Visual Pathway and Visual Pathologies

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

Petr Maršálek

First presented in 2020, version 24+

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, Strabism
- Saccades, Visual Following, Nystagmus
- Visuo-motor Eye Movement Control, Basic Concepts
- Optical nerve, Perimeter, Objective Perimeter
- Color Opponent System in the Visual Pathway

Snellen (N/36)

Optotypes have (N/32)

letters with defined (N/28)

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

seen from a calibrated distance. (N/24)

This is written as fraction. (N/22)

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

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

denominator: we see six points (B/16)

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

Hermann Snellen, 1834 -1908

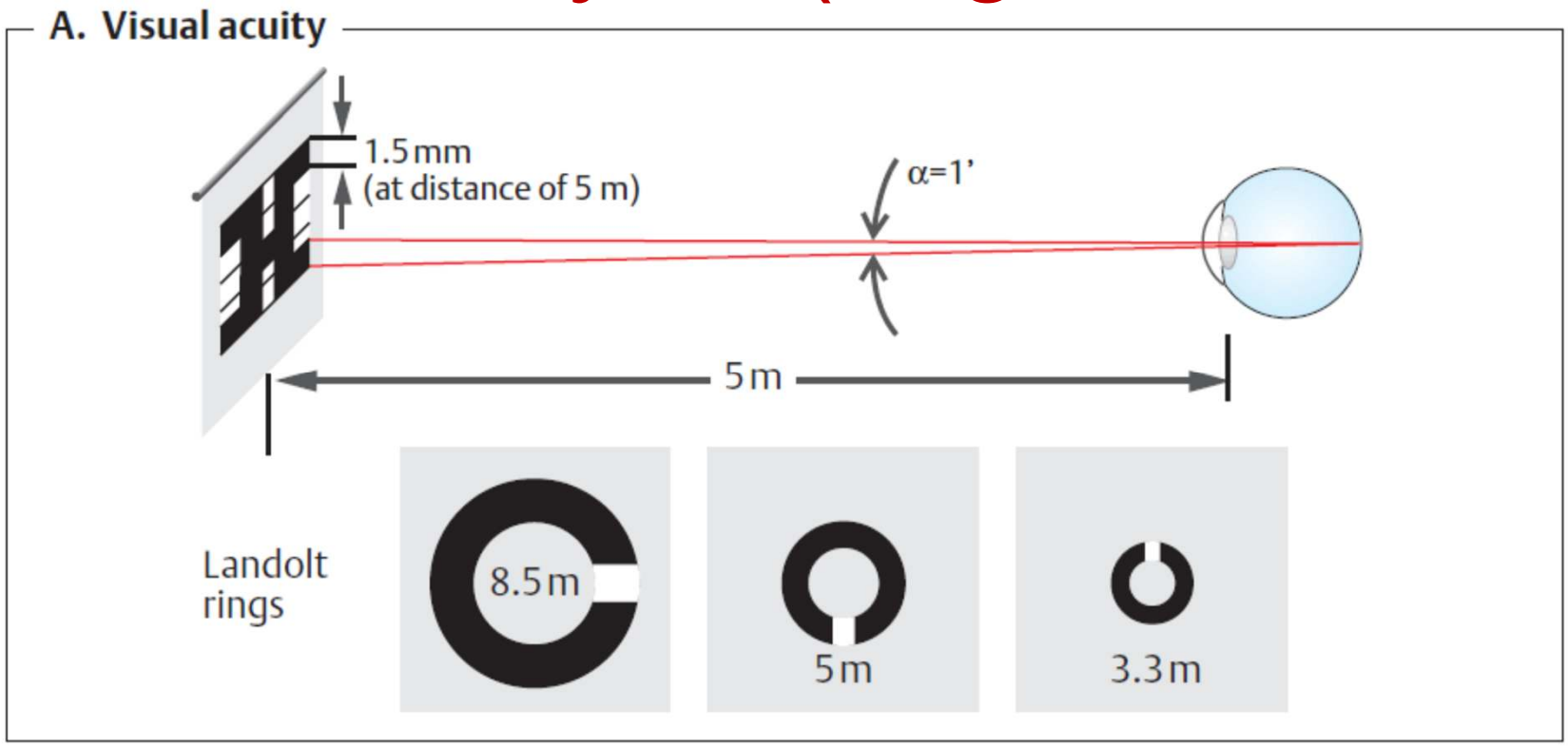
Functional Classification of Vision Impairment

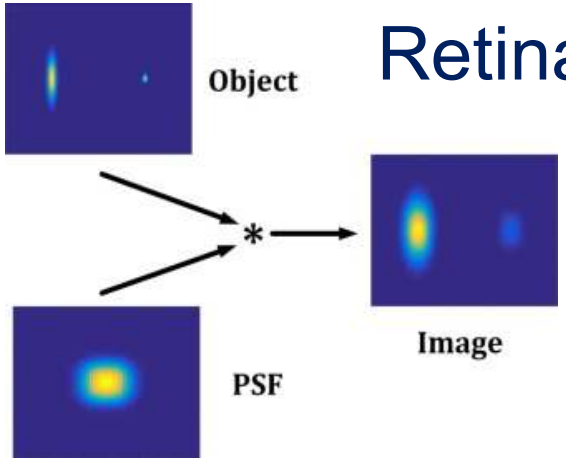
A fraction, written as numerator/ denominator denotes:
given a 6 m viewing distance, /or 20 feet/, how many points are seen as one point? (hence best is 6/6 or 20/20)
(Geometry of 2D angle is simplified to a square patch angular_deg^{o} (*= times) angular_deg^{o}.)

1 normal vision		6/6
2 low vision	worse than	(<) 6/18
(on the best eye with corrective lenses)		
3 (practical) blindness (EU)		< 3/60
or narrowing of visual angle less than		< 10^{o}*10^{o}
other more strict norm	(US) < 6/60,	< 20^{o}*20^{o}

4 *amblyopia* also known as *„lazy eye“*
(= lower acuity due to central causes*)*

Visual Acuity: 1’ (angular minute)

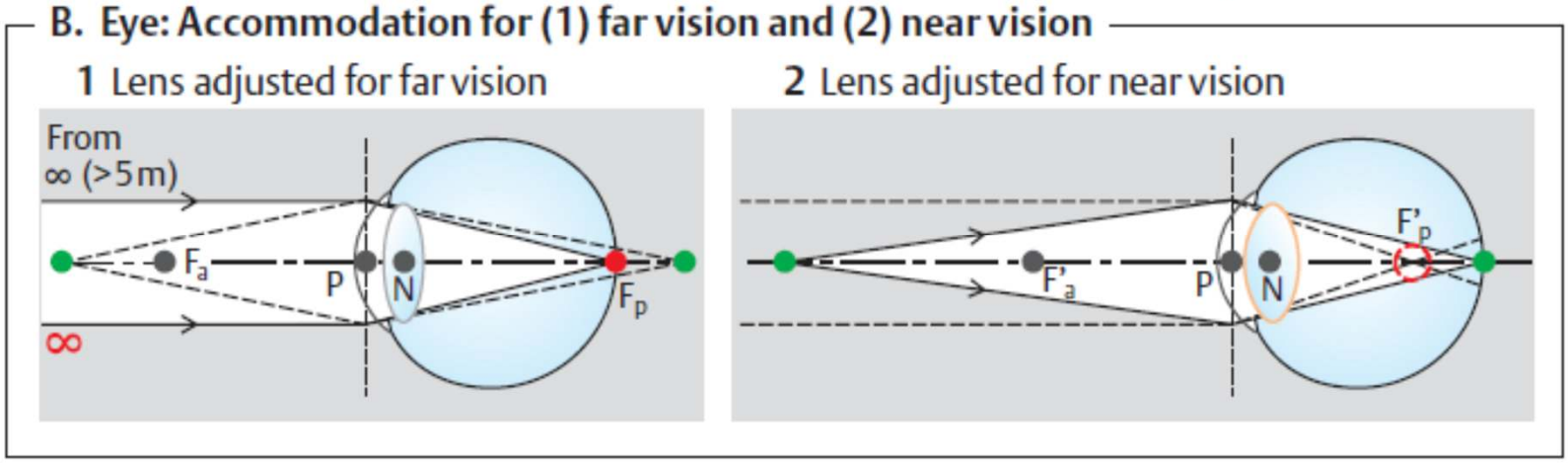


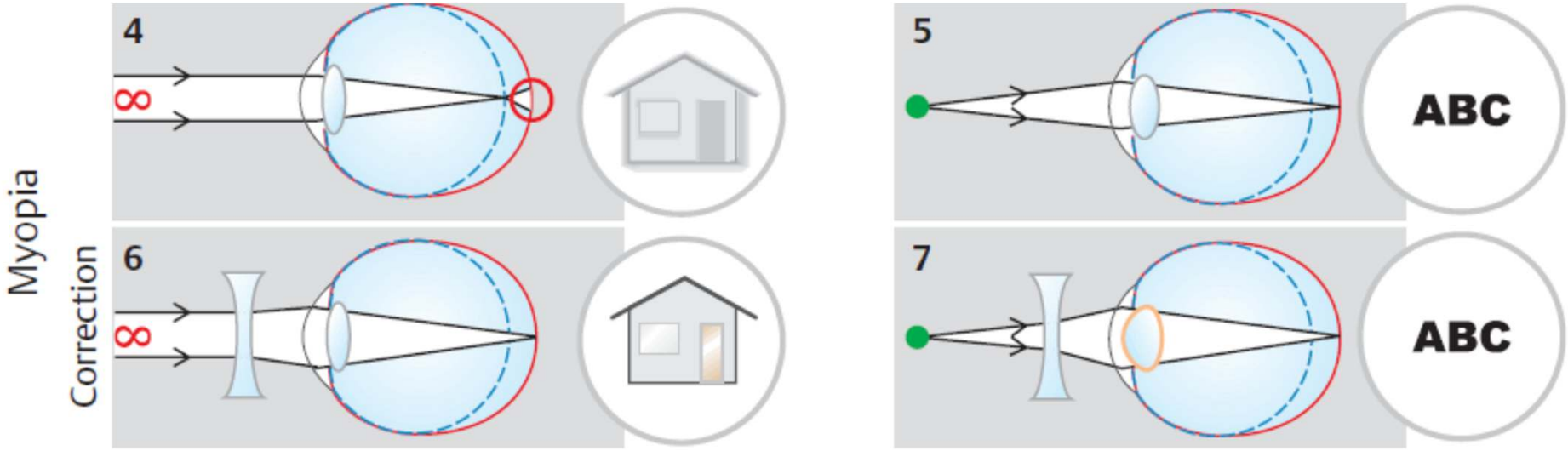


Retinal image results from convolution of object and point spread function

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

Far and Near Point/ or How Eye Focuses

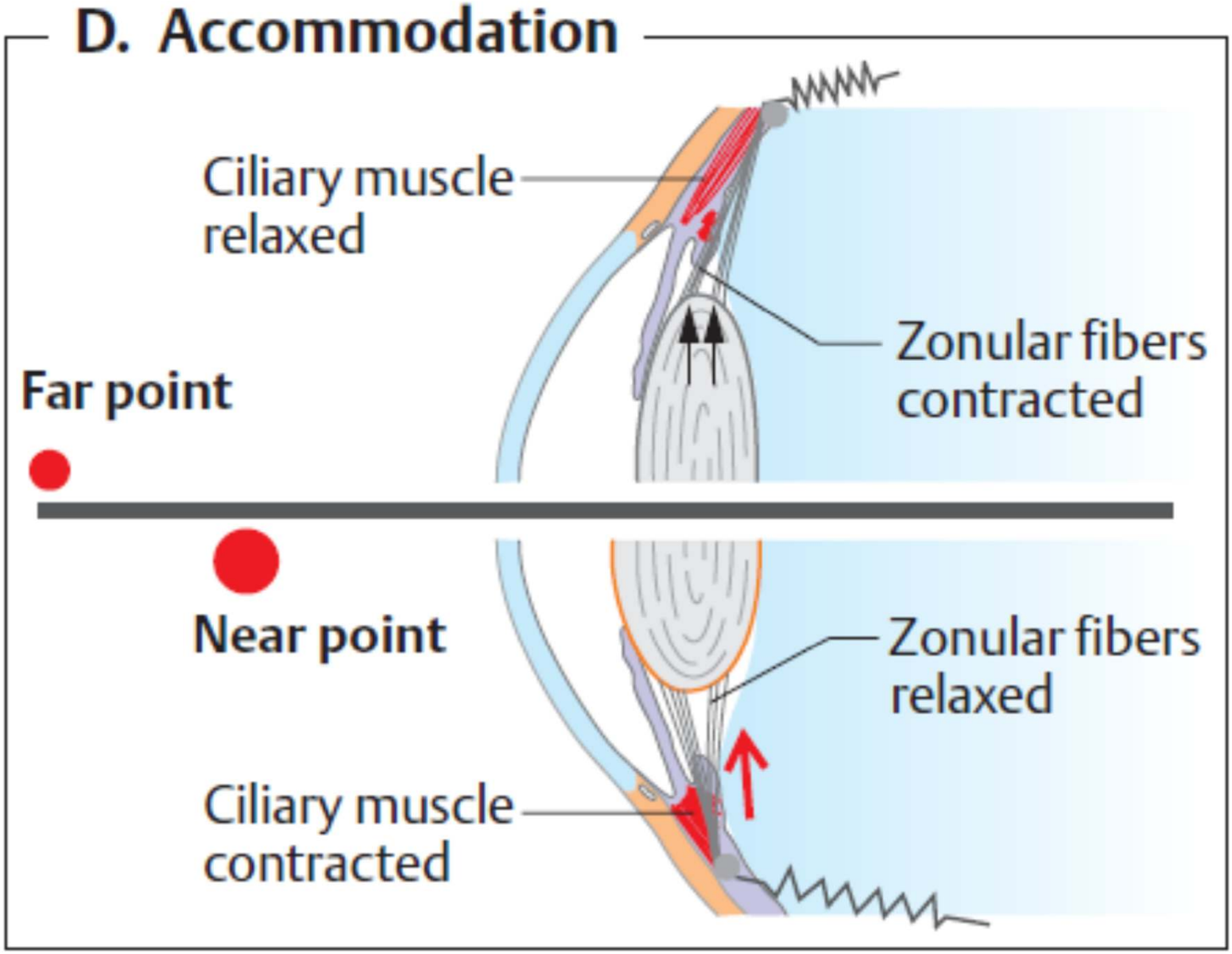




Myopia = Near-sightedness

The opposite is Hypermetropia = Far-sightedness

Accommodation = Focusing to Get a Sharp Image



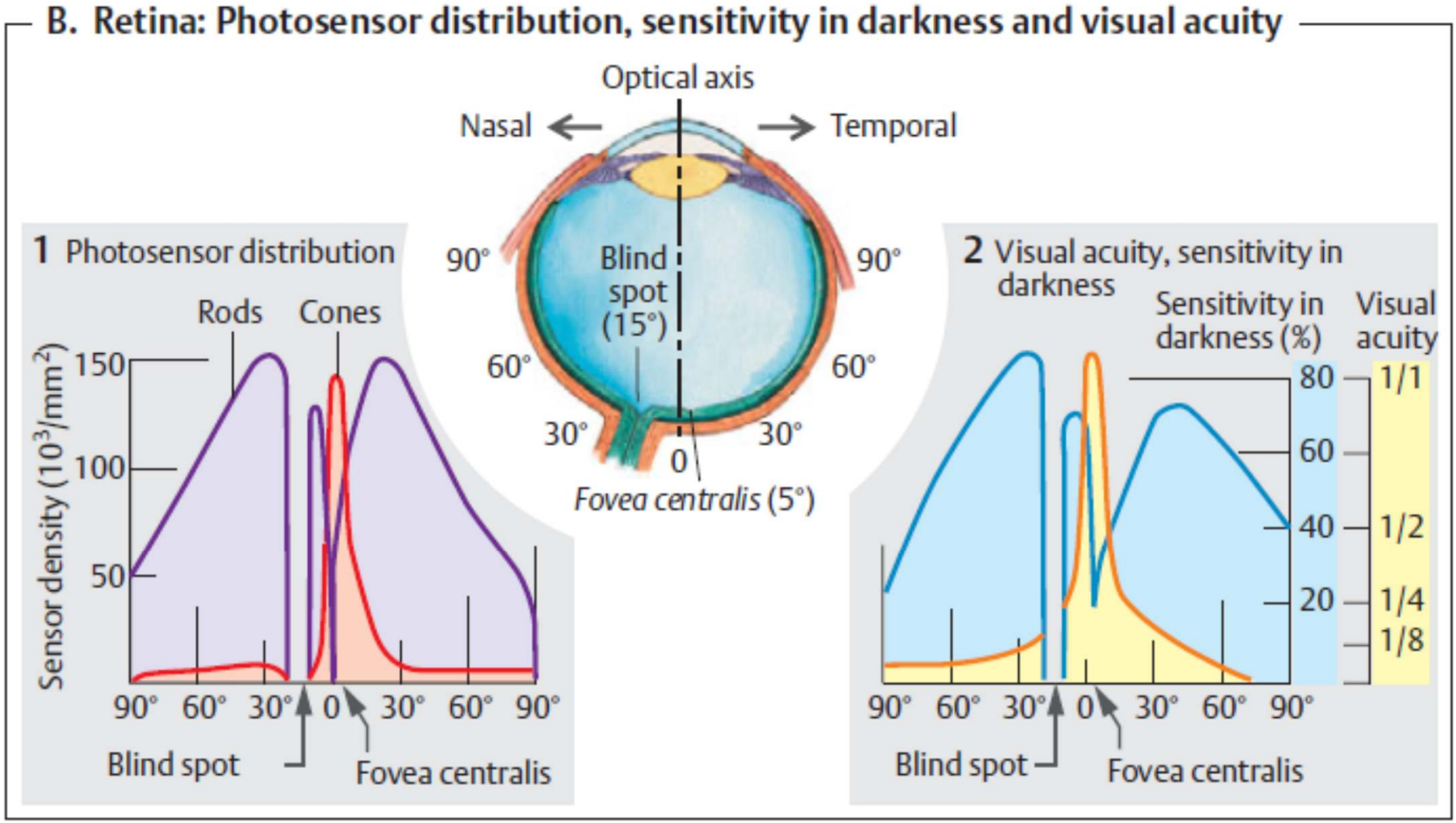
Accommodation = Focusing to Get a Sharp Image

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

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.

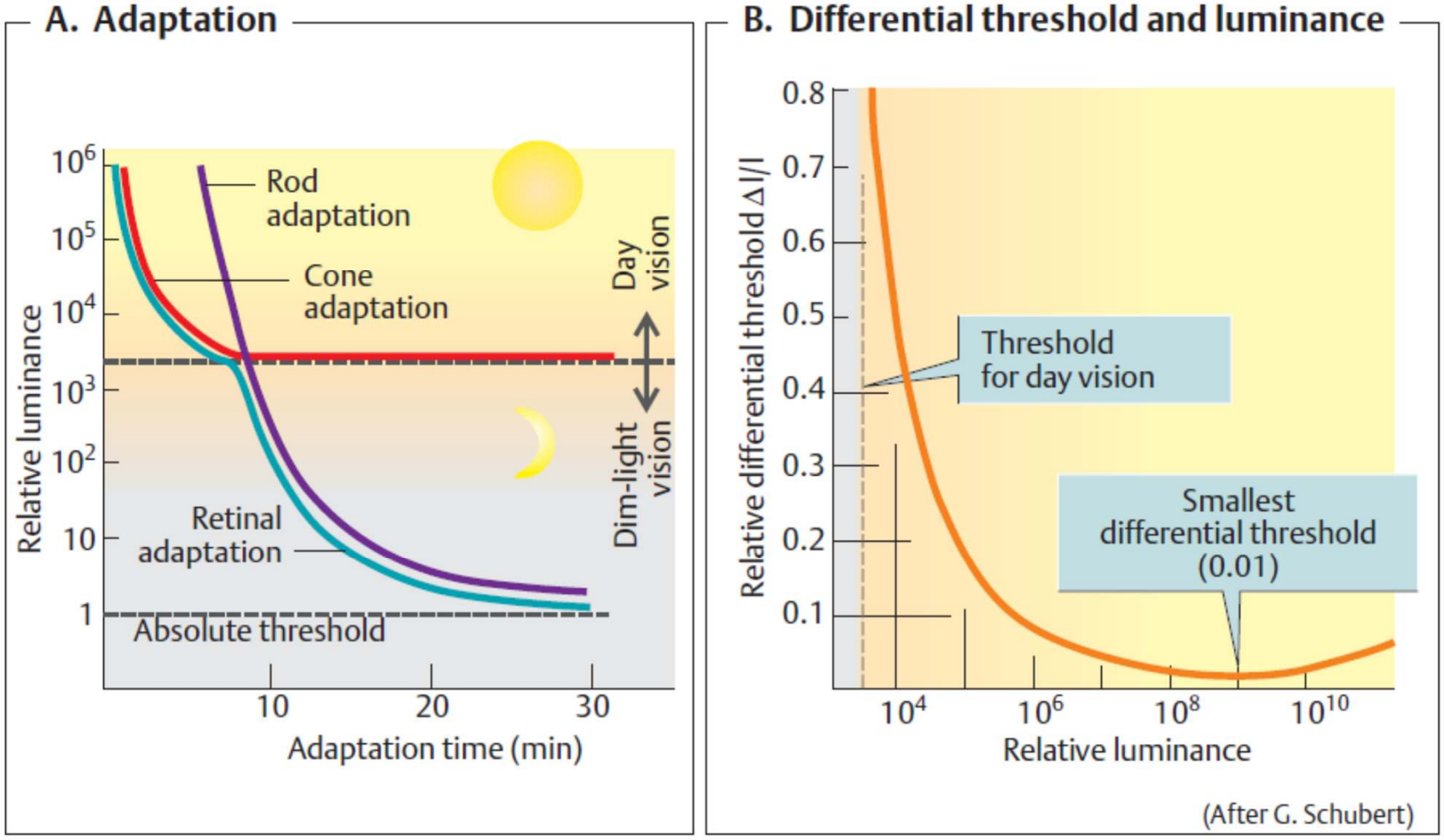
(As the next stage, with the use of current eye treatment, patients with cataract have implanted artificial lenses…)

Visual Acuity, Day and Night Acuity



Blind Spot and Yellow Spot in Retina <stop>, test yourself…

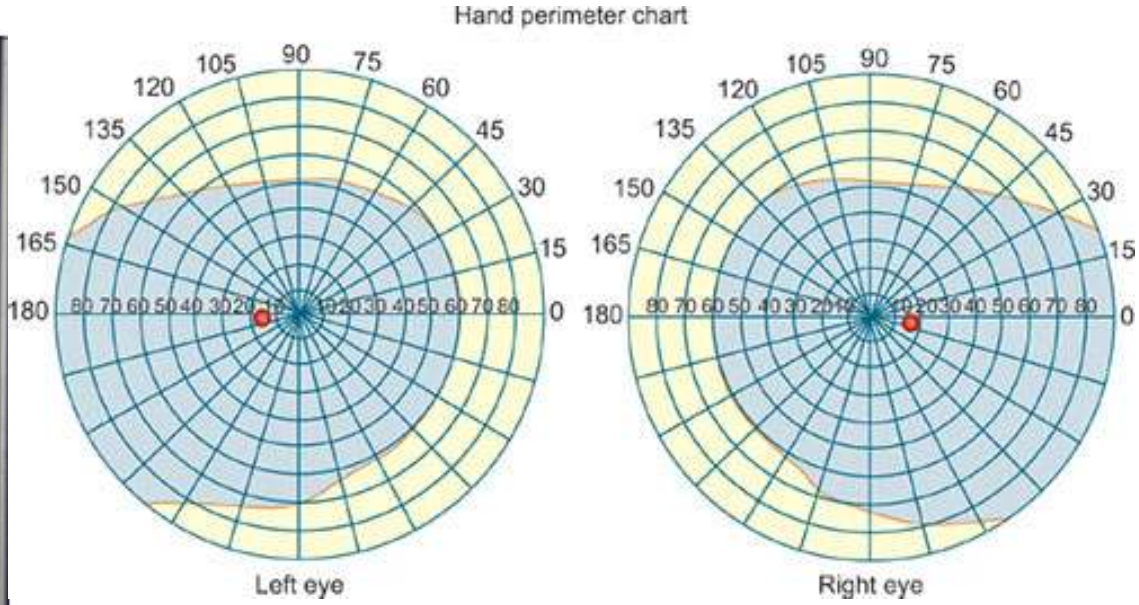
Adaptation to Day and Night Illumination Conditions



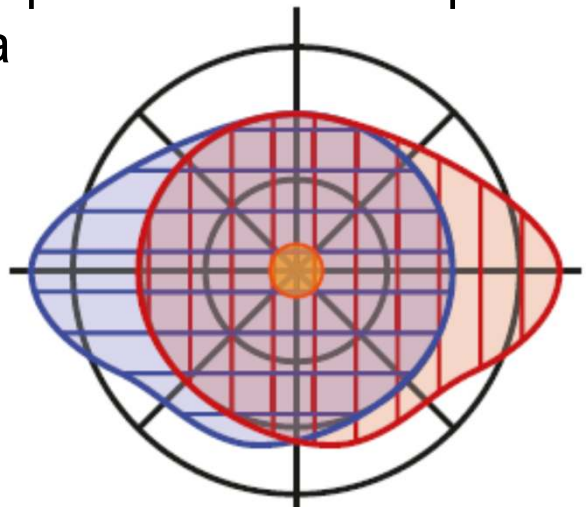
Adaptation to lighter conditions is instant.
Adaptation to the dark takes tens of minutes.

Perimeter investigation

The perimeter can be measured objectively



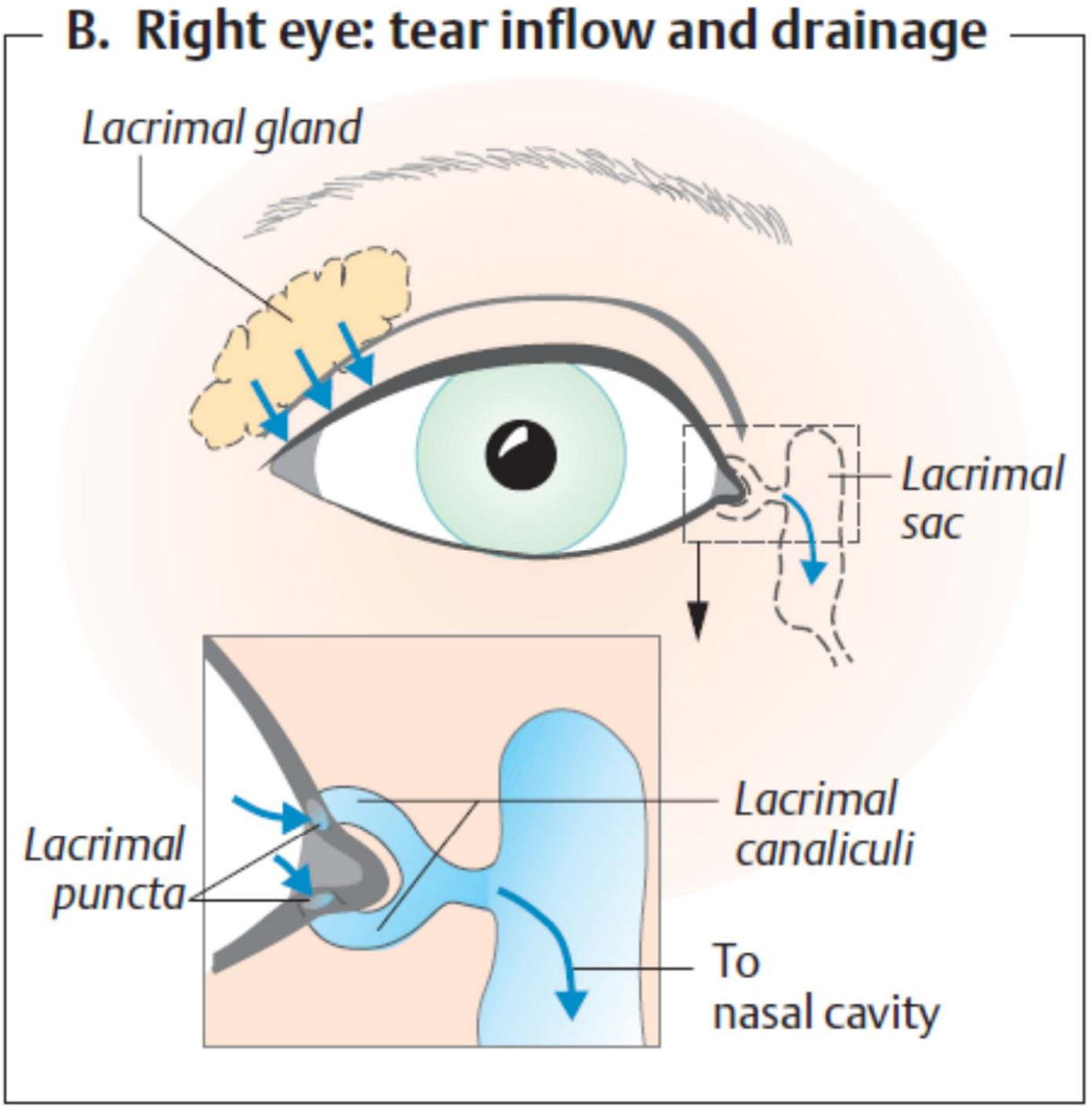
Blind Spots and Yellow Spots in L and R Retina

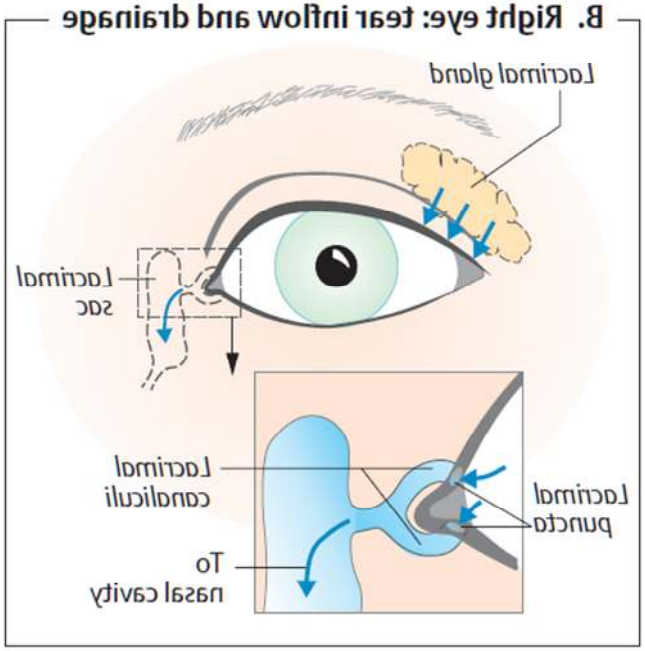


A normal visual field is a combination of left and right eye views

Lacrimal Gland and Duct, Eye Muscles

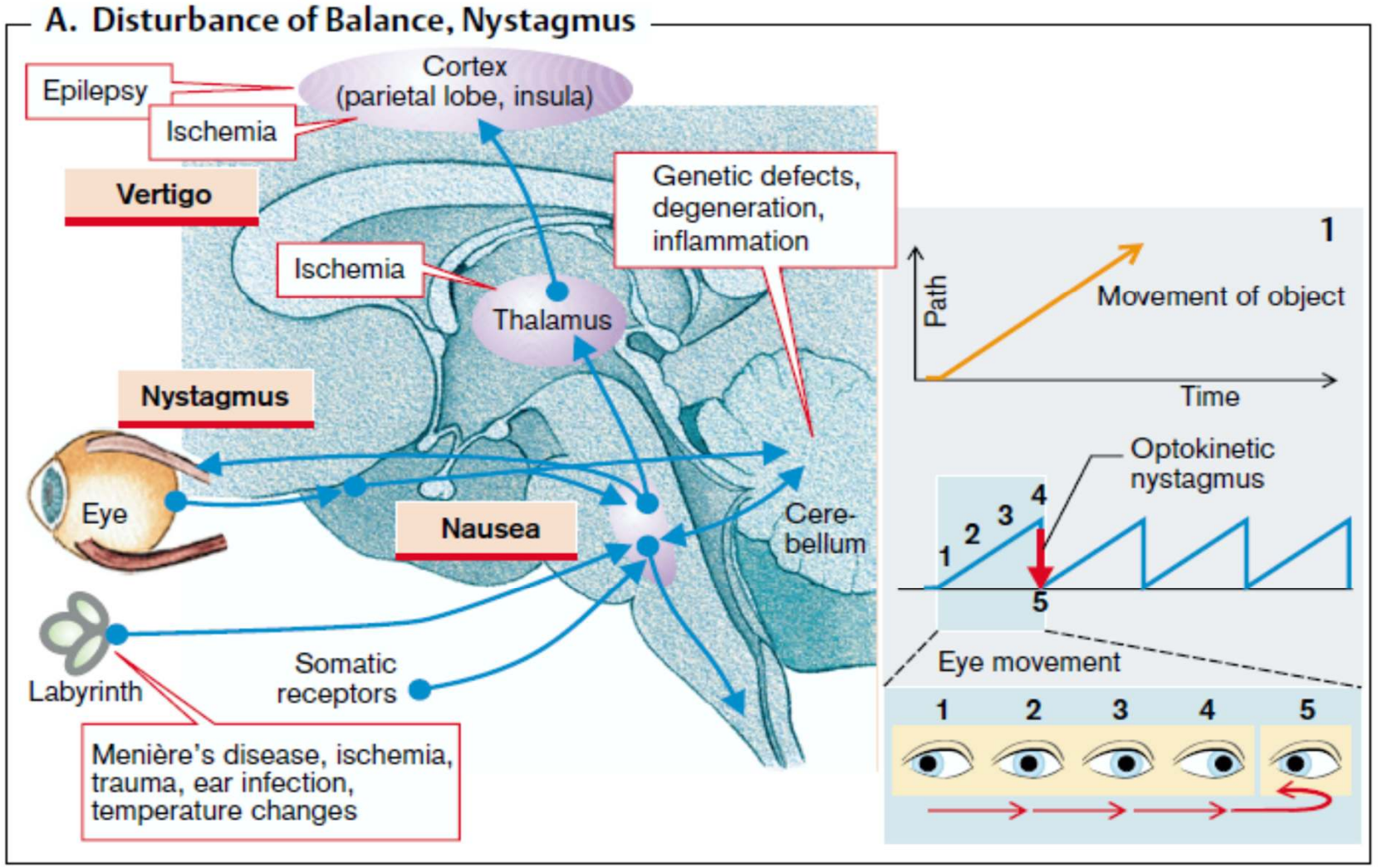
Left-right symmetry, eye movements





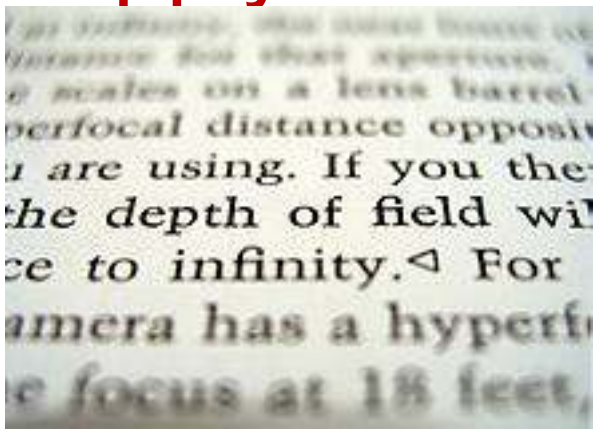
Oculo-motor muscles

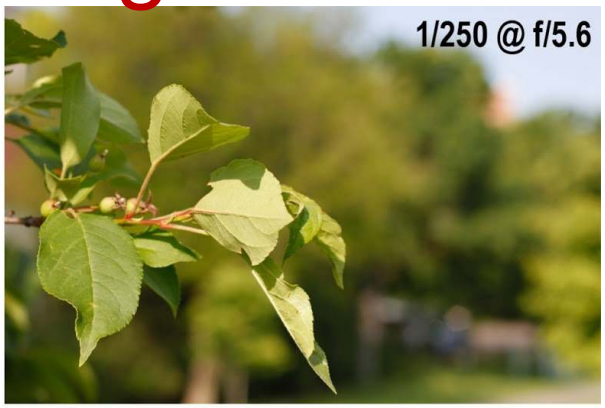
Nystagmus

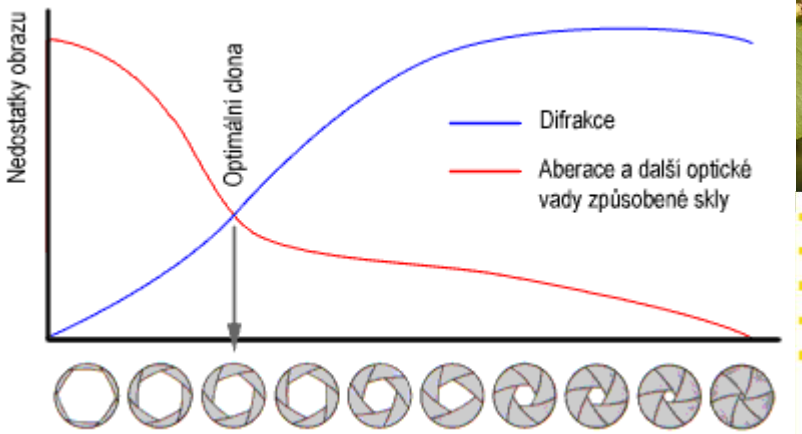

A. Disturbance of Balance, Nystagmus
Epilepsy
Ischemia
Cortex
(parietal lobe, insula)
Vertigo
Genetic defects,
degeneration,
inflammation
Ischemia
Thalamus
Nystagmus
Eye
Nausea
Cere-
bellum
Labyrinth
Somatic
receptors
Menière's disease, ischemia,
trauma, ear infection,
temperature changes
1
Path
Movement of object
Time
Optokinetic
nystagmus
1
2
3
4
5
Eye movement
1
2
3
4
5

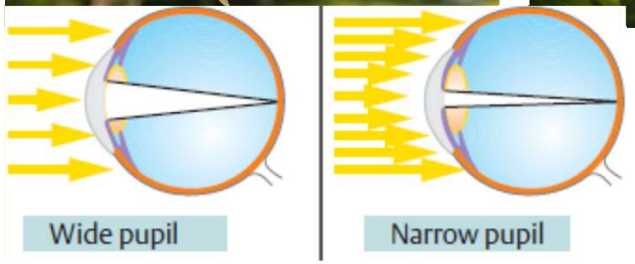
Aperture Versus Depth of Field (světelnost/ clona, hloubka ostrosti)

Apply to Human Eye Functioning as Well

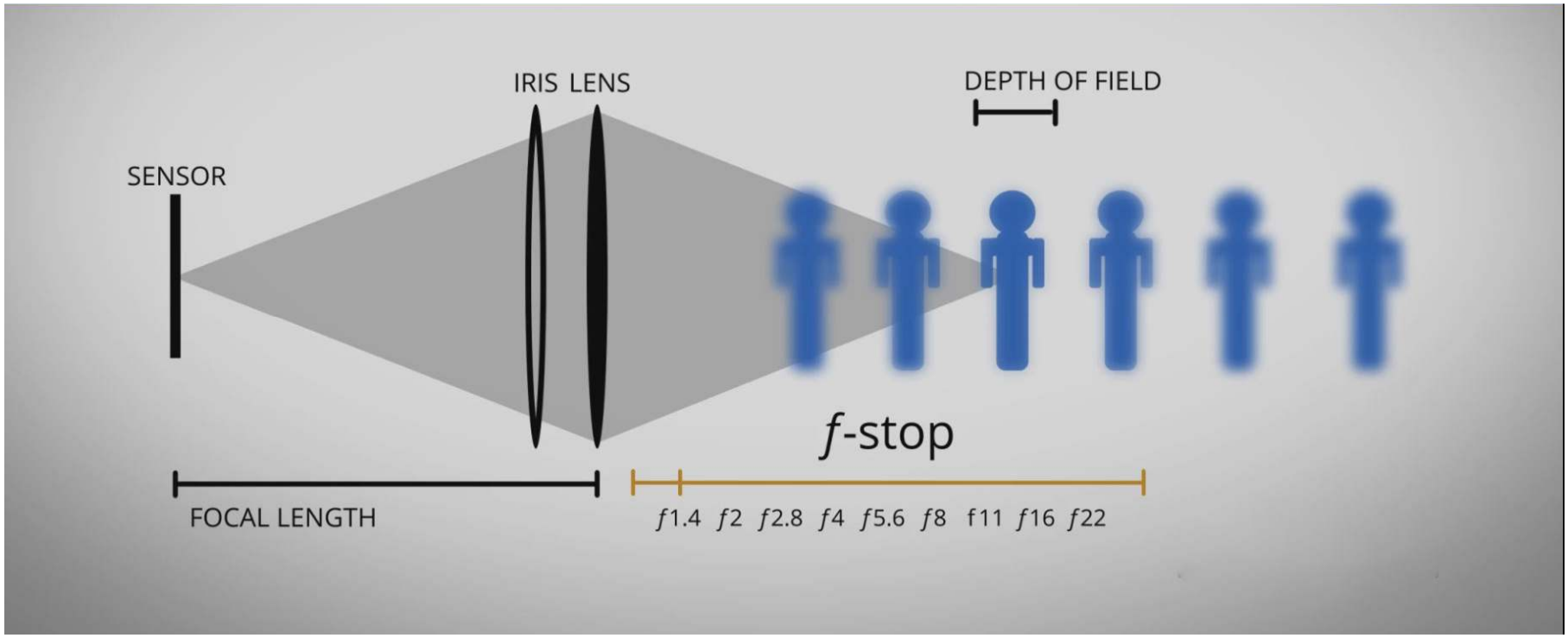








In Photography, these are Shutter Speeds and Apertures…



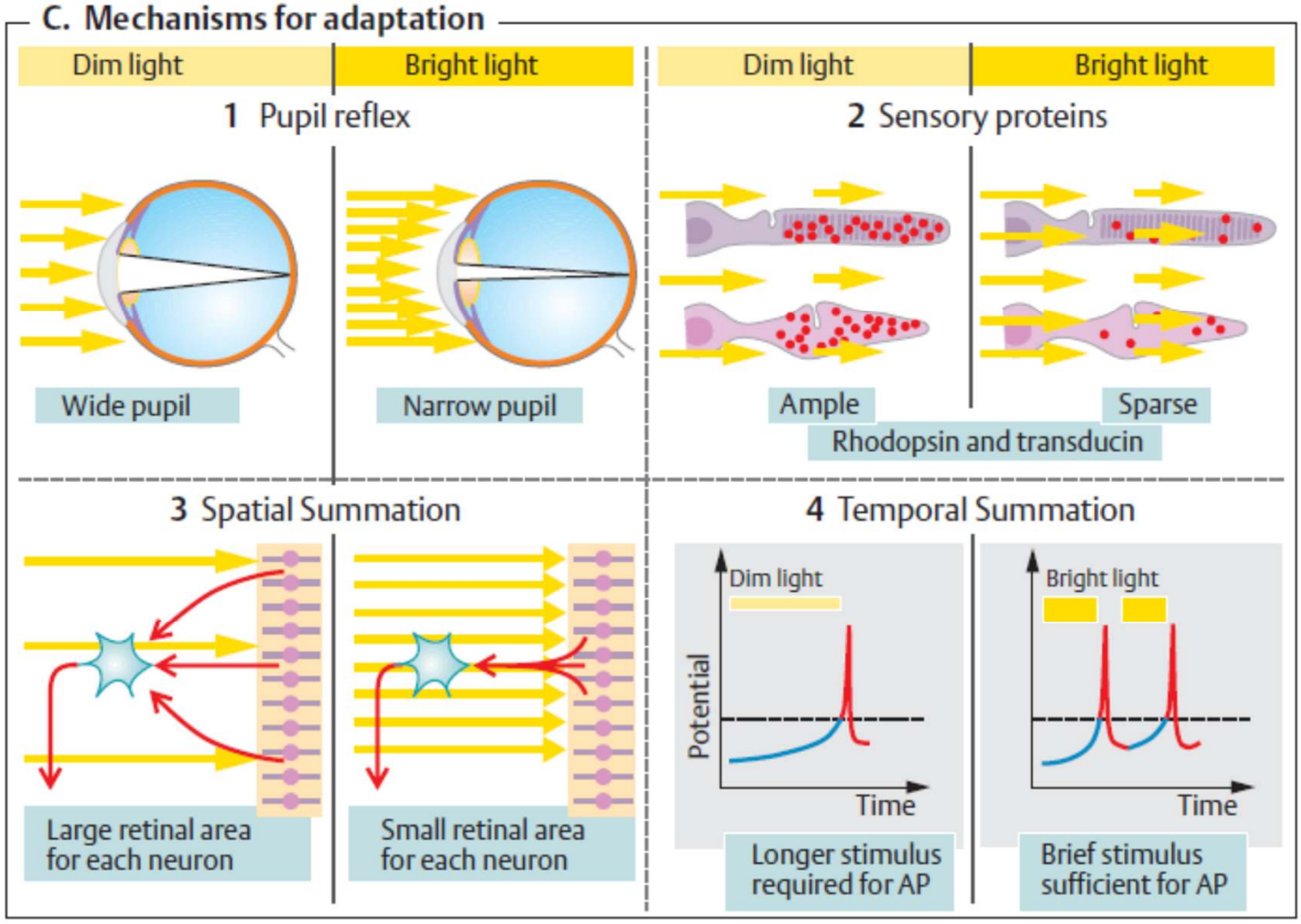
Aperture Versus Depth of Field

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

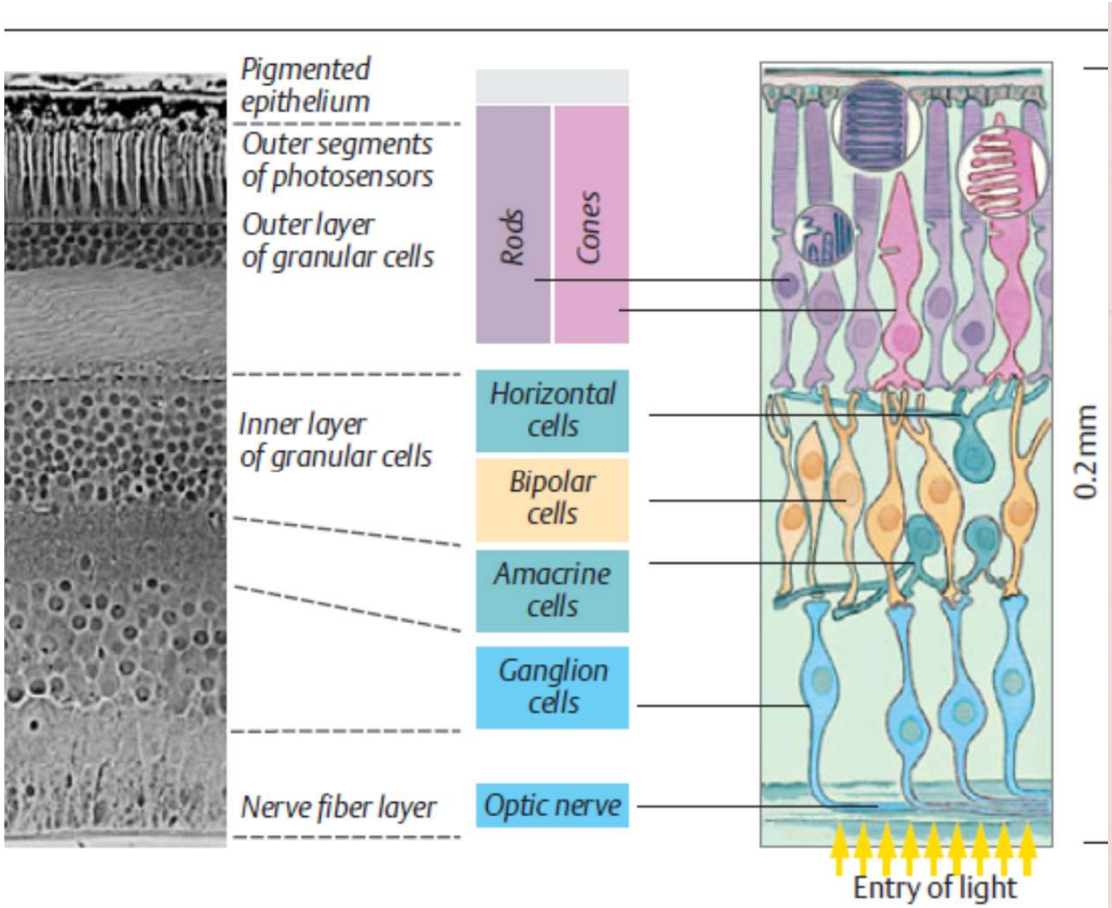
Depth of field *D* is approximately proportional to this formula, entered by An acceptable circle of confusion diameter (*c*), aperture diameter(*A*), and distance to the subject (*u*), divided by the square of the focal length (*f*), all in length units. The dimensionless f-number is *N* = *f/A.*

Aperture Versus Depth of Field

Apply to Human Eye Functioning as Well



These are ‘digital’ processes, encoded by action potentials



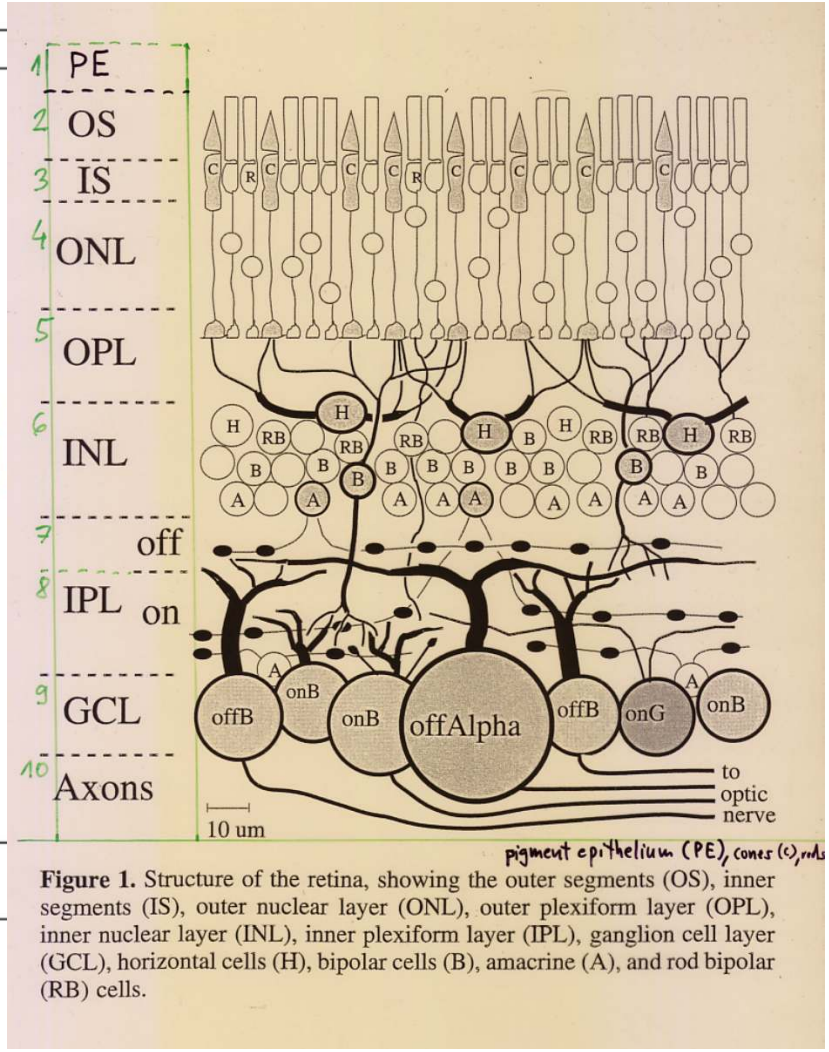
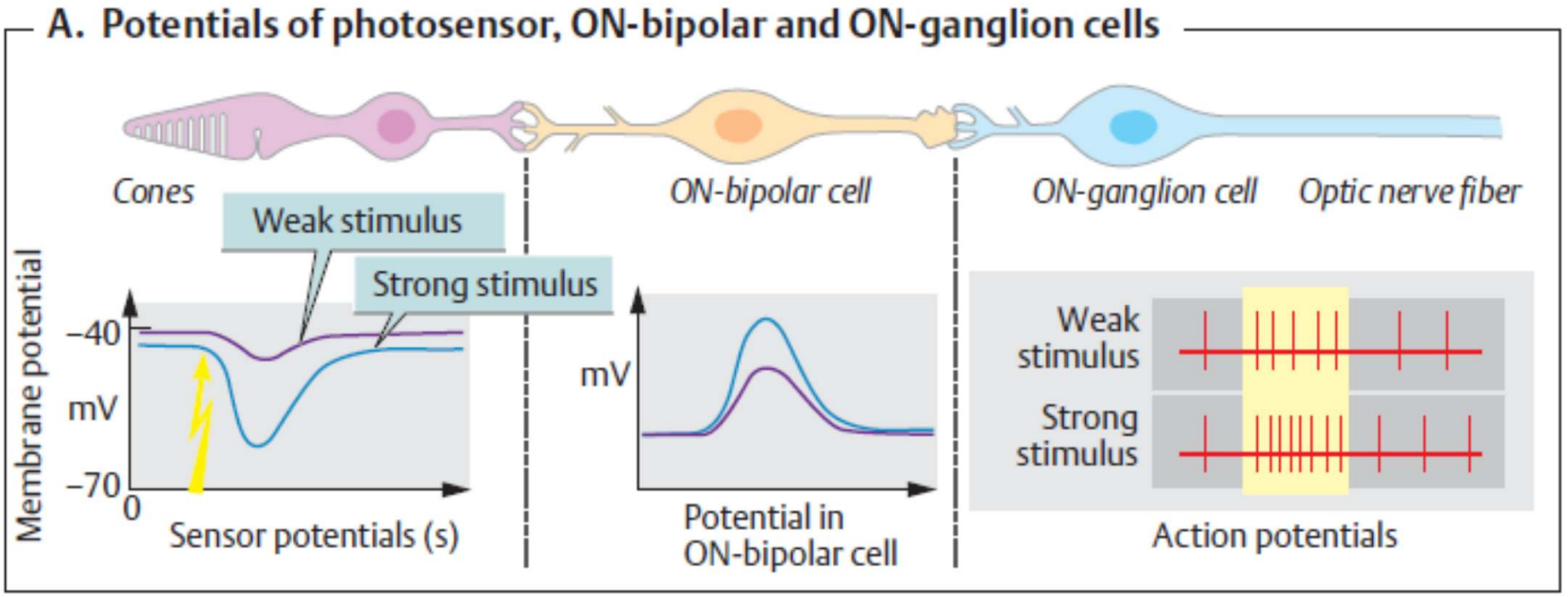


Figure 1. Structure of the retina, showing the outer segments (OS), inner segments (IS), outer nuclear layer (ONL), outer plexiform layer (OPL), inner nuclear layer (INL), inner plexiform layer (IPL), ganglion cell layer (GCL), horizontal cells (H), bipolar cells (B), amacrine (A), and rod bipolar (RB)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

Ten Layers of Retina

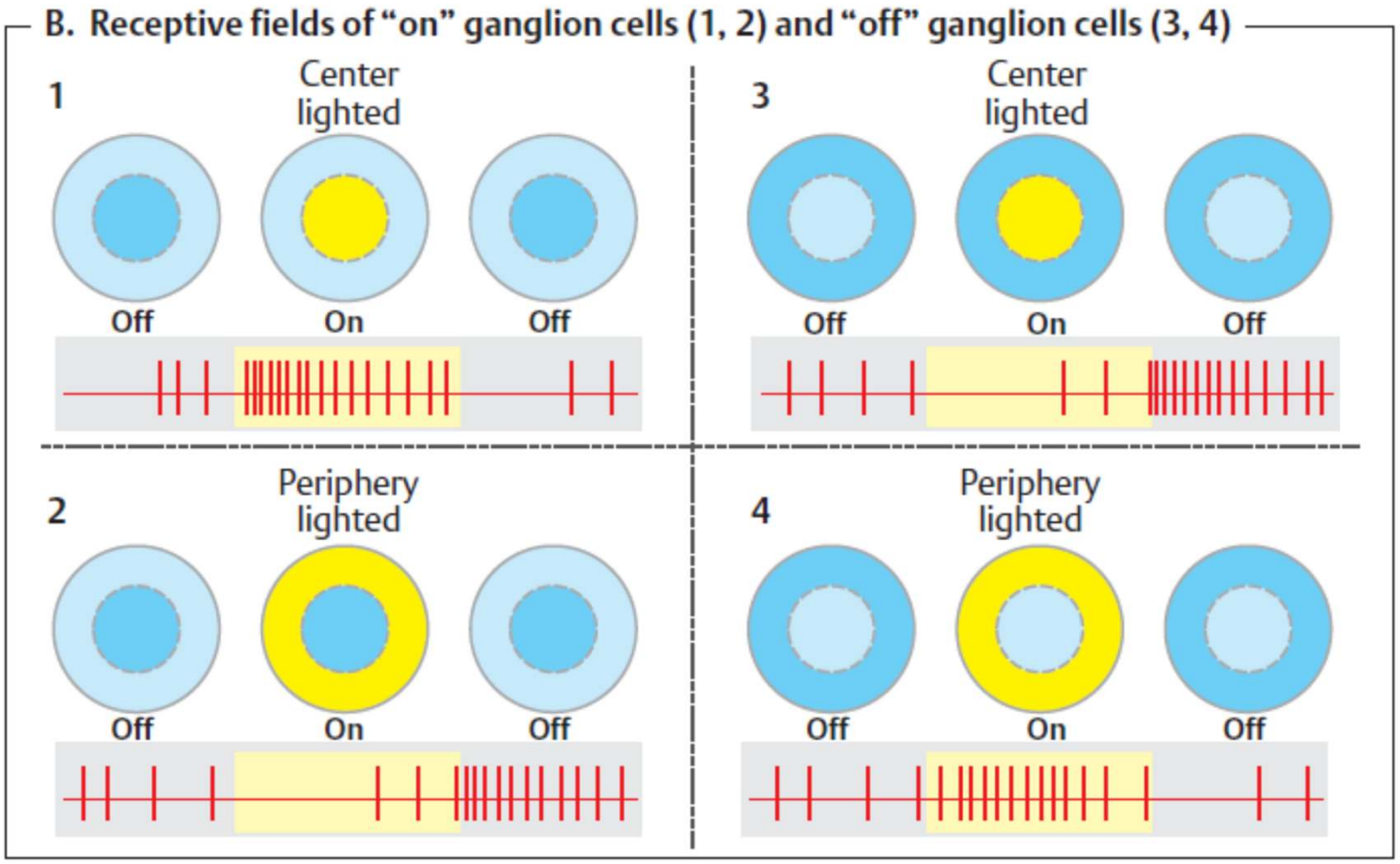
The optic nerve is the output of the retina.
The retina is a unique neural network of the immense size of one million output lines, a patch of = 10^3*10^3 pixels. Its functions are poorly understood…

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

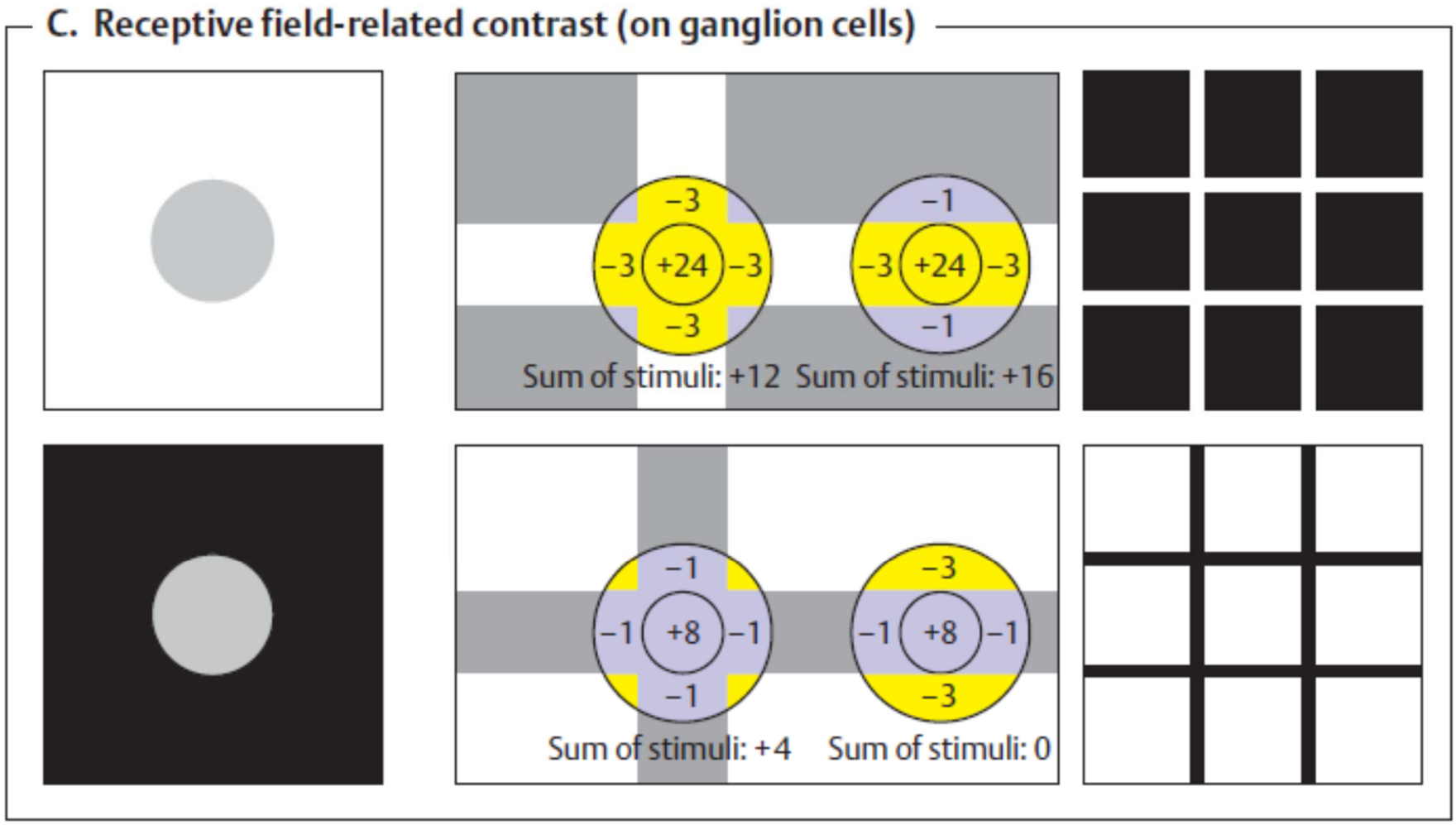
From Light Through Receptor Potential to Action Potentials and Coding in Optical Nerve



Retinal 'On' and 'Off' ganglion cells

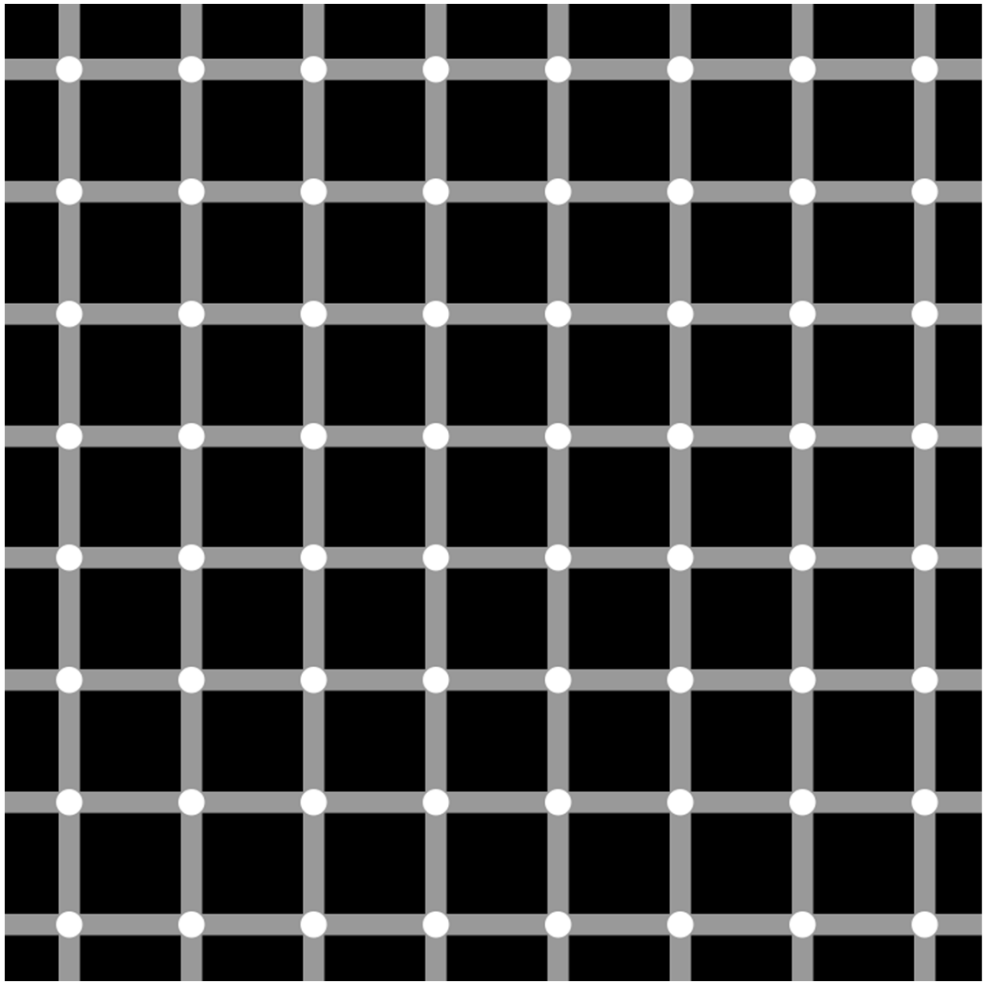
From Light Through Receptor Potential to Action Potentials and Coding in Optical Nerve

Origin of visual illusions...



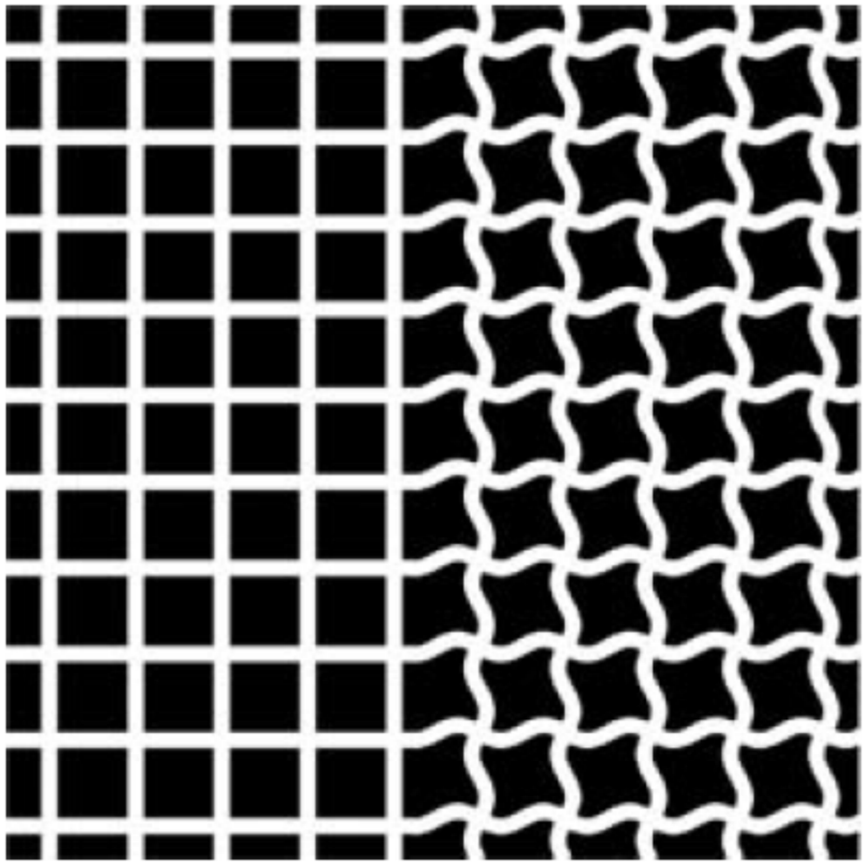
Peripheral (=Retinal) and Central (=Cortical) Mechanisms…

The (Ludimar) Hermann Grid Illusion, 1870



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

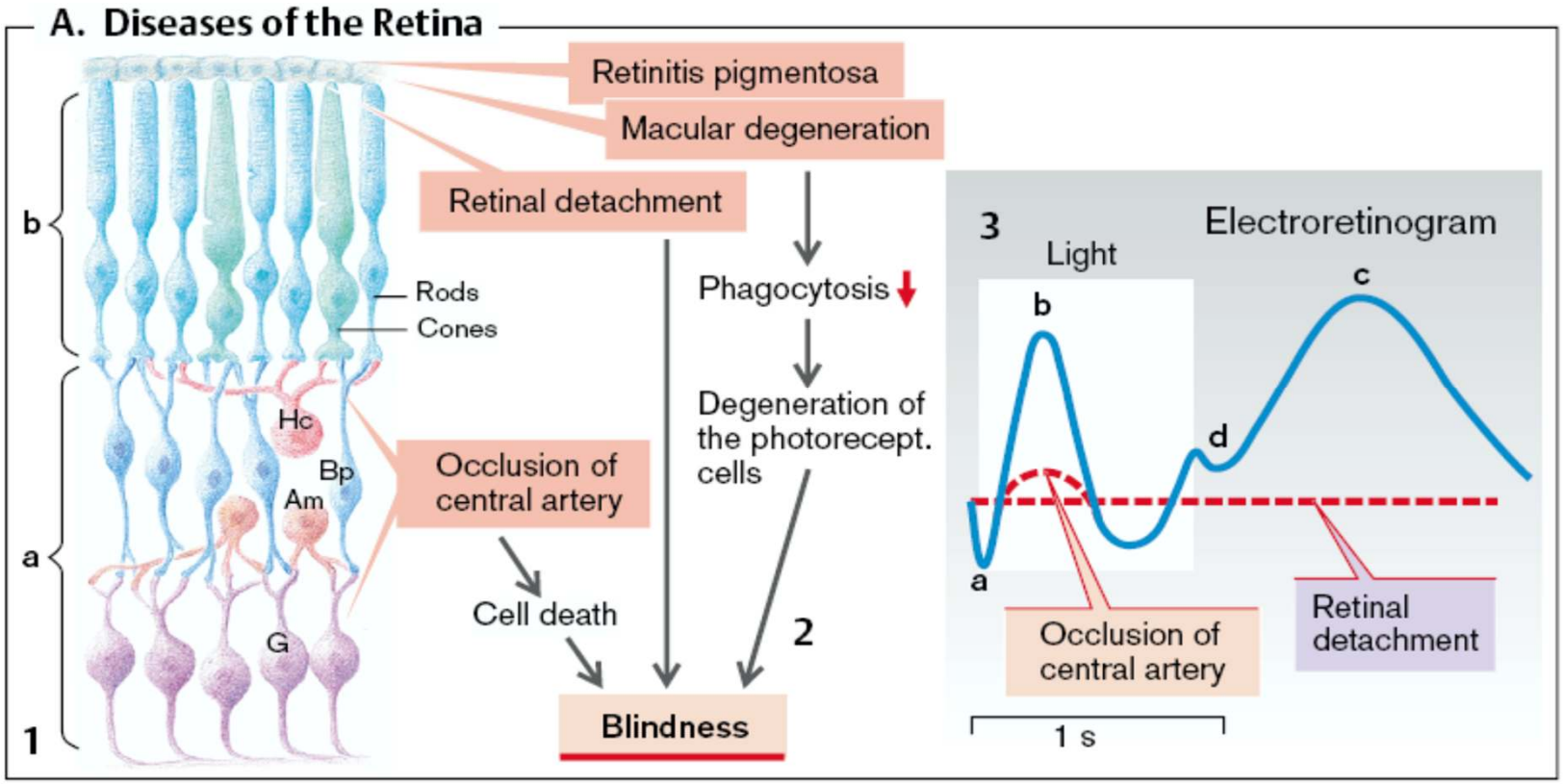
The (Ludimar) Hermann Grid Illusion, 1870



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.

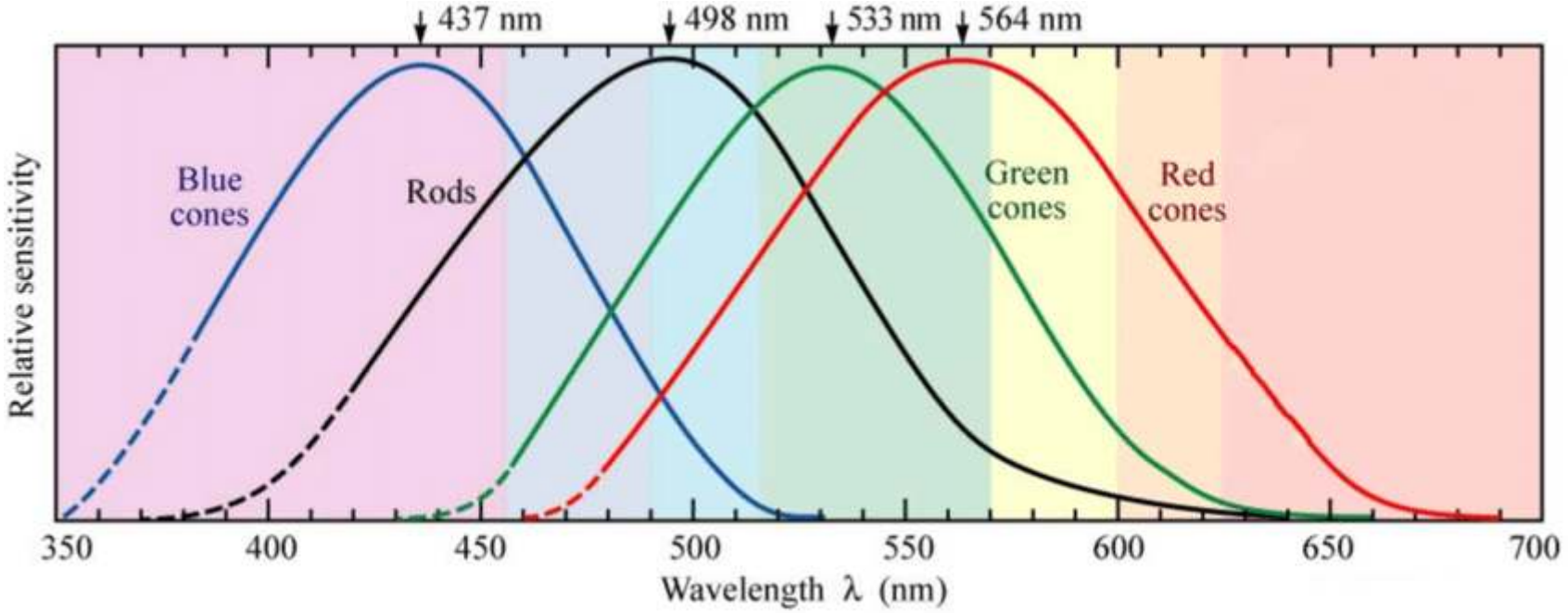
[M. Bach and C. M. Poloschek, Visual Neuroscience 2006]

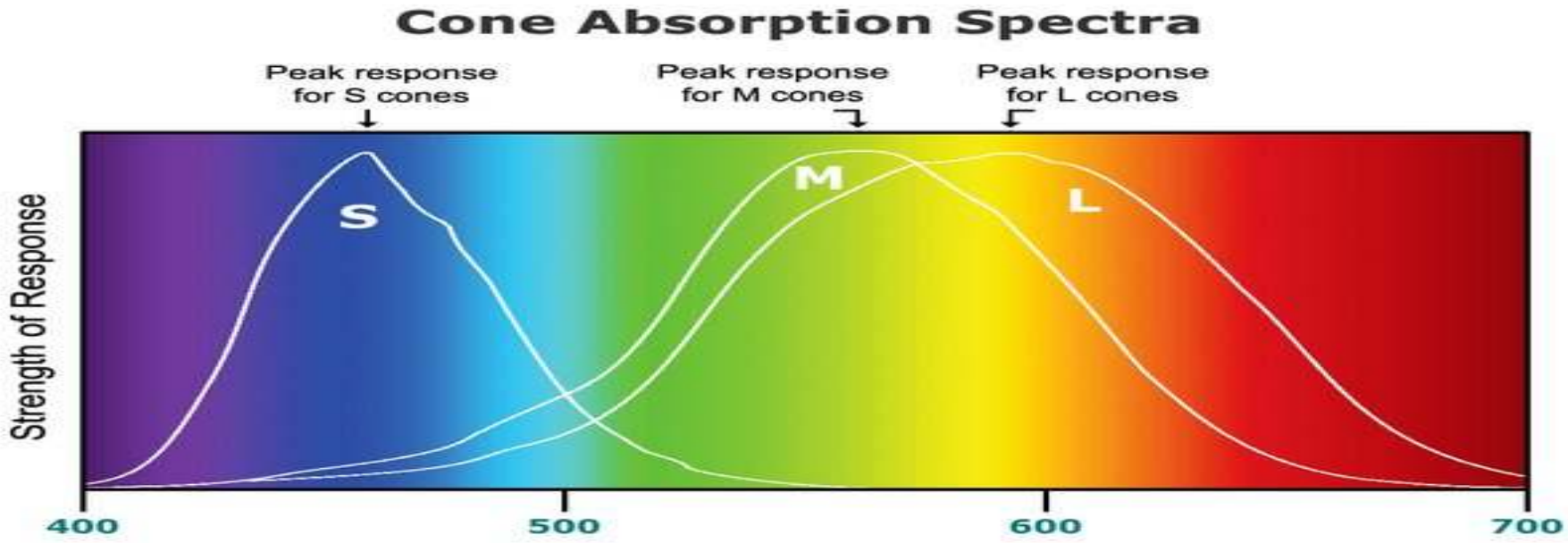
Electric Potentials of Retina



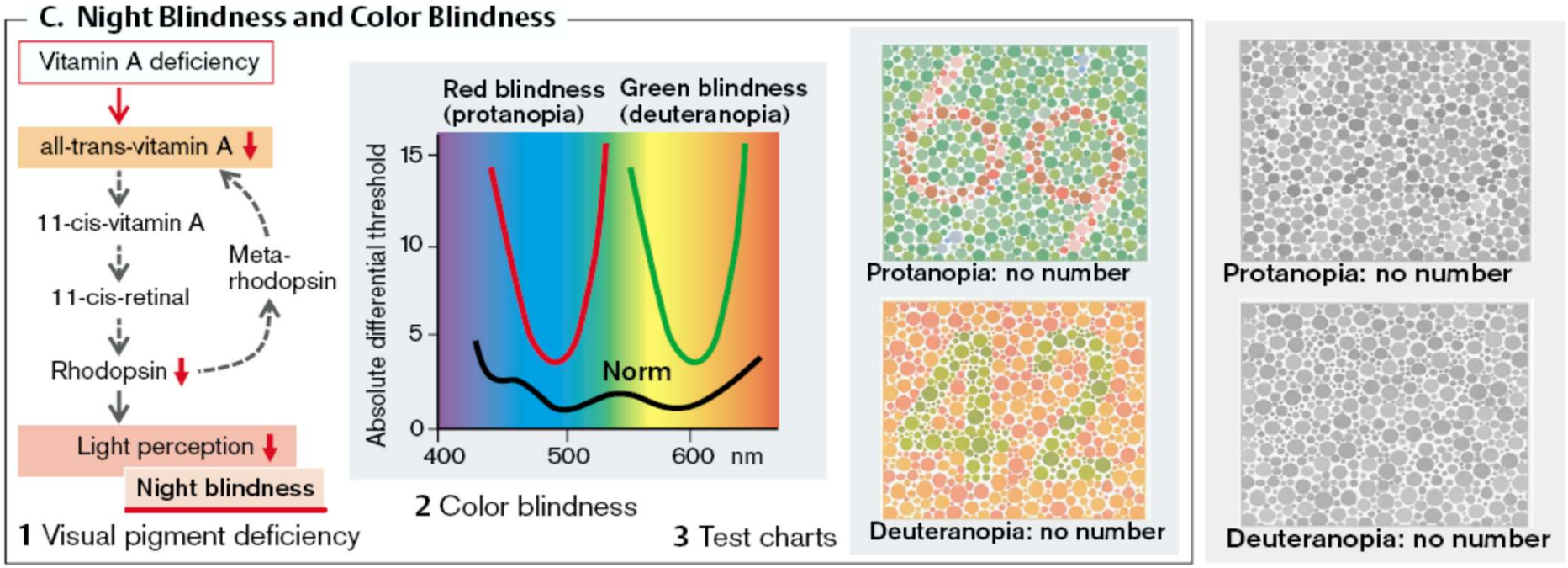
Electro-Retino-Gram in analogy to the EEG can record retinal activity and eye movements.

Spectral sensitivities of cones and rods



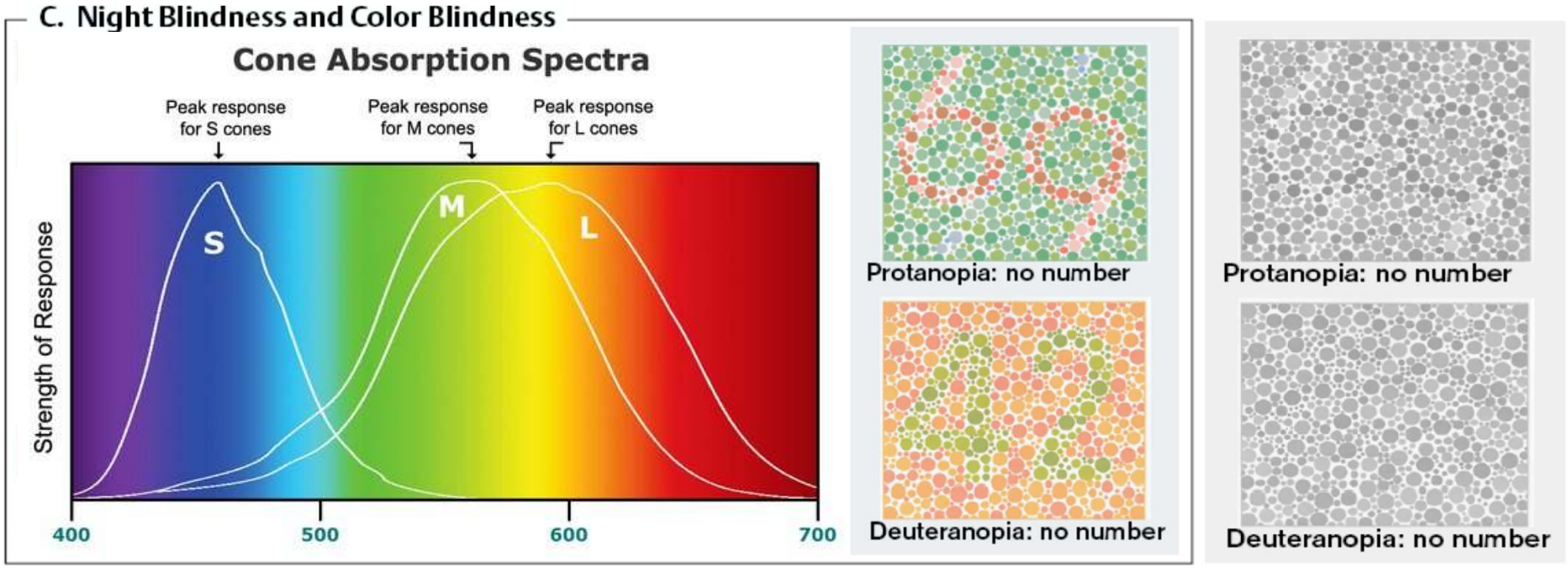


Day and Night Vision, with Rods and Three Cone Types



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.

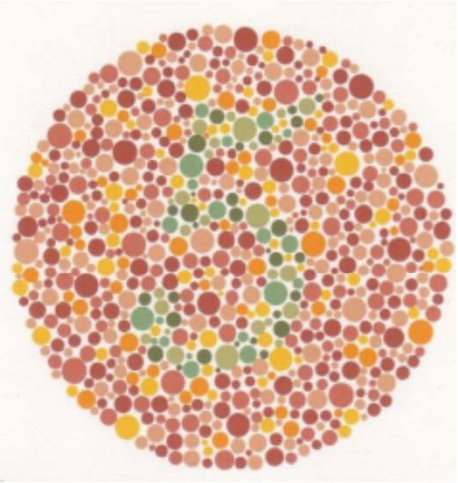
Day and Night Vision, with Rods and Three Cone Types

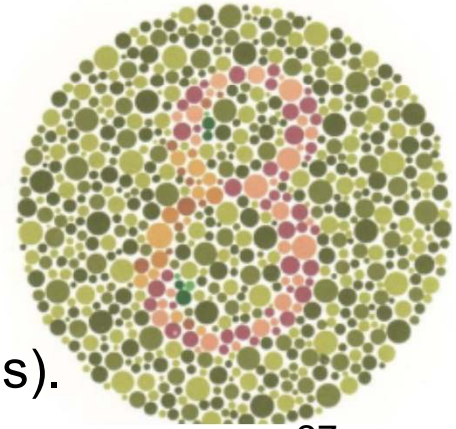


Color Blindness is manifested in men (XY) only, as it is located on the X chromosome. Women have the X in duplicate (XX). It also includes visual acuity impairment due to different than normal densities of cones.

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

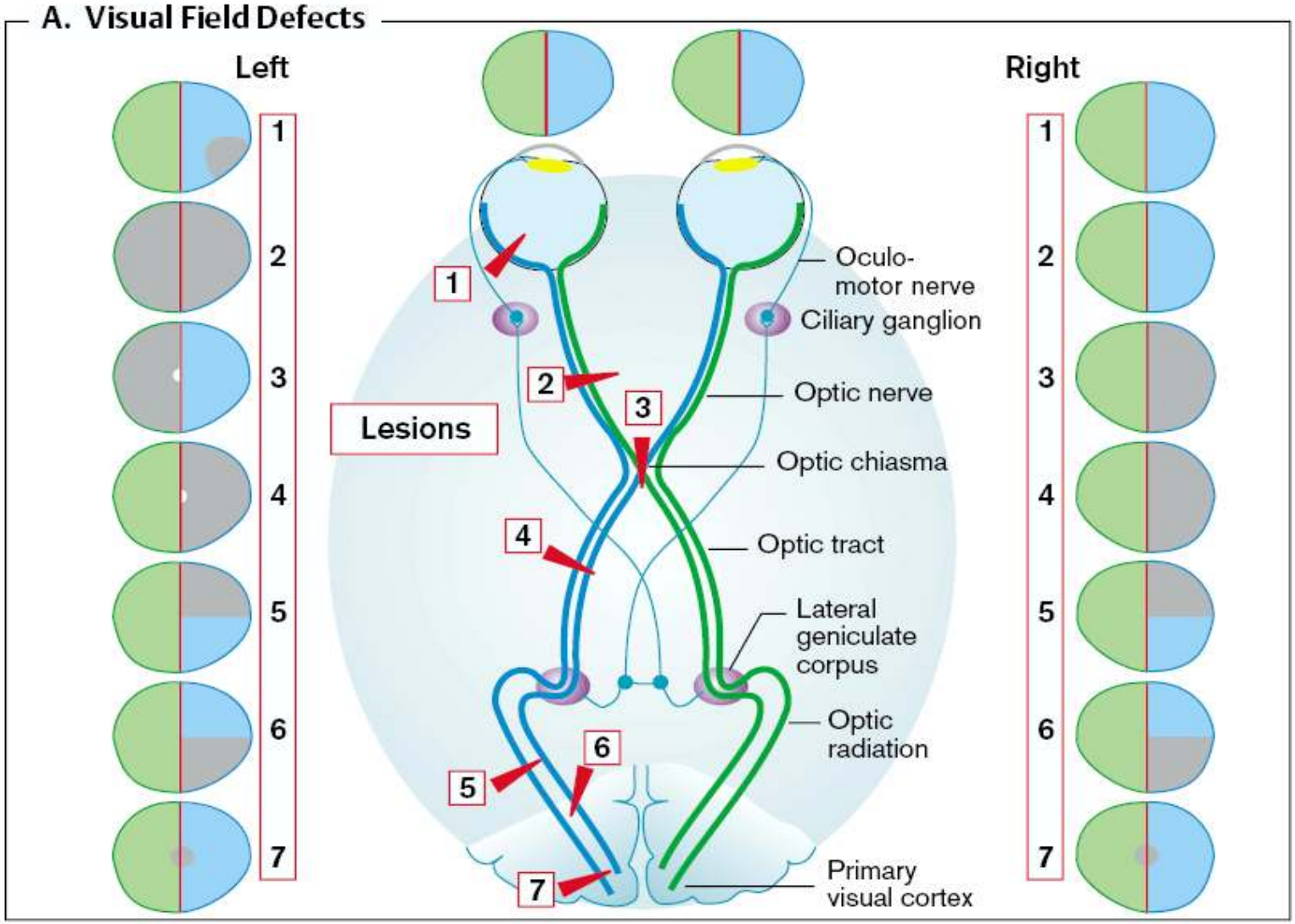
Viděné barvy	Normální oko	Barvoslepé oko	
		na červenou barvu	na zelenou barvu
	červená	špinavě zelená	žlutočervená
	oranžová	žlutá	žlutá
	žlutá	světle žlutá	žlutá
	žlutozelená	šedožlutá až bílá	žlutá
	zelená	šedá	šedožlutá až bílá
	modrá	světle modrá	světle modrá
	fialová	modrá	modrá



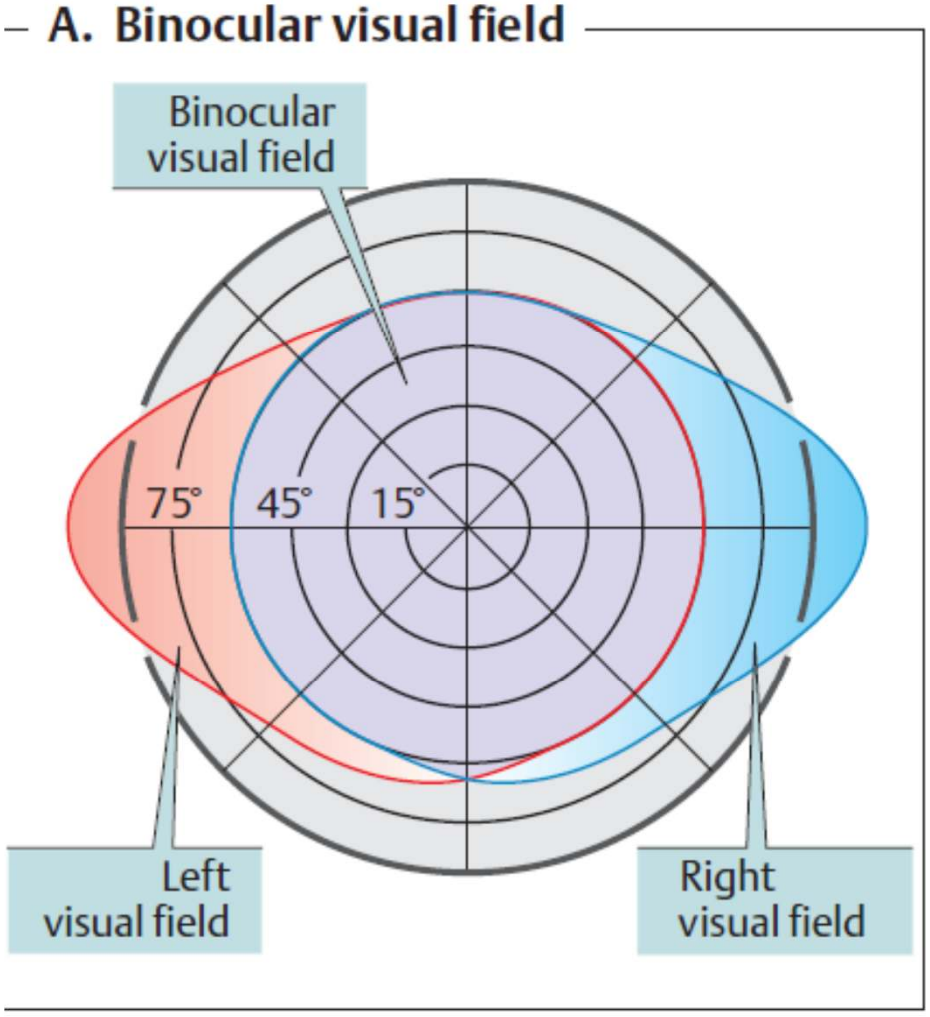


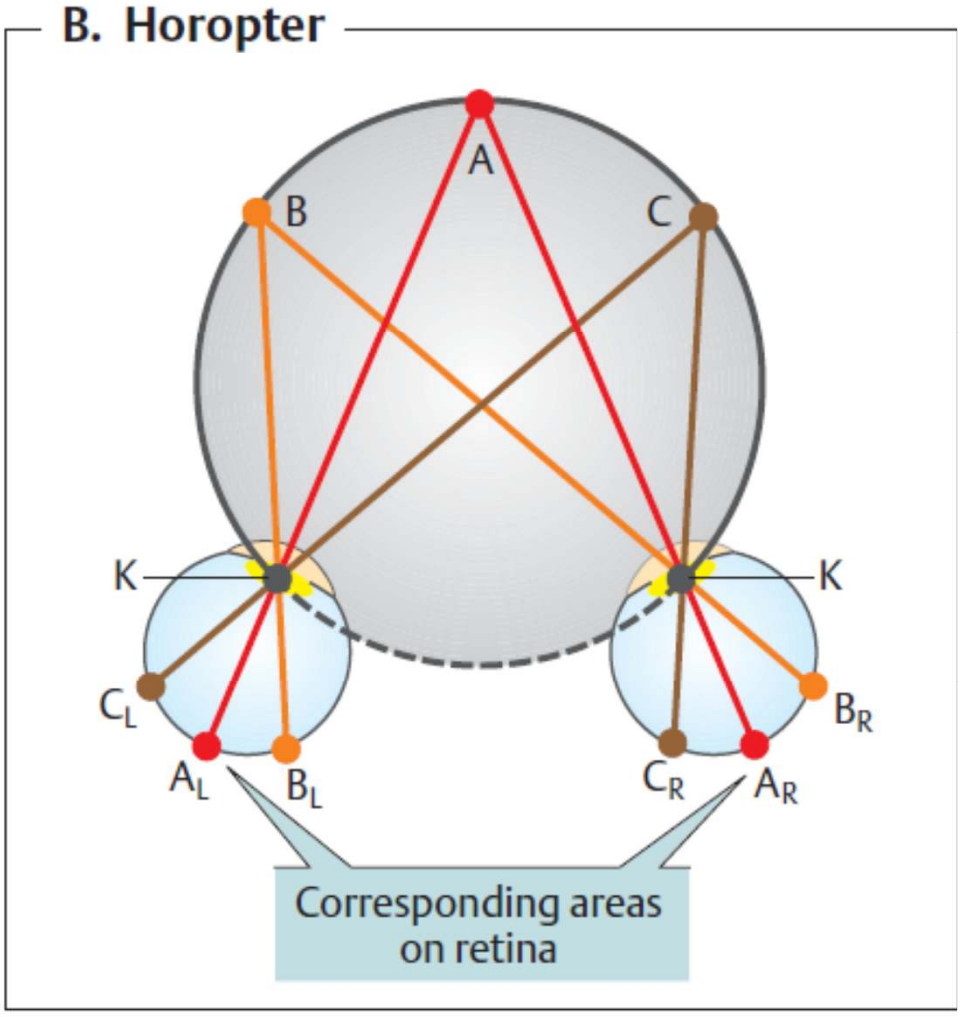
Normal, protan-opia (2%), deutan- (6% of males).

Visual Fields in Optic Nerve and their Defects

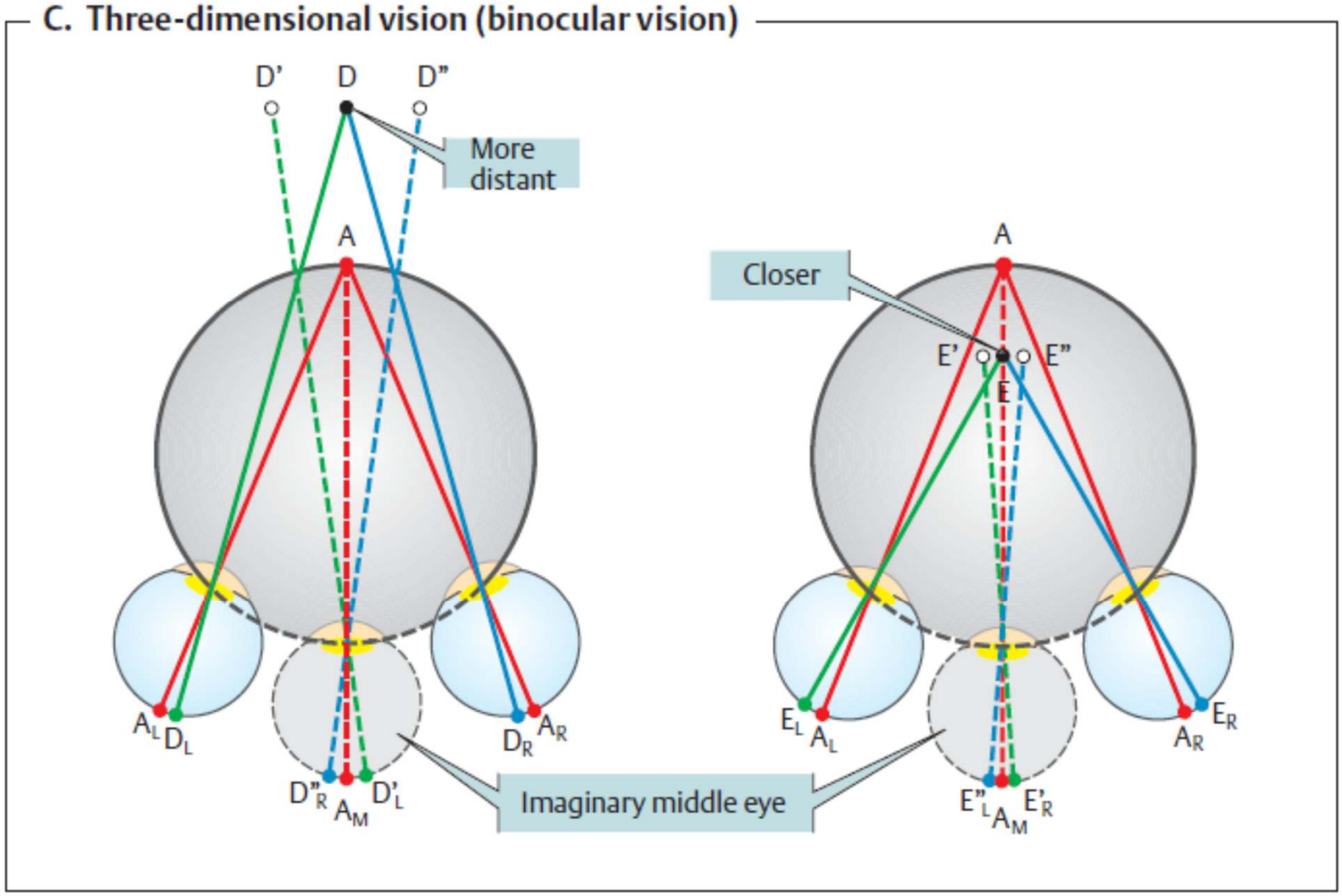


Binocular/ Stereoscopic Vision





Binocular/ Stereoscopic Vision



Geometry of disparities using the Cyclopean Eye
[Julesz, Bela. "*Foundations of cyclopean perception*." 1971]

Red and Cyan Anaglyphs for Stereoscopic Images

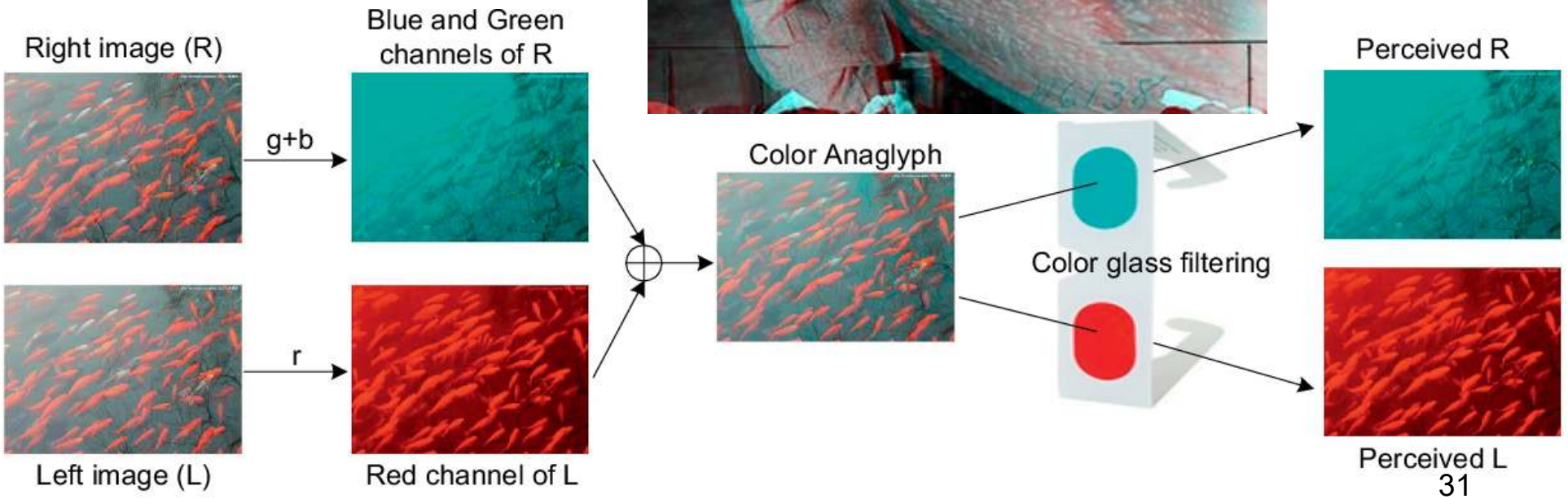


Fig. 1. An illustration of anaglyph 3D displaying using Color anaglyph.

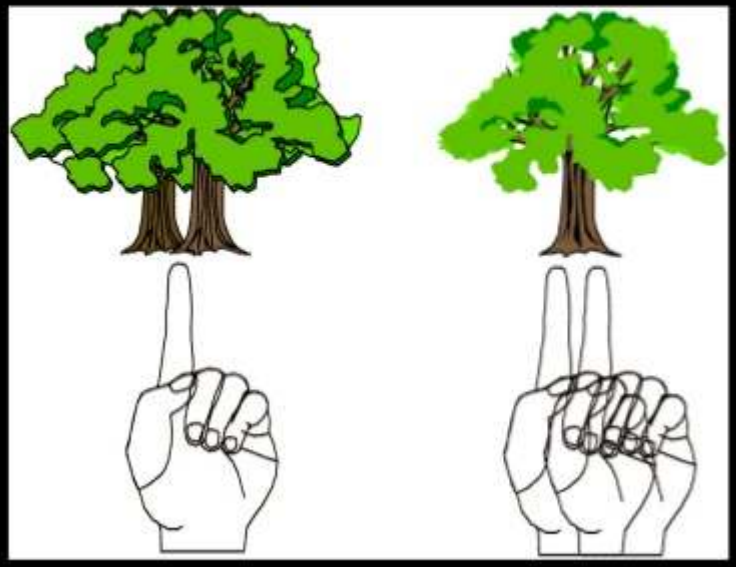
There is More to Depth of Field: Binocular Focusing is Realized by Eye Con- and Di-Vergence

Vergence eye movements

Either blur or retina disparity will generate vergence.

Latency for vergence movements is ~160 ms.

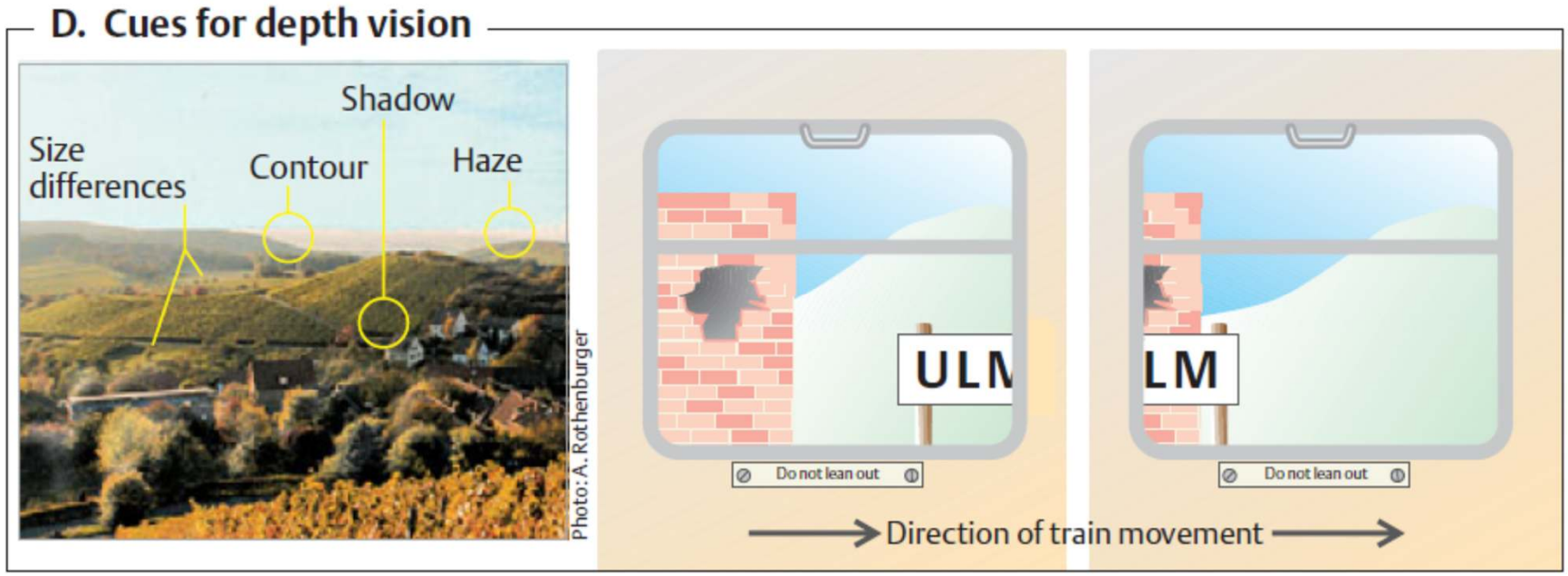
Maximum velocity is 20°/sec.



(Con)vergence disorder is called strabism.

Stereoscopic Vision

Binocular: Stereo Disparity, in Near Field Scene Only
Monocular: - By Perspective
- By Known Object Sizes
- By Parallax (in Disparity and Relative Motion)



Literary references

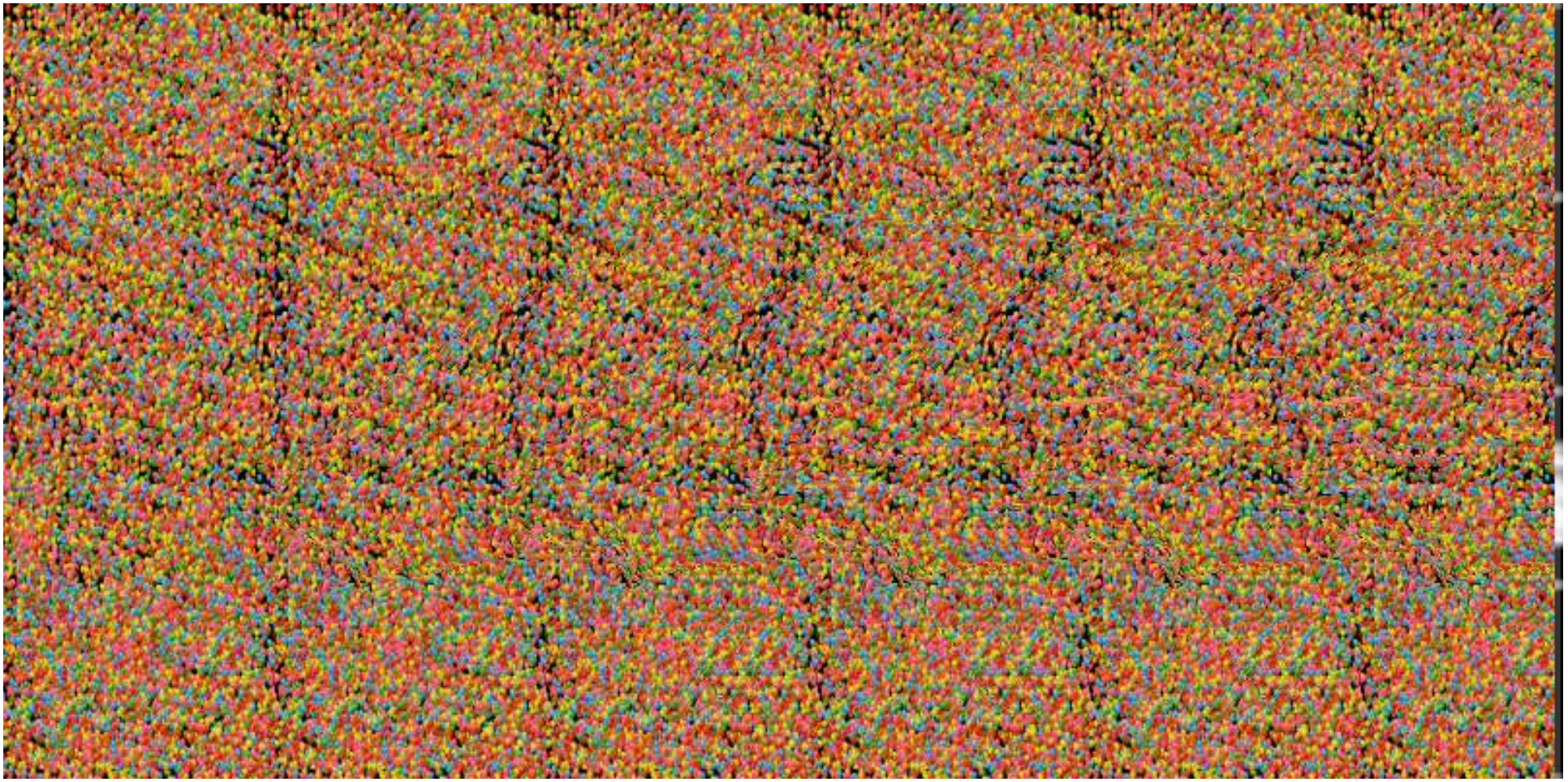
[Despopoulos, A; Silbernagl, S,
Color Atlas of Physiology, 1991],

[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)



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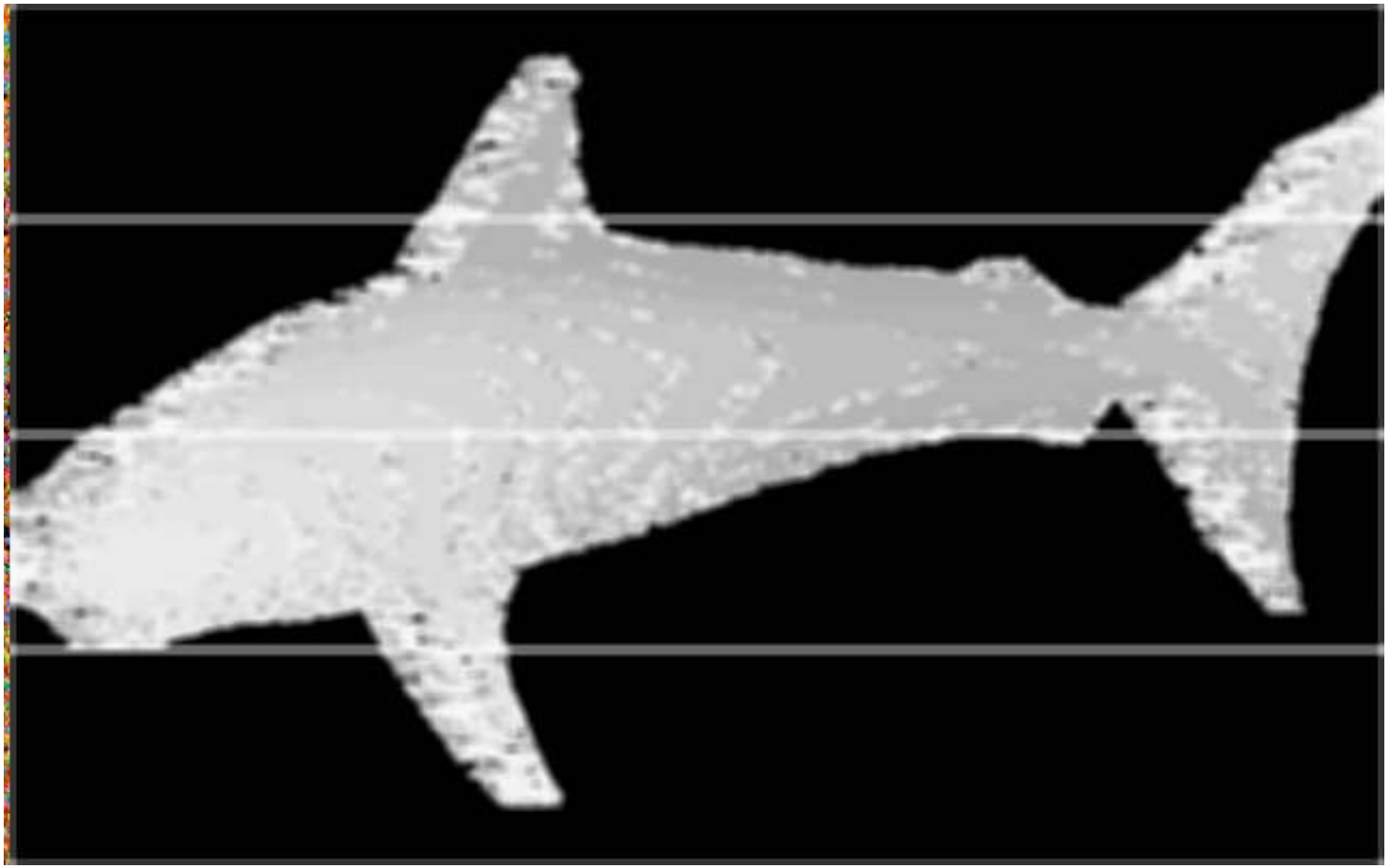

Another stereoscopic perception mode can be obtained using red and blue anaglyphs.
This is also a subject in the following two lectures:
- Visual cortex
- Vision/ hearing cross, also about space perception

END

OF THE LECTURE

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