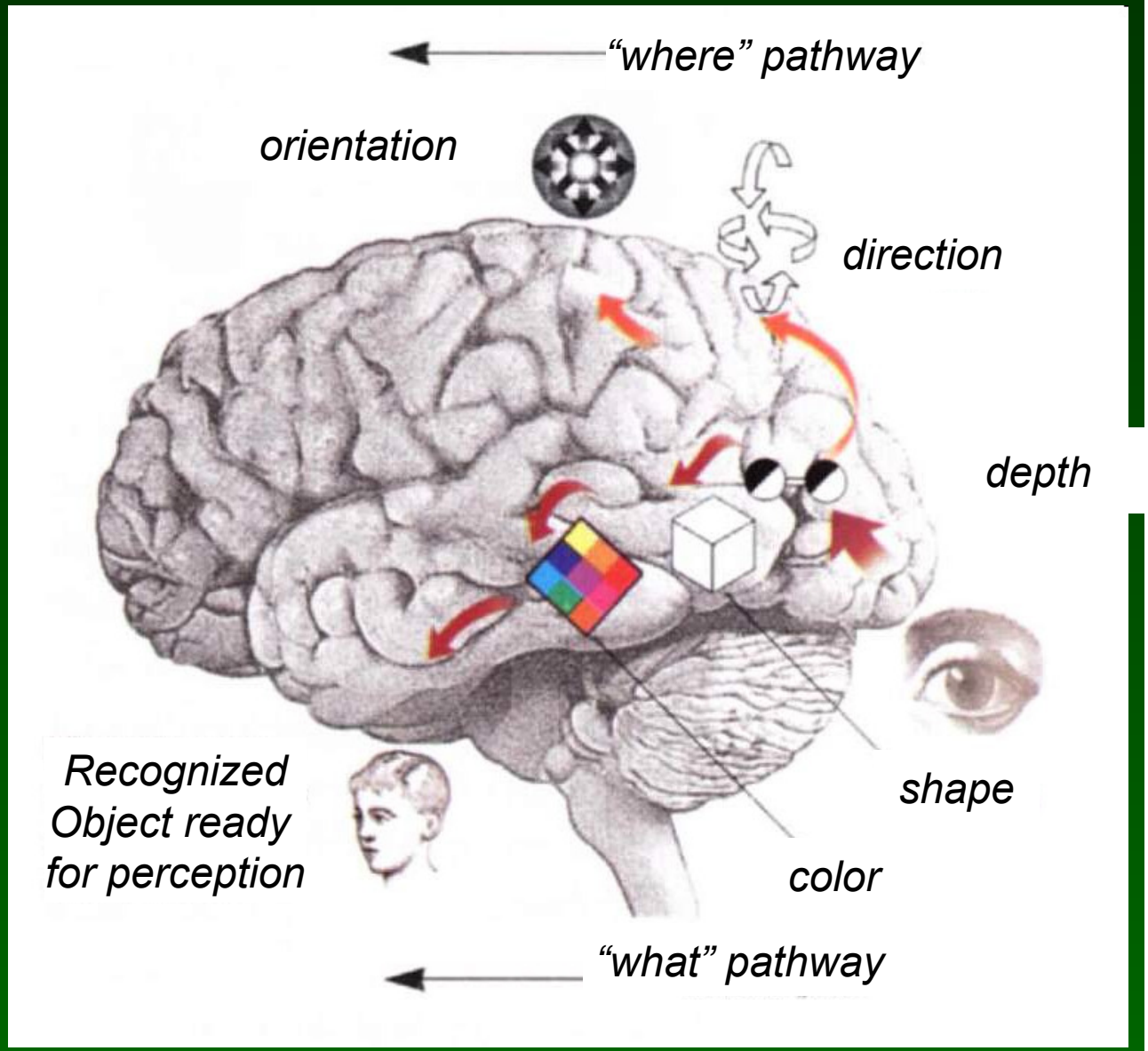


Another view (Milner, Goodale 1995):

Dorsal stream serves action: where, how.

Ventral stream serves perception: what, who.

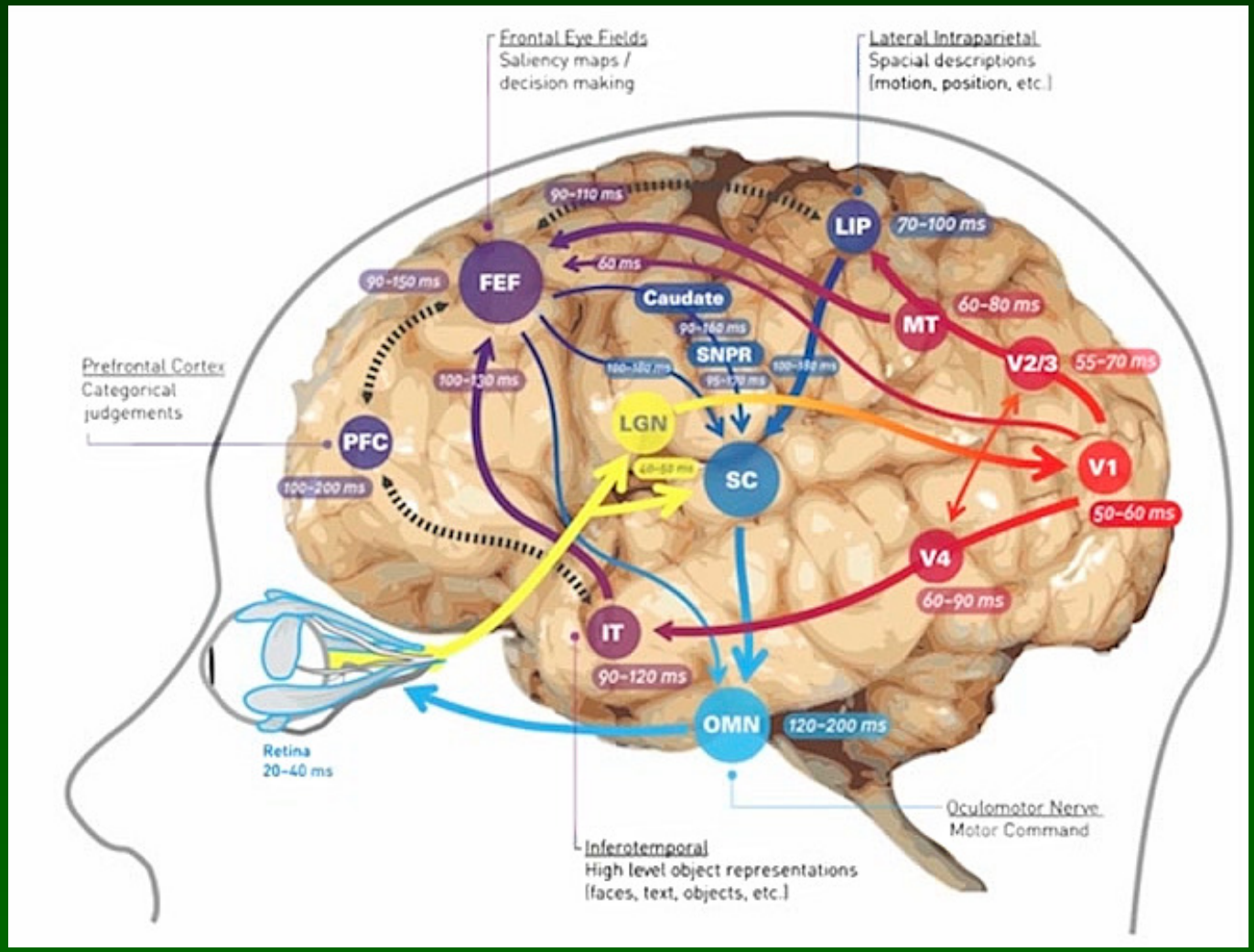
Ex. dissociation between two pathways leads to optic ataxia.



Visual latencies

A lot is happening between perception and movement, although it takes only 200 ms. Eye orientation may be even faster.

LGN can alarm limbic system after 50 ms.



Rough division of the brain regions involved in analysis of visual stimuli.
Felleman & Van Essen (1991).

Most of these regions extract precise information useful for some specific motor actions.

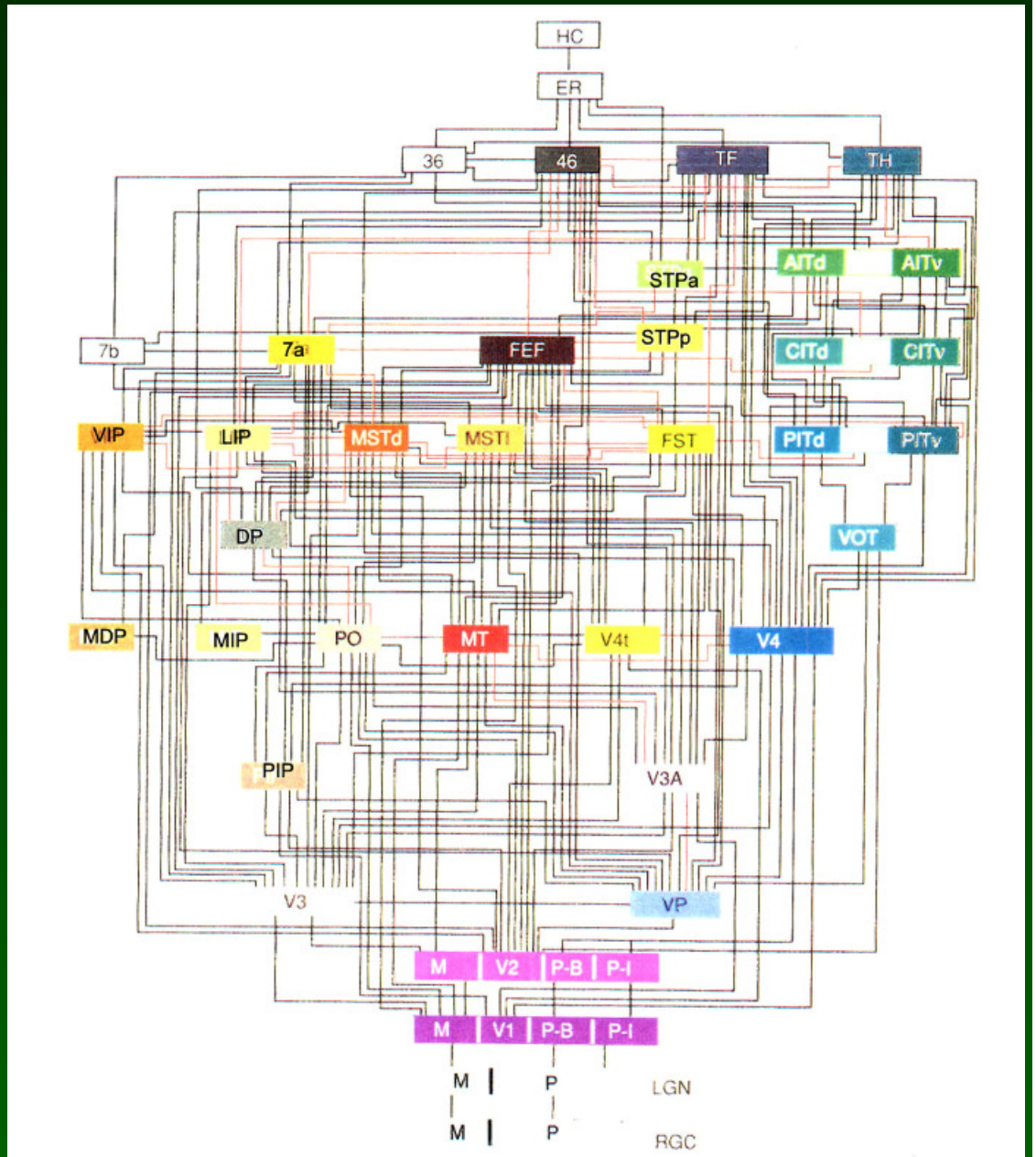


Figure 4. Hierarchy of visual areas. This hierarchy shows 32 visual cortical areas, shaded according to the same scheme as in Figure 2, 2 subcortical visual stages (the retinal ganglion cell layer and the LGN), plus several nonvisual areas (area 7b of somatosensory cortex, perirhinal area 36, the ER, and the hippocampal complex). These areas are connected by 187 linkages, most of which have been demonstrated to be reciprocal pathways.

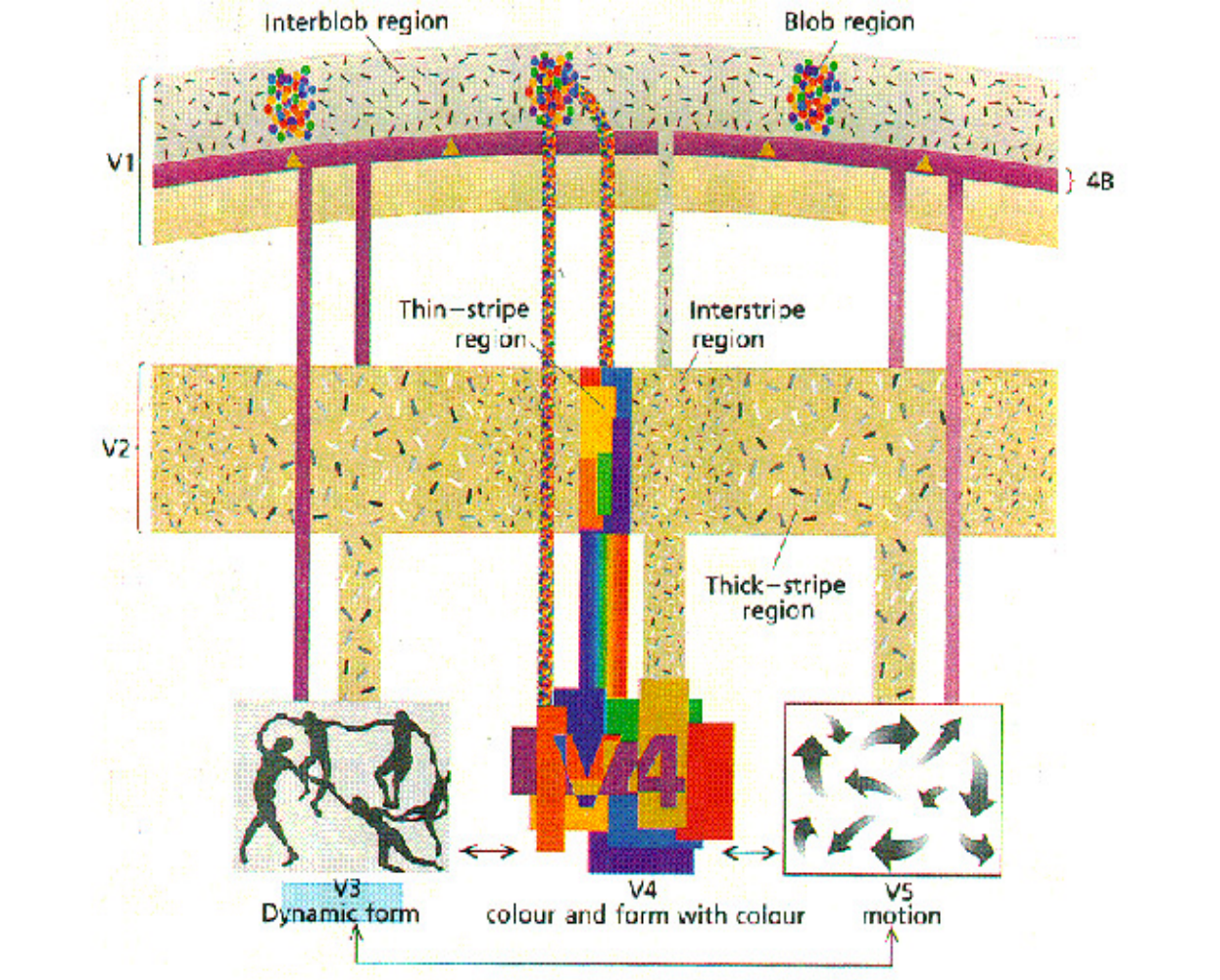
Dorsal pathway

Large-cell pathway (magnocellular): from the occipital lobe through the dorsal pathway to the parietal cortex. Fast, low contrast, motion, localization (PPC).

Arrives at the 4B layer in V1, from here to the thick dark stripes of the V2 region, analyzes information about object motion.

In V1, layer 4B => V5, localization in the field of vision, motion.

V5 stimulates the parietal lobe, PPC (posterior parietal cortex), regions BA7 and BA5; this enables spacial orientation, depth and motion perception, gaze orientation.



Ventral pathway

Small-cell pathway (parvocellular): the ventral pathway => the inferior temporal cortex (IT). Slower, high contrast, object recognition, complex objects.

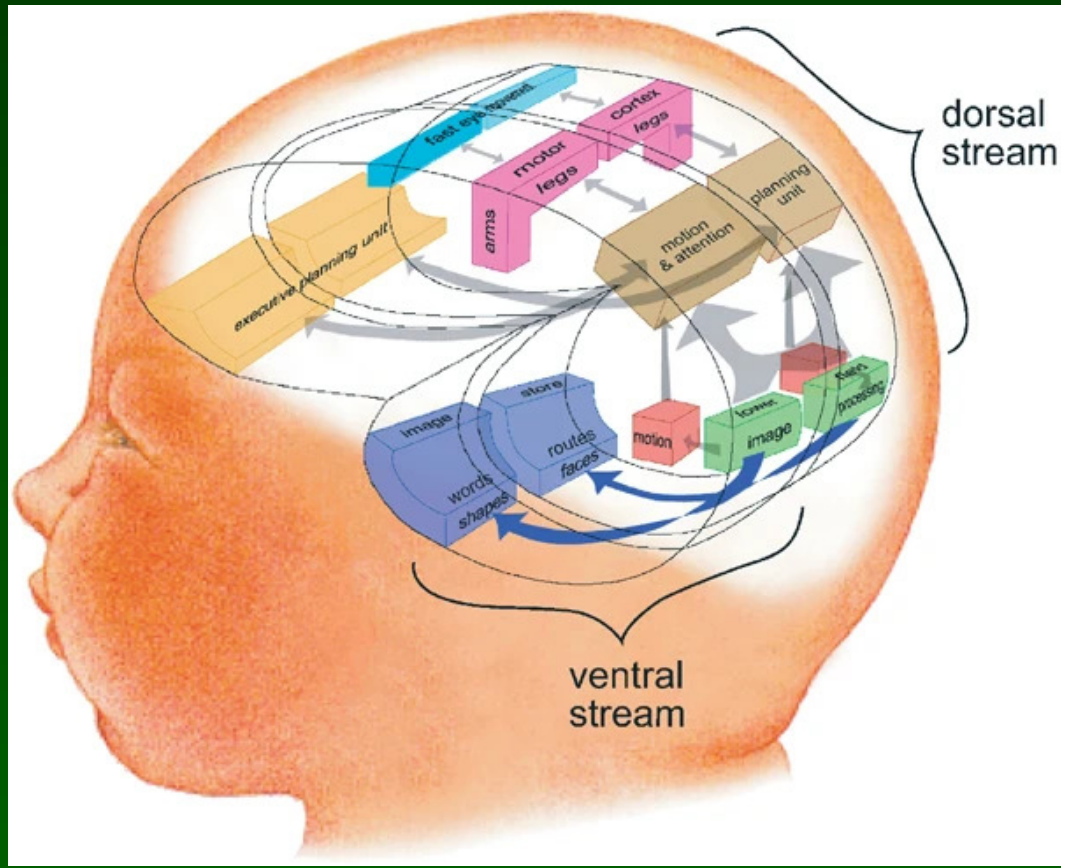
V1 => V2 interblob region, reacts to line orientation, gives a large visual acuity, without color.

V1 => V3 blob region, reacts to shapes; neurons in the dark stripes of V3 react to color.

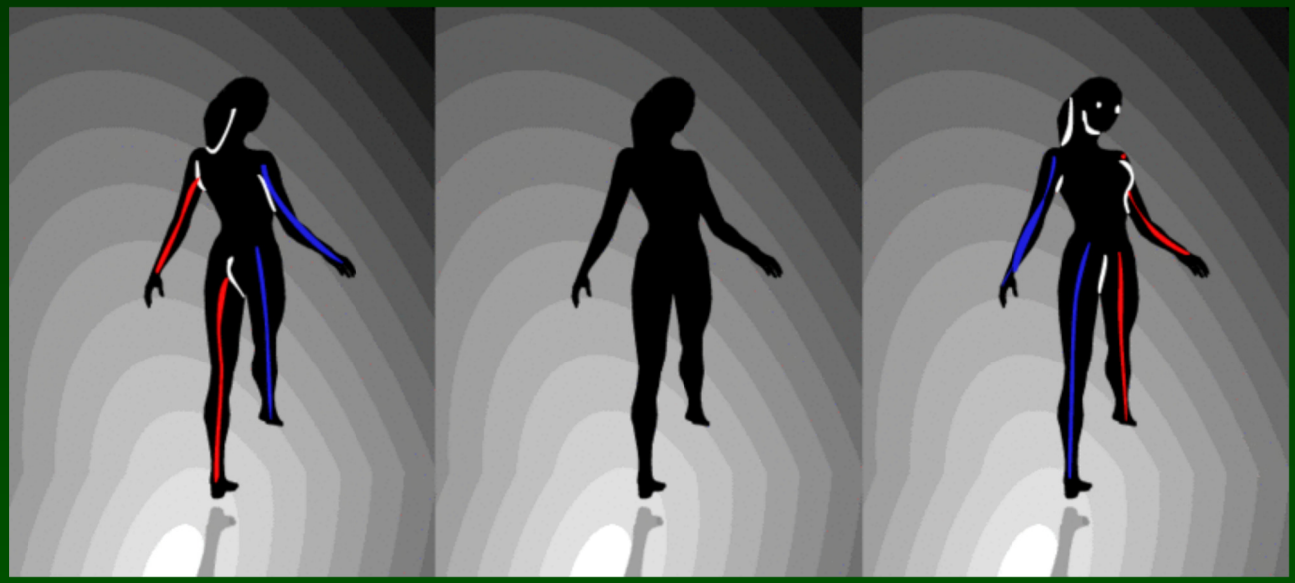
V2 => V4, main area of **perceived** color analysis, not just the wavelength.

Inferior temporal cortex (IT) has neurons that react to complex objects, shapes of words, faces.

Fig: G.N. Dutton, Eye 17, 289 (2003)



It is your mind that moves



“Whilst part of what we perceive comes through our senses from the object before us, another part (and it may be the larger part) always comes out of our own mind.”

William James, The Principles of Psychology, 1890

Can we believe what we see?

Amazing, but culture and our memory decides what you see here …