

Smell and Taste (CN I) (CNs VII, CIX, CNX)

**NEW YORK INSTITUTE
OF TECHNOLOGY**

College of Osteopathic
Medicine

Special Afferents of the Head and Neck

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Do.
Make.
Heal.
Innovate.
Reinvent the Future.

Olfactory

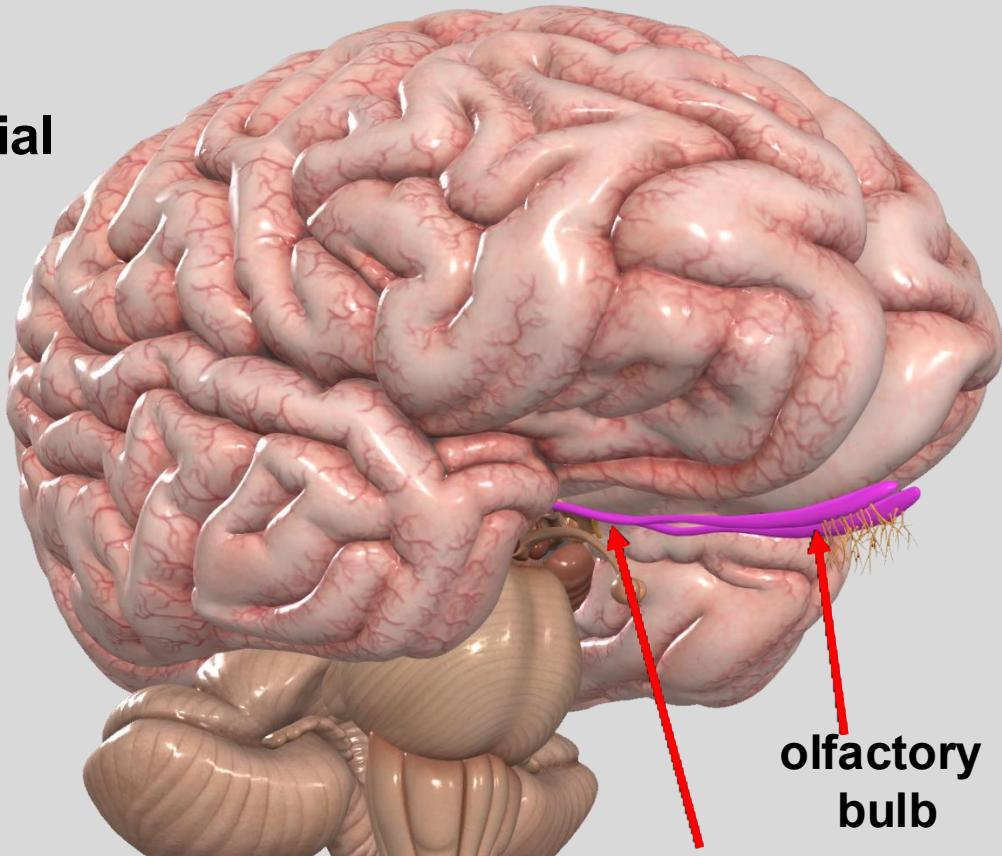
Olfaction is the least studied cranial nerve

Olfactory stalk

olfactory tract

olfactory bulb

Olfactory “nerve” is an anterior extension of the forebrain

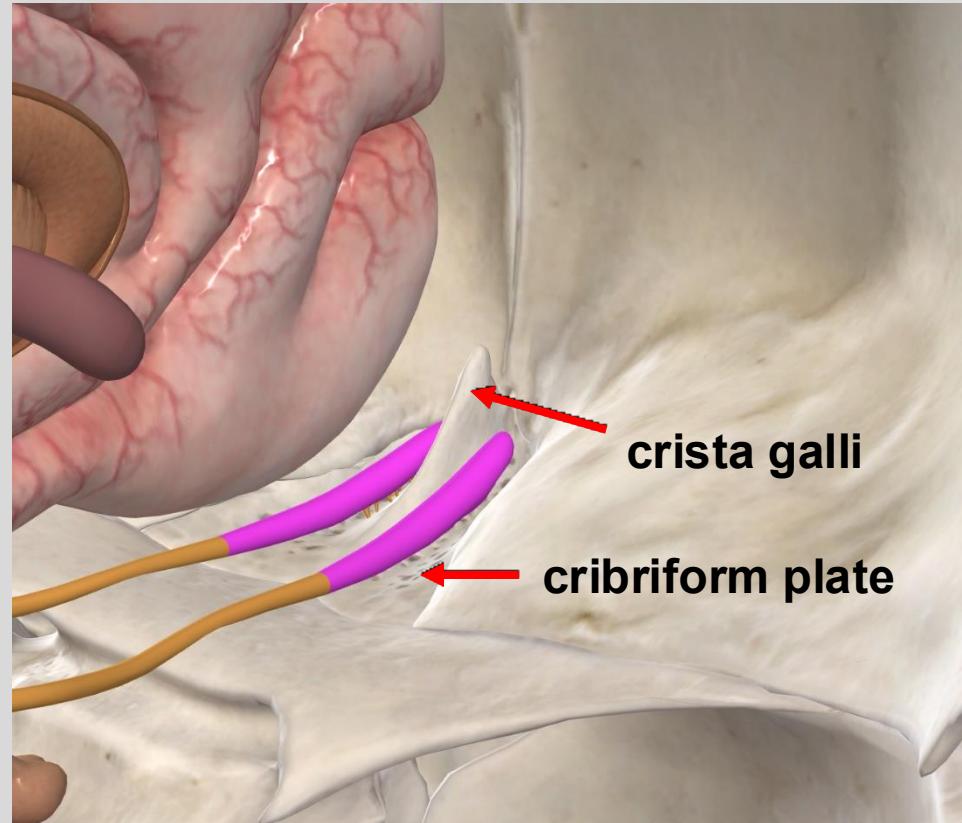


anterolateral view

Olfactory

~10 nerves / bulb exit endocranum through the cribriform plate

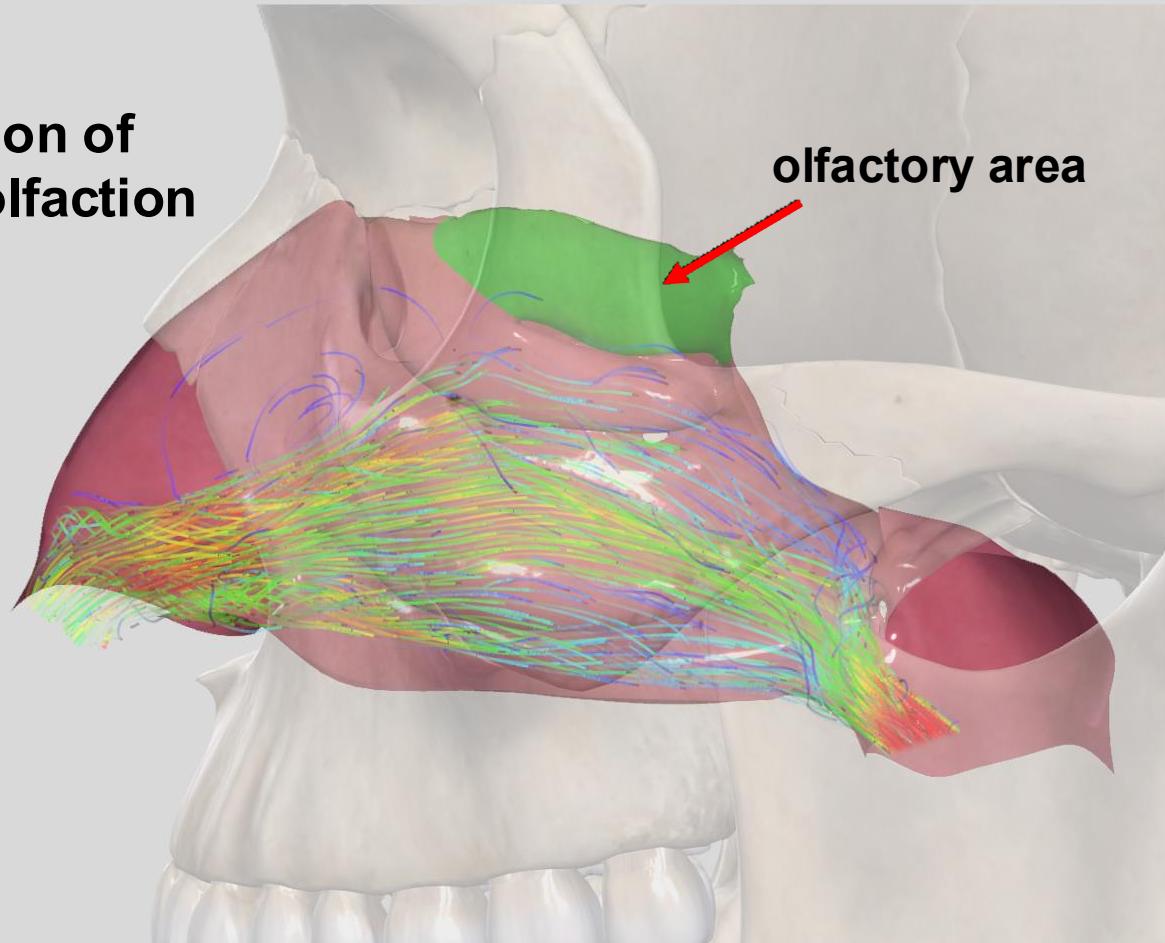
The nerves end in the mucosa of the superior part of the nasal cavity



superolateral view

Olfactory

Only the superior-most portion of the nasal passage handles olfaction

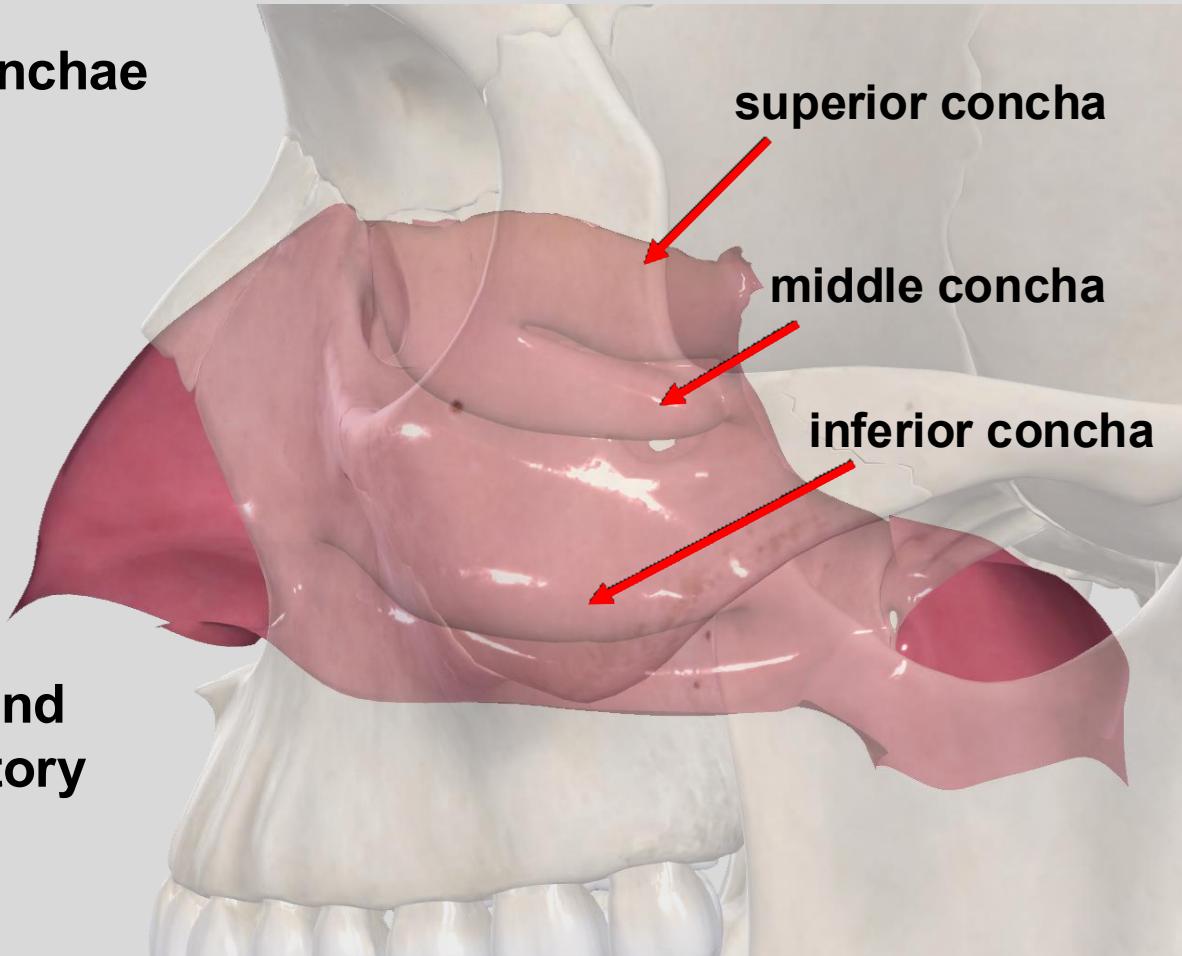


Most of the nasal passage functions in head thermoregulation and water loss

Olfactory

Nasal passage houses 3 conchae

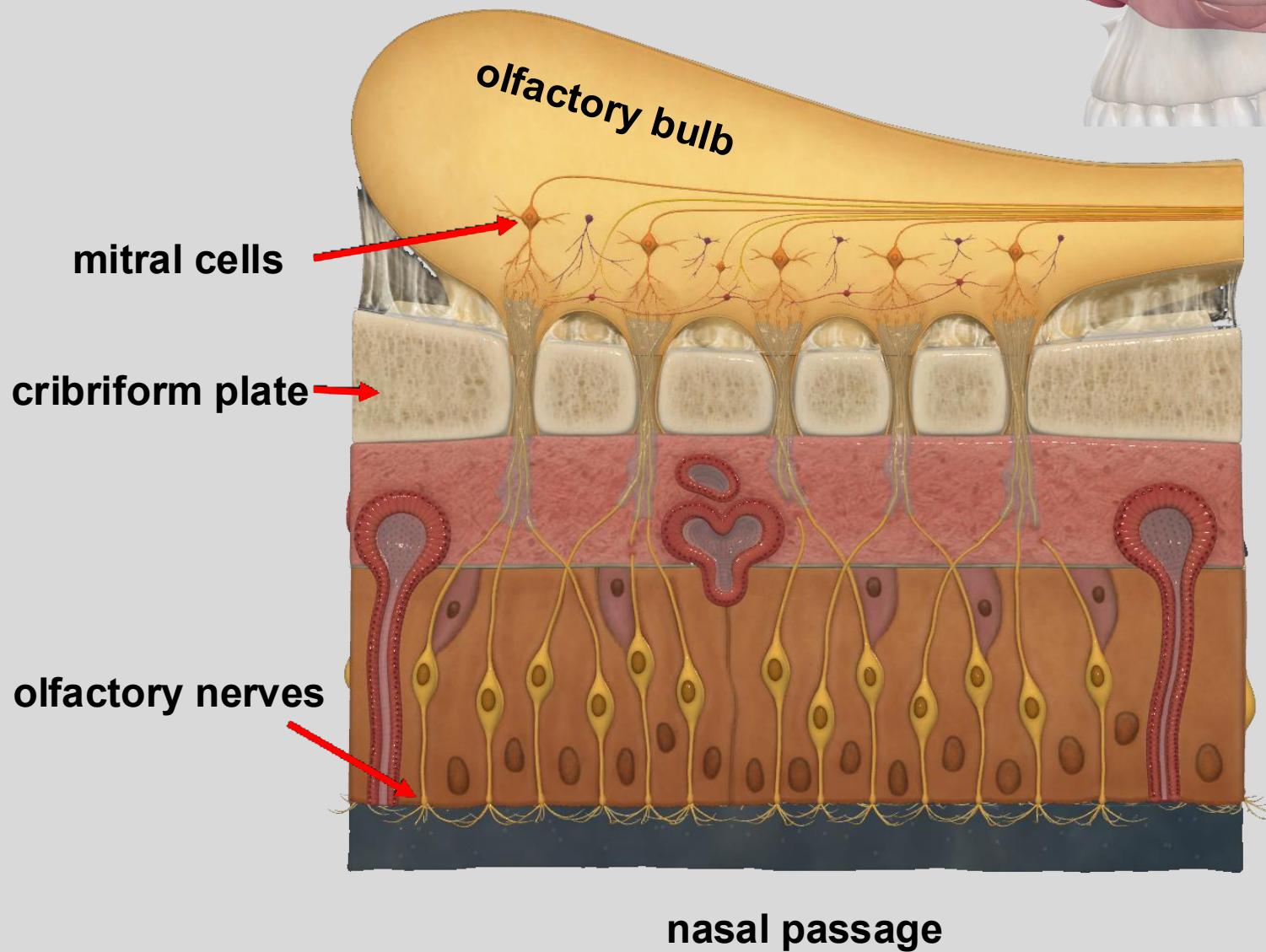
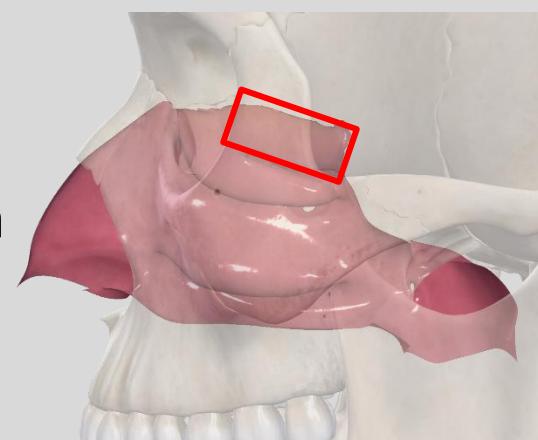
1. superior concha
2. middle concha
3. inferior concha



Only the superior concha and adjacent walls house olfactory epithelia

Olfactory

Path of olfactory information back to the brain



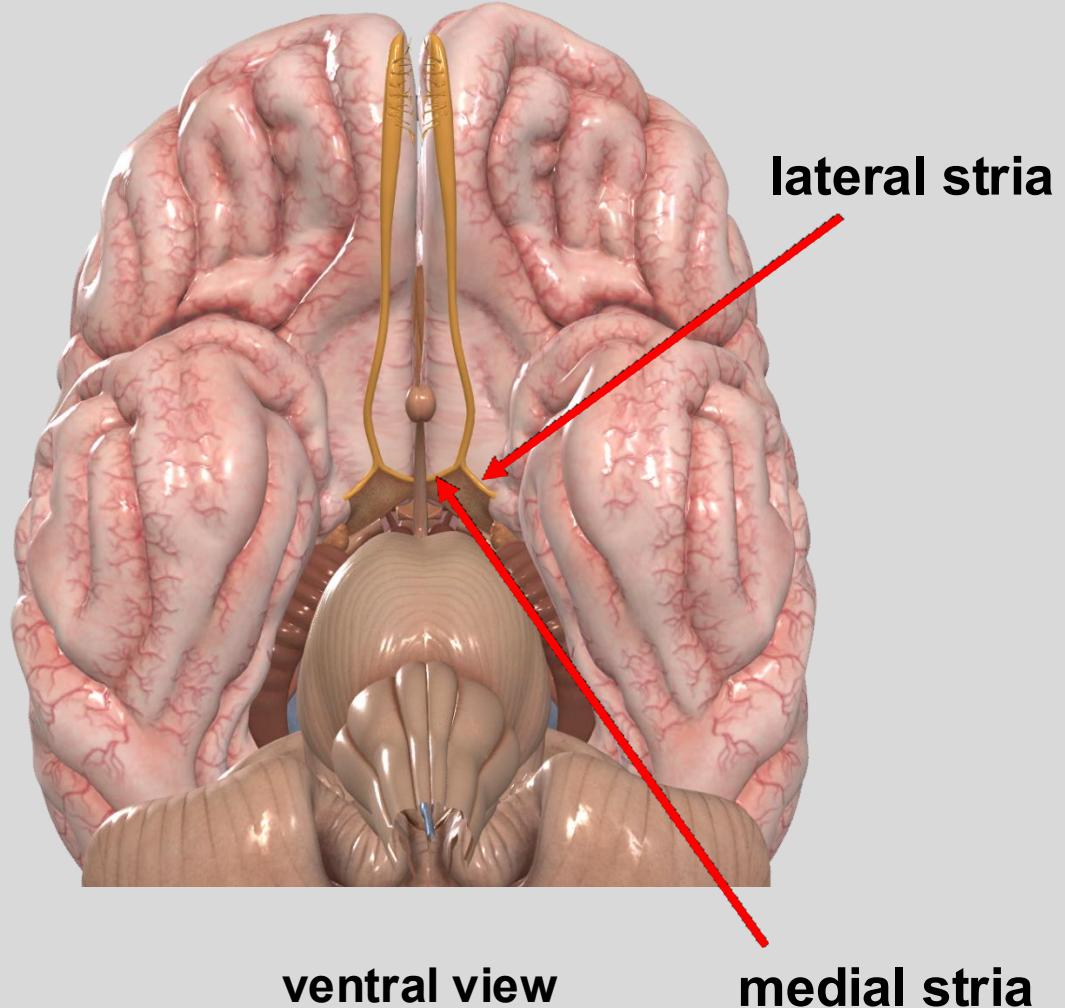
Olfactory

Olfactory signal travels back to the brain along the olfactory stalk

Stalk splits into 2 striae

1. lateral stria
2. medial stria

Olfactory is the only cranial nerve to directly enter the cerebrum



Olfactory Clinical Correlates

Anosmia

Smell “blindness”

Causes can be

Chemical (damage to epithelium)

Mechanical (damage to cribriform plate)

Congenital (failure of proper CN I development)

Viral — originally a CoViD-19 symptom



Anosmia affects quality of life

Affects taste and appetite

Inability to detect spoiled food and dangerous situations (e.g., gas leaks)

Taste

Taste is conveyed along multiple cranial nerve (CN VII, IX, X)

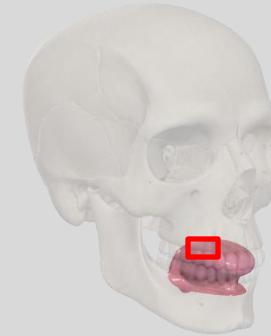
The tongue is our main organ for taste

However, taste receptors are also (sparsely) located on:

oral soft palate

parts of pharynx

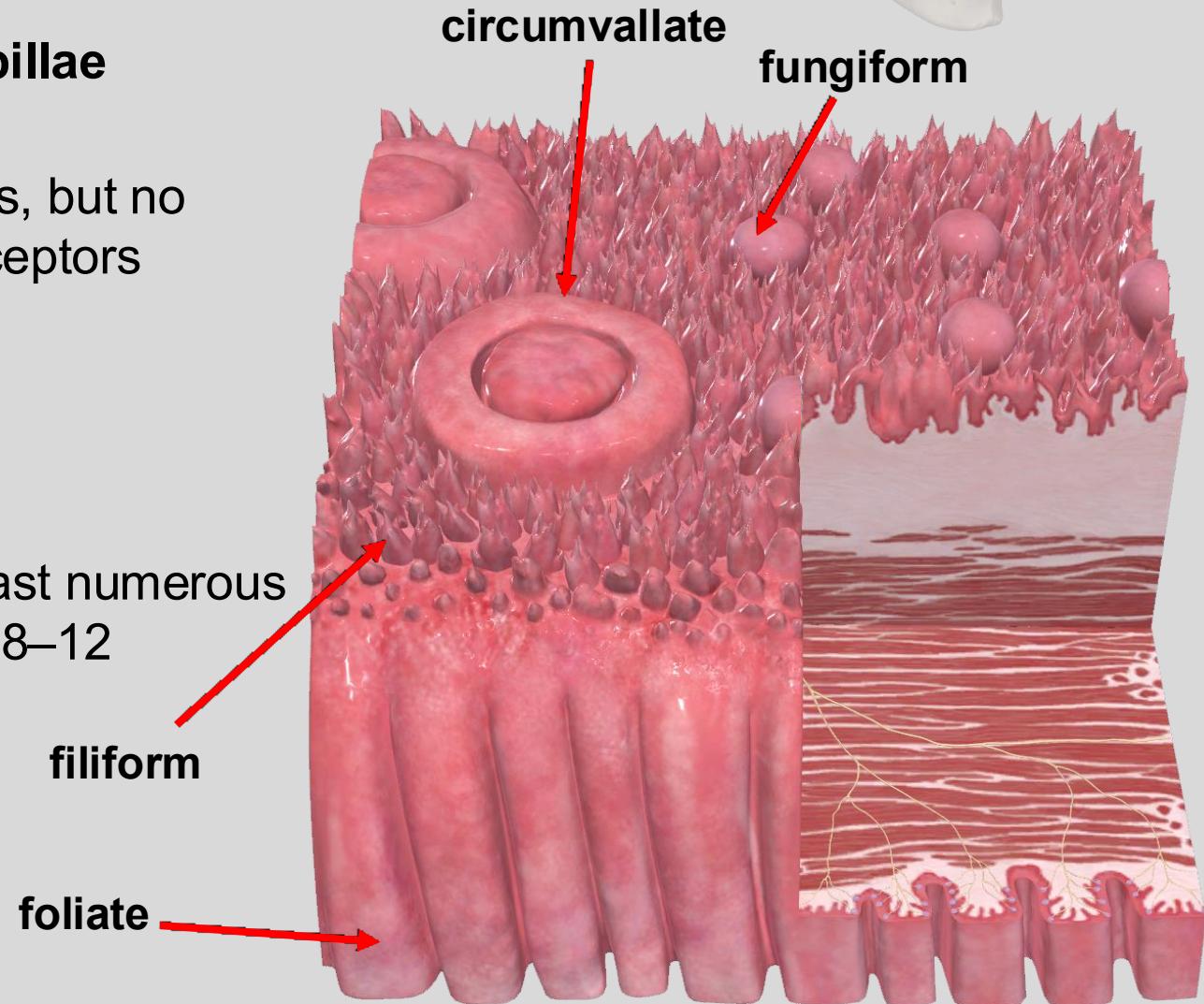
Taste



Taste receptors reside on lingual papillae

4 types of lingual papillae

1. filiform — hundreds, but no taste receptors
2. foliate
3. fungiform
4. circumvallate — least numerous at 8–12



Taste

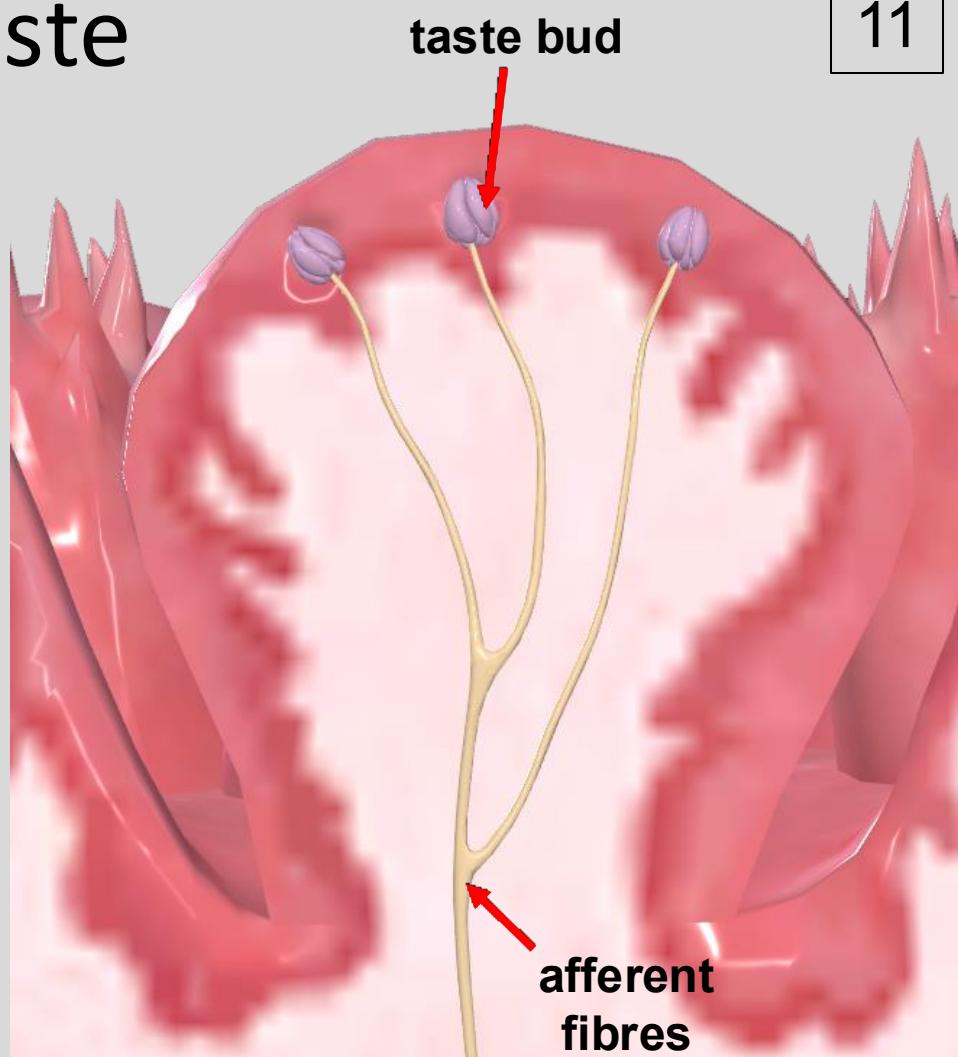
Taste buds

50–150 taste receptors / taste bud

Hundreds of taste buds /
lingual papilla

5 recognized taste categories

- 1) Sweet
- 2) Salty
- 3) Sour
- 4) Bitter
- 5) Umami (savory)



sagittal view of fungiform papilla

Taste

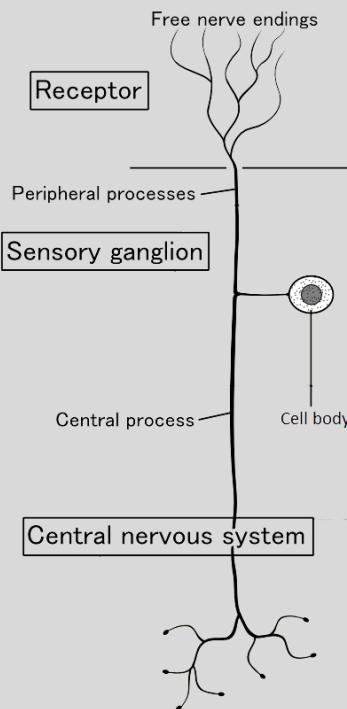
Spicy is not a true taste but more of a neurological phenomenon

Nociception (pain) from spices like capsaicin are treated by the brain as a taste rather than normal pain

Any mucosal lining can “taste” spicy food

Spice tolerance = pain tolerance

We can't all be as cool as Lorde



Taste

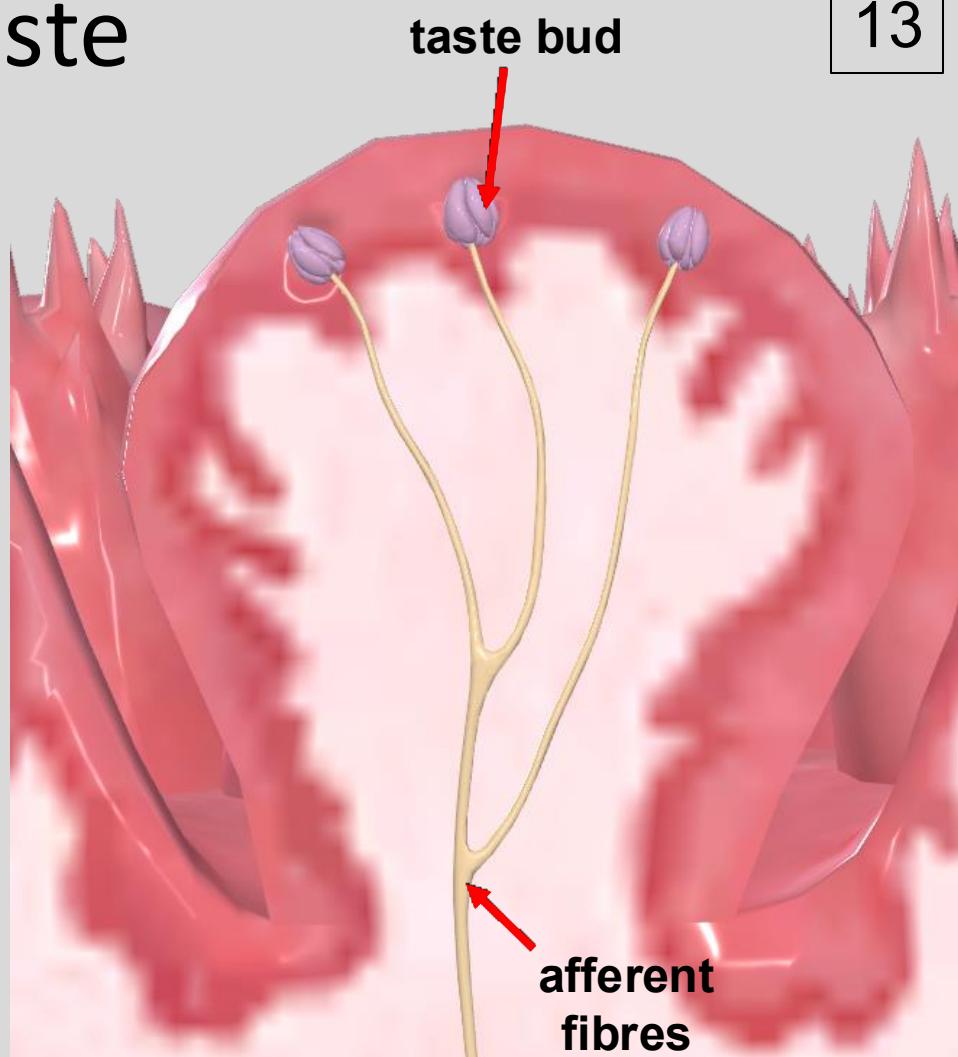
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sagittal view of fungiform papilla

All 5 categories can be recognized everywhere on the tongue (no regionalization)

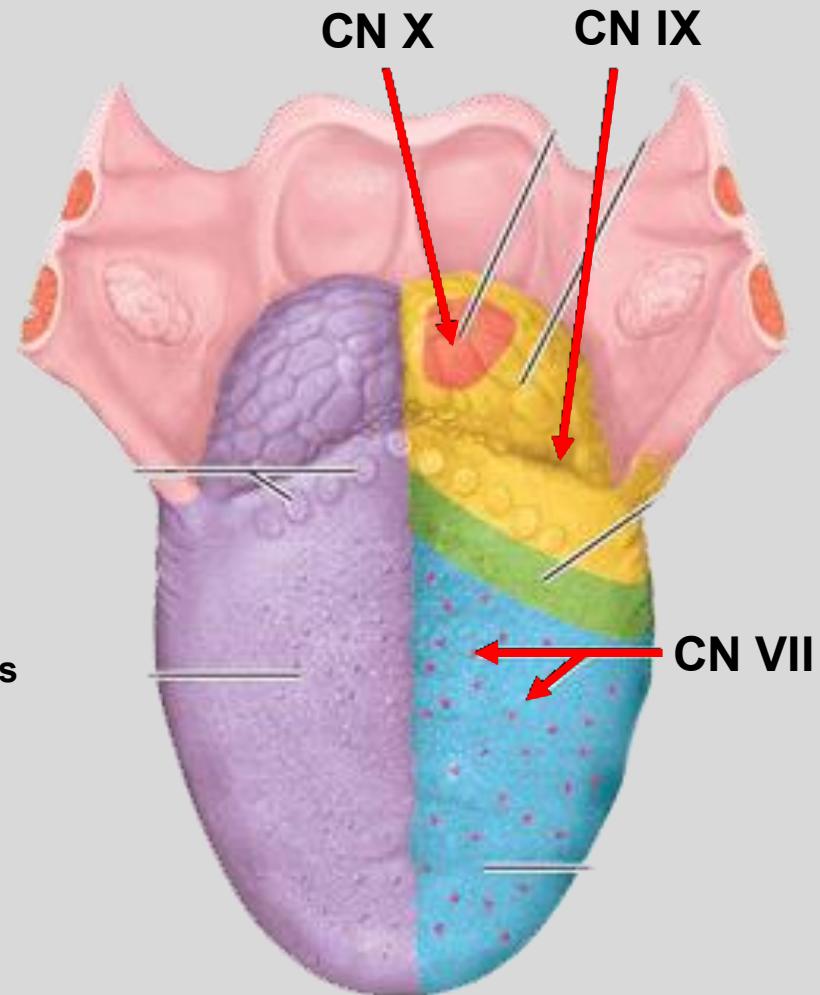
Taste

Multiple cranial nerves convey taste from the tongue

Glossopharyngeal (CN IX) innervates the posterior 1/3rd

Vagus (CN X) innervates small regions of the tongue, oral soft palate and pharynx

Facial (CN VII) innervates the anterior 2/3^{rds} of the tongue via chorda tympani



superior view

Figure 8.91

Taste

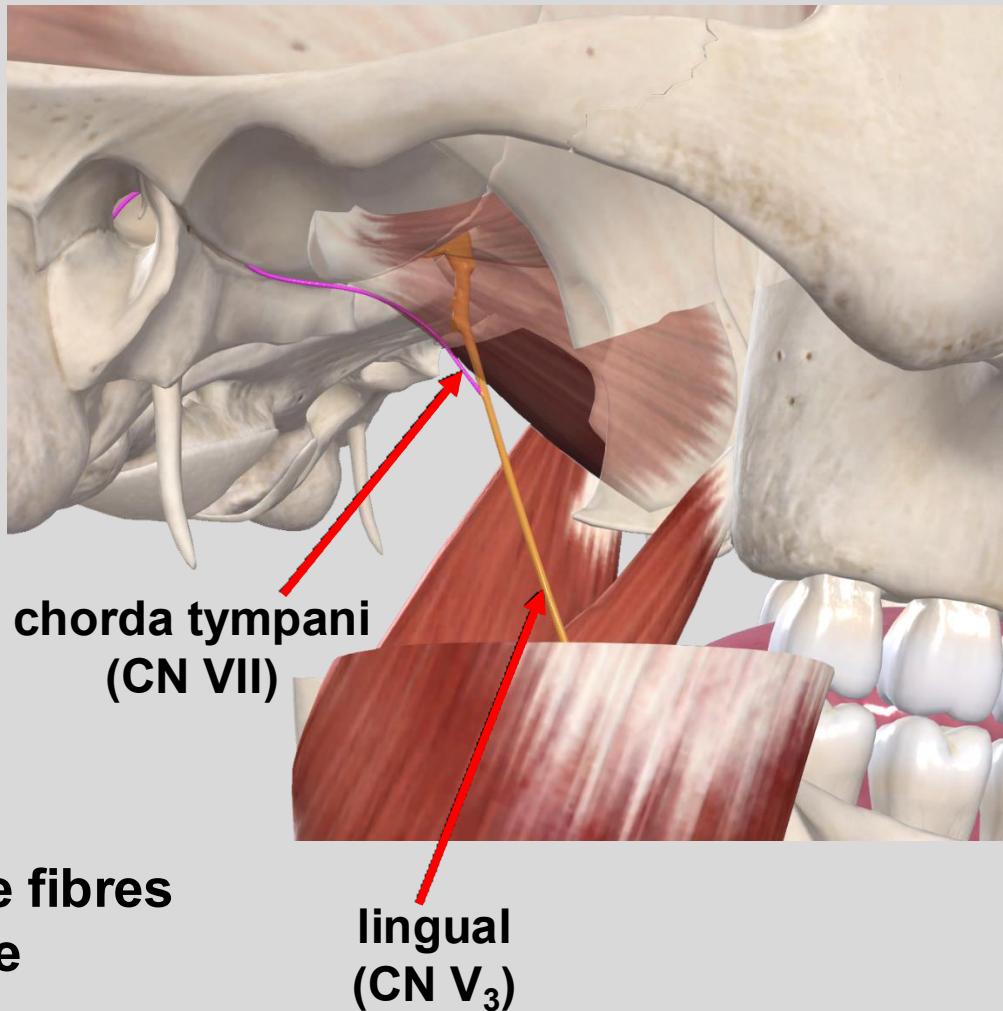
Chorda tympani

Branch of facial that *exits the skull* through the petrotympanic fissure

“Hitches a ride” with the lingual nerve (CN V₃) to enter the tongue

Though bundled together, the nerve fibres of CN V₃ and CN VII remain separate

infratemporal fossa

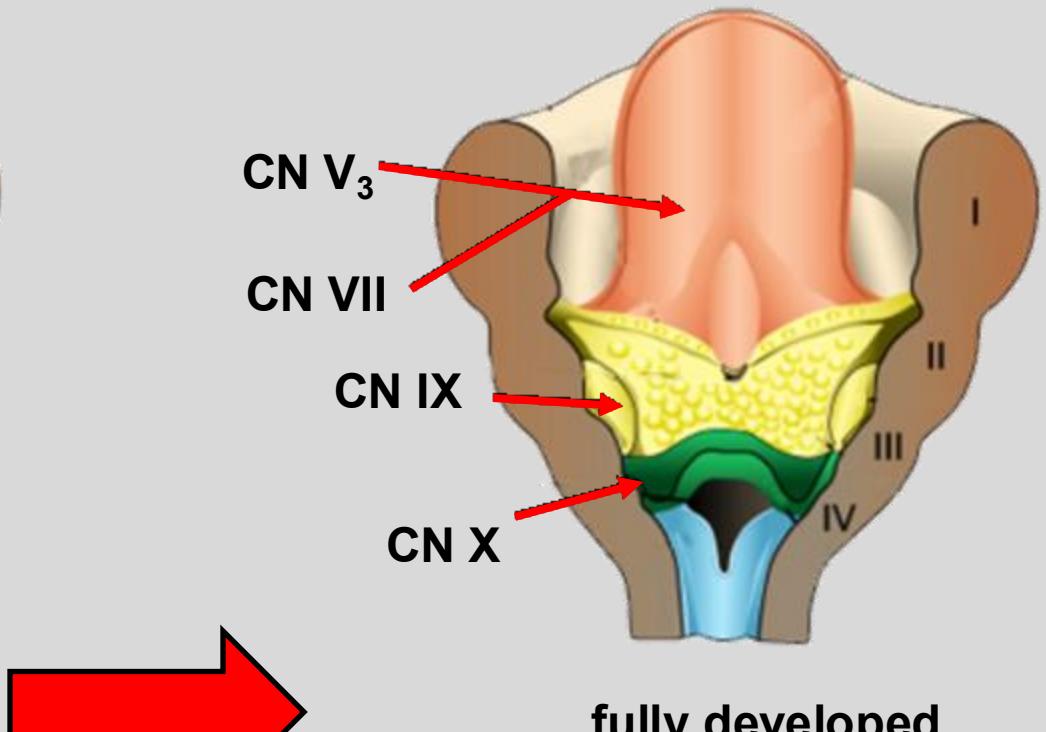
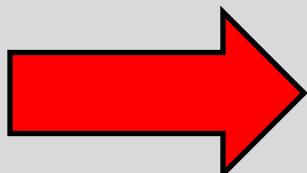
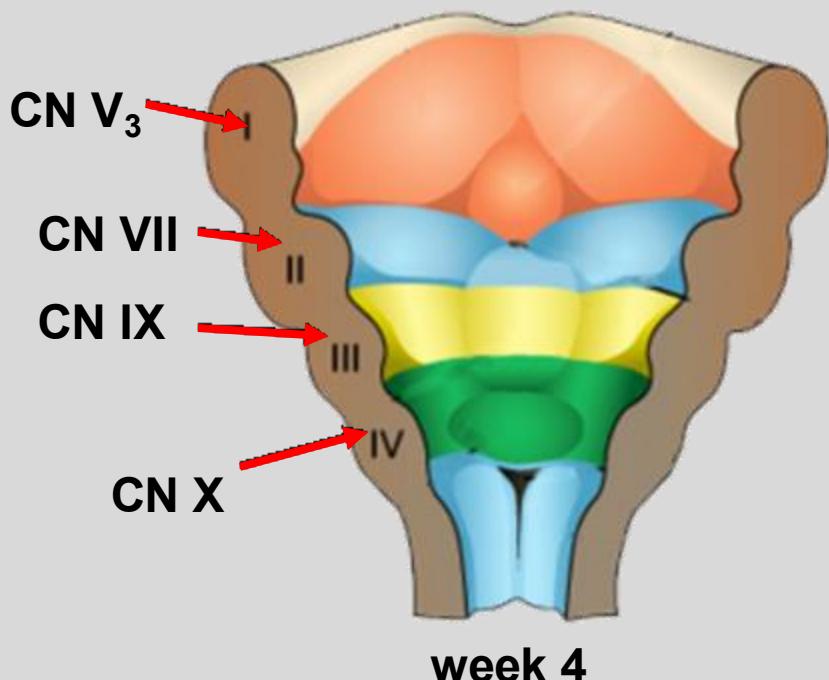


Taste

The tongue forms from the first 4 pharyngeal arches

Each pharyngeal arch is associated with its own cranial nerve

Primordial tongue had proto facial nerve fibres that migrated from arch II to arch I and were dragged into the anterior tongue as it developed



fully developed

Taste

Clinical Correlate

Ageusia

Taste loss

Often coupled (and confused) with
anosmia

Caused by:

Toxic chemical exposure

Head trauma

Viral — originally a CoViD-19 symptom

Largely affects quality of life

Can lead to inadvertent food poisoning

Can also lead to poor nutrition

adding more sugar and salt to foods in an attempt to regain taste



Coupled Senses: Flavour

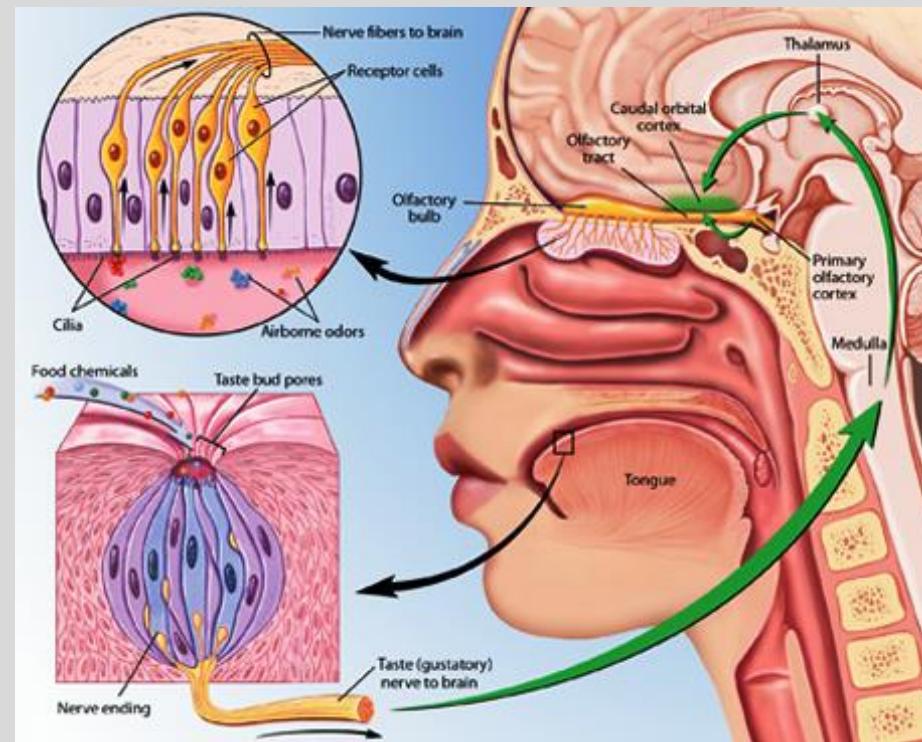
Coupled senses = 2 or more senses that work together to perform a new function

Smell and taste are deeply intertwined

Taste requires smell to bring out flavour

80% of flavour is smell (allegedly)

Olfaction and gustation information is combined in the thalamus and orbitofrontal cortex



Lower air density in planes means these taste sweeter on the ground than in the air



Lecture Feedback Survey

<https://comresearchdata.nyit.edu/redcap/surveys/?s=HRCY448FWYXREL4R>

Vision (CN II)

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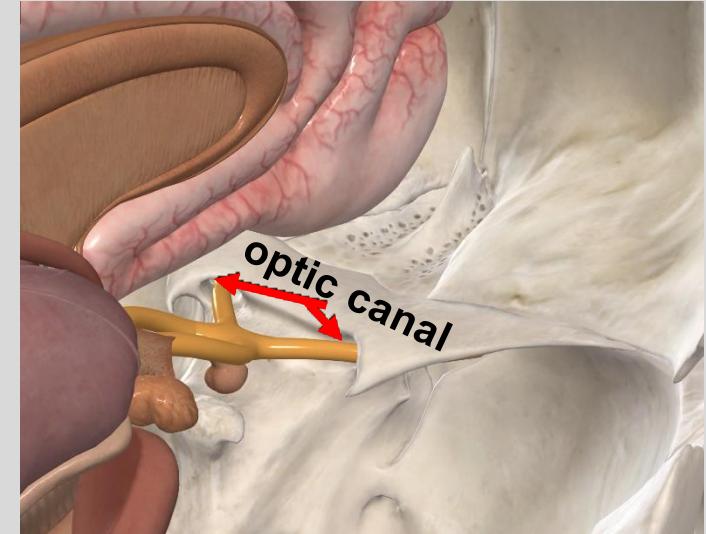
Vision

The most important special afferent
in our body

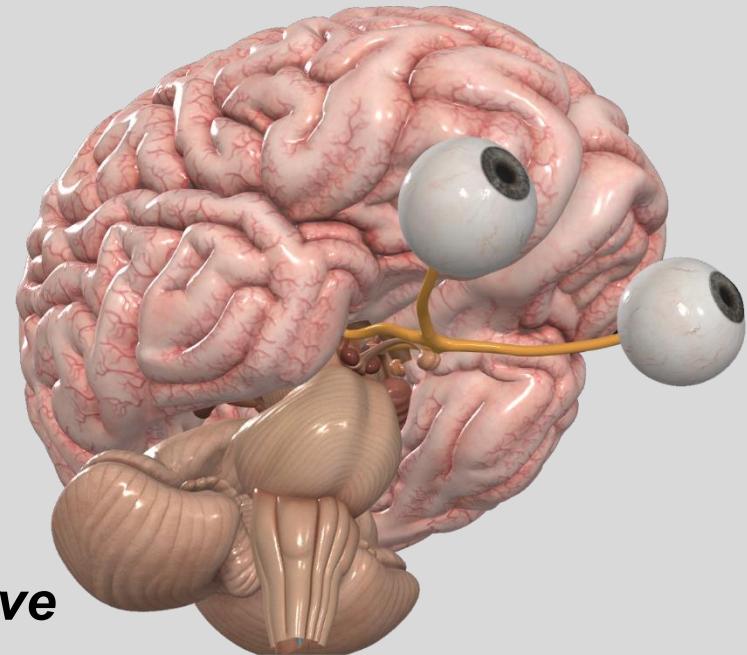
30–60% of our brain is
dedicated to visual processing

Optic nerve is an anterior extension
of the forebrain

Optic nerve exits *the endocranum*
through the optic canal



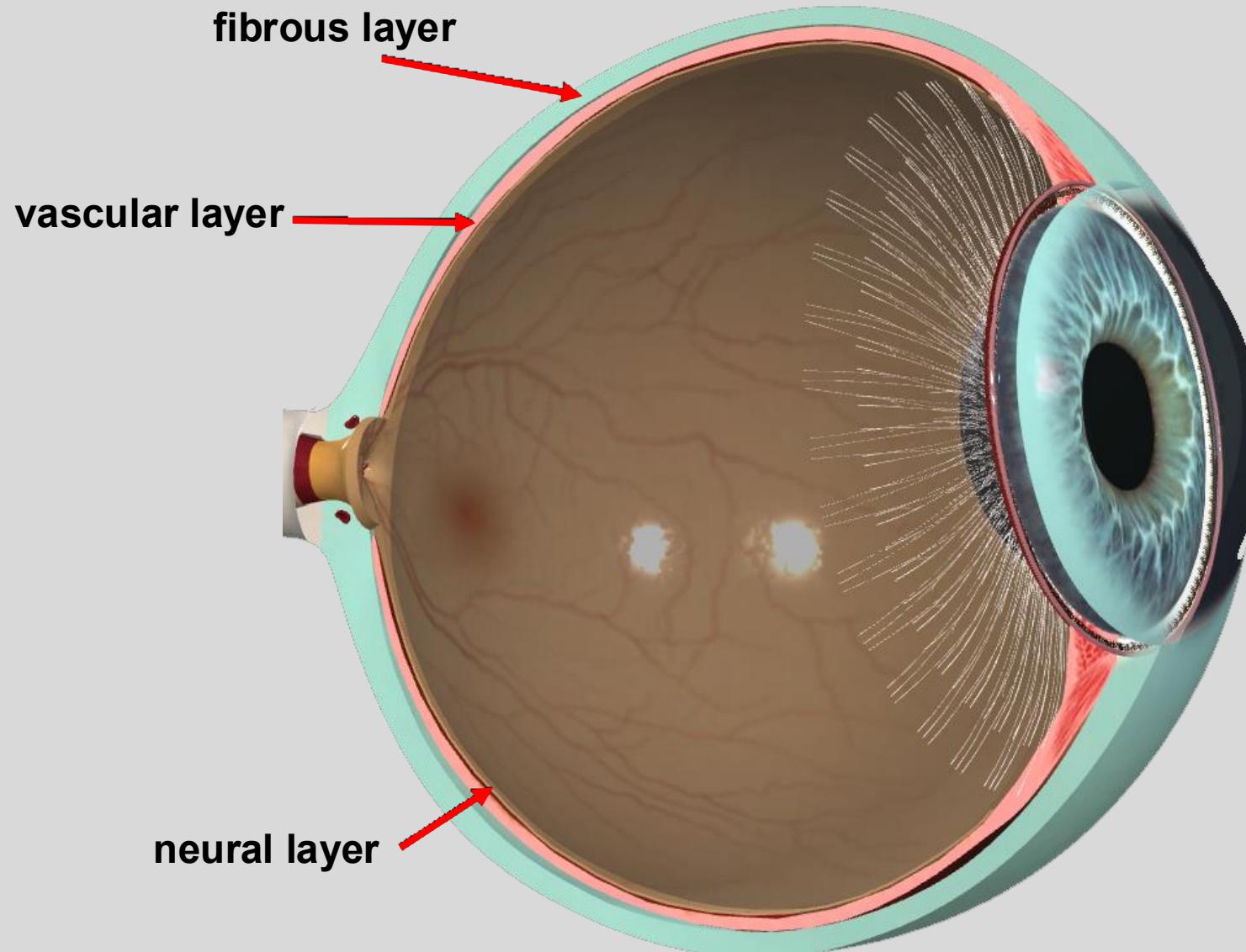
superolateral view



The eye is the terminal nerve of the optic nerve

Vision

The eye can be divided into 3 layers



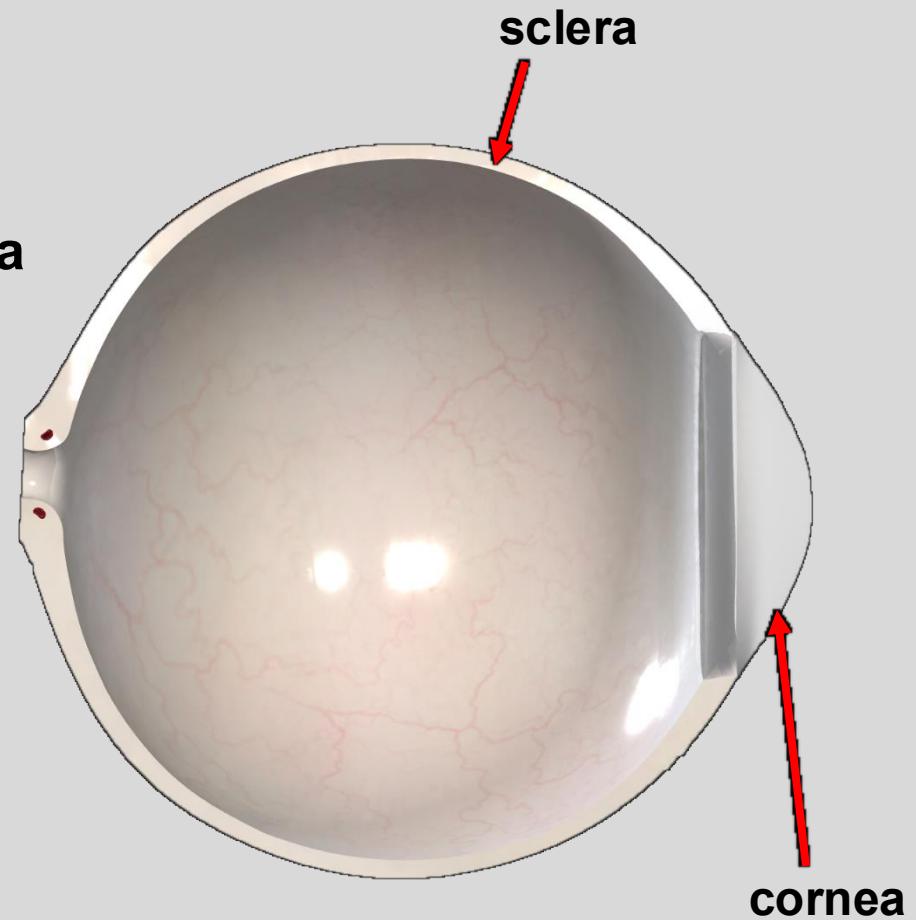
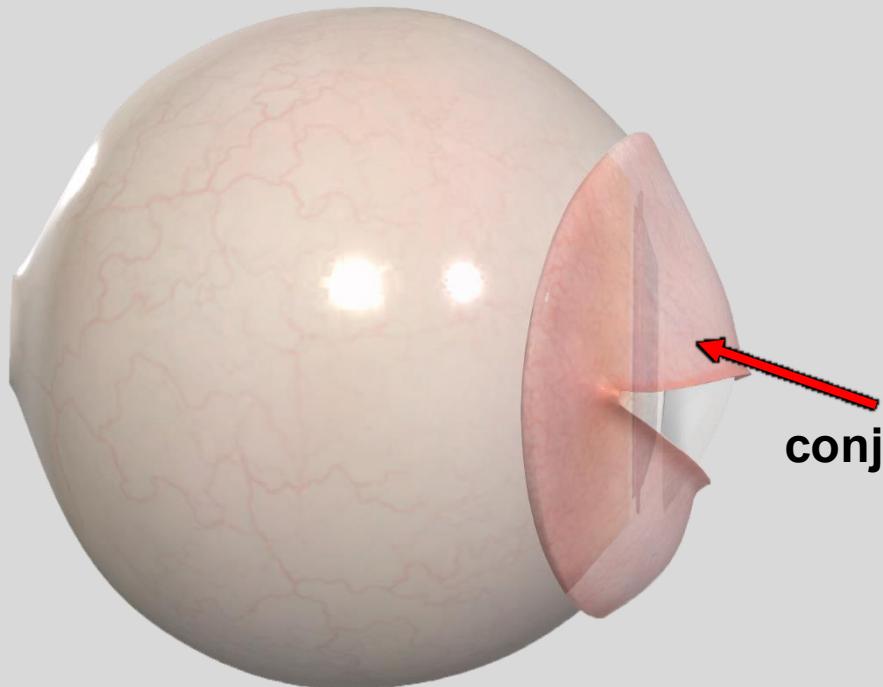
Vision

Fibrous Layer

Outer covering is the sclera

Cornea is the clear part of the sclera

Conjunctival Layer



The conjunctival layer supports, protects, and moistens the eye

Vision

Fibrous Layer

Sclera and cornea have the same composition

Collagen fibre orientation determines if light can pass through or not

Sclera blocks out light and protects against physical damage

Distal attachment site for all extraocular muscles

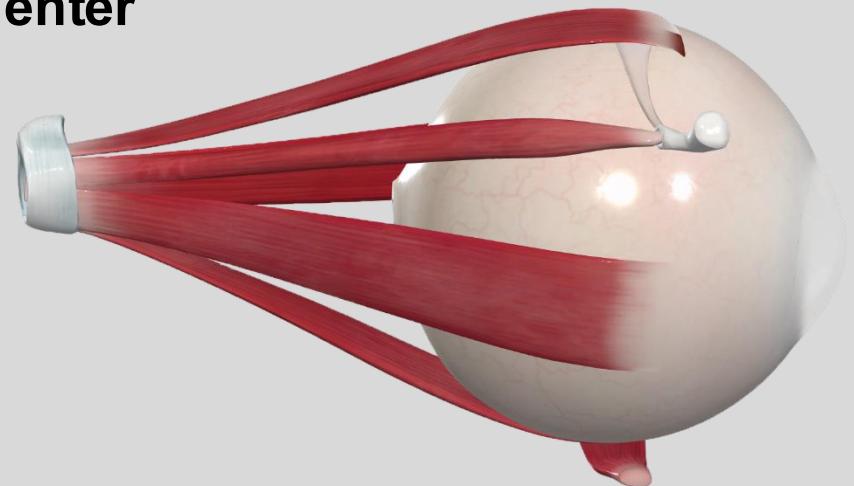
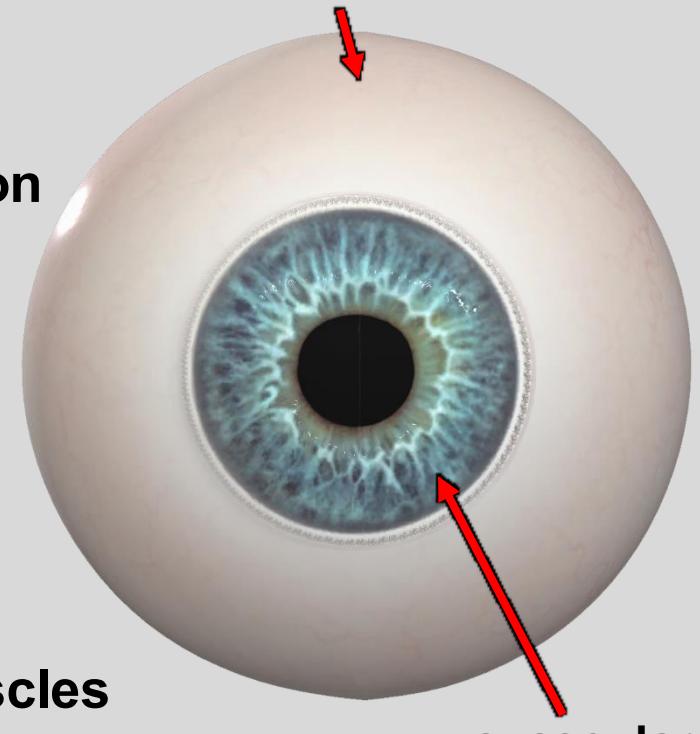
The cornea is the window for light to enter

Cornea blocks most UV light

Cornea is the main light refractor
(2/3^{rds} of refraction)

Cornea is highly sensitive to touch

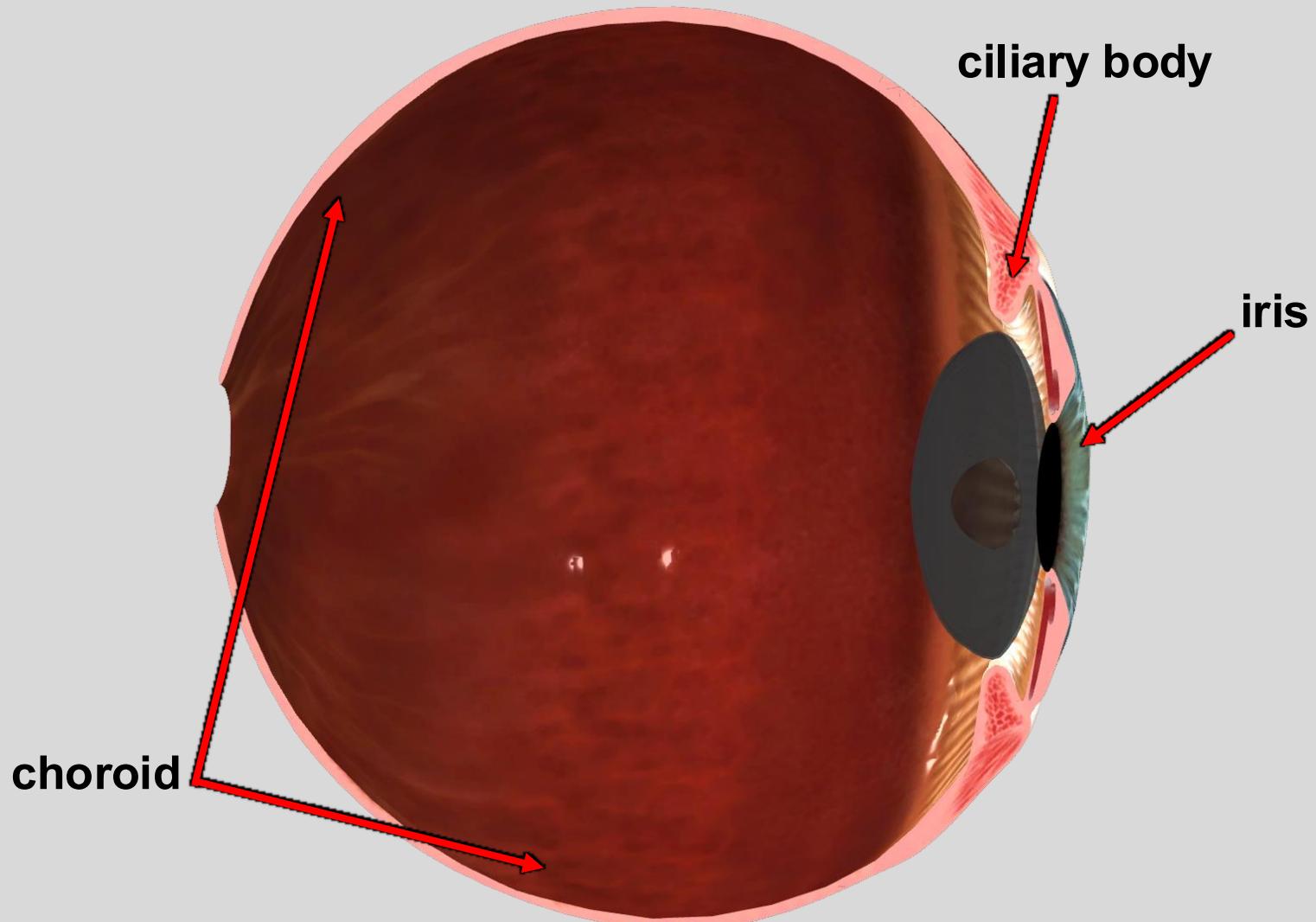
low blood flow



Vision

Vascular Layer

3 layers comprise the vascular layer



Vascular Layer: Iris

Lies anterior to the lens

Gives colour to the eyes

Adjusts pupil diameter

Iris houses 2 muscles

sphincter pupillae (constricts)

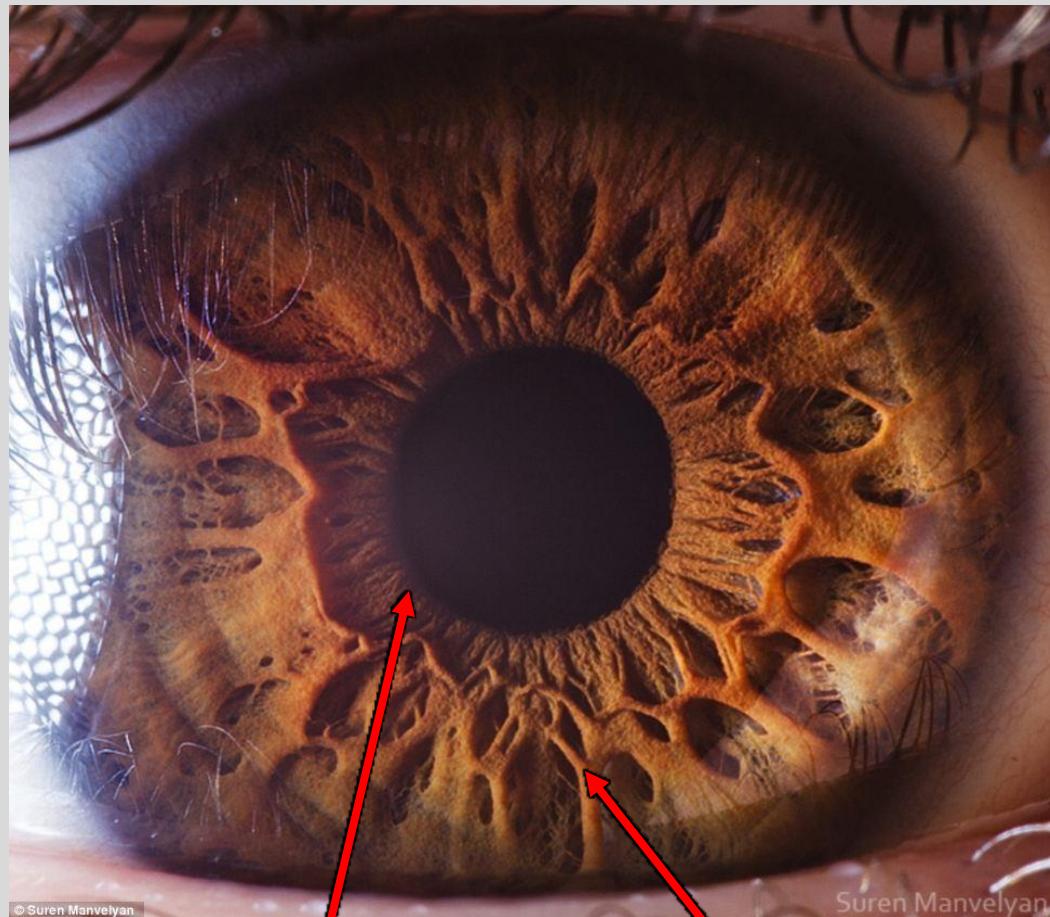
ring of smooth muscle

parasympathetically activated

dilator pupillae (expands)

radially arranged smooth muscle

sympathetically activated



sphincter pupillae

dilator pupillae

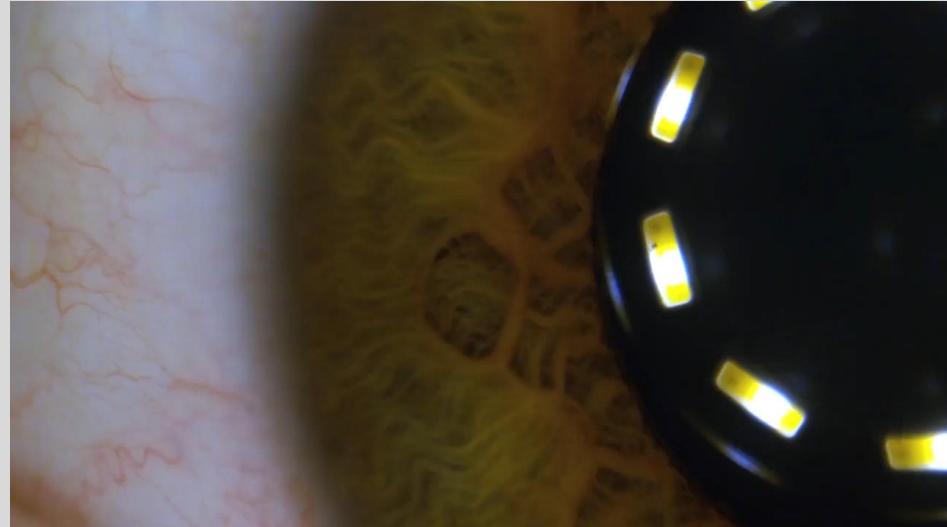
Vision

Vascular Layer

Movies

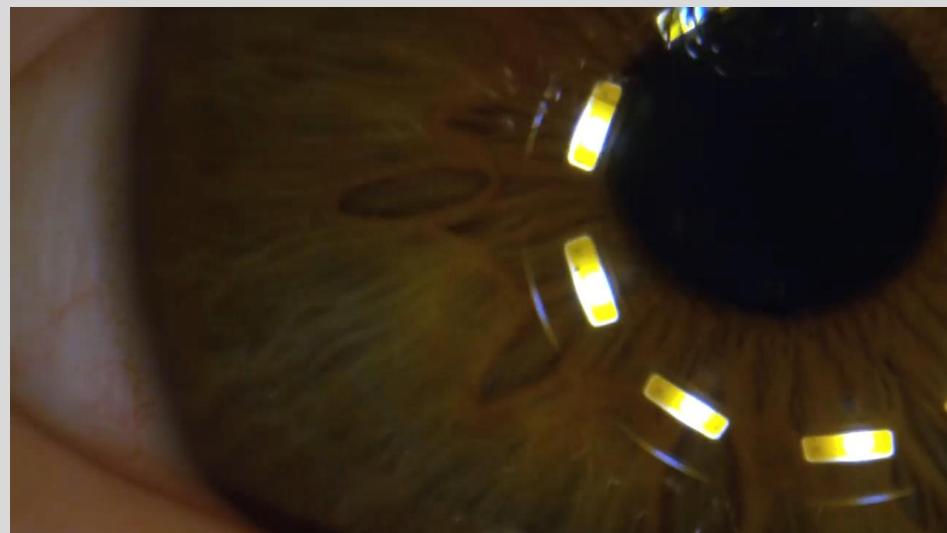
sphincter pupillae

circular fibres
parasympathetic
fast contraction



dilator pupillae

radial fibres
sympathetic
“slow” contraction



Vision

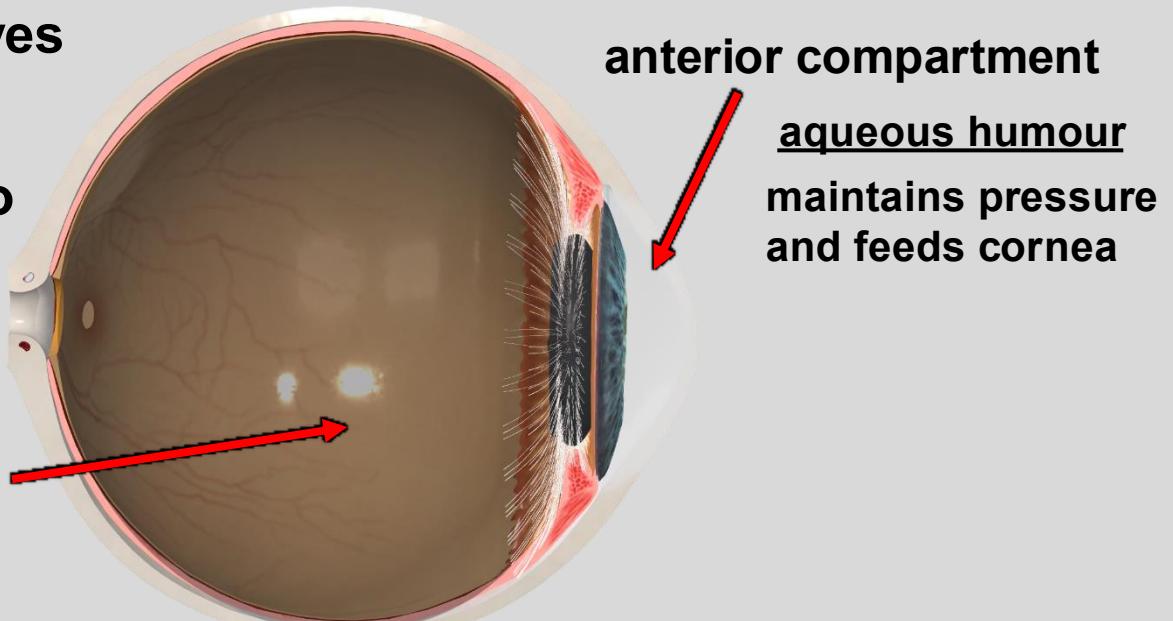
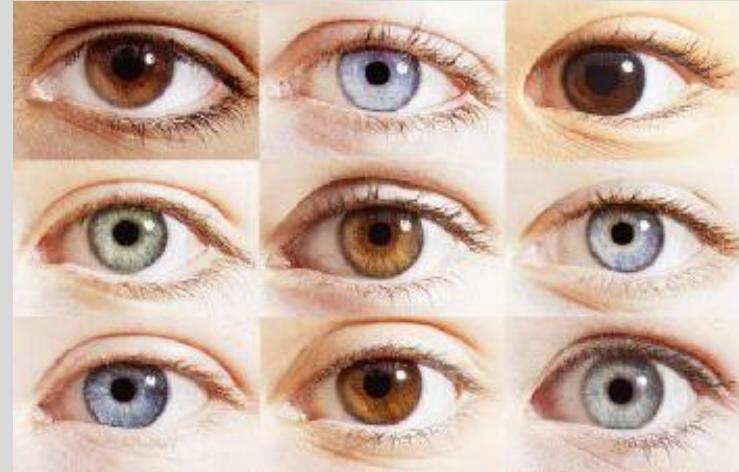
Vascular Layer: Iris

Melanocytes in pigmented layer produce melanin

Trapped melanin granules produce eye colour

More melanin = darker eyes

The iris separates the two compartments of the eye



Vision

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Vascular Layer: Ciliary Body

A ring of smooth muscle attached to the lens

Responsible for deforming the lens

Produces aqueous humour

Attached to lens via zonular fibres
(Zonule of Zinn)

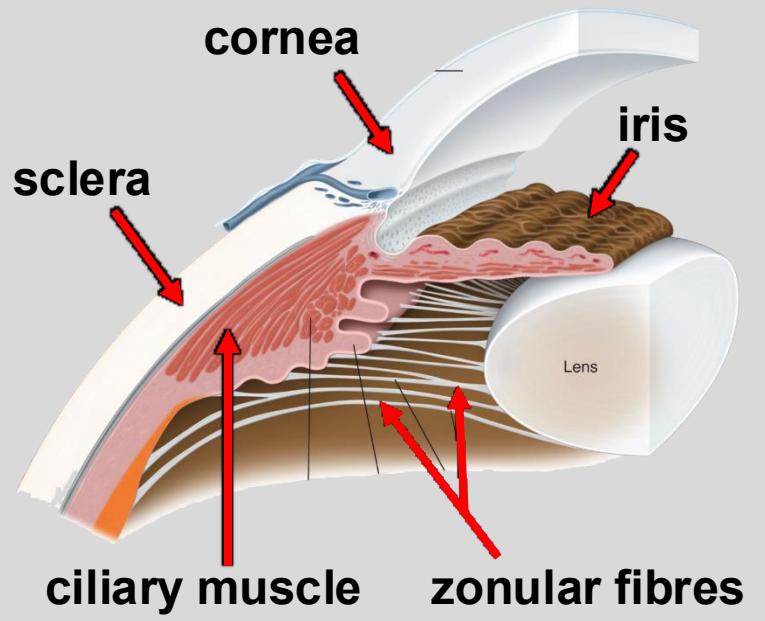
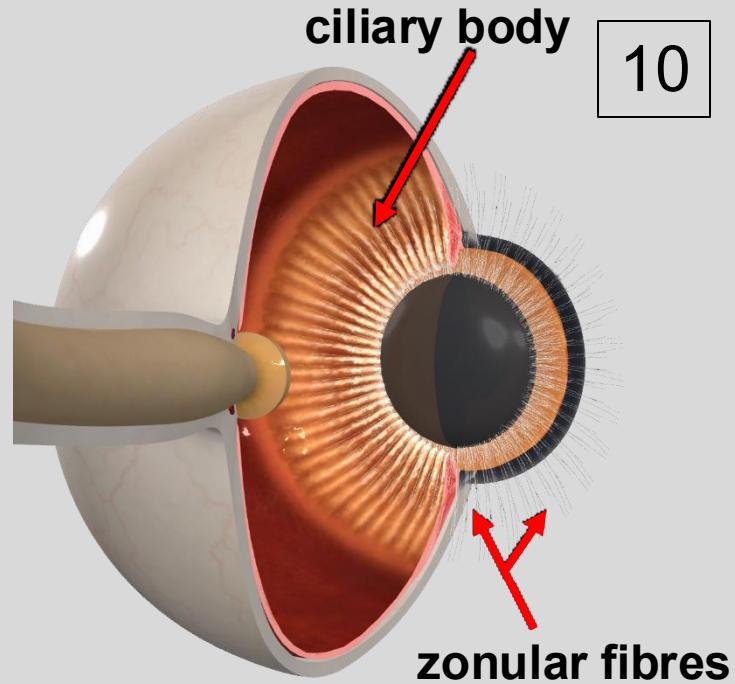
At rest, zonular fibres are tensed

lens is stretched

Contraction of ciliary body loosens
zonular fibres

lens returns to original (biconvex) shape

Ciliary body is parasympathetically
innervated via the short ciliary nerves)



Vision: The Eye

Vascular Layer: Choroid

Feeds the internal structures of the eye

Dark red in colour

Blood supply to the retina

tightly adhered to posterior retina

loosely attached to anterior retina

Anterior retina requires constant pressure
from the vitreous humour to maintain
attachment to choroid



red eye is reflection of the choroid



Vision: The Eye

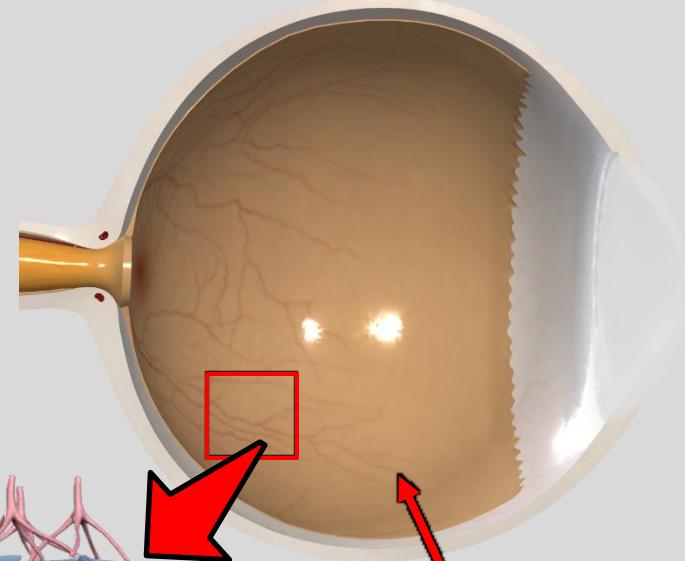
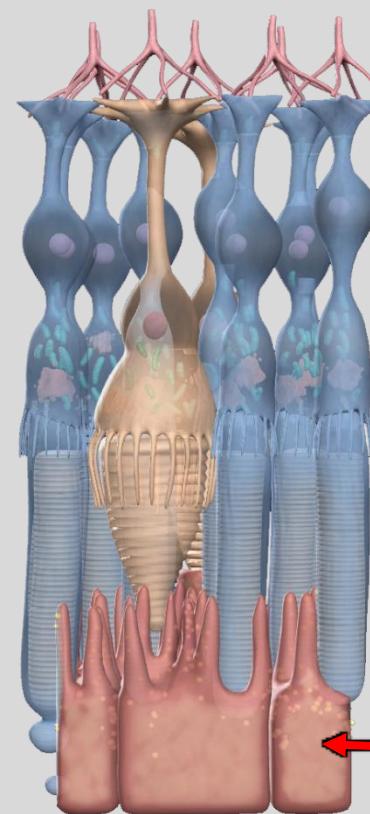
Neural Layer

The retina is the innermost layer of the eye

~150 million different neurons

Consists of two layers

neural layer
(again)



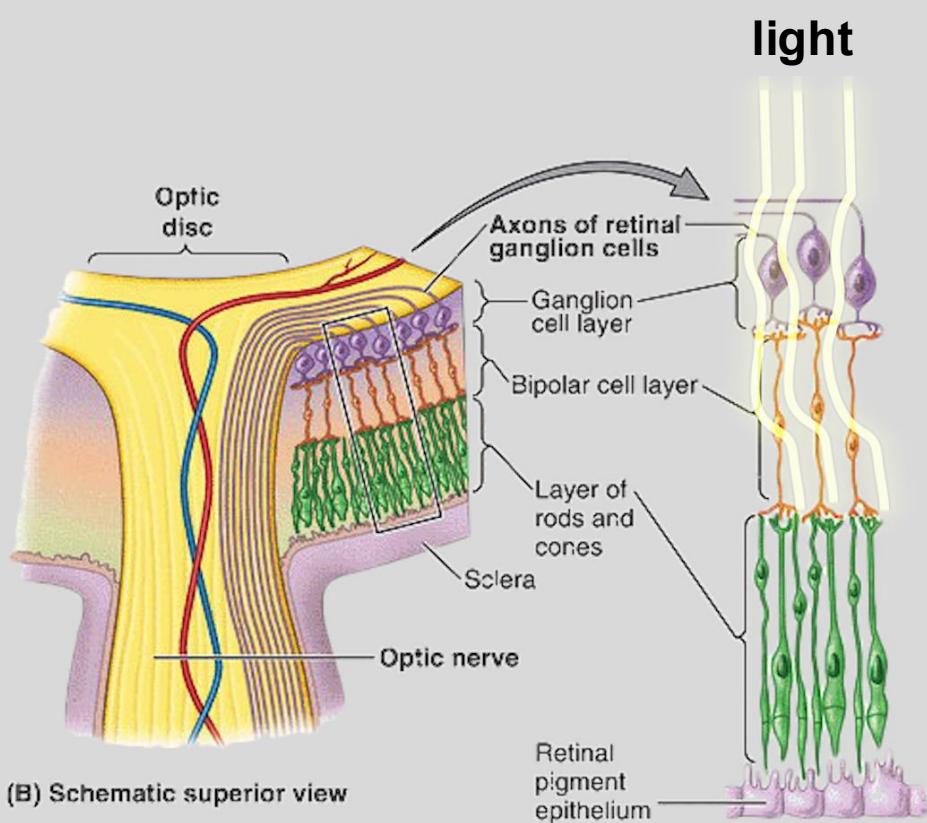
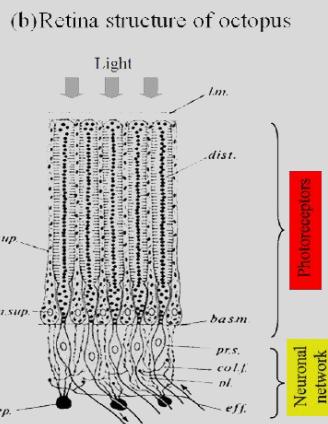
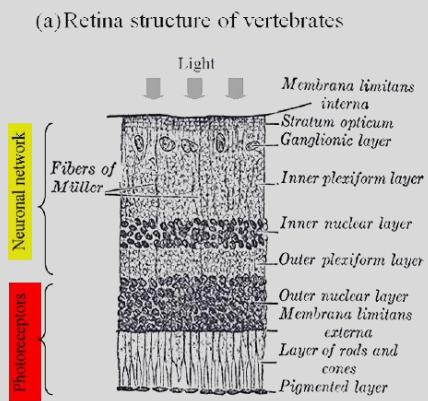
pigmented layer

Vision: The Eye

Neural Layer: Retina

Our eyes are built backwards

Light must pass through a mesh of non-photoreceptive neurons before reaching the photoreceptors



octopus arranged it “right”

Vision: The Eye

Neural Layer: Retina

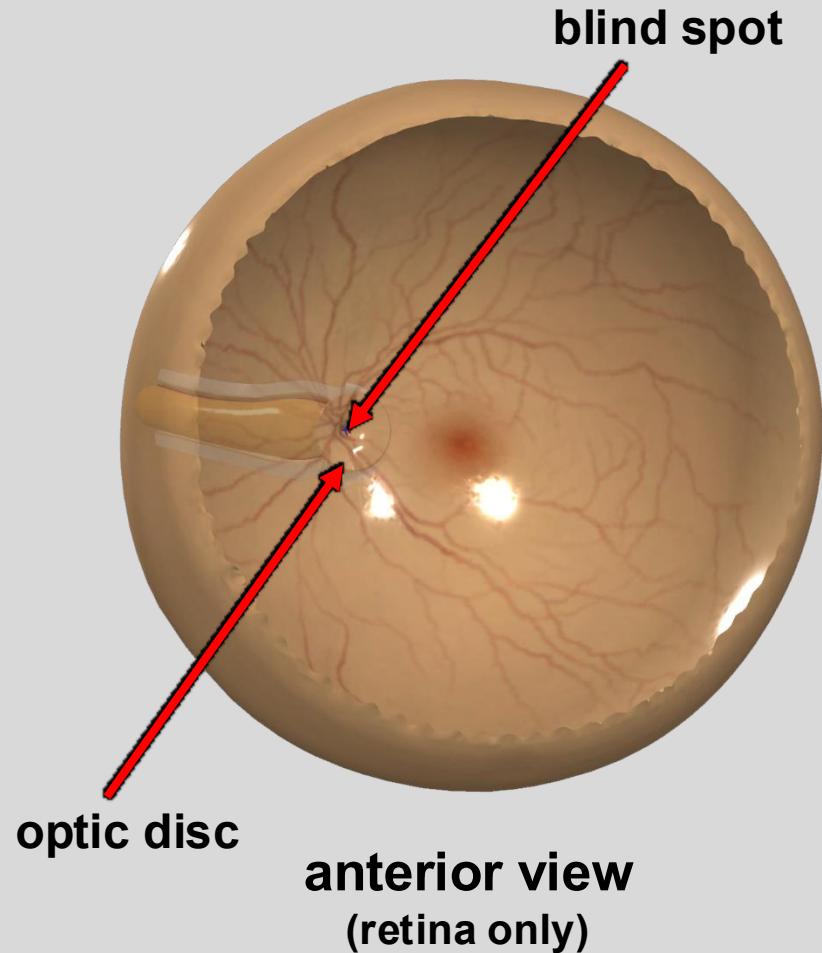
Backwards construction of eye results in two unique anatomical structures

1. Optic disc

Convergence point for all blood vessels and neurons of the retina

No light passes through resulting in a *blind spot*

The brain pieces multiple images together to fill in the blind spot



Vision: The Eye

15

Neural Layer: Retina

2. Macula lutea

“Pit” in retina formed from non-photoreceptive cells angling away from incoming light

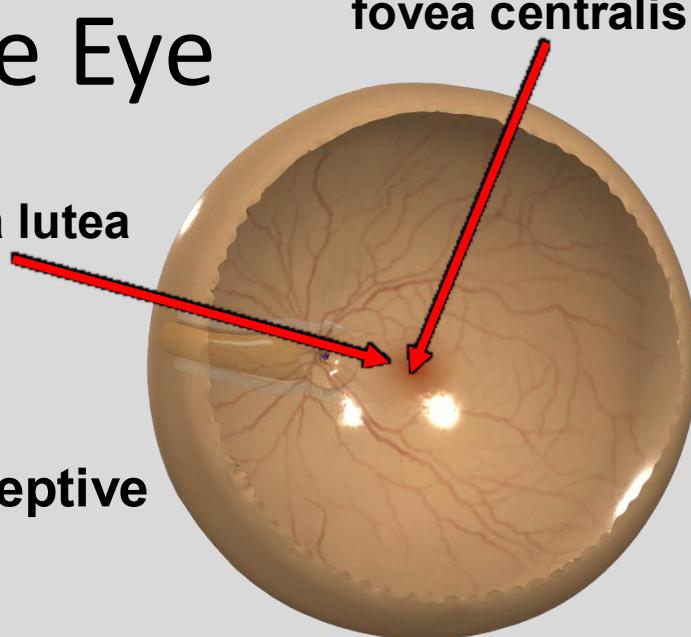
The area of clearest vision is at the center of the macula lutea (= fovea)

Foveation

Focusing on an object by moving the image onto the fovea

macula lutea

fovea centralis

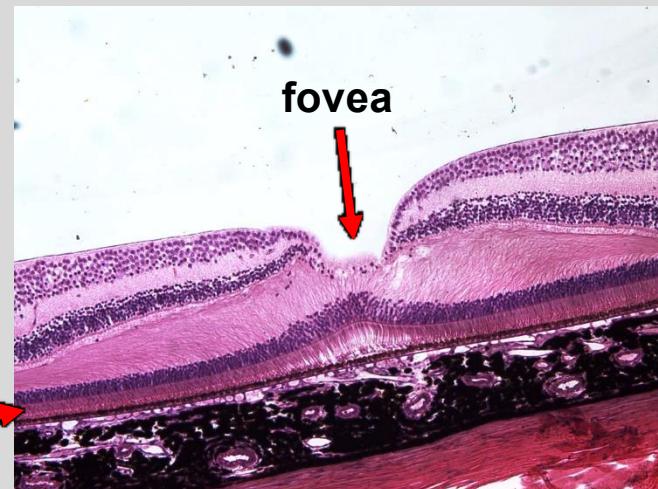


anterior view
(retina only)

non-photoreceptive
cells

photoreceptors

fovea

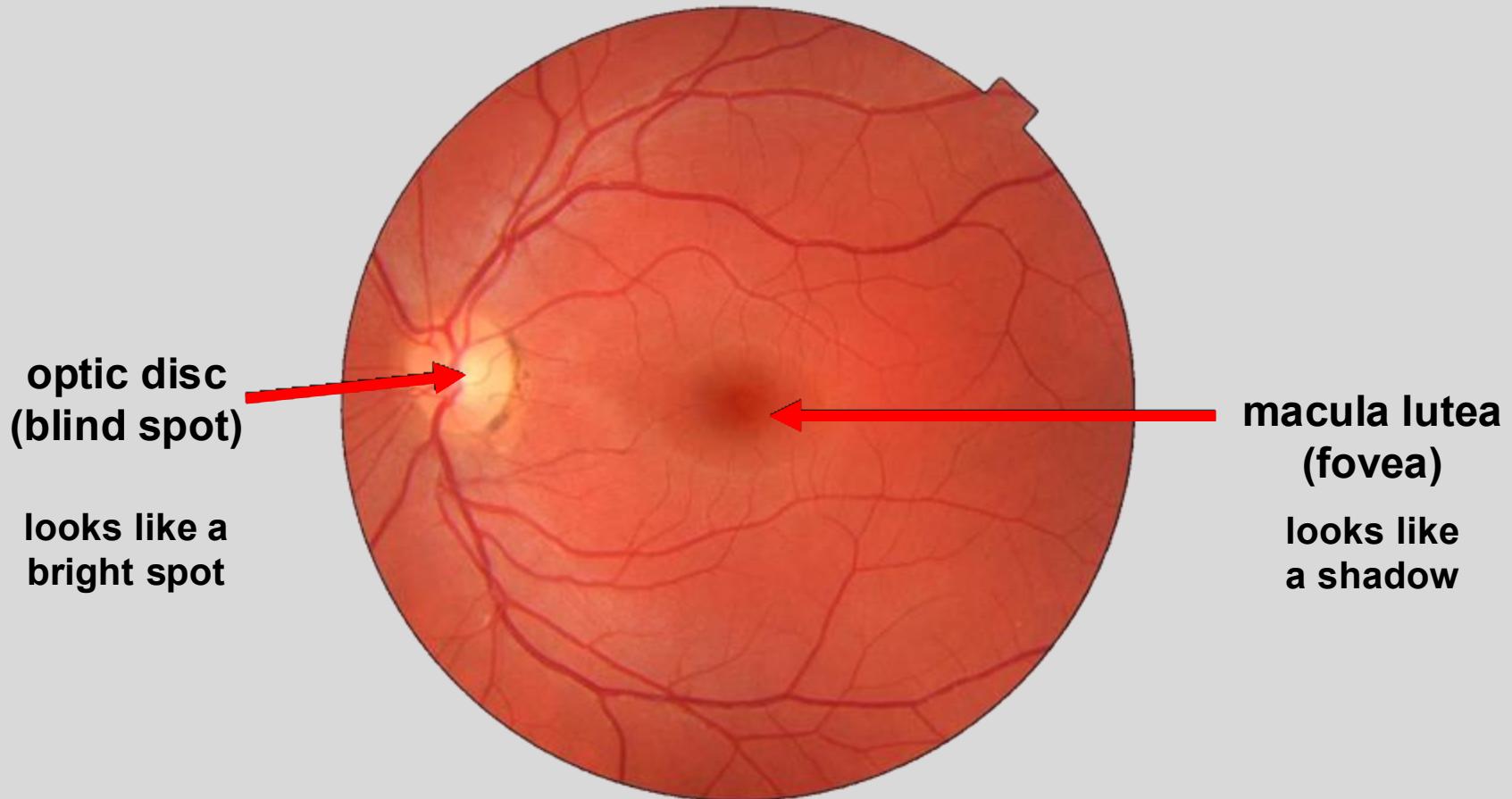


Latin: *macula* = spot / stain + *lutea* = yellow

Latin: *fovea* = small pit + *centralis* = center

Vision: The Eye

Neural Layer: Retina

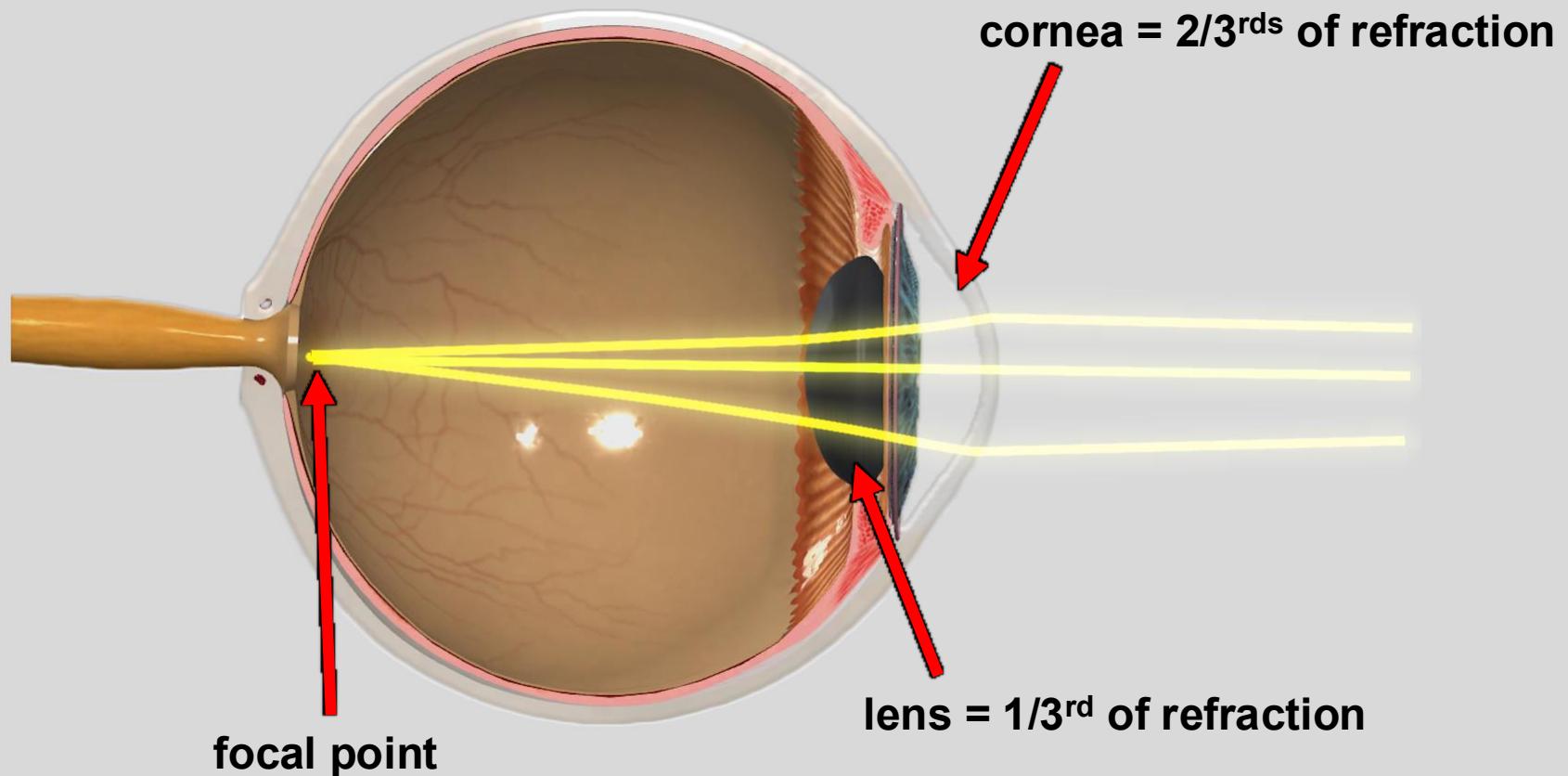


ophthalmoscopic view

Vision: The Eye

Accommodation

This is the ability to adjust the focal point in the eye



Vision: The Eye



dissected lens
(cow)

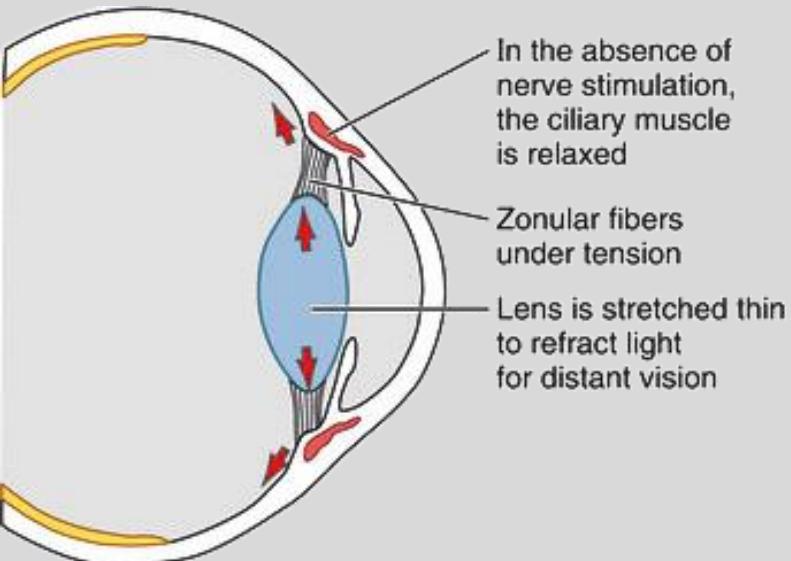
Accommodation

The lens is spherical and elastic

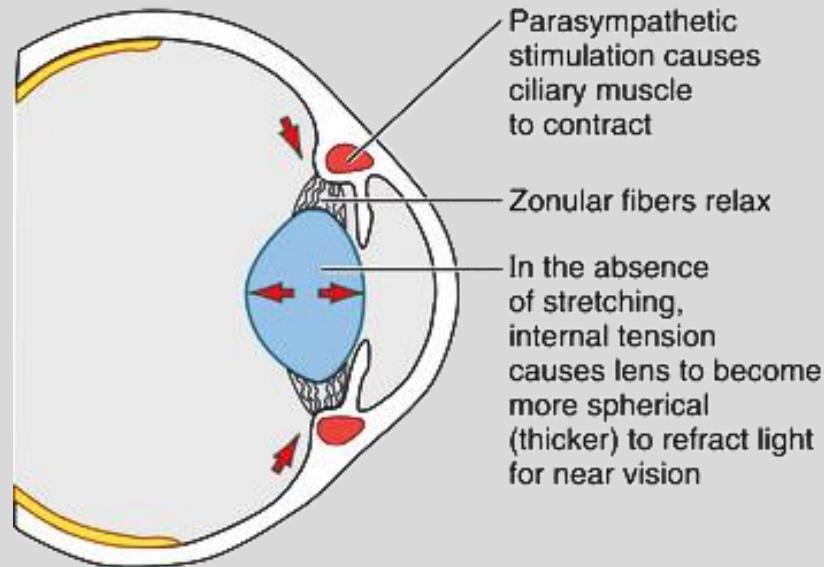
Deforming the lens changes the focal point

Distance focus stretches the lens

Near point focus = rounder lens



Stretching is a **passive** act



Active contraction of ciliary body

Vision: The Eye

Accommodation

Accommodation is counterintuitive

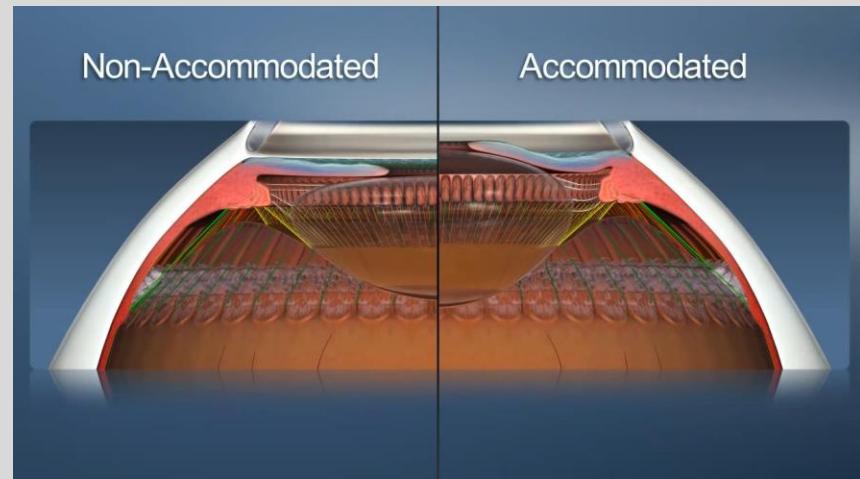
Changing lens shape (stretching) is a passive process

Distance focus *does not require* nerve stimulation

Relaxing the lens requires *active contraction* of the ciliary muscle

Eye strain is the result of an exhausted ciliary muscle

Movie



Goldberg 2011. Computer-animated model of accommodation and theory of reciprocal zonular action

<https://www.youtube.com/watch?v=1ylpyitm6eE>

Vision: The Eye

Visual Field

Eyes are divided into 2 hemiretinae

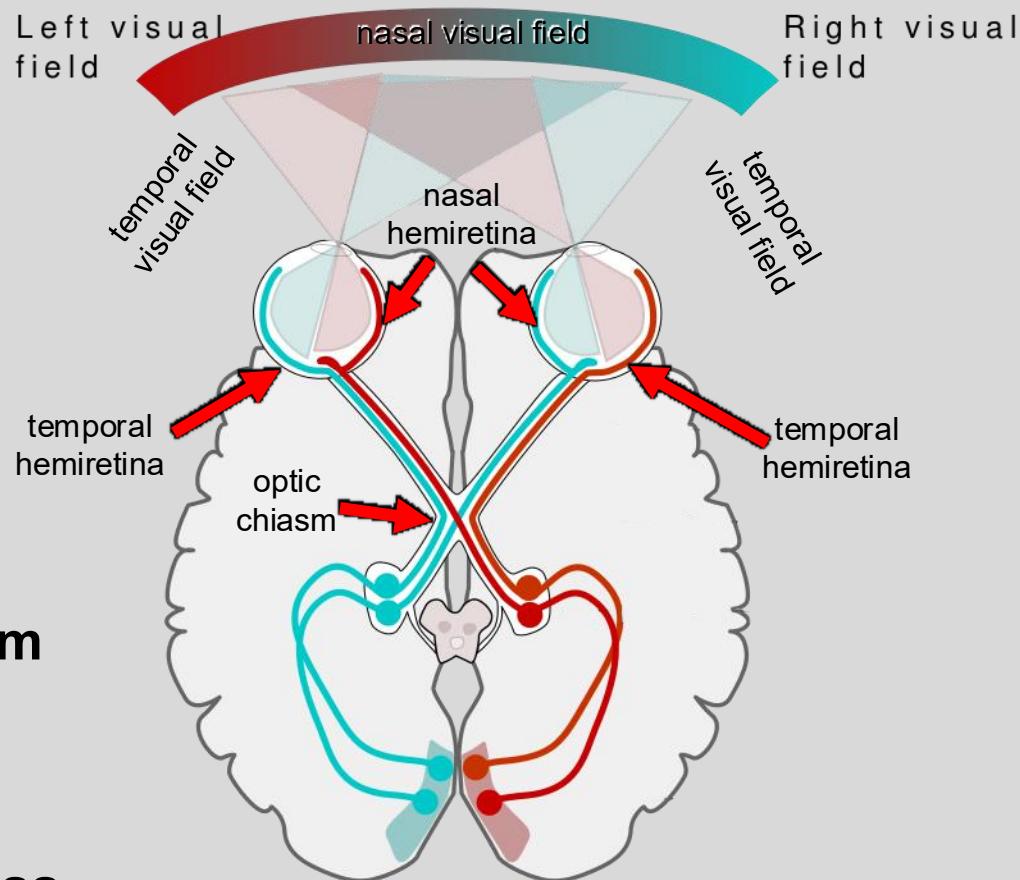
1. Temporal hemiretina
2. Nasal hemiretina

This splits the visual field in two

1. Temporal visual field
2. Nasal visual field

Each hemiretina receives input from
the opposite visual field

Only nasal hemiretina neurons cross
over (decussate) at the optic chiasm



Vision: The Eye

Clinical Correlates

Presbyopia

Lens loses elasticity with age

Stretched lens has trouble “bouncing back” to its original shape

Near-point focusing ability is reduced

Treatment includes corrective lenses or multifocal / presbyLASIK



Vision: The Eye

Clinical Correlates

Cataracts

Protein breakdown exceeds repair rate as we age

Denatured proteins build up in the lens thickening and clouding it

Hypertension, poor nutrition & smoking may increase rates of cataract formation

Down and Turner's syndrome may increase chance of cataracts

68% of U.S. pop over 80, have / had cataracts

Requires surgical intervention

Partial / total lens replacement



Cataract in 55-year old male



Healthy lens next to two lenses with various degrees of cataracts

Vision: The Eye

Clinical Correlates

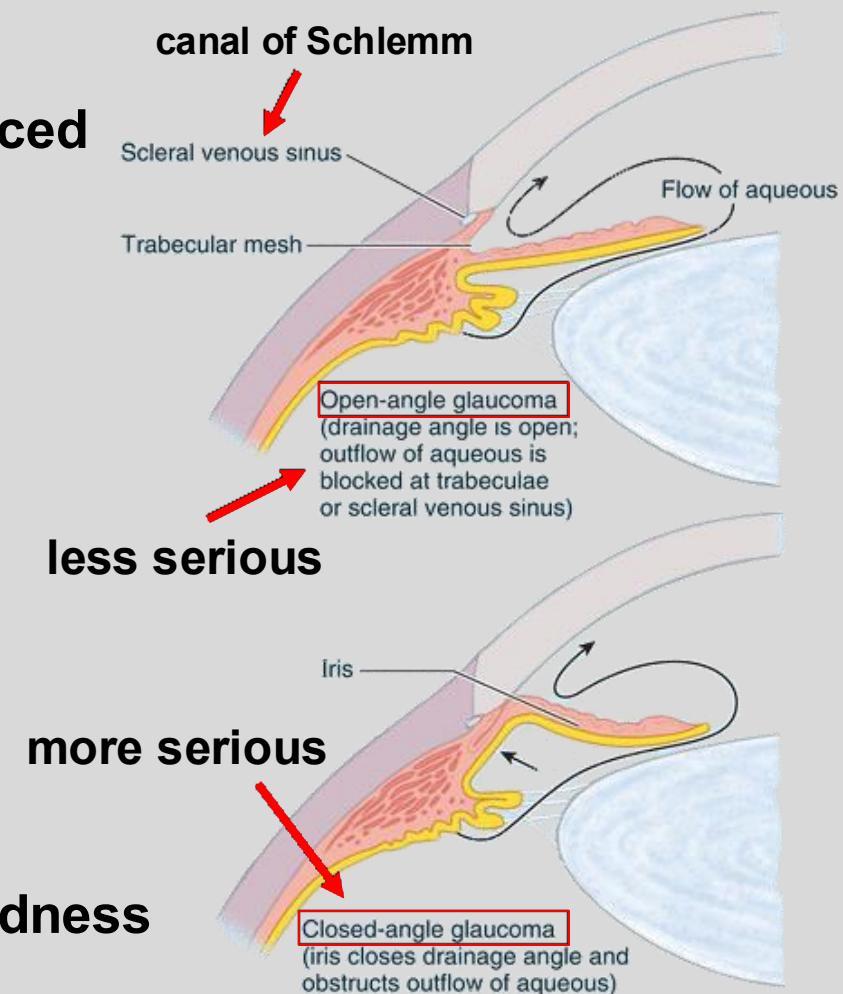
Glaucoma

Aqueous humour is continuously produced by the ciliary body

The humour is continuously drained through the scleral venous sinus (canal of Schlemm)

Blockage of this flow causes stagnation and cloudiness

Left untreated, glaucoma will cause blindness due to optic nerve compression



Vision: The Eye

Clinical Correlates

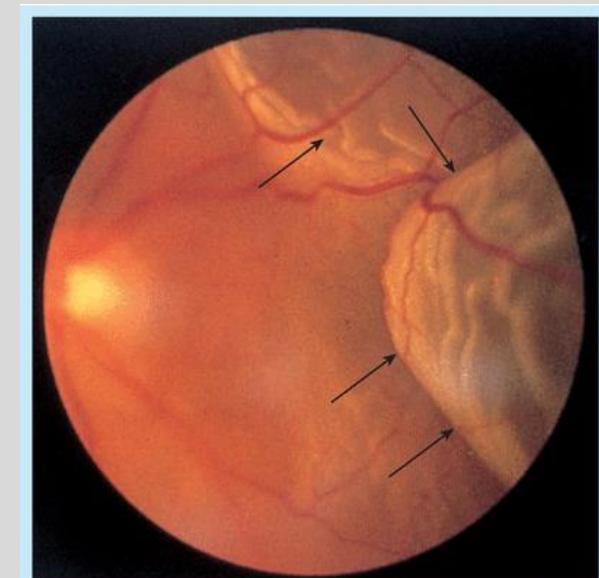
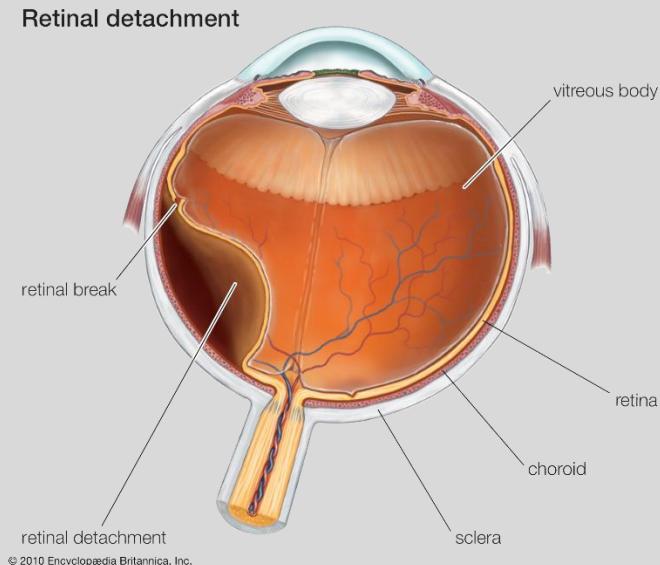
Retinal detachment

Neural layer of retina requires ocular pressure to maintain attachment to choroid

Injuries that reduce intraocular pressure put the retina at risk of detachment

Patients complain of flashes and specs of light

Retinal detachments are immediate medical emergencies



Ophthalmoscopic view (arrows, wrinkles in detached retina)

Lecture Feedback Survey

<https://comresearchdata.nyit.edu/redcap/surveys/?s=HRCY448FWYXREL4R>

Hearing and Balance (CN VIII)

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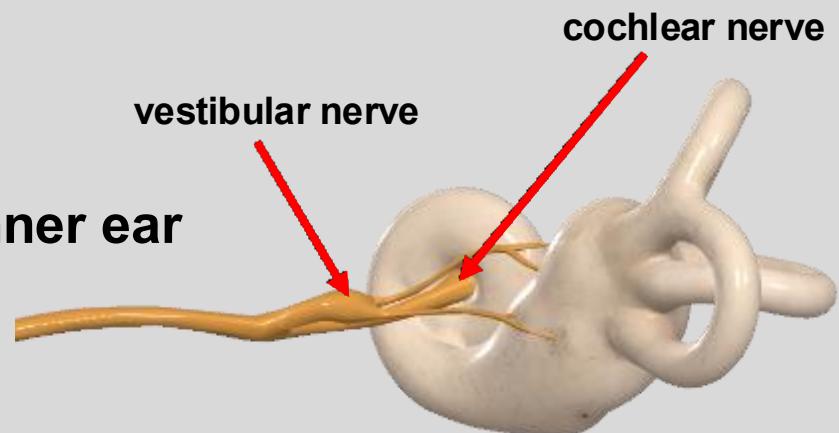
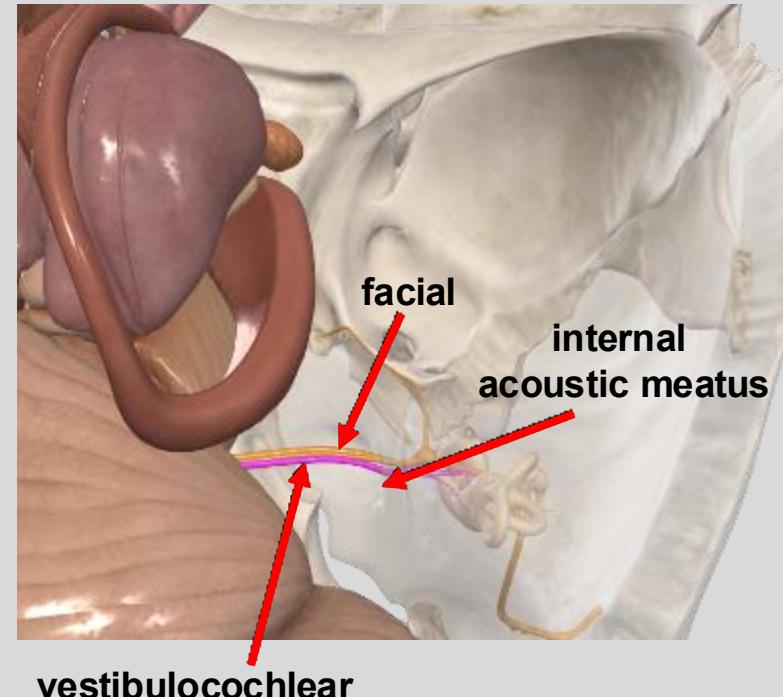
CN VIII — Vestibulocochlear

Exits endocranum through internal acoustic meatus

Shares this exit with facial (CN VII)

Vestibulocochlear quickly splits into 2 nerves

1. Vestibular nerve
vestibular system (balance)
2. Cochlear nerve
cochlea (hearing)



Vestibulocochlear does *not* leave the inner ear

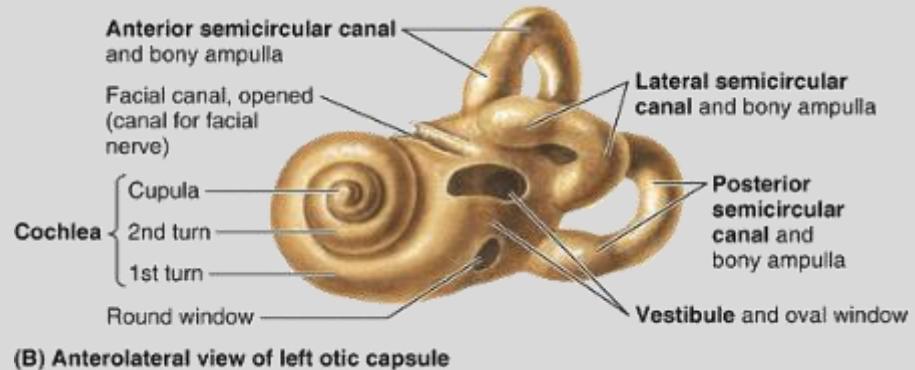
Otic Capsule

Comprised of an **endosseous (bony) labyrinth**

endosseous (bony) labyrinth

Filled with **perilymph**

Same constituency as
extracellular fluid



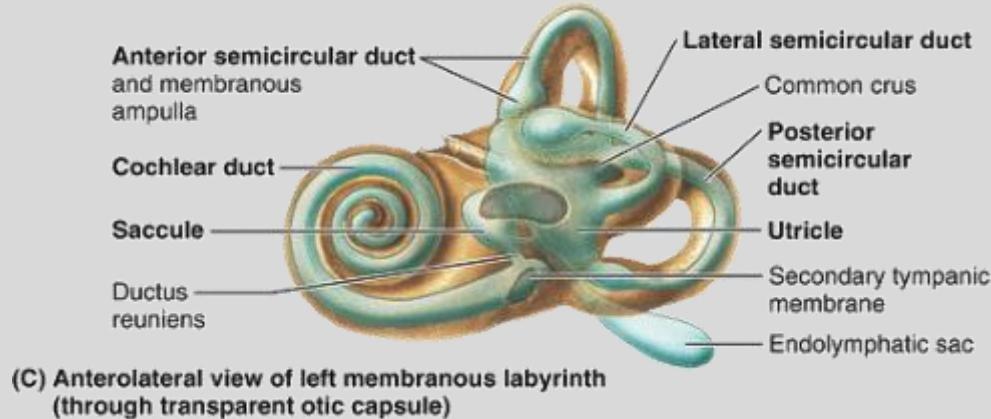
Deep to the bony labyrinth is the **membranous labyrinth**

membranous labyrinth

This is the physiologically active part of the inner ear

Filled with **endolymph**

Same constituency as
intracellular fluid



Vestibular Organ

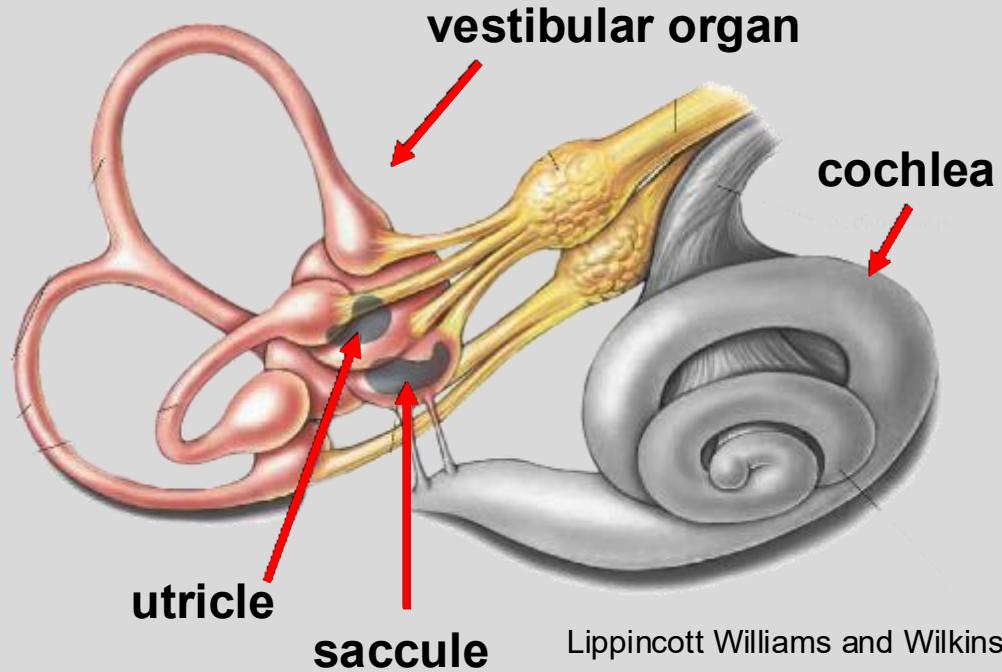
Provides our sense of balance and direction

Comprised of 2 structures

- 1) Otolith organs
- 2) Semicircular canals

There are 2 otolith organs

- 1) Utricle
- 2) Saccule



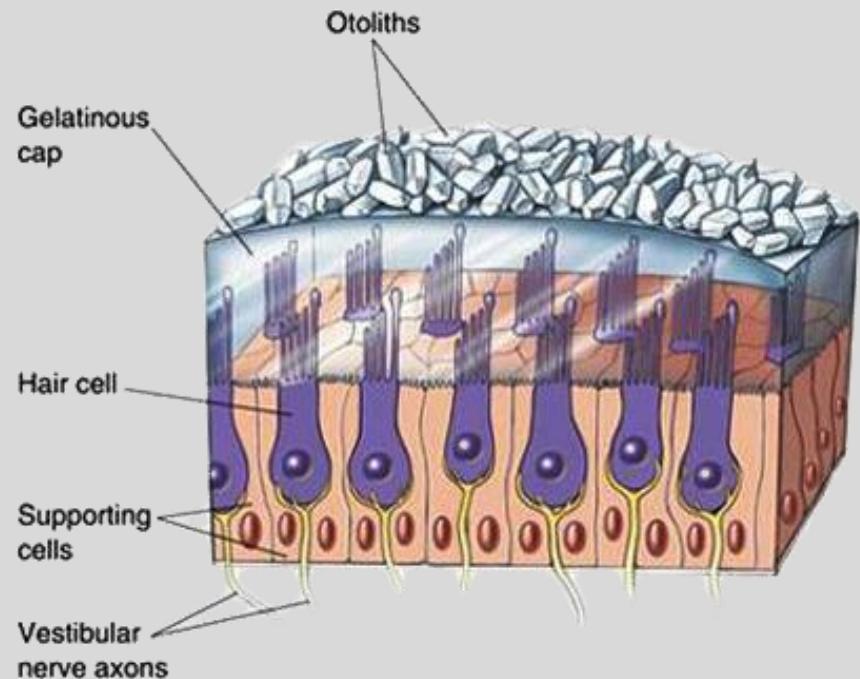
Lippincott Williams and Wilkins

Vestibular Organ

Otolith organs

Greek: *oūs* = ear + *lithos* = stone

Otoliths are small calcifications



They give weight to the utricle and saccule

Vestibular Organ

Otolith organs

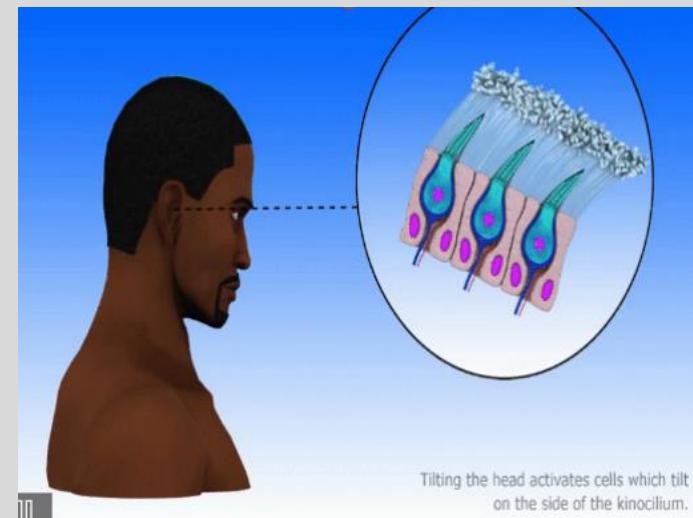
Utricle

Horizontally aligned in the inner ear

Sensory neurons lie on the floor of the utricle (macula)

Senses horizontal acceleration

Works in tandem with the semicircular canals to determine head position in space



Tilting the head activates cells which tilt on the side of the kinocilium.

Adapted from 3D Anatomy Lyon
<https://www.youtube.com/watch?v=ZiFyIfBWYoO>

Vestibular Organ

Otolith Organs

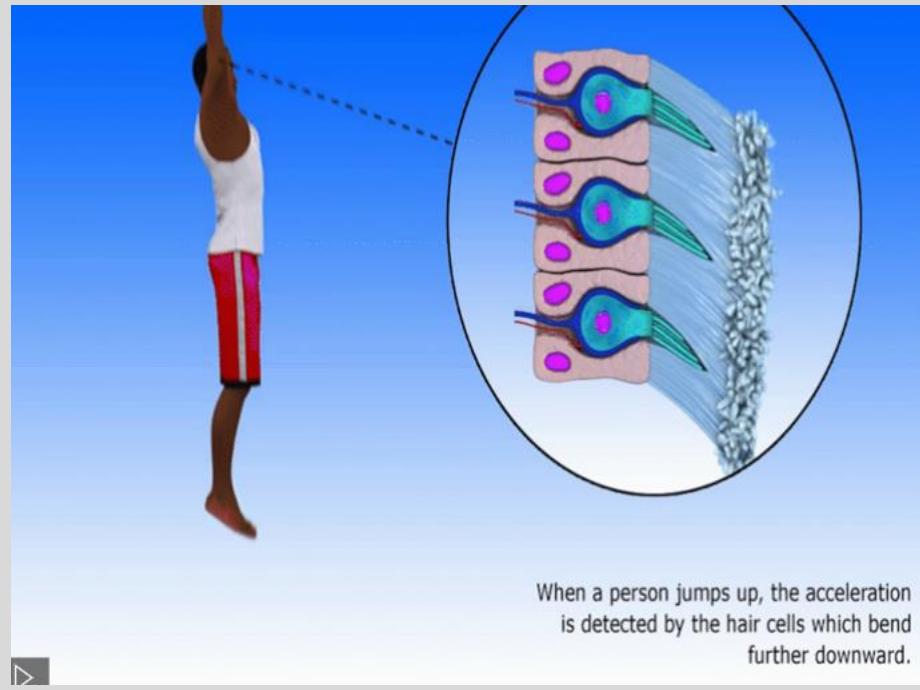
Otolith organs

Saccule

Neurons lie on the medial wall of the saccule (macula)

Senses vertical acceleration

Functions as our gravity sensor



When a person jumps up, the acceleration is detected by the hair cells which bend further downward.

Adapted from 3D Anatomy Lyon
<https://www.youtube.com/watch?v=ZiFyIfBWYo>

Vestibular Organ

Semicircular canals (SCC)

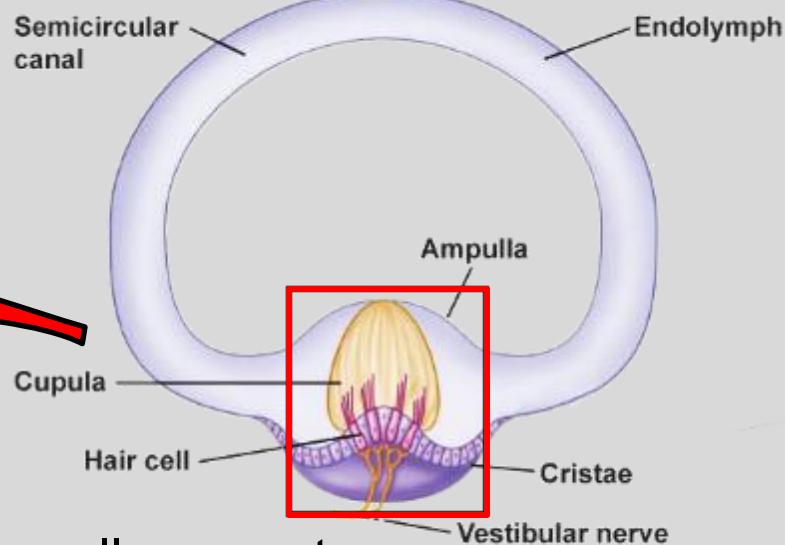
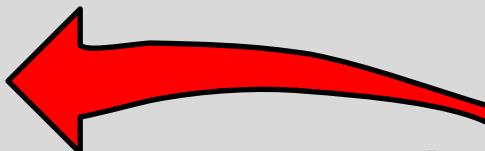
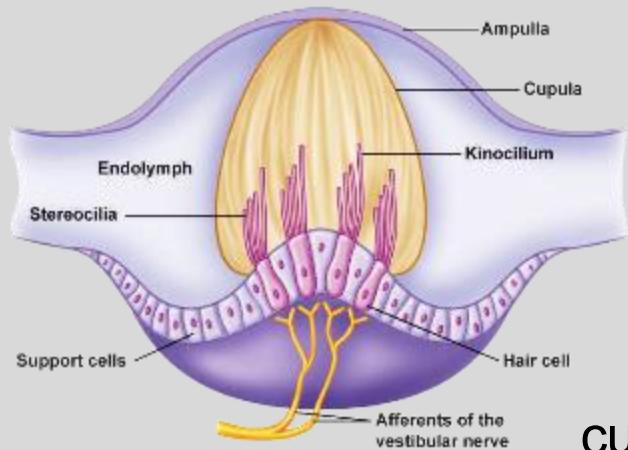
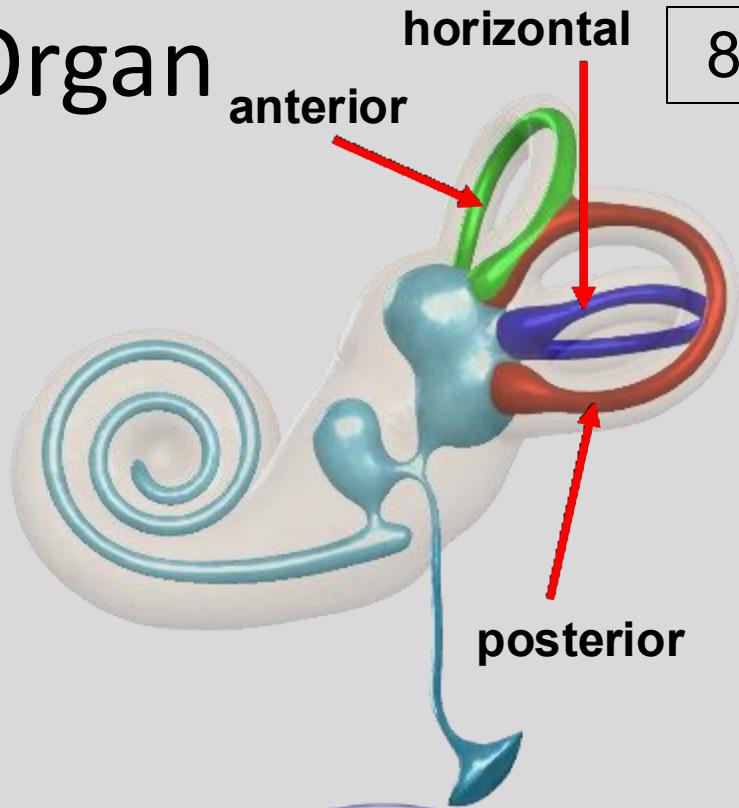
Provide head orientation information

3 semicircular canals

- 1) Anterior
- 2) Posterior
- 3) Horizontal

Canals are filled with endolymph

Each canal expands into an ampulla



cupula + cristae = ampullary crest

Vestibular Organ

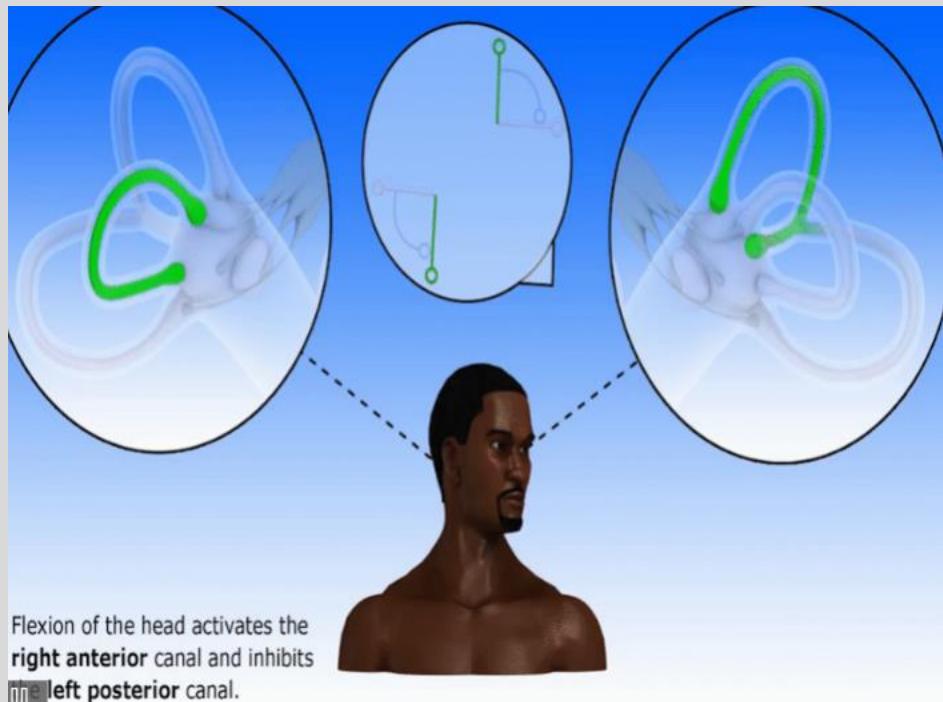
Semicircular canals (SCC)

SCCs works as pairs with a contralateral SCC

Info from each pair determines head position in space

3 pairs of SCCs

1. right & left horizontal
2. right anterior & left posterior
3. left anterior & right posterior



Adapted from 3D Anatomy Lyon
<https://www.youtube.com/watch?v=ZiFylfBWYoO>

Vestibular Organ

Semicircular canals (SCC)

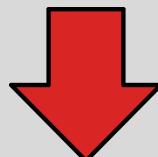
Head rotation moves endolymph in SCCs

Places uneven pressure on cupula, bending it

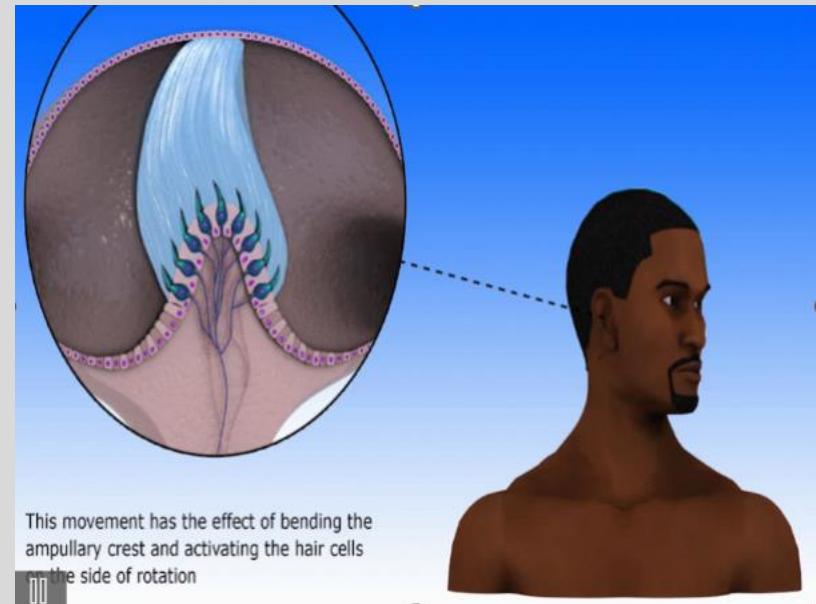
Bending of cupula results in:



Depolarizing afferent neurons on **turning** side



Hyperpolarizing afferent neurons on **opposite** side



Adapted from 3D Anatomy Lyon

<https://www.youtube.com/watch?v=ZiFyIfBWY0o>

Asymmetry of firing pattern determines which way the head is turning

Cochlea

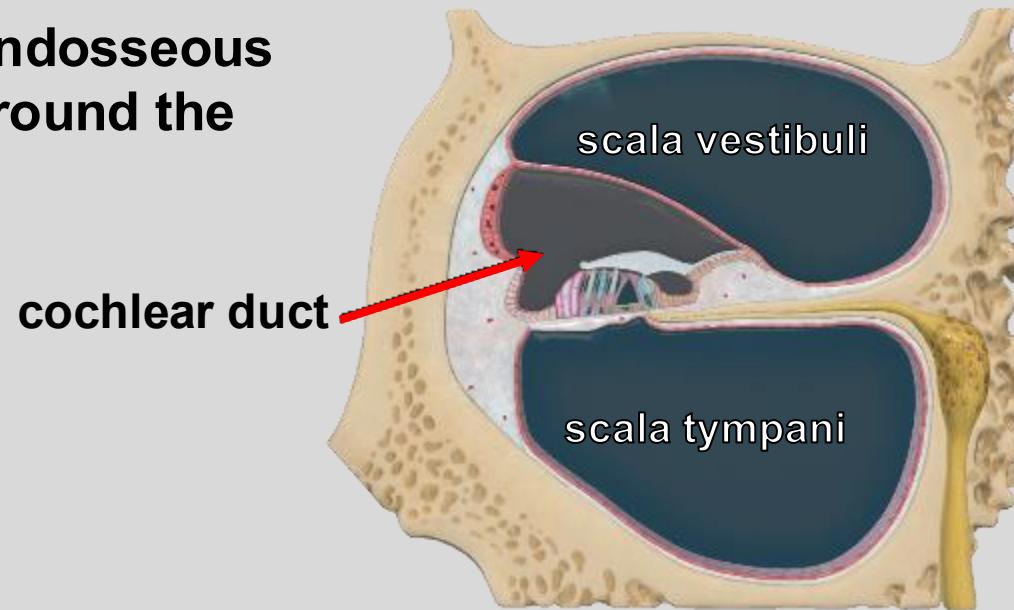
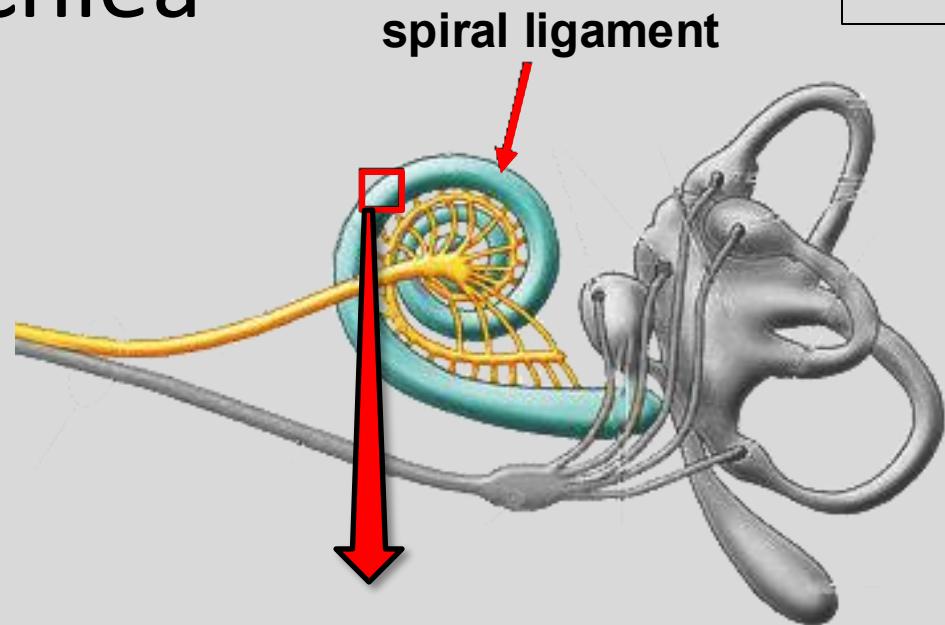
Cochlea is our spiral hearing organ

Hearing information is sent back on the cochlear nerve

The spiral ligament houses the cochlear duct

Spiral ligament splits the endosseous labyrinth into 2 channels around the cochlear duct

1. scala vestibuli
2. scala tympani



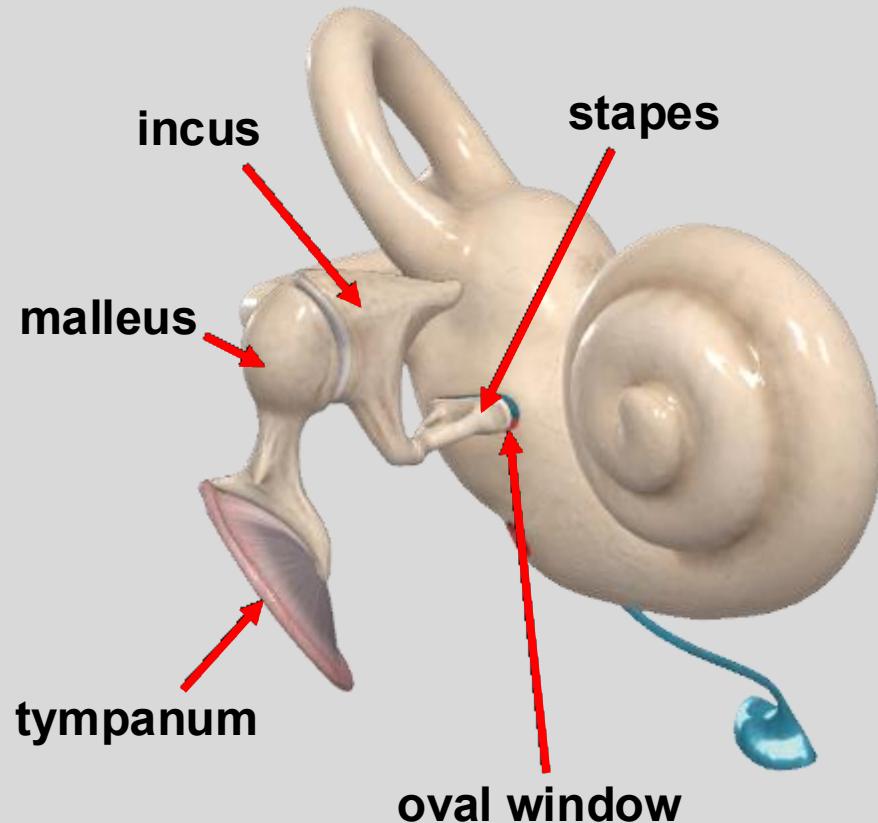
Sound Transmission

Middle Ear

Sound waves hit tympanic membrane

Sound is transduced through middle ear via the ear ossicles

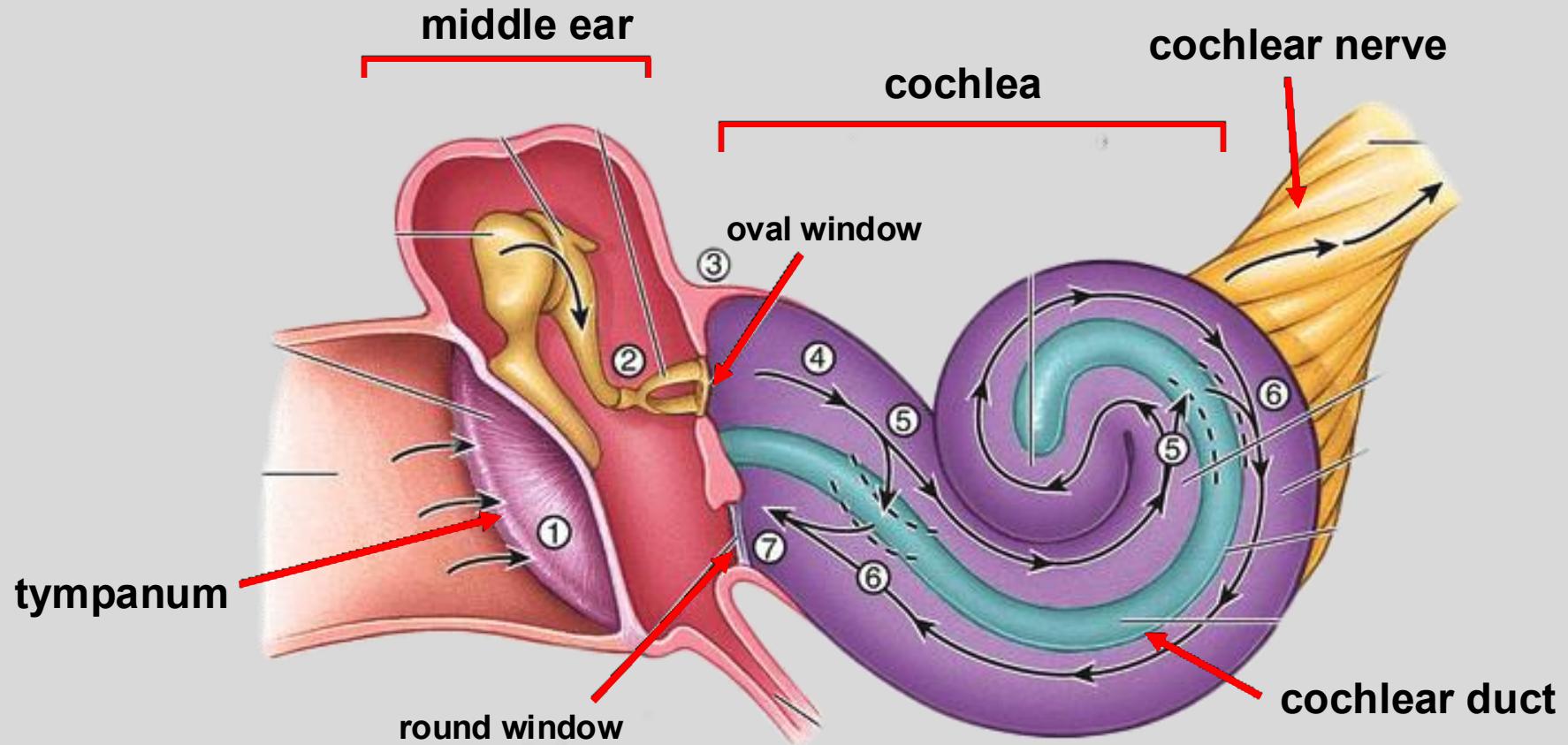
Footplate of stapes transfers energy to inner ear via the oval window



Sound Transmission

Inner Ear

Pressure wave travels through the endosseous labyrinth distorting the cochlear duct at specific frequencies



Moores Fig. 8.12

Cochlea

Organ of Corti

Sensory unit of the cochlea

Stereocilia and endolymph composition are similar to rest of inner ear

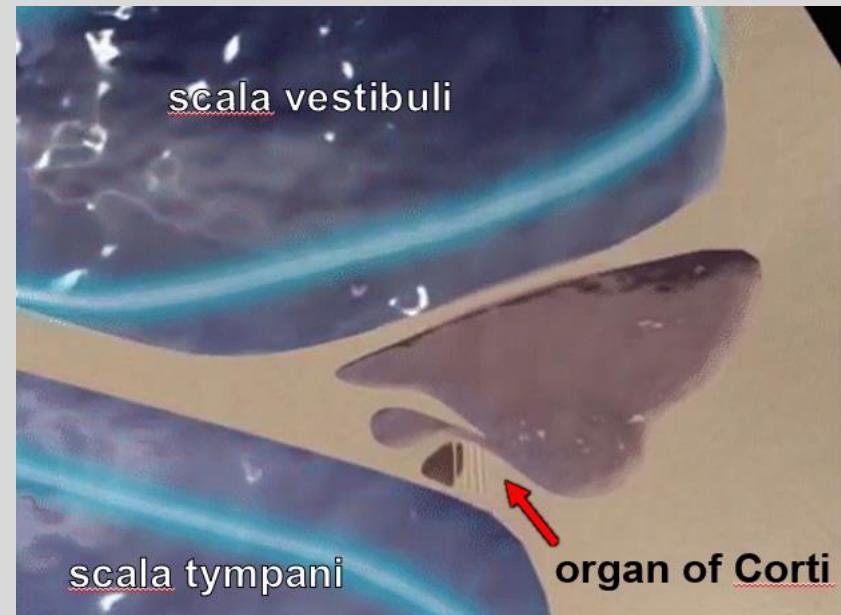
Depolarization occurs at specific frequencies

Pressure wave is transferred from scala vestibuli to scala tympani

The remaining energy is released at the round window

Neuron activation occurs at different frequencies along the cochlea

Lower frequencies travel further up the spiral

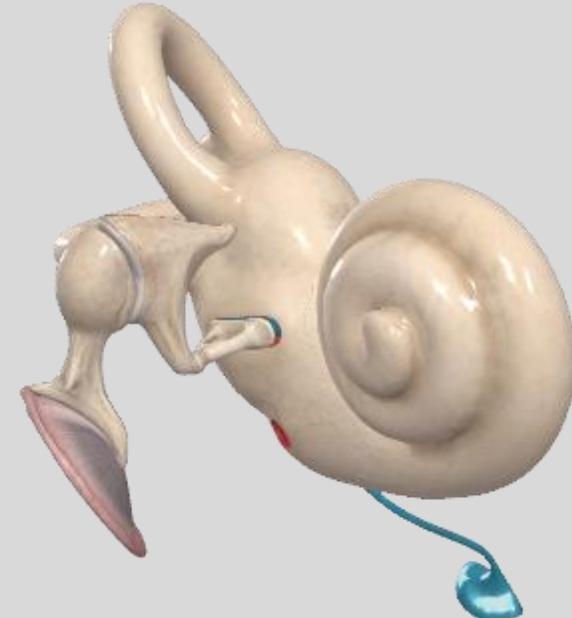


Brandon Pletsch

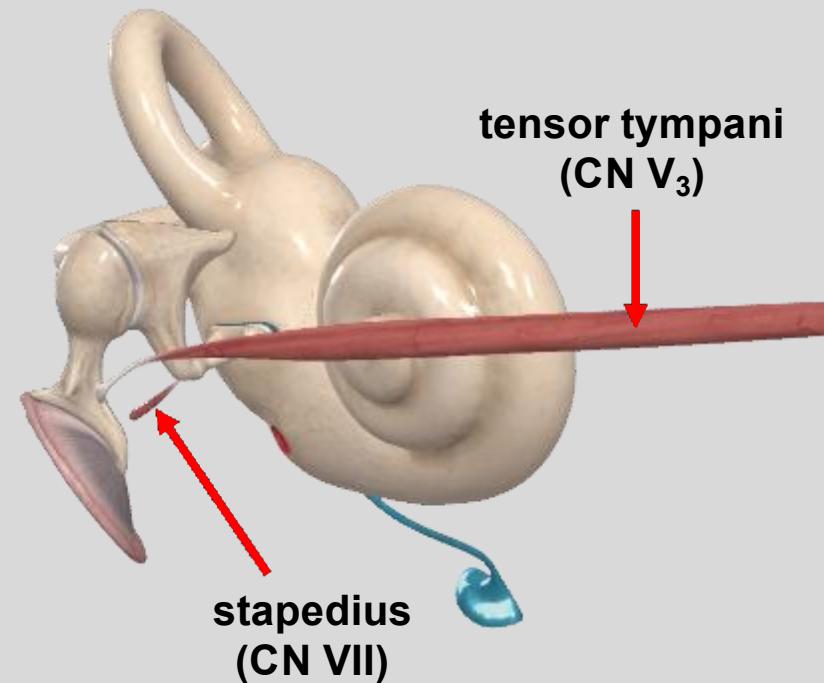
<https://www.youtube.com/watch?v=PeTriGTENoC>

Cochlea

**Size difference between tympanum
and stapes, naturally amplifies sounds**



**Middle ear muscles reduce vibration of
ear ossicles, dulling sound and
protecting the inner ear**



Hearing

Clinical Correlates

Hearing Loss

Can be congenital or acquired

Conductive hearing loss

Affects the *middle ear*

Result of damage to:

Tympanum — perforation / tear

Ear ossicles — scarring from prolonged
inflammation

People speak softly thinking they are loud

Can be treated surgically or with a hearing aid



Hearing

Clinical Correlates

Hearing Loss

Can be congenital or acquired

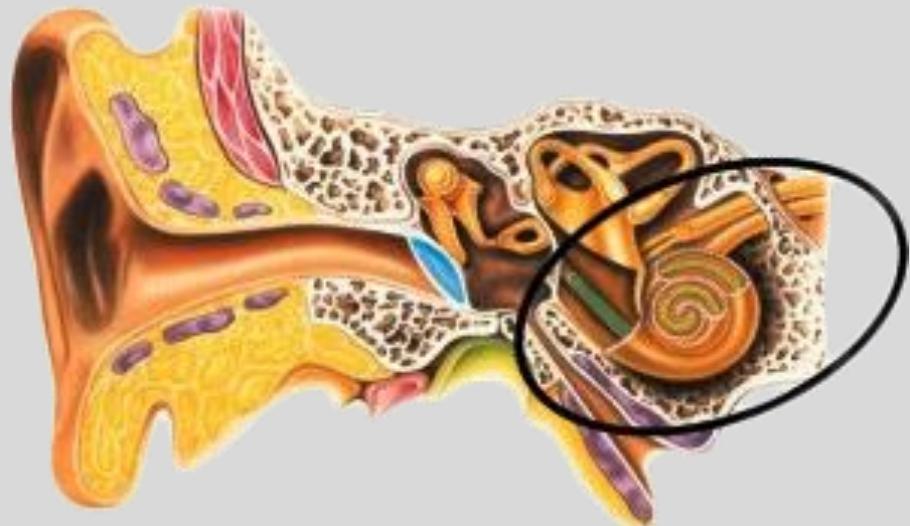
Sensorineural hearing loss

Affects the *inner ear*

Result of damage to:

stereocilia ("hair" cells)

cochlear nerve or associated brain relays



Cochlear implants used, but reclaimed sound is still crude

Hearing

Clinical Correlates

Tinnitus

Affects 15–20 % of U.S. population

Age-related loss of “hair” cells along cochlea

Loss is often at higher frequencies

Ringing sensation whenever brain “checks” those frequencies



Symptom of some other causes such as:

excessive noise (construction sites, concerts)

side-effect of some drugs

Ringing is constant and often without a stimulus

Hearing Clinical Correlates

Sensorineural hearing loss has increased 30% in the past 20 years

Ear buds are likely to blame as they don't form a tight seal around the ear

Sound leakage is countered by increasing volume to deceptively dangerous levels



<https://osteopathic.org/what-is-osteopathic-medicine/headphones-hearing-loss/>

Hearing

Clinical Correlates

Benign Paroxysmal Position Vertigo (BPPV)

Occurs when otoliths break free from utricle

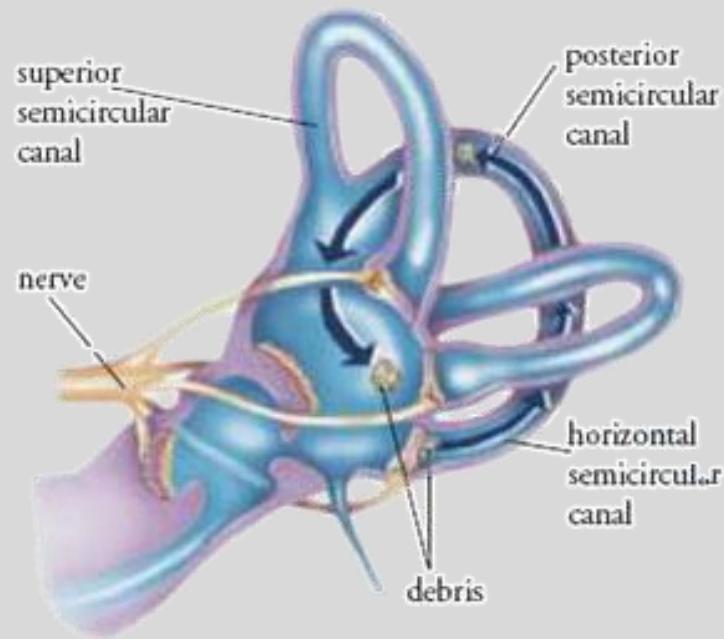
Free-floating otoliths enter SCC producing conflicting signals to the brain about head orientation

BPPV has multiple causes

blunt trauma to head

age-related weakening of tissue

idiopathic (most common)



Hearing

Clinical Correlates

Benign Paroxysmal Position Vertigo (BPPV)

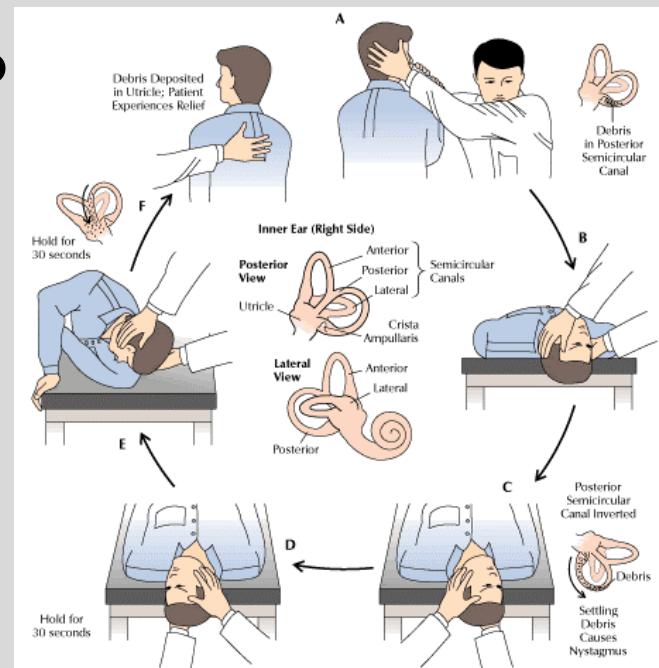
Patients experience intense, debilitating vertigo

Vertigo lasts anywhere from minutes to months

BPPV usually resolves on its own via otolith resorption

Canalith repositioning (Epley Maneuver)

Surgery



Epley maneuver

Coupled Senses

Coupled senses = 2 or more senses that work together to perform a new function

Vestibulo-ocular reflex

Provides gaze stabilization

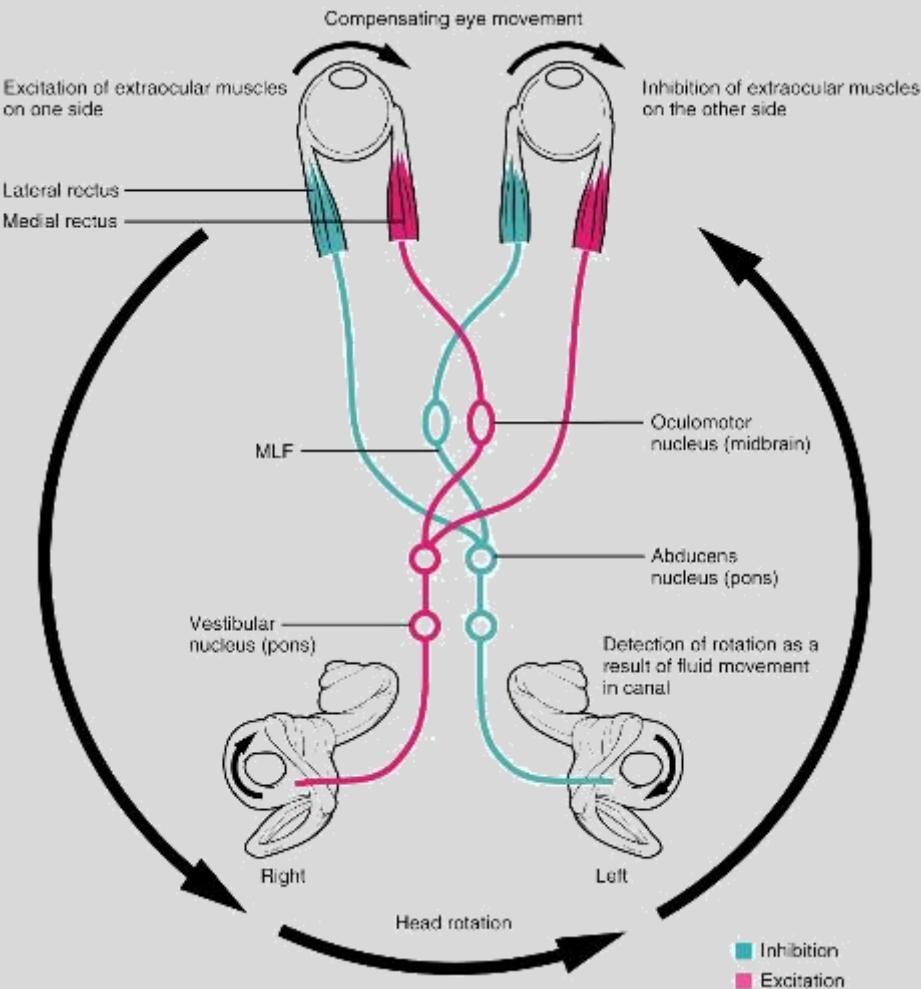
Couples the vestibular system with the eyes

Afferent limb: vestibulocochlear

sends balance information to specific nuclei in the brain

Efferent limb: CNs III, IV, VI

Extraocular muscles move eyes to compensate for head position



Coupled Senses

Vestibulo-ocular reflex

This reflex extends into the neck muscles of birds

Providing for this dramatic example of gaze stabilization



Coupled Senses

Clinical Correlate

Nystagmus

Result of a delay in the vestibulo-ocular reflex

Acquired nystagmus

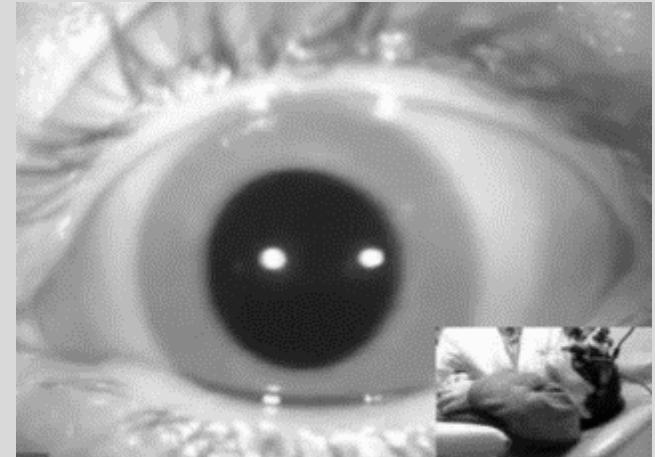
alcohol

drug use (opiates, barbiturates, marijuana)

Congenital nystagmus

heritable trait (recessive)

results in resting nystagmus



Michael Teixido MD

<https://www.youtube.com/watch?v=zeuYnPUv5YU>

Often benign, but rare debilitating cases can be treated pharmacologically

Lecture Feedback Survey

<https://comresearchdata.nyit.edu/redcap/surveys/?s=HRCY448FWYXREL4R>