Sensation, Part 3
Gleitman *et al*. (2011), Chapter 4

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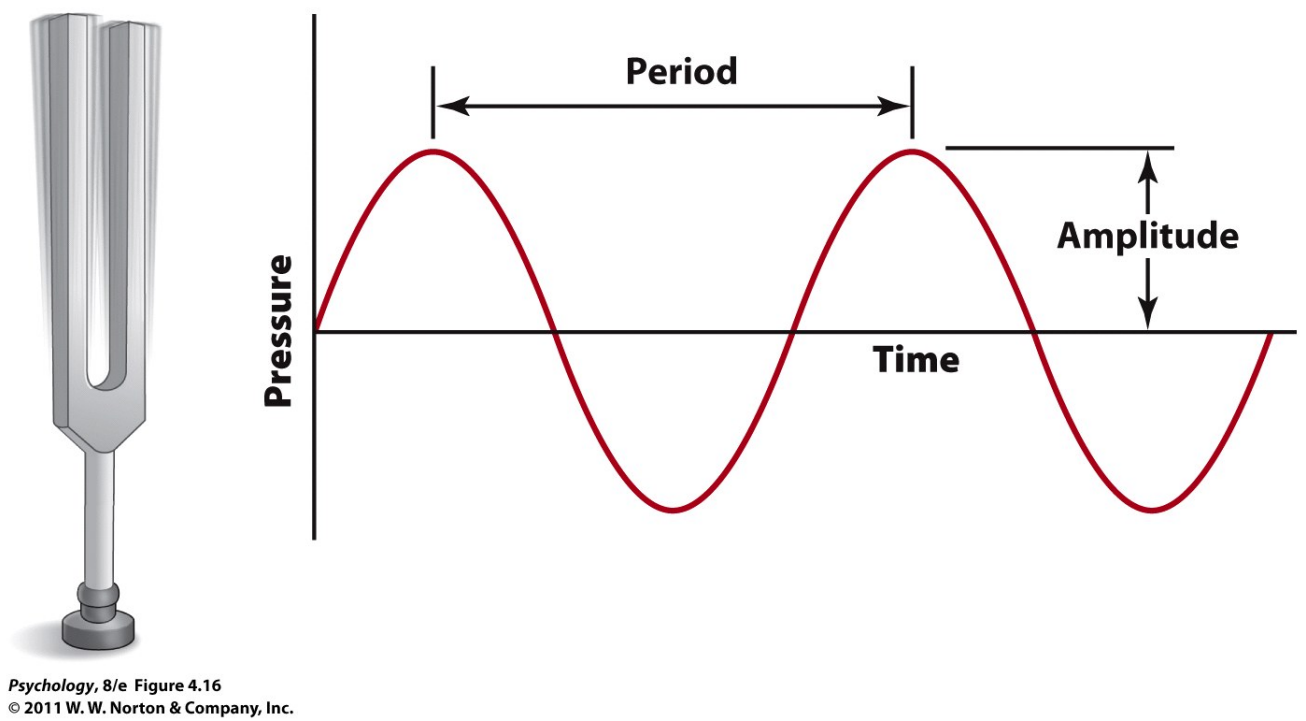
Psych 9A / Psy Beh 11A
February 18, 2014

Hearing - *Audition*

A brief recap from last week on sound stimuli…

- *Sound waves*
  - can vary in *amplitude* and *frequency*
  - create vibrations in eardrum
  - transmitted by the *auditory ossicles*
  - to the *oval window*—movements create waves in the *cochlea*
  - *hair cell* receptor neurons in the cochlea transduce sound pressure waves into neural signals

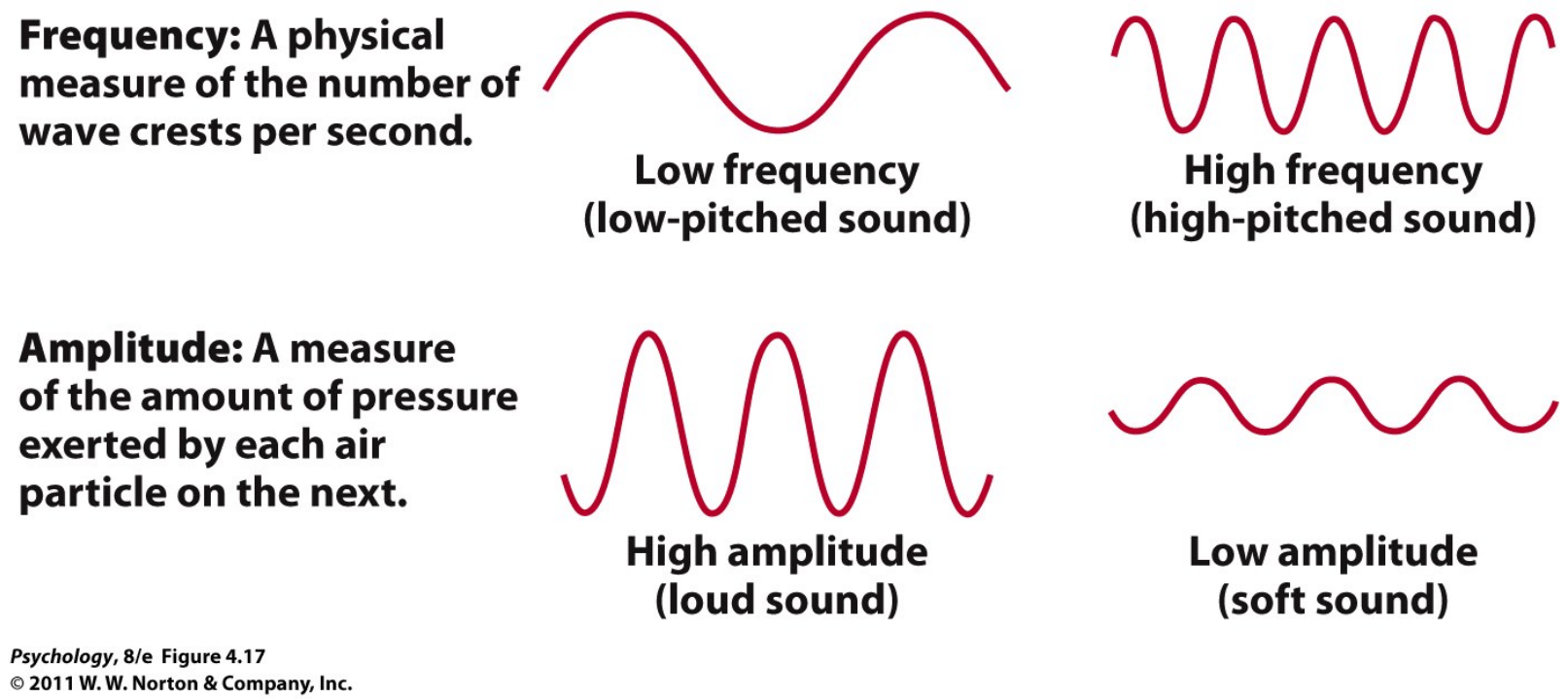
A *pure tone* has a sound pressure wave described by a sinusoidal function.



Psychology, 8/e Figure 4.16

Pure tones vary in their

- *amplitude* (related to the perceptual variable *loudness*)
- *frequency* (related to the perceptual variable *pitch*)



Units of frequency are Hertz (Hz):

number of cycles (full waves) per second

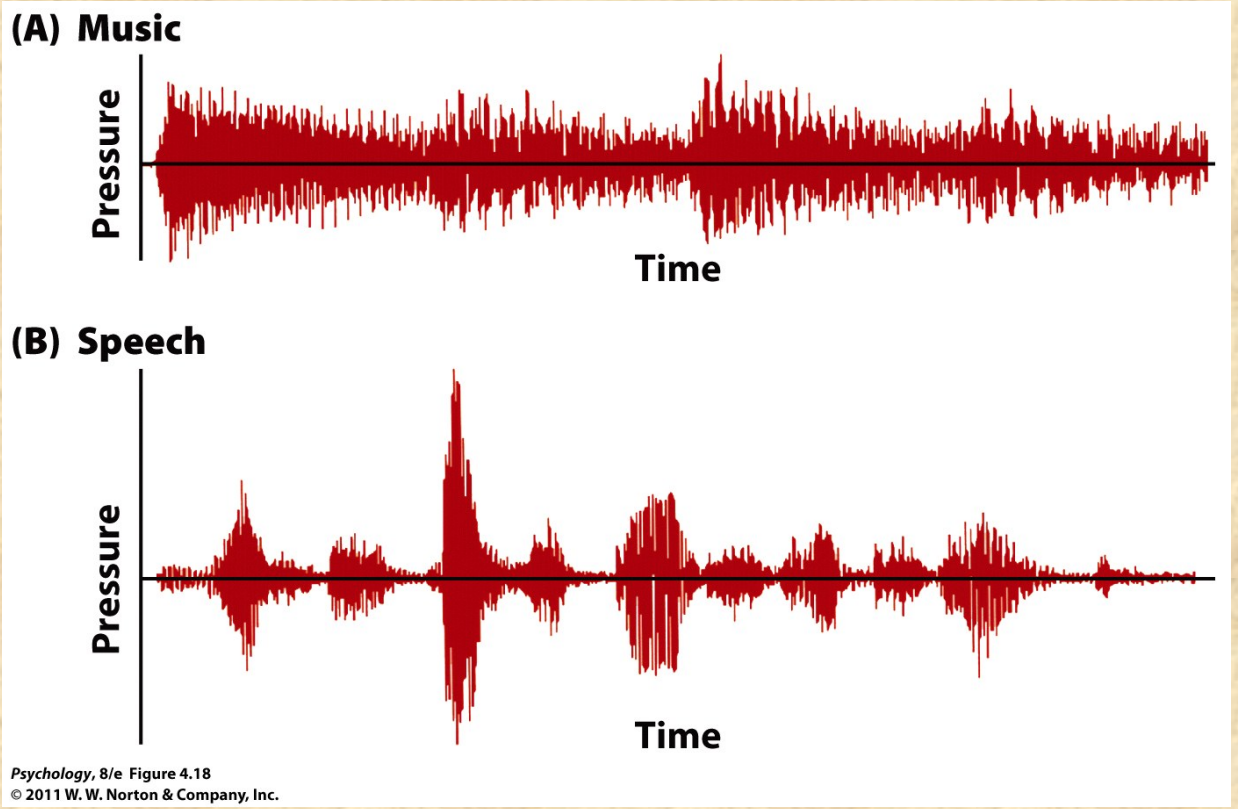
TABLE 4.3 Sound Frequencies of Some Musical Tones

Sound	Frequency (hertz)*
Top note of grand piano	4,244
Top note of piccolo	3,951
Top range of soprano voice	1,152
Top range of alto voice	640
Middle C	261
Bottom range of baritone voice	96
Bottom range of bass voice	80
Bottom note of organ (can be felt but not heard)	16

*Note that some orchestras, and some musicians, choose to tune their instruments differently. Middle C, for example, is sometimes tuned to a frequency of 256 hertz, or one as high as 264.

Psychology, 8/e Table 4.3

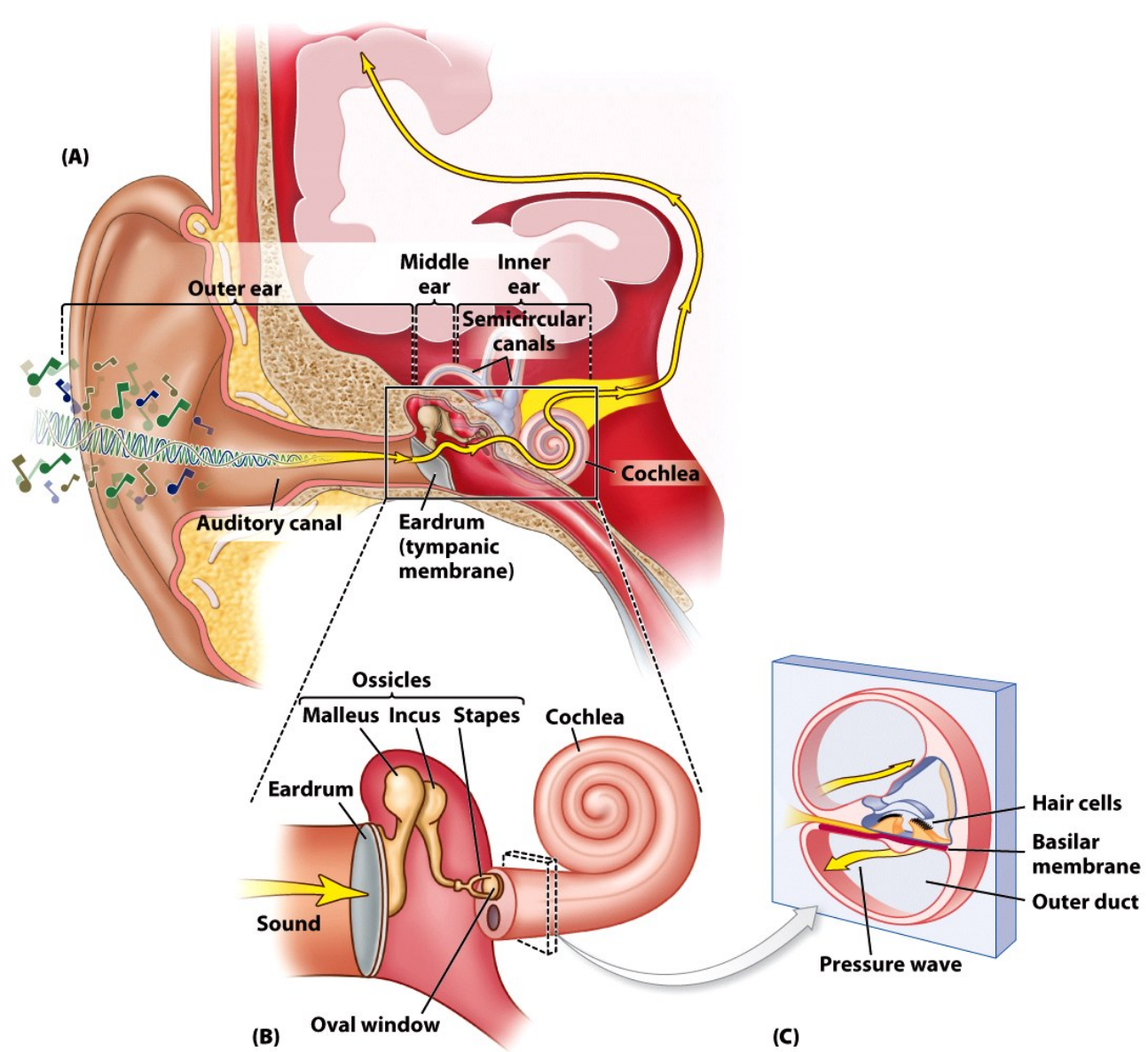
Almost all sounds are described by *complex* waveforms. These can be analyzed in terms of a sum of pure tone waveforms (Fourier analysis)



try the sound-generating Java applet at http://www.phys.hawaii.edu/~teb/java/ntnujava/sound/sound.html

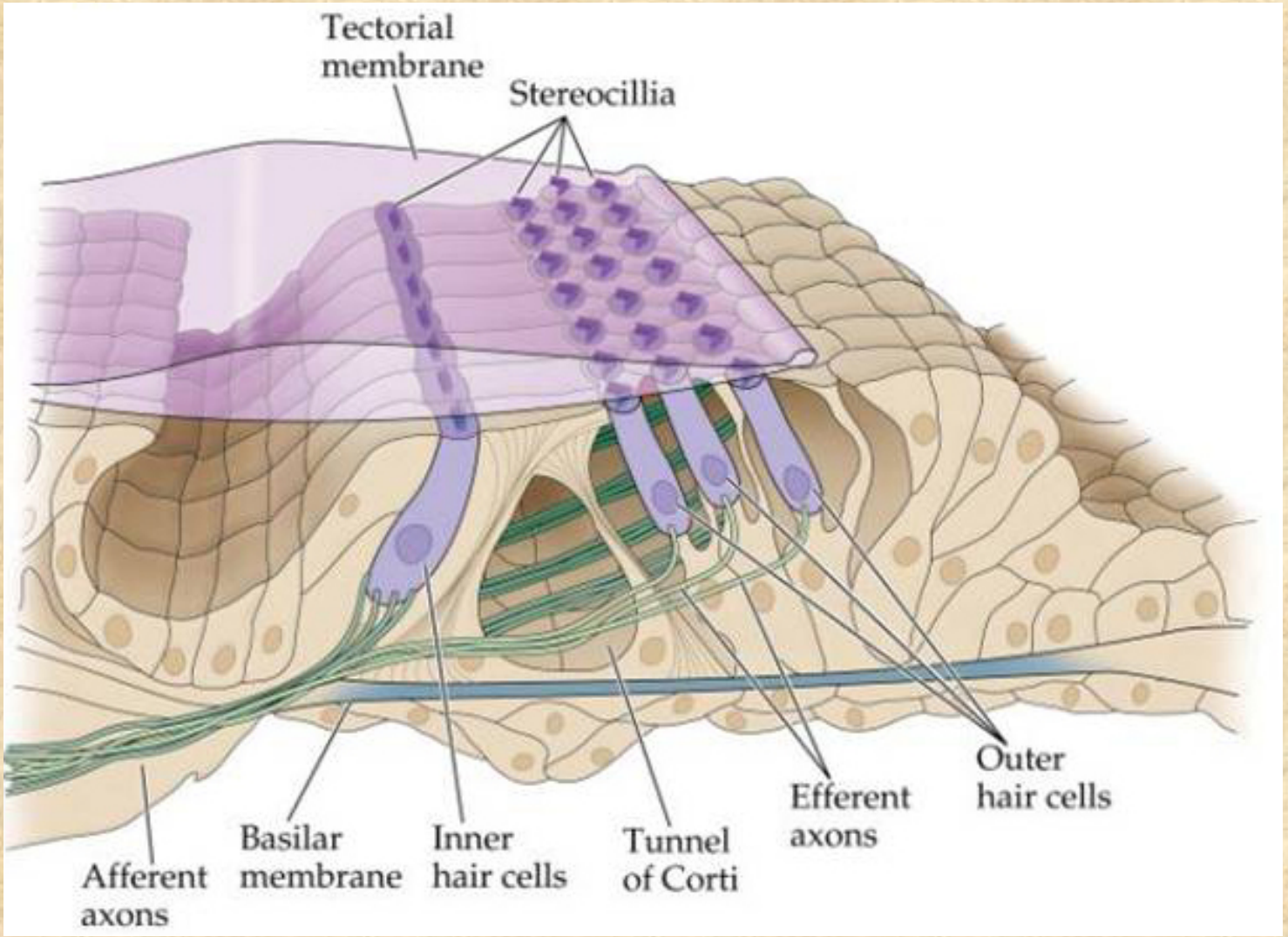
Hearing

- Within the cochlea is the *basilar membrane.*
  - contains receptors stimulated by the membrane's deformation



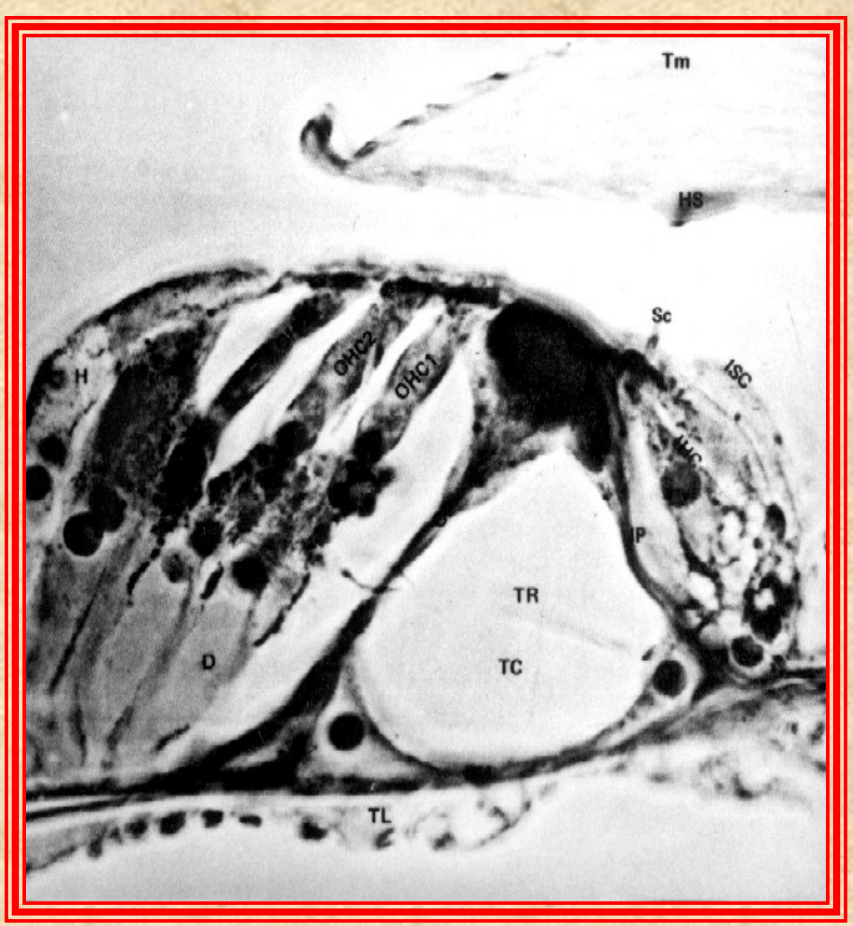
Psychology, 8/e Figure 4.19

Organ of Corti

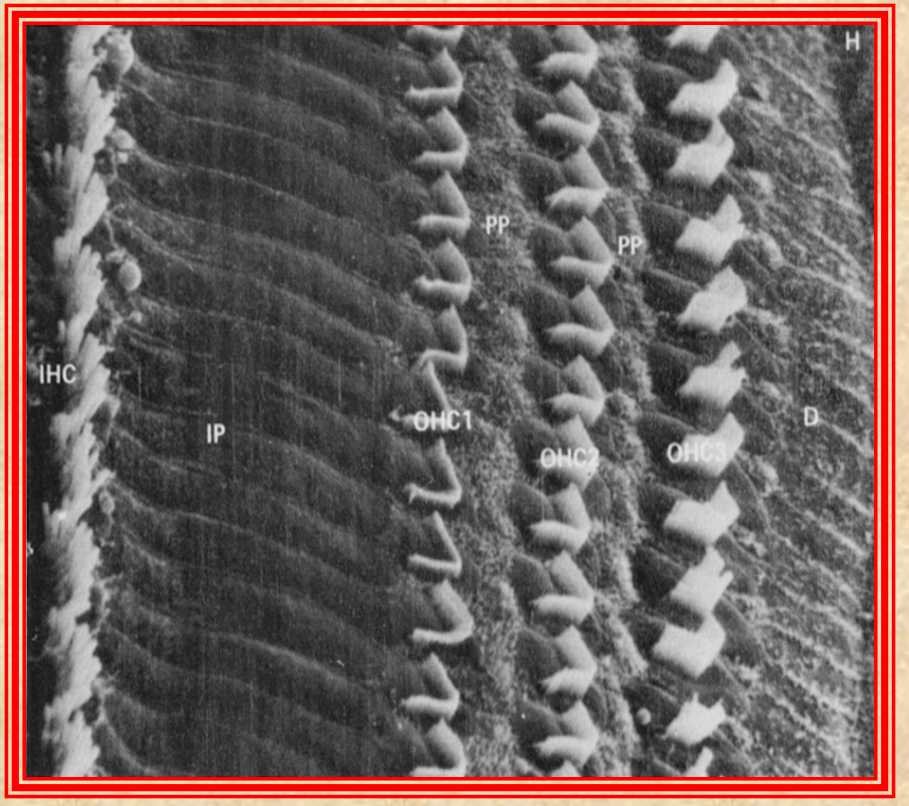


Organ of Corti with
Inner and Outer Hair Cells

(IHC and OHC)

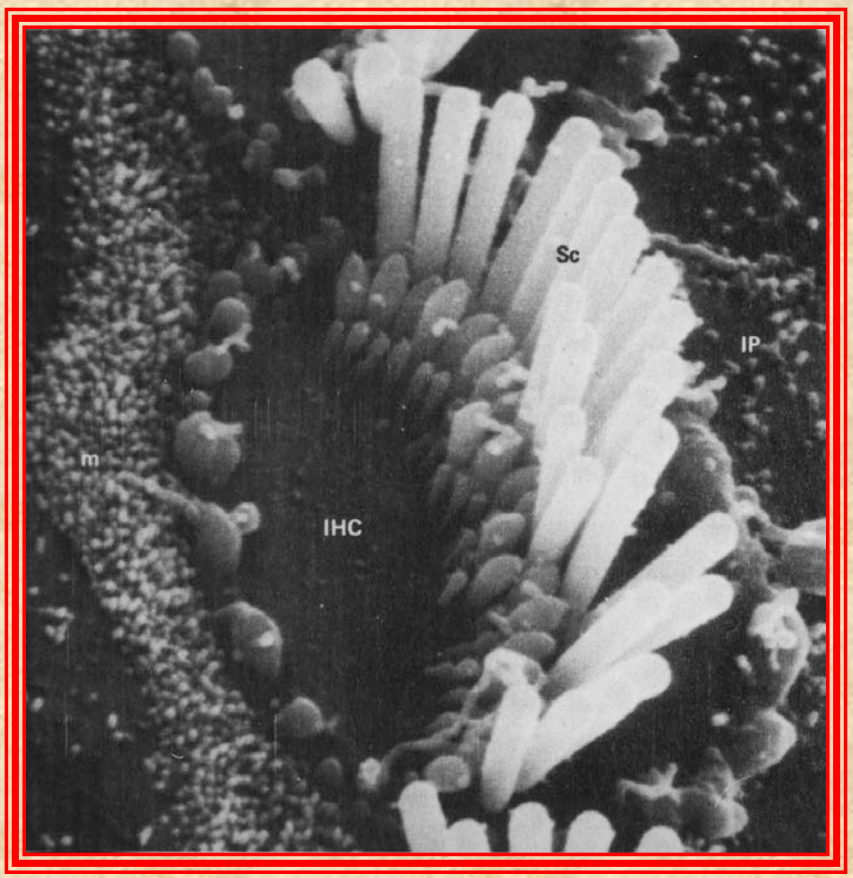


Inner and Outer
Hair Cell Stereocilia



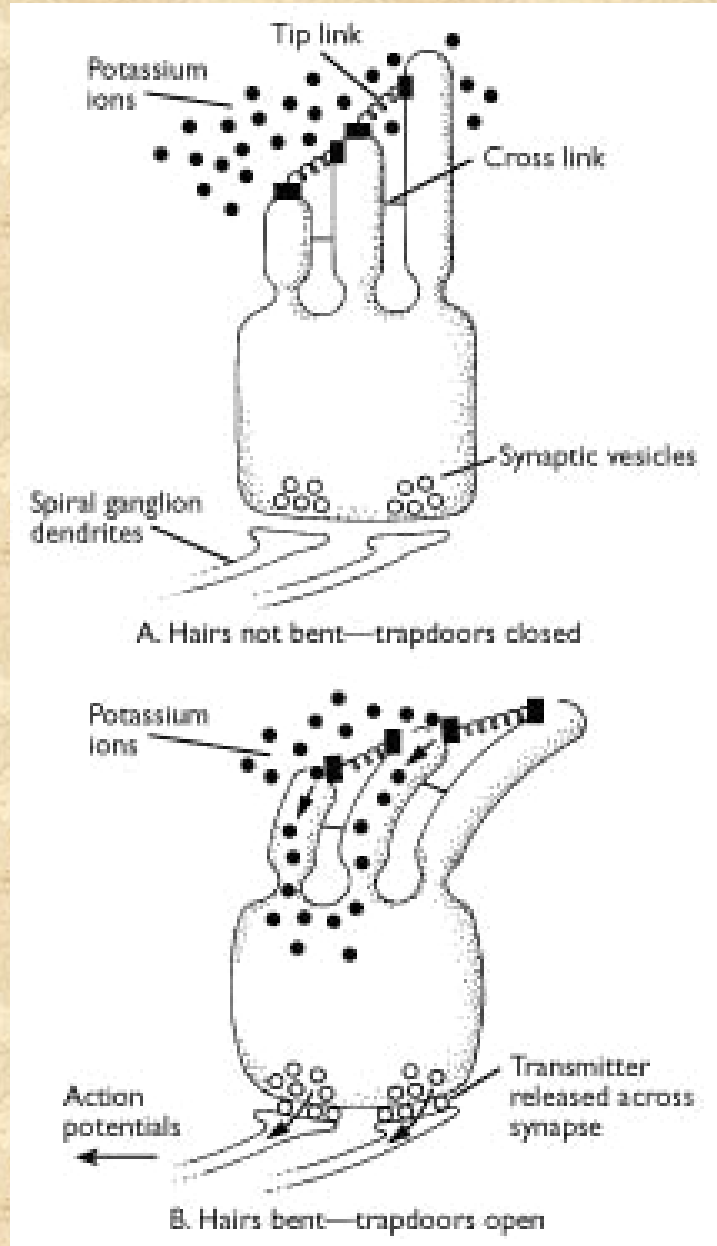
IHC cilia – not attached to the tectorial membrane
OHC cilia – attached to the tectorial membrane

Inner Hair Cell Stereocilia

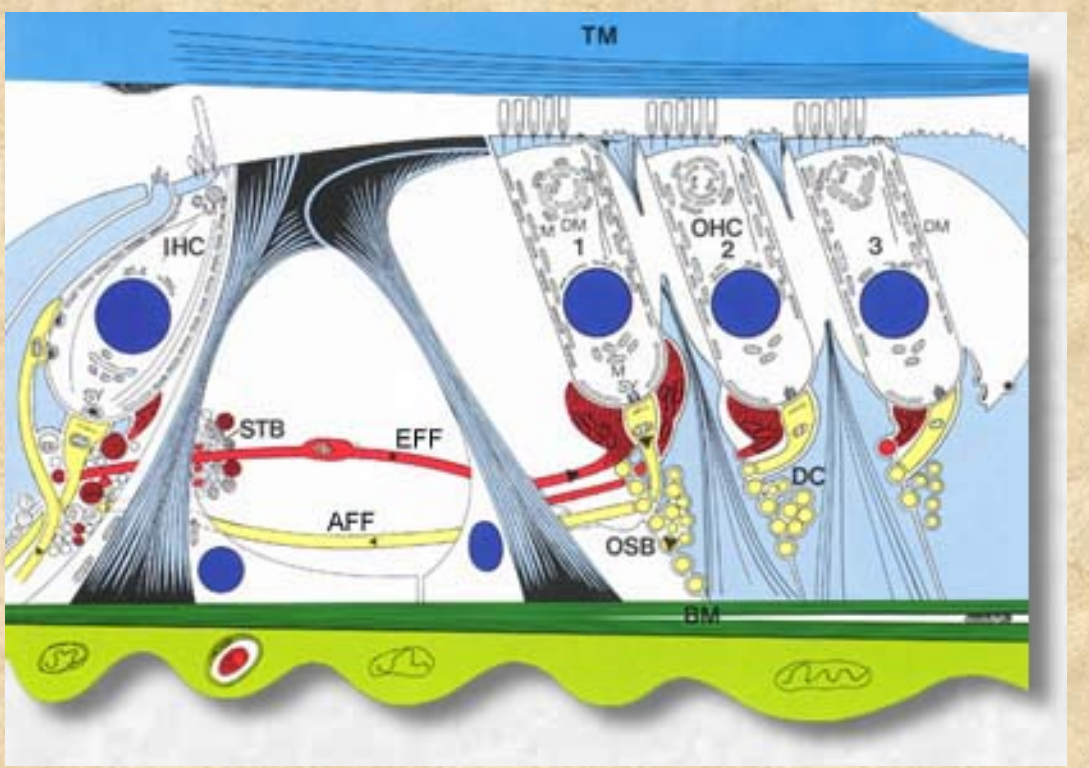


Tip links on haircell stereocilla

Inner Hair Cell Transduction



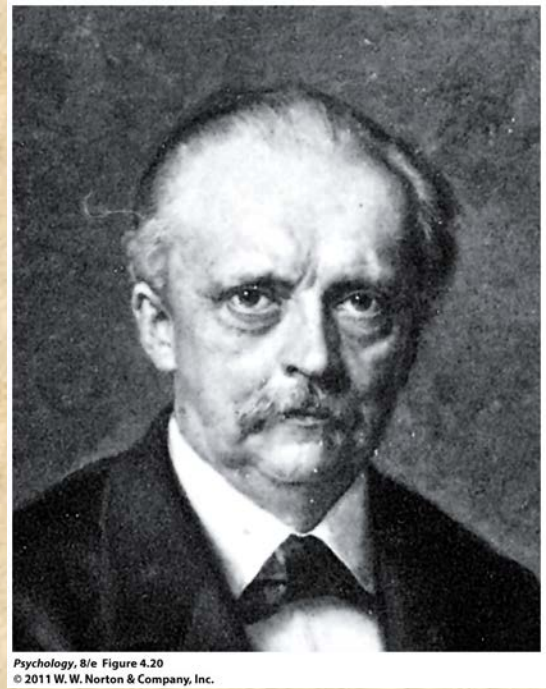
Dendrites of the spiral ganglion cells
collect signals from the hair cells



AFF – afferent fibers to the brain
EFF – efferent fibers out of the brain

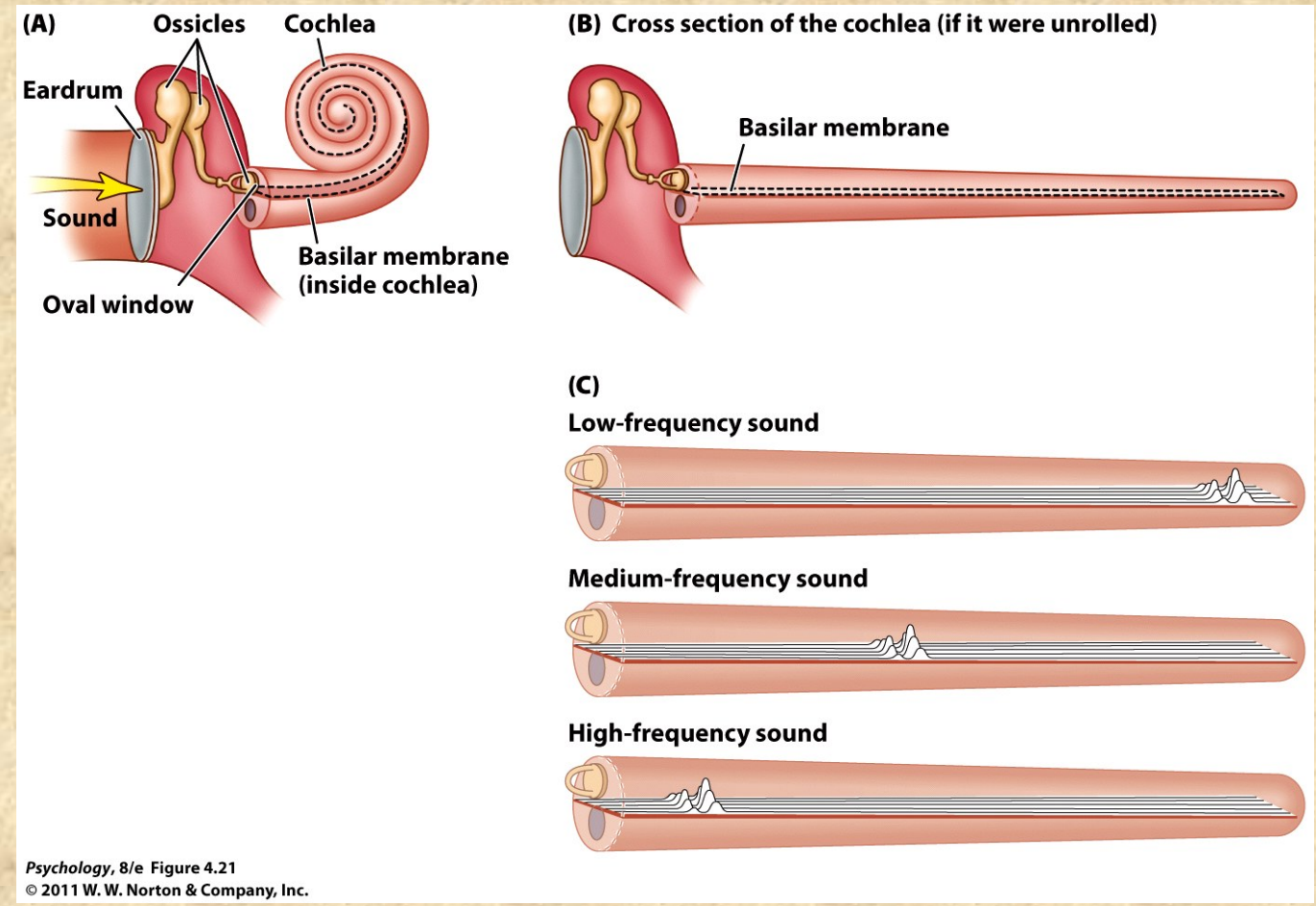
Theories About Pitch

- *Place theory*
  - Pitch is based on the place where the basilar membrane is most stimulated.
    - Different places are more responsive to particular frequencies and generate particular pitch sensations.
- *Frequency theory*
  - Pitch depends on firing frequency of the auditory nerve.


Psychology, 8/e Figure 4.20

Hermann von Helmholtz

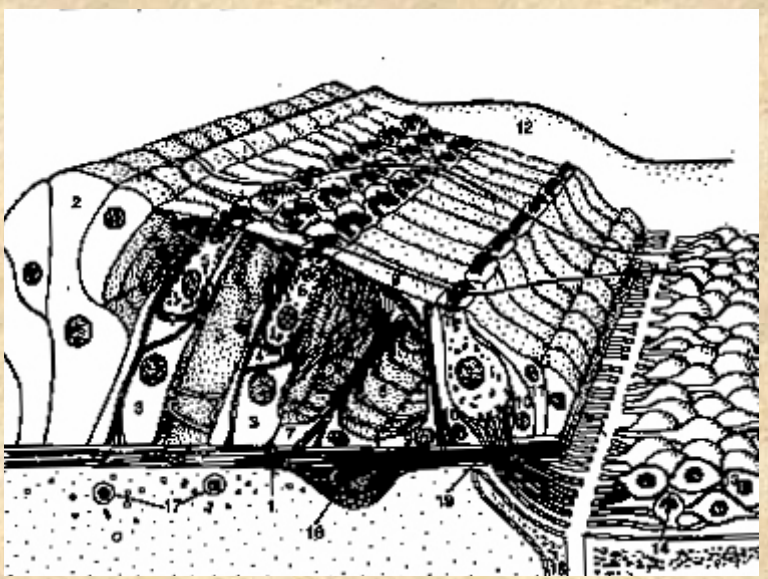
Idea behind place theory: the place of maximum stimulation along the basilar membrane depends on frequency, so that the hair cell receptor neurons convey frequency information simply by virtue of their position along the basilar membrane.

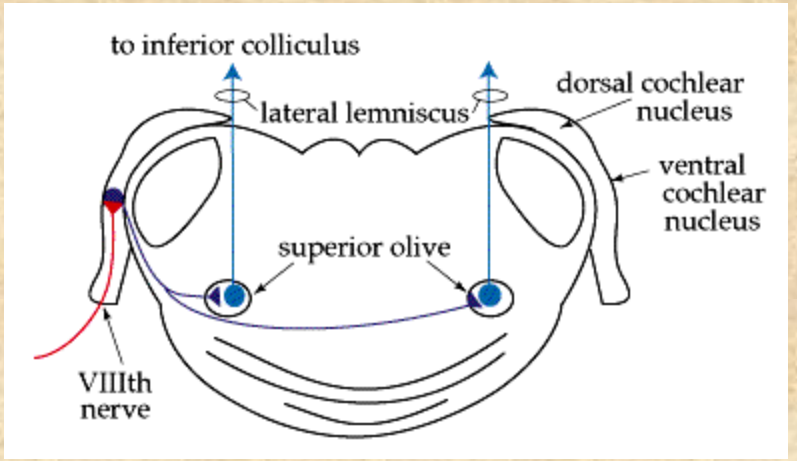


Theories About Pitch

- Evidence suggests that both theories are correct.
  - Perception of higher frequencies depends on the place where the basilar membrane is stimulated.
  - Perception of the lower frequencies depends on firing frequency.

Axons of the spiral ganglion neurons,
which pass through the auditory nerve (VIIIth nerve),
project to the *cochlear nucleus*





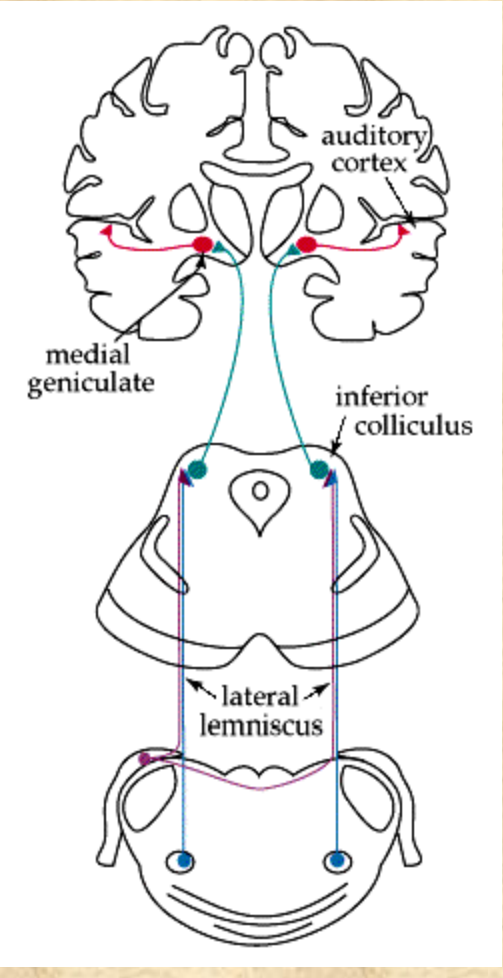
Inferior colliculus neurons receive signals
from ipsilateral and contralateral ears
via the superior olive and the
dorsal cochlear nucleus

Commissural axons connect the inferior
colliculi on either side of the head
(not shown in the figure at right)

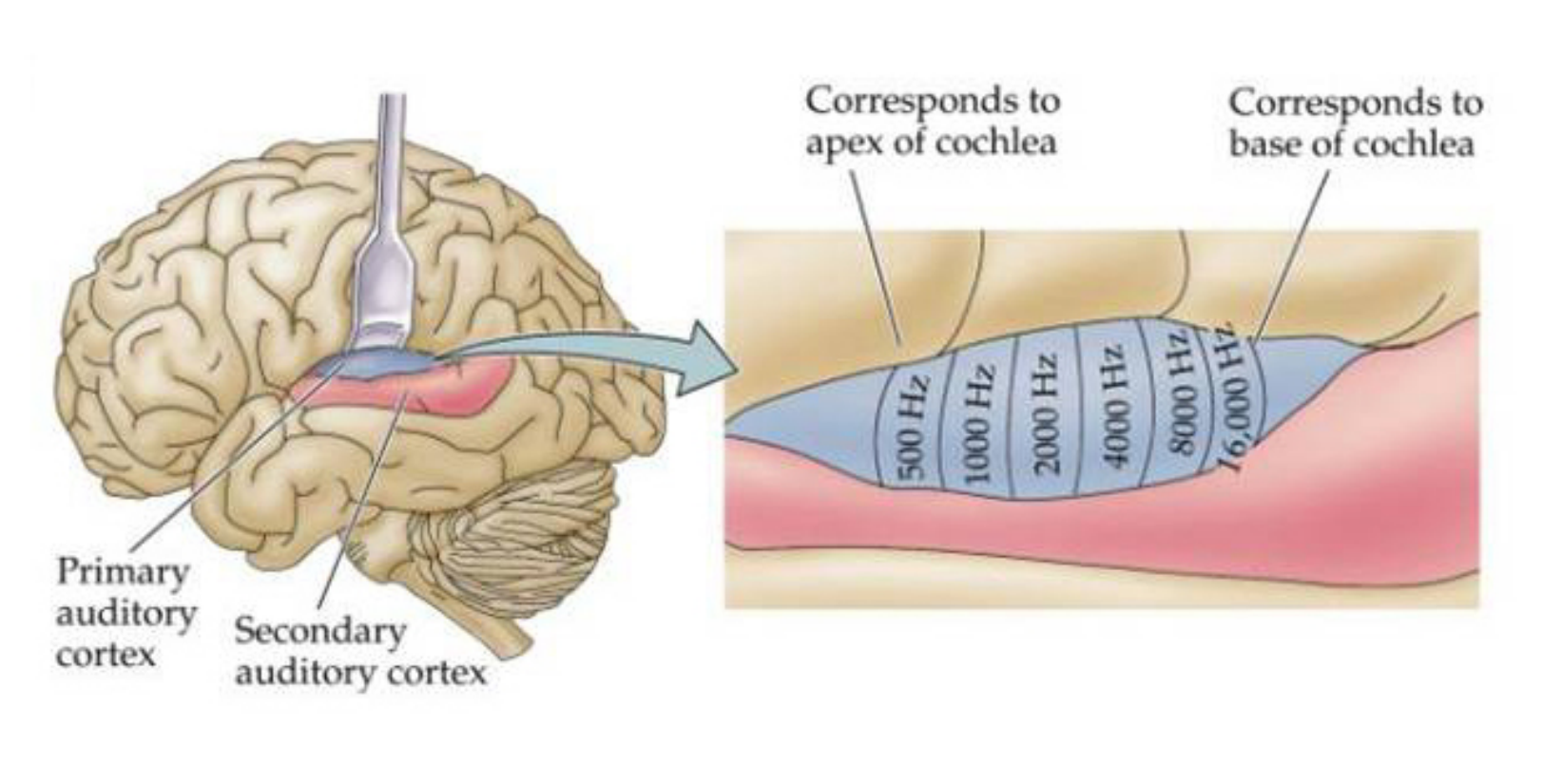
Inferior colliculus neurons project primarily
to the ipsilateral
medial geniculate nucleus

Some inferior colliculus neurons project
to the superior colliculus
(multimodal integration; not shown)

MGN neurons project to auditory cortex
(superior temporal gyrus)

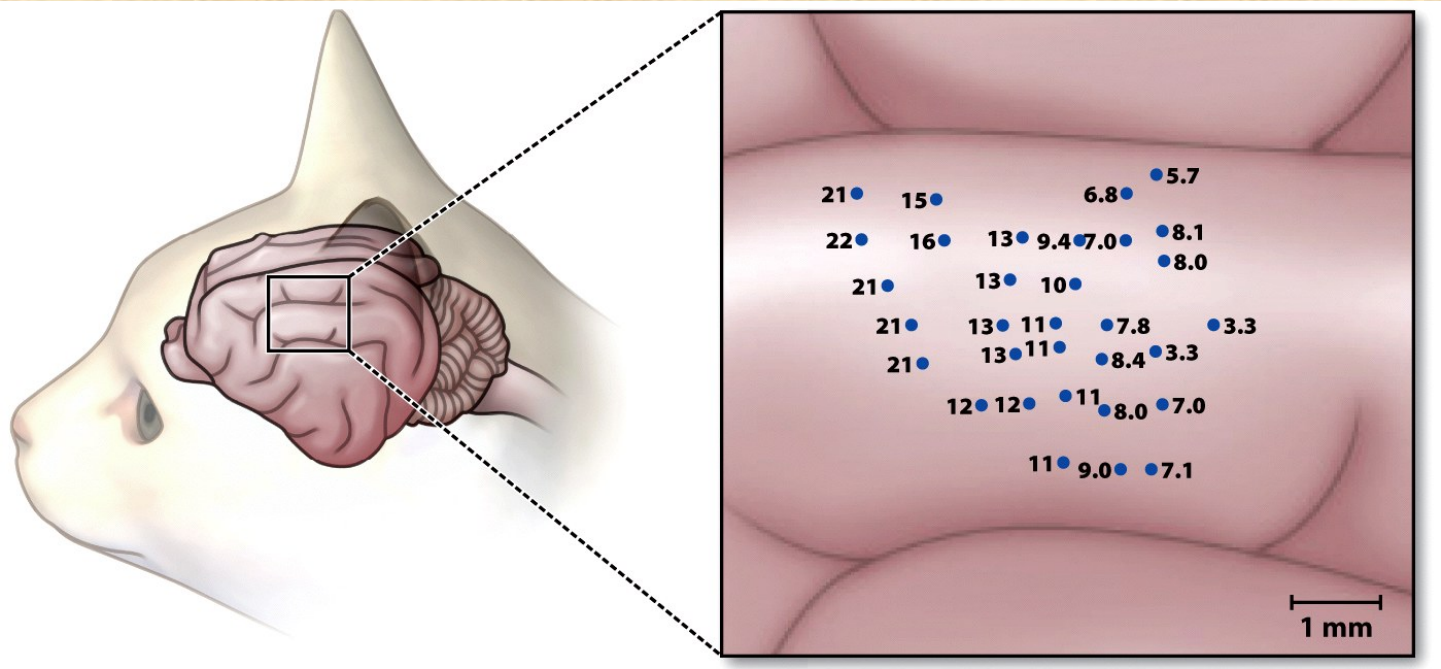


Tonotopic (or cochleotopic) organization of primary auditory cortex



High-frequency sounds stimulate best the base (oval window) end of the cochlea, while low-frequency sounds stimulate the apical end.
There is a progression in best frequency (*tono* – "tone" *)* as one moves along the basilar membrane (*topus* – "place").

Tonotopic (or cochleotopic) organization of primary auditory cortex in cat
Neuron preferred frequencies are shown in units of kiloHertz (kHz)

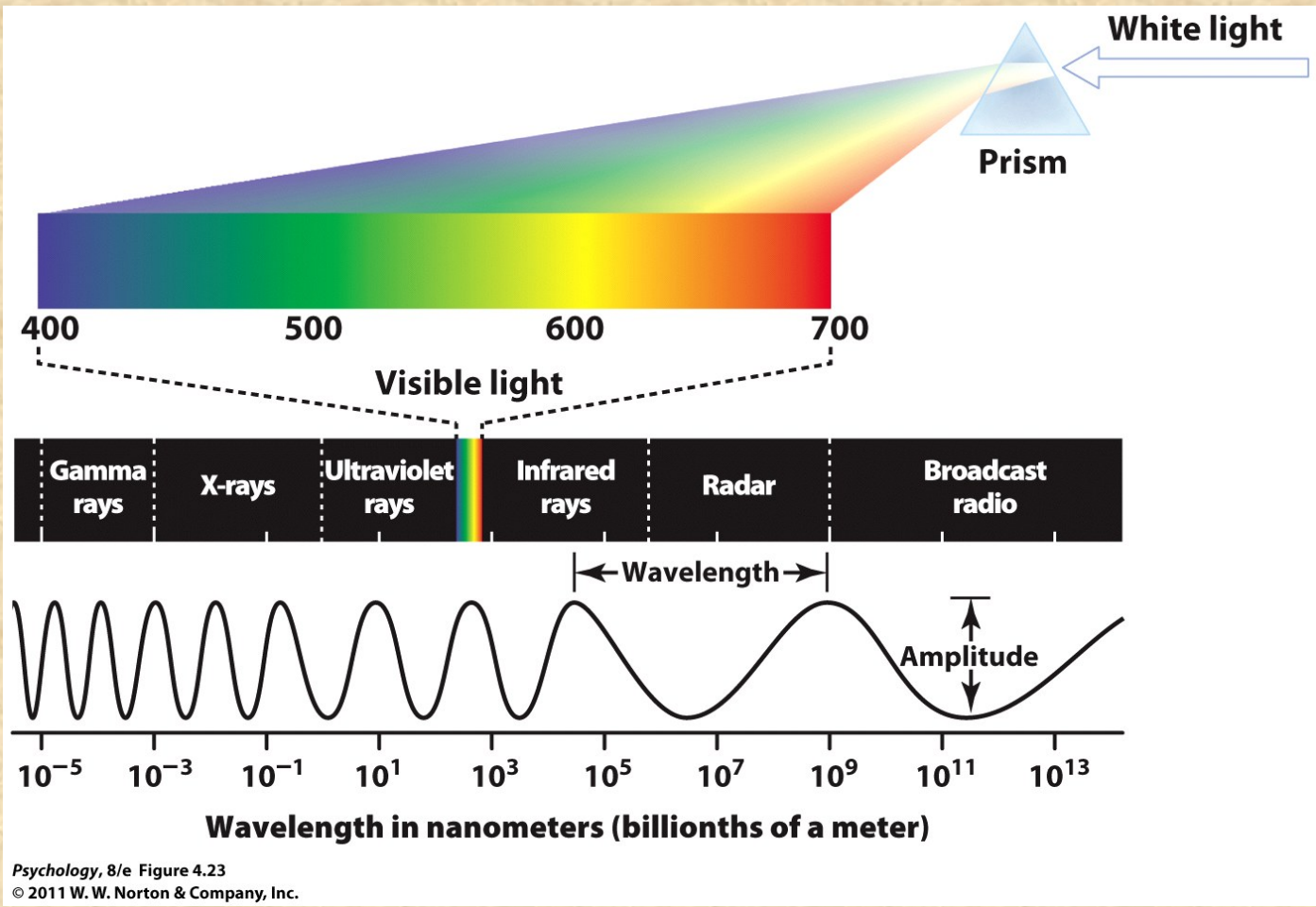


Psychology, 8/e Figure 4.22

Vision

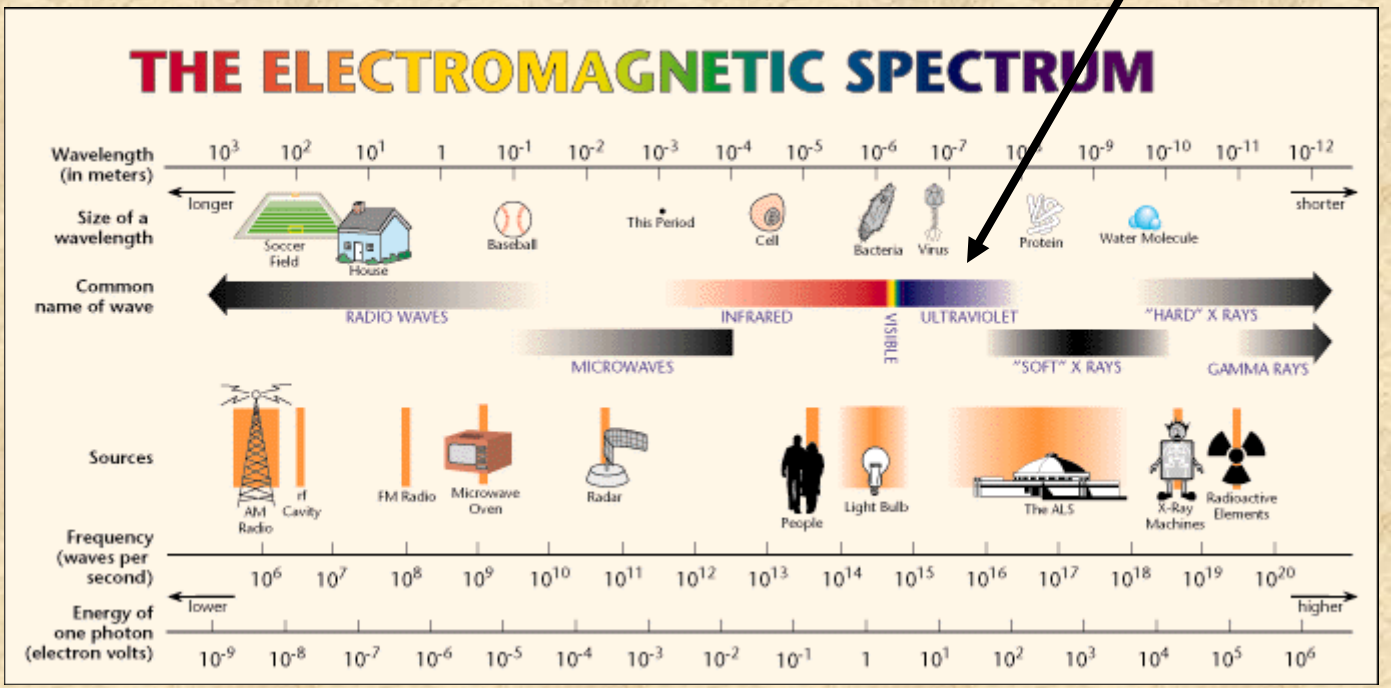
- Vision is our primary distance sense.
  - Its stimulus is light, which varies in *intensity* and *wavelength.*
- Eye structures, like the cornea, iris and lens,
  - control the amount of light entering the eye.
  - form the *retinal image.*

Electromagnetic Spectrum



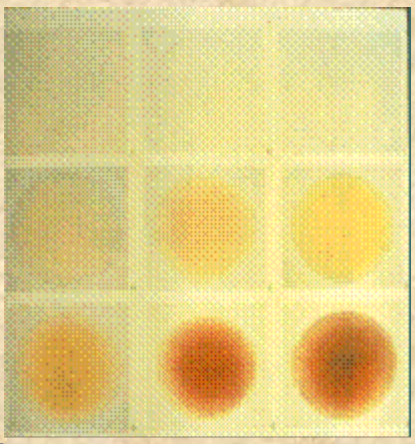
Psychology, 8/e Figure 4.23

UV and Lens Brunescence



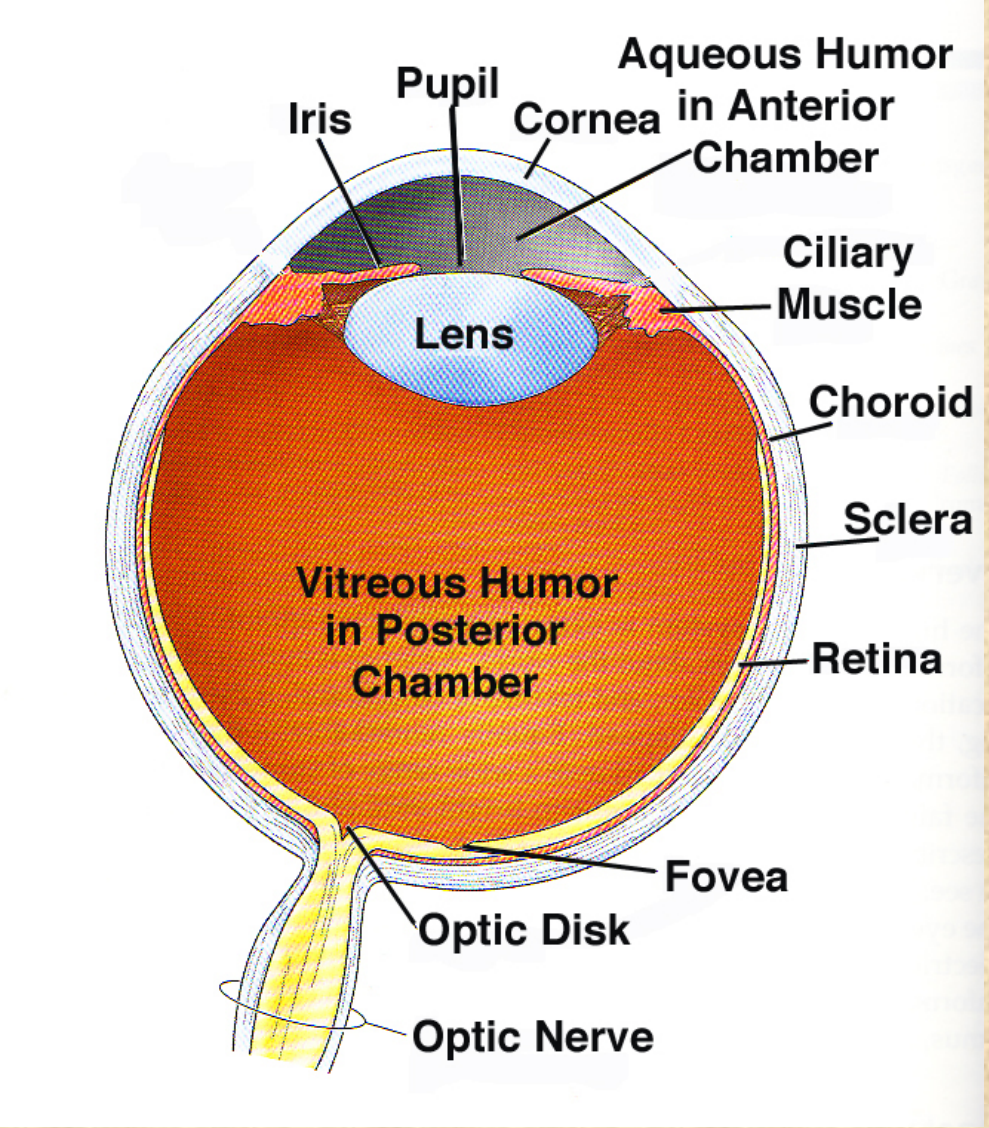
The lens absorbs UV radiation. This causes the lens to yellow and eventually become brown and more opaque.

Moral:
Wear UV-filtering sunglasses when outdoors!



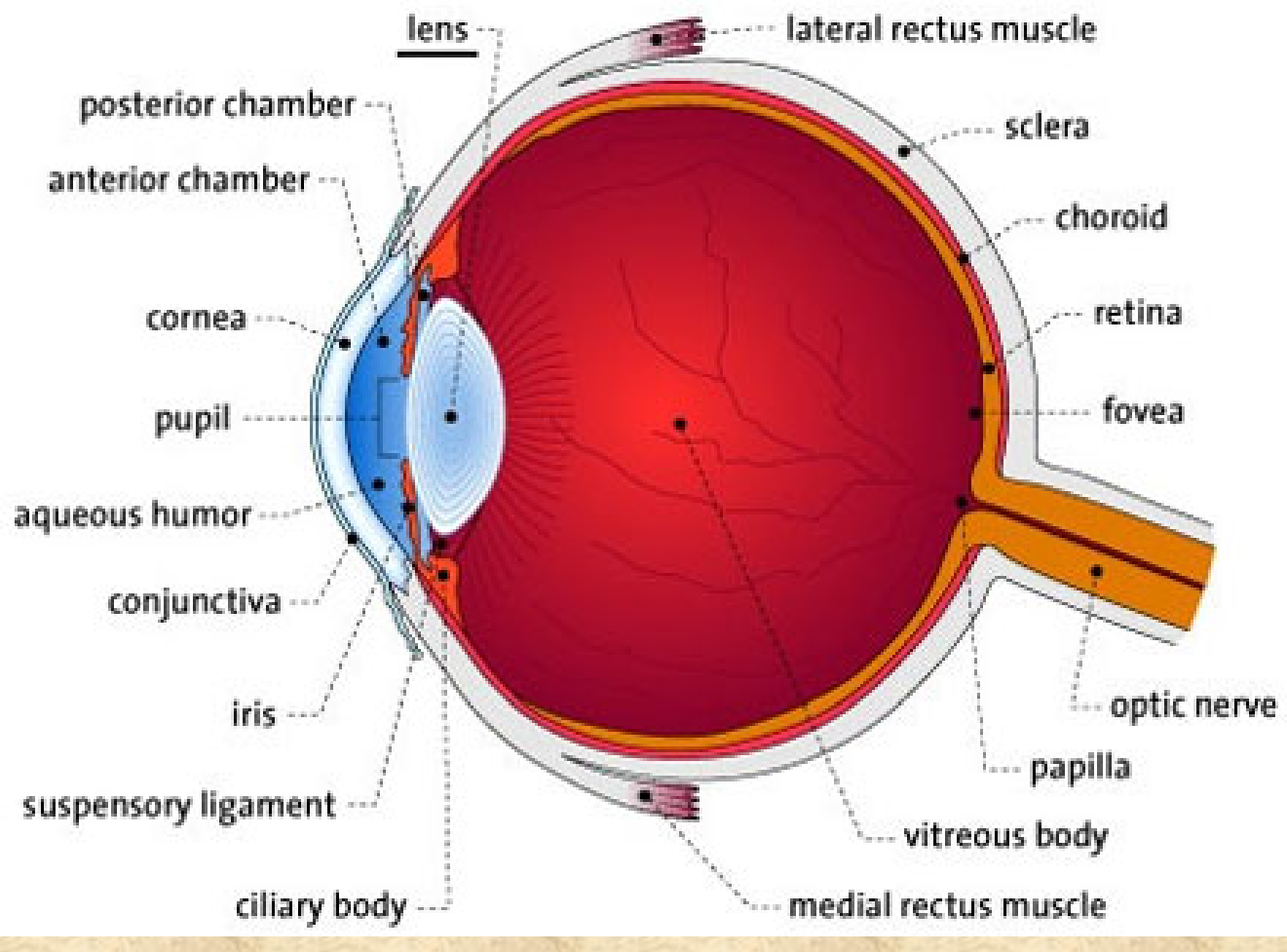
photos of peoples lenses, arranged by age

The Eye



cornea – transparent surface that acts as eye's principal focusing element
aqueous and vitreous humors - effectively salt water
sclera – whites of the eyes
iris – colored muscle that contracts and dilates
pupil – disk in center of iris through which light passes
lens – crystalline structure providing secondary focus
ciliary muscle – changes shape of the lens
retina – layered sheet of neurons lining back of the eye
optic nerve – bundle of retinal ganglion cell axons passing up into the brain
optic disk – blind spot
fovea – region of retina used to view objects directly ahead

The Eye



retina – sheet of nerve cells (part of *central* nervous system) lining back of the eye

fovea – small region of retina on which falls light from objects directly ahead (look straight at ‘em)

Layers of the Retina

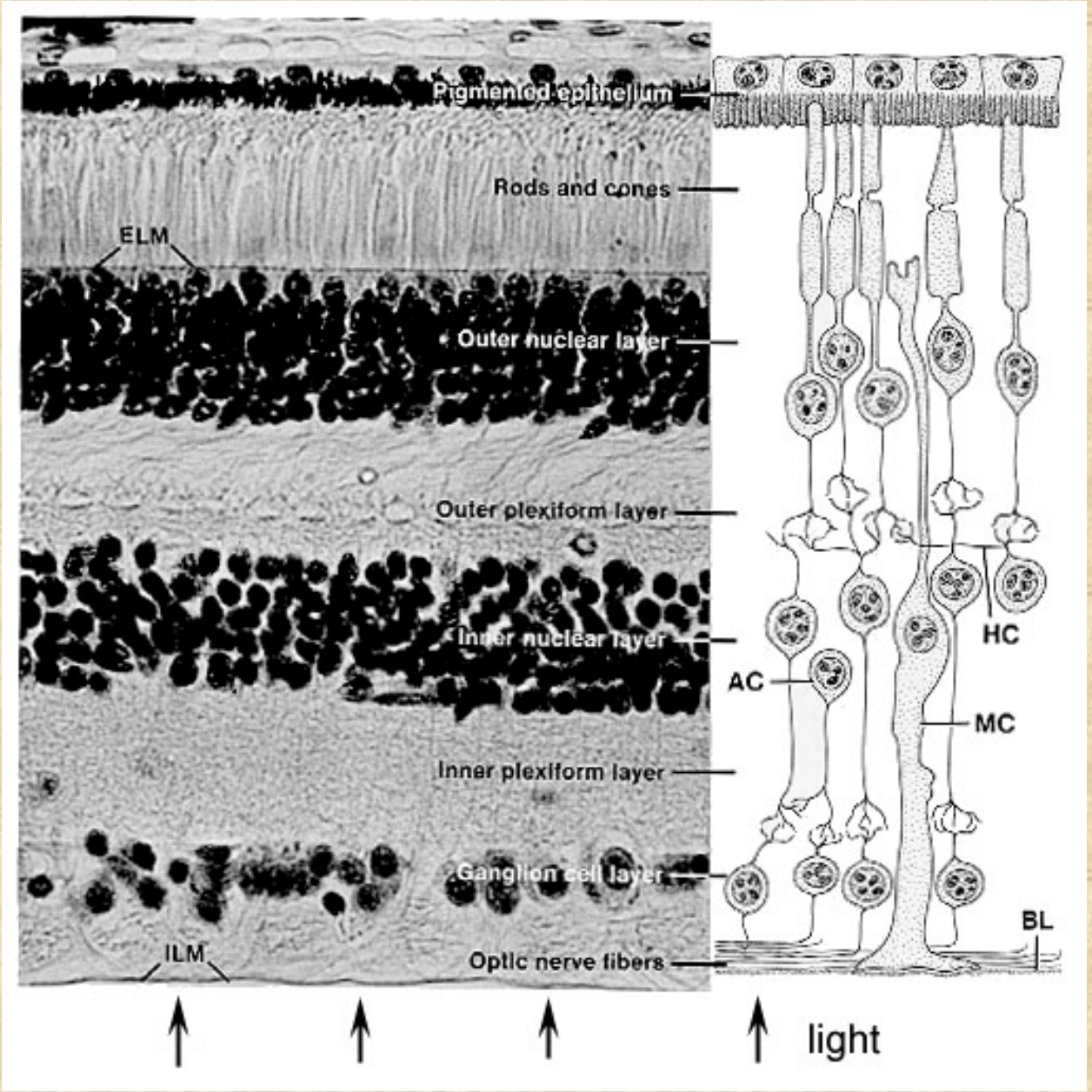
cell bodies →

axons, dendrites →

cell bodies →

axons, dendrites →

cell bodies →

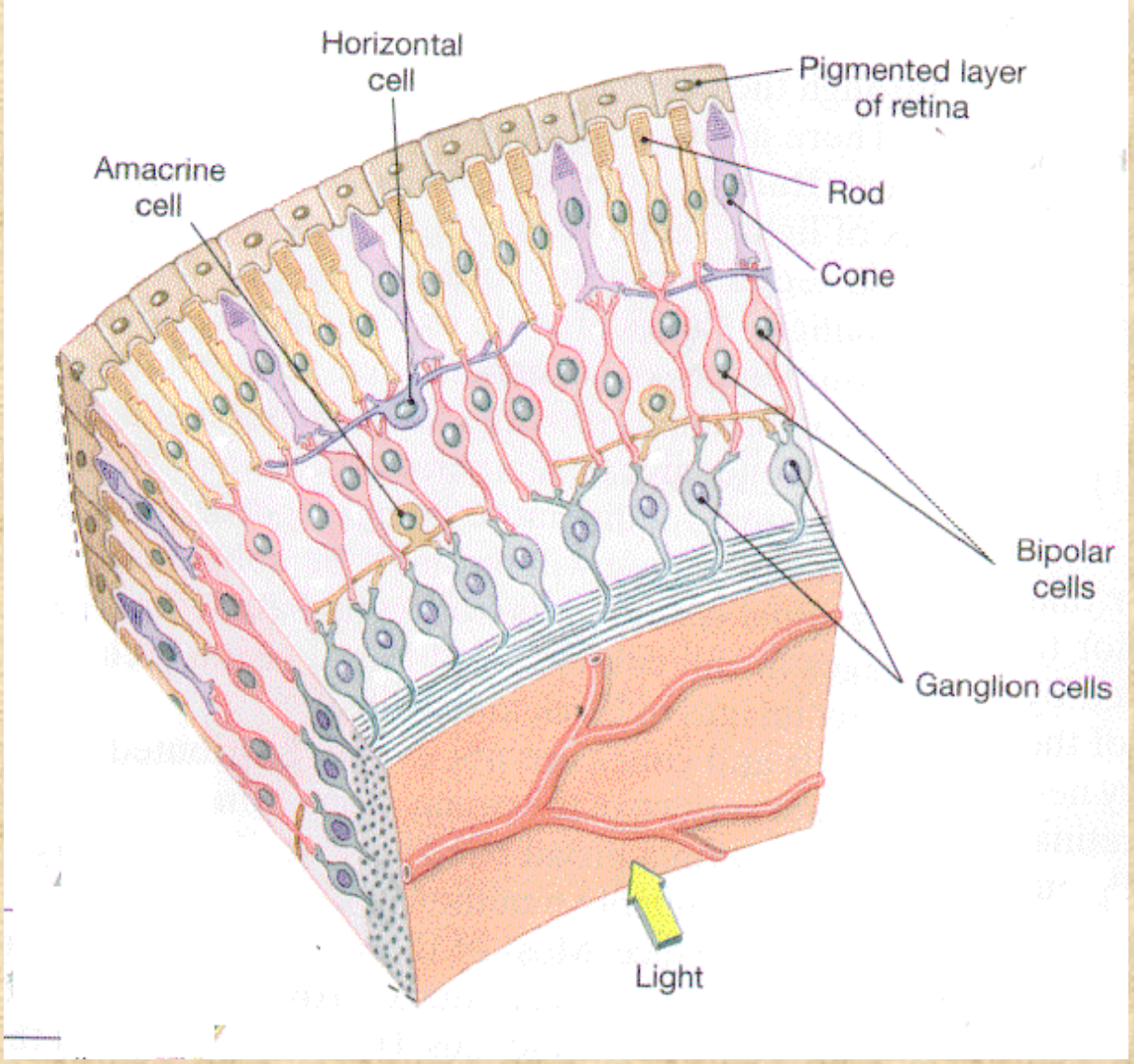


AC amacrine cell
HC horizontal cell
MC Müller cell

rods and cones
signal light
absorption

direct path
to the brain:

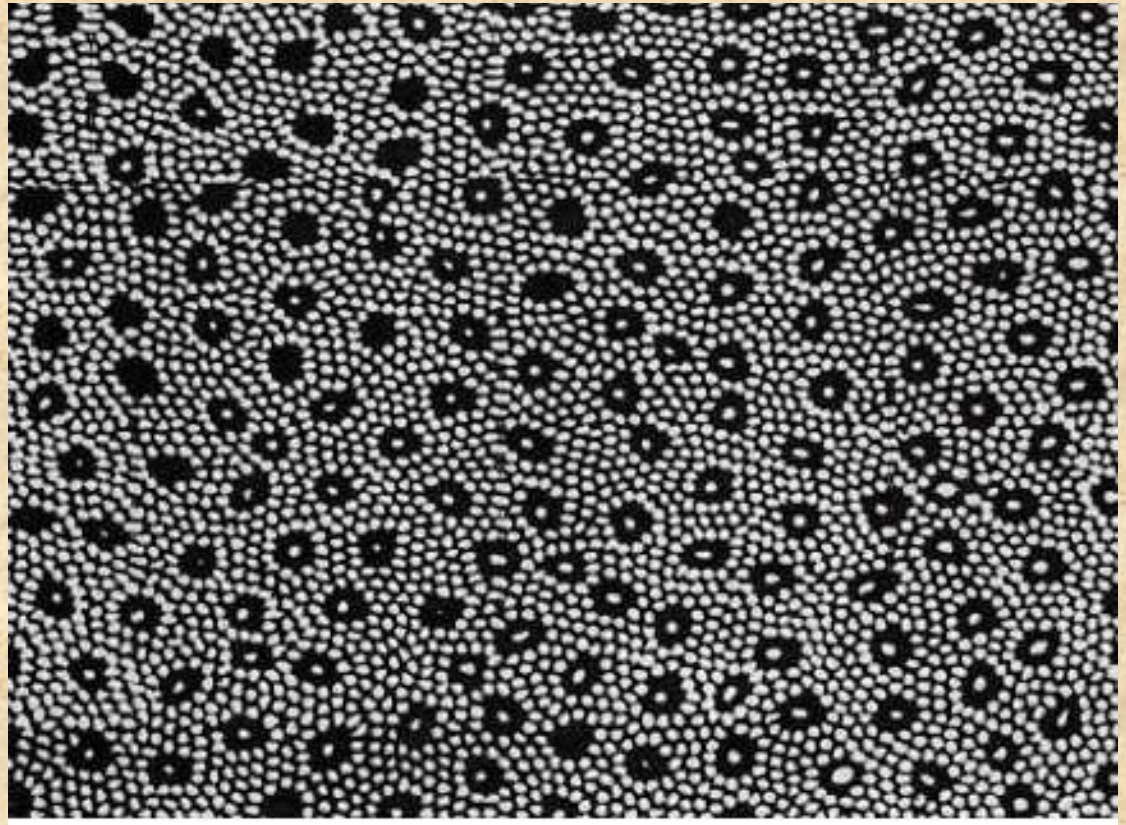
photoreceptor
to
bipolar cell
to
ganglion cell
to
higher brain centers
via optic nerve:
ganglion cell axons



Rod and cone photoreceptors

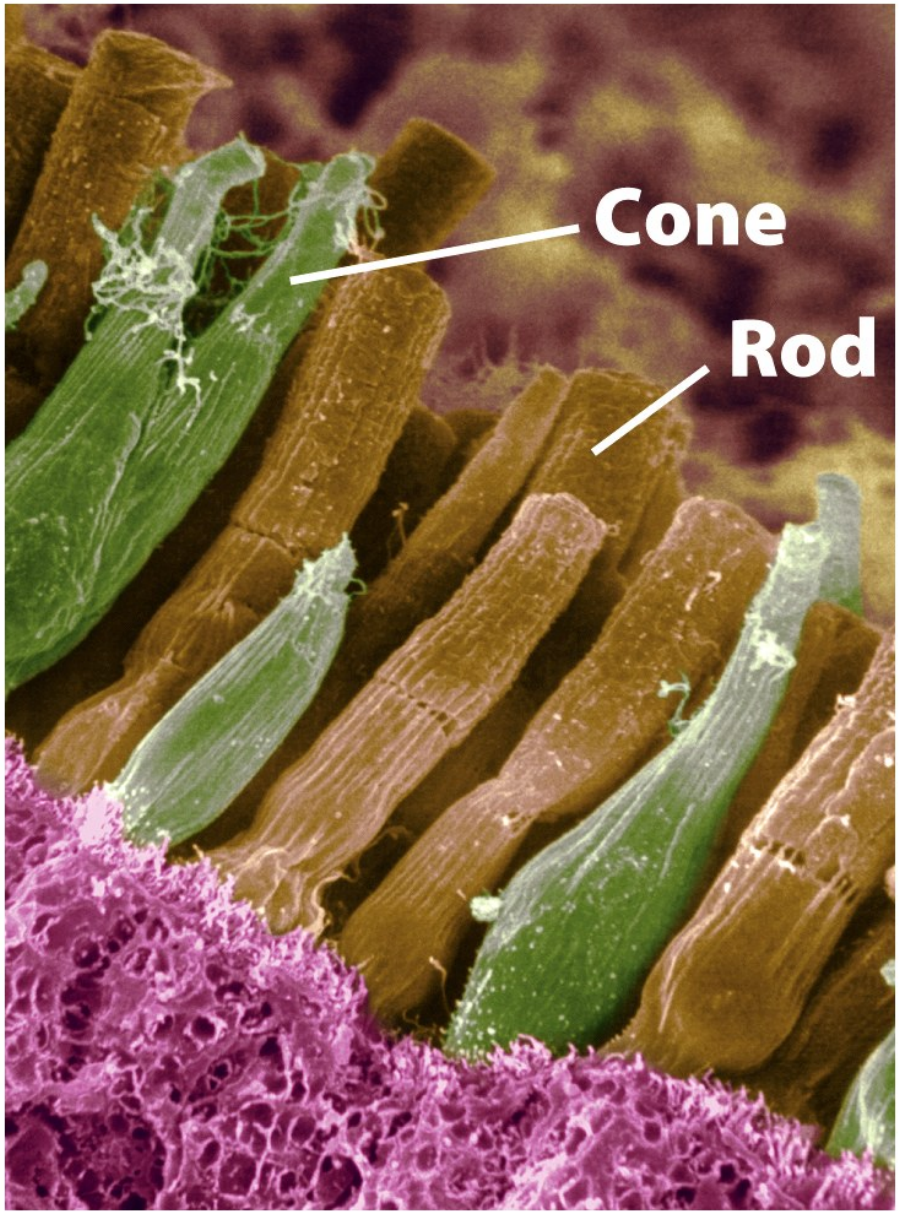
- The light stimulus is transduced by *rods* and *cones*
- Rods and cone photoreceptors contain pigment molecules that change shape when they absorb a photon of light
- Rods and cones differ in function.
  - rods: active at low light levels (night time: *scotopic* vision), shades of gray
  - cones: active at high light levels (daytime: *photopic* vision), responsible for sensations of color
    - *Acuity* is greatest in the *fovea*, where the most cones are located.

Rod and Cone Photoreceptors



electron micrograph of a small part of monkey retina showing sheet of rod (small, numerous) and cone (surrounded by black, fewer) photoreceptors

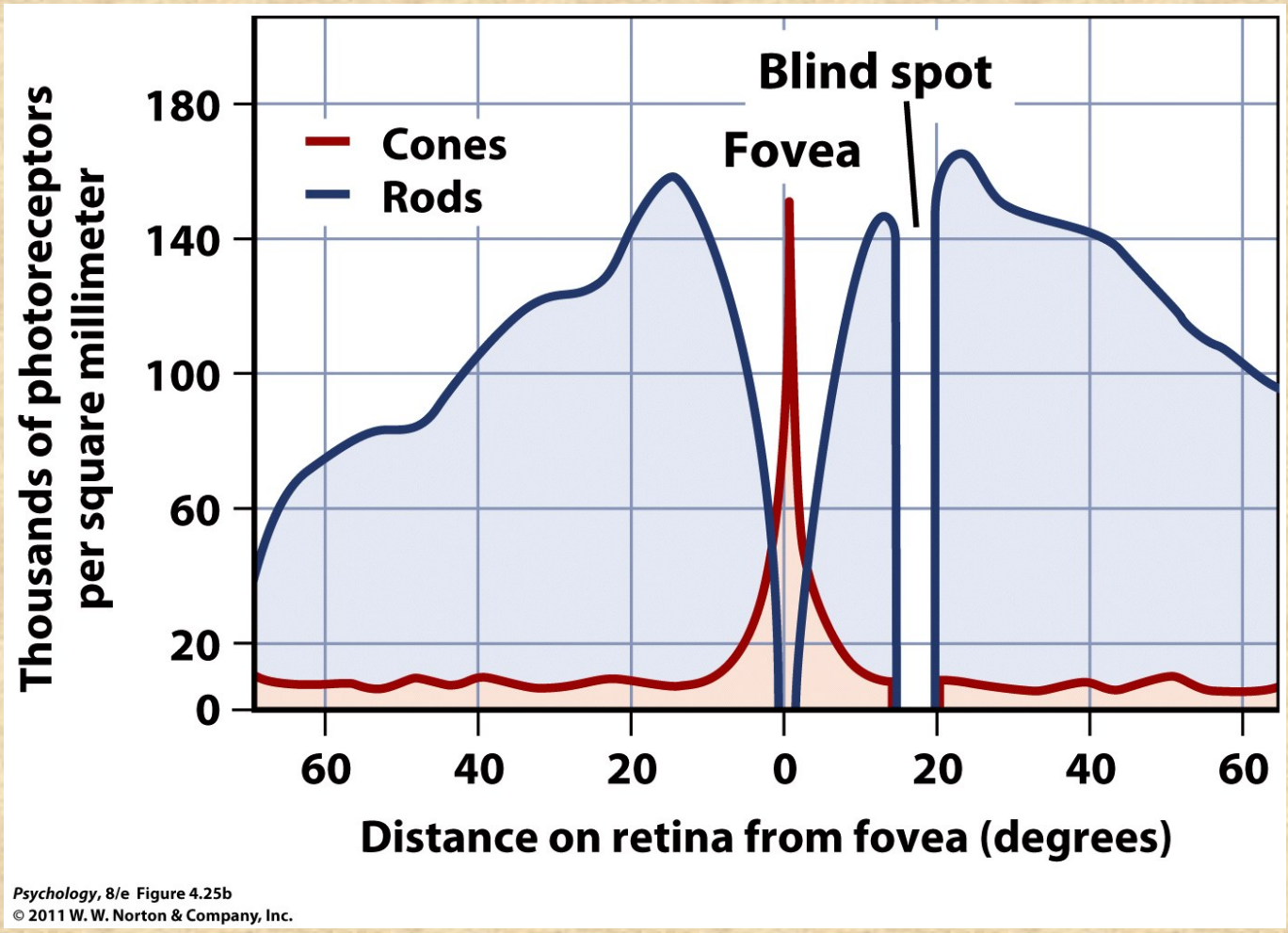
from http://neuro.med.harvard.edu/site/dh/b11.htm



Psychology, 8/e Figure 4.25a

Rod and cone distribution across the retina

- Cones: high density in the fovea
- Rods: none in the periphery



Psychology, 8/e Figure 4.25b

Fovea and Optic Nerve

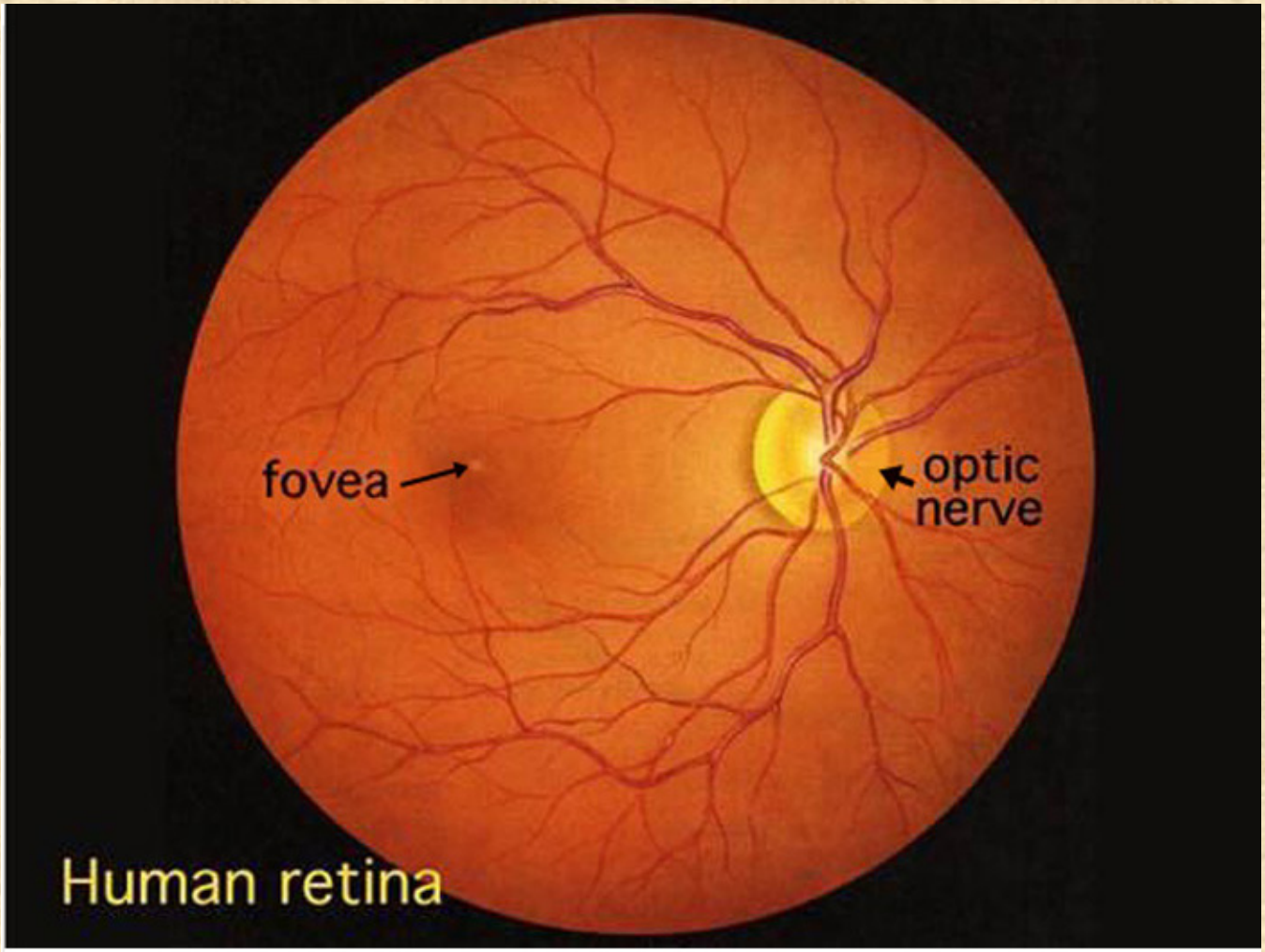


Fig. 1. Human retina as seen through an opthalmoscope.

great site: webvision.med.utah.edu