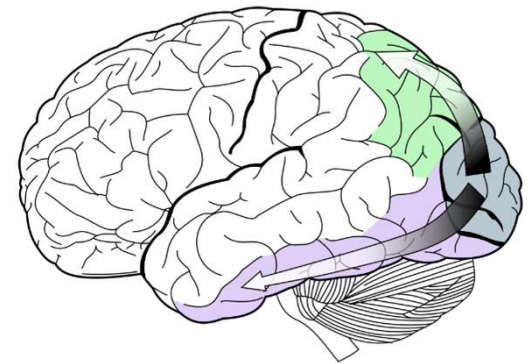


FAV, Talk no. 9, Visual Cortex,



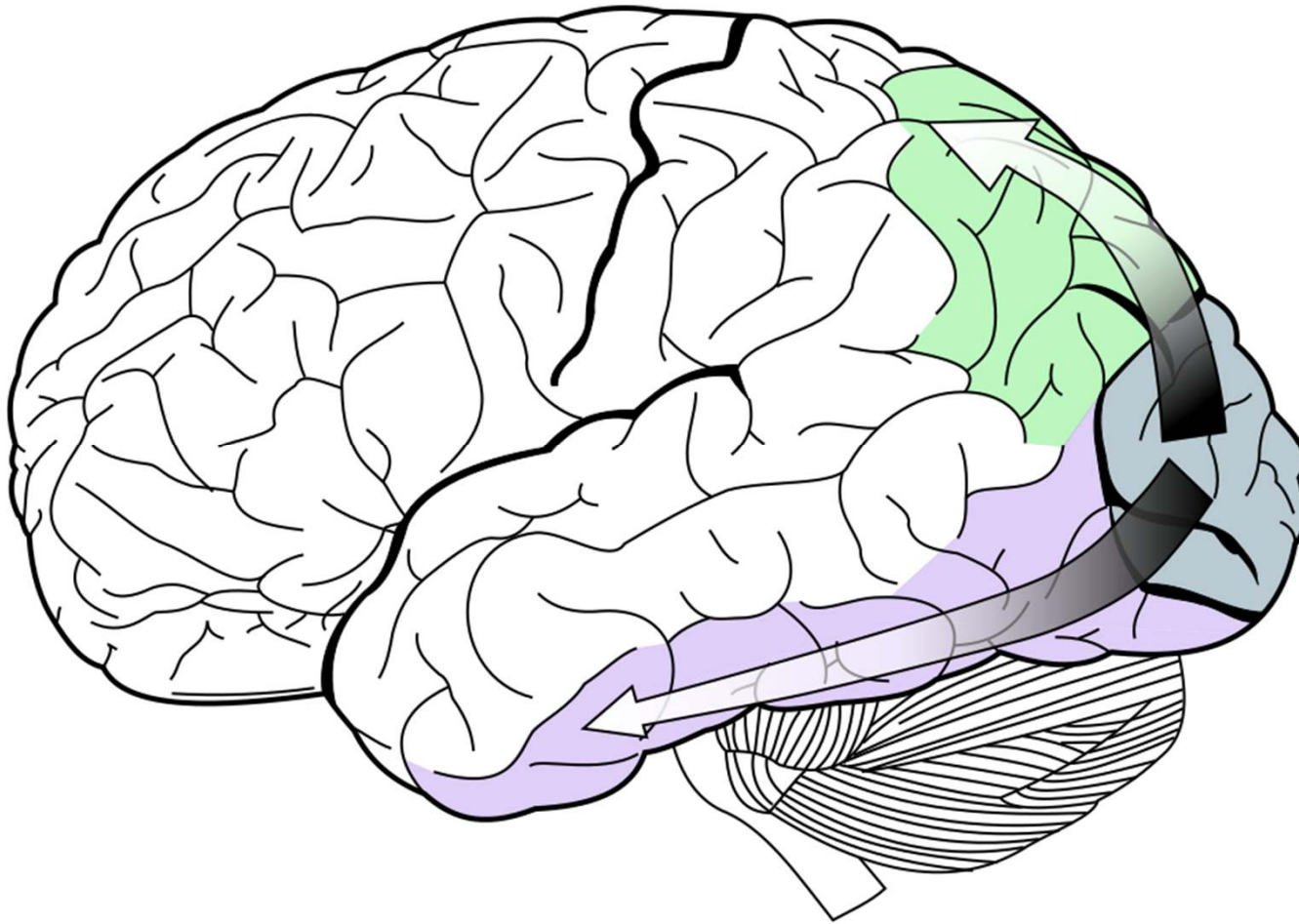
Petr Maršálek

Years 2020/ 2021/ 2022

Outline 9 – Visual Cortex

- Primary and Secondary Visual Areas
- Synthetic Overview: Image Processing, Receptive Fields, Physiological ‘Laws’
- Not All Visual Areas Contain Consciously Accessible Representation – Eye Rivalry
- Magnocellular and Parvocellular Pathways
- V1, V2, V3, V4, MT (=V5) and Other Areas
- Modalities of Vision Based on Cortical Processing
- Features not Residing in Unique Areas: Stereo Disparity, Color
- Features Located To Areas: Dorsal (Location and Motion) versus Ventral (Object) Streams
- Controversies
- Processing Hierarchy of the Visual Cortex

Ventral and Dorsal Stream



THIS PANEL IS A SPECULATIVE ATTEMPT TO CLASSIFY BRODMANN AREAS DIFFERENTLY

“Binary Trees of Brodmann Areas” and Beyond Brodmann Areas

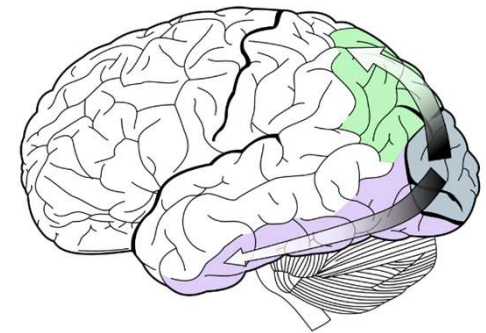
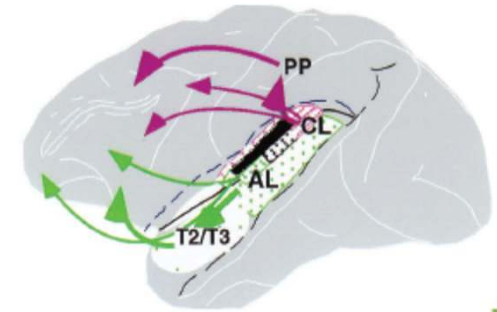
- Bit 1: (Left) vs. (Right) Hemisphere
- Bit 2 and 3: (Motor/ Frontal Lobe) (Somatosensory/ Parietal L.)
- Bit 2 and 3: (Auditory/ Temporal L.) (Visual/ Occipital L.)
- Bit 4: (Primary) vs. (Secondary) Sensory projection areas
- Bits 5, 6, 7: subdivisions of visual/ sensory areas
- Sensory Domains: Bits 1 and 7: (Left/ Right) vs. (Bottom/ Top) Extensions, Retinotopy, Spatial Maps
- Bit 8: Temporal encodings: subcortical
- Bit 9: Other modality encodings – Hippocampus (Archi-cortex)/ space navigation, and so on.

Olfactory cortex and Hippocampus (Archi-cortex), Olfactory Bulb (Paleo-cortex), Vestibular Cortex (Part of Temporal lobe), Cortical Projections, Remaining senses: Olfaction, Taste and Touch

CORTICAL MICROCIRCUIT

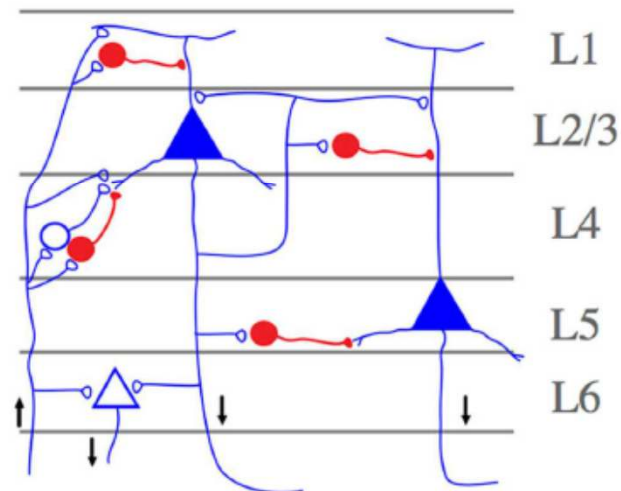
Neocortex and Other Cortices

(Paleocortex, Olfact. Only: 3 Layers, Archicortex,
Olfact. and Hippocampus,
3 or 4 Layers)

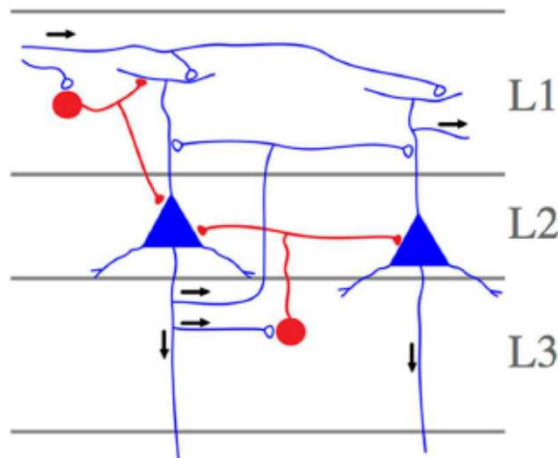


A

6-layer circuit

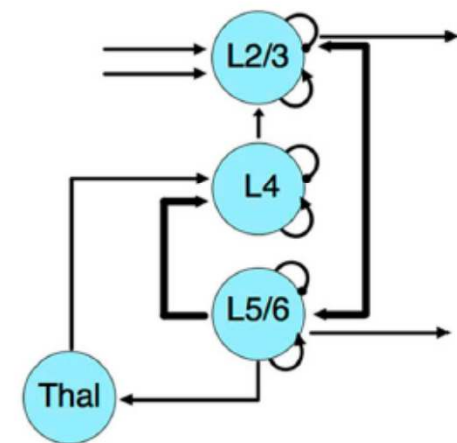


3-layer circuit

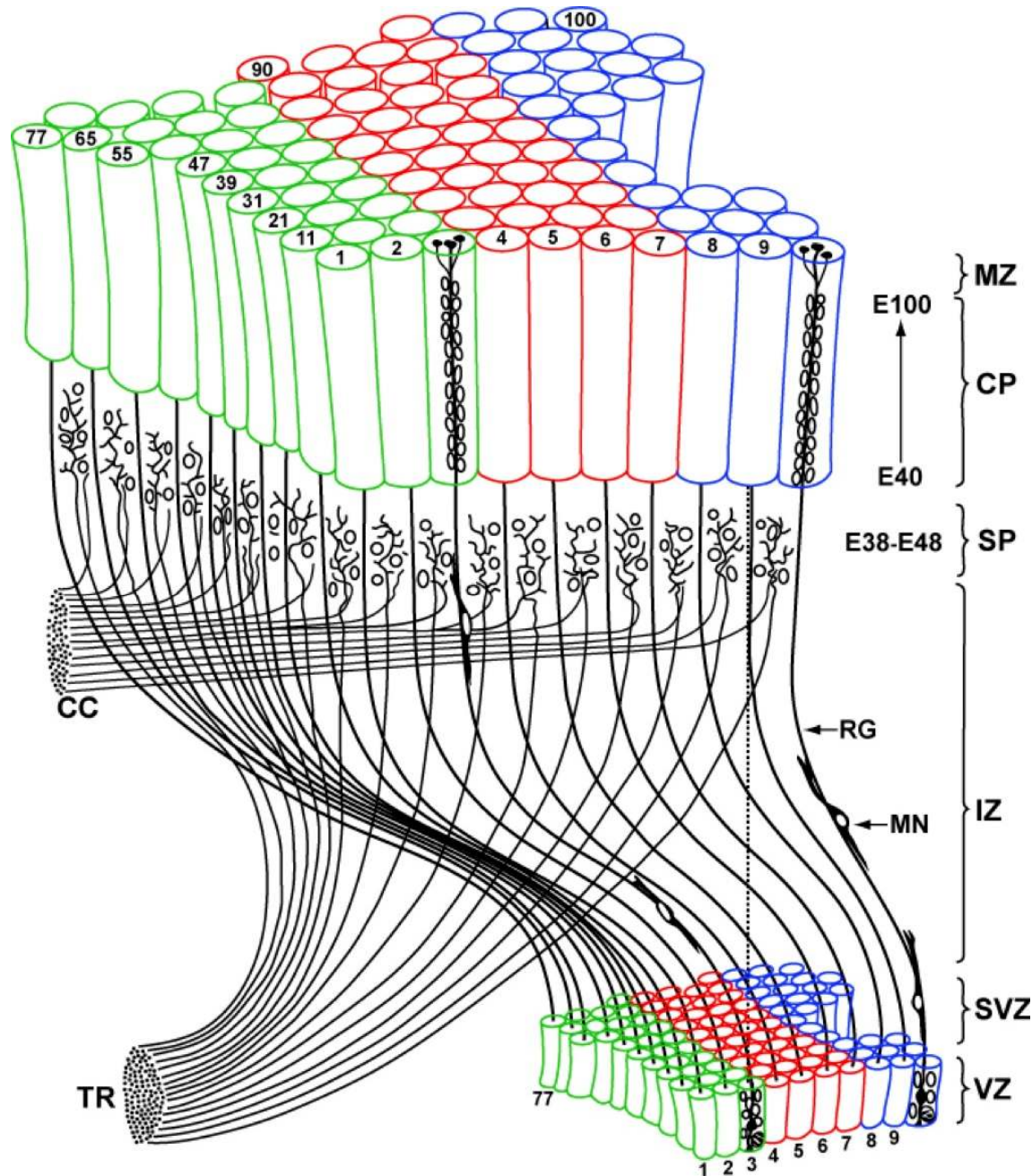


B

Canonical circuit



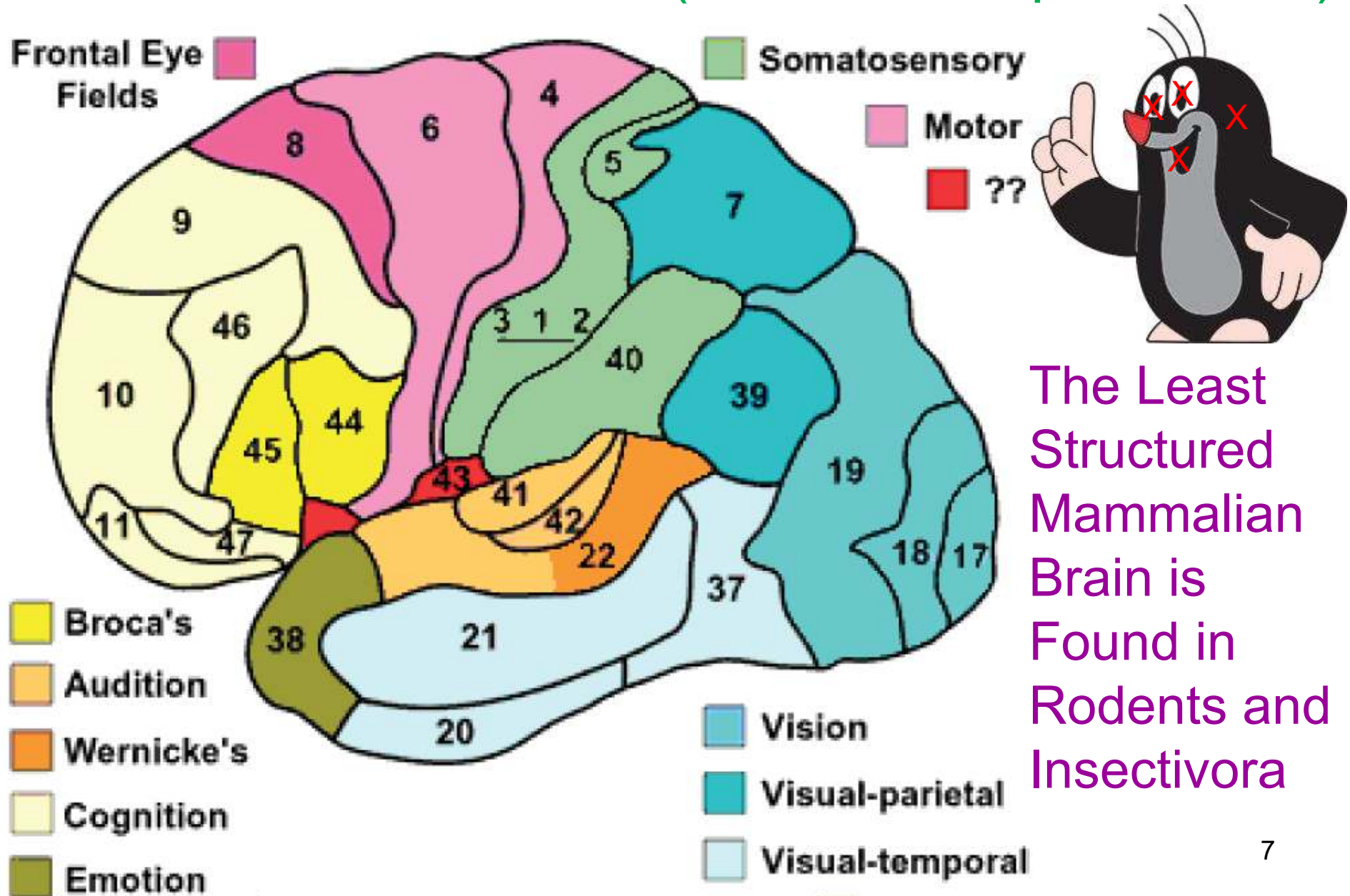
Cortex Consists of Columns as Functional Units



Area of Cerebral Cortex Correlates with the Size and Surface Area of the Mammal

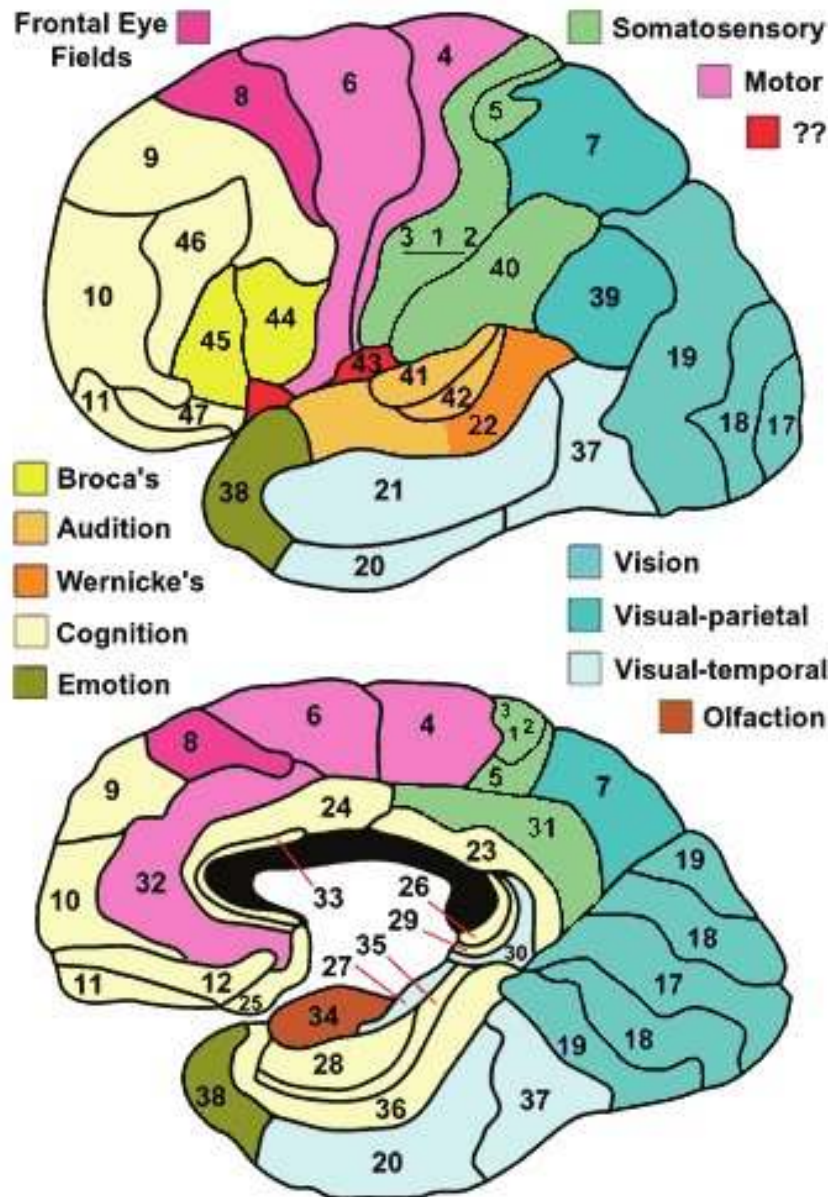
CC = Cortico-Cortical Connections,
TR = Thalamic Radiation

Brodmann Areas (Outer Hemisphere Part)



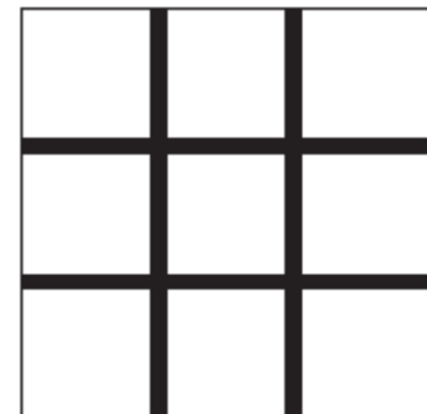
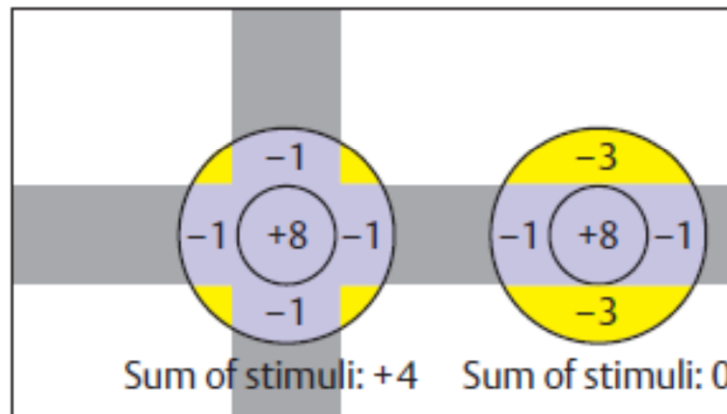
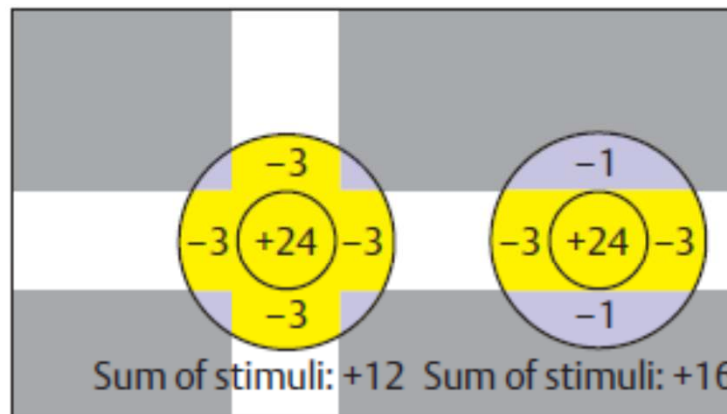
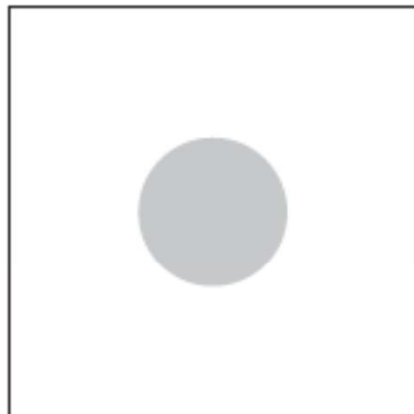
The Least Structured Mammalian Brain is Found in Rodents and Insectivora

Brodmann Areas (Outer and Inner Hemisphere Parts)

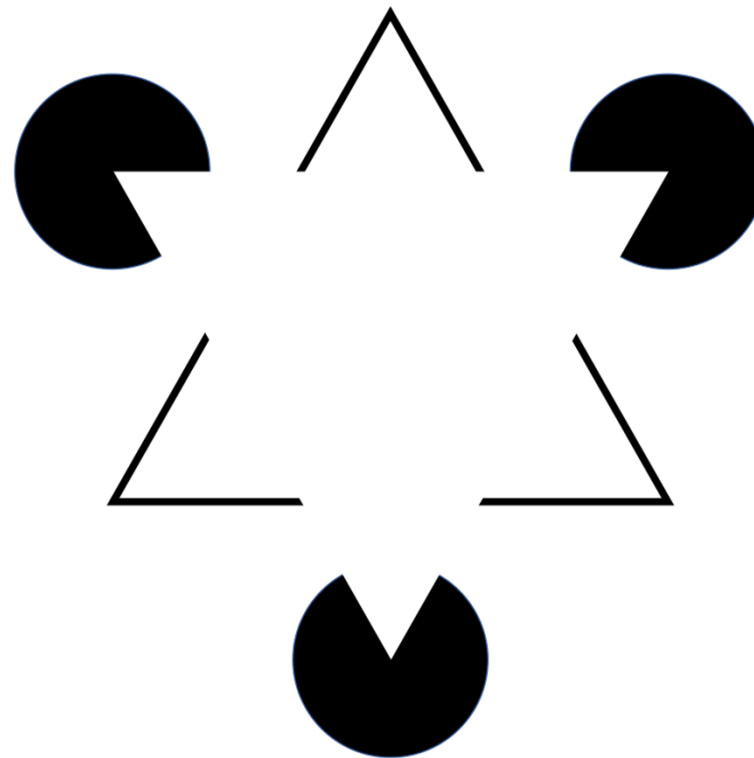


Visual Pathway Inner Workings

C. Receptive field-related contrast (on ganglion cells)

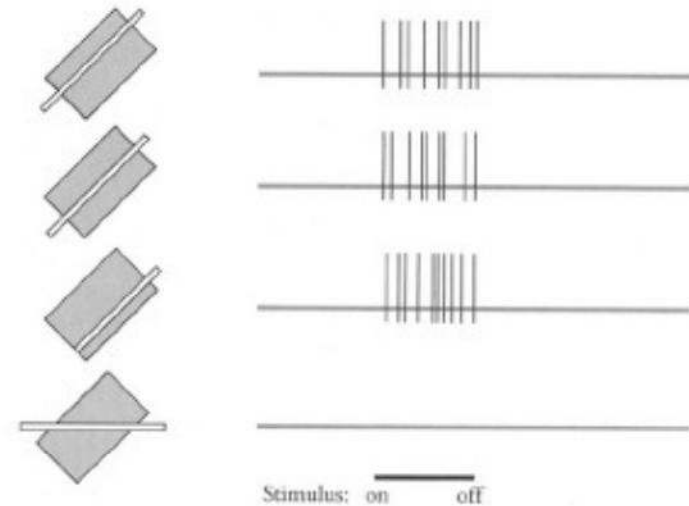
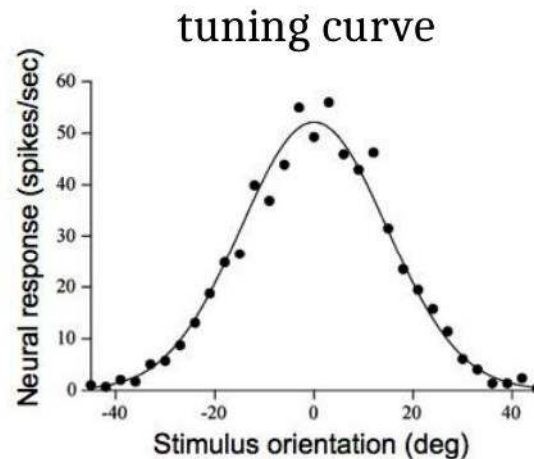
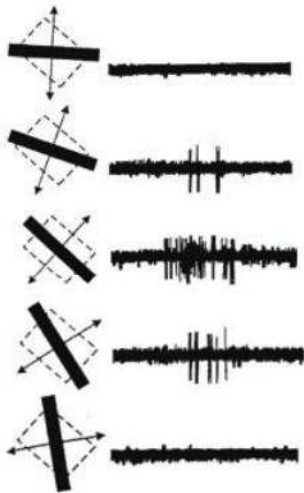


Experimental Construction of Receptive Fields:
Simple and Complex Cells in Primary Visual Cortex, Area V1,
Illusory Contours by von der Heydt, Area V2, and Higher Areas



V1 simple & complex cells

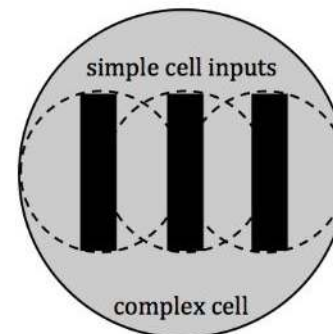
simple cells respond best to edges or bars of a particular position, orientation, and sign of contrast



complex cells have larger receptive fields and are more tolerant to position

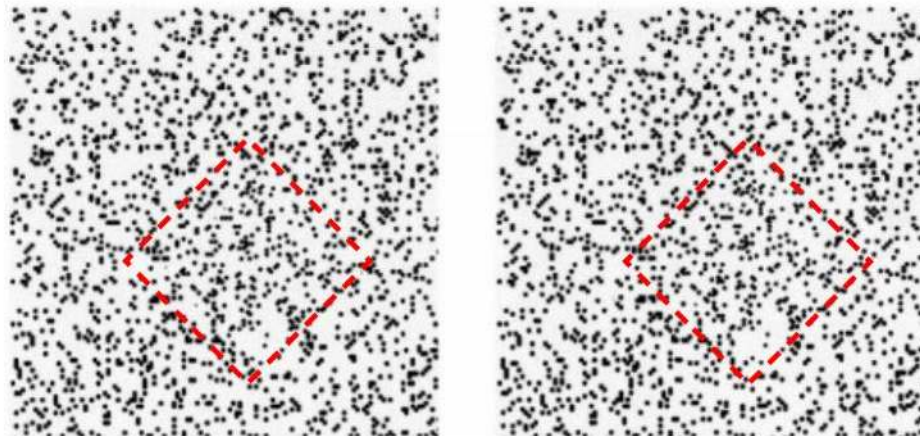
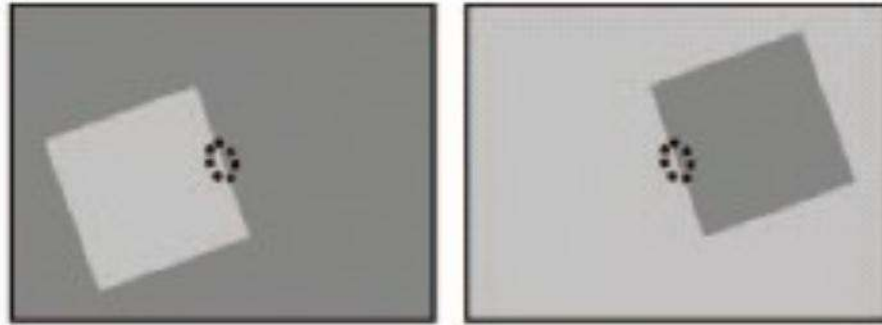


Kreiman, 2013



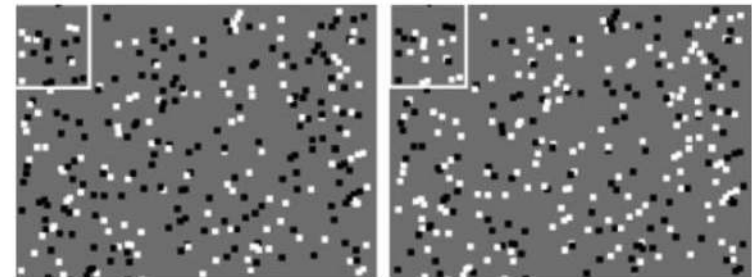
complex cell may "pool" inputs from many simple cells within receptive field

Selectivity for *stereo boundaries* in V2



Von der Heydt & colleagues:

Some V2 cells are selective for the orientation, contrast, and *side of border ownership* of an edge ... for edges defined by luminance *or stereo disparity*



“anti-correlated” stereogram

Later, in area V4, neural responses to stereo disparity appear to correspond more closely to perceived depth

Too Complicated Way to Explain Visual Cortex Connectivity and Function...

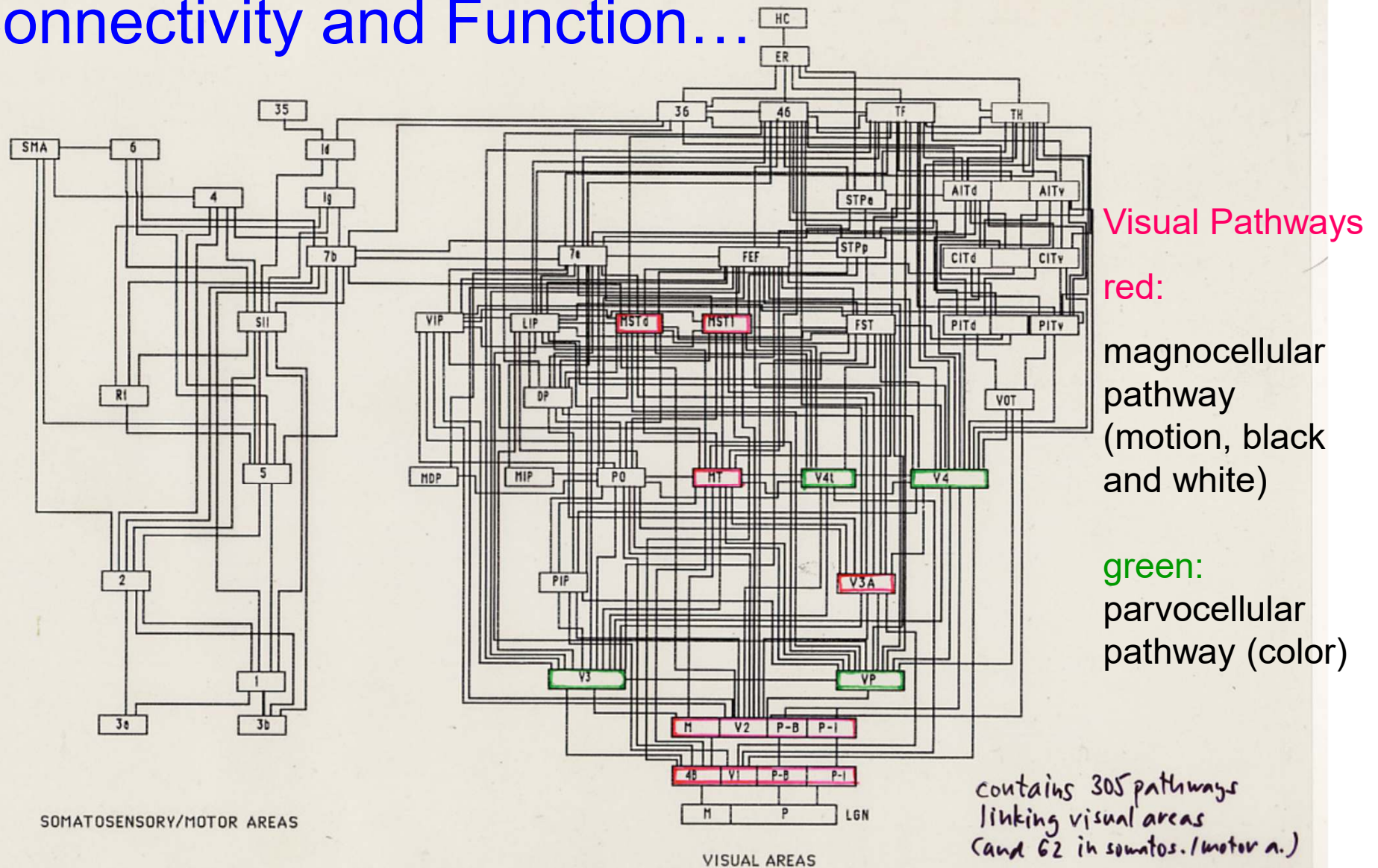


Figure 8. (See facing page for legend.)

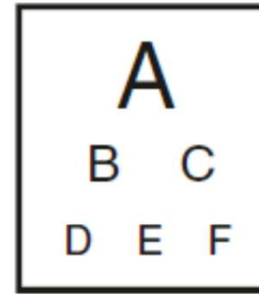
Van Essen D.C. et al., 1990, Cold Spring Harbor Symp. Quant. Biol., 55: 679-696

Alternative Way to Explain Vision...

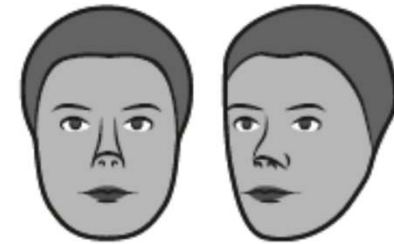
Overview of higher functions of visual cortex



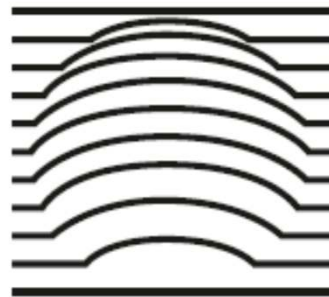
Navigation



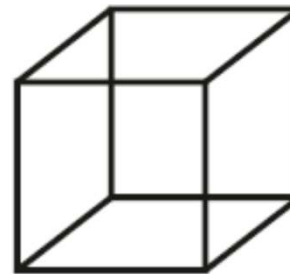
Reading



Face recognition



Shades

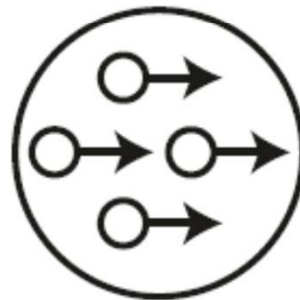


Contours



Stereo disparity

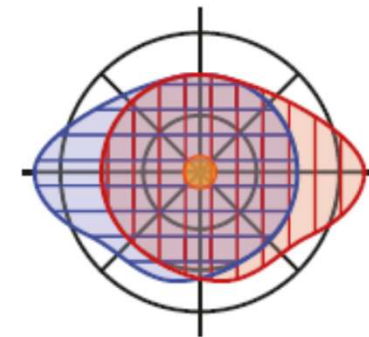
Early vs. Late vision



Motion



Color



Form

Face recognition – to recognize these blurred faces, some degree of visual acuity is needed



Blurred faces, however these famous people are recognizable from the context

2 G. Bush Sr.[+] – 5 B. Obama – 4 G.W. Bush – 3 B. Clinton – 1 J. Carter

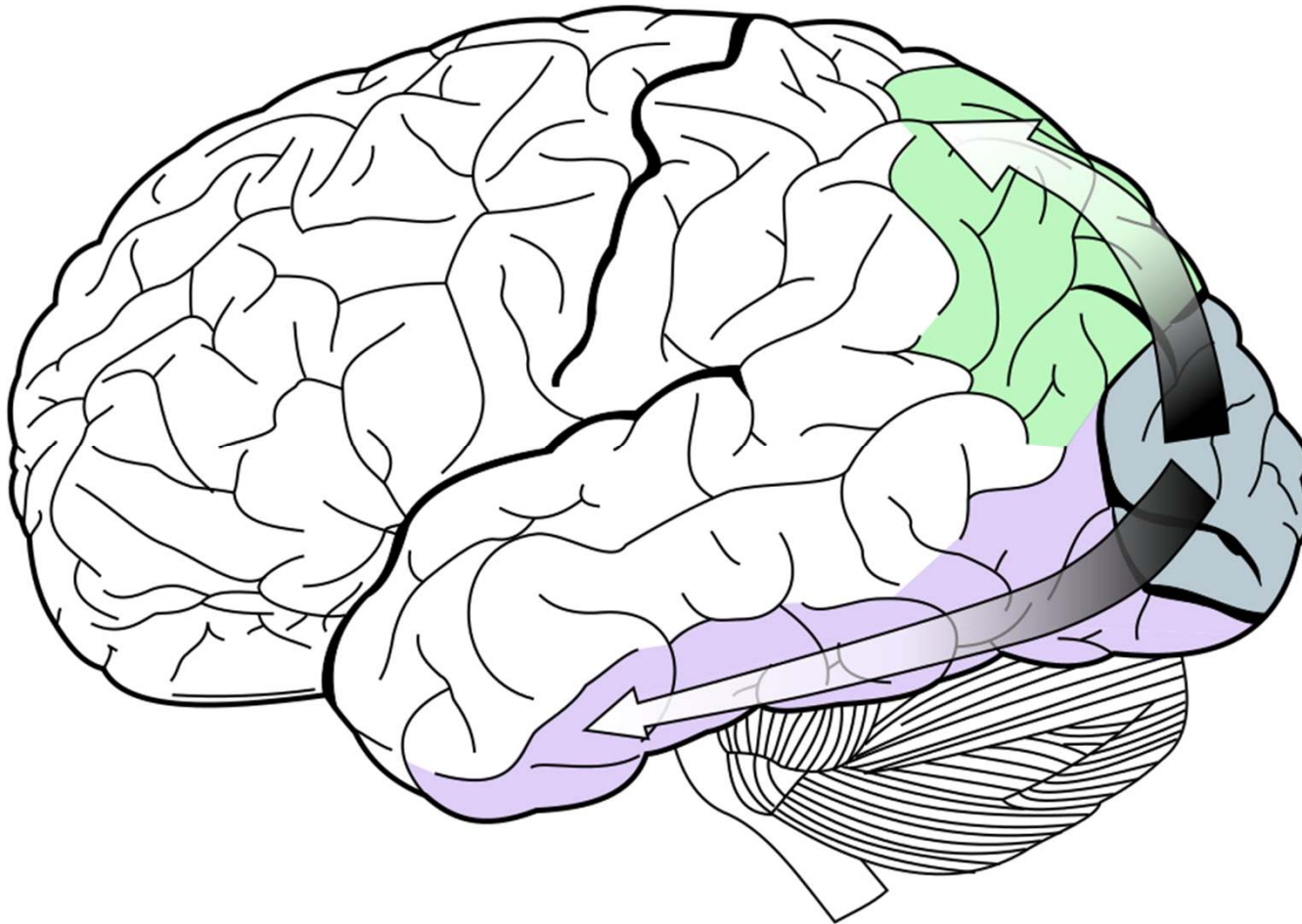




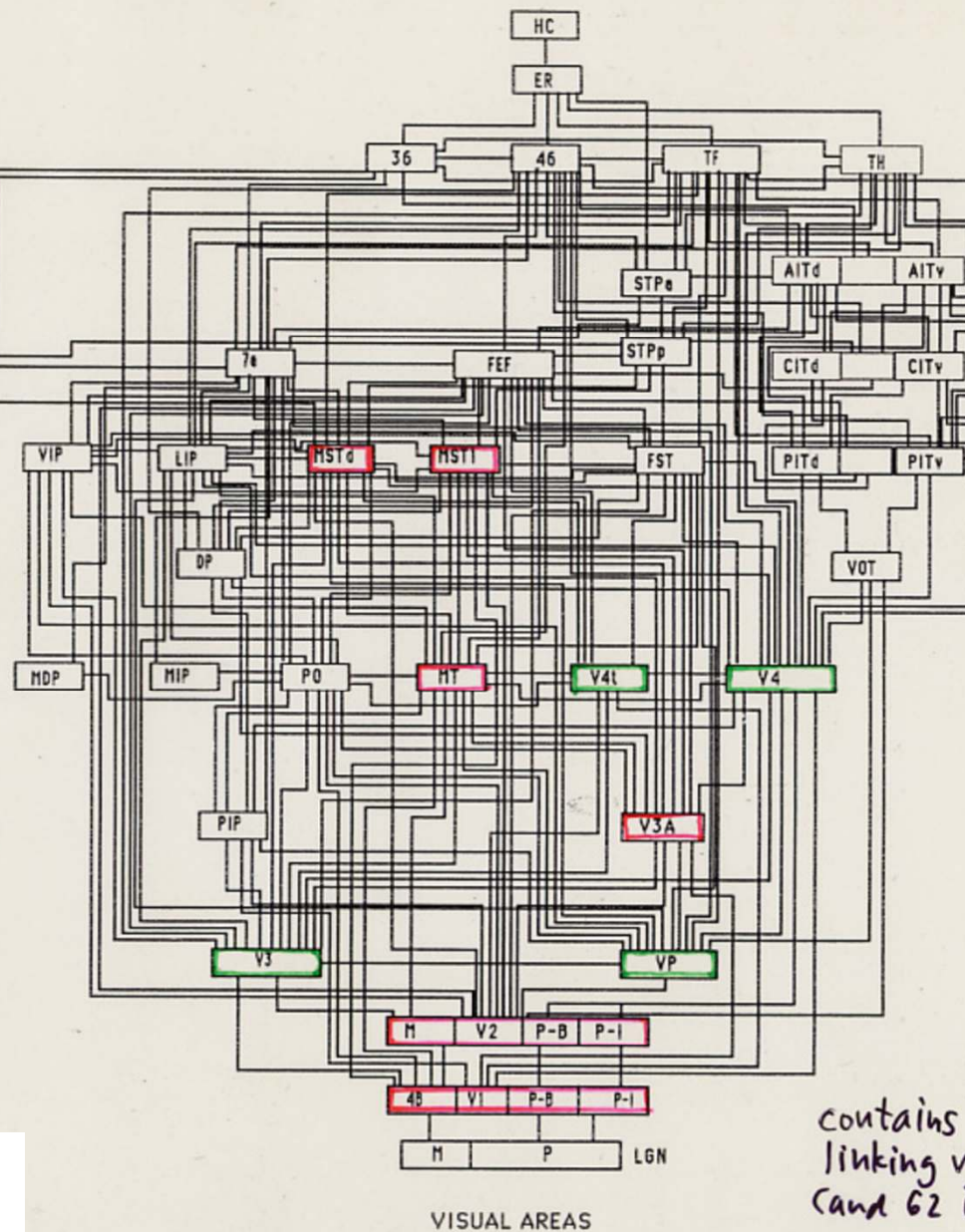
2 G. Bush Sr.[+] – 5 B. Obama – 4 G.W. Bush – 3 B. Clinton – 1 J. Carter



Ventral **What** and Dorsal **Where** Stream



Co? a Kde?
ve zrakové
kůře

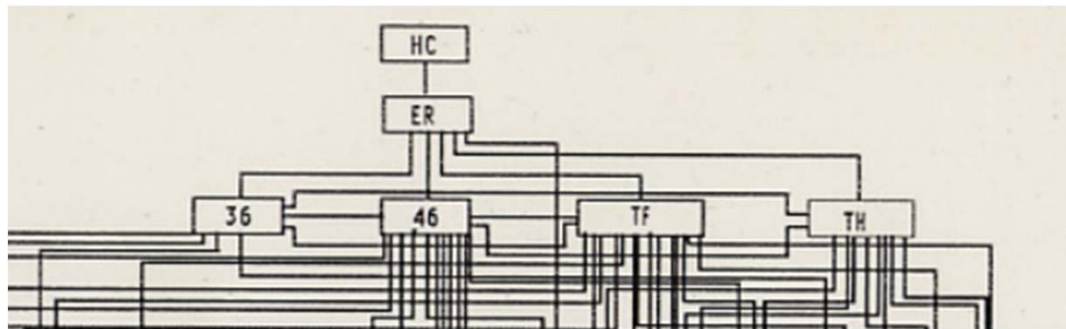


contains 305 pathways
linking visual areas
(and 62 in somatos./motor a.)

Figure 8. (See facing page for legend.)

Van Essen D.C. et al., 1990, Cold Spring Harbor Symp. Quant. Biol., 55:679-696

Co je HC? Higher Center, Hippocampus, Homunculus,..., je vůbec něco na vrcholu hierarchie projekčních oblastí mozkové kůry?



Je primární a sekundární zraková kůra
What je ve (ventrálních=) v předních
korových projekčních oblastech
Where je v (dorzálních=) v zadních
korových projekčních oblastech

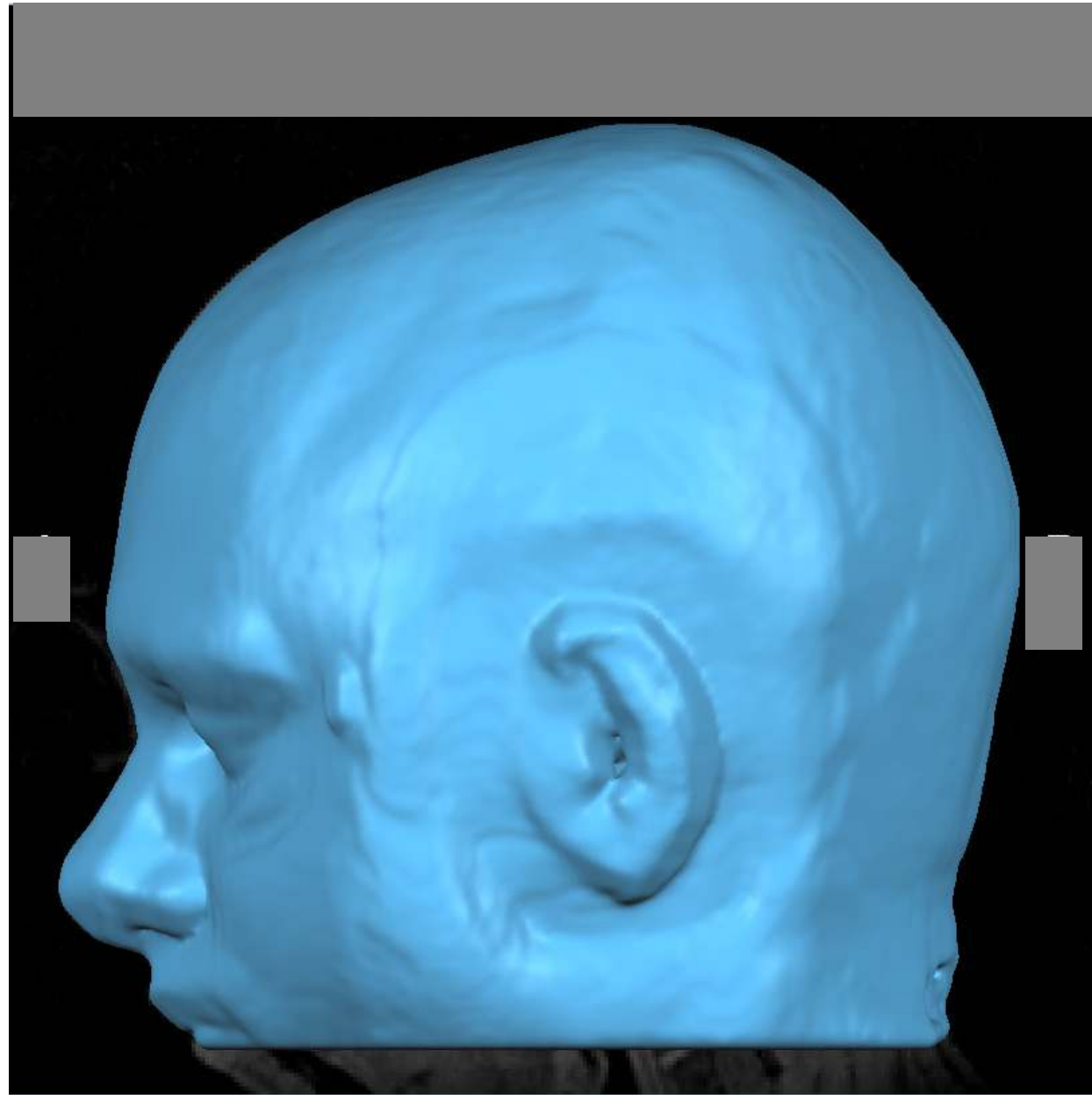
Retreating to Sensory Diagnostic Methods

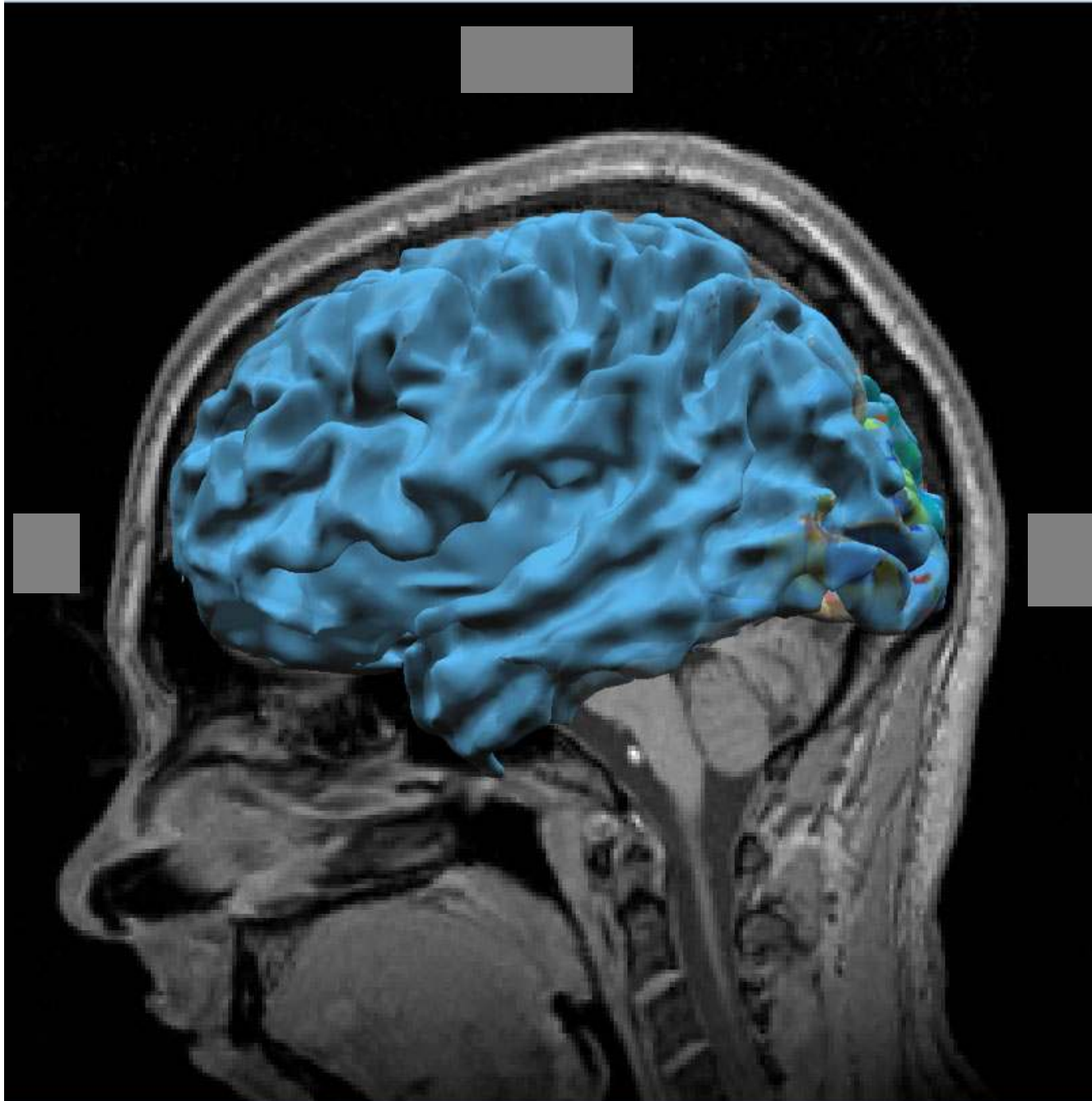
Magnetic Resonance Imaging (MRI)
(Spatial Domain)

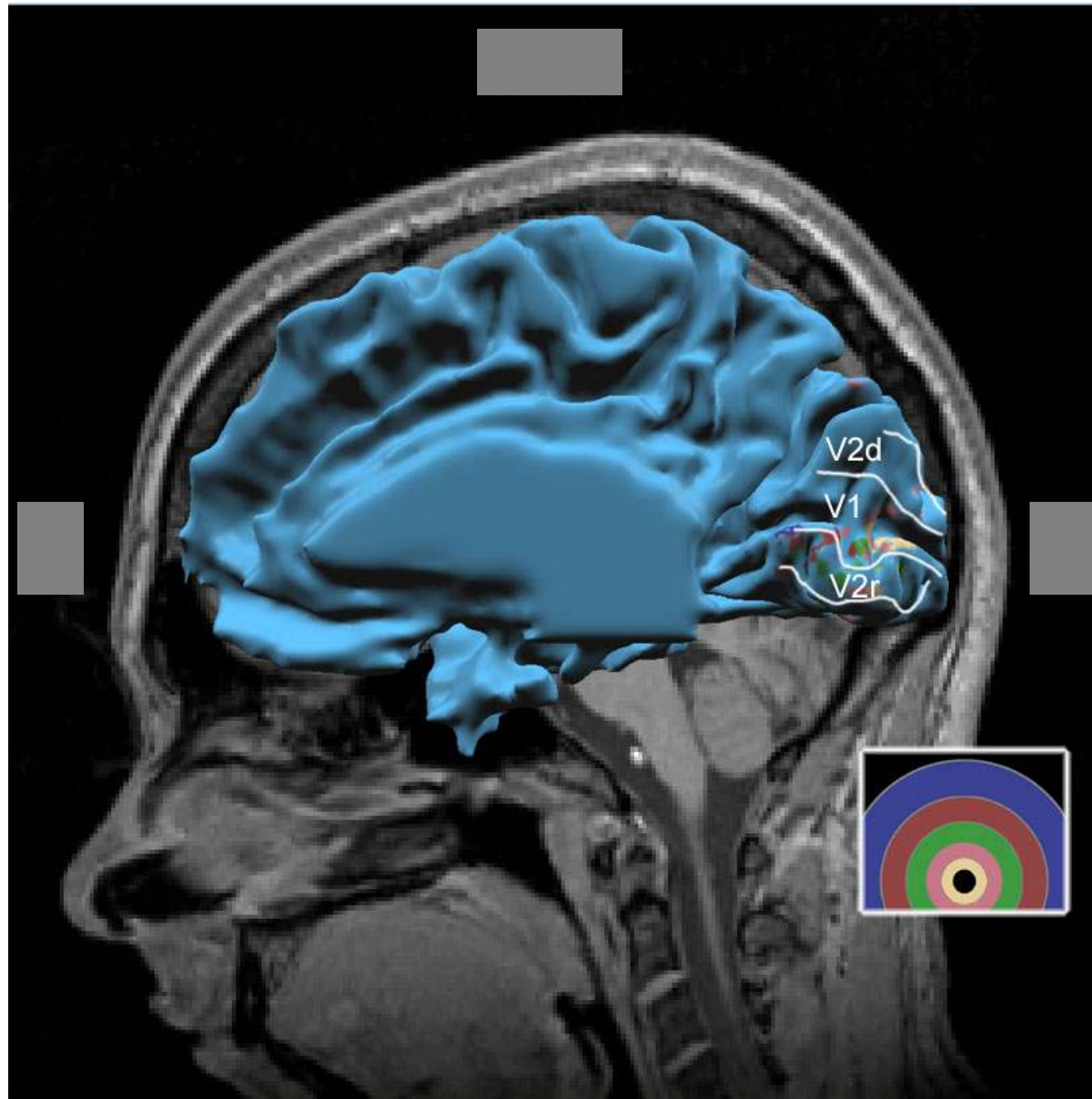
Functional MRI, fMRI
(Spatial and Time Domain)

Evoked Responses, ER, EP, EEG
(Time Domain)

Around year 2000:
Caltech's 3.0 T Trio
Siemens magnetic
scanner



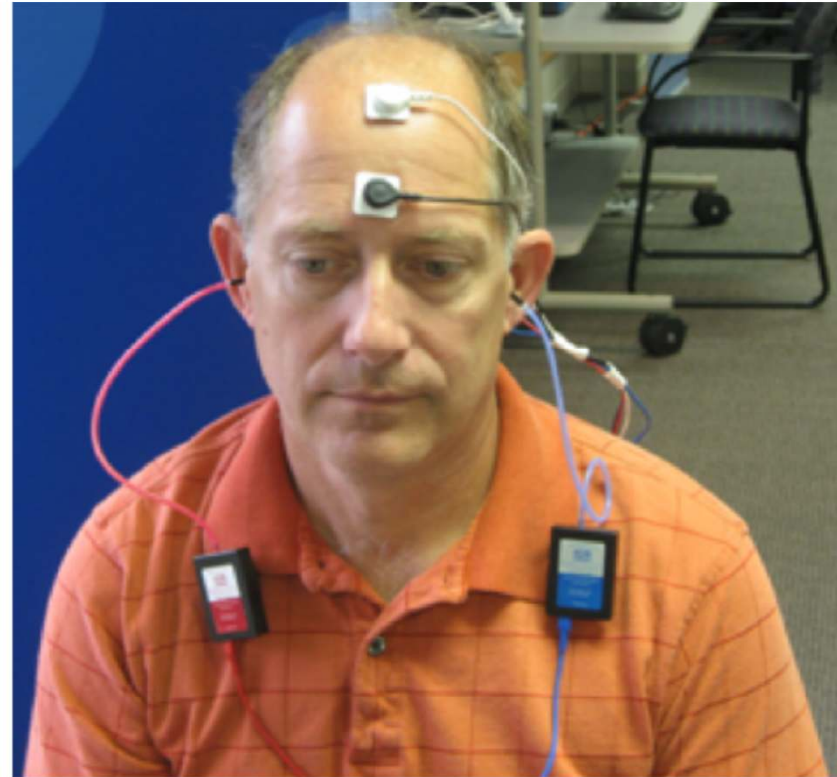




Auditory brainstem responses

Talk no. 4 – Hearing Loss, Diagnostic Methods in Audiology

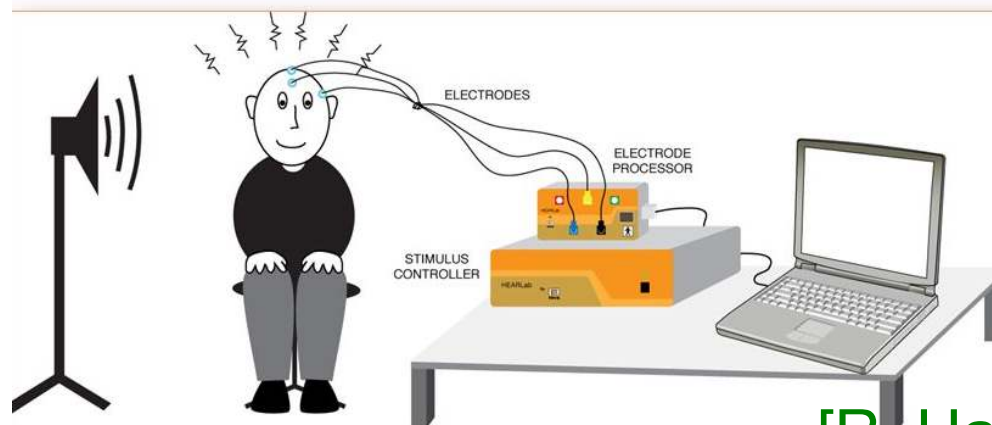
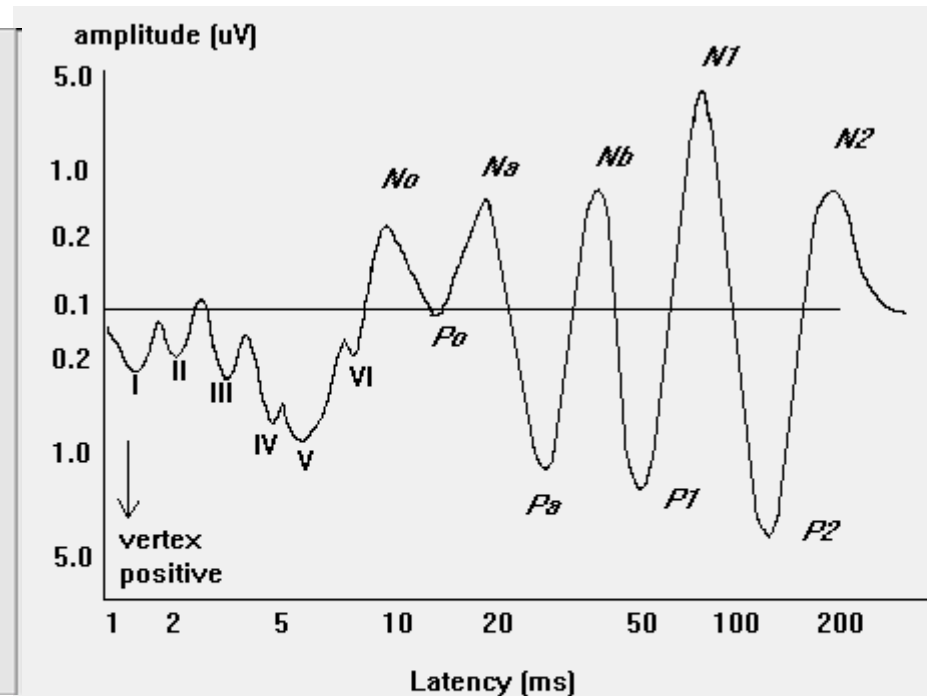
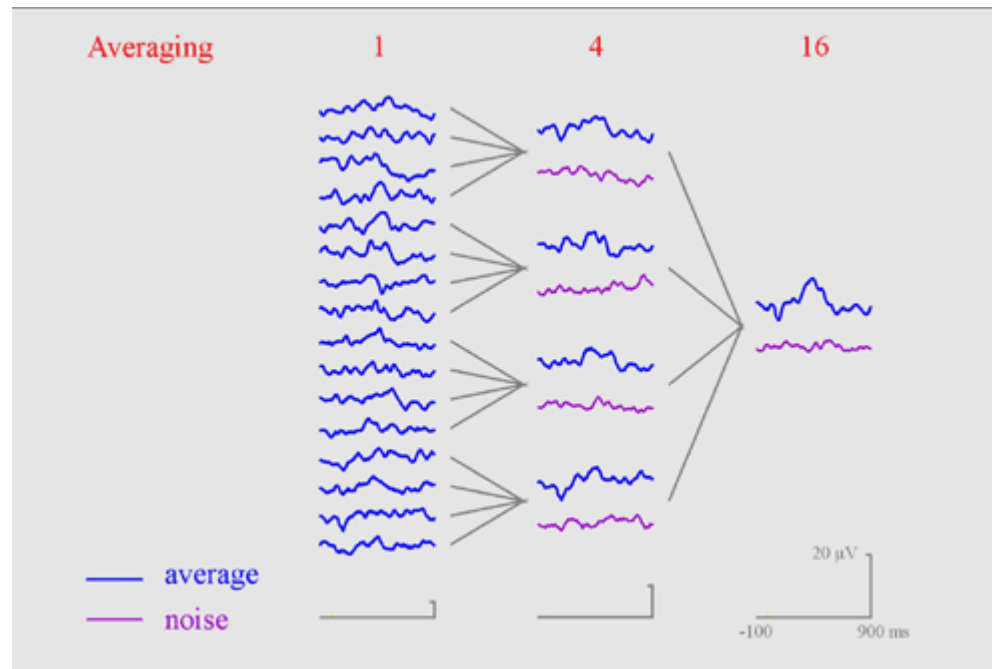
- Auditory brainstem responses (ABR or BERA) can be recorded by using electrodes placed on the scalp
- Responses are evoked potentials, i.e. electrical potentials generated in the neural system due to external stimulation (acoustical stimulation in case of ABR)
- Evoking stimulus is a transient signal (click)



Taken from <https://www.audiologyonline.com/articles/evoked-potentials-part-1-good-23607>

Auditory and Visual Cortical Evoked (Response) Potentials

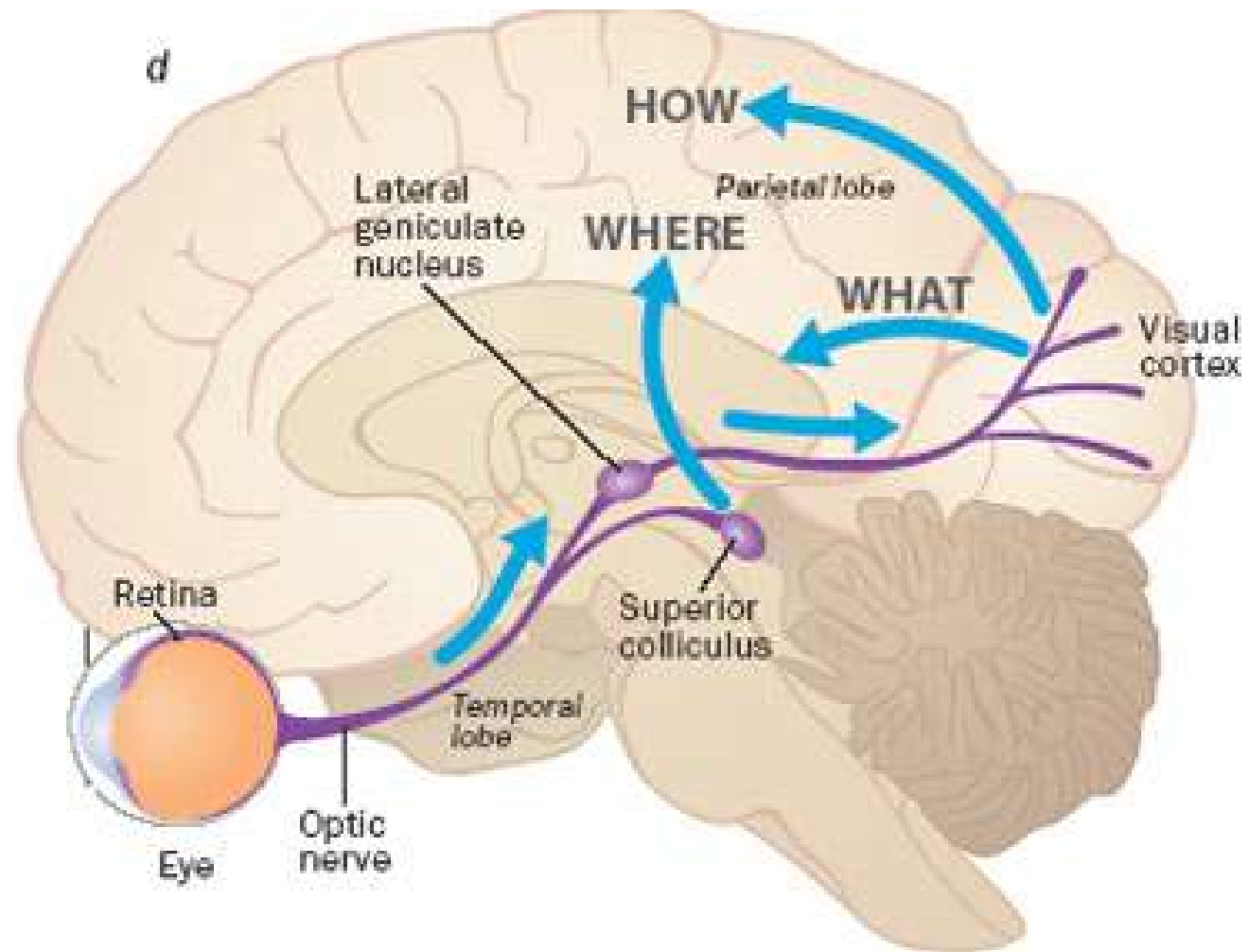
AEP – Auditory EP
VEP – Visual EP



Repetition rate in
brainstem ER audiometry
Can be of low freq. sound
(40 Hz). CZ:BERA, EN:ABR

[R. Hari et al., Exp. Brain Res., 1980]

Overview of visual pathway



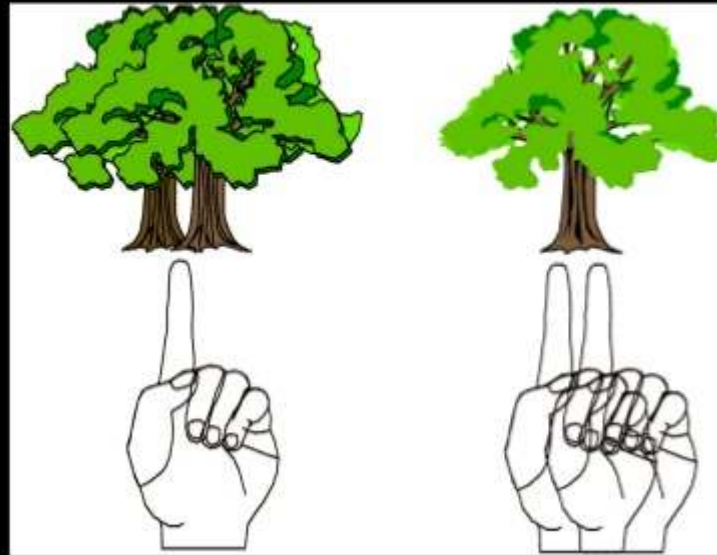
Binocular Focusing is Realized by Eye Con- and Di-Vergence

Vergence eye movements

Either blur or retina disparity will generate vergence.

Latency for vergence movements is ~160 ms.

Maximum velocity is 20°/sec.



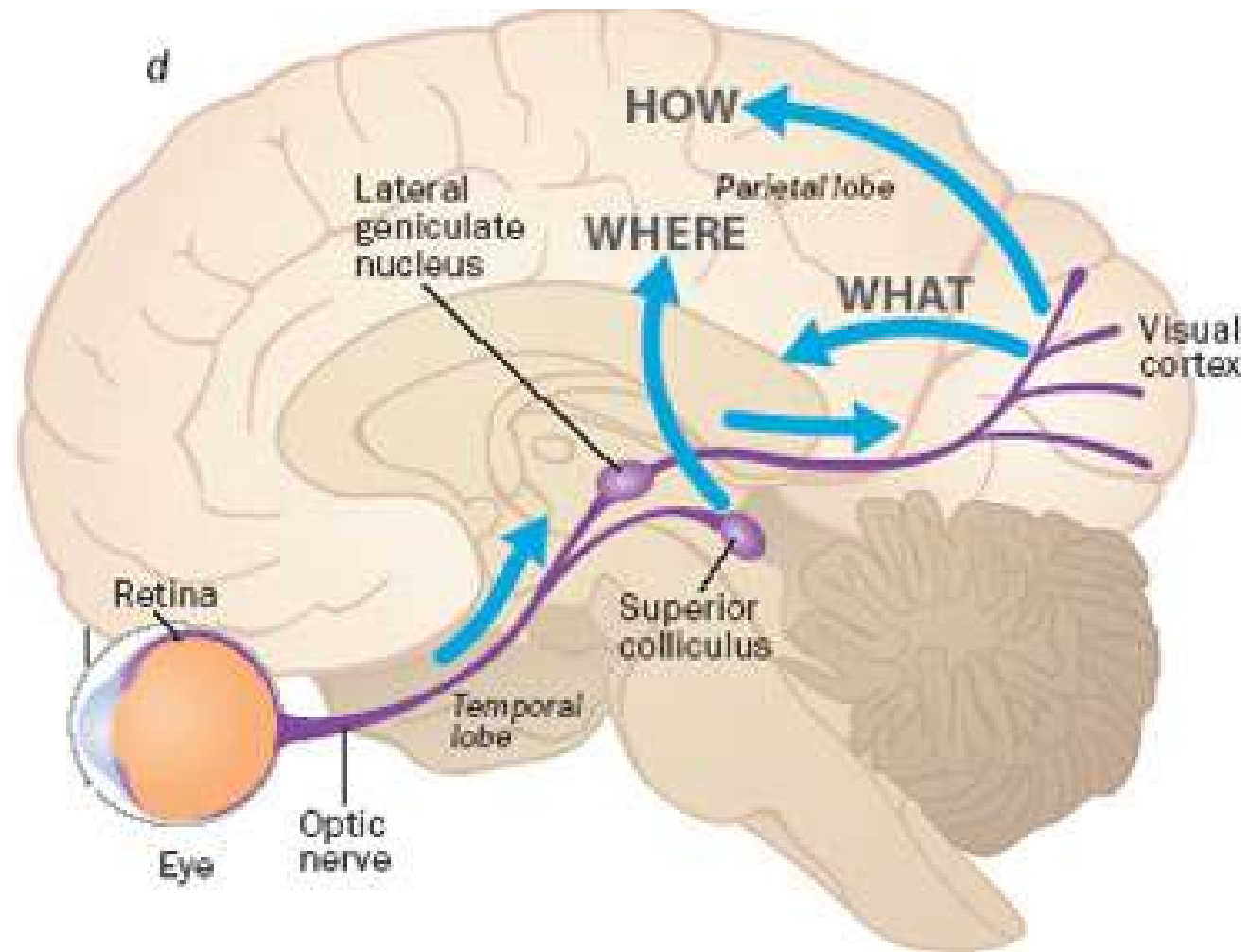
(Con)vergence disorder is called strabismus.

Binocular Rivalry in Conflicting Images To Left and Right Eye

What Functional Purpose This May Have?

- Not All Visual Areas Contain Consciously Accessible Representation → Eye Rivalry

Blindsight (= slepo-zrakost...)



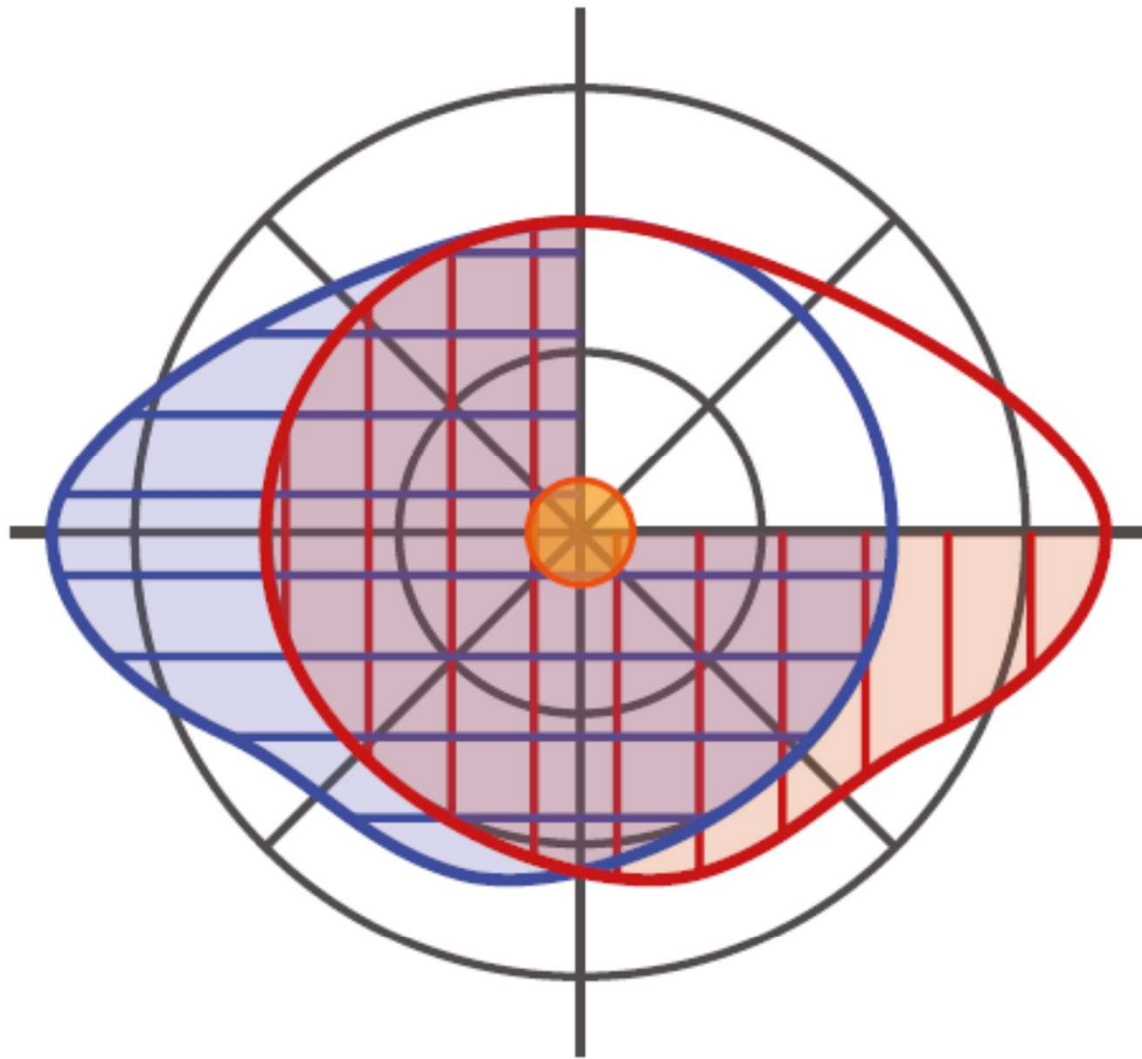
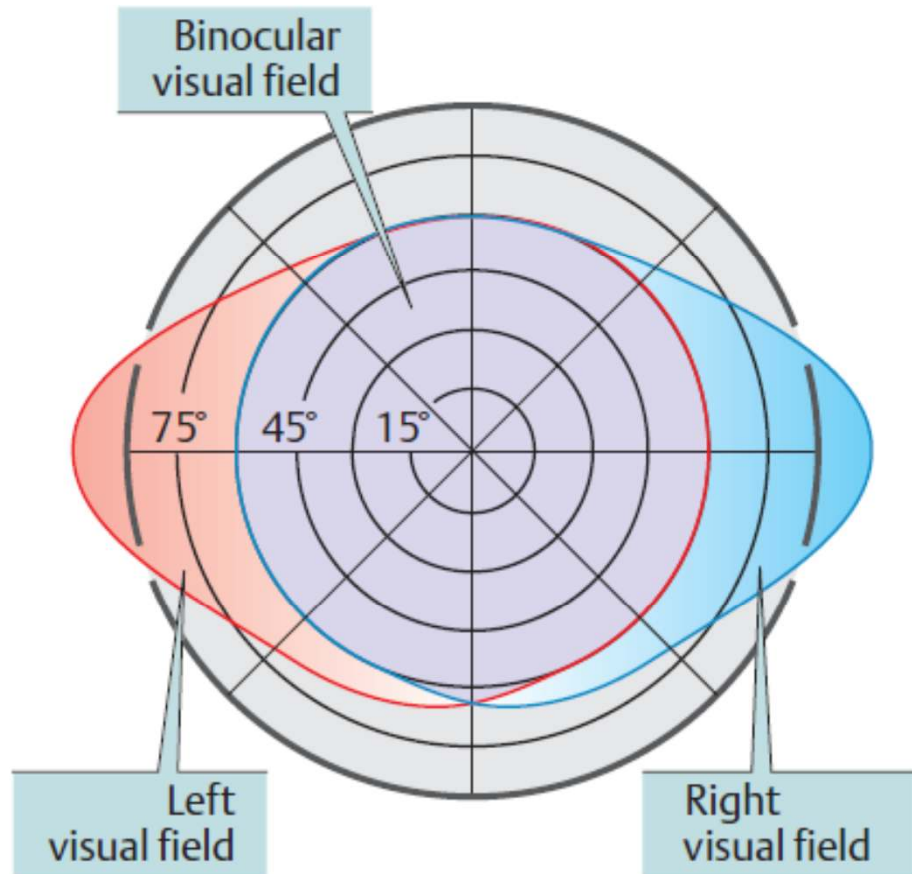


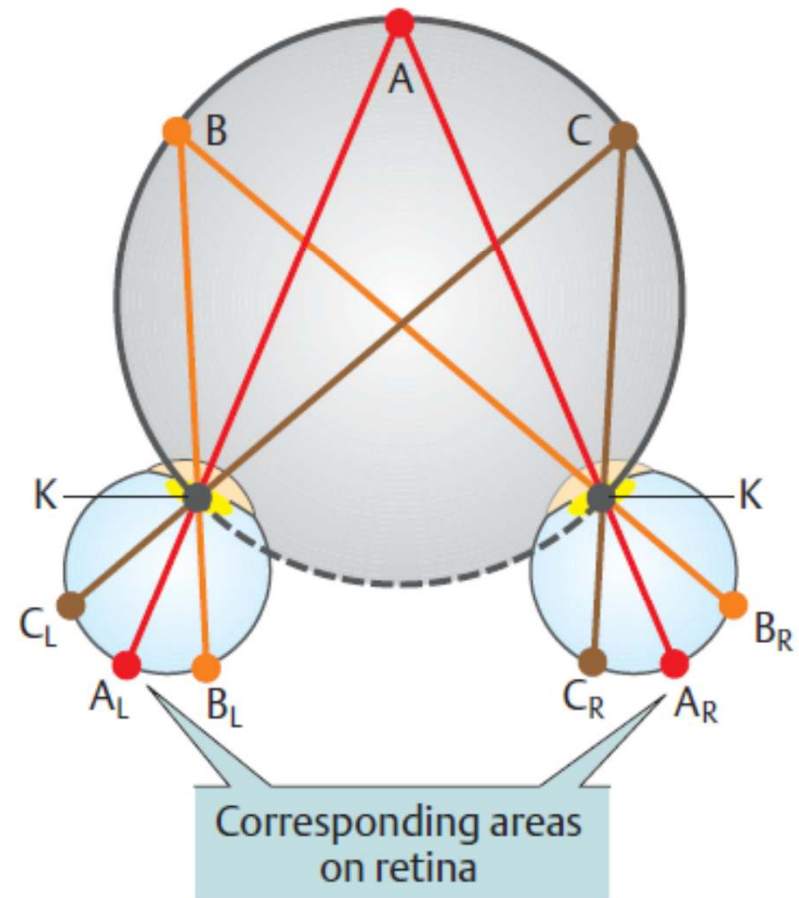
Fig. 2.3 Binocular visual field, subjective view. The binocular visual field spans $40,000 \text{ deg}^2$. The homonymous visual defect typically affects one quadrant (here top right) while the region of best visual acuity (fovea) is spared, due to the overlap of left and right optic radiation

Binocular Fusion

A. Binocular visual field

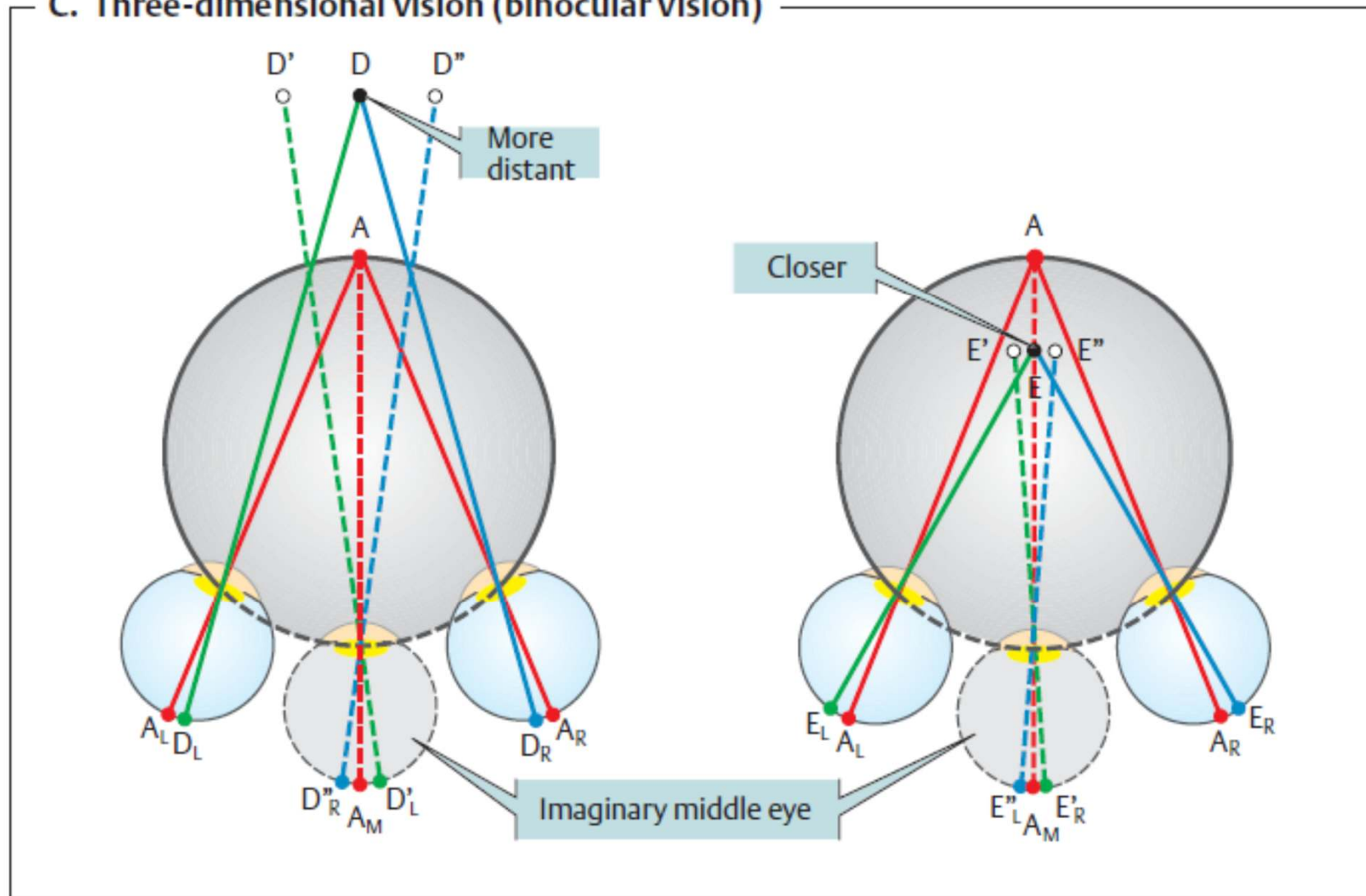


B. Horopter



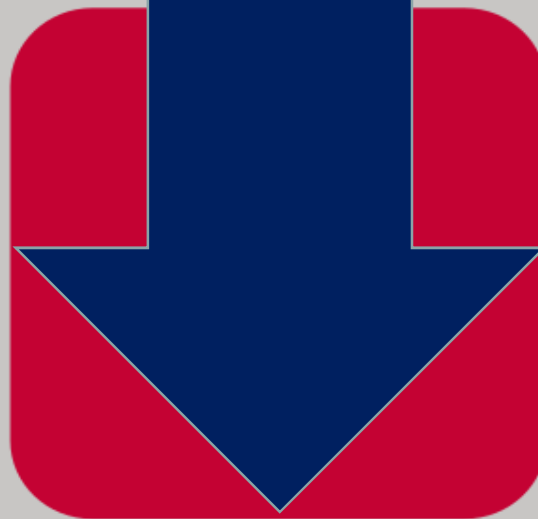
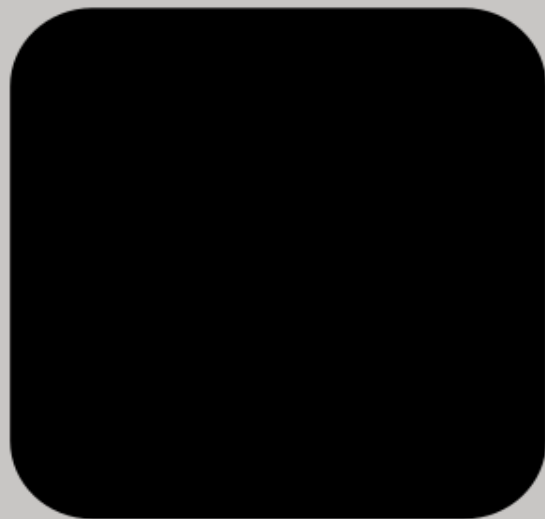
Binocular Fusion

C. Three-dimensional vision (binocular vision)

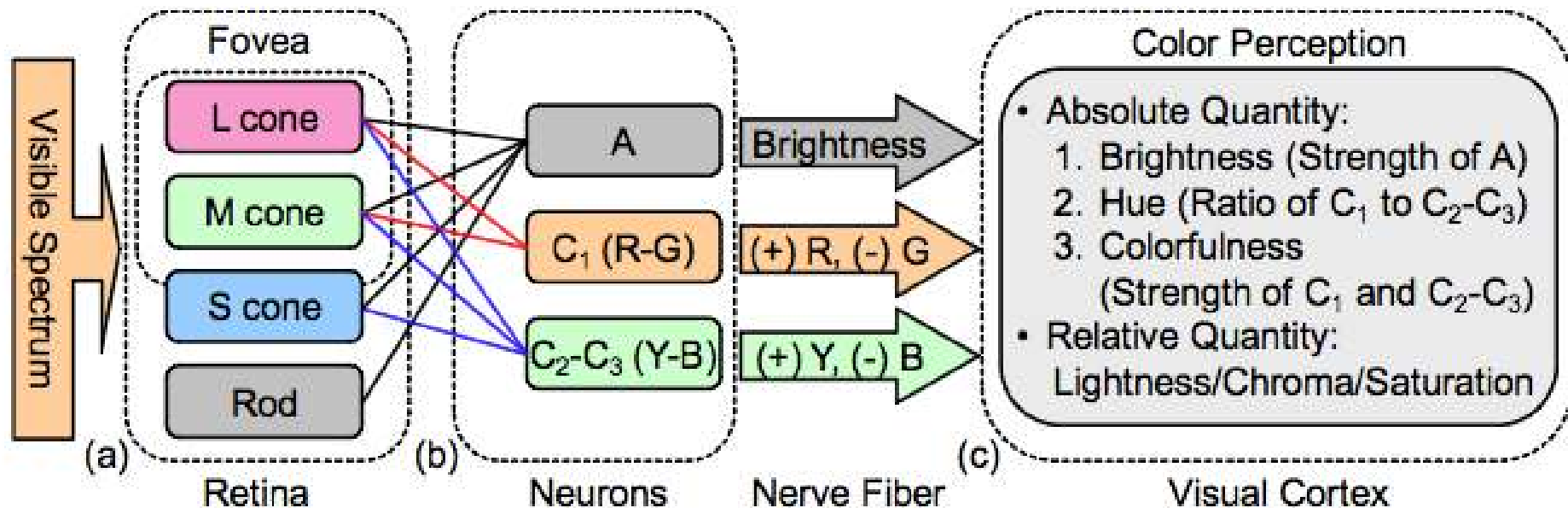


Geometry of disparities using the Cyclopean Eye

Color Opponent Processes

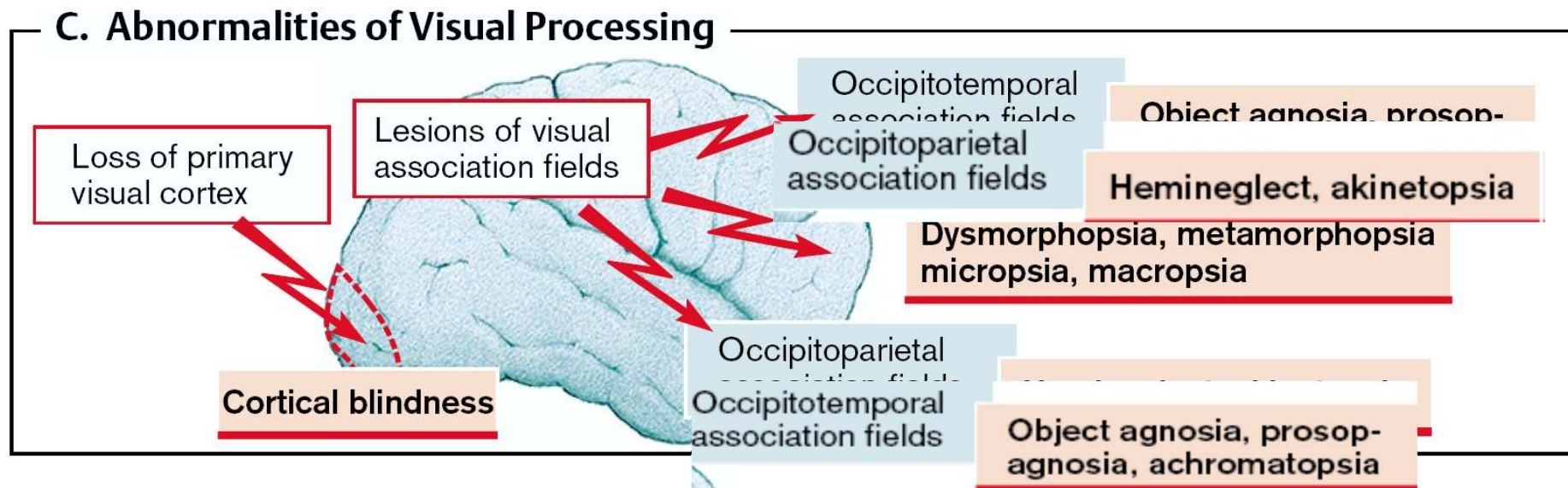
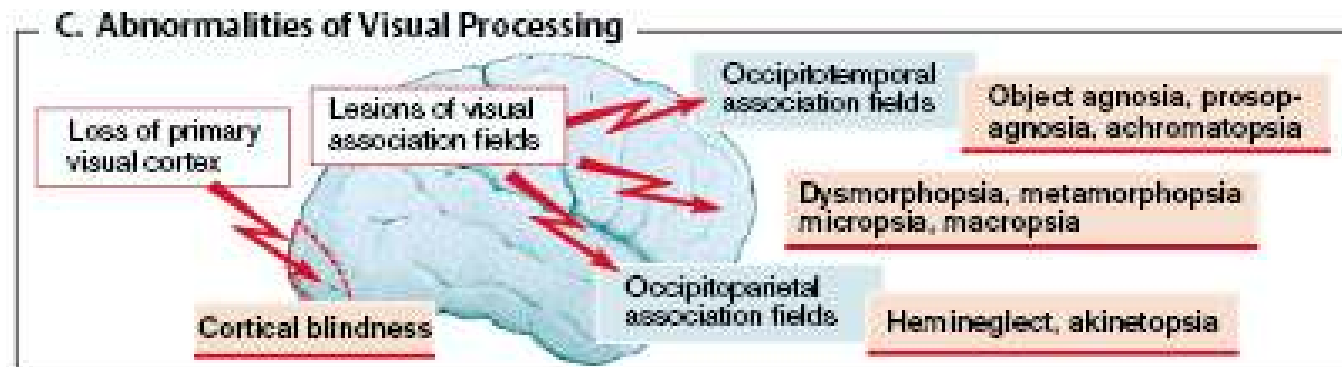


Color Opponent Processes



Color Opponent Processes

Understanding and Interpretation
Difficulties,
How To Explain Visual Perception
as...
Physiological, Neural,
Psychological Process...



Disorders of Visual Association Cortices

Atlas of Patophysiology, 1st English edition, 2000, p. 327

Summary – Visual Cortex

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Literature

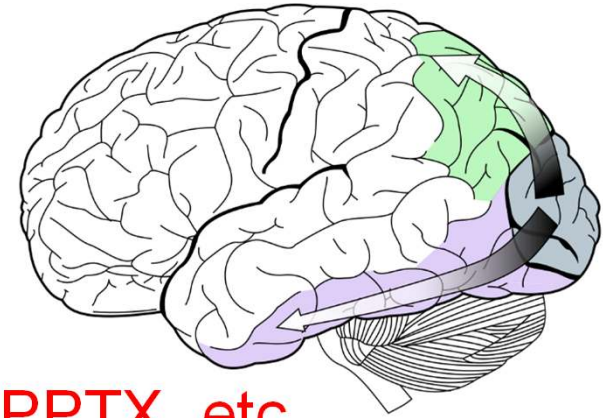
- (3) SCOVILLE William Beecher and MILNER Brenda, Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology, Neurosurgery and Psychiatry* 20, (1): 11–21, 1957.
- (2) TURING A. M., Computing Machinery and Intelligence. *Mind* 49: 433-460, 1950.
- (1) FECHNER G.T., Foundations of psychophysics, *Elemente der Psychophysik*, 1860.
- (4) WERNER G., MOUNTCASTLE V.B., Neural activity in mechano-receptive cutaneous afferents: stimulus-response relations, Weber functions, and information transmission, *J. Neurophysiology*, 28(2), 359-397, 1965.
- (5) KANDEL E., SCHWARTZ JH, JESSELL TH, *Principles of Neural Science*, 2000.
- (6) KOCH C., *The Quest for Consciousness*, 2004.
- (7) LODGE D., *Thinks...*, 2002

Literature

- (1) KURISCAK E., MARSALEK P., STROFFEK J. and TOTH P.G., Biological context of Hebb learning in artificial neural networks, a review. *Neurocomputing*, 152, 27-35, 2015.
- (2) GRUNDA T., MARSALEK P. and SYKOROVA P., Homonymous hemianopia and related visual defects: Restoration of vision after a stroke. *Acta Neurobiol. Exp. (Wars.)*, 73(2), 237-249, 2013.
- (3) HRUBY T. and MARSALEK P. Event-related potentials - the P3 wave. *Acta Neurobiol. Exp. (Wars.)*, 63(1), 55-63, 2003.
- (4) MARSALEK P., SANTAMARIA F. Investigating spike backpropagation induced Ca^{2+} influx in models of hippocampal and cortical pyramidal neurons. *Biosystems*, 48, 147-156, 1998.
- (5) MARSALEK P., KOCH C. and MAUNSELL J. On the relationship between synaptic input and spike output jitter in individual neurons. *Proc. Natl. Acad. Sci. USA*, 94, 735-740, 1997.

Thanks for your attention

CTU FEE



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<http://nemo.lf1.cuni.cz/mlab/ftp/PPT-CVUT/>

END
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