A. Polimeni, R. Filipo, G. Iannetti, P. Pivetti Pezzi

"Manuale di Patologia degli Organi di Senso"

Casa Editrice "EDRA LSWR", Milano, 2014

1) Kanski's Clinical Ophthalmology: A Systematic Approach, 8th Edition
by Brad Bowling
Elsevier Ed.

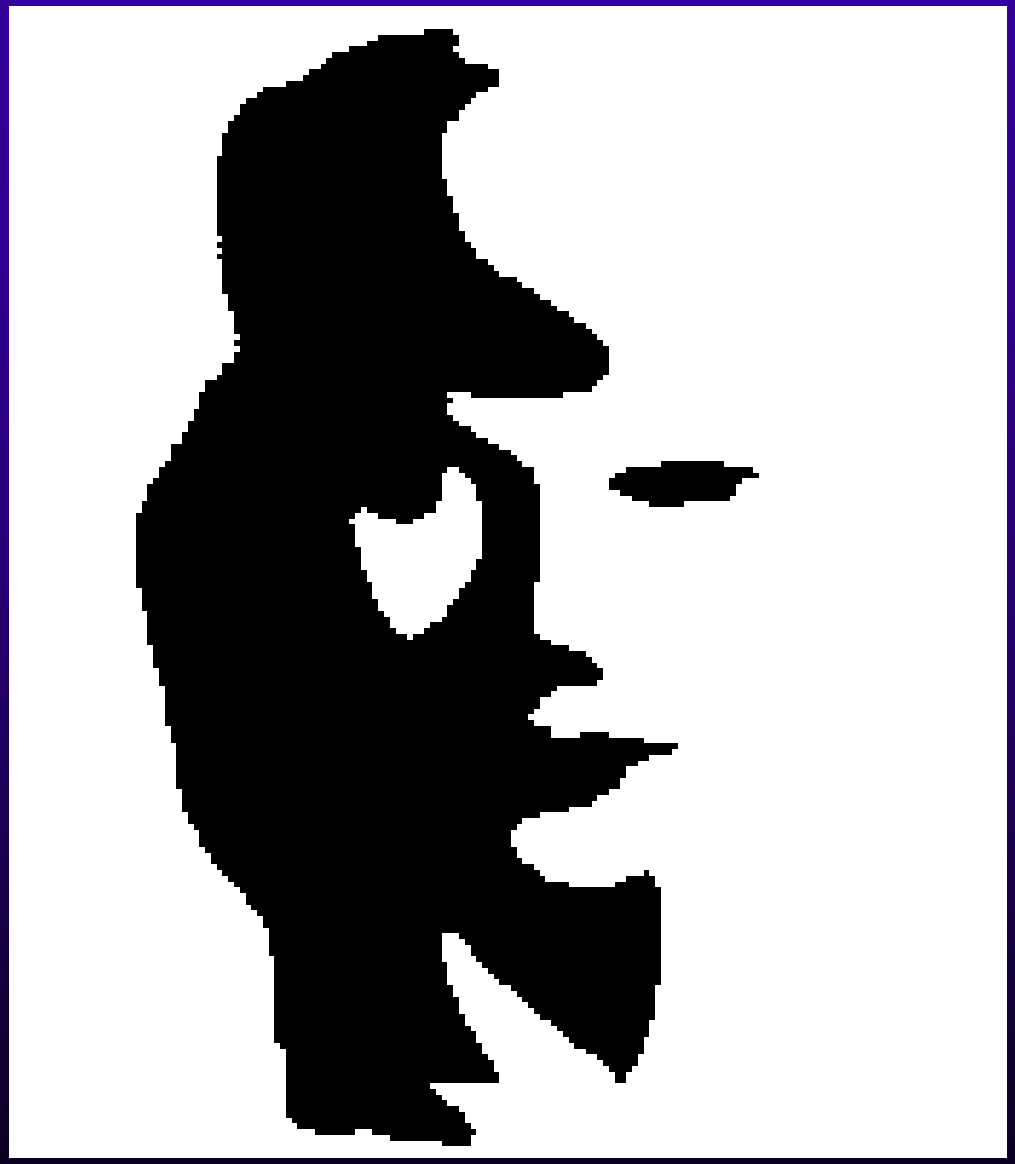
2) The Massachusetts Eye and Ear Infirmary Illustrated Manual of Ophthalmology, 4th Edition
by Peter K. Kaiser, Neil J. Friedman, Roberto Pineda
Elsevier Ed.

"Sapienza" Università di Roma
Policlinico Umberto I
U.O.C. Oftalmologia
Clinica Oculistica
Direttore: Prof. Leopoldo Spadea

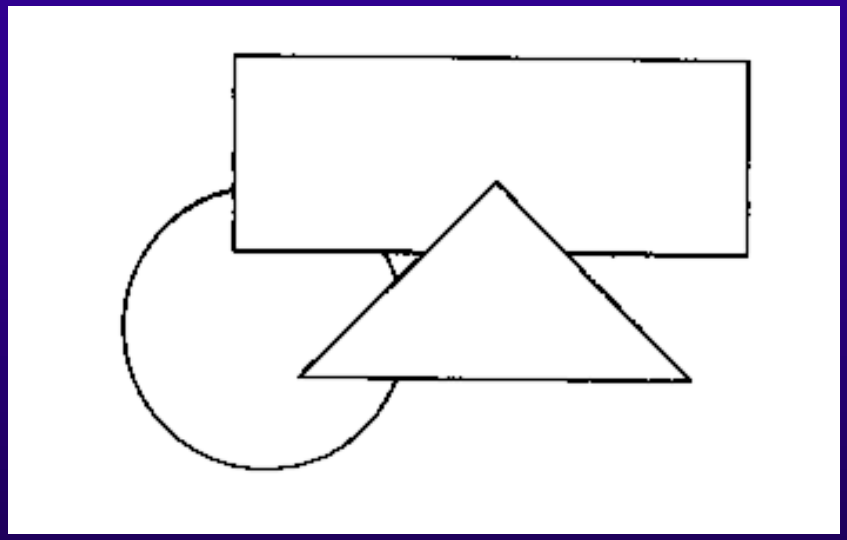
Optics and refractive errors

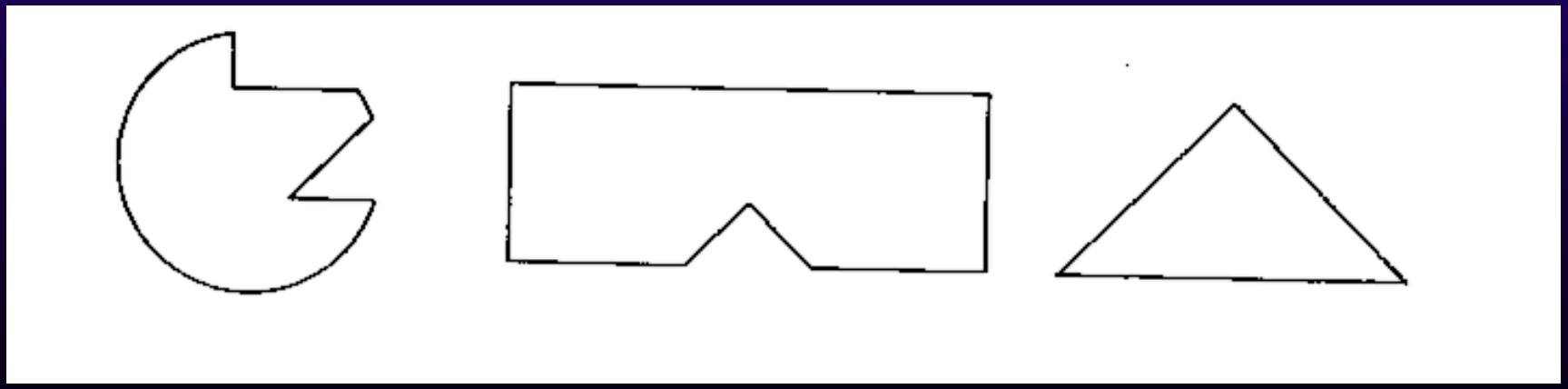
Prof. Leopoldo Spadea

Perception and recognition of objects

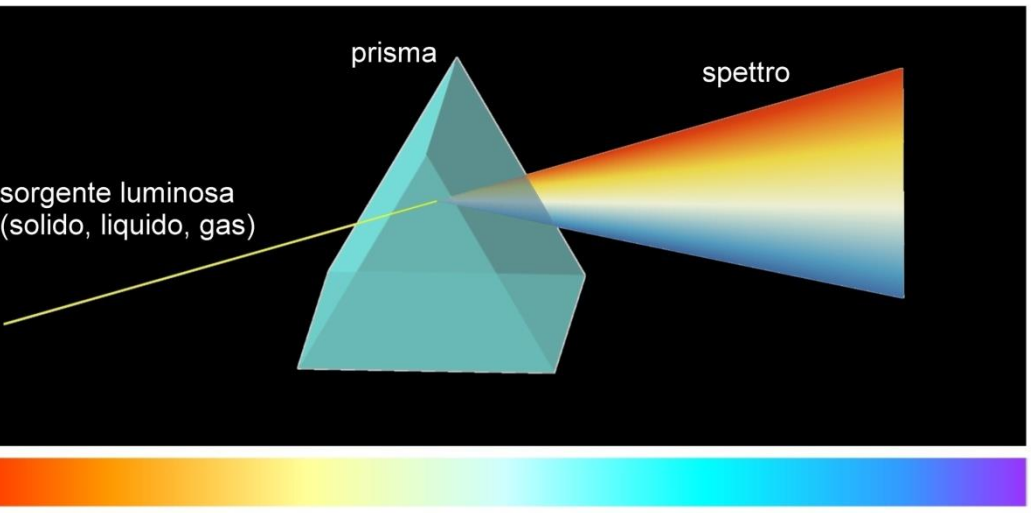


The interposition





Light: form of radiant energy.
It makes visible the objects that surround.
Speed: 300.000 Km for second.



lunghezza d'onda in millimicron	*colori*
700 - 610	rosso
610 - 590	arancione
590 - 570	giallo
570 - 500	verde
500 - 440	blu
440 - 400	violetto

The electromagnetic spectrum

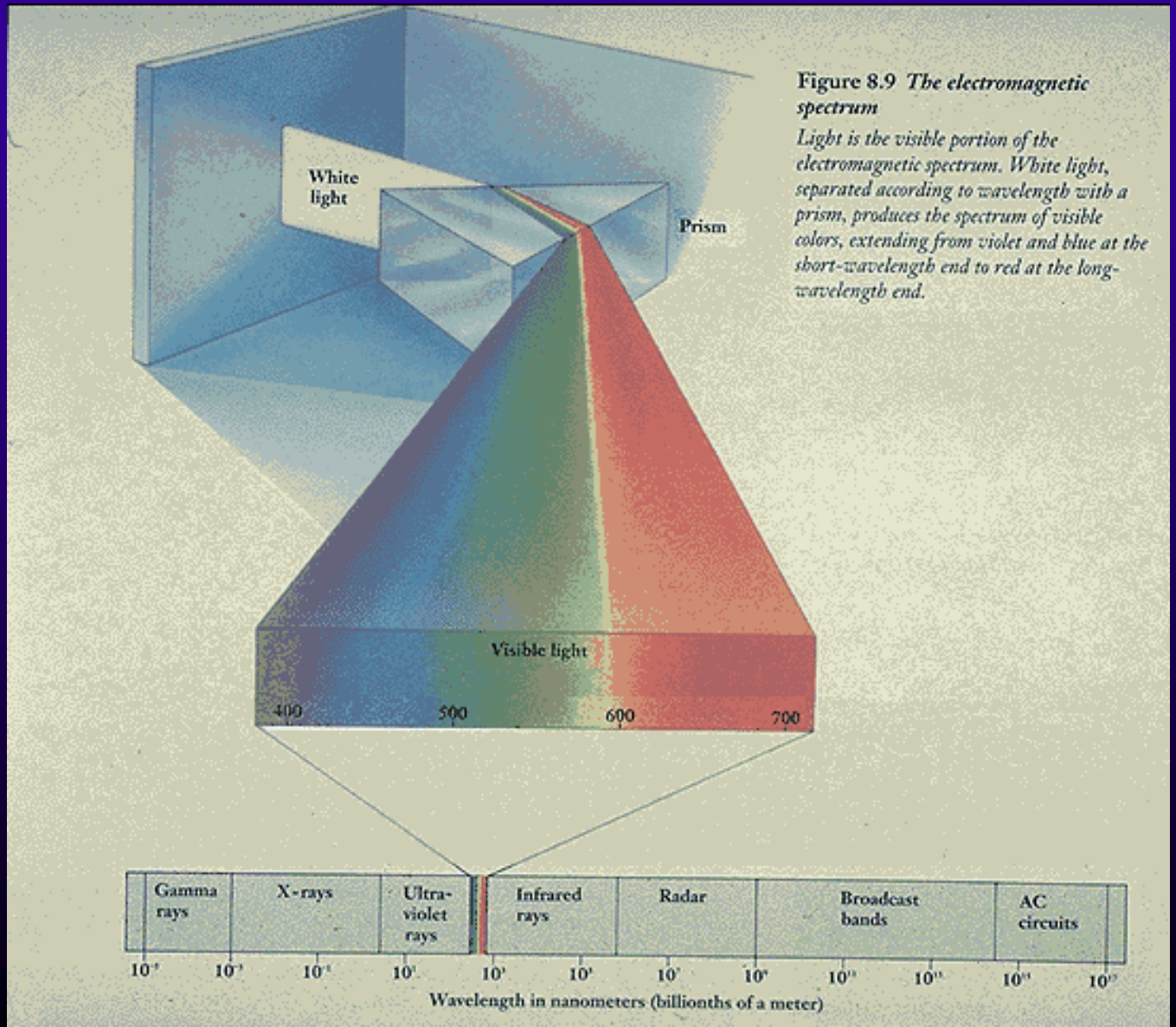


Figure 8.9 ***The electromagnetic spectrum***

Light is the visible portion of the electromagnetic spectrum. White light, separated according to wavelength with a prism, produces the spectrum of visible colors, extending from violet and blue at the short-wavelength end to red at the long-wavelength end.

The light propagates in a straight line

Light rays:

- ✓Convergent
- ✓Divergent
- ✓Parallel

The point at which the rays diverge or converge is called FOCUS

VERGENCE: inverse of distance in meters

$$\frac{1}{d} = D$$

Distanza in metri	Vergenza in diottrie	Distanza in metri	Vergenza in diottrie
∞	0,00	0,75	1,33
10,00	0,10	0,66	1,50
5,00	0,20	0,57	1,75
4,00	0,25	0,50	2,00
3,00	0,33	0,40	2,50
2,50	0,40	0,33	3,00
2,00	0,50	0,25	4,00
1,50	0,66	0,20	5,00
1,33	0,75	0,17	6,00
1,25	0,80	0,14	7,00
1,10	0,90	0,125	8,00
1,00	1,00	0,11	9,00
0,90	1,10	0,10	10,00
0,80	1,25	0,05	20,00

Refraction index

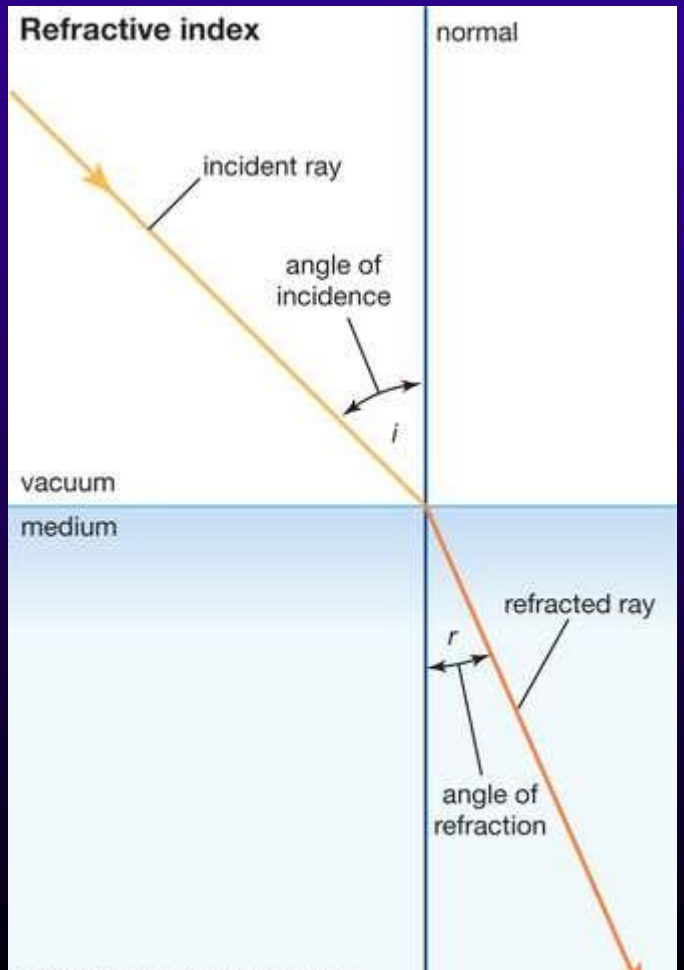
$$n\,(\text{medium}) = \frac{c\,(\text{speed of light in vacuum})}{v\,(\text{speed of light in medium})}$$

index of refraction

$$n = \frac{c}{v}$$

velocity of light in vacuum

velocity of light in the medium



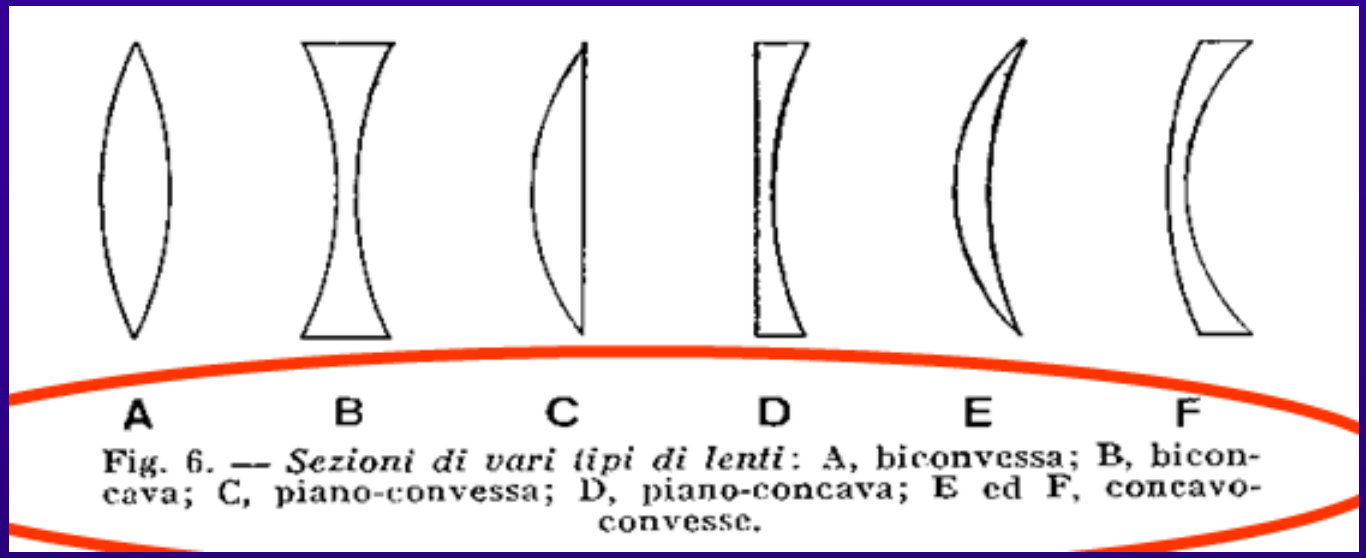
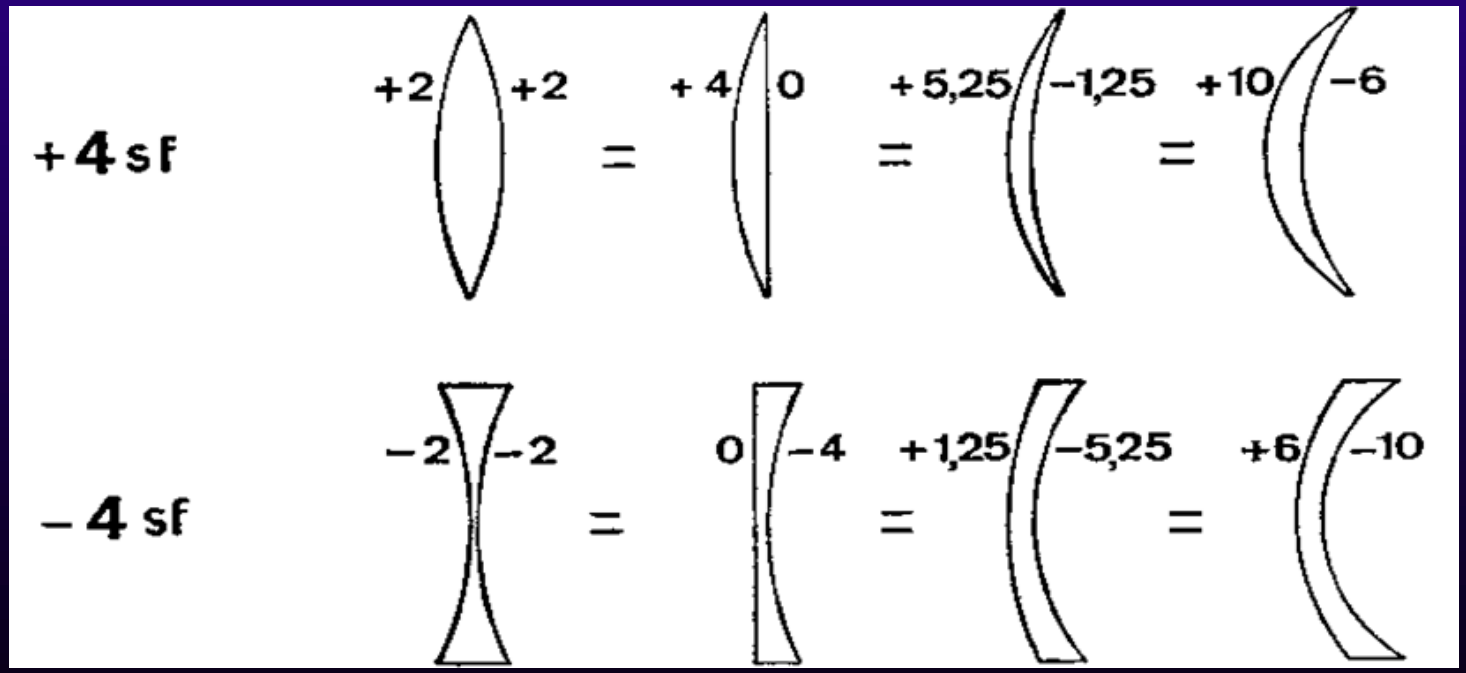
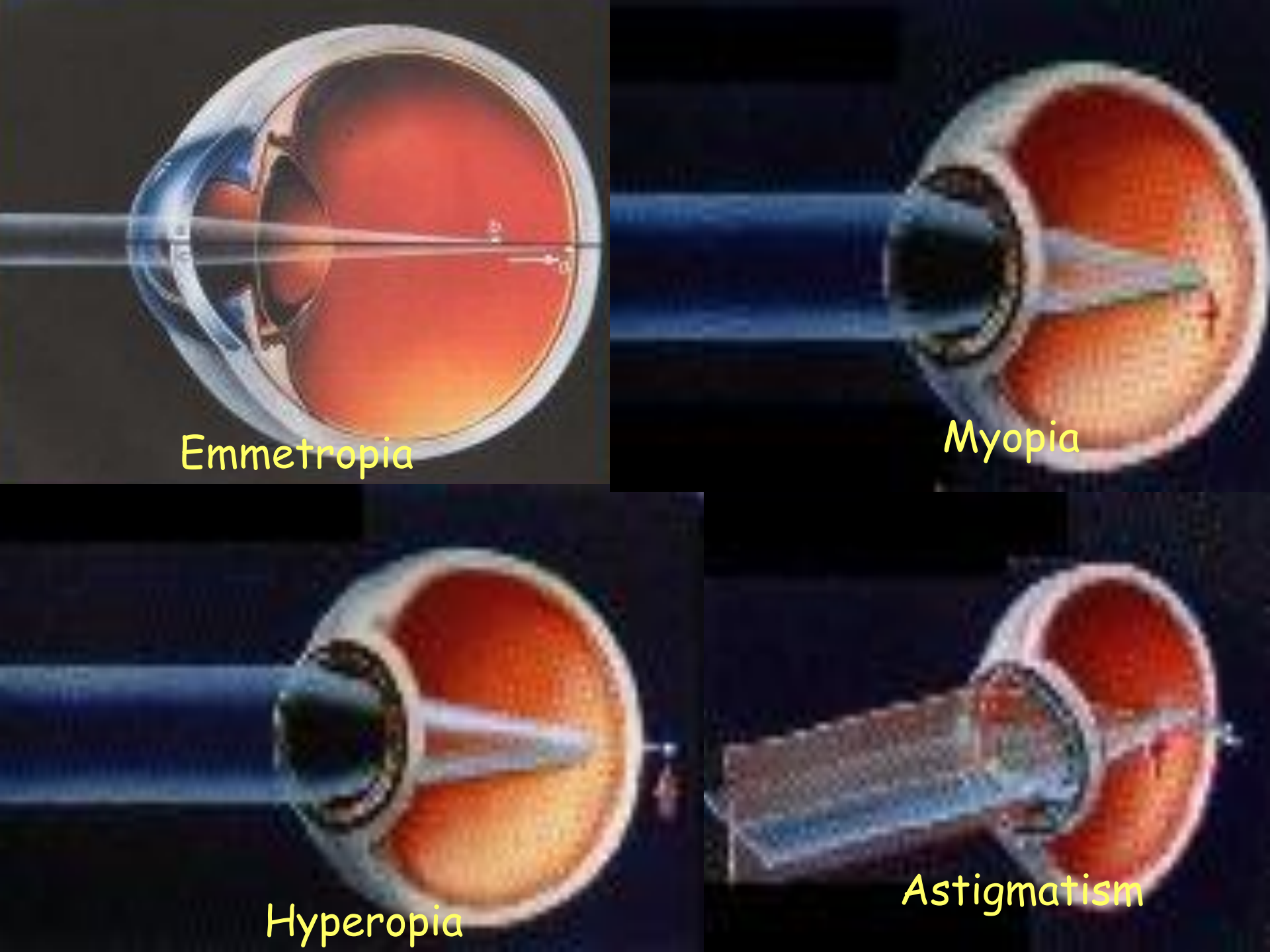


Fig. 6. — *Sezioni di vari tipi di lenti*: A, biconvessa; B, biconcava; C, piano-convessa; D, piano-concava; E ed F, concavo-convesse.



REFRACTIVE ERRORS

- ✓MYOPIA
- ✓HYPEROPIA
- ✓ASTIGMATISM
- ✓PRESBIOPIA


Emmetropia
Myopia
Hyperopia
Astigmatism

Distance Visual Acuity Test (E Game)

(Read in good light at 10 feet.)

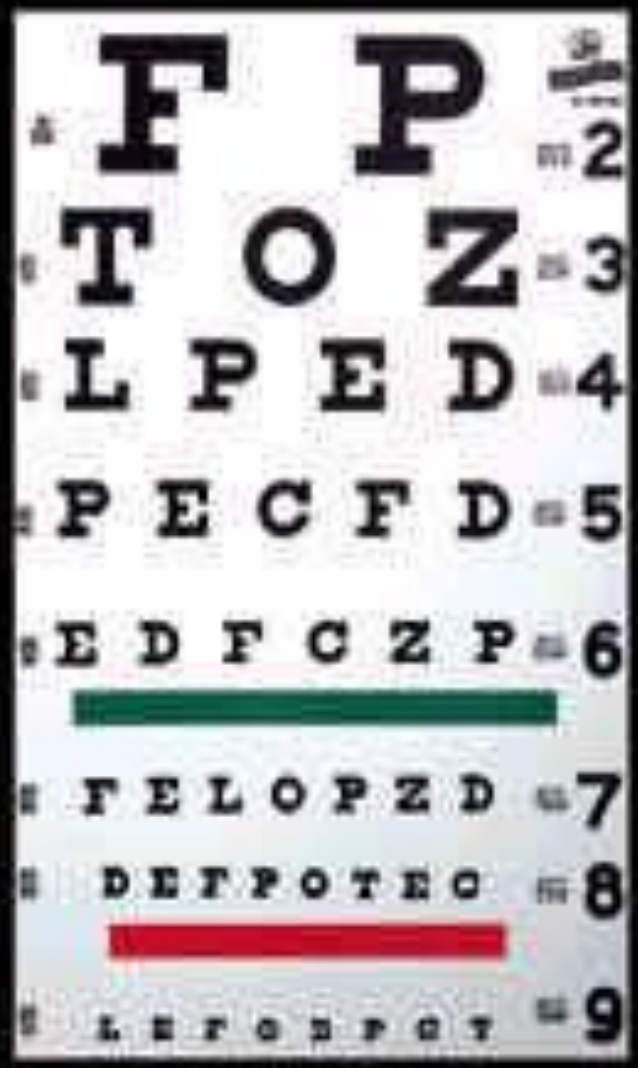
Line 1
20/200

Line 2
20/100

Line 3
20/40

Line 4
20/20

100 Millimeter Calibration Bar

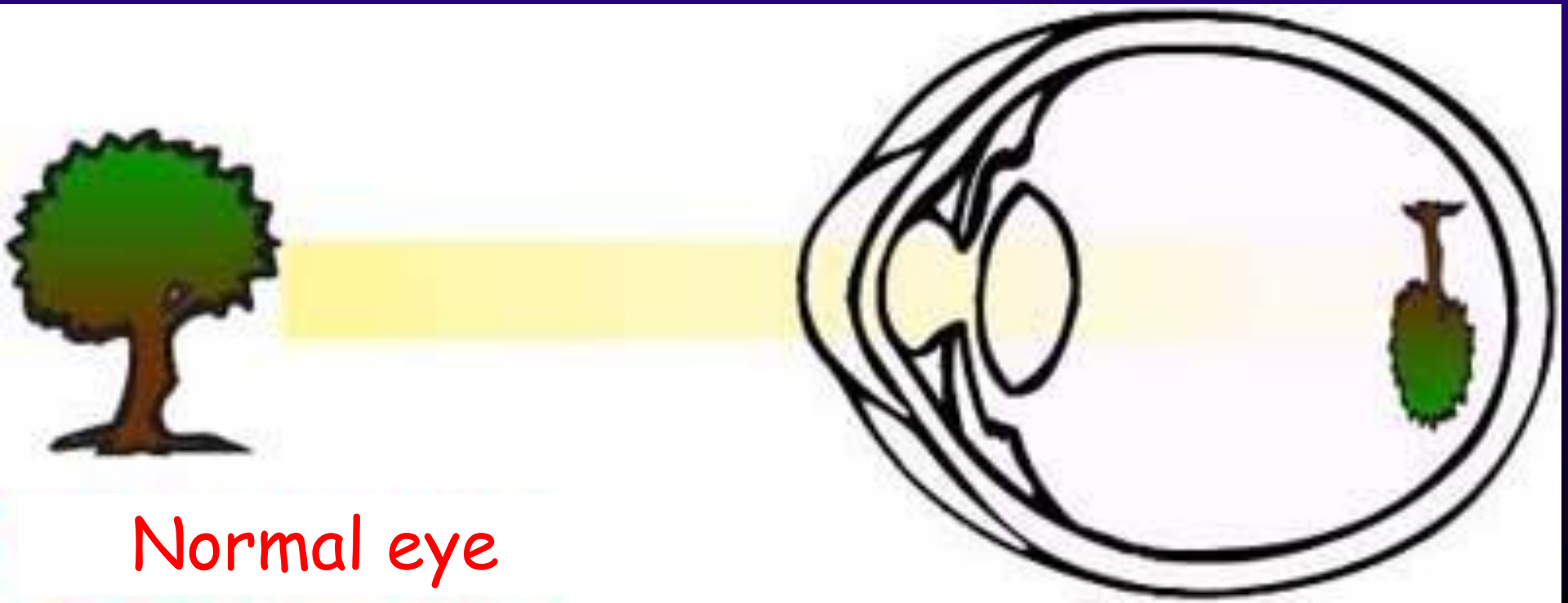


MYOPIA
NEARSIGHTEDNESS

Myopia is a refractive error, a visual defect of the system that focus the images.

EMMETROPIA

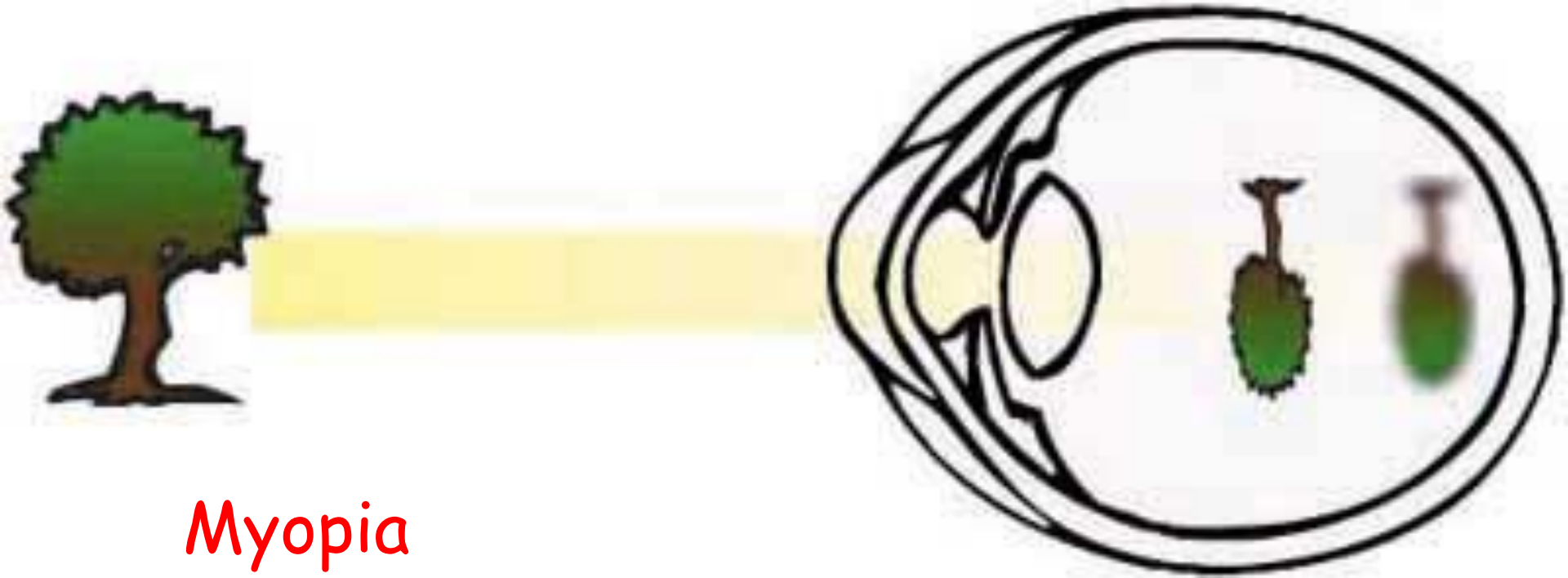
The parallel rays of light coming from infinity are focused on the retina with accommodation being at rest.



Normal eye

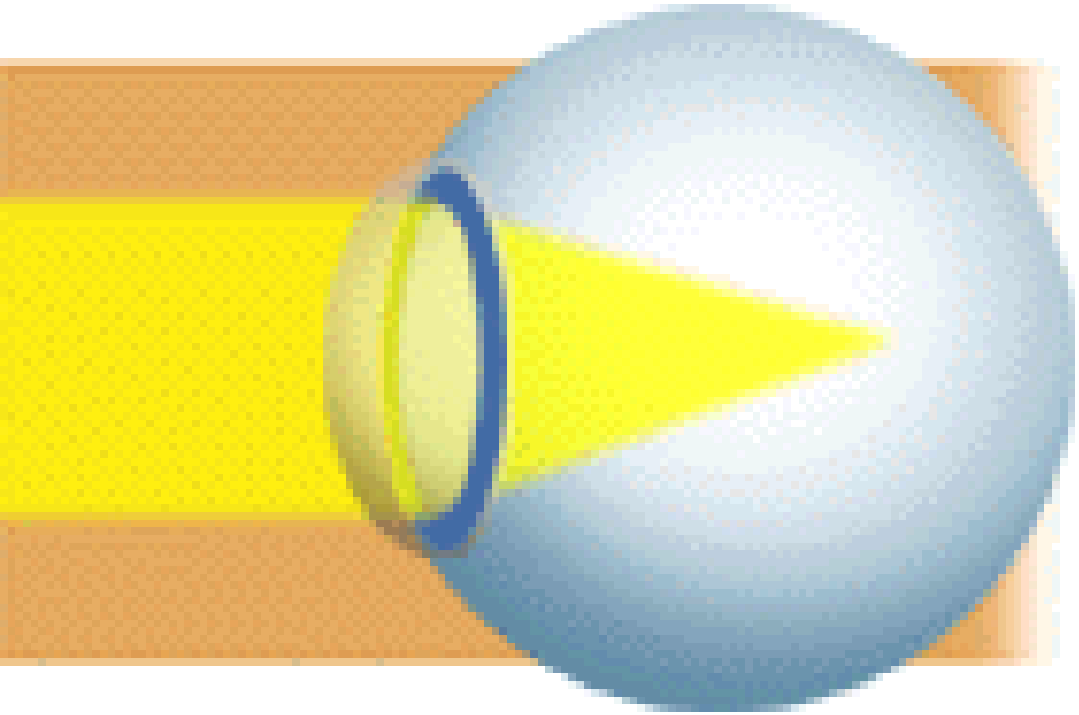
MYOPIA

A refractive error in which parallel rays of light entering the eye are focused in front of the retina with accommodation being at rest.



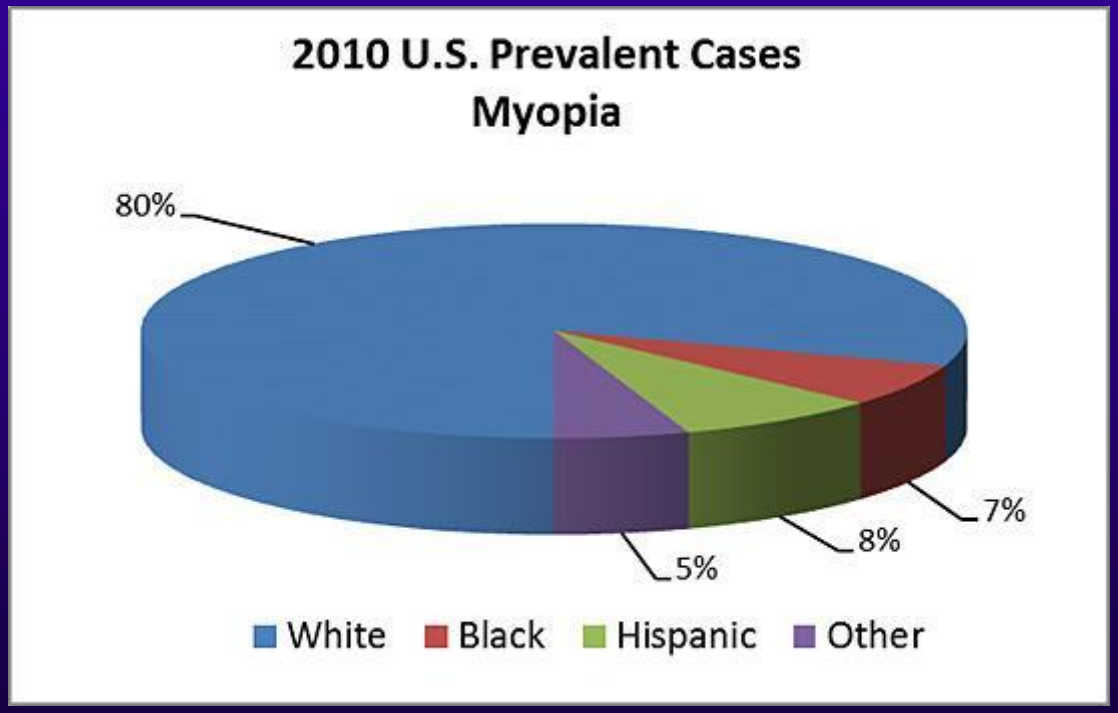
Myopia

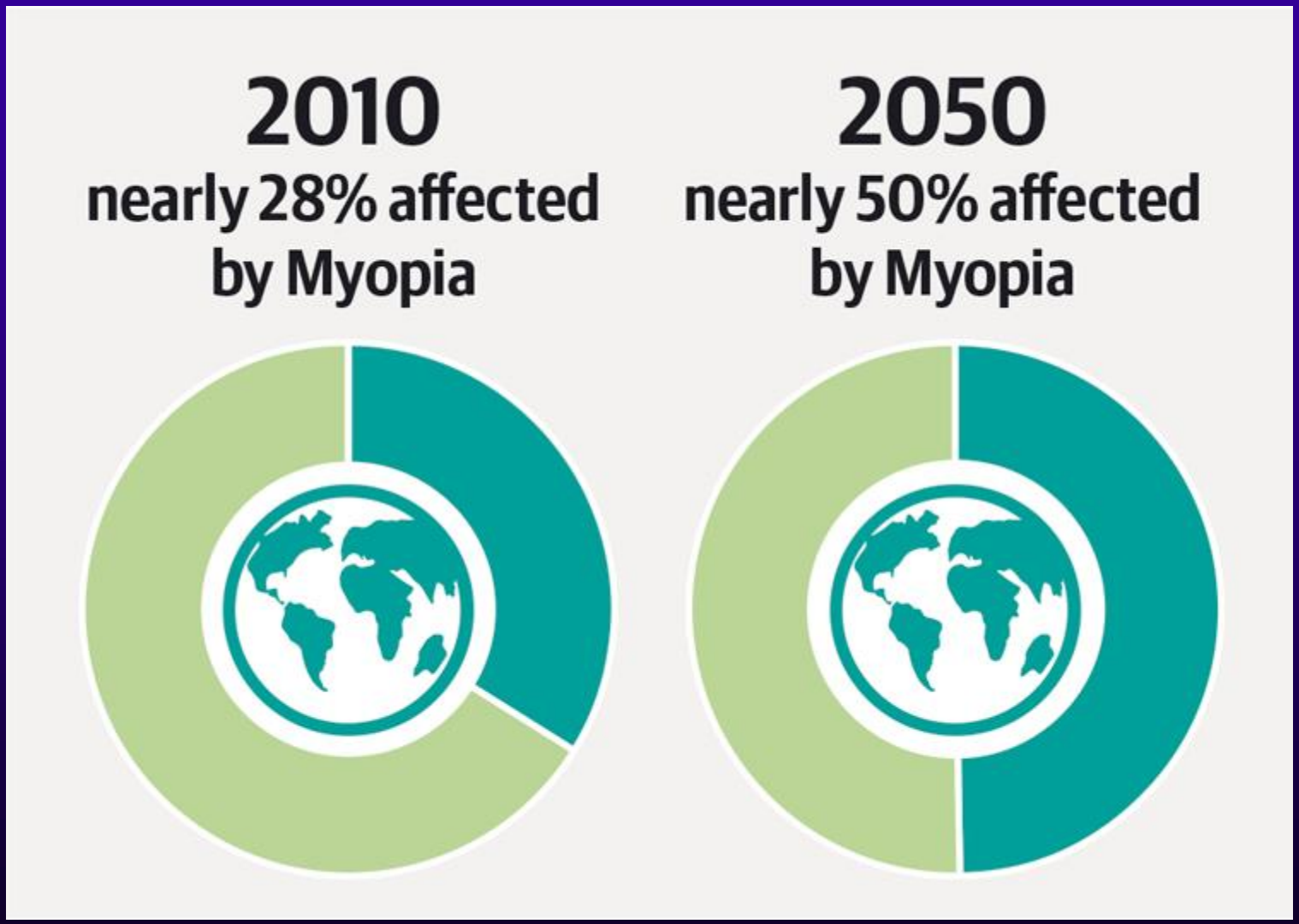
In Italy about 14 million people are myopes. In western countries 20% of population,
in Asiatic countries 50-70%.

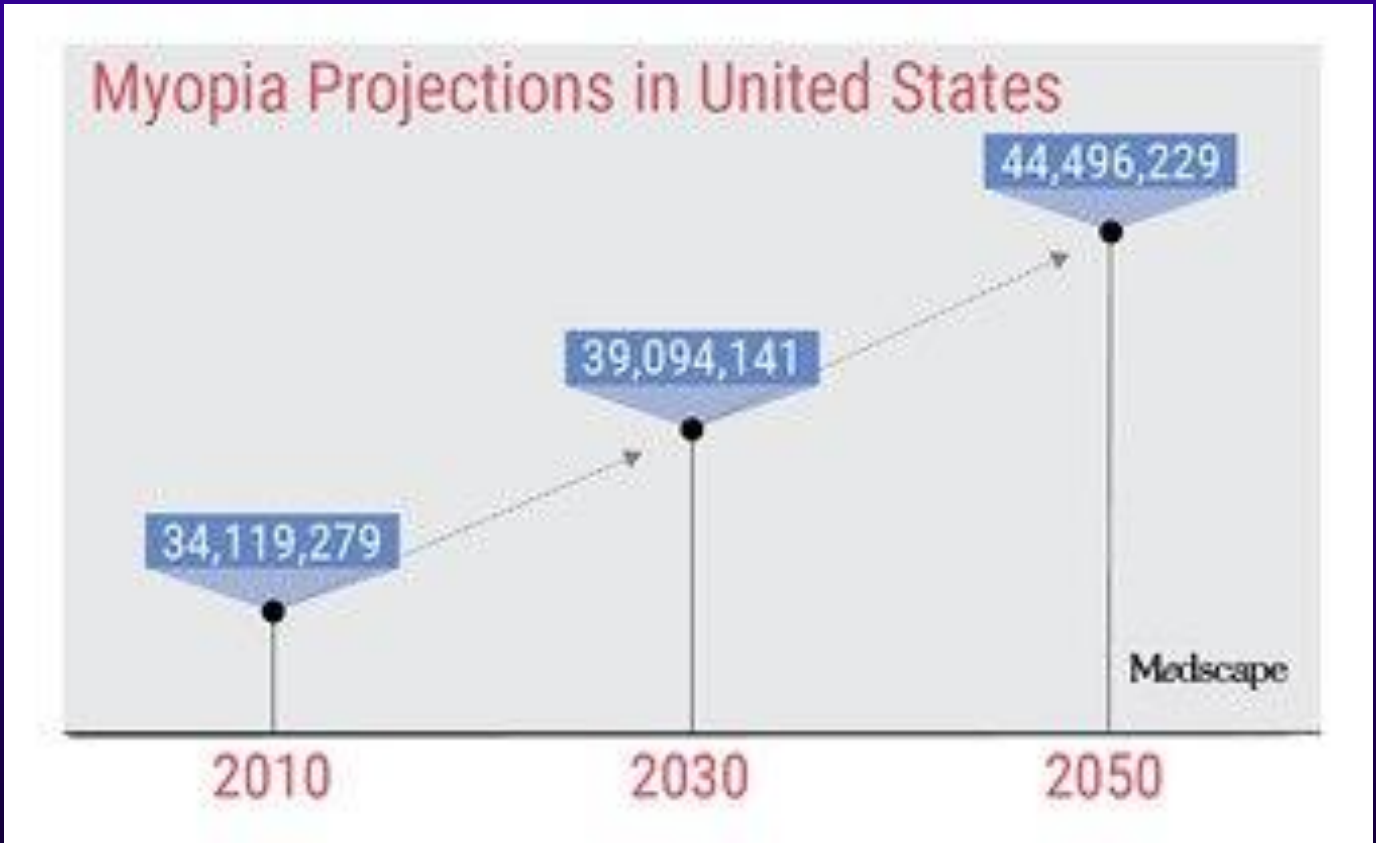


Nearsightedness

Normal Vision


2010 U.S. Prevalent Cases
Myopia
80%
7%
8%
5%
White
Black
Hispanic
Other


2010
nearly 28% affected
by Myopia
2050
nearly 50% affected
by Myopia


Myopia Projections in United States
44,496,229
39,094,141
34,119,279
Medscape
2010
2030
2050

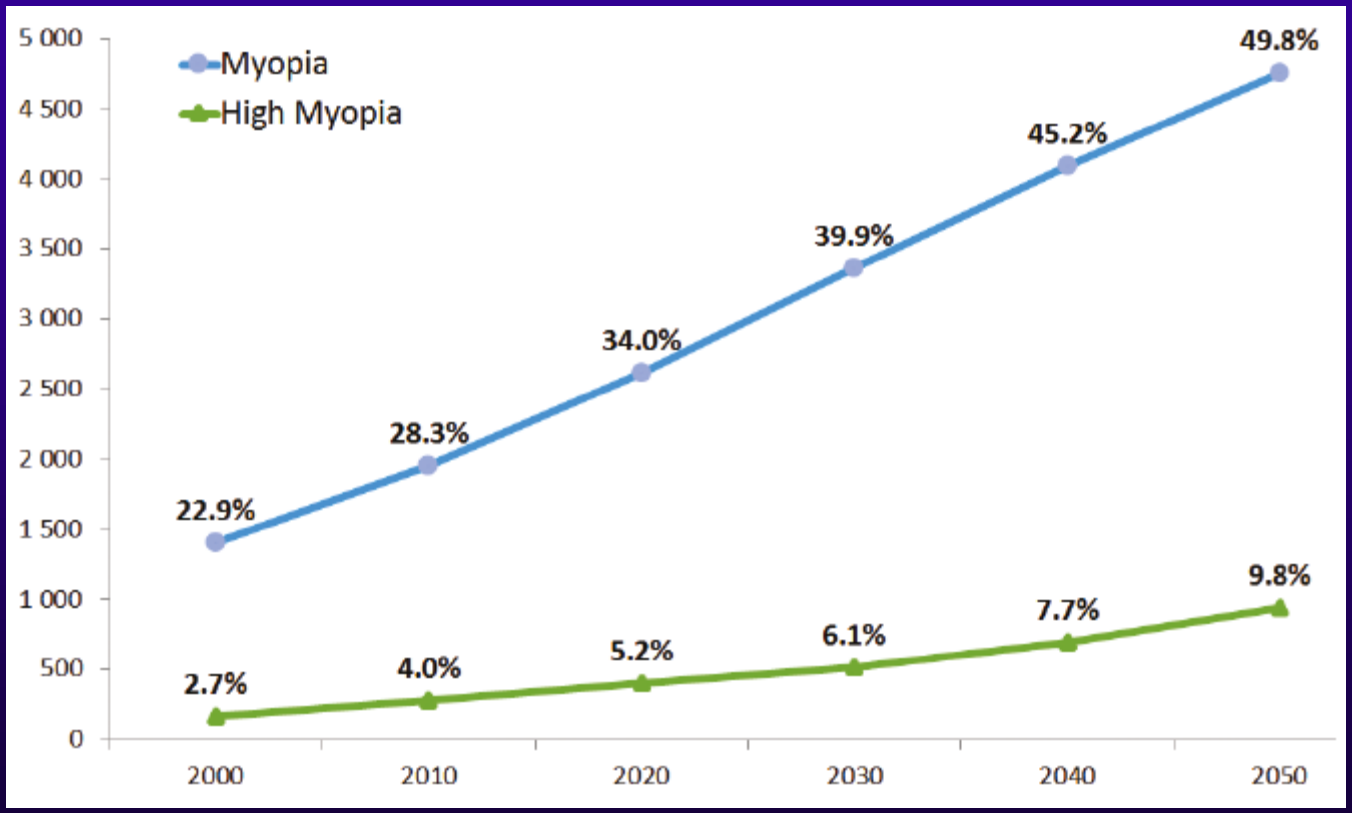
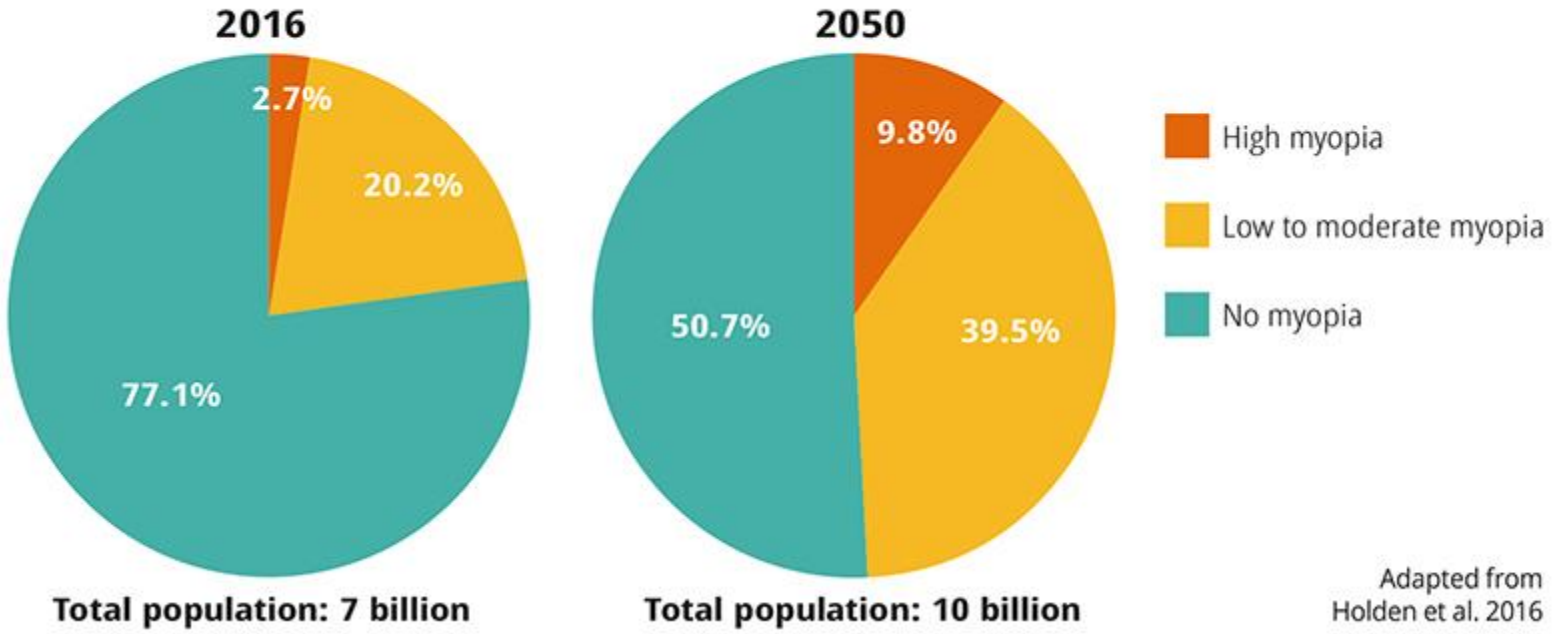

Myopia
High Myopia
5 000
4 500
4 000
3 500
3 000
2 500
2 000
1 500
1 000
500
0
2000
2010
2020
2030
2040
2050
22.9%
28.3%
34.0%
39.9%
45.2%
49.8%
2.7%
4.0%
5.2%
6.1%
7.7%
9.8%

Figure 1 Myopia and high myopia are rapidly increasing worldwide



CLASSIFICATION OF MYOPIA

According to amount

Low (less -3.00 D)

Medium (-3.00 D to -6.00 D)

High (more -6.00 D).

In Italy:

- 10% with low myopia
- 70% with medium myopia
- 20% with high myopia

ETIOLOGICAL TYPES:

1. AXIAL: Increased ant/post length of eyeball
2. CURVATURE: Increased curvature of cornea, lens or both
3. INDEX: Increased refractive index of lens with nuclear sclerosis

The majority of myopia is due to an excessive length of the eyeball

MYOPIA

NORMAL EYE

AXIAL MYOPIA

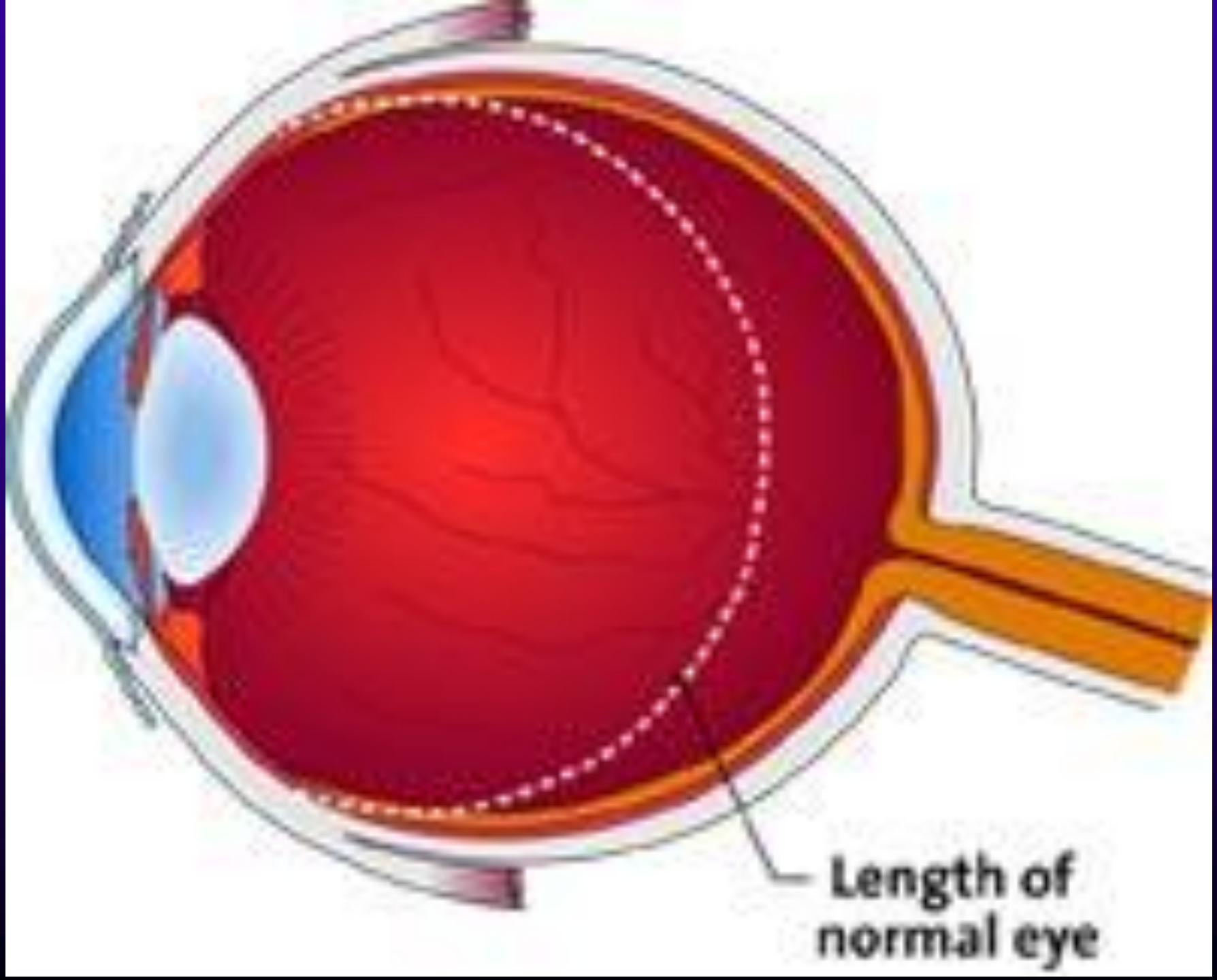
STEEP CORNEA MYOPIA

INDEX MYOPIA

There are two reasons why an eye may be longer than necessary.

1) excessive stimulus to the growth.

During the period of puberty and adolescence all the body and the eye receive some stimulus to the growth. The eye responds stretching too much. Usually the eye growth end at the age of 20-25 years.


Length of
normal eye

2) Yielding of the sclera's structure.

Sclera is a rigid structure,
but it is formed by collagen fibers that could be low resistance.
The bulging is more visible in the central part of the retina and it is called myopic stafiloma.

- ✓ Stretching of eye ball
- ✓ Instability of vitreous

→ periphery retinal degeneration with retinal detachment risk.

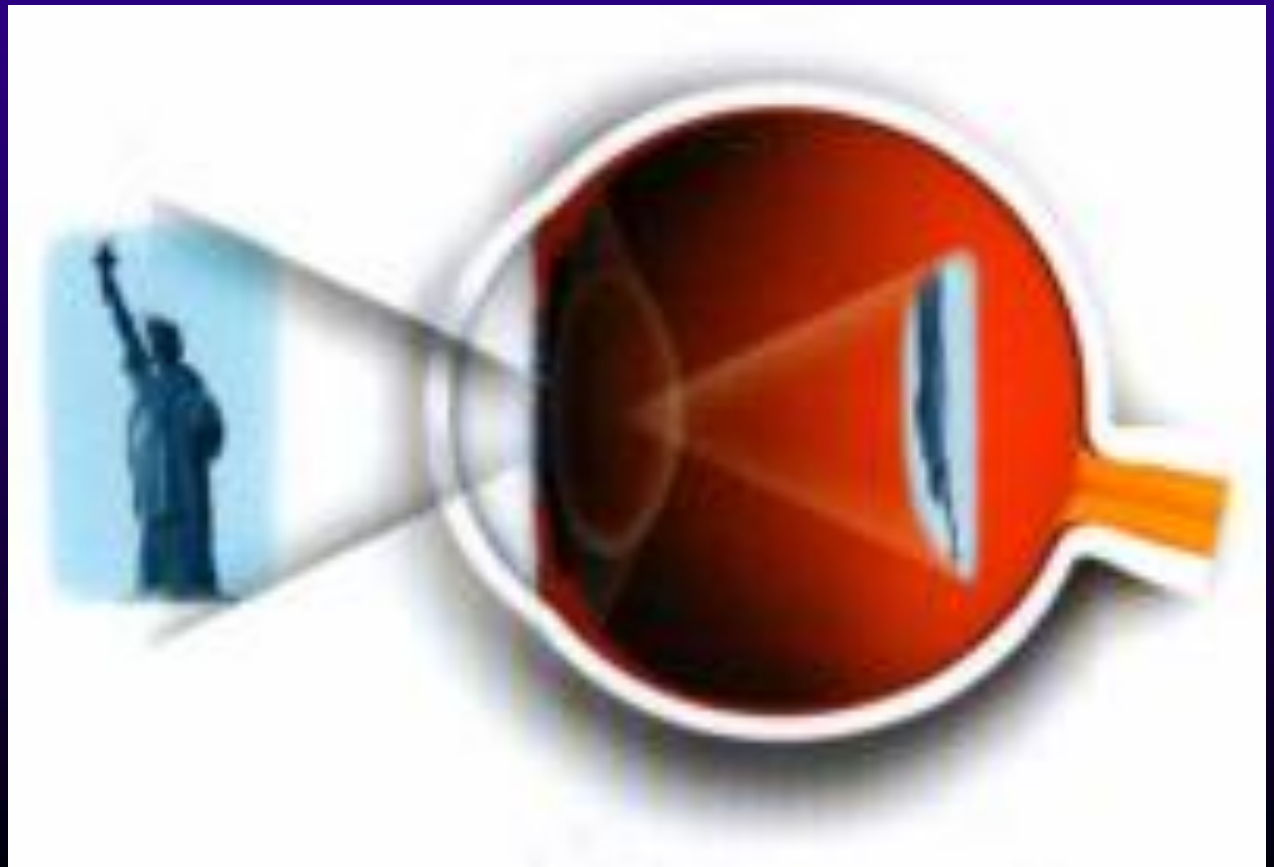
Congenital and Acquired myopia

Congenital myopia is already present at birth

Acquired myopia can be classified in:

- simple myopia: it arise in school children and increases in the period of body development
- degenerative: it arise in children, around 2-3 years of age, increases in the next years up to (30D)
- age related: due to cataract (index myopia)

Myopic patients have good near visual acuity but haven't a good distance acuity: this patients often squeeze eye to focus a far object.



Myopia is most commonly corrected through the use of corrective negative lenses, such as glasses or contact lenses.

This lenses have a negative optical power which compensates for the excessive positive power of the myopic eye.

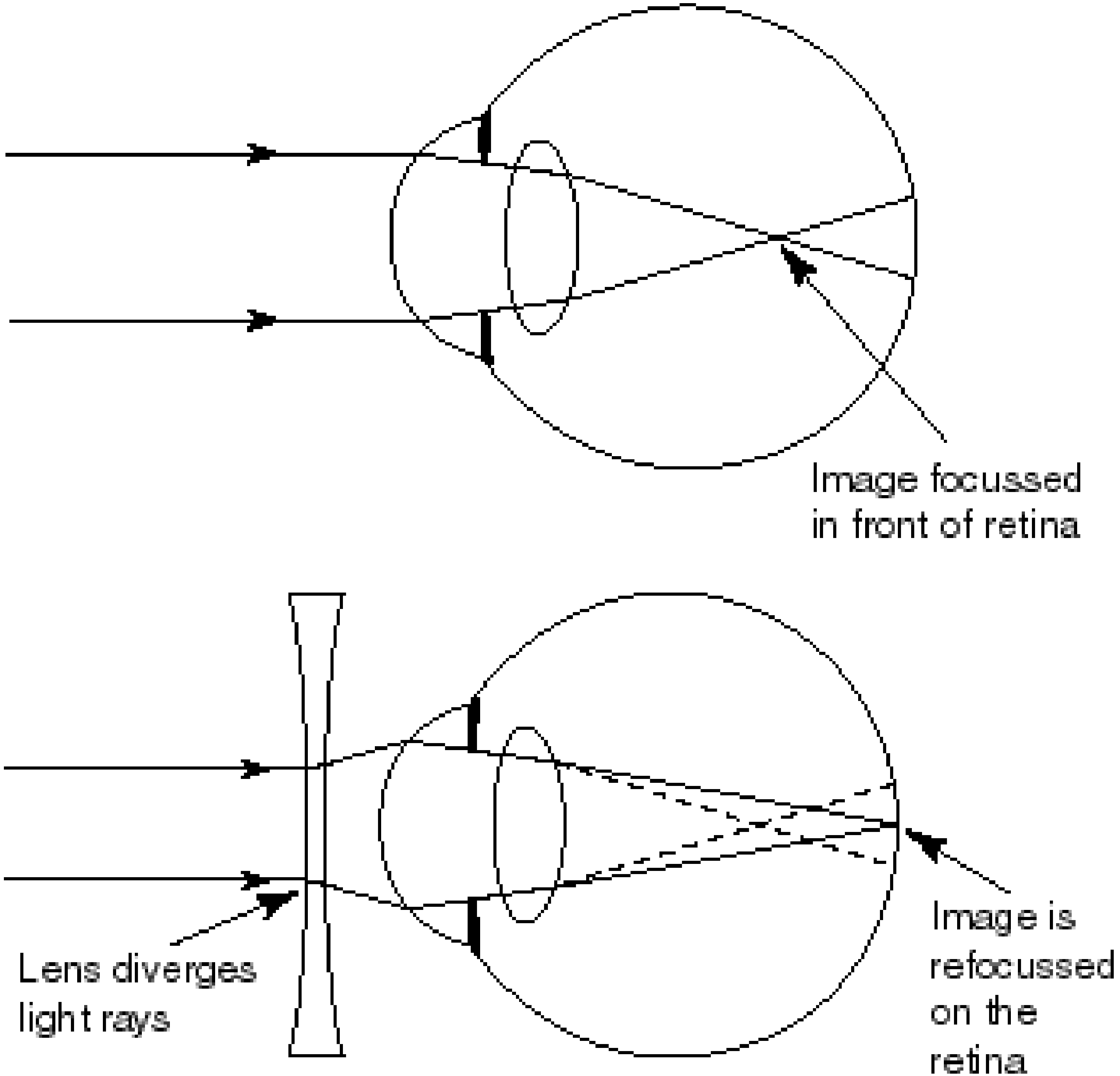
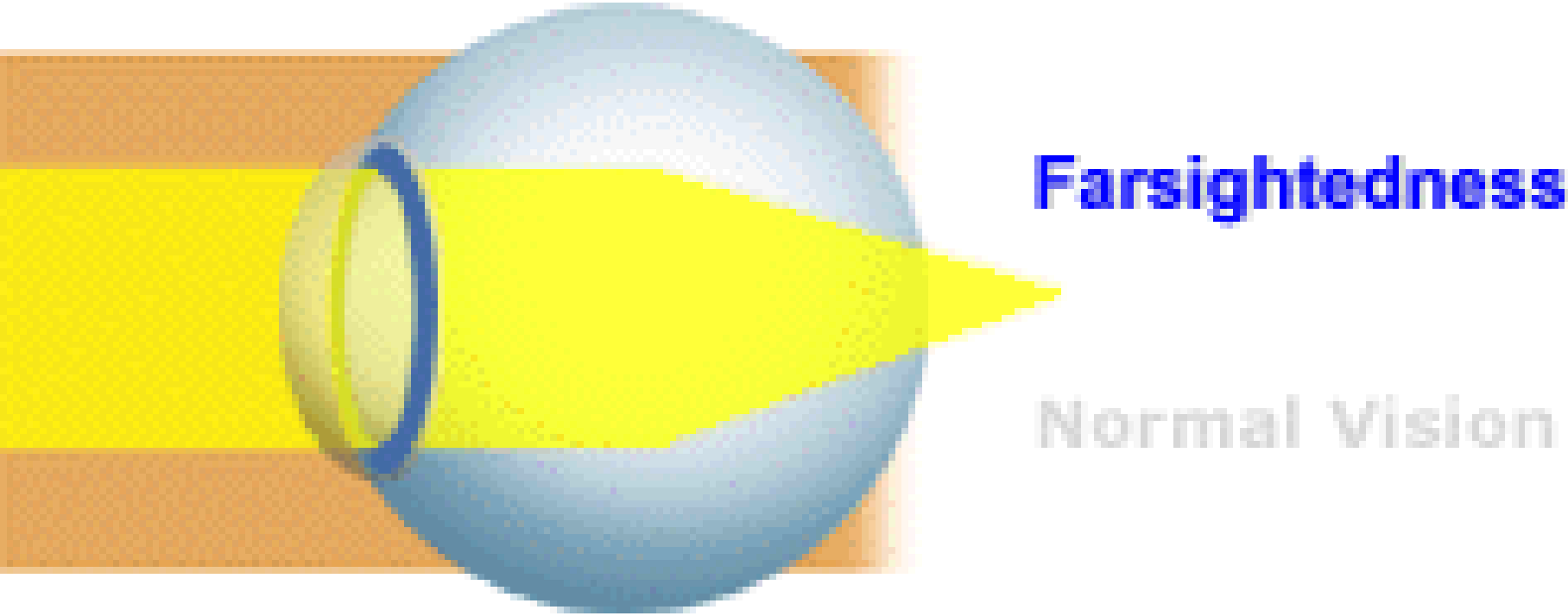


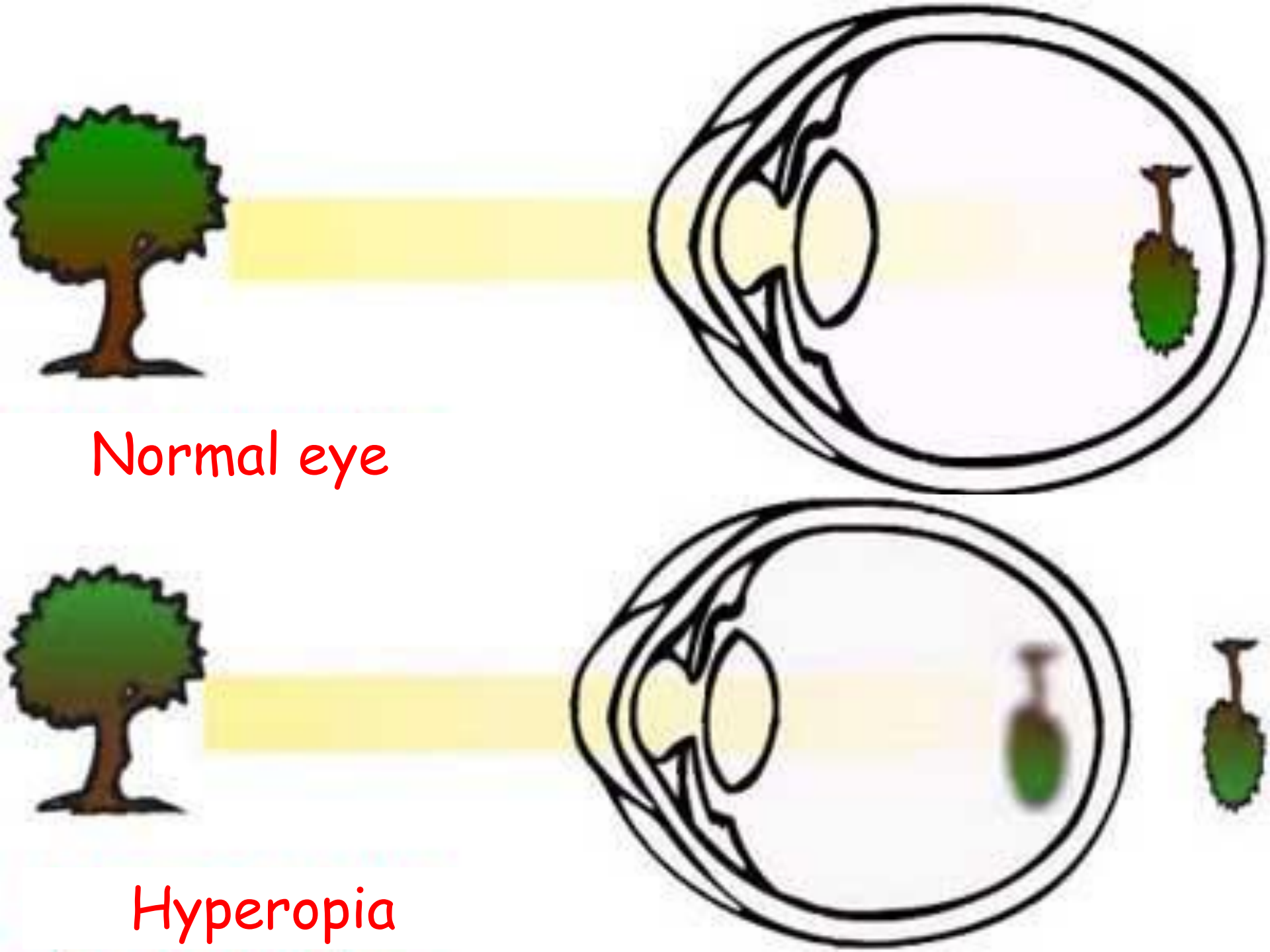
Image focussed
in front of retina
Lens diverges
light rays
Image is
refocussed
on the
retina

HYPEROPIA
FARSIGHTEDNESS

It is a refractive defect that occur in about 9 million people in Italy. In the normal eye the light ray that came from distant objects focus on retinal plan.

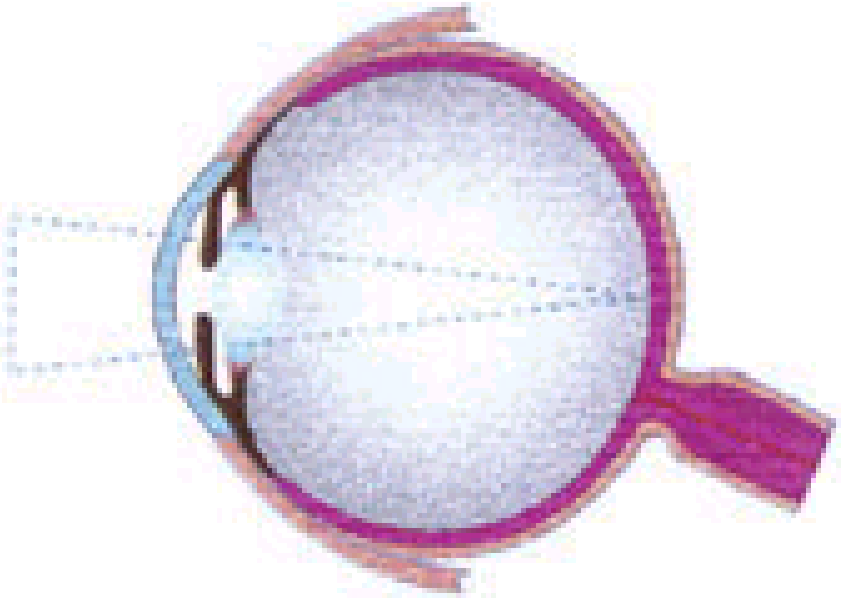


In the hyperopic eye the light ray focus behind the retinal plan: the patients receive a blurred image.

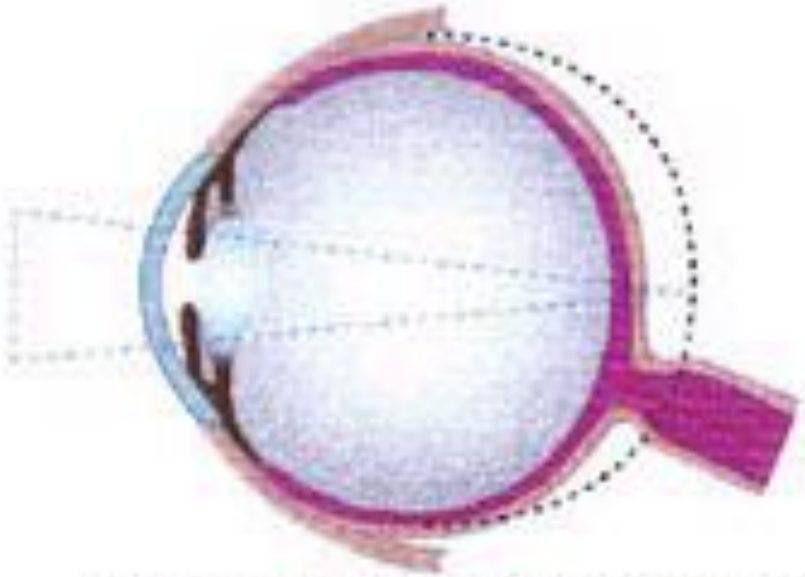

Normal eye
Hyperopia

Etiology of hyperopia:

1. short eyeball
2. cornea and/or lens less steep
3. lens refractive index changes
4. luxated lenses (it is not in the physiologic position)
5. aphakia (absence of lens)



occhio normale



il globo oculare è più corto della norma

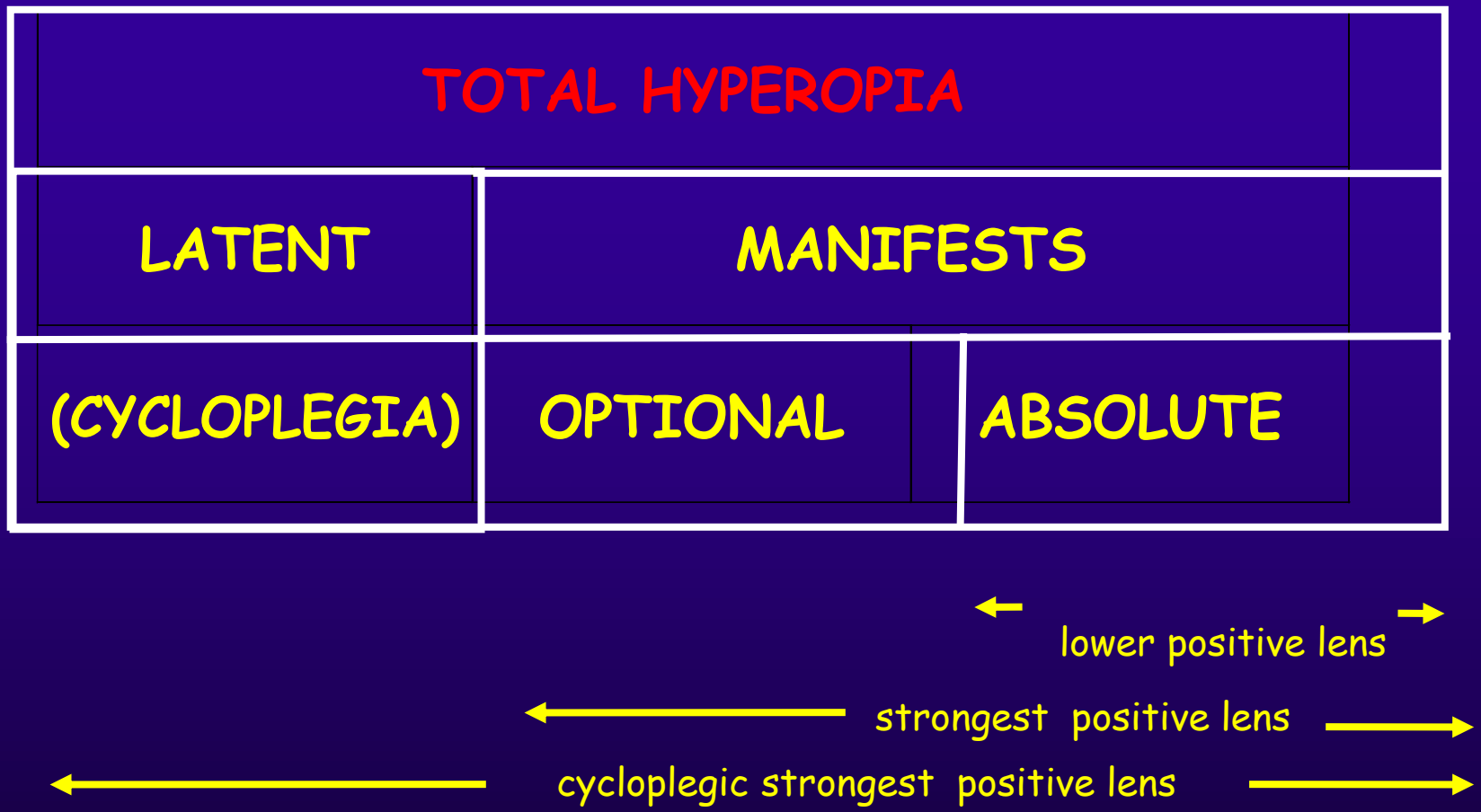
la cornea è meno curva che di norma

1) The more frequent etiology is short eyeball

Every children have physiological hyperopia,
with the growth it happens a gradual reduction of hyperopia.
It disappeared with puberty.
Patients with hyperopia have not a good far and near visual acuity

Hyperopia is most commonly corrected through the use of corrective positive lenses, such as glasses or contact lenses

- ✓ low (< 2 D)
- ✓ moderate (< 4 D)
- ✓ high (> 4 D)



- < 40 ys CYCLOPLEGIC REFRACTION
- > 40 ys MANIFEST REFRACTION (blurring technique)

LATENT HYPEROPIA

As long as the patient is young and mild hyperopia, the subject is able to compensate for this with the accommodation process, which is a physiological compensatory mechanism that permits changing the curvature of the lens to focus images on the retina. Therefore often hyperopic patient remains asymptomatic and hidden for long time

MANIFEST HYPEROPIA

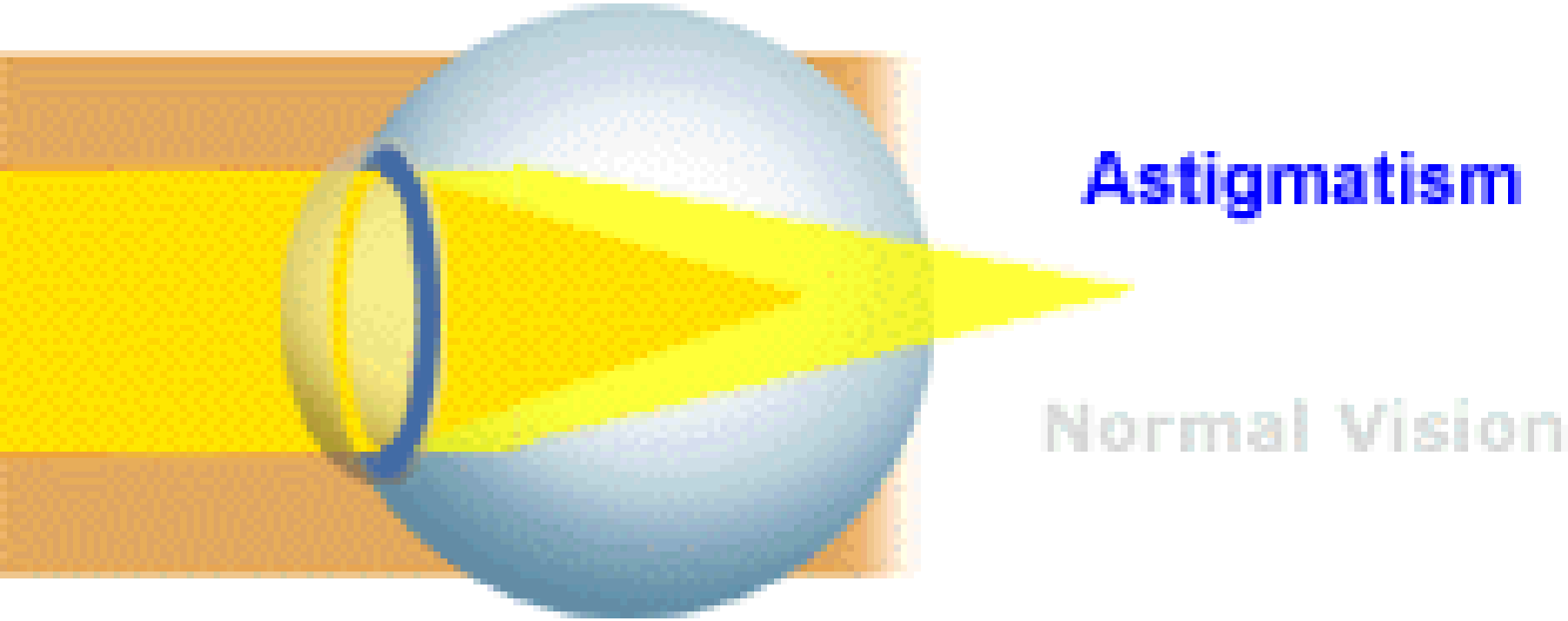
The accomodative effort is very tiring when protracted: hyperopes often do not complain to see bad for distance, but accuse fatigue i.e. when they study.

Very often in this accommodative effort it follows the appearance of eye strain.

Sometimes also convergent strabismus.

ASTIGMATISM

Astigmatism is a refractive defect due to the shape of the cornea than in normal subjects has spherical symmetrical shape, while in astigmatic patients has asymmetrical shape, ellipsoidal, oval.



In the normal eye all meridians have the same refractive power while in astigmatic patients meridians have different refractive power. In other refractive errors a simple object, as a point of light is seen blurred but maintains the shape of a blurry dot. In astigmatism due to non-roundness of the diopter it is unable to identify more than the shape of the dot itself. Astigmatism is indeed a word that comes from the old Greek and means “vision with no dot".

Normal eye

basketball shape

Astigmatic eye

football shape

Astigmatism is linked to an abnormality of curvature of the cornea, rarely the cause is an abnormality of curvature of the lens or even the shape of the sclera.

It is a congenital abnormality that is detected early in life and that remains unchanged over the years.

Astigmatism can however also occur secondary to surgical procedures (cataract, corneal transplantation, retinal detachment, or after ocular trauma).

A minimum astigmatism, less than 0.5 diopter, is considered physiological, and generally does not require a correction.

Astigmatism can be:

- ✓ isolated (simple astigmatism)
- ✓ associated with myopia (compound myopic astigmatism)
- ✓ hyperopia (compound hyperopic astigmatism)
- ✓ both (mixed astigmatism)

This defect is corrected with cylindrical lens positive or negative depending on the case.

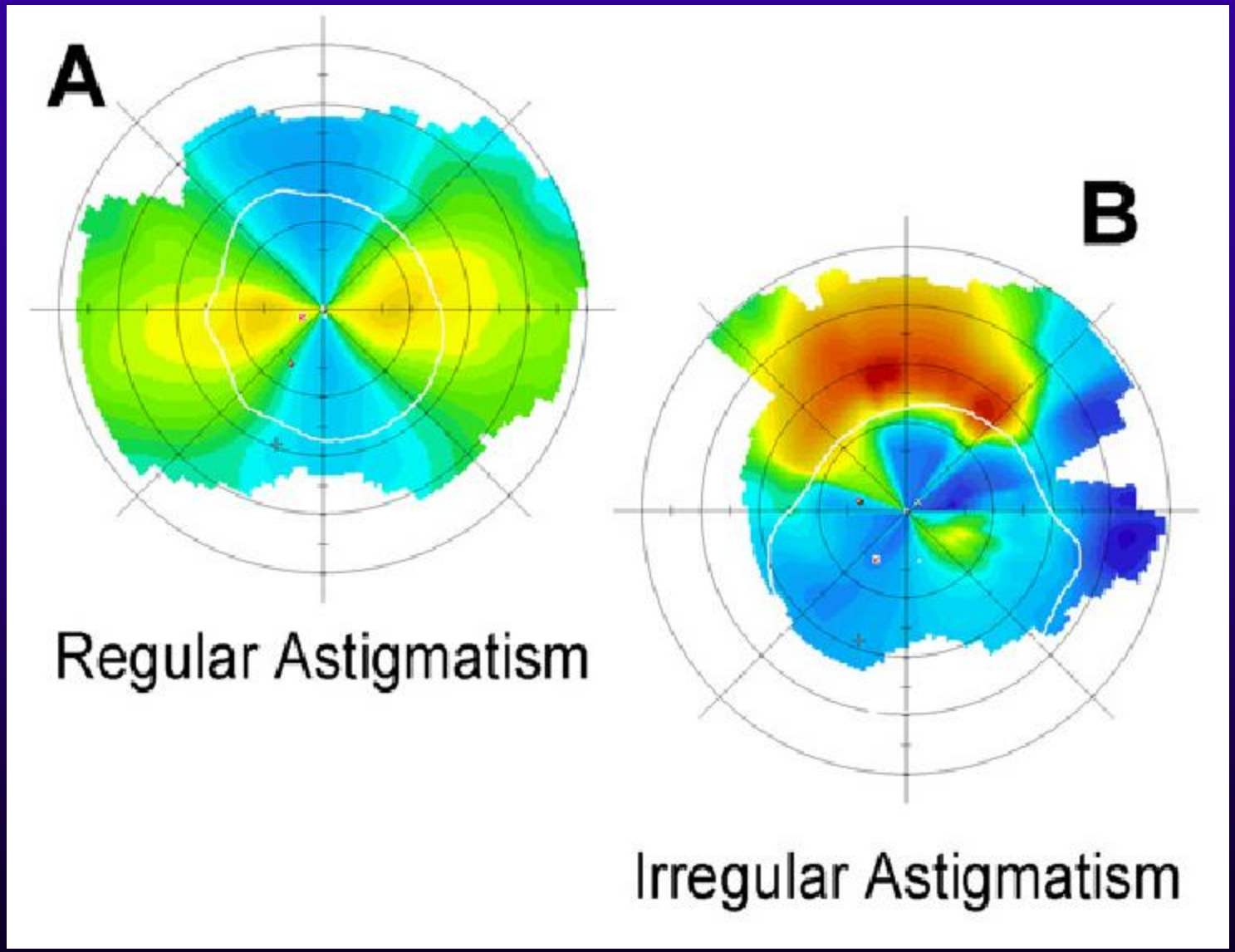
Classification of astigmatism

Regular Astigmatism

1. The two main meridians are perpendicular to each other (90°)

2. Power along each meridian remains constant

Otherwise → **Irregular Astigmatism**

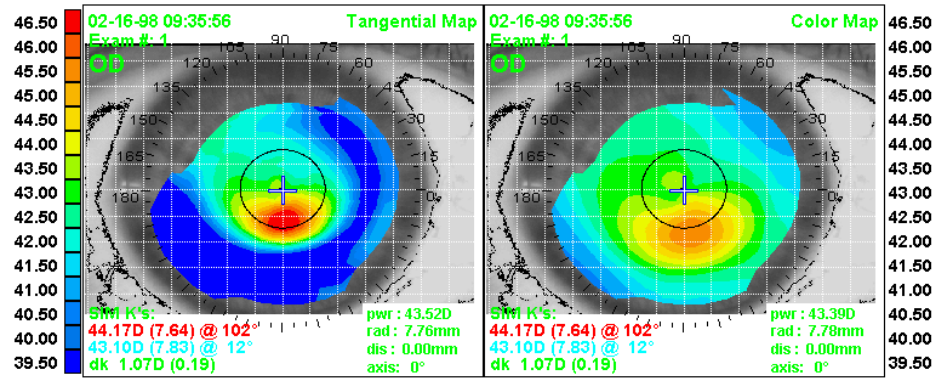

A
B
Regular Astigmatism
Irregular Astigmatism

L'AQUILA UNIVERSITY - EYE CLI

Patient ID: 900072

Dr L Spadea

EyeSys

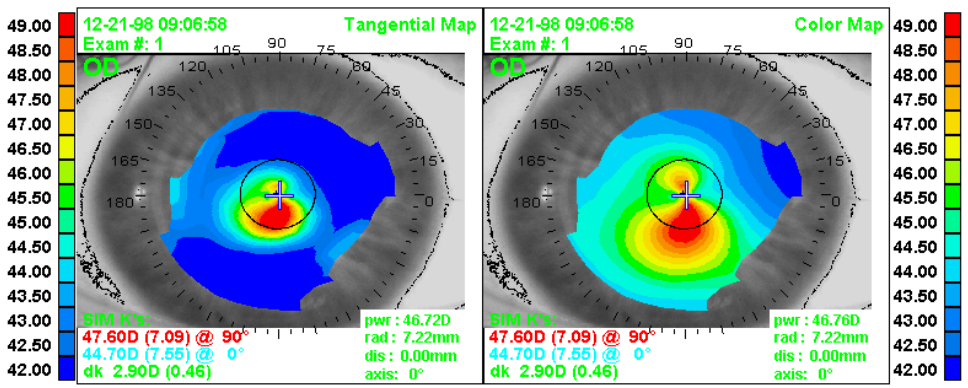


L'AQUILA UNIVERSITY - EYE CLINIC

Patient ID: 220874

Dr L Spadea

EyeSys

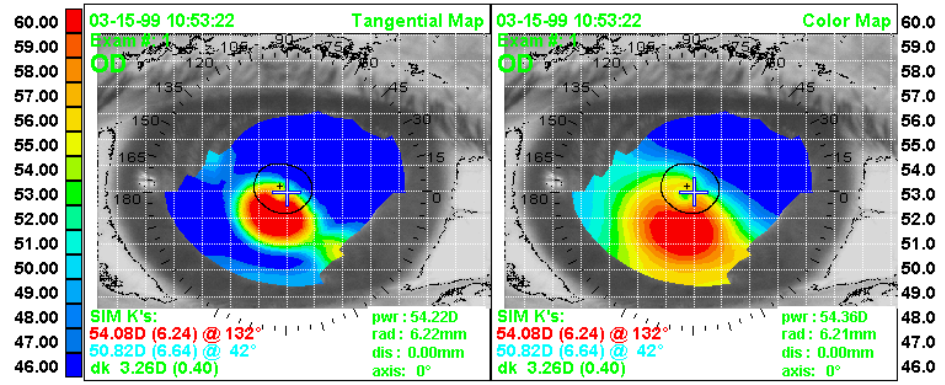


L'AQUILA UNIVERSITY - EYE C

Patient ID: 310563

Dr L Spadea

EyeSys



Pre-Op

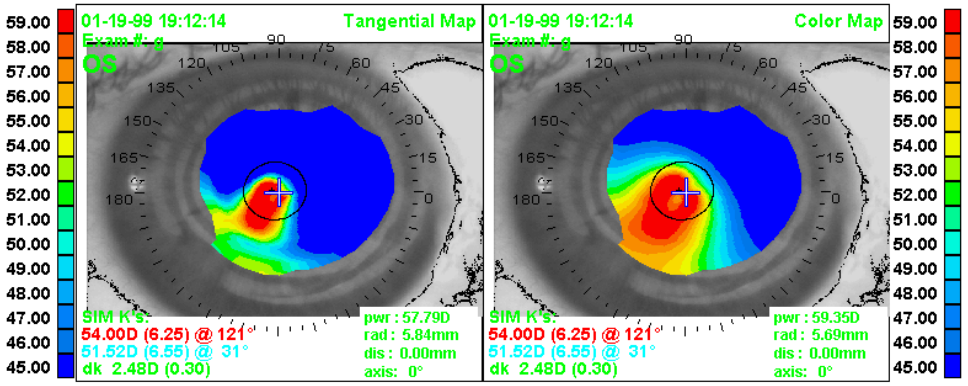
Pre-Op

L'AQUILA UNIVERSITY - EYE CLINIC

Patient ID: 110547

Dr L Spadea

EyeSys



Pre-Op PK

Pre-Op PK

OCULUS - KERATOGRAFO — Dr. Leopoldo Spadea

Paziente Esame Visualizza Lenti a contatto Impostazioni Varie Stampa

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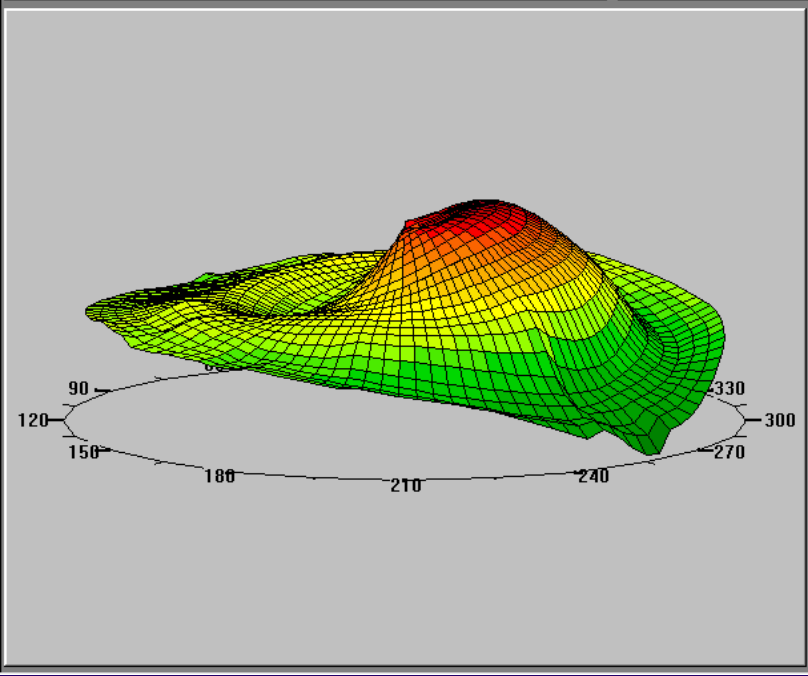

Amplificazione - +

Movimento Lento Veloce Ampio Stretto

Inclina Ruota

Rotazione 0

72.0 70.0 68.0 66.0 64.0 62.0 60.0 58.0 56.0 54.0 52.0 50.0 48.0 46.0 44.0 42.0 40.0 38.0 36.0 34.0 32.0 30.0 28.0 26.0 24.0 22.0 20.0 18.0 16.0 14.0 12.0 1.00D Tangen. Relativ

TOGRAFO — Dr. Leopoldo Spadea

alizza Lenti a contatto Impostazioni Varie Stampa

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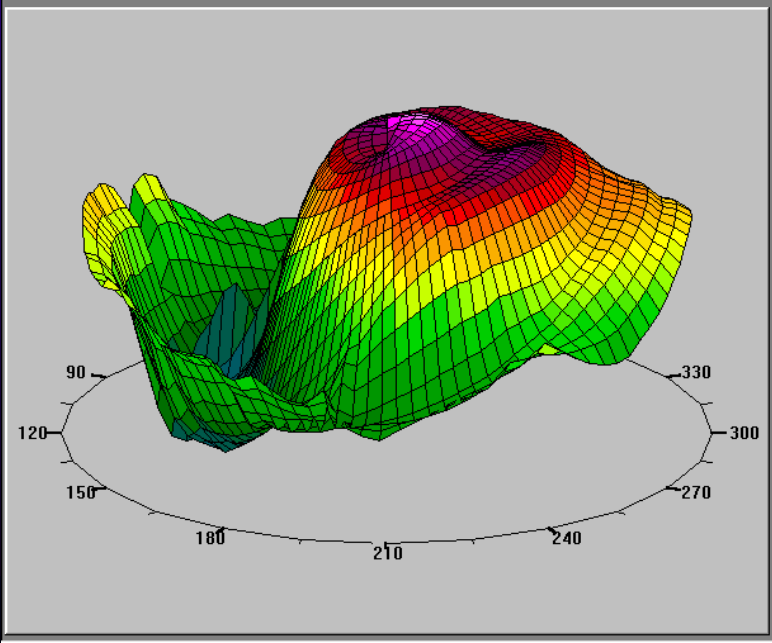

Amplificazione - +

Movimento Lento Veloce Ampio Stretto

Inclina Ruota

Rotazione 0

73.0 71.0 69.0 67.0 65.0 63.0 61.0 59.0 57.0 55.0 53.0 51.0 49.0 47.0 45.0 43.0 41.0 39.0 37.0 35.0 33.0 31.0 29.0 27.0 25.0 23.0 21.0 19.0 17.0 15.0 13.0 1.00D Tangen. Relativ

Patient ID: 080347

EyeSys

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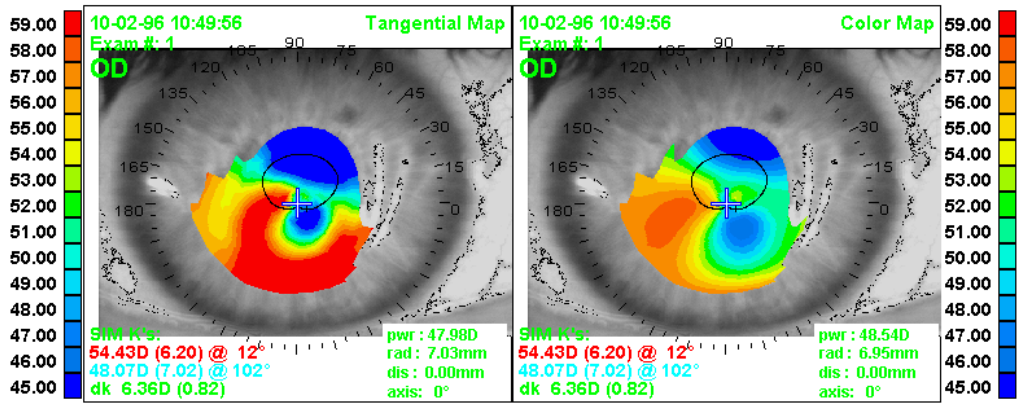
Dr. L. Spadea



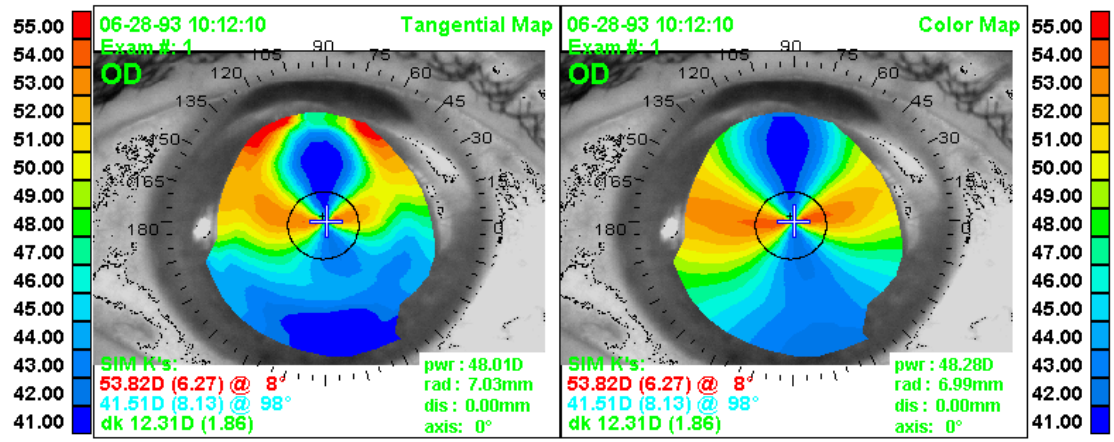
Degenerazione marginale pellucida

Patient ID: 220228

EyeSys

L'AQUILA UNIVERSITY - EYE CLINIC

Dr. L. Spadea



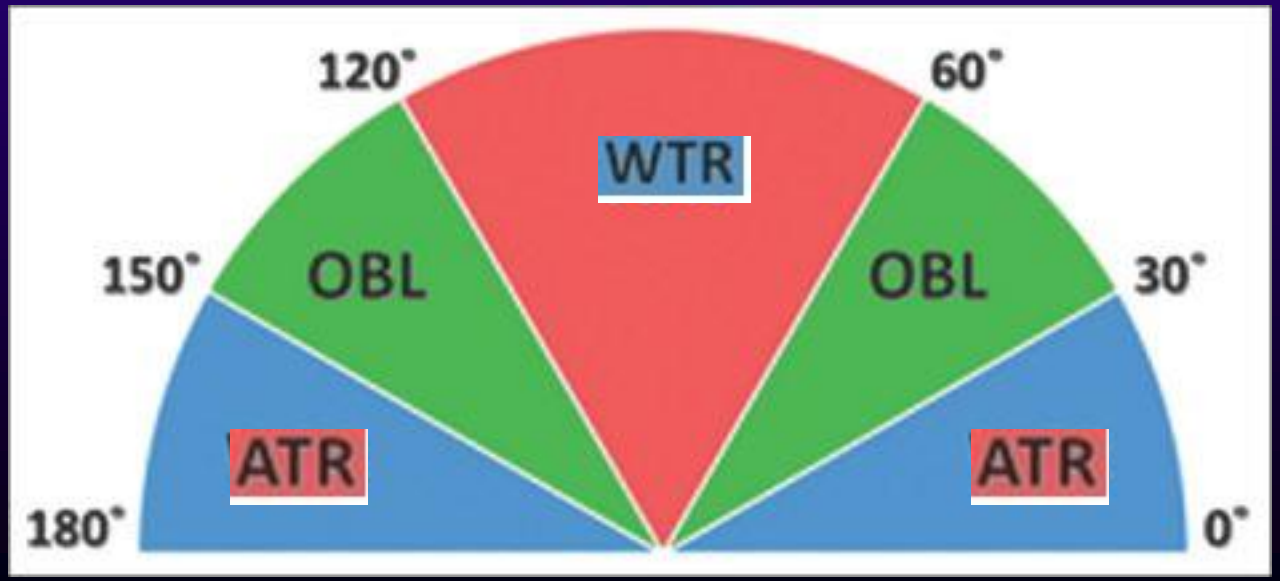
Degenerazione marginale di Terrien

Classification of astigmatism

With the rule astigmatism (WTR)

Against the rule astigmatism (ATR)

Oblique astigmatism (OBL)



ANISOMETROPIA

The anisometropia is a fairly frequent condition in which there is a difference in the refractive power of the two eyes.

Combinations:

- ✓ A normal eye and the other one myopic or hyperopic,
- ✓ both hyperopic,
- ✓ both myopic,
- ✓ one myopic and one hyperopic (antimetropia)

When the difference is more than 3-4 diopters, the different power of the lenses of the glasses produces the perception of images of different size of the two eyes in the brain causing problems in binocular vision. **(aniseiconia)**

The brain receives the images that come from the two eyes: one more confusing, less clear (from the eye with major defect) is deleted (suppression) to promote the perception of the sharp images provided by eye with lower refractive defect.

In the long period time this mechanism do not utilizes the eye with worst images making it lazy.

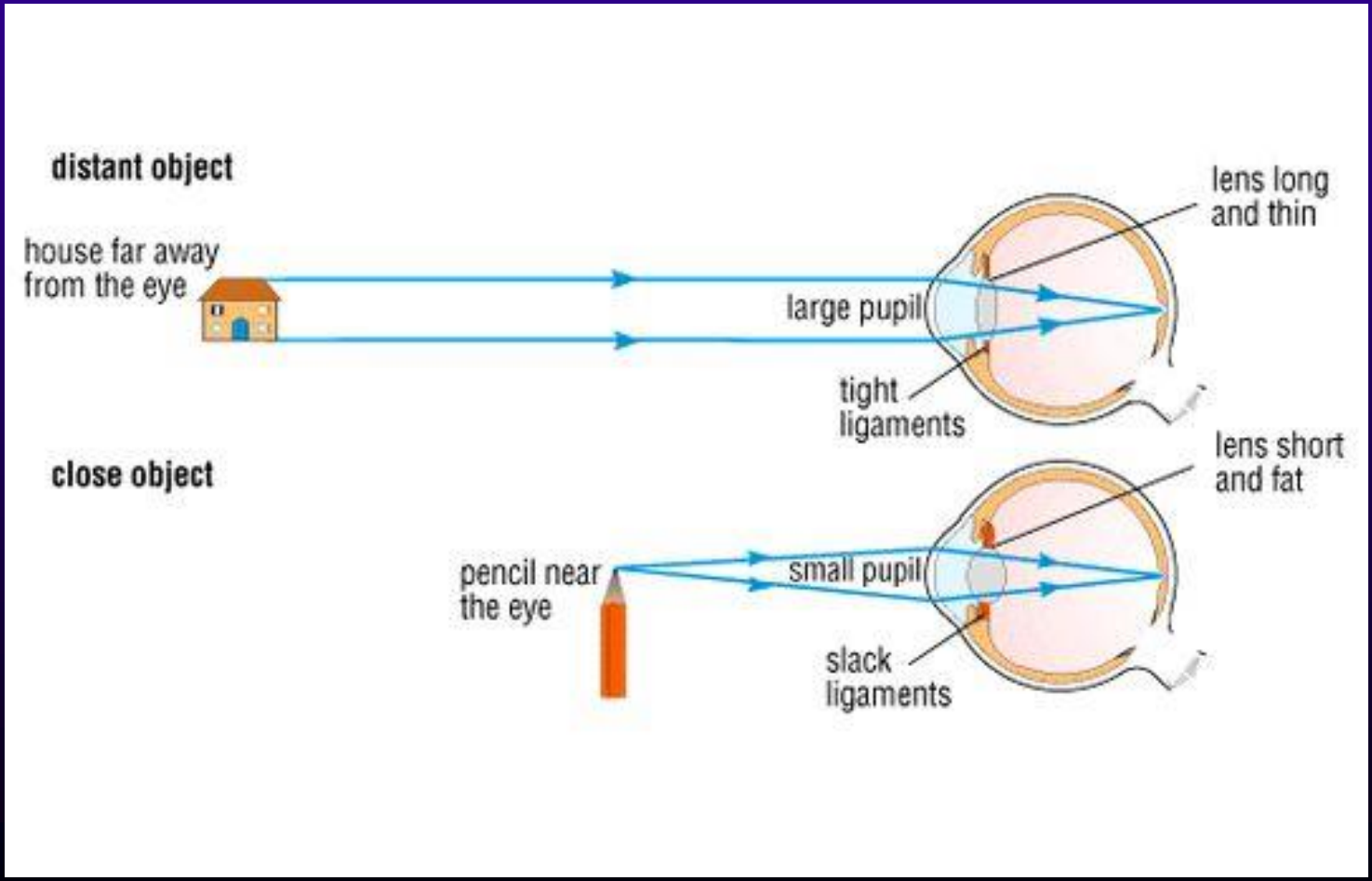
Amblyopia → Often the amblyopic eye, not used, is diverted (strabismus)

Children can tolerate lenses with different power on both eyes while adults can tolerate at most a difference correction between the two eyes of 2-3 diopters.
Therefore is more indicated the correction by contact lenses

PRESBYOPIA

Presbyopia is an accommodation disorder secondary to the physiological reduction of the ability to focus, with resulting difficulty in visual activities to close.
The child emmetropic focuses
to 7 centimeters.
The young adult emmetrope
than 10-14 cm.
The subject of 60 years at 1 meter.

The accommodation is the main mechanism that allows to focus on the retina objects placed between the remote point and the near point



The nervous reflex mechanism that allows the normal activation of this feature include:

afferent way (sensory fibers)

efferent way (parasympathetic)

effectory muscle (ciliary muscle "Rouget-Muller")

The accommodation is accompanied by two reflections dyskinetic:

- ✓ Convergence
- ✓ Miosis

Ophthal. Physiol. Opt. 2007 **27:** 342–352

Age-related changes in static accommodation and accommodative miosis

Hema Radhakrishnan and W. Neil Charman

The amplitude of accommodation (*A*) is measured in diopters and represents the difference between the near point (P) and the remote point (R):

$$A = P - R$$

2 factors determine the accommodative amplitude:

- ✓ Refraction (remote point)
- ✓ Near point

If the eye is emmetropic the next point is equal to the accommodative amplitude

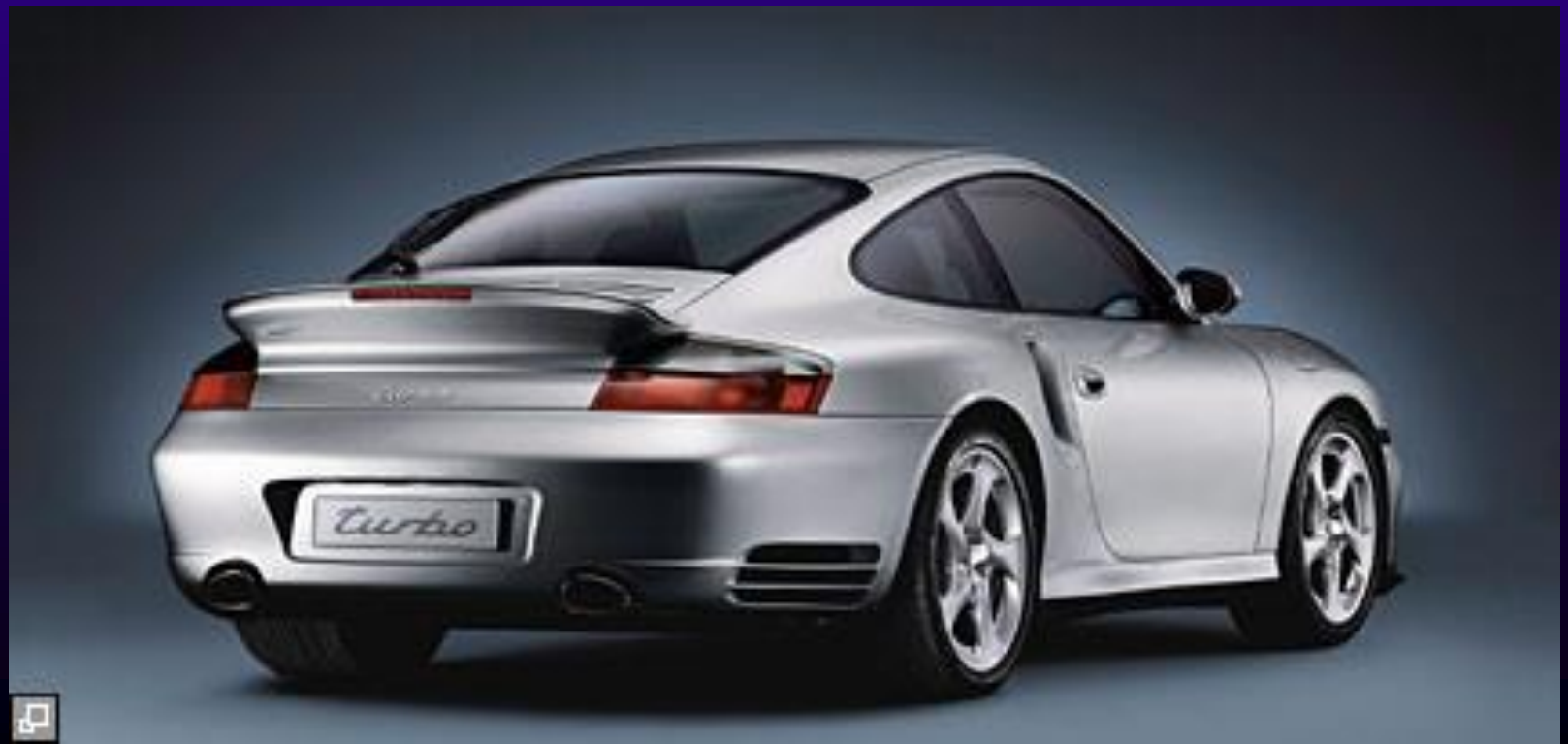
The accommodative amplitude decreases with age:

- ✓ 10 years = 14D
- ✓ 65 years= 0
- ✓ 45 years = 4D ➡ near point close to 25 cm. At this age, for comfortable reading at 33 cm, the individual needs a lens +1 D, it is called presbyopic

The speed of accommodation, about 0.5"

from distance to near vision,

decreases with age



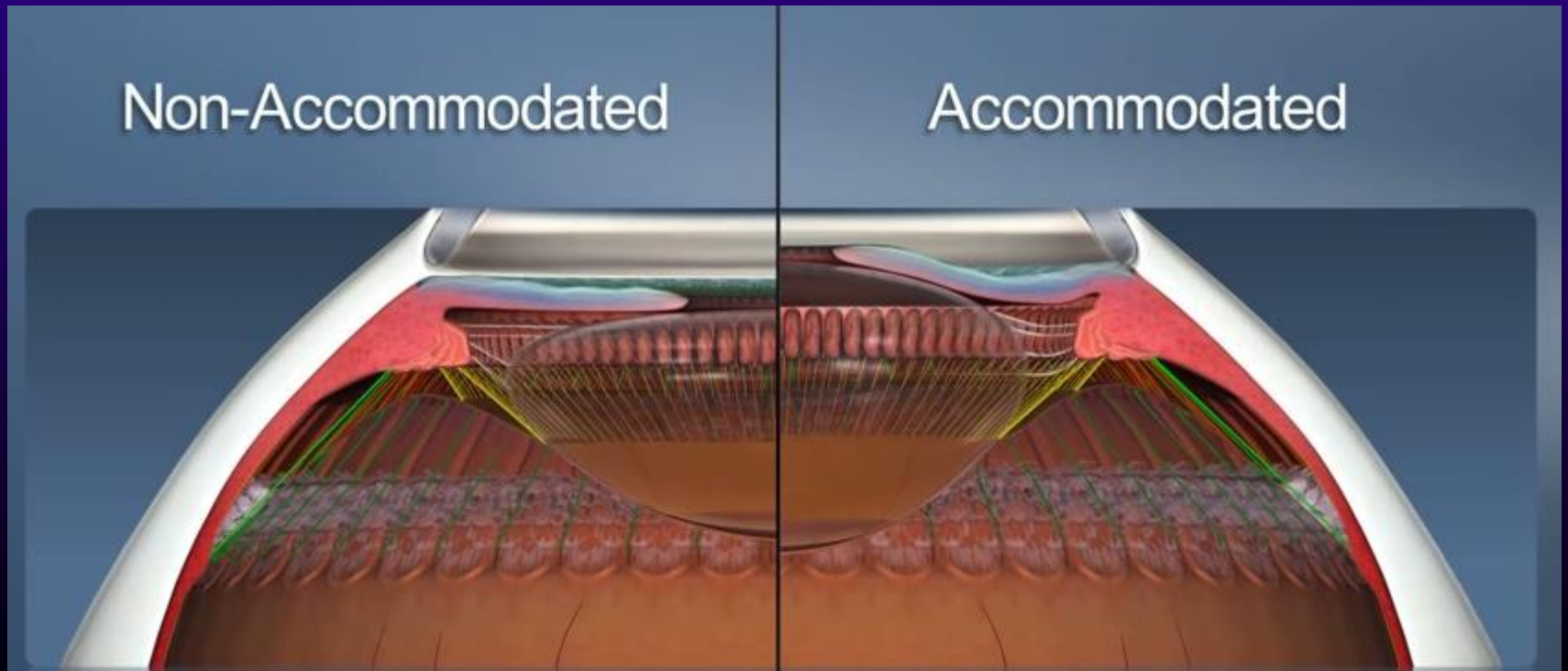
Pathology of accommodation

- Astenopy
- Accommodative deficiency
- Paralysis or paresis
- Spasm (hypertonic ciliary muscle)
- Presbyopia

The changes of accommodation can be linked to:

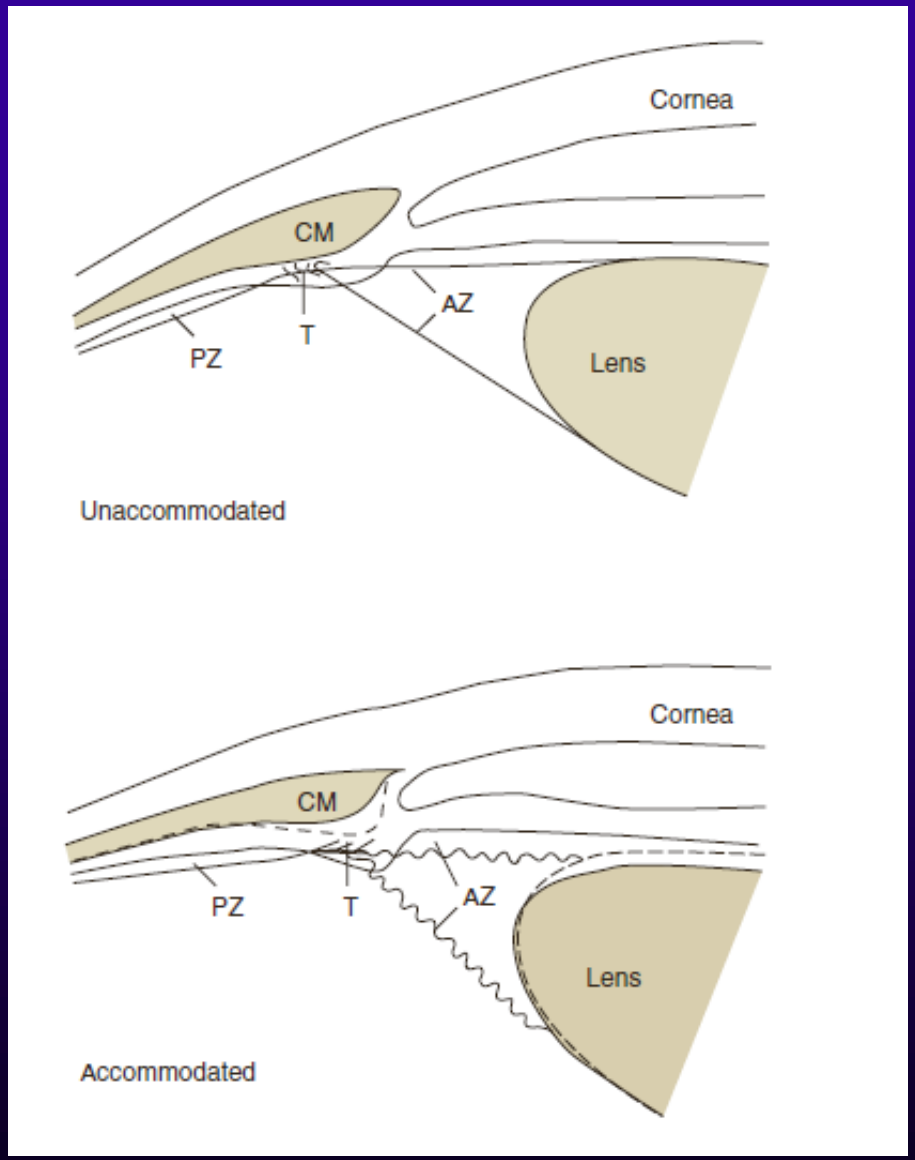
- ✓ disorders of innervation
- ✓ drug and toxic
- ✓ eye disorders (anterior uveitis)
- ✓ pathologies of lens or ciliary muscle
- ✓ refractive defects (anisometropia)
- ✓ environmental causes (lighting)

The dynamics of the accommodative function is still under investigation, as some phenomena alone do not justify all the events

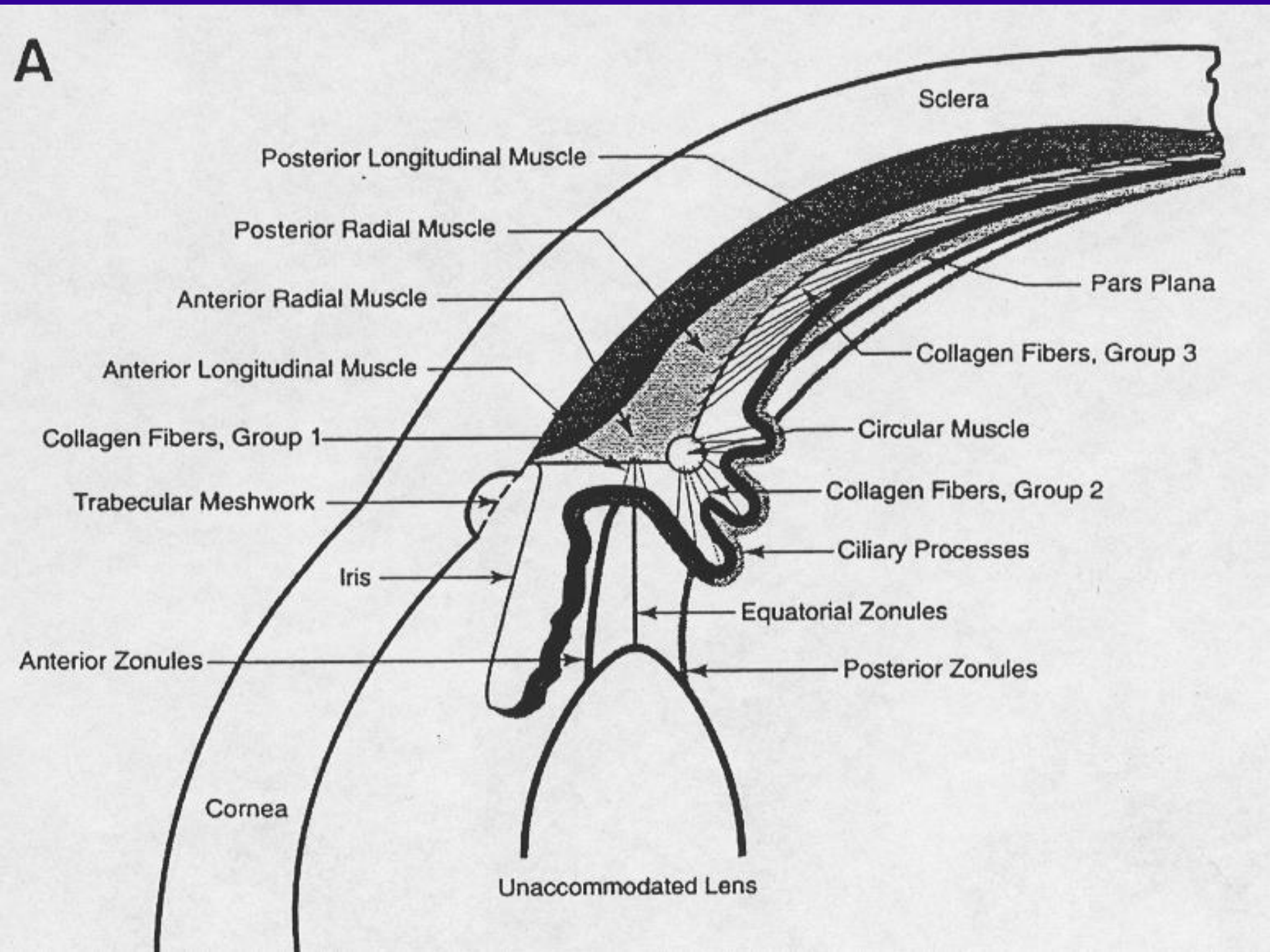


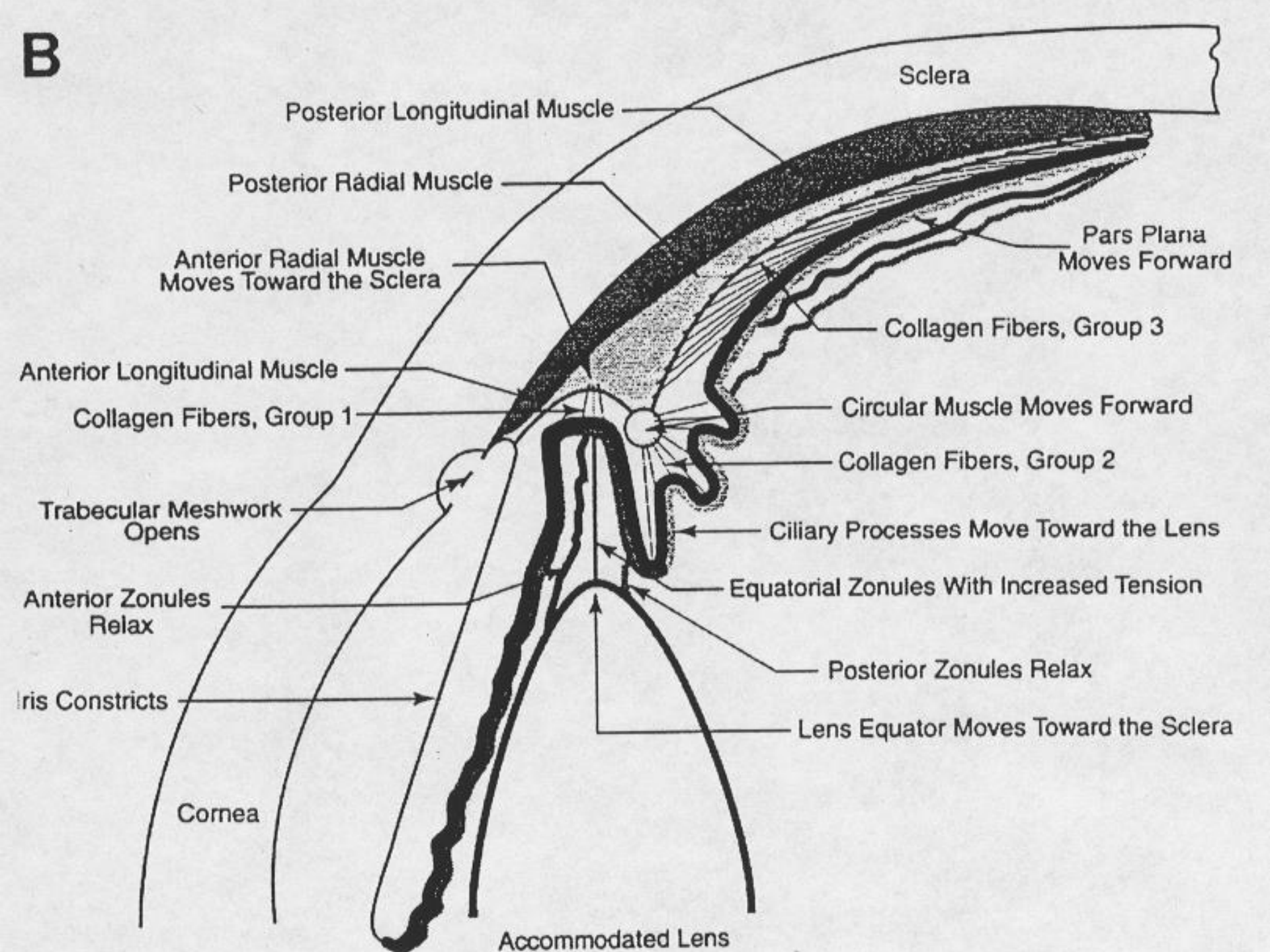
In the past many errors were made, such as the action of the extrinsic muscles, the change of curvature of the cornea, the elongation of the eyeball, the exclusive action of the pupillary miosis

Helmholtz (1855) exposes the first thesis about of accommodation explaining how the change of the radius of curvature of the lens is due to the relaxation of the zonule consequent to the contraction of the ciliary muscle


Cornea
CM
AZ
T
PZ
Lens
Unaccommodated
Cornea
CM
PZ
T
AZ
Lens
Accommodated

Tshering (1898) opposing Helmholtz introduced the possibility of a traction zonular which results in an equatorial flattening and a central steepening

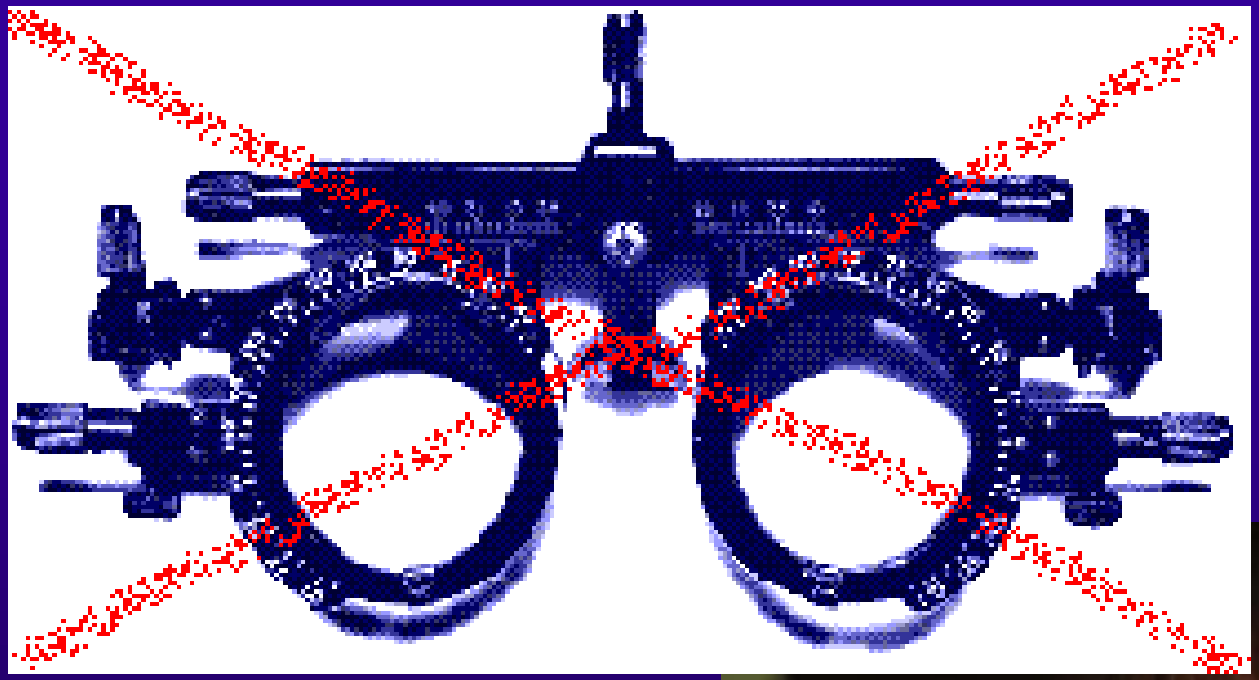

A
Sclera
Posterior Longitudinal Muscle
Posterior Radial Muscle
Anterior Radial Muscle
Anterior Longitudinal Muscle
Collagen Fibers, Group 1
Trabecular Meshwork
Iris
Anterior Zonules
Cornea
Pars Plana
Collagen Fibers, Group 3
Circular Muscle
Collagen Fibers, Group 2
Ciliary Processes
Equatorial Zonules
Posterior Zonules
Unaccommodated Lens

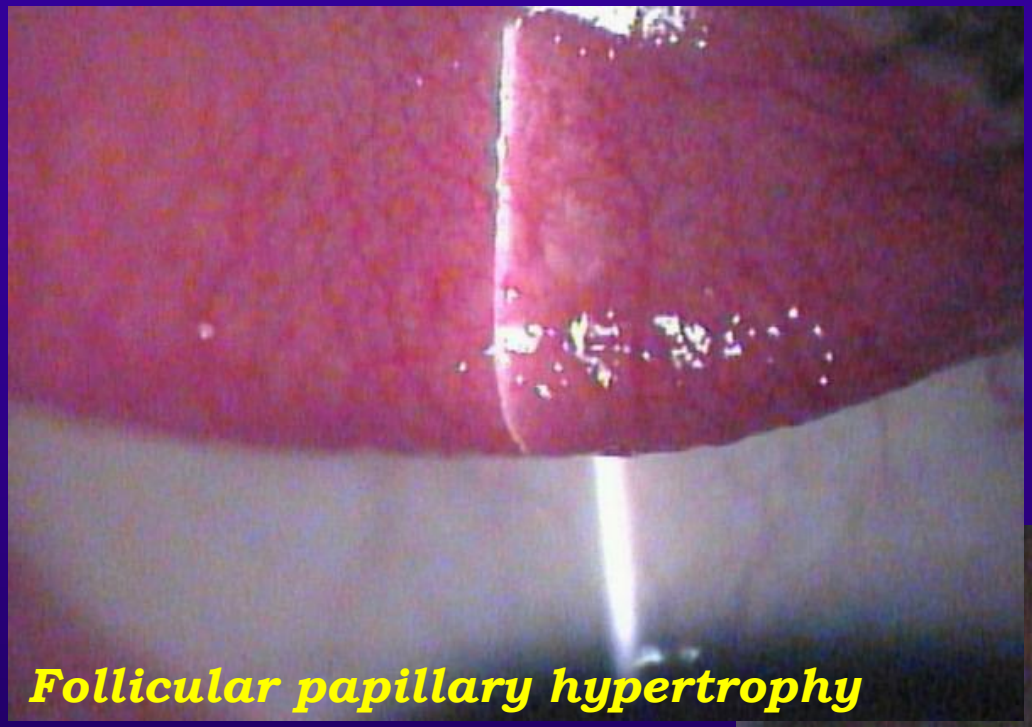

B
Sclera
Posterior Longitudinal Muscle
Posterior Rádial Muscle
Anterior Radial Muscle
Moves Toward the Sclera
Pars Plana
Moves Forward
Collagen Fibers, Group 3
Anterior Longitudinal Muscle
Collagen Fibers, Group 1
Circular Muscle Moves Forward
Collagen Fibers, Group 2
Trabecular Meshwork
Opens
Ciliary Processes Move Toward the Lens
Anterior Zonules
Relax
Equatorial Zonules With Increased Tension
Posterior Zonules Relax
ris Constricts
Lens Equator Moves Toward the Sclera
Cornea
Accommodated Lens

Presbyopia is corrected by convergent (positive) lenses in subjects emmetropes.

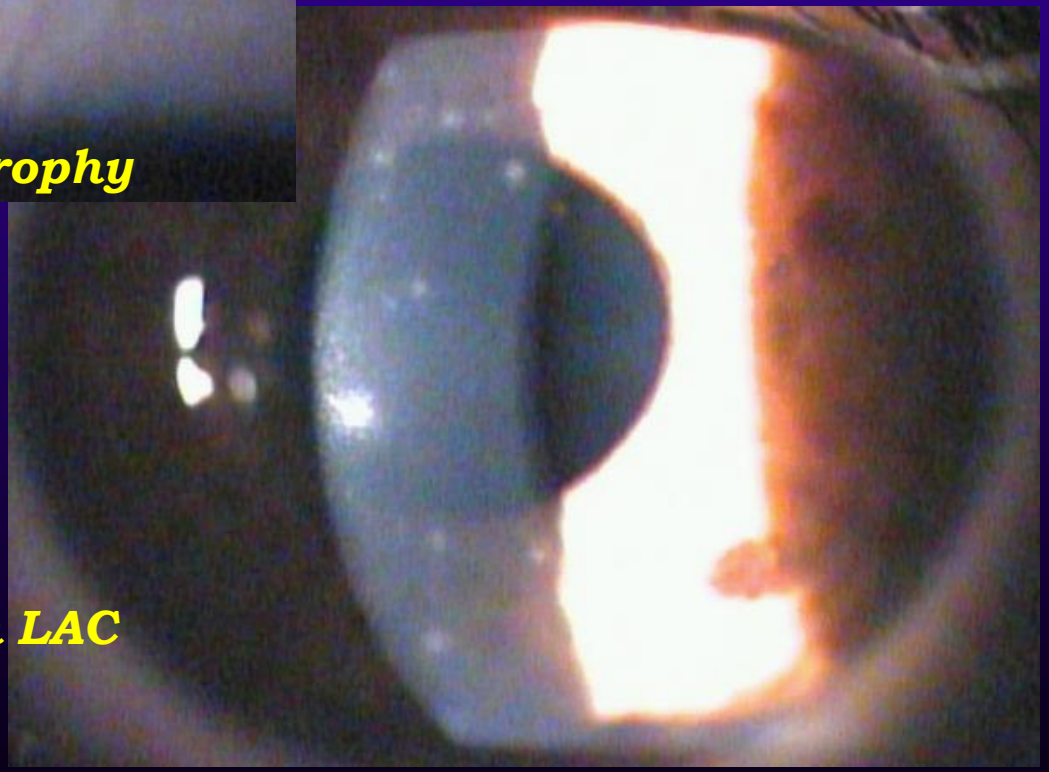
In hyperopic correction amount for presbyopia is in addition to the value of the lens for distance;

in myopic patients presbyopia correction must be subtracted from the value of the lens used for far vision





Follicular papillary hypertrophy



Corneal infiltrates from LAC

PATIENT SELECTION

INDICATIONS

- ✓ Age >20 years
- ✓ Refractive stability at least 2 years
- ✓ Sphere-equivalent range

8 -10D myopia

3-5D hyperopia

absolute contraindications

- ✓exophthalmos
- ✓corneal diseases inflammatory / infectious
- ✓ectatic disorders

REASON FOR CAUTION IN PRK/LASIK

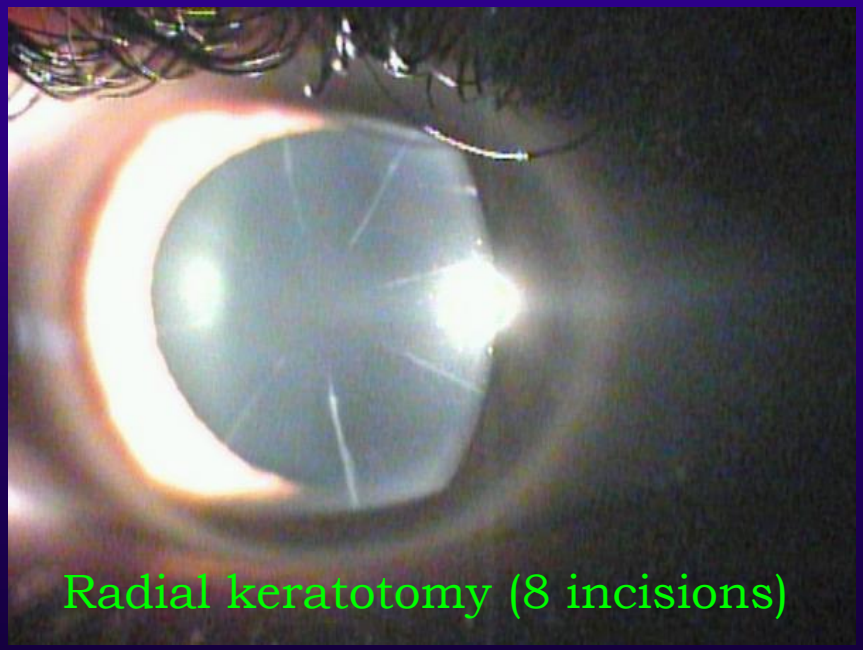
AMERICAN ACADEMY OF OPHTHALMOLOGY
The Eye M.D. Association

- ✓ *Autoimmune diseases (ex: Rheumatoid arthritis, Sjogrens syndrome, Lupus, scleroderma)*
- ✓ *Diabetes*
- ✓ *Immune deficiencies (ex: HIV/AIDS, history of an organ transplant, undergoing chemotherapy for cancer, taking oral corticosteroids)*
- ✓ *Personal or family history of corneal diseases, such as Keratoconus or Pellucid Marginal Degeneration*
- ✓ *History of Herpes Simplex or Zoster eye infections.*
- ✓ *History of other eye diseases (Glaucoma, Fuchs Dystrophy, Macular degeneration, Cataract, Amblyopia or lazy eye)*
- ✓ *Pregnancy or Nursing*
- ✓ *Certain medications: Accutane® (isotretinoin), Cordarone® (amiodarone)*
- ✓ *Dry Eyes*

radial keratotomy (4 incisions)

Incisional surgery

Incisions in the cornea involves a modification of its curvature: the execution of each incision leads to the formation of an area of flattening



Radial keratotomy (8 incisions)

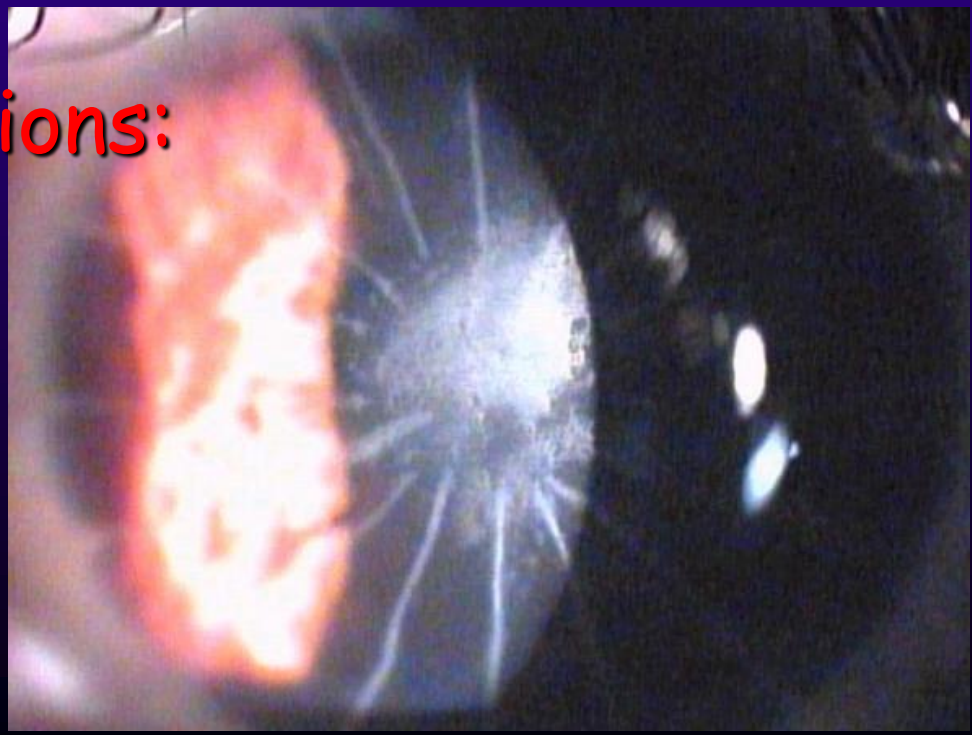
Incisional surgery

Perioperative complications:

- micro-perforations (incidence: 2.3-7.4%)
- macro-perforations (incidence: 0.2%)

Refractive complications:

- hypo / hypercorrections
- regression
- decentrations
- small optic zones

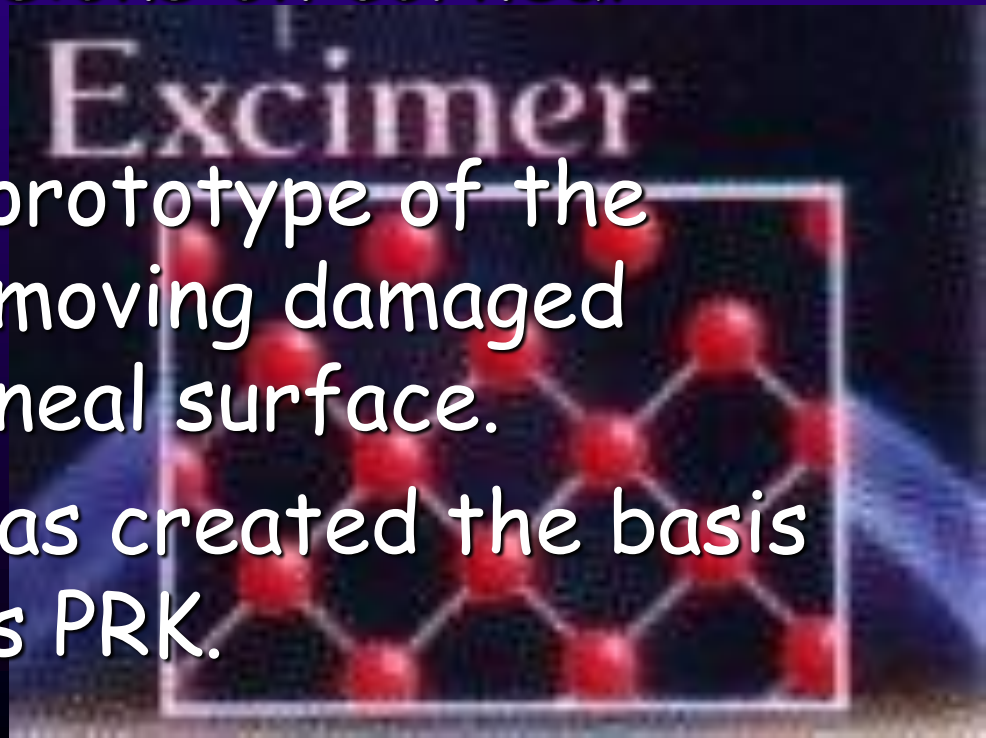


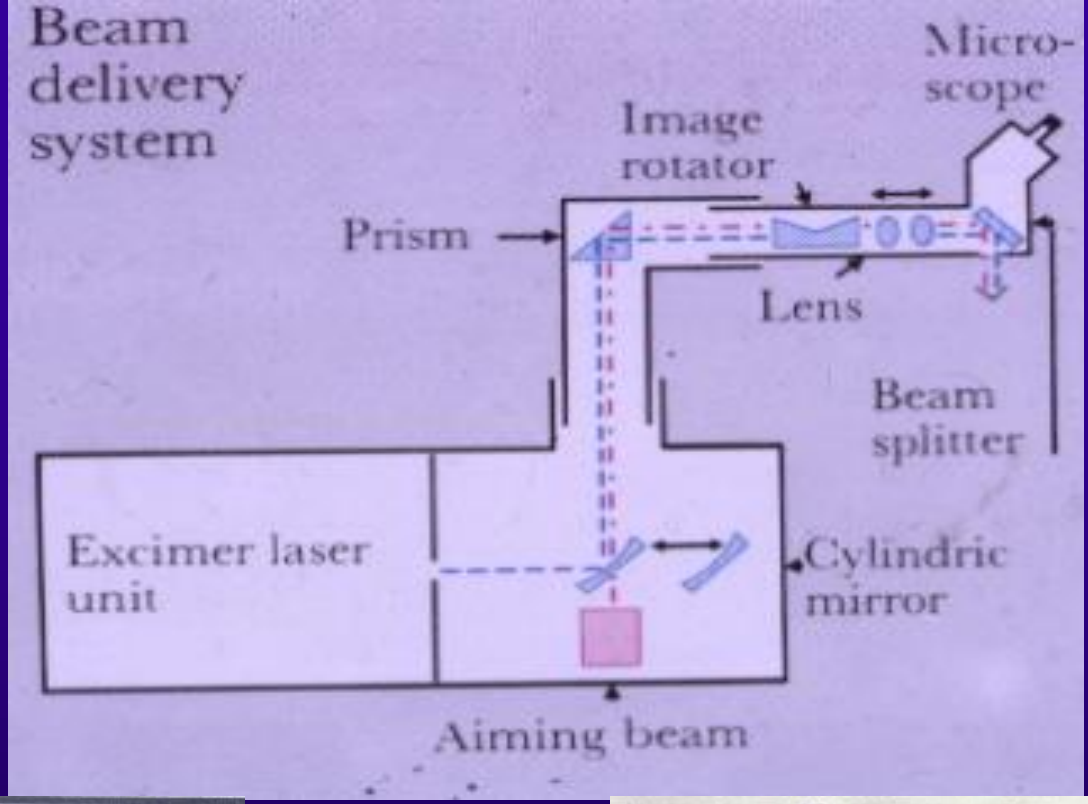
EXCIMER LASER

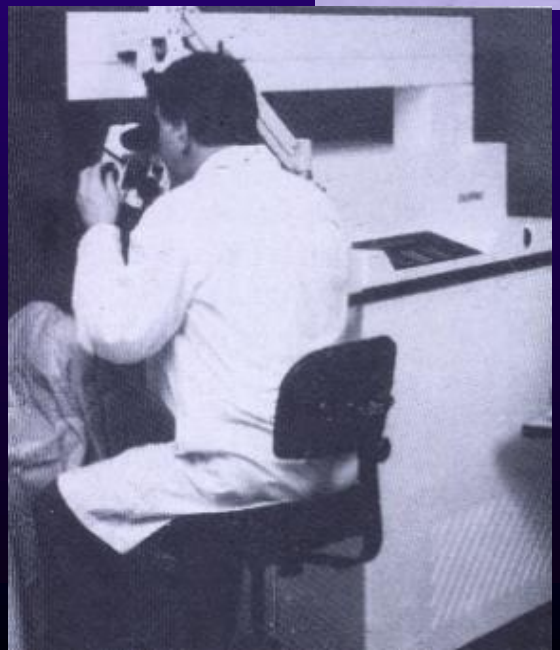
1983: Trokel has realized that an intense laser light could be used not only for engraving on plastic materials, but also to create radial incisions on corneal stroma.

1986 Seiler used a prototype of the excimer laser by removing damaged tissue from the corneal surface.

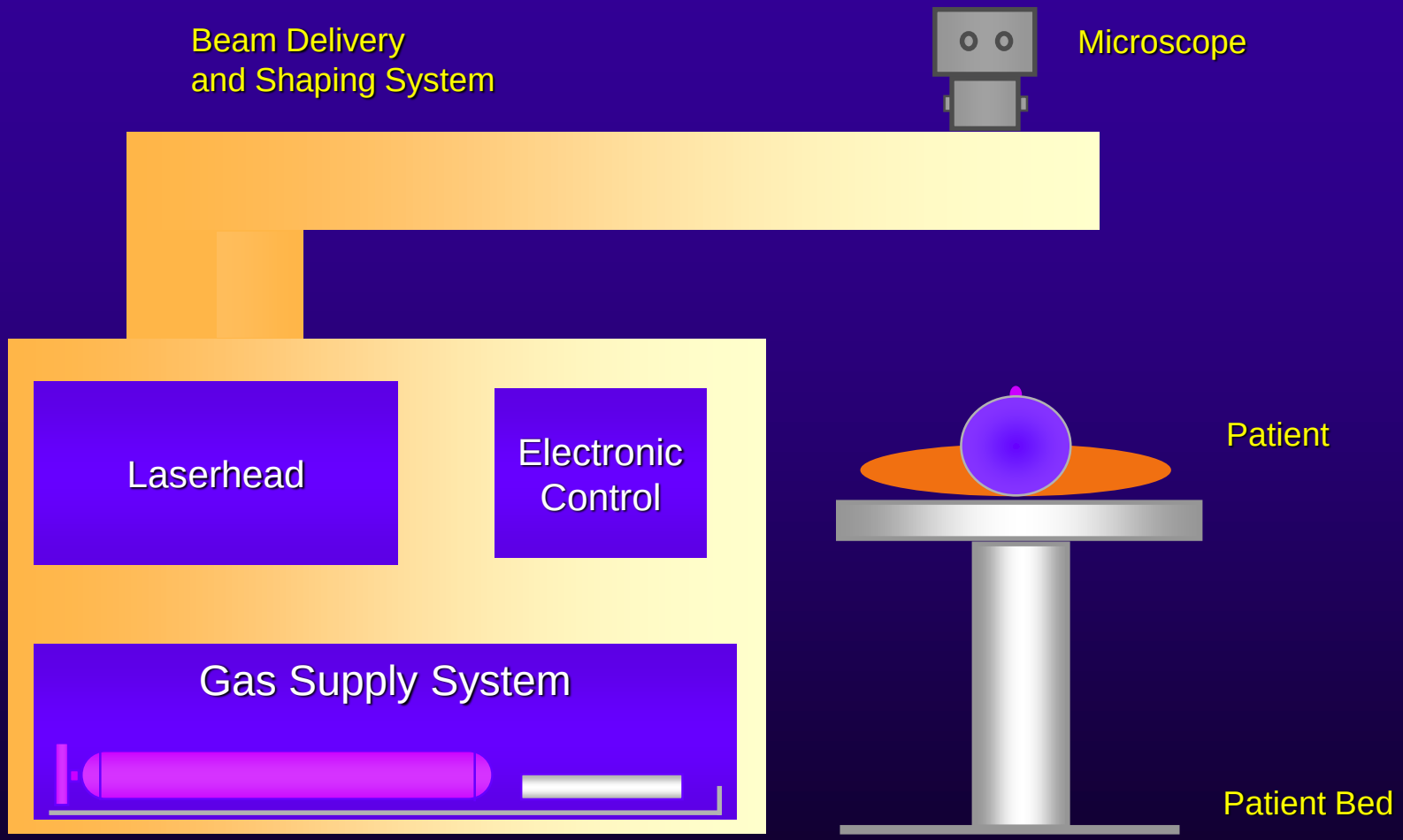
1988: McDonald's has created the basis for what is known as PRK.



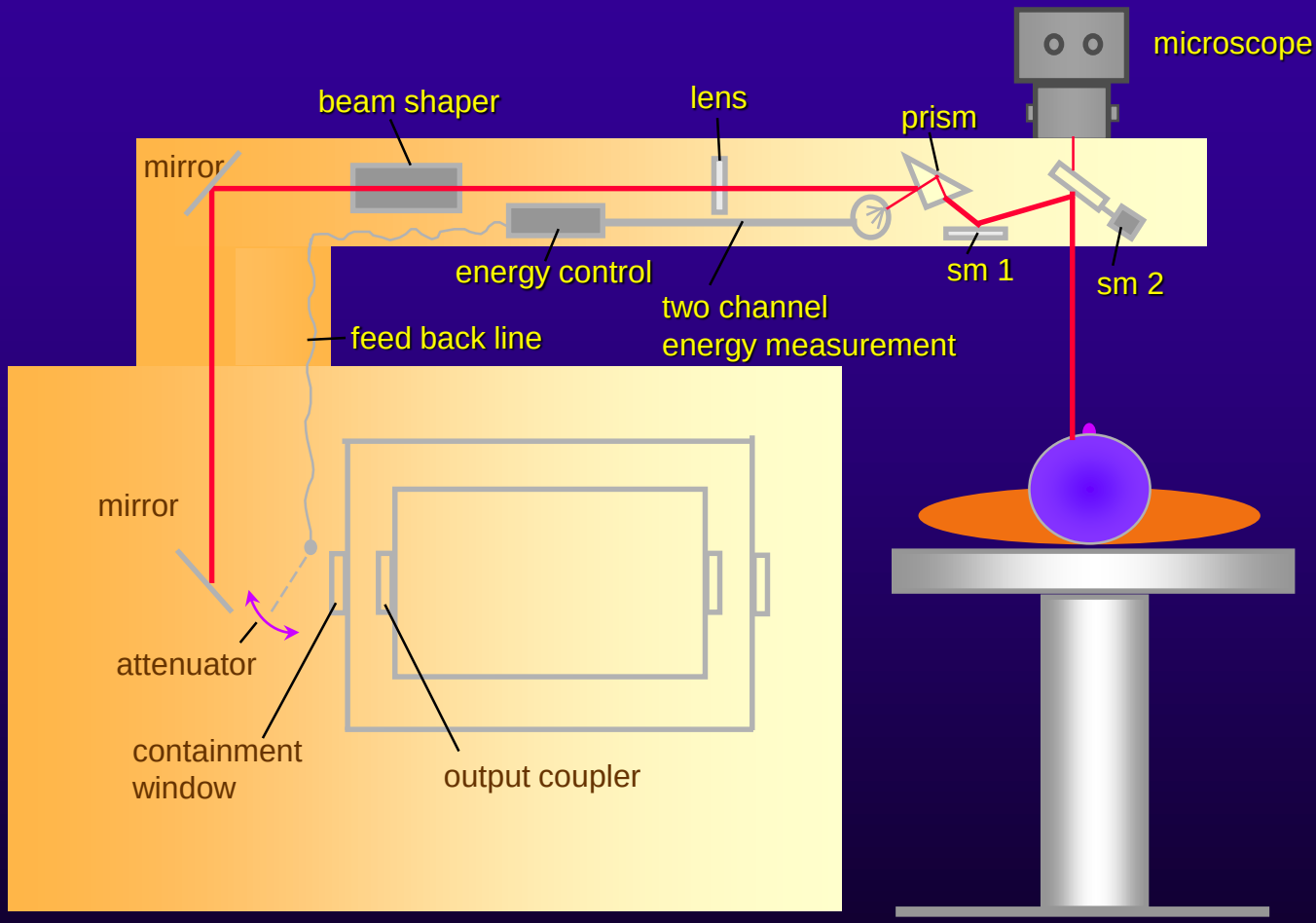

Beam delivery system
Micro-scope
Image rotator
Prism
Lens
Beam splitter
Excimer laser unit
Cylindric mirror
Aiming beam



Basic Components of an Excimer Laser



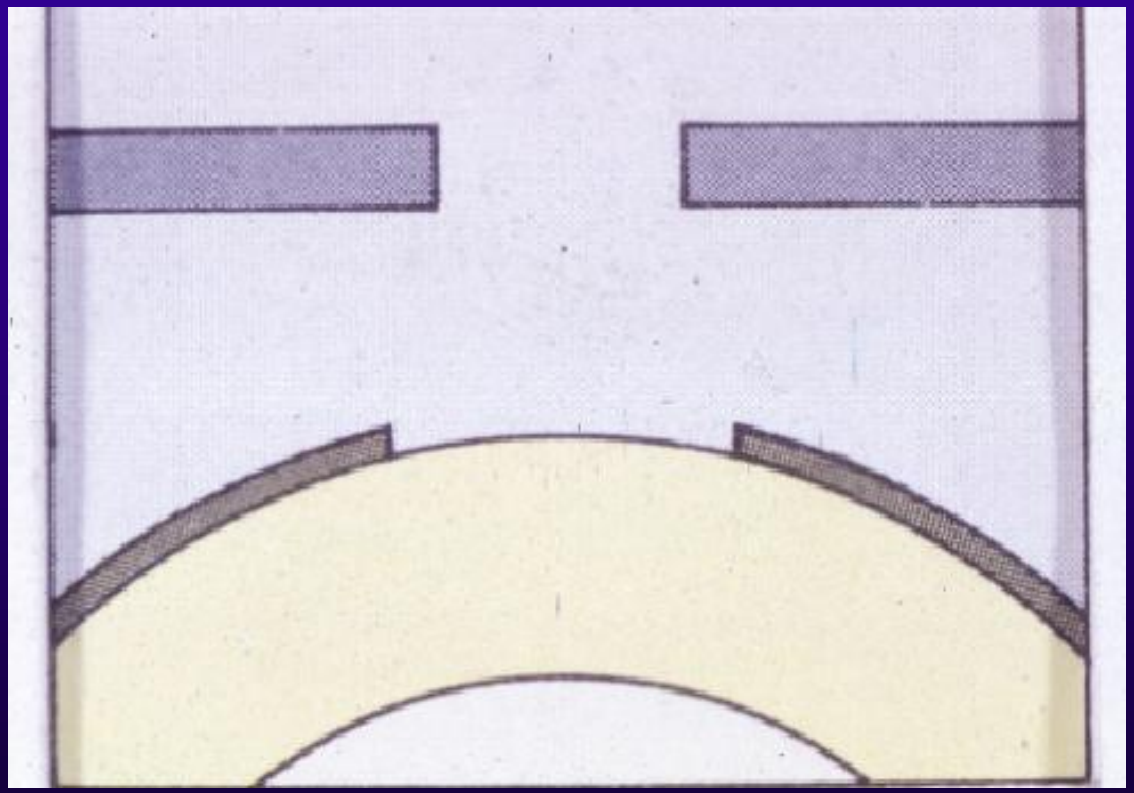
Optical System of an Excimer Laser

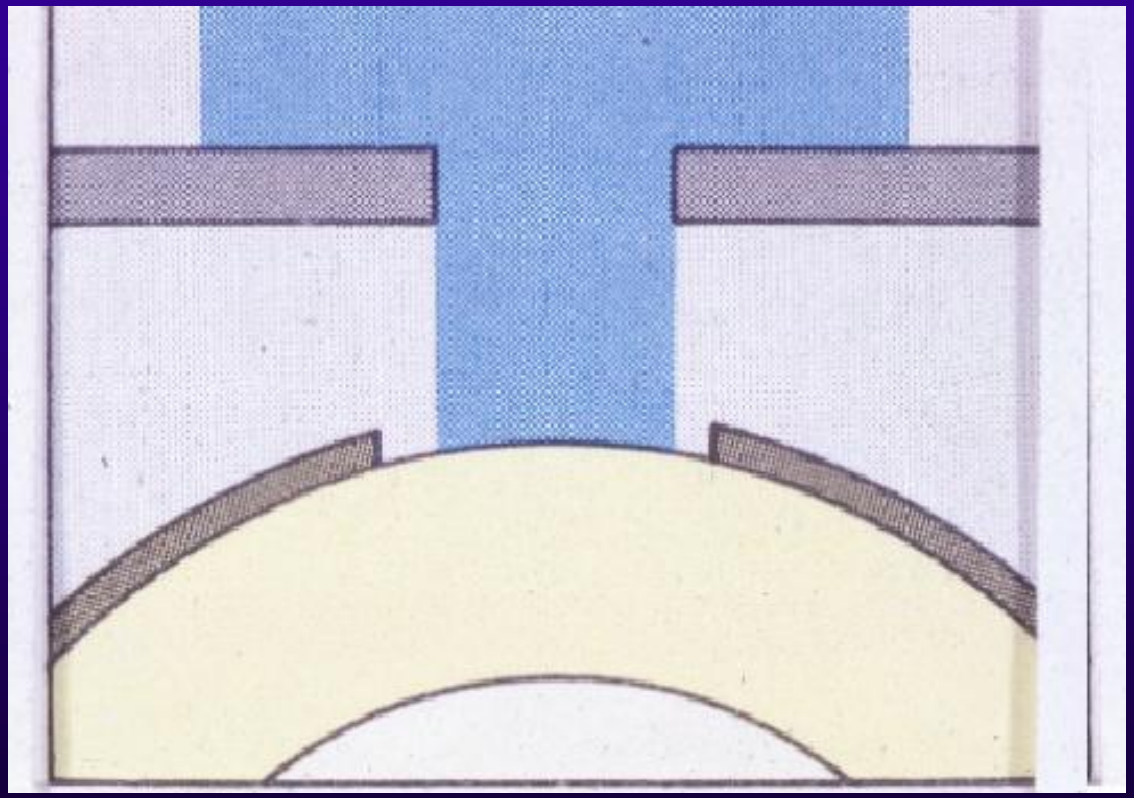


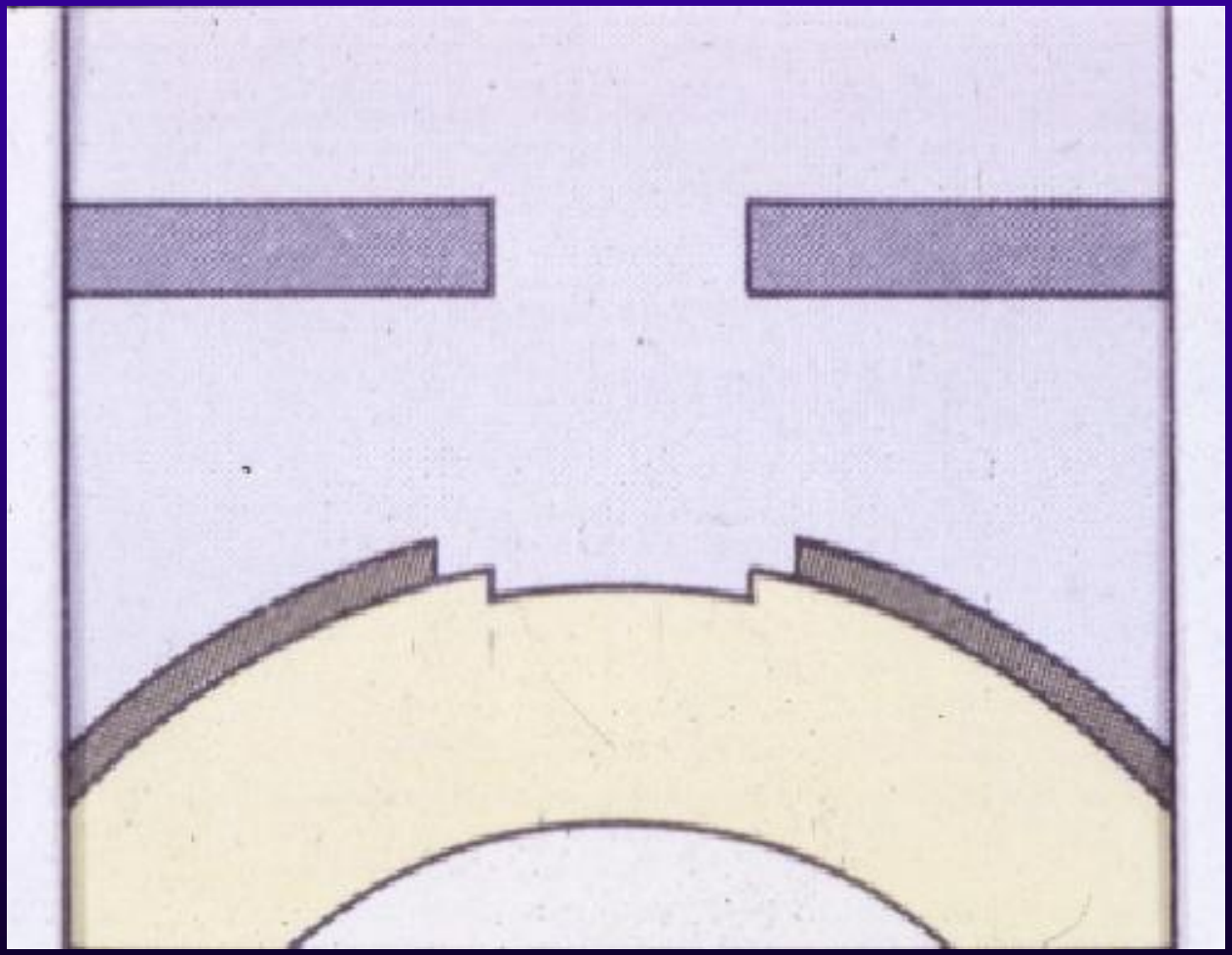

MEL 70

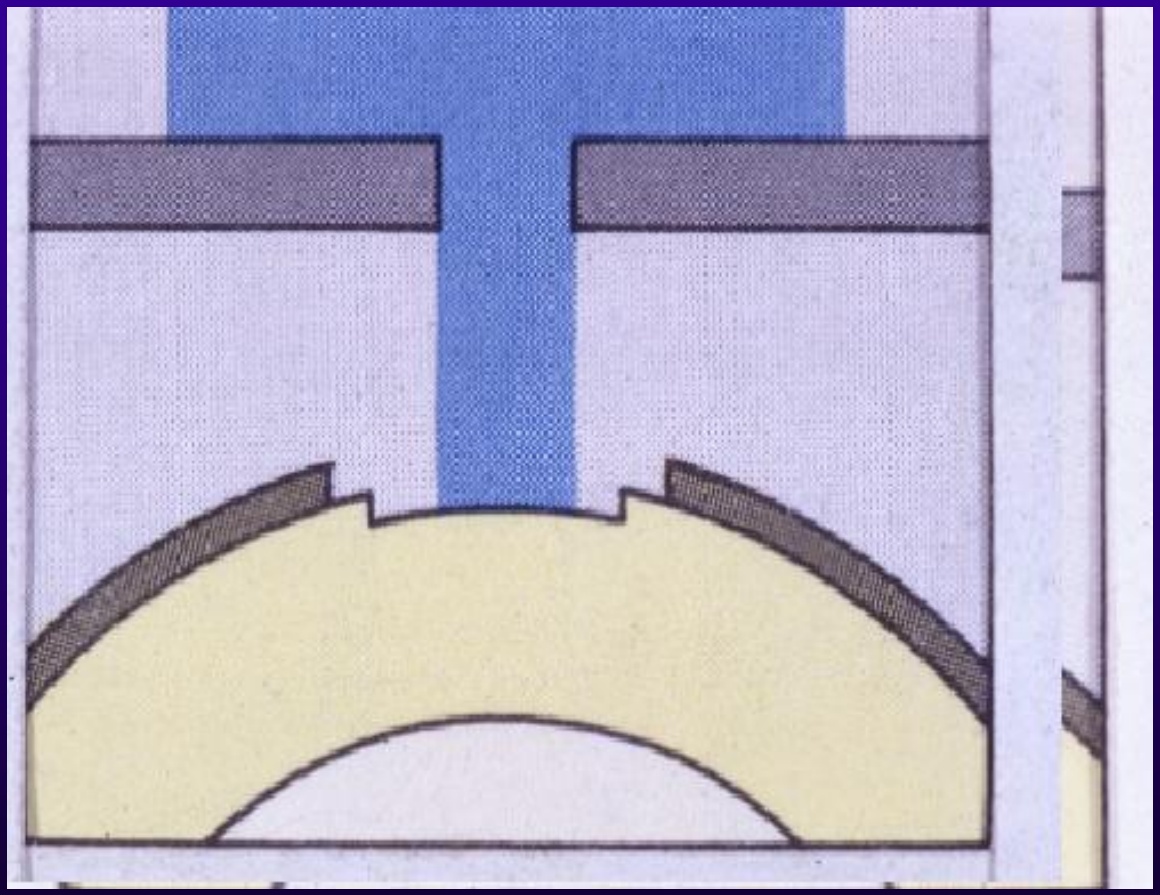
PRK

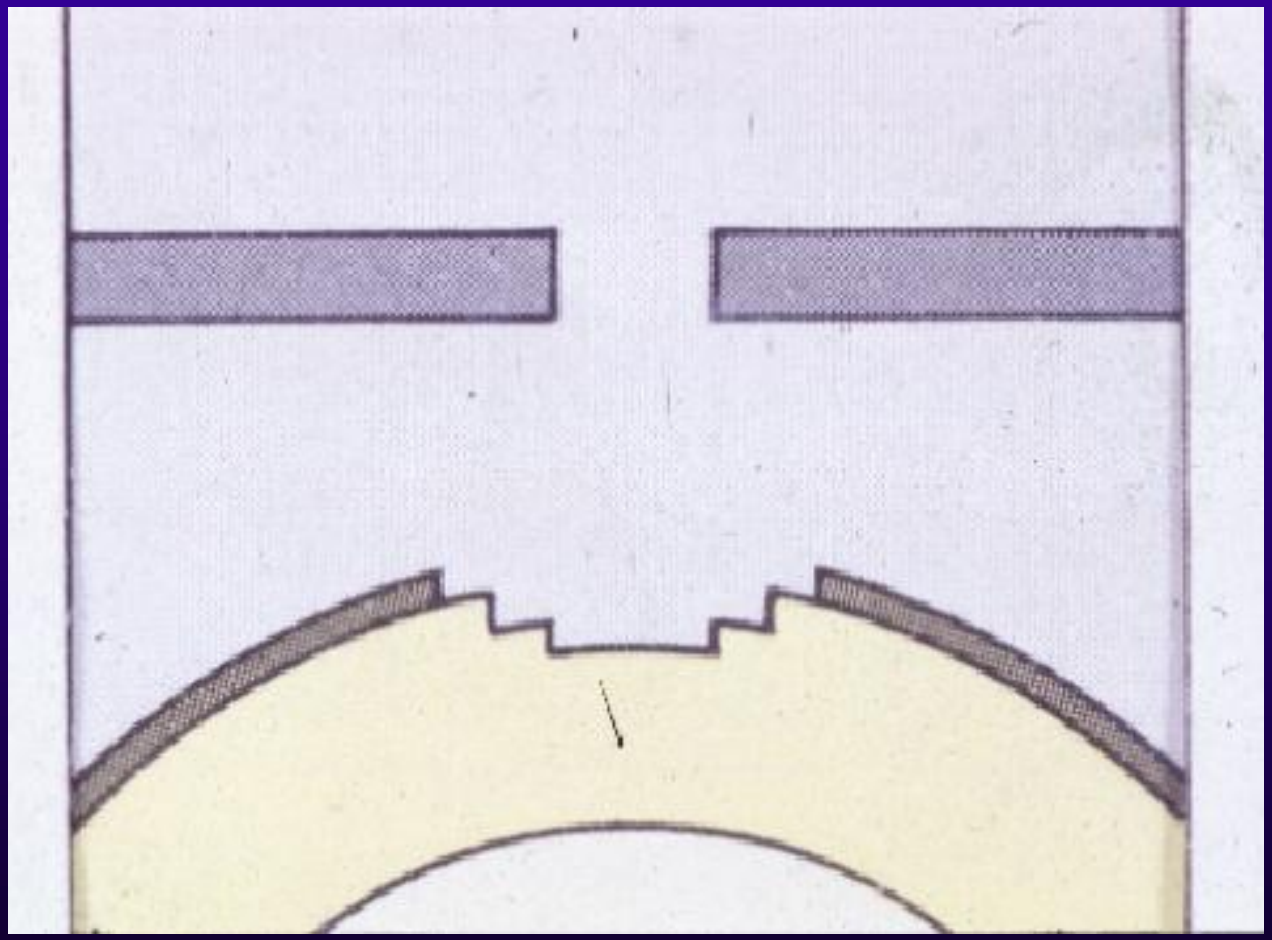
photorefractive keratectomy with excimer laser

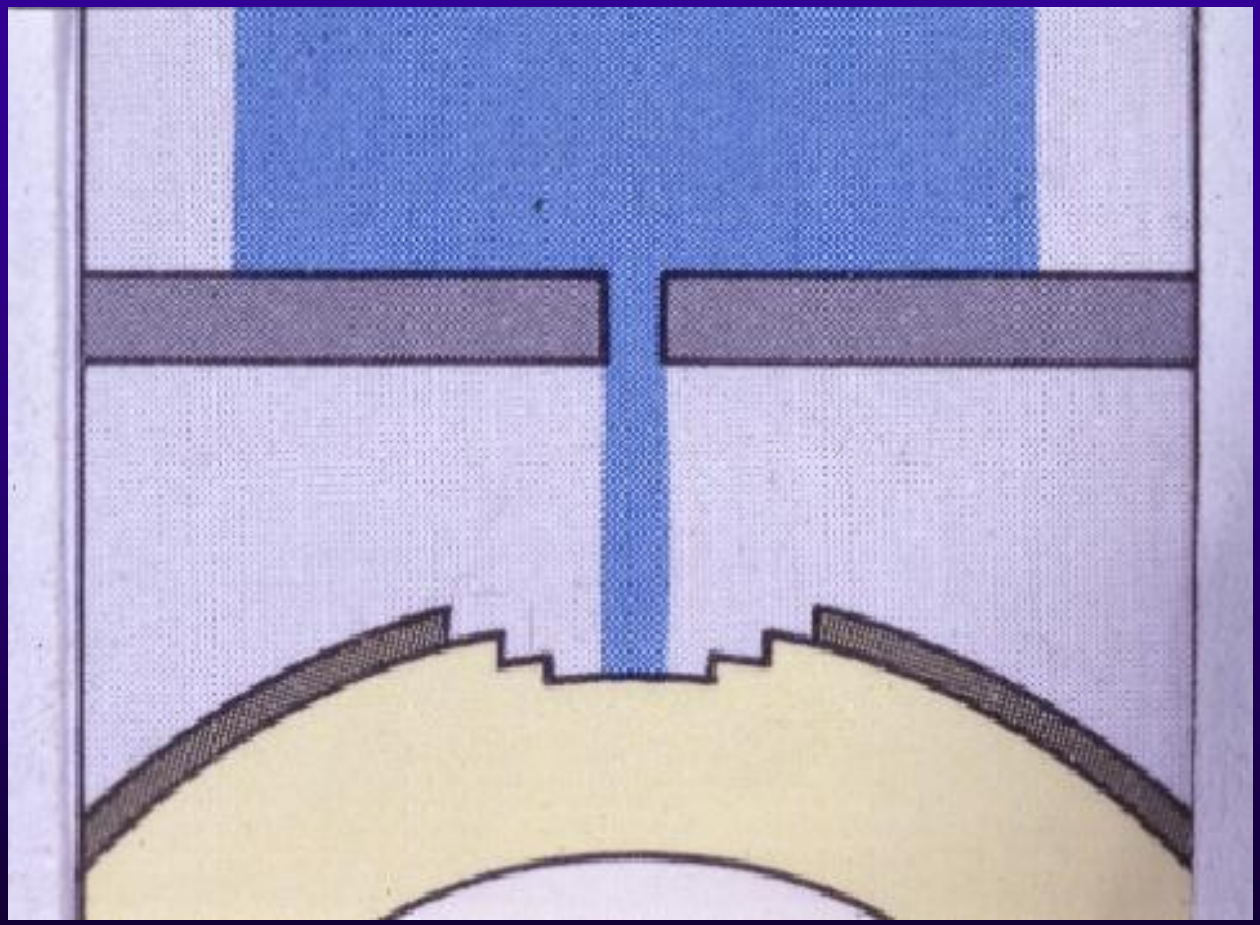


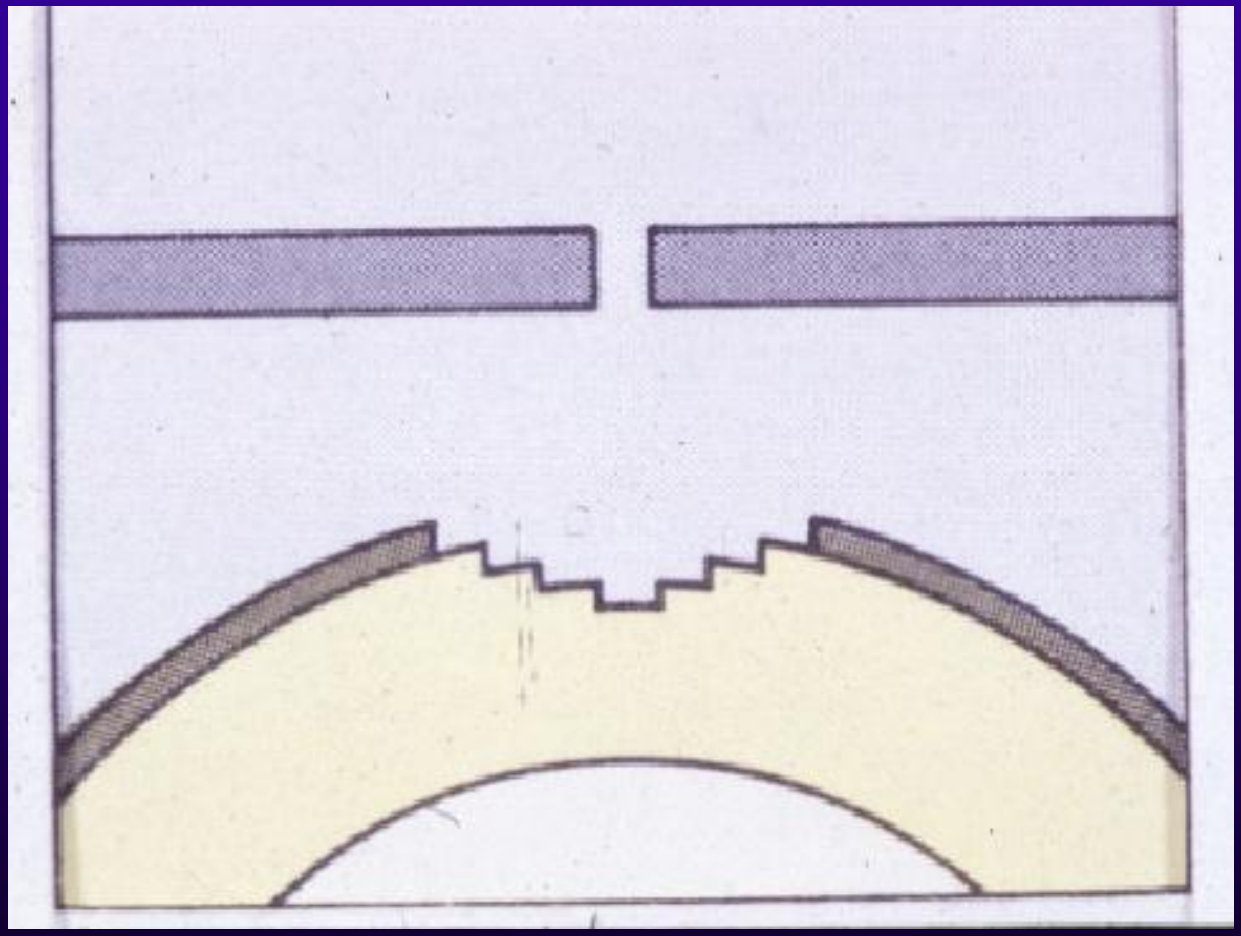


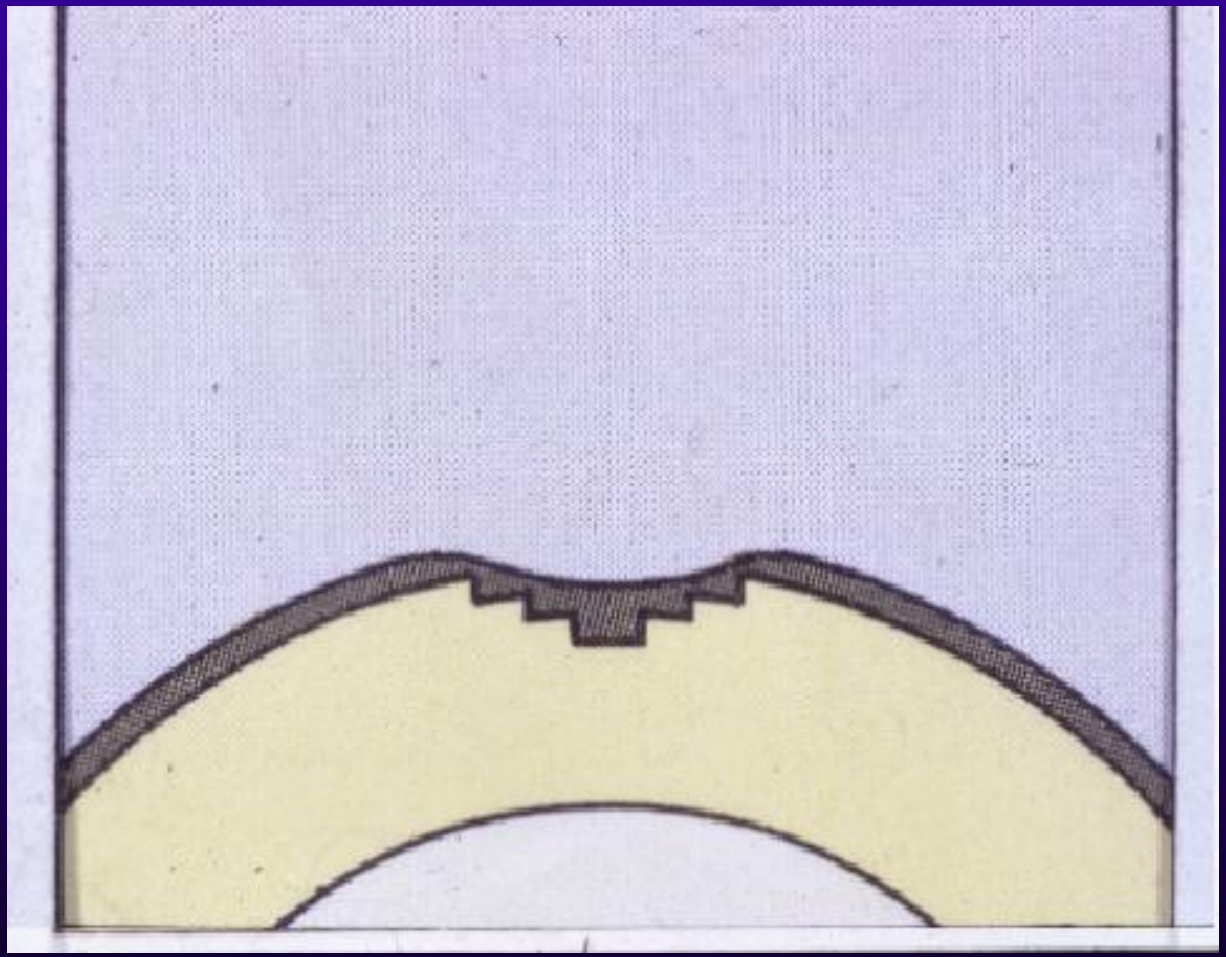


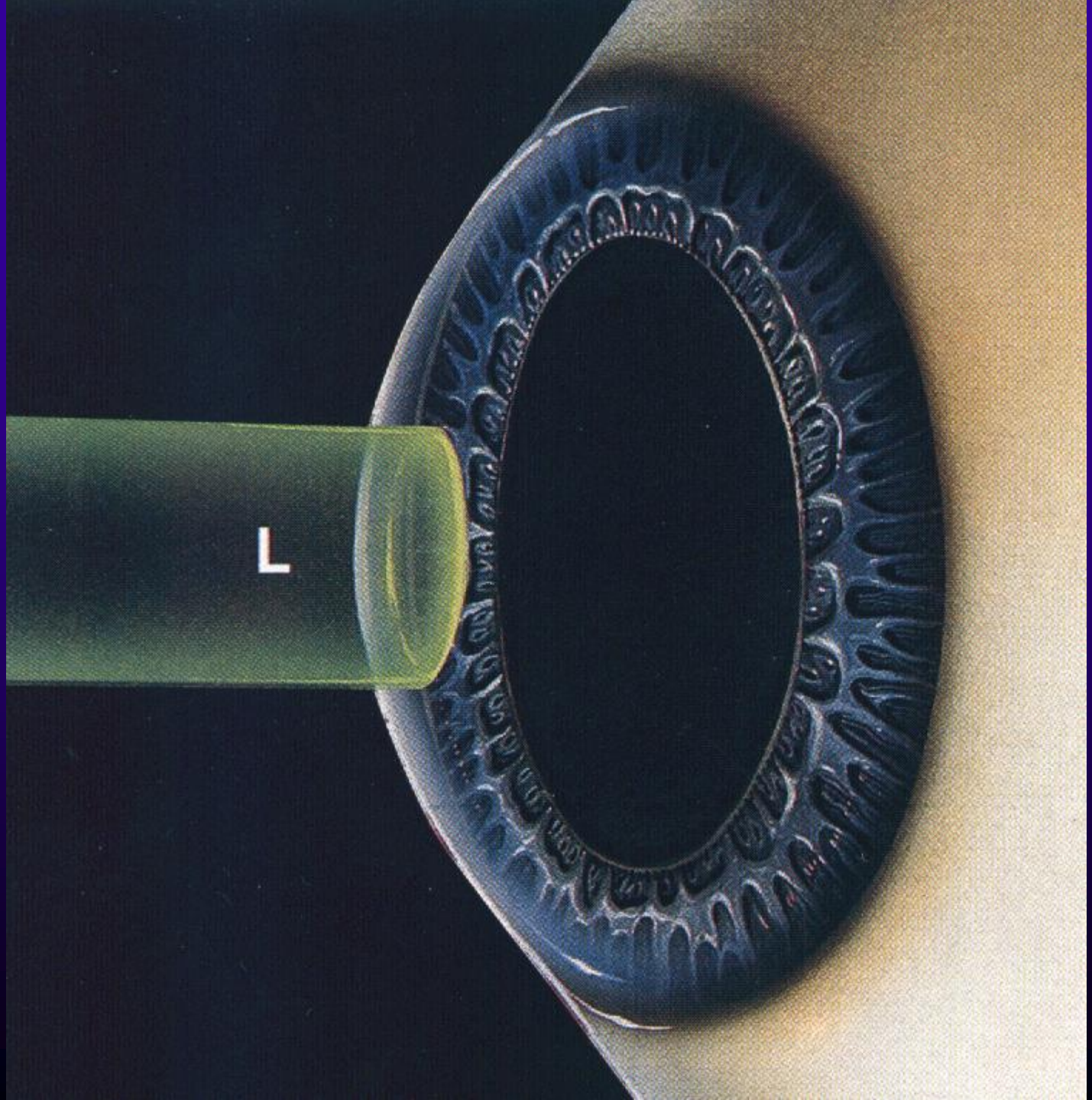











L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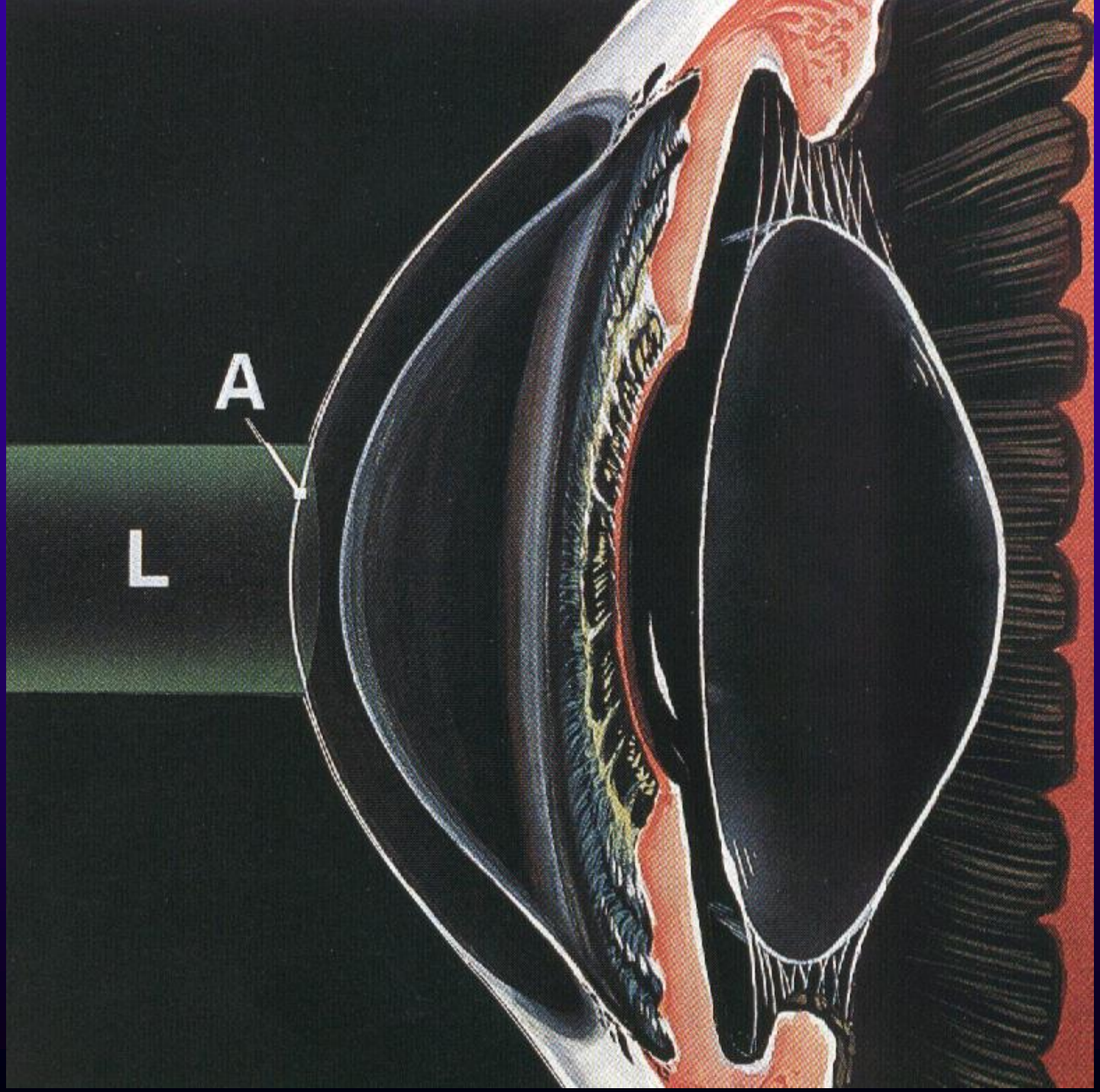
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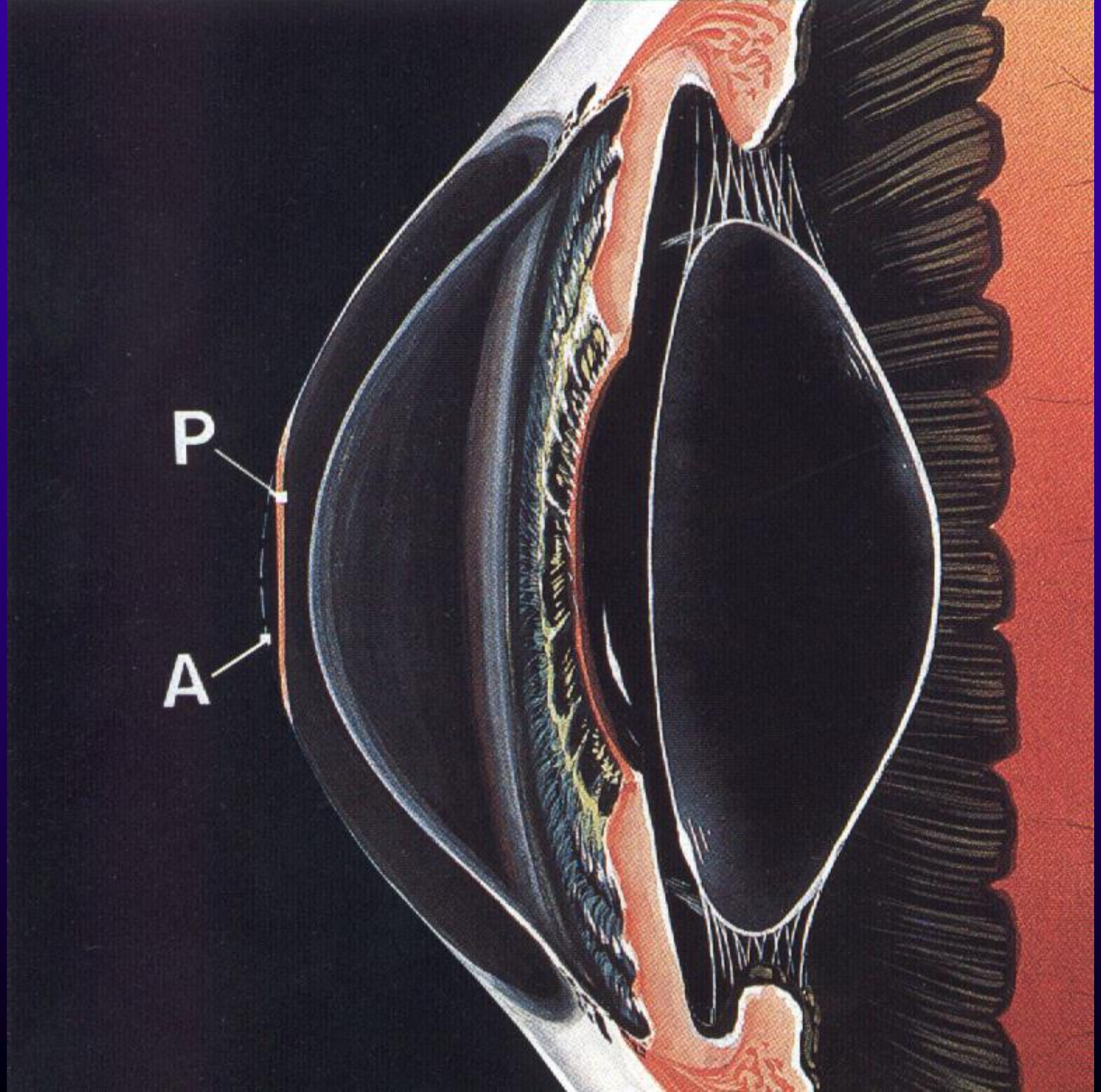
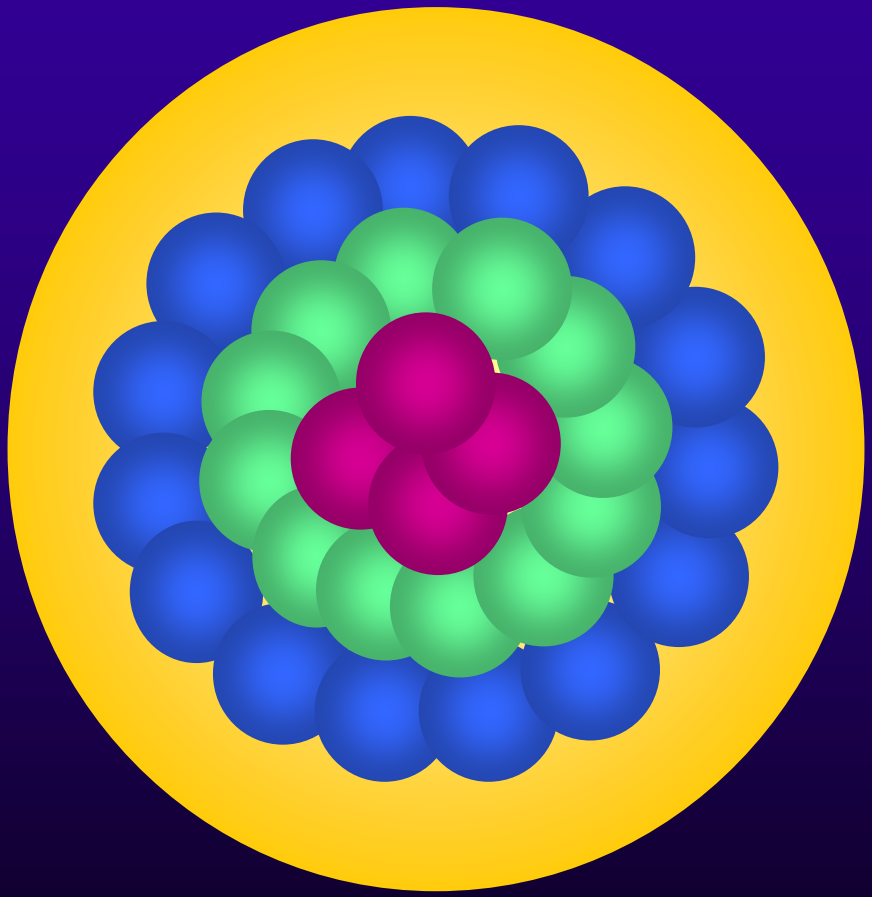
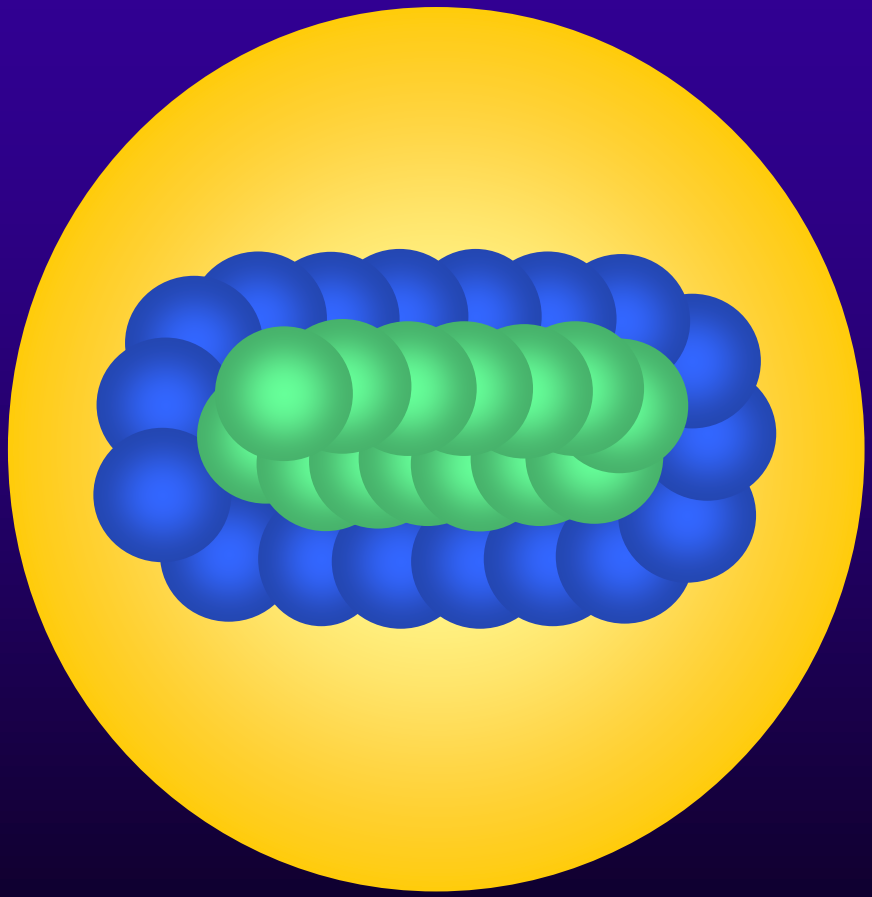
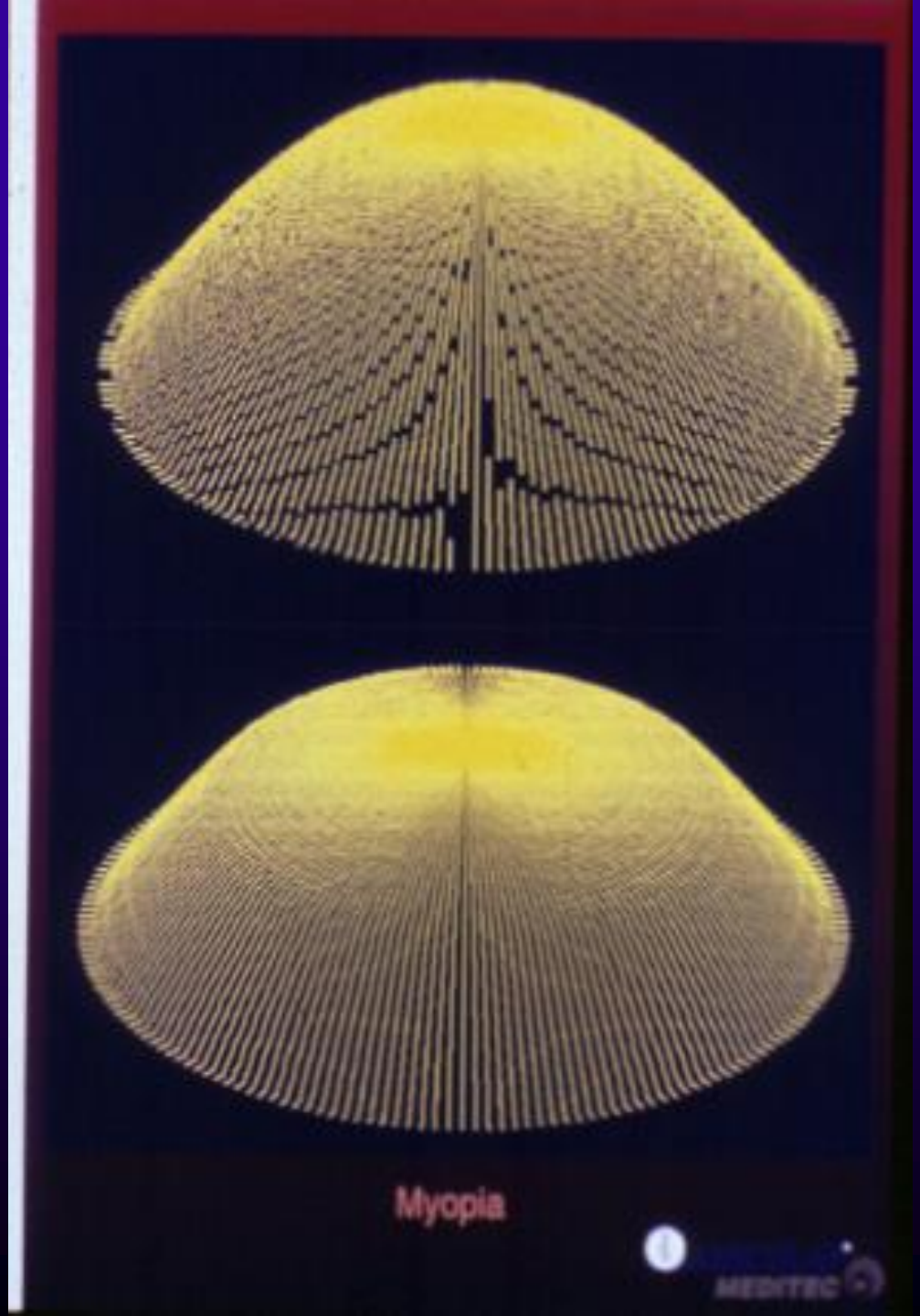

P
A

Myopia



Myopic Astigmatism




Myopia

OCULUS - KERATOGRAFO

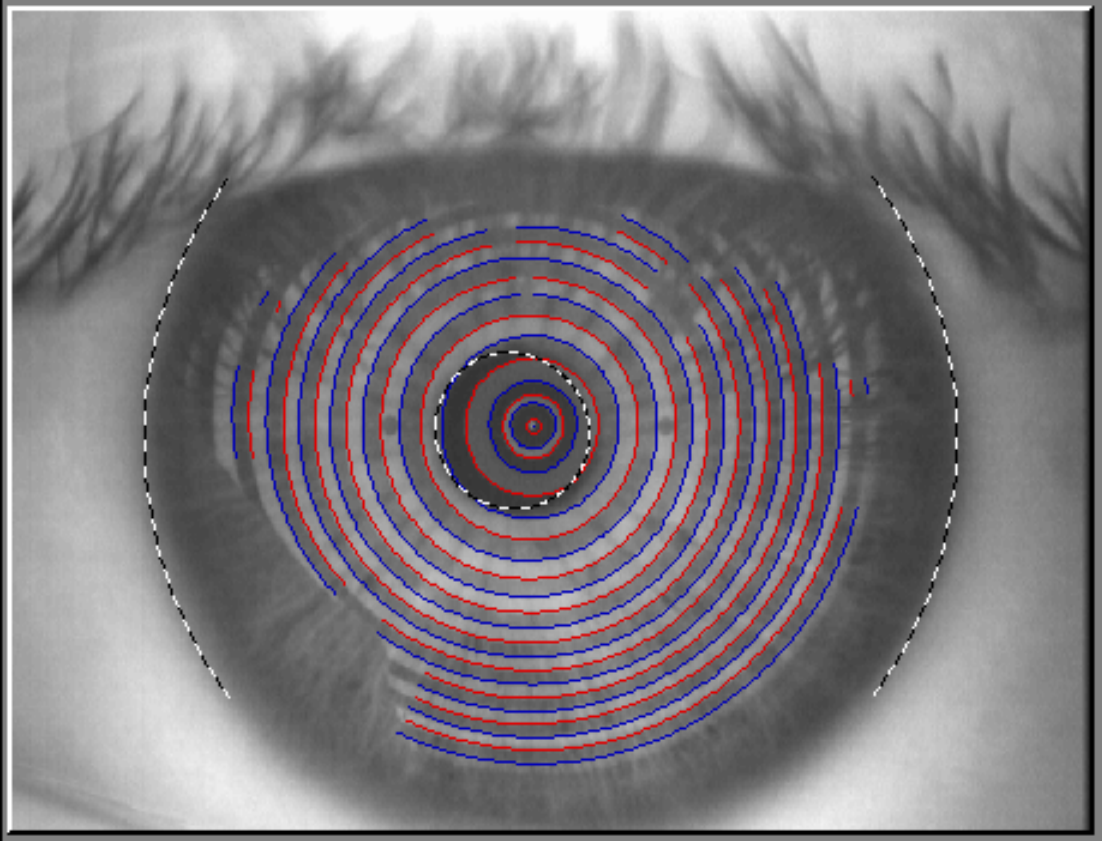
Dr. Leopoldo Spadea

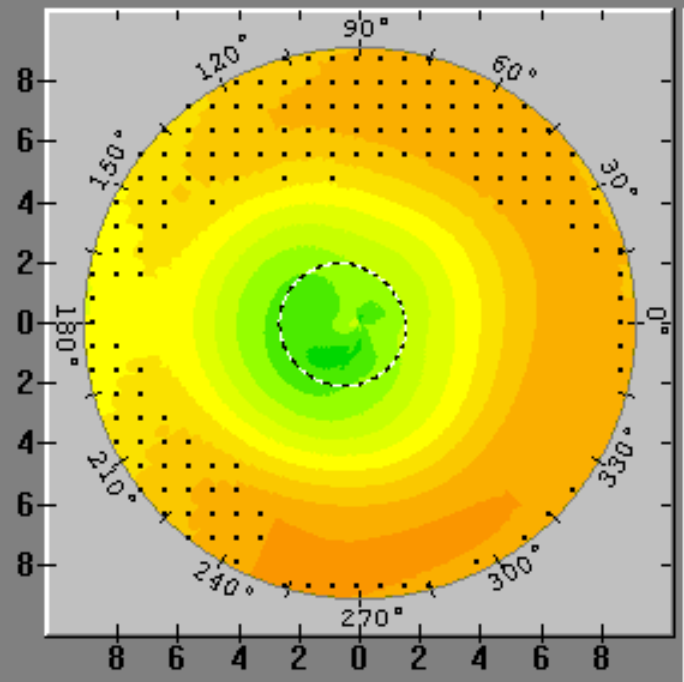
Paziente | Esame | Visualizza | Lenti a contatto | Impostazioni | Varie | Stampa

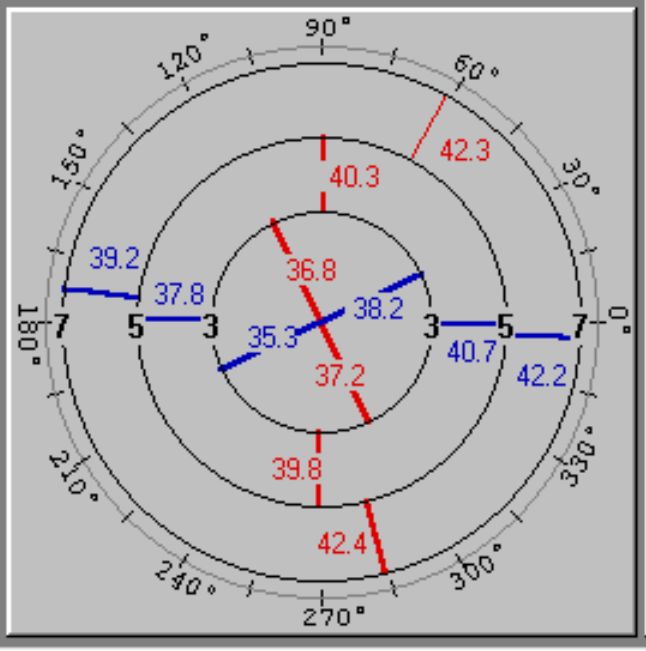
Nome:

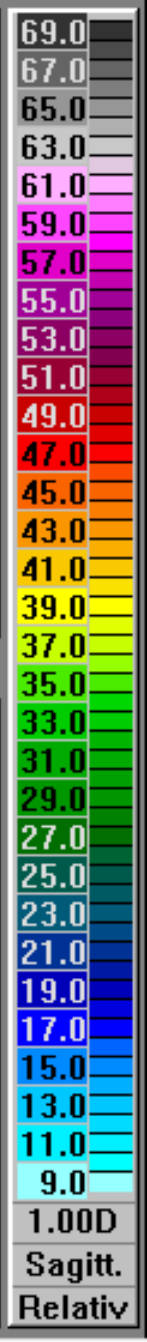
Data es.: 20.05.99

Data di n.: 06.08.63 Occhio: Sinistro Data tie.: 16:50









Dati keratometrici : meridiani perpendicolari principali (d=3mm)

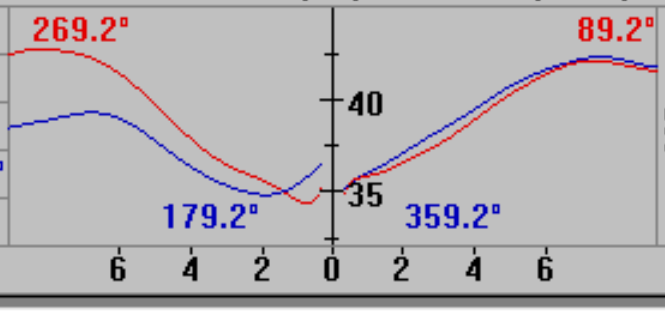
Ro: 38.6D

Rv: 39.3D

Ast.: -0.7D

Asse: 179.2°

Ecc.: -0.69



OCULUS - KERATOGRAFO

Dr. Leopoldo Spadea

Paziente Esame Visualizza Lenti a contatto Impostazioni Varie Stampa

Nome:

Data di n.: 06.08.63 Occhio: Sinistro

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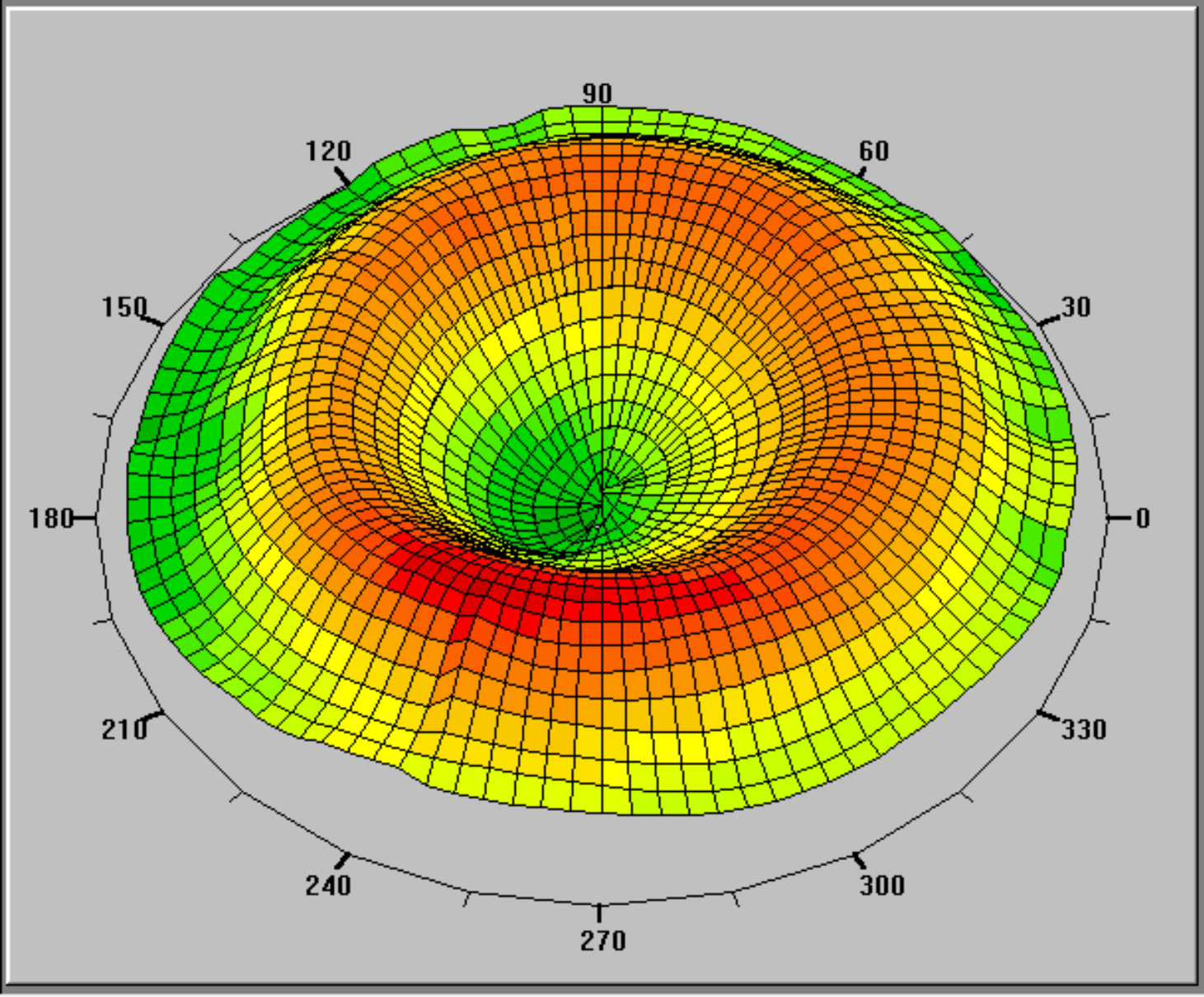
Colorata Realistica

Rosso/Verde Curvatura



Amplificazione

\- +

Movimento

Lento Veloce

Ampio Stretto

Inclina

Ruota

Rotazione

0

71.0
69.0
67.0
65.0
63.0
61.0
59.0
57.0
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53.0
51.0
49.0
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15.0
13.0
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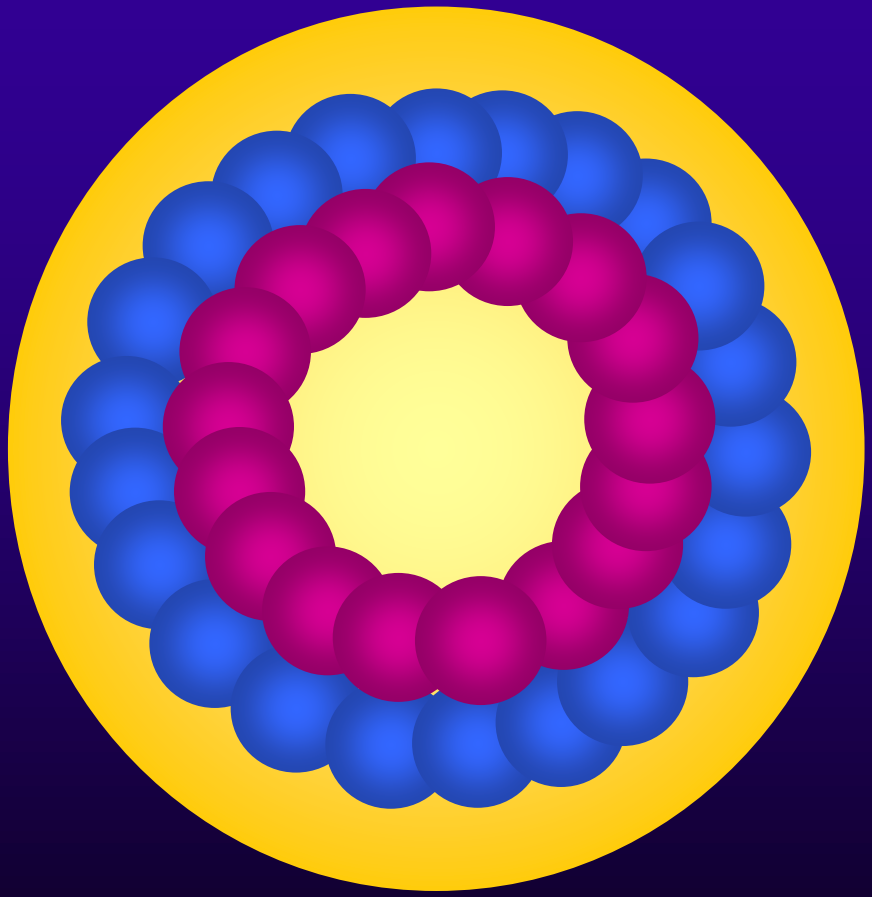
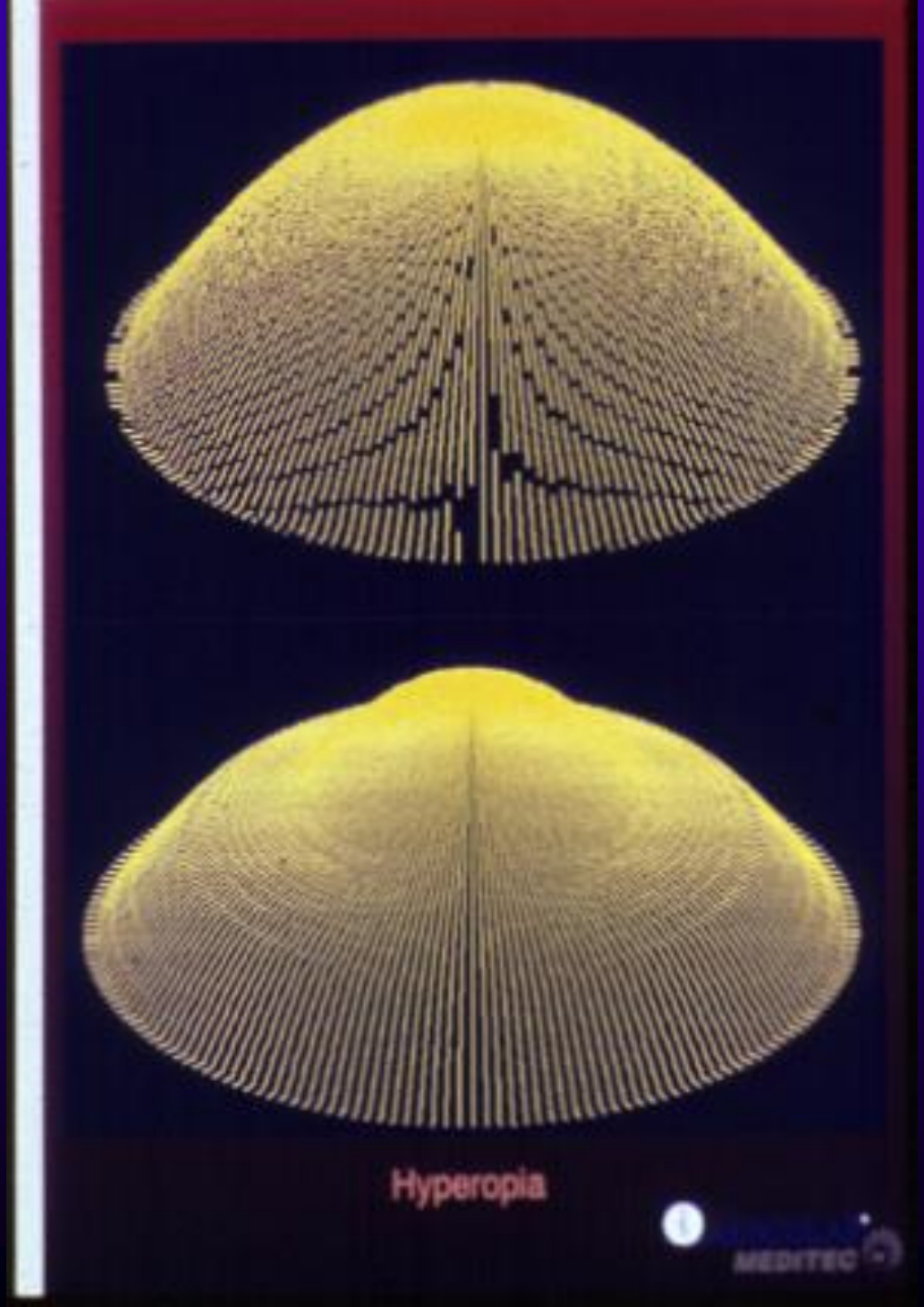
1.00D

Tangen.

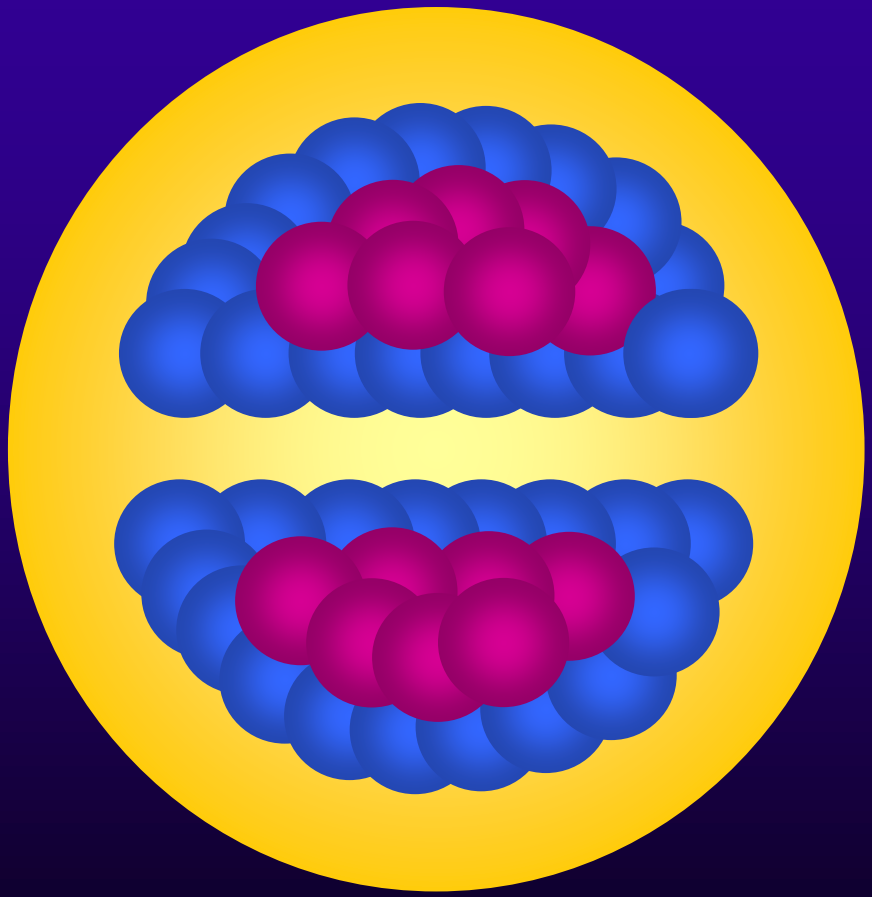
Relativ

Hyperopia




Hyperopia

Hyperopic Astigmatism



LASIK

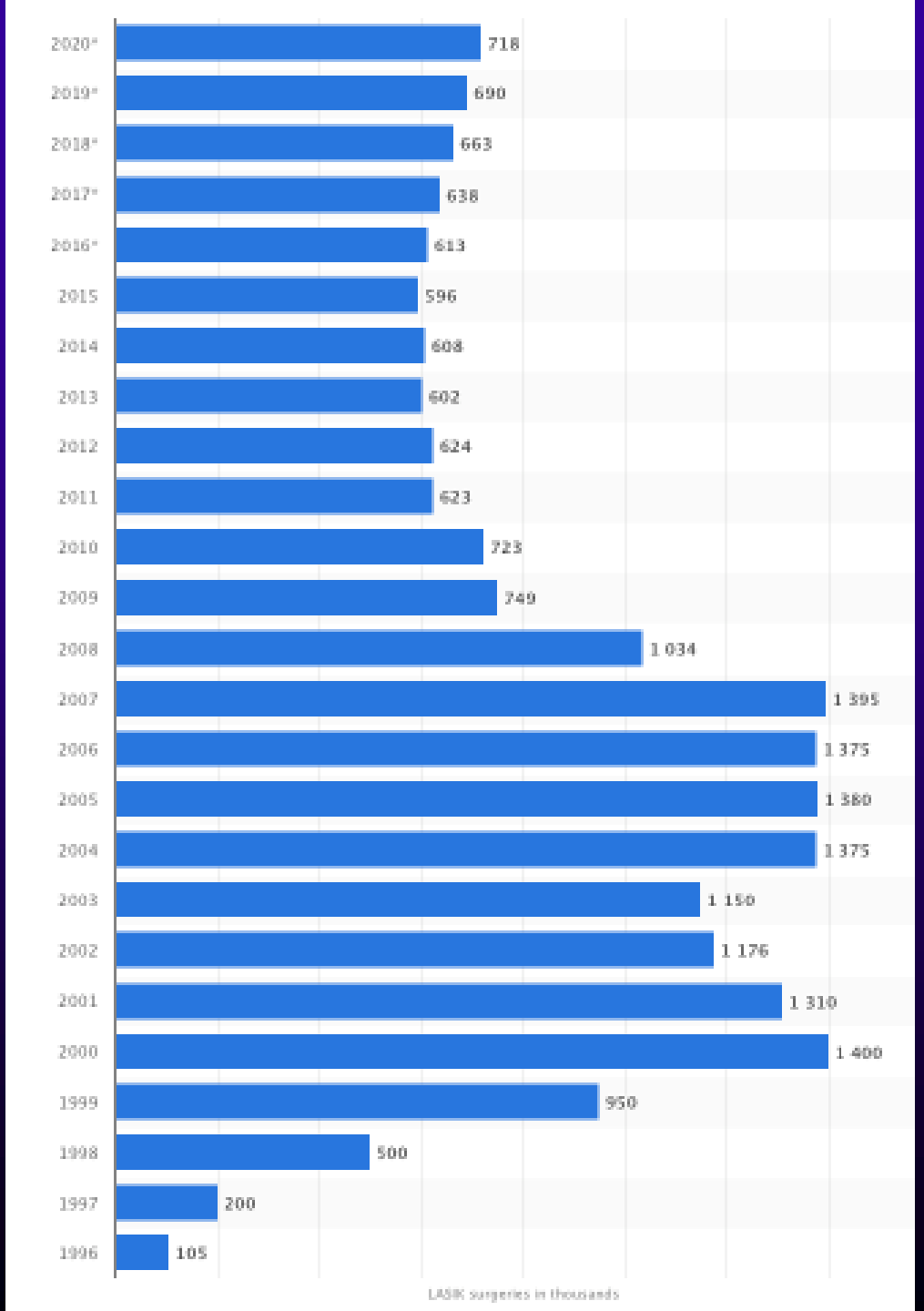
laser in situ keratomileusis assisted by excimer laser


ALLERGAN SURGICAL

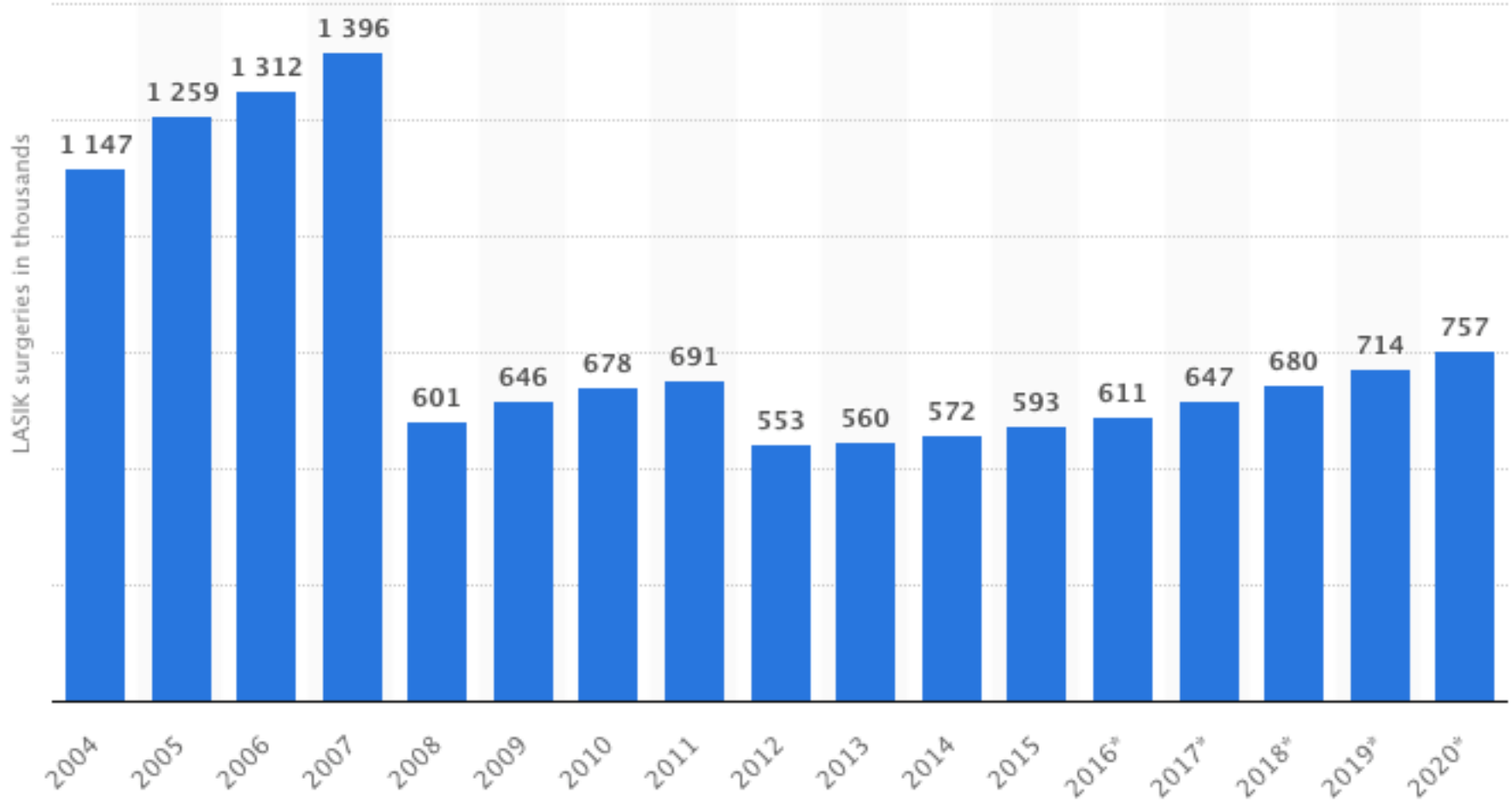

HANSAT ME

In the world until 2015 were performed more than 40 million LASIK

USA LASIK


2020*
718
2019*
690
2018*
663
2017*
638
2016*
613
2015
596
2014
608
2013
602
2012
624
2011
623
2010
723
2009
749
2008
1 034
2007
1 395
2006
1 375
2005
1 580
2004
1 375
2003
1 150
2002
1 176
2001
1 310
2000
1 400
1999
950
1998
500
1997
200
1996
105
LASIK surgeries in thousands

EUROPE LASIK



In USA the percentage of medical-ophthalmologists who has undergone refractive surgery is higher than that of the general population

LASIK

(Laser Assisted in Situ Keratomileusis)

Surgical technique with laser ablation on the corneal stroma after making a corneal flap (flap).

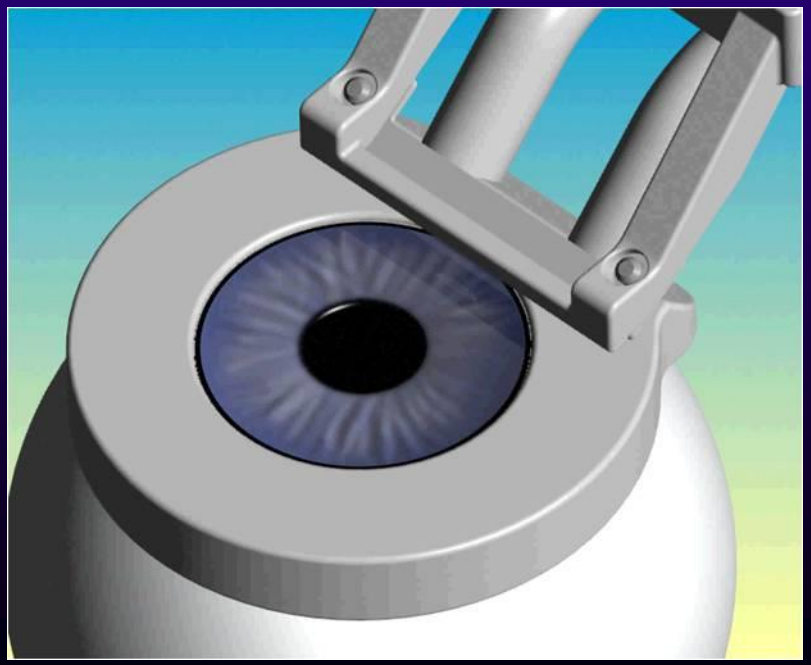
So it is a procedure based on the use of two tools:

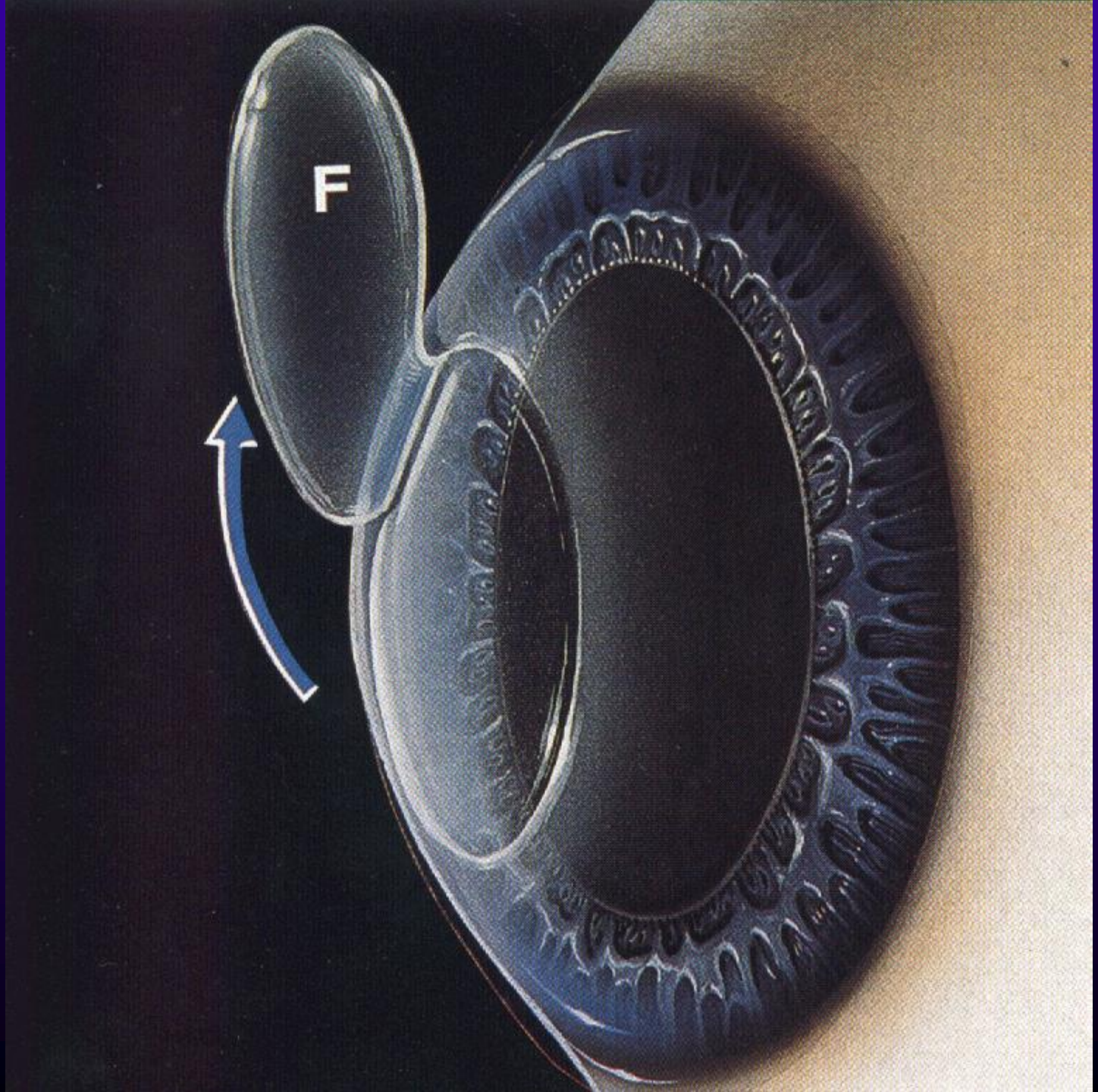
MICROKERATOME

EXCIMER LASER

"... LASIK was created independently by Buratto and Pallikaris between 1989 and 1990 by the combination of keratomileusis and ablation with the excimer laser ..."

(Sekundo W, J Cat Refract Surg 2002)

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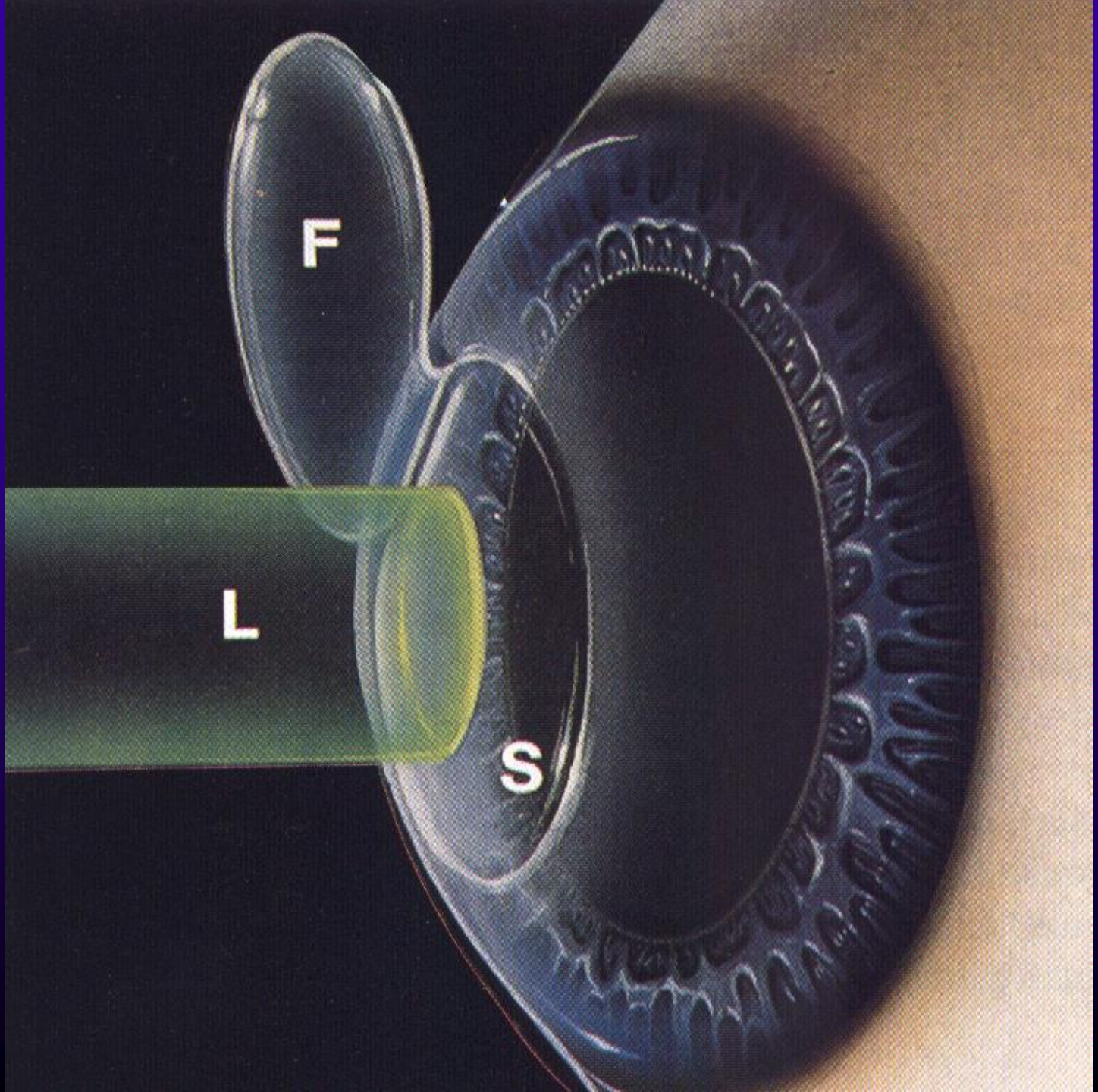
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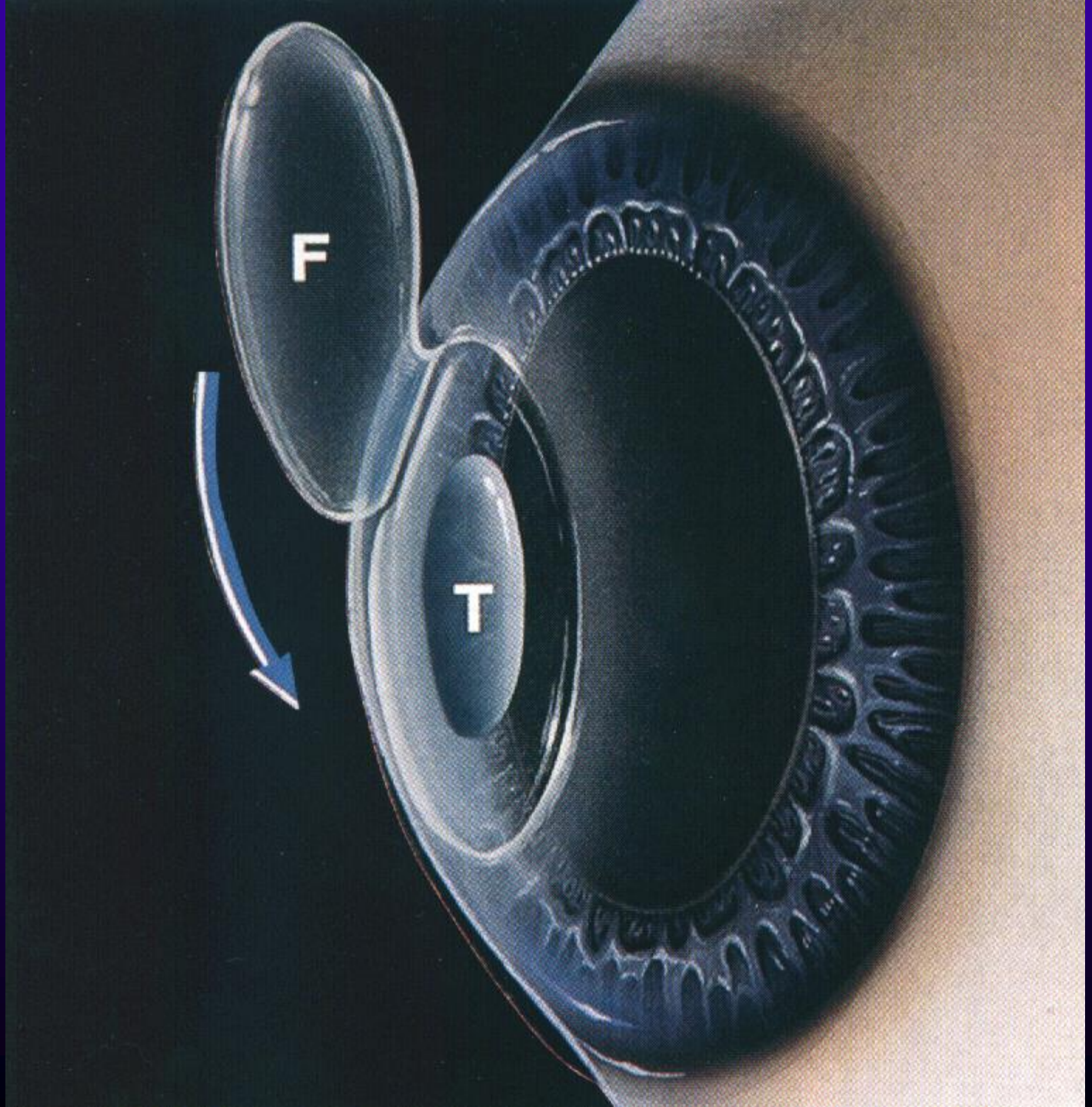
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