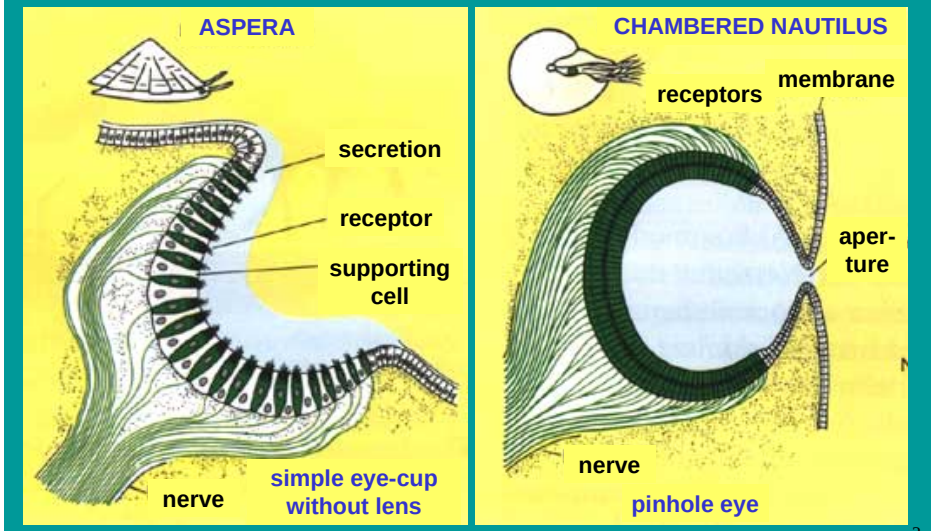
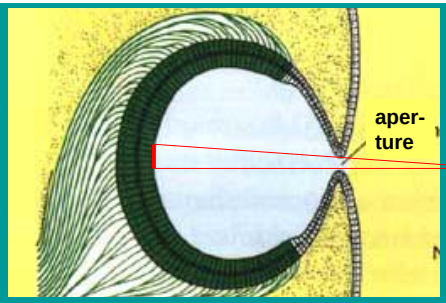
OPTICS OF THE EYE 1.

Development of the visual organ

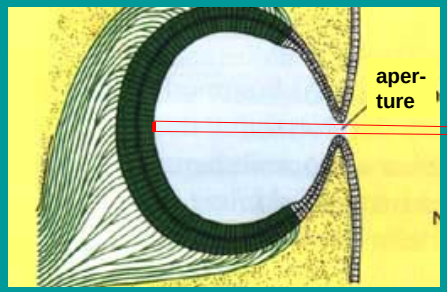
Development of the visual organ





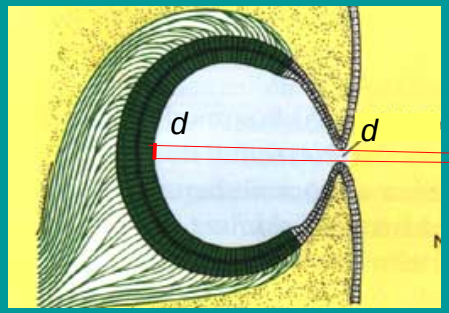
Disadvantages:

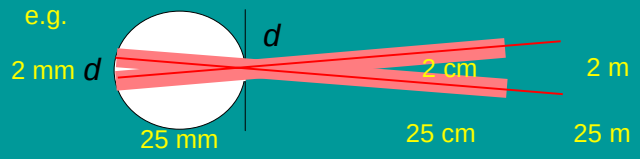
- ☹ open
- ☹ not point like imaging
- ☹ poor resolution



Size of the spot ≈ size of the aperture (d)

Resolution:

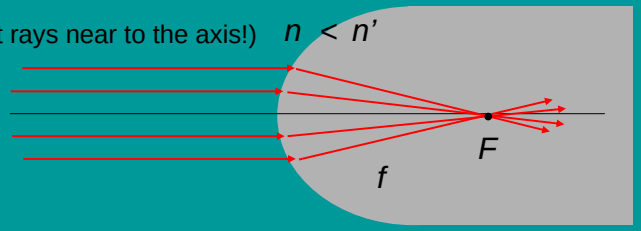




➡ smaller *d* for better resolution ➡ loss of intensity and diffraction

Refraction on curved surface

(for light rays near to the axis!) $n < n'$



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

Power of the surface (D): $D = \frac{n'}{f} = \frac{n'-n}{R}$

n: refractive index of the 1. medium

n': refractive index of the 2. medium

R: radius of the curved surface

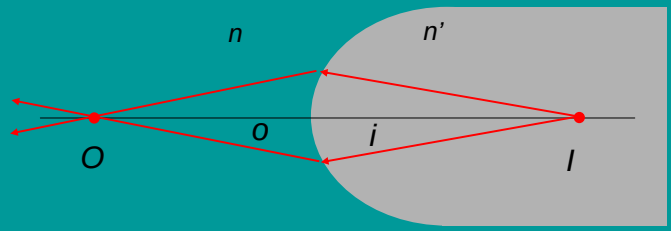
>0, when convex

<0, when concave

D>0 ⇒ convergent

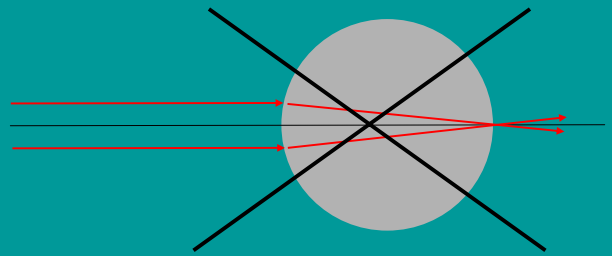
D<0 ⇒ divergent

Image formation on curved surface



$$D = \frac{n'}{i} + \frac{n}{o}$$

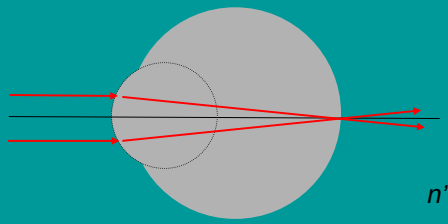
Simple sphere as eye?



$$f \le 2R$$

$$f = R\frac{n'}{n'-n} \le 2R$$

$n = 1 \Rightarrow n' \ge 2$!!

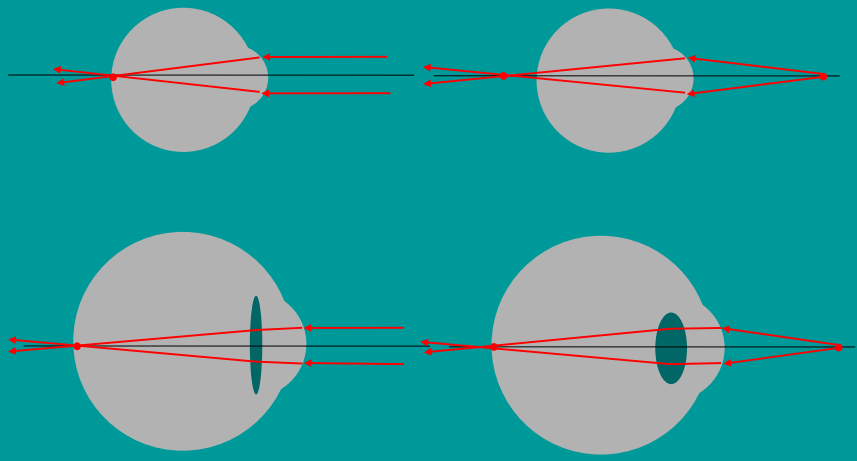


n' = 1.333

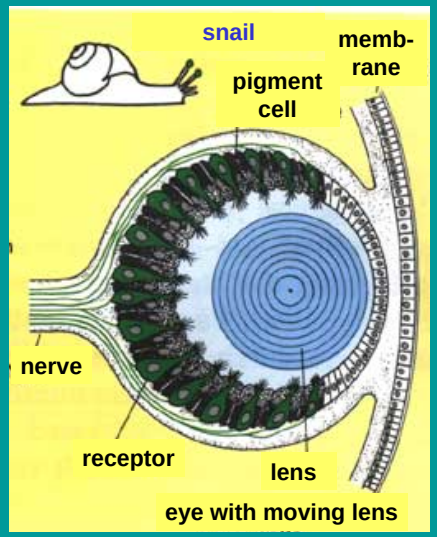
$f = 2R$ = 25 mm

⇒ $r \approx 6.25$ mm

Accommodation?

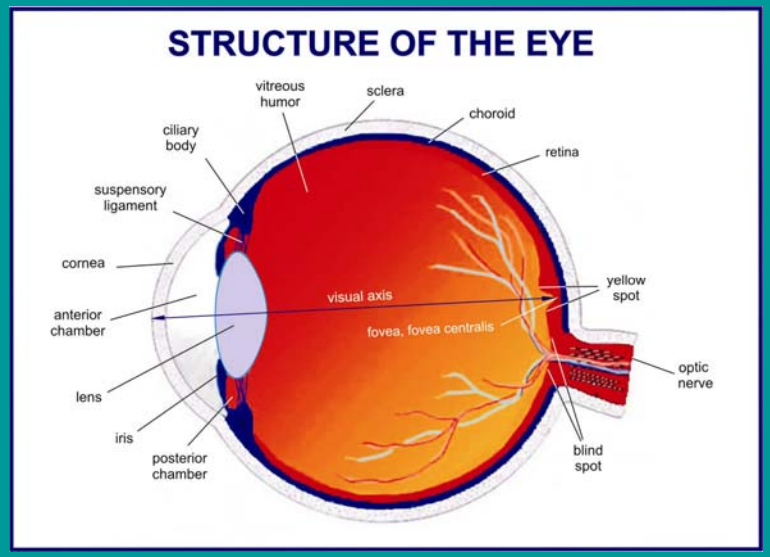


Development of the visual organ



OPTICS OF THE EYE 2.

The human eye



Power of the human eye

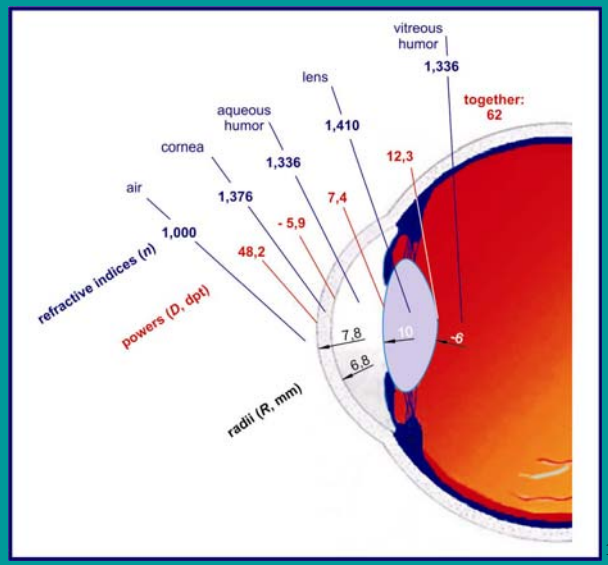
$$D = \frac{n' - n}{R}$$

D : power (dpt)

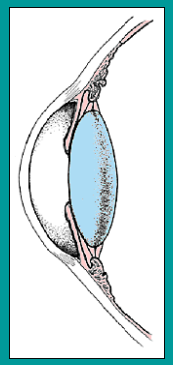
n : refr. index of the 1. medium

n' : refr. index of the 2. medium

R : radius (m)
+ convex
– concave



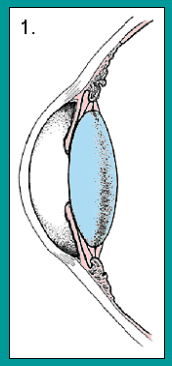
Accommodation

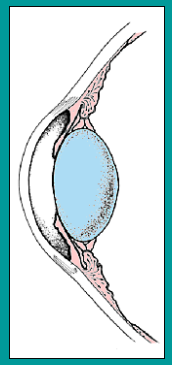


focused to a far object

(just sharp)

far point of vision: o_r



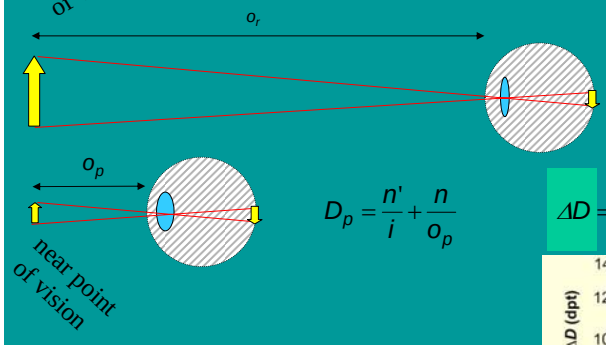


focused to a near object

(just sharp)

near point of vision: o_p

Accommodation power (ΔD)

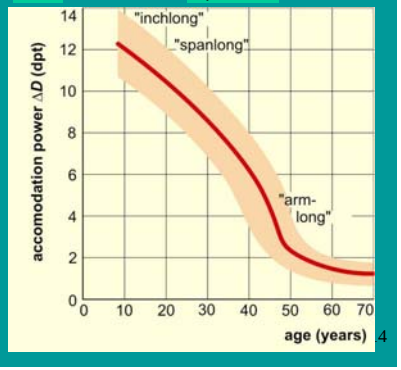


$$D_r = \frac{n'}{i} + \frac{n}{o_r}$$

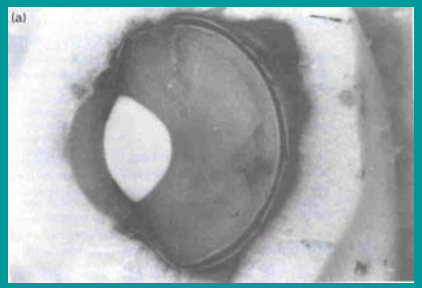
$$D_p = \frac{n'}{i} + \frac{n}{o_p}$$

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

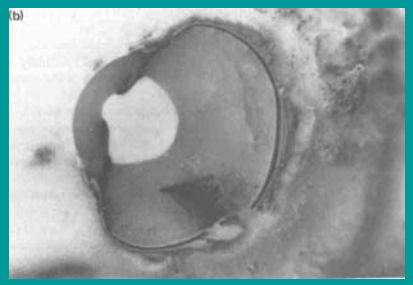
e.g. $o_r = \infty$, $o_p = 0.07\ \text{m}$ $\Rightarrow$ $\Delta D = 13\ \text{dpt}$



Extrem example: induced accomodation of duck's eye

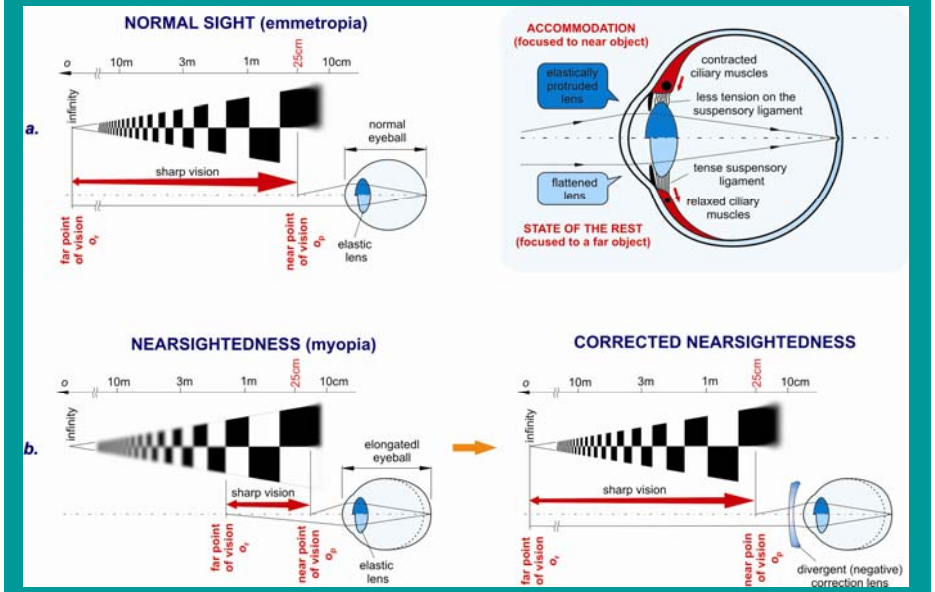


overland

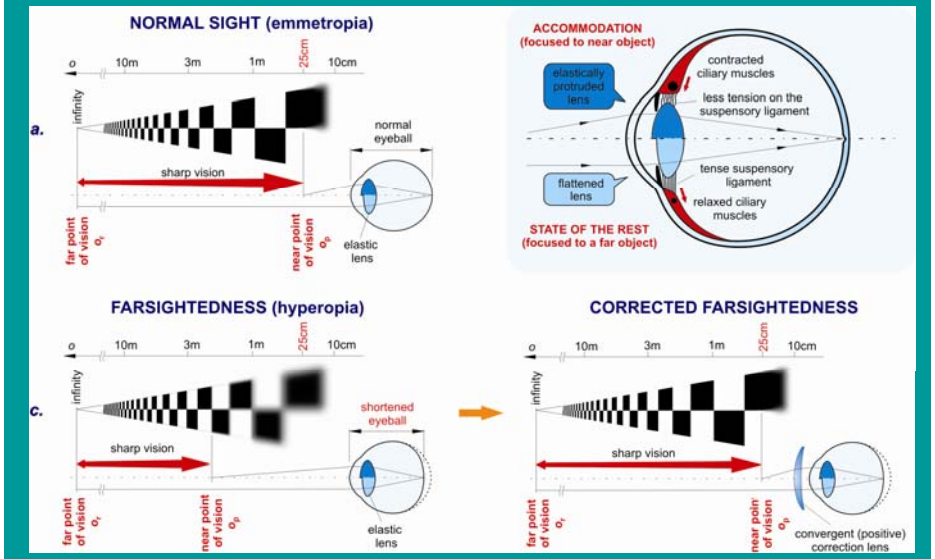


under water

Defects of the eye: nearsightedness



Defects of the eye: farsightedness



Defects of the eye: aging of the eye

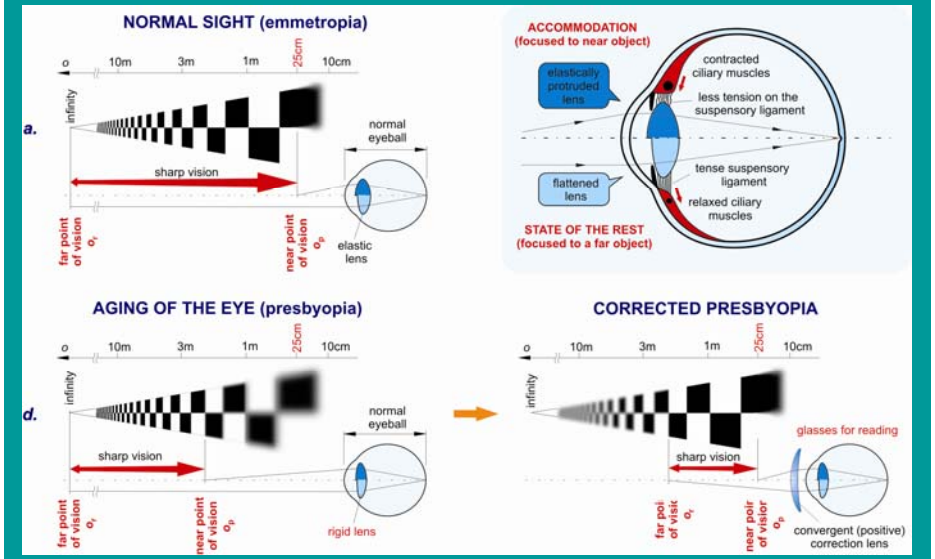
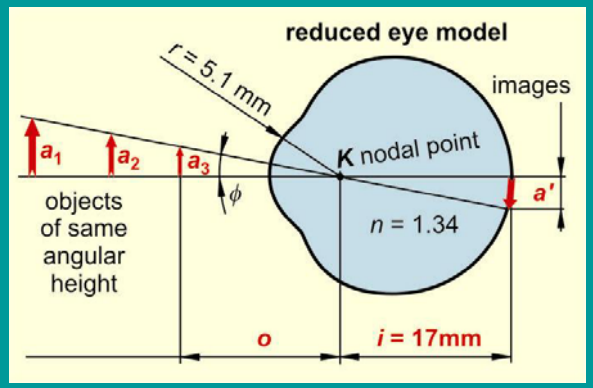


Image formation

Model:

reduced eye

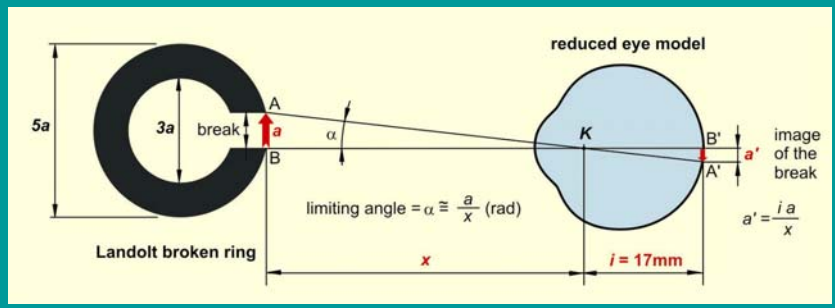


The image:

- real
- diminished
- inverted

D = 67 dpt

Visual acuity (resolution)



Limiting angle:

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

Visual acuity:

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

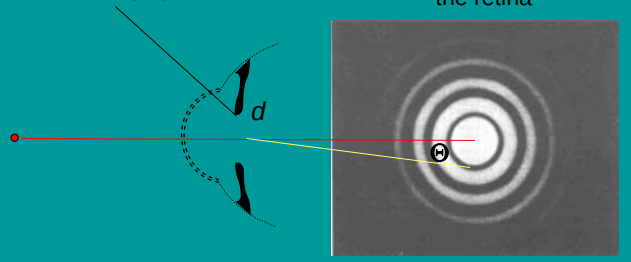
Limiting angle of average healthy eye is 1', so the visual acuity is 100 %.

Explanation of visual acuity 2.

Wave optical explanation:

Diffraction on the pupil

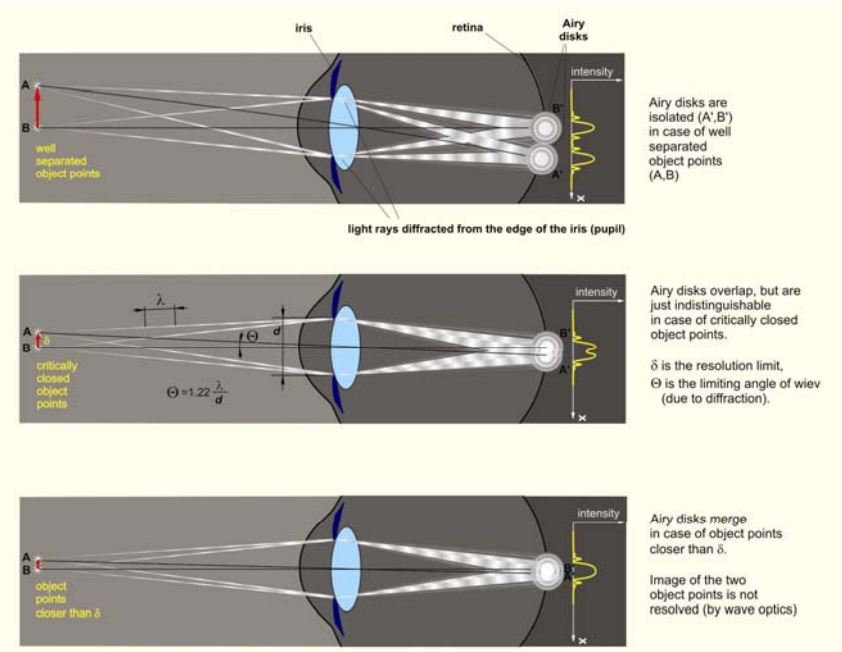
Image of an object point on the retina

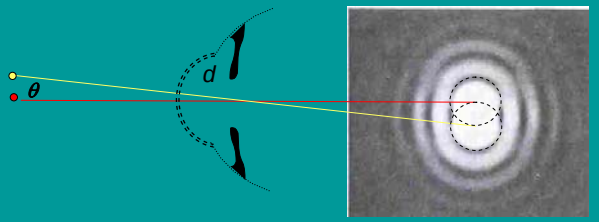


„Airy disk”

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

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





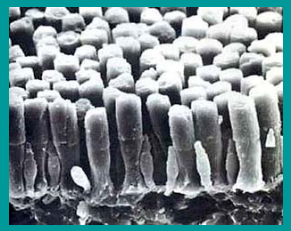
Condition to resolve two object points, that their diffraction patterns shift compared to each other at least so, that the maximum of one coincides with the first minimum of the other.

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

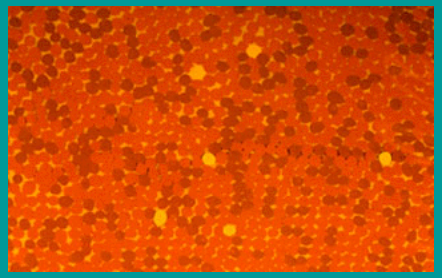
e.g. λ = 0.55 μm,
d = 3.5 mm = 3500 μm
⇒ θ = 0.7’

Explanation of visual acuity 3.

discrete receptor field



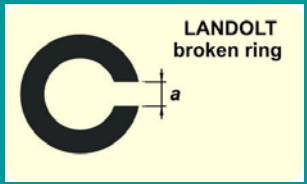
Cones and rods
(in the peripheral part of the retina)



Cones of different wavelength sensitivity

(fovea centralis)

Measurement of visual acuity



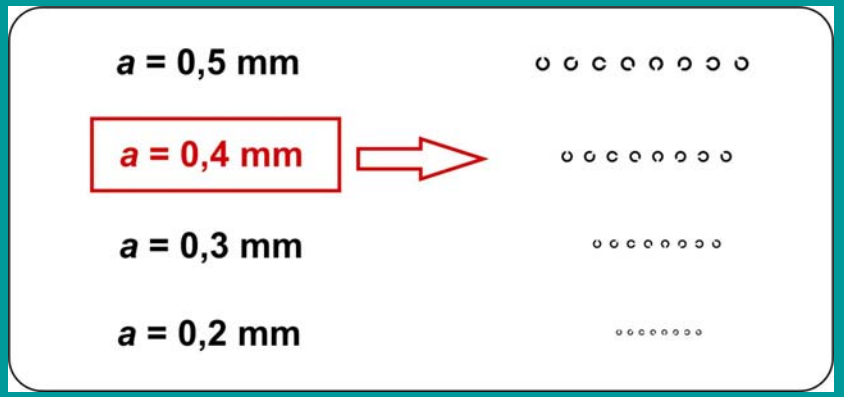


Image of Landolt broken ring on the yellow spot 1.

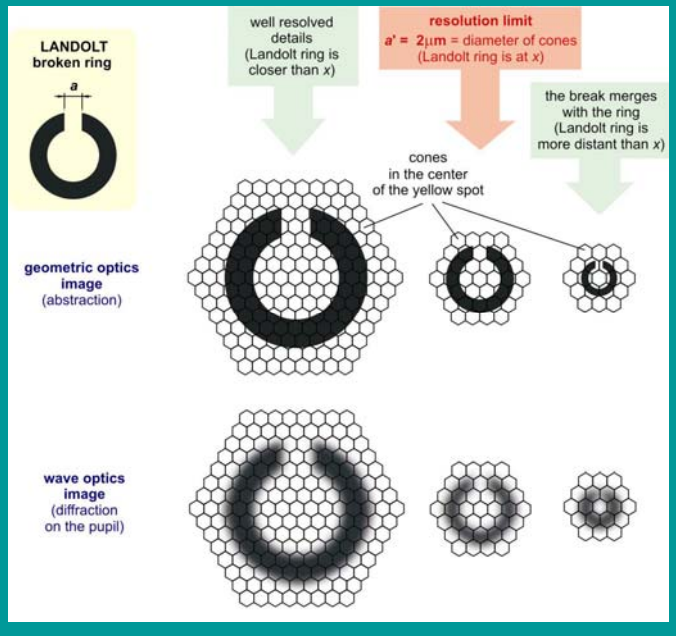
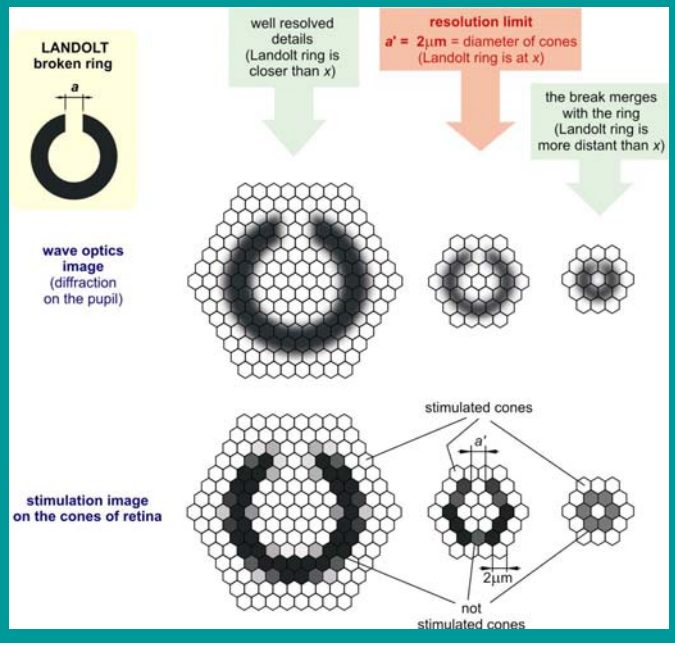
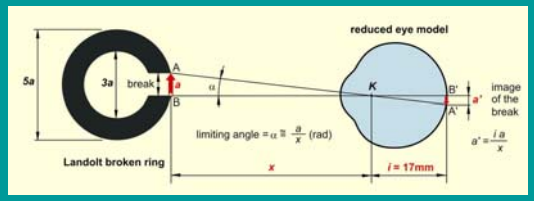


Image of Landolt broken ring on the yellow spot 2.



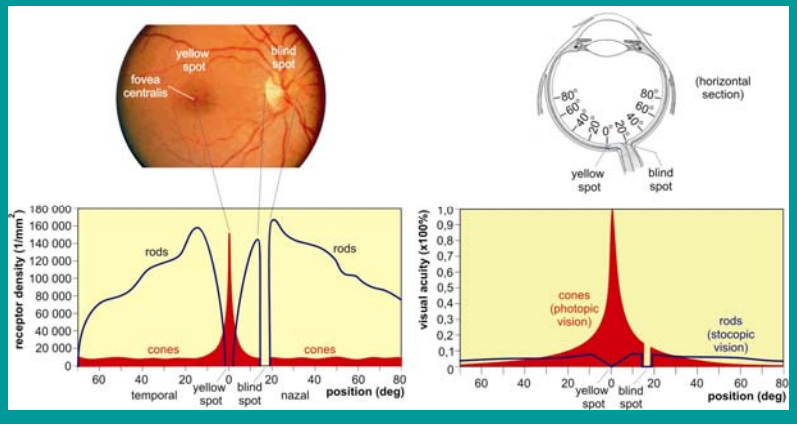
Density and distribution of receptor cells



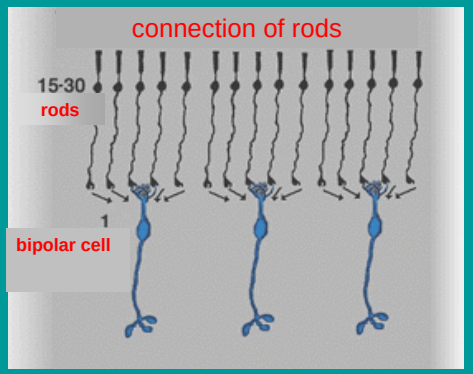
(mm)!

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

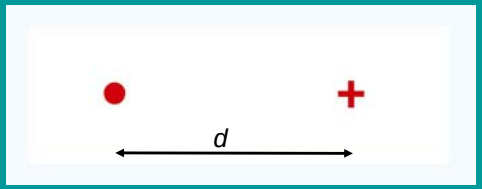
→ x → receptor density = $\frac{1}{A}$

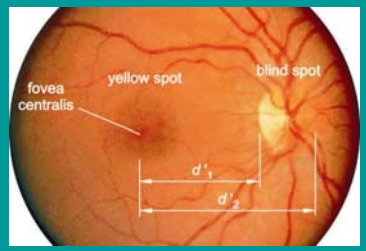


Reduction of information, convergence:

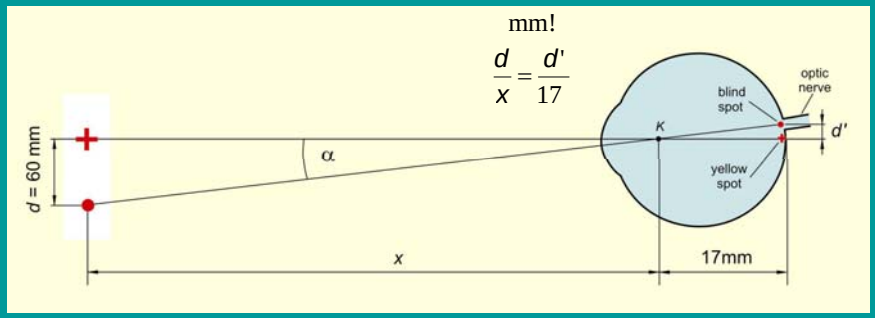


Blind spot



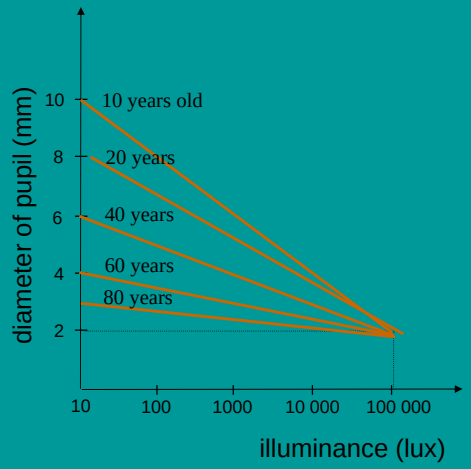


On the printed figure: $d = 60$ mm

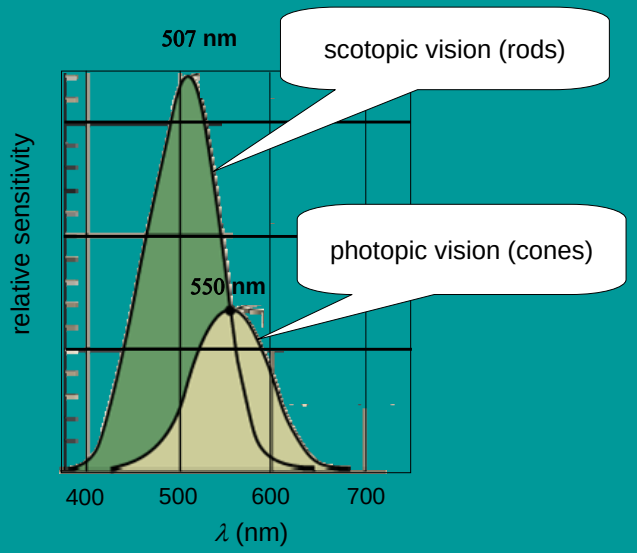


OPTICS OF THE EYE 3.

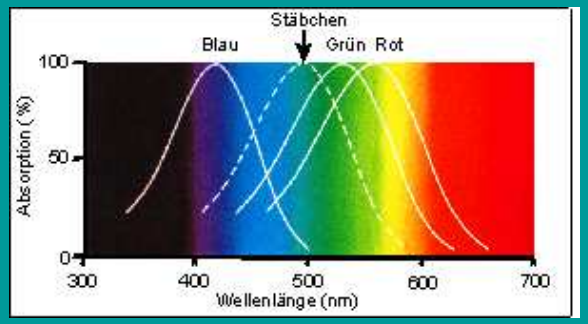
Adaptation

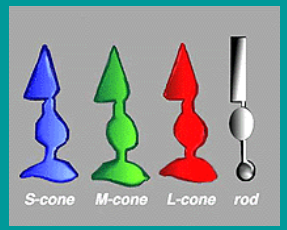


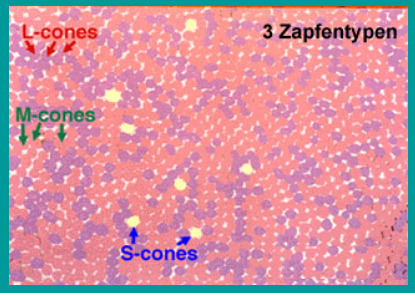
Sensitivity curve



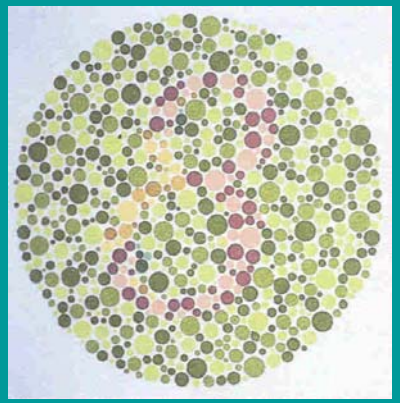
Color vision







Color blindness



Which number you see on the figure?

OPTICAL ILLUSIONS