Astronomy 80 B: Light

Lecture 14: vision, instruments

15 May 2003

Jerry Nelson

Topics for Today

- Total eclipse of the moon 15 May 2003!!!
- Status of field trip (16 may)
- review research/term papers
- Optical illusion
- Atmospheric picture
- Principles of vision
- Optical instruments

Total eclipse of moon

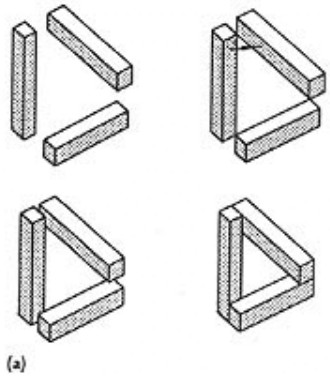
- Start of partial eclipse (enter penumbra) 19:03
- Total eclipse starts (enter umbra) 20:14
- Sunset 20:15
- Mid-eclipse 20:40
- Total eclipse ends (exit umbra) 21:07
- Partial eclipse ends (exit penumbra) 22:18

Research papers

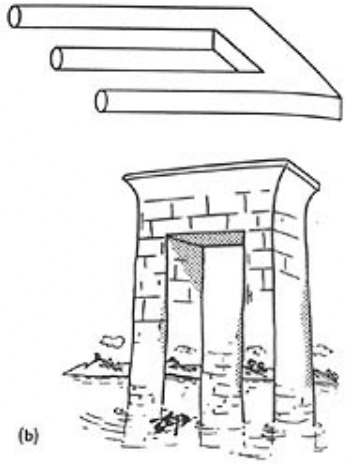
- **I need your subject and I need to approve it**
- **So far, 25 paper subjects have been approved!**
- **Paper must include observations or actual measurements of experimental tests**
- **Process**
  - Select subject
  - Get subject approved
  - Make outline of your planned paper with desired measurements
  - Write draft of paper, emphasizing the data
  - Bring draft to class on 15may, for review by class (we will break up into small groups and pass around drafts for comment by students)

FIGURE 8.17

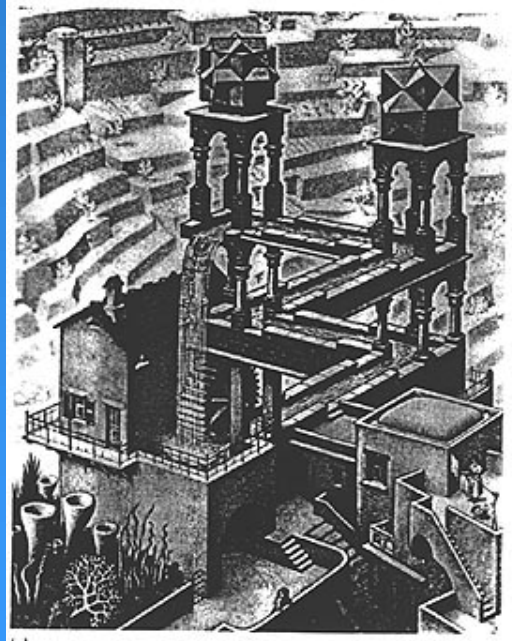
Impossible objects: various versions of illusions that contain depth cues designed to mislead the eye. The cues convey depth in a manner that contradicts the structure of the objects, which can only be two-dimensional. **(a)** The apparent construction of an impossible triangle out of three solid blocks. **(b)** A mechanical and an architectural example of the same impossible object. **(c)** "Waterfall" by M. C. Escher. **(d)** Frontispiece in *Dr. Brook Taylor's Method of Perspective Made Easy*, Book I, by Joshua Kirby (1754). The artist, William Hogarth, wrote, "Whoever makes a design, without the knowledge of perspective, will be liable to such absurdities, as are shown in this frontispiece." **(e)** A crate for shipping optical illusions.



(a)

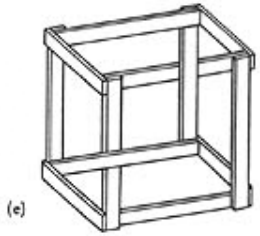


(b)



(c)

(d)

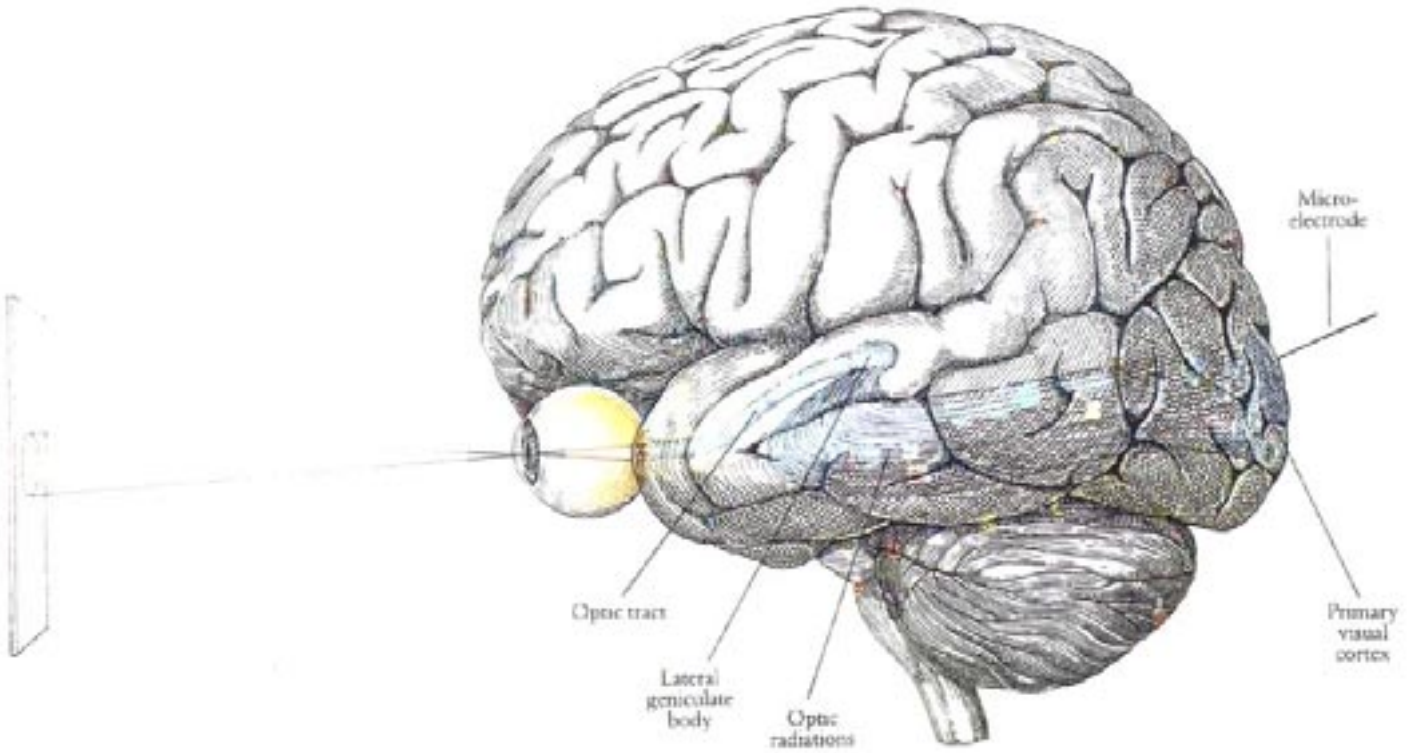


(e)

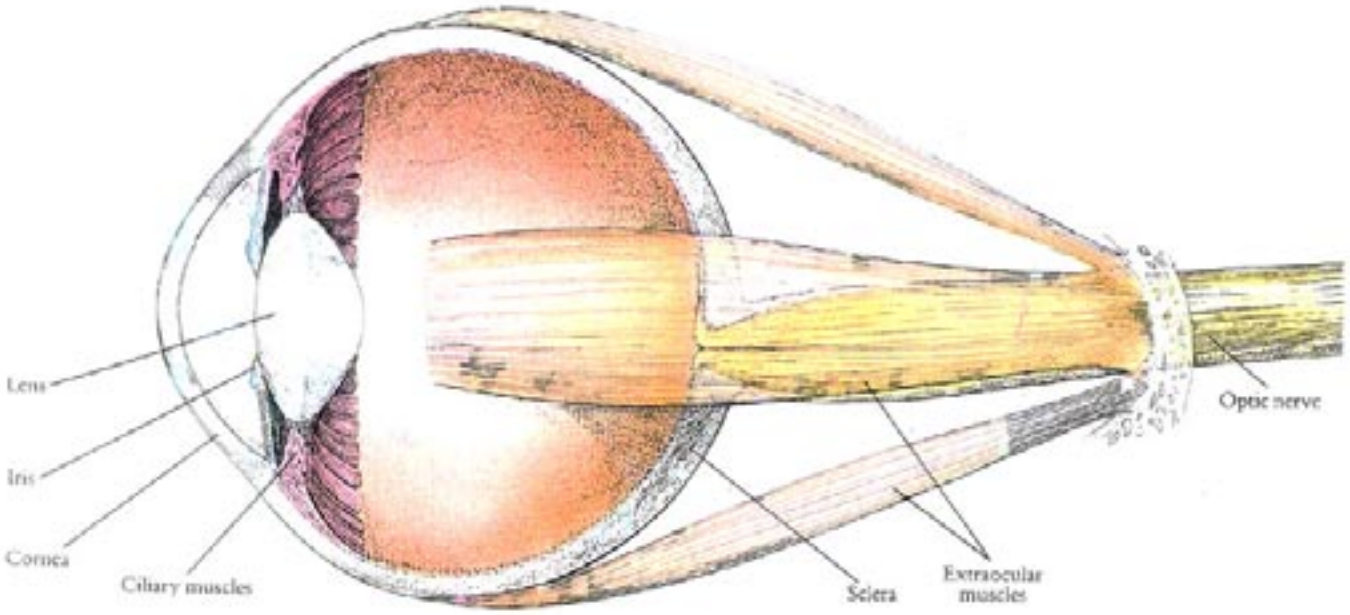
Vision

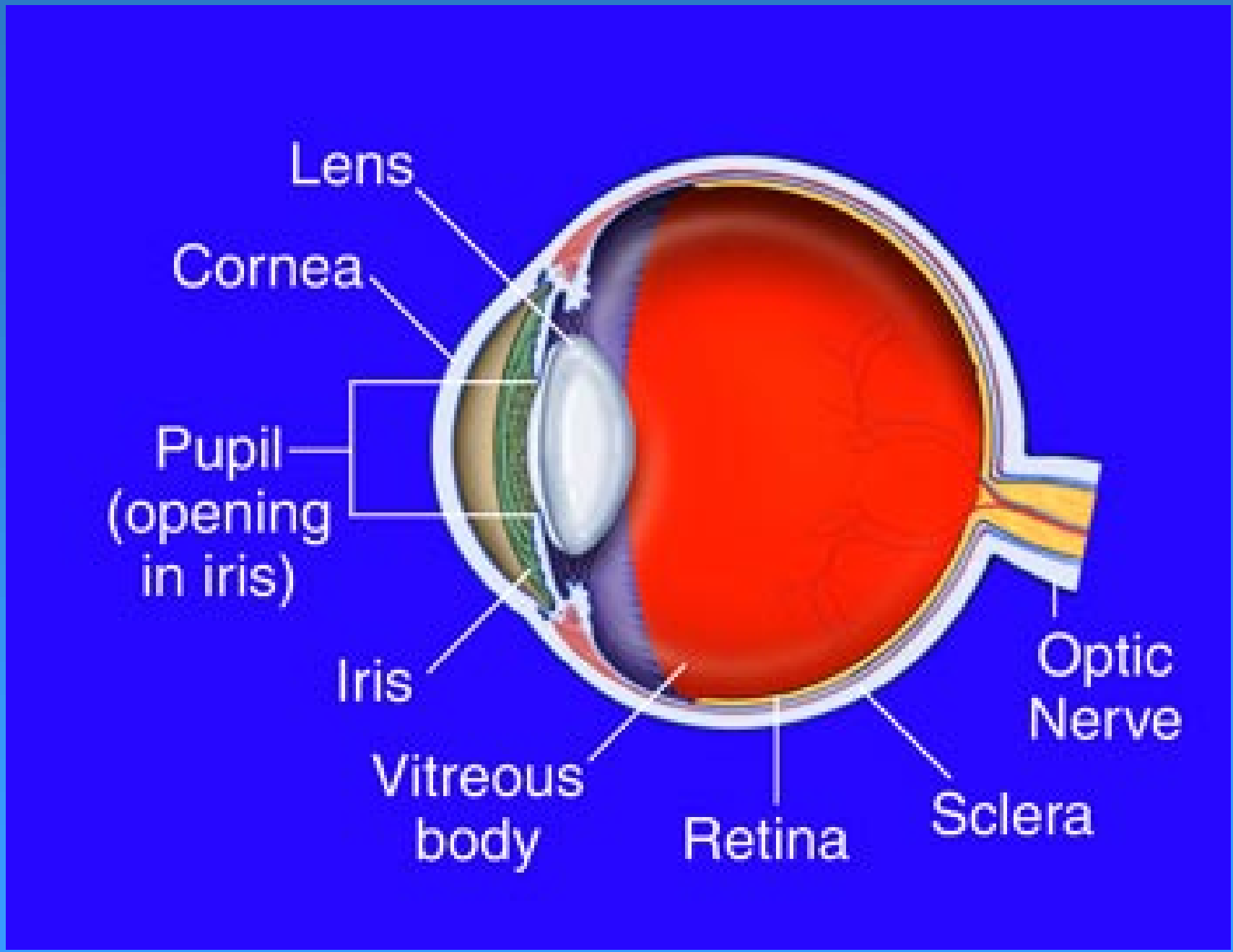
- **Many animals have light sensors**
- **These vision systems vary greatly in complexity**
  - Angular resolution
  - Number of light sensors
  - Wavelength range of sensors
  - Number of kinds of wavelength sensors
  - Wavelength sensitivitites of sensors (color vision)
- **Human vision is extremely sophisticated**
- **Beyond the optics, the processing of the information is complex and only partially understood**

Eye and brain



Eye system


Lens
Iris
Cornea
Ciliary muscles
Sclera
Extraocular muscles
Optic nerve


Lens
Cornea
Pupil
(opening
in iris)
Iris
Vitreous
body
Retina
Sclera
Optic
Nerve

Eye and camera optics

- **Many elements of the human vision system match those of cameras**
  - pupil
  - iris
  - Lens
  - Focussing system
  - Image plane
  - Light sensors
  - aberrations

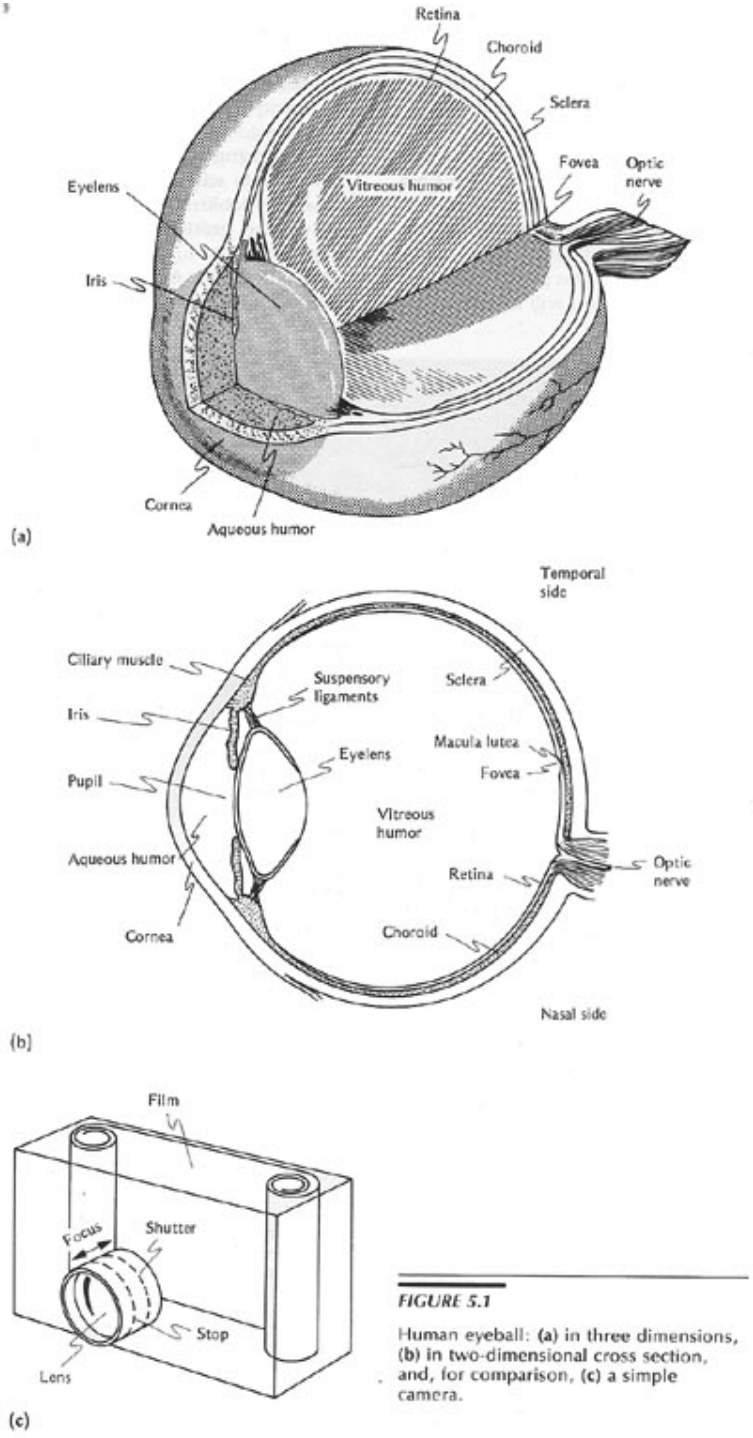


FIGURE 5.1

Human eyeball: **(a)** in three dimensions, **(b)** in two-dimensional cross section, and, for comparison, **(c)** a simple camera.

Fundus

- The retina needs to be supplied with blood
- Fundus camera shows the retina, and if dyed, shows the blood vessels too
- Note the lack of blood vessels over the fovea

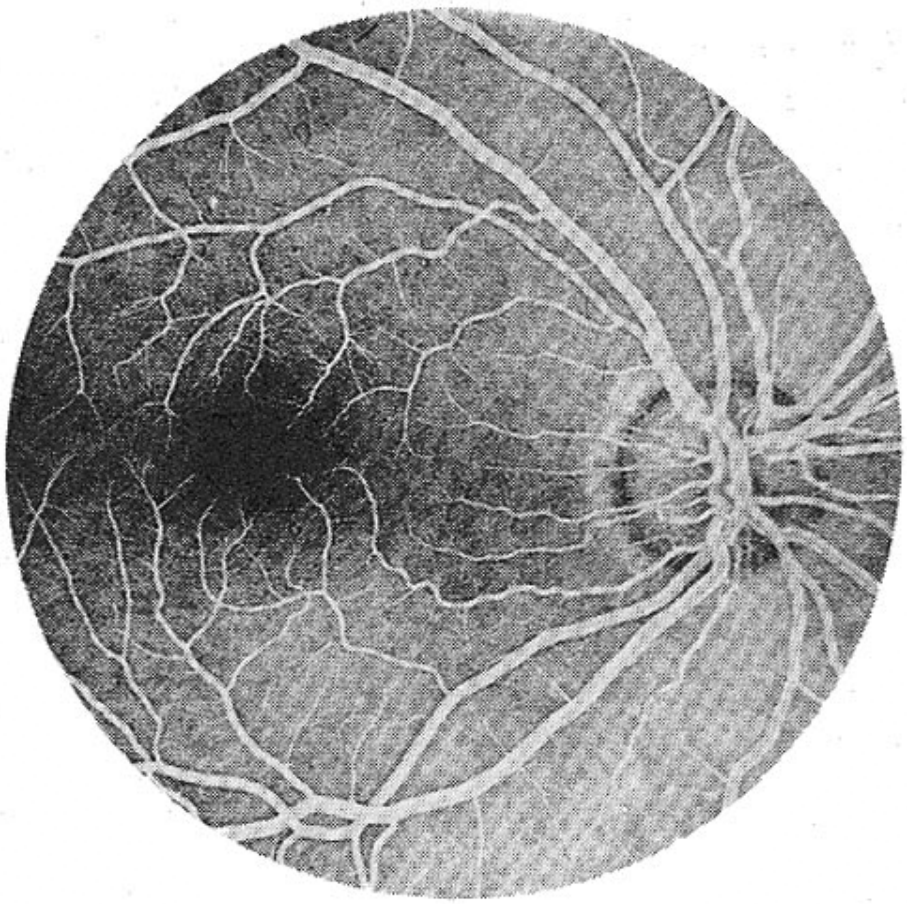
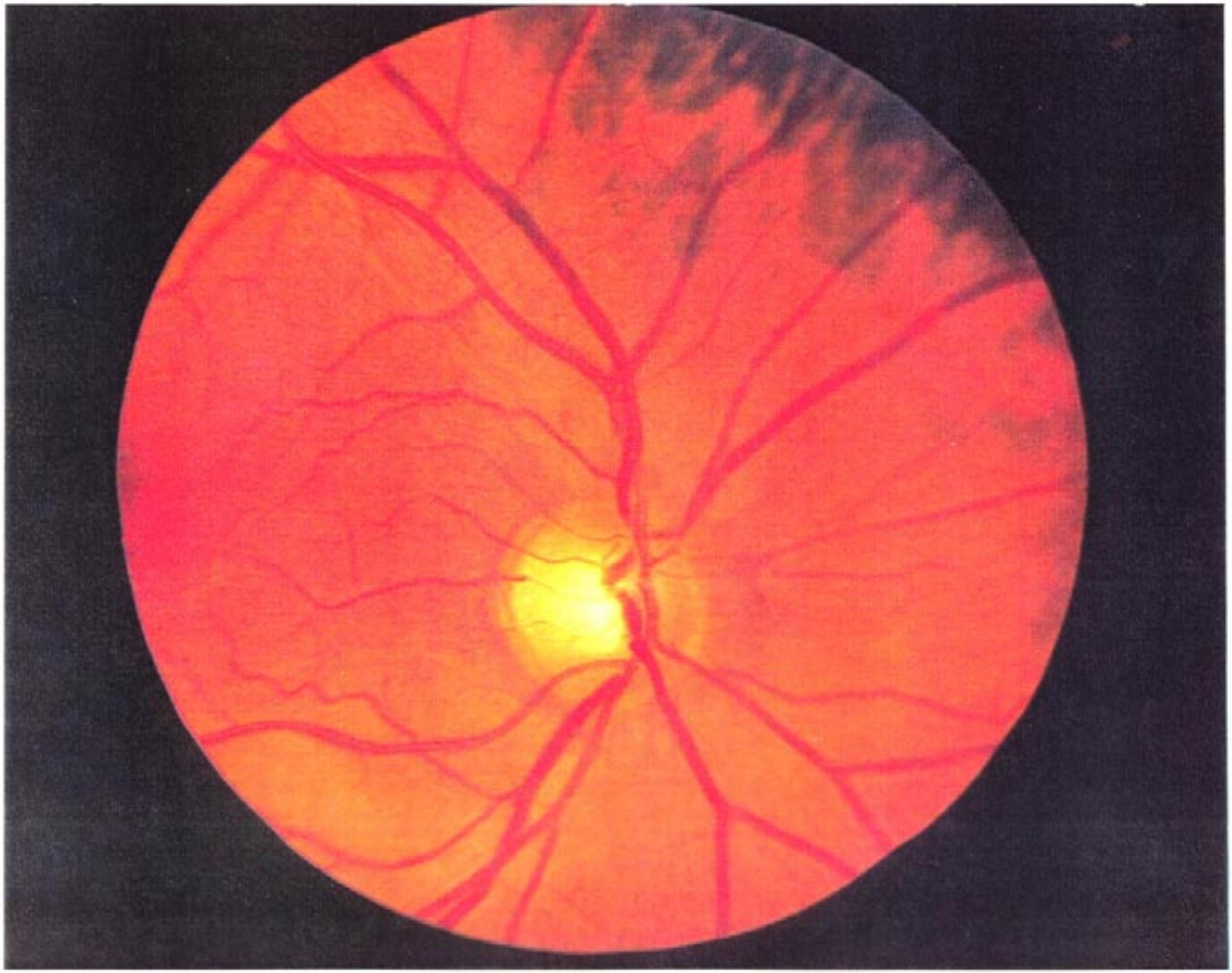


FIGURE 5.2

In this fluorescein angiograph, the blood vessels in the retina are made visible by injecting a fluorescent substance into the blood system. Note the fine network of blood vessels, except over the fovea.



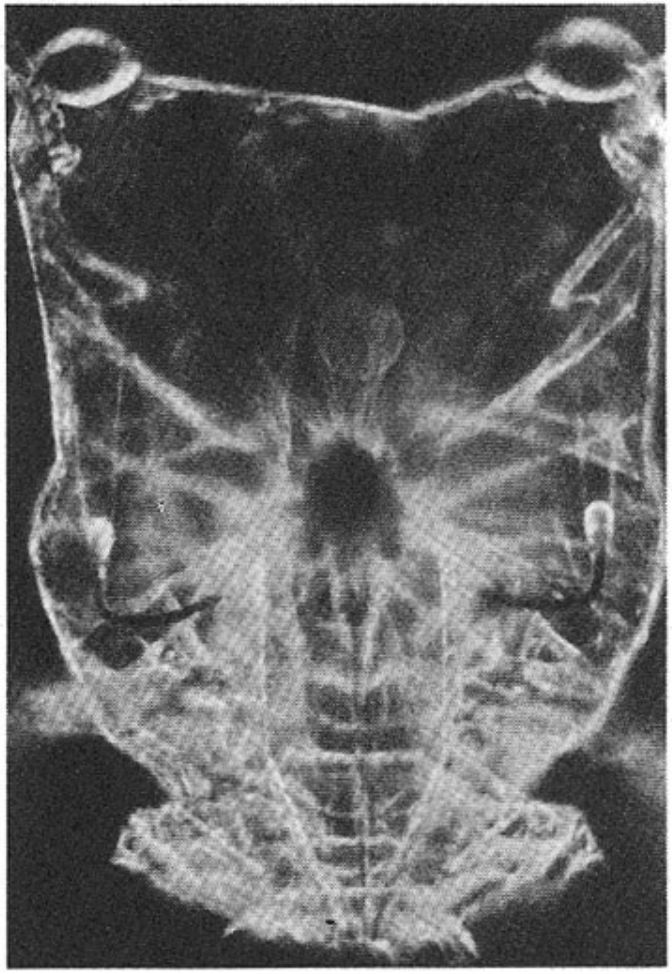
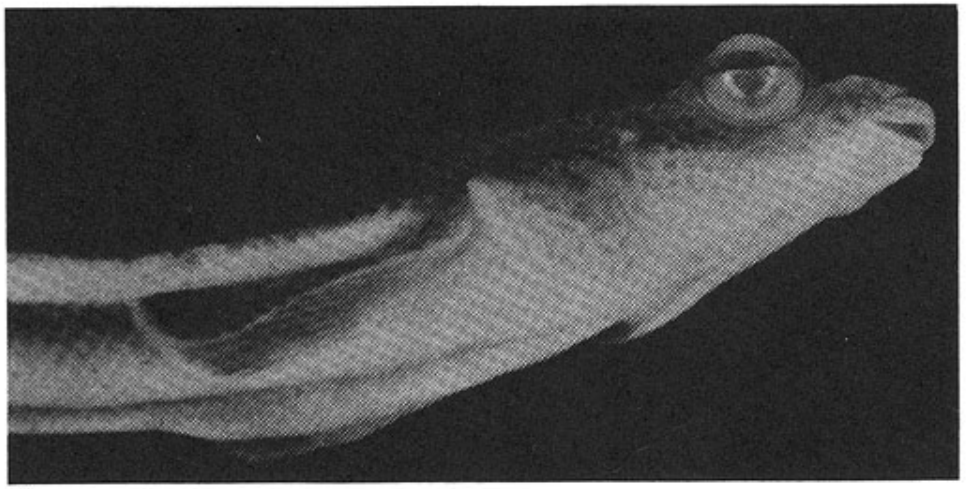


FIGURE 5.4

Photograph of the tiny (millimeter size) sea animal *Copilia*. Each eye contains an outer (corneal) lens and an inner lens attached to the photoreceptor. The inner lens and its associated receptor sweep side to side while sending signals through a single optic nerve to the brain.



(a)

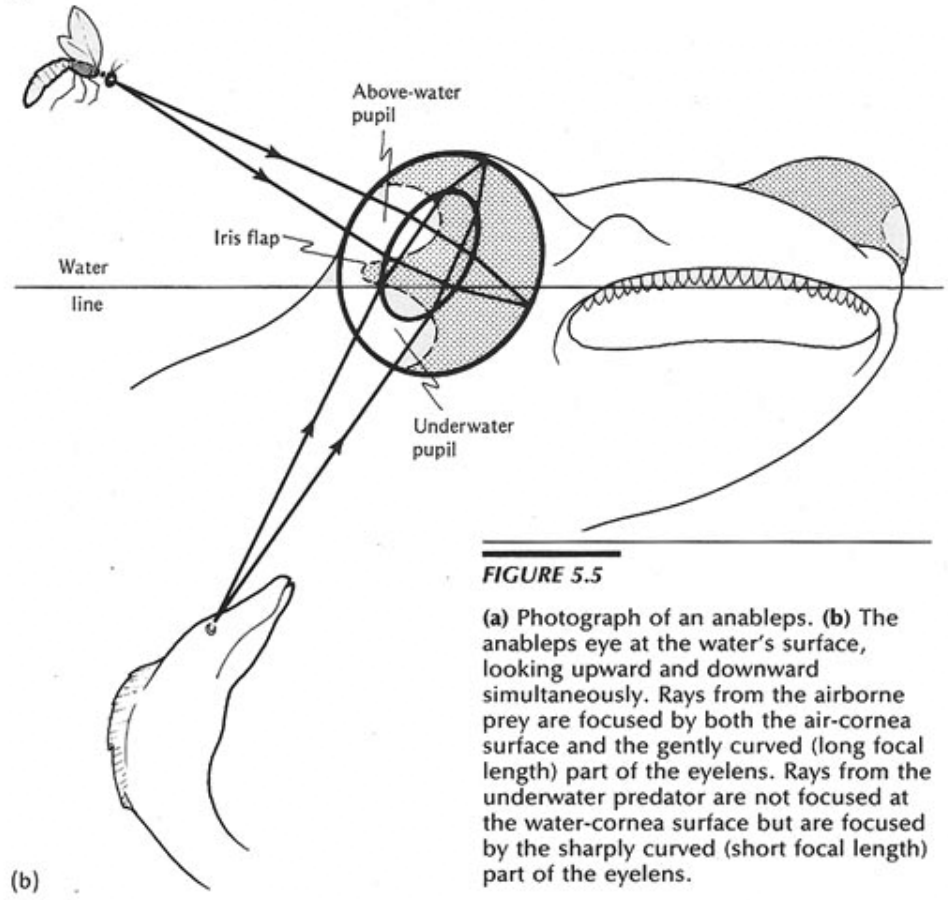
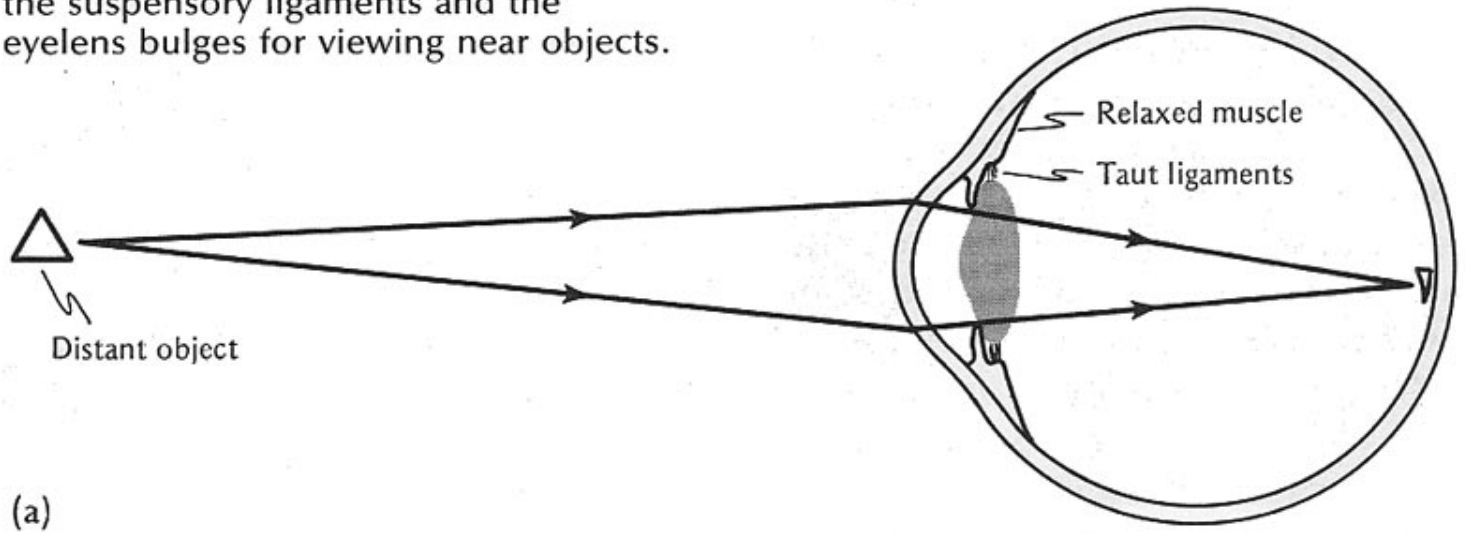


FIGURE 5.5

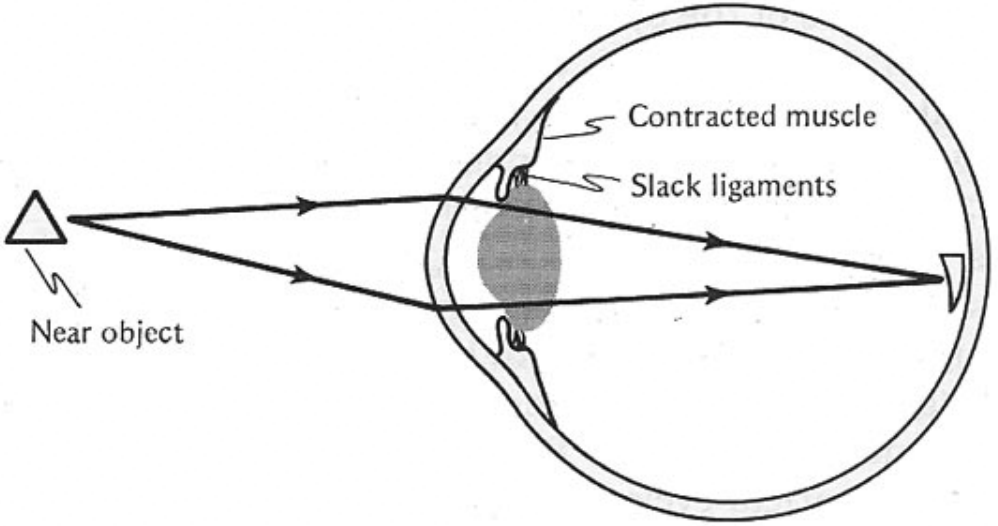
(a) Photograph of an anableps. **(b)** The anableps eye at the water's surface, looking upward and downward simultaneously. Rays from the airborne prey are focused by both the air-cornea surface and the gently curved (long focal length) part of the eyelens. Rays from the underwater predator are not focused at the water-cornea surface but are focused by the sharply curved (short focal length) part of the eyelens.

FIGURE 5.6

Accommodation. **(a)** Relaxed ciliary muscles allow the suspensory ligaments to stretch the eyelens, which then has a long focal length for viewing distant objects. **(b)** Tense ciliary muscles release the suspensory ligaments and the eyelens bulges for viewing near objects.



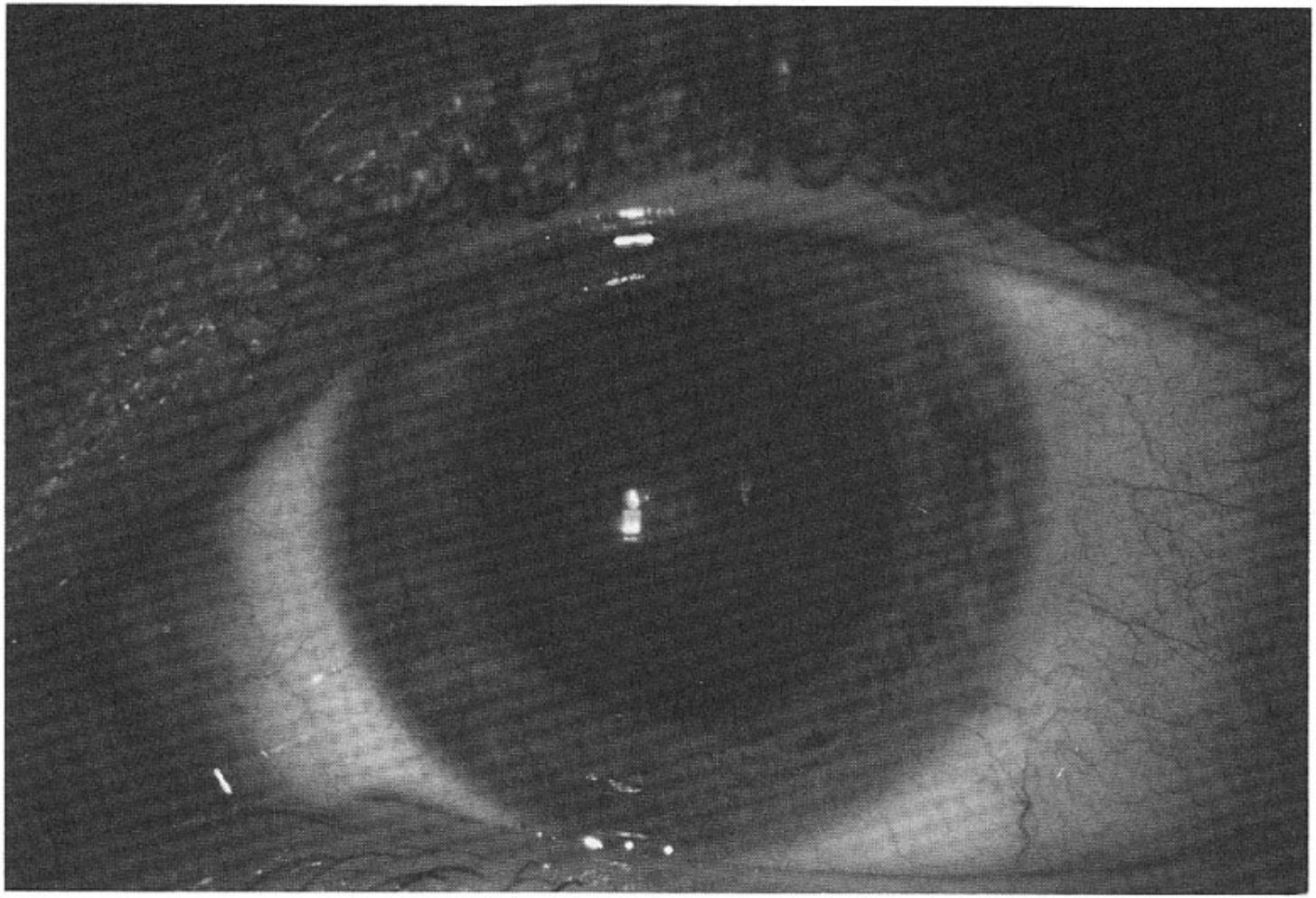
(a)



(b)

FIGURE 5.7

The first, third, and fourth Purkinje images. The third image is blurred because it is reflected from the pebbly front surface of the eyelens. The fourth (inverted) Purkinje image moves during accommodation, implying that the rear surface of the eyelens changes shape.



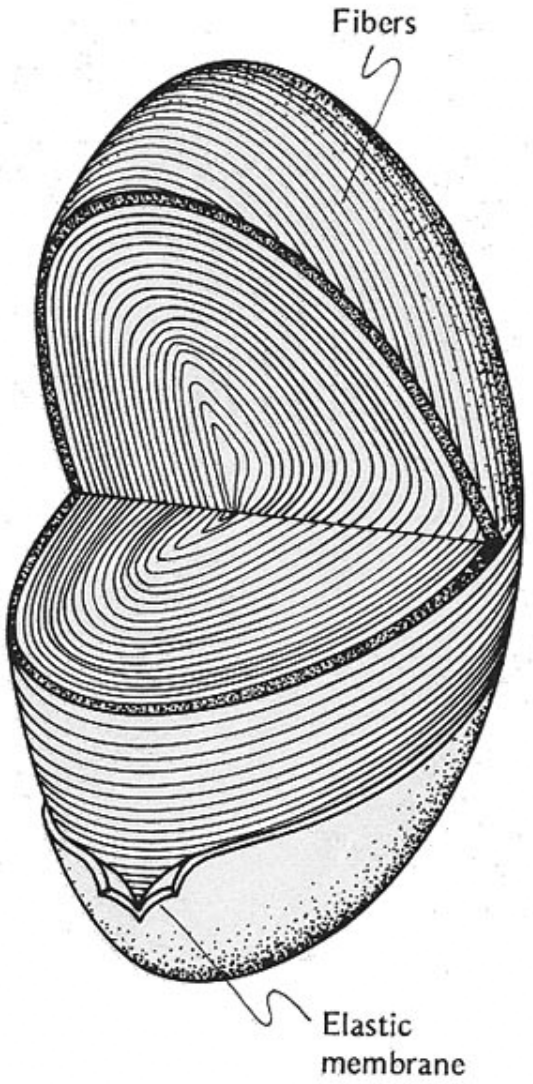


FIGURE 5.9

Eyelens consisting of layers of transparent fibers in clear elastic membrane. The lens of an 80 year old is $1\frac{1}{2}$ times as thick as that of a 20 year old.

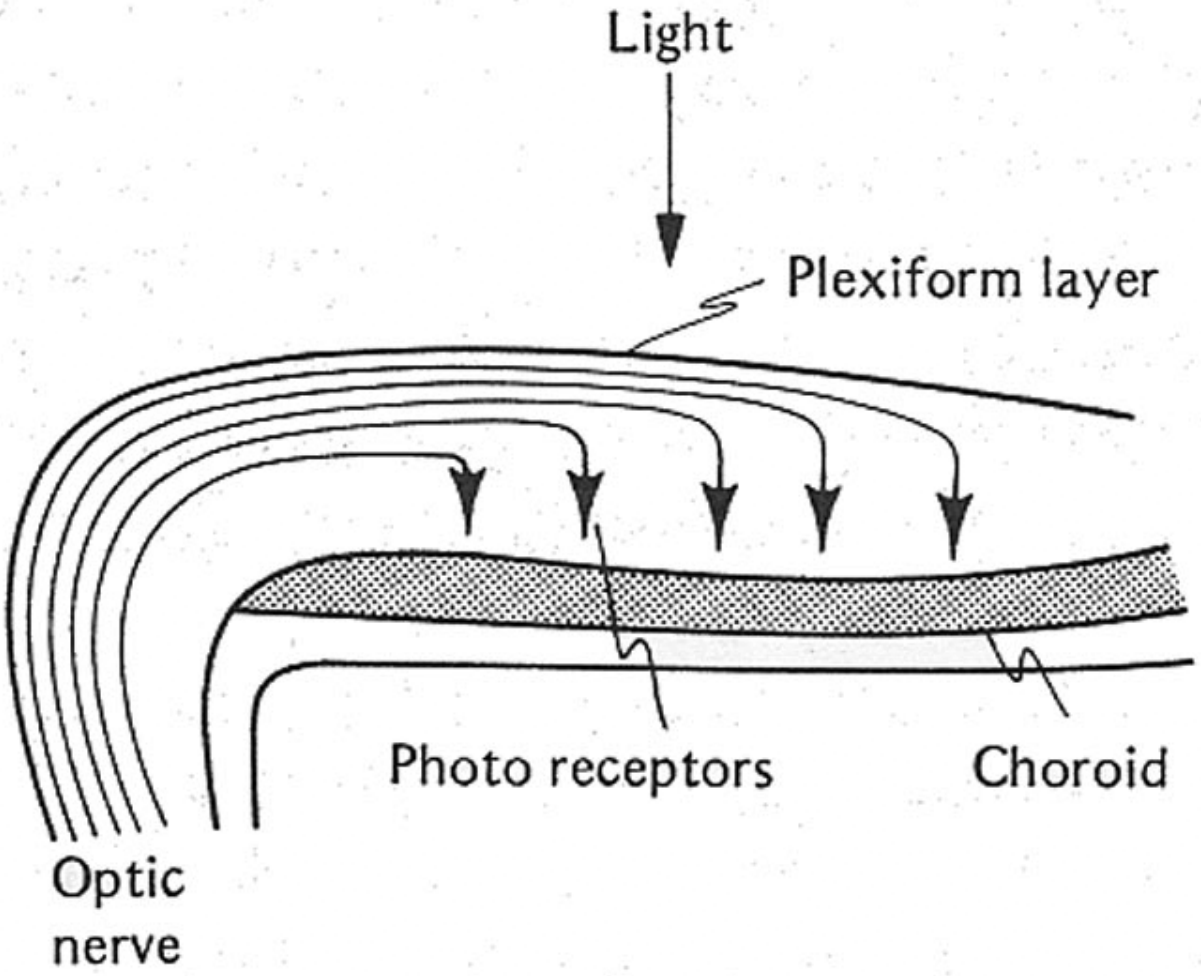


FIGURE 5.10

Layers of the human retina (at a point other than the fovea).

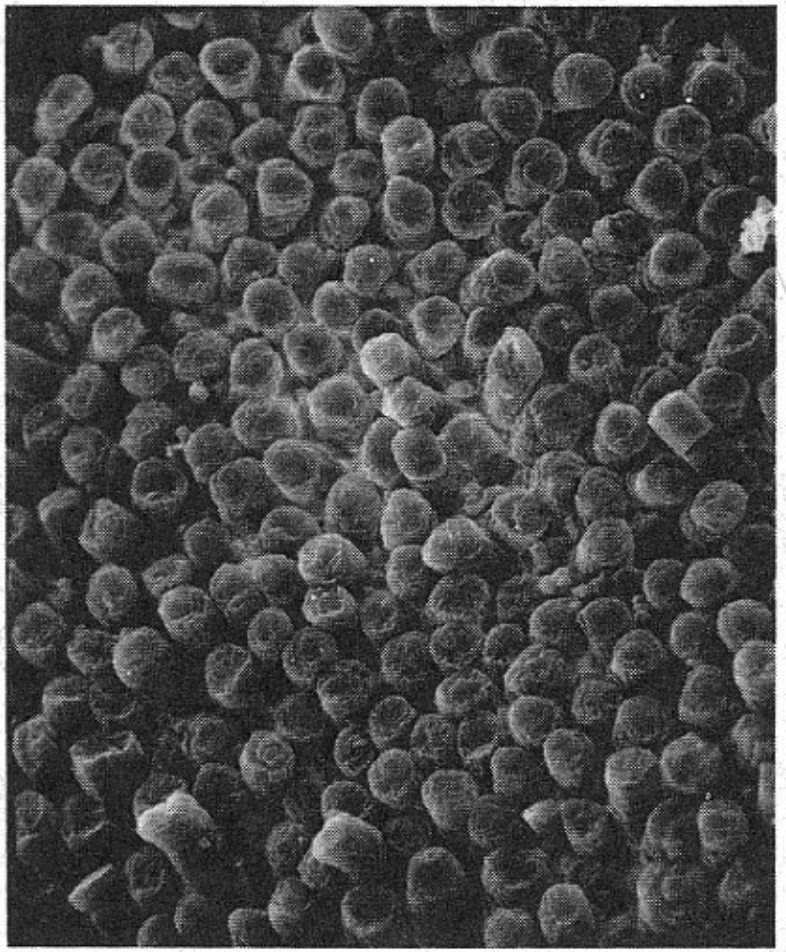
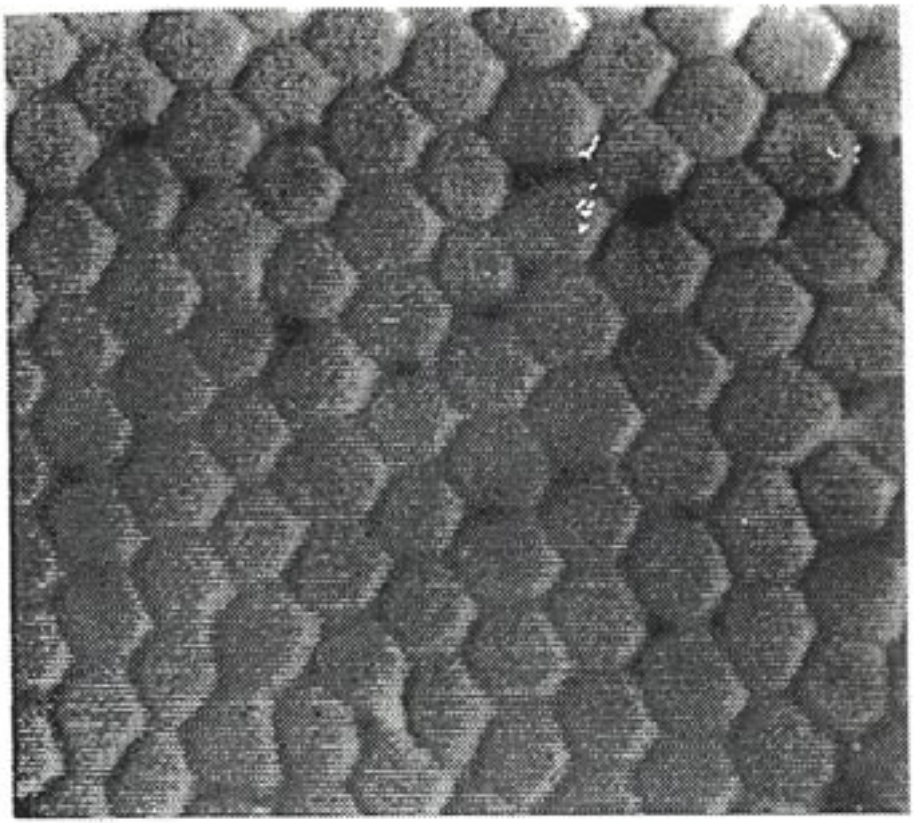


FIGURE 5.11

Electron micrograph of the back of a retina. The photoreceptors face you, and the light would strike them from the far side. The rods are big and blunt; the cones are smaller and pointy. Each cone is about 1 μm across, and each rod is about 5 μm across.

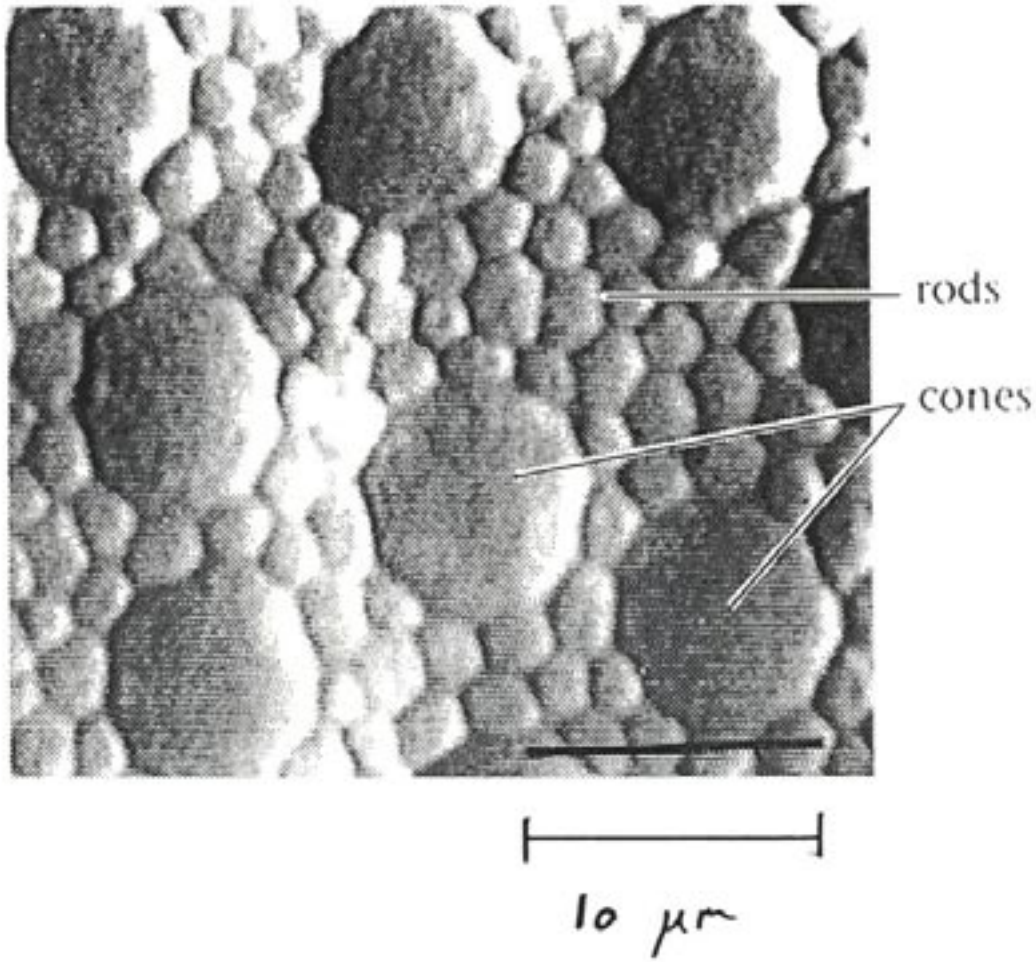
Cone mosaic

Retina- individual cones in the fovea



Mosaic in periphery

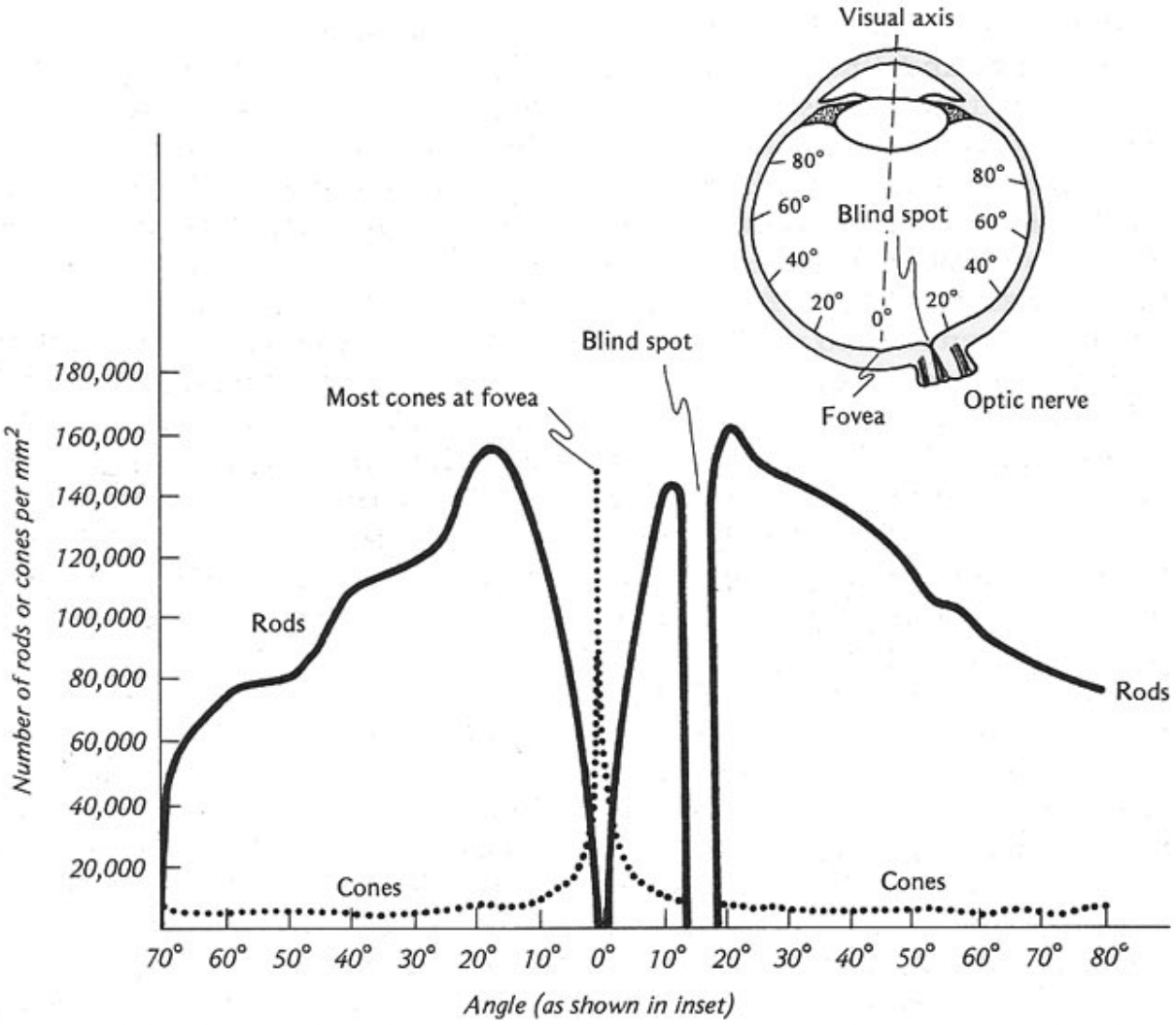
Rods and cones in the periphery of the retina



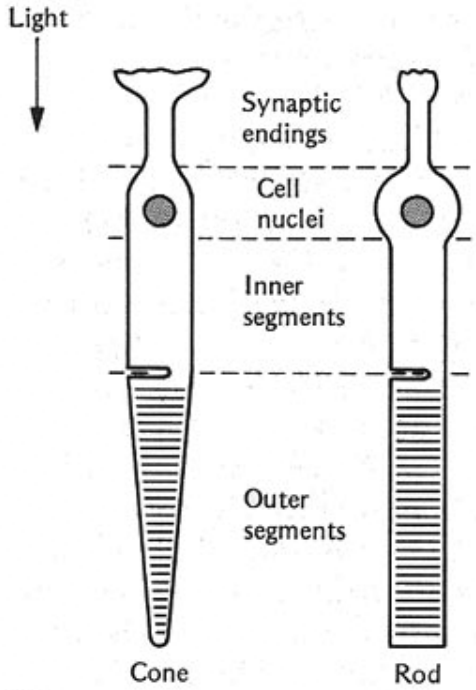
2003 May 15

FIGURE 5.12

Distribution of rods and cones along the equator of an eyeball. The fovea has no rods but many cones. Rods predominate in the periphery. The blind spot has no photoreceptors. Inset shows left eye viewed from above. (Check your answer to the PONDER of Sec. 5.2.)



Find your blind spot



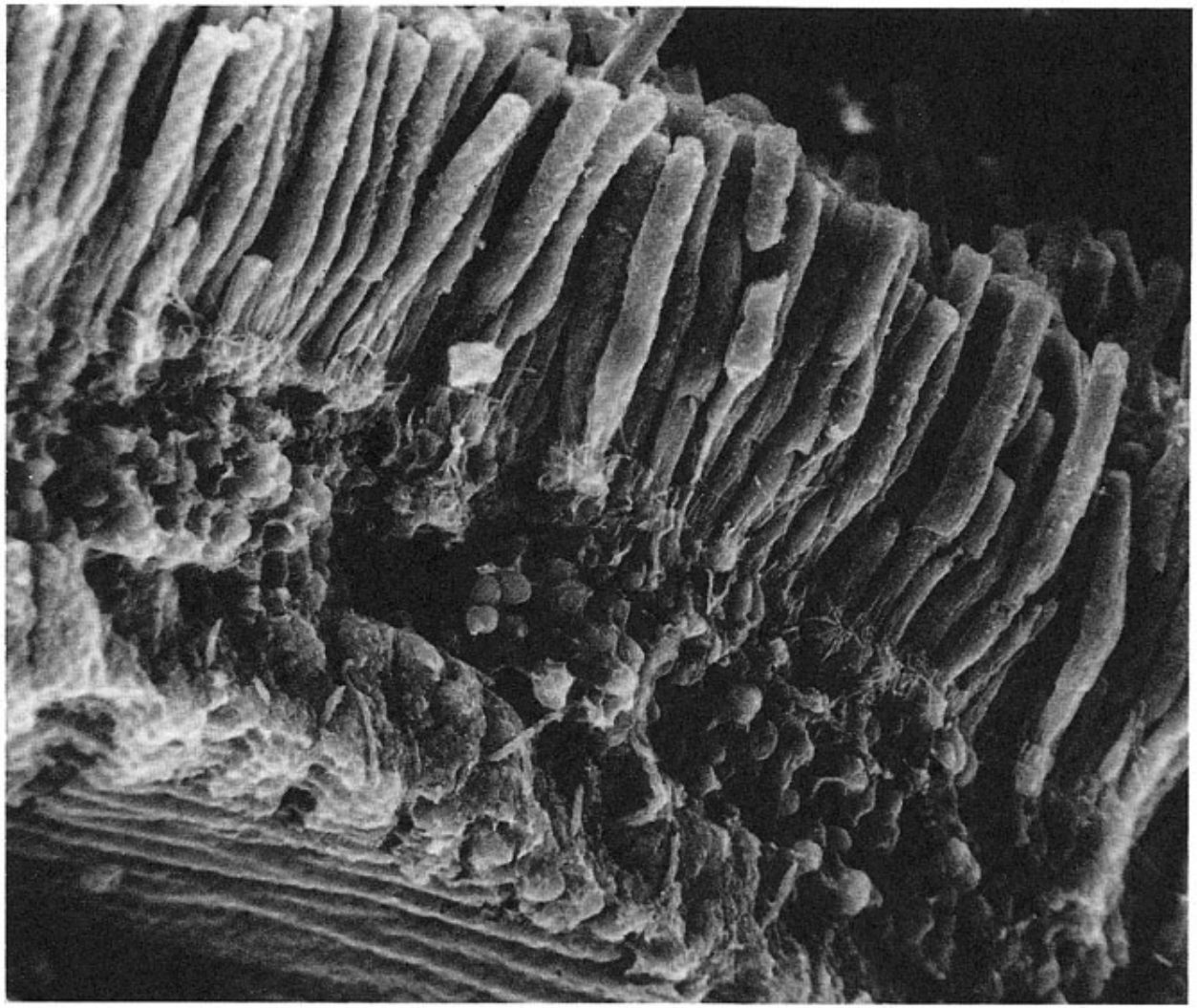
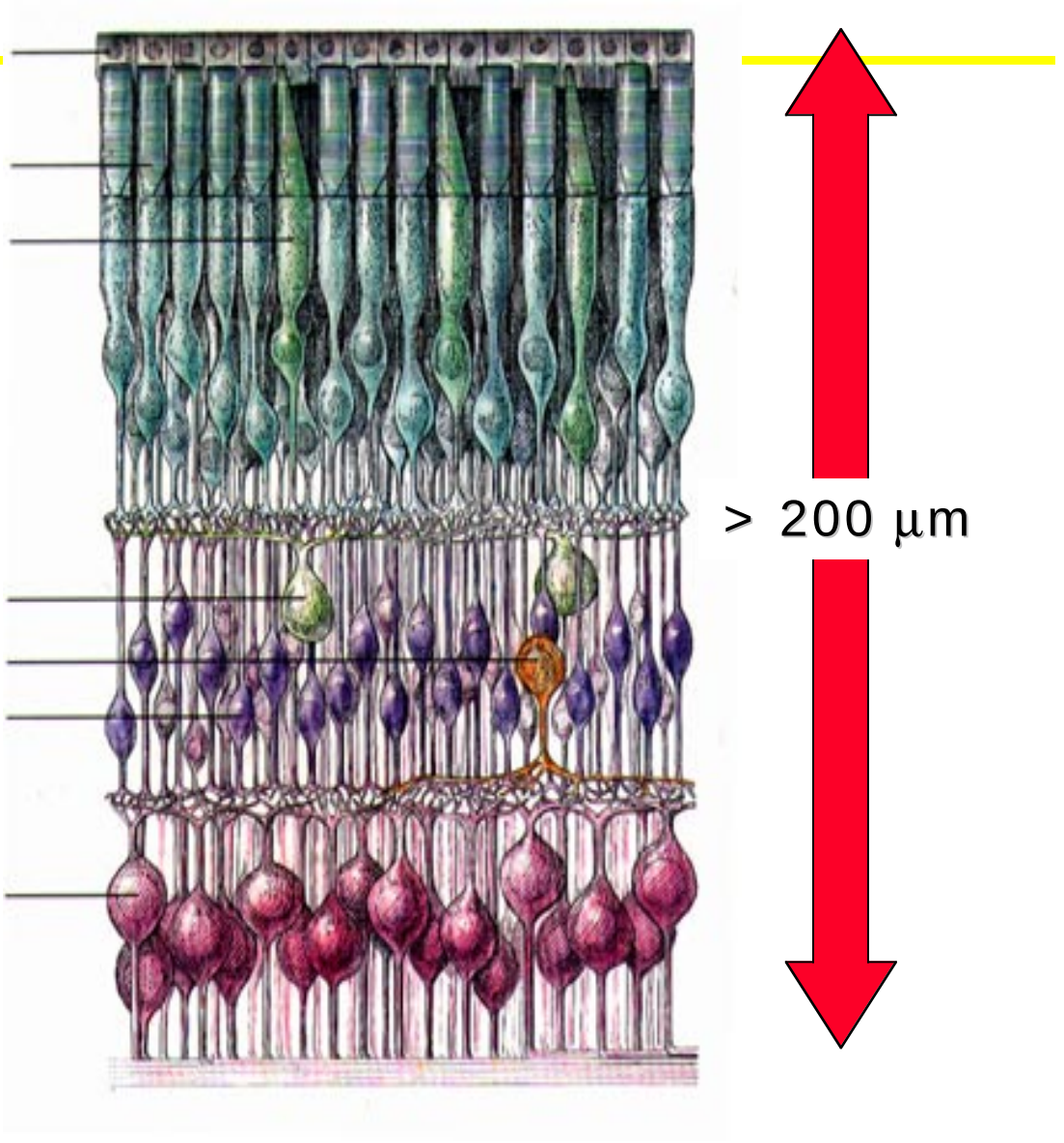


FIGURE 5.13

Physiology of the photoreceptors: **(a)** schematic, **(b)** actual photograph of rods.

Retina Cross Section



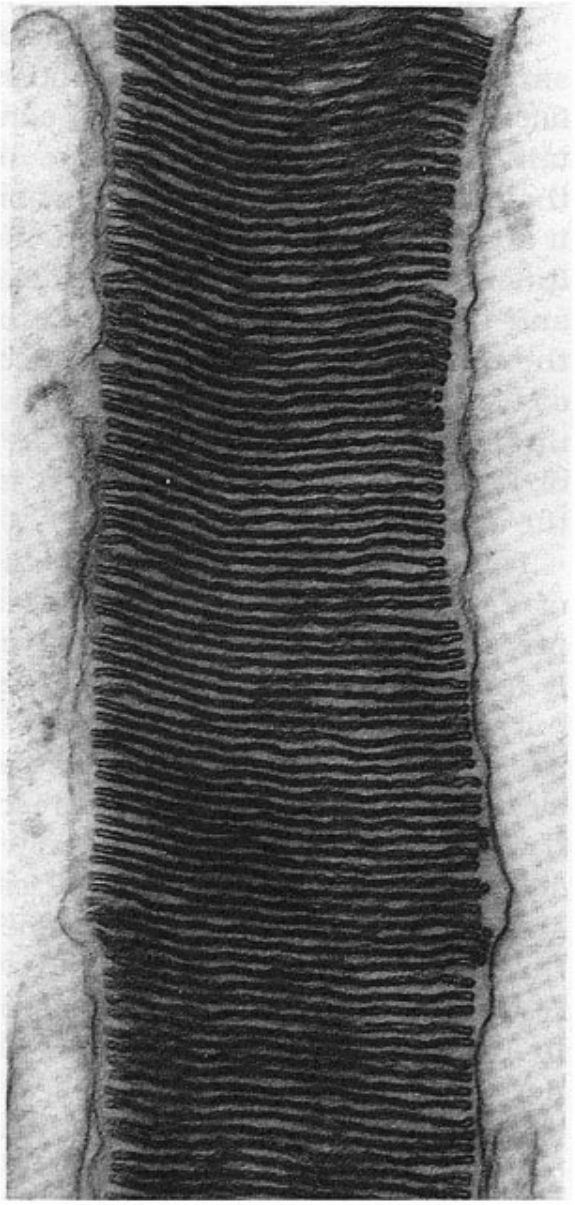


FIGURE 5.14

Electron micrograph of the outer segment of a cone.

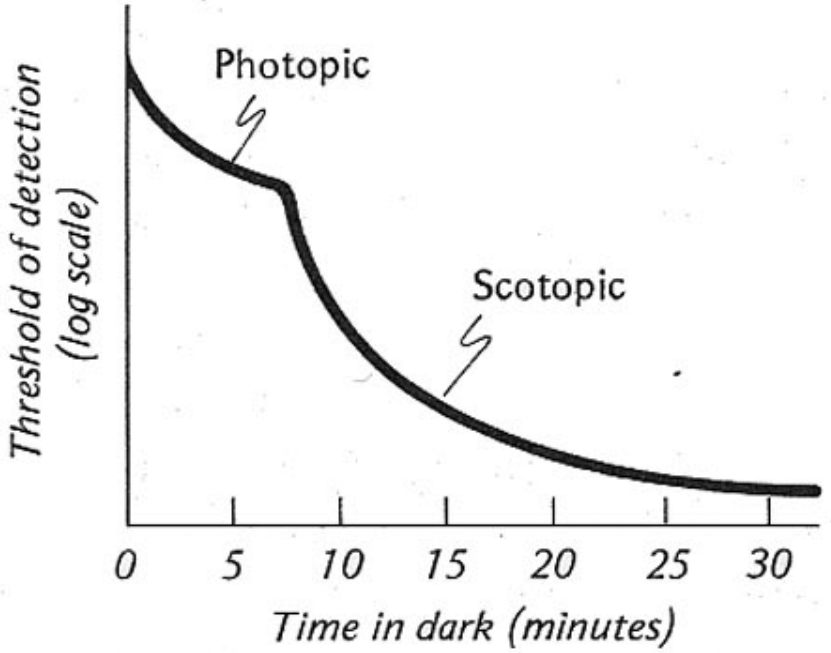


FIGURE 5.16

Dark adaptation. The threshold of detection (log scale) versus time in the dark. The first section (photopic) is due to the cones. You sense color at these thresholds. The second section (scotopic) is due to the rods. You see the world as black, white, and gray at these thresholds. Details of this curve will vary, depending upon the specific conditions and the individual subject.

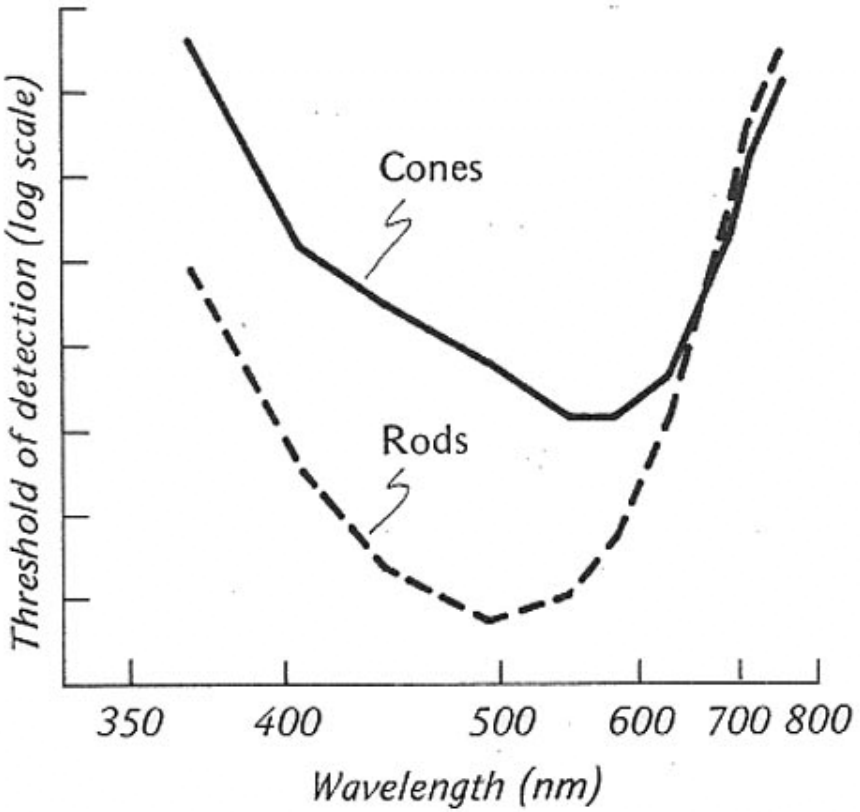
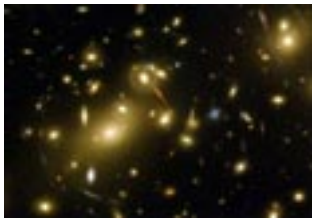
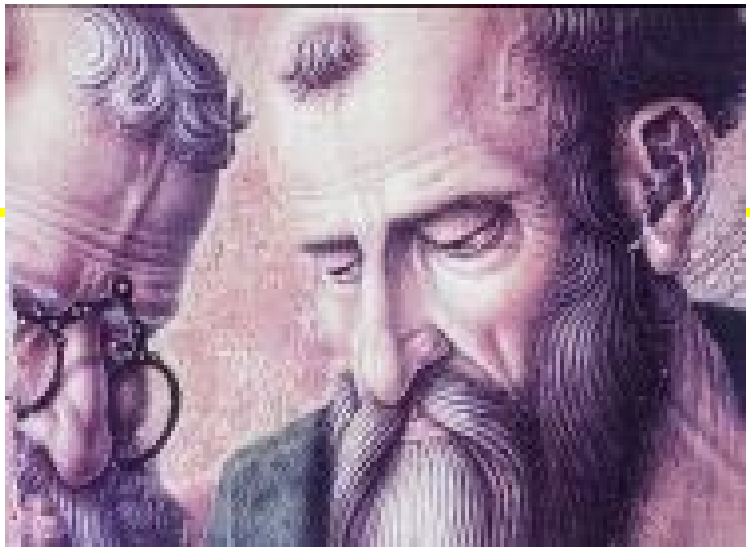


FIGURE 5.17

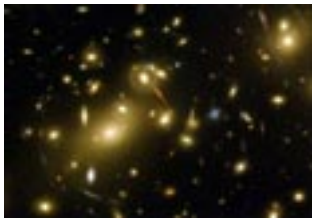
Relative thresholds of the rod and cone systems versus wavelength of light at some late stage of dark adaptation. The rod system is, overall, more sensitive than the cone system and is most sensitive at about 505 nm. The cone system is most sensitive at about 555 nm.



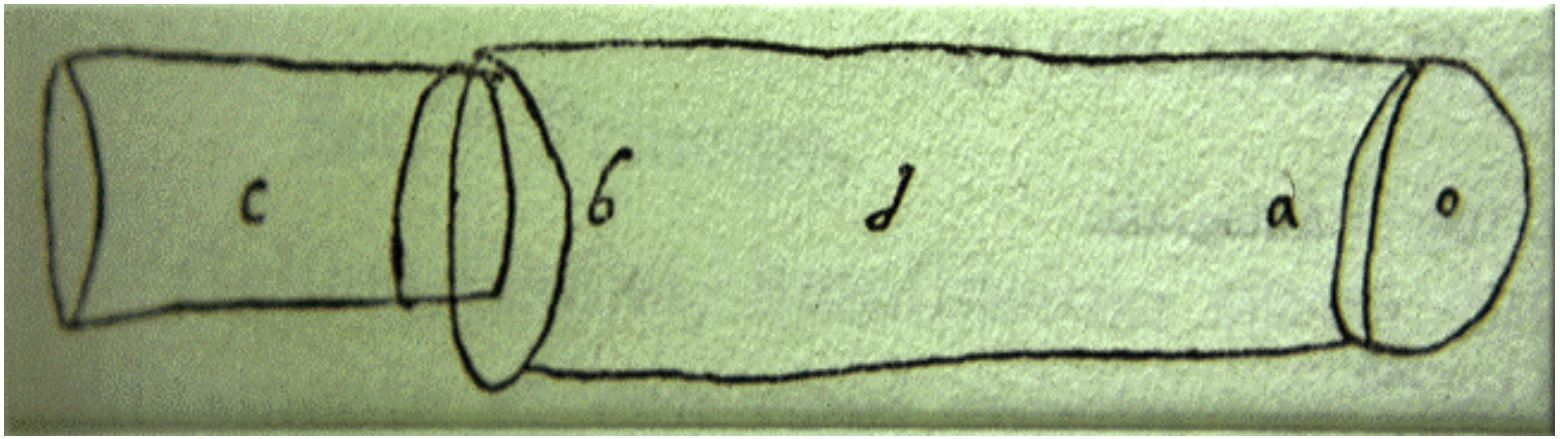


Detail of *Hugh of St. Cher*, painted in 1352 by Crivelli

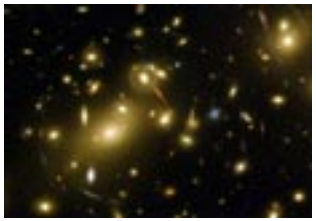
Detail of *Death of the Virgin* painted between 1400 and 1410 by the Master of Heiligenkreuz



The earliest known illustration of a telescope

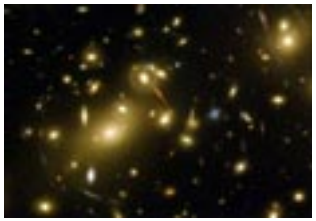


Giovanpattista della Porta, August 1609



Kepler

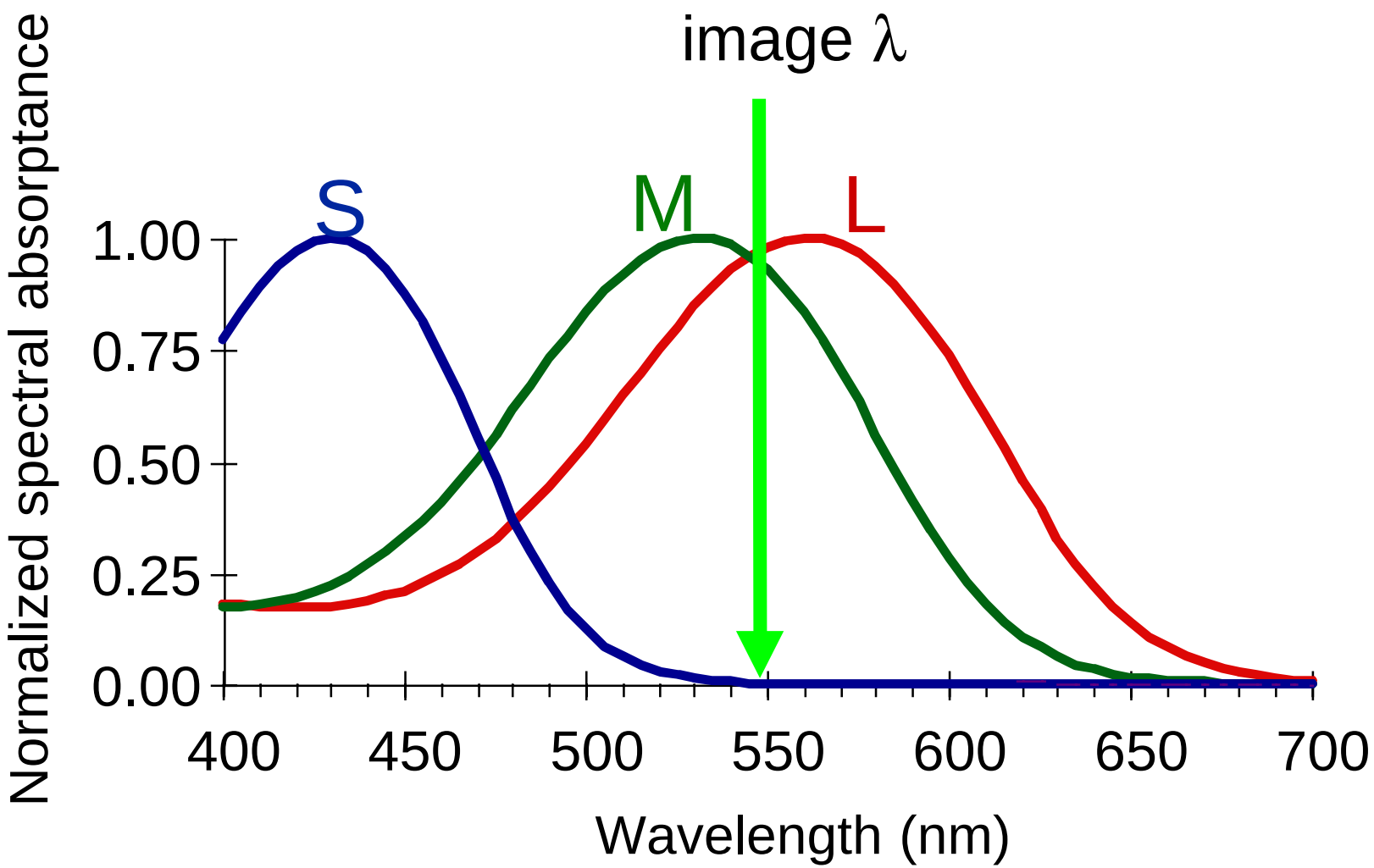
1604: Kepler explains optics of near- and far-sightedness



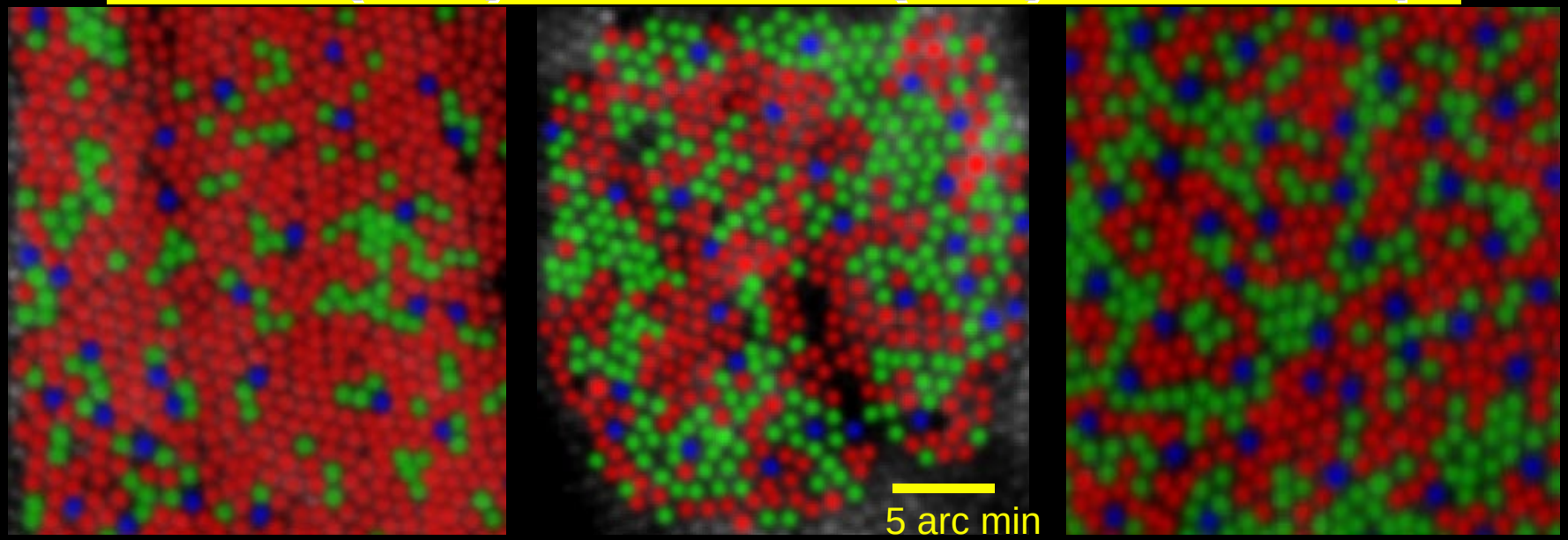
"*Now, it is not too much to say that if an optician wanted to sell me an instrument which had all these defects, I should think myself quite justified in blaming his carelessness in the strongest terms and giving him back his instrument*"

Helmholtz (1881) on the eye's optics.

The Trichromatic Cone Mosaic

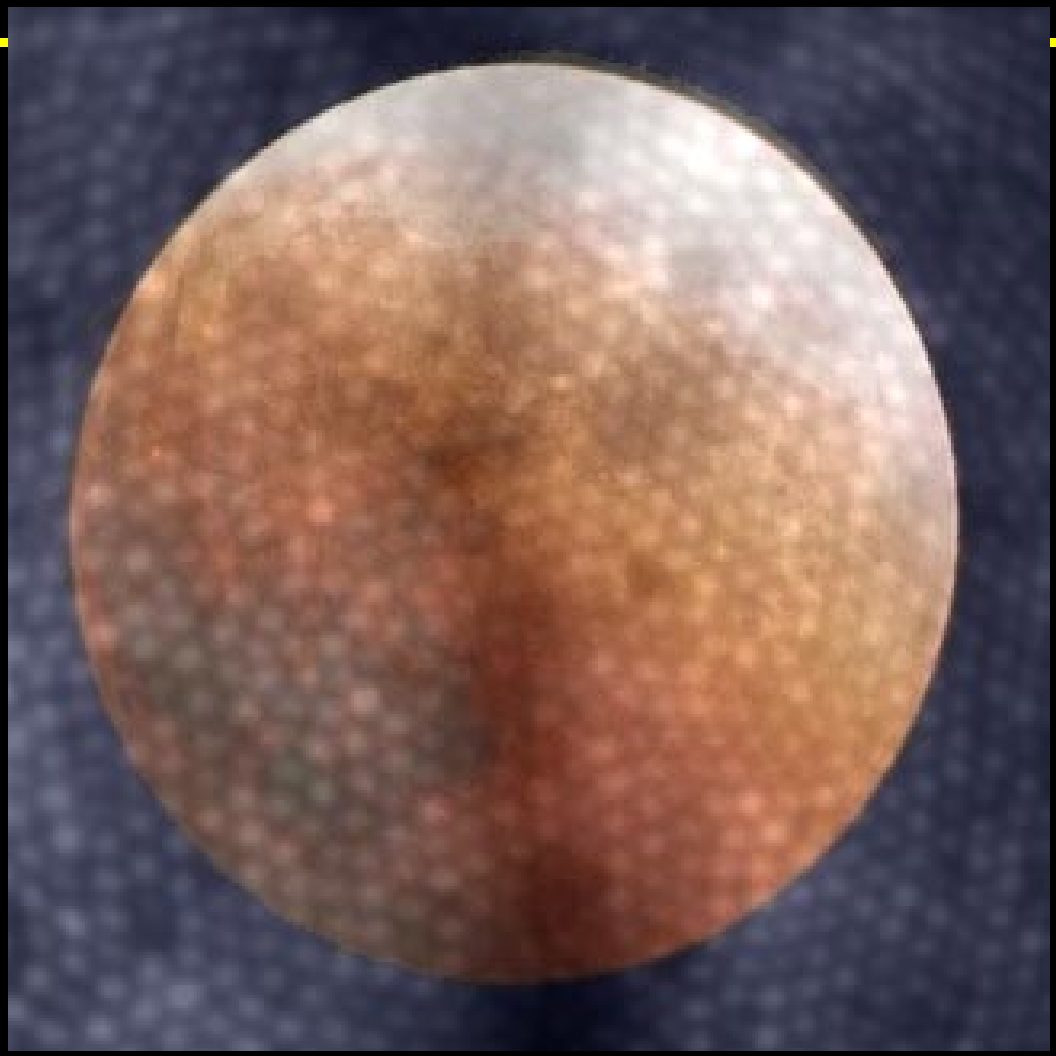


human (JW) **human (AN)** **macaque**

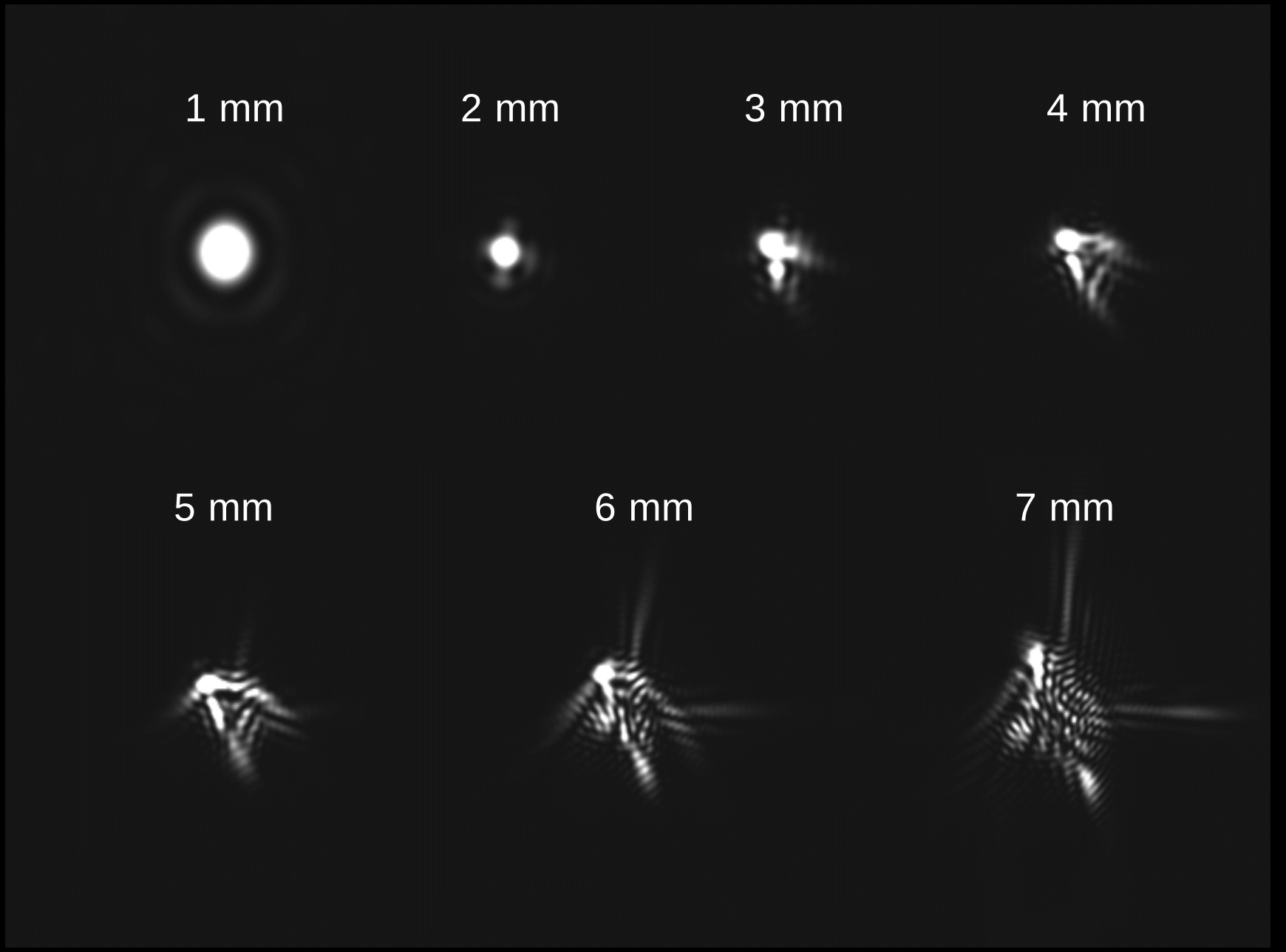


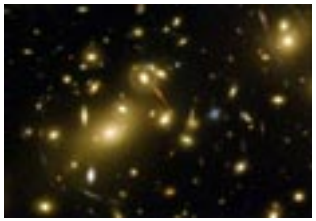
L	75.8%	L	50.6%	L	53.4%
M	20%	M	44.2%	M	38%
S	4.2%	S	5.2%	S	8.6%
L/M = 3.79		L/M = 1.14		L/M = 1.40	

View of Lunar Eclipse

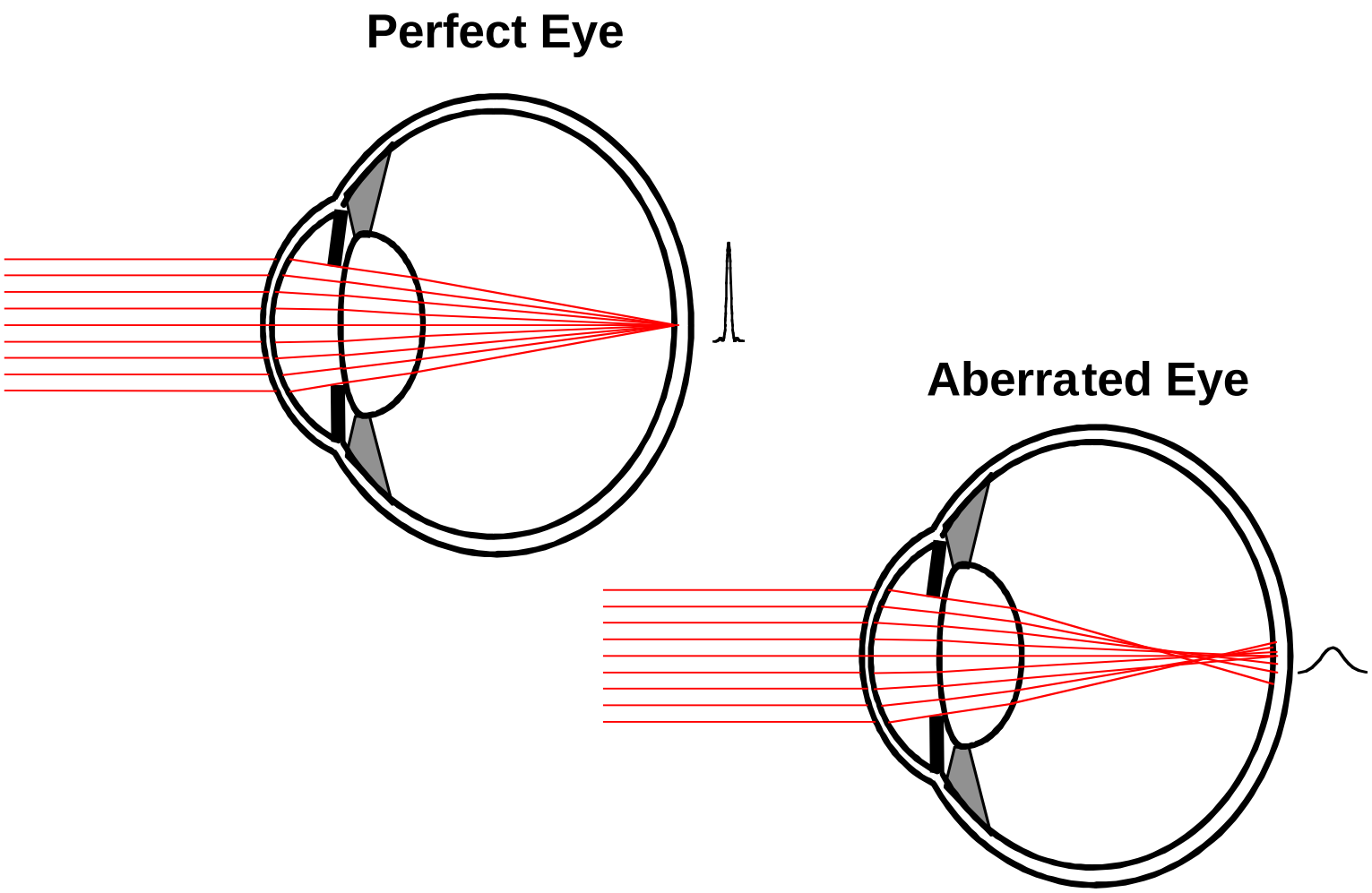


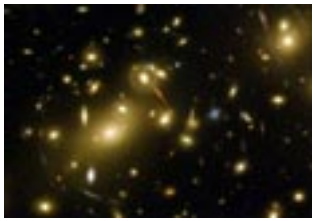
PSF Changes with Pupil Size





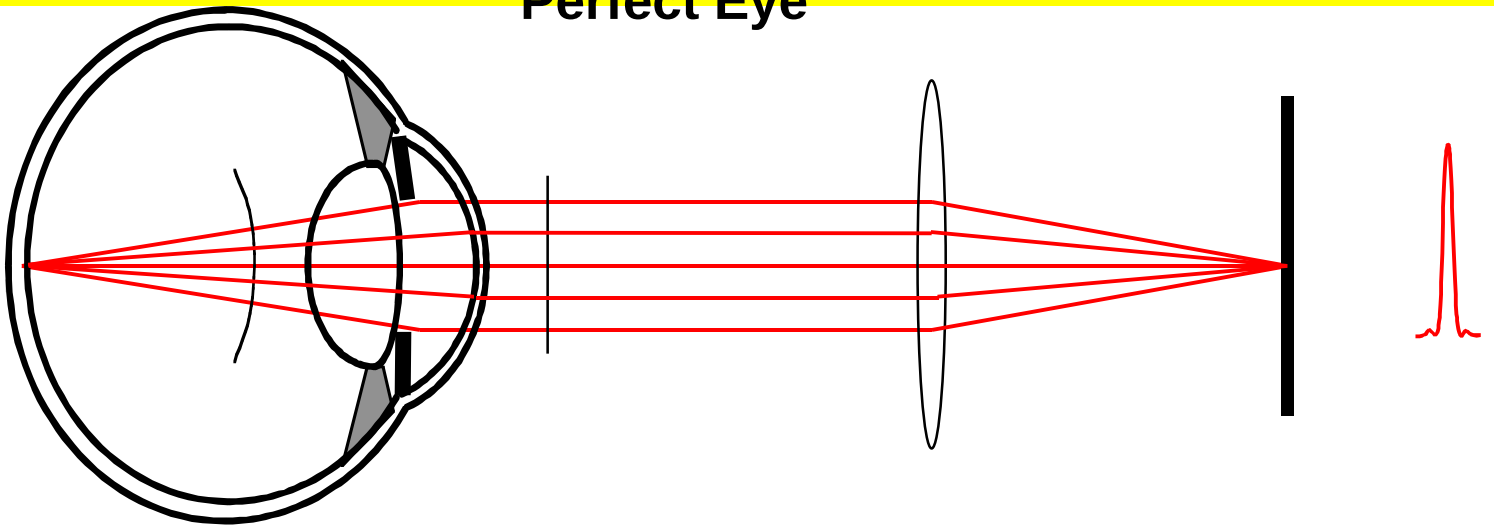
Why Correct the Eye's Optics?





Why Correct the Eye's Optics?

Perfect Eye



Aberrated Eye