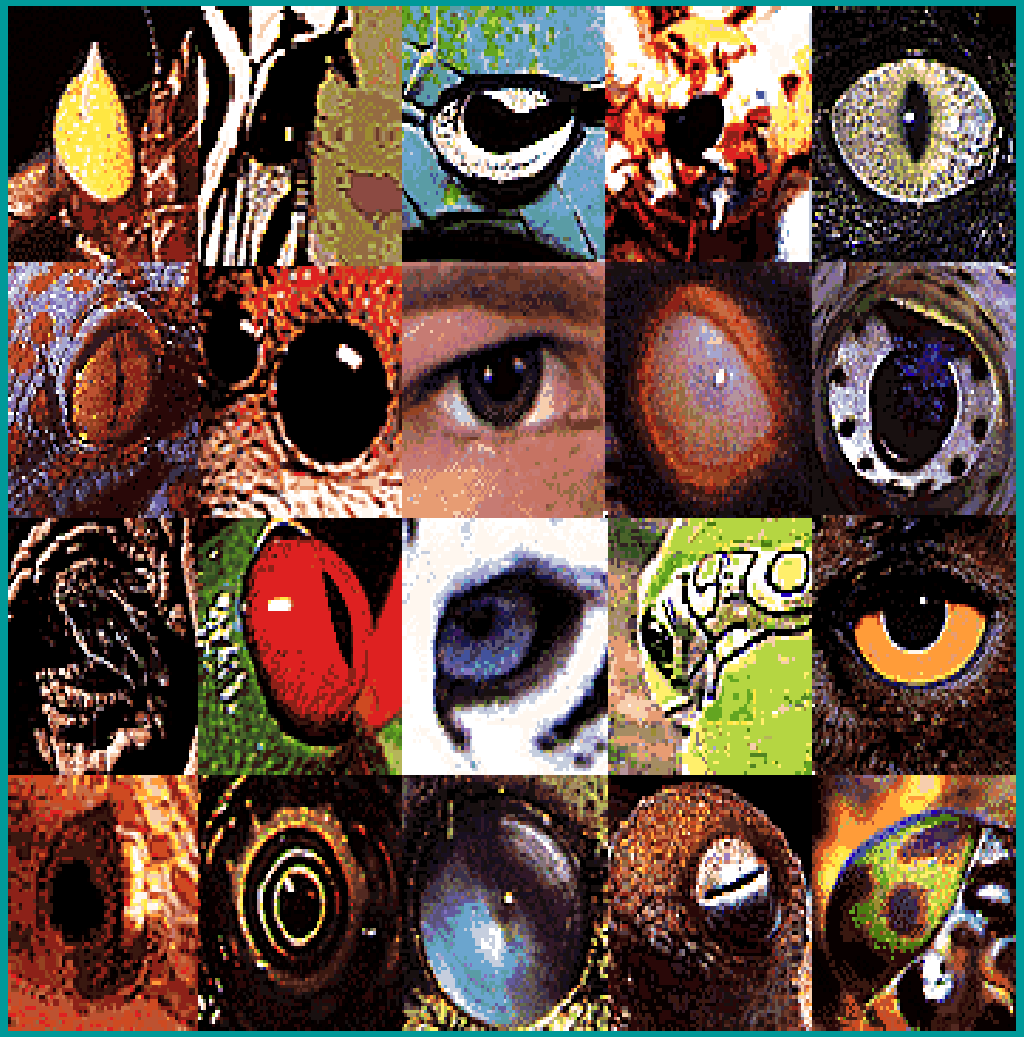
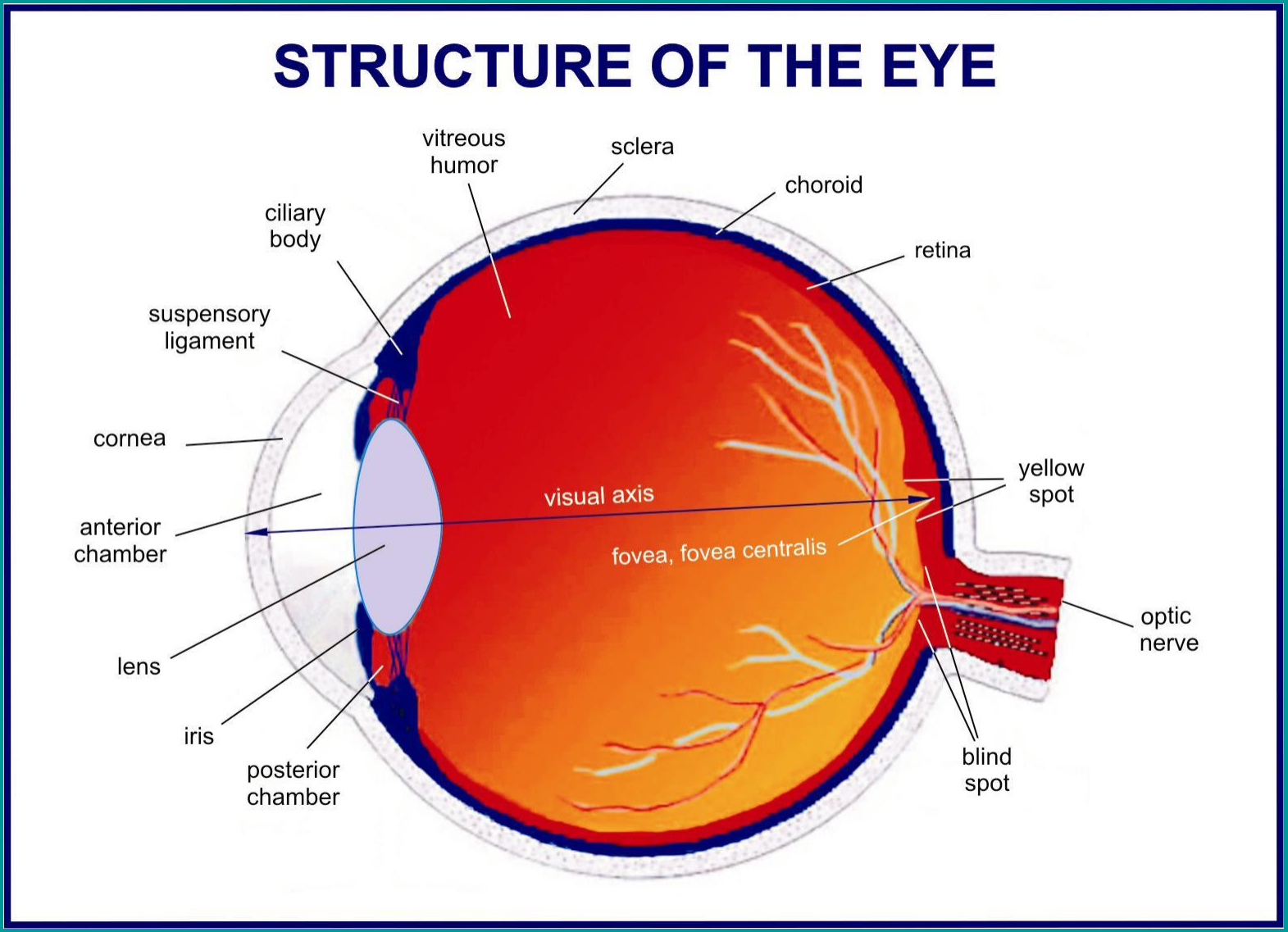
OPTICS OF THE EYE 2.



The human eye



Power of the human eye

$$D = \frac{n' - n}{R}$$

D : power (dpt)

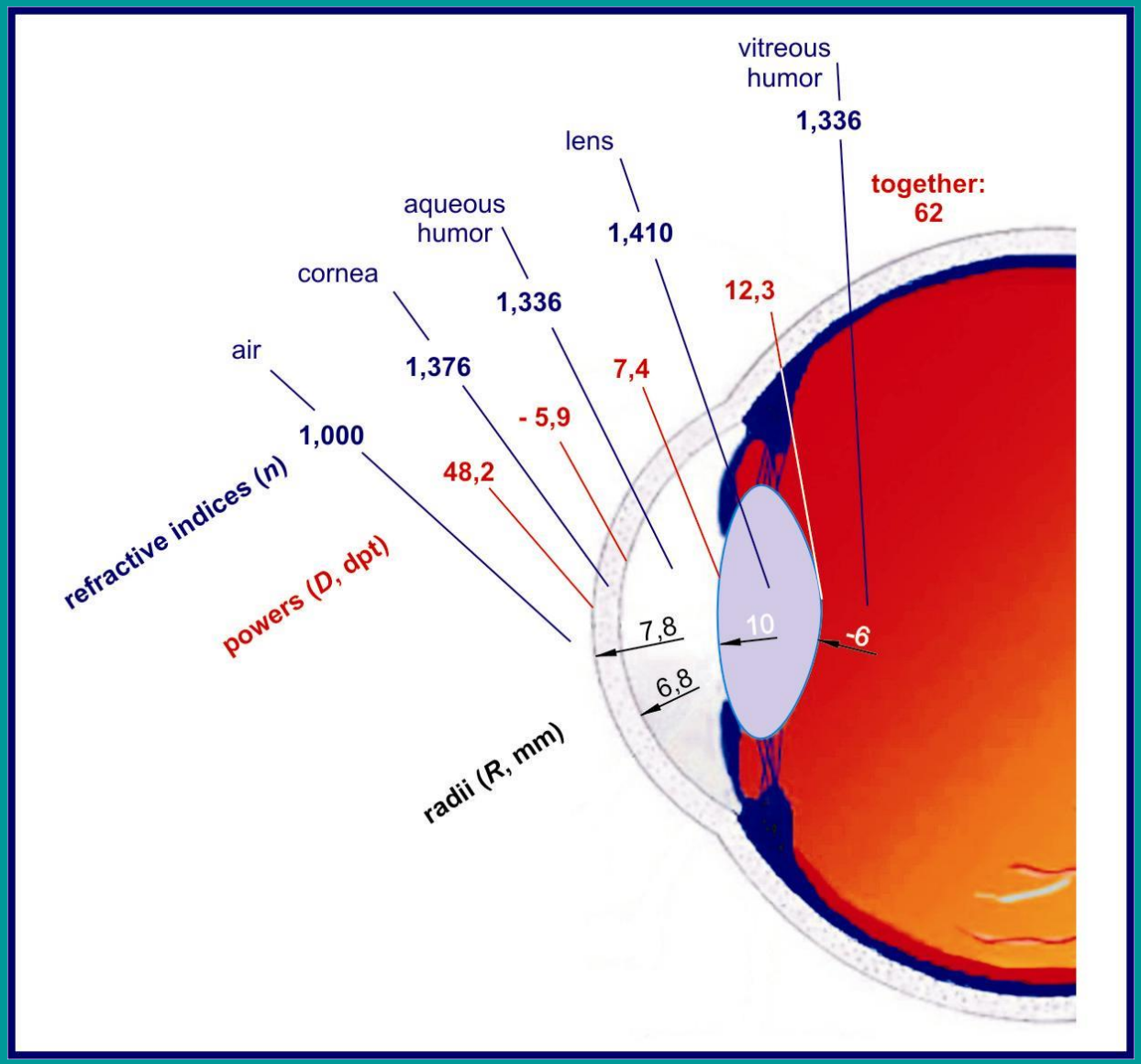
n : refr. index of the 1. medium

n' : refr. index of the 2. medium

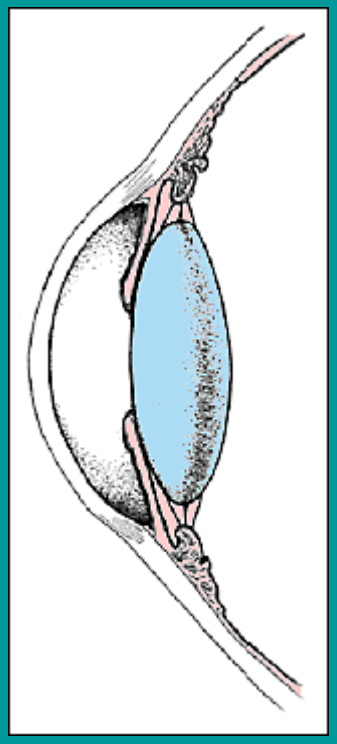
R : radius (m)

+ convex

– concave



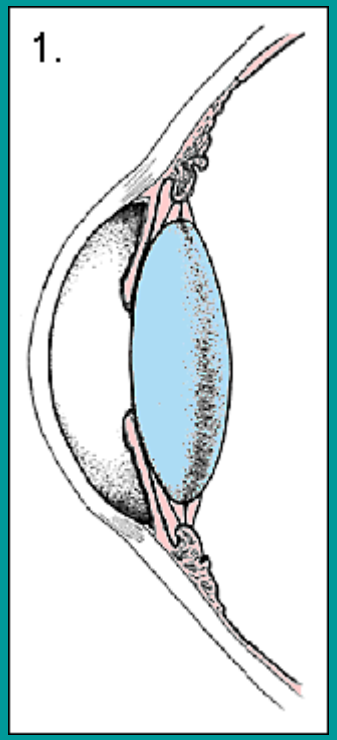
Accommodation

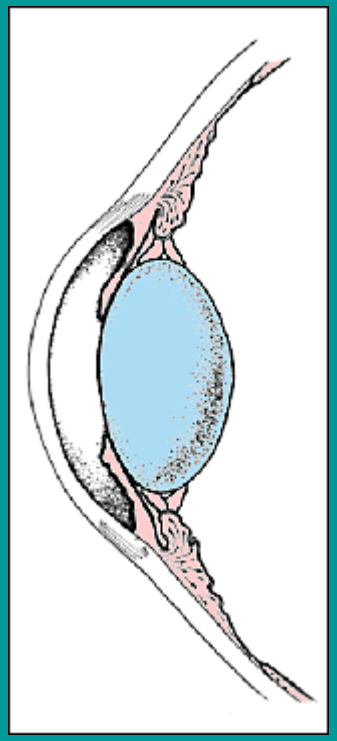


focused to a far object

(just sharp)

far point of vision: o_r





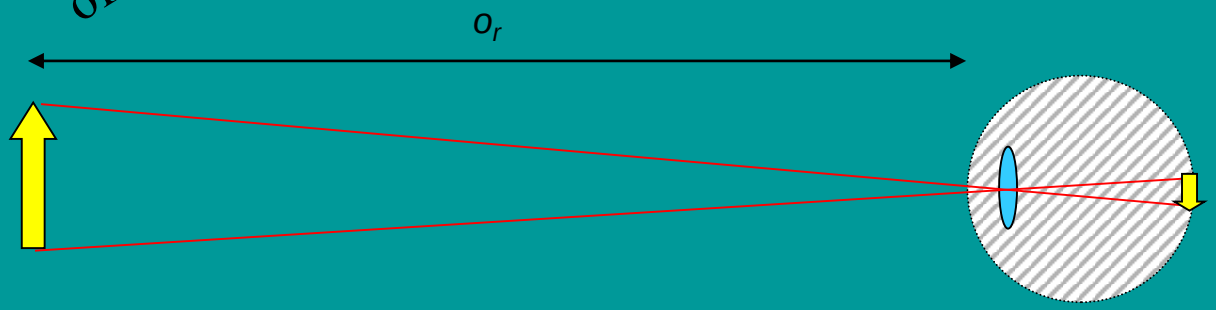
focused to a near object

(just sharp)

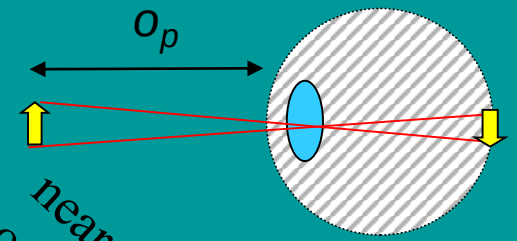
near point of vision: o_p

Accommodation power (ΔD)

far point of vision



$$D_r = \frac{n'}{i} + \frac{n}{o_r}$$



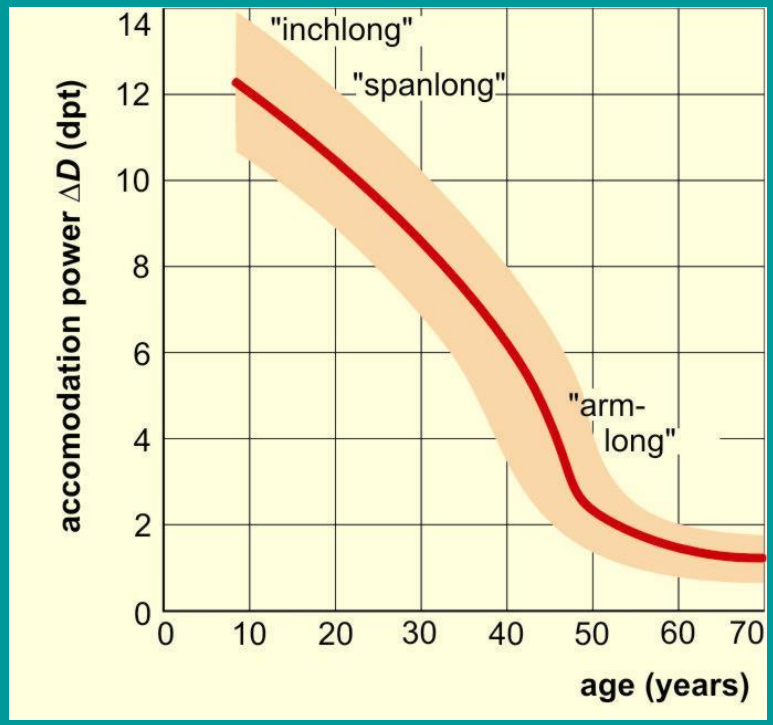
near point of vision

$$D_p = \frac{n'}{i} + \frac{n}{o_p}$$

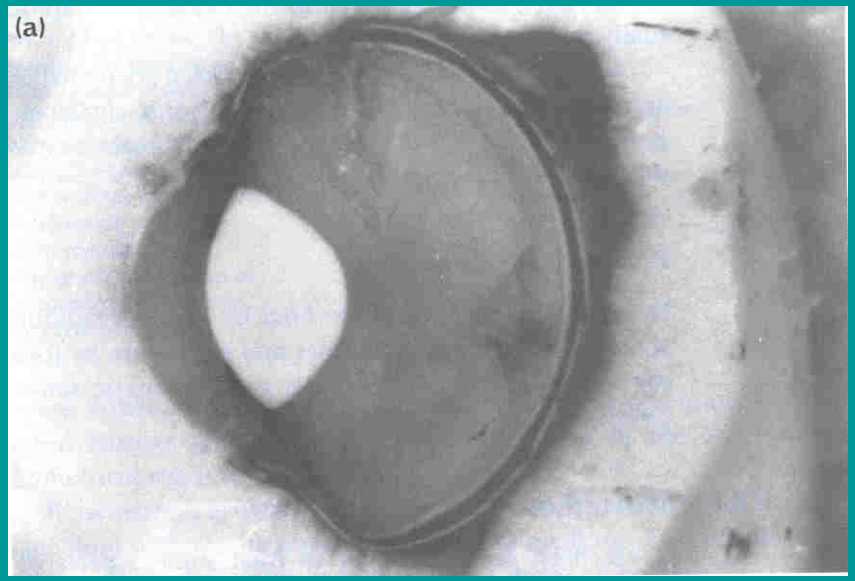
$$\Delta D = D_p - D_r = \frac{1}{o_p} - \frac{1}{o_r}$$

e.g. $o_r = \infty$

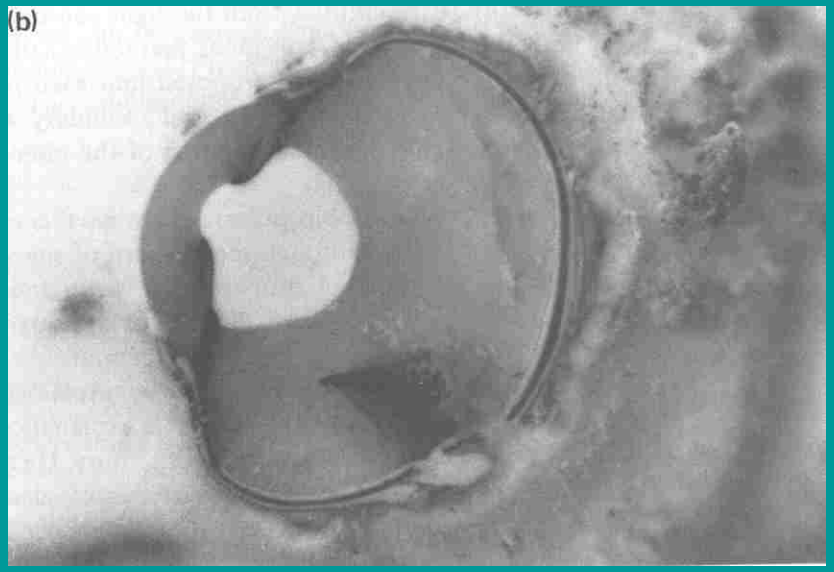
$o_p = 0.07\,\mathrm{m}$ $\Rightarrow$ $\Delta D = 13\,\mathrm{dpt}$



Extrem example: induced accomodation of duck’s eye



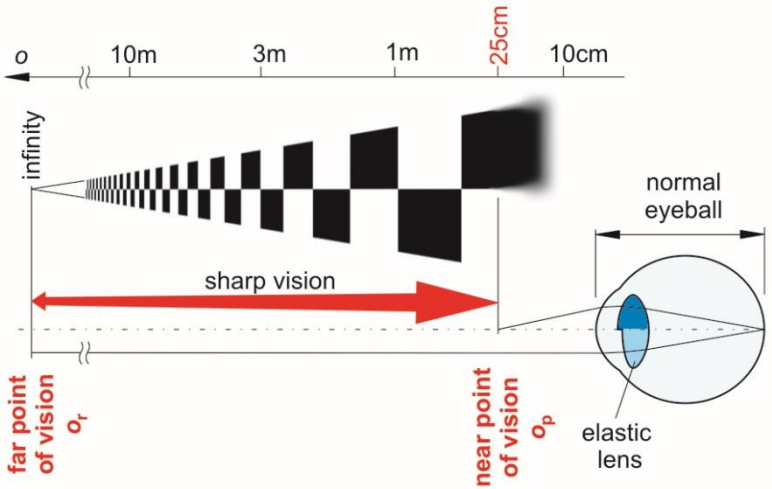
overland

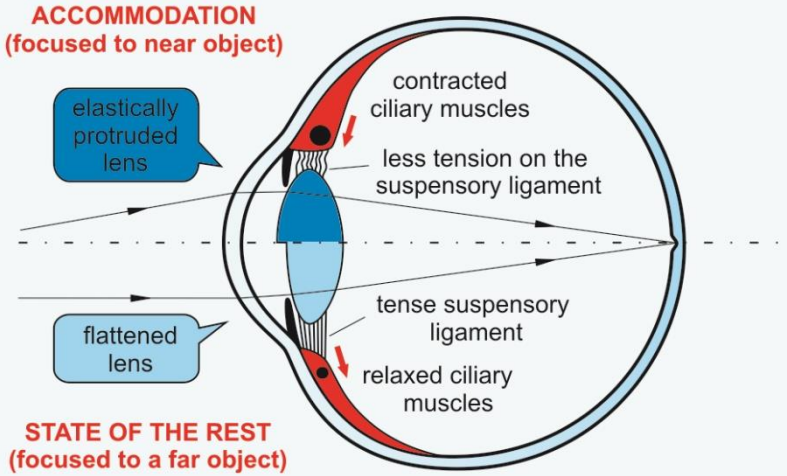


under water

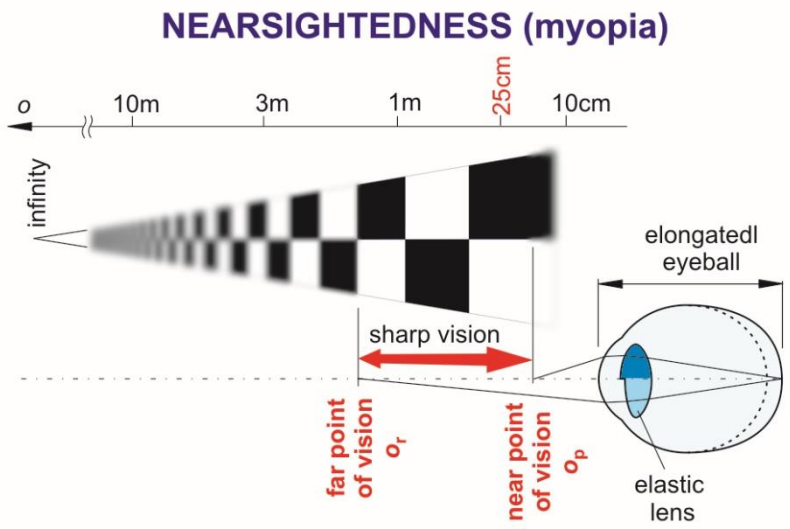
Defects of the eye: nearsightedness

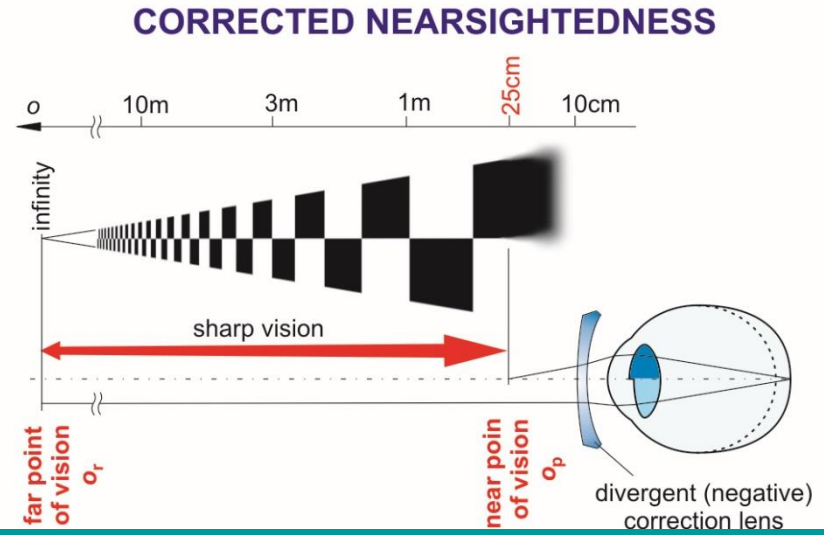
a.



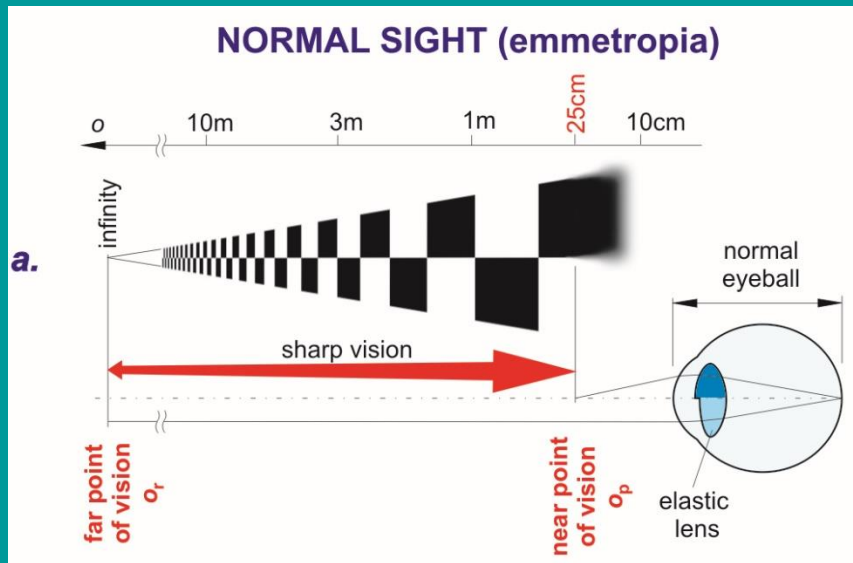


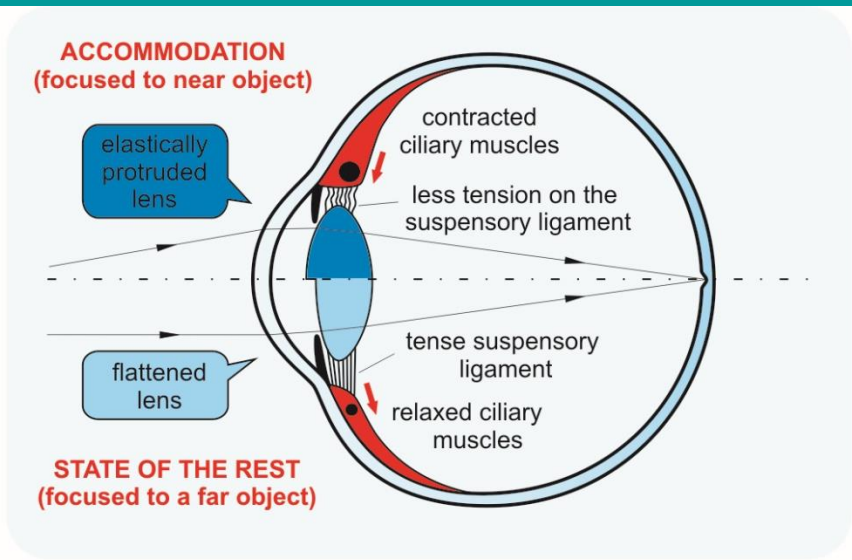
b.

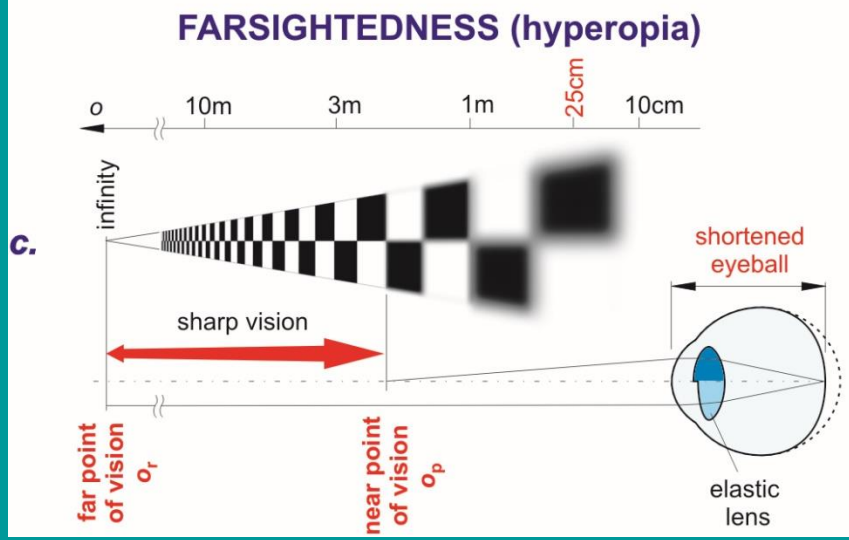


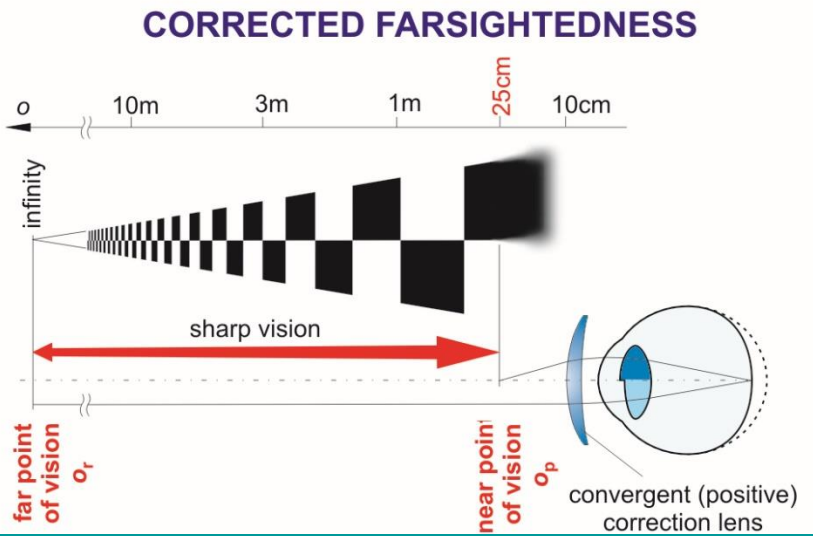


Defects of the eye: farsightedness









Defects of the eye: aging of the eye

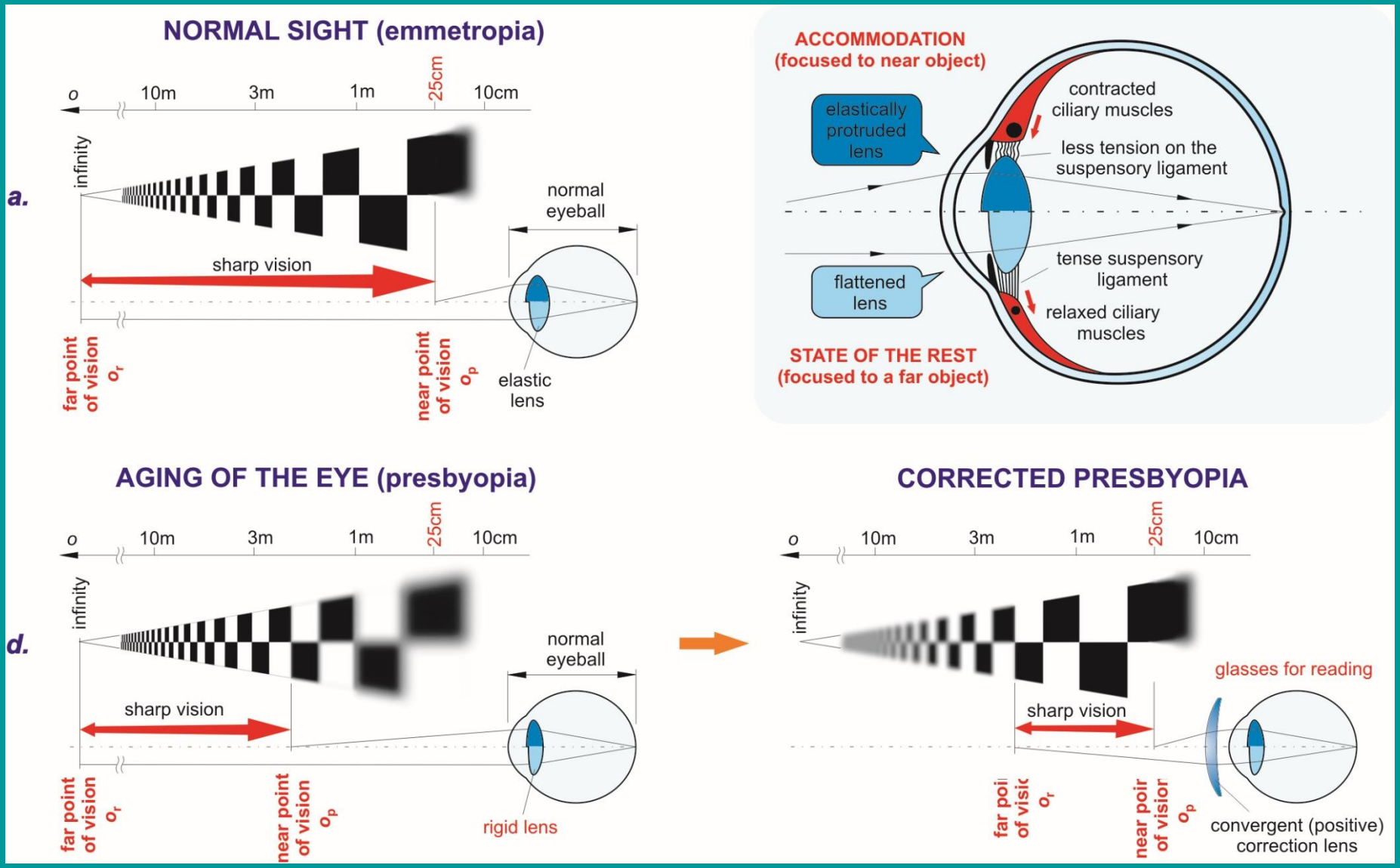
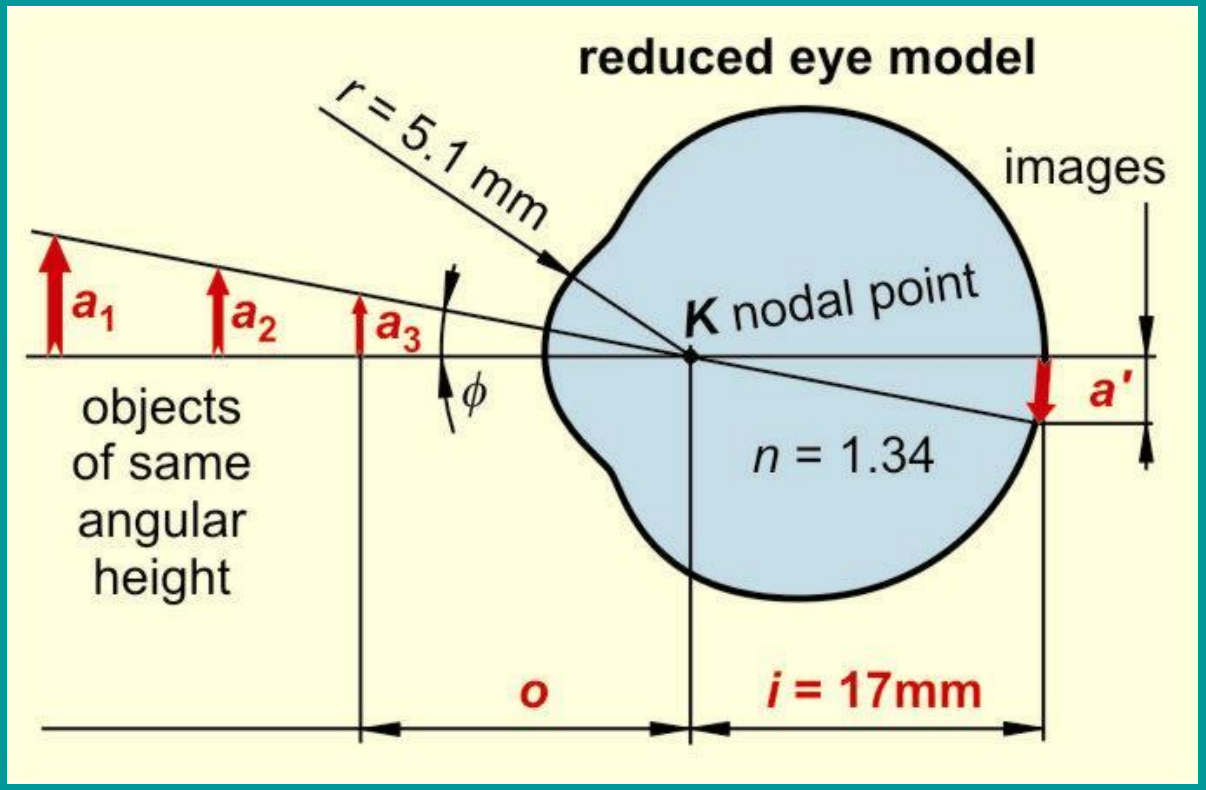


Image formation

Model:

reduced eye

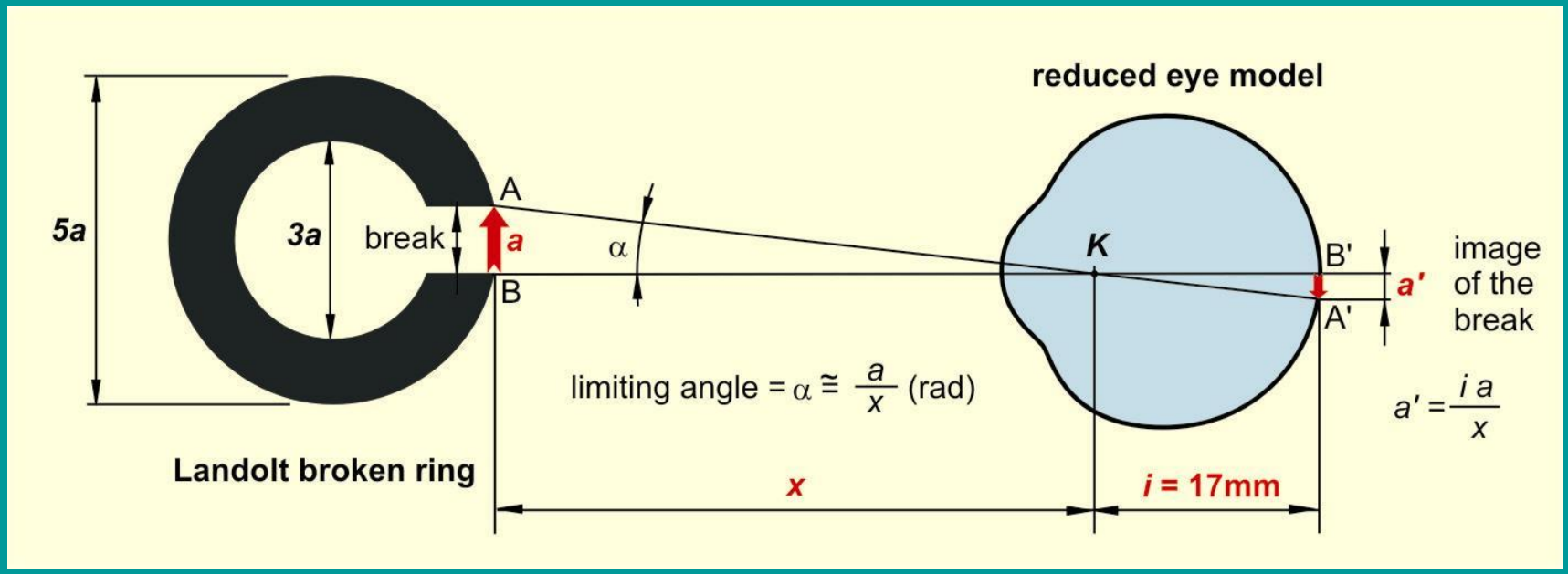


The image:

- real
- diminished
- inverted

D = 67 dpt

Visual acuity (resolution)



Limiting angle:

$$\alpha \cong \frac{a}{x}\,(\mathrm{rad}) \qquad \alpha(') = \frac{a}{x}(rad)\cdot\frac{360(°)}{2\pi(rad)}\cdot 60\left(\frac{'}{°}\right)$$

Visual acuity:

$$\mathrm{visus} = \frac{1(')}{\alpha(')}\,(\cdot 100\,\%)$$

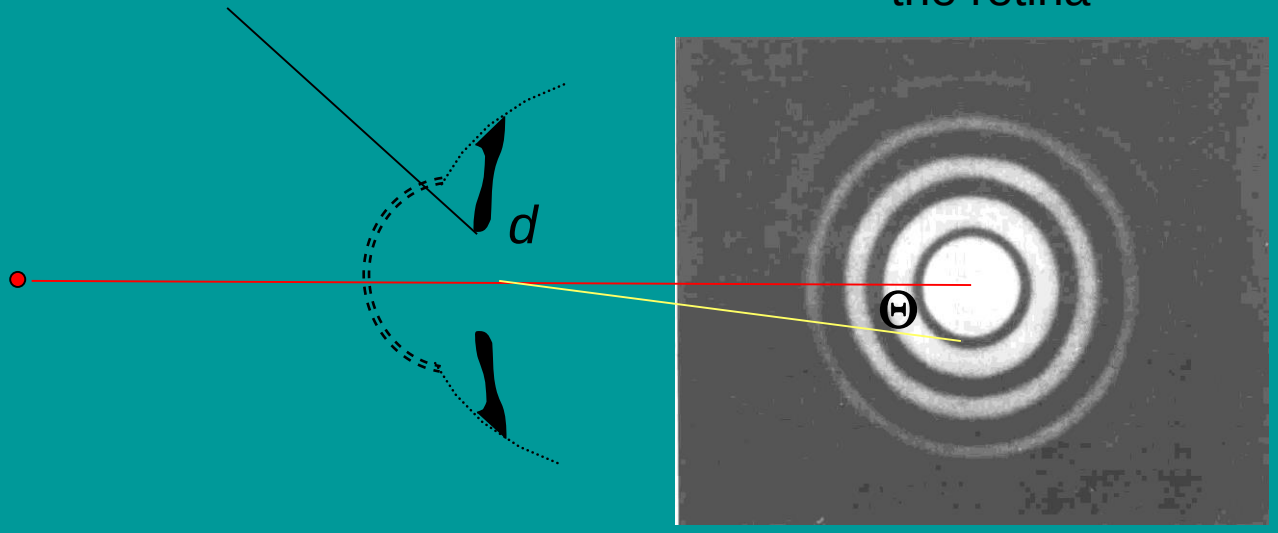
Limiting angle of average healthy eye is 1', so the visual acuity is 100 %.

Explanation of visual acuity 2.

Wave optical explanation:

Diffraction on the pupil

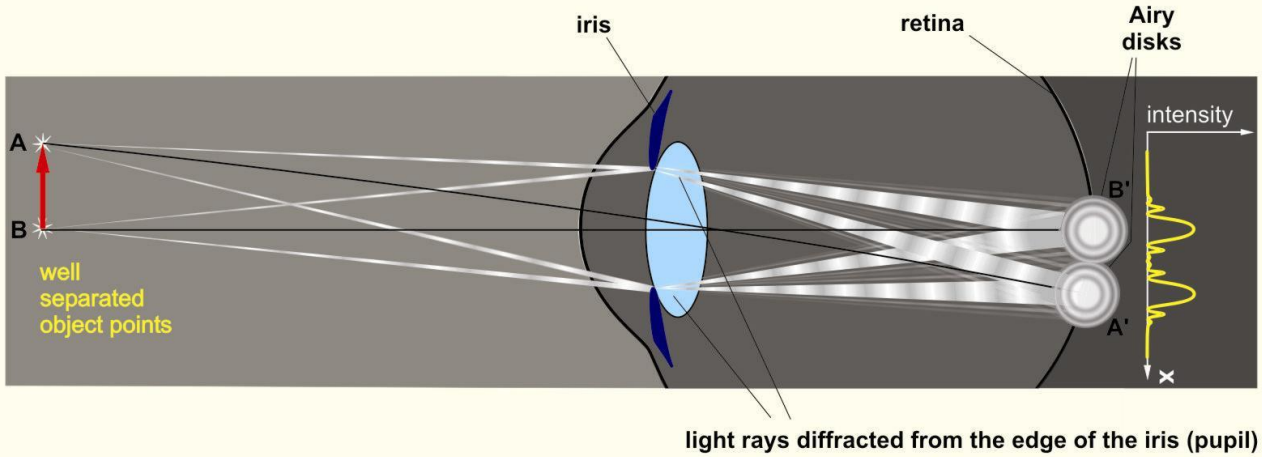
Image of an object point on the retina



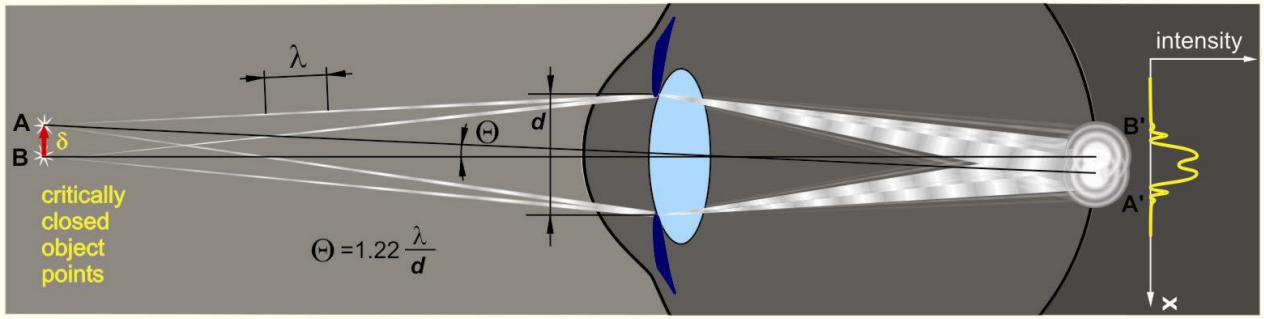
„Airy disk”

Angle of the first minimum interference relative to the principal maximum:

$$\sin\Theta = 1.22\,\frac{\lambda}{d} \approx \Theta$$



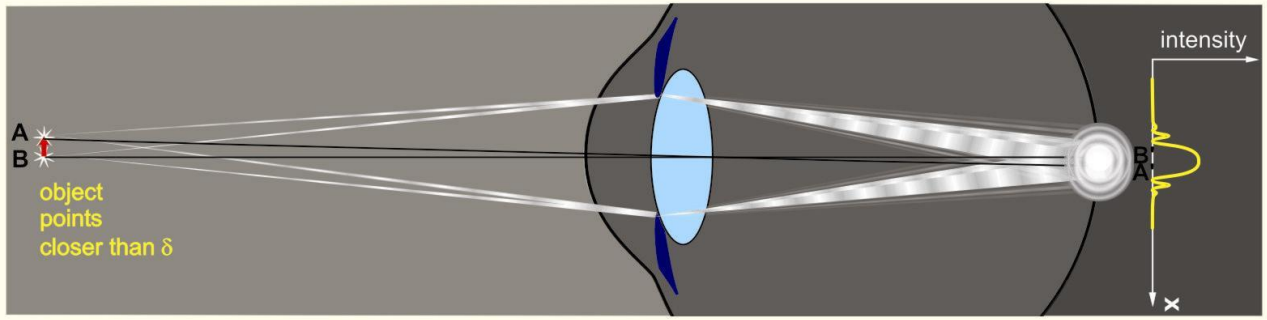
Airy disks are isolated (A',B') in case of well separated object points (A,B)



Airy disks overlap, but are just indistinguishable in case of critically closed object points.

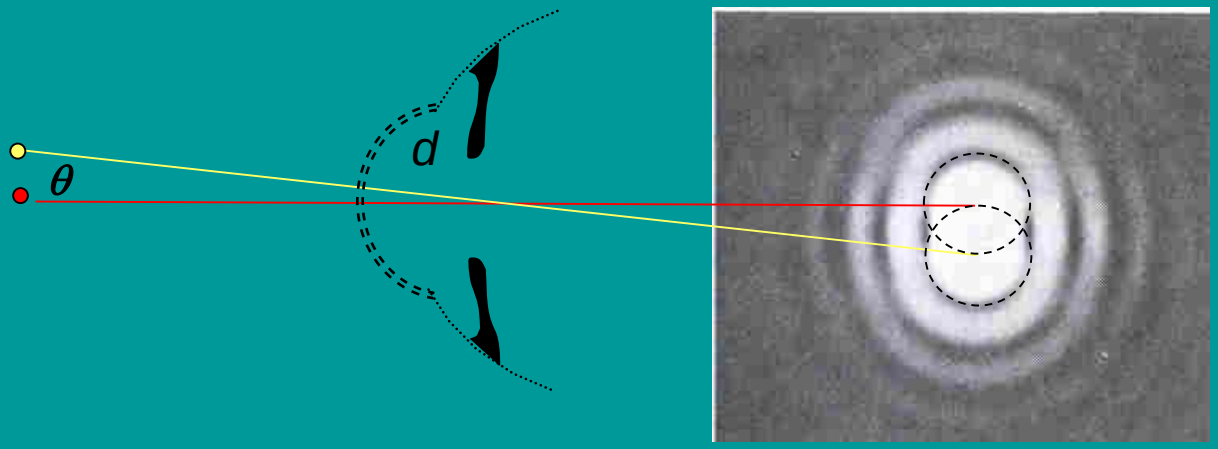
δ is the resolution limit,

Θ is the limiting angle of wiev (due to diffraction).



Airy disks merge in case of object points closer than δ.

Image of the two object points is not resolved (by wave optics)



Condition to resolve two object points, that their diffraction patterns shift compared to each other at least so, that the maximum of one coincides with the first minimum of the other.

In this case the visual angle of the object points: $\theta = 1.22\frac{\lambda}{d}$

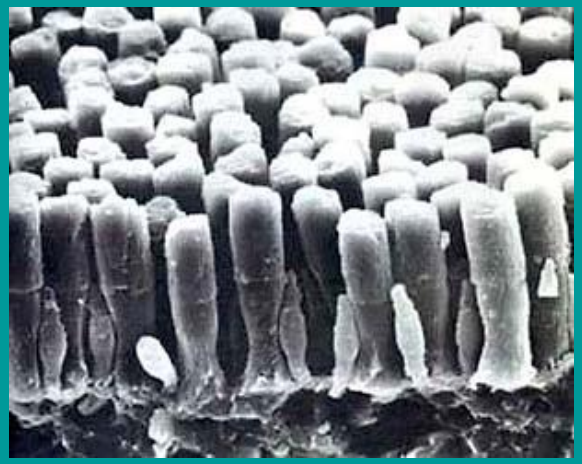
e.g. λ = 0.55 μm,

d = 3.5 mm = 3500 μm

$\Rightarrow$ θ = 0.7’

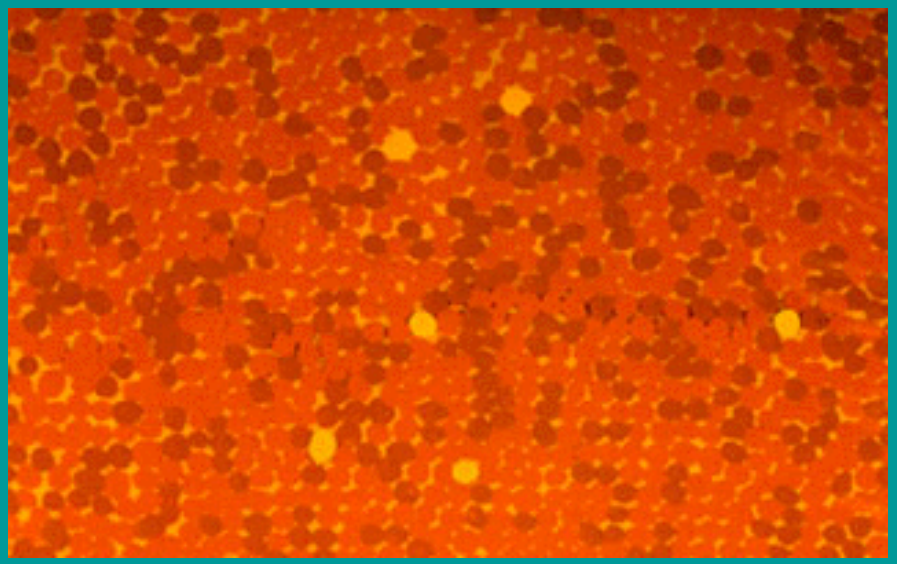
Explanation of visual acuity 3.

discrete receptor field



Cones and rods

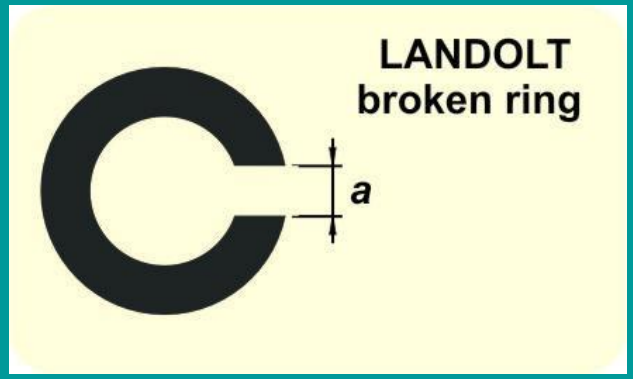
(in the peripheral part of the retina)



Cones of different wavelength sensitivity

(fovea centralis)

Measurement of visual acuity



***a* = 0,5 mm**

a = 0,4 mm

***a* = 0,3 mm**

***a* = 0,2 mm**

Image of Landolt broken ring on the yellow spot 1.

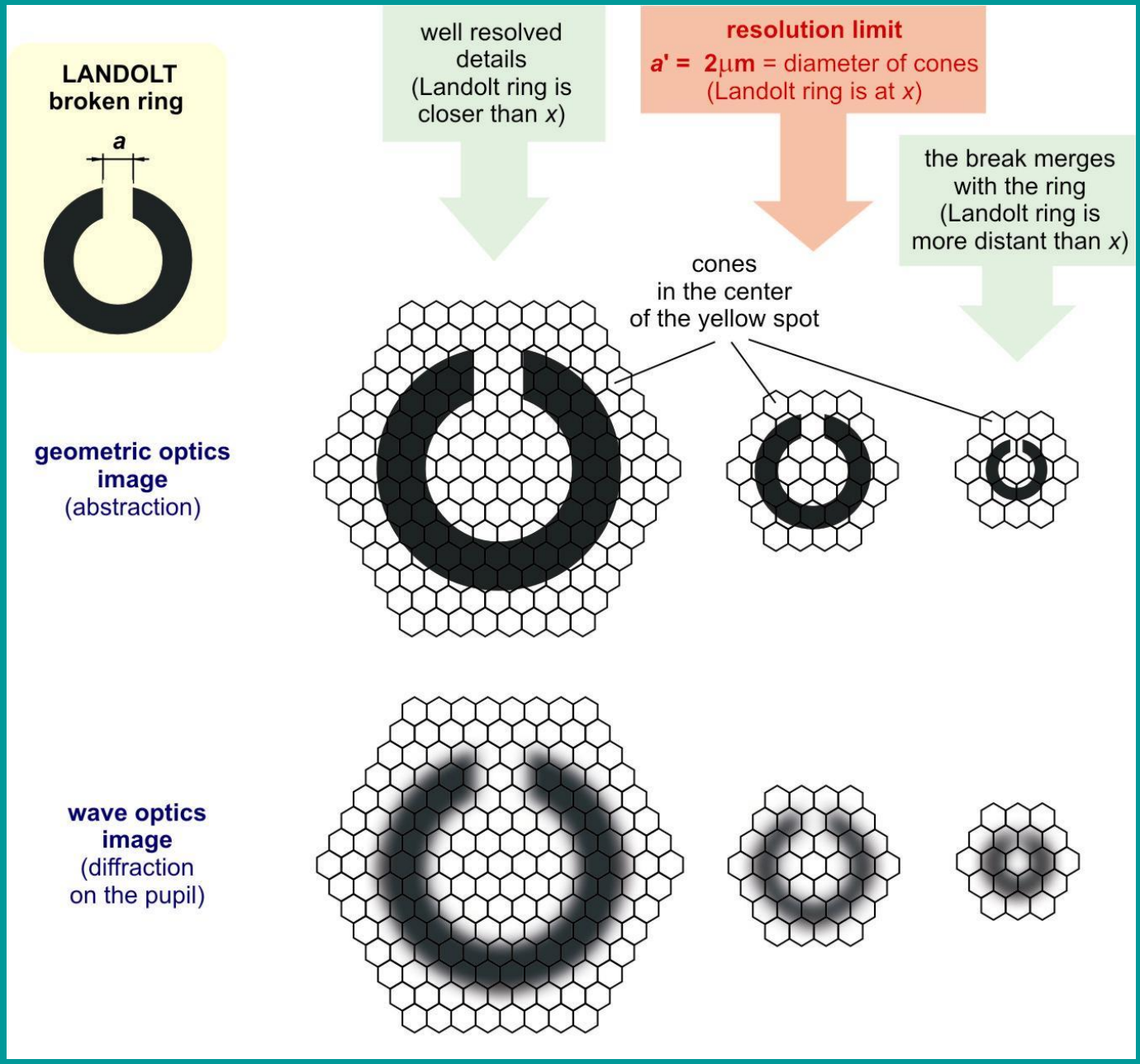
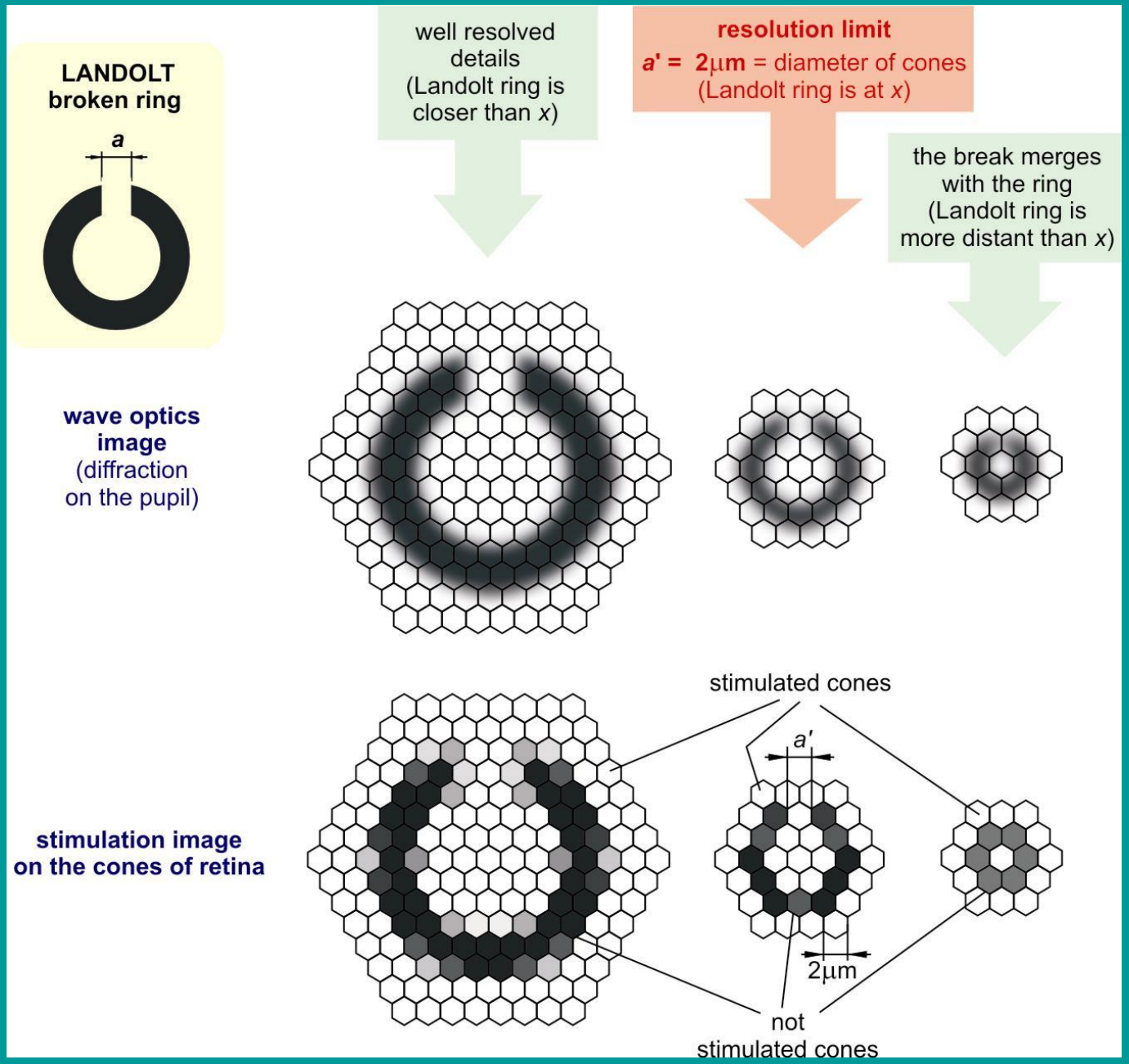
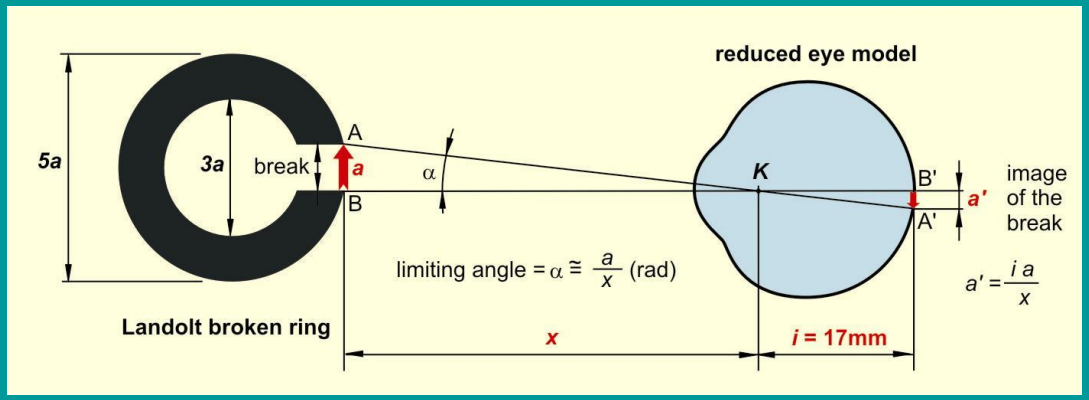


Image of Landolt broken ring on the yellow spot 2.



Density and distribution of receptor cells

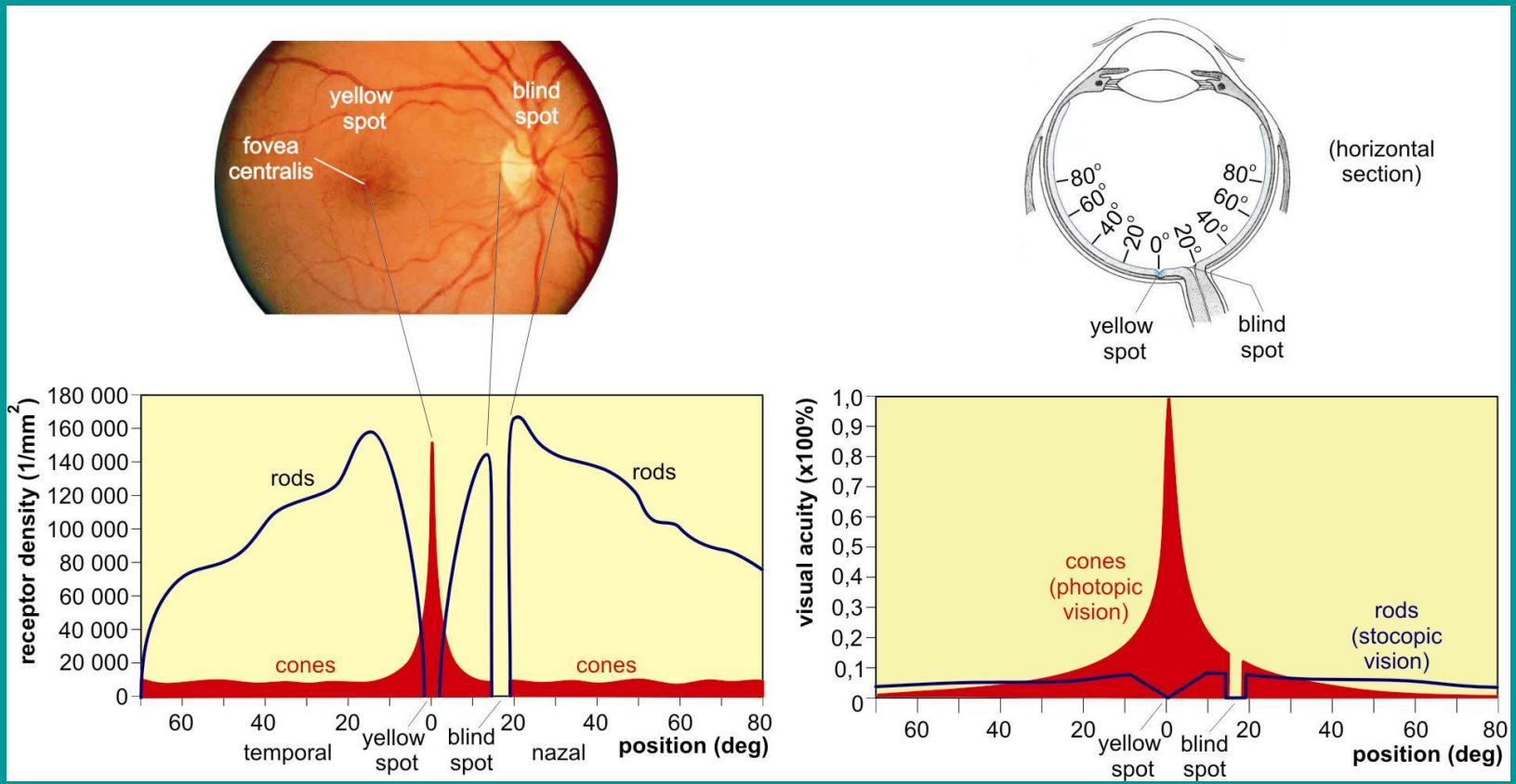


(mm)!

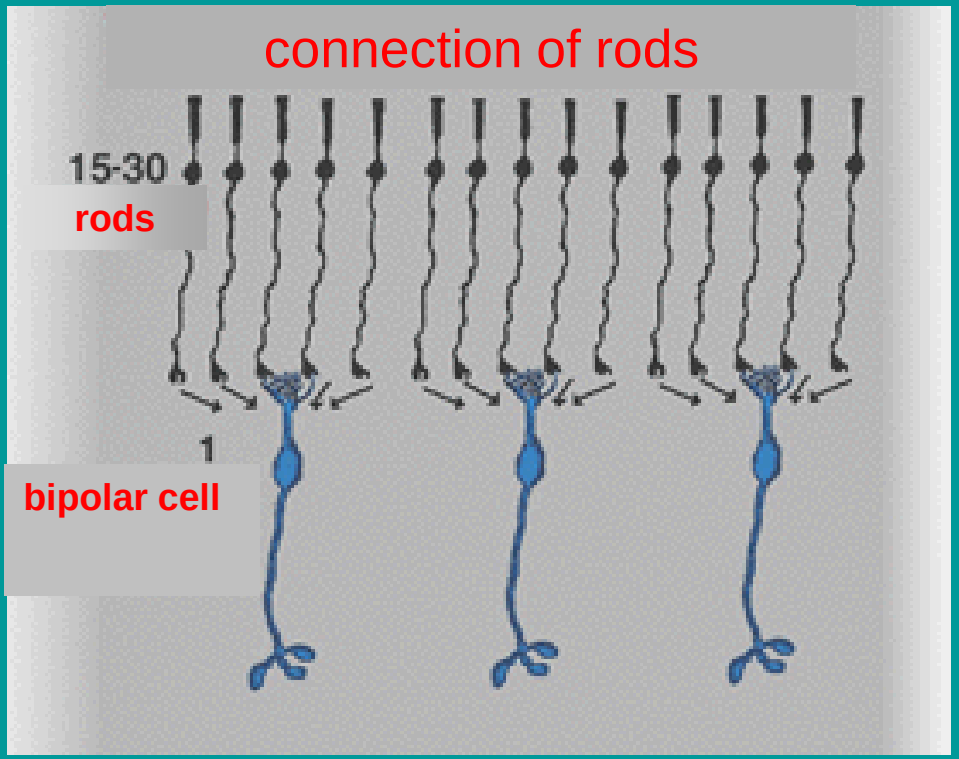
→ a' → $\frac{0.4}{x} = \frac{a'}{17}$ → $A \cong (a')^2$

→ x

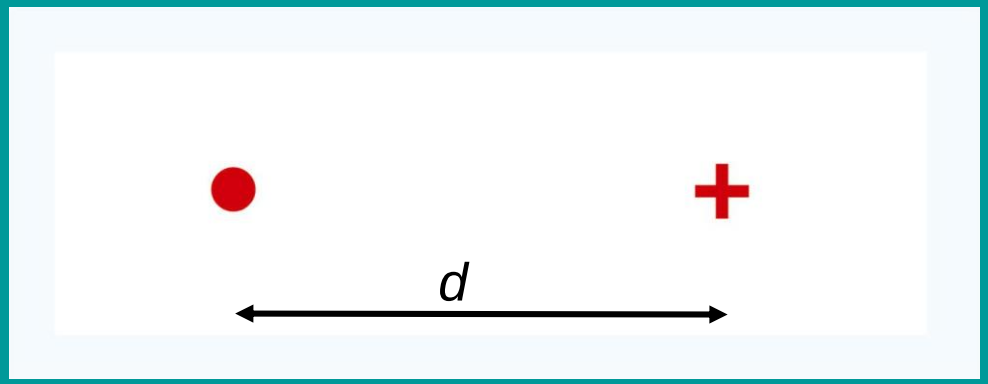
receptor density = $\frac{1}{A}$

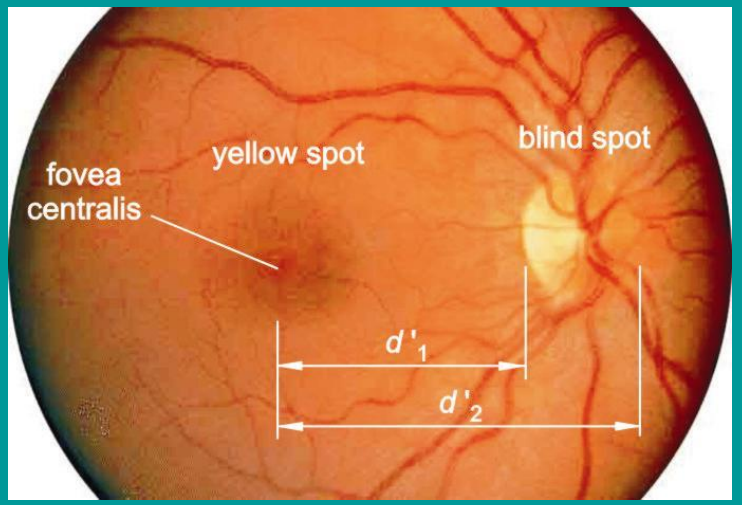


Reduction of information, convergence:



Blind spot





On the printed figure: $d = 60\,\text{mm}$