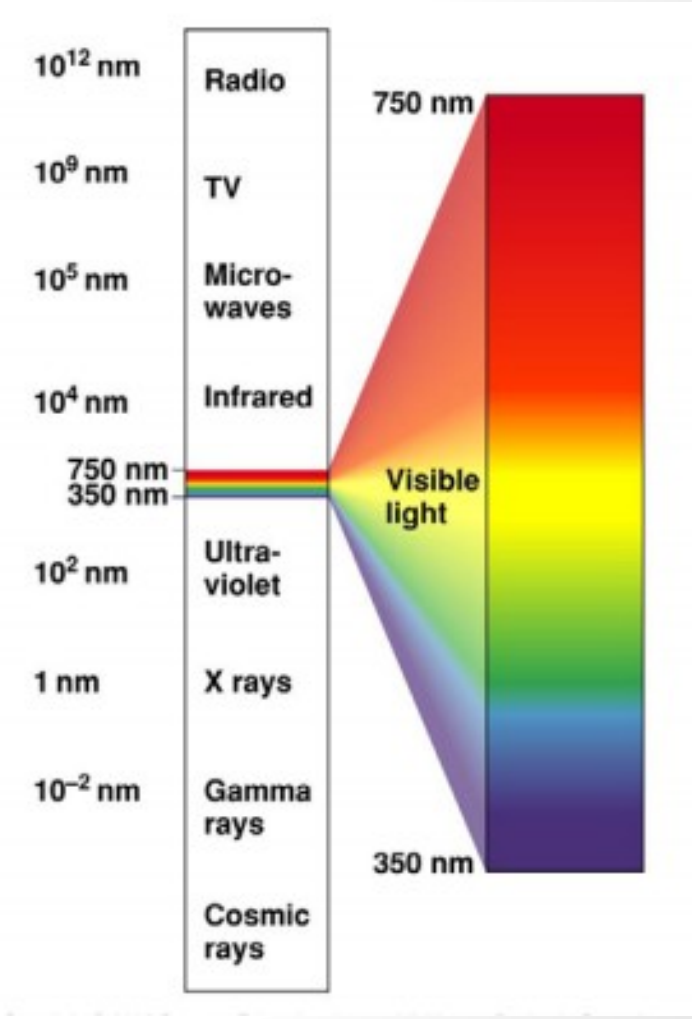
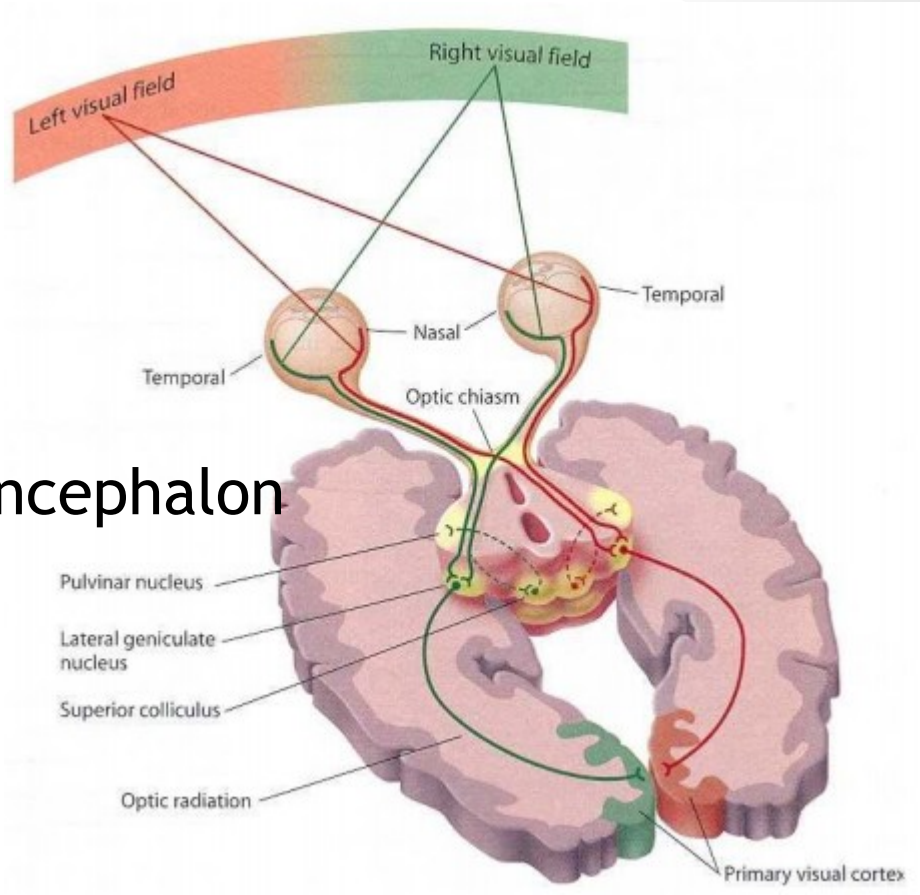
VISUAL PATHWAYS



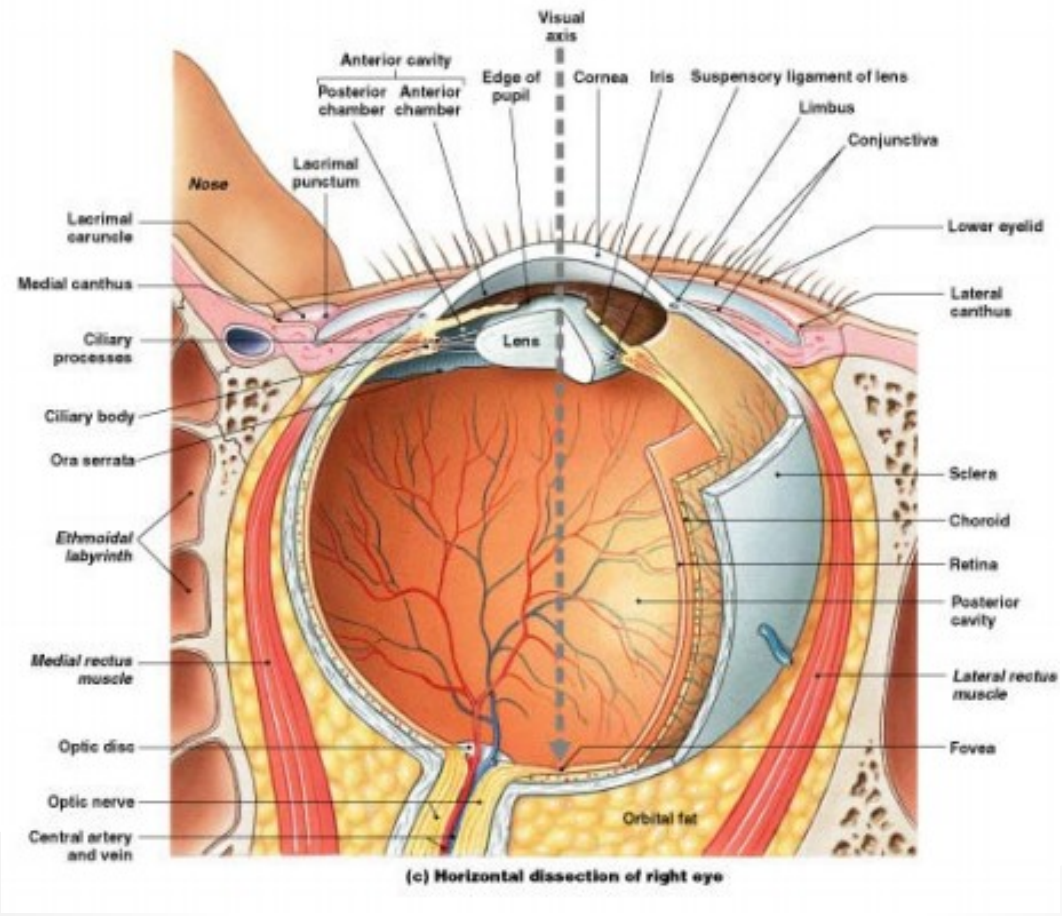
VISUAL SYSTEM

- **Perception of**
  - shape
  - motion
  - color

- **Two pathways**
  - retina – cortex
    - visual perception
  - retina – brainstem, diencephalon
    - eye movements
    - circadian photoentrainment
    - accommodation
    - pupillary reflexes

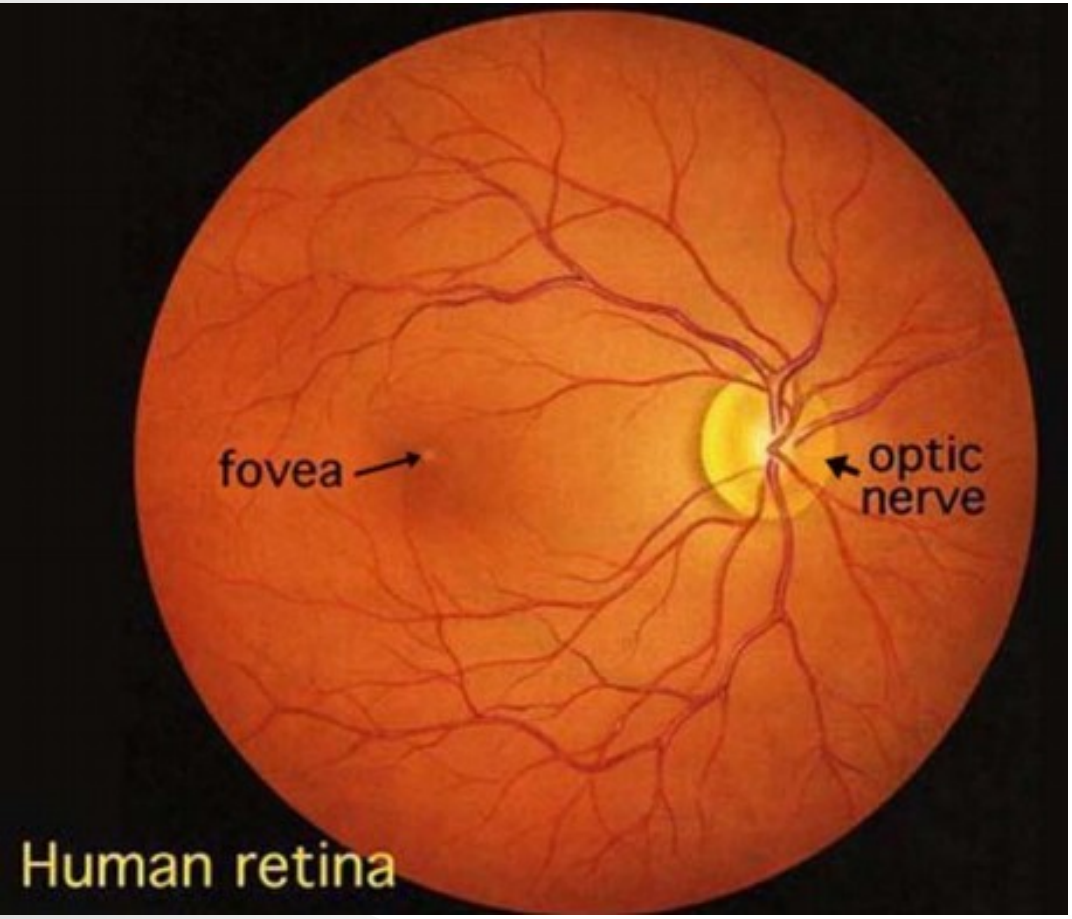


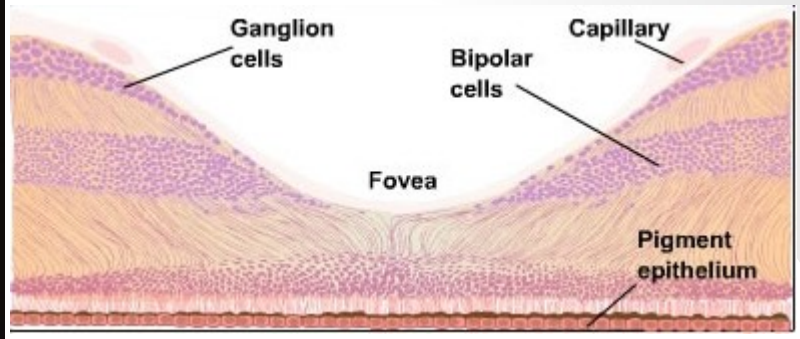
Light passes through the cornea, aqueous humor, lens, and vitreous body to form an image on the retina.

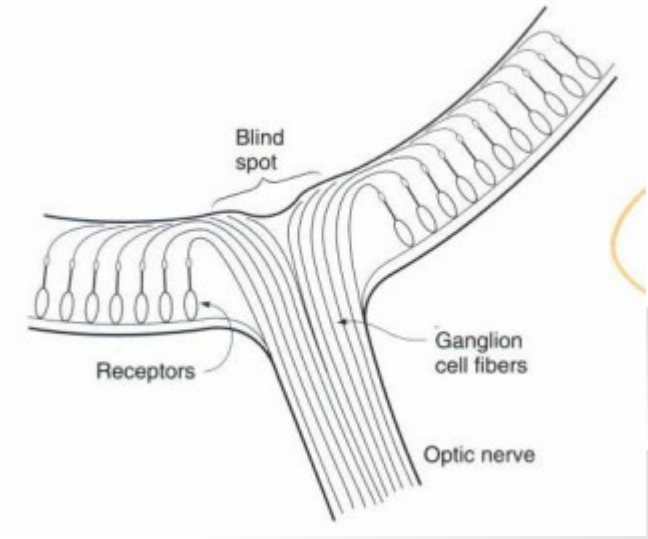


(c) Horizontal dissection of right eye

Macula lutea + fovea centralis
= areas of the highest visual acuity



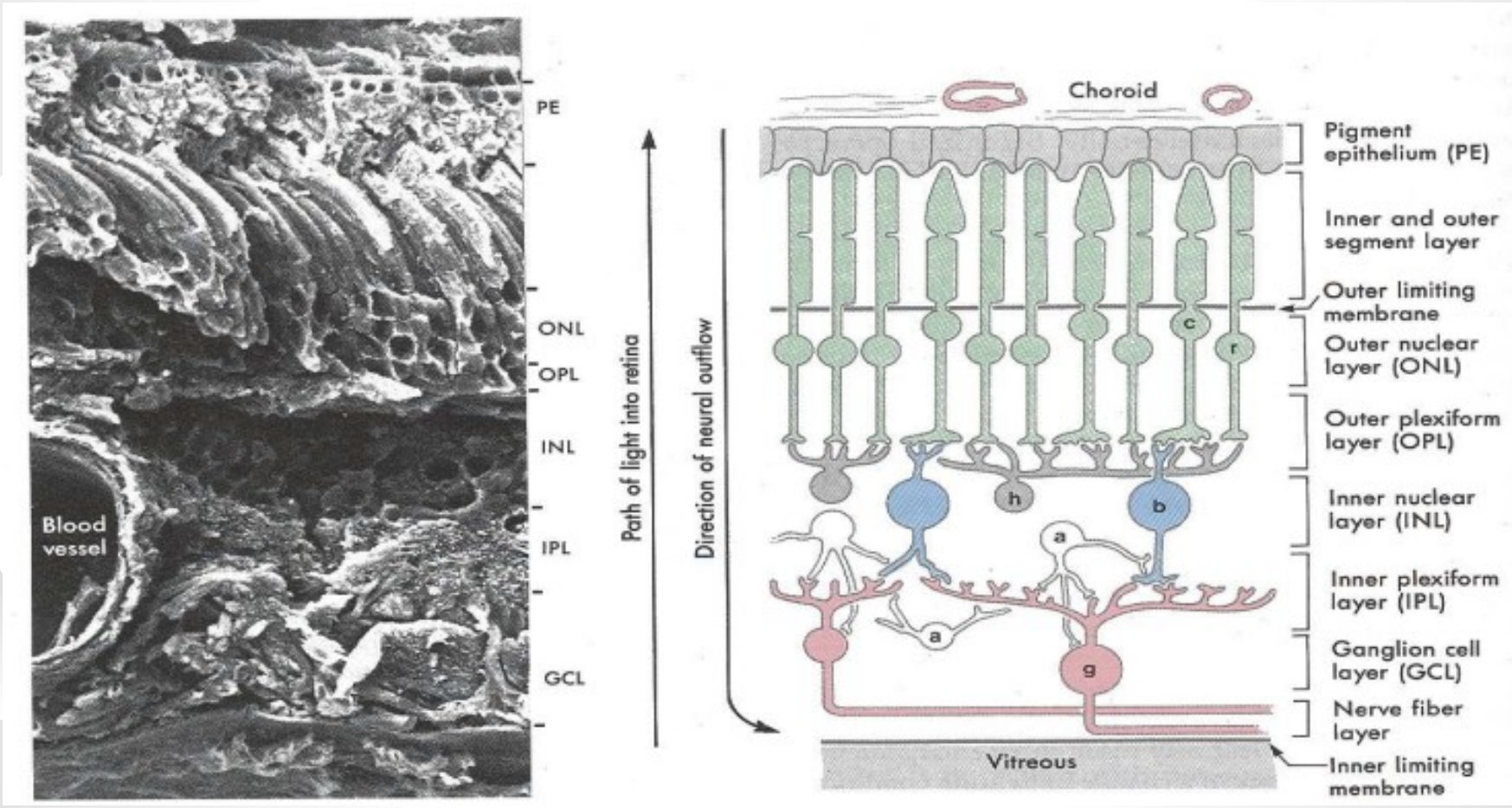




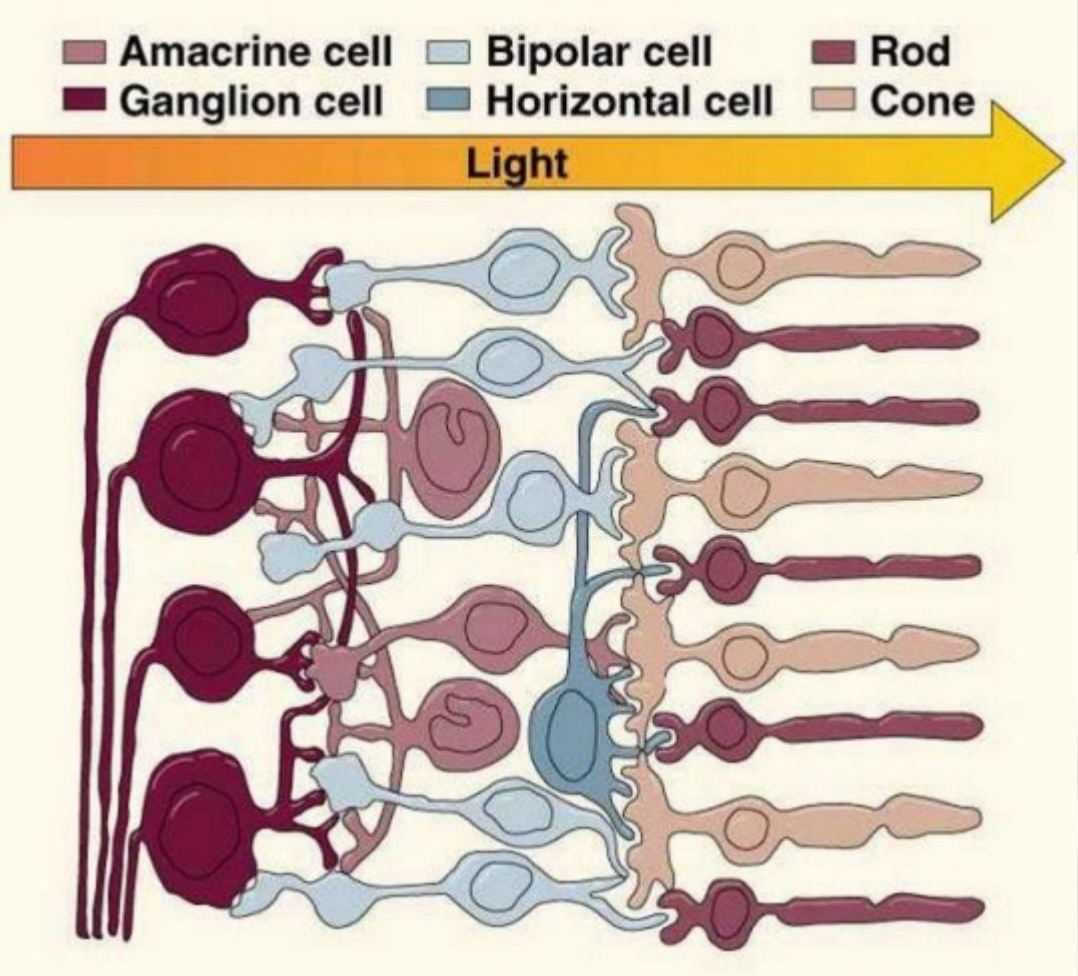
Fundus oculi

RETINA

10 layers: mainly separated by cell bodies (nuclear layers) and axons (plexiform layers)

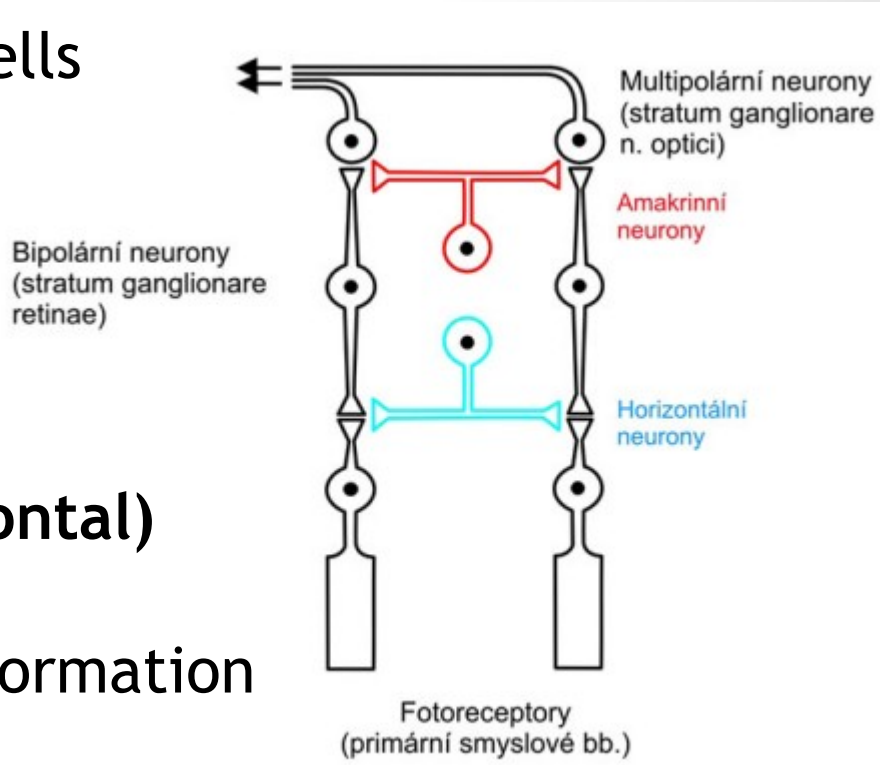


- **5 main cell types:**
  - photoreceptors
  - bipolar cells
  - horizontal cells
  - amacrine cells
  - ganglion cells

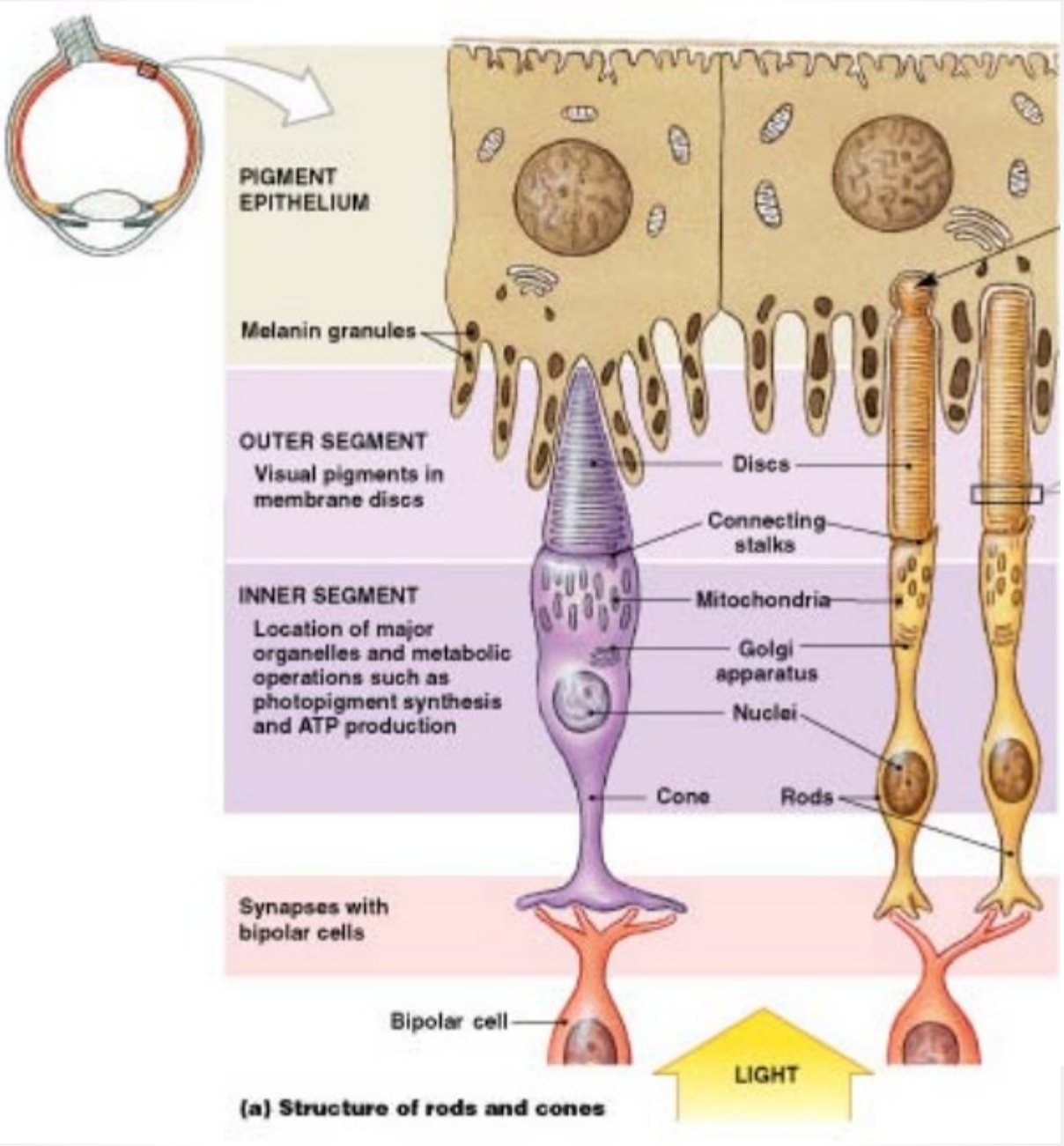


- **Photoreceptors:**
  - rods and cones
  - involved in transduction converting the light signal into a nerve impulse

- **neurons with serial (vertical) connection**
  - the main visual pathway
  - photoreceptors → bipolar cells → ganglion cells

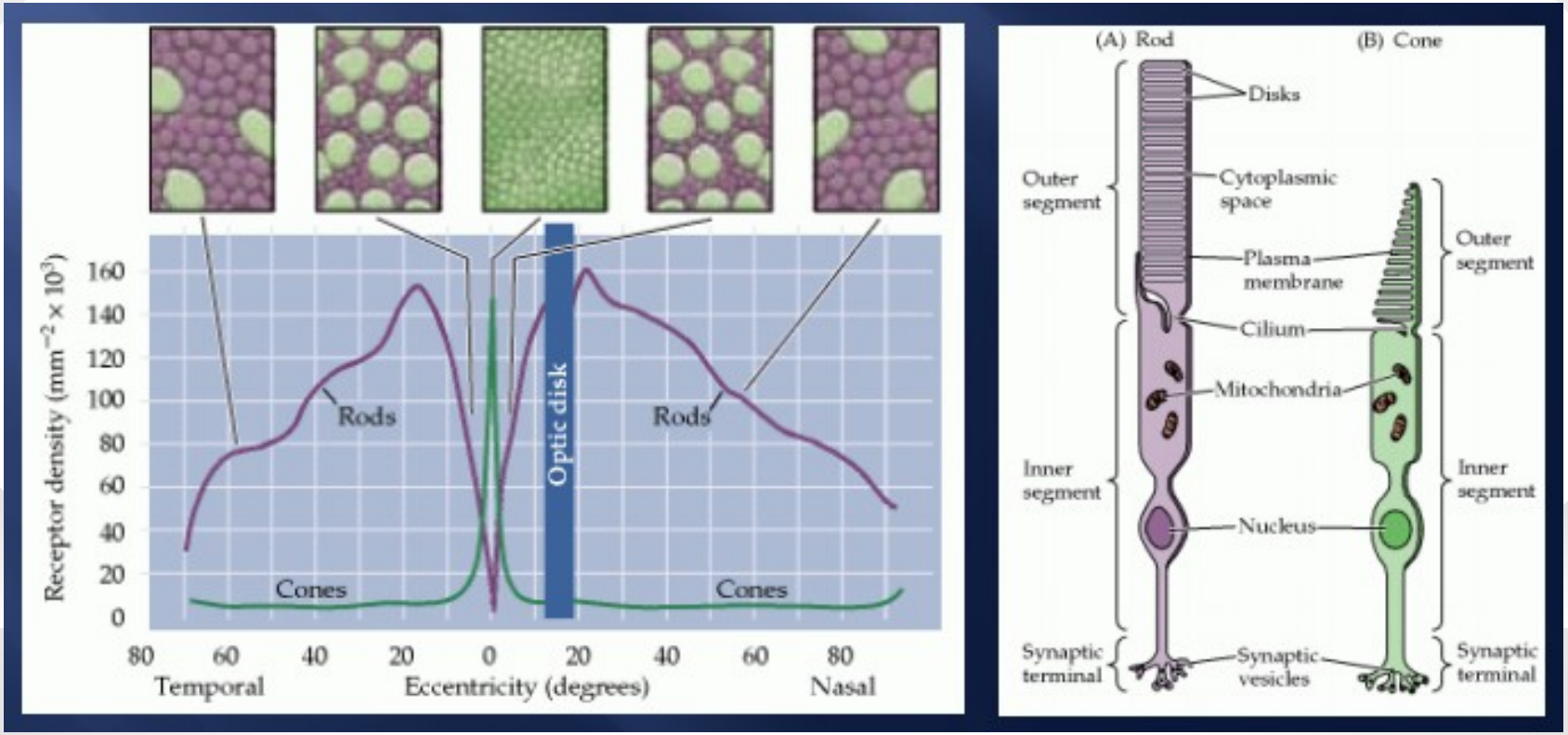


- **neurons with parallel (horizontal) connection**
  - modulation of the visual information by retina
  - horizontal cells
  - amacrine cells



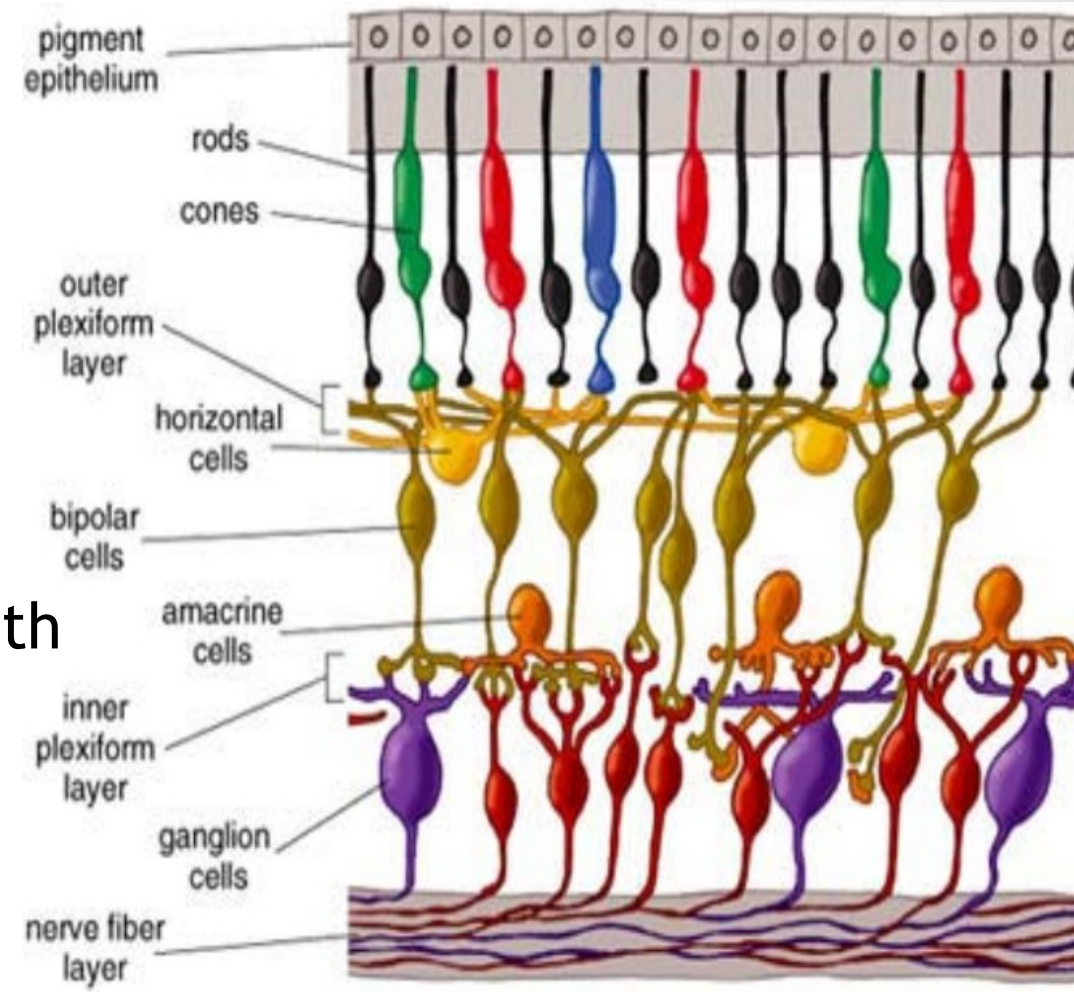
(a) Structure of rods and cones

- **Cones (7 million)**
  - cluster at fovea (macula lutea)
  - detect color in bright light = photopic vision
- **Rods (100 million)**
  - outside the fovea
  - sensitive to shape and movement = scotopic vision



CONES

- 3 different types with three different photopigments: blue, green and red
- Each type is maximally sensitive to the wavelength that corresponds to the specific color range (spectral sensitivity)



GANGLION CELLS

- **P cells (80%)**
  - ganglion cells that monitor cones
  - smaller, more numerous
  - axons end on parvocellular laminae of LGN
  - provide information about fine detail and color

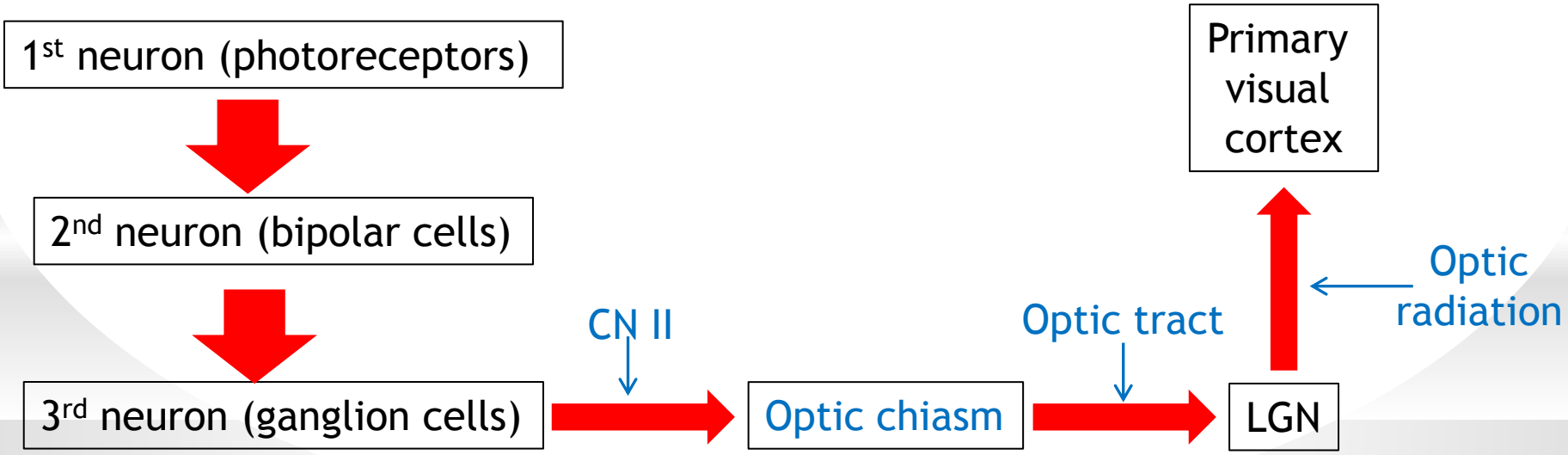
- **M cells (10%)**
  - ganglion cells that monitor rods
  - relatively large
  - axons end on magnocellular laminae of LGN
  - provide information about a general form of an object, motion, and shadows in dim light

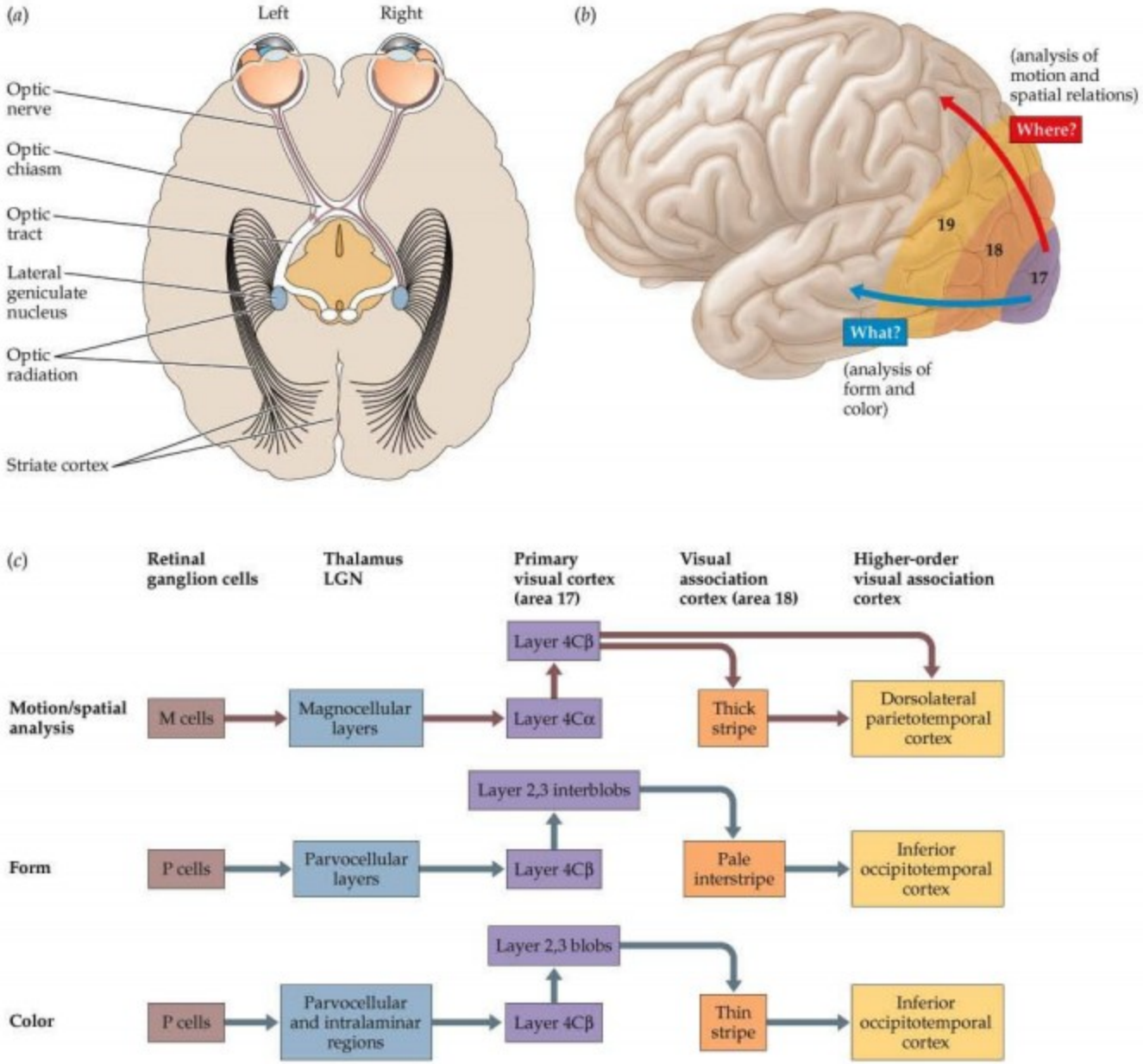
- **non-P non-M cells (10%)**
  - projection to subcortical nuclei, koniocellular cells of LGN

PRIMARY VISUAL PATHWAY

- The primary visual pathway connects the retina with lateral geniculate nucleus and primary visual cortex (retinogeniculostriate pathway)

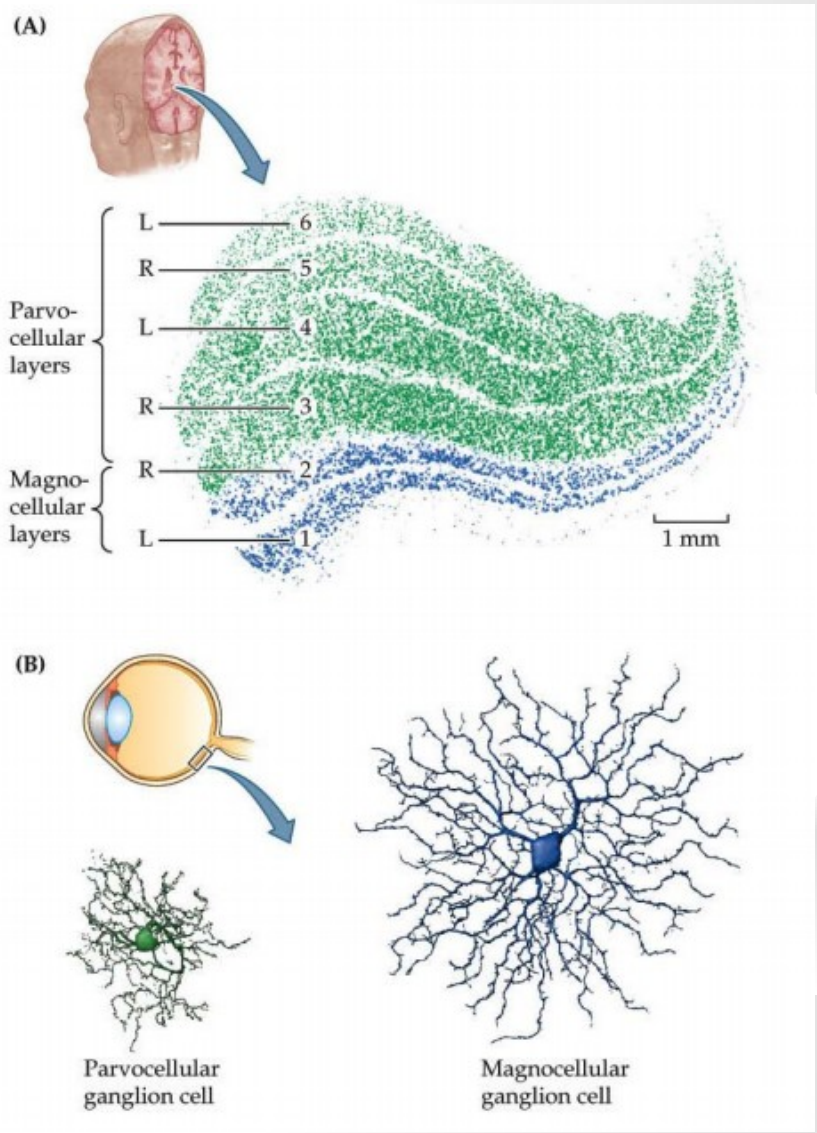
- It is responsible for detection of shape, movement and color

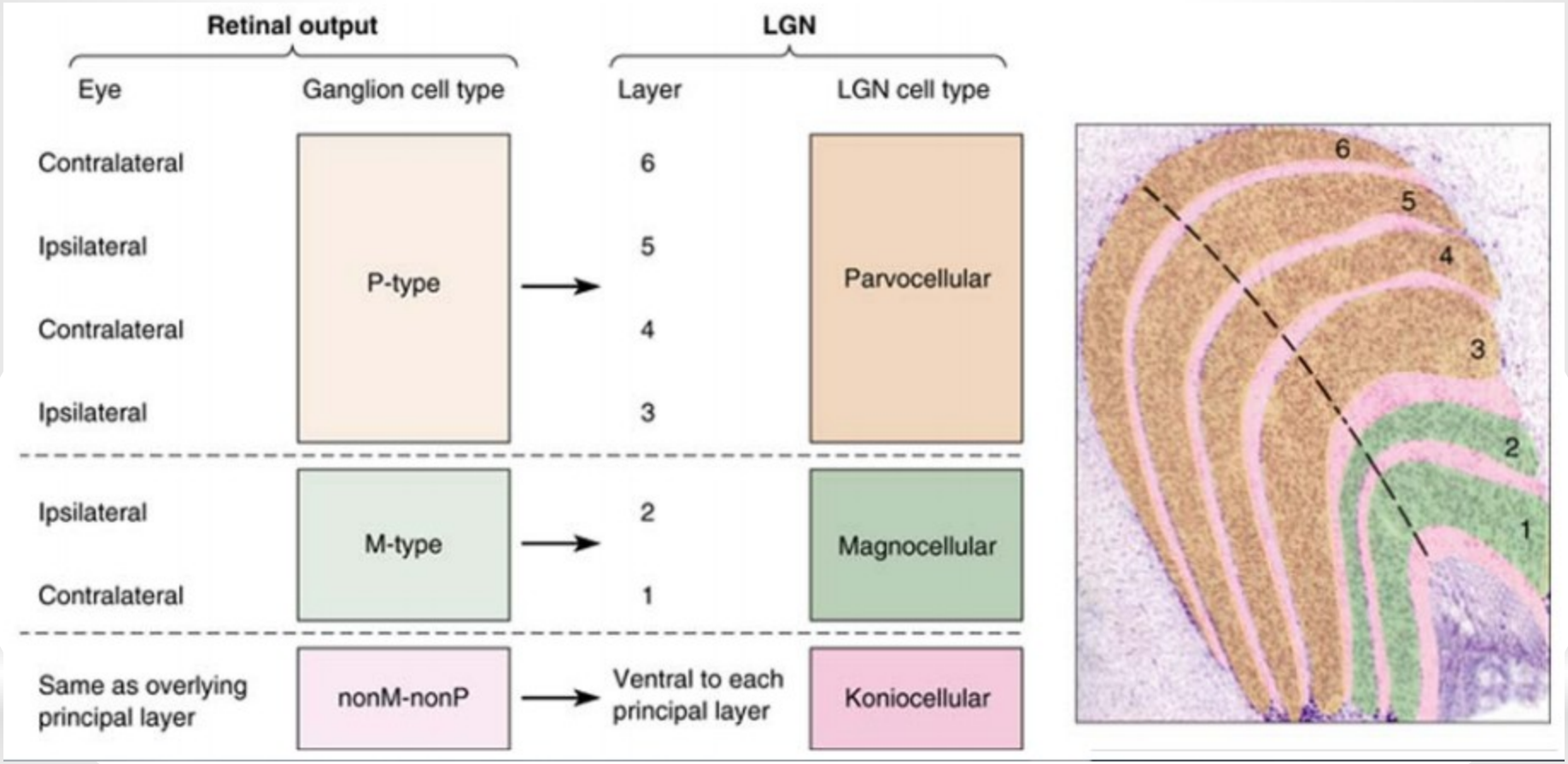



(a)
Left
Right
Optic nerve
Optic chiasm
Optic tract
Lateral geniculate nucleus
Optic radiation
Striate cortex
(b)
(analysis of motion and spatial relations)
Where?
19
18
17
What?
(analysis of form and color)
(c)
Retinal ganglion cells
Thalamus LGN
Primary visual cortex (area 17)
Visual association cortex (area 18)
Higher-order visual association cortex
Layer 4Cβ
Motion/spatial analysis
M cells
Magnocellular layers
Layer 4Cα
Thick stripe
Dorsolateral parietotemporal cortex
Layer 2,3 interblobs
Form
P cells
Parvocellular layers
Layer 4Cβ
Pale interstripe
Inferior occipitotemporal cortex
Layer 2,3 blobs
Color
P cells
Parvocellular and intralaminar regions
Layer 4Cβ
Thin stripe
Inferior occipitotemporal cortex

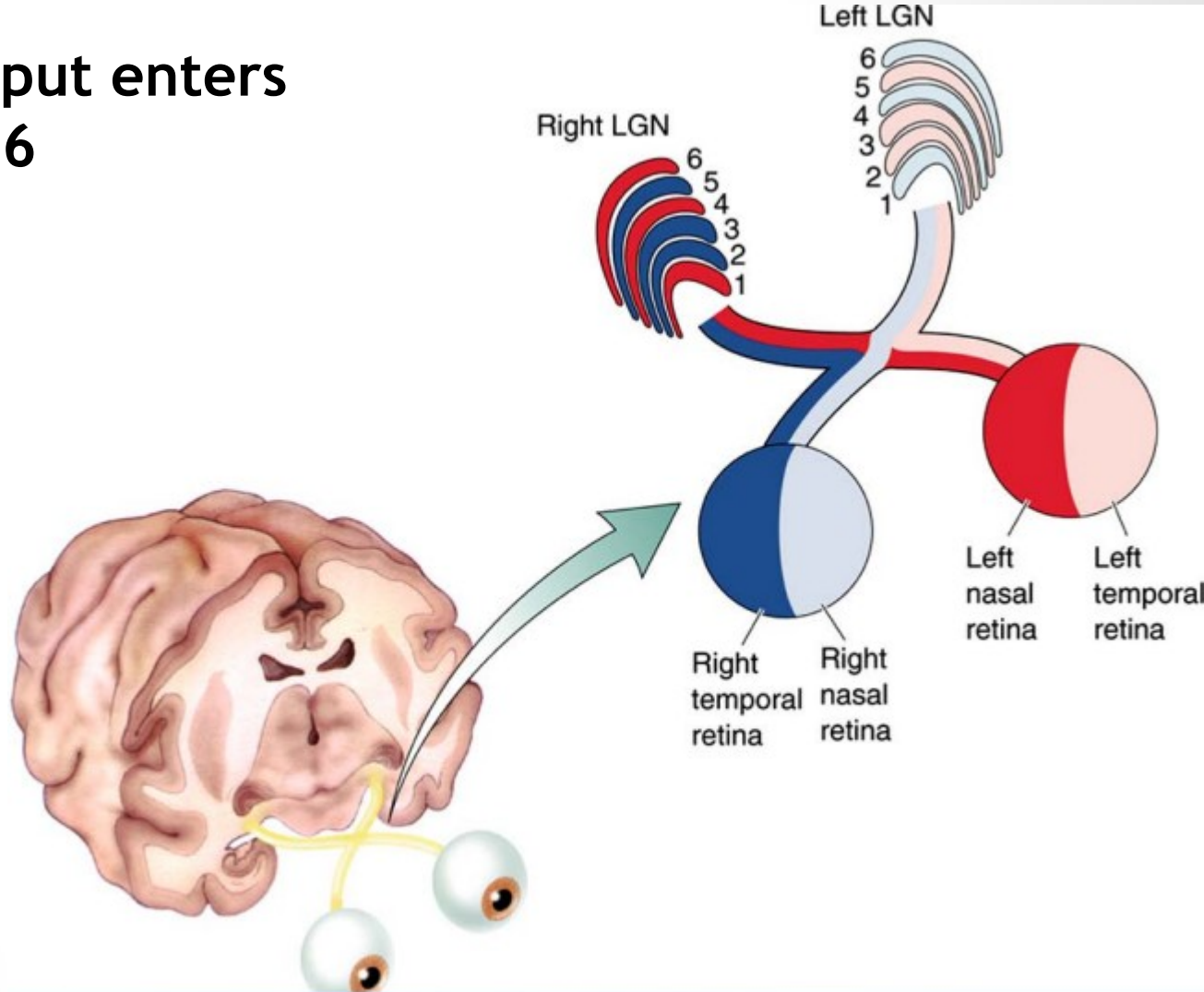
LATERAL GENICULATE NUCLEUS (LGN)

- LGN is composed of 6 layers
- Layers 1 and 2 contain larger neurons
- Layers 3 - 6 contain smaller neurons

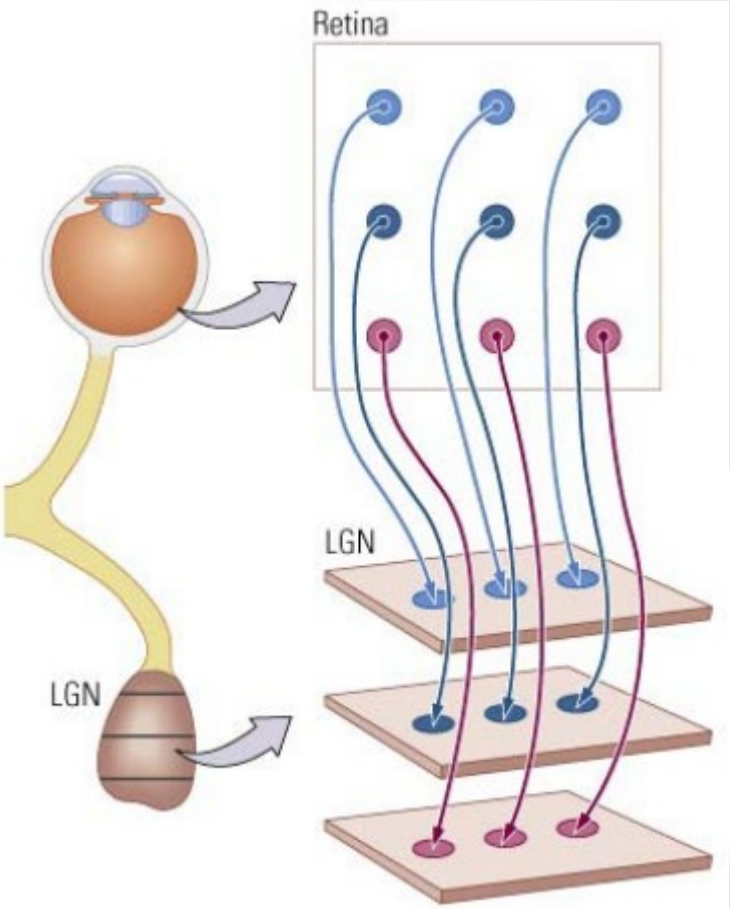



Retinal output
LGN
Eye
Ganglion cell type
Layer
LGN cell type
Contralateral
Ipsilateral
Contralateral
Ipsilateral
P-type
6
5
4
3
Parvocellular
Ipsilateral
Contralateral
M-type
2
1
Magnocellular
Same as overlying principal layer
nonM-nonP
Ventral to each principal layer
Koniocellular
6
5
4
3
2
1

- Ipsilateral input enters layers 2,3 and 5
- Contralateral input enters layers 1, 4 and 6

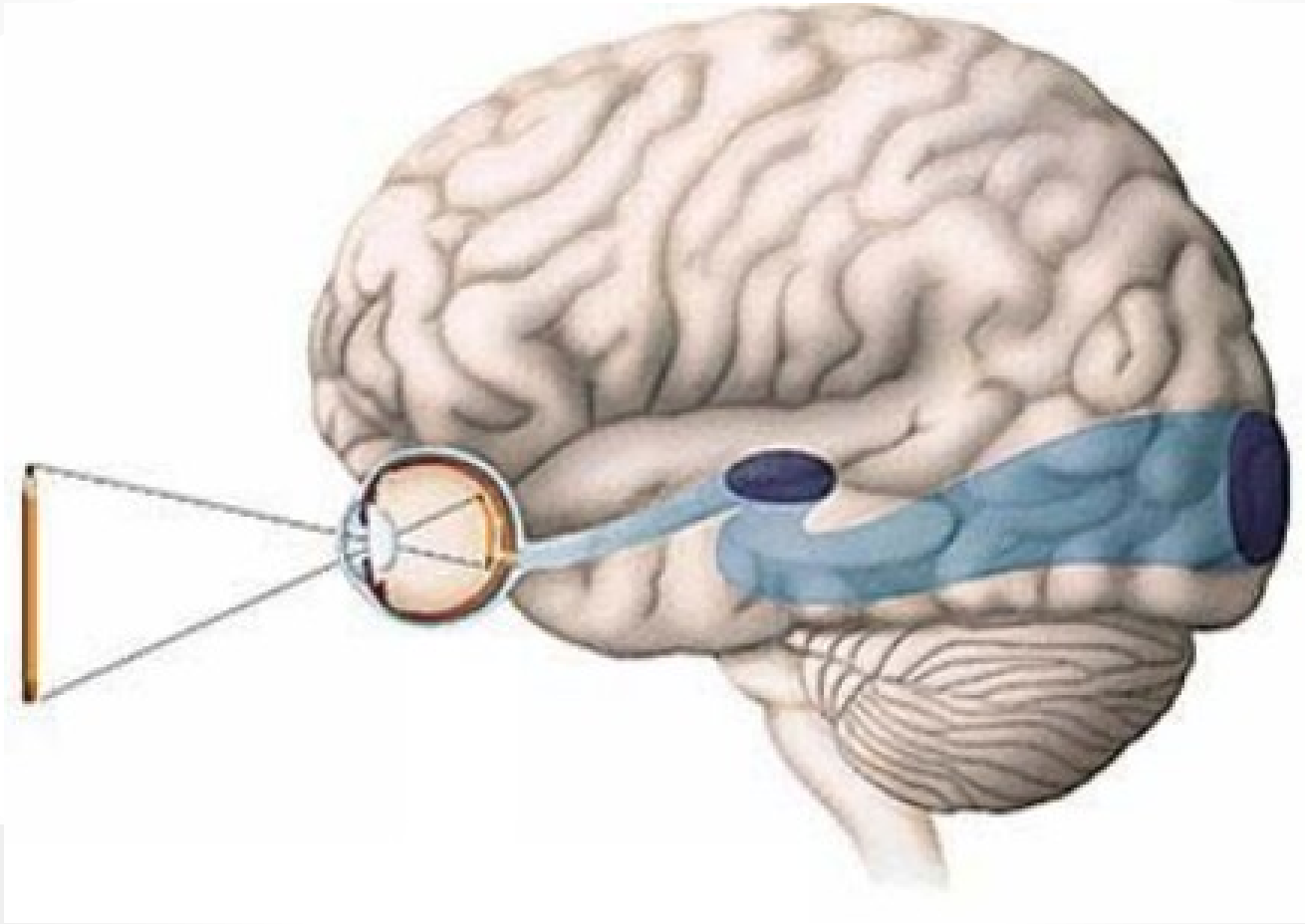


- LGN contains the topographic representation of what the retina " sees". This **retinotopic** map is sent to the cortex.
- LGN modulates and regulates the flow of visual information to the primary visual cortex
- cortex can control efficiency of thalamic input



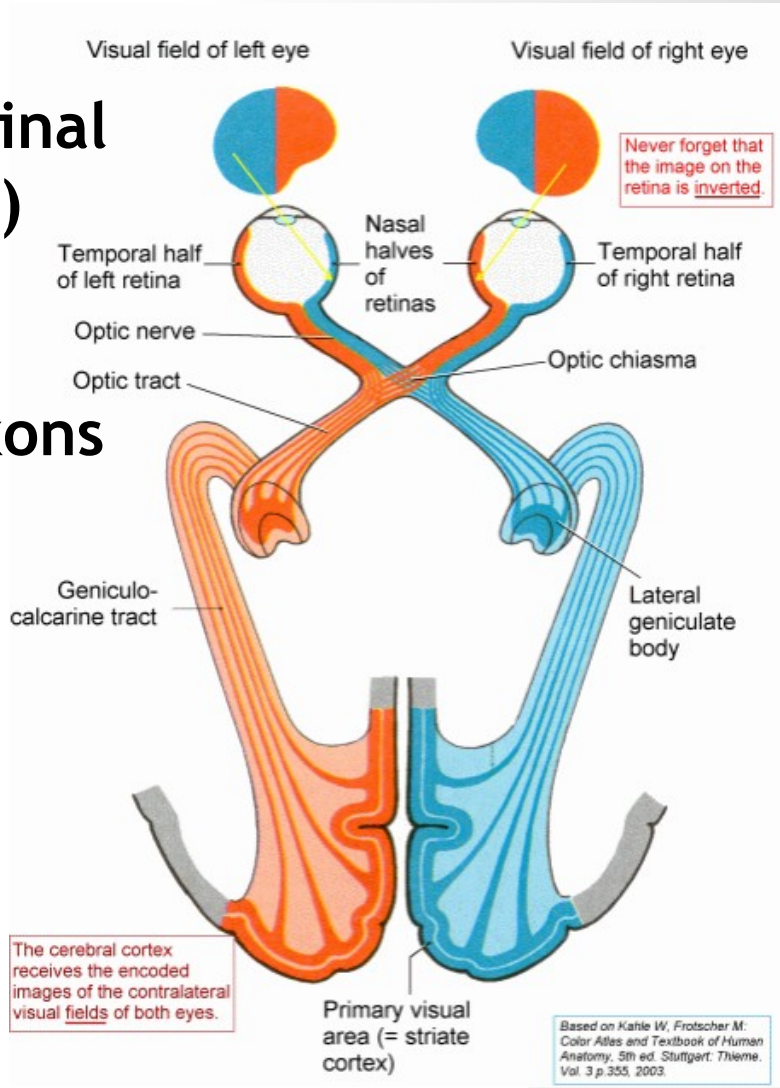
GENICULOSTRIATE PATHWAY

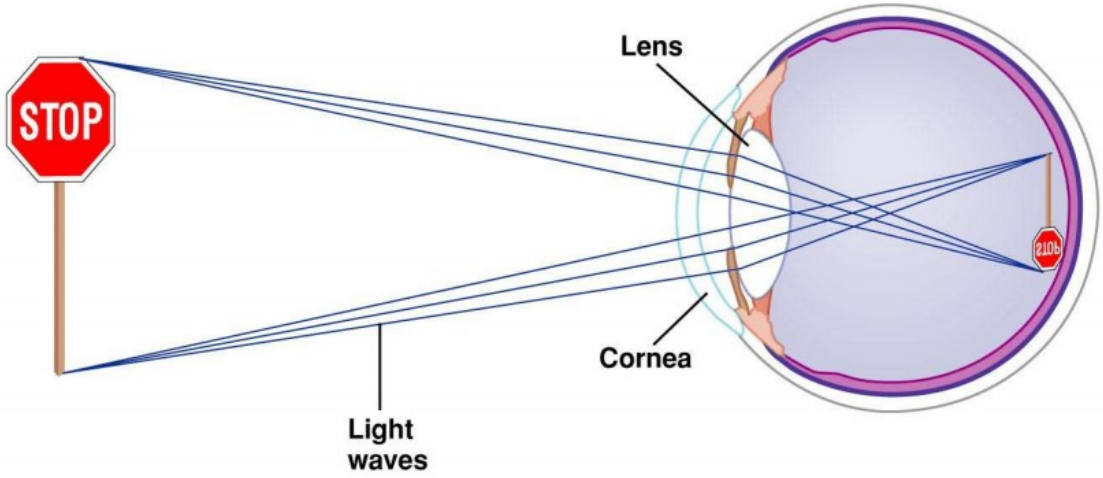
optic radiation (geniculocalcarine fibres) runs under the temporal lobe to the occipital lobe

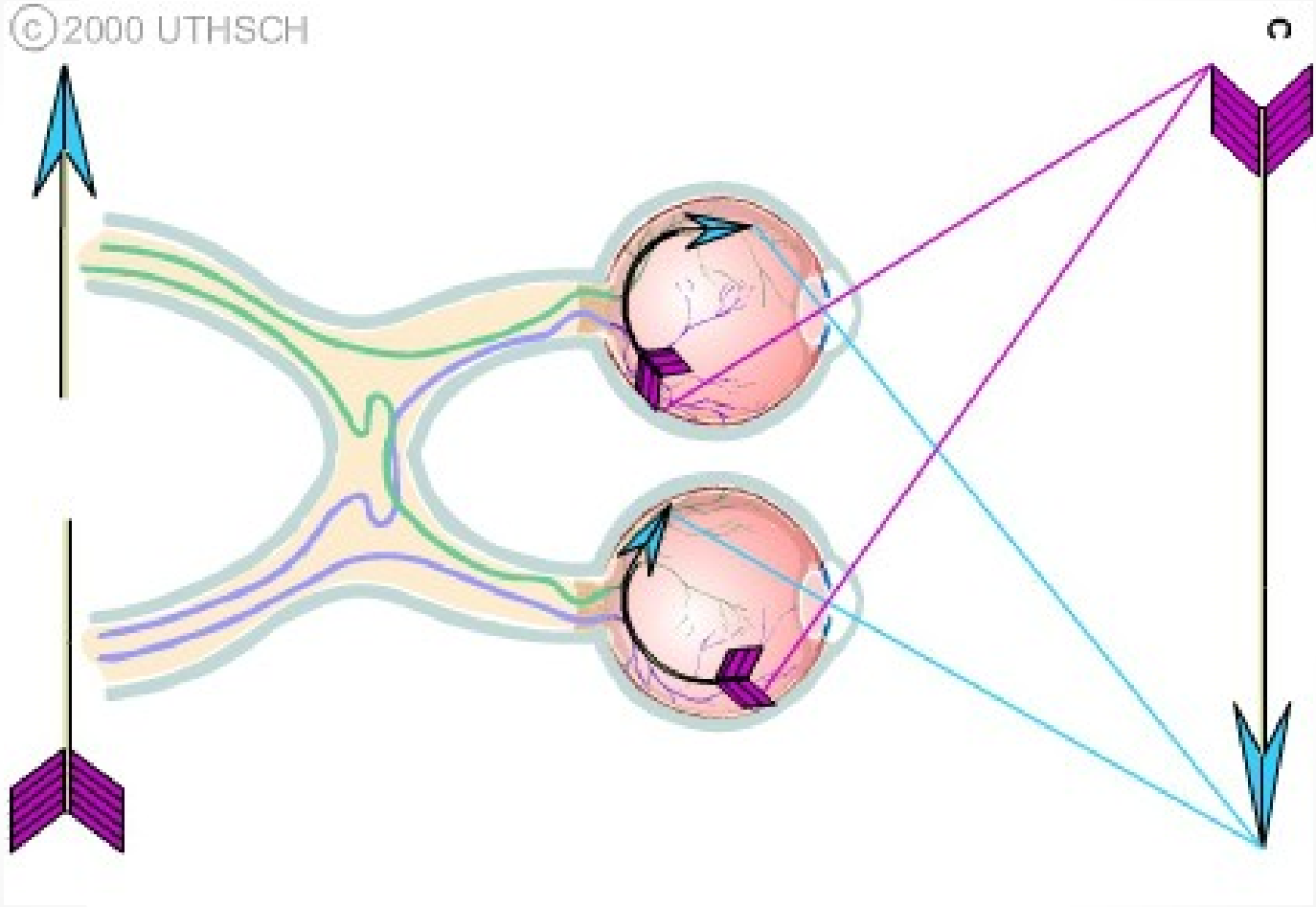


RETINOTOPIC REPRESENTATION

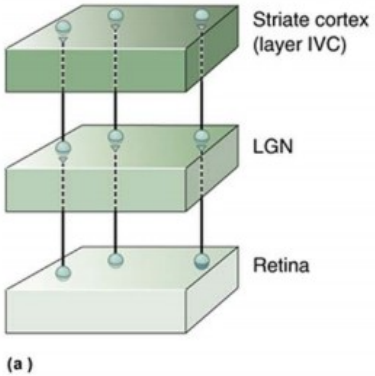
- Nasal and temporal visual fields
- Reversed to opposite halves of retinal representative fields (hemiretinas)
- Inverted and reversed
- Nasal visual fields project to temporal hemiretinas and their axons do not cross at the optic chiasm
- Temporal visual fields project to nasal hemiretinas and their axons cross at the optic chiasm

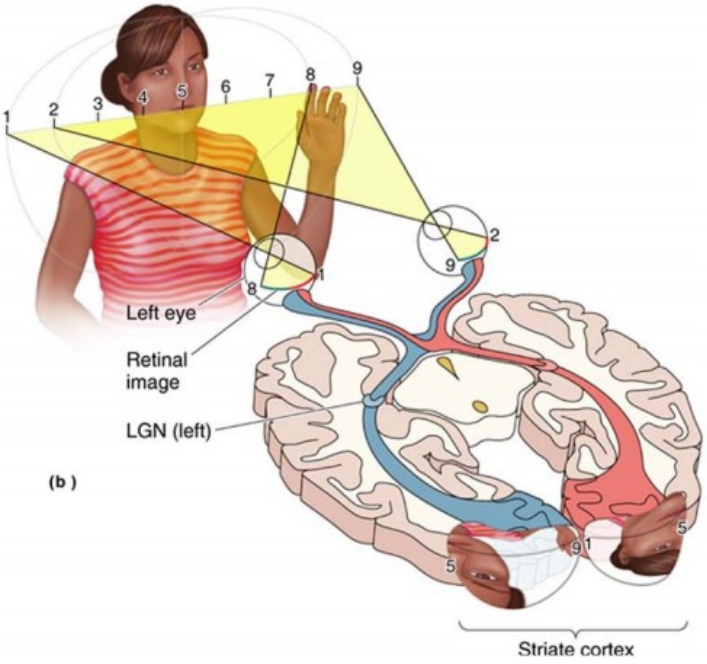


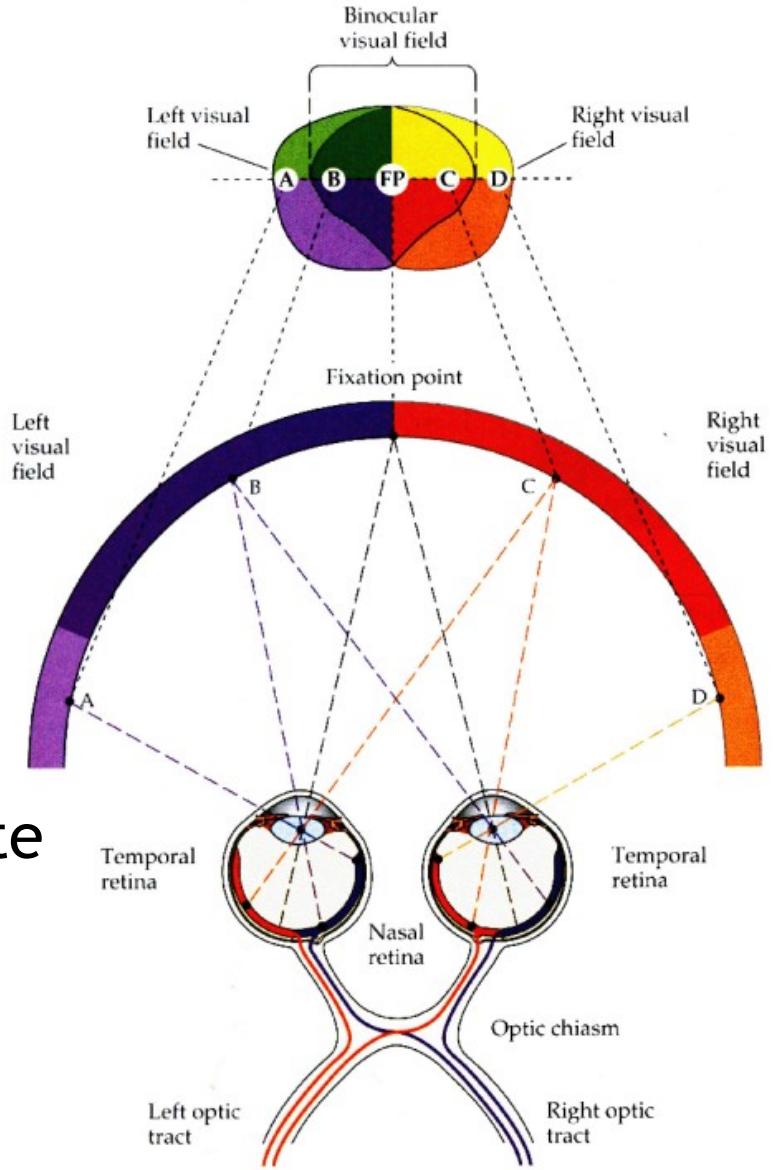



©2000 UTHSCH

RETINOTOPY

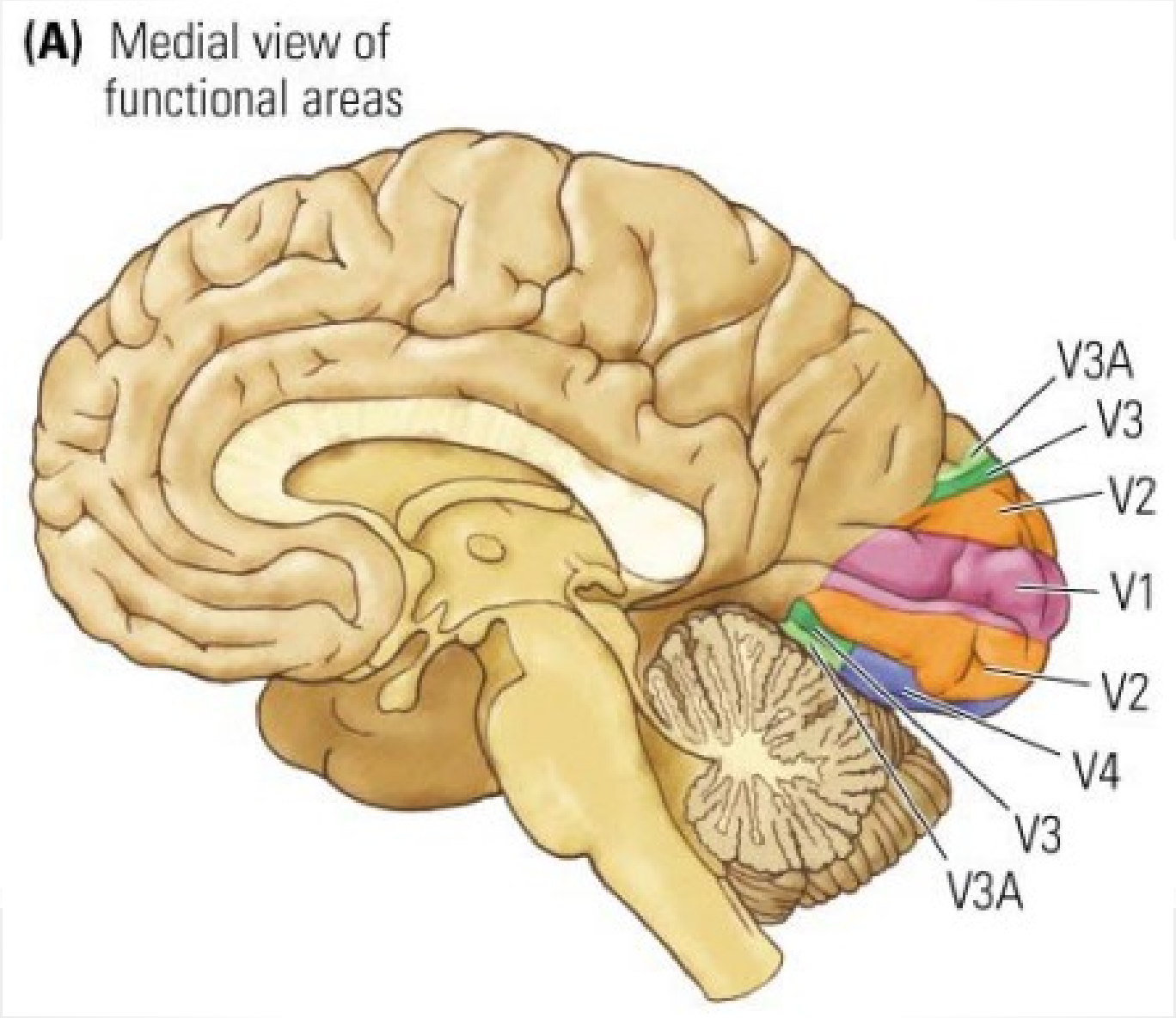






- Most of the visual field is shared by the two eyes (binocular field)
- Representation of different parts of the visual field is disproportionate in size

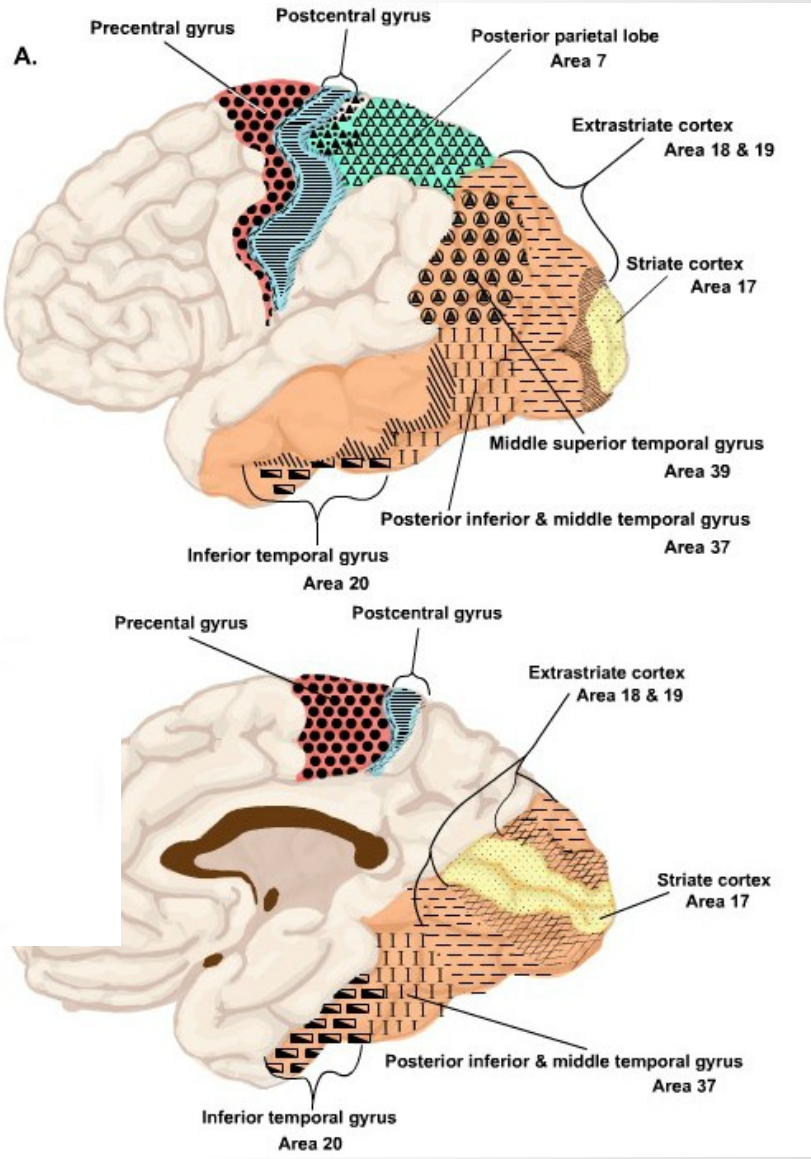
VISUAL CORTEX



PRIMARY VISUAL CORTEX (V1)

- Most LGN axons terminate in V1
- All V1 neurons respond to visual stimuli exclusively
- Ablating V1 results in blindness in the contralesional hemifield (homonymous hemianopsia)

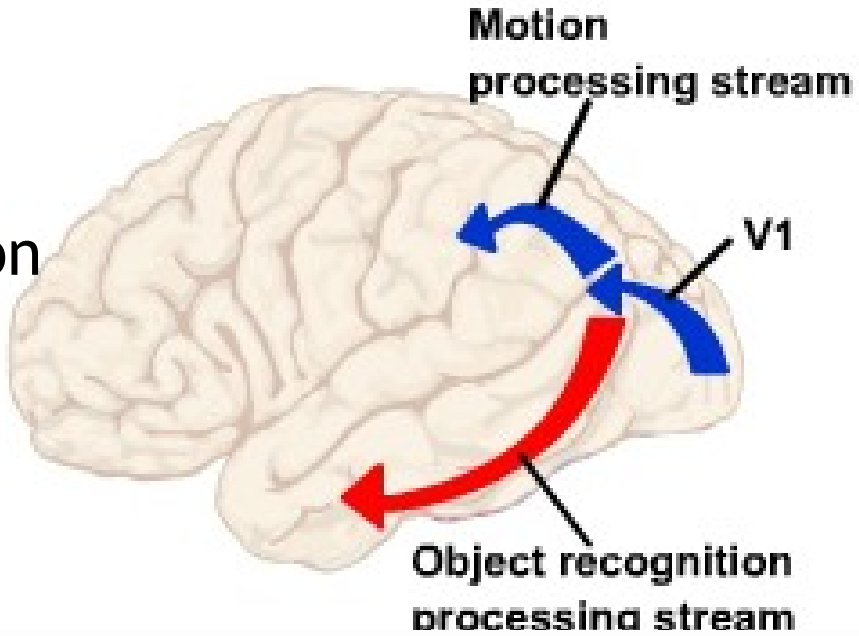
- Electrical stimulation of V1 elicits visual sensations



VISUAL ASSOCIATION CORTEX

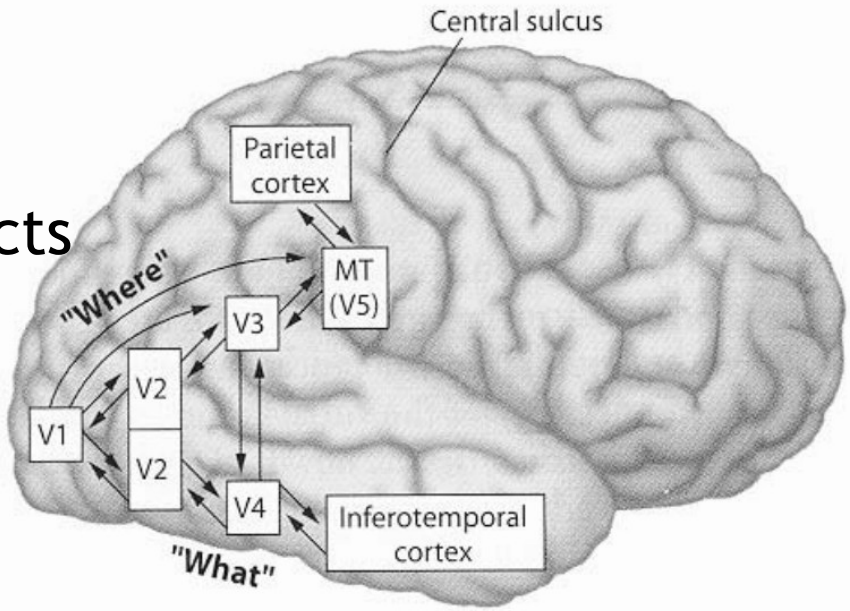
Dorsal Stream

- spatial orientation
- binocular fusion/depth perception
- the location, the movement and the movement direction and velocity of objects in space



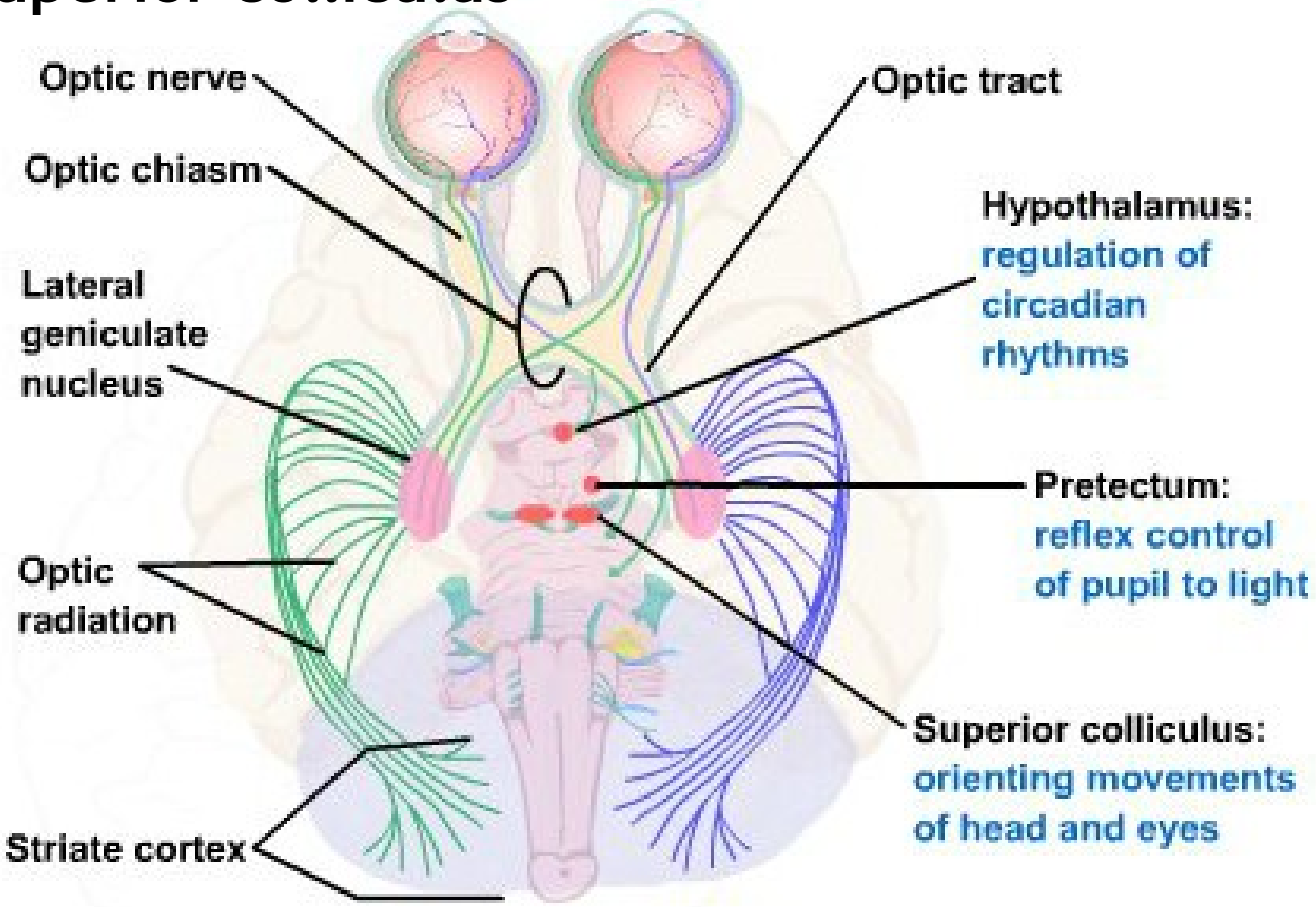
Ventral Stream

- recognize objects and colors
- read text
- learn and remember visual objects (e.g., words and their meanings)



VISUAL PATHWAYS TO SUBCORTICAL STRUCTURES

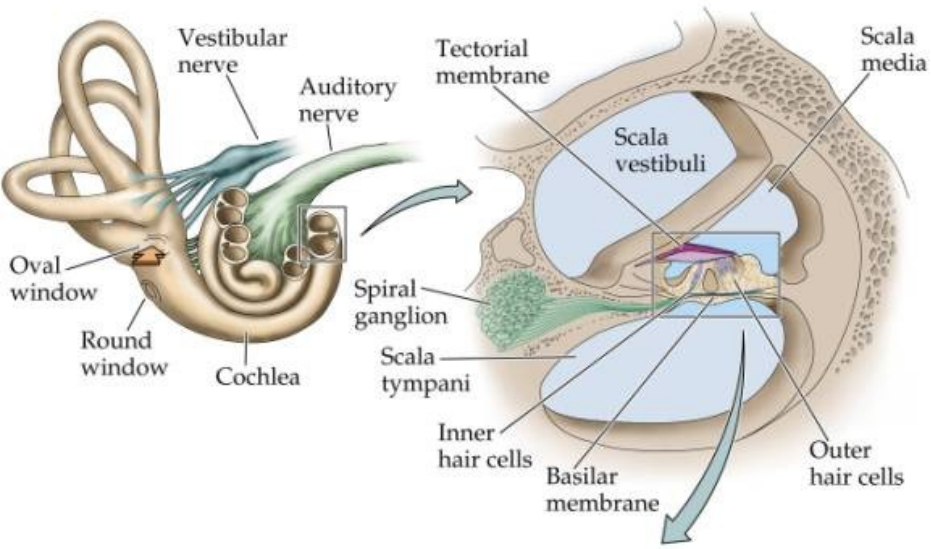
- to the suprachiasmatic nucleus of hypothalamus
- to the pretectum of the midbrain
- to the superior colliculus

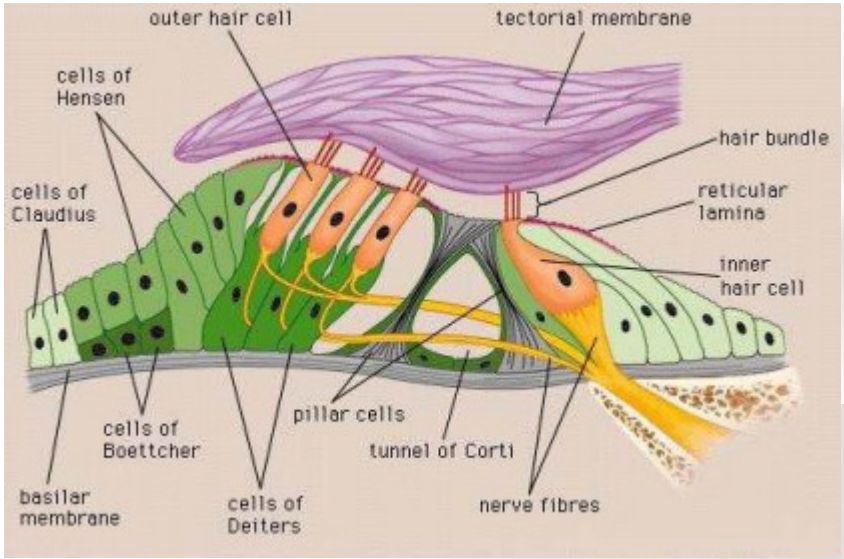


AUDITORY PATHWAY

1st order neuron

- bipolar neuron of the spiral ganglion
- dendrites make synapses with hair cells
- axons form the cochlear part of CN VIII





2nd order neuron

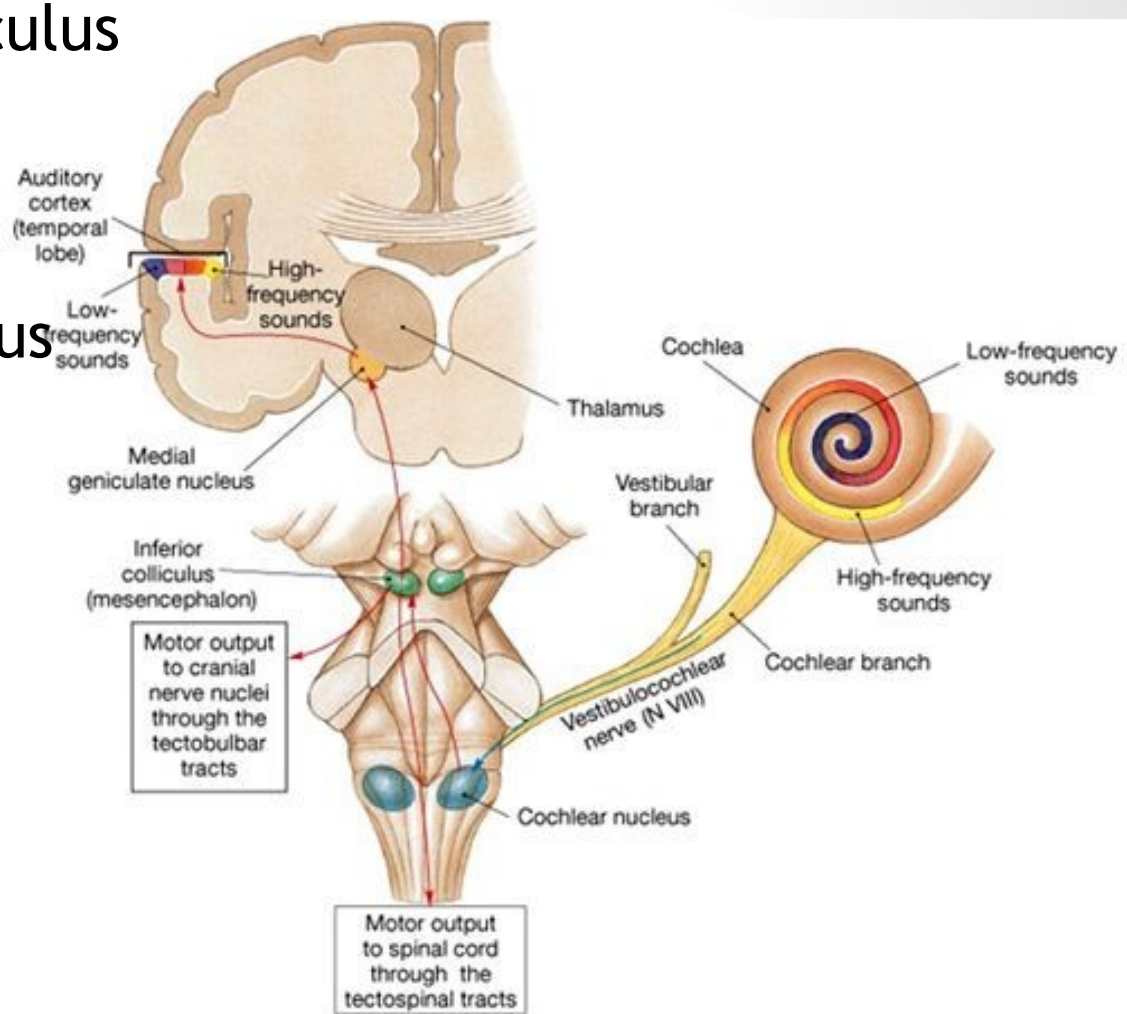
- ventral cochlear nucleus → trapezoid body → lateral lemniscus
- dorsal cochlear nucleus → lateral lemniscus

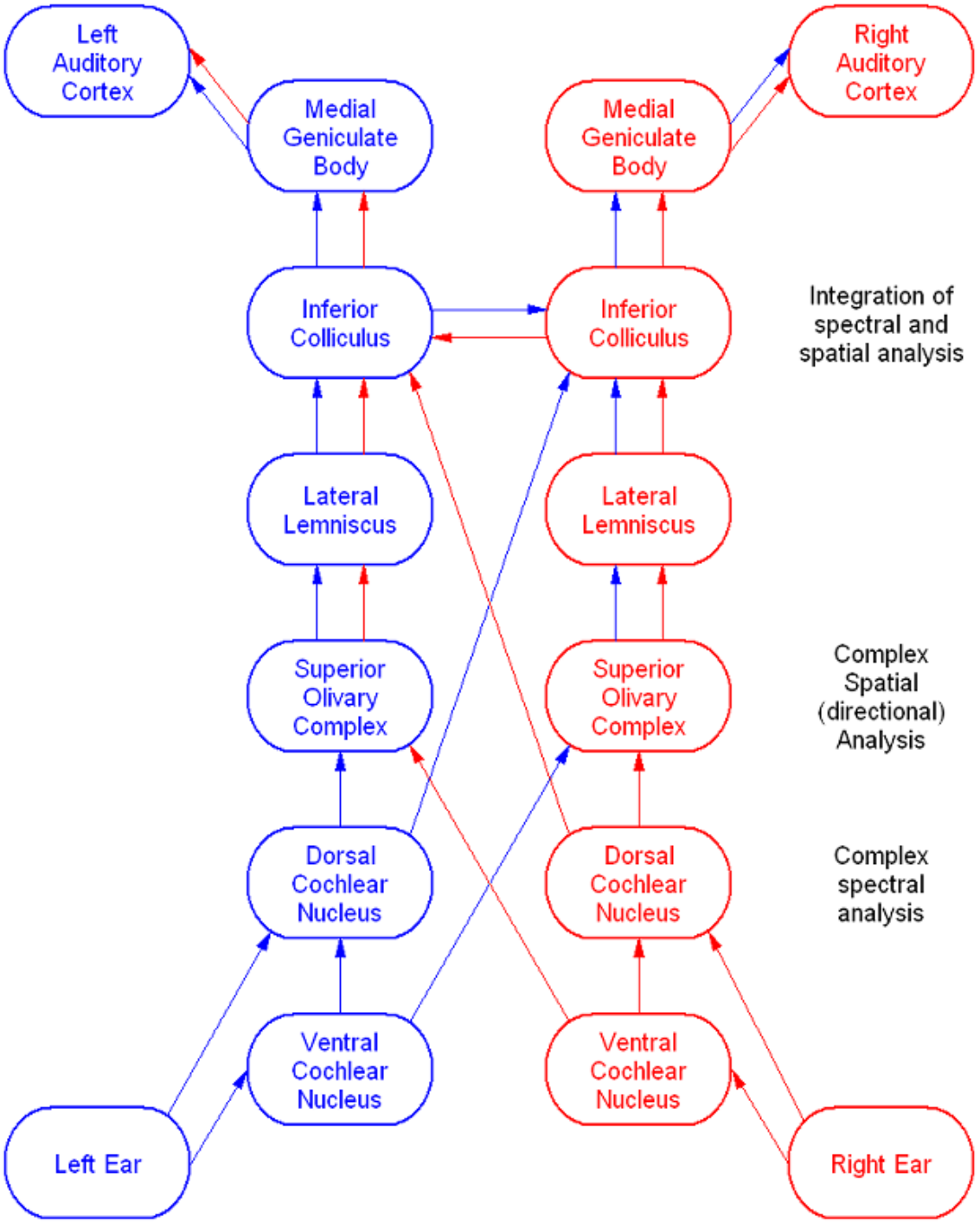
3rd order neuron

- nucleus of inferior colliculus
  → brachium c.i.

4th order neuron

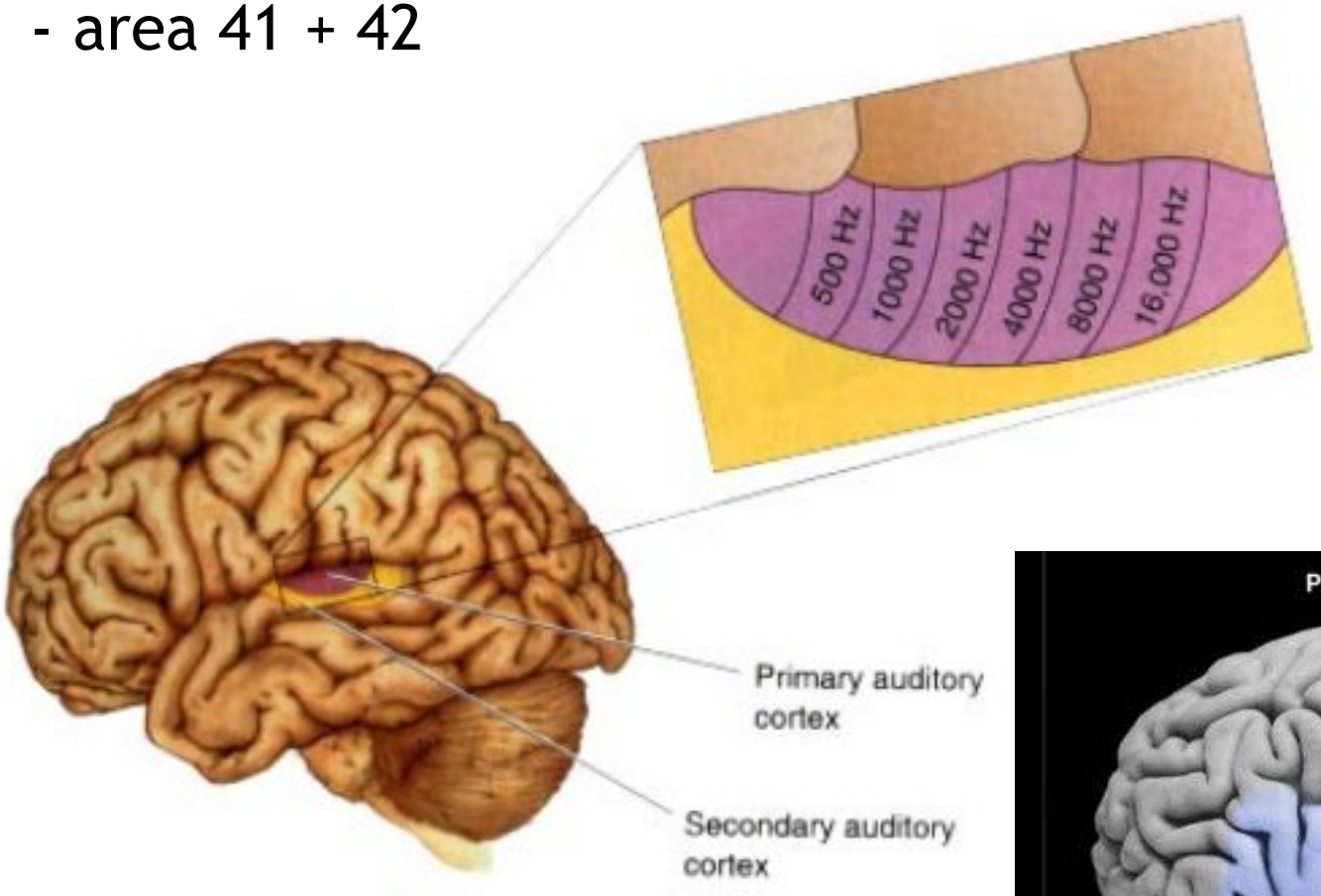
- medial geniculate nucleus
  → radiatio acustica
  (internal capsule)

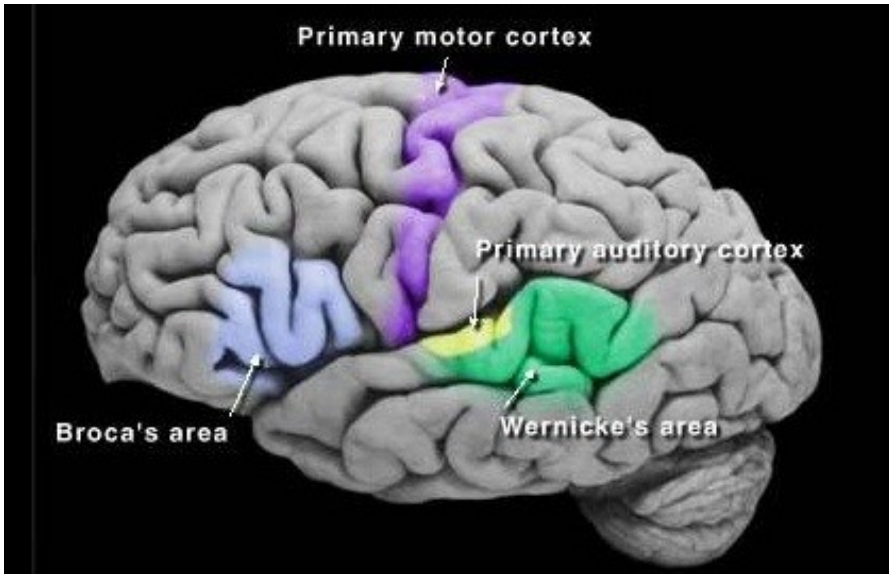



Left Auditory Cortex
Right Auditory Cortex
Medial Geniculate Body
Medial Geniculate Body
Inferior Colliculus
Inferior Colliculus
Integration of spectral and spatial analysis
Lateral Lemniscus
Lateral Lemniscus
Superior Olivary Complex
Superior Olivary Complex
Complex Spatial (directional) Analysis
Dorsal Cochlear Nucleus
Dorsal Cochlear Nucleus
Complex spectral analysis
Ventral Cochlear Nucleus
Ventral Cochlear Nucleus
Left Ear
Right Ear

PRIMARY AUDITORY CORTEX

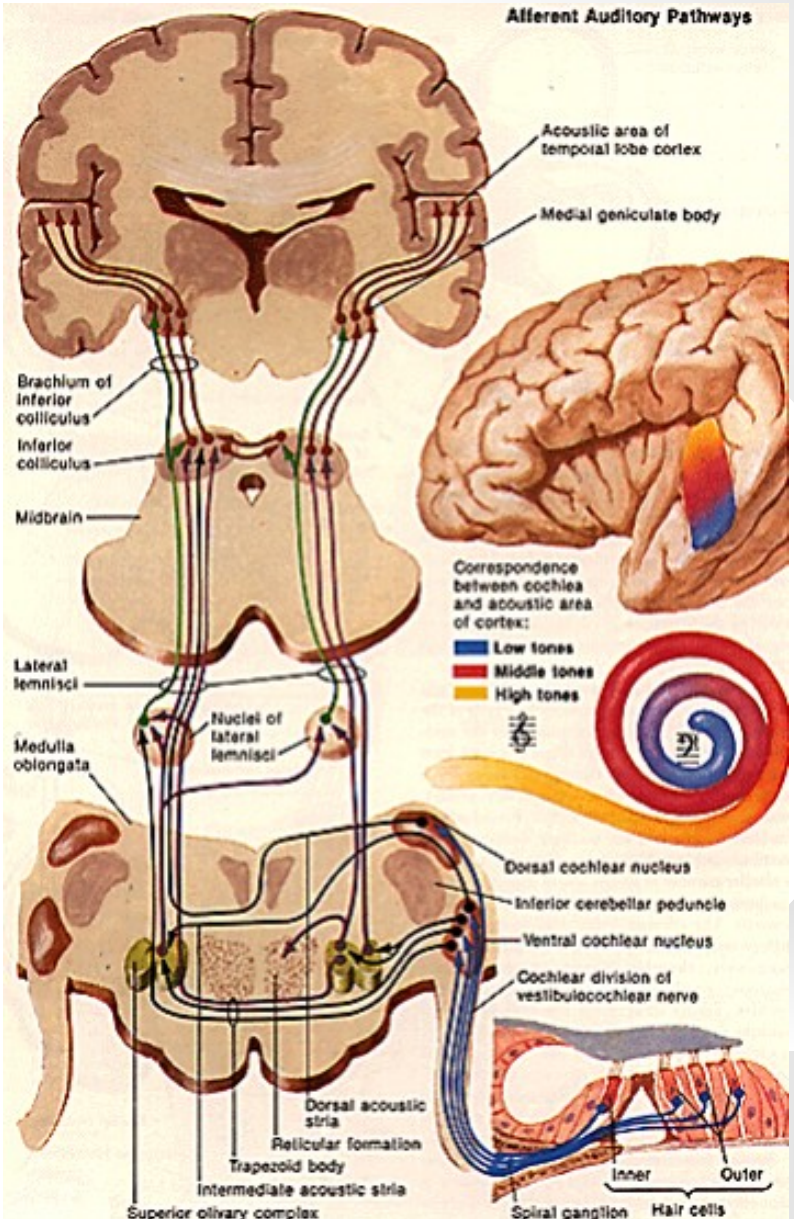
gyrus temporalis superior (gyri temporales transversi of Heschl) - area 41 + 42





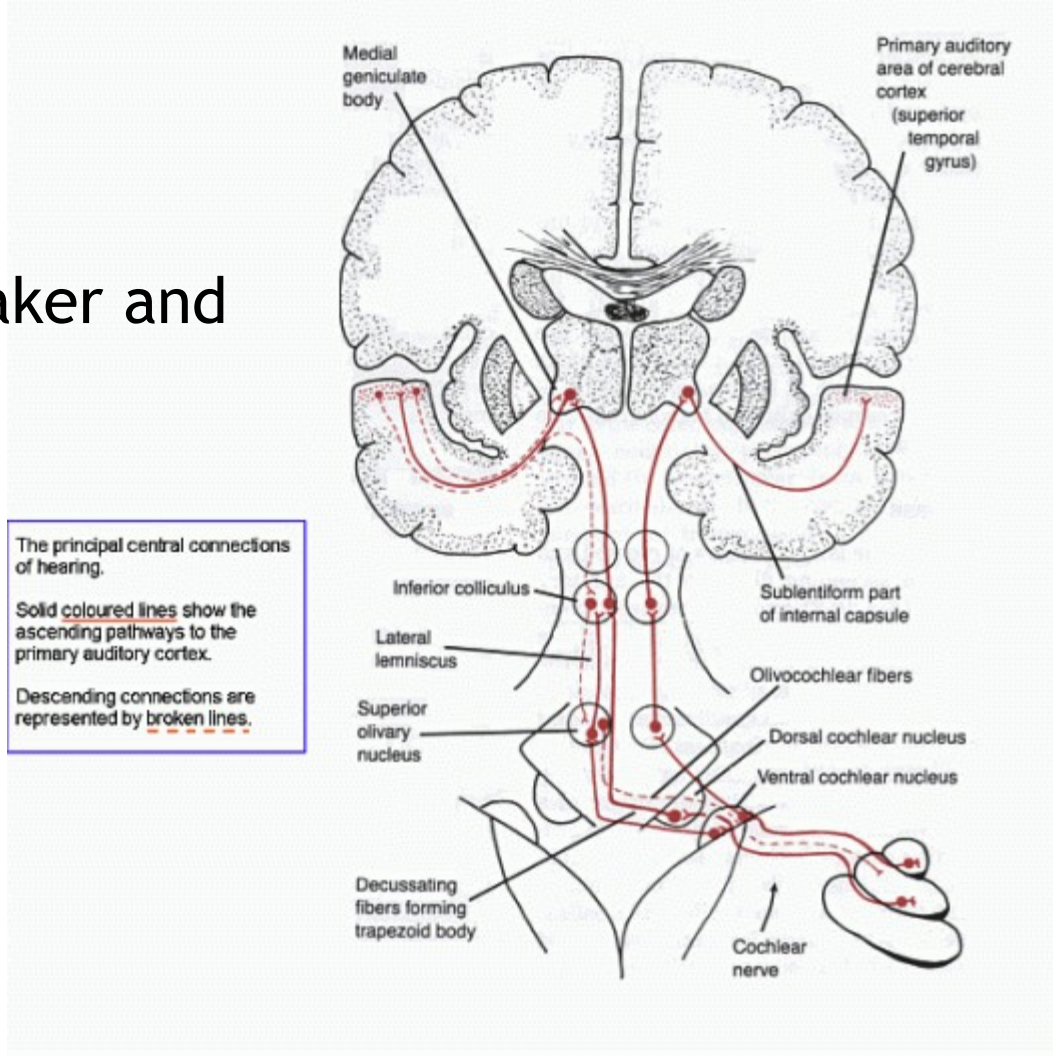
Two functionally significant features:

- ❑ tonotopical organization
- ❑ bilateral projection



DESCENDING PATHWAYS

- feedback system processing ascending information
- enhance signals
- supress noise
- mainly functions of the superior olivary complex
- focus on a particular speaker and inhibit other voices



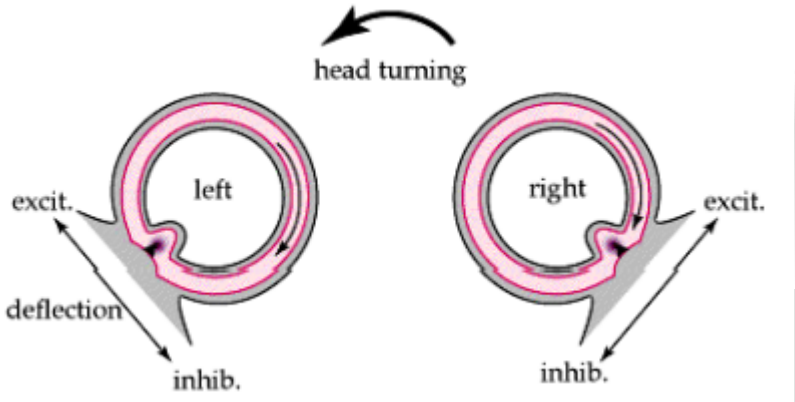
VESTIBULAR PATHWAYS

- changes in the motion of the head (kinetic) and in the position of the head with respect to gravity (static)
- 3 afferent sources: the eyes, general proprioceptive receptors throughout the body, and the vestibular receptors in the inner ear
- to maintain equilibrium, to direct the gaze of the eyes, and to preserve a constant plane of vision

VESTIBULAR APPARATUS

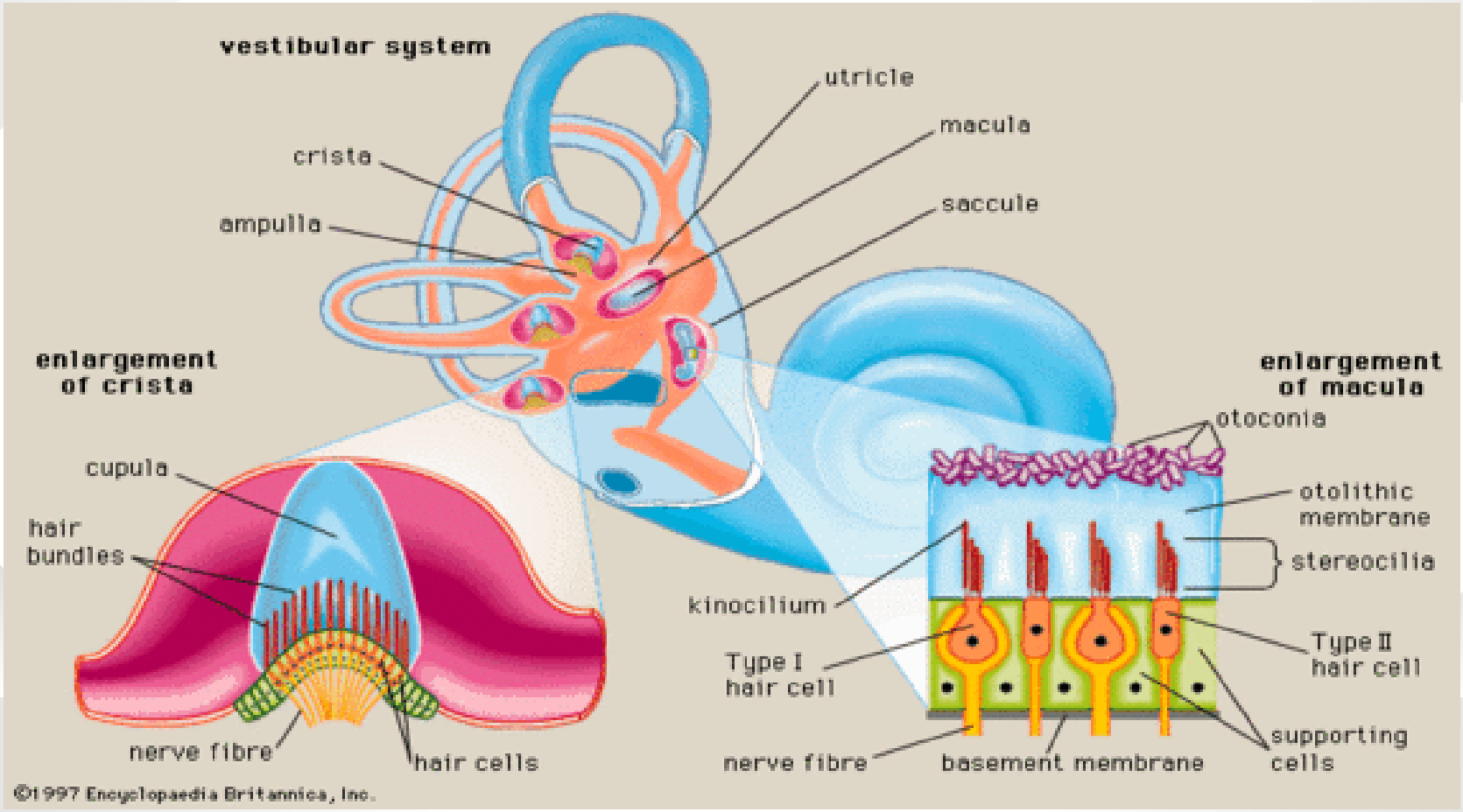
- **Labyrinth of static apparatus**
  - macula utriculi – orientation in horizontal position
  - macula sacculi – orientation in vertical position

- **Labyrinth of kinetic apparatus**
  - cristae ampullares of semicircular ducts



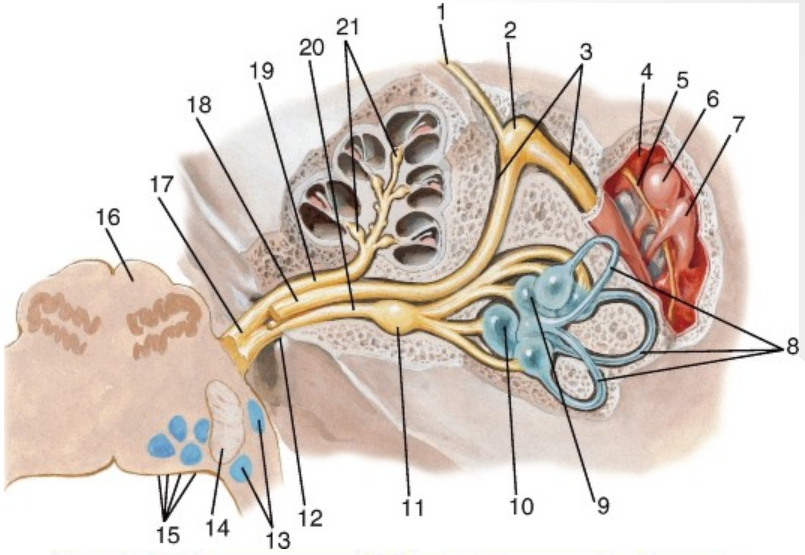
- Hair cells in the maculae of the saccule and the utricle respond to **linear acceleration** (gravity).

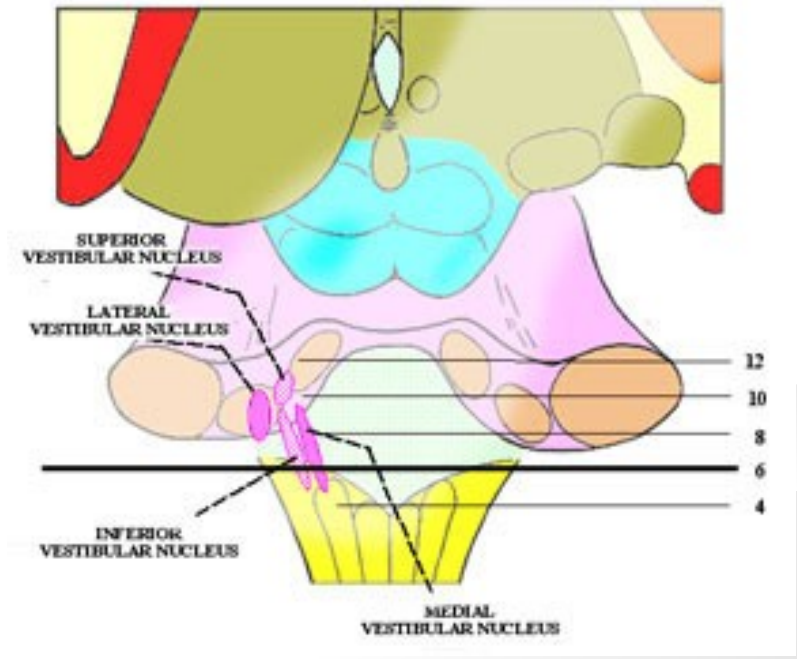
- Hair cells in the cristae ampullares in the semicircular ducts respond to **angular acceleration** (rotation of the head).

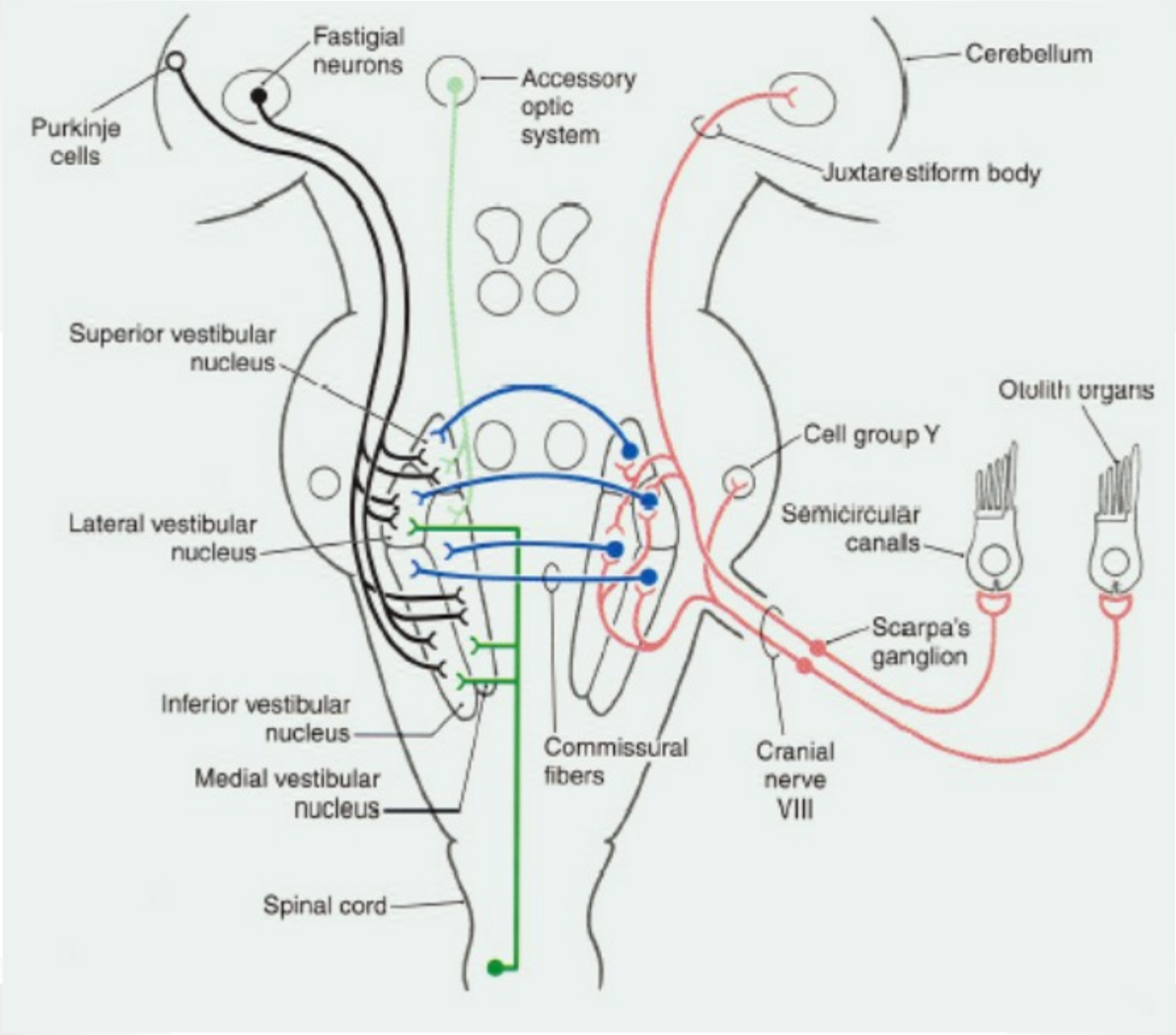


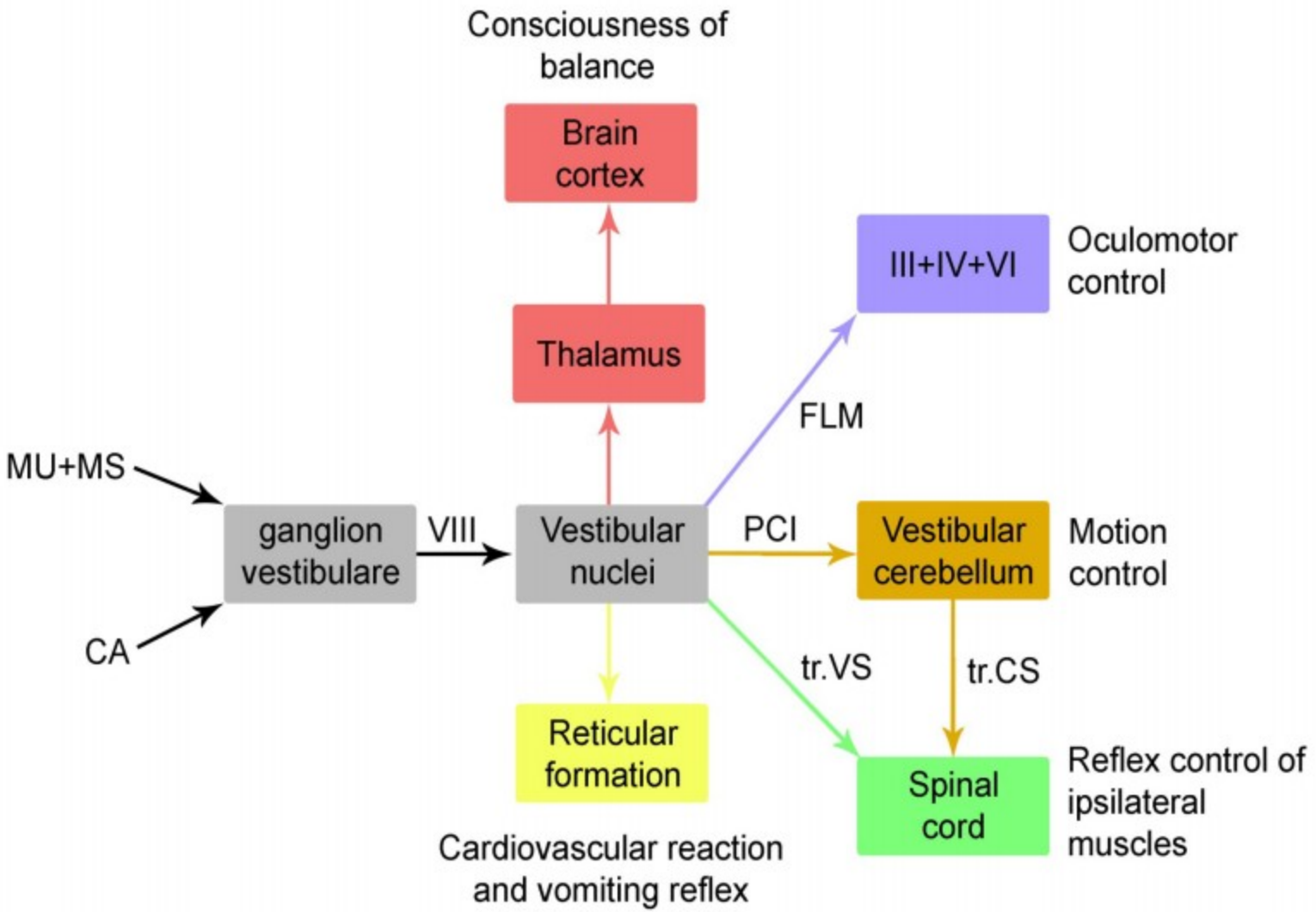
VESTIBULAR PATHWAY

- 1st order neuron – vestibular ganglion (utriculoampullar nerve, saccular nerve, posterior ampullar nerve)
- 2nd order neuron – vestibular nuclei (superior, inferior, medial, lateral)






Fastigial neurons
Purkinje cells
Accessory optic system
Cerebellum
Juxtarestiform body
Superior vestibular nucleus
Otolith organs
Cell group Y
Lateral vestibular nucleus
Semicircular canals
Scarpa's ganglion
Inferior vestibular nucleus
Commissural fibers
Cranial nerve VIII
Medial vestibular nucleus
Spinal cord


Consciousness of balance
Brain cortex
Thalamus
III+IV+VI
Oculomotor control
FLM
MU+MS
CA
ganglion vestibulare
VIII
Vestibular nuclei
PCI
Vestibular cerebellum
Motion control
tr.VS
tr.CS
Reticular formation
Spinal cord
Reflex control of ipsilateral muscles
Cardiovascular reaction and vomiting reflex

Connections with the cerebellum

- vestibular portion of the CN VIII – inferior cerebellar peduncles – ipsilateral vestibulocerebellum
- vestibular nuclei – inferior cerebellar peduncles – vestibulocerebellum

 maintenance of balance

Connections with the spinal cord

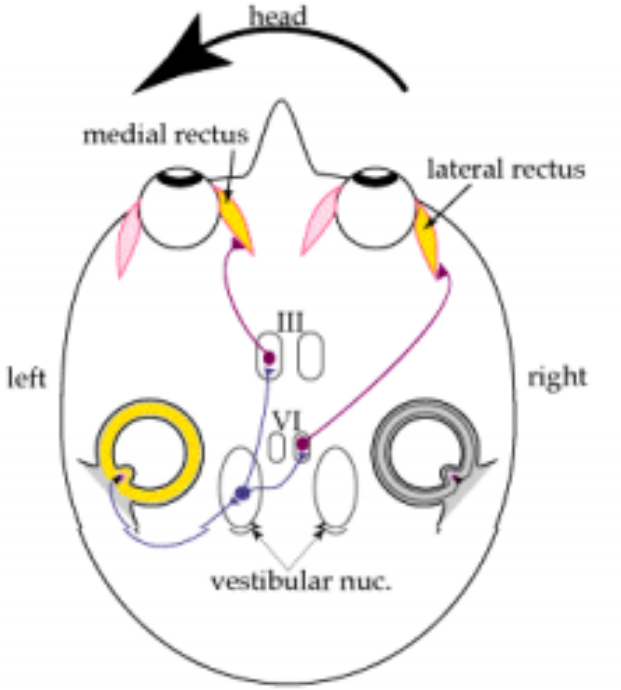
to motoneurons that innervate axial and proximal limb muscles

- **lateral vestibulospinal tract**
  - from lateral vestibular nucleus
  - uncrossed
  - terminating at all levels of the spinal cord
  - excitatory influences for extensors

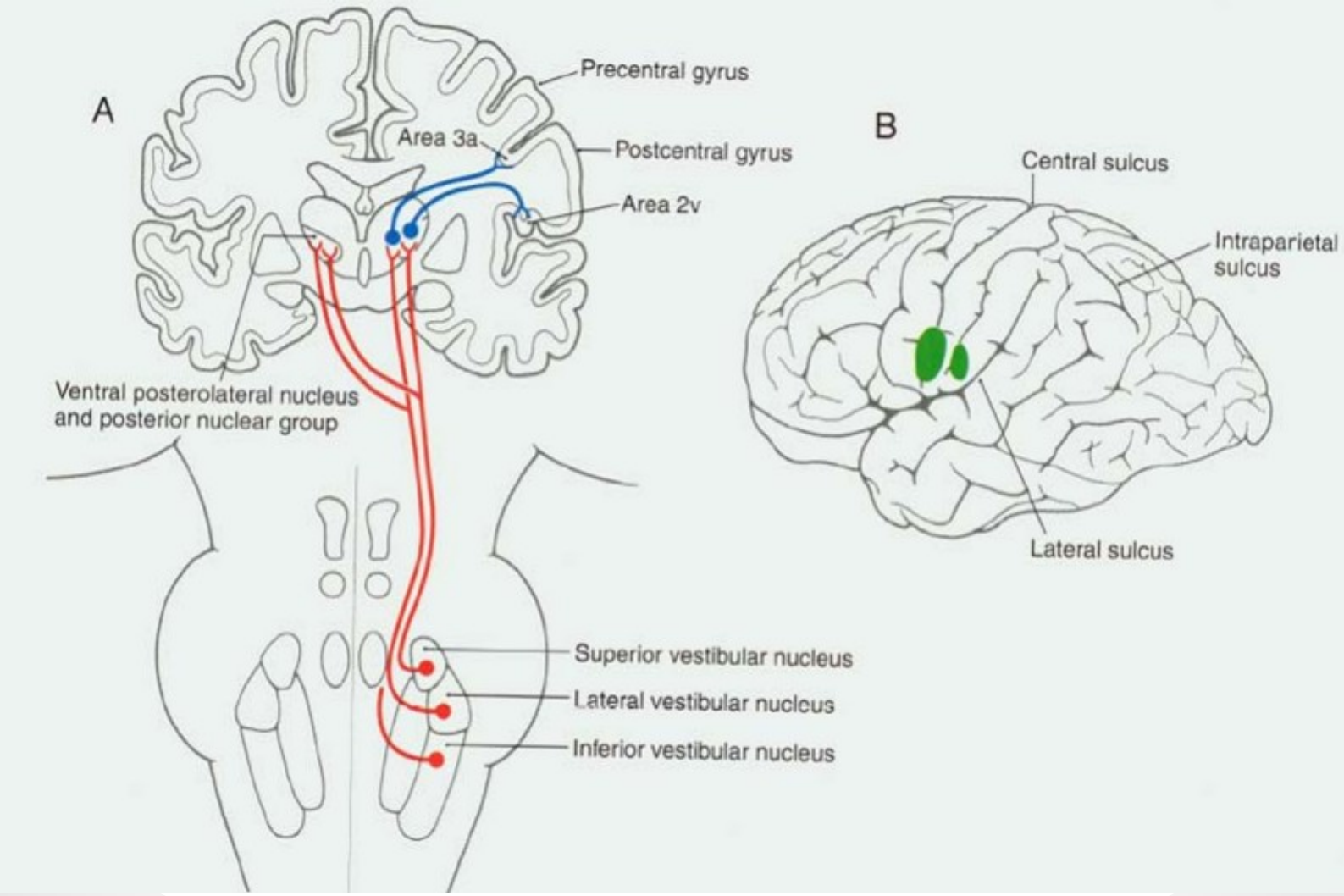
- **medial vestibulospinal tract**
  - from medial vestibular nucleus
  - uncrossed
  - descends in the MLF
  - terminates mainly at cervical levels
  - coordination of head position and eye movements

Connections with the brain stem

- ascending portion of MLF
  - CN III, IV, VI
  - Darkschewitsch and Cajal nuclei
  - coordination of eye movements in response to head movements

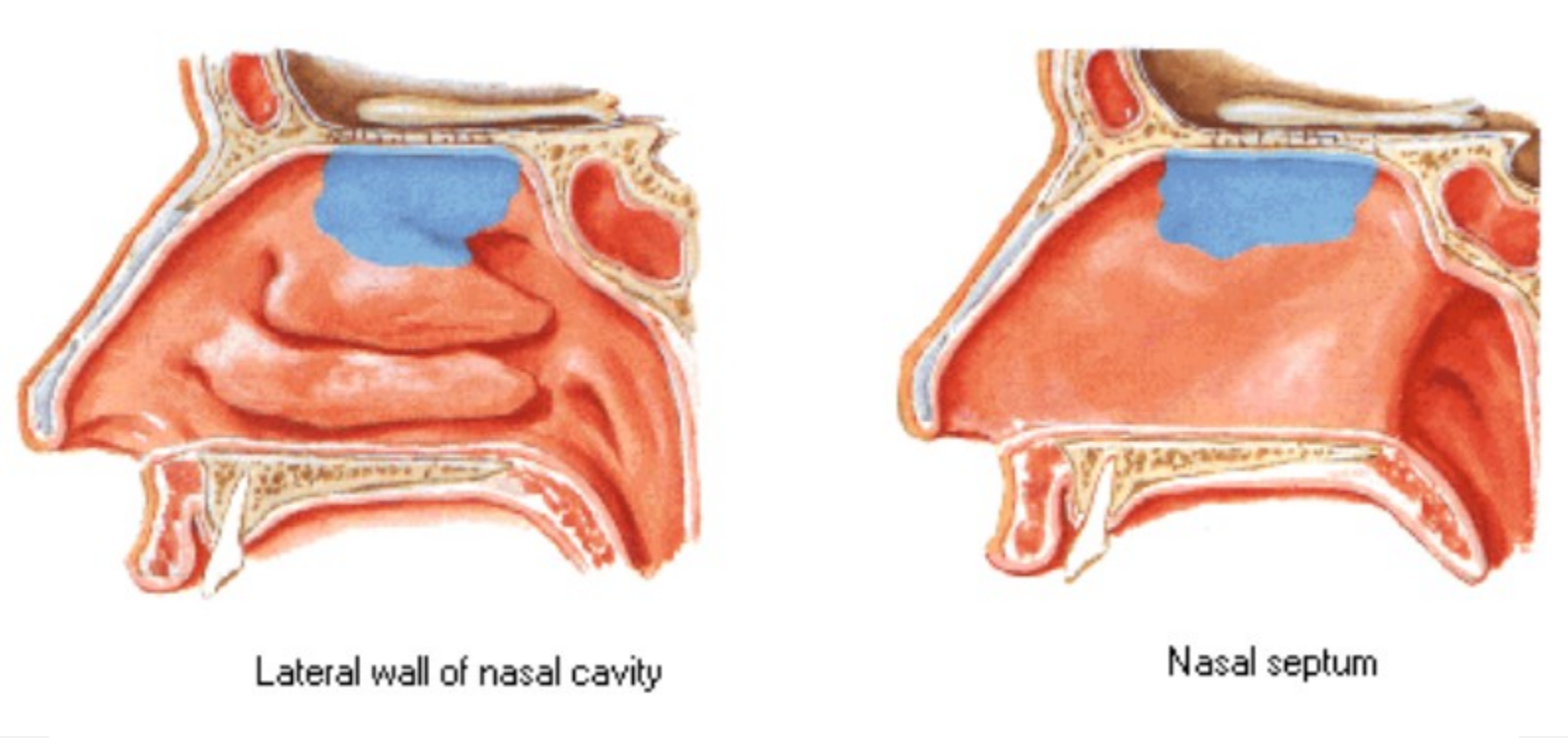


Connection with the thalamus (cortex)



conscious perception of movement and gravity

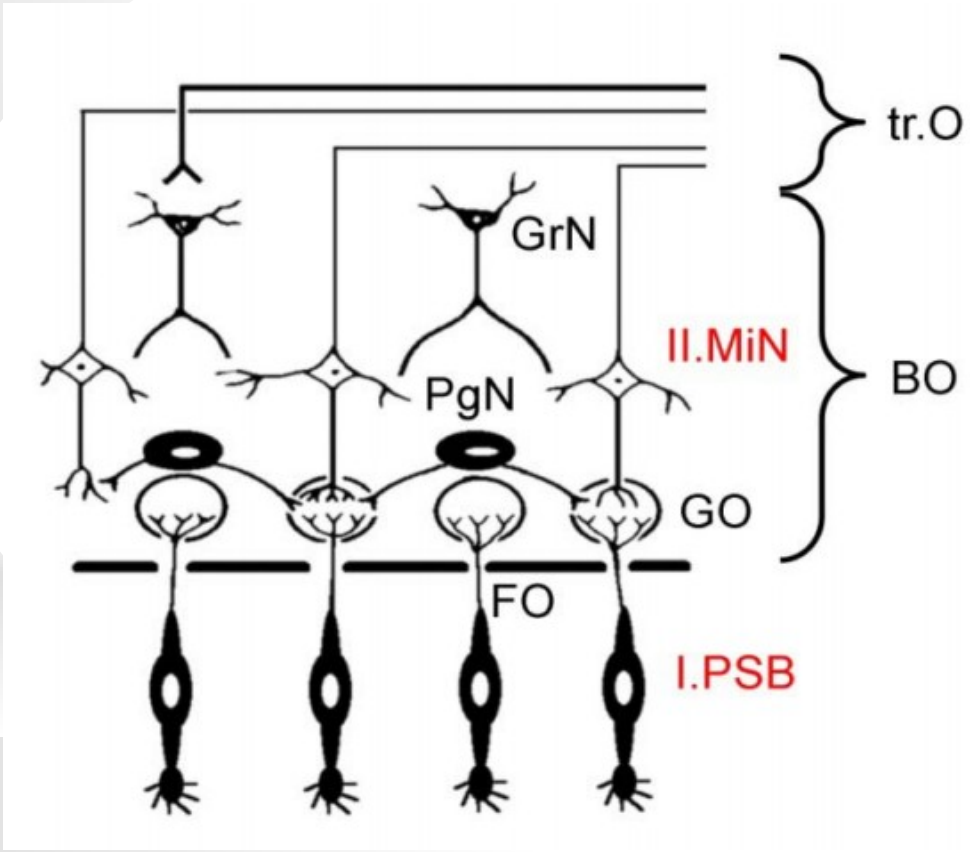
OLFACTORY PATHWAY

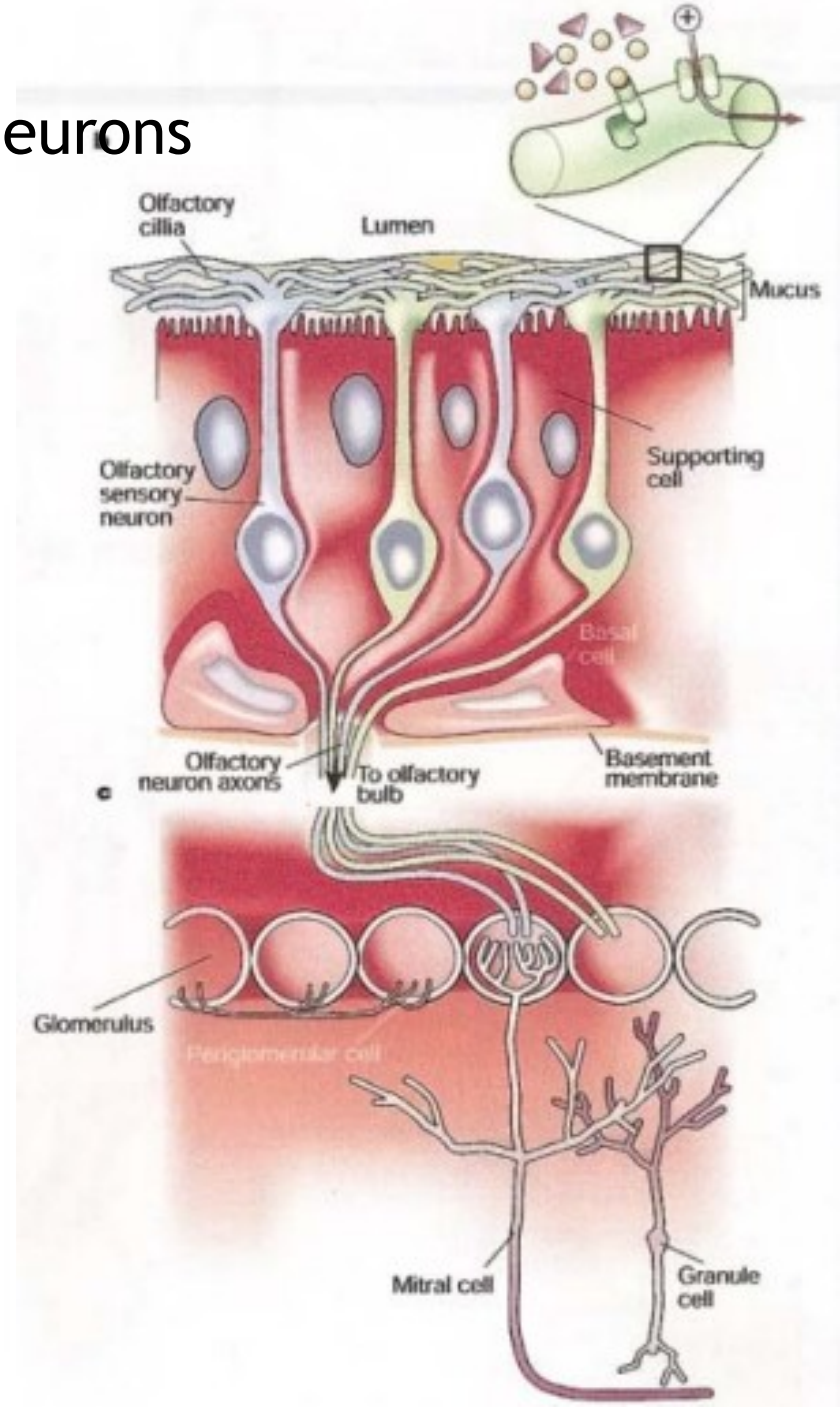


Olfactory region

1st order neuron – bipolar olfactory neurons

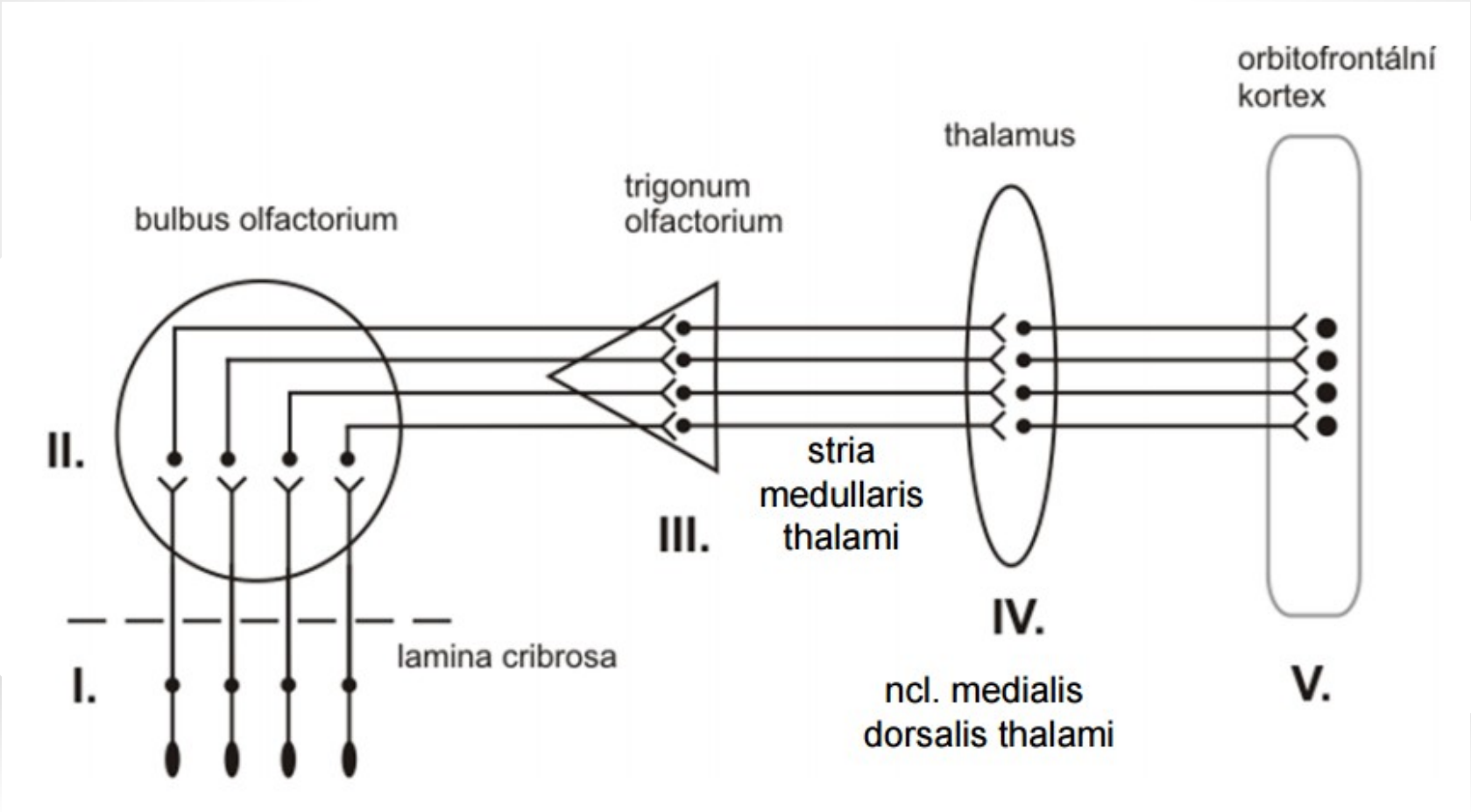
2nd order neuron – mitral cells – olfactory tract



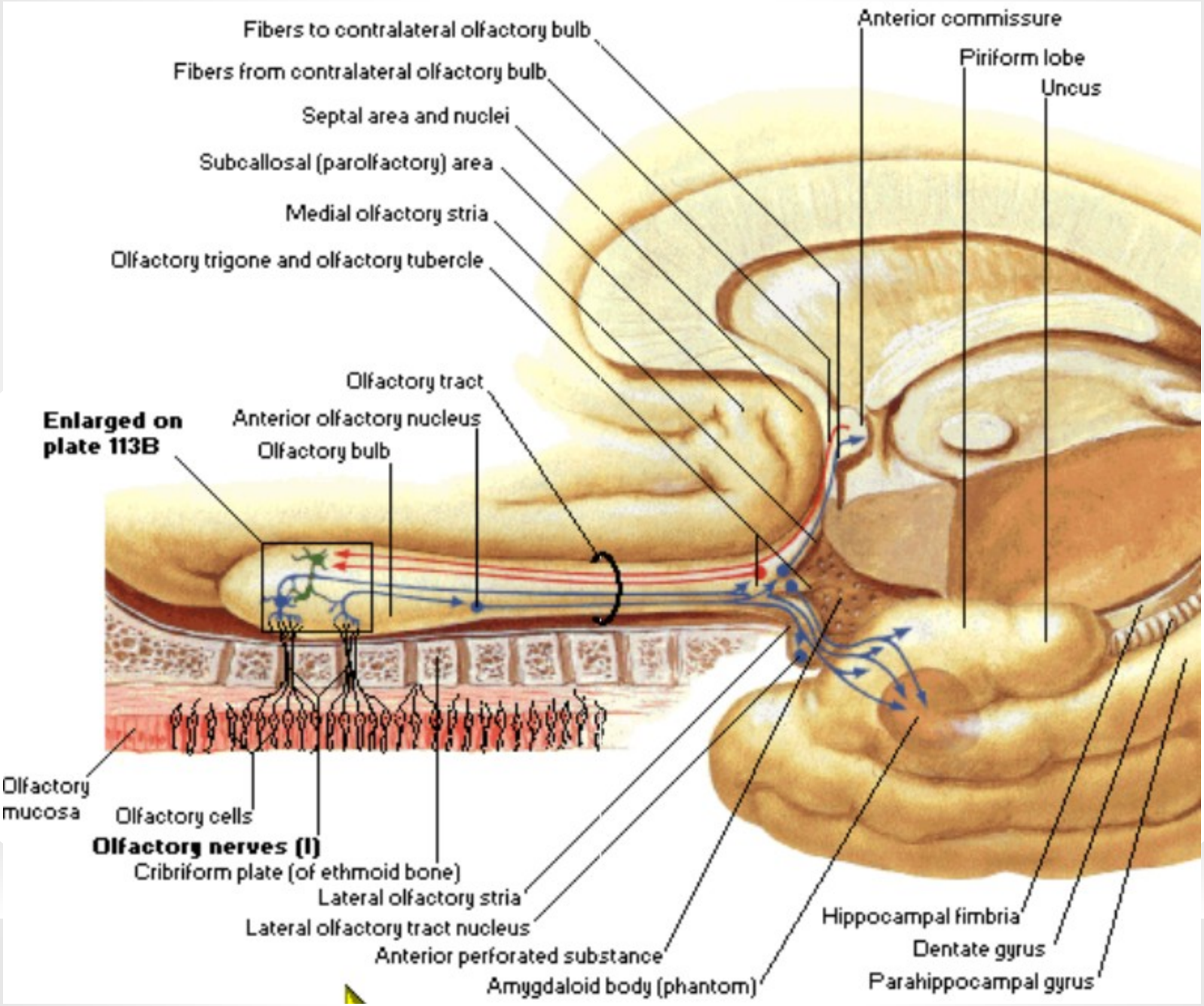


3rd order neuron – olfactory tubercle

4th order neuron – dorsomedial nucleus of thalamus



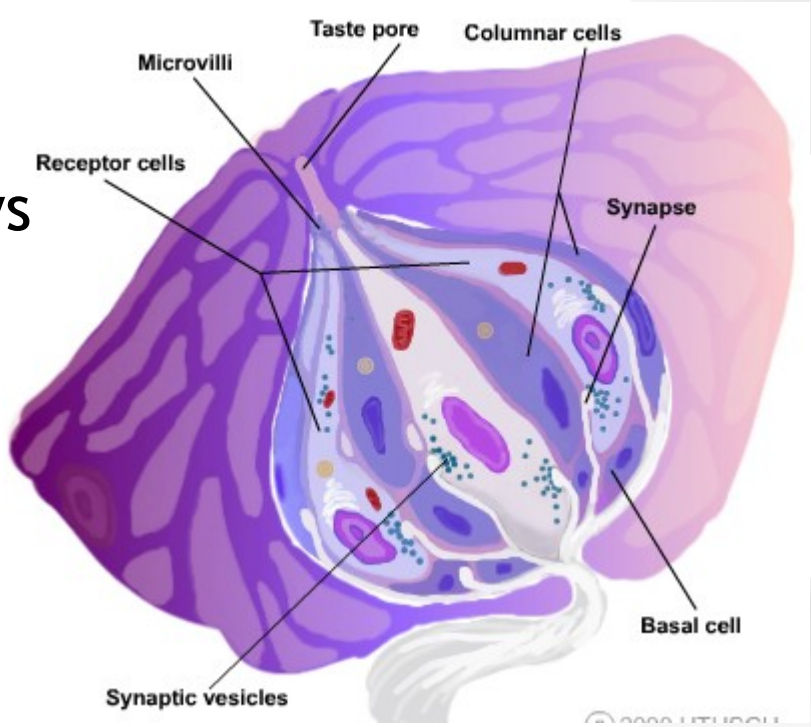
Orbitofrontal cortex (perception of olfactory information)

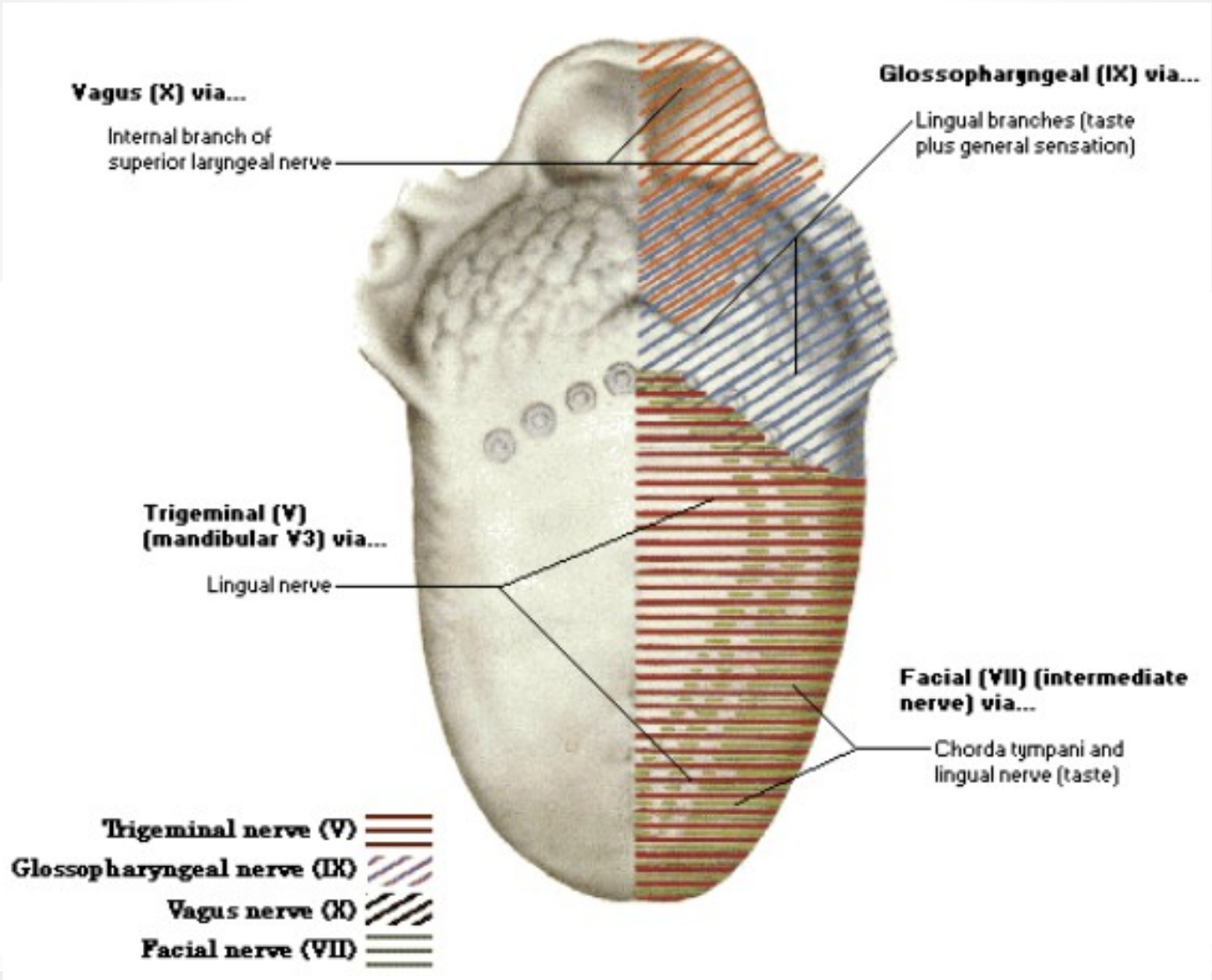

Fibers to contralateral olfactory bulb
Fibers from contralateral olfactory bulb
Septal area and nuclei
Subcallosal (parolfactory) area
Medial olfactory stria
Olfactory trigone and olfactory tubercle
Anterior commissure
Piriform lobe
Uncus
Olfactory tract
Anterior olfactory nucleus
Olfactory bulb
Enlarged on plate 113B
Olfactory mucosa
Olfactory cells
Olfactory nerves (I)
Cribriform plate (of ethmoid bone)
Lateral olfactory stria
Lateral olfactory tract nucleus
Anterior perforated substance
Amygdaloid body (phantom)
Hippocampal fimbria
Dentate gyrus
Parahippocampal gyrus

GUSTATORY PATHWAY

Taste buds

- receptor cells
  (replaced about every 9-10 days
  by differentiating basal cells)
- supportive columnar cells
- basal cells



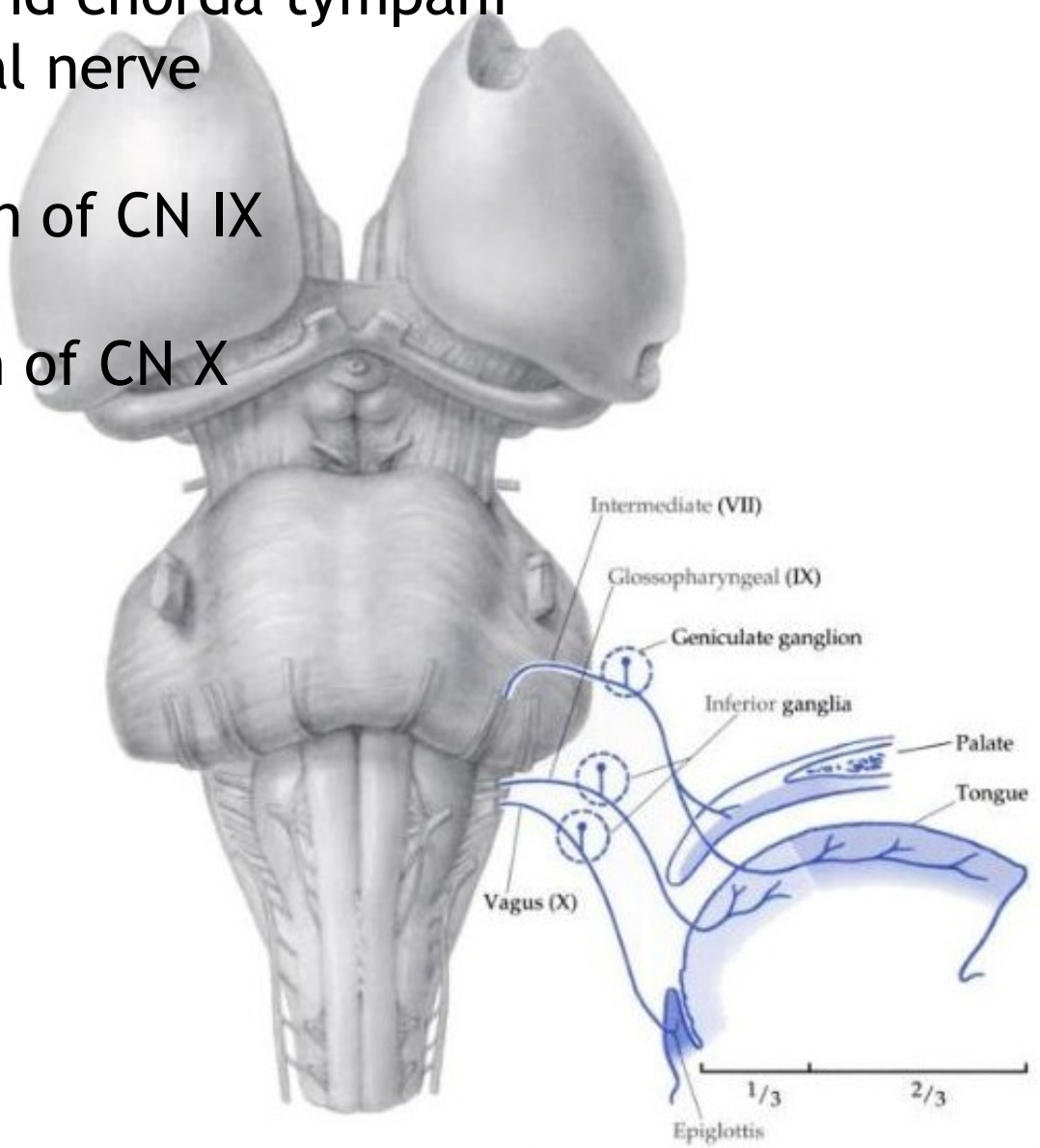

Vagus (X) via...
Internal branch of superior laryngeal nerve
Glossopharyngeal (IX) via...
Lingual branches (taste plus general sensation)
Trigeminal (V) (mandibular V3) via...
Lingual nerve
Facial (VII) (intermediate nerve) via...
Chorda tympani and lingual nerve (taste)
Trigeminal nerve (V)
Glossopharyngeal nerve (IX)
Vagus nerve (X)
Facial nerve (VII)

1st order neuron –

- CN VII –geniculate ganglion
  - via lingual nerve and chorda tympani
  - via greater petrosal nerve

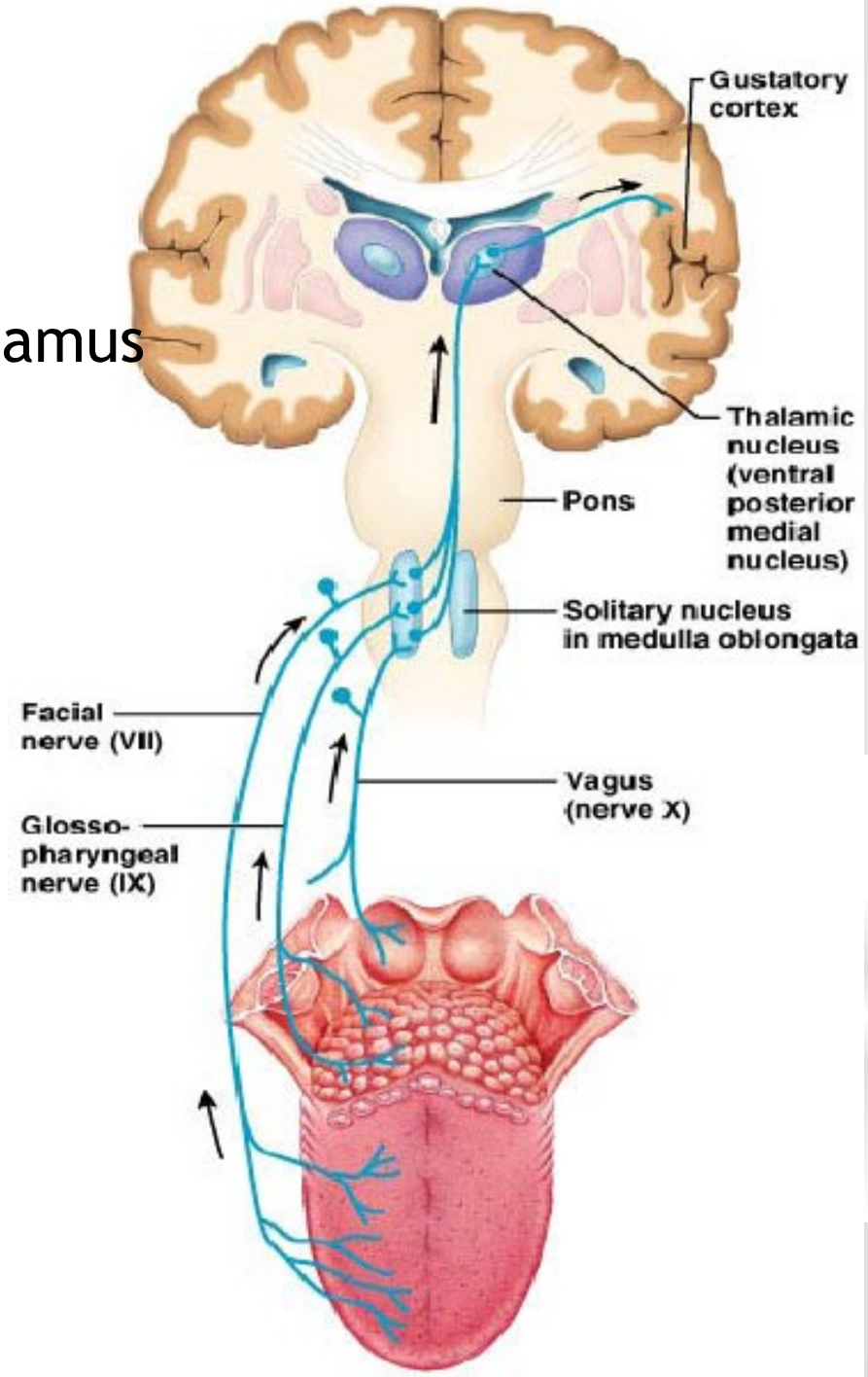
- CN IX – inferior ganglion of CN IX

- CN X – inferior ganglion of CN X



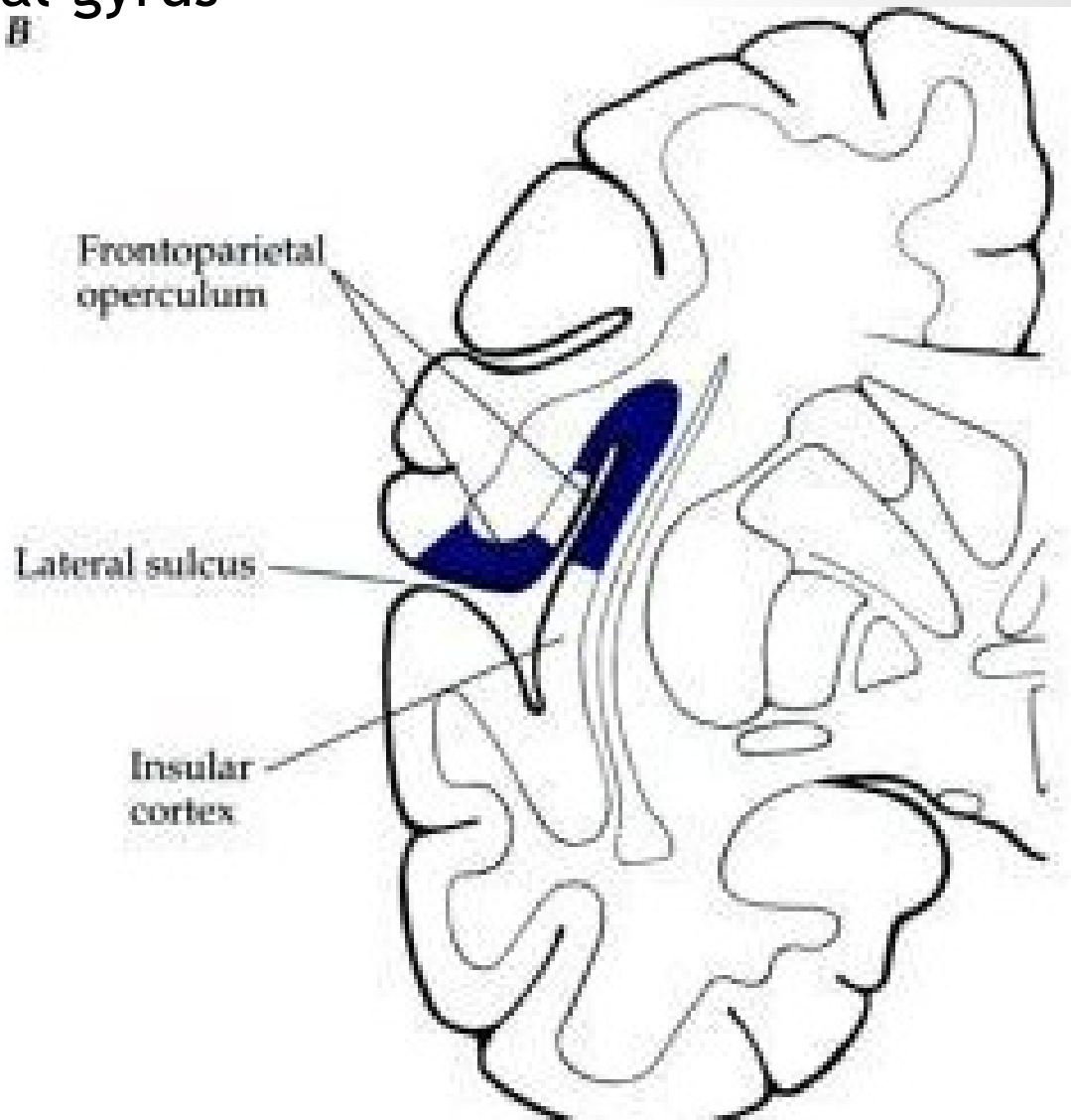
2nd order neuron - rostral part of the solitary nucleus

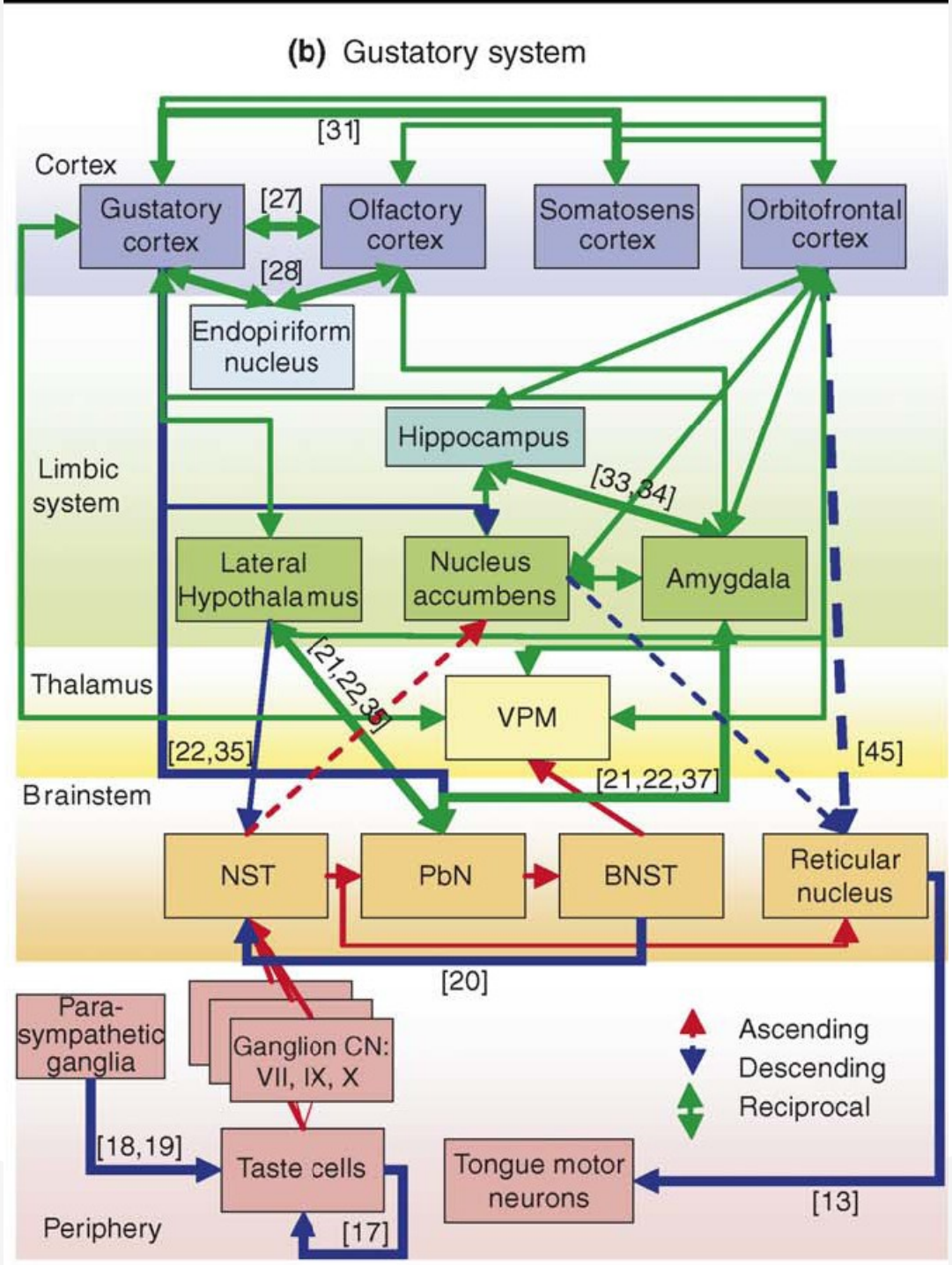
3rd order neuron – ventral posteromedial nucleus of thalamus



Primary gustatory cortex

- a. 43 in the postcentral gyrus
- insula




(b) Gustatory system
[31]
Cortex
Gustatory cortex
[27]
Olfactory cortex
Somatosens cortex
Orbitofrontal cortex
[28]
Endopiriform nucleus
Hippocampus
Limbic system
[33,34]
Lateral Hypothalamus
Nucleus accumbens
Amygdala
[21,22,35]
Thalamus
VPM
[22,35]
[45]
[21,22,37]
Brainstem
NST
PbN
BNST
Reticular nucleus
[20]
Para-sympathetic ganglia
Ganglion CN: VII, IX, X
Ascending
Descending
Reciprocal
[18,19]
Taste cells
Tongue motor neurons
[13]
Periphery
[17]

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