

Human Visual System summary

S. Kostoglou, Prof. Ioannis Pitas
Aristotle University of Thessaloniki
pitas@csd.auth.gr
www.aiia.csd.auth.gr
Version 2.2.1

Human Visual System

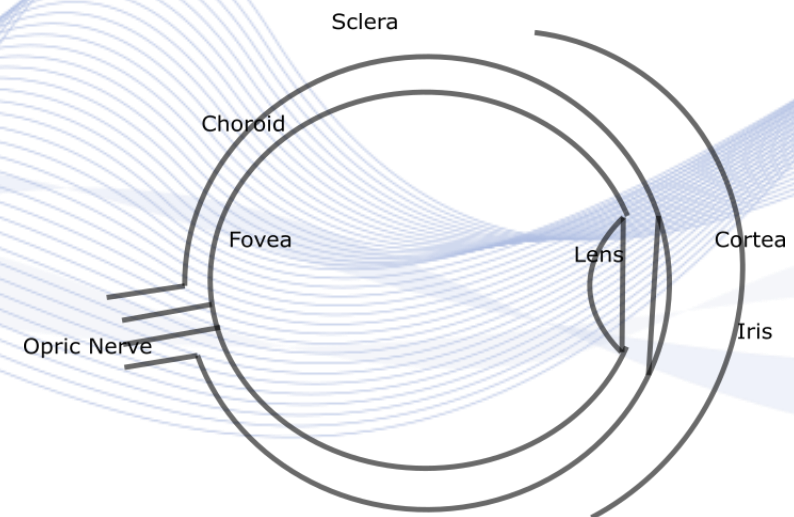
- **Human Visual System**
- Retina
- Visual Pathway
- Visual Cortex
- Visual defects

Human Visual System

- **Human Visual System (HVS)** is a nervous sub-system (neural network), which allows humans to transform the light input arriving at the eye into a **visual experience** [SAR2017].
- It consists of the **eyes** (notably lens, retina) and the following parts of parts of the central nervous system:
- **optic nerve, optic tract** and **visual cortex**.

Human Visual System

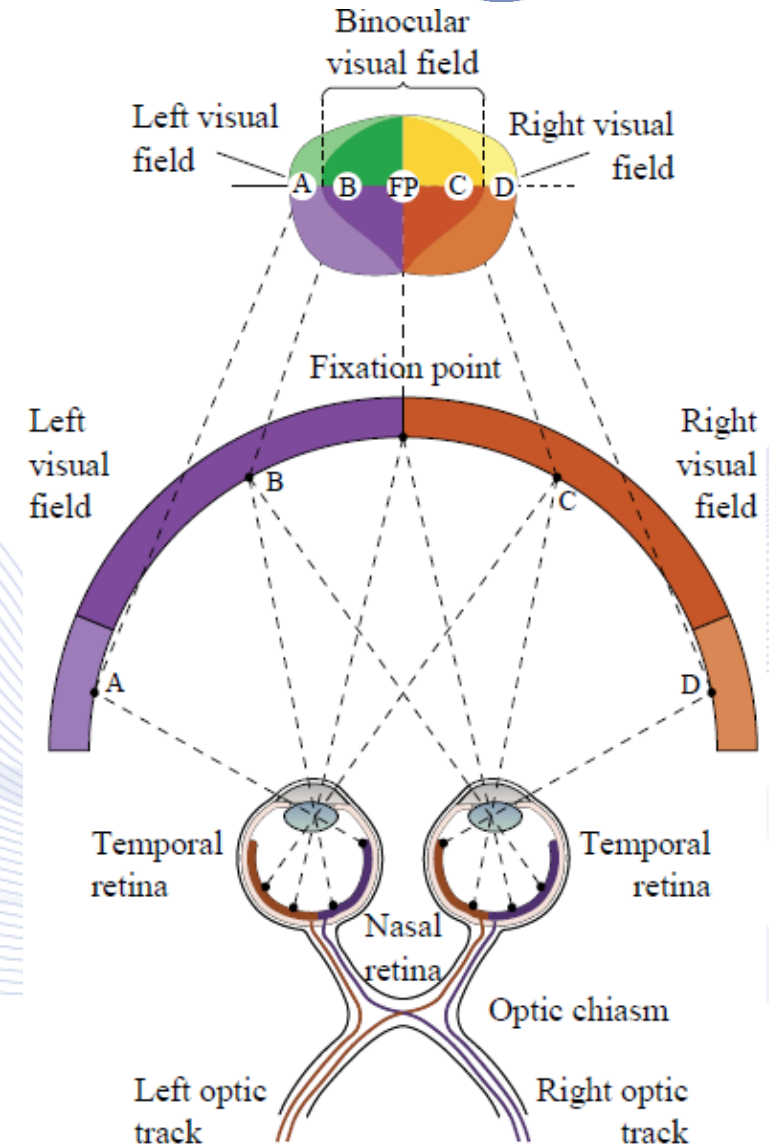
- **Human eye:** spherical shape with a diameter of 20 mm.
- Light enters through the **pupil** of the **iris** (diameter 2-8 mm).
- It passes through the cornea, the **lens**, the **vitreous (humour)** and is focused on the **retina**.



Human eye.

Human Visual System

- The horizontal separation of the eyes leads to a difference, ***stereo parallax***, in image location and appearance of an object between the two eyes, called ***stereo disparity***.
- Stereo parallax is utilized by the brain in order to extract depth information.



Human Visual System

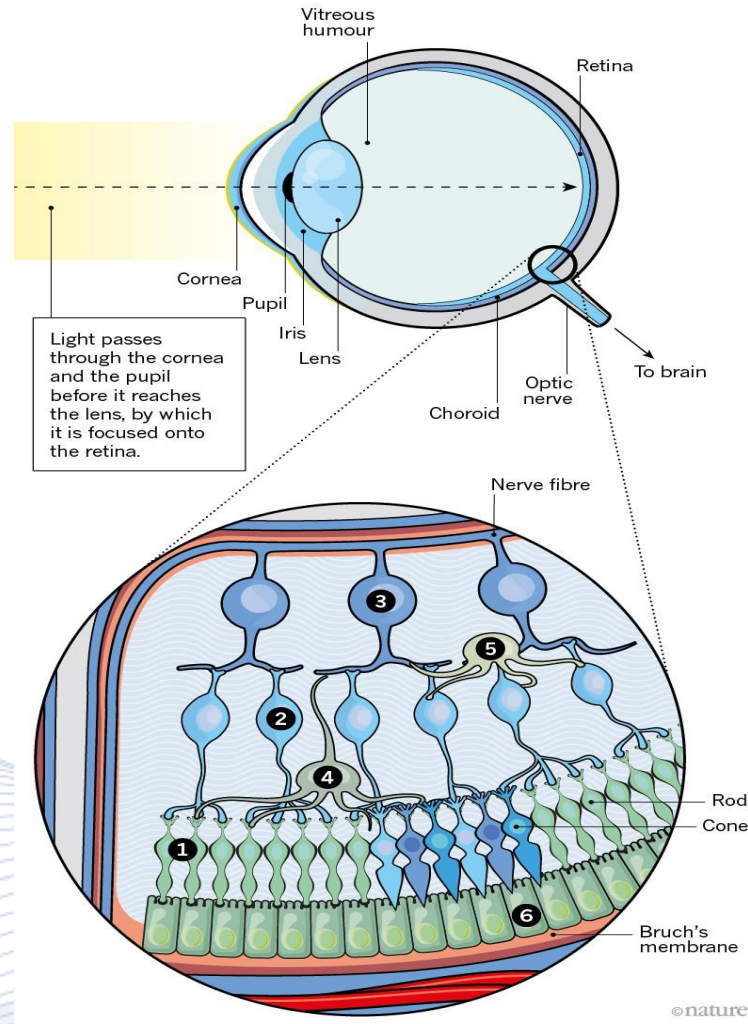
Human eye is a visual system consisting of:

- Cornea
- Iris/pupil,
- Lens
- Vitreous humor consisting primarily of water (60-70%).
- Retina.



Eye visual system model.

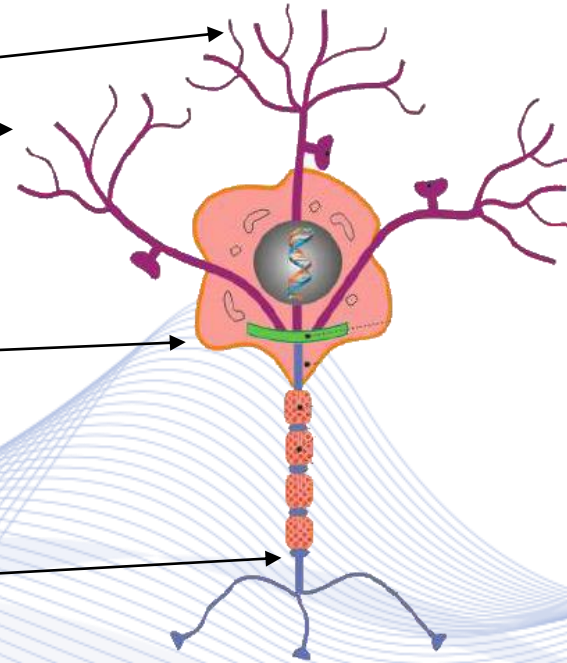
Retina



Retina structure [DAV2018].

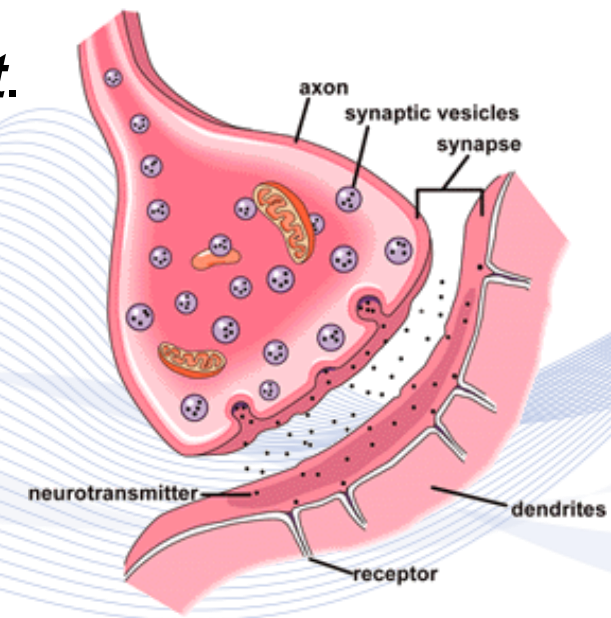
Biological Neuron

- Basic computational unit of the brain.
- Main parts:
 - **Dendrites**
 - They act as inputs.
 - **Soma**
 - Main body of neuron.
 - **Axon**
 - It acts as neuron output.



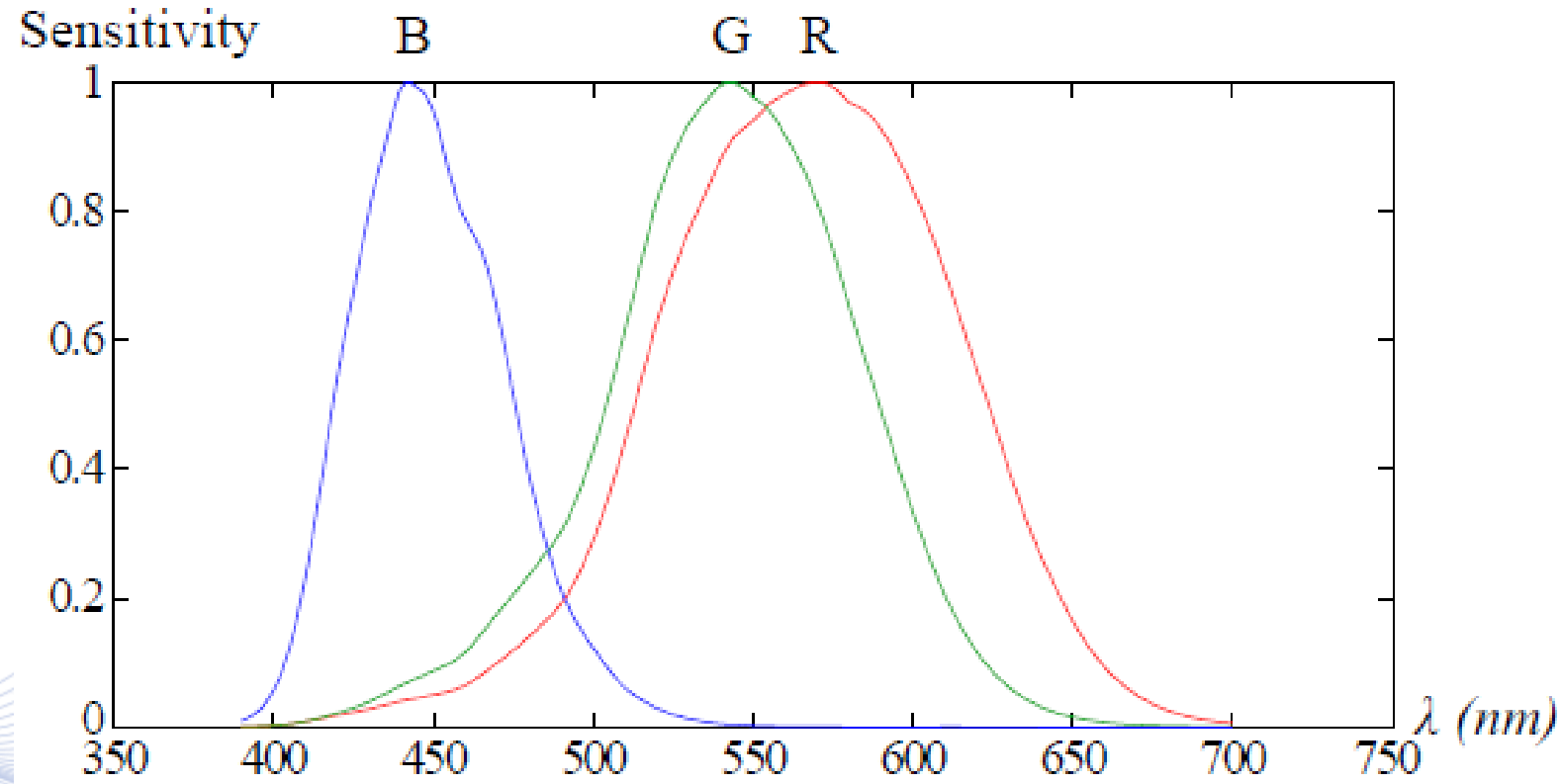
Biological Neuron Connectivity

- An electric action potential is propagated through the axon.
- Signal is transmitted through the synapse gap by neurotransmitter molecules.
- Each synapse has its own ***synaptic weight***.
- Synaptic weights can be:
 - positive (***excitatory synapses***).
 - Negative (***inhibitory synapses***).
- Transmitted signal is a series of electrical impulses.



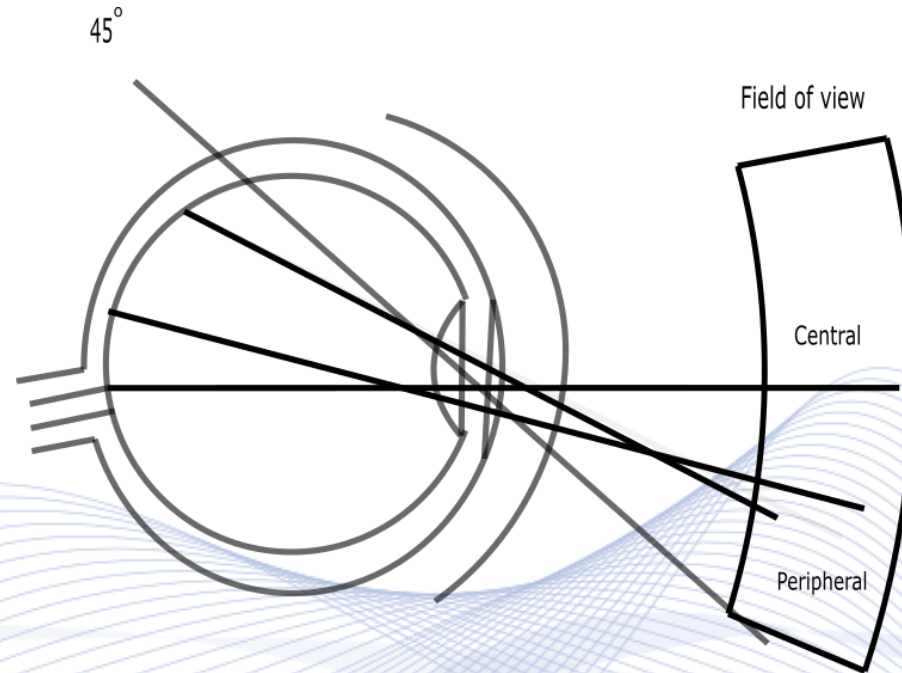
- The stronger the transmitted signal, the

Color theory



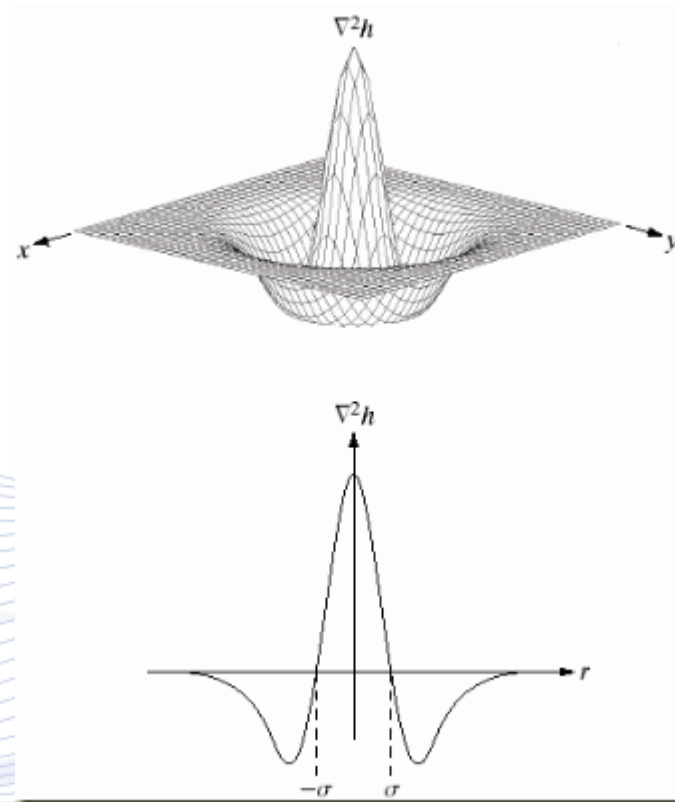
R, G, B cone sensitivity.

Retina



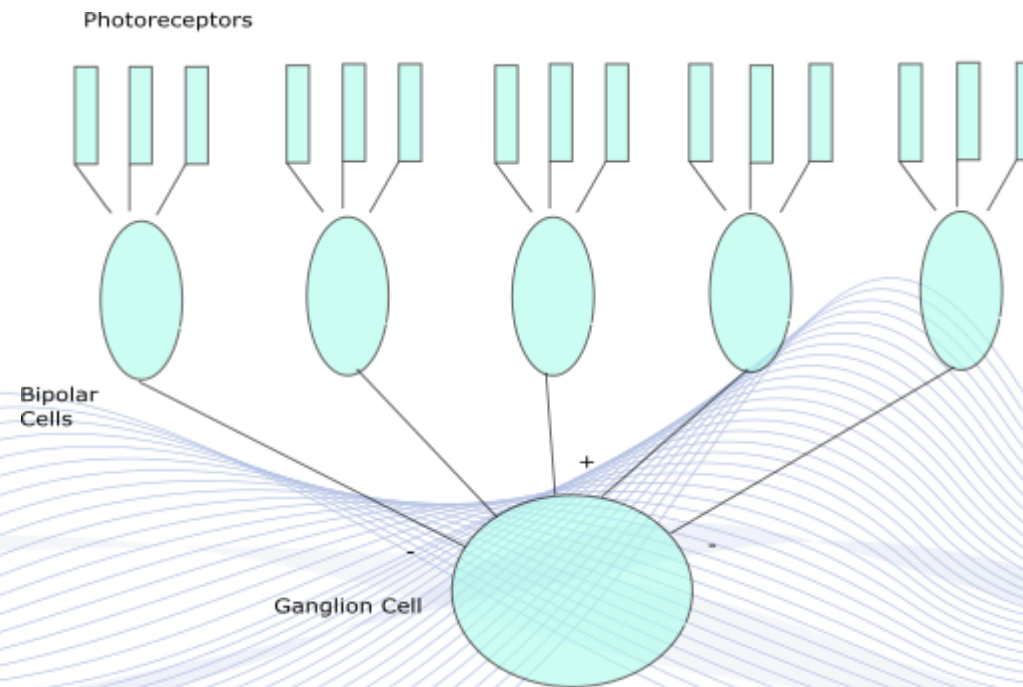
Rod and cone density change from retina center to its periphery.

Retina



Laplacian-of-Gaussian (LoG) function [LOG].

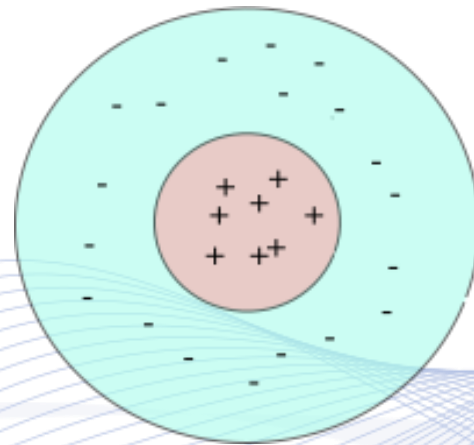
Retina



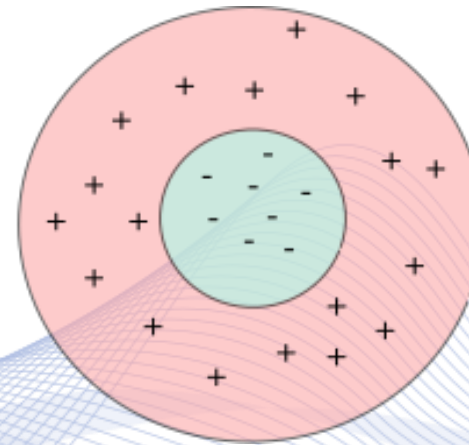
Ganglion receptive fields.

Retina

Receptive Fields



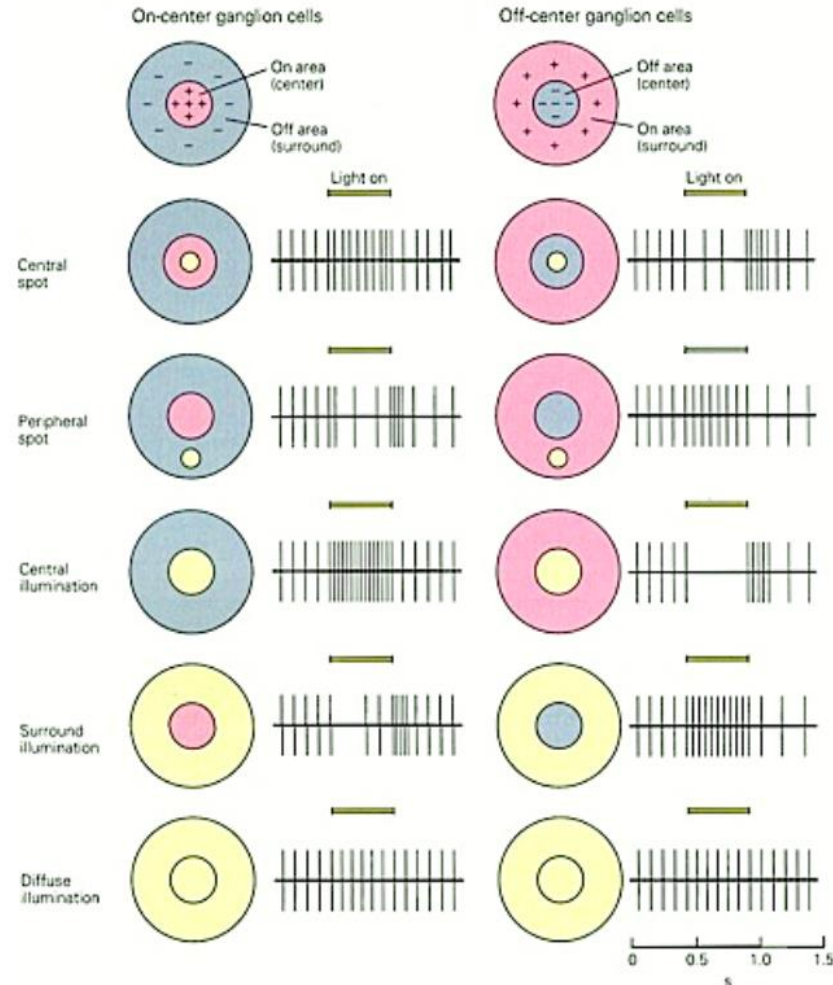
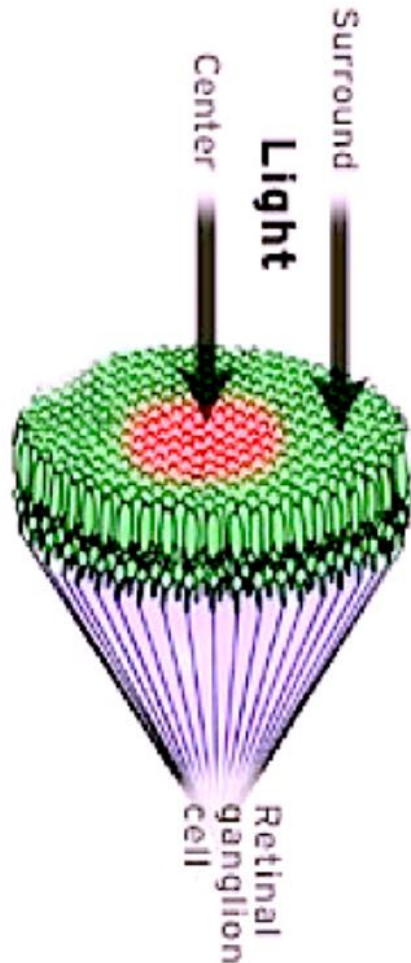
On-center, Off-surround



Off-center, On-surround

Center-surround organization of ganglion receptive fields.

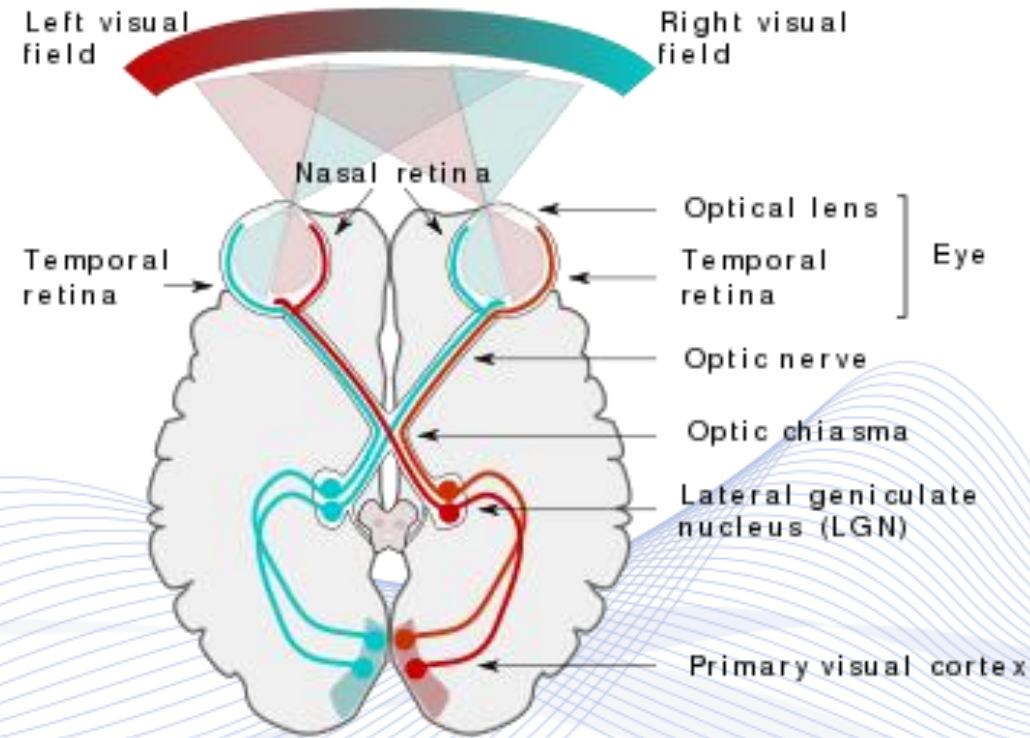
Retina



Human Visual System

- Human Visual System
- Retina
- **Visual Pathway**
- Visual Cortex
- Visual defects

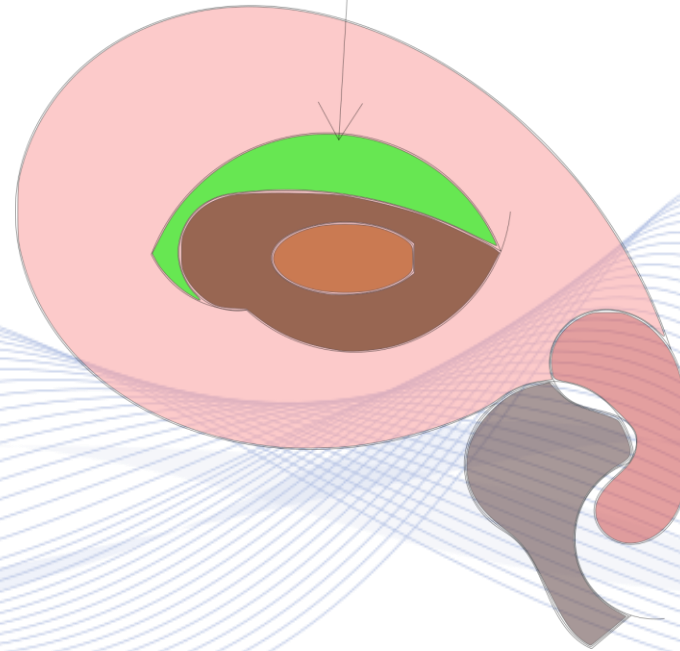
Visual Pathway



Human Visual System structure [WIKVS].

Corpus Callosum

CORPUS CALLOSUM

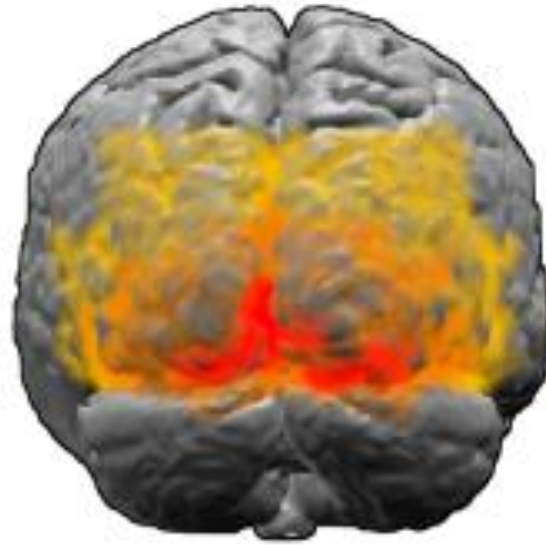


Corpus callosum.

Human Visual System

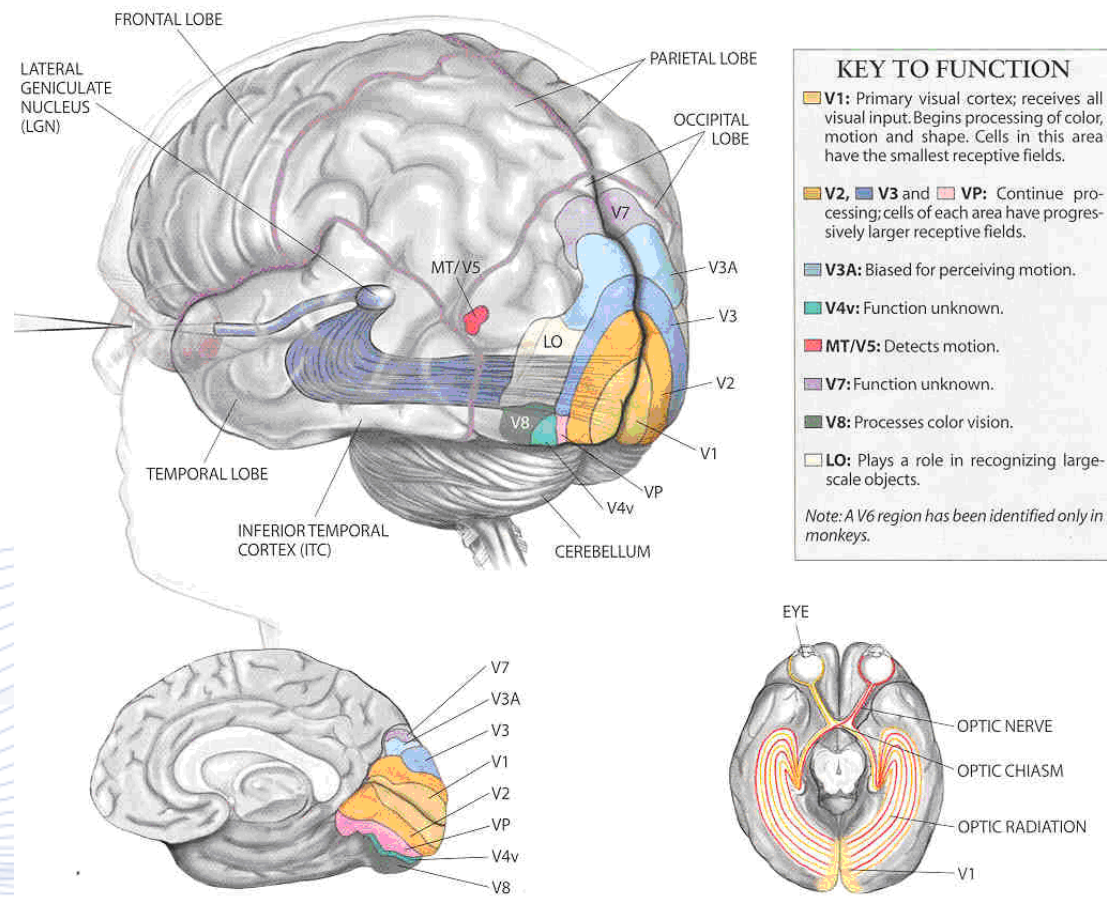
- Human Visual System
- Retina
- Visual Pathway
- **Visual Cortex**
- Visual defects

Visual Cortex



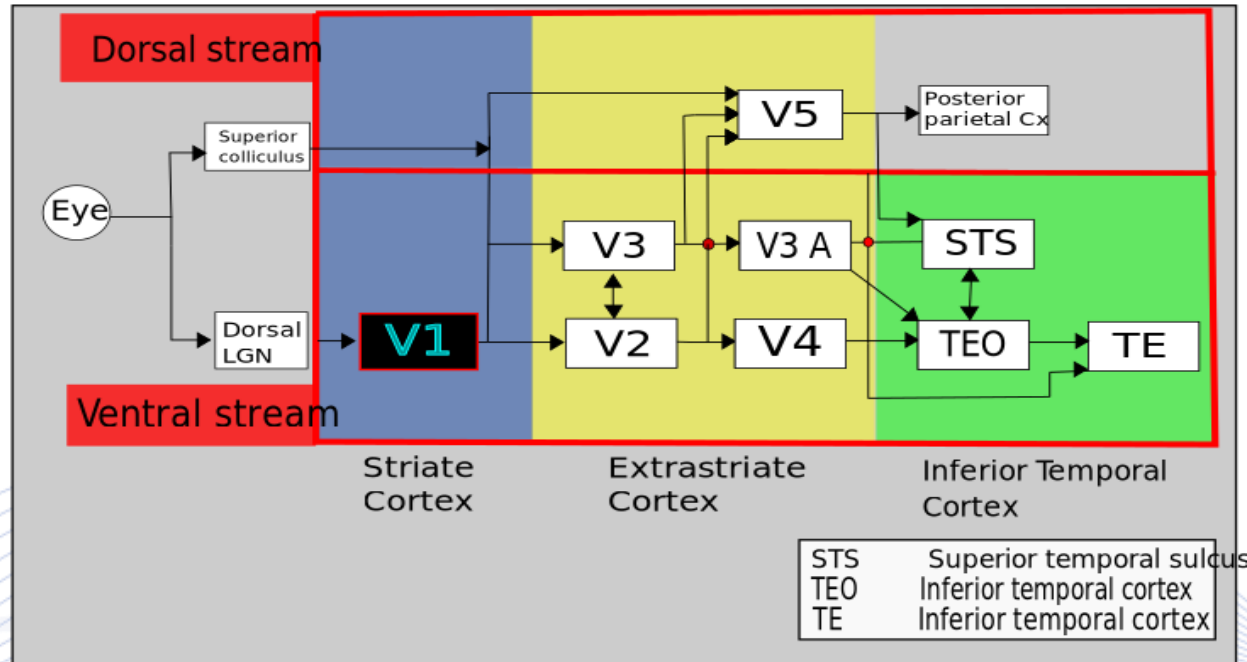
Visual cortex topology [WIKVC].

Visual Cortex



Visual cortex structure [NEUCC].

Visual Cortex



Organization of virtual cortex.

Human Visual System

- Human Visual System
- Retina
- Visual Pathway
- Visual Cortex
- **Visual defects**

Visual defects

Any damage of any HVS subsystem can create vision disorders or visual defects:

- Eye disorders: **refractive errors** (myopia, hyperopia, astigmatism and presbyopia)
 - **Cataract** is a clouding of the eye lens.
 - **Age-related Macular Degeneration (AMD)** affects the macula, (central part the retina), damaging sharp and central vision.
 - **Diabetic retinopathy** is progressive damage to retina blood vessels.
 - **Retinal detachment.**

Visual defects

- ***Glaucoma*** can damage the optic nerve, typically associated to eye fluid pressure increase.
- ***Amblyopia*** (“***lazy eye***”) is due to abnormal development of visual acuity, typically found in some children.
- ***Strabismus*** is an imbalance in eye vergence or gaze orientation.

Defects related to visual path or Visual cortex:

- They result from brain dysfunction due to lesions, trauma or other defects.

Visual defects

Color related visual defects.

- The most common are retinal ones in nature and are genetically passed on between generations.
- Some retinal color deficiencies are:
 - a shift in cone wavelength sensitivity of cones or
 - degenerate or missing cones.
- Most often only one type of cone is affected (***dichromasy***).
- Total color blindness (***monochromasy***) is extremely rare.

References



- [PIT2000] I. Pitas, Digital Image Processing Algorithms and Applications, J. Wiley, 2000.
- [PIT2013] I. Pitas, “Digital Video and Television”, Createspace/Amazon, 2013.
- [PIT2000] I. Pitas, Digital Image Processing Algorithms and Applications, J. Wiley, 2000.
- [PIT2017] I. Pitas, “Digital video processing and analysis”, China Machine Press, 2017 (in Chinese).
- [SAR2017] S. Ajina, H. Bridge, “Blindsight and Unconscious Vision: What They Teach Us about the Human Visual System”, The Neuroscientist, 2017.
- [WIKVS] “Visual System”, Wikipedia.
- [GR2009] U. Grünert, “Retinal Bipolar Cells” In: Binder M.D., Hirokawa N., Windhorst U. (eds) Encyclopedia of Neuroscience. Springer, Berlin, Heidelberg (2009).
- [WIKLGN] “Lateral Geniculate Nucleus”, Wikipedia.
- [BEN2010] A. Benoit, A. Caplier, B. Durette, J. Herault, “Using Human Visual System modeling for bio-inspired low level image processing”, Computer Vision and Image Understanding 114 (2010) 758–773.

References



[DAV2018] D. Holmes, A. Macdonald, “Reconstructing the retina”, 2018 Springer Nature Limited.

[LOG] <http://weisu.blogspot.com/2009/05/laplacian-of-gaussian-log.html>

[EXT] <https://www.extremetech.com/extreme/144248-neuristors-the-future-of-brain-like-computer-chips>

[CIR] <https://www.circuitstoday.com/working-of-scanner>

[WIKVC] “Visual Cortex”, Wikipedia.

[NEUCC] Neuroscientificallychallenged, “Know your brain: Corpus callosum”

[FRE1991] W.T. Freeman, E.H. Adelson, D.J. Heeger, “Motion without movement”, ACM Siggraph 25, 4 (August 1991), pp. 27–30.

[HOF2000] D.D. Hoffman, “Visual Intelligence: How We Create What We See”, W.W. Norton & Company, 2000.

[ZEK1993] S. Zeki, “A Vision of the Brain”, Blackwell Scientific Publications, Oxford, 1993.

[STE] https://www.seevividly.com/info/Physiology_of_Vision/Optical_Illusions/Stereo_Illusio

Q & A

Thank you very much for your attention!

**More material in
<http://icarus.csd.auth.gr/cvml-web-lecture-series/>**

**Contact: Prof. I. Pitas
pitass@csd.auth.gr**