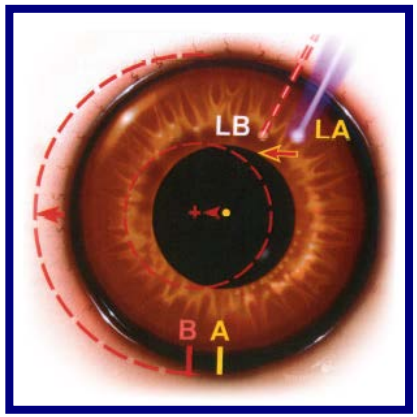
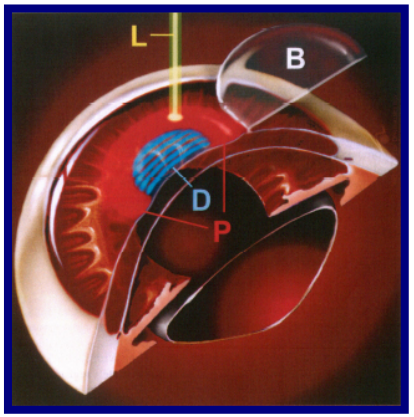
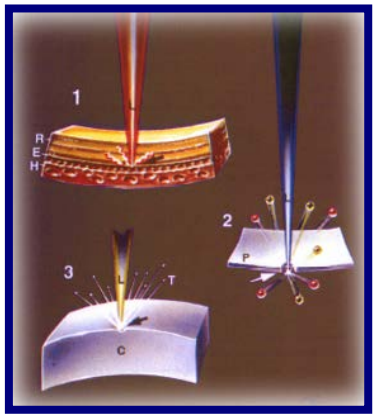
# Optical Systems in Medical Technology



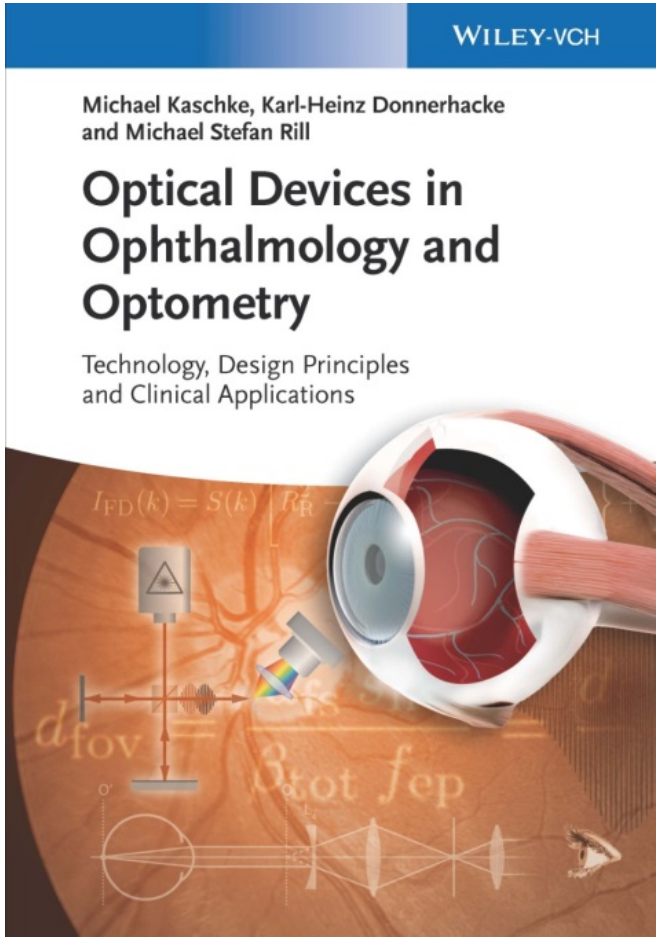




Prof. Dr. Michael Kaschke u. Prof. Dr. Werner Nahm
KIT - KSOP| Sommersemester 2018

## Content of the course

- This short three day course (two day à 4 hours theory, one day 4 hours practical device training) will allow the student to understand how basic optical principles are applied in the design of modern optical medical equipment, such as optical coherence tomographes and low coherence light interferometric biometers.
- The student will get insights how industrial research and design of optical medical devices is conducted. LBNL the students will work themselves on exercises and do measurements on the medical devices.
- Objectives:
  - Getting an understanding of optical design principles in the medical device development
  - Being able to do a basic layout of some optical devices
  - Being able to make some estimate calculations on
  - Getting the understanding of the realization of the principles in a hands on use of the devices
  - Getting insights how industrial research and design ofoptical medical devices

# References:

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Scripts and solutions for download:

www.kaschke-medtec.de

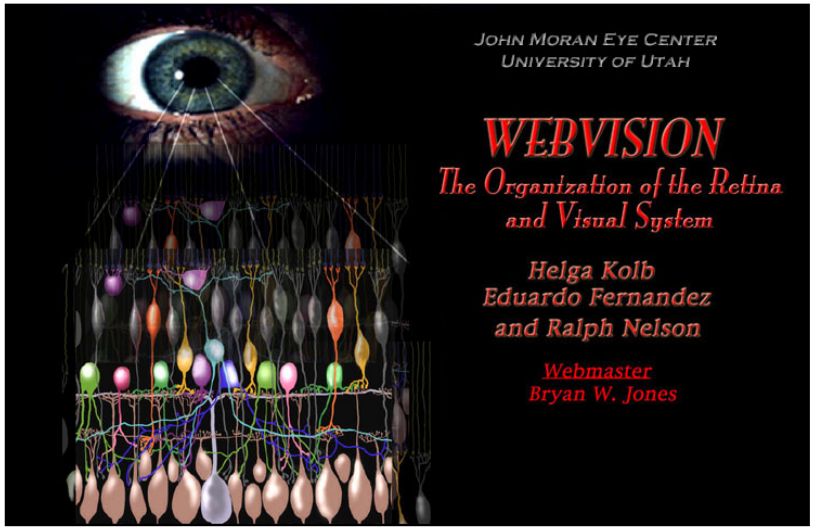
## References:

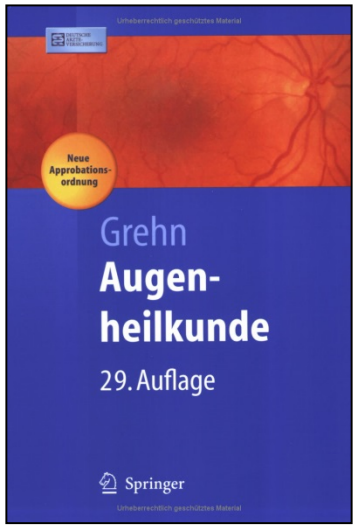

/1/ National Eye Institute http://www.nei.nih.gov/index.asp

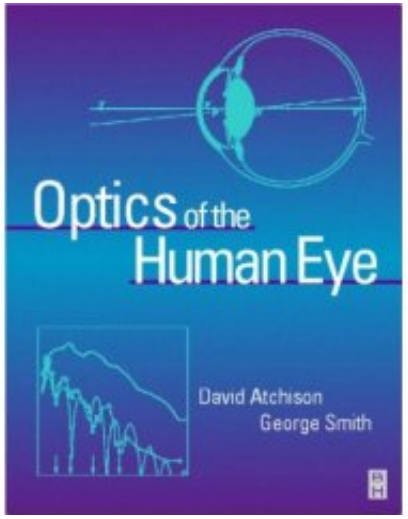
/2/ http://webvision.med.utah.edu

/3/ F. Grehn; Augenheilkunde; Springer 2006

/4/ D.A. Atchison, G. Smith: Optics of the Human Eye; Butterworth 2002

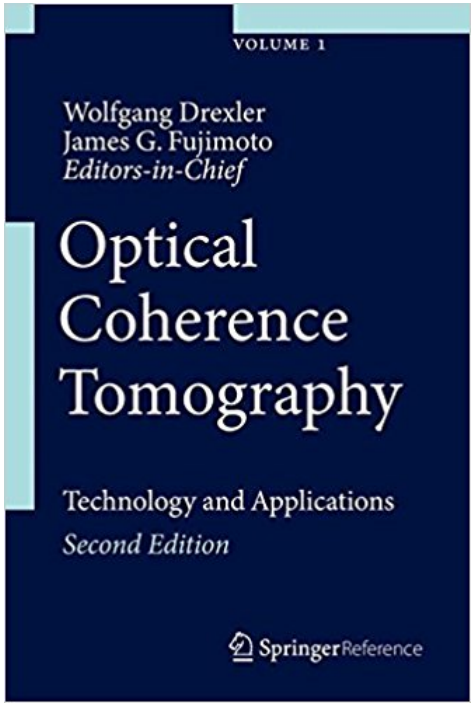



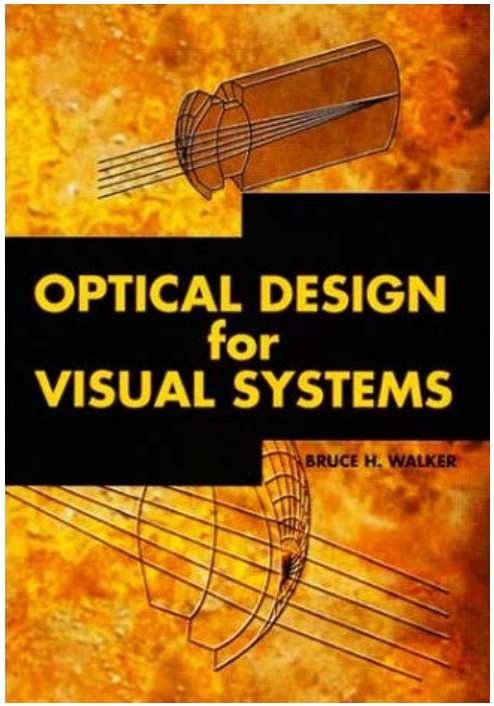
## References:

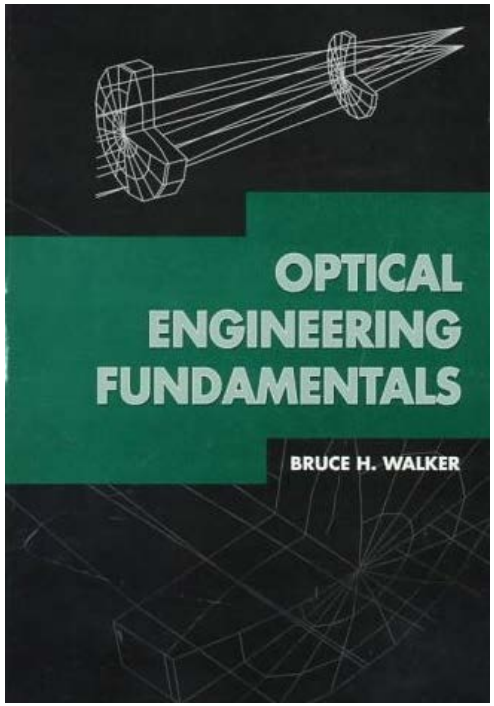
/5/ W. Drexler, J..G. Fujimoto, Optical Coherence Tomography 2005; Springer, 2015

/6/ B. Walker ; Optical Design for Visual Systems; 2000

/7/ B. Walker ; Optical Engineering Fundamentals; 1997

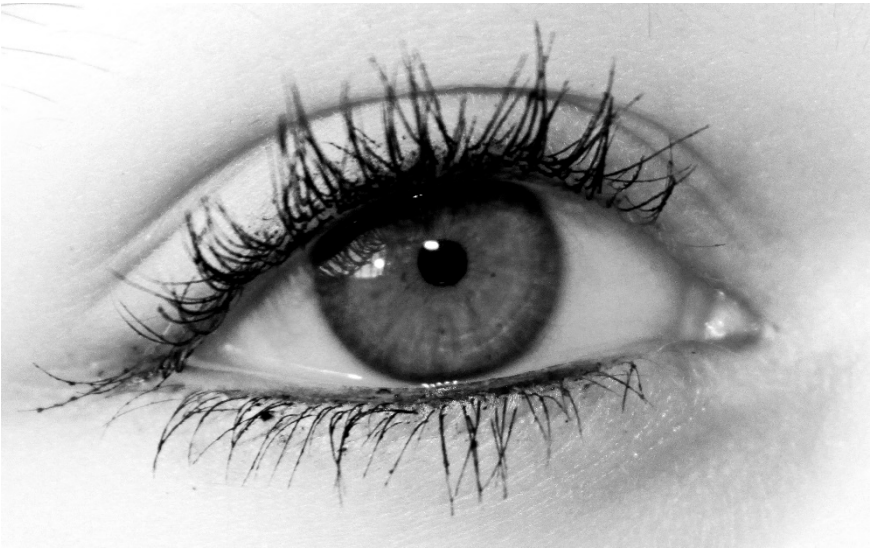


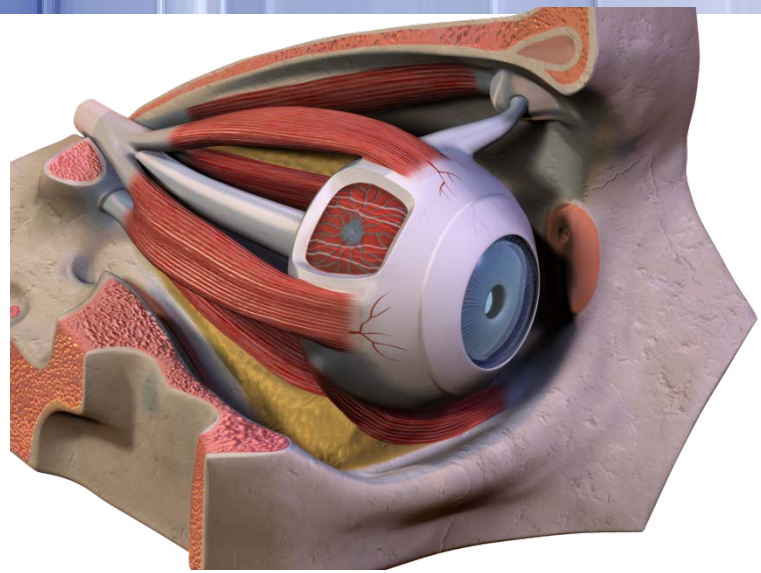



# Optical Systems in Medical Technology

## The Human Eye

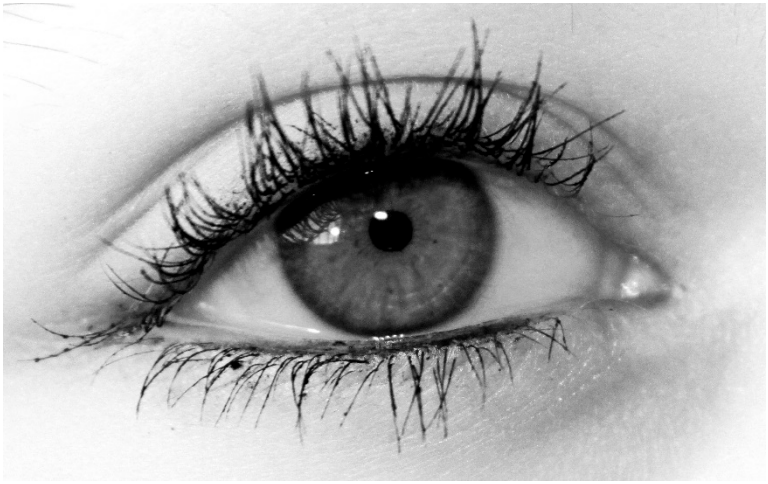




# Introduction

**Ophthalmology**

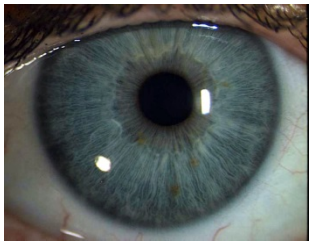
**The eye is our most important sensor!**

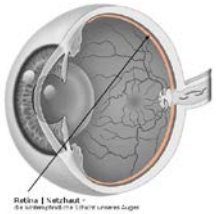


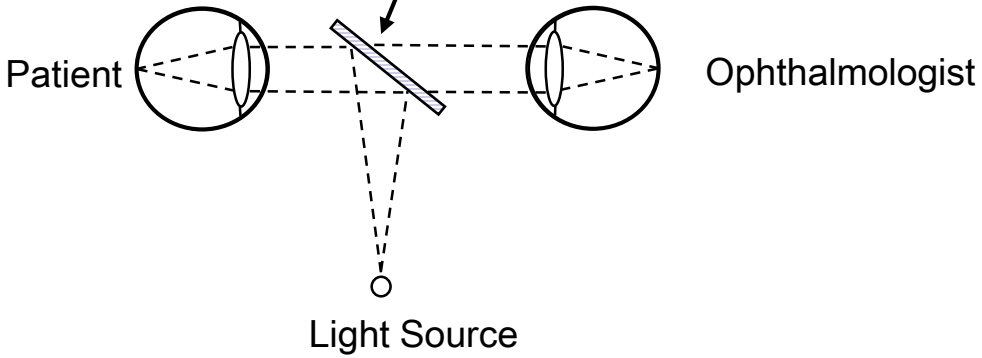
- Surprisingly opthalmology as a science only started in the middle of the 19th century
- Since then a continuously evolving Medtech and Medical field

## Introduction

- 1850 Herrmann von Helmholtz developed the ophthalmoscope
- Begin of modern ophthalmology and medical device technology



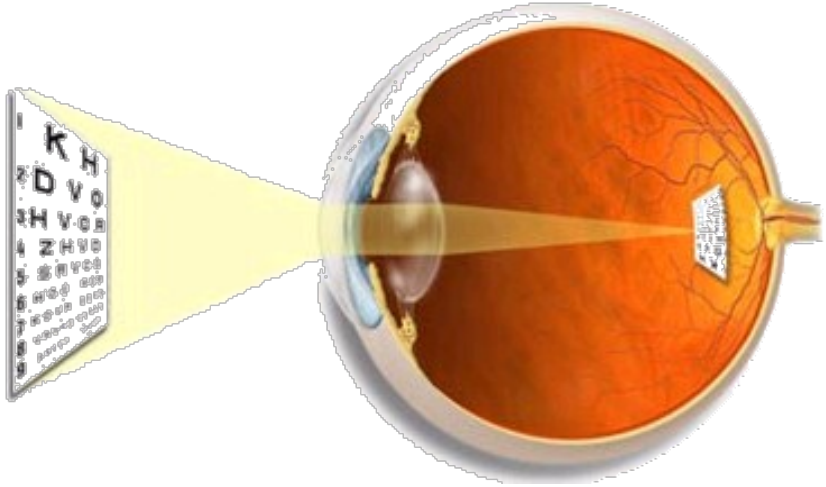




## Light, Human, and Vision

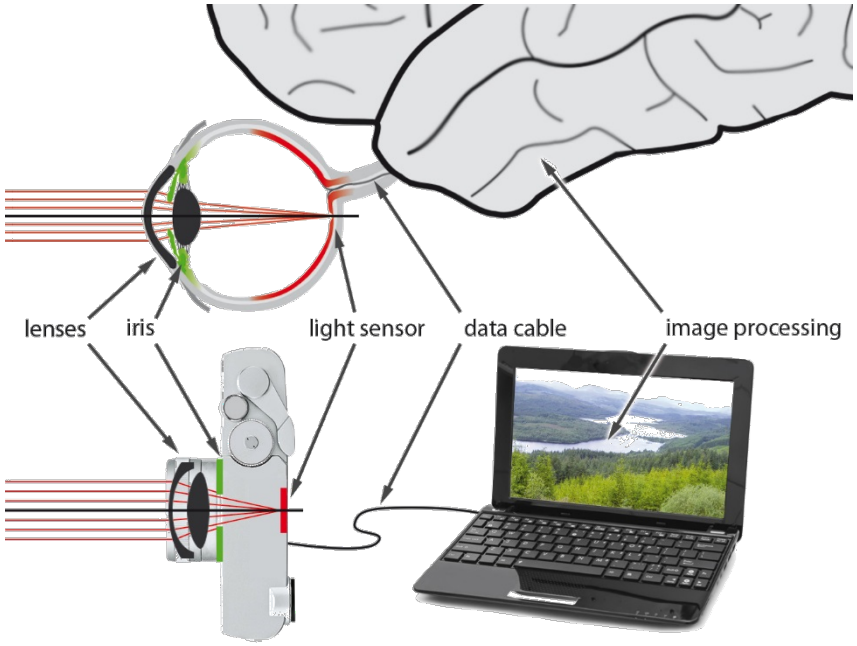
More than 80% of our informationen we perceive through the eye, which has a processing power of 10 Mbit/s and a dynamic range of 11 orders of magnitude.

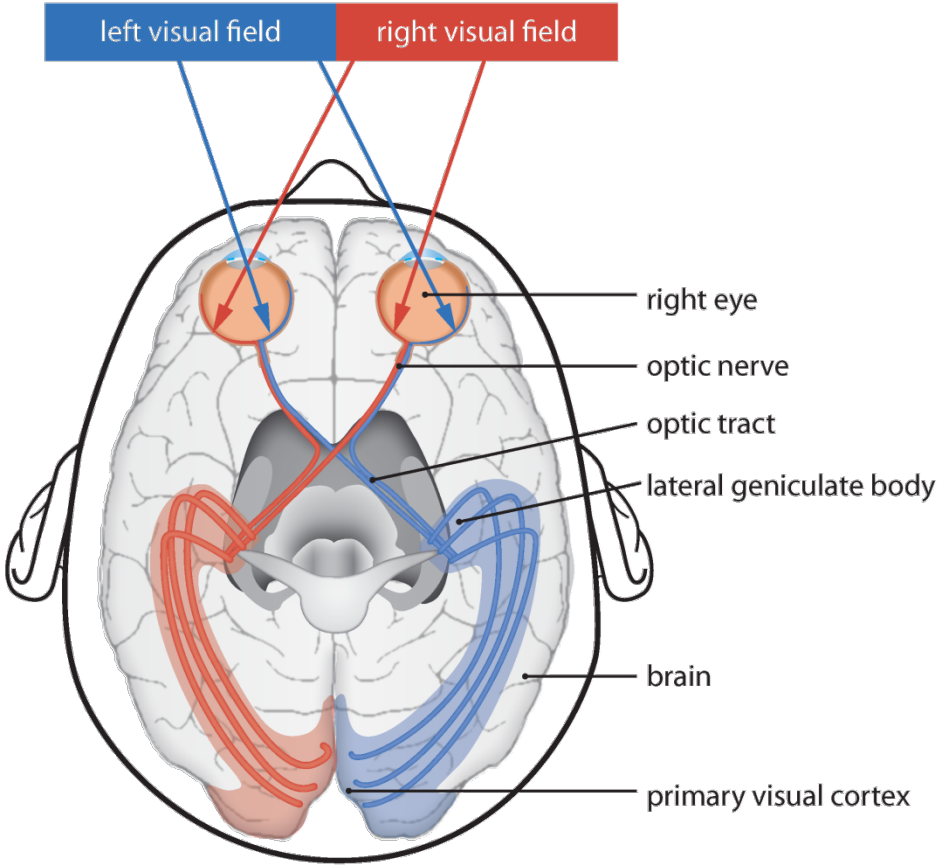
Vision is more than the simple projection of the reality on a passive screen.



## Light, Human, and Vision

The eye has a relatively simple „camera optics“ but with an adapted intelligent sensor and powerful image processing „firm- and software“.



## Light, Human, and Vision

**Example: Reading is more the recognizing individual letters:**

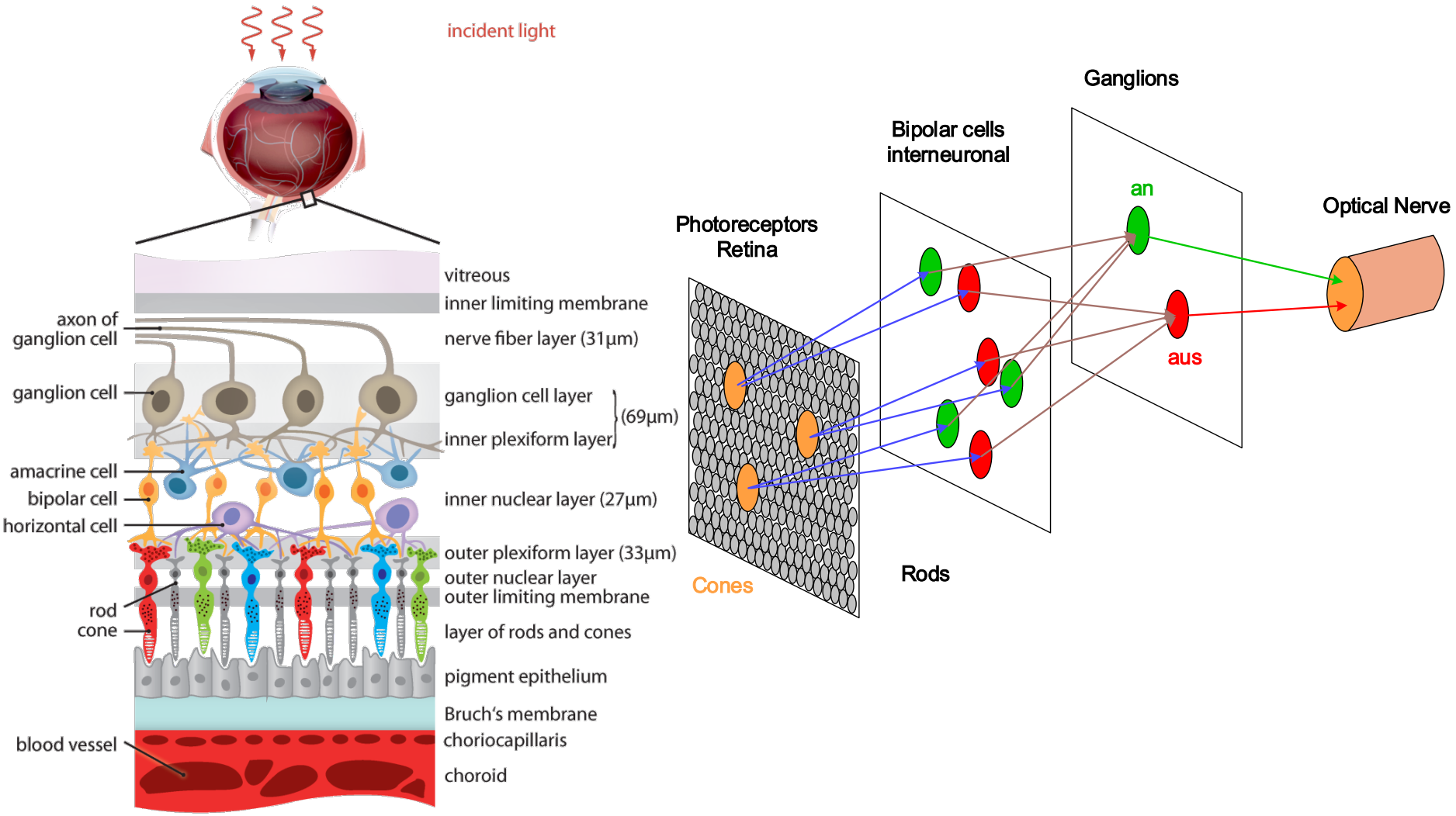
Gmäeß eneir Sutide eneir elgnihcesn Uvinisterät, ist es nchit witihcg in wlecehr Rneflogheie die Bstachuebn in eneim Wrot snid, das ezniige was wcthiig ist, ist daß der estre und der leztte Bstabchue an der ritihcegn Pstoiion snid. Der Rset knan ein ttoaelr Bsinöldn sien, tedztorm knan man ihn onhe Pemoblre lseen.

# Neuronal Proecssing of the Eye

Image on the retina

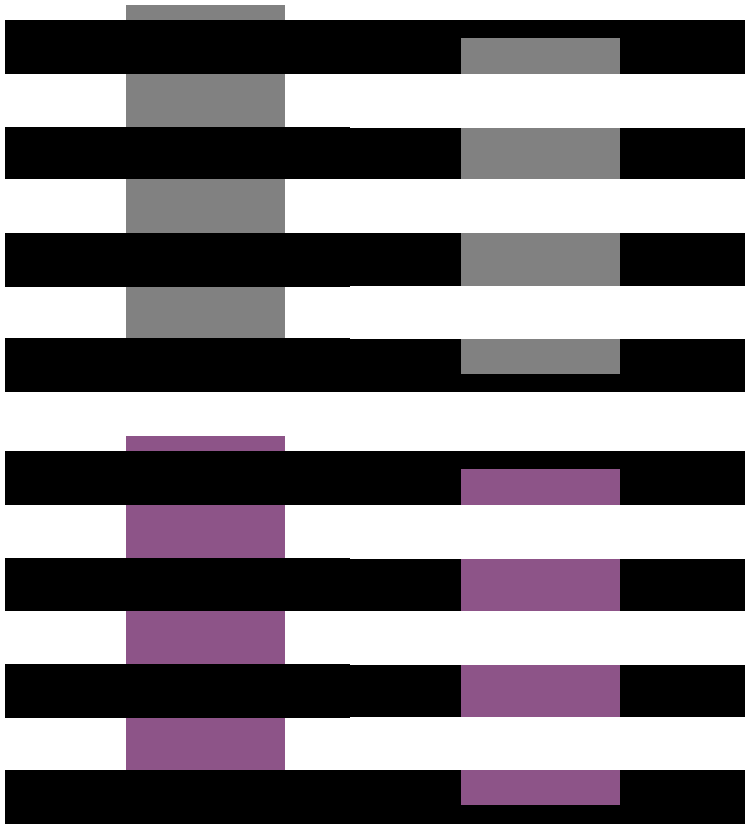
Image as „perceived“ by the brain

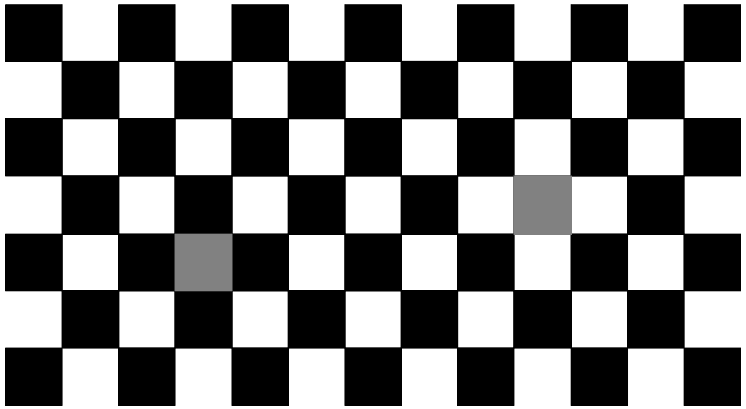
# Neuronal Processing of the Eye



# Optical Illusions

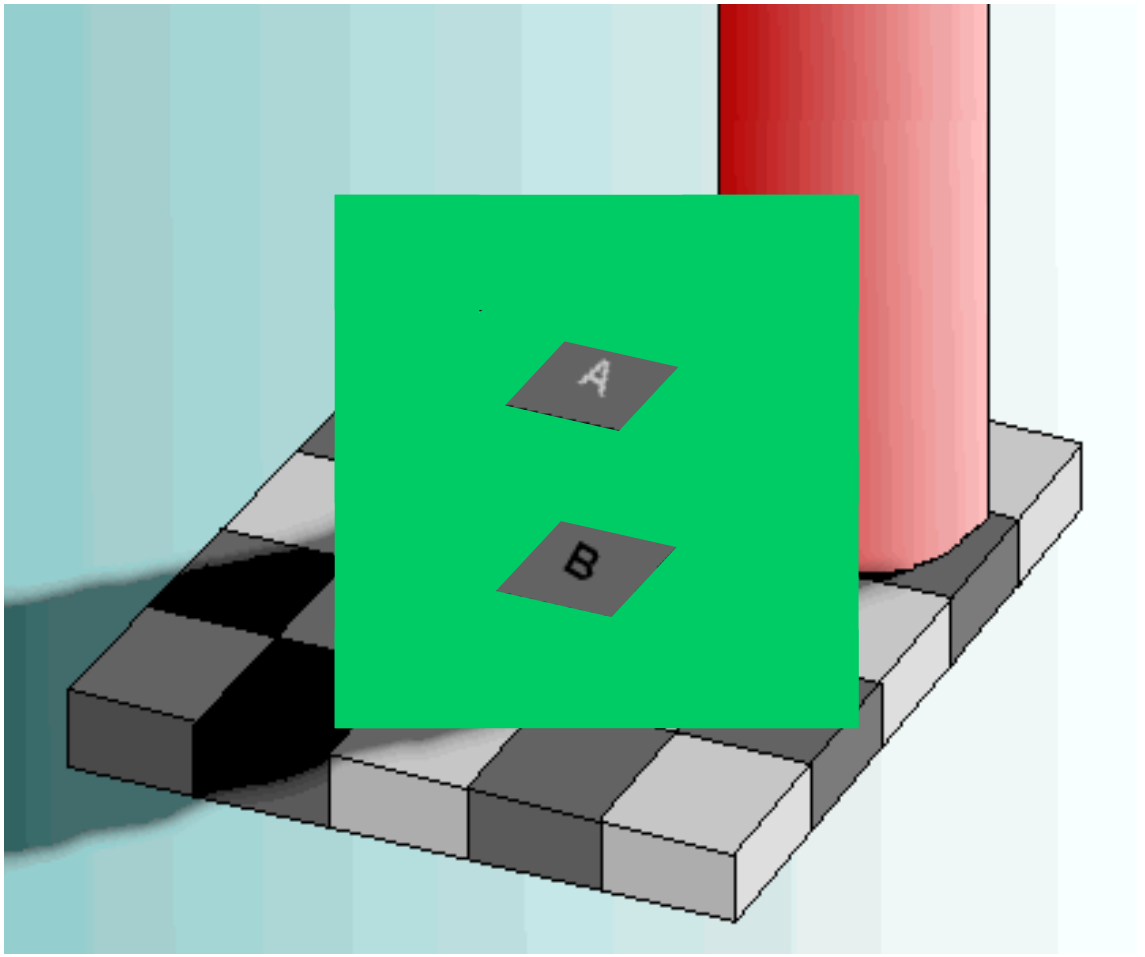
Brightness of the environment effect:





# Optical Illusions

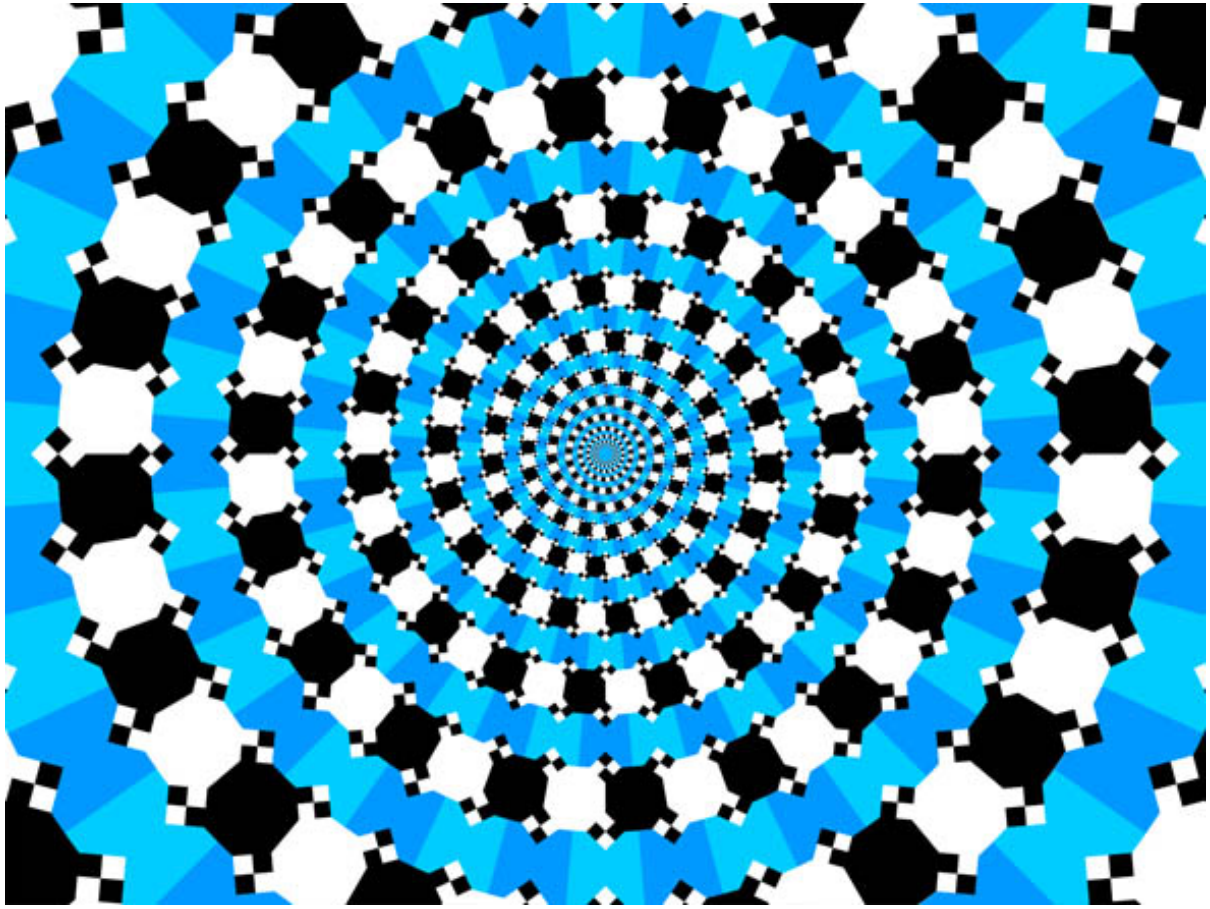
Brightness of the environment effect:



# Optical Illusions

Blue spiral?

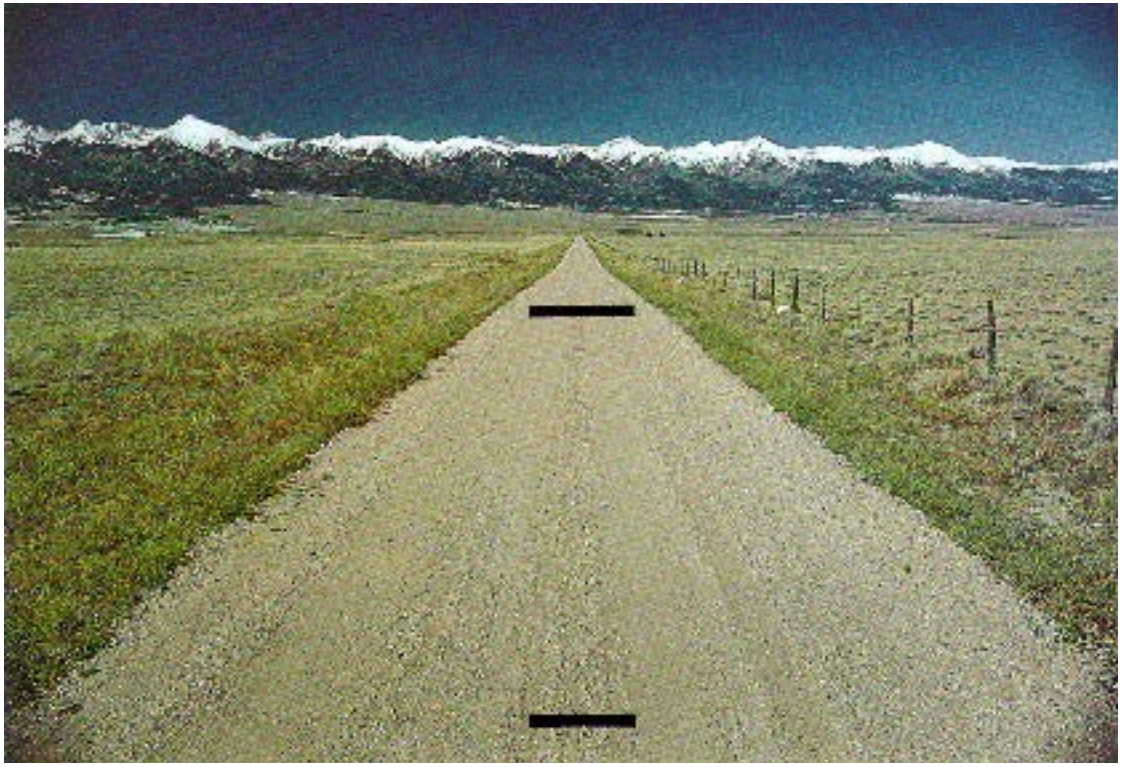
Concentric circles?



# Optical Illusion

## Ponzo-Illusion

Bars are equal in length, brain assumes depth in the image.



## Facts around Vision

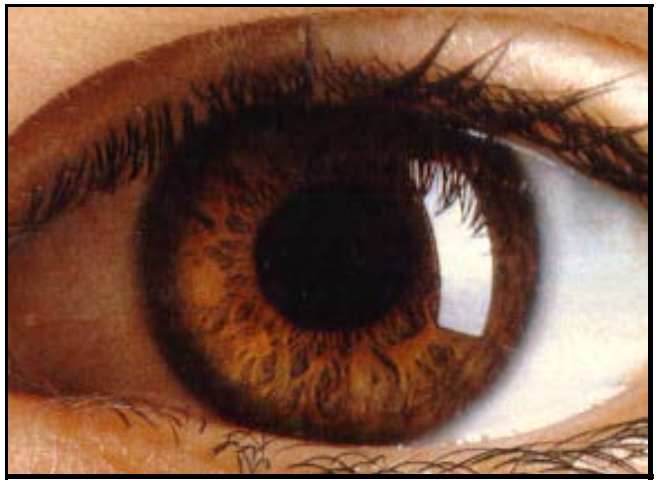
- **41 million of Germans need eyeglasses,** 35% hyperopes, 25% myopes. 14% night blinded.
- **Myopia is progressing**, in **Asia > 60%.**
- Germany has **6500 ophthalmologists** (not enough!)
- **10.000 opticians sell** more than **35 million eyeglasses p.a.**

- **Around 600.000 Germans** get a **cataract** operation p.a.
- **37 million people are blind.** 90% in 3rd world countries.
- Most eye diseases are age related diseases, therefore becausea of aging population growing.

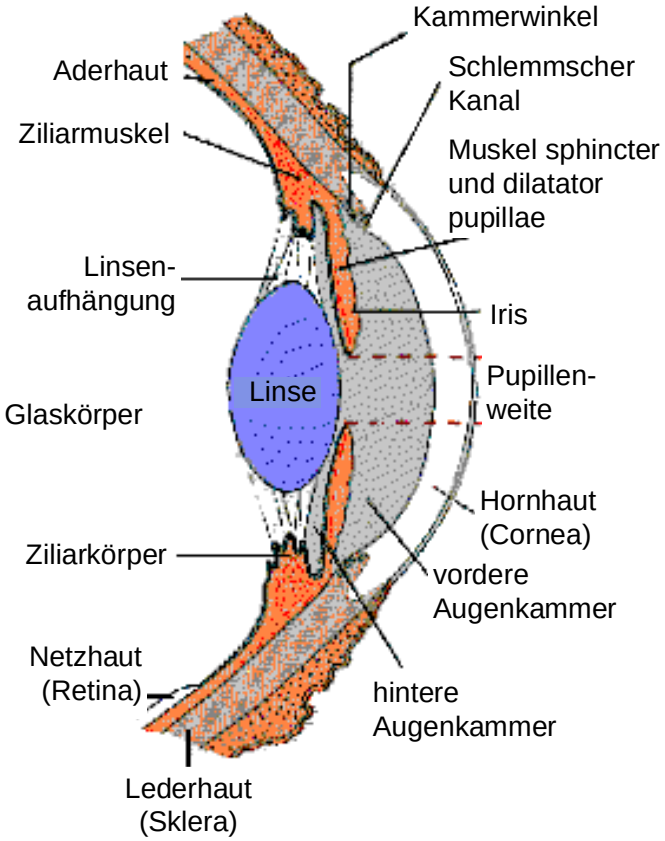
- **1920** ZEISS brought the first contact lens to the market
- **1987** first **laser** for corneal surgery
- **1995** first commercial **OCT** by ZEISS
- **1998** first optical **biometer** IOL-Master by ZEISS

Optical Systems in Medical Technology

# Optics of the Human Eye

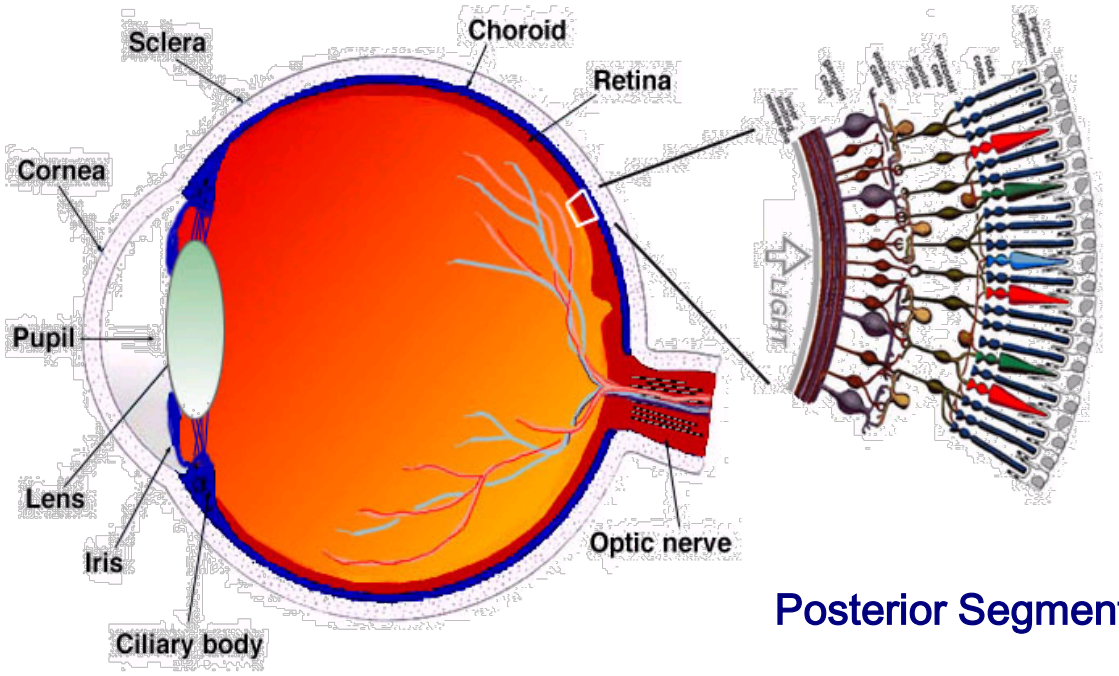


# Anterior and Posterior Segment



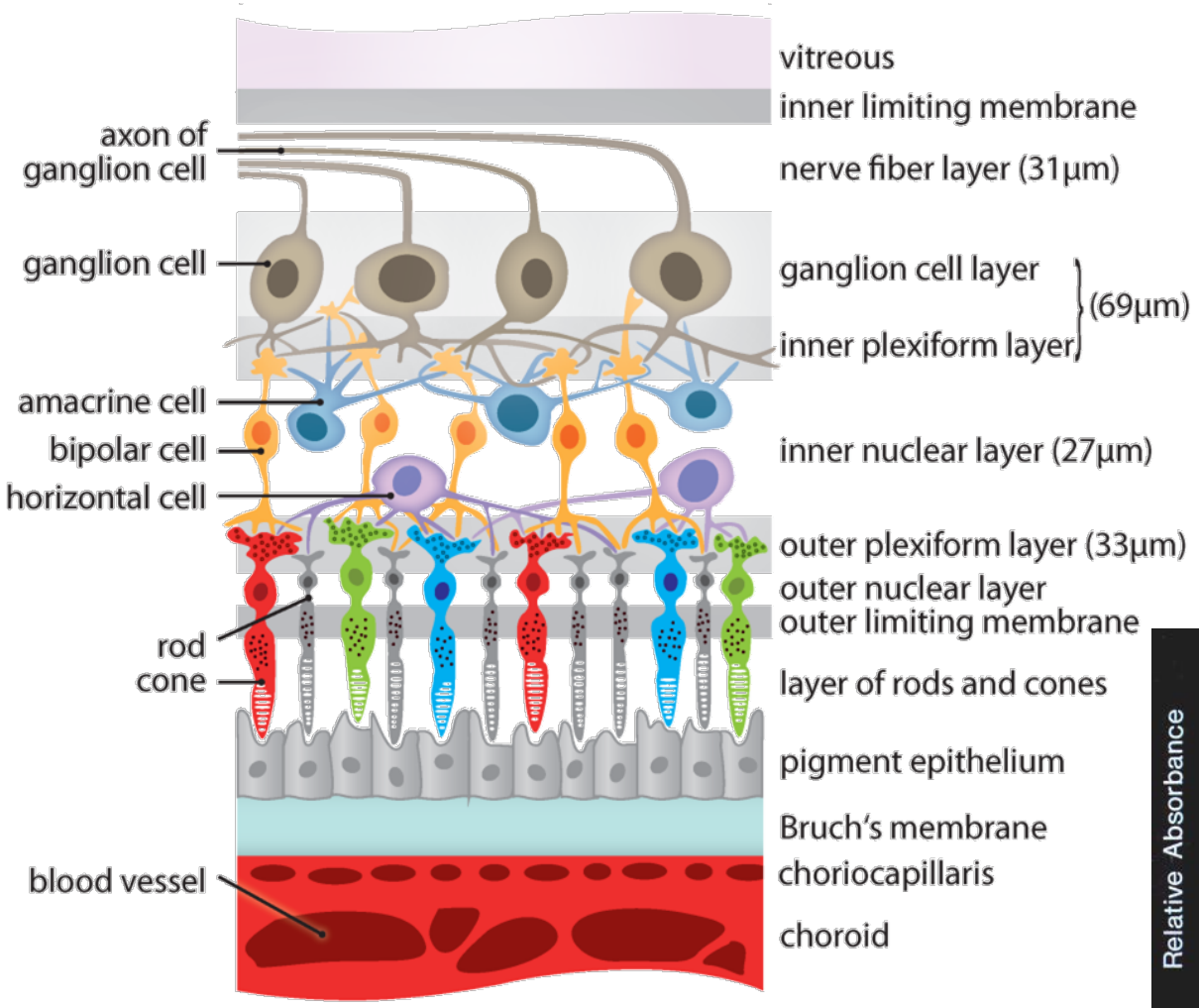

## Anterior Segment

## Schematics

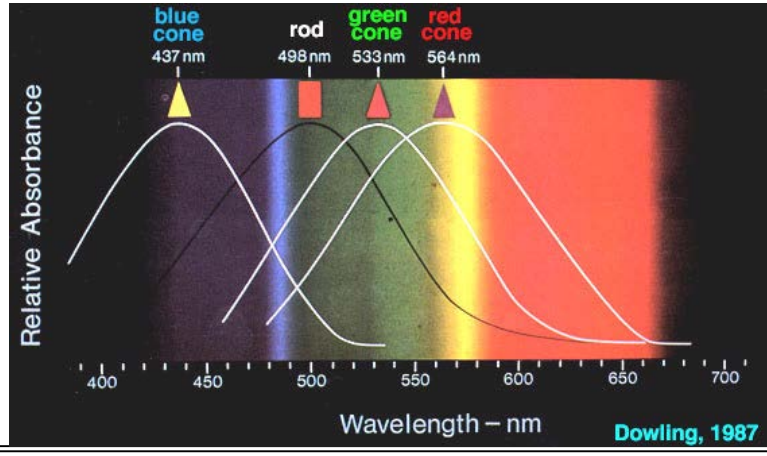



## Posterior Segment

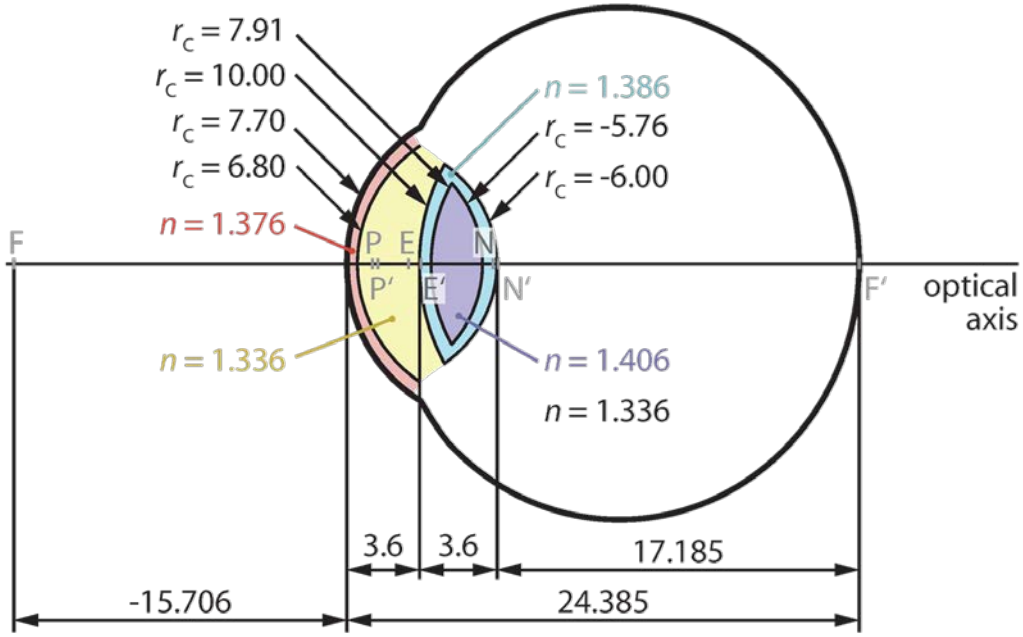
# Structure of Retina




## Spectral Sensitivity of rods and cones



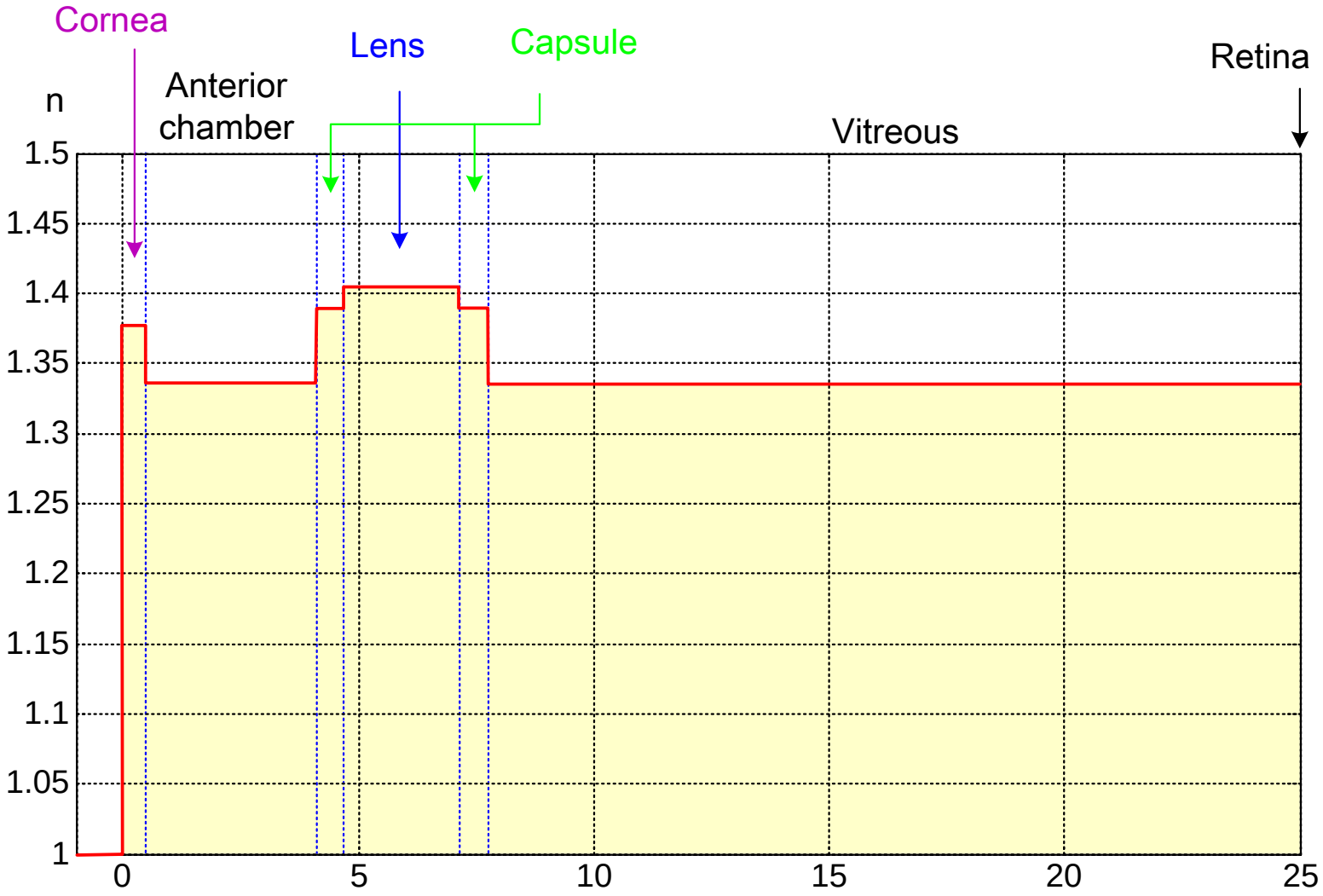
# Dimension of the Eye (Gullstrand Model Eye)




| Parameter | Relaxed Vision | Accommodated Vision |
|---|---|---|
| Location of object-side focal point F (mm) | −15.706 | −12.397 |
| Location of image-side focal point F′ (mm) | 24.385 | 21.016 |
| Location of object-side nodal point N (mm) | 7.078 | 6.533 |
| Location of image-side nodal point N′ (mm) | 7.331 | 6.847 |
| Location of object-side principal point P (mm) | 1.348 | 1.772 |
| Location of image-side principal point P′ (mm) | 1.601 | 2.086 |
| Location of entrance pupil E (mm) | 3.047 | 2.668 |
| Diameter of entrance pupil (mm) | 8.000 | 8.000 |
| Location of exit pupil E′ (mm) | 3.665 | 3.212 |
| Diameter of exit pupil (mm) | 7.276 | 7.524 |
| Refractive power of cornea (D) | 43.053 | 43.053 |
| Refractive power of lens (D) | 19.111 | 33.057 |
| Refractive power of eye (D) | 58.636 | 70.576 |
| Total eye length (mm) | 24.385 | 24.385 |

| | $r_C$ (mm) | $L$ (mm) | $n$ | $r_C$ (mm) | $L$ (mm) | $n$ |
|---|---|---|---|---|---|---|
| Corneal front surface | 7.700 | – | – | 7.700 | – | – |
| Cornea | – | 0.500 | 1.376 | – | 0.500 | 1.376 |
| Corneal back surface | 6.800 | – | – | 6.800 | – | – |
| Anterior chamber | – | 3.100 | 1.336 | – | 2.700 | 1.336 |
| Front surface of lens cortex | 10.000 | – | – | 5.333 | – | – |
| Anterior lens cortex | – | 0.546 | 1.386 | – | 0.673 | 1.386 |
| Front surface of lens core | 7.911 | – | – | 2.655 | – | – |
| Lens core | – | 2.419 | 1.406 | – | 2.655 | 1.406 |
| Back surface of lens core | −5.760 | – | – | −2.655 | – | – |
| Posterior lens cortex | – | 0.635 | 1.386 | – | 0.673 | 1.386 |
| Back surface of lens cortex | −6.000 | – | – | −5.333 | – | – |
| Vitreous | – | 17.185 | 1.336 | – | 16.800 | 1.336 |

# Refractive indices along the optical axis of the eye

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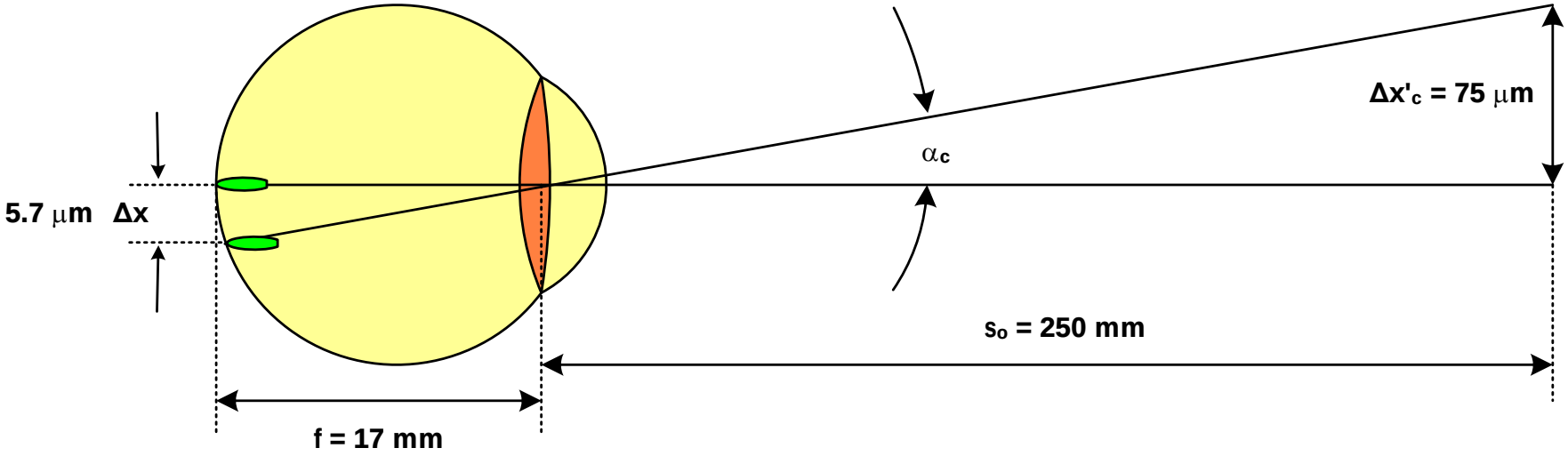
# Angular Resolution and Visual Acuity



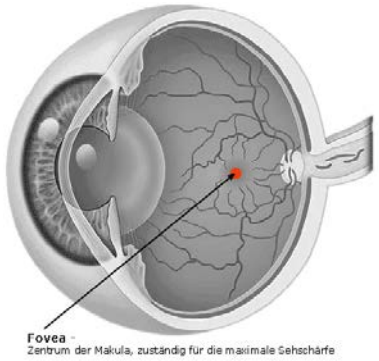

## Visual Acuity = 1/ α

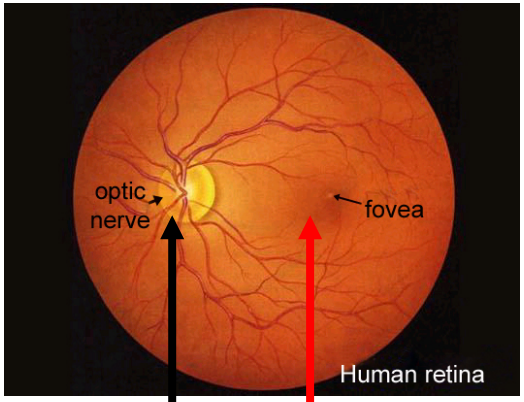
Visus (visual acuity) is the reciprocal of the angular resolution.

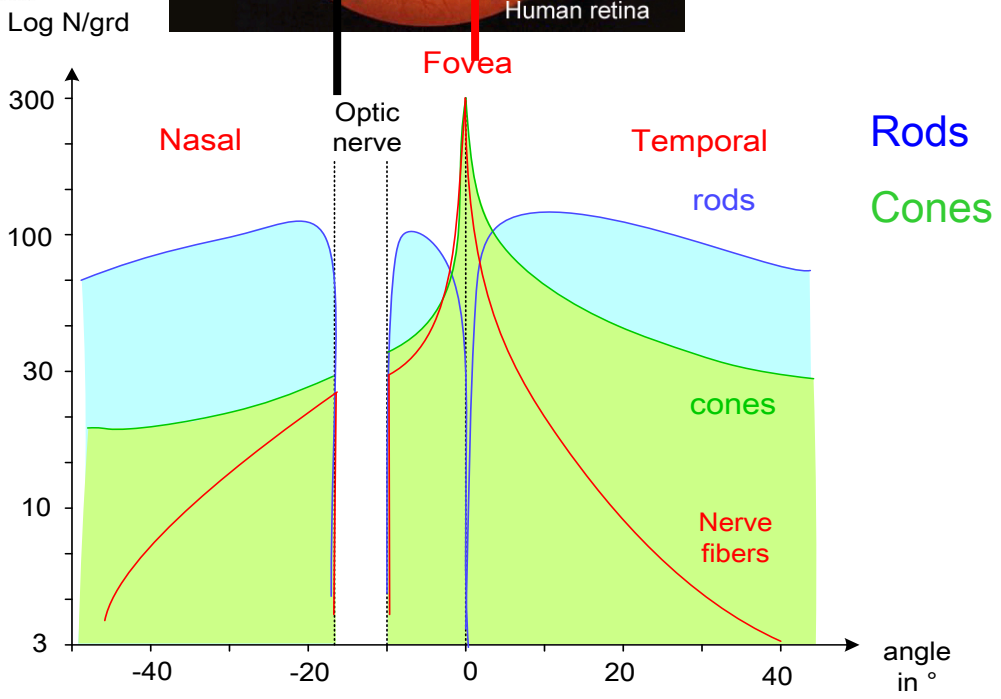
**1,0 (Normal visual acuity)** corresponds to an angular resolution of one arc second:

$$a = \frac{75}{250 \cdot 1000} \cdot 3600 \approx 1\ arc\ sec$$

# Retina – Distribution of Receptors (rods and cones)

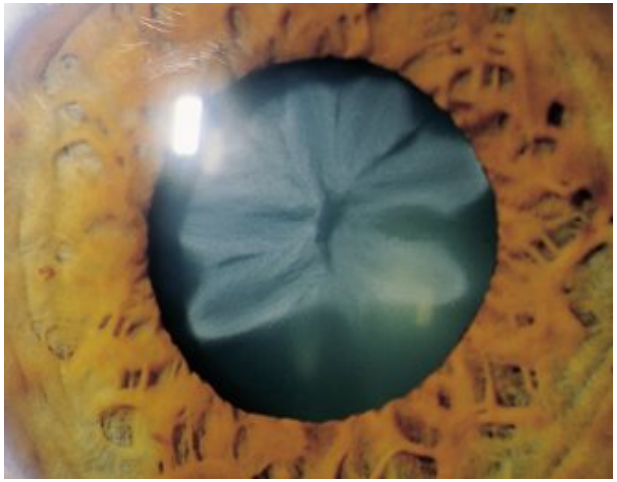


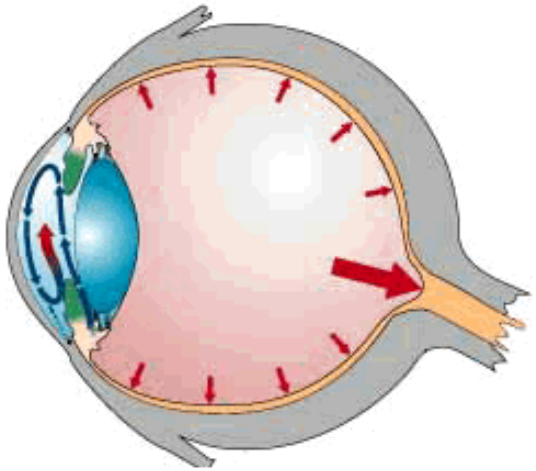



# Optical Systems in Medical Technology

## Eye Diseases





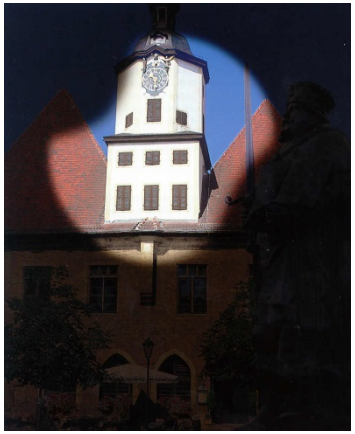
# Eye Diseases

NORMAL

REFRACTIVE ERROR

CATARACT

RETINAL DISEASES



GLAUCOMA

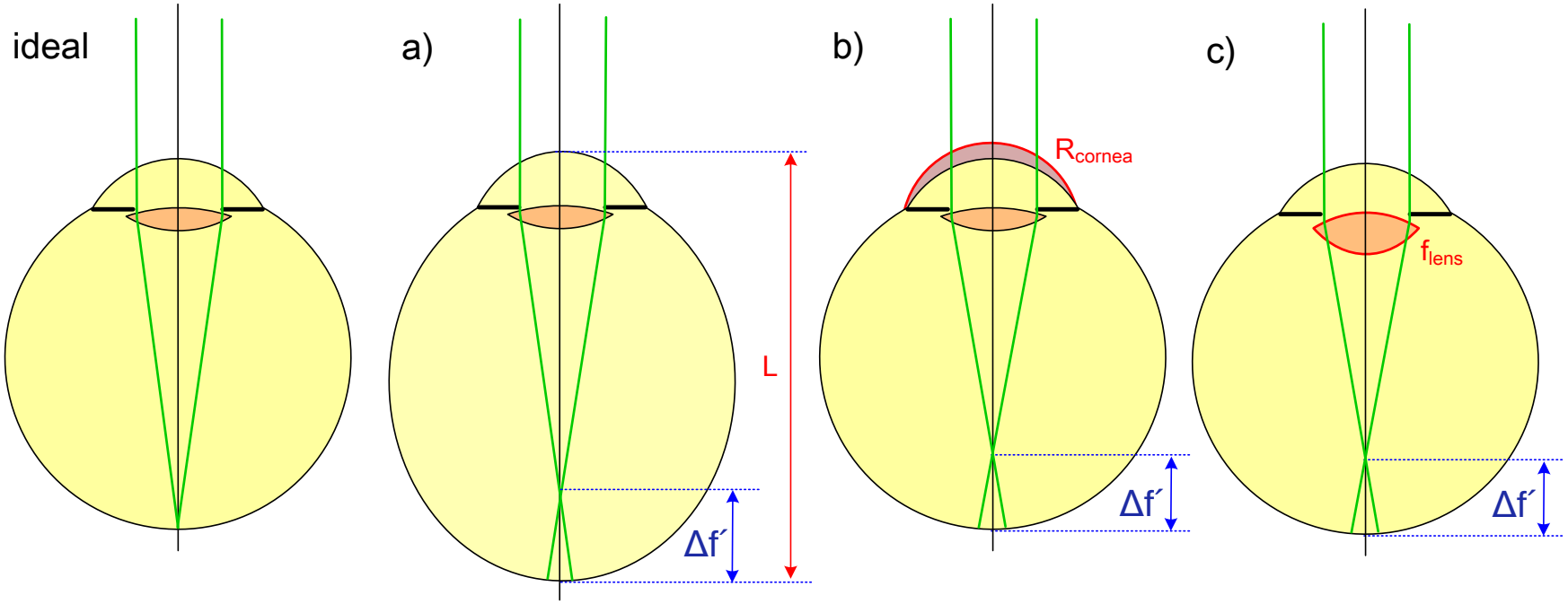
# Myopia (Kurzsichtigkeit)

a) Eyeball too long

b) Curvature of cornea too strong

c) Focal length of lens to short

Correction with negative lens.



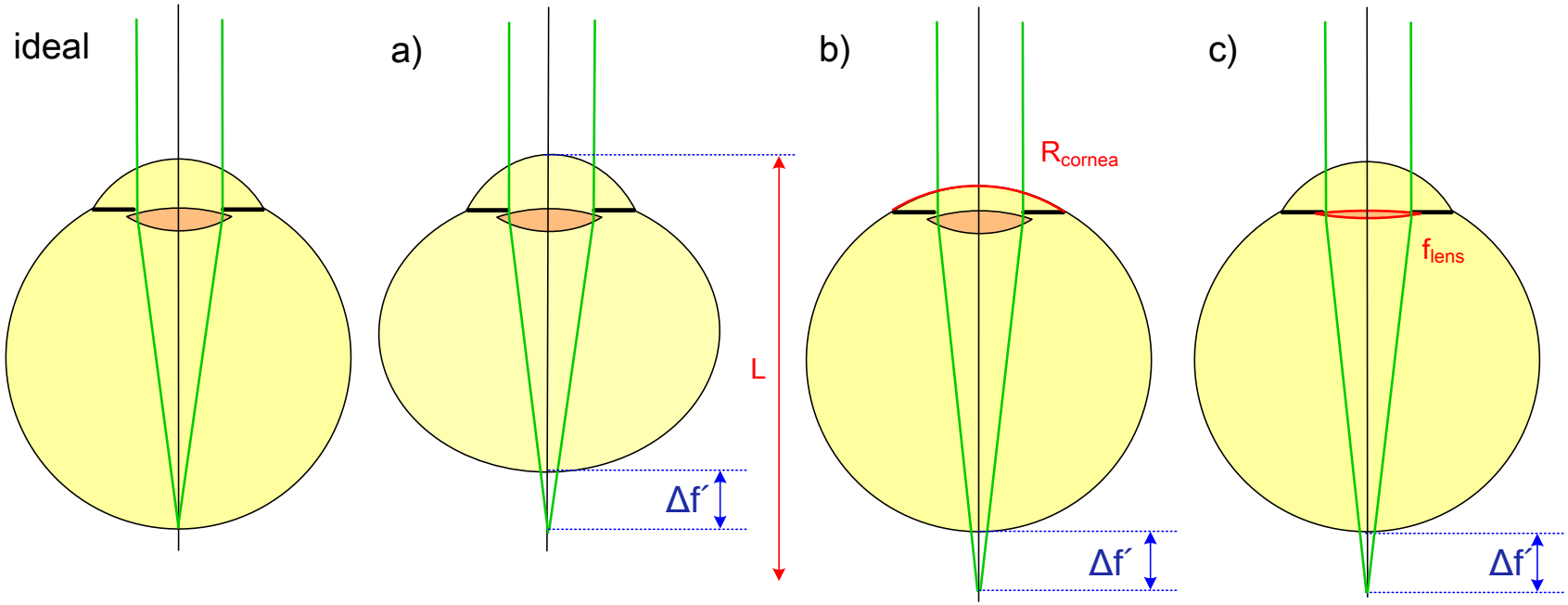
# Hyperopia (Weitsichtigkeit)

a) Eyeball too short

b) Curvature of cornea too weak

c) Focal length of lens too long

Correction with positive lens, partially self-correction by accomodation



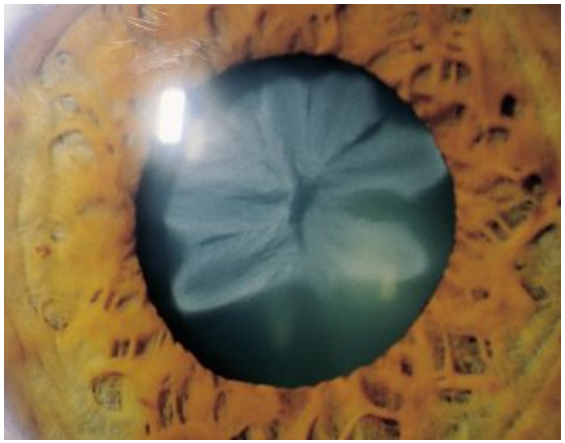
# Cataract (Grauer Star)

CATARACT

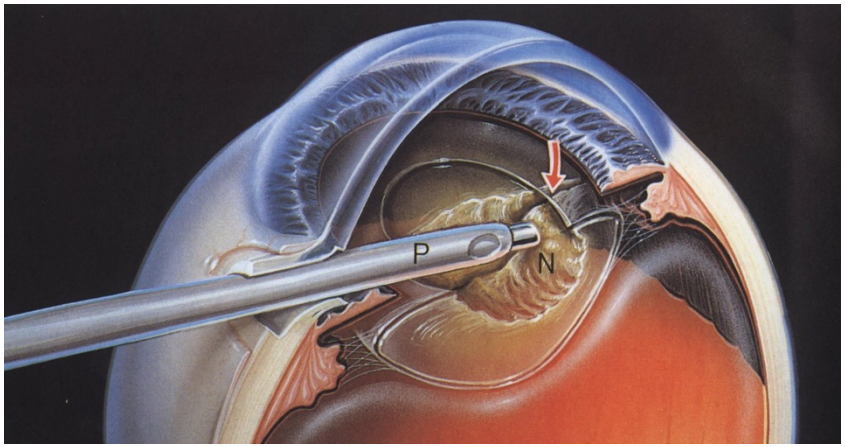
NORMAL

20 million Operations p.a.

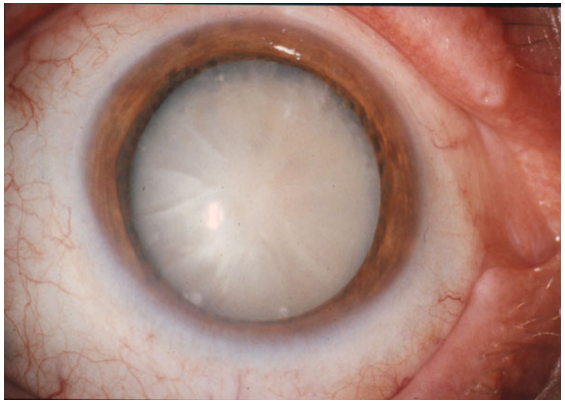
# Cataract-Operation



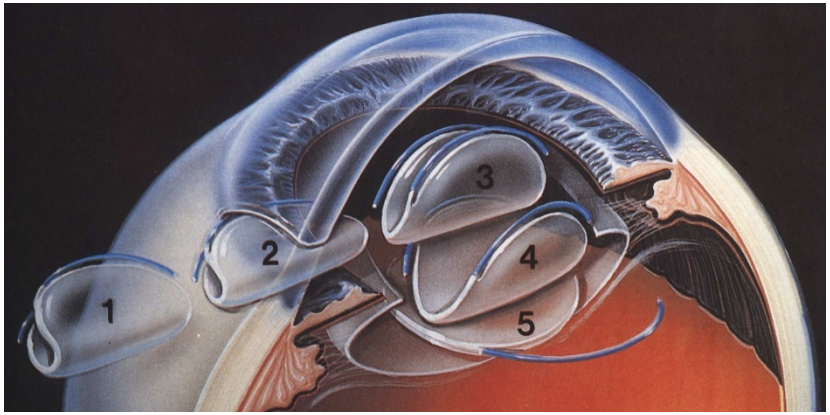
Opacification of lens




Extraction of natural lens



Cataract (extreme)

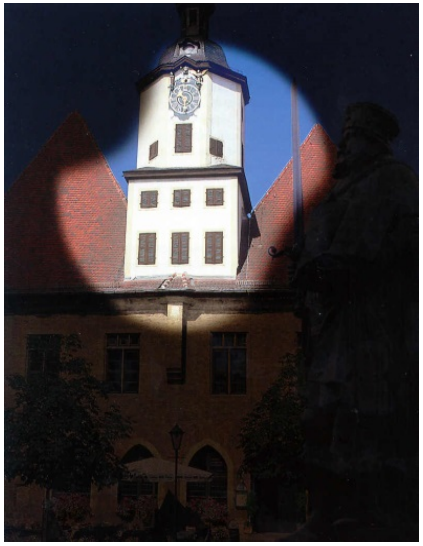



Insertion of an artificial IOL

# Posterior Segment Diseases (DR, AMD, Glaucoma)

NORMALE

RETINAL DISEASES



GLAUCOMA

Diabetic Retinopathie (DR)

Age-Related Macula-Degeneration (AMD)

Glaucoma (Grüner Star)

# Age-Related Macula-Degeneration (AMD)