HUMAN PHYSIOLOGY (normal)

LECTURE 8. Physiology of Sensor Systems. Visual & Audition, Vestibular and Somatosensory Systems

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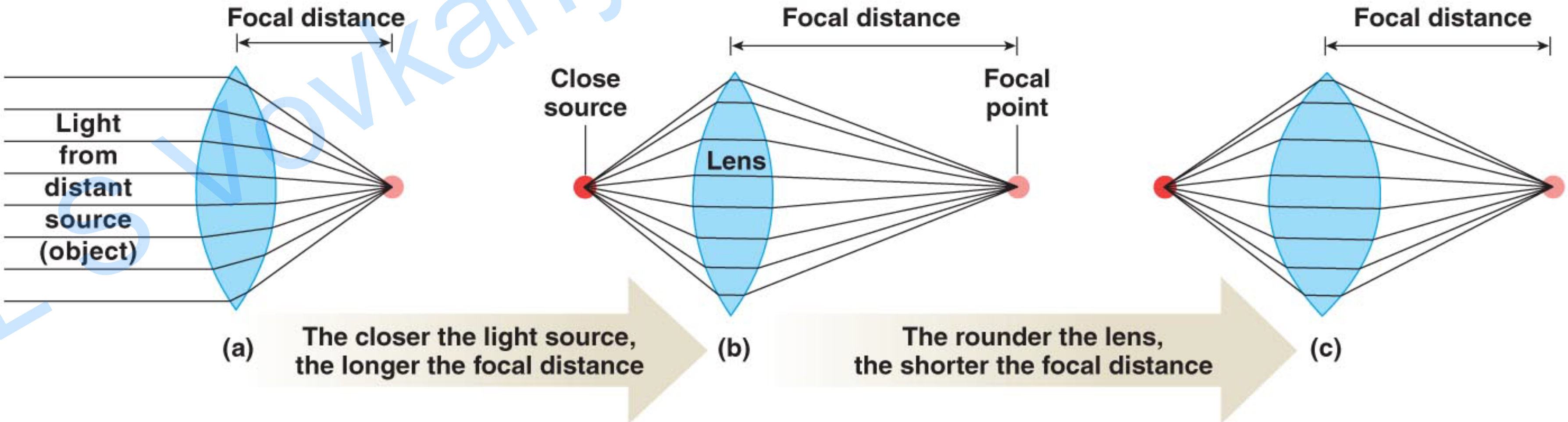
Light Refraction

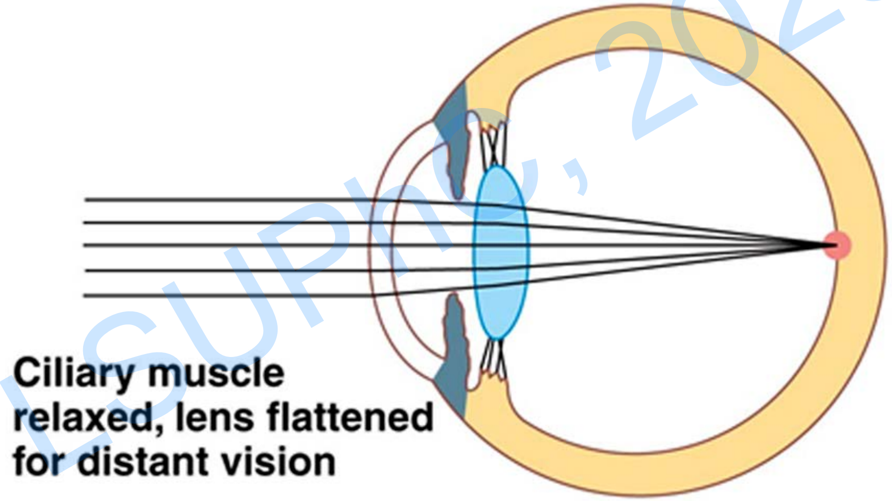
- Bending of light by **cornea** and **lens**
- **Focal point** must be located on **retina**
- The **focal distance** (distance between center of lens and focal point) is different for the distant and close objects
- That is why the **change of lens shape** is necessary in order to keep the focal point on the retina

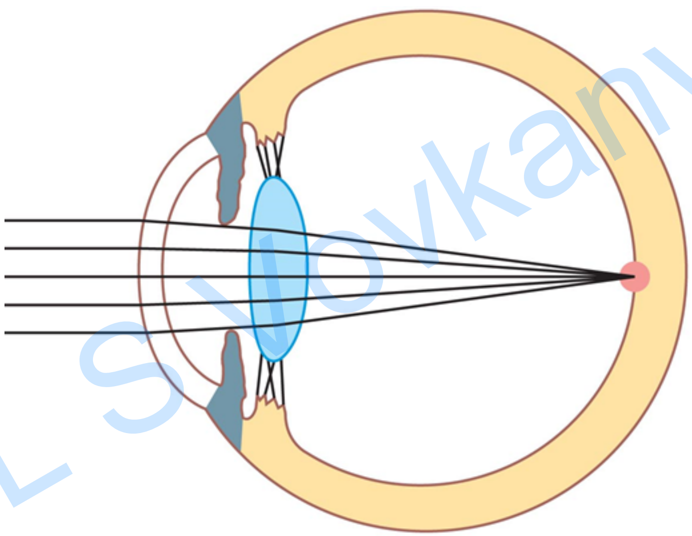


Accommodation

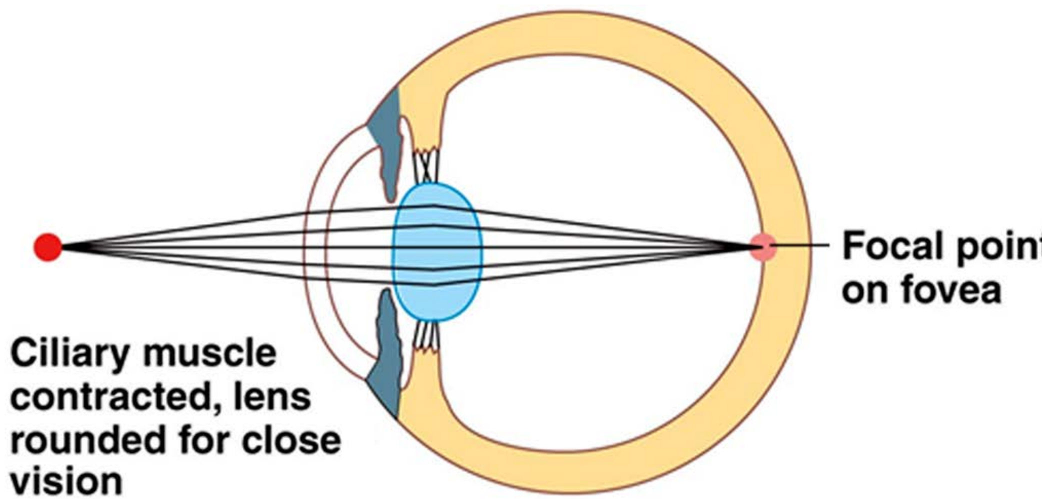
The reflex of the shape of lens changes to focus image on retina

Emmetropia - the focal point lays exactly on the retina, resulting in perfect vision

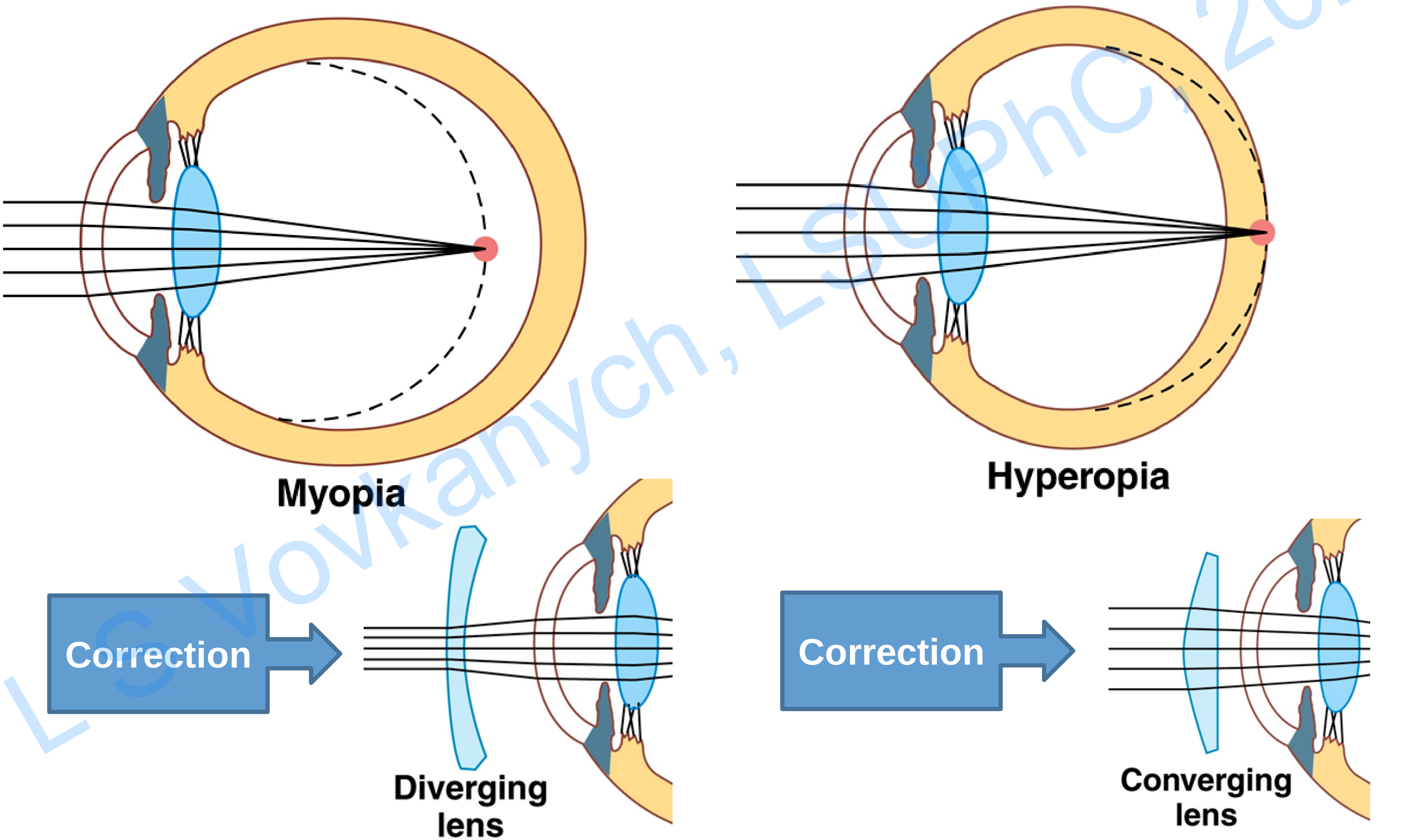




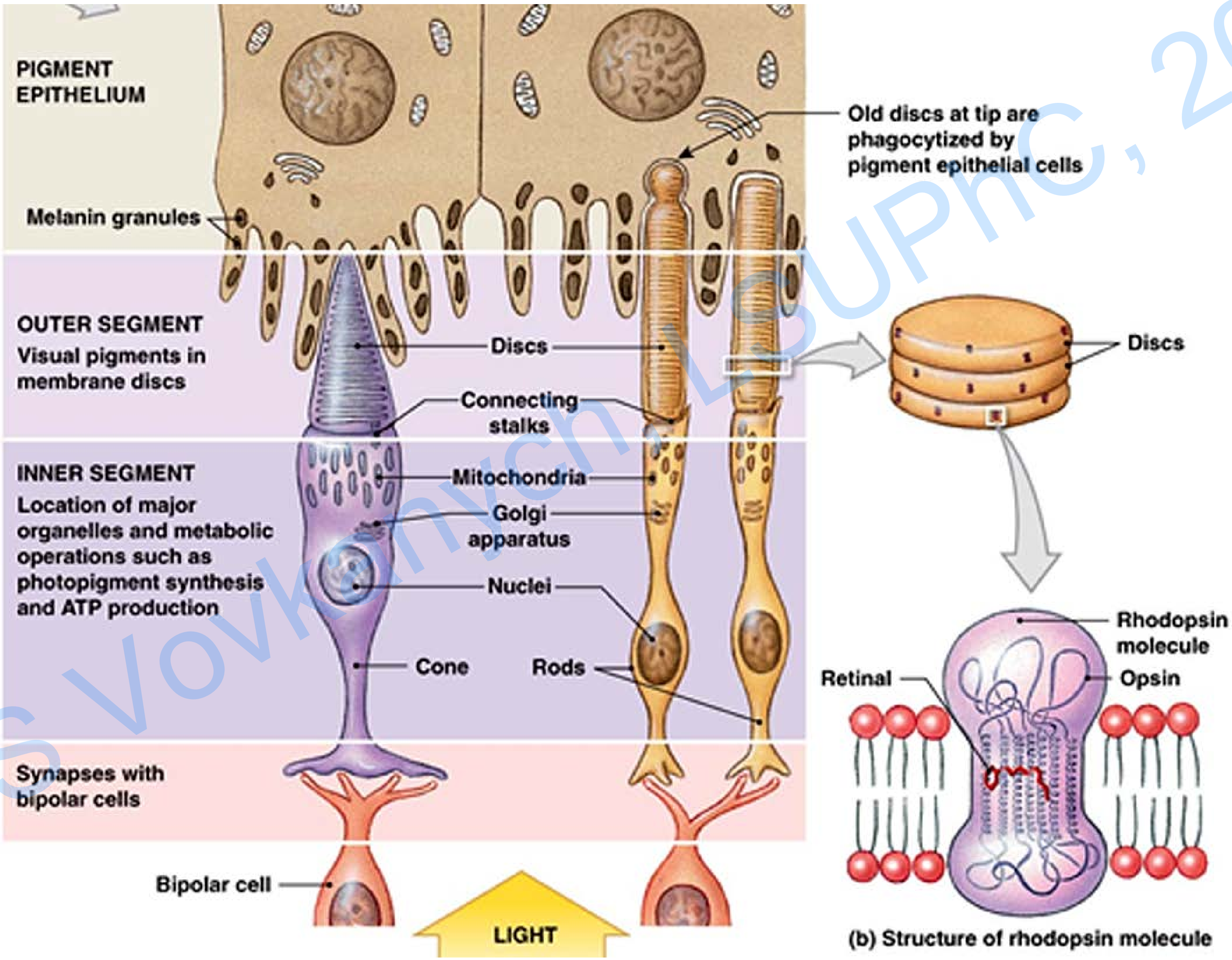
Emmetropia



Visual Abnormalities

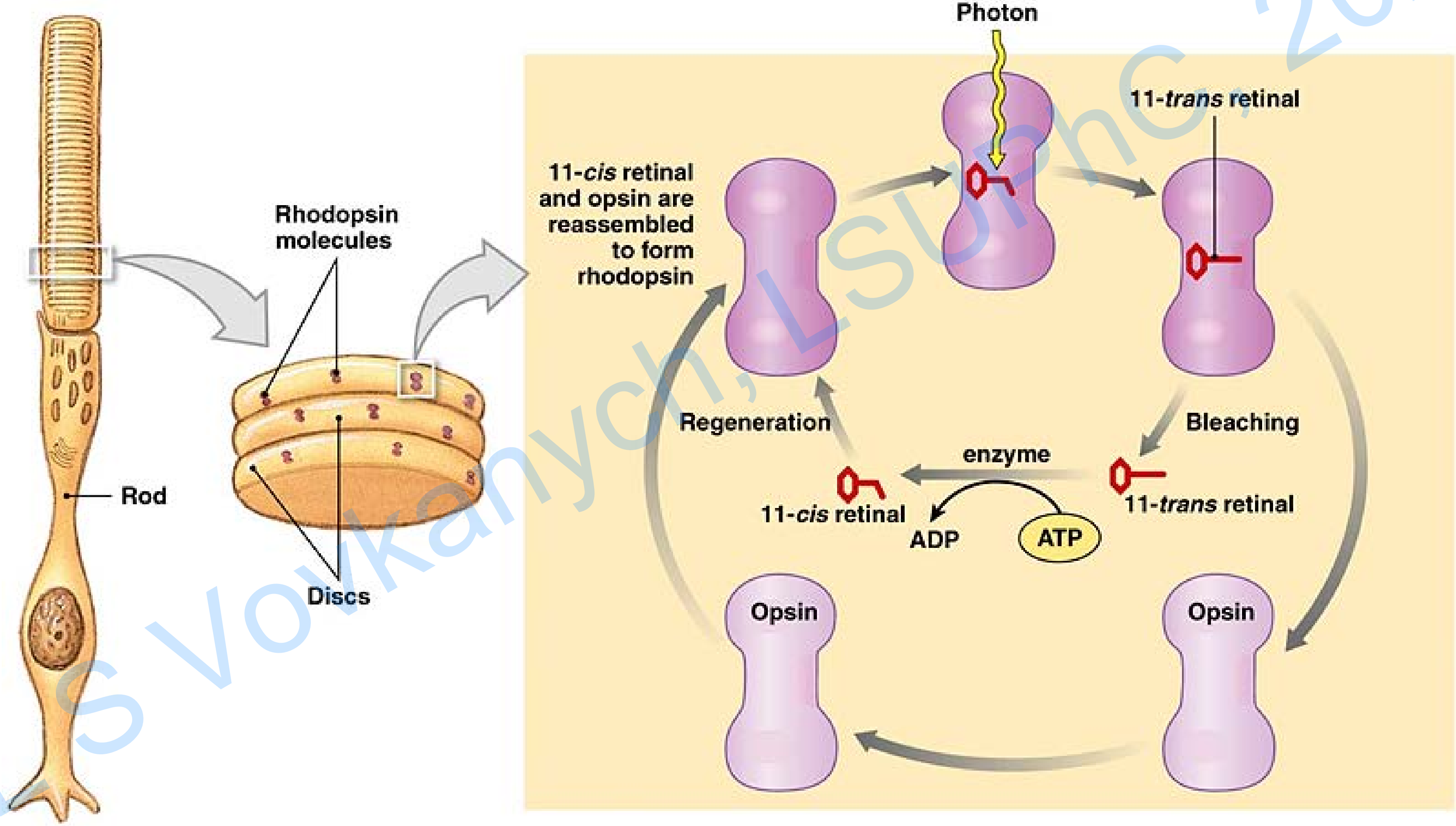


Photoreceptors (Rods and Cones)

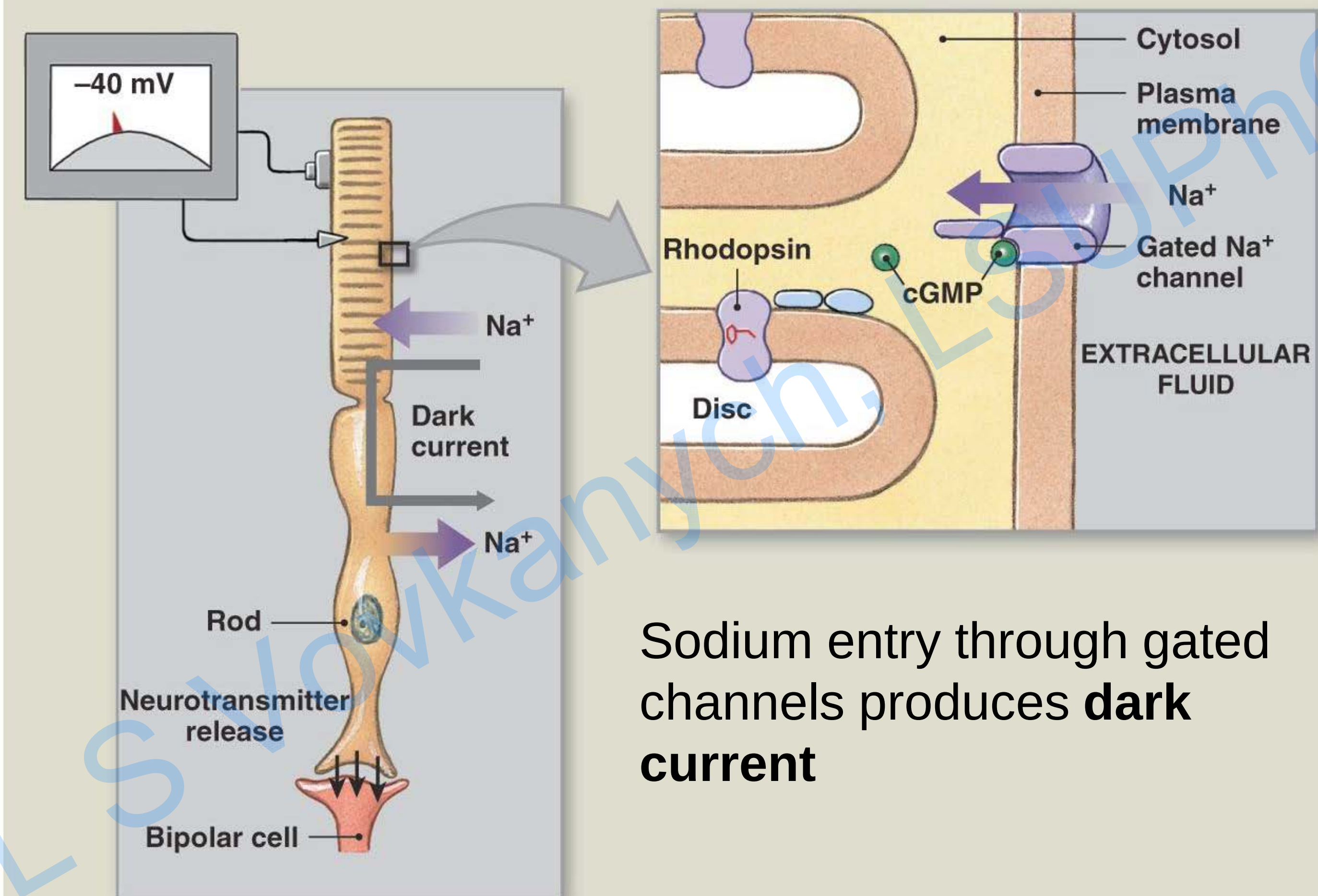


(b) Structure of rhodopsin molecule

Photoreception

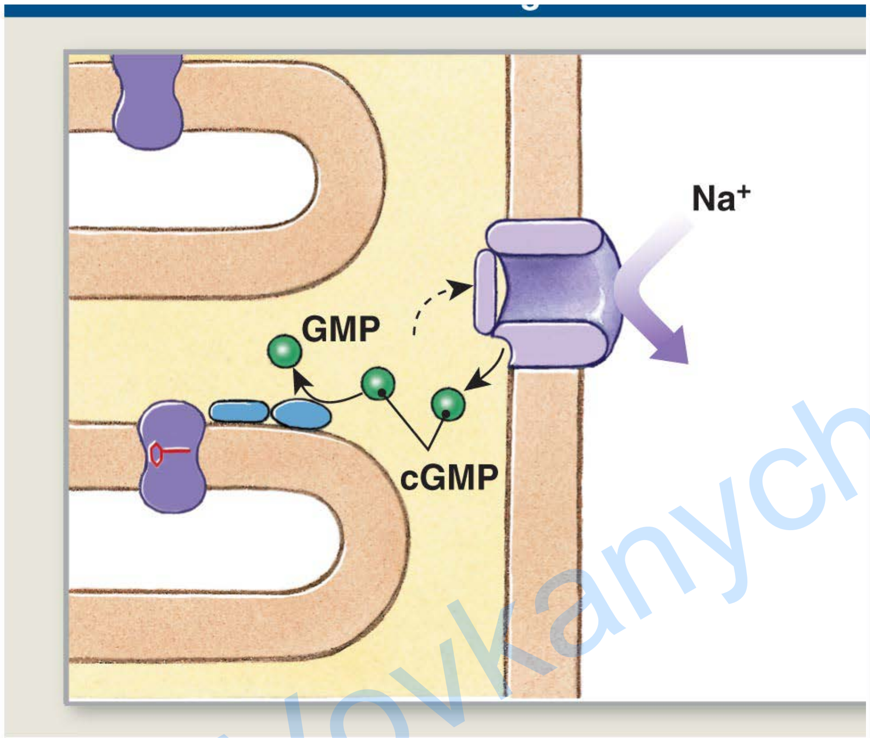


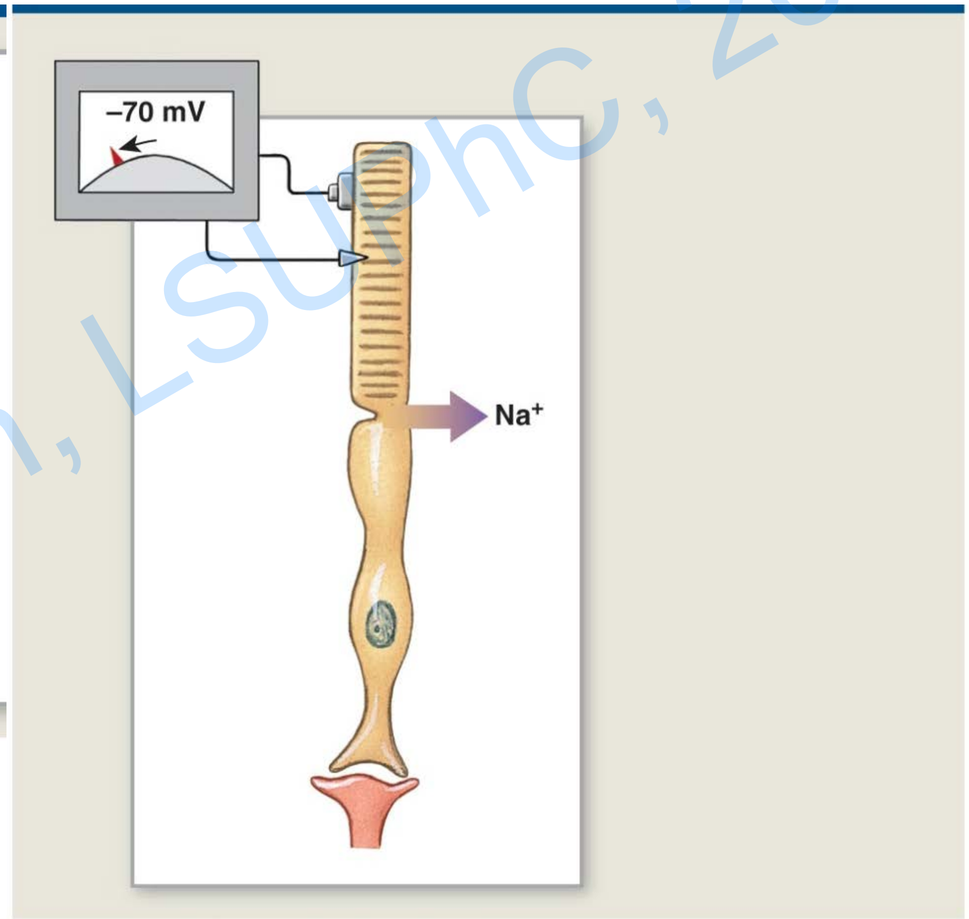
Darkness



Sodium entry through gated channels produces **dark current**

Light





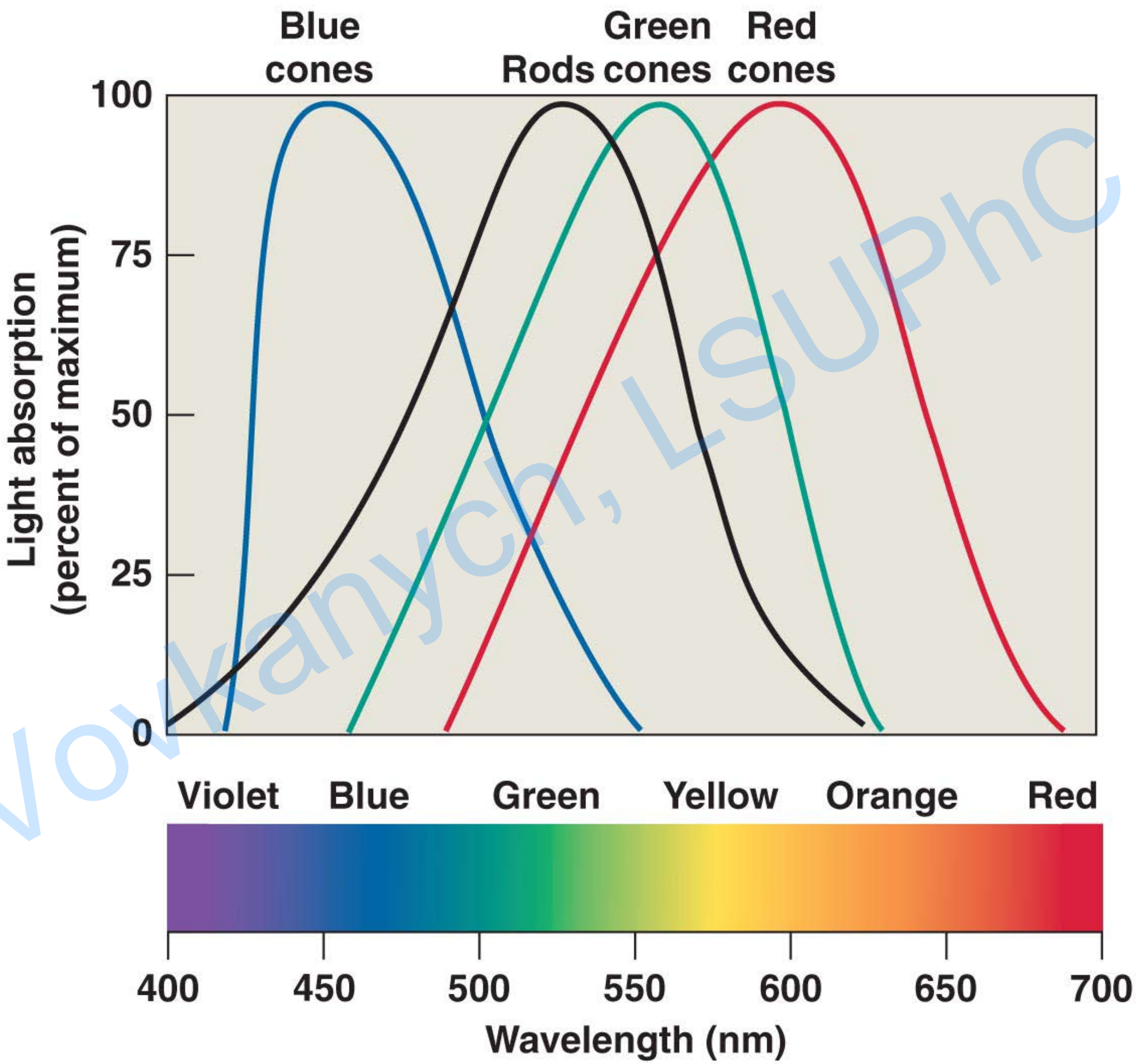
Dark current is **reduced**, rate of neurotransmitter release declines

Color vision

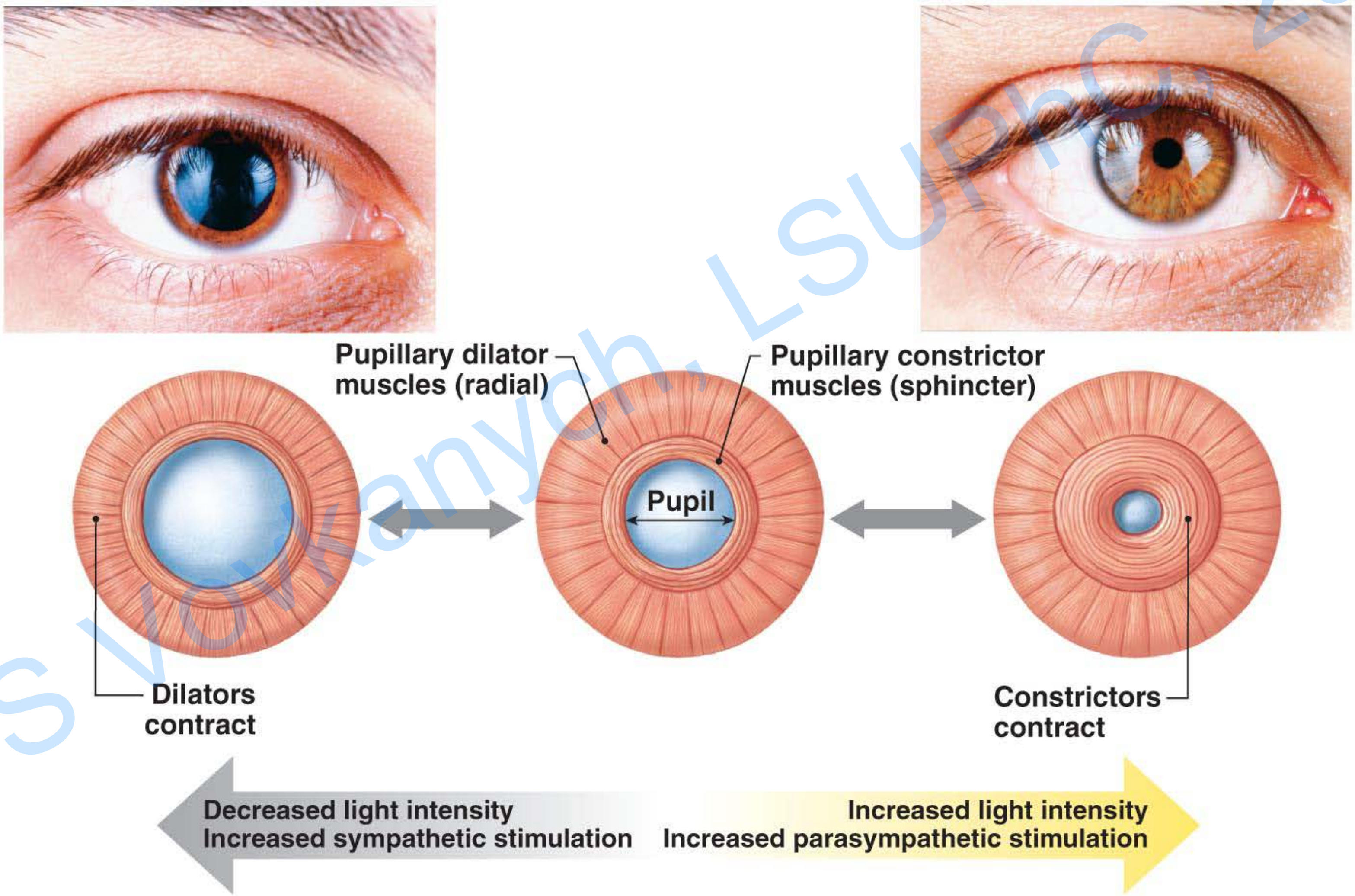
- The human eye can distinguish about **10 million** different colors
- Perception of color begins with **cone cells** with different spectral sensitivities
- In humans, there are **three types of cones**, resulting in **trichromatic** color vision
- The cones are labeled according to the peaks of their spectral sensitivities: **short** (S), **medium** (M), and **long** (L) cone types
- The perception of color is a complex process that starts with the differential output of cones and is finalized in the **visual cortex**

Cone type	Name	Range	Peak wavelength
S ("blue")	β	400–500 nm	420–440 nm
M ("green")	γ	450–630 nm	534–555 nm
L ("red")	ρ	500–700 nm	564–580 nm

Cone types


Blue cones
Rods
Green cones
Red cones
100
75
50
25
0
Light absorption (percent of maximum)
Violet
Blue
Green
Yellow
Orange
Red
400
450
500
550
600
650
700
Wavelength (nm)

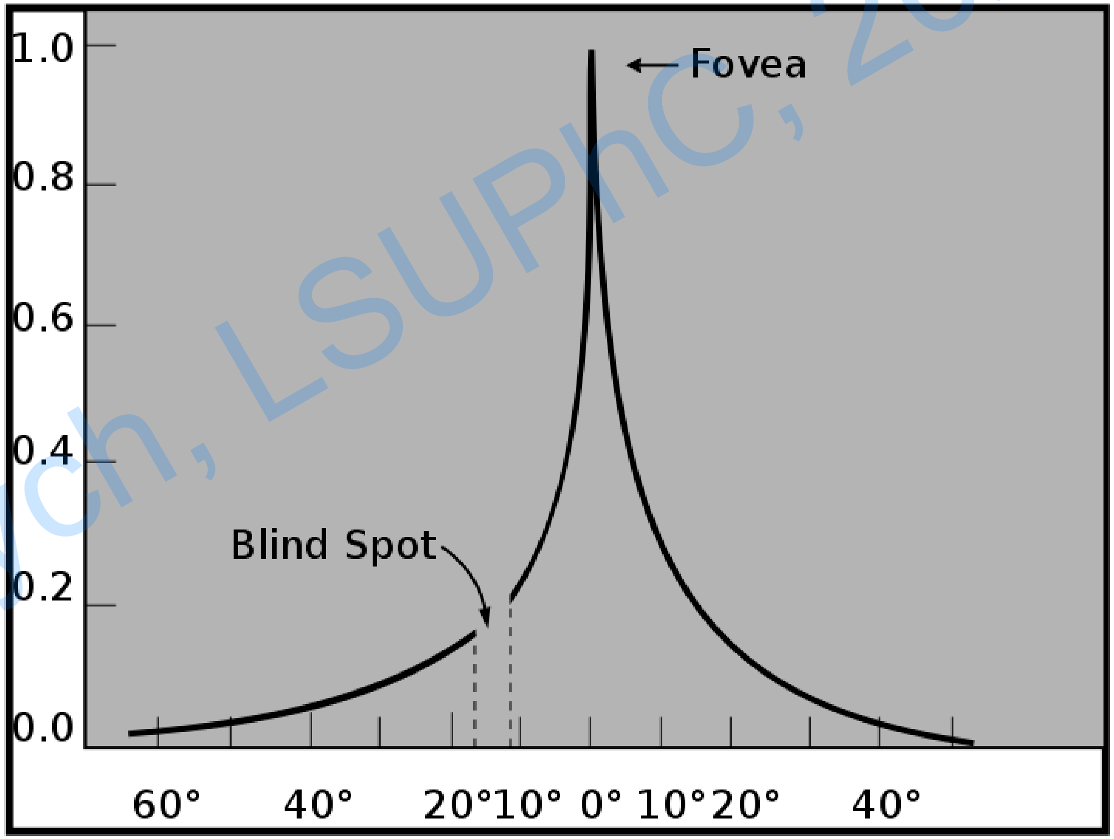
Light and Dark Adaptation



Visual acuity

Visual acuity is a measure of the **spatial resolution** of the visual processing system

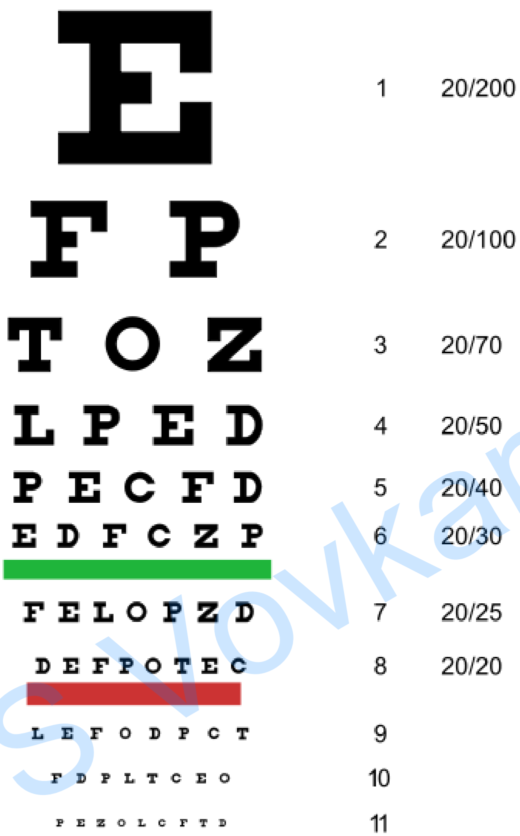
The reference value above which visual acuity is considered normal is called 6/6 vision, the USC equivalent of which is 20/20 vision (minimal angle size 1 arc min)



The diagram shows the **relative acuity** of the human eye on the horizontal meridian in degrees visual angle from foveal vision

Visual acuity

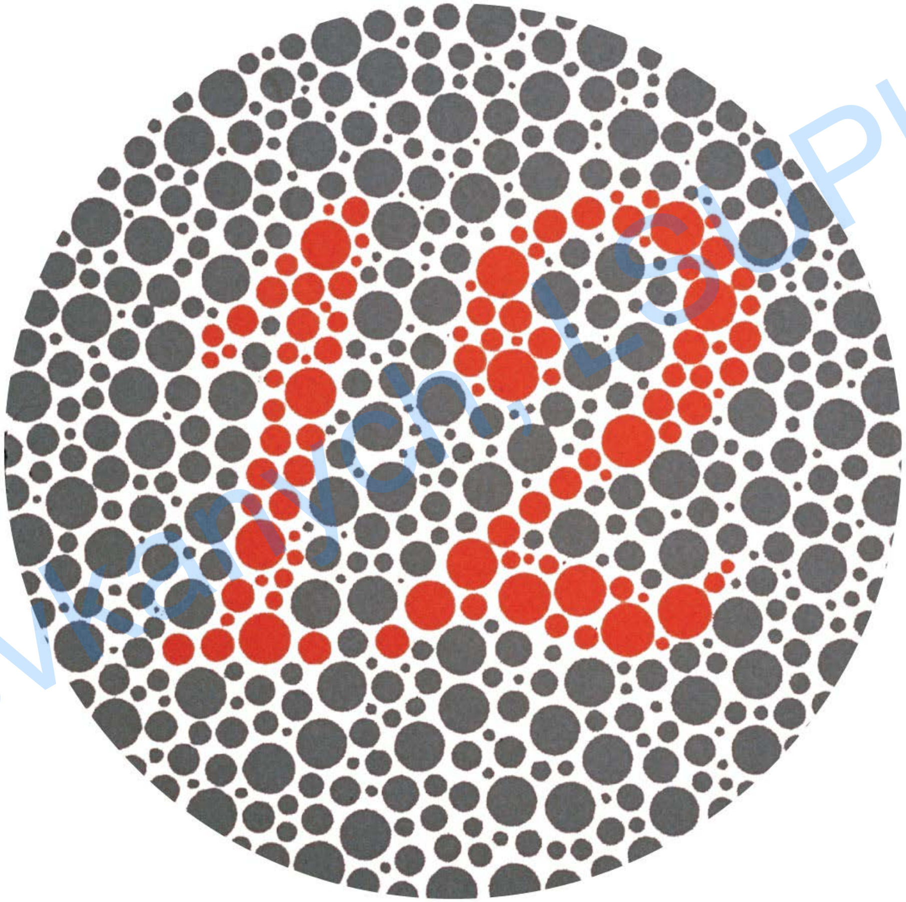
Measurement can be by using an **eye charts**



Snellen chart

Golovin–Sivtsev chart

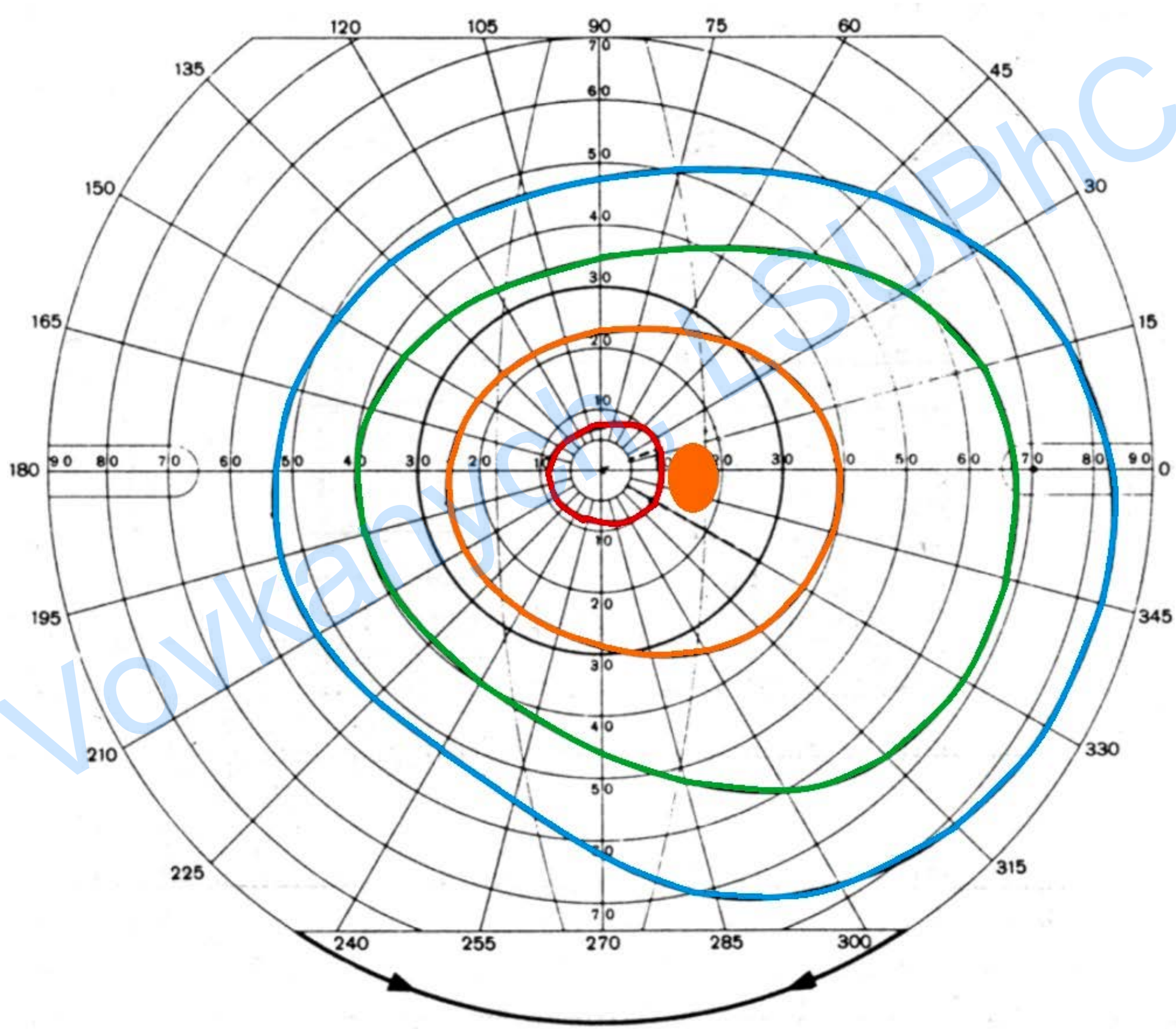
Test for Color Vision



Visual field

- It is that **portion of space** in which objects are visible at the same moment during steady fixation of the eyeball
- The monocular human visual field is **not equal in different directions**, it extends to approximately
    - 60 degrees **nasally** (toward the nose, or inward)
    - 107 degrees **temporally** (away from the nose, or outwards)
    - 70 degrees **above** the horizontal meridian
    - 80 degrees **below** the horizontal meridian
- The **binocular visual** field is the superimposition of the two monocular fields
- The visual field is measured by **perimetry**

Visual field

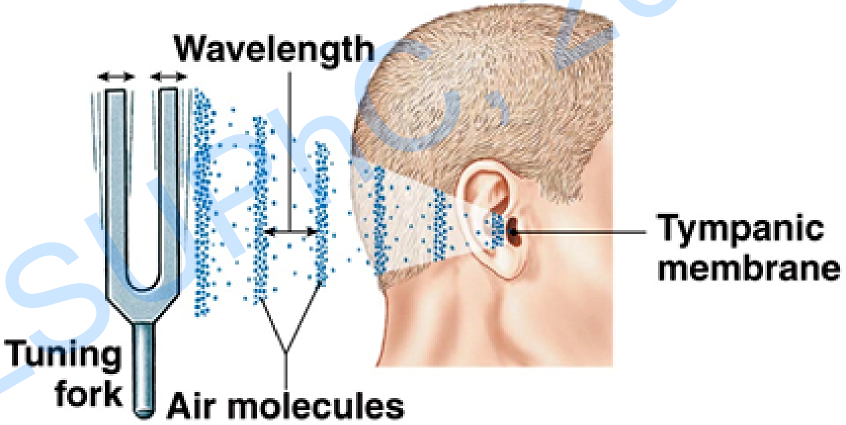


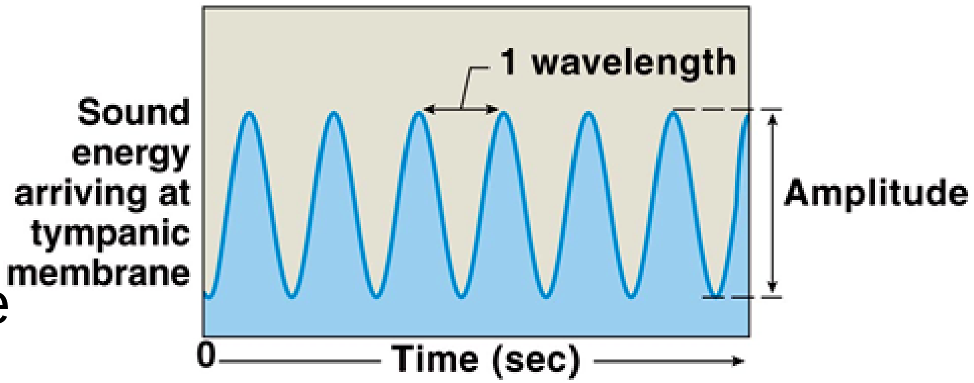
Nature of Sound

Pressure waves reach the tympanic membrane

Amplitude of the waves determines the **intensity** of sound sensation
Sound energy is reported in **decibels**

Frequency of waves determines the **sound pitch**
Is the number of waves that pass fixed reference point at given time (depends on wavelength) is measured in **hertz** (Hz) - number of cycles per second (cps)





Hearing

Tympanic Membrane

- Converts arriving pressure (sound) waves into mechanical movements

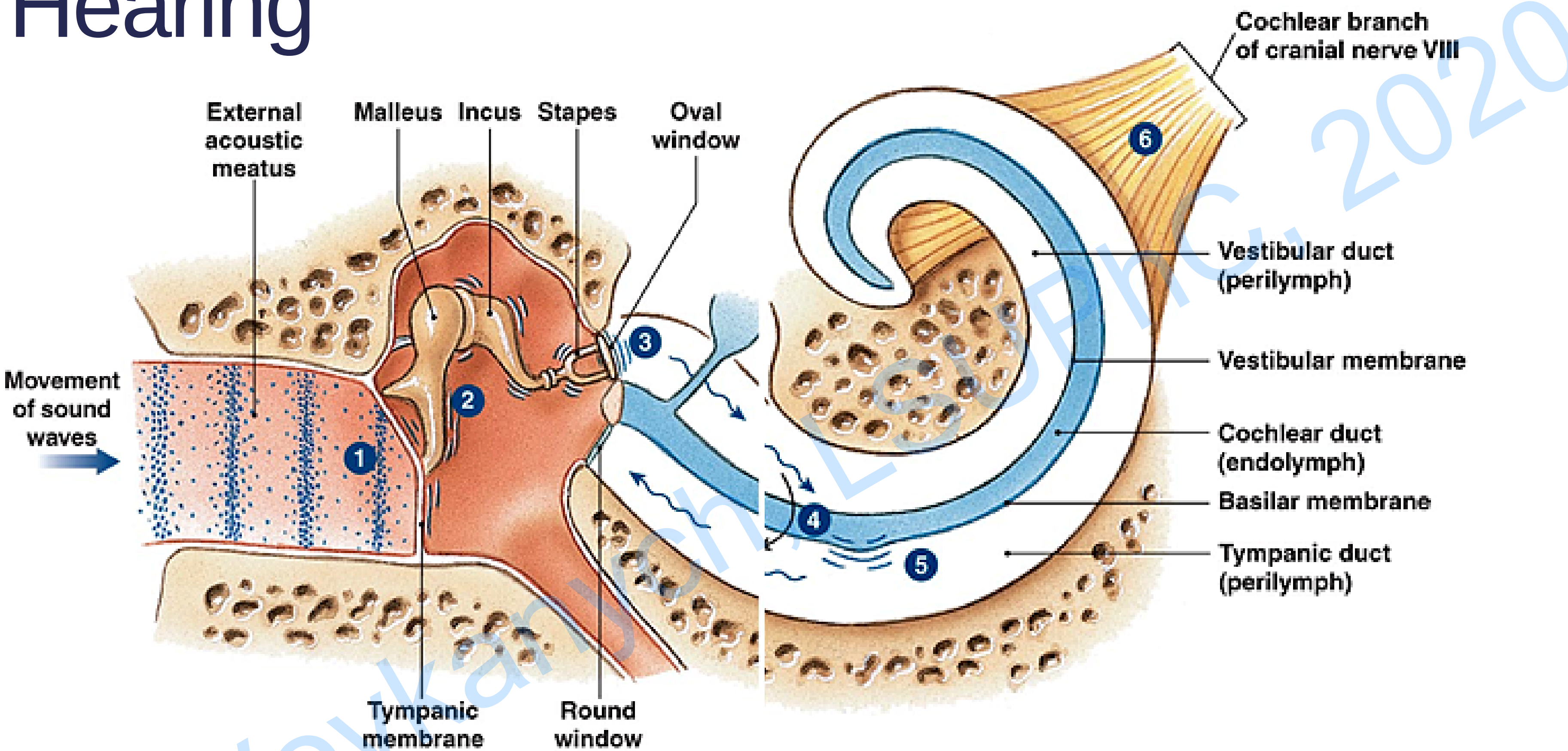
Auditory ossicles

- Auditory ossicles conduct vibrations to inner ear
- Convert pressure fluctuation in air into much greater pressure fluctuations in perilymph of cochlea

Cochlear duct receptors

- Provide sense of hearing
- Frequency of sound (sound pitch): determined by which part of cochlear duct is stimulated
- Intensity (volume): determined by number of hair cells stimulated

Hearing



Sound waves cause the **vibration of tympanic membrane.** It causes the **displacement of auditory ossicles**. Movement of stapes establishes pressure waves in the perilymph of the vestibular duct. Due to these the **basilar membrane vibrate**, caused the movements of the hair cells against the tectorial membrane. It causes the **generation of bioelectrical potentials** in the hair cells.

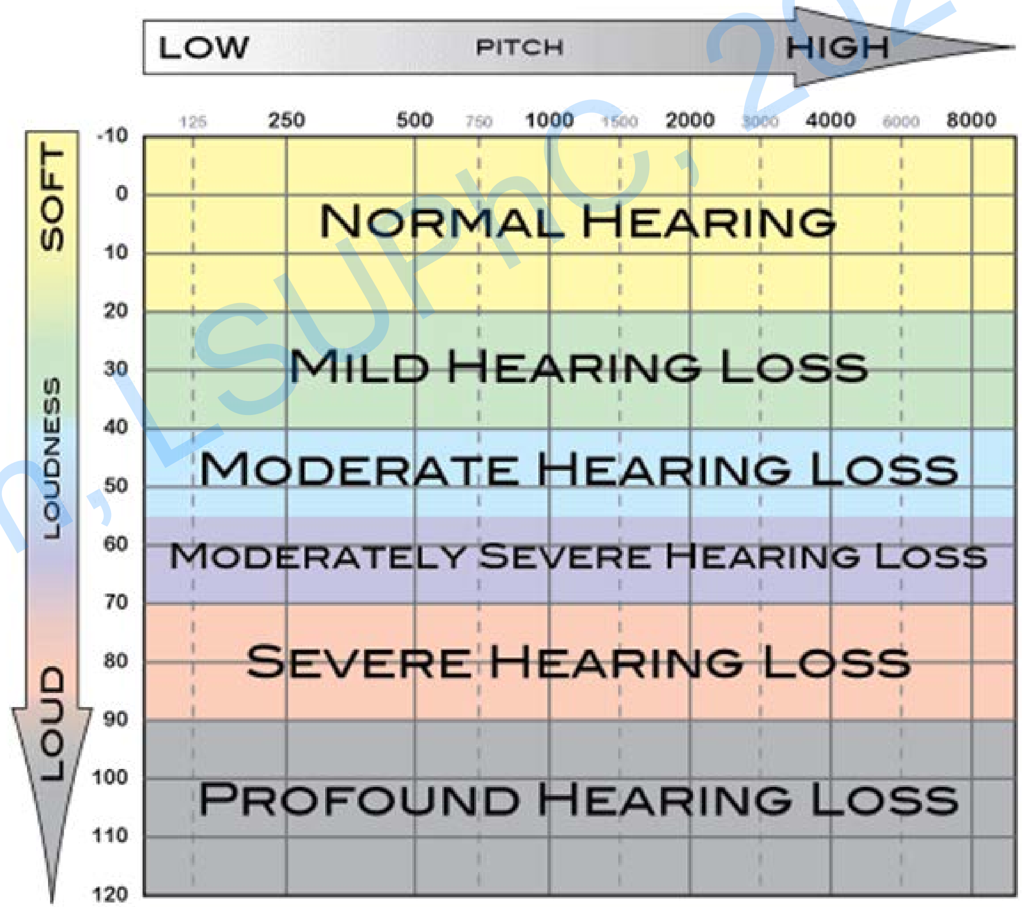
Audiometry

During the **audiometry** the hearing thresholds are determined

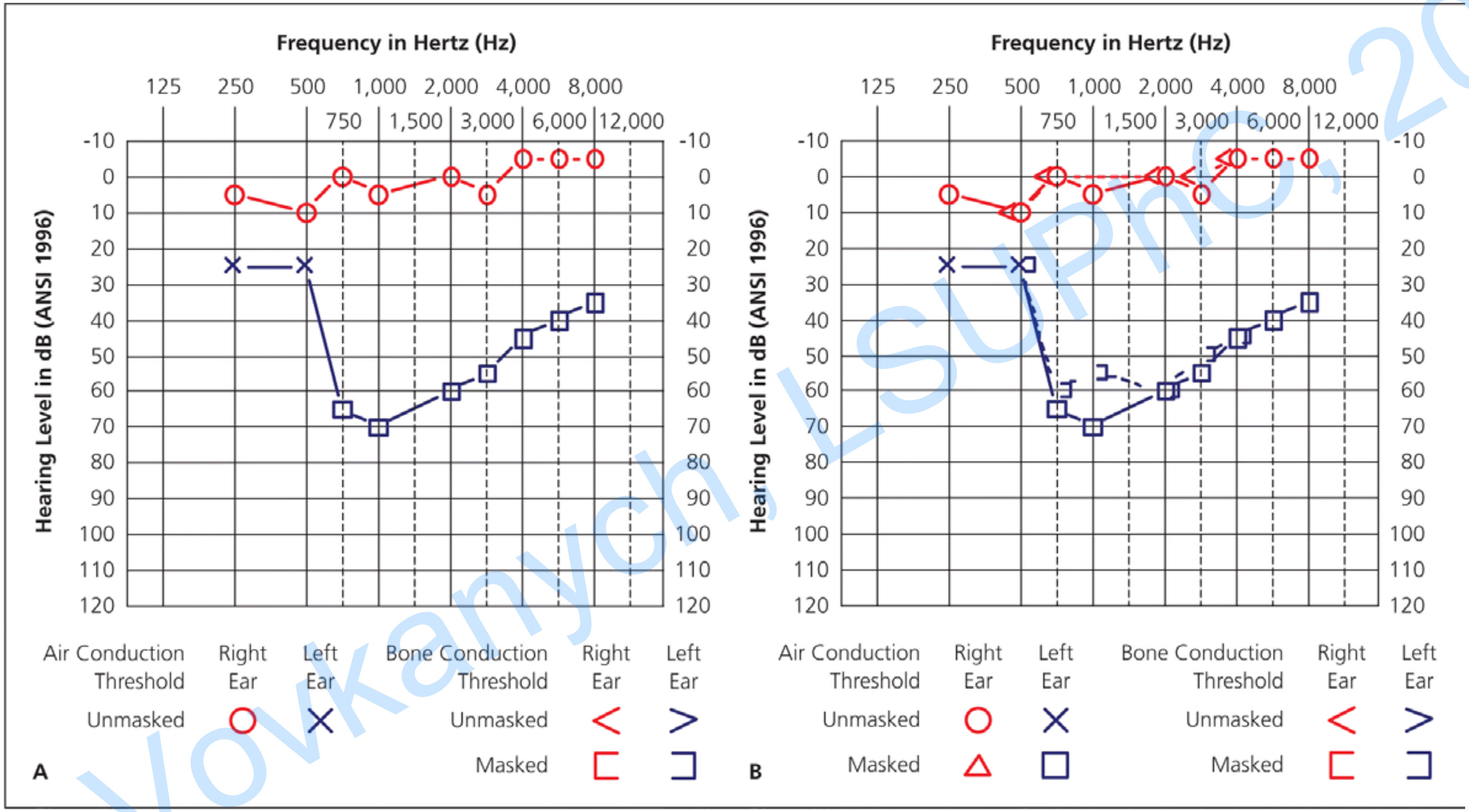
Hearing thresholds are defined as the lowest level sound (in decibel or dB) that can be heard

The thresholds are measured at **different frequencies** (or Hertz, Hz) in each ear

An **audiogram** is a graph that shows the audible threshold for standardized frequencies as measured by an audiometer



Audiogram



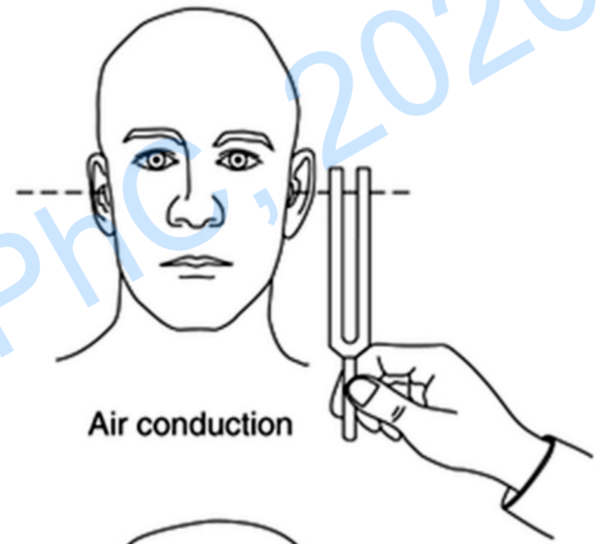
Mild hearing loss: the threshold is 25 to 40 dB higher than normal
Moderate hearing loss: 40 to 55 dB higher than normal
Moderate-to-severe hearing loss: 55 to 70 dB higher than normal
Severe hearing loss: 70 to 90 dB higher than normal
Profound loss: 90 dB or more

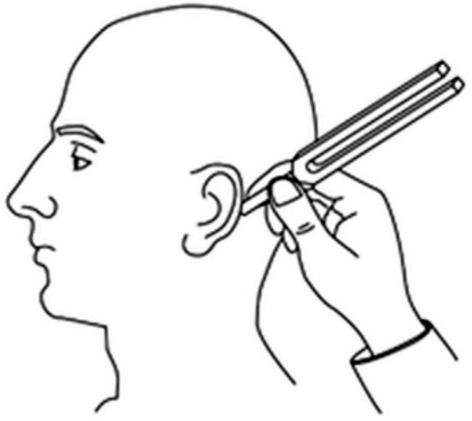
The Rinne test

- Measurement of **bone conduction** (BC)

  The vibrating tuning fork (typically 512 Hz) is placed on the mastoid process behind ear until sound is no longer heard
- Measurement of **air conduction** (AC) - without re-striking the fork

  The fork is quickly placed just outside the ear until sound is no longer heard
- A normal or **positive Rinne** test is when sound is still heard when the tuning fork is moved to air near the ear and therefore, AC > BC.
- The **negative Rinne -** bone conduction is better than air or BC > AC, and the patient will report that they do not hear the fork once it is moved. It may caused by conductive hearing loss.





The Sounds Level

Level (dB)	Example	Dangerous time
0	Lowest audible sound	
30	Quiet library; soft whisper	
40	Quiet office; living room	
50	Light traffic at a distance; refrigerator	
60	Air conditioner at 20 feet; conversation; sewing machine in operation	
70	Busy traffic; noisy restaurant	Some damage if continuous
80	Subway; heavy city traffic; factory noise	> 8 hours
90	Truck traffic; noisy home appliances	<8 hours
100	Chain saw; boiler shop; pneumatic drill	2 hours
120	"Heavy metal" rock concert; thunderclap nearby	Immediate danger
140	Gunshot; jet plane	Immediate danger

Exam of neurological function for Balance

A person requires **at least two of the three** following senses to maintain balance while standing:

- **Proprioception** (the ability to know one's body position in space)
- **Vestibular** function (the ability to know one's head position in space)
- **Vision** (which can be used to monitor and adjust for changes in body position)

In the **Romberg test**, the standing patient is asked to close his or her eyes. An **increased loss of balance** (up to fall) is interpreted as a positive Romberg's test

Romberg test

Ask the subject to **stand erect** with **feet together** and **eyes closed**, hands by the sides

Stand close by as a precaution in order to stop the person from falling over and hurting himself or herself.

Watch the movement of the body in relation to a perpendicular object behind the subject

A **positive sign** is noted when a **swaying**, sometimes irregular swaying **and even falling** occurs

The essential feature is that the **patient becomes more unsteady with eyes closed**

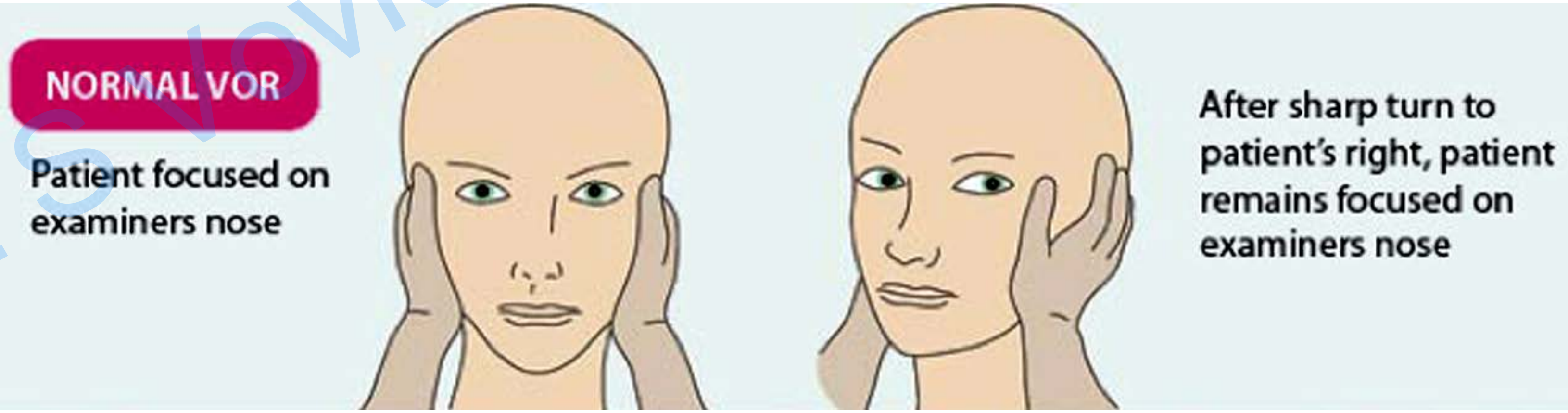
Vestibulo-ocular Reflexes

Vestibulo-ocular reflex (**VOR**) is a reflex, where activation of the **vestibular** system causes eye movement

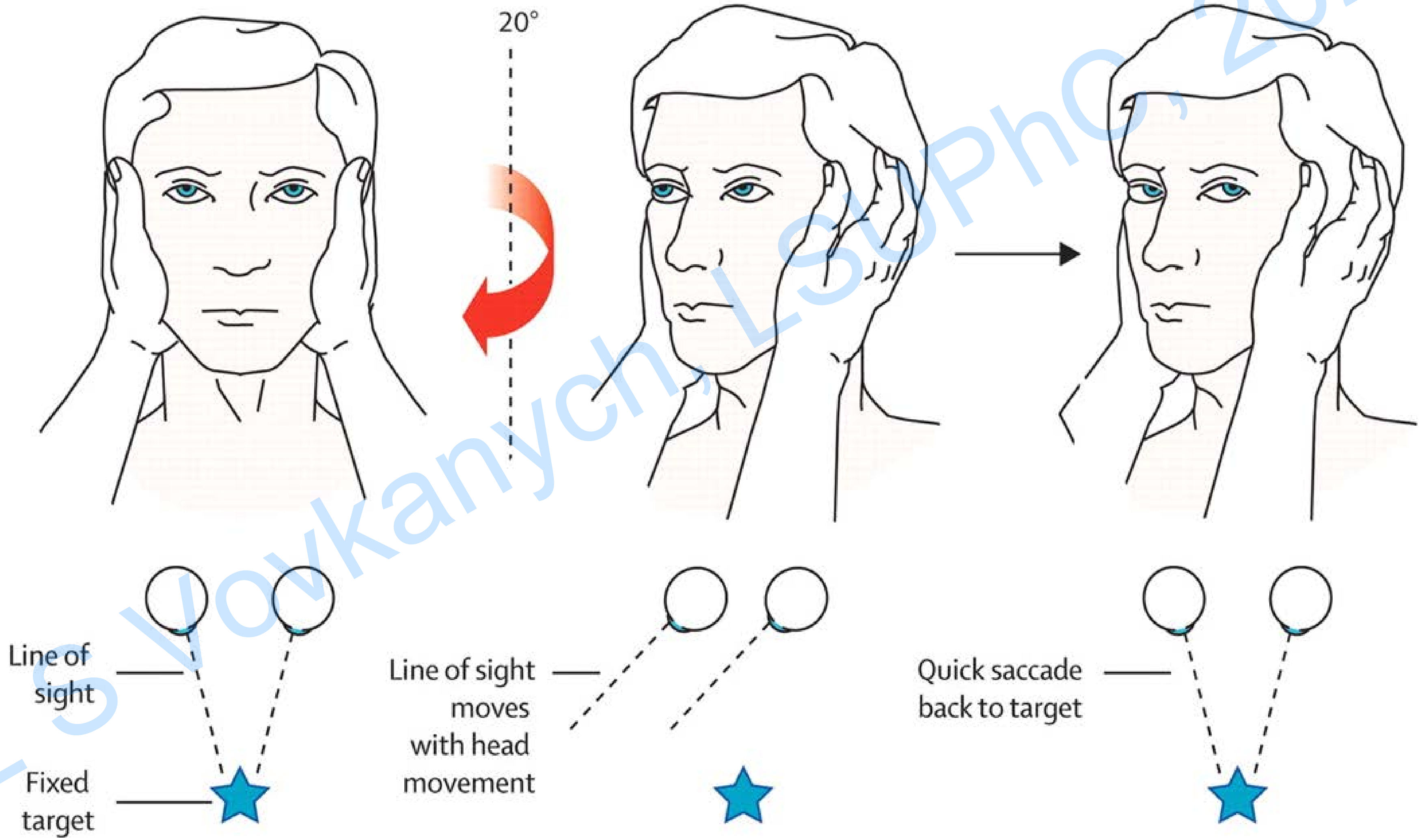
The VOR **does not depend on visual input**, it can be elicited by stimulation of the **inner ear**

The VOR produces **eye movements** in the direction **opposite to head movement**, thus serving to automatically stabilize vision relative to space

This reflex **can be tested by the rapid head impulse** test or Halmagyi–Curthoys test



Abnormal Vestibulo-ocular Reflex



Vestibulo-ocular Reflexes

Tests	Directions to perform	Positive sign
VOR Gain	"Keep your eyes on my finger." "Move your head to the left ... right ...up...down" (rate of >60d / sec)	Excessive saccades, dizziness
Head Thrust Test (eyes open)	Move the patient's head slowly back and forth being sure the patient is relaxed. Then, suddenly move the patient's head in one direction and stop. Observe for the patient's ability to maintain visual fixation.	Saccade
Head Shaking Induced Nystagmus (eyes closed)	Eyes are closed and with 30º neck flexion (horizontal SCC position). Patient shake their head vigorously (2 Hz) L&R for 20 cycles. Stop and then open their eyes.	Nystagmus

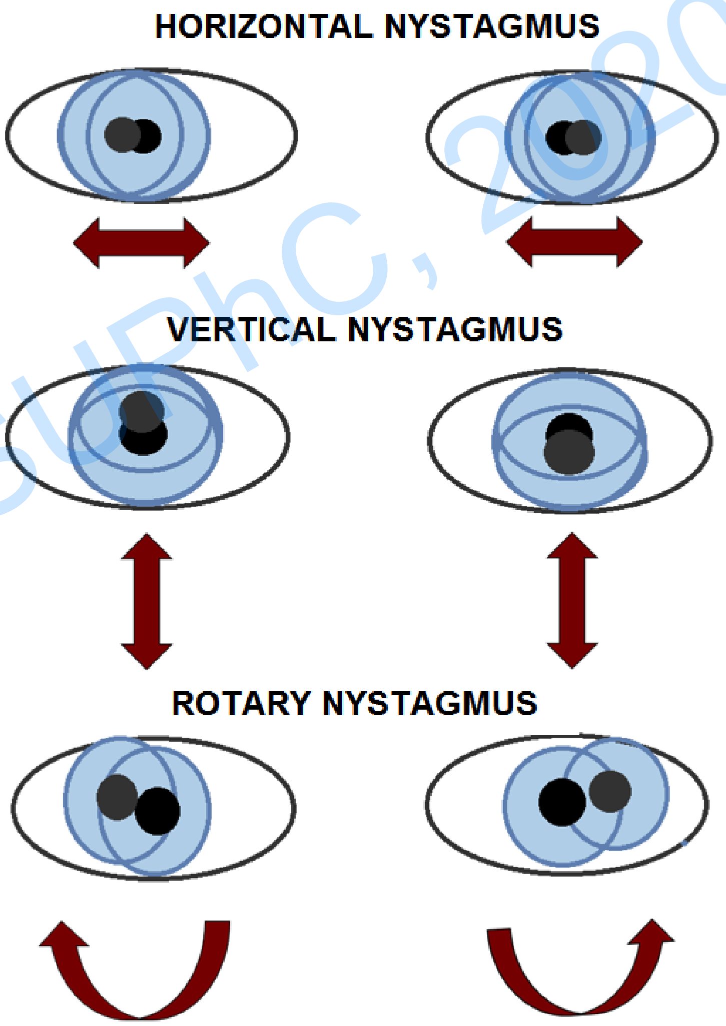
Nystagmus

Nystagmus is a condition of involuntary eye movement

Nystagmus occurs when the **semicircular canals** are being **stimulated**

While the **head rotates** about an axis the **semicircular canals** in the vestibule of the ear **sense angular acceleration**

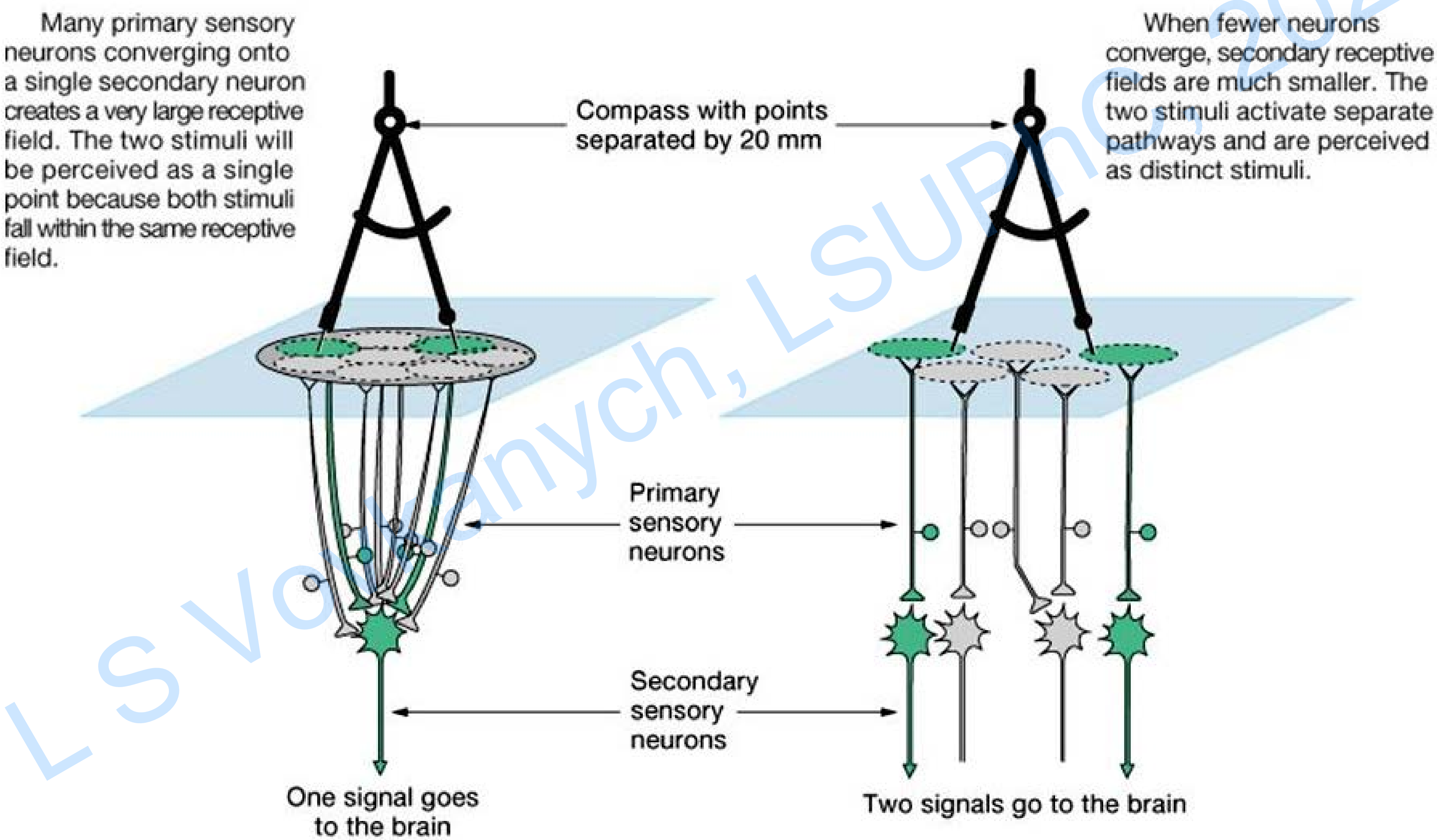
The **direction** of ocular movement is related to the semicircular canal that is being stimulated



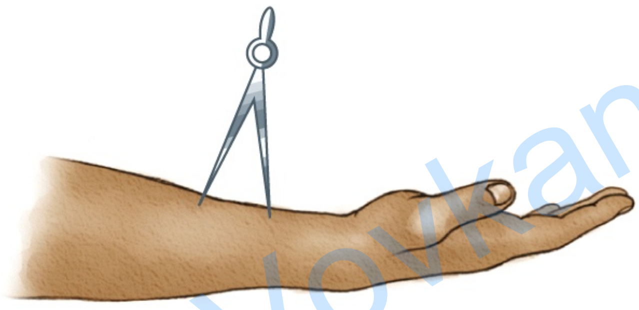
Testing the Somatosensory System

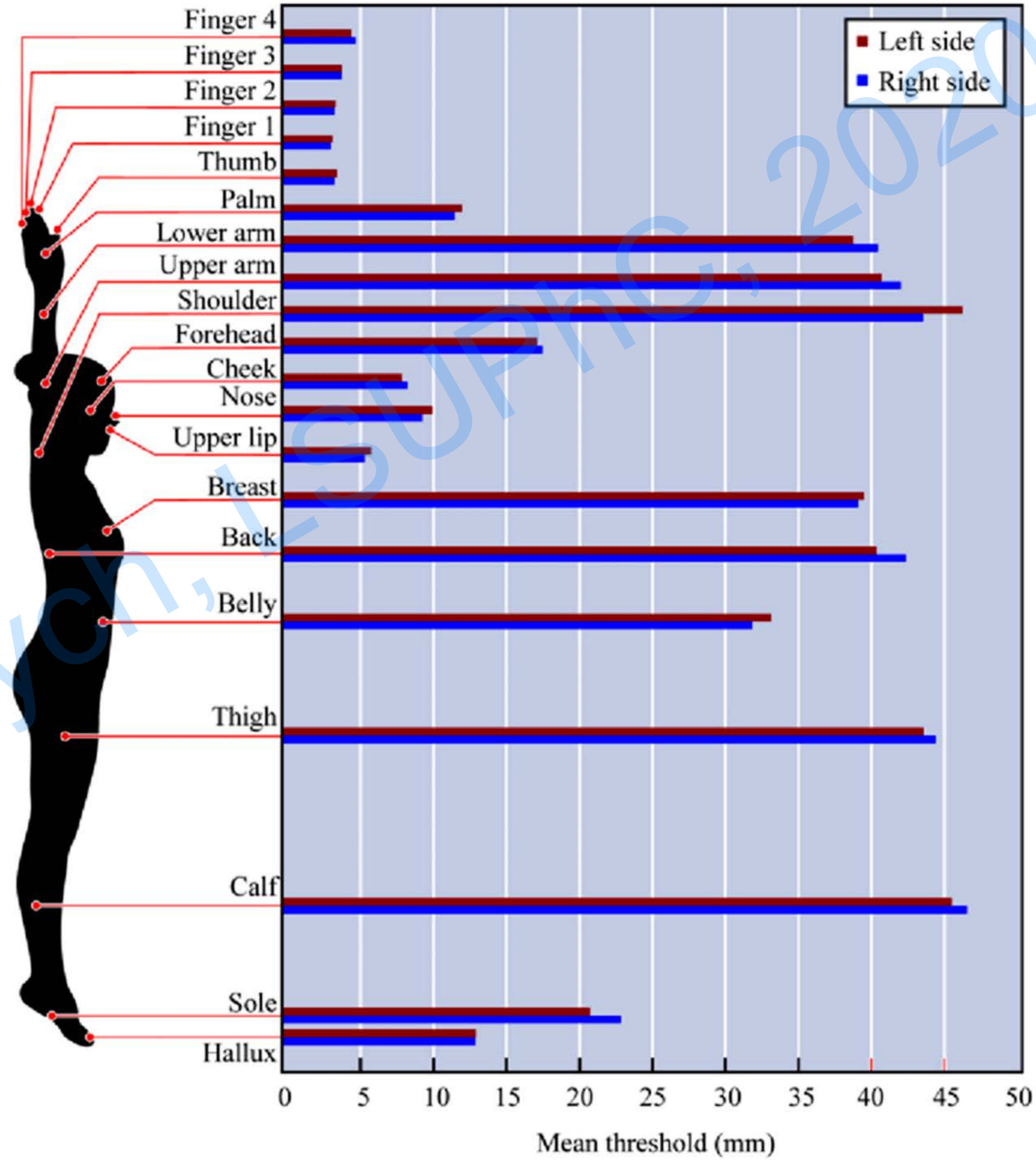
Tests location/aim	Test description
Tests **location of touch**	Ask subject to say "Yes" when they feel the touch and then point to or tell me where you feel it Lightly touch pad of subject's fingertips with your fingertip or wisp of cotton
Tests **two-point discrimination**	Ask subject to say whether they feel one point or two points; test hands and feet; Apply light equal pressure to two points, begin with calipers far apart and move them closer together until patient only feels one point
Bilateral simultaneous touch	Ask subject to say left if left side is touched, right if right side is touched, and both if both sides are touched; Lightly touch limbs; test forearms and shins
Joint position	Tell subject you are going to move a joint; after movement has stopped, ask subject to match final joint position with opposite limb or to report position of the joint

Two-point Discrimination

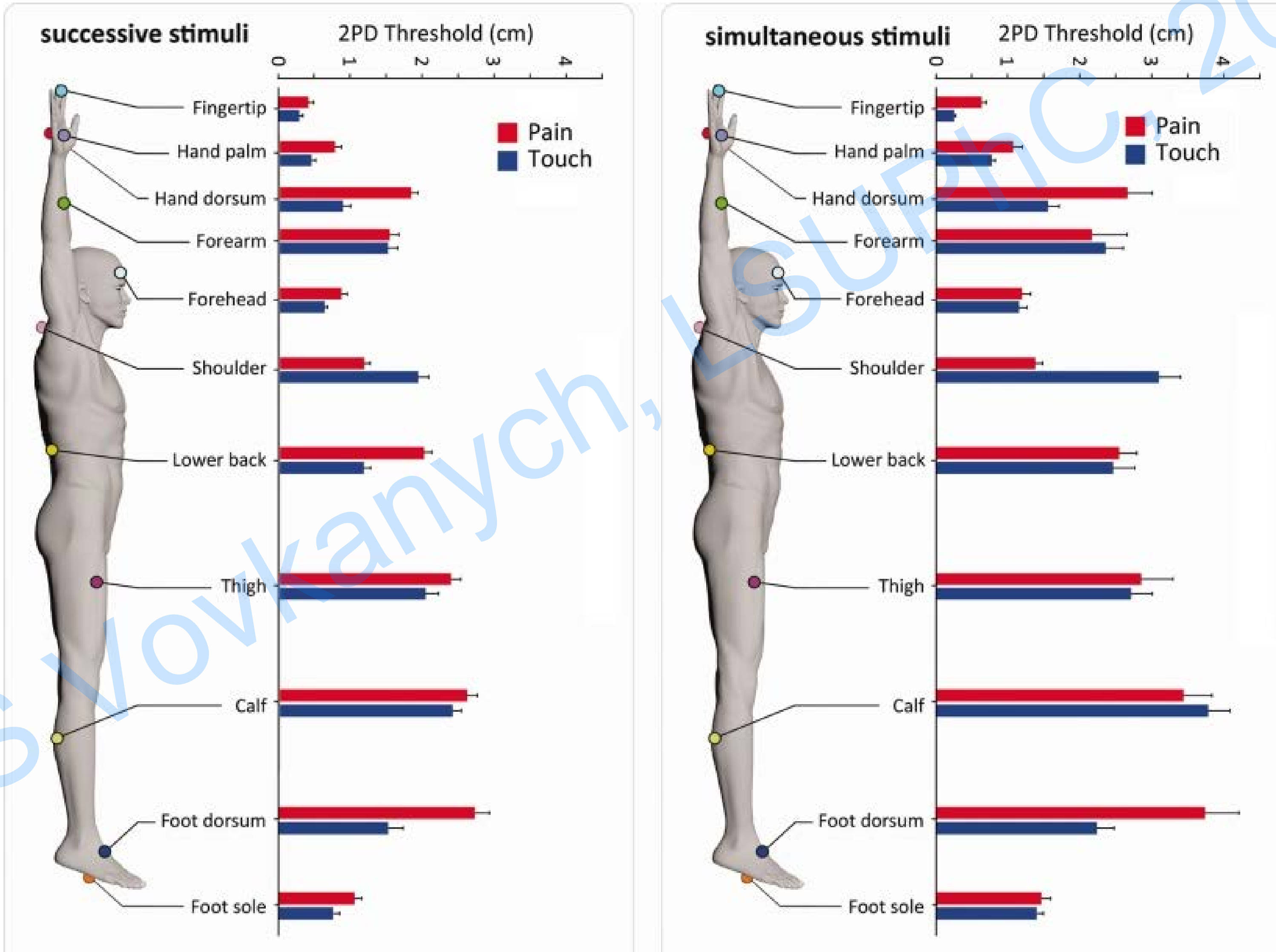


Two-point discrimination thresholds





Two-point Discrimination Thresholds



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