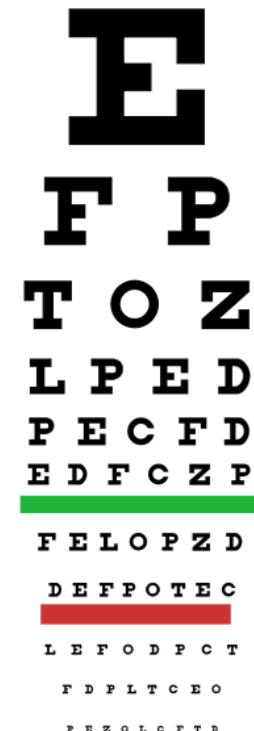


Visual Pathway and Visual Pathologies

(Human Visual System: Visual Periphery, Visual Pathway, Normal Function and Impairment)

Petr Maršálek



2020 - 2022

Outline 8 – Retina and Subcortical Visual Pathway

- Retina, Point Spread Function
- Adaptation, Accommodation
- Visual Acuity, Optical Eye Media, Lens, Illumination,
- Rods, Cones, Black and White /and Color Vision
- Ten Neural Layers in Retina, Functional Aspects
- Binocular Vision and Its Disorders, Vergence, Strabismus
- Saccades, Visual Following, Nystagmus
- Visuo-motor Eye Movement Control, Basic Concepts
- Optical nerve, Perimeter, Objective Perimeter
- Color Opponent System in the Visual Pathway



1 20/200

Snellen (N/36)
Optotypes have (N/32)
letters with defined (N/28)

2 20/100

letter size, (or number of points) (N/26)

3 20/70

seen from a calibrated distance. (N/24)

4 20/50

This is written as fraction. (N/22)

5 20/40

6 20/30

The best vision is: 6/6 (N/20)

7 20/25

Numerator: From distance six meters/ (N/18)

8 20/20

denominator: we see six points (B/16)

9

(one arch minute each). (B/14)

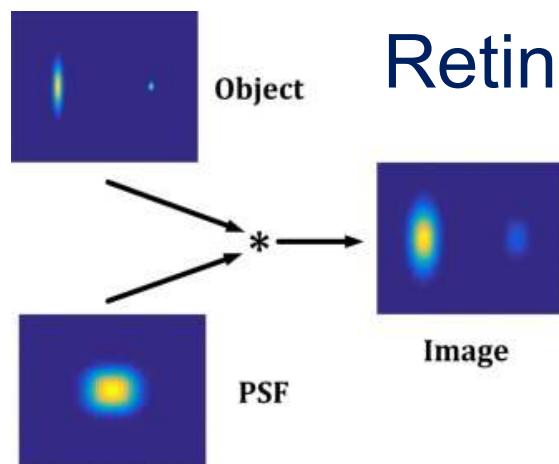
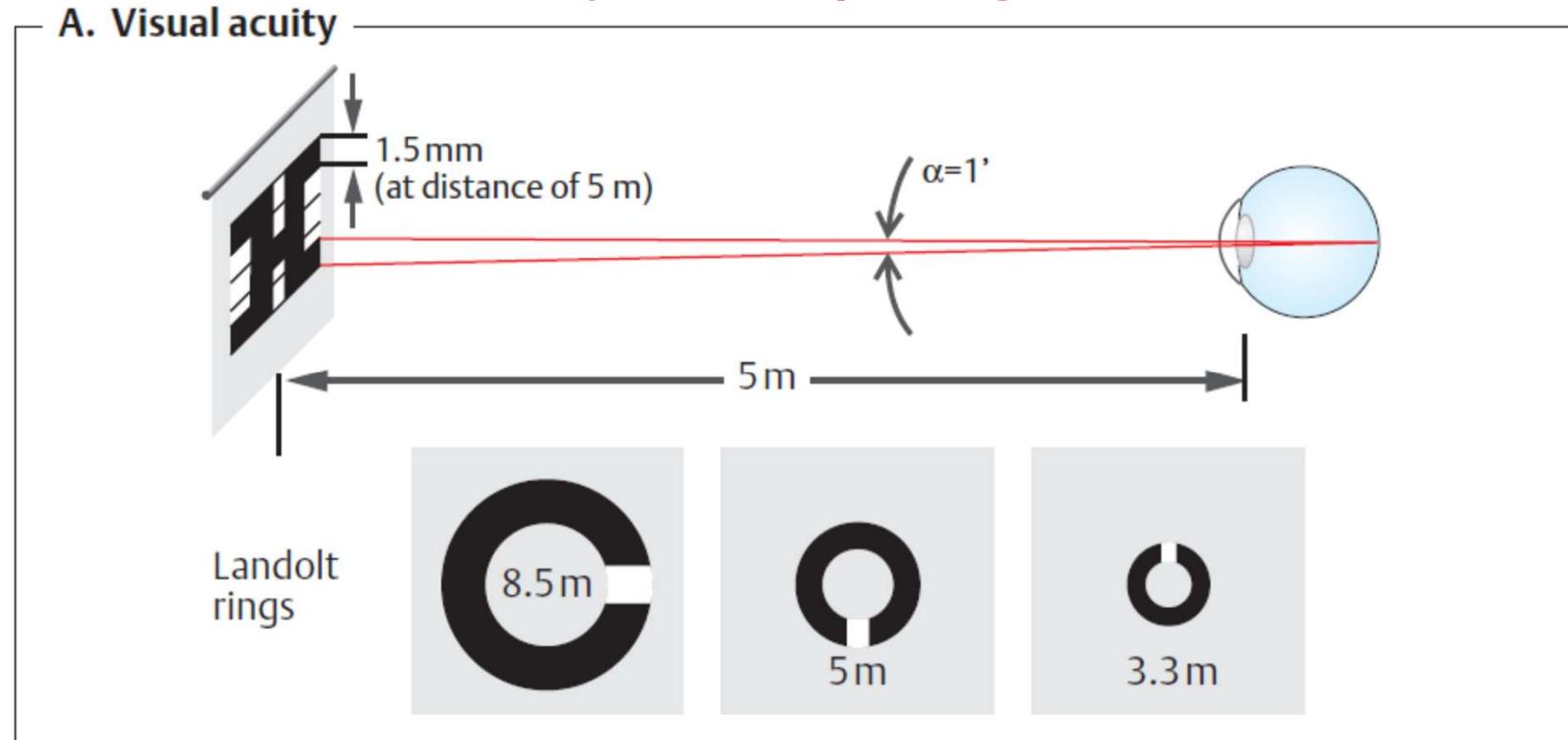
10

Functional Classification of Vision Impairment

A fraction, written as numerator/ denominator denotes:
given a 6 m viewing distance, /or 20 feet/, how many
points are seen as one point?
(Geometry of 2D angle is simplified to a square patch.)

1 normal vision		6/6
2 low vision	worse than (on the best eye with corrective lenses)	(<) 6/18
3 (practical) blindness (EU)		< 3/60
	or narrowing of visual angle less than other more strict norm (US)	< 10°*10° < 6/60, < 20°*20°
4 <i>amblyopia a k a lazy eye</i>		
(= lower acuity due to central causes)		

Visual Acuity: 1' (angular minute)



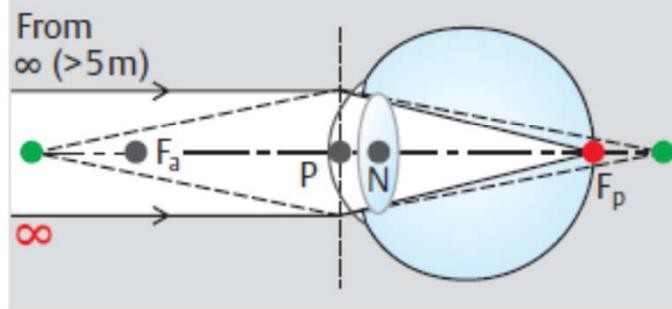
Retinal image results from convolution of object and point spread function

The sharp image results when the object plane is focused and spherical aberration is minimal

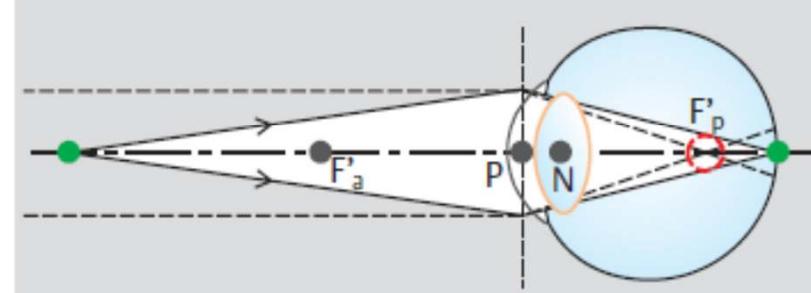
Far and Near Point/ or How Eye Focuses

B. Eye: Accommodation for (1) far vision and (2) near vision

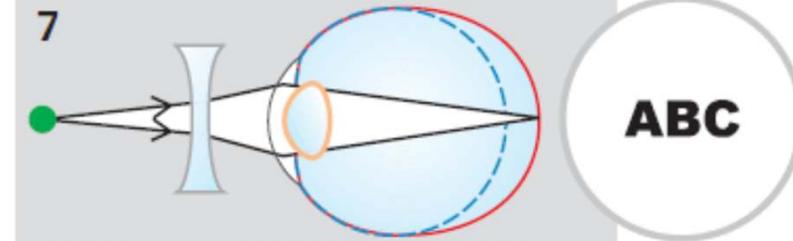
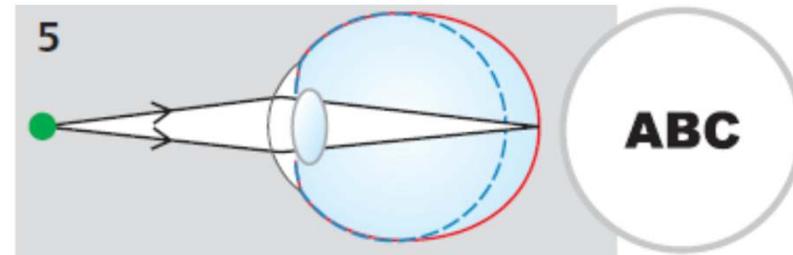
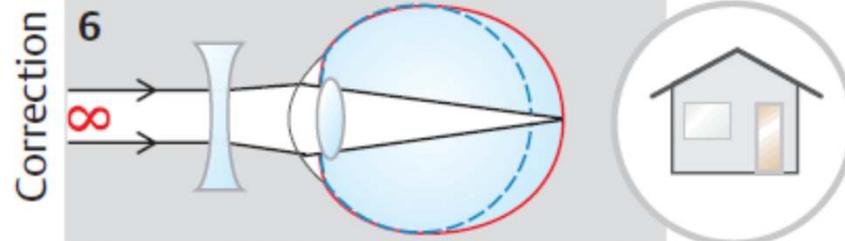
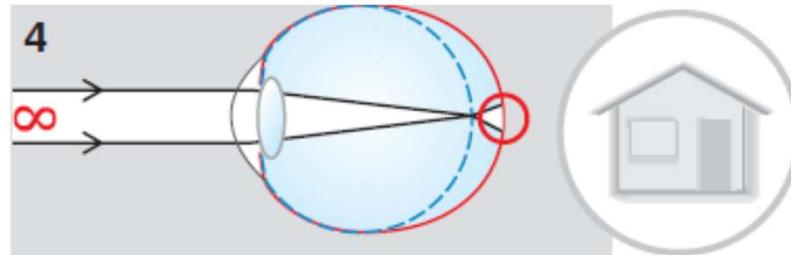
1 Lens adjusted for far vision



2 Lens adjusted for near vision



Myopia

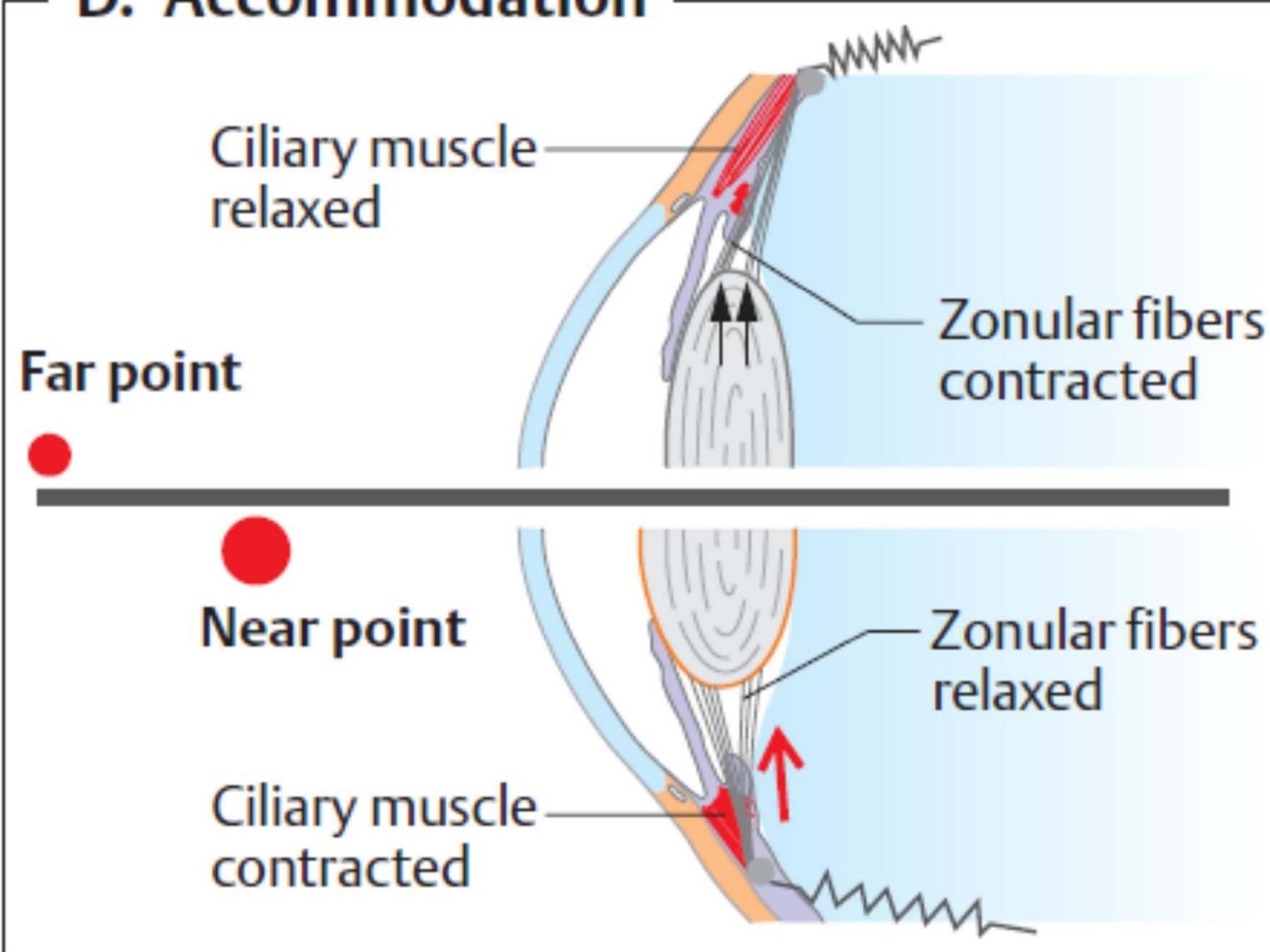


Myopia = Near-sightedness

The opposite is Hypermetropia = Far-sightedness

Accommodation = Focusing to Get a Sharp Image

D. Accommodation



Accommodation = Focusing to Get a Sharp Image

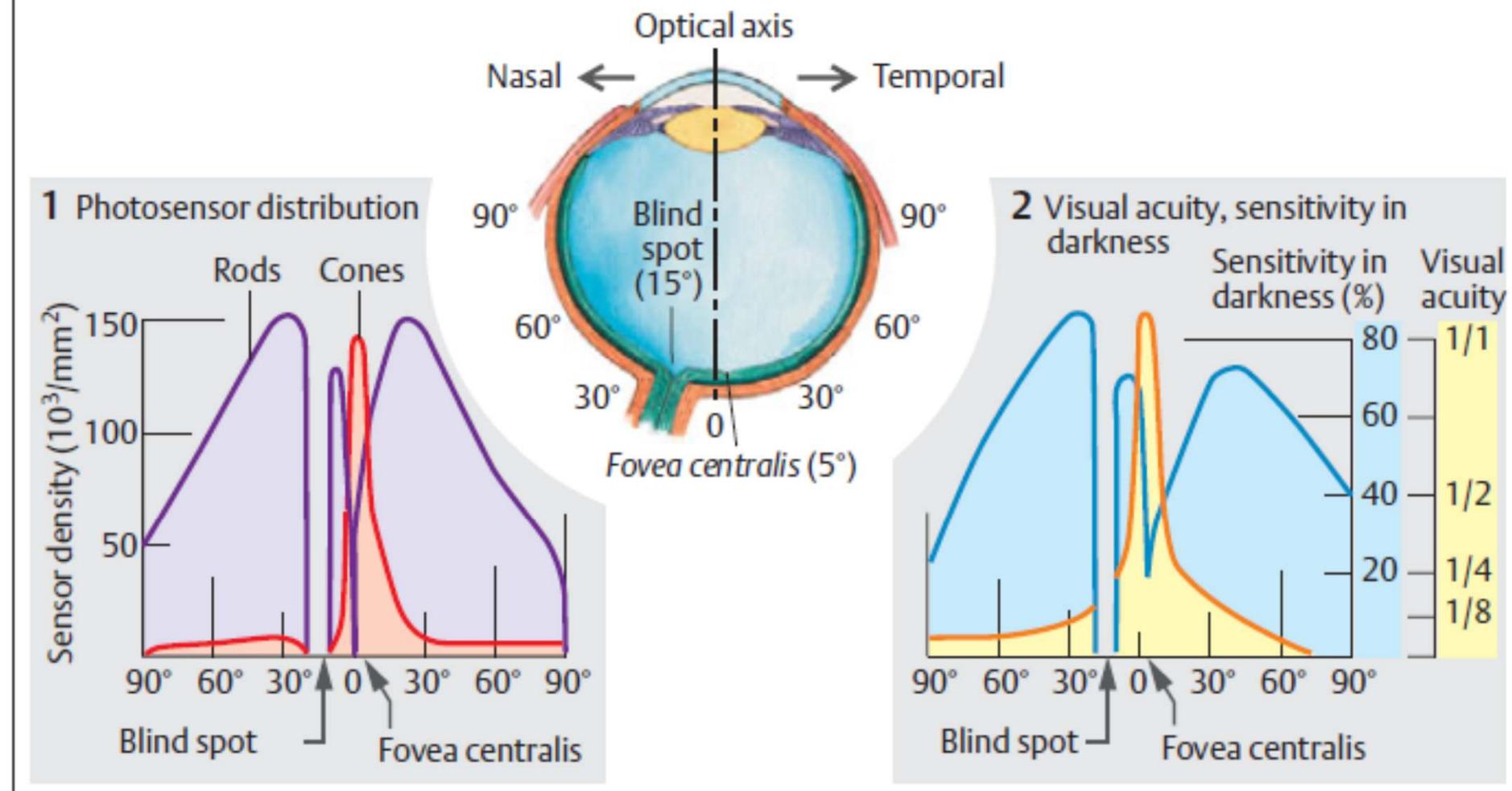
In individual development and ageing, far and near point positions change. A common effect of this presbyopia is a hypermetropia.

Around the age of 50, the elasticity of the lens drops to the point that the near point is distant enough that practically merges with the far point.

(As the next stage, with the use of current eye treatment, patients with cataract have implanted artificial lenses...)

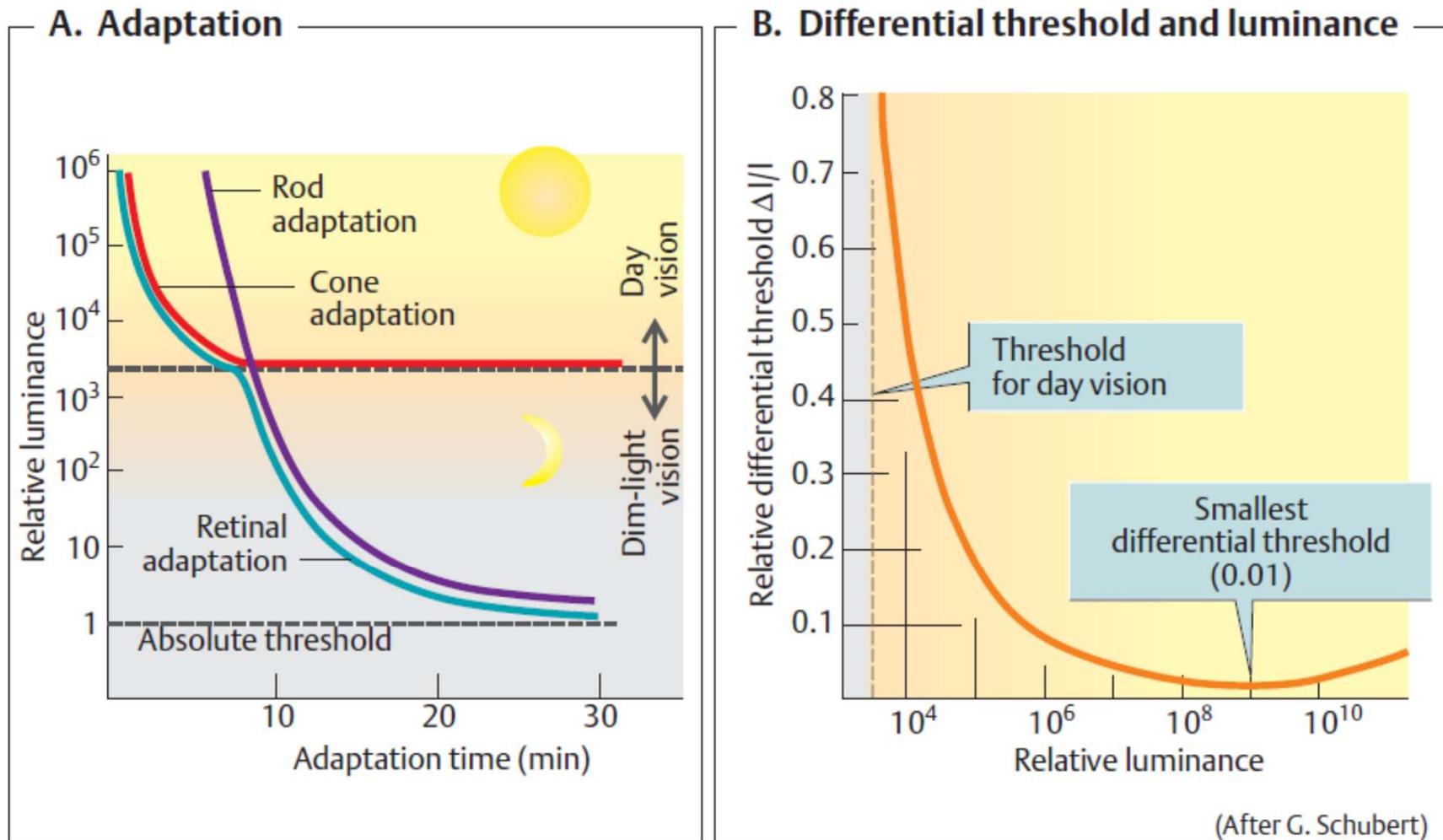
Visual Acuity, Day and Night Acuity

B. Retina: Photosensor distribution, sensitivity in darkness and visual acuity



Blind Spot and Yellow Spot in One Retina

Adaptation to Day and Night Illumination Conditions



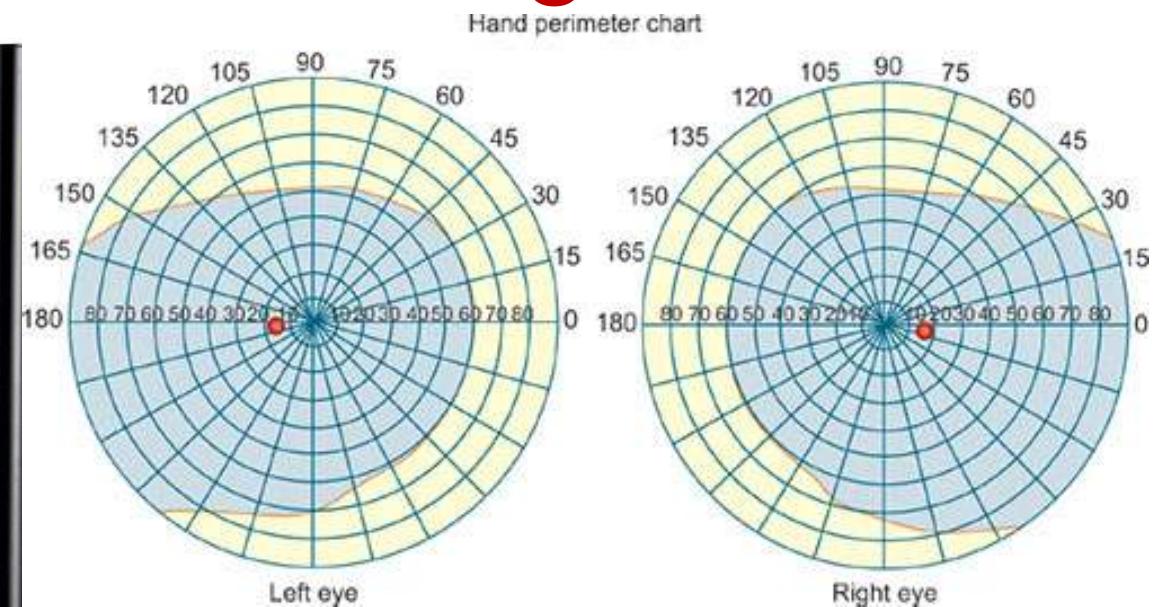
Adaptation to lighter conditions is instant.

Adaptation to the dark takes tens of minutes.

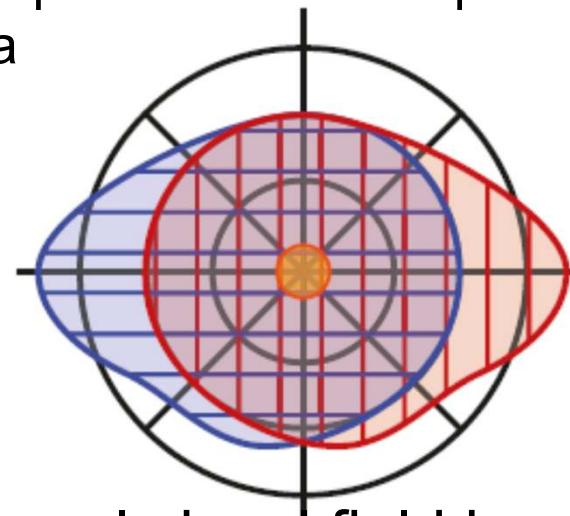
Perimeter investigation



The perimeter can be measured objectively



Blind Spots and Yellow Spots in L and R Retina

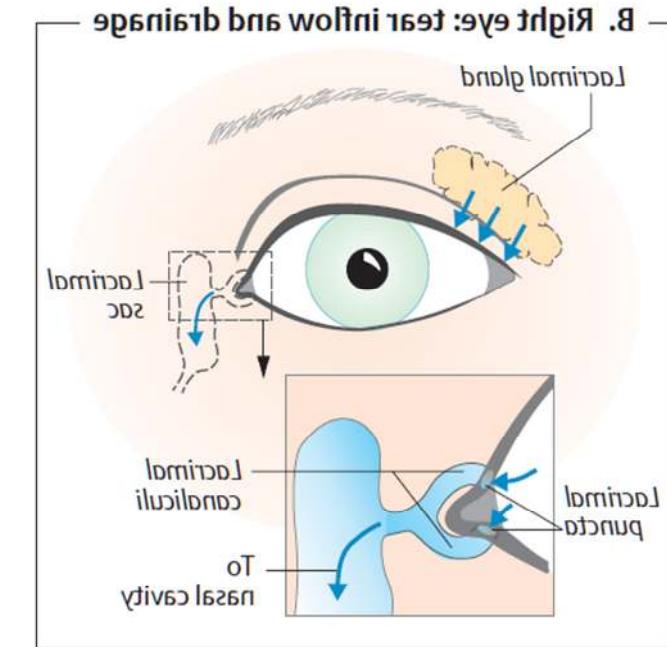
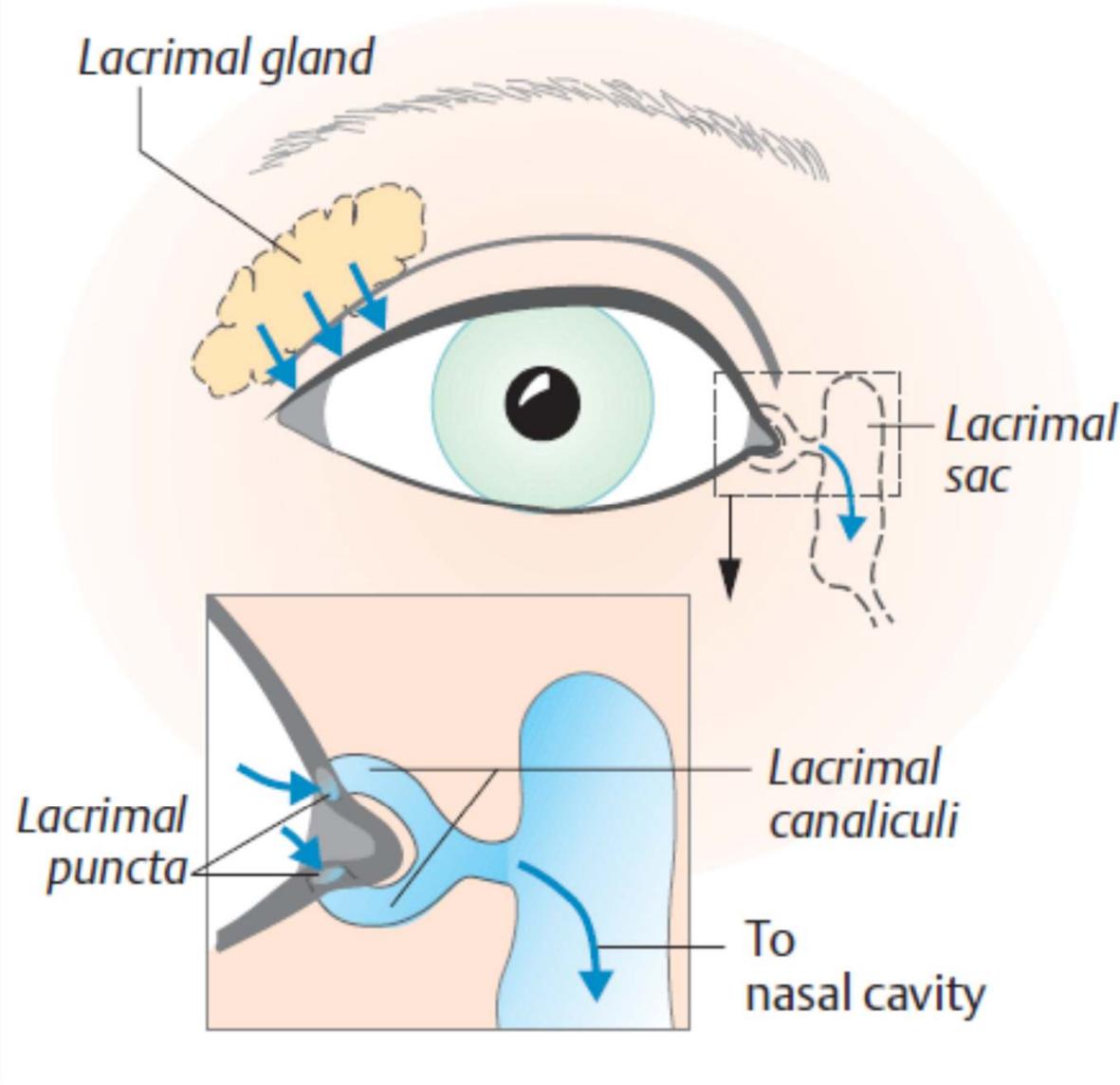


A normal visual field is a combination
of **left** and **right** eye views 11

Lacrimal Gland and Duct, Eye Muscles

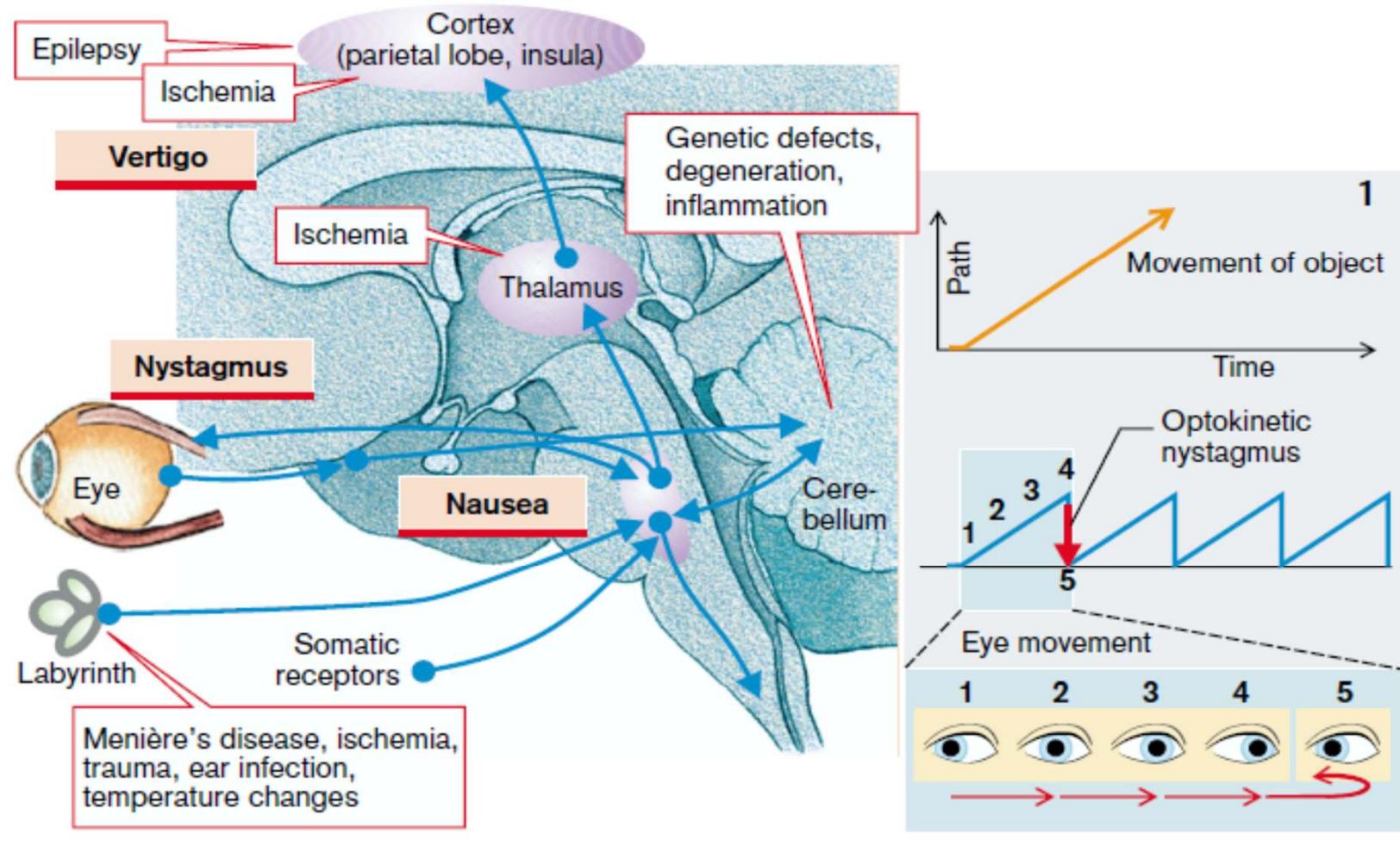
Left-right symmetry,
eye movements

B. Right eye: tear inflow and drainage



Nystagmus

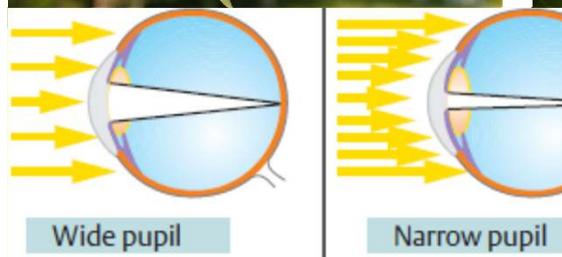
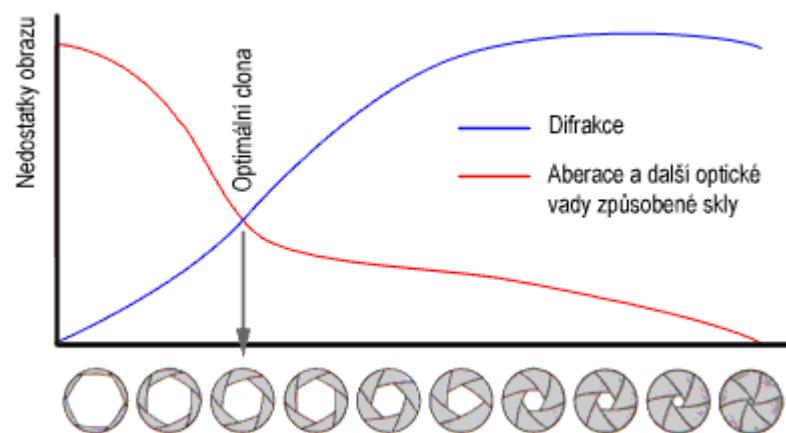
A. Disturbance of Balance, Nystagmus



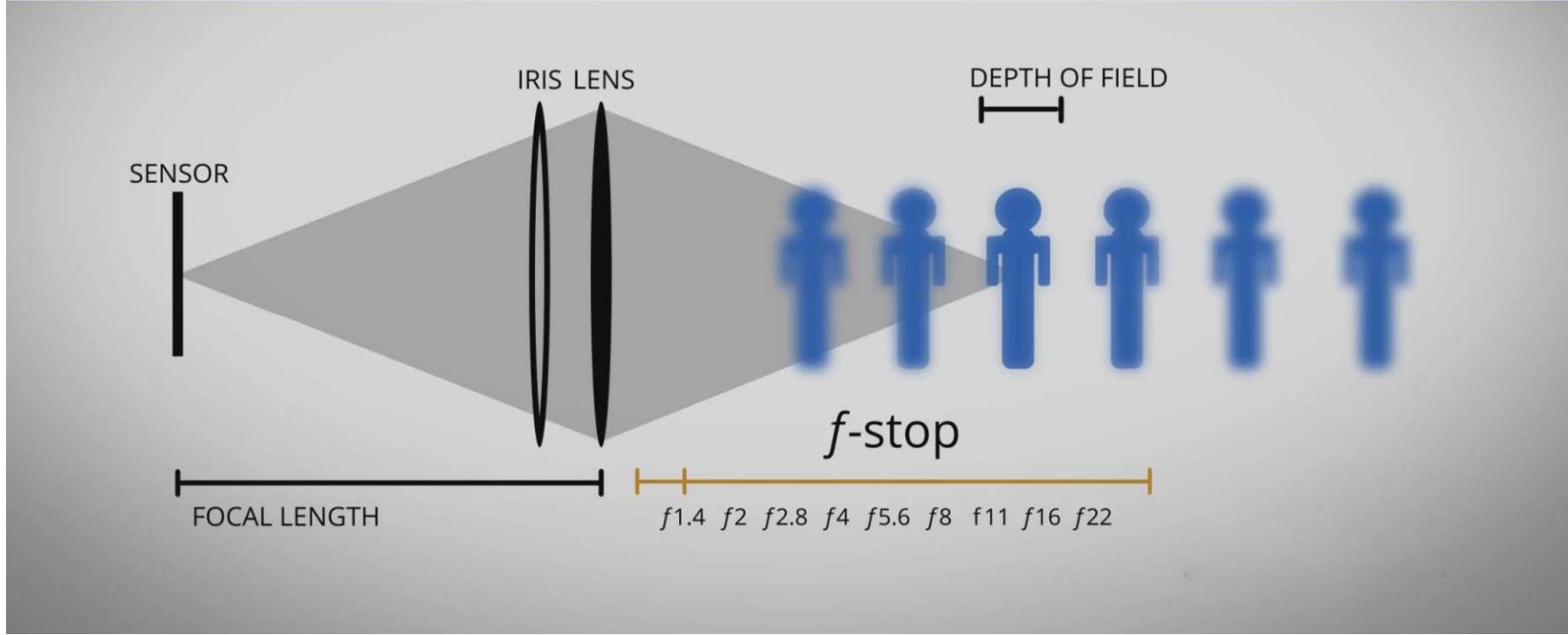
Aperture Versus Depth of Field (světelnost/ clona, hloubka ostrosti)

Apply to Human Eye Functioning as Well

The depth of field will increase as you open up your aperture or move on a lens barrel to a point called the hyperfocal distance opposite the focal length you are using. If you then move closer to the subject, the depth of field will decrease to infinity. For example, if your camera has a hyperfocal distance of 18 feet, focus at 18 feet,



In Photography, these are Shutter Speeds and Apertures... 14

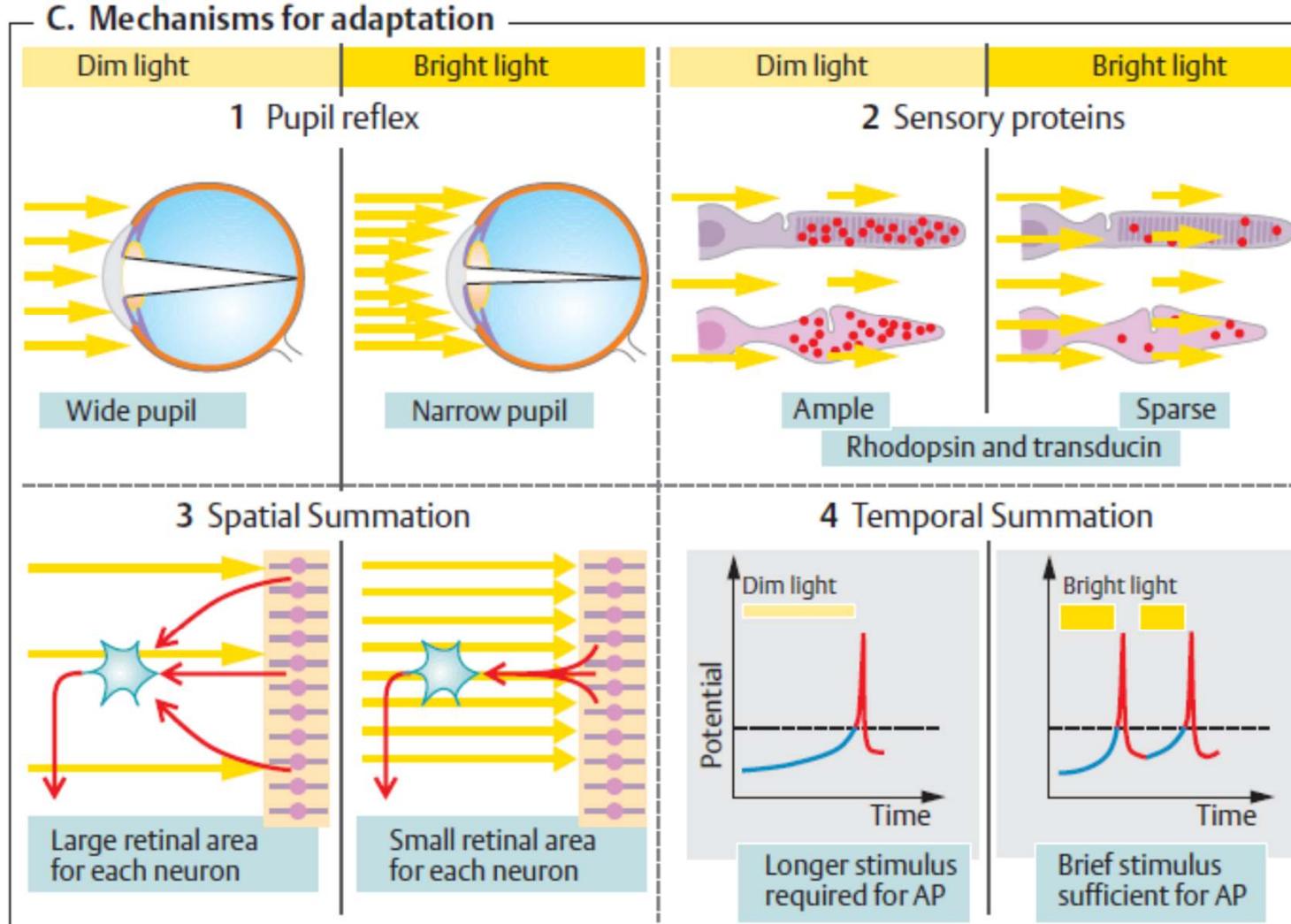


Aperture Versus Depth of Field

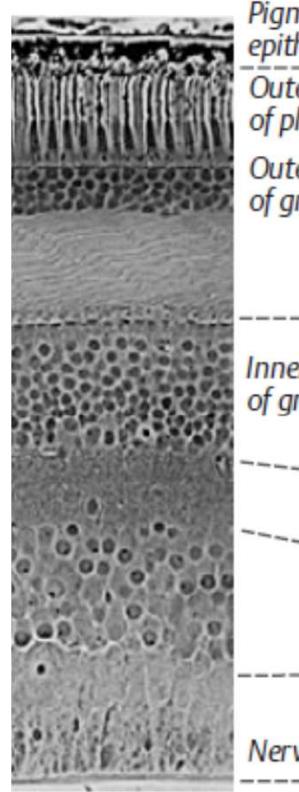
$$D_{\text{DOF}} \approx 2u^2 Nc/f^2$$

Depth of field D is approximately proportional to this formula, entered by An acceptable circle of confusion diameter (c), aperture diameter(A), and distance to the subject (u), divided by the square of the focal length (f), all in length units. The dimensionless f-number is $N = f/A$.

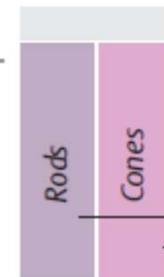
Aperture Versus Depth of Field Apply to Human Eye Functioning as Well



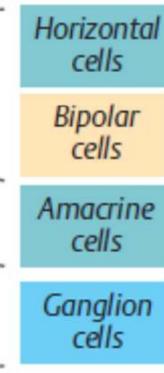
These are 'digital' processes, encoded by action potentials



Pigmented epithelium
Outer segments of photosensors
Outer layer of granular cells



Inner layer of granular cells



Nerve fiber layer

Optic nerve

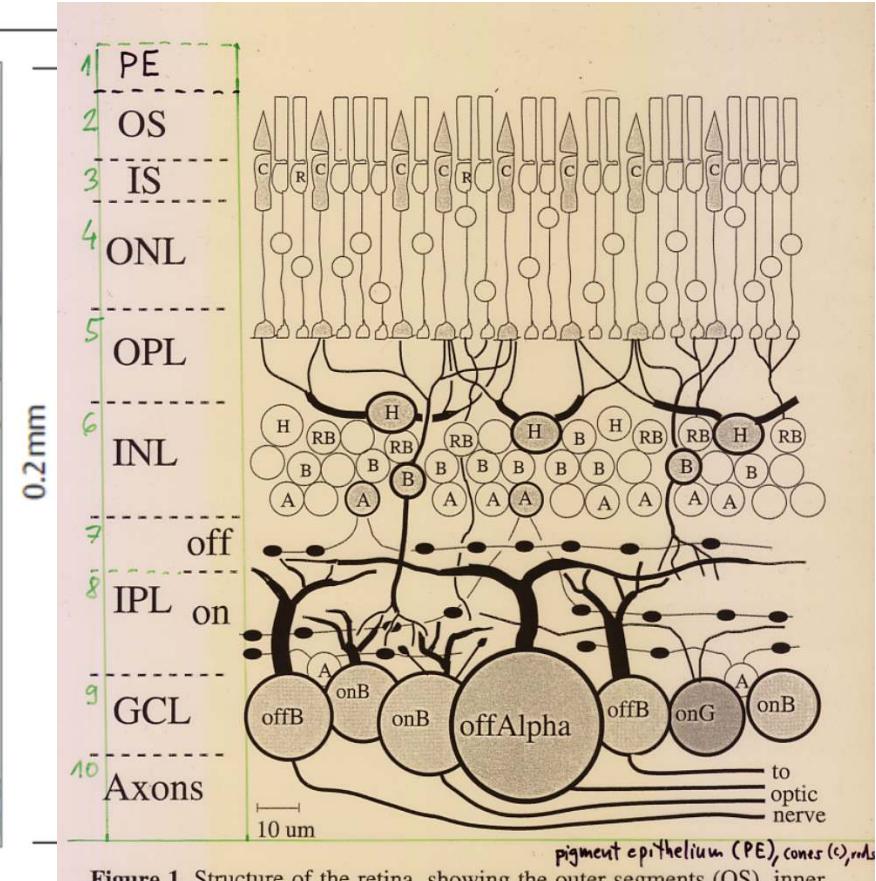
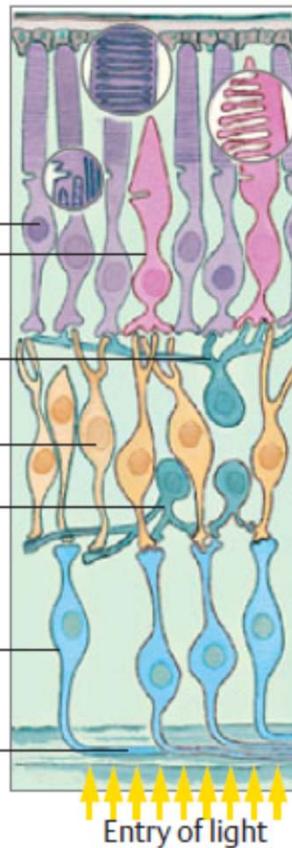


Figure 1. Structure of the retina, showing the outer segments (OS), inner segments (IS), outer nuclear layer (ONL), outer plexiform layer (OPL), inner nuclear layer (INL), inner plexiform layer (IPL), ganglion cell layer (GCL), horizontal cells (H), bipolar cells (B), amacrine (A), and rod bipolar (RB) cells.

Ten

Layers

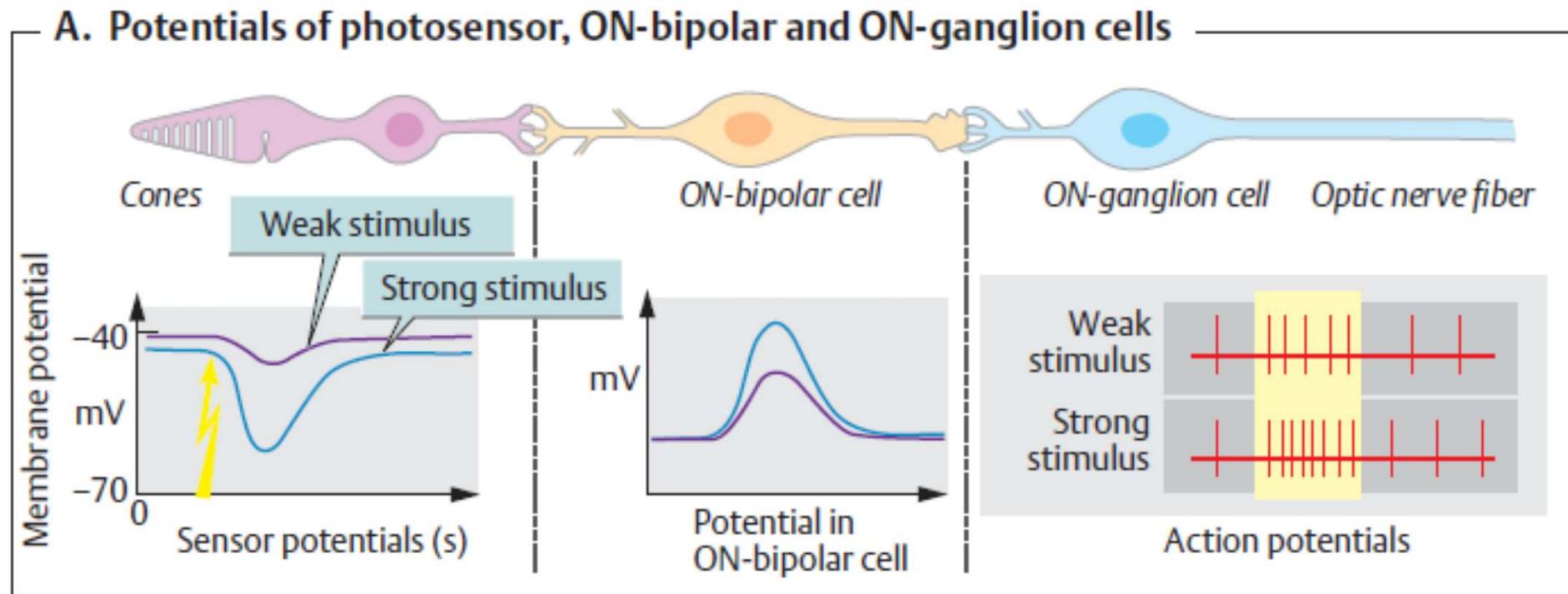
of

Retina

The optic nerve is the output of the retina.

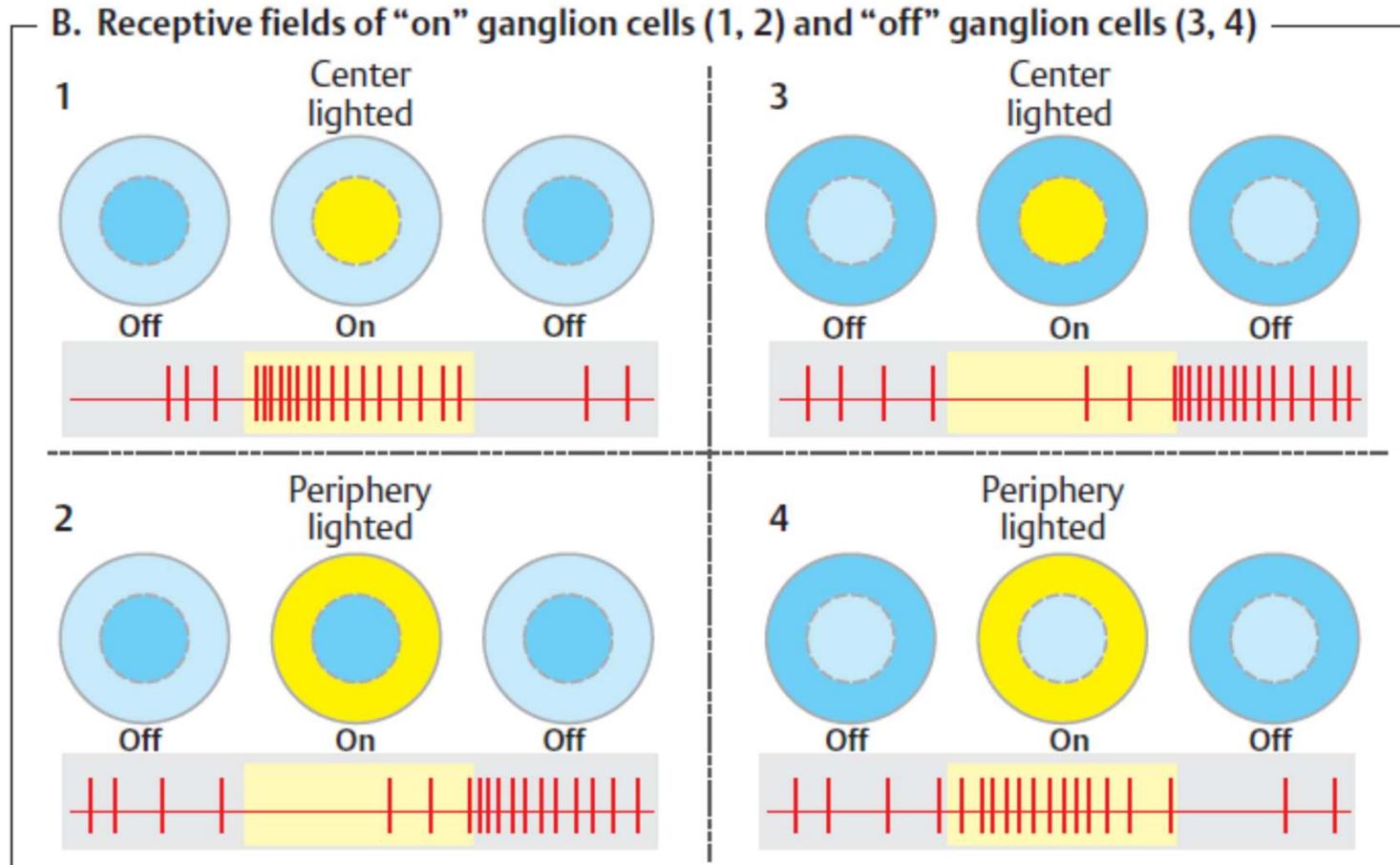
The retina is a unique neural network of the immense size of one million output lines, a patch of = $10^3 \times 10^3$ pixels. Its functions are poorly understood...

From Light Through Receptor Potential to Action Potentials and Coding in Optical Nerve



Od světla přes receptorový potenciál k akčním potenciálům a kódování ve zrakovém nervu

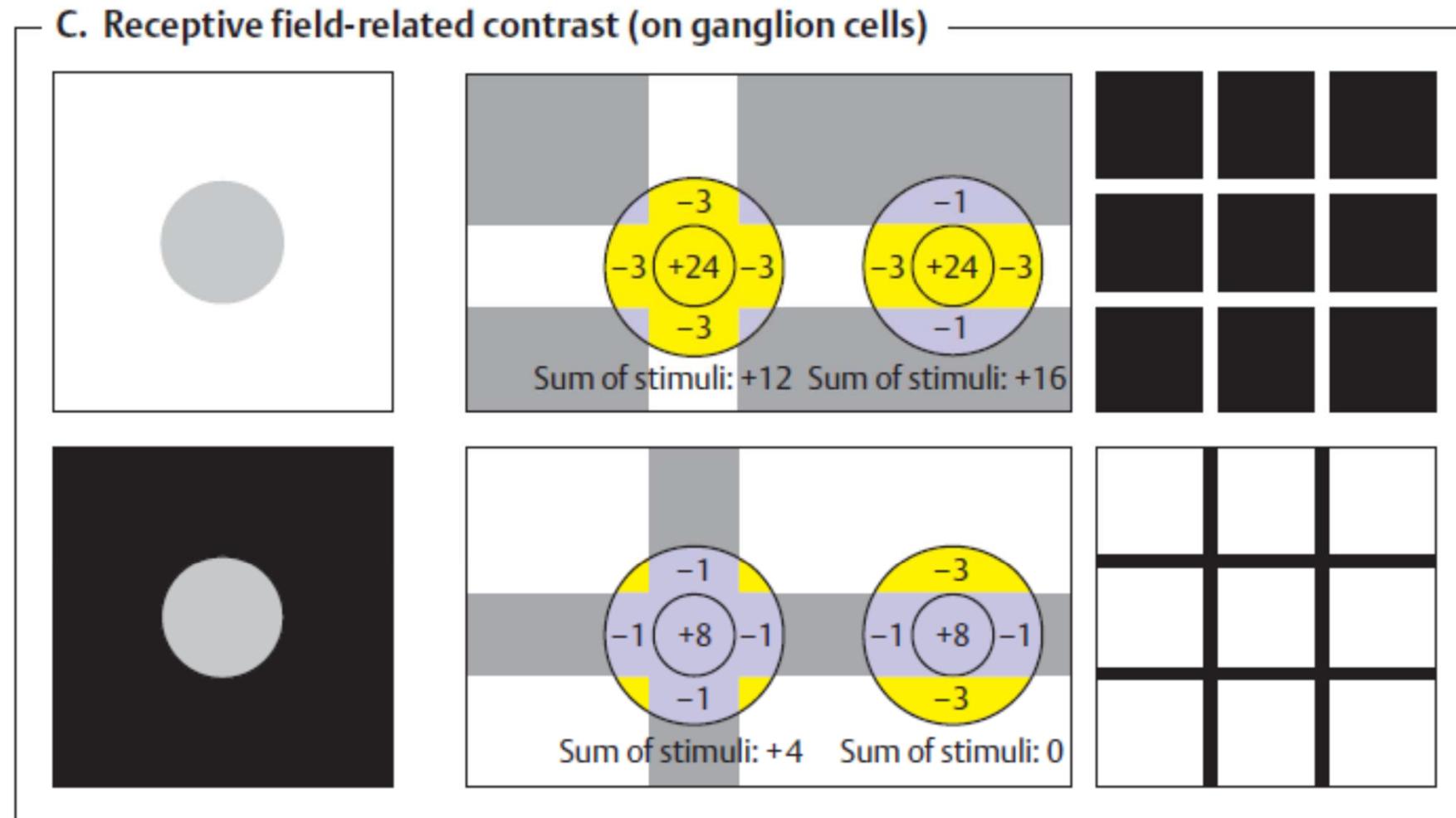
From Light Through Receptor Potential to Action Potentials and Coding in Optical Nerve



Retinal ‘On’ and ‘Off’ ganglion cells

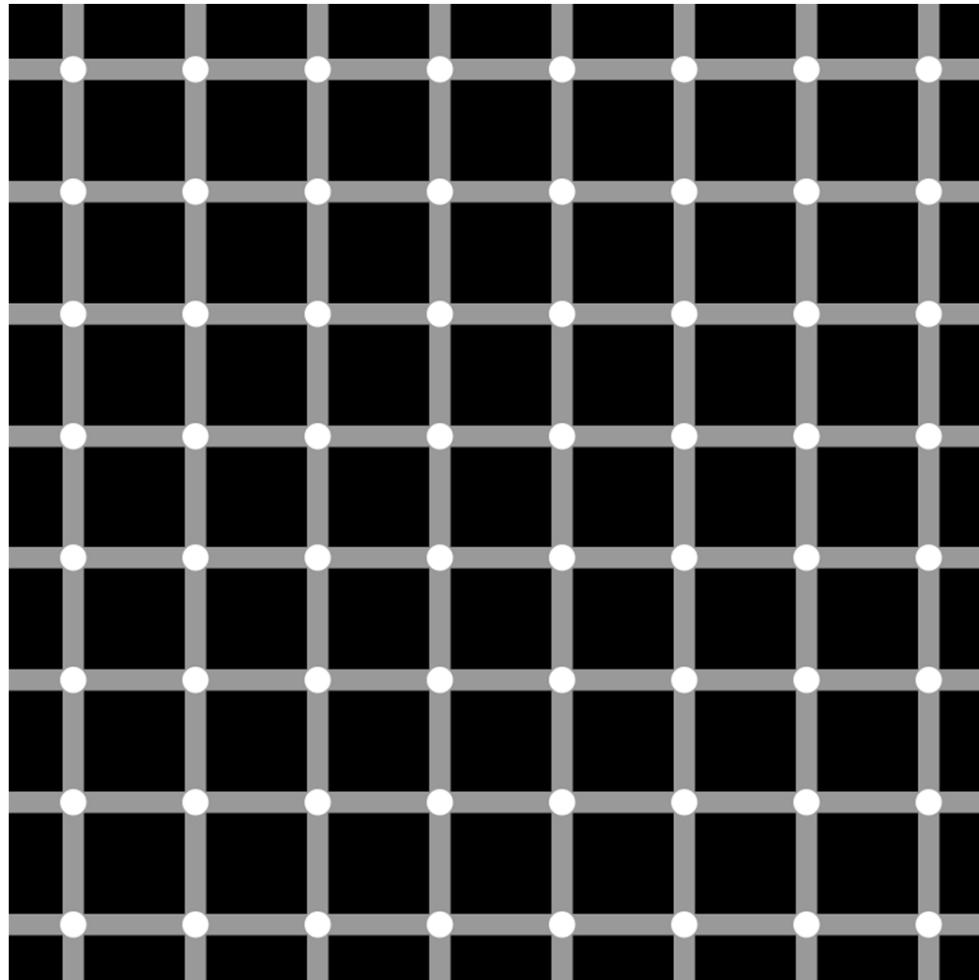
From Light Through Receptor Potential to Action Potentials and Coding in Optical Nerve

Origin of visual illusions...



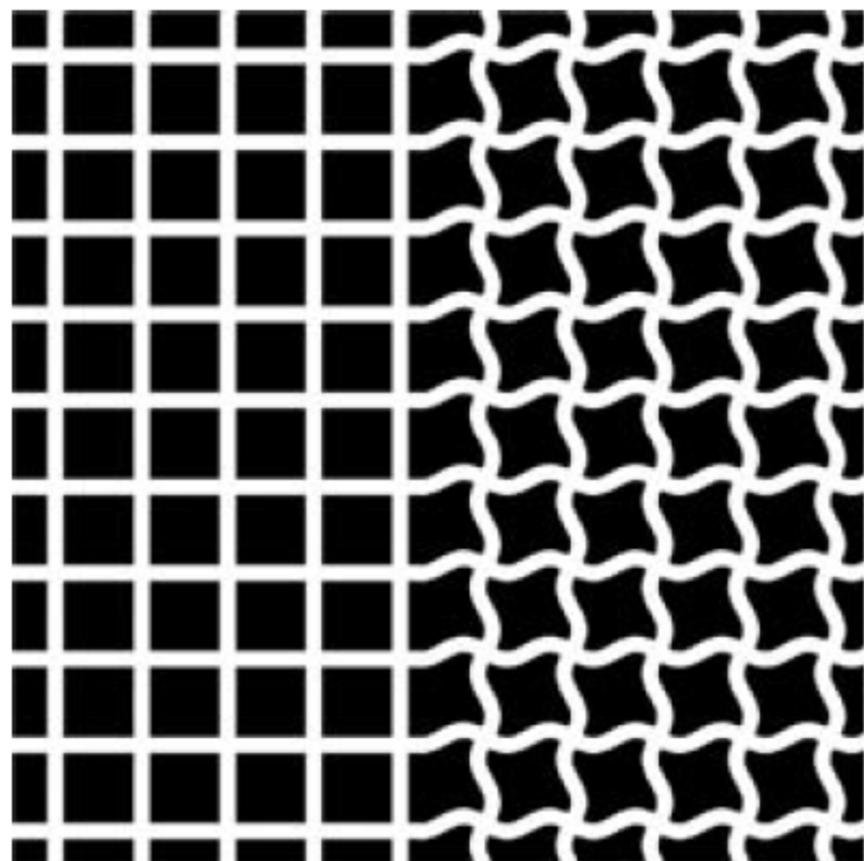
Peripheral (=Retinal) and Central (=Cortical) Mechanisms... ↵

The (Ludimar) Hermann Grid Illusion, 1870



Note the white ‘lightning’ and ‘darkening’ of the grid nodes. 21

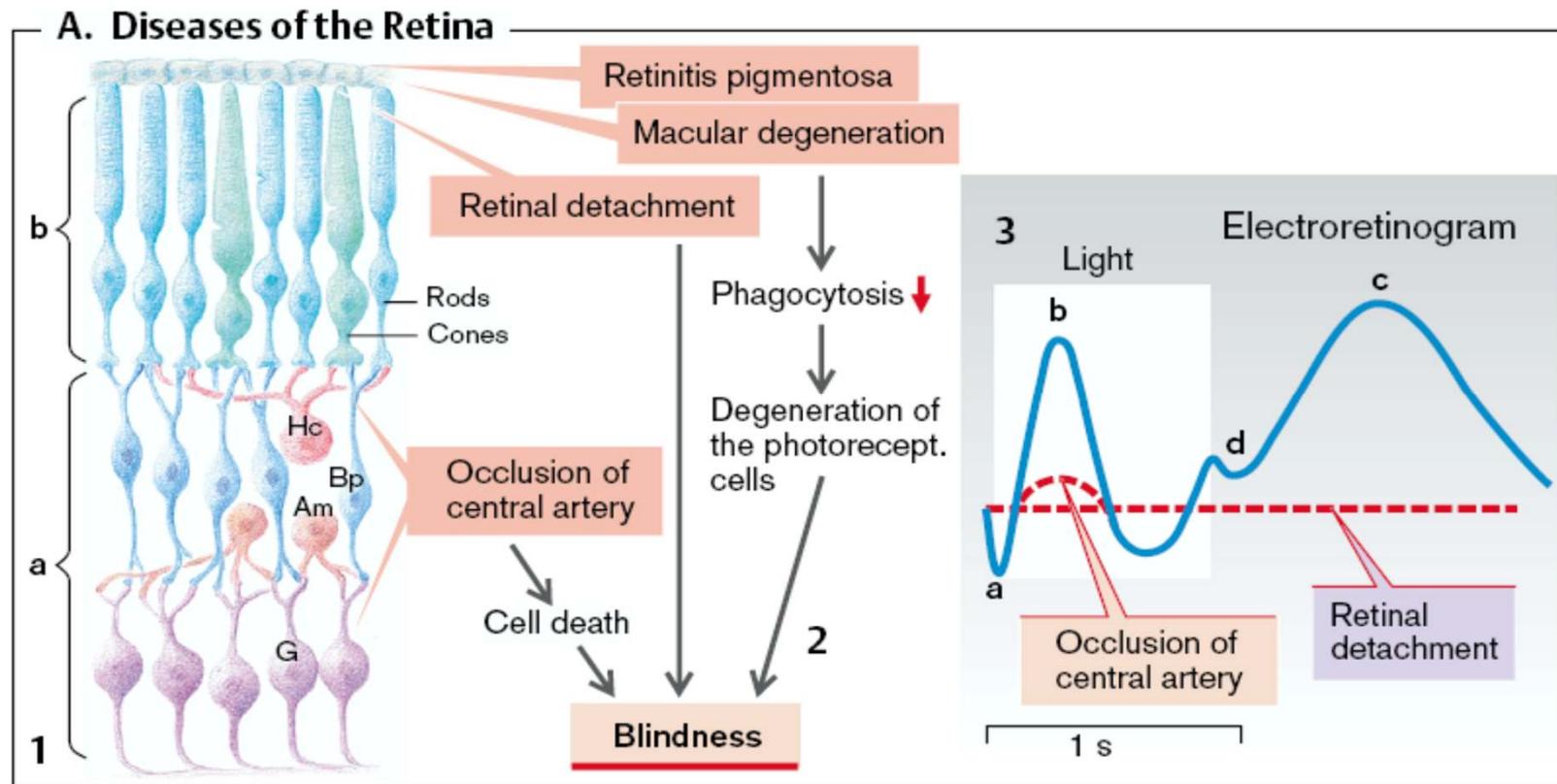
The (Ludimar) Hermann Grid Illusion, 1870



Comment:

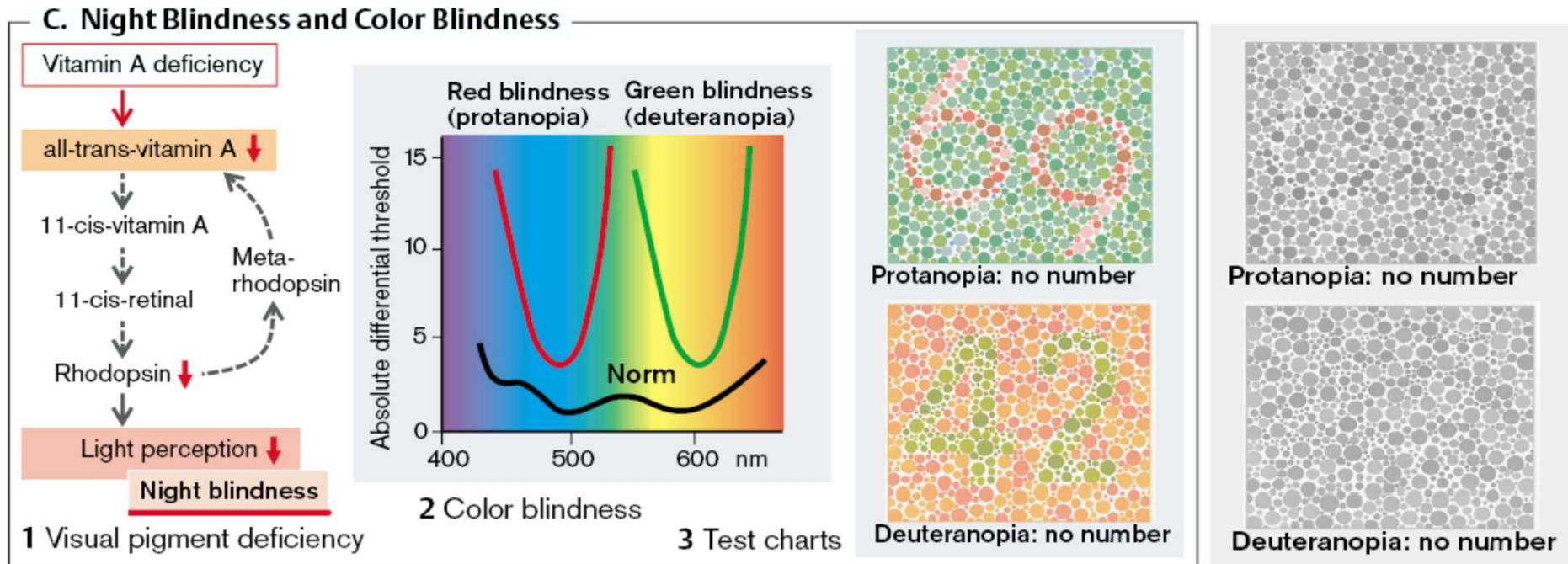
The right side does not show illusory darkened centers compared to the left side. The illusion producing the mechanism acts probably only on perpendicular neighbourhoods. This locates the illusion to the central (cortical) part of the visual pathway.

Electric Potentials of Retina



Electro-Retino-Gram in analogy to the EEG can record retinal activity and eye movements.

Day and Night Vision, with Rods and Three Cone Types



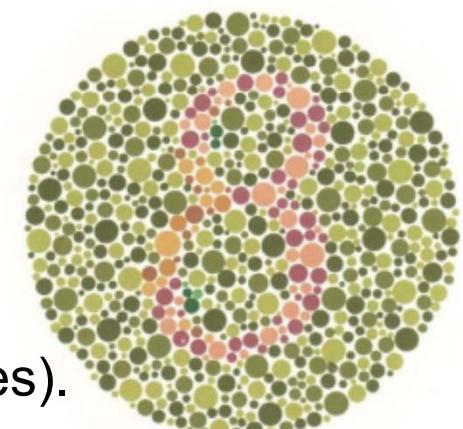
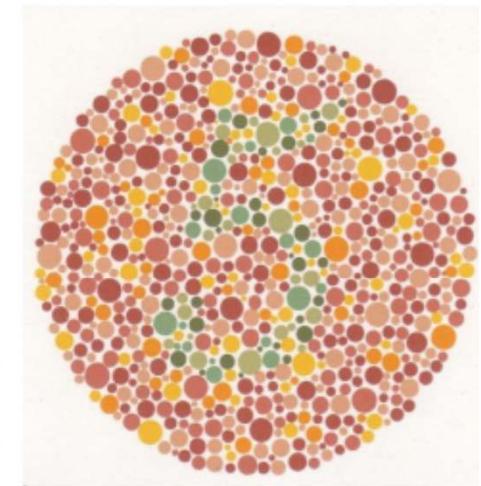
Color Blindness is manifested in men (XY) only, as it is located on the X chromosome. Women have the X in duplicate (XX). It also includes visual acuity impairment due to different than normal densities of cones.

Protanopia (no red cones) and Deutanopia (no red cones) and How They (May) See Colors

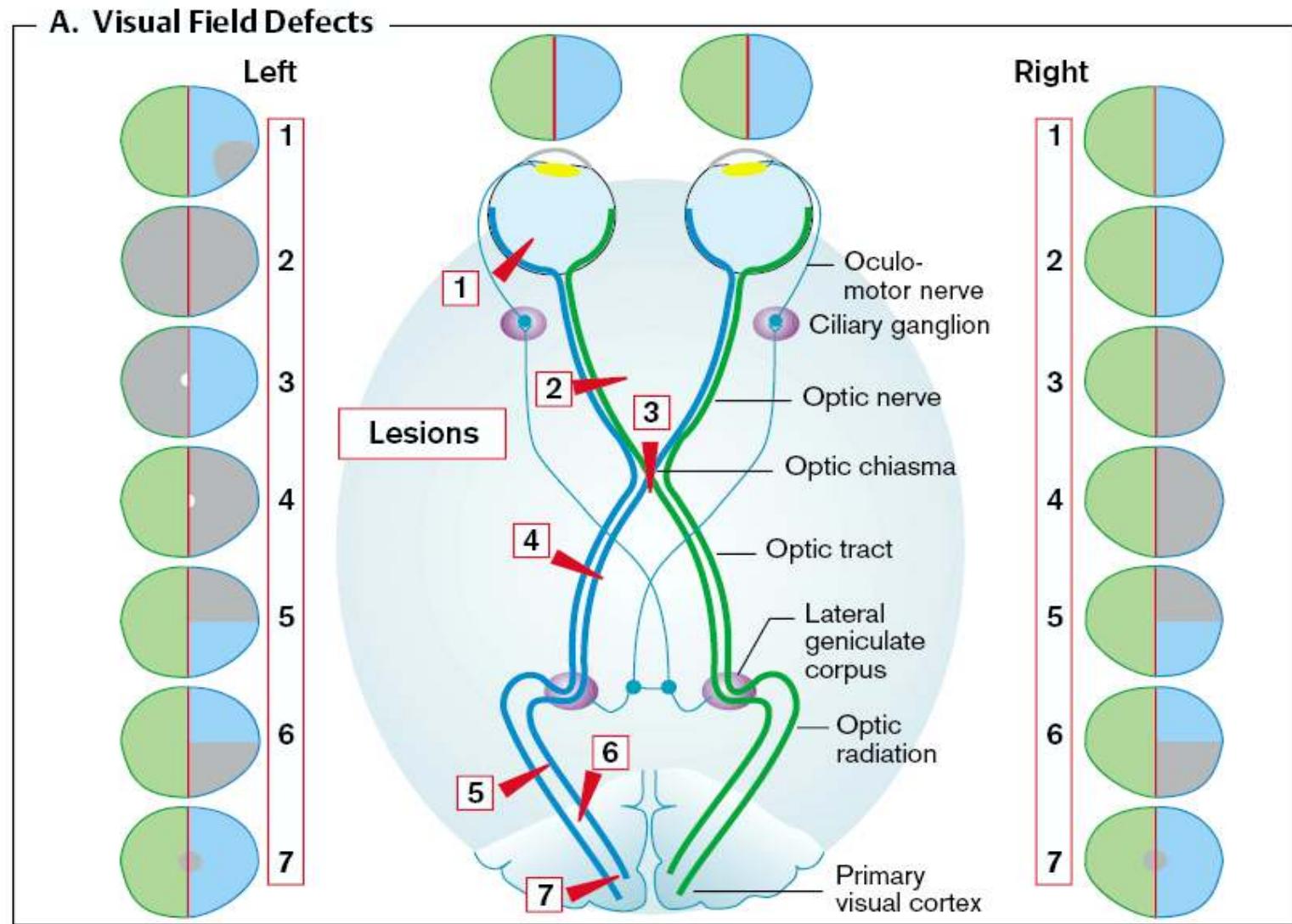
Viděná barvy	NORMÁLNÍ OKO		BARVOSLEPÉ OKO	
		na červenou barvu		na zelenou barvu
červená	červená	špinavě zelená	žlutočervená	
oranžová		žlutá	žlutá	
žlutá		světle žlutá	žlutá	
žlutozelená		šedožlutá až bílá	žlutá	
zelená		šedá	šedožlutá až bílá	
modrá		světle modrá	světle modrá	
fialová		modrá	modrá	

Normal,

protan-opia (2%), deutan- (6% of males).

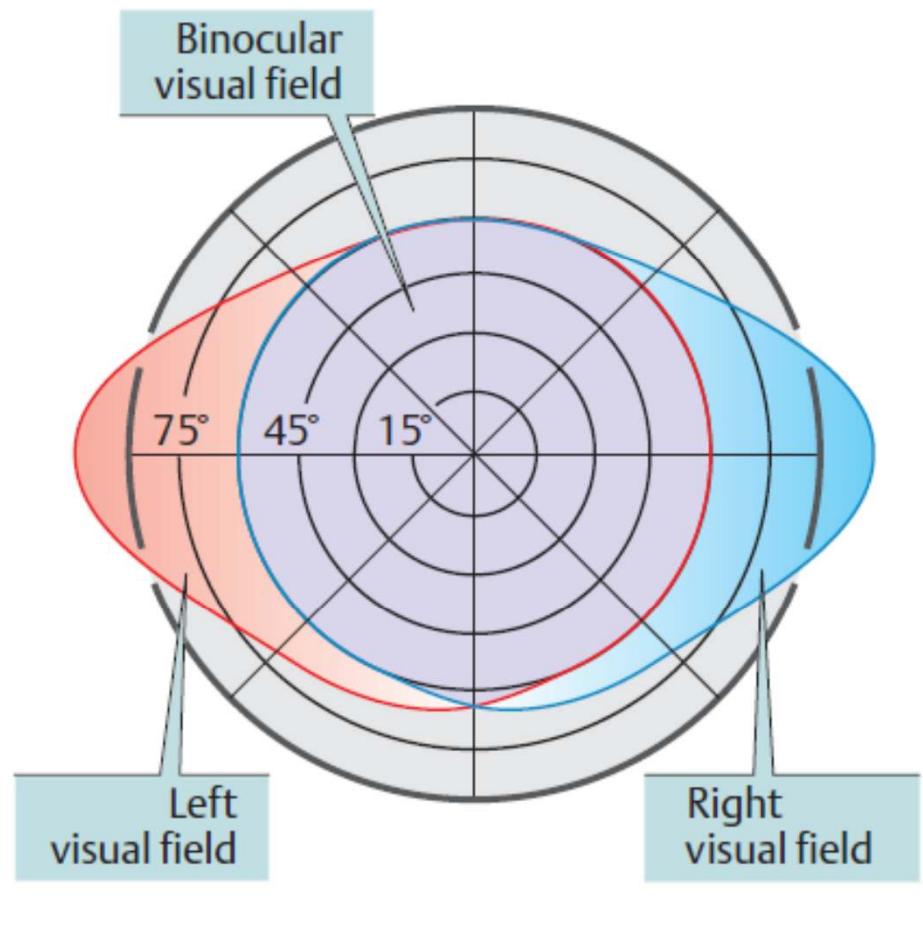


Visual Fields in Optic Nerve and their Defects

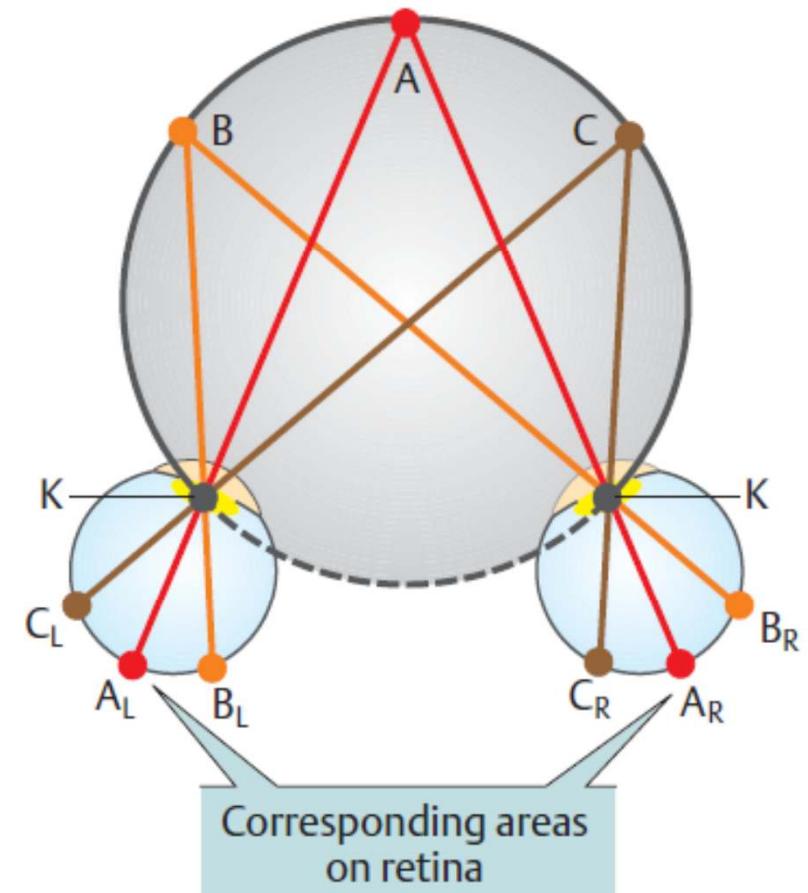


Binocular/ Stereoscopic Vision

A. Binocular visual field

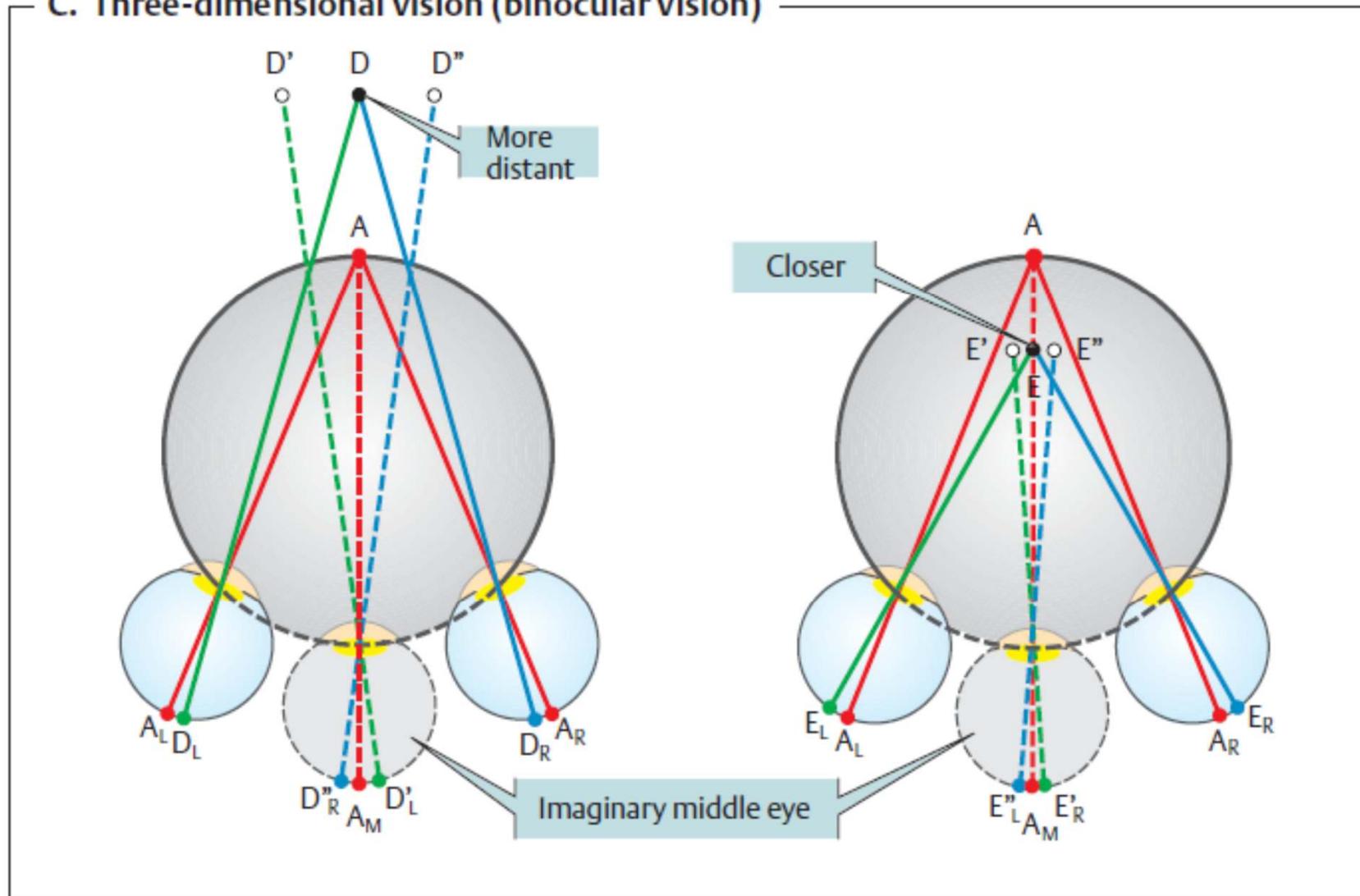


B. Horopter



Binocular/ Stereoscopic Vision

C. Three-dimensional vision (binocular vision)



Geometry of disparities using the Cyclopean Eye

[Julesz, Bela. "Foundations of cyclopean perception." 1971]

Red and Cyan Anaglyphs for Stereoscopic Images

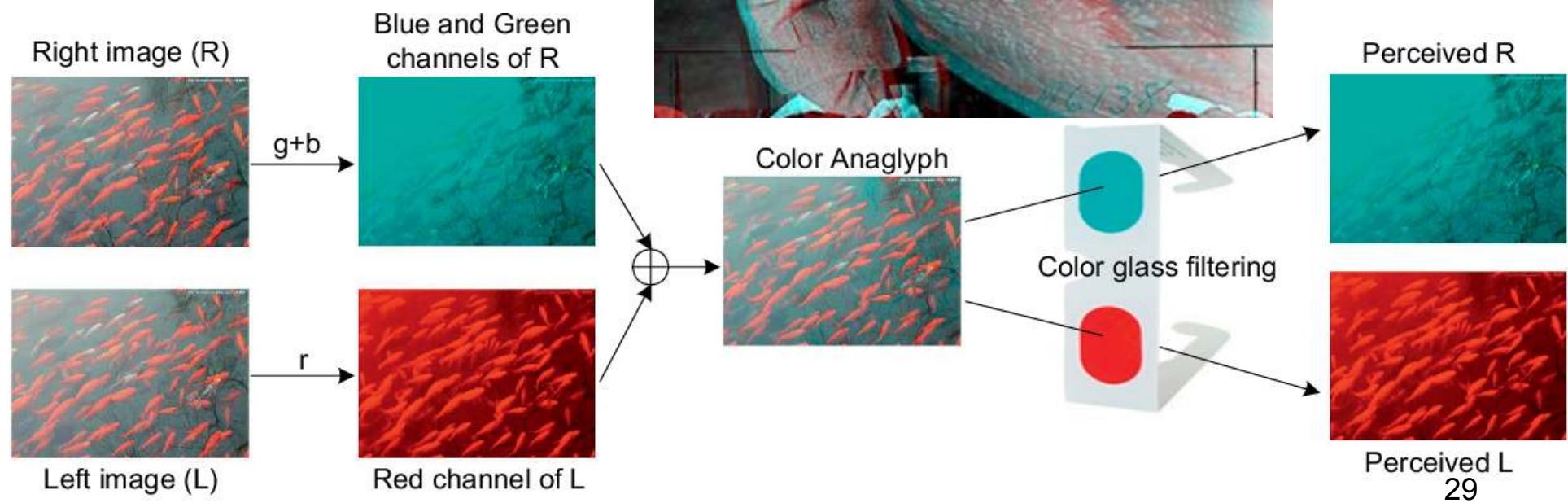


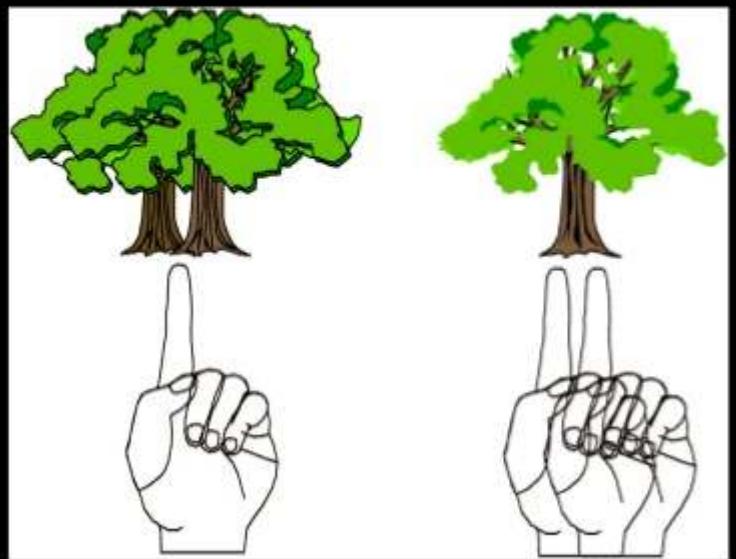
Fig. 1. An illustration of anaglyph 3D displaying using Color anaglyph.

There is More to Depth of Field: 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.



Stereoscopic Vision

Binocular: Stereo Disparity, in Near Field Scene Only

Monocular:

- By Perspective
- By Known Object Sizes
- By Parallax (in Disparity and Relative Motion)

D. Cues for depth vision



Literary references

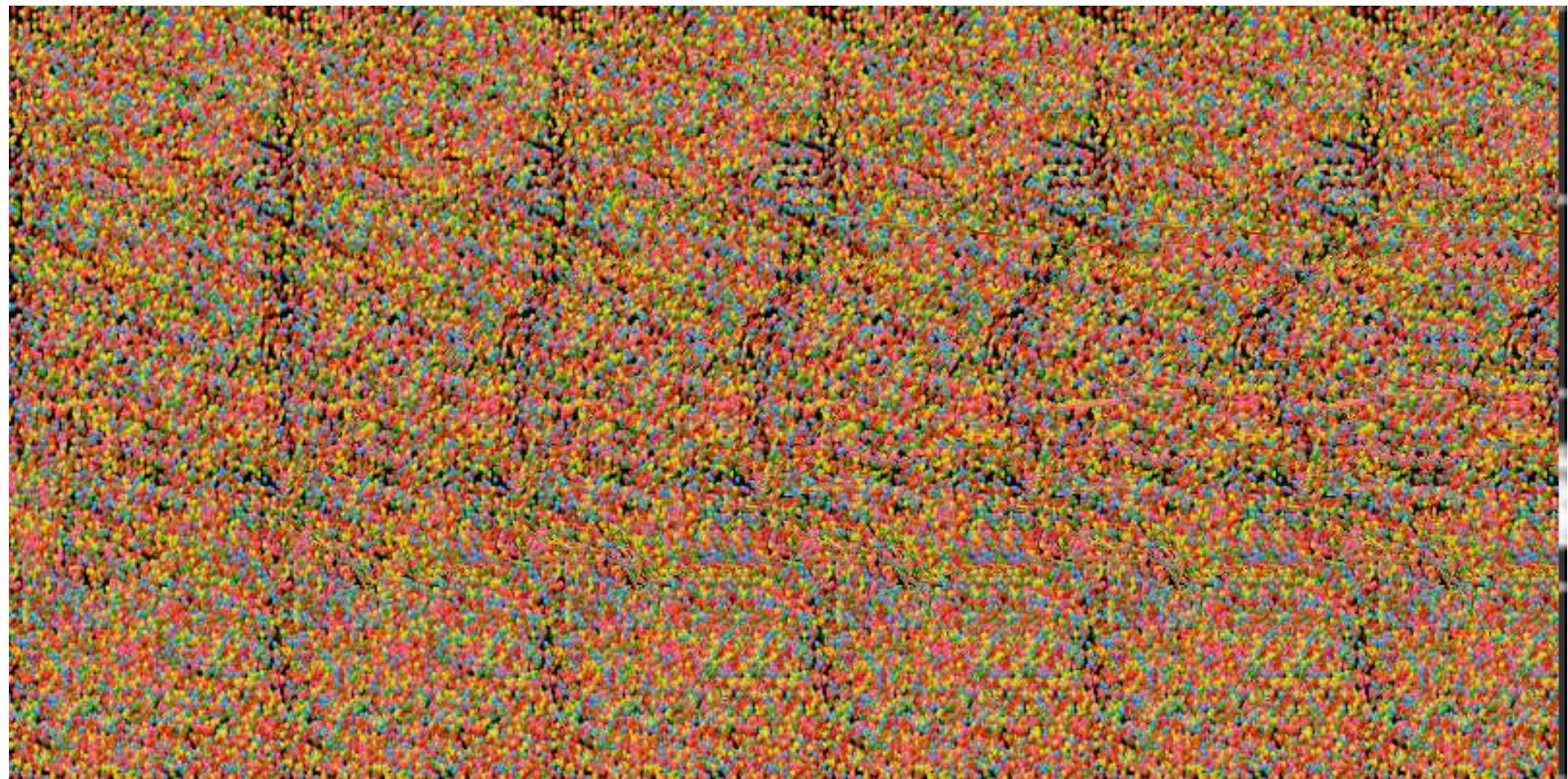
[Despopoulos, A; Silbernagl, S,
Color Atlas of Physiology, 1991],

[Marsalek, P.; Hajny, M.; Vokurka, M.
(2017). Pathological Physiology of the
Visual Pathway. In *Homonymous Visual
Field Defects*, edited by K. Skorkovska
(pp. 17-29). Springer, Cham]

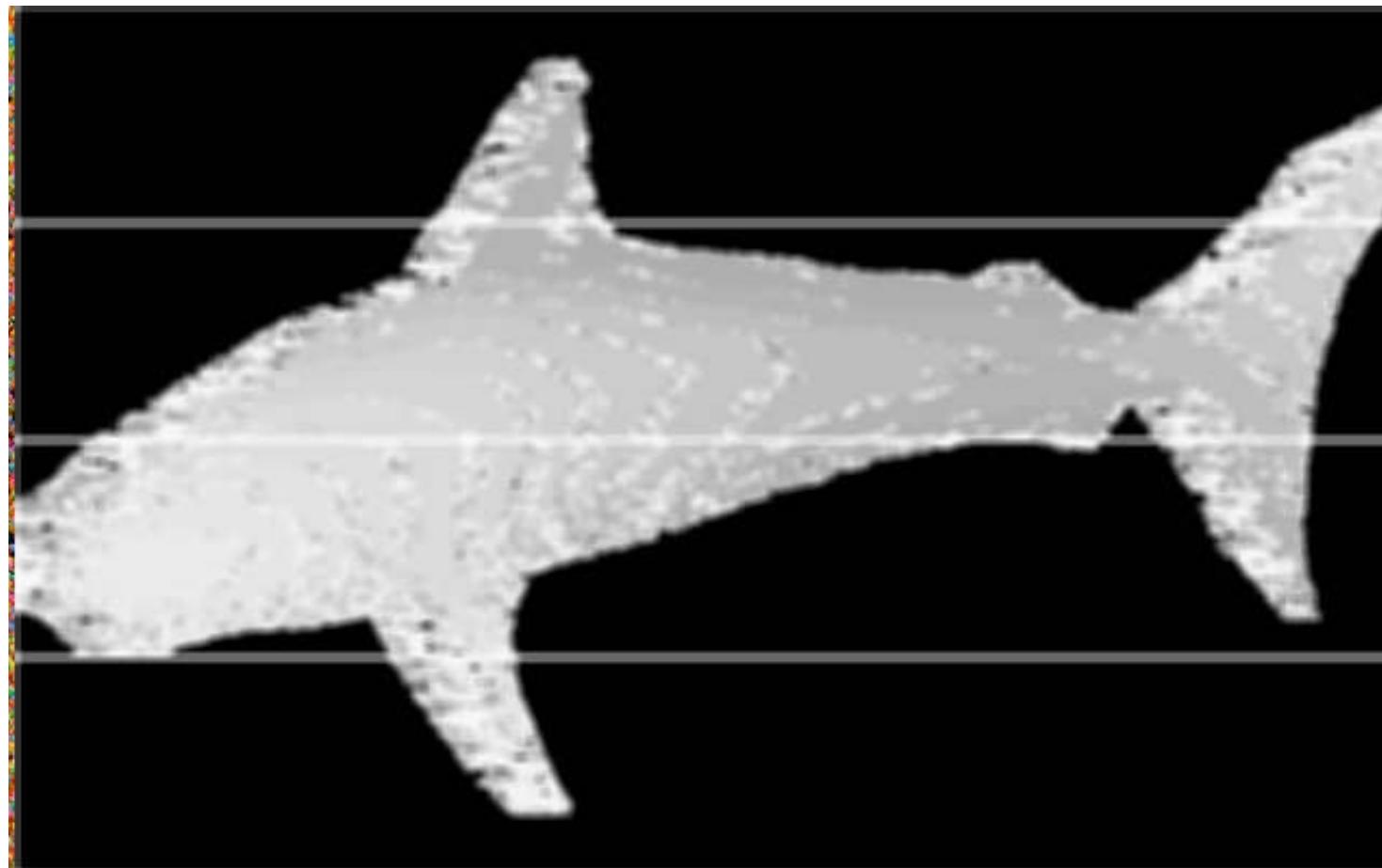
[Julesz, Bela. "Foundations of cyclopean
perception." 1971]

[Julesz Bela. Stereoscopic vision. Vision
Research. 26 (9): 1601-12, 1986]

Random dot stereogram (autostereogram)



Random dot stereogram (autostereogram)



Another stereoscopic perception mode can be obtained using red and blue anaglyphs.

This is also a subject in the following two lectures:

- Visual cortex
- Vision/ hearing cross, also about space perception

END

**OF THE
LECTURE**



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