MUNI

MED

Senses
Motor system

Olfactory and gustatory system

Olfaction and sense of taste are closely interconnected „chemical senses“

Olfaction and sense of taste are cl… onnected „chemical senses“

Odour lasts in time

Olfaction

- Ability to sense chemical compounds dispersed in the air
- Influenced evolution of neocortex

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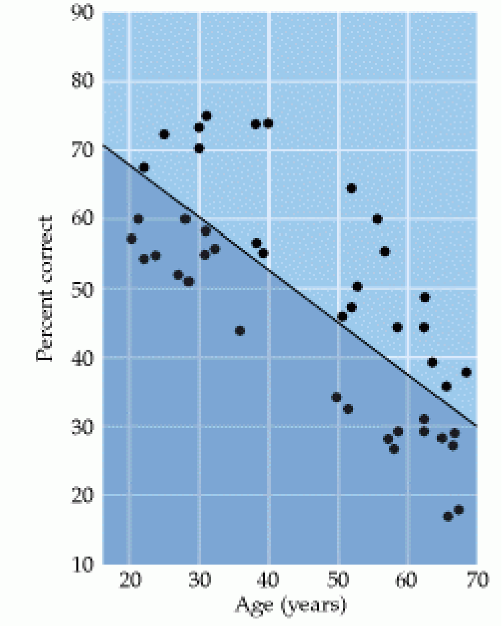
- Place identification
- Food identification

Olfaction

- Ability to sense chemical compounds dispersed in the air
- Influenced evolution of neocortex
- Place identification
- Food identification
- Humans are microolfactoric organisms
  - Loss of analytic capabilities led to a relative enhancement of psychological component

Olfaction

- Humans can distinguish about 80 chemicals and 144-10000 odors
- Better sensitivity to liposoluble molecules
- Olfaction degenerates with age



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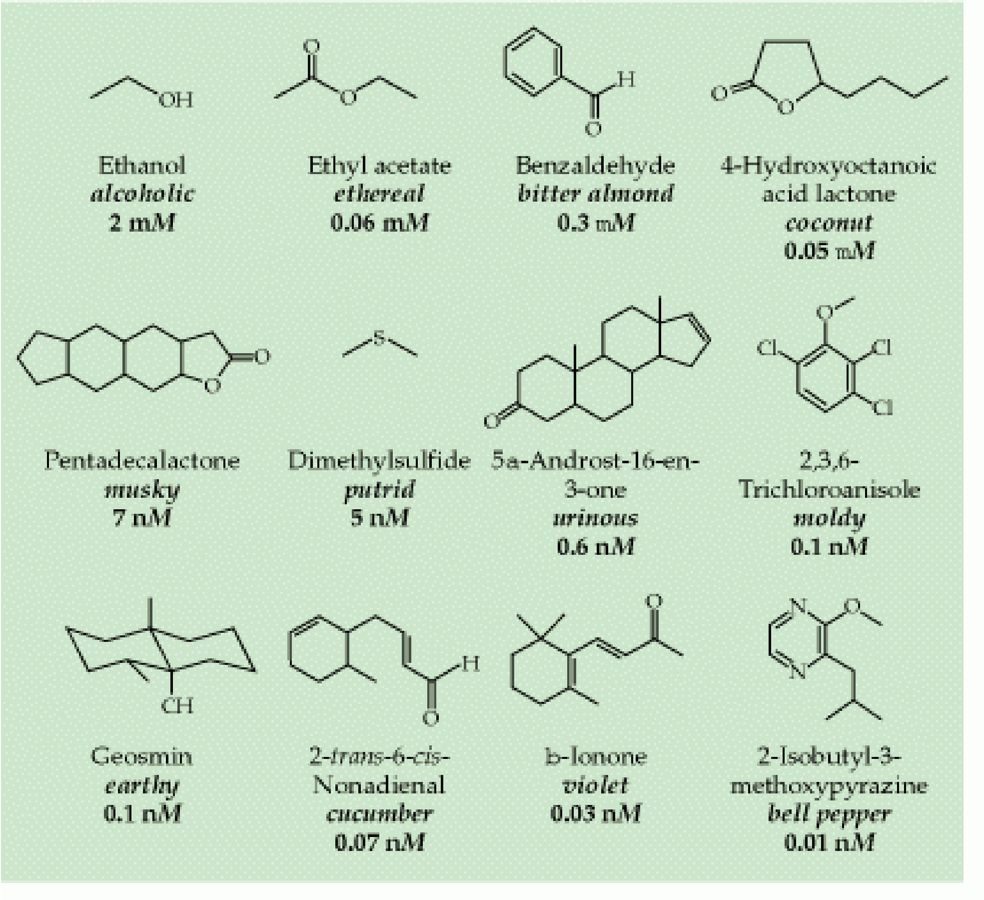

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10 basic categories of odors

- ✓ fragnant
- ✓ woody/resinous
- ✓ fruit (other than citrus)
- ✓ putrid
- ✓ chemical
- ✓ minty/peppermint
- ✓ sweet
- ✓ popcorn
- ✓ burning
- ✓ lemon

Categorical dimensions of human odor descriptor space revealed by non-negative matrix factorization.
Castro JB, Ramanathan A, **Chennubhotla** CS.
PLoS One. 2013 Sep 18;8(9):e73289. doi: 10.1371/journal.pone.0073289. eCollection 2013.
PMID:24058466

10 largest-valued descriptors for each of the 10 basis vectors obtained from non-negative matrix factorization.

W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
FRAGRANT	WOODY, RESINOUS	FRUITY, OTHER THAN CITRUS	SICKENING	CHEMICAL	MINTY, PEPPERMINT	SWEET	POPCORN	SICKENING	LEMON
FLORAL	MUSTY, EARTHY, MOLDY	SWEET	PUTRID, FOUL, DECAYED	ETHERISH, ANAESTHETIC	COOL, COOLING	VANILLA	BURNT, SMOKY	GARLIC, ONION	FRUITY, CITRUS
PERFUMERY	CEDARWOOD	FRAGRANT	RANCID	MEDICINAL	AROMATIC	FRAGRANT	PEANUT BUTTER	HEAVY	FRAGRANT
SWEET	HERBAL, GREEN, CUT GRASS	AROMATIC	SWEATY	DISINFECTANT, CARBOLIC	ANISE (LICORICE)	AROMATIC	NUTTY (WALNUT ETC)	BURNT, SMOKY	ORANGE
ROSE	FRAGRANT	LIGHT	SOUR, VINEGAR	SHARP, PUNGENT, ACID	FRAGRANT	CHOCOLATE	OILY, FATTY	SULFIDIC	LIGHT
AROMATIC	AROMATIC	PINEAPPLE	SHARP, PUNGENT, ACID	GASOLINE, SOLVENT	MEDICINAL	MALTY	ALMOND	SHARP, PUNGENT, ACID	SWEET
LIGHT	LIGHT	CHERRY (BERRY)	FECAL (LIKE MANURE)	PAINT	SPICY	ALMOND	HEAVY	HOUSEHOLD GAS	COOL, COOLING
COLOGNE	HEAVY	STRAWBERRY	SOUR MILK	CLEANING FLUID	SWEET	CARAMEL	WARM	PUTRID, FOUL, DECAYED	AROMATIC
HERBAL, GREEN, CUT GRASS	SPICY	PERFUMERY	MUSTY, EARTHY, MOLDY	ALCOHOLIC	EUCALIPTUS	LIGHT	MUSTY, EARTHY, MOLDY	SEWER	HERBAL, GREEN, CUT GRASS
VIOLETS	BURNT, SMOKY	BANANA	HEAVY	TURPENTINE (PINE OIL)	CAMPHOR	WARM	WOODY, RESINOUS	BURNT RUBBER	SHARP, PUNGENT, ACID

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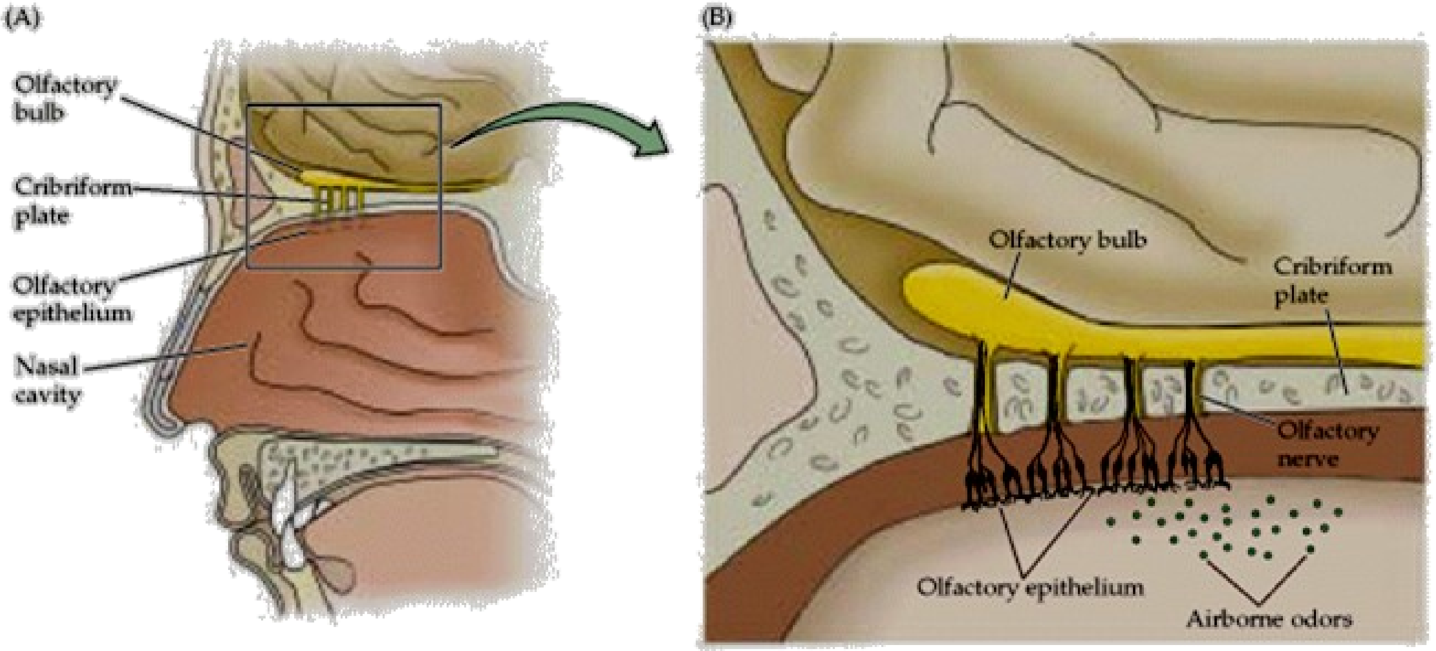
Olfaction



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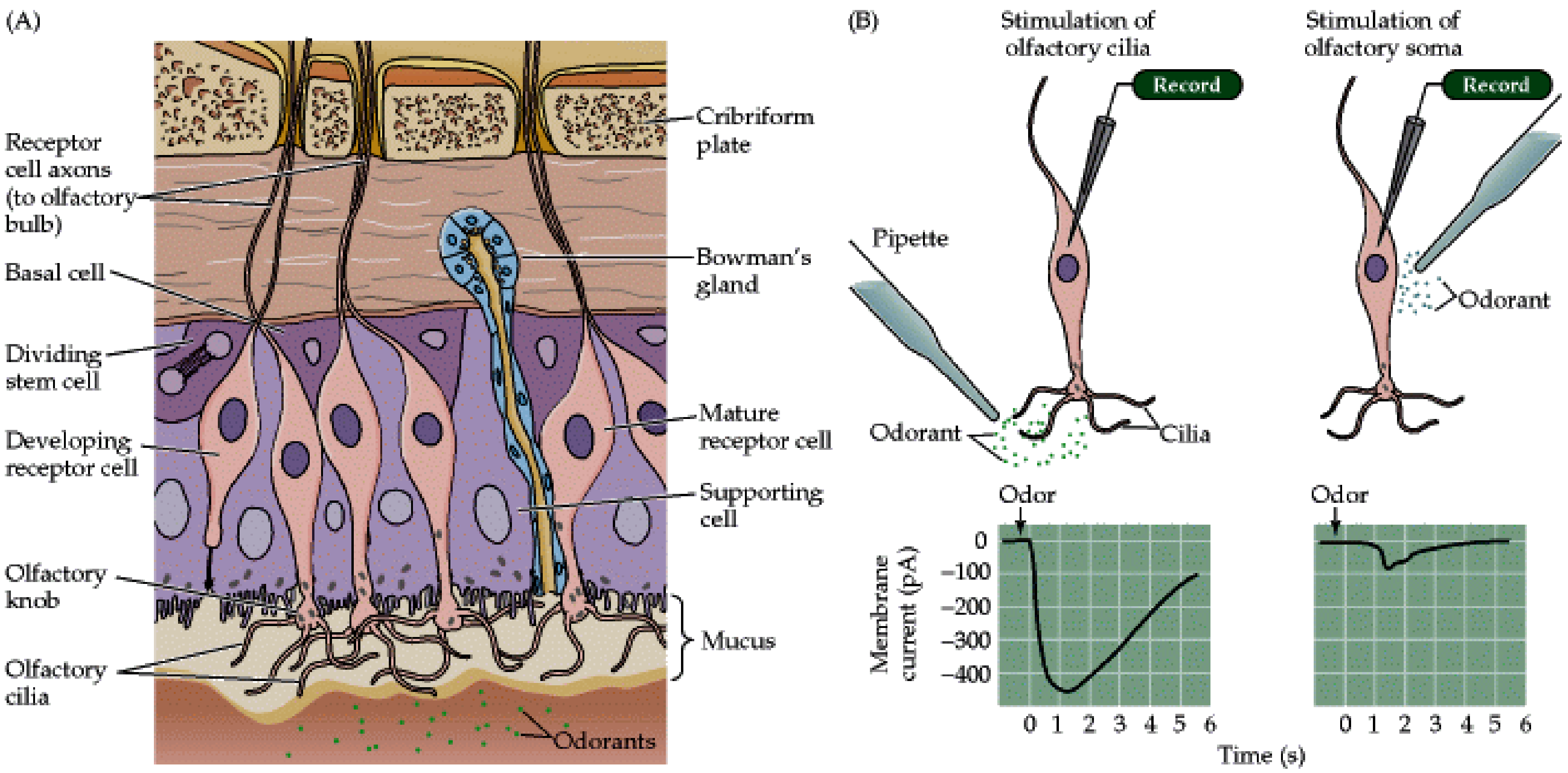
Olfaction



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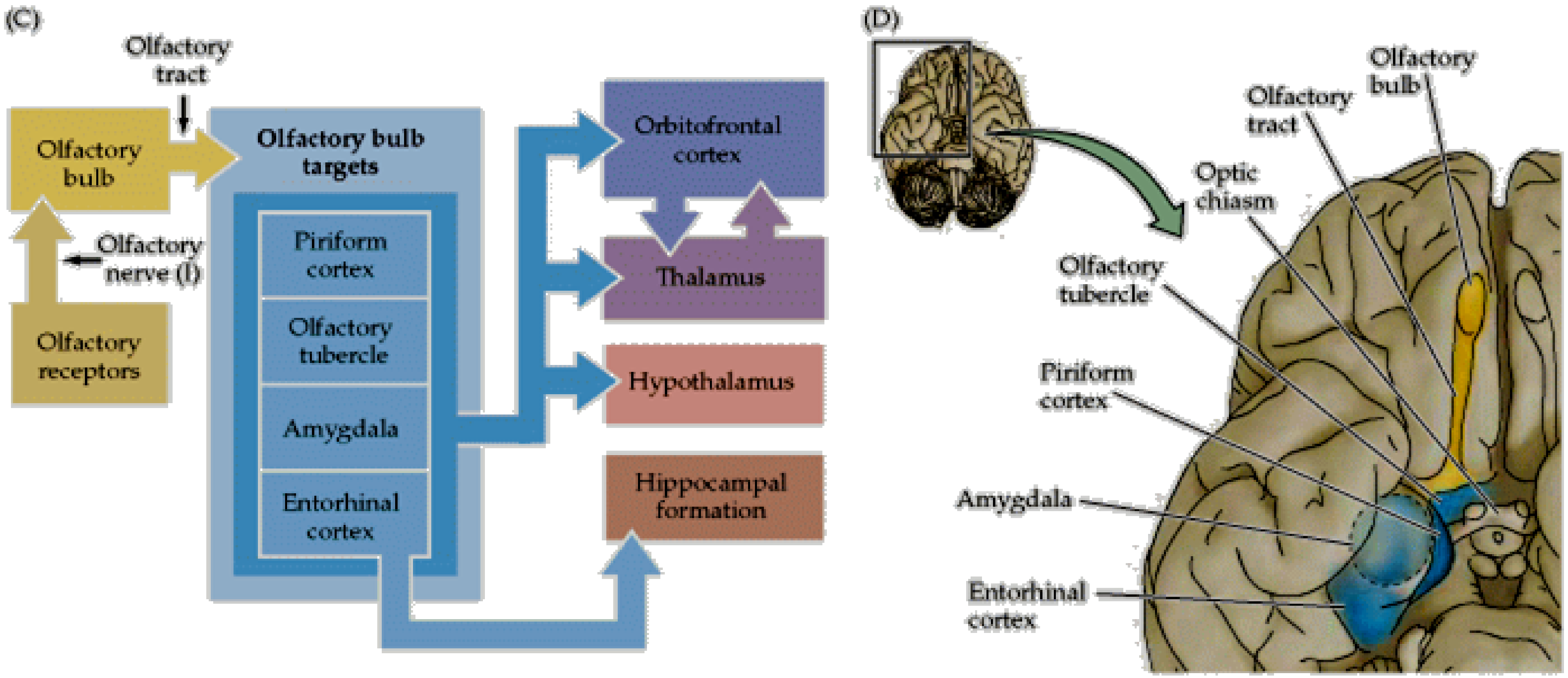
Olfaction



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Sense of taste

- Ability to sense chemical compounds dissolved in saliva
- Close connection with olfaction
- Food identification
- Connection to the reward system

Sense of taste

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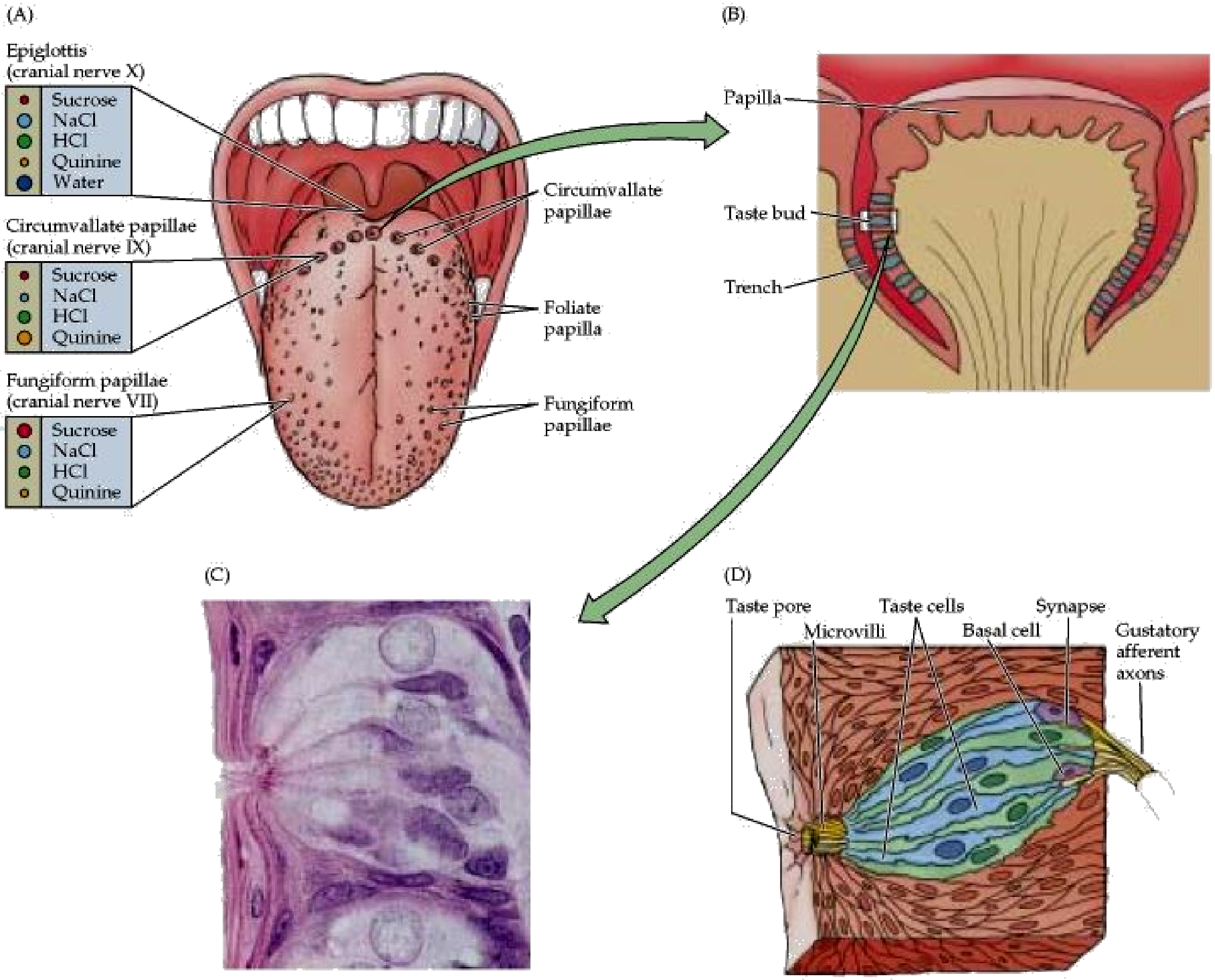
✓ Sweet
✓ Salty
✓ Sour
✓ Bitter

✓ Umami
➢ Taste-mGluR4 receptor – L - glutamate

✓ Hot
➢ Nociceptors and thermoreceptors

Gustatory system



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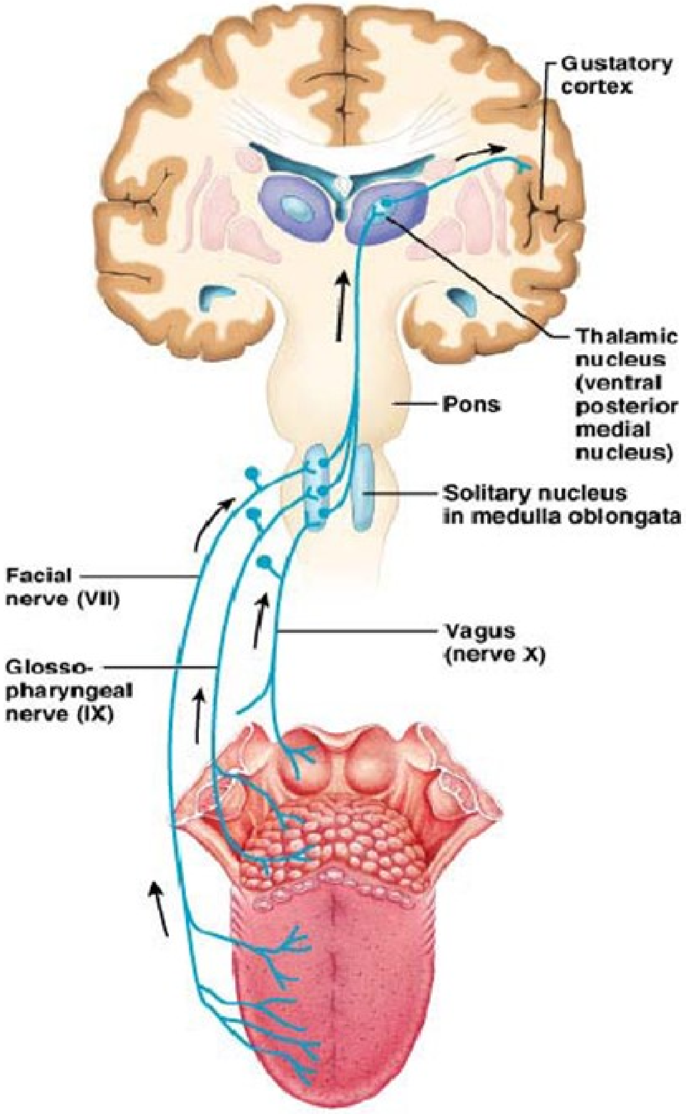
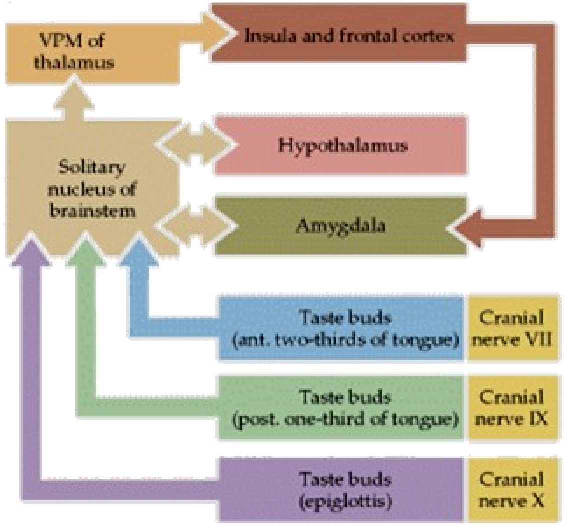
Gustatory system





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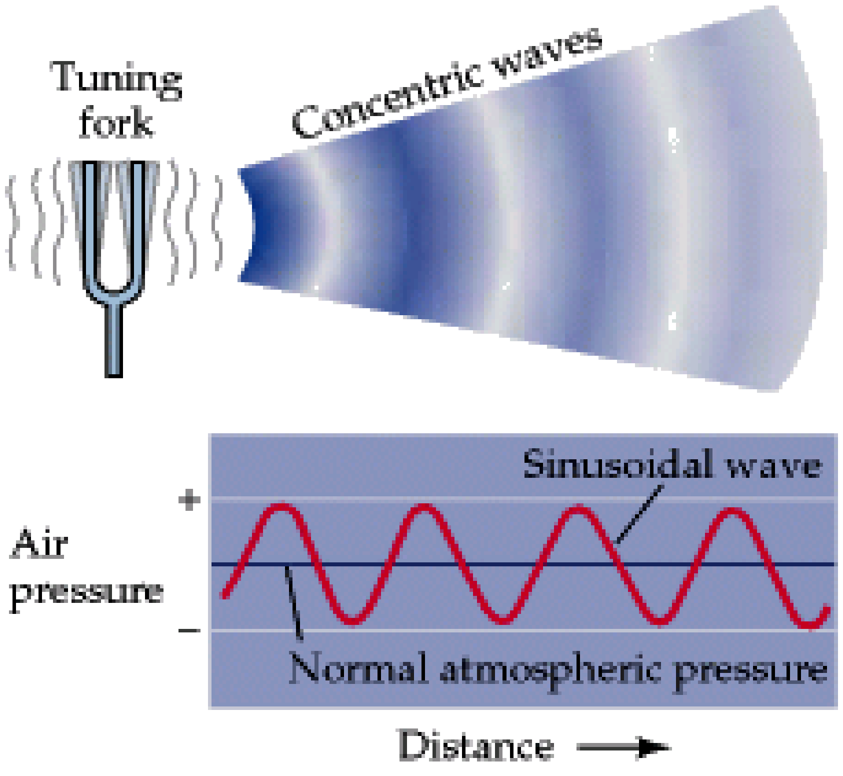
http://media.tumblr.com/1abd820225a3792d0787cd3b53ada989/tumblr_inline_mqyyza95I71qz4rgp.png

Auditory and vestibular system

Auditory system

- Transduction of sound waves to the receptor and the action potential
- Transmission to CNS
- Signal processing
  - Sound decoding
  - Interpretation

Sound is audible mechanical vibration of an elastic medium such as air



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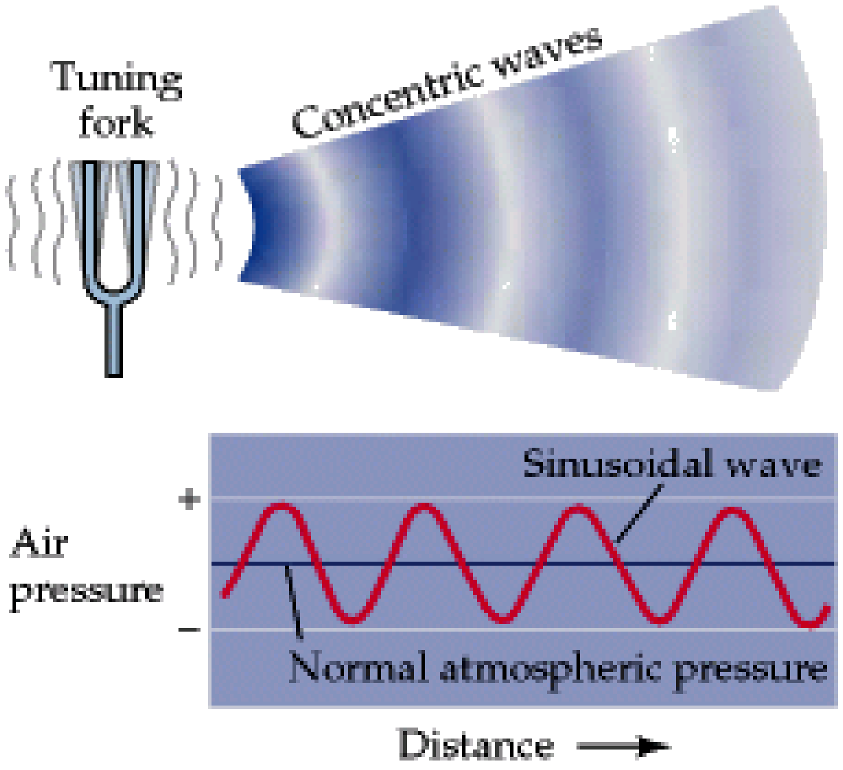
Auditory system

- Produced by vibration of solid object in the air or water
- Sound characteristics
  - Frequency – pitch
  - Amplitude – intensity
  - Timbre – given by representation of harmonic frequencies of the oscillation
- Pure tone
- Complex sound



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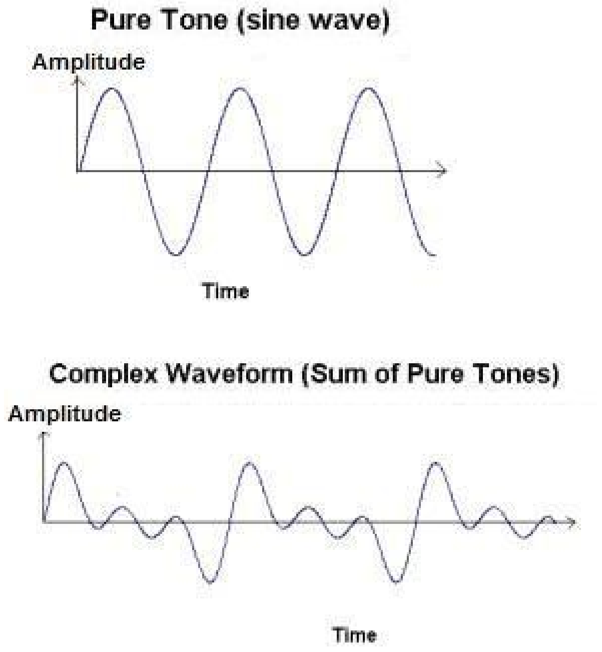
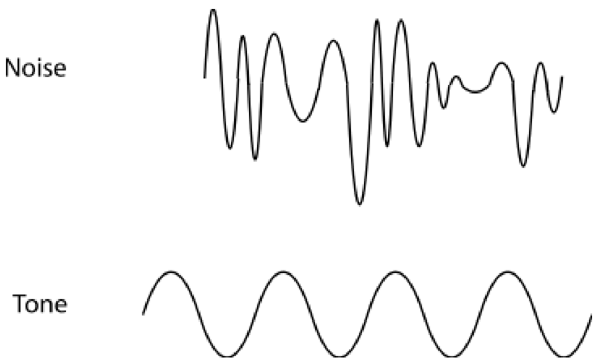
Sound

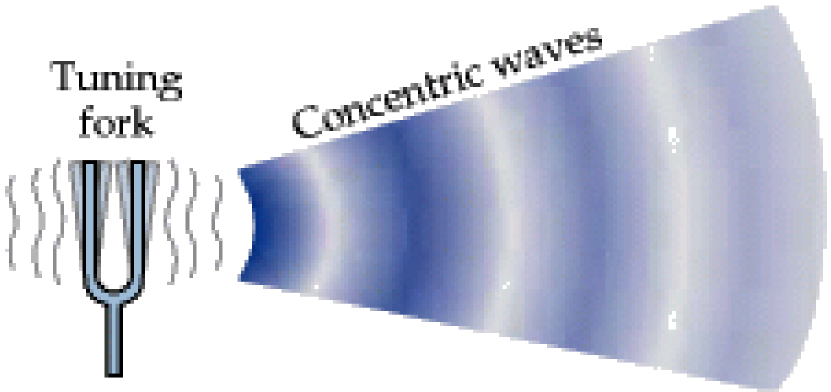
- Pure tone
  - Determined by frequency
- Complex sound
  - Sum of pure tones
  - ➢ Harmonic (musical)
    - periodic
  - ➢ Disharmonic (noise)
    - aperiodic

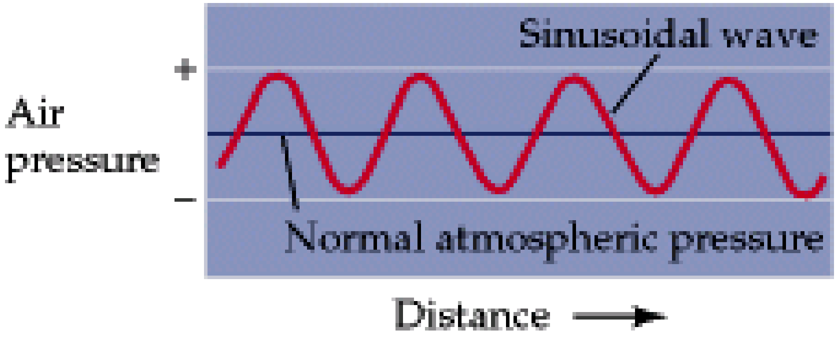


http://www.acoustics.salford.ac.uk/acoustics_info/sound_synthesis/



http://www.earmaster.com/music-theory-online/ch03/chapter-3-2.html





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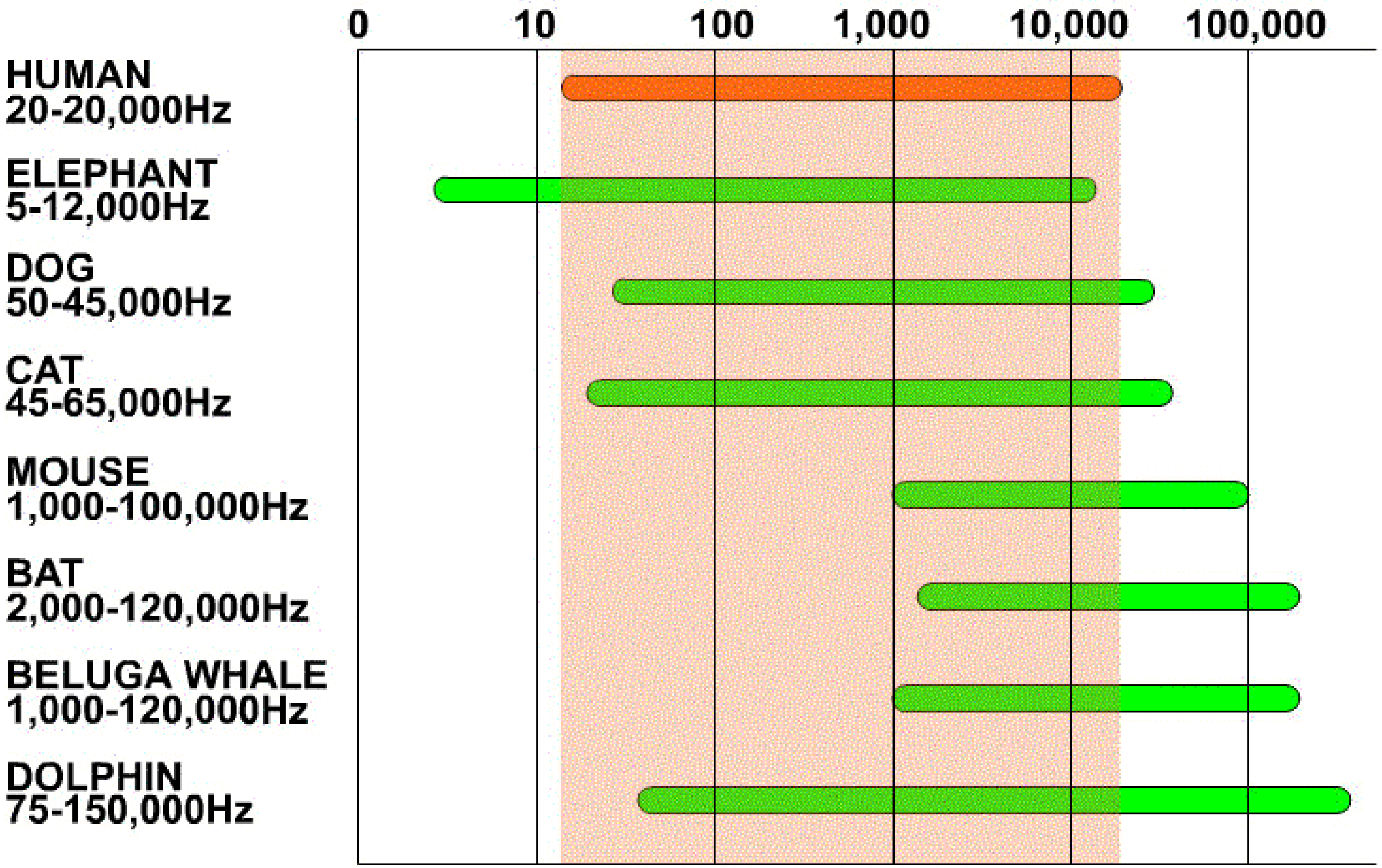
Audible spectrum



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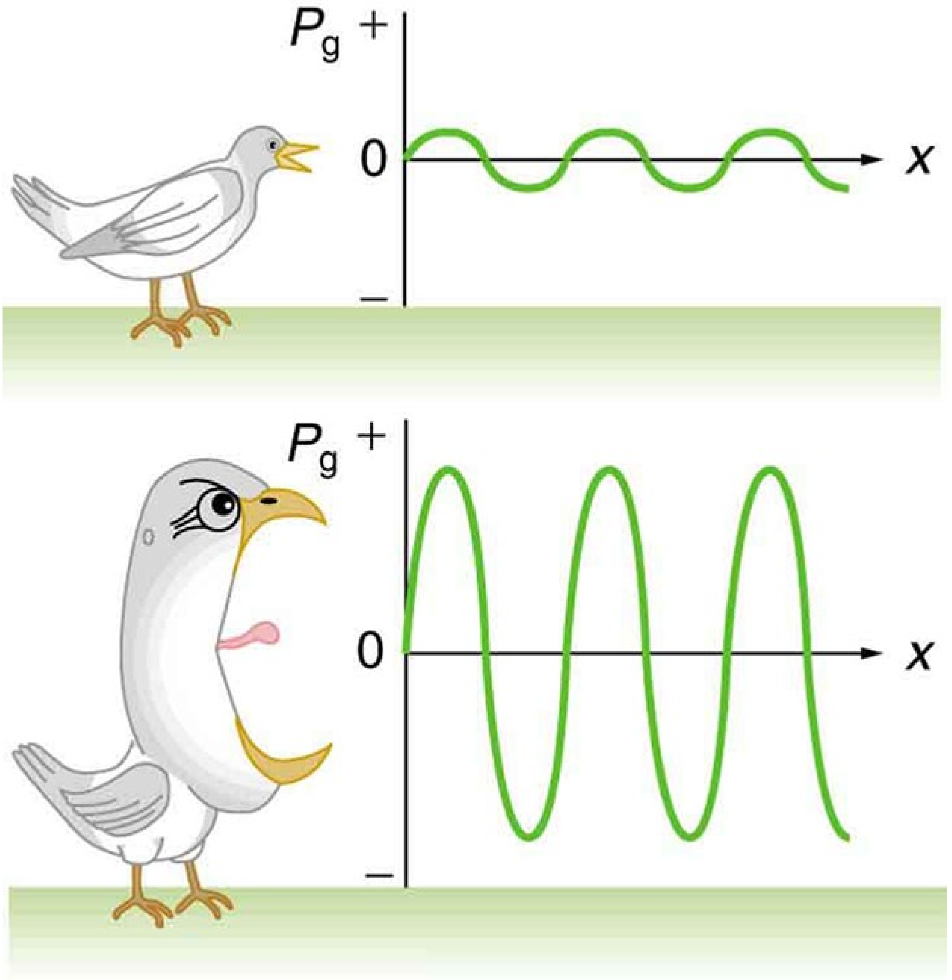
The intensity and volume of sound

- Intensity of sound
  - Amplitude
  - ➢ Whisper – 20 dB
  - ➢ Speaking - 65 dB
  - ➢ Jet engine – 100 dB
  - ➢ Pain treshold – 120 dB



- Volume
  - Subjectively perceived intensity

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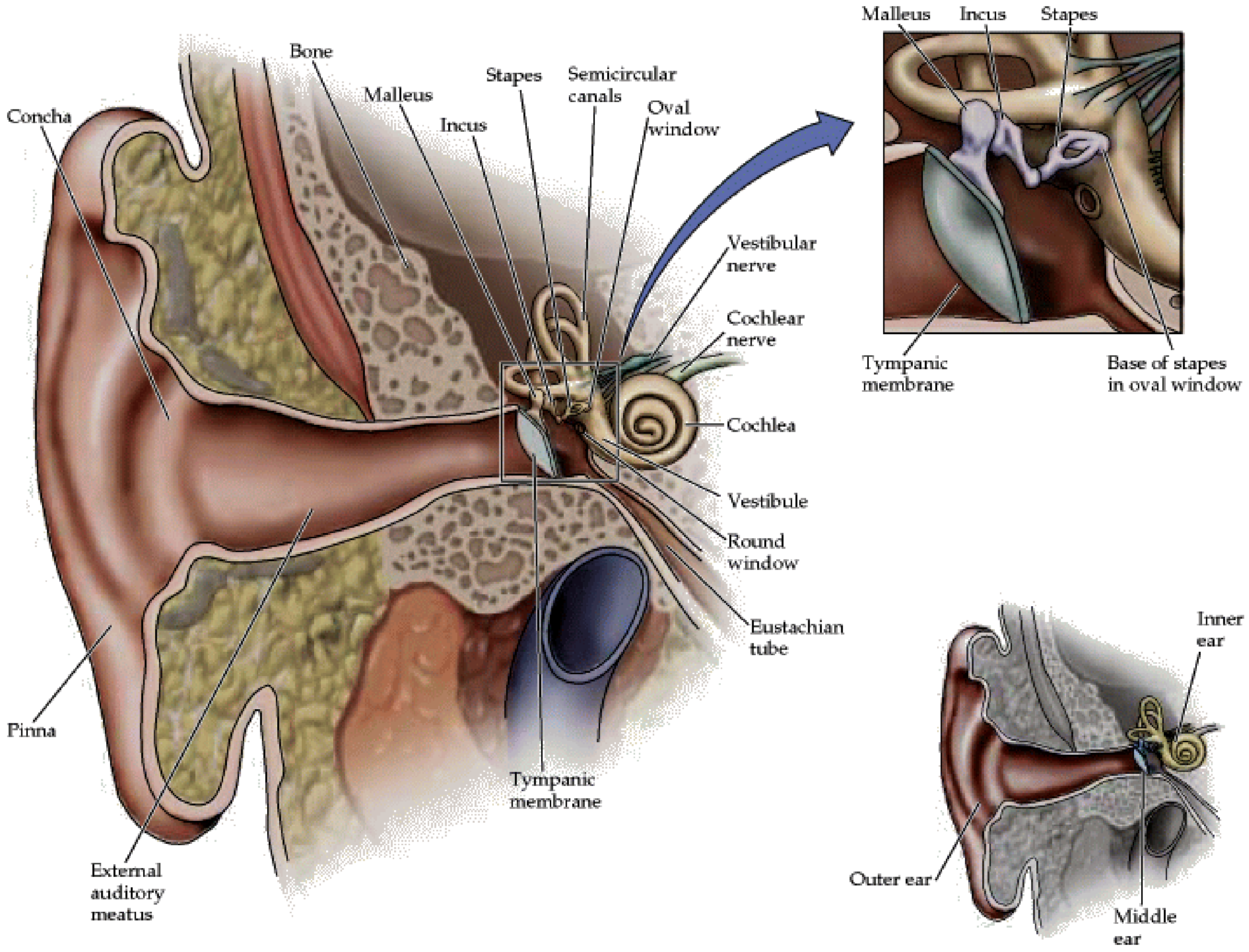
External ear

✓ Transmission of acoustic signal from environment to the tympanic membrane



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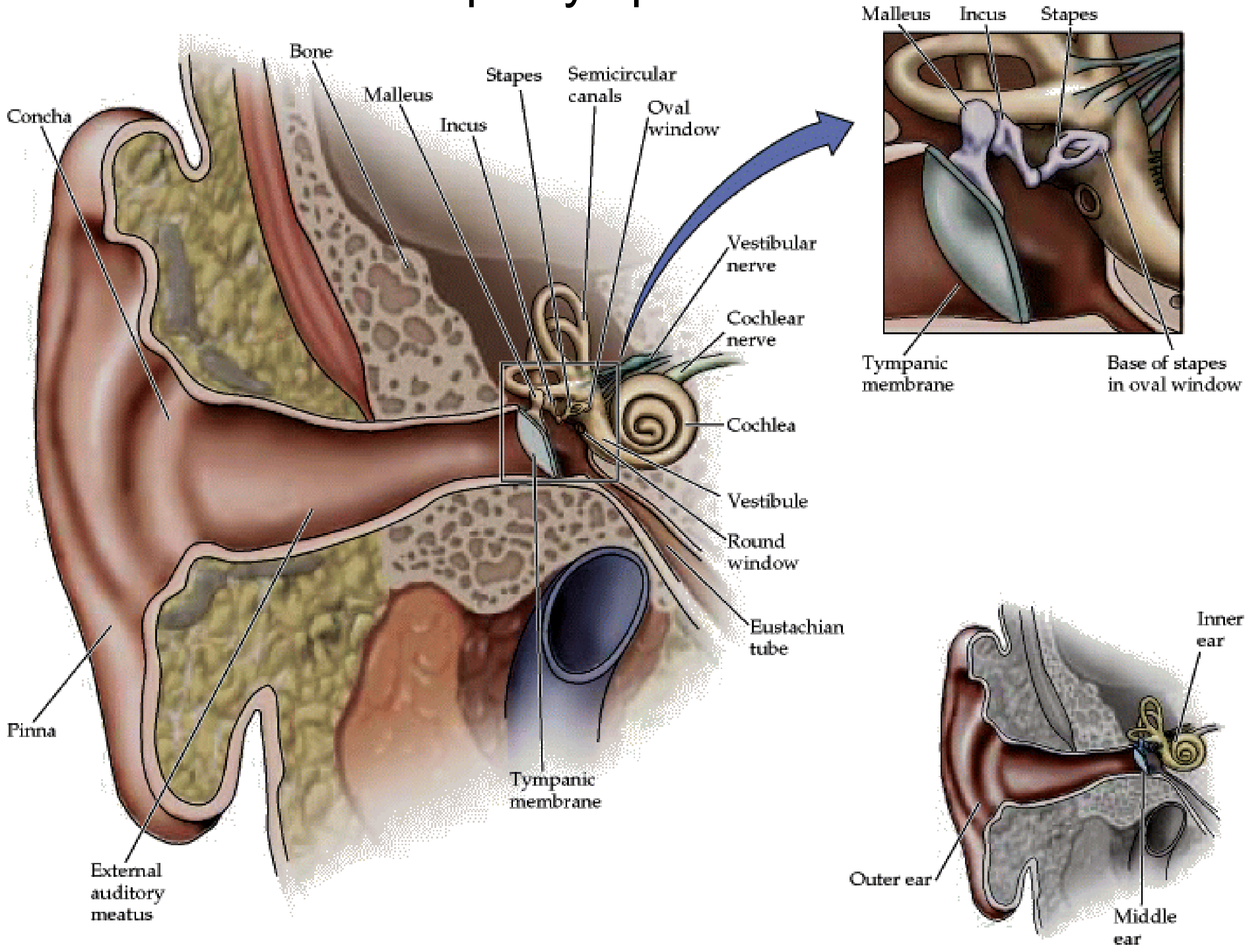
Middle ear

- ✓ Transmission of acoustic signal from the tympanic membrane to the oval window and perilymph/basilar membrane



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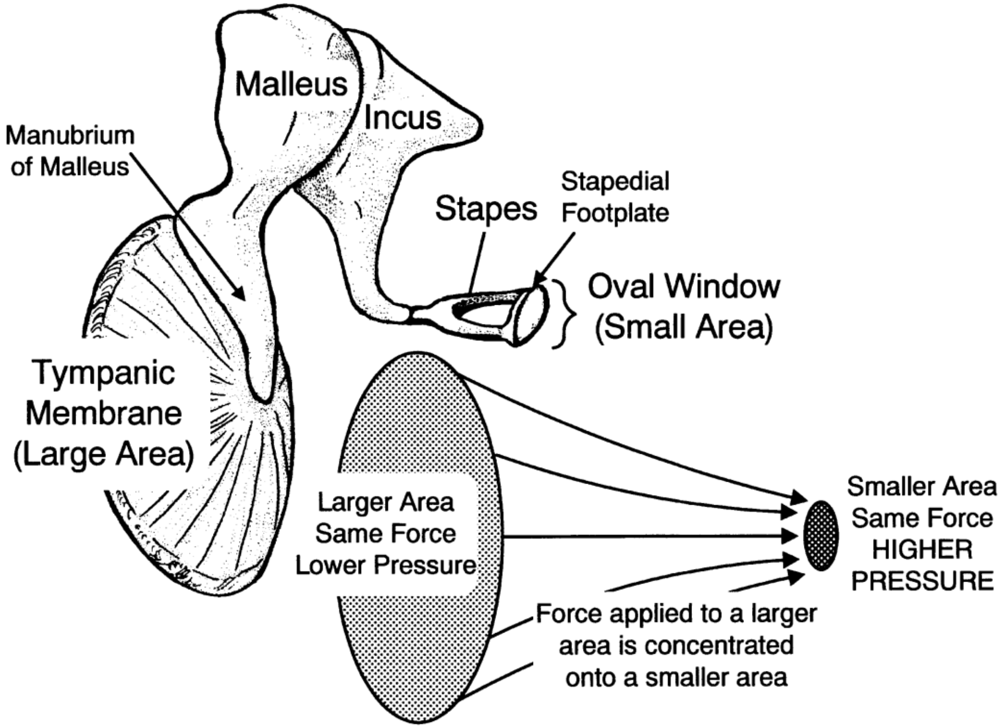
Middle ear

- A significant difference in acoustic impedance between air and perilymph
- Signal amplification
  - Tympanic membrane area/oval window area
  - Ossicles
- Protective function
  - m.stapedius and tensor tympani
  - Eustachian tube



http://slideplayer.com/slide/3433153/

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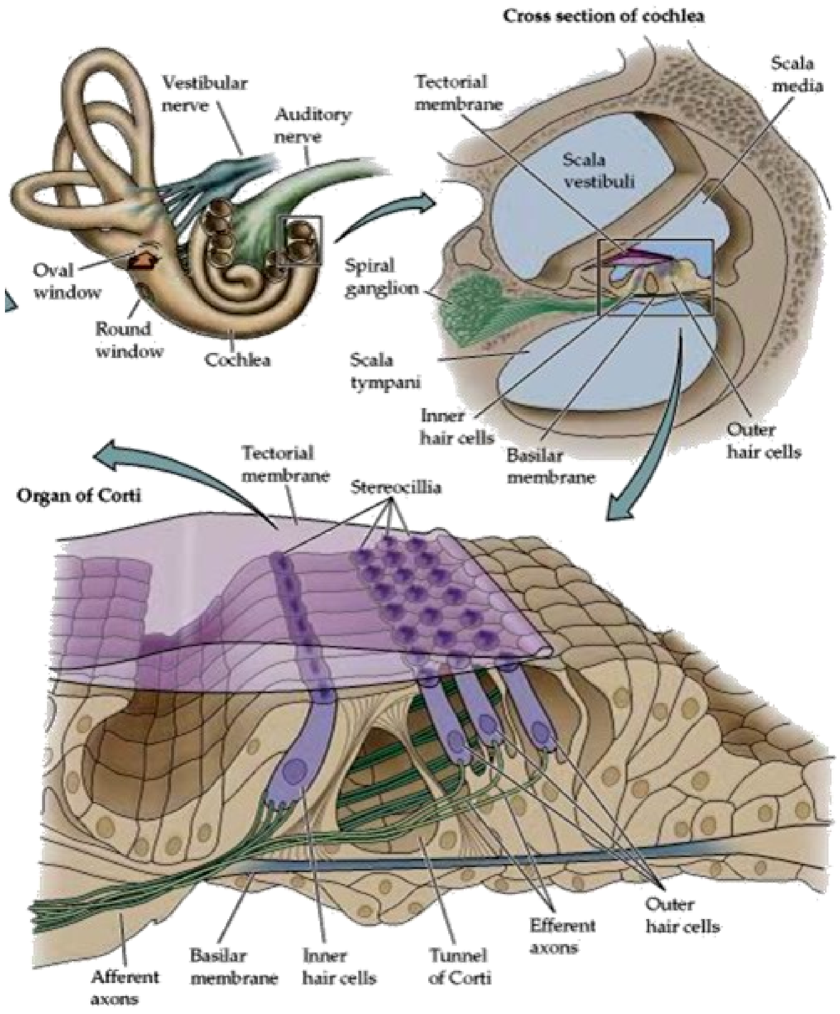
Inner ear

- ✓ Transduction of perilymph/basilar membrane vibrations to receptor and action potential



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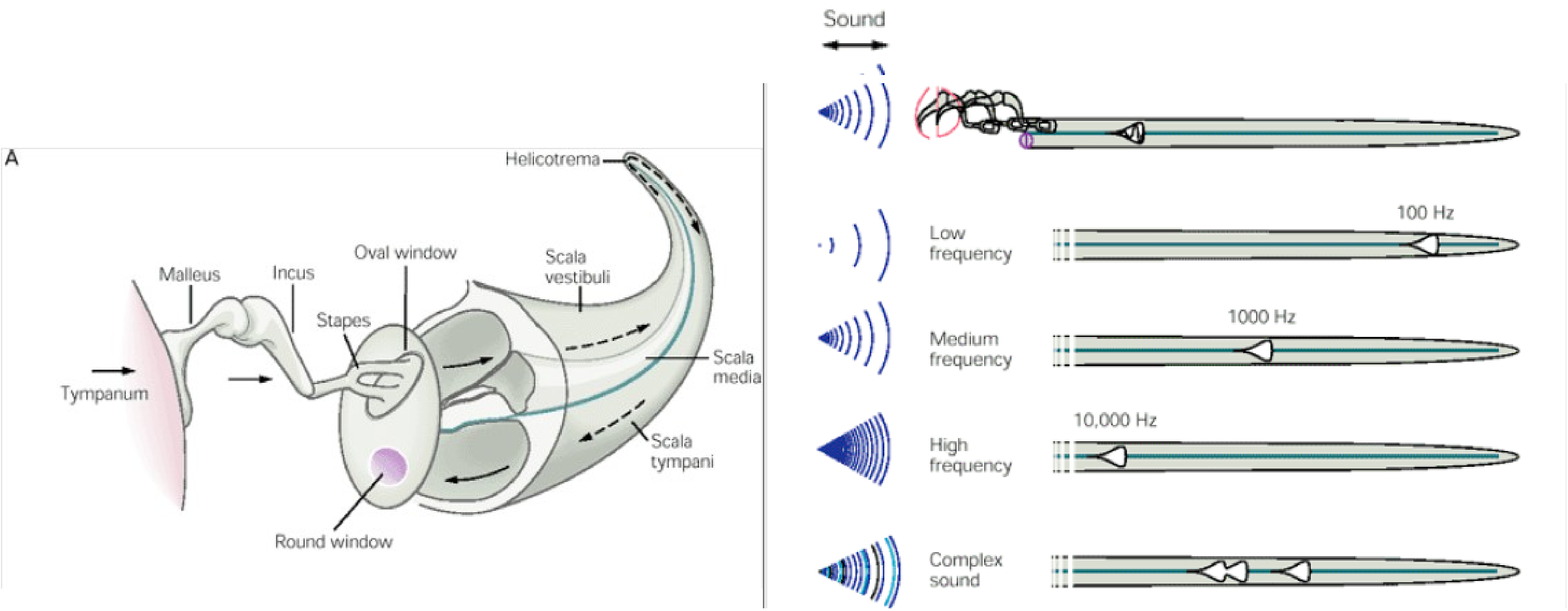
Tonotopic arrangement

- Proximal part
  - high frequency
- Distal part
  - low frequency



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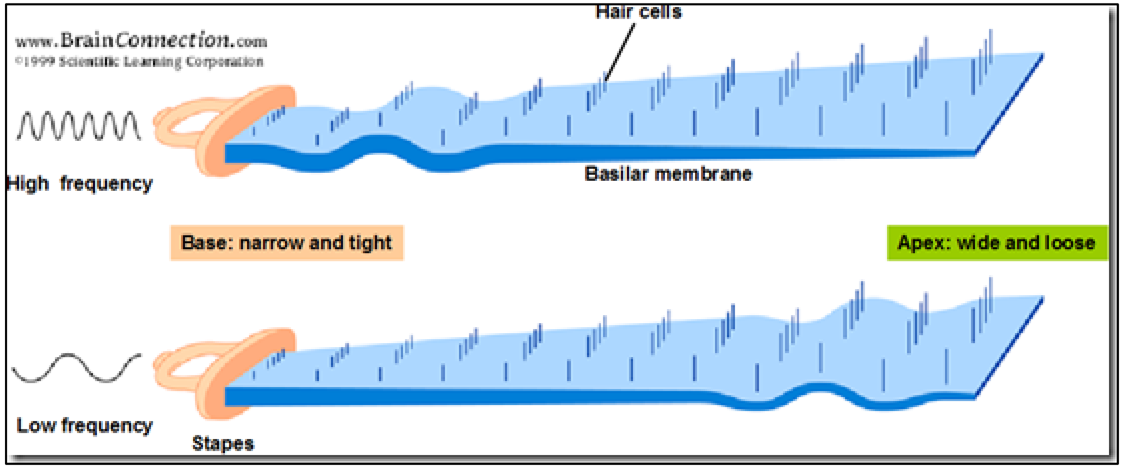
Basilar membrane

- Basal part
  – Narrow and tight
  High frquencies

- Apical part
  – Wide and loose
  Low frequencies



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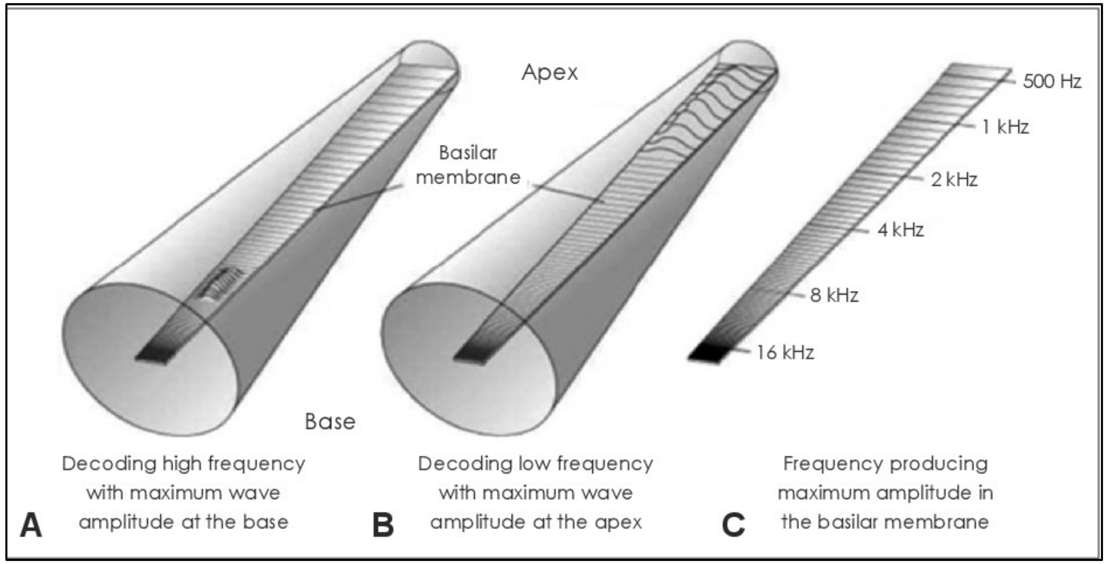

https://www.semanticscholar.org/paper/Mass-and-Stiffness-Impact-on-the-Middle-Ear-and-the-Kim-Koo/16a2a6b5ffd1c963efd906cea109277bfbf0d7e3/figure/3

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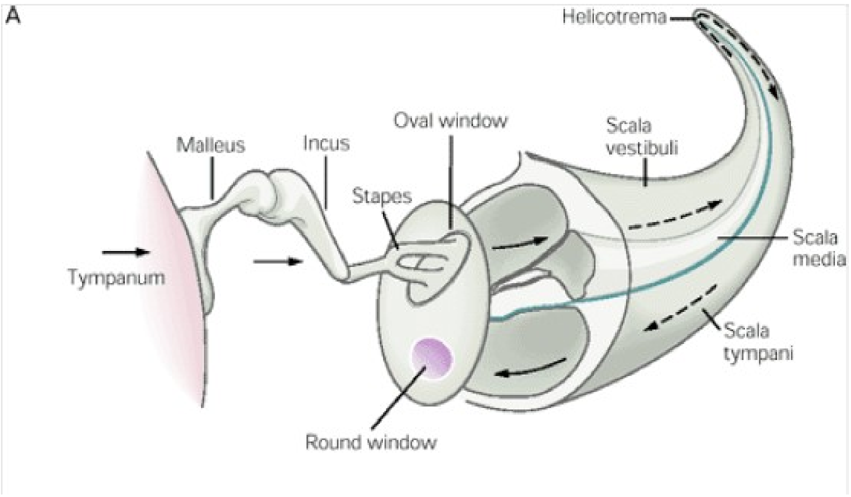
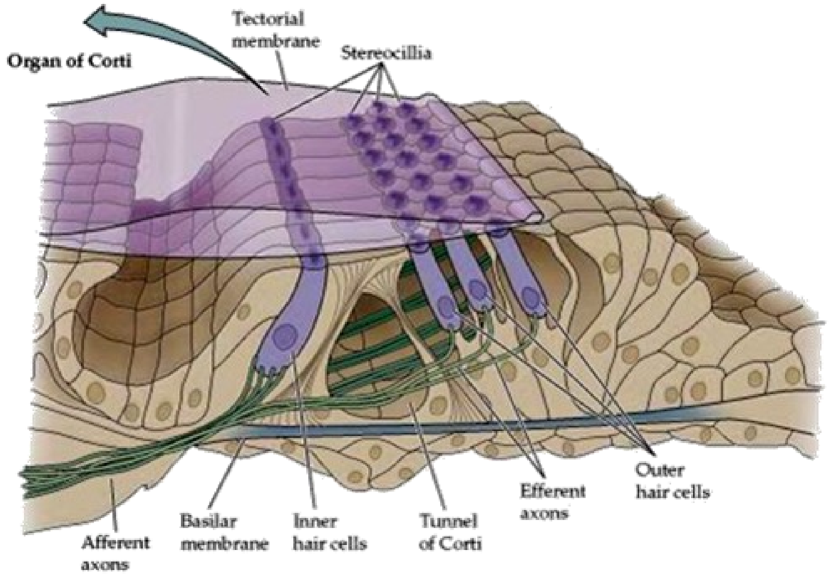
Organ of Corti

- ➢Inner hair cells
  - ➢ aprox. 3 500
- ➢Outer hair cells
  - ➢ aprox. 12 000
- ➢Tectorial membrane





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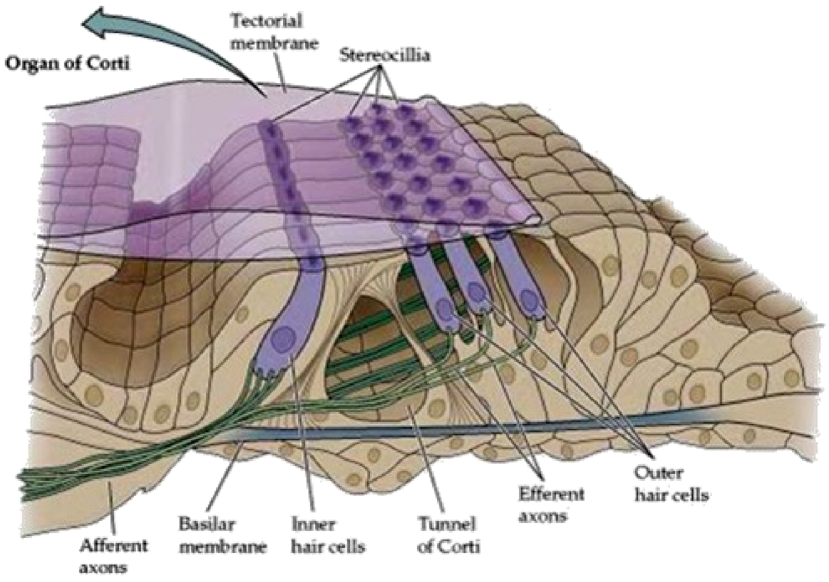
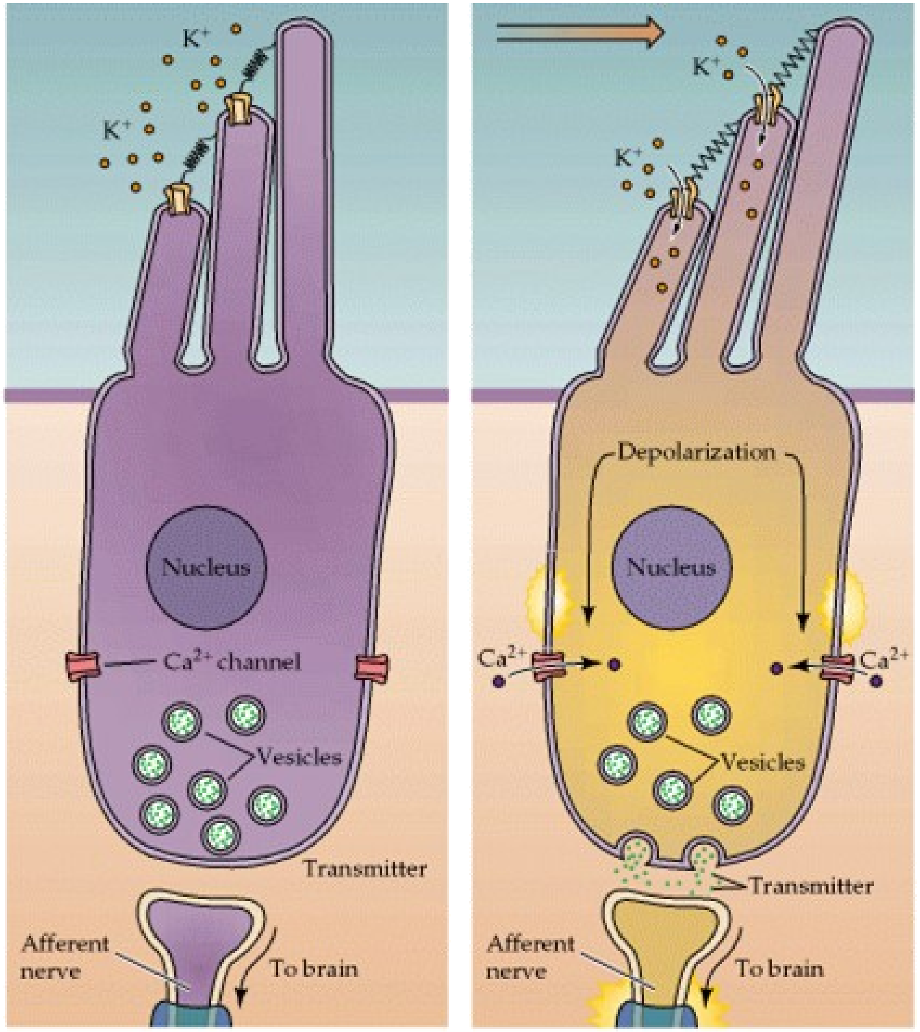
Inner hair cells

➢ Sensory function





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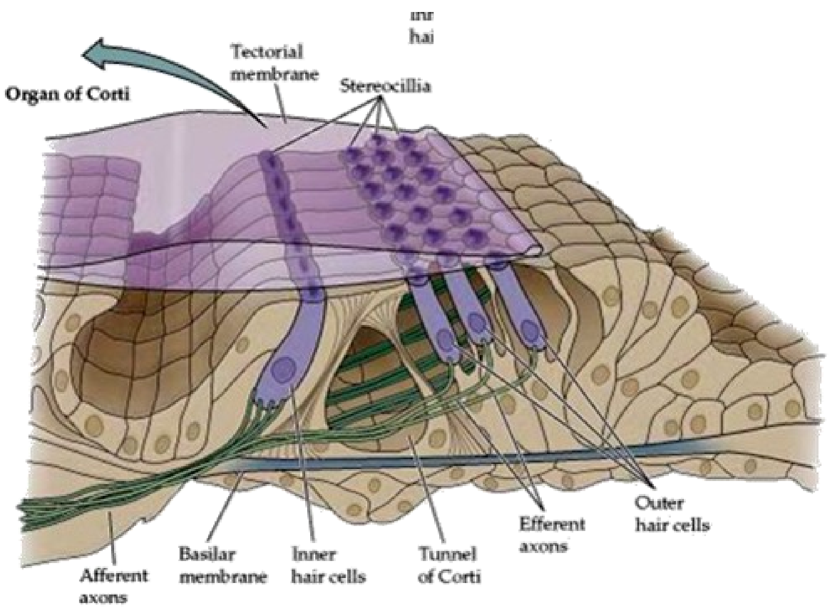
Outer hair cells

- Modulation of the signal
  - ✓ Amplification of required frequencies
- The number increases towards apex (low frequencies)



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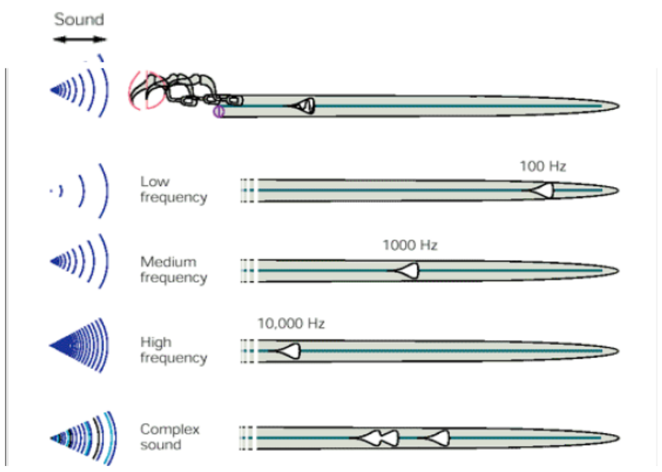
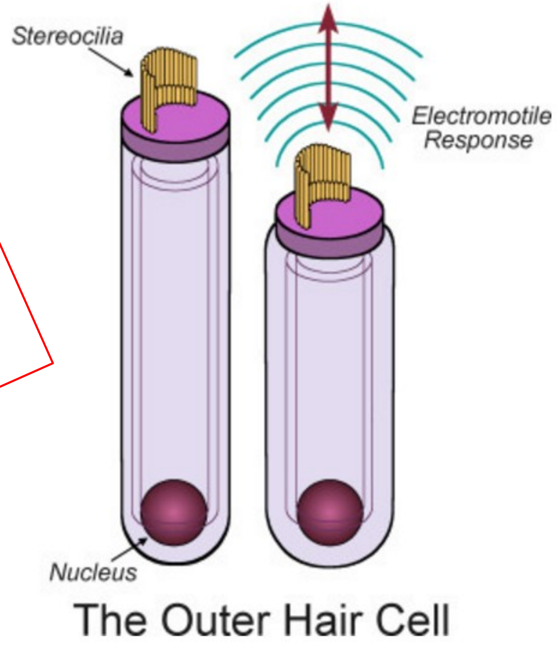
Their action may be detected

Otoacustic emissions





http://www.neurophys.wisc.edu/auditory/johc.html

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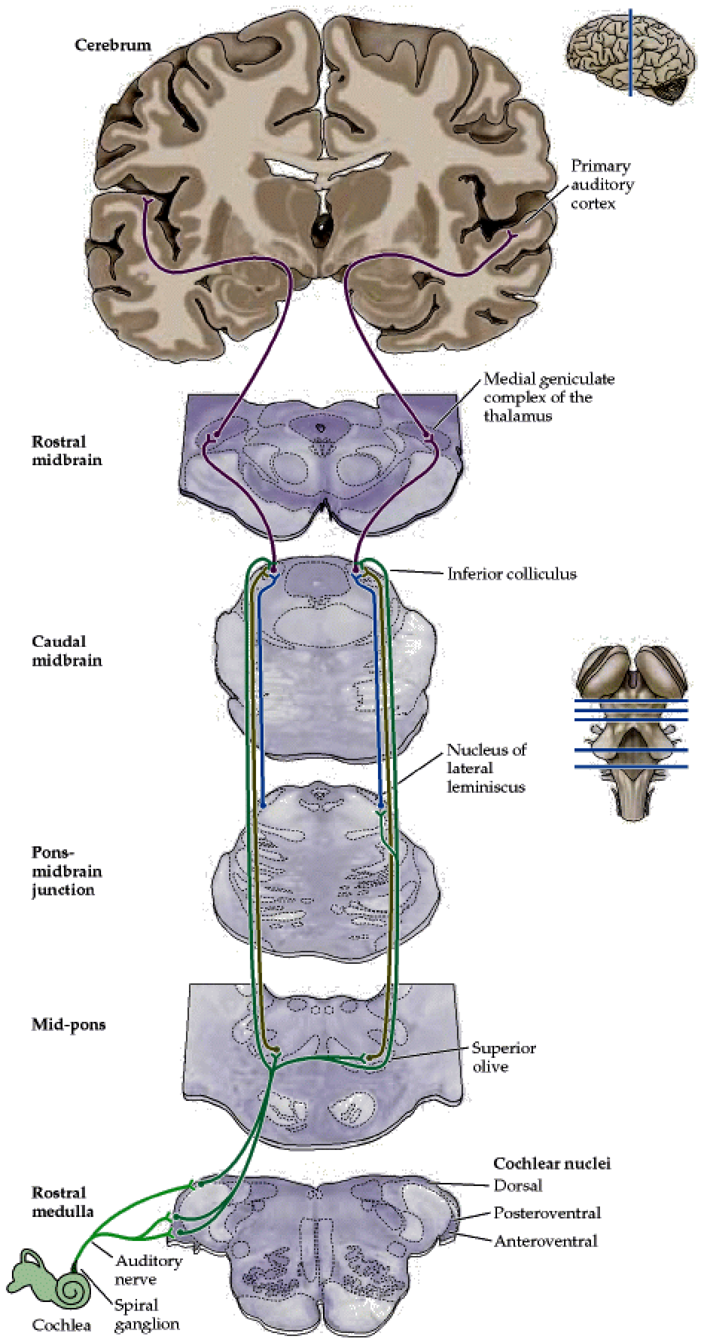
Sound processing

- Nucleus spiralis cochleae
- Nucleus cochlearis ventralis
  - Information about intensity
  - Time delay – the sound direction
- Nucleus cochlearis dorsalis
  - Information about frequency
- Olivary nuclei
  - Analysis of direction
  - Modulation (increase) of the outer hair cells sensitivity
- Colliculi inferiores
  - Integration of information from the lower structures
  - Centre of acoustic reflexes
- N. corporis geniculati medialis
  - Thalamus
- Auditory cortex



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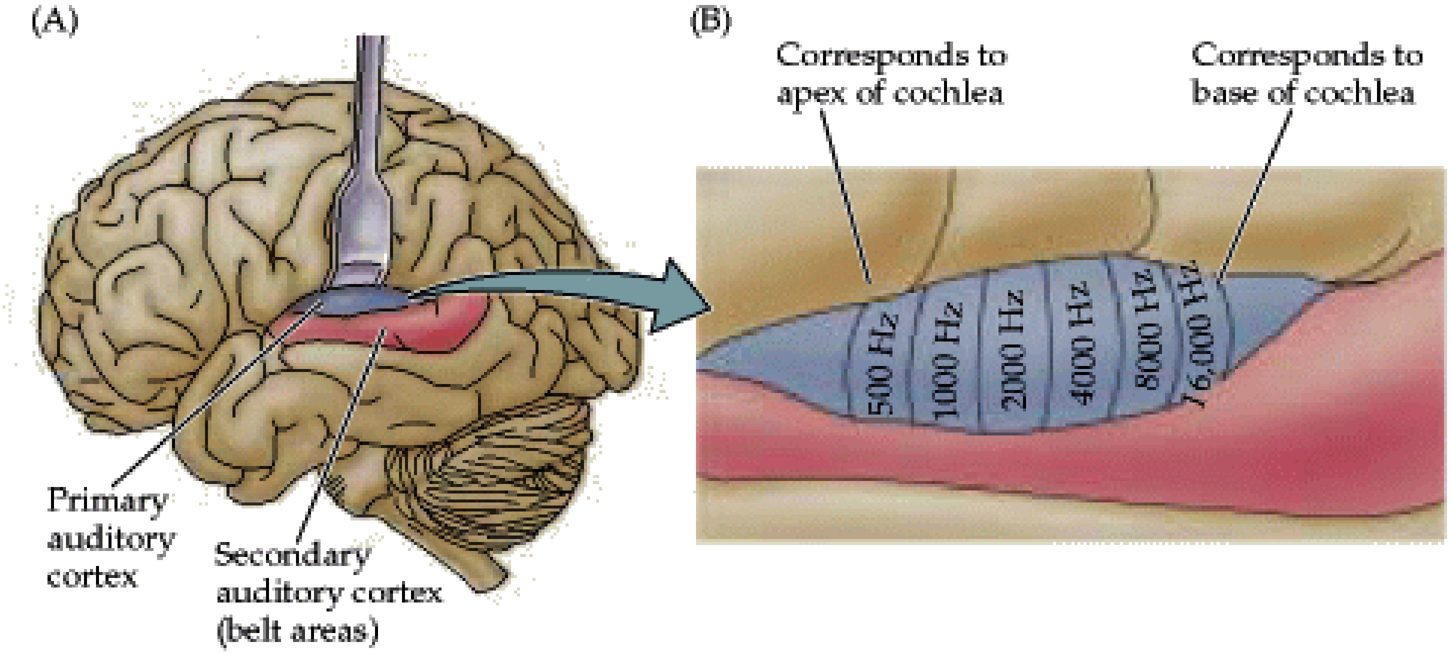
Auditory cortex



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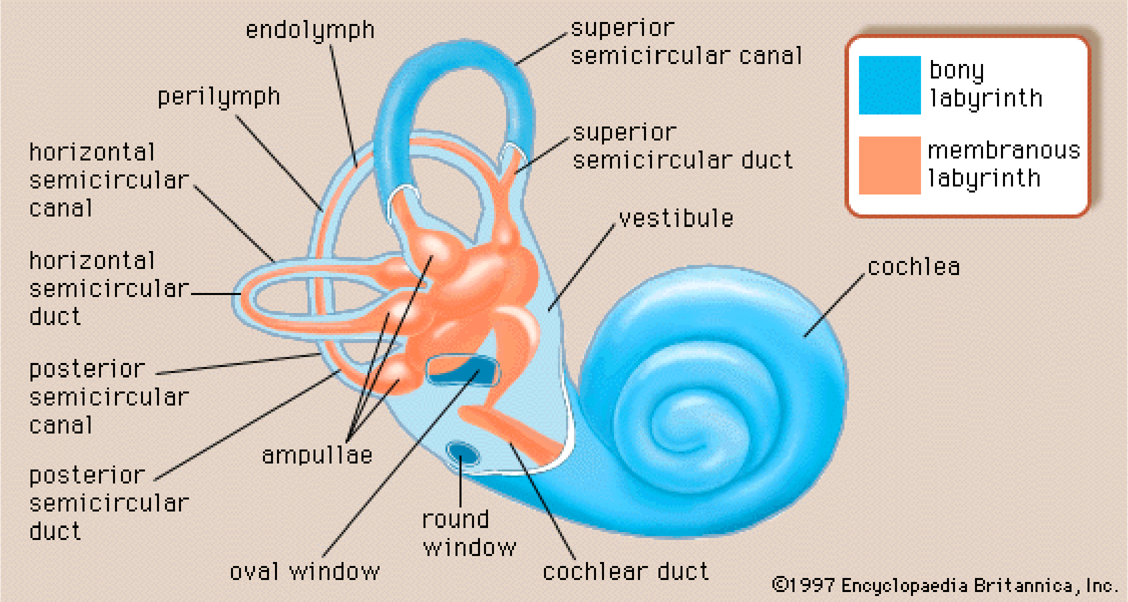
Vestibular system

- Associated with auditory system
  - Anatomic localization
  - Hair cells
- Information about
  - Position
  - Acceleration
    - ✓ Linear
    - ✓ Angular



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Maintenance of the balance
Muscle tone modification

„Maintenance of the balance“ of the sight
Vestibuloocular reflexes (VOR)

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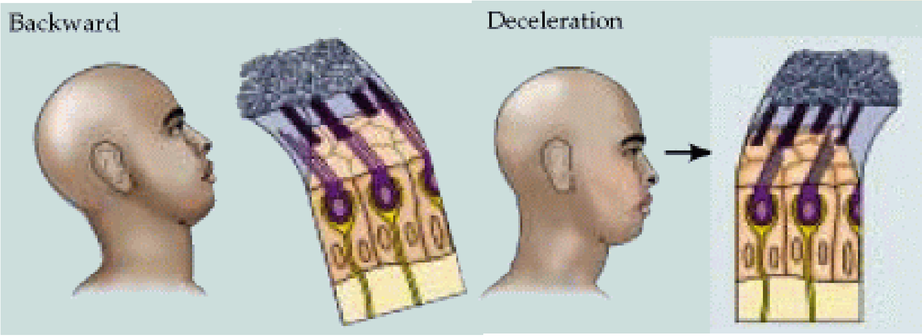
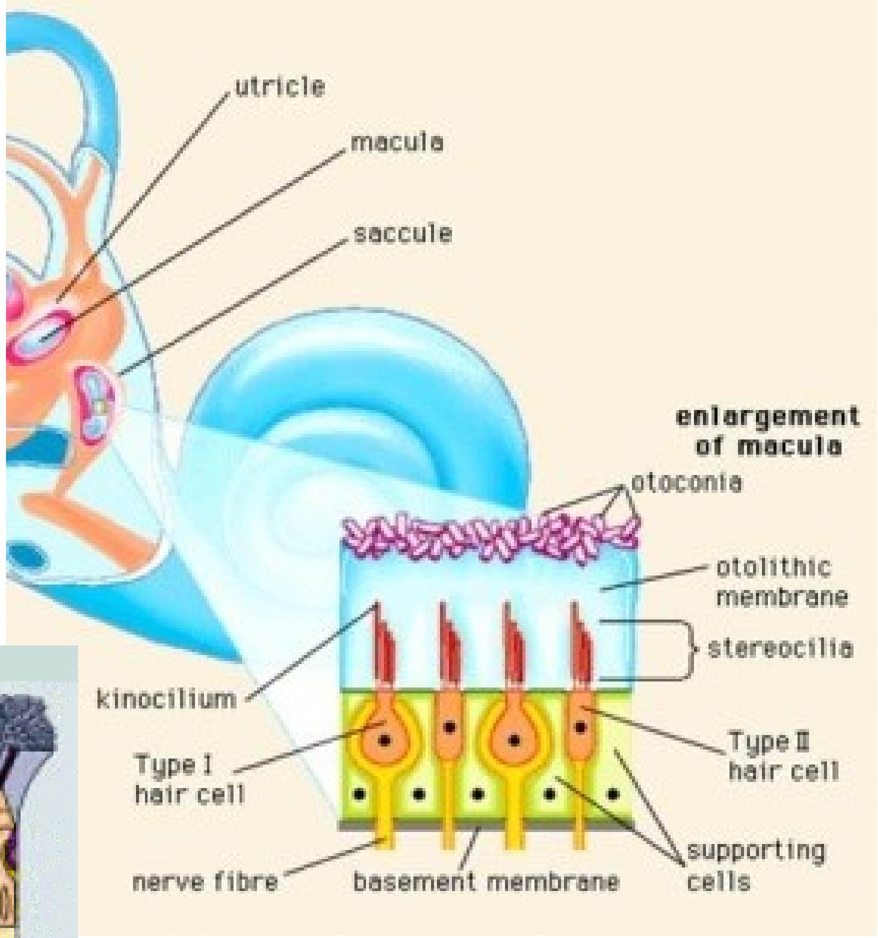
Information about position and linear acceleration

- Macula
  - $CaCO_3$ crystals
- Utriculus
  - Horizontal macula
- Sacculus
  - Vertical macula





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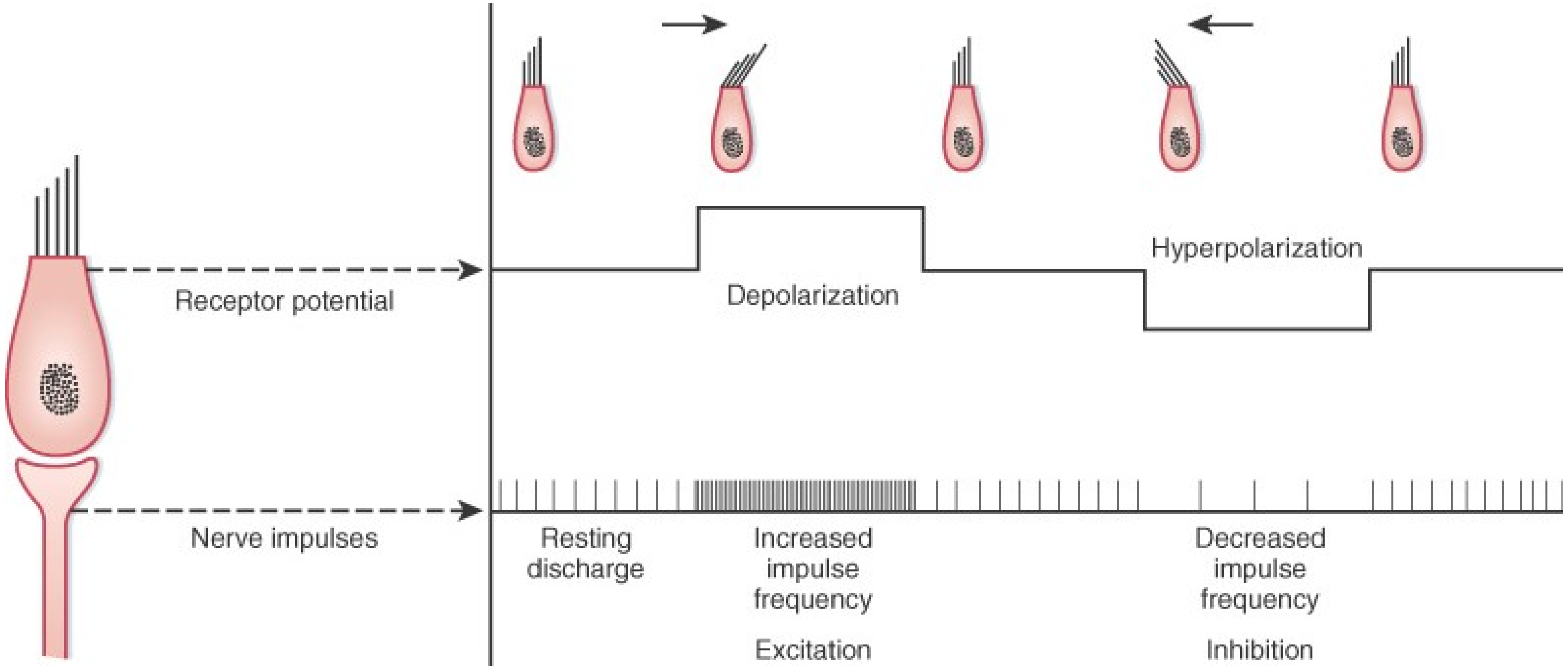
Mechanism of reception

- Flexion towards stereocilia
  - Mechanically activated K^+ channels are opened –depolarization
- Flexion away from stereocilia
  - The channels are clsed - hyperpolariztion



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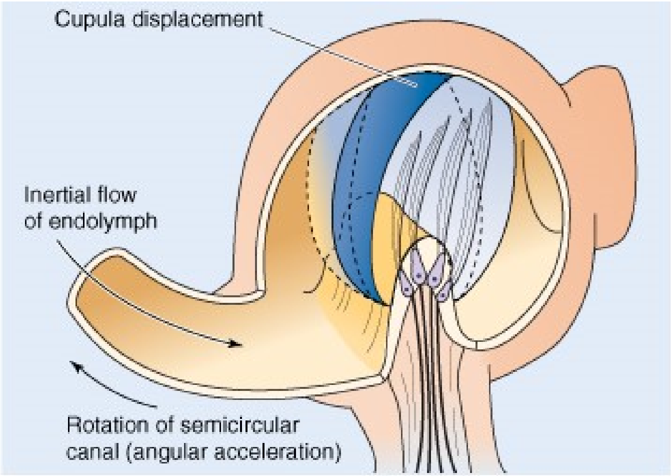
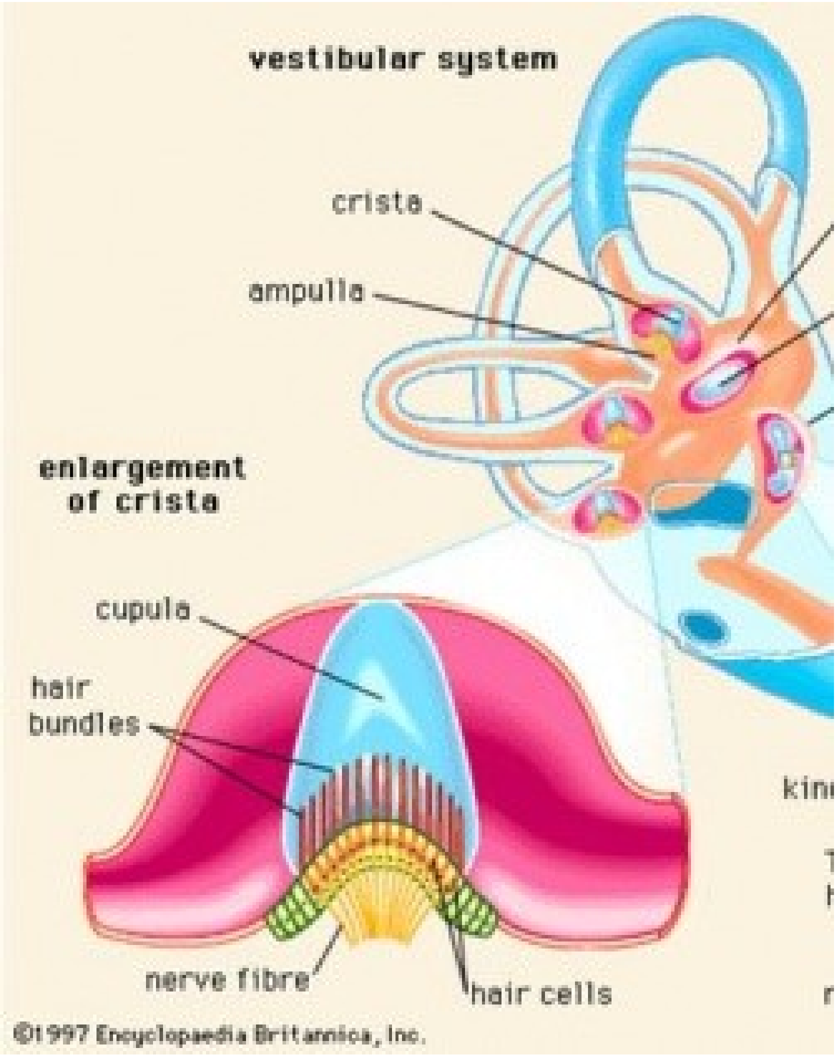
Information about angular acceleration

- Ampulla
- Semicircular canals
  - Upper
  - Horizontal
  - Posterior





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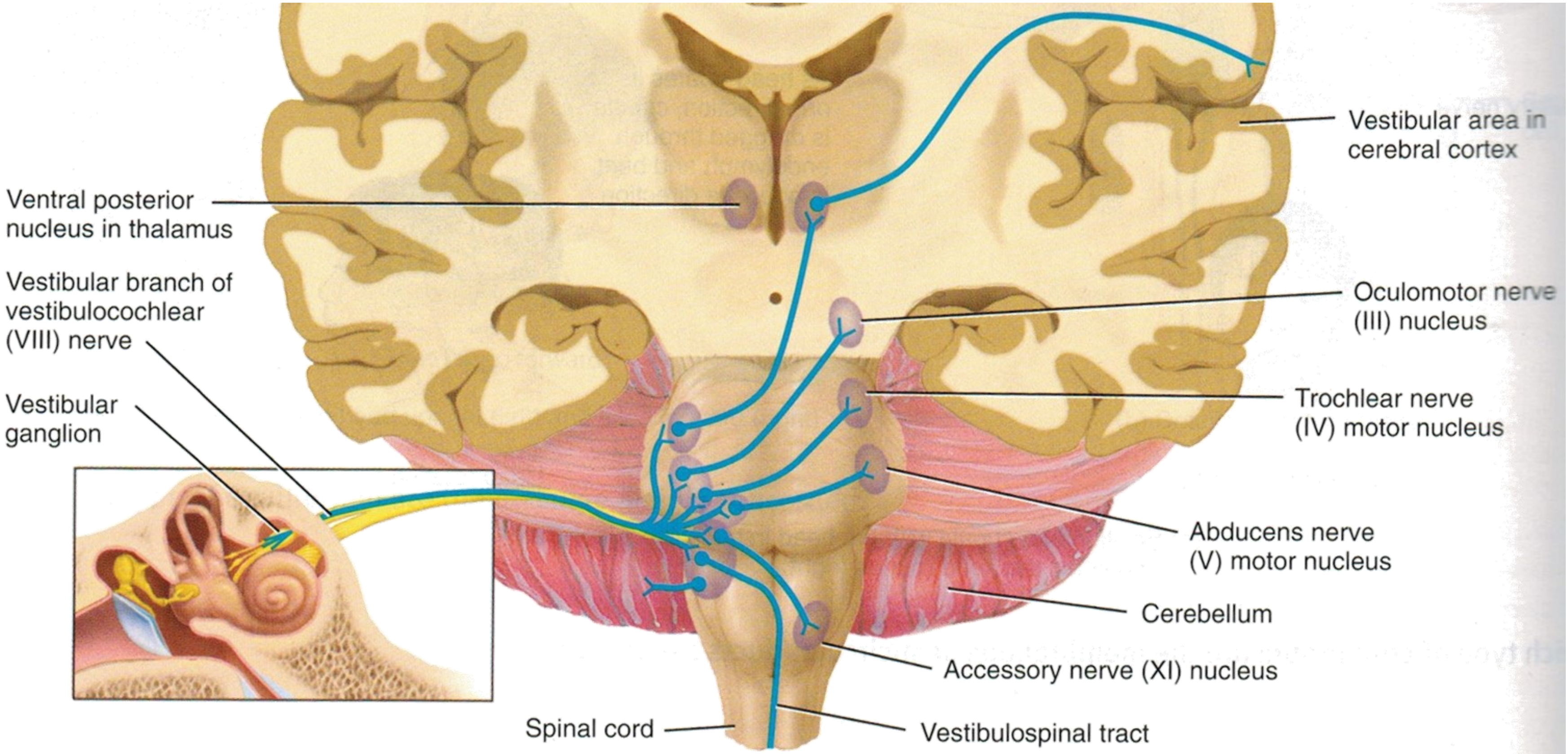
Vestibular nuclei

- ✓ Integration of vestibular, visual and somatosensoric information

- ✓ Projections
- Cerebellum
- Oculomotoric nuclei
- Nucleus of n. Accessorius – the muscles of the neck
- Spinal nuclei
- Thalamus - cortex



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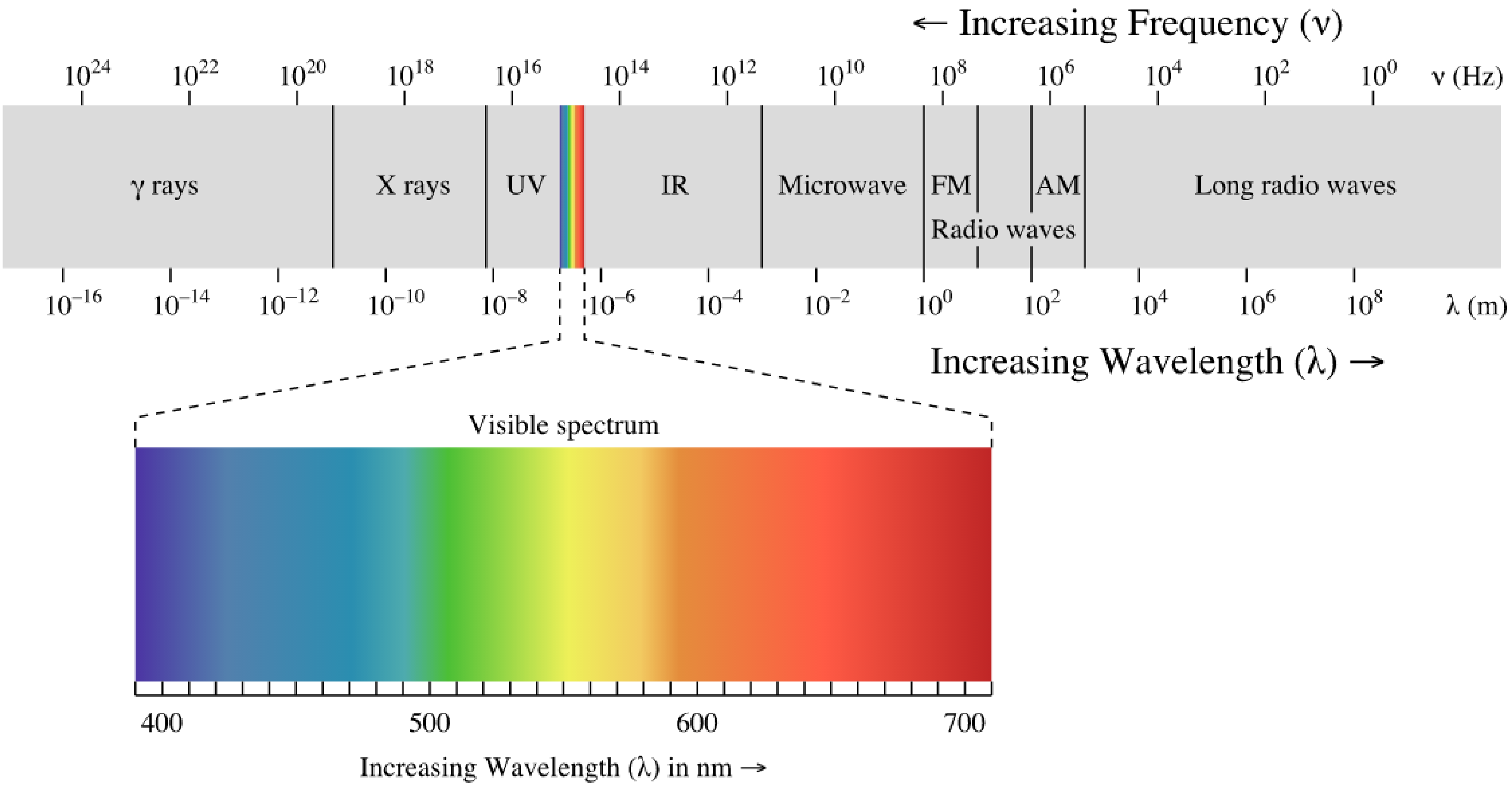
Vision

Light

✓ Electromagnetic radiation with wavelengths in range of 400 – 700 nm



https://upload.wikimedia.org/wikipedia/commons/f/f1/EM_spectrum.svg

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Color mixing

http://www.indiana.edu/~jkmedia/classes/images/colormodes.jpg

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Photoreceptive organ

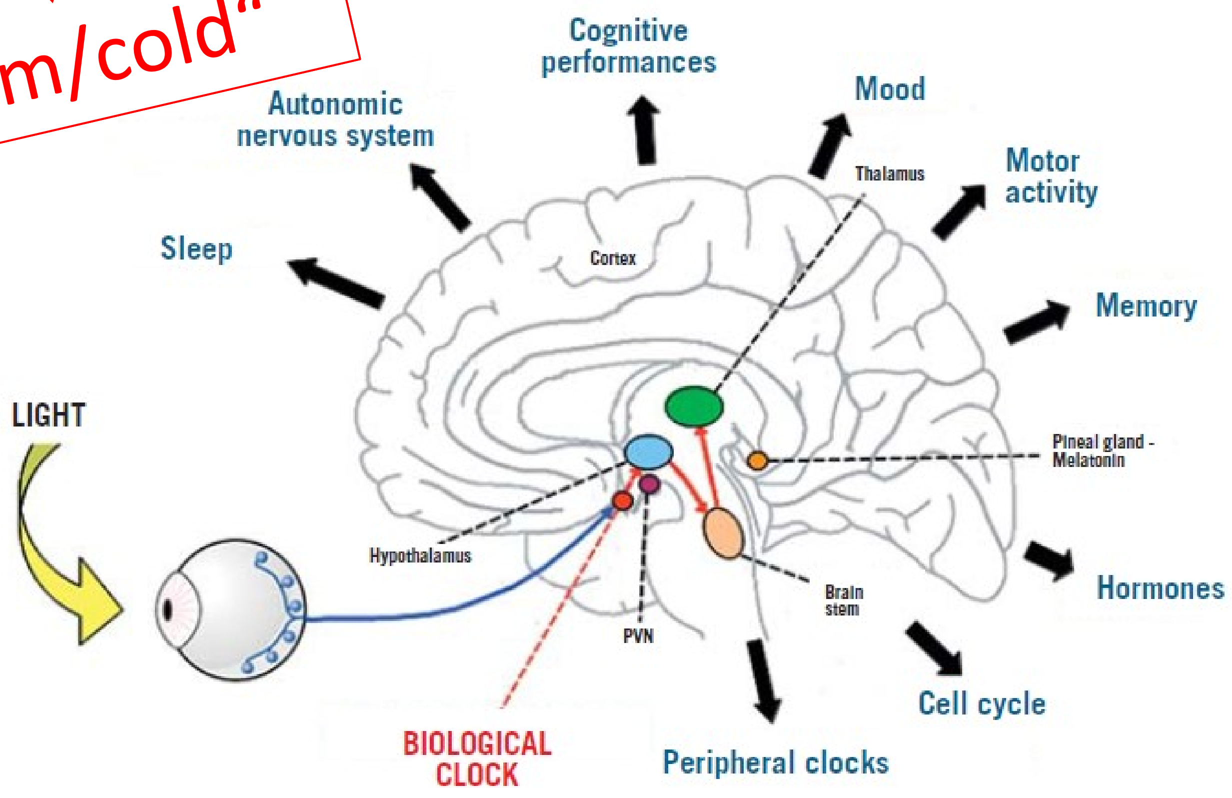
✓Light detection

✓Image formation

Light detection

Light/dark
↓
„warm/cold"

- Circadian activity
  - Both prokaryotes and eukaryotes
  - Day/night cycle is the most influential and the most stable biorhythm

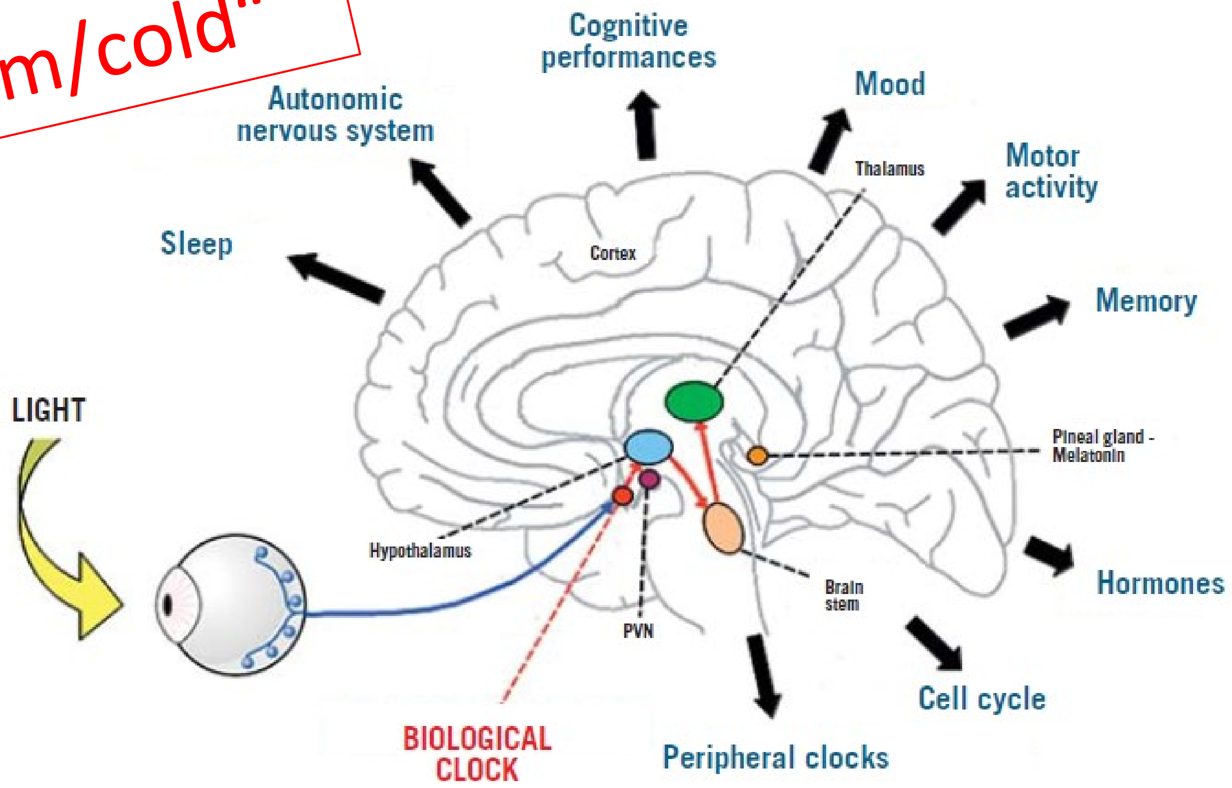


https://www.pointsdevue.com/article/good-blue-and-chronobiology-light-and-non-visual-functions

Light detection

„Light/dark
↓
„warm/cold“

- Circadian activity
  - Both prokaryotes and eukaryotes
  - Day/night cycle is the most influential and the most stable biorhythm
  - Oscillation with a period of aprox. 24 hours even without signals from environment
  - Environmental signals synchronize circadian activity
- Seasonal activity



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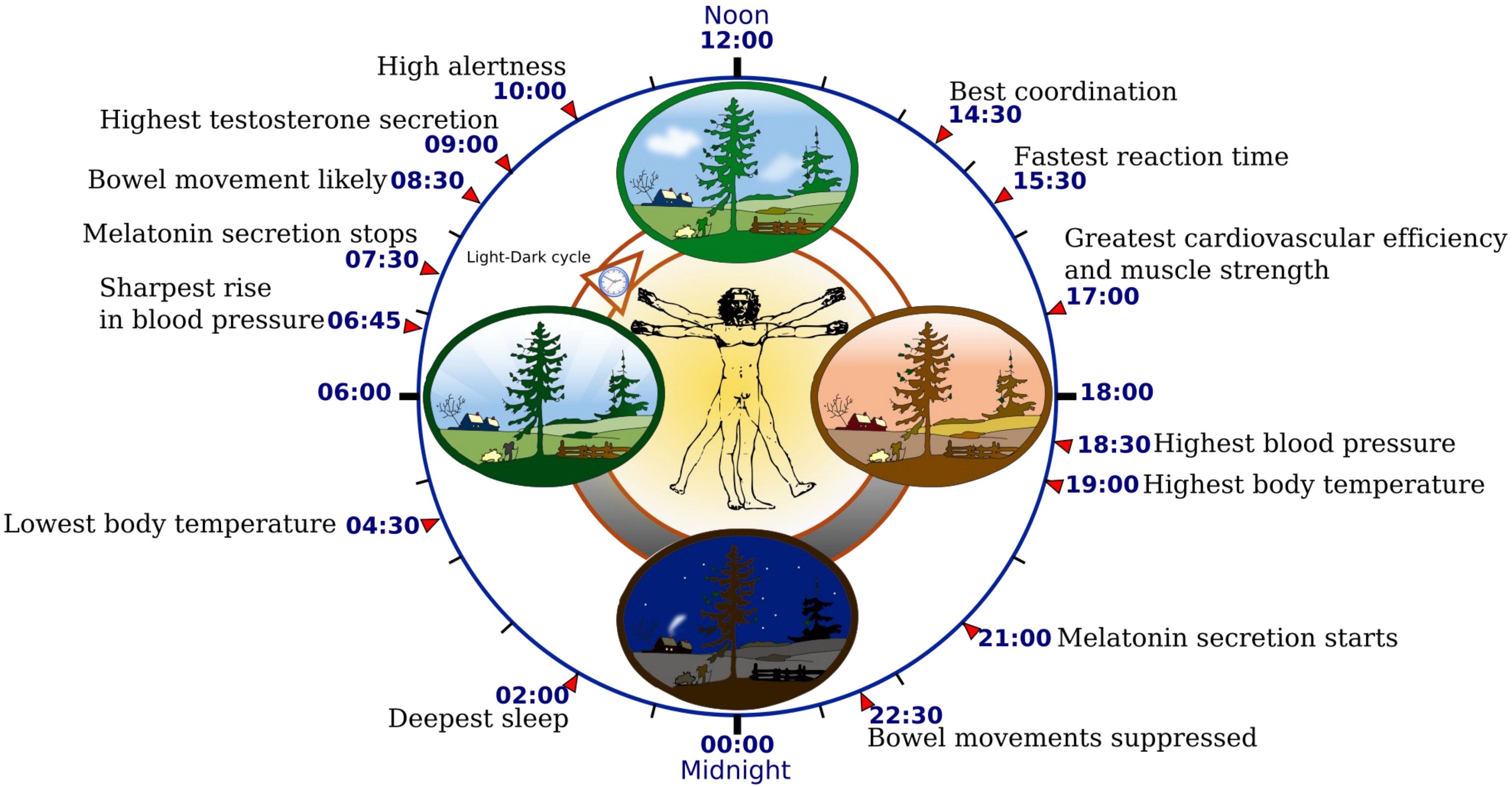
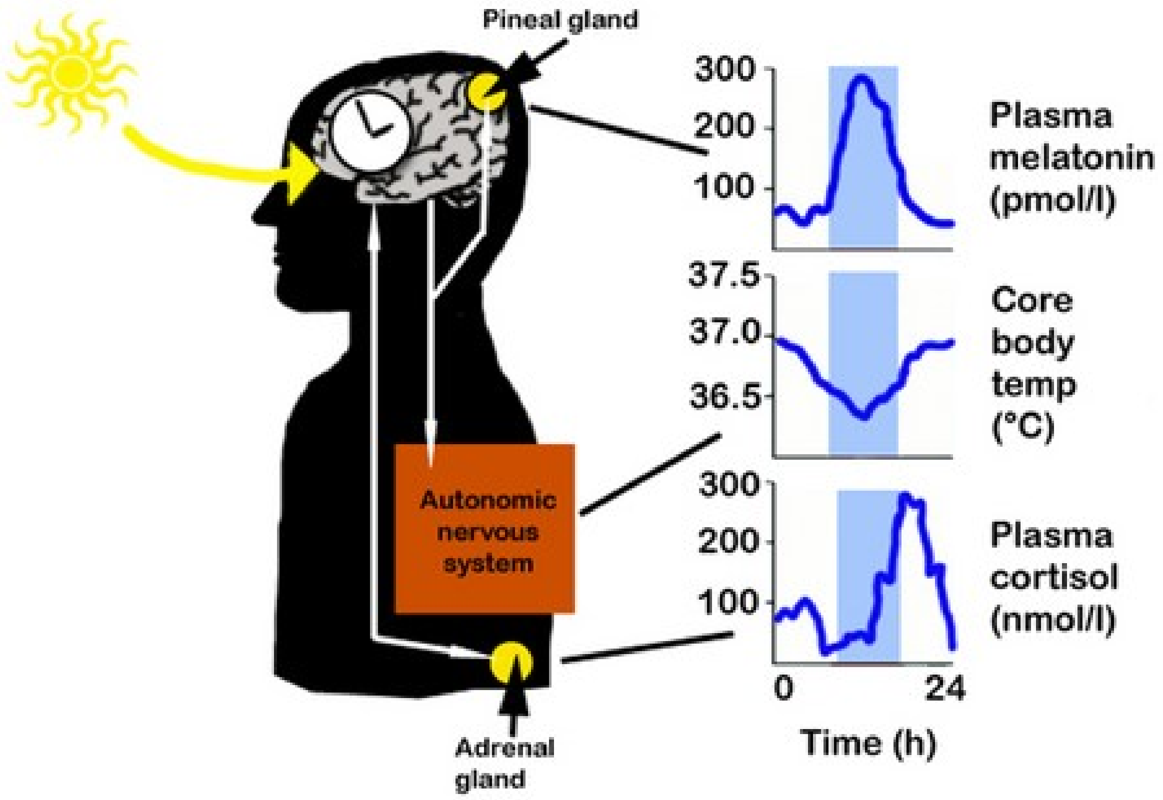
Circadian activity



https://upload.wikimedia.org/wikipedia/commons/thumb/3/30/Biological_clock_human.svg/2000px-Biological_clock_human.svg.png

Biological clock

- Cellular level
  - Group of proteins rhythmically expressed creating interconnected feedback loops (about 24hours)
    - Peripheral Clock protein expression
- Tissue level
  - Peripheral oscillators
  - Adrenal gland, lung, liver, pancreas, skin
  - Influenced by neurohumoral factors and also by light
- Central pacemaker
  - Hypothalamus (nucleus suprachiasmaticus)
    - Central clock protein expression
    - Information about illumination from retina (specialized ganglion cells) – synchronization of central pacemaker
  - ➢ Pineal gland - melatonin
  - ➢ Autonomnic nervous system – adreanl gland - cortisol



A.J. Hesse, G.E. Duffield adapted from Hastings, M. BMJ 1998;317:1704-1707

http://slideplayer.com/slide/7013288/

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Central pacemaker synchronization

Wahl S, Engelhardt M, Schaupp P, Lappe C, Ivanov IV. The inner clock-Blue light sets the human rhythm. *J Biophotonics*. 2019; e201900102.

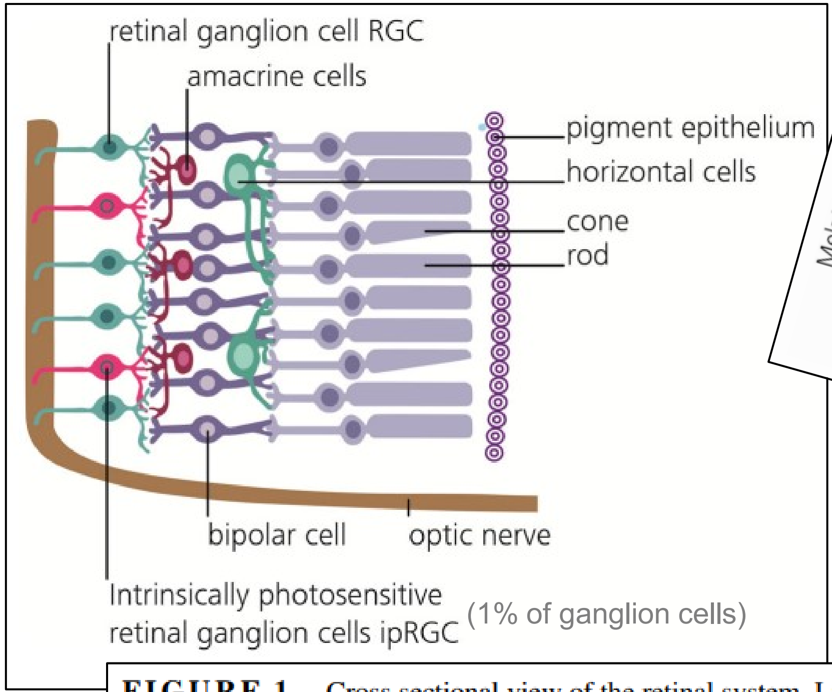
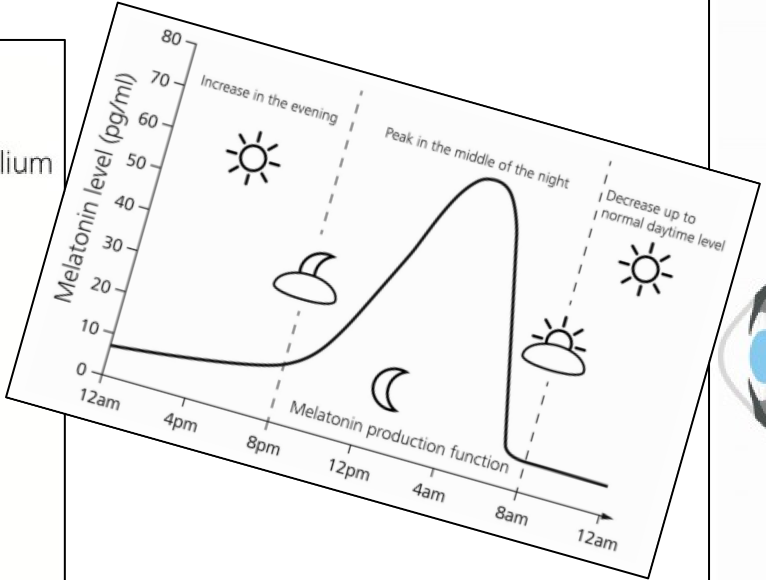


FIGURE 1 Cross sectional view of the retinal system. Light traverses the system from the left, cones and rods transmit visual information via the bipolar cells, amacrine cells, and ganglion cells to the optic nerve. The sparse subset of intrinsic photosensitive retinal ganglion cells can induce signals themselves, due to their possession of a separate photopigment, melanopsin



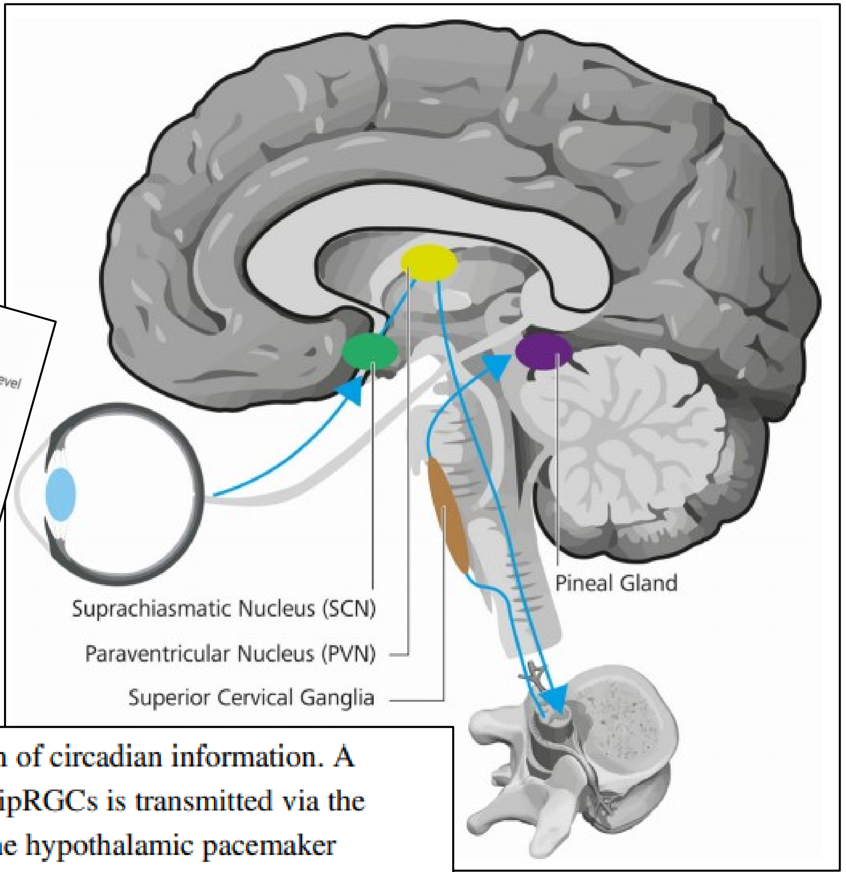
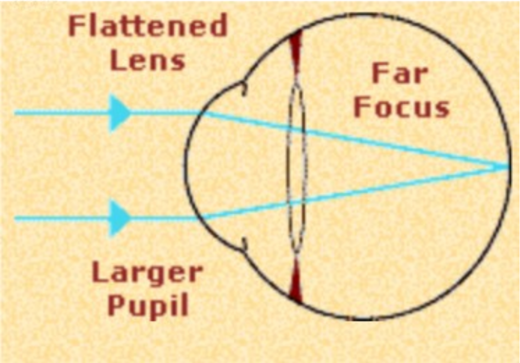


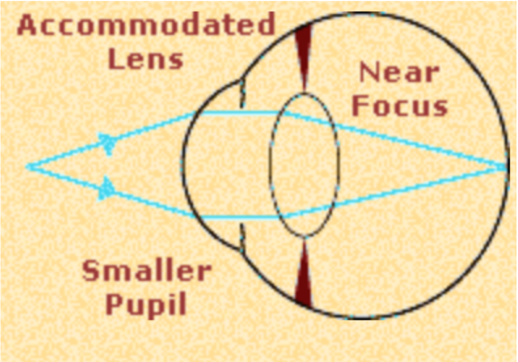
FIGURE 2 Signal transduction of circadian information. A melanopsin induced signal from the ipRGCs is transmitted via the retino-hypothalamic tract (blue) to the hypothalamic pacemaker neurons in the suprachiasmatic nucleus (green), the human "master clock". The circadian information is transmitted further downstream via the paraventricular nucleus (yellow), intermediolateral cell column in the vertebral gray matter, superior cervical ganglion (brown) to the pineal gland (purple), which is responsible for melatonin secretion

Image formation

- Shape
- Color
- Localization
- Movement

- Image interpretation - CNS





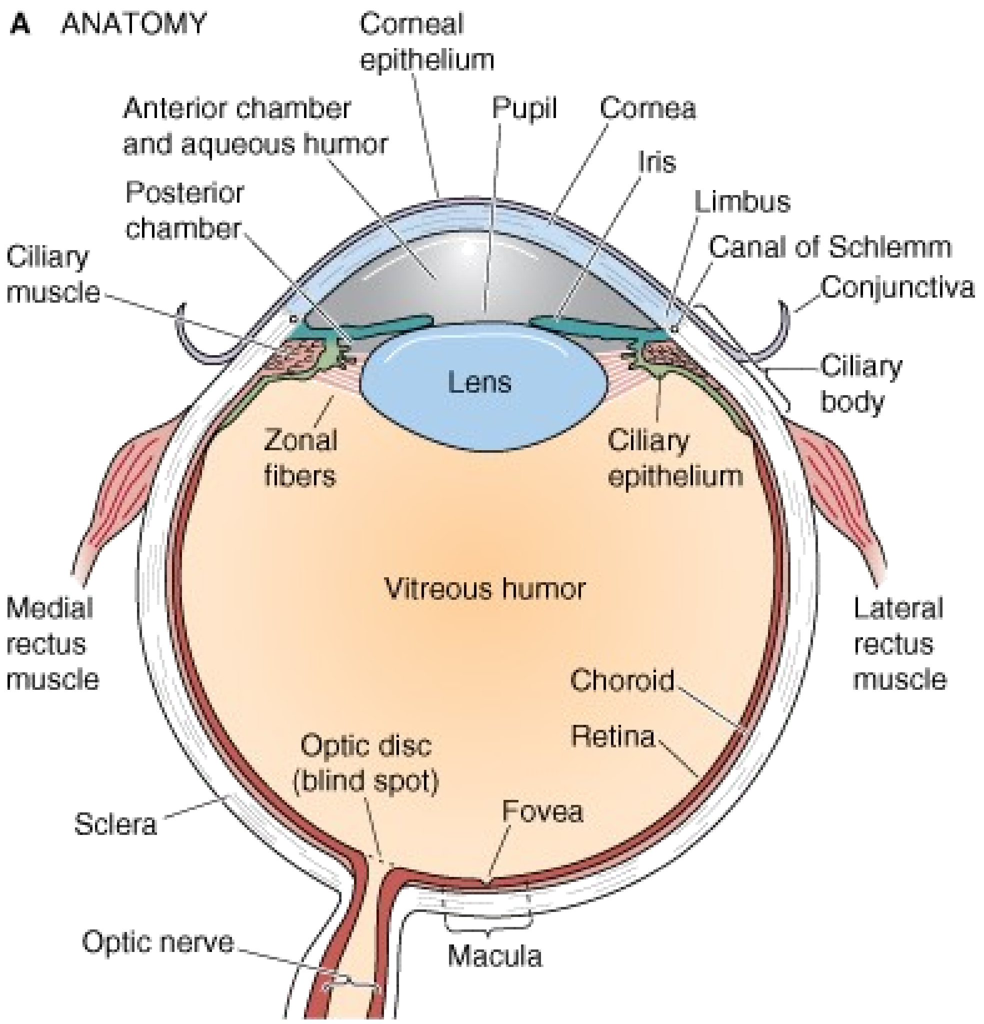


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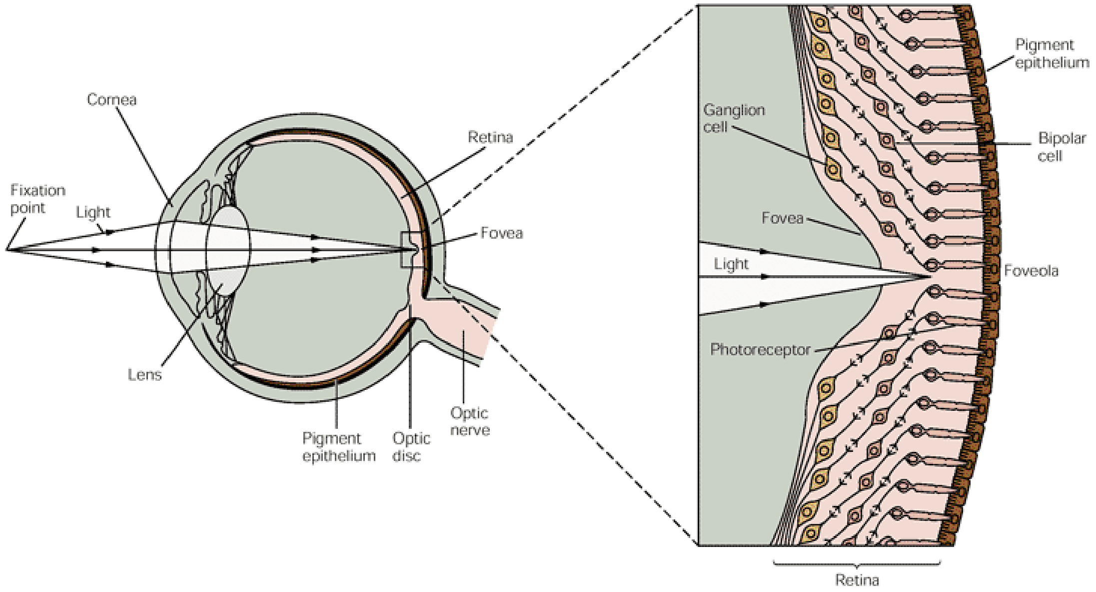
Image formation



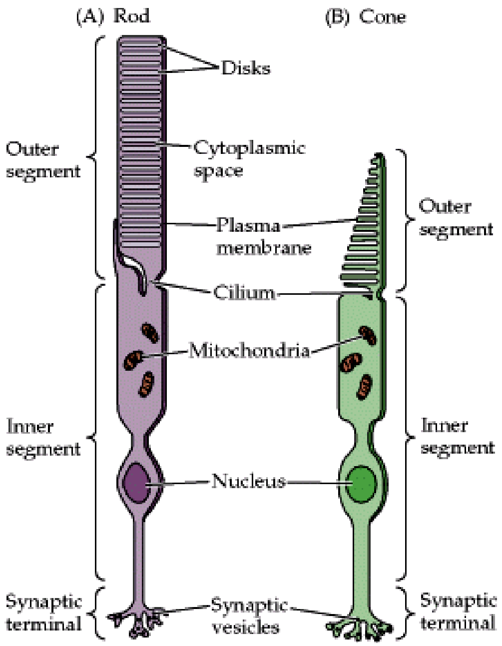


Table 26-1 Differences Between Rods and Cones and Their Neural Systems

Rods	Cones
High sensitivity to light, specialized for night vision	Lower sensitivity, specialized for day vision
More photopigment, capture more light	Less photopigment
High amplification, single photon detection	Lower amplification
Low temporal resolution: slow response, long integration time	High temporal resolution: fast response, short integration time
More sensitive to scattered light	Most sensitive to direct axial rays
Rod system	**Cone system**
Low acuity: not present in central fovea, highly convergent retinal pathways	High acuity: concentrated in fovea, dispersed retinal pathways
Achromatic: one type of rod pigment	Chromatic: three types of cones, each with a distinct pigment that is most sensitive to a different part of the visible light spectrum

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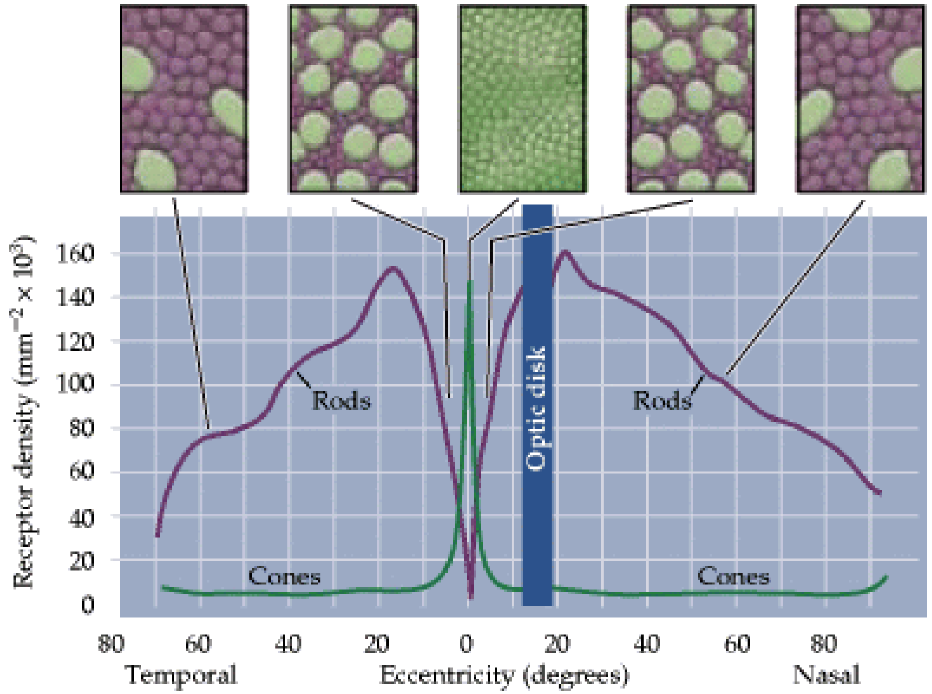

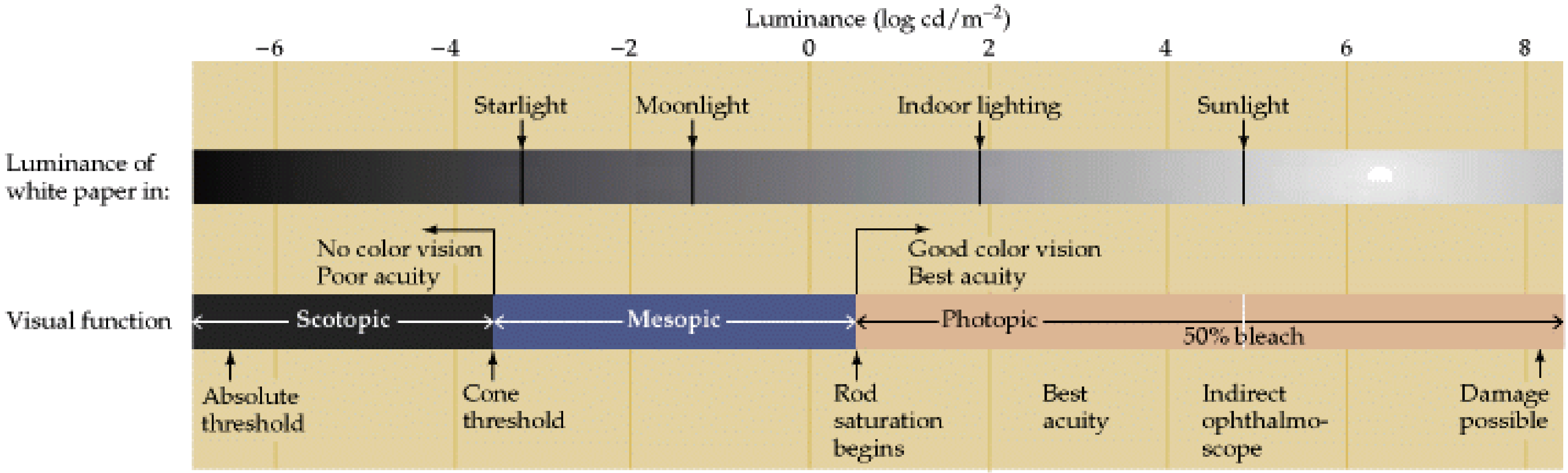

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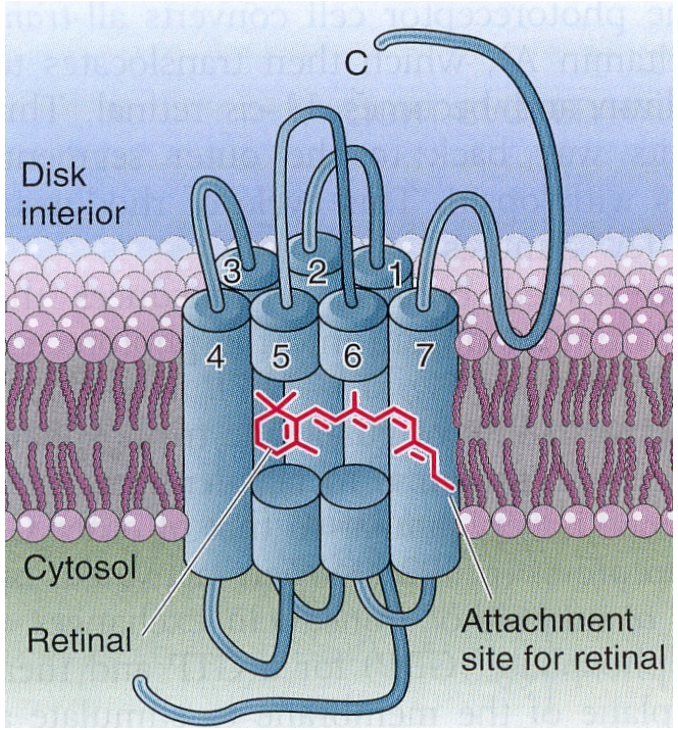
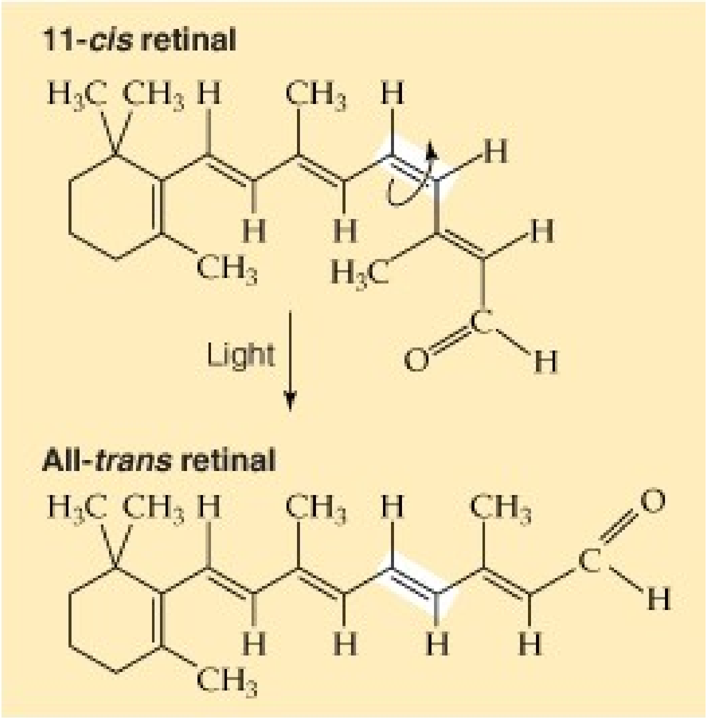
Photopigment of rods

Rhodopsin

- Opsin
  - G – protein



- Retinal
  - Retinol aldehyde (vit. A)



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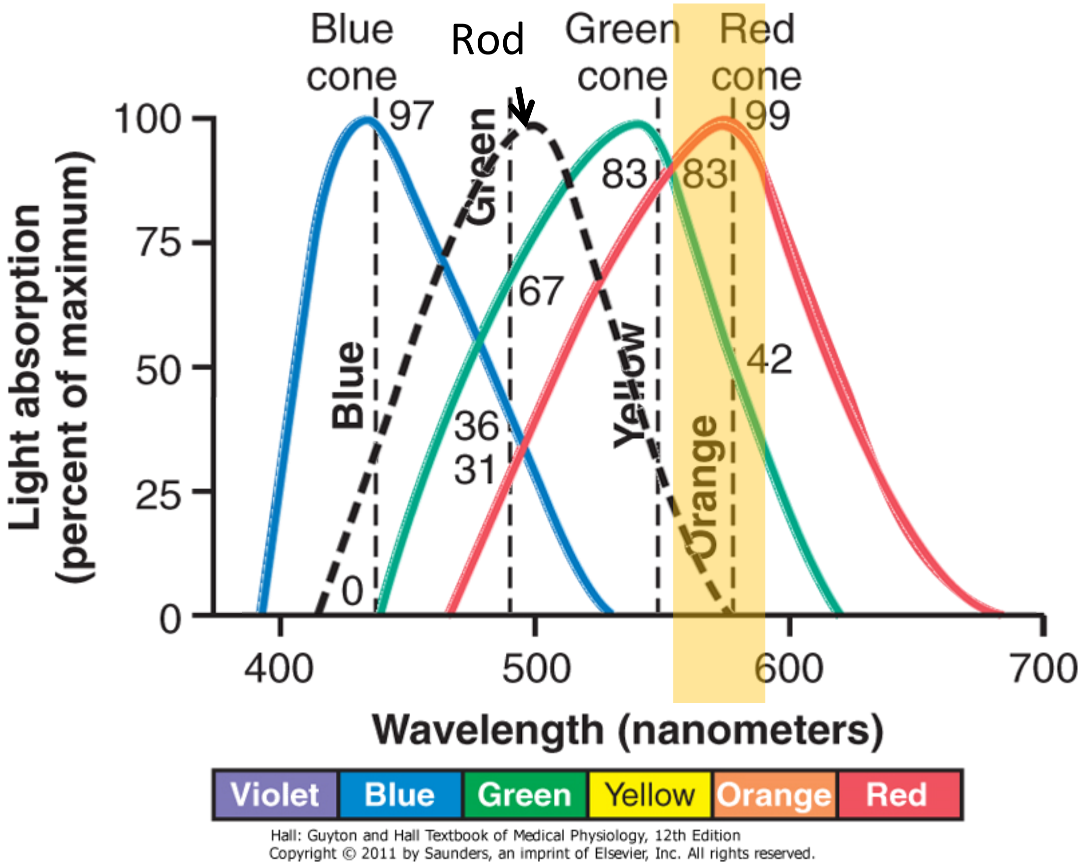
Photopigments of cones

- 3 types of cones - 3 types of photopigment
  - Blue(420nm)
  - Green (530nm)
  - Red (560nm)

- Color is interpreted by ratio of cone stimulation
  - Orange (580nm)
    - Blue: 0%
    - Green: 42%
    - Red:99%



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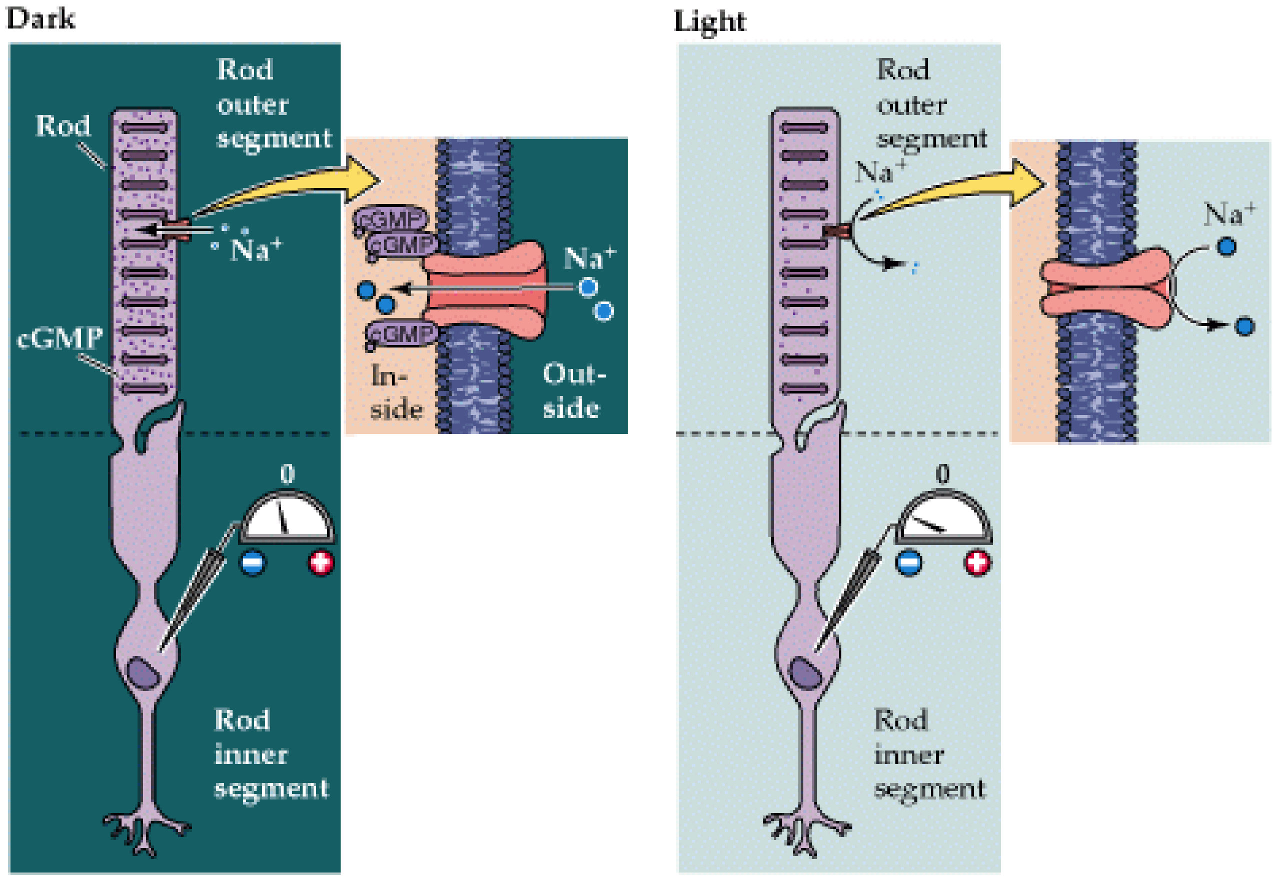
Phototransduction

- Photoreceptors continuously release neurotransmitter (glutamate) in darkness
- In response to the light, the membrane **hyperpolarizes** and release less neurotransmitter



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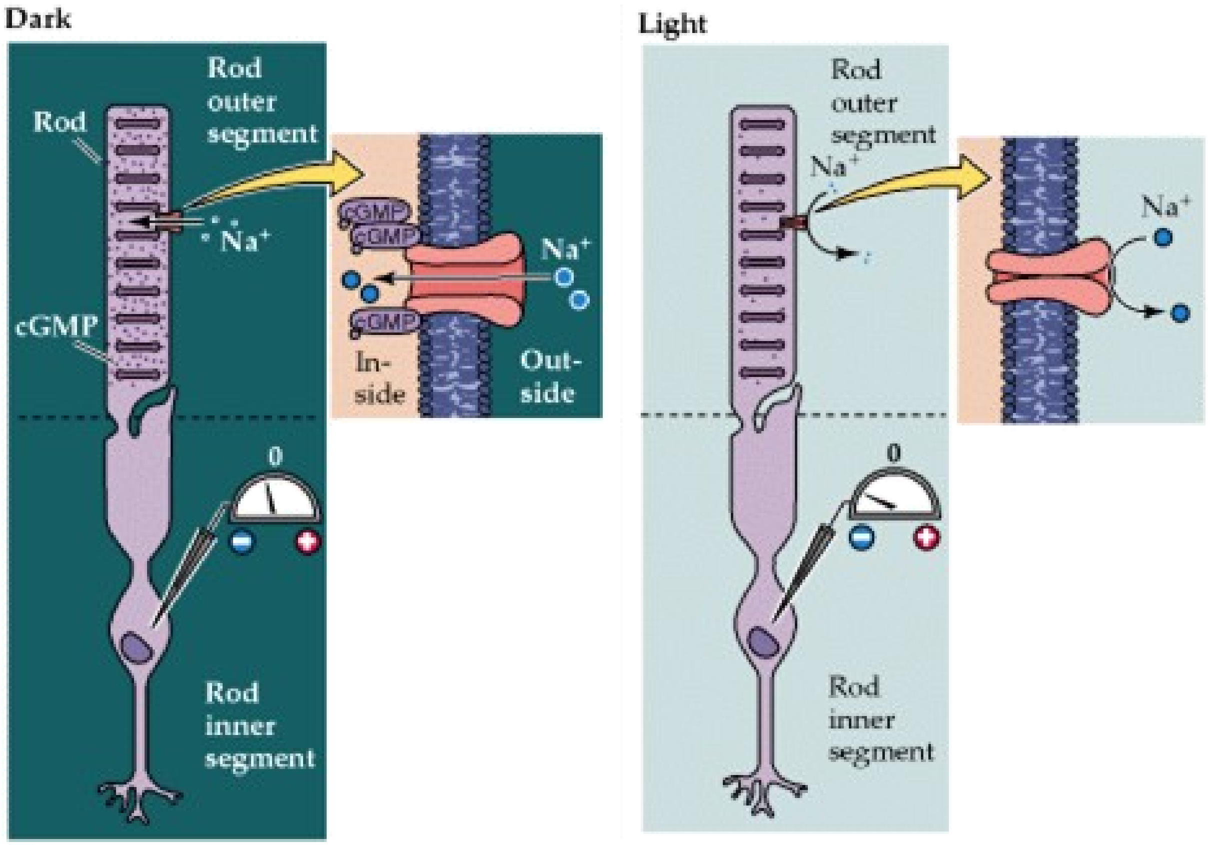
Adaptation to the light/darkness

- **Optic adaptation**
  - Constriction of pupils

- **Photoreceptor adaptation**
  - **Ca^{2+} inhibits guanylate cyclase**
  - cGMP gated Na^{+} channels...
  - Darkness
    - Higher Ca^{2+} levels → cGMP decreased → membrane more hyperpolarized → **„higher sensitivity to light“**
  - Light
    - Lower Ca^{2+} levels → cGMP increased → membrane more depolraized → **„lower senzitivity to light“**



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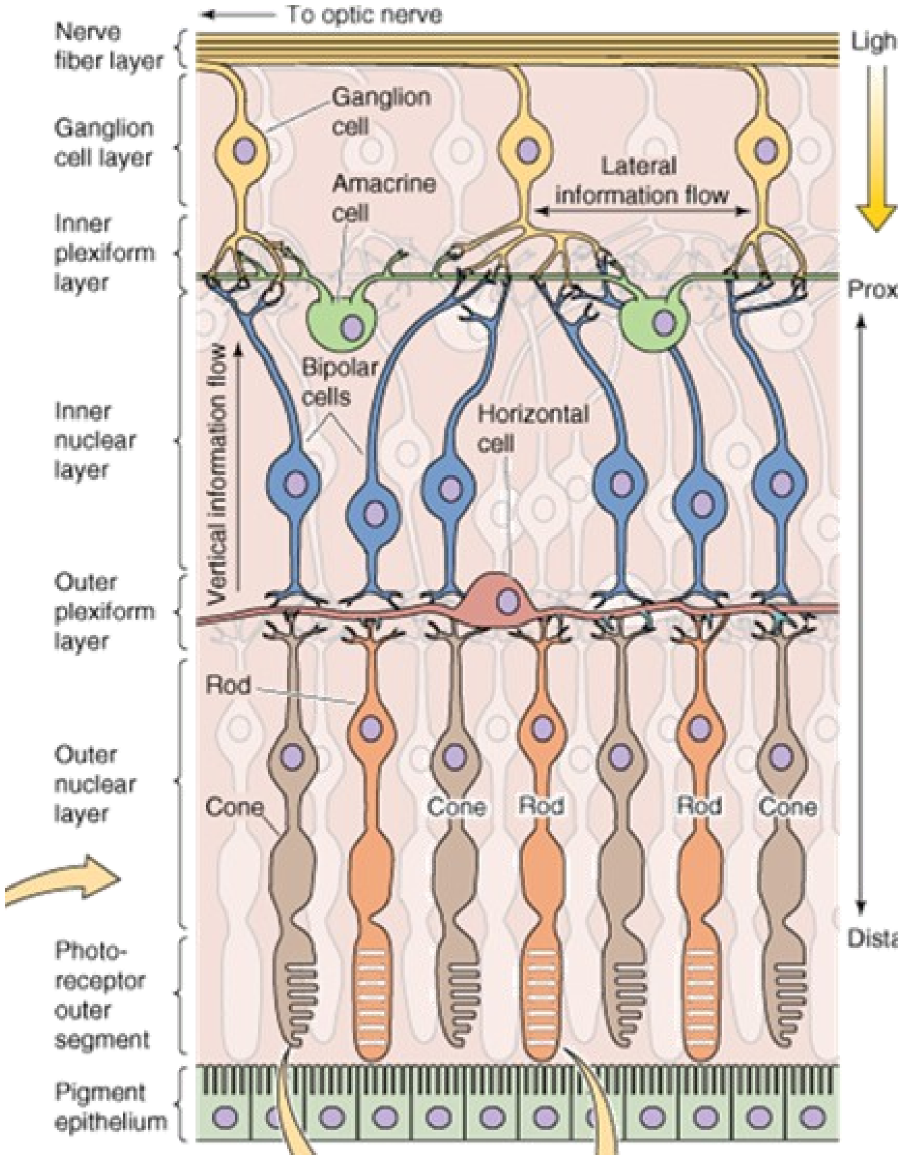
Retina

- Photoreceptors
- Interneurons
  - Horizontal cells
    - Horizontal interconnection
  - Bipolar cells
    - Vertical interconnection
  - Amacrine cells
    - Both horizontal and vertical interconnection
- Ganglion cells
  - AP generation
  - Transmission of AP to the brain



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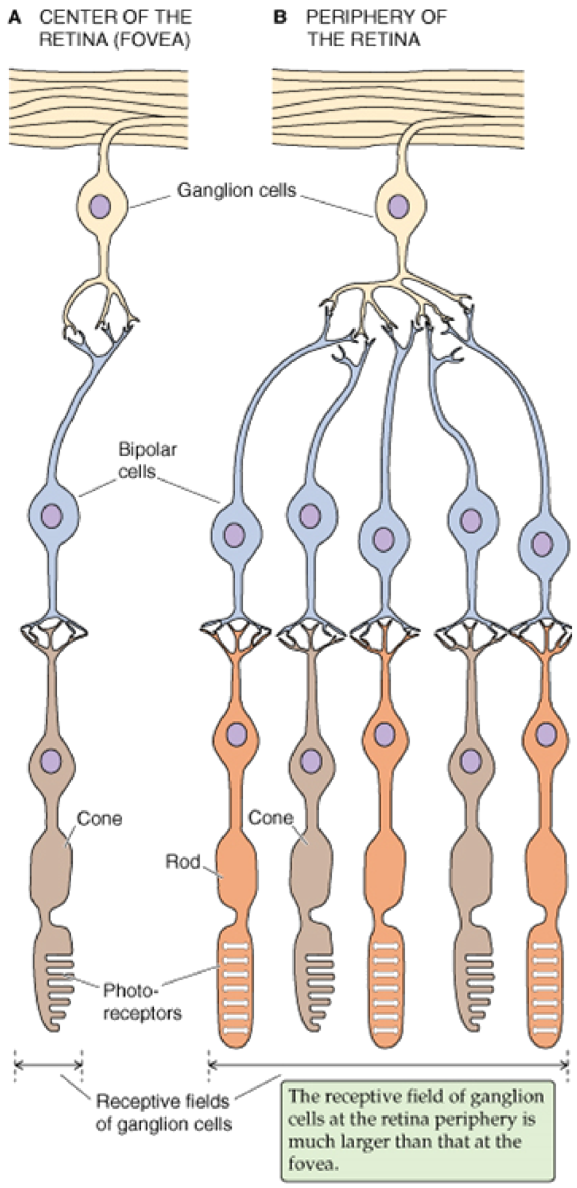
Retina

- Fovea
  - Low convergence
    - Small receptive field
    - High resolution
  - Lower sensitivity to light

- Periphery of retina
  - High degree of convergence
    - Large receptive field
    - Low resolution
  - High sensitivity to light



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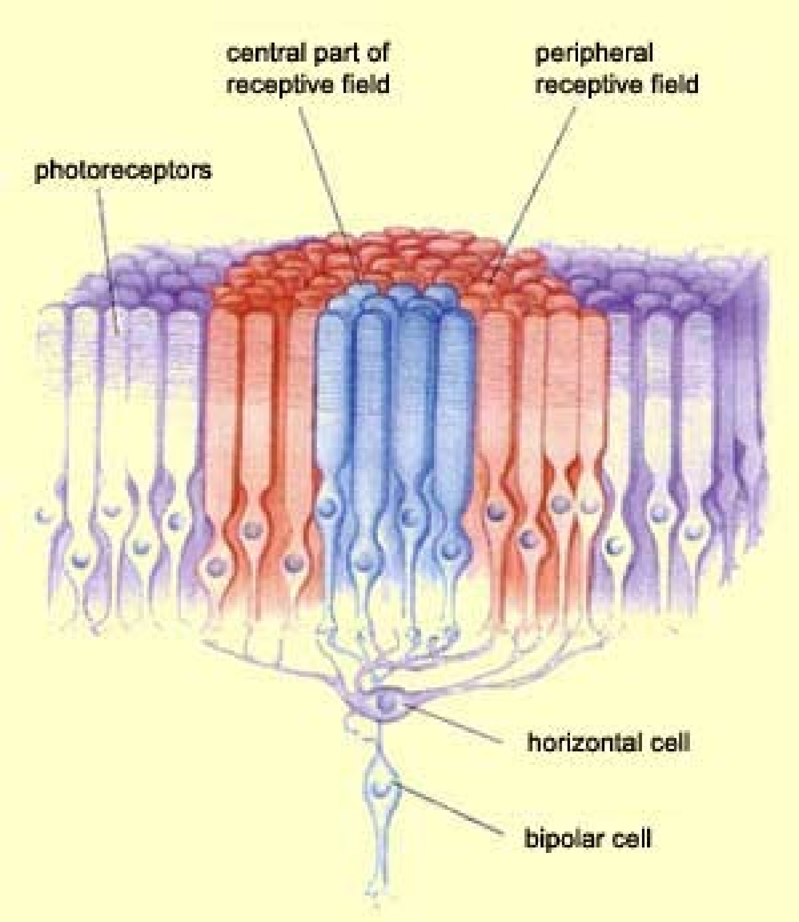
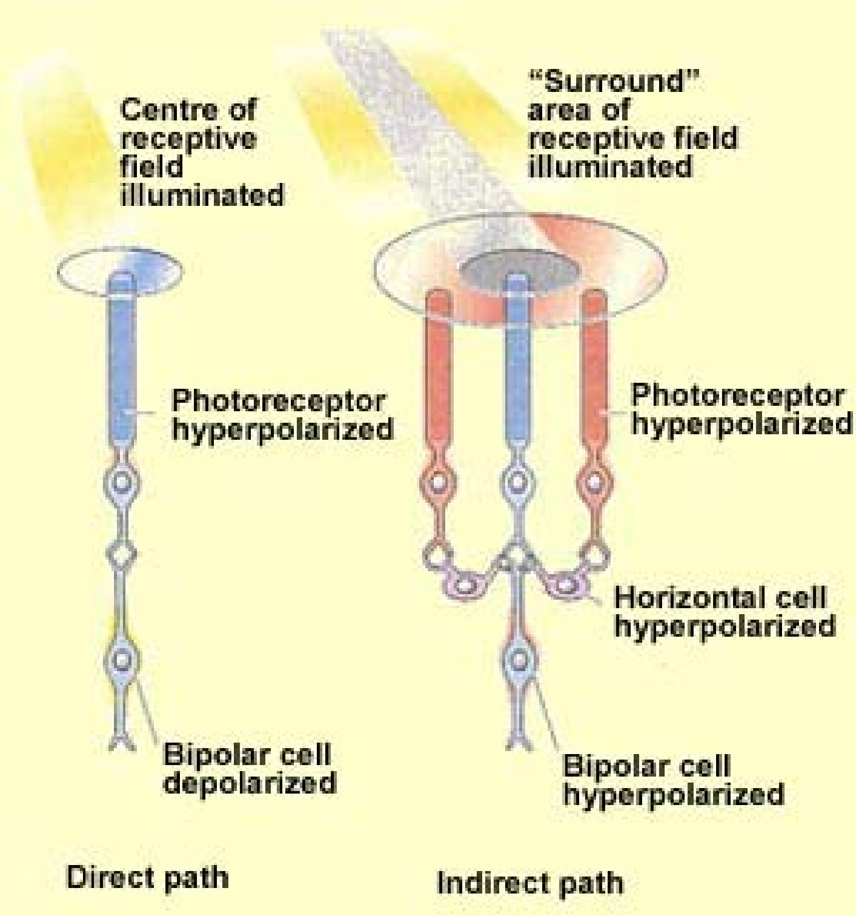
Receptive field





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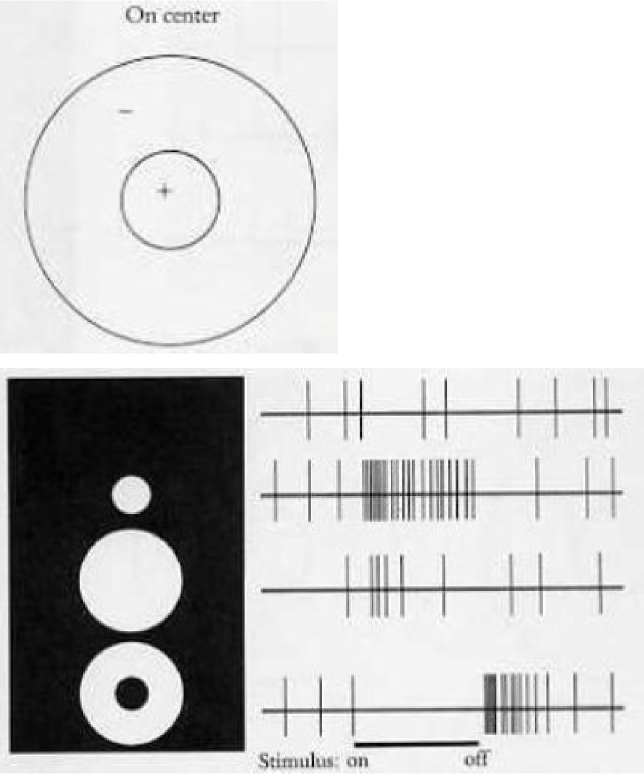
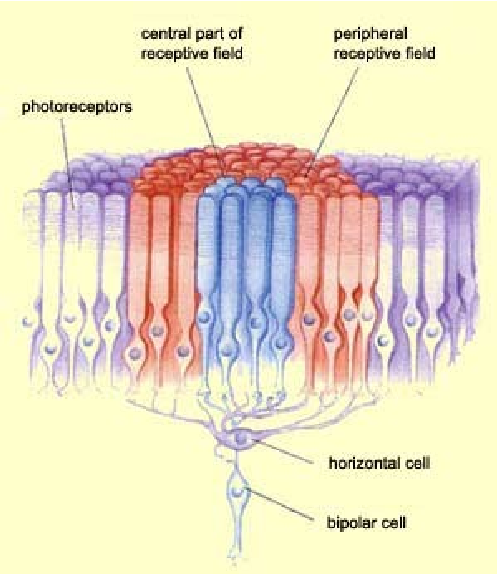
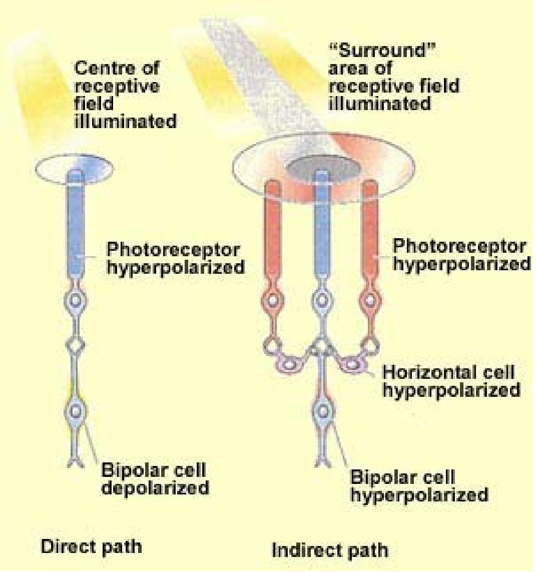
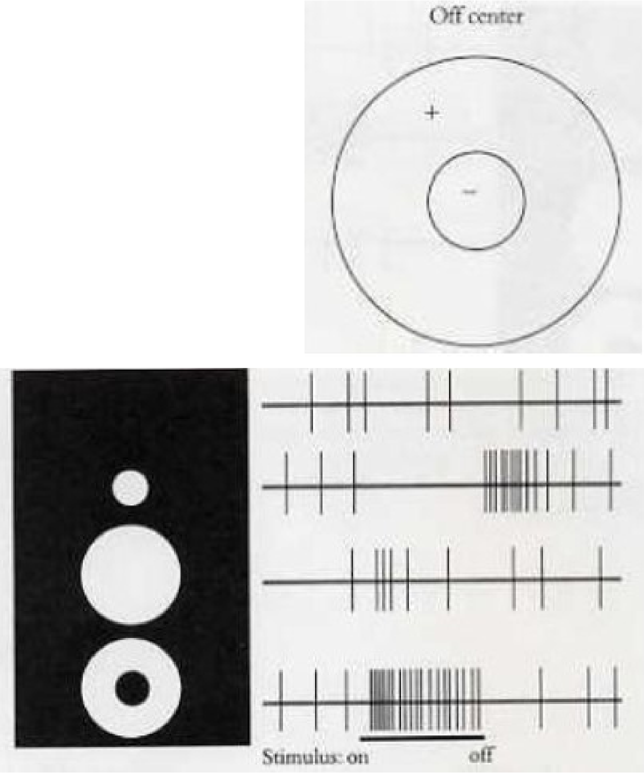
Receptive field









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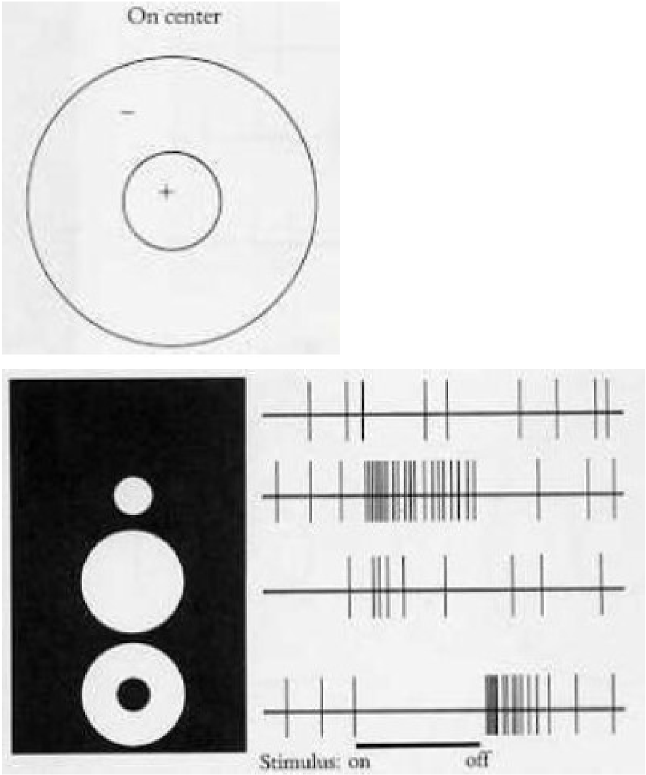
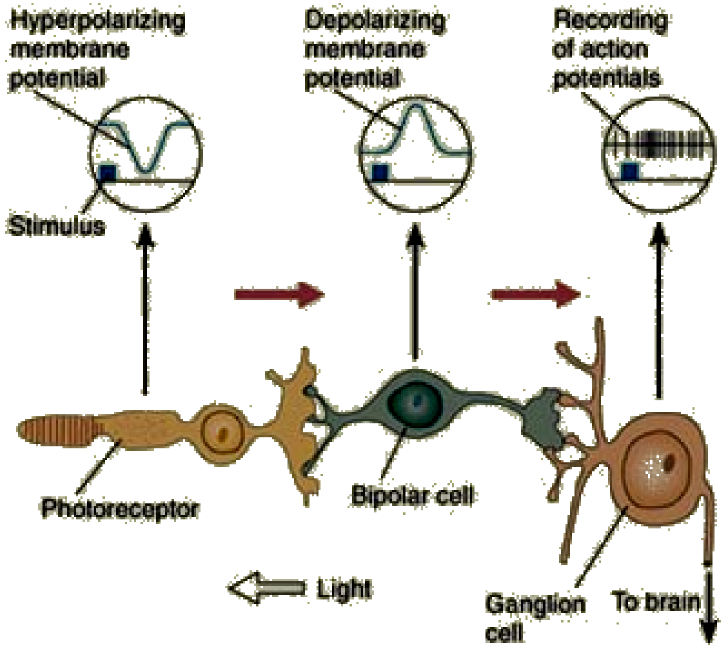
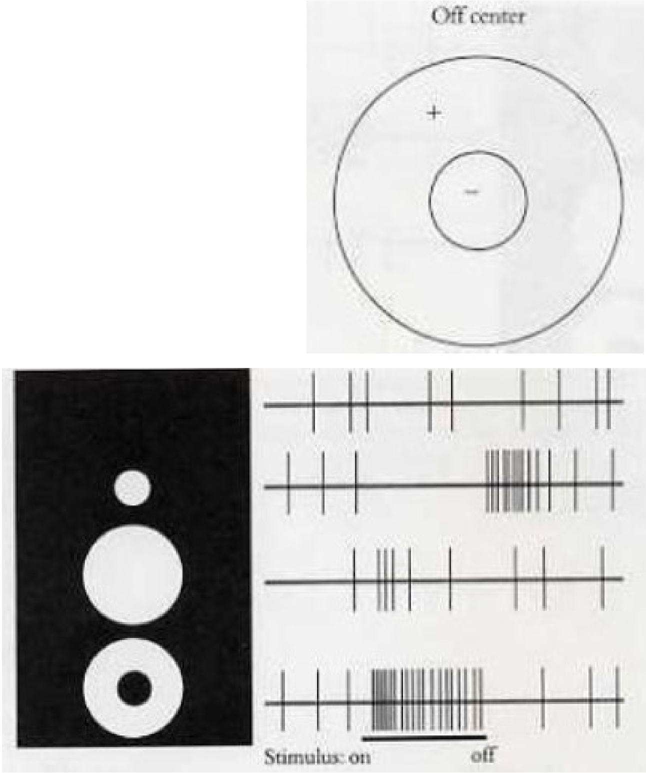
Receptive field







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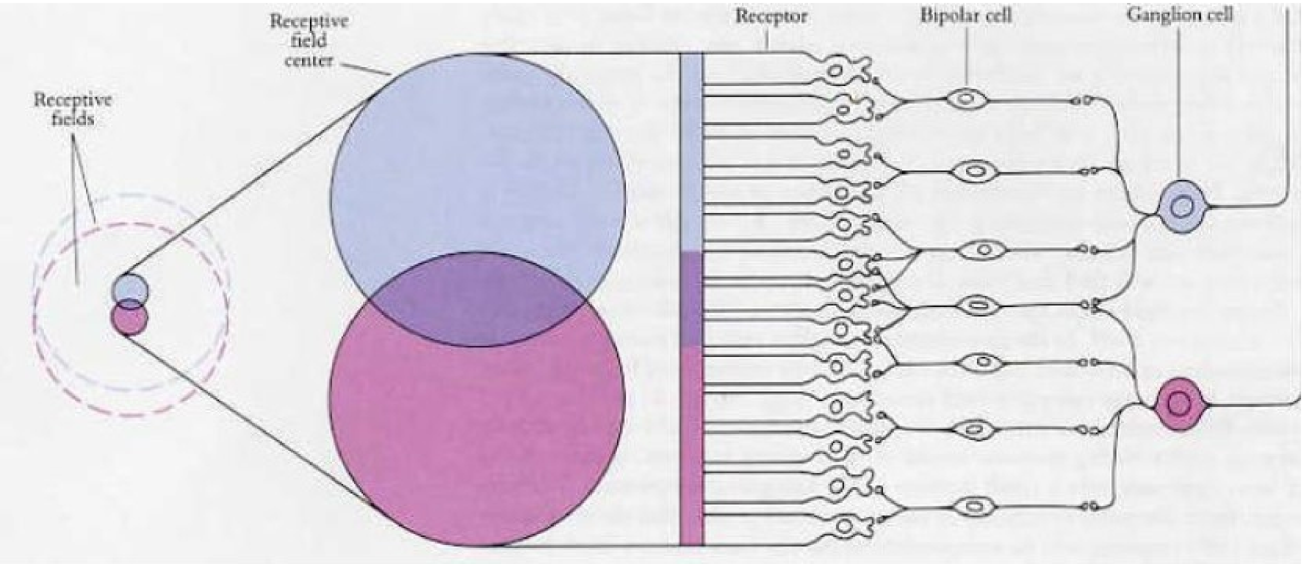
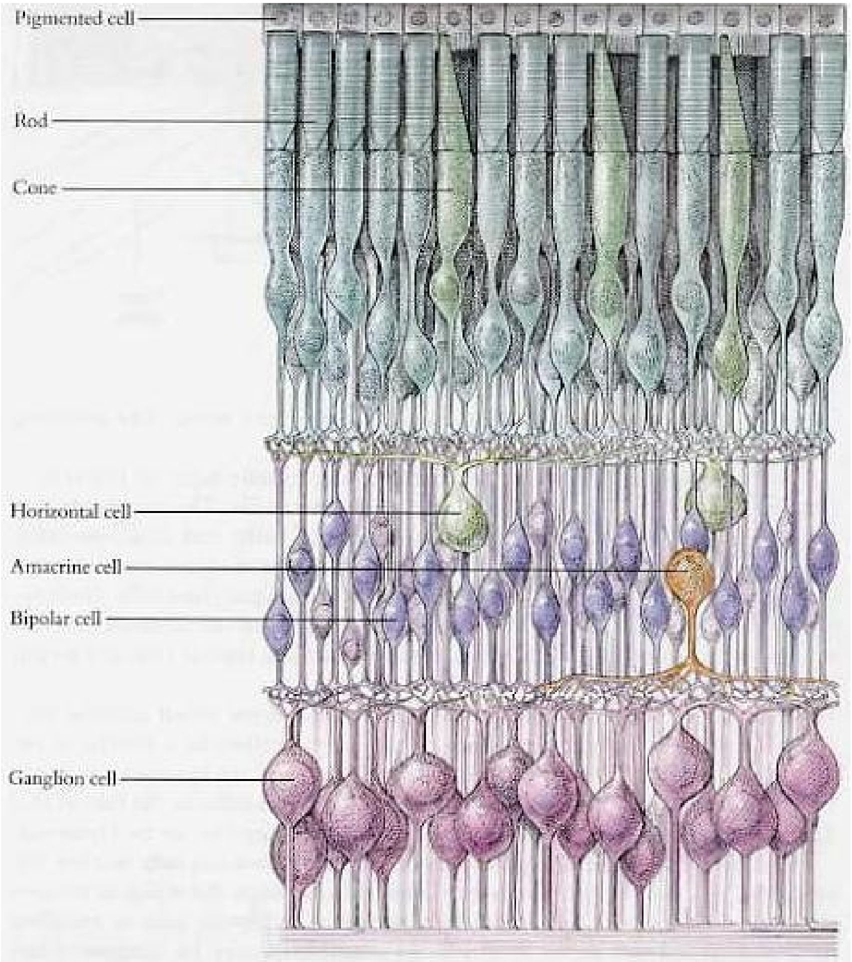
Receptive field





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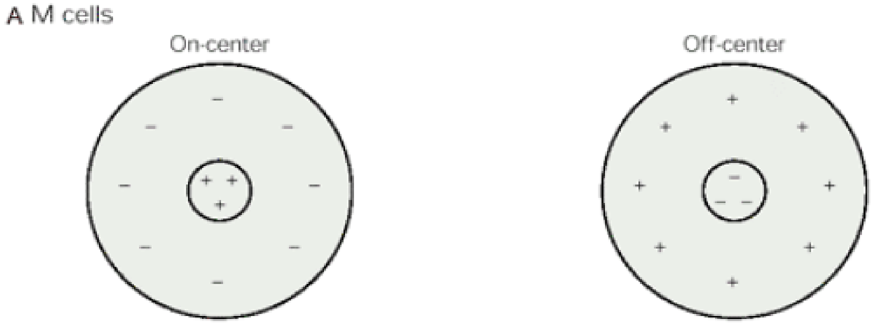
Receptive field

- Magnocellular system
  - Large receptive field
  - Rods and cones
  - **M ganglion cells (10%)**
  - High speed of velocity
  - Brightness/low contrast sensitivity
  - Minimal sensitivity to color



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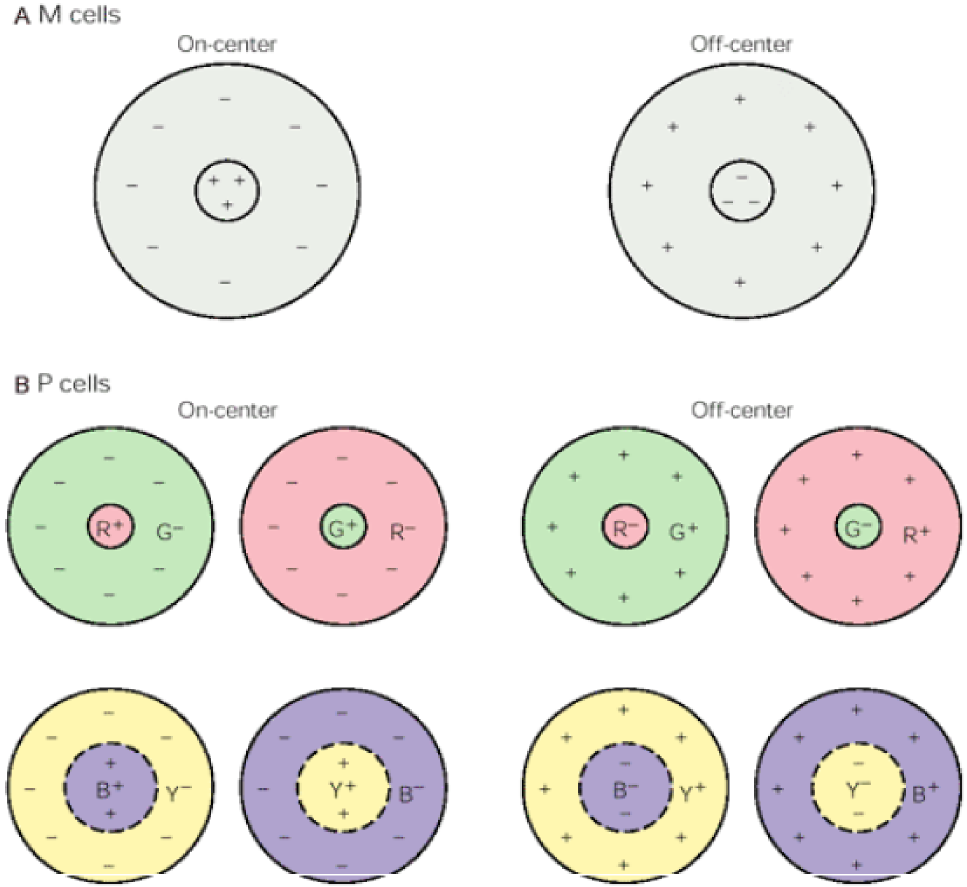
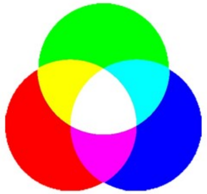
Receptive field

- Magnocellular system
  - Large receptive field
  - Rods and cones
  - **M ganglion cells (10%)**
  - High speed of velocity
  - Brightness/low contrast sensitivity
  - Minimal sensitivity to color
- Parvocellular system
  - Small receptive field
  - Cones and rods
  - **P ganglion cells (80%)**
  - Low speed of velocity
  - Low sensitivity in low contrast
  - Good sensitivity to color





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Receptive field

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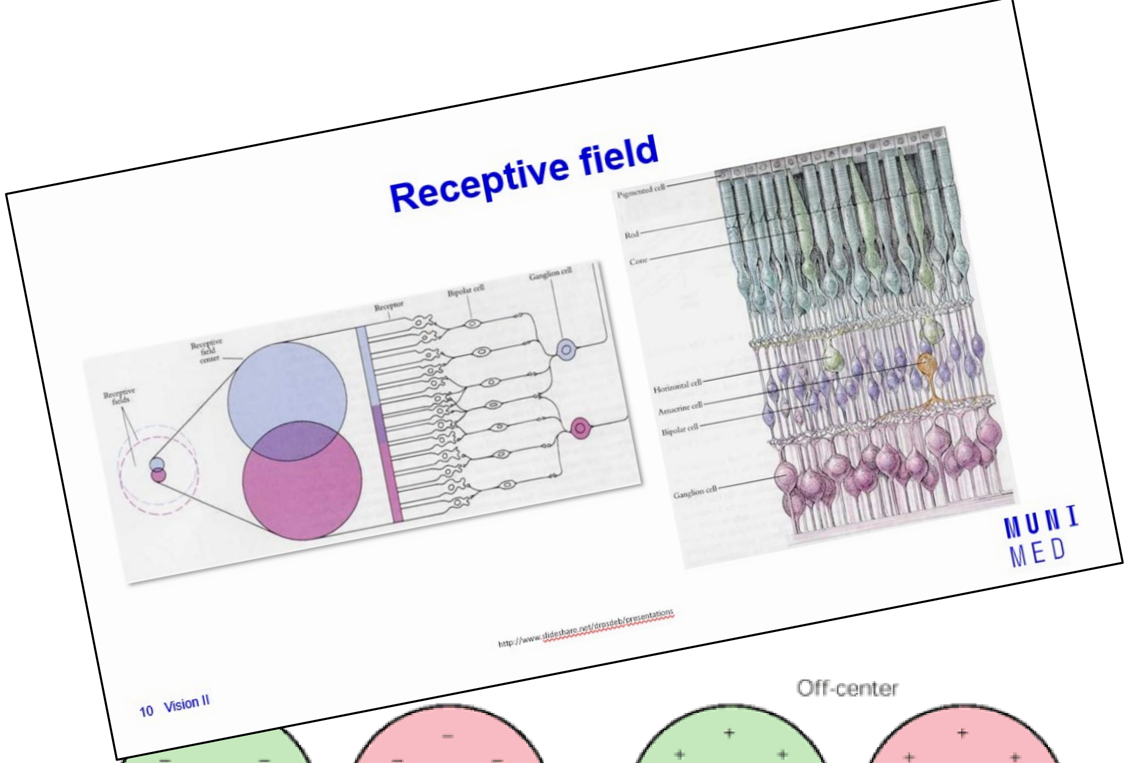

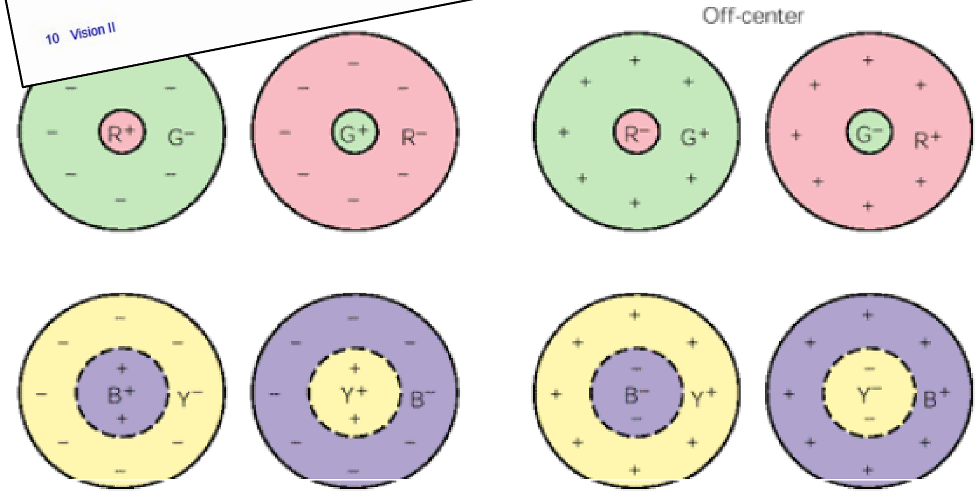

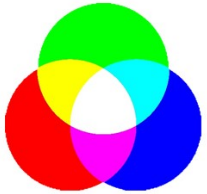

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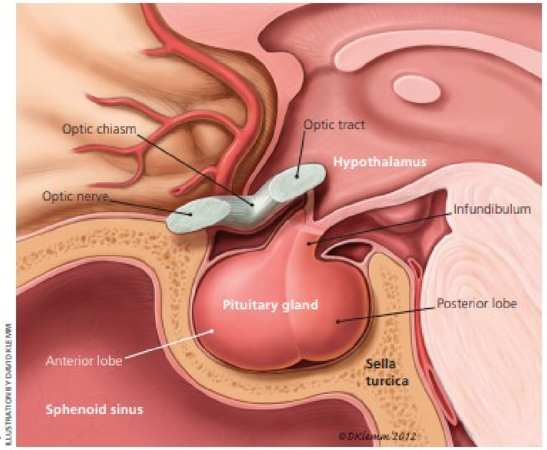
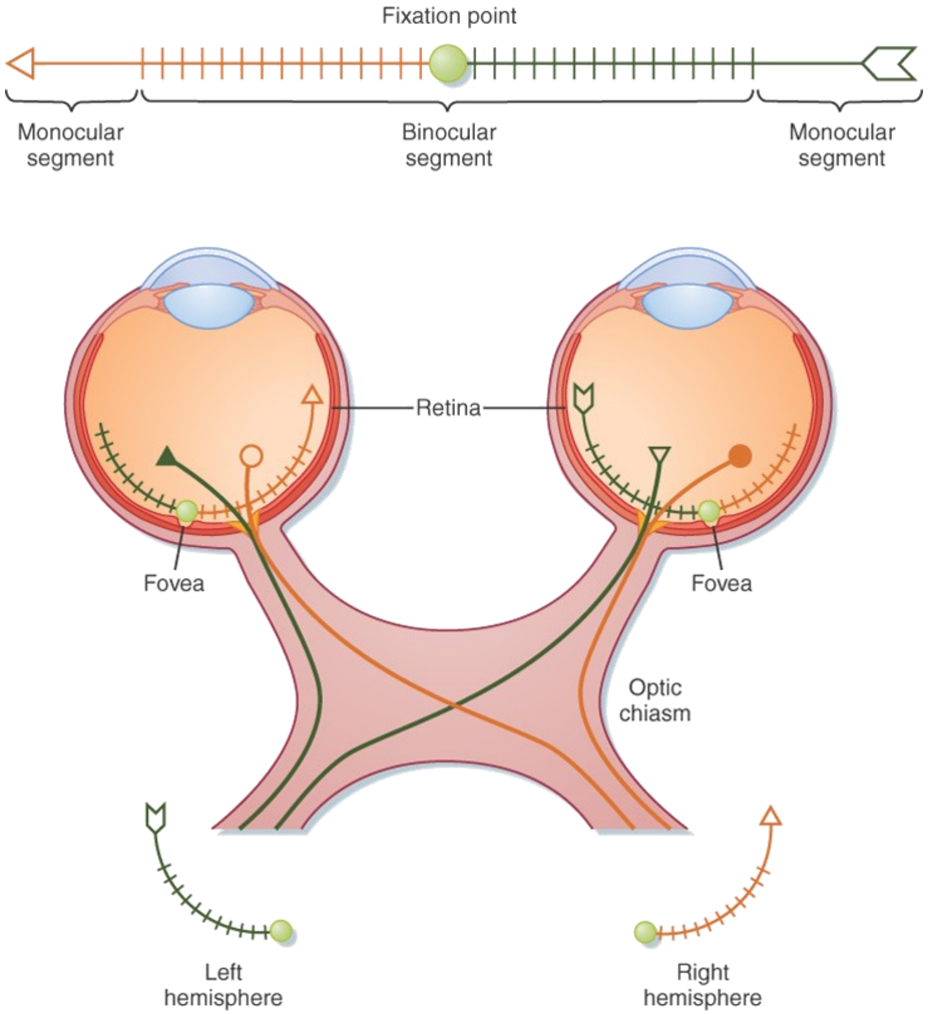
Optic nerve and optic tract

- Optic nerve
  - Signal from one eye
  - Signal from „whole“ visual field
- Optic tract
  - Signal from both eyes
  - Signal from half of visual field



https://www.aafp.org/afp/2013/0901/p319.pdf



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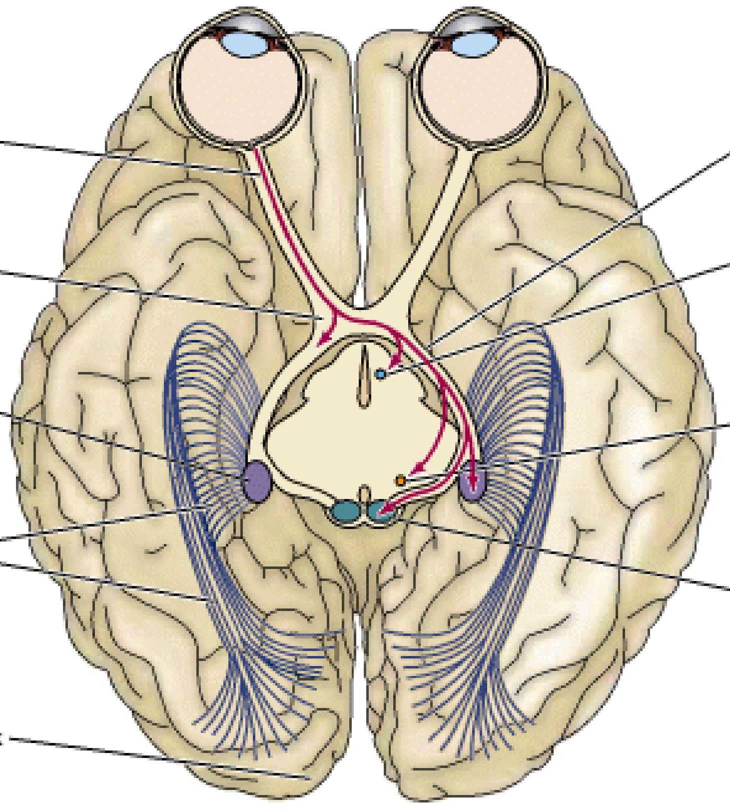
Visual pathways

- Nucleus corporis geniculati lateralis
  - Thalamus
  - Majority of projections
  - Via optic radiation to neocortex

- Hypothalamus
  - Regulation circadian activity

- Pretectum
  - Pupillary reflex
- Colliculi superiores
  - Reflex movement of eyes and head



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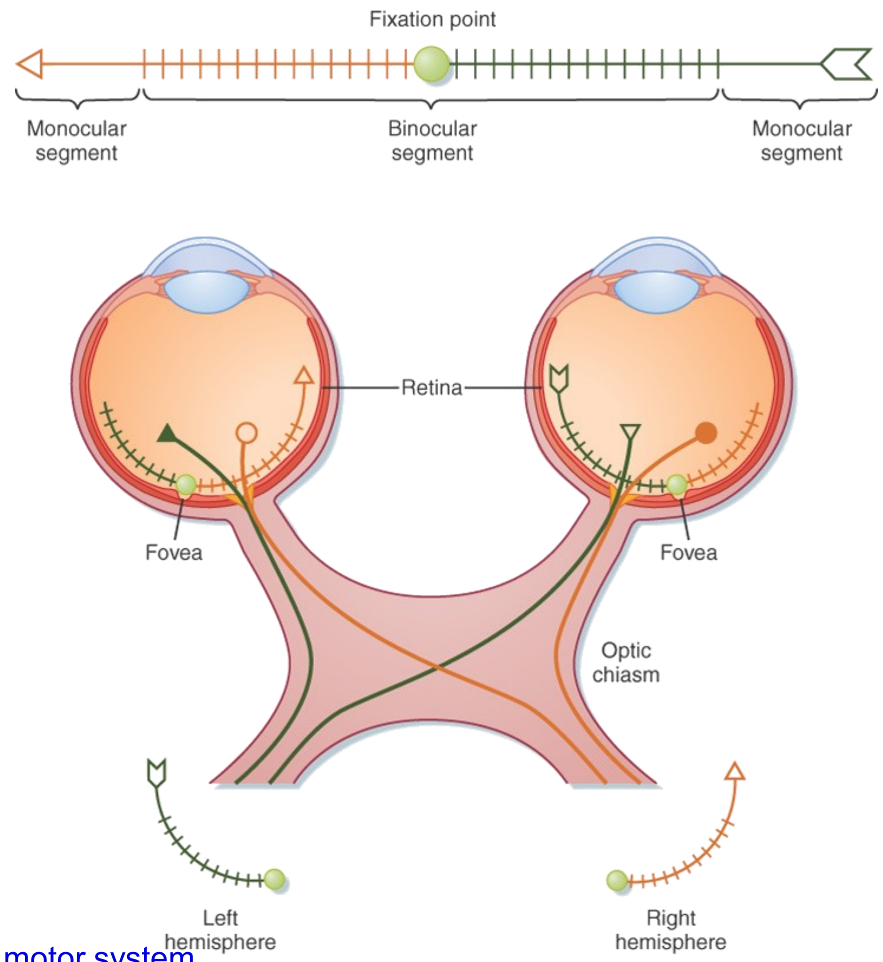
Primary visual cortex

Retinotopic organization



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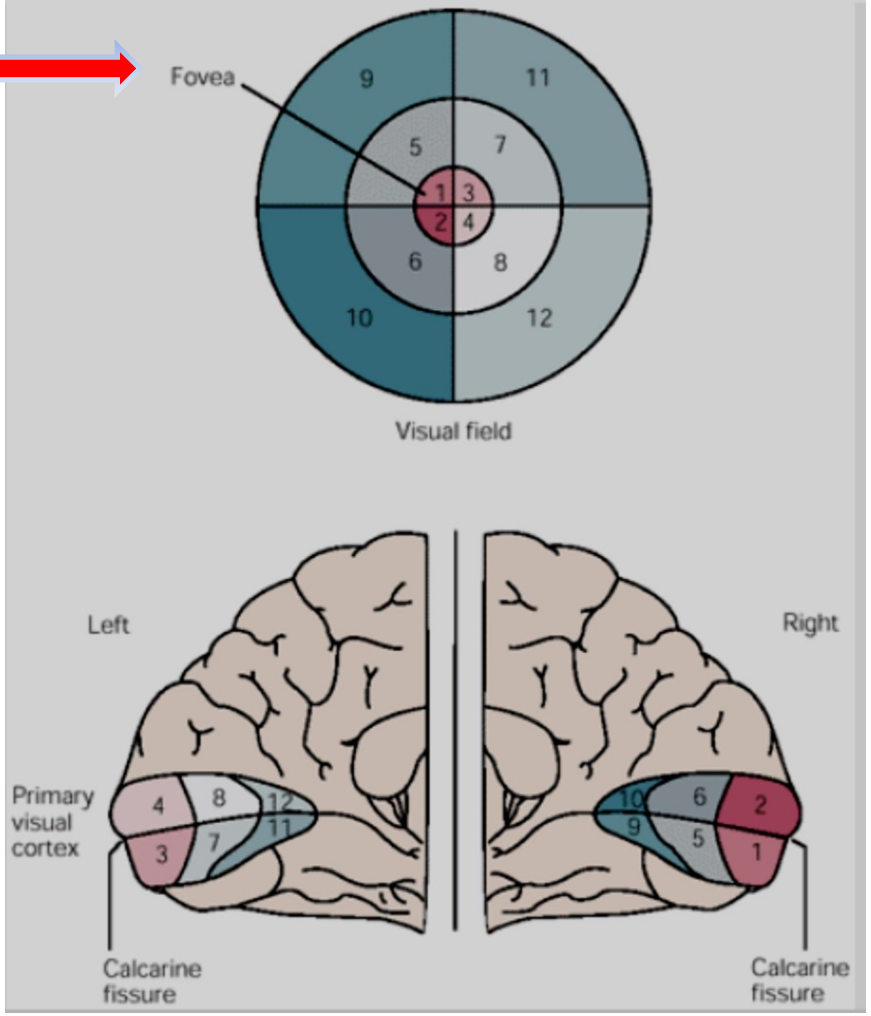

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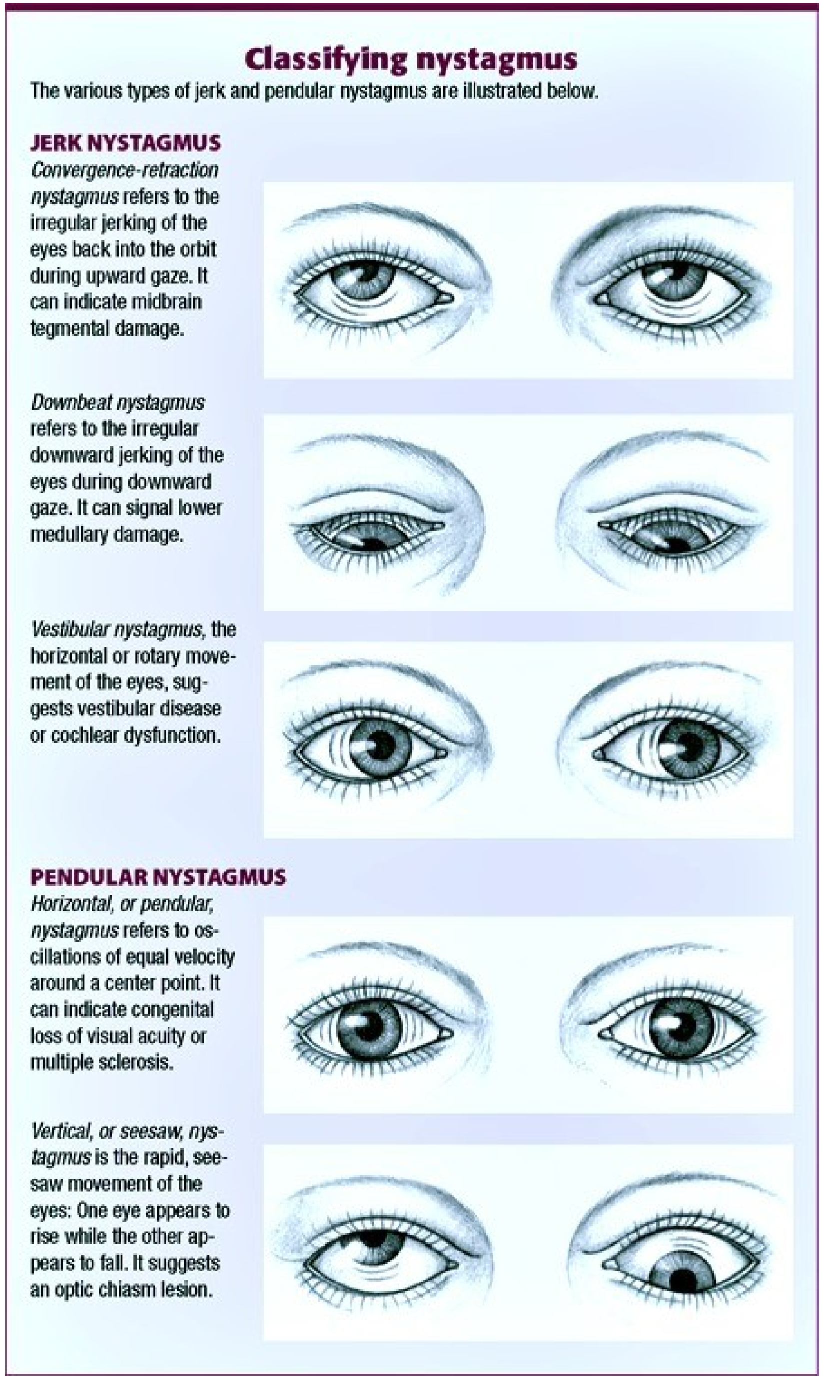
Nystagmus

- Involuntary rhythmic eye movement

- Physiological
  - Postrotatinal
  - Optokinetic

- Pathologic
  - ✓ Peripheral
    - Vestibular system pathologies
  - ✓ Central
    - CNS damage (cerebellum, midbrain…)



http://dxline.info/img/new_ail/nystagmus.jpg

Saccadic eye movements

https://en.wikipedia.org/wiki/Saccade#/media/File:Szakkad.jpg

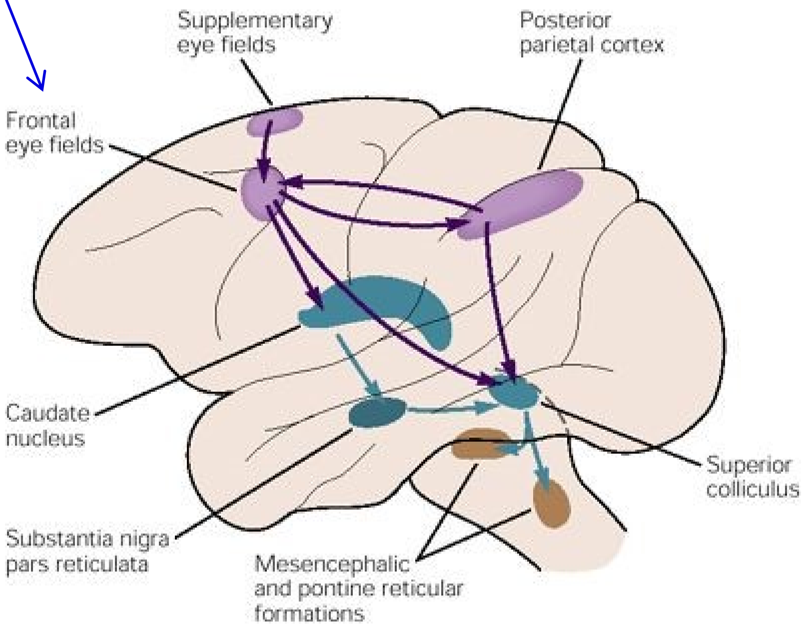
Saccadic eye movements

https://en.wikipedia.org/wiki/Saccade#/media/File:Szakkad.jpg

Intentional exploration

Assistance in controlling saccades during movement

Reflexive exploration



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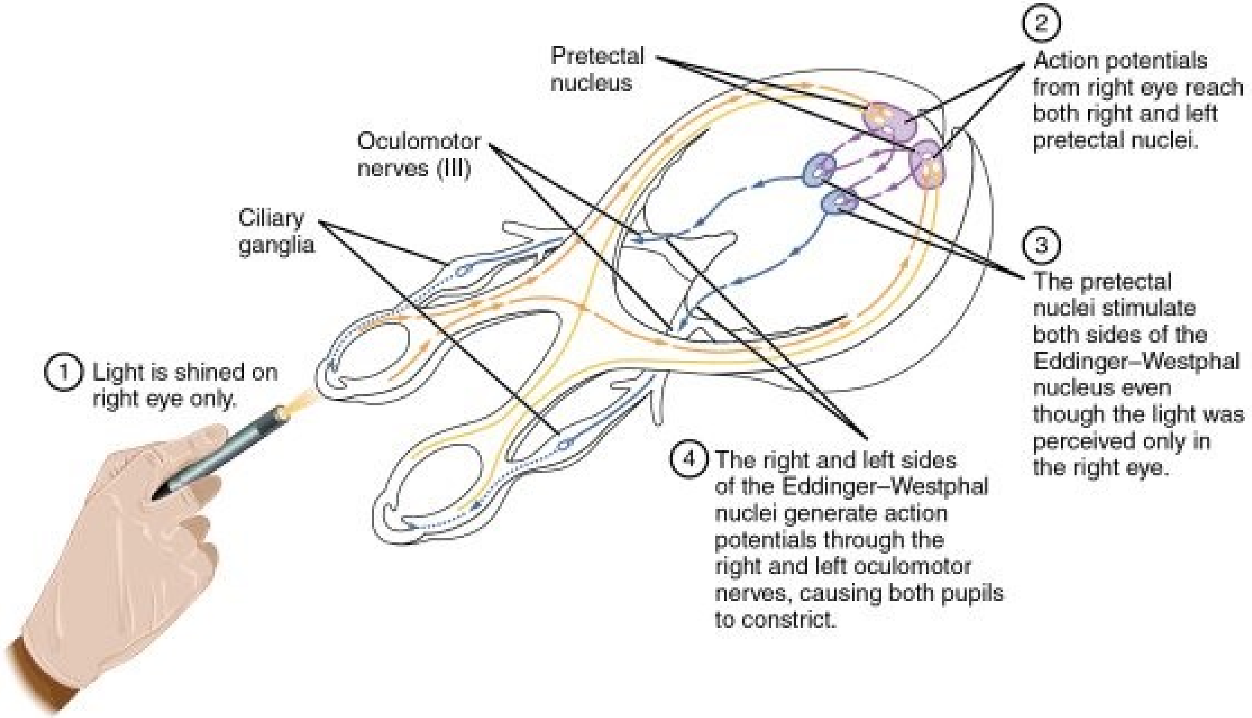
https://nasregion.cz/praha/praha-5-i-letos-podpori-filmovy-festival-febiofest

Pupillary reflex

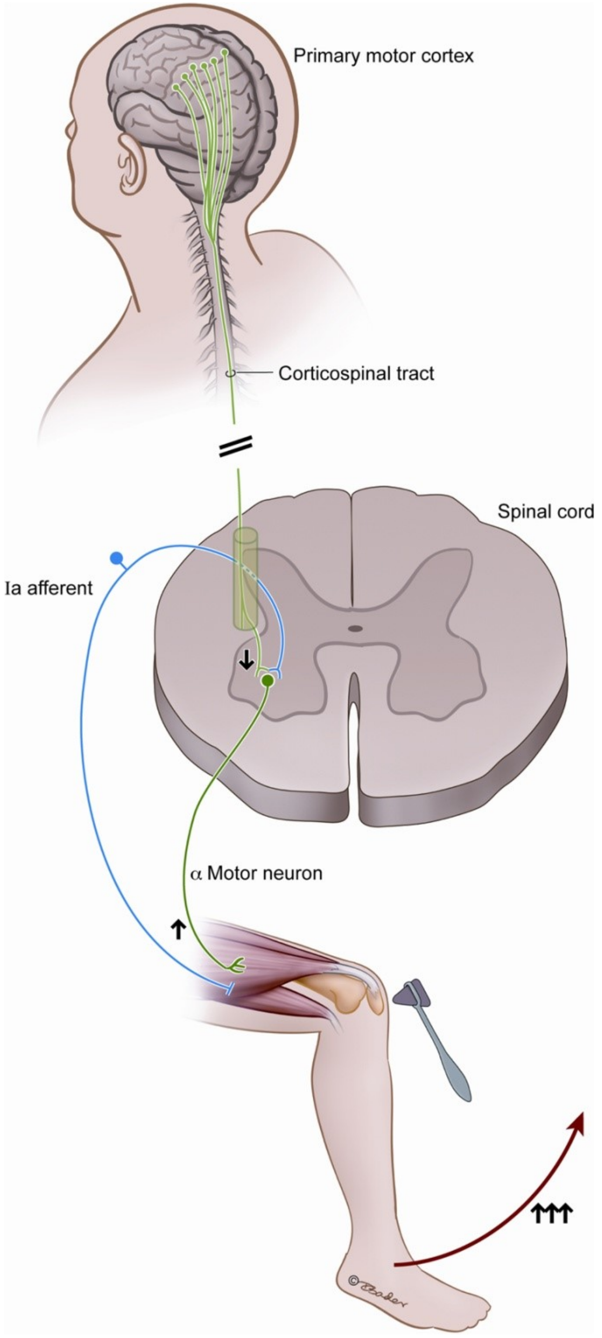


http://www.ubooks.pub/Books/B0/E27R7642/MAIN/images/1509_Pupillary_Reflex_Pathways.jpg

Motor system

Introduction

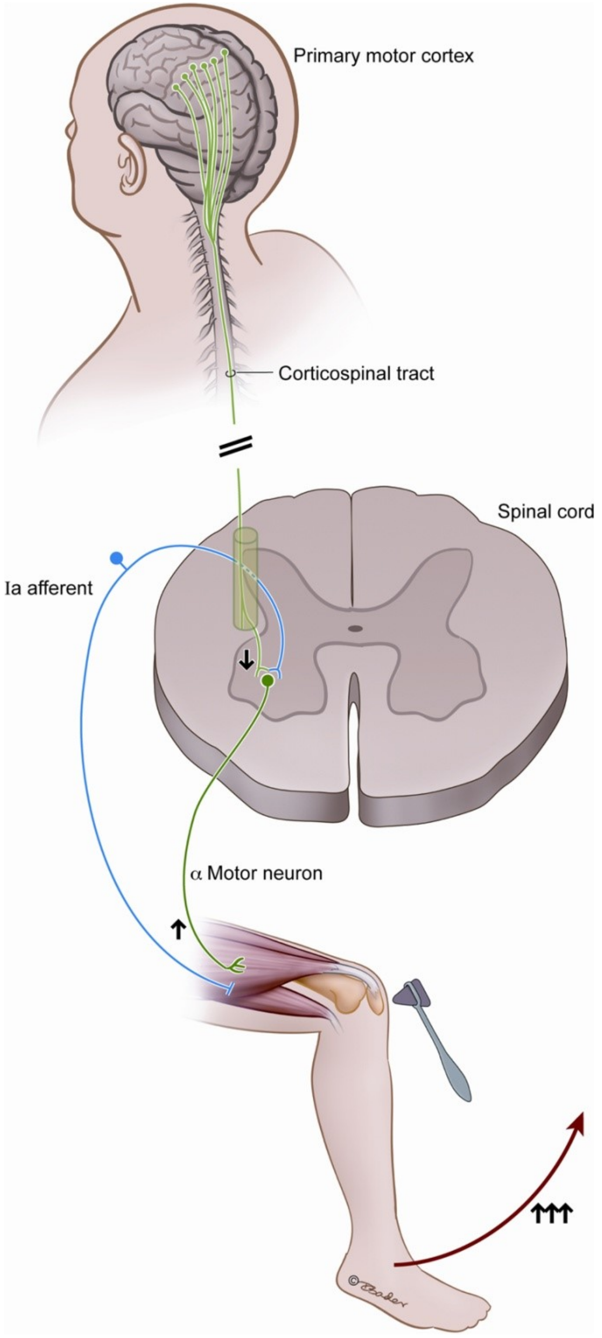
- Skeletal muscle contraction is initiated by lower motor neuron
- Lower motor neuron is a part of local reflex circuits



http://www.frontiersin.org/files/Articles/42416/fnhum-07-00085-HTML/image_m/fnhum-07-00085-g001.jpg

Introduction

- Skeletal muscle contraction is initiated by lower motor neuron
- Lower motor neuron is a part of local reflex circuits
- The information from several sources is integrated in the lower motor neuron
  - Higher levels of CNS
    - Upper motor neuron, tectum, n. ruber, brain stem
  - Proprioception



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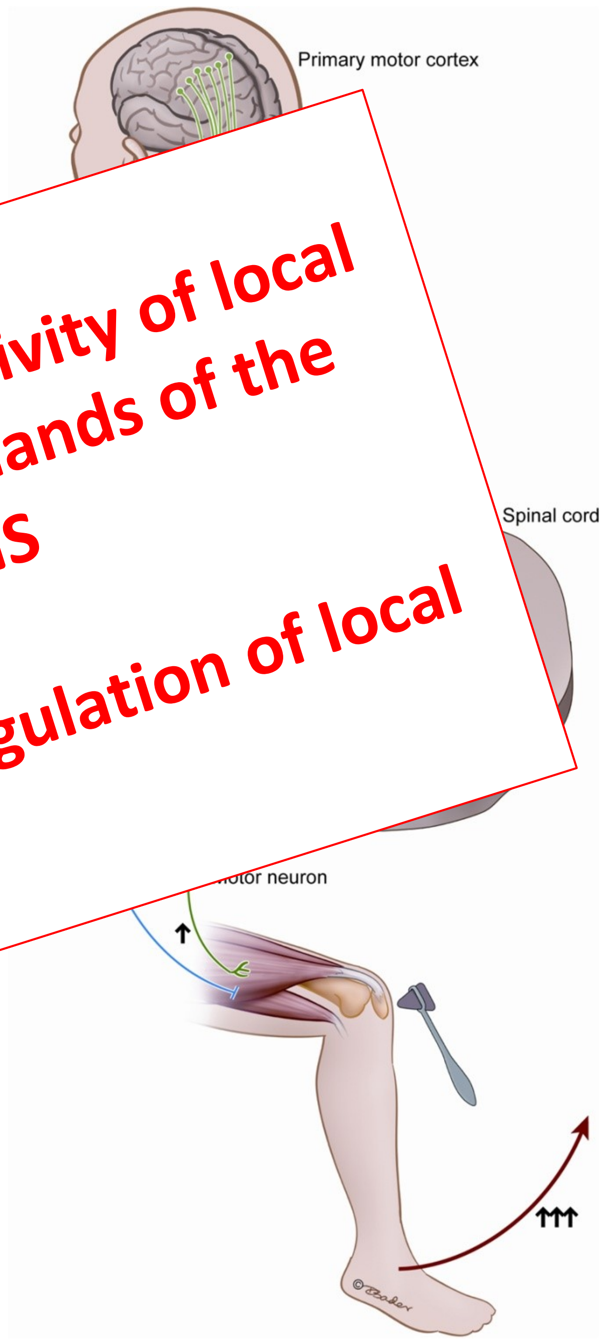
Introduction

- Skeletal muscle contraction is initiated …
  lower motor neuron
- Lower motor …
  reflex …
- The inf…
  integrat…
  - Highe…
    - Upp…
      rube…
  - Propriocе…

Lower motor neuron regulates the activity of local reflex circuits, according to the demands of the higher regions of the CNS

Proprioception is crucial for the regulation of local circuit activity



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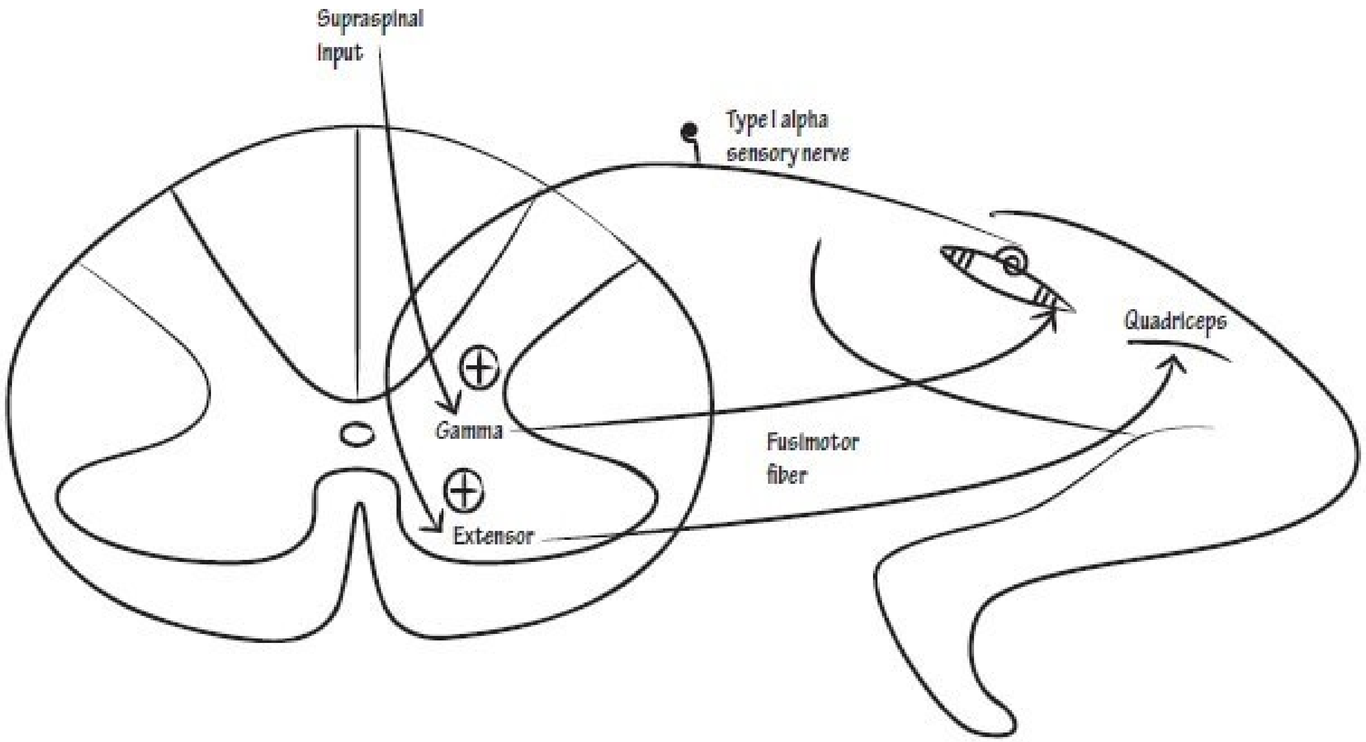
Lower motor neuron

- **α motoneuron**
  - Innervation of contractile elements
  - Extrafusal fibers
  - Muscle contraction

- **γ motoneuron**
  - Innervation of muscle spindles
  - Intrafusal fibers
  - Alignment of muscle spindles
  - Gamma loop

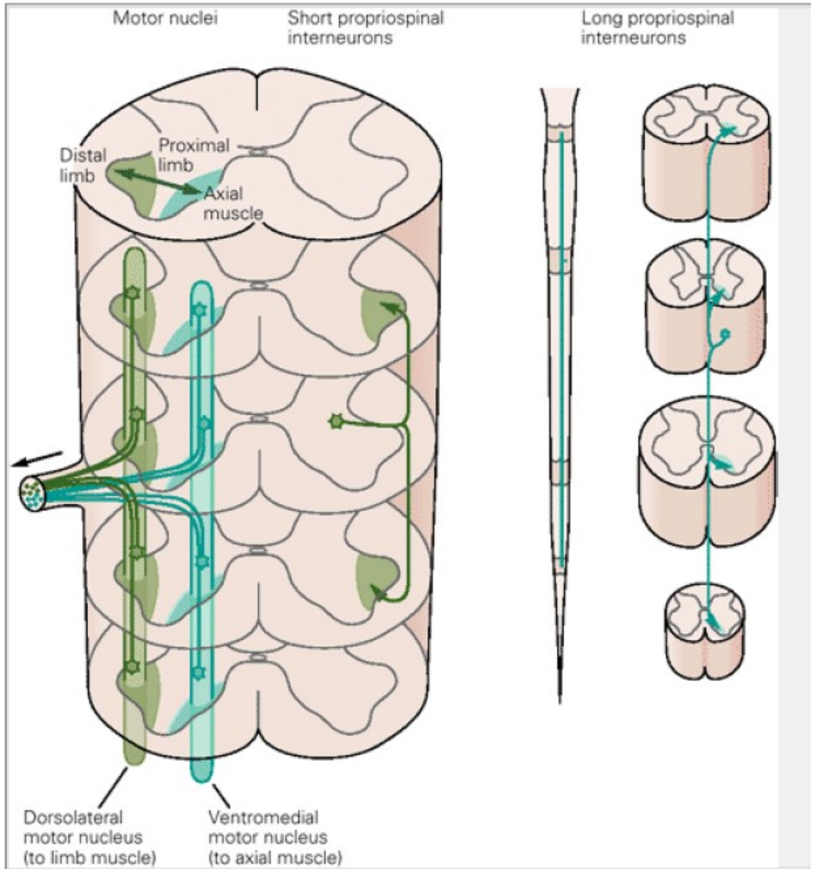
- **β motoneuron**
  - **Both extrafusal and intrafusal fiberrs**

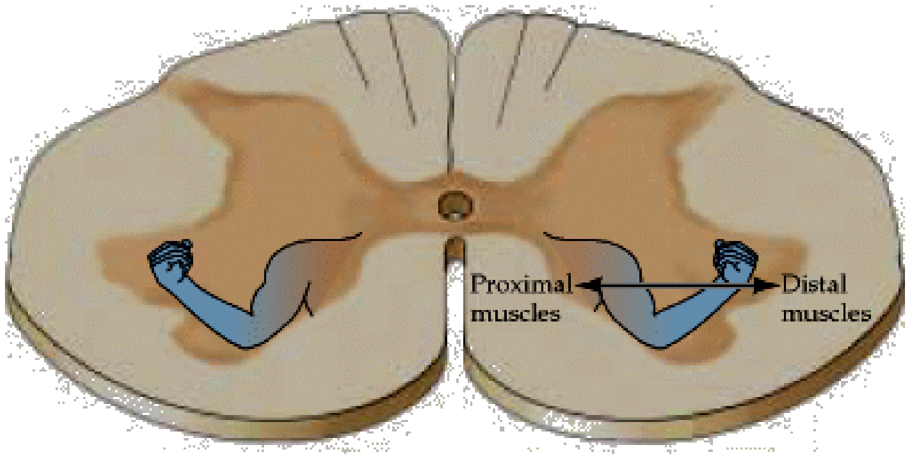


http://epomedicine.com/wp-content/uploads/2016/07/gamma-loop.jpg

Lower motor neuron

Topography





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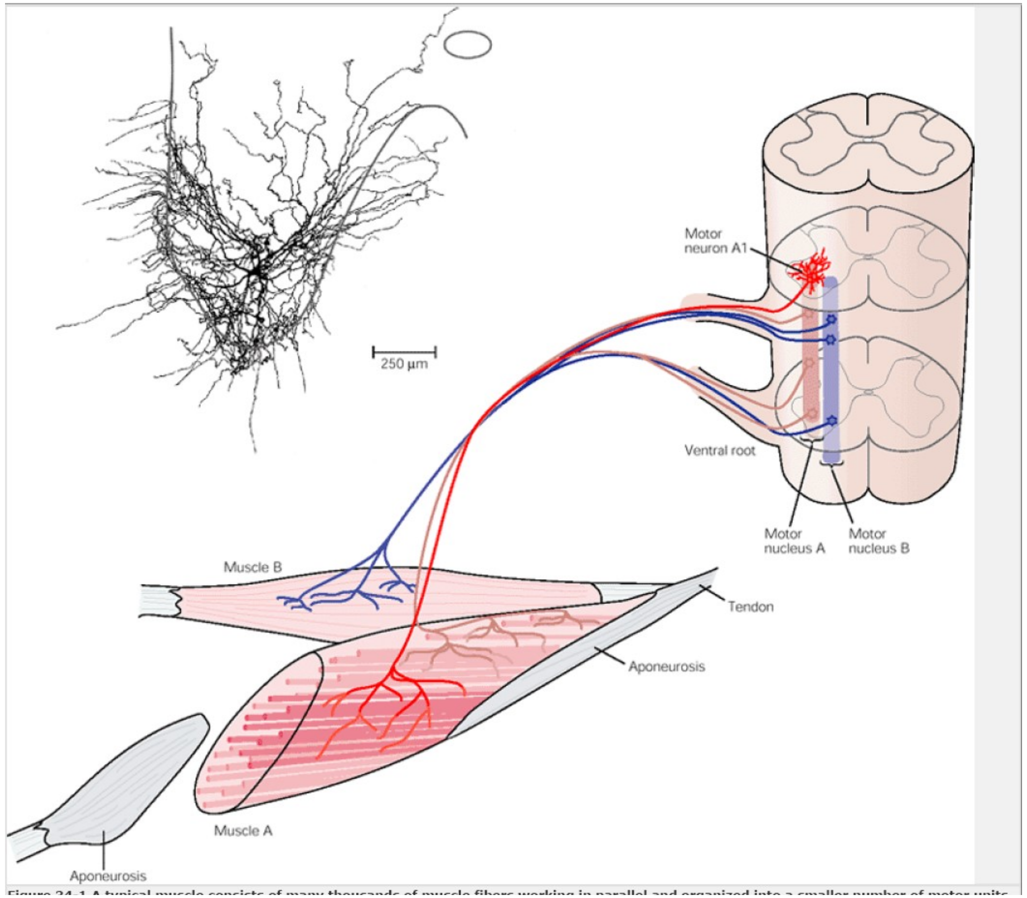
Motor unit

- A typical muscle is innervated by about 100 motoneurons which are localized in motor nucleus
- Each motoneuron innervate from 100 to 1000 muscle fibers and one muscle fiber is innervated by a single motoneuron



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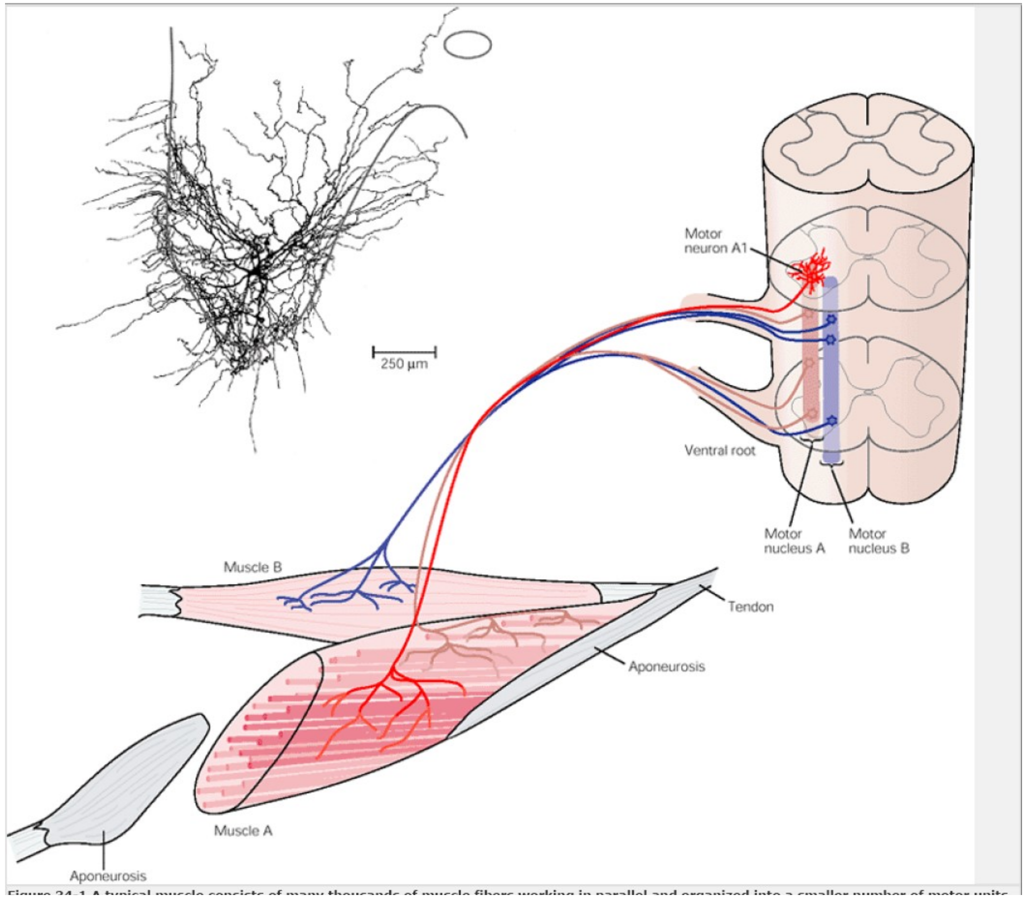
Motor unit

- A typical muscle is innervated by about 100 motoneurons which are localized in motor nucleus
- Each motoneuron innervate from 100 to 1000 muscle fibers and one muscle fiber is innervated by a single motoneuron
- The ensemble of muscle fibers innervated by a single neuron and corresponding motoneuron constitutes the motor unit



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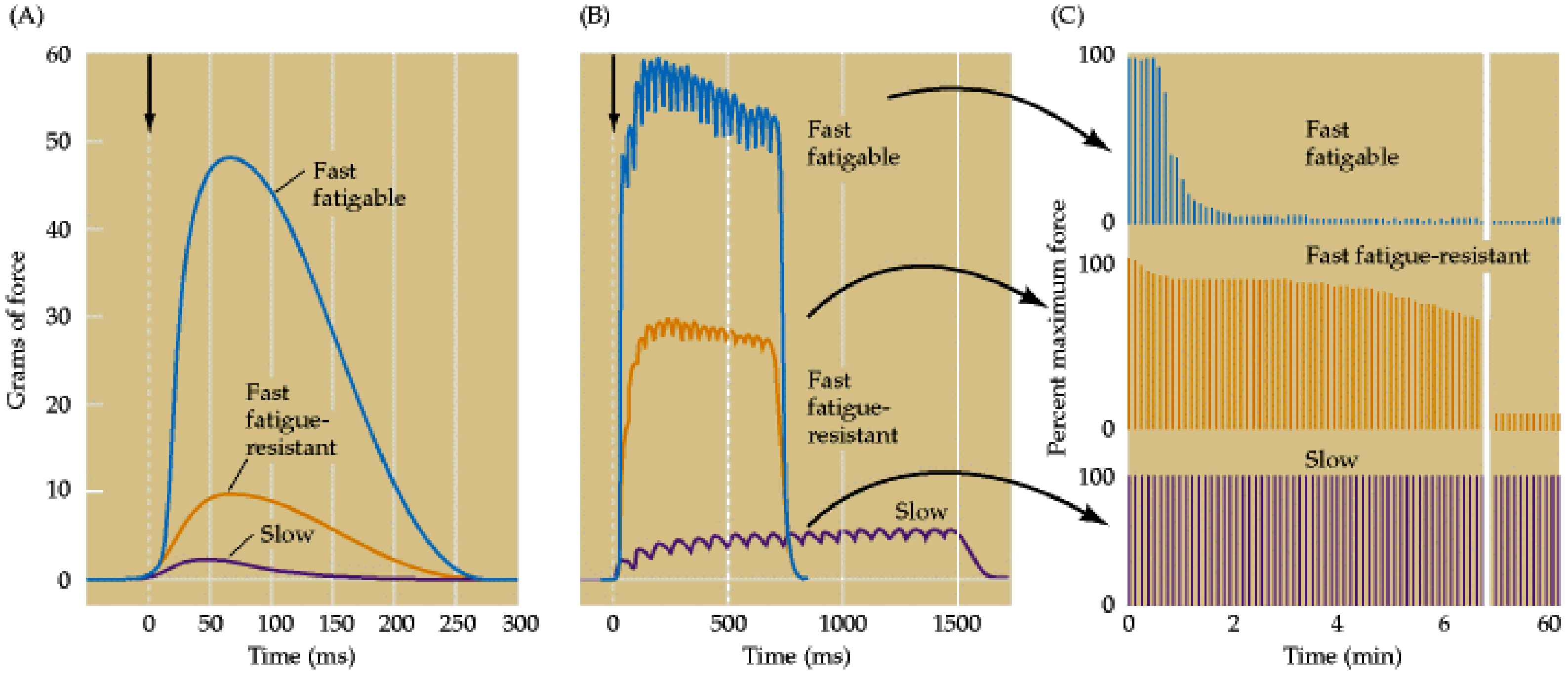
Types of muscle fibers

Fast fibers

- Performance
- Fast fatigue-resistant – normal performance
- Fast fatigable – high performance

Slow fibers

- Endurance
- Fatigue resistant



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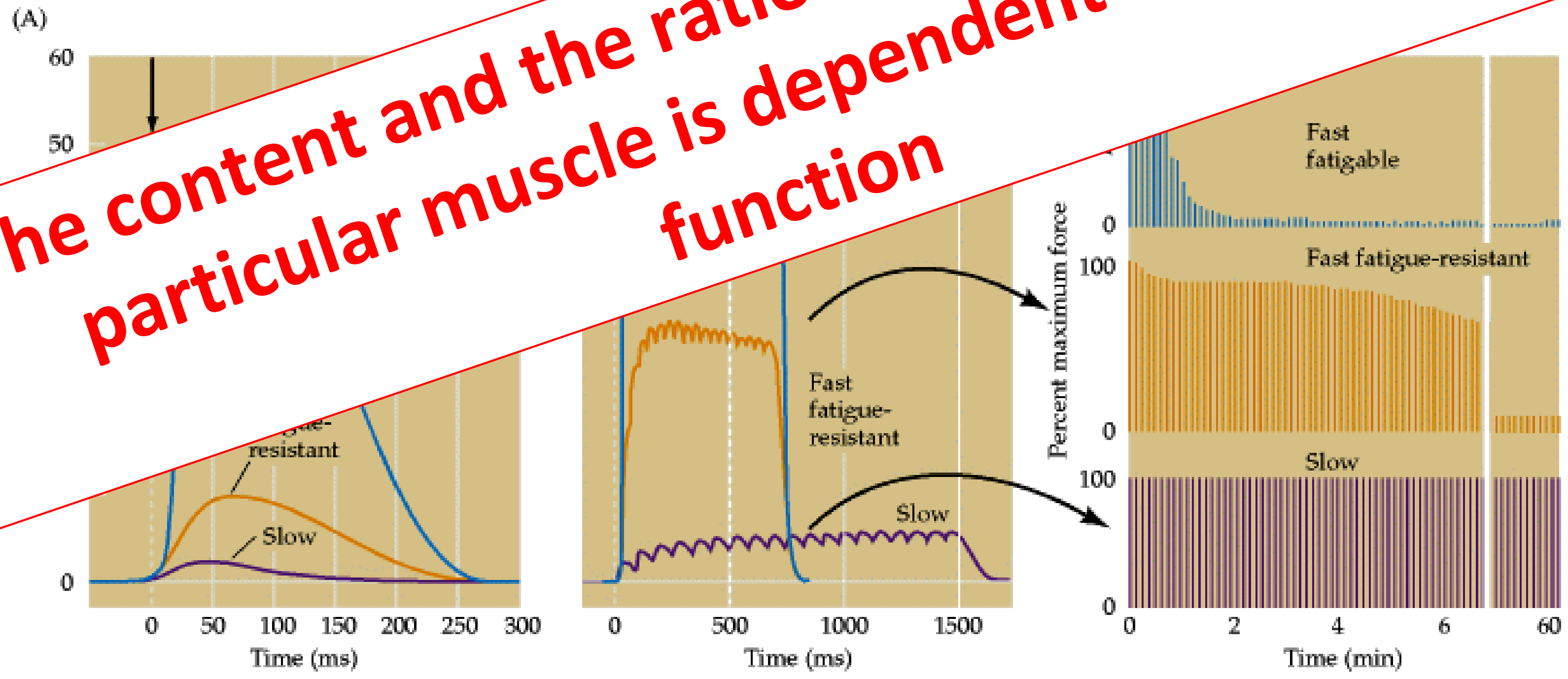
Types of muscle fibers

Fast fibers

- Performance
- Fast fatigue-resistant – normal performance
- Fast fatigable – high performance

Slow fibers

The content and the ratio of fast/slow fibers in particular muscle is dependent on muscle function



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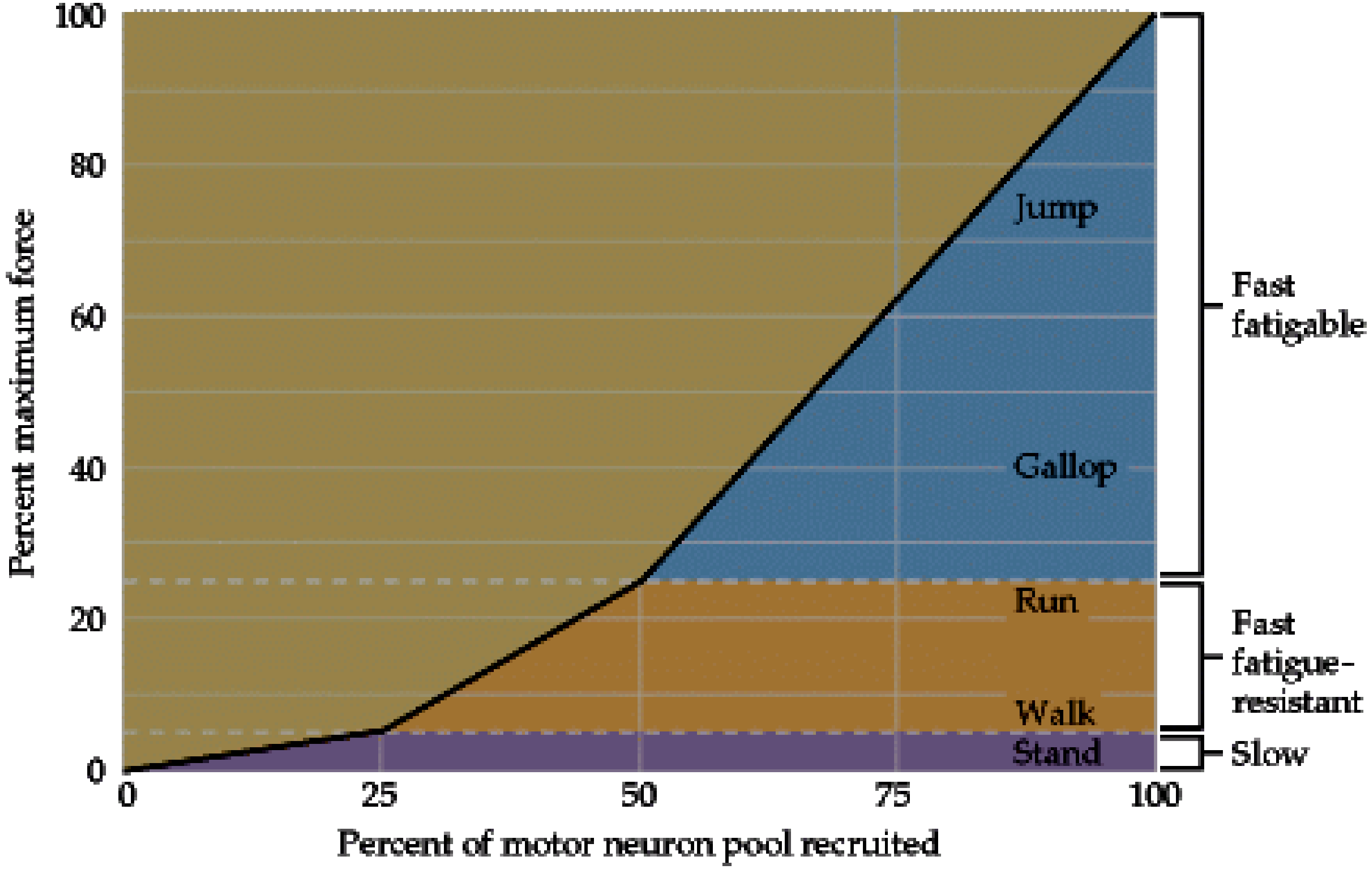
The recruitment of motor neurons

m. gastrocnemius in a cat



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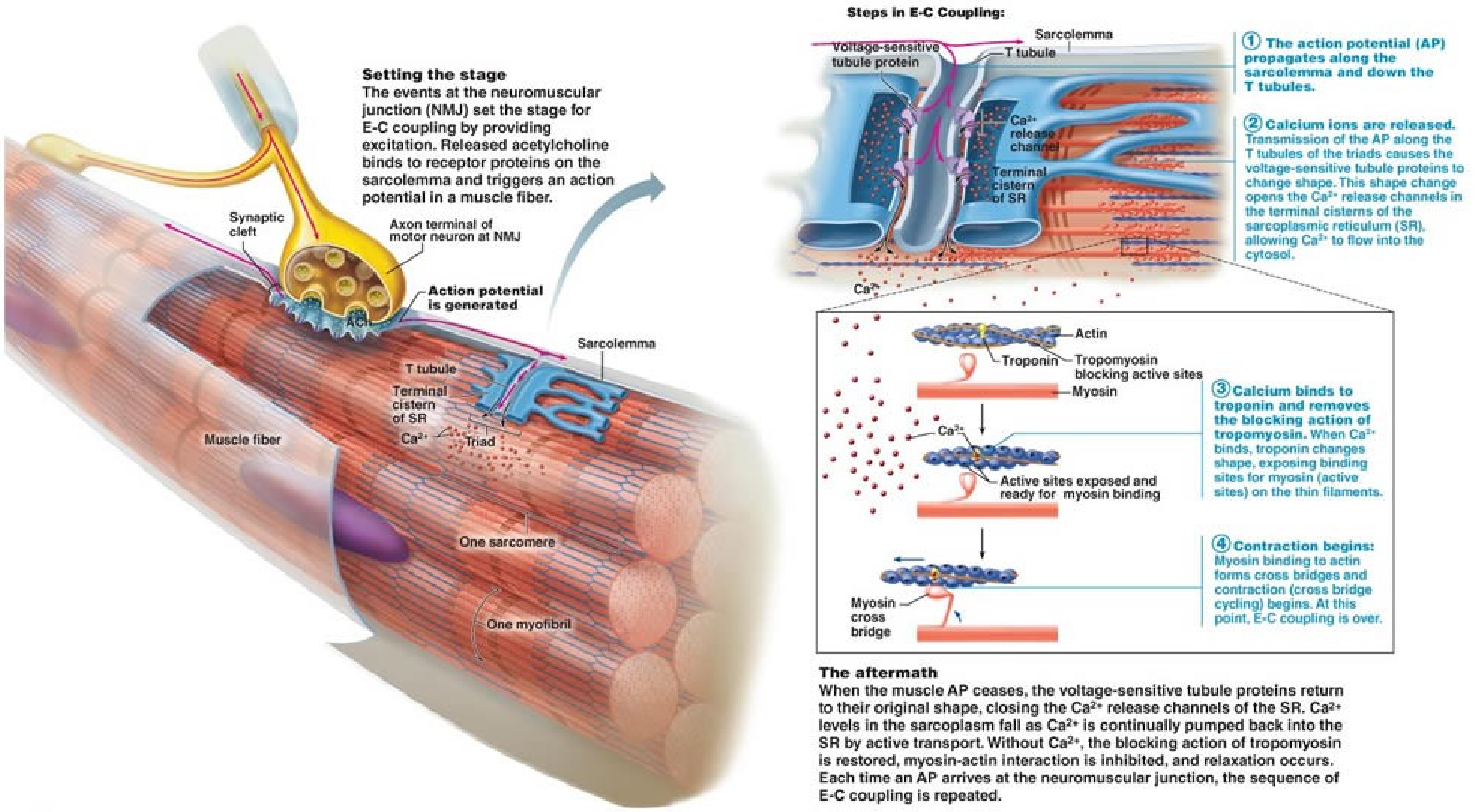
Neuromuscular junction



http://classes.midlandstech.edu/carterp/Courses/bio210/chap09/210_figure_09_11_labeled.jpg

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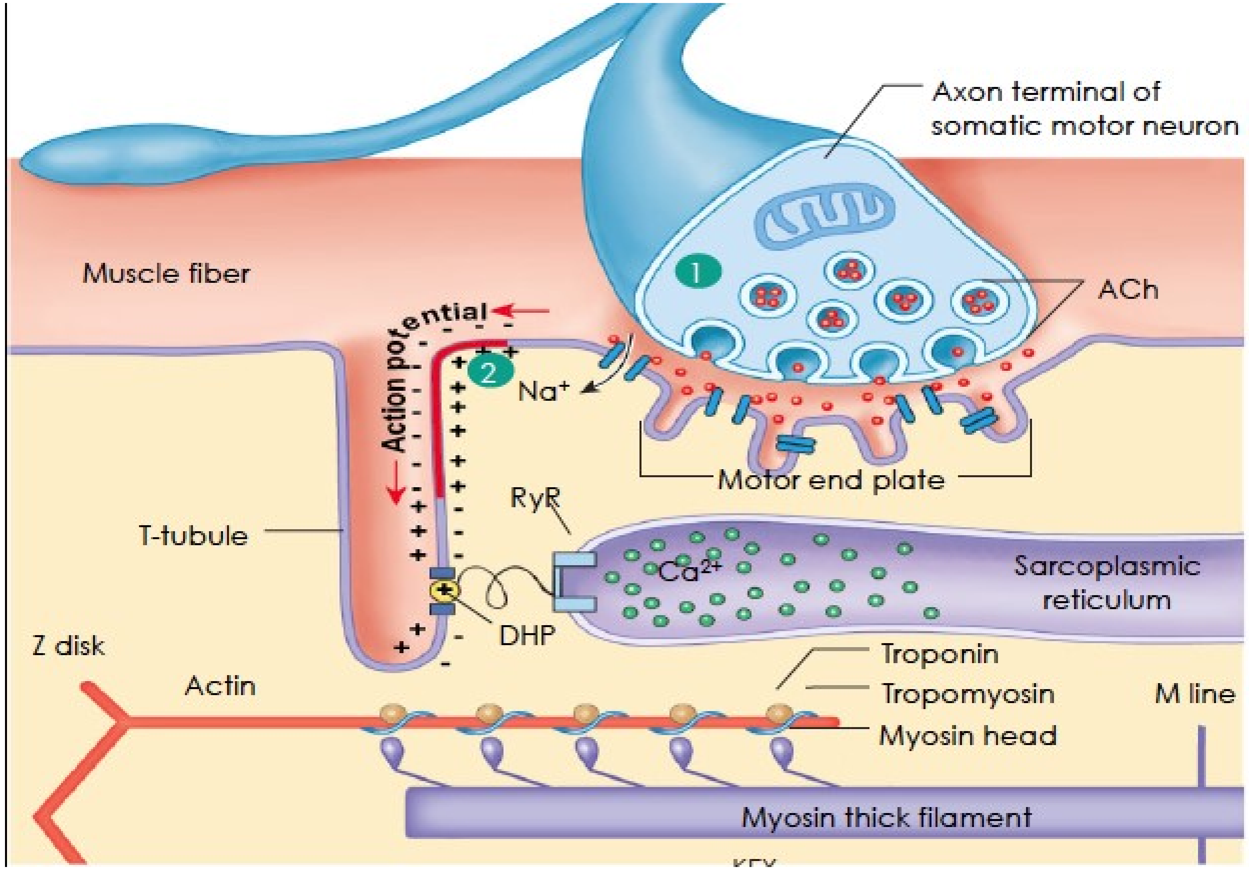
Neuromuscular junction



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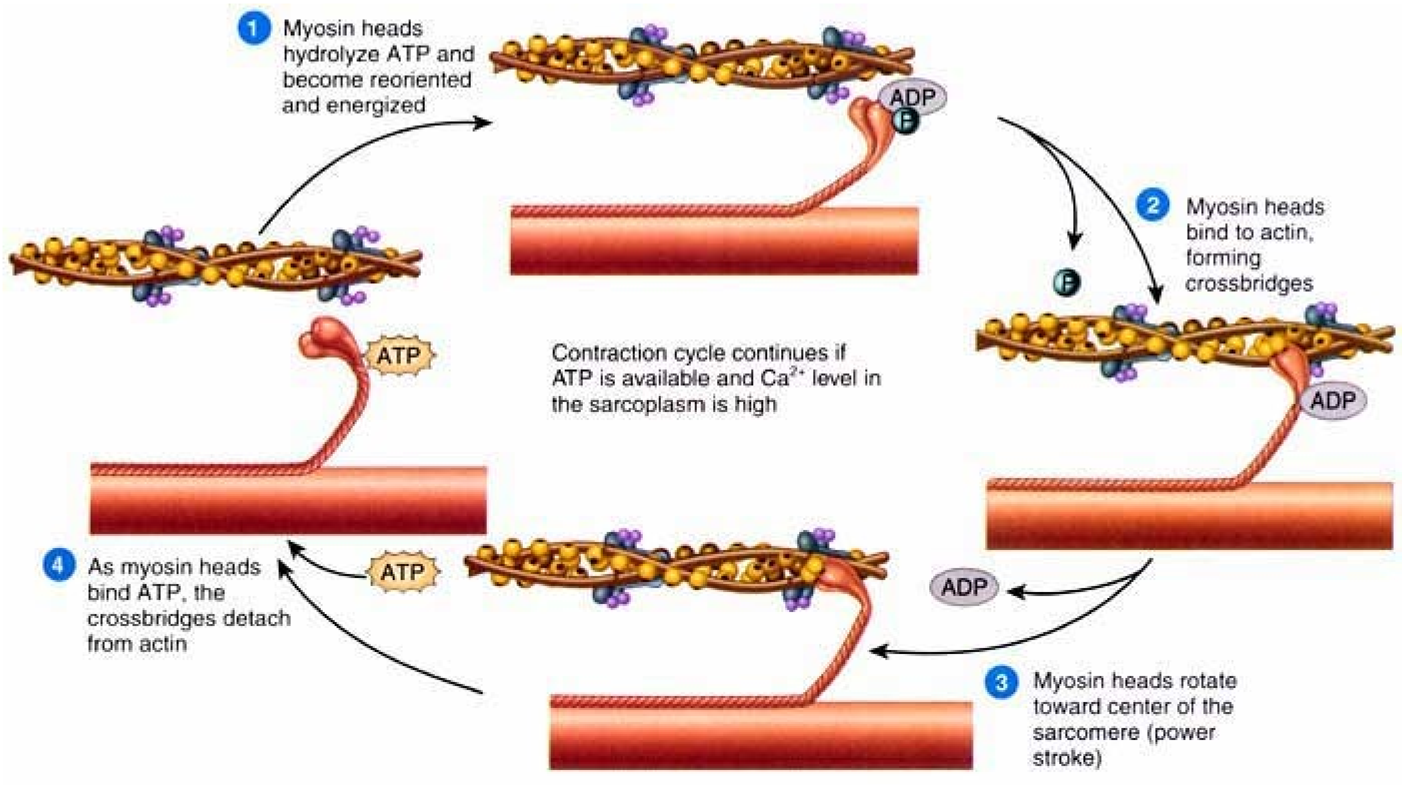
Muscle fibers

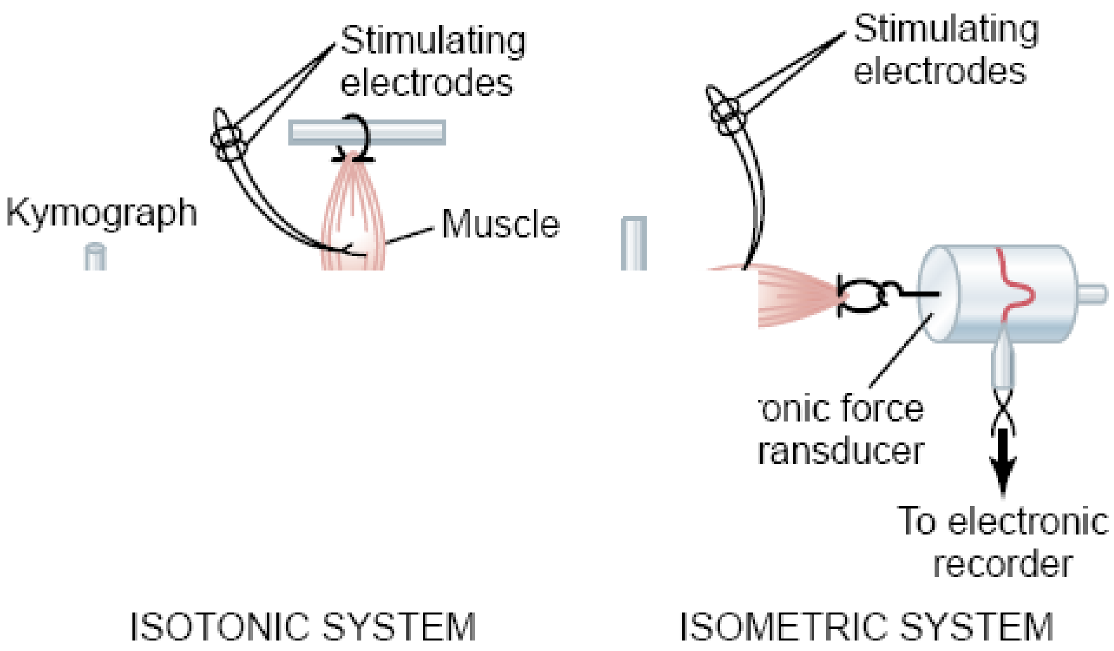


http://www.sivabio.50webs.com/mus019.jpg

Types of muscle contraction

- Isotonic contraction
  - ➢ Constant tension
  - ➢ Concentric x excentric contraction

- Isometric contraction
  - ➢ Constant length



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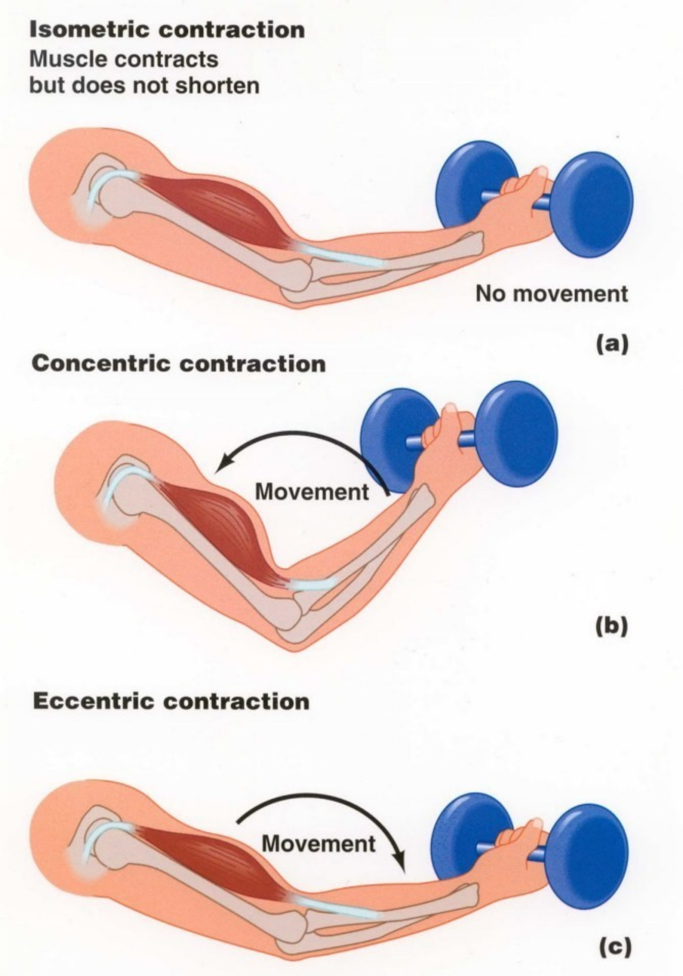

https://i0.wp.com/colebradburn.com/wp-content/uploads/2013/02/contractions.jpg

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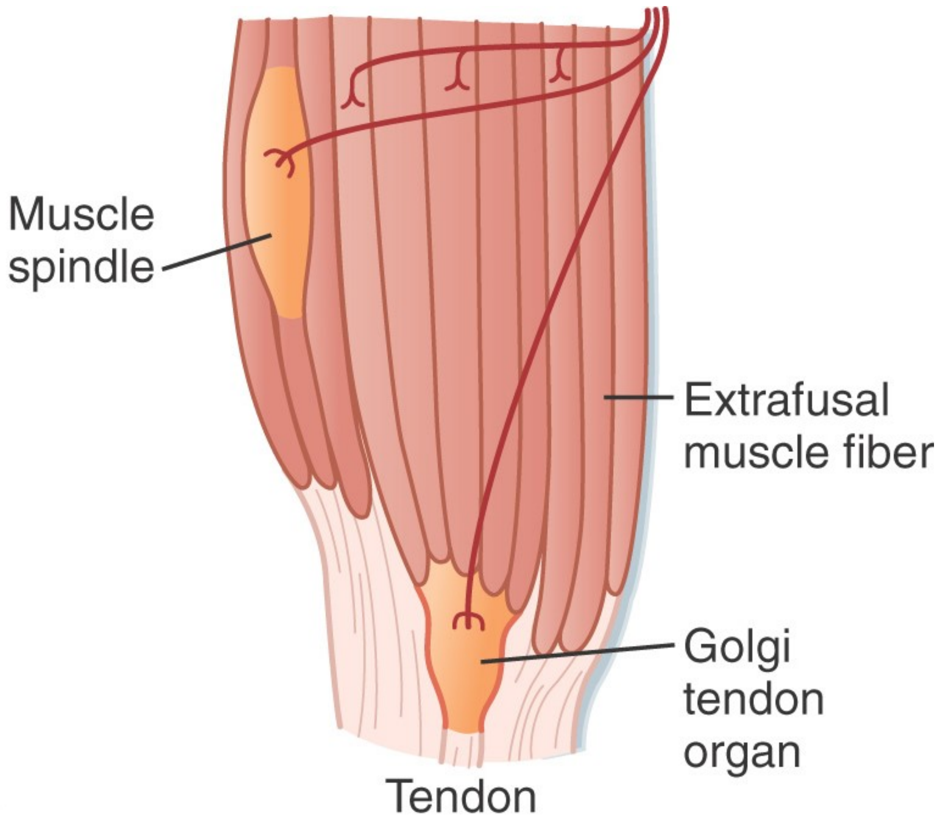
Proprioception

- Information about the position of body parts in relation to each other
  (The sum of information about lengths of particular muscles)
- Information about movement
  (The force and speed of muscle contraction)
- Reflex regulation of muscle activity
- Muscle spindles
  – Lie in parallel with extrafusal muscle fibers
- Golgi tendon organ
  – Arranged in series with extrafusal muscles



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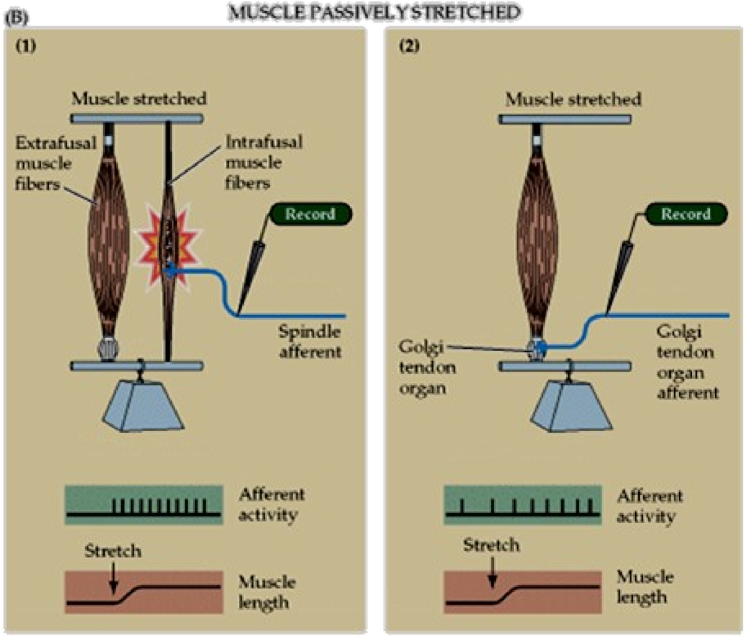
Reaction of muscle spindles and the Golgi tendon organs to muscle fiber stretch/contraction



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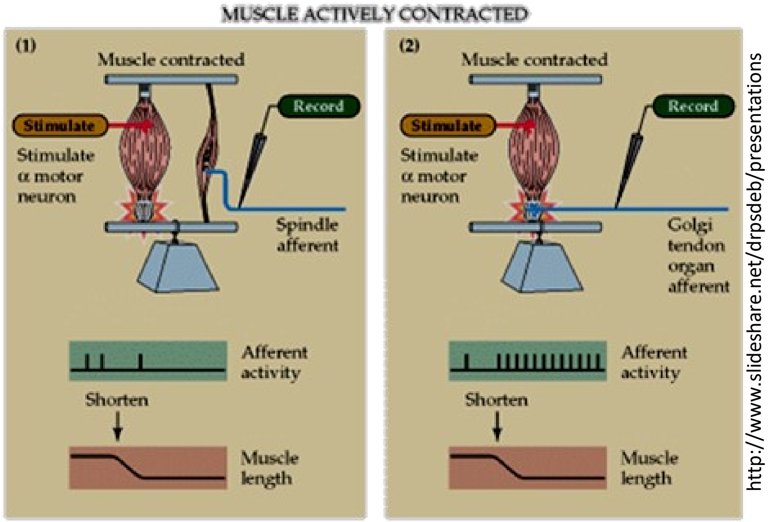

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Stretch (passive)

Muscle spindles reaction

Contraction (active)

Golgi tendon organ reaction

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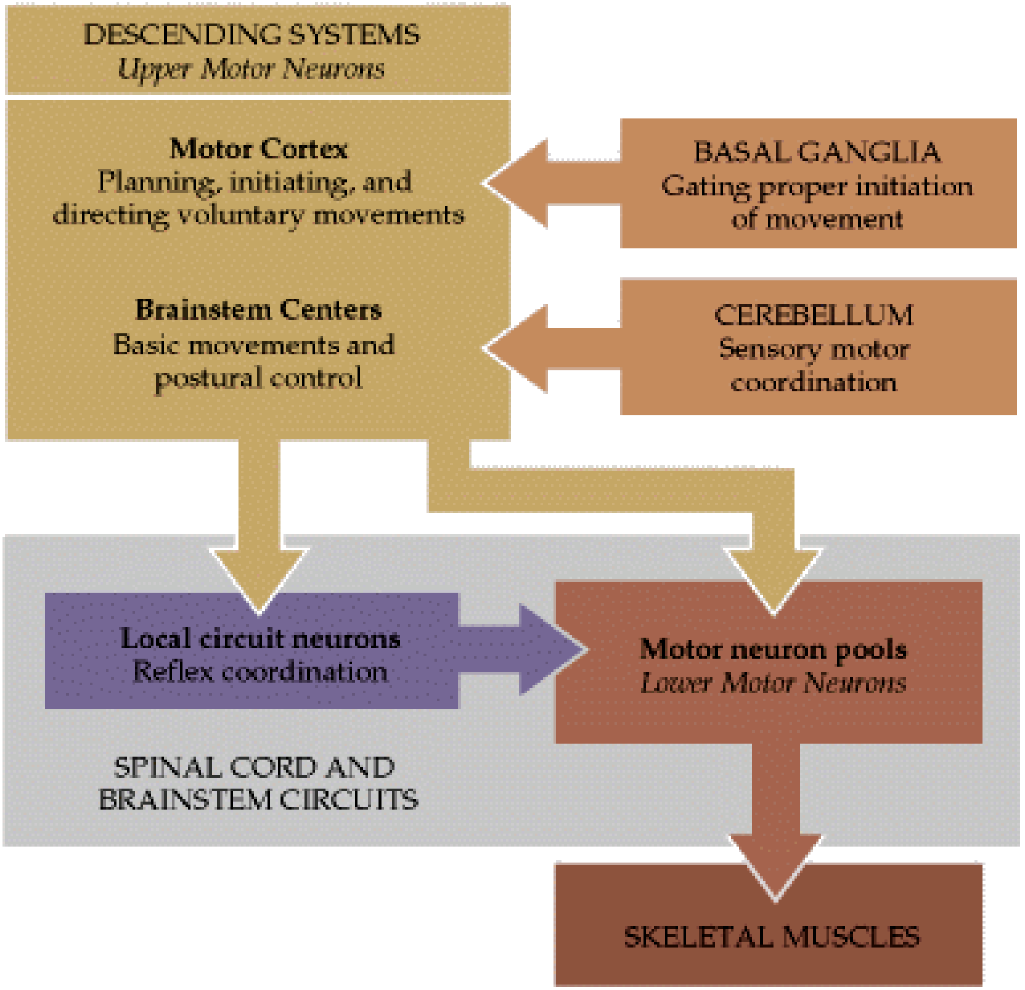
Hierarchic organization of motor system



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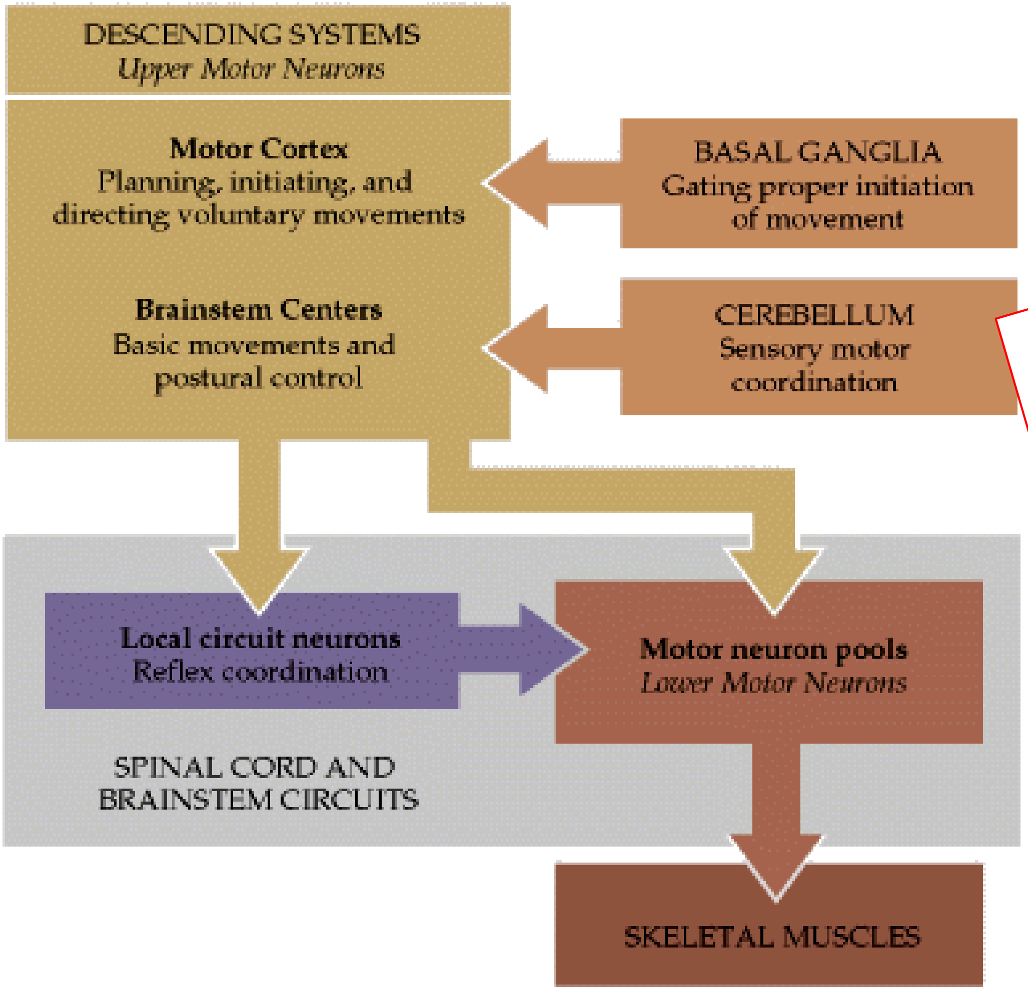
Hierarchic organization of motor system



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Reflex movement
Rhythmic movement
Voluntary movement

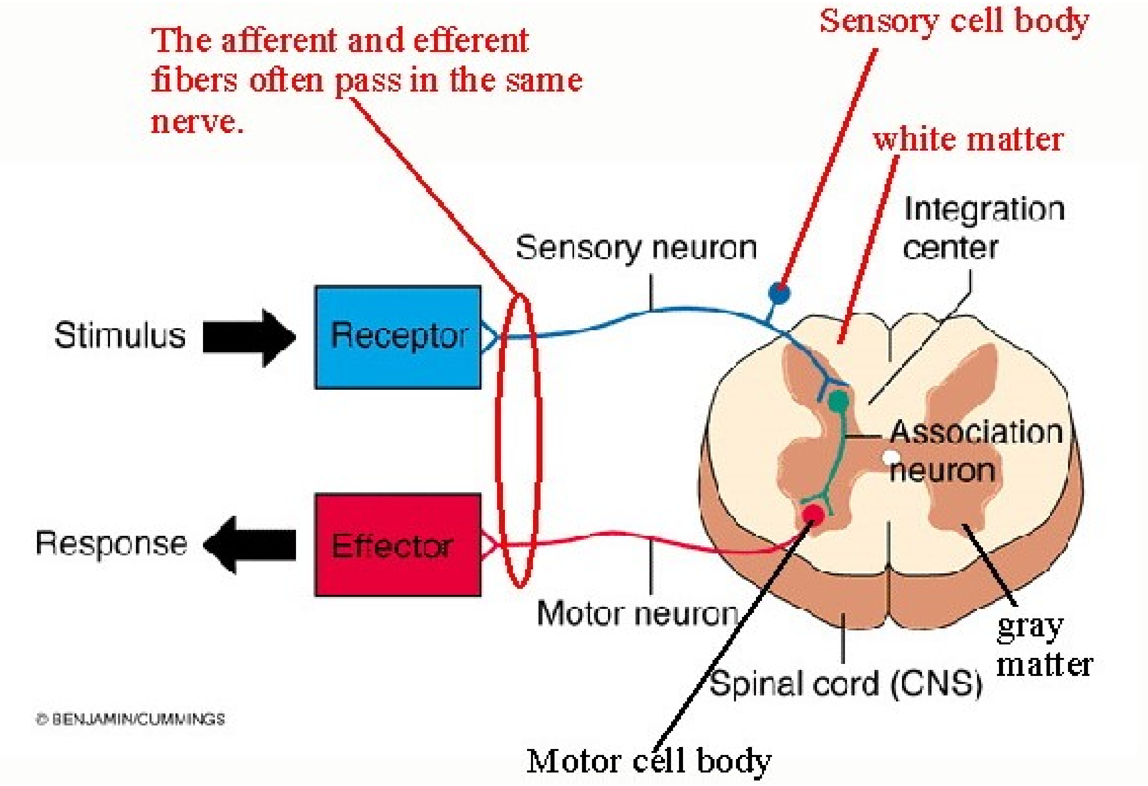
Reflex

- Reflex movement
  - Stereotype (predictable)
  - Involuntary

- Proprioceptive
- Exteroceptive

- Monosynaptic
- Polysynaptic

- Monosegmental
- Polysegmental



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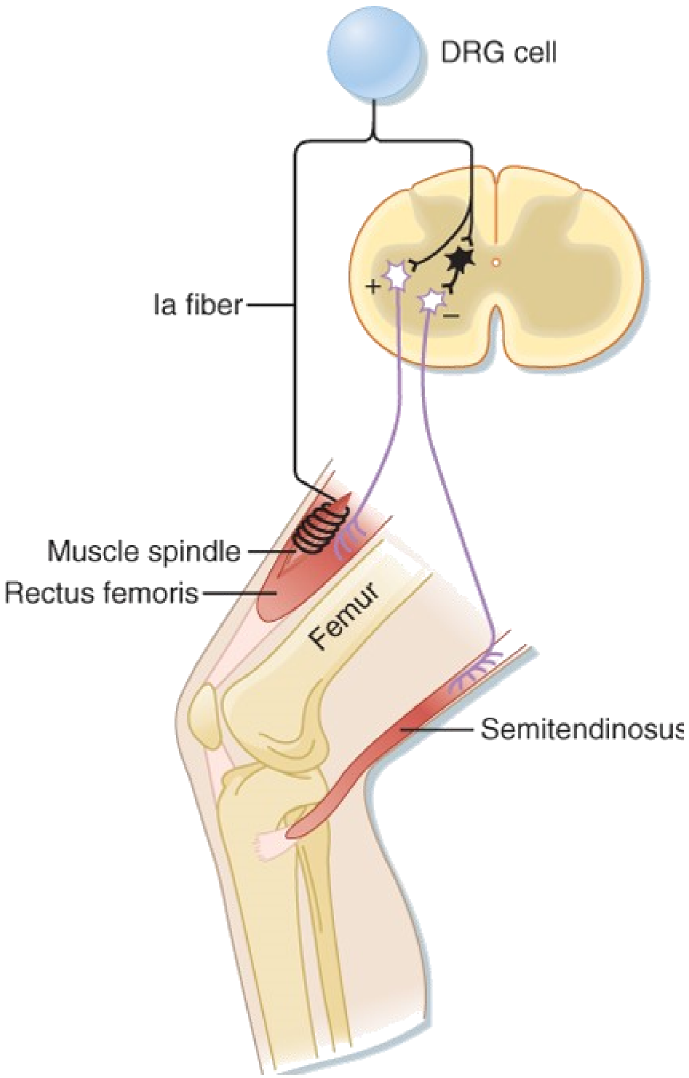
Proprioceptive reflexes

- **Myotatic reflex**
  - Monosynaptic
  - Monosegmental
  - Muscle spindle
  - ➢ Homonymous muscle - activation
  - ➢ Antagonist muscle - inhibition
- ✓ Phasic response (Ia)
  - Protection against overstretch of extrafusal fibrers
- ✓ Tonic response (Ia a II)
  - Maintains muscle tone



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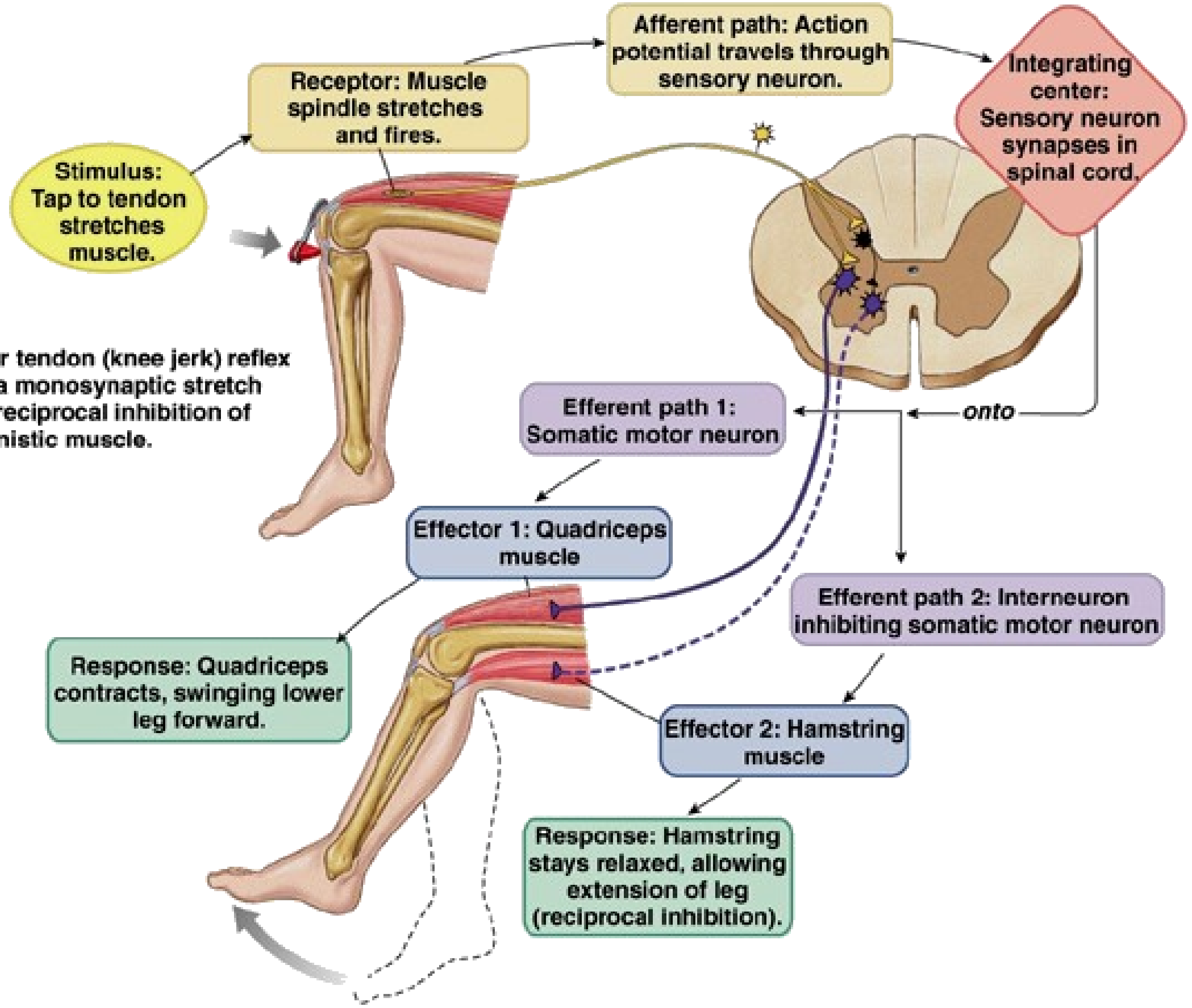

The patellar tendon (knee jerk) reflex illustrates a monosynaptic stretch reflex and reciprocal inhibition of the antagonistic muscle.

Fig. 13-7

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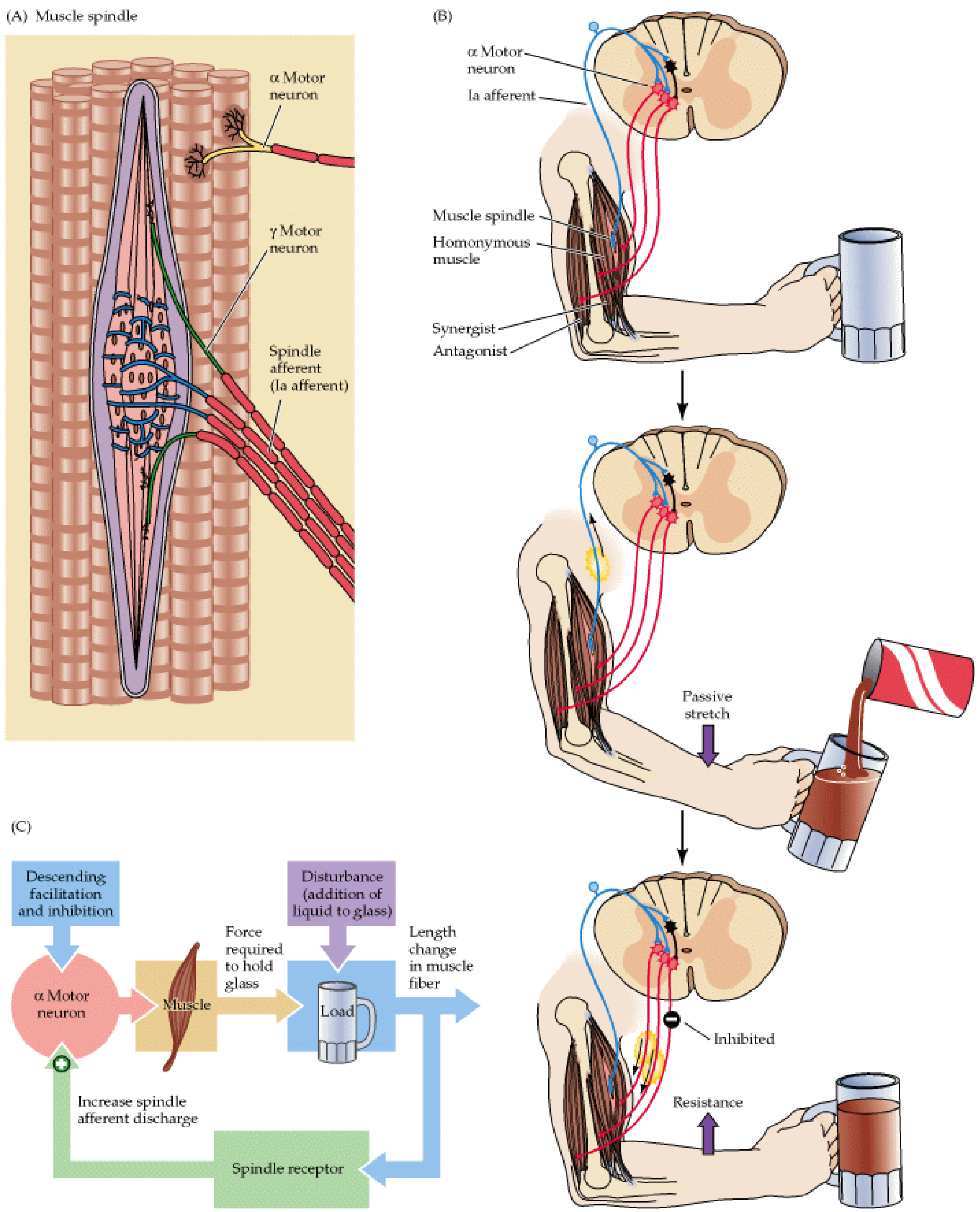

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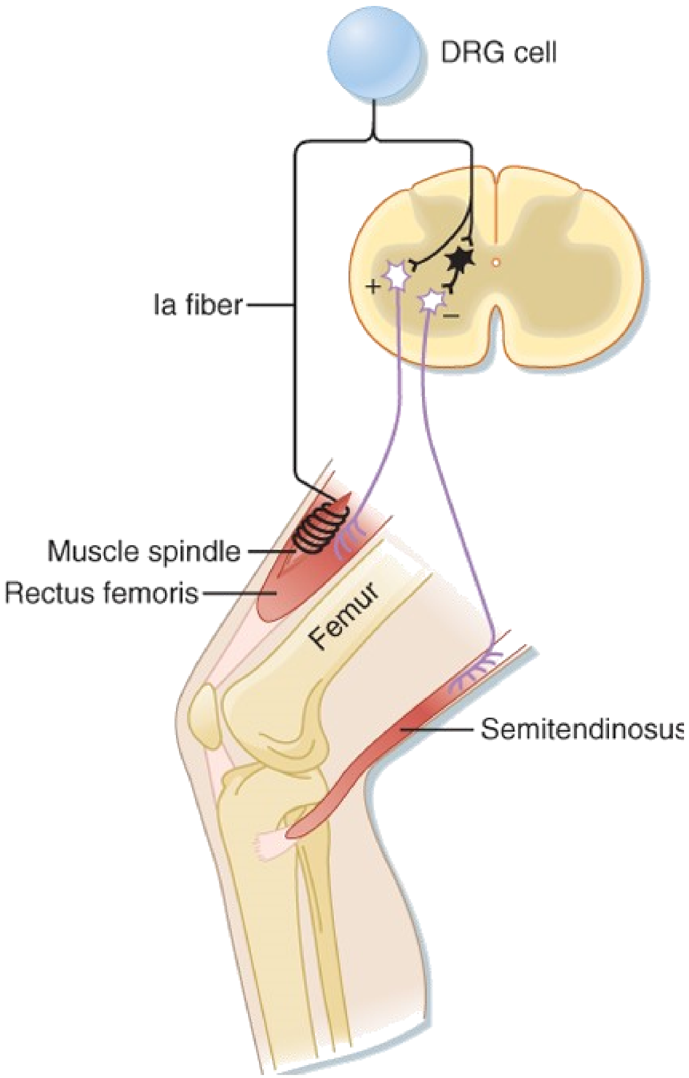
Proprioceptive reflexes

- **Inverse myotatic reflex**
  - Monosegmental
  - Disynaptic/polysynaptic
  - Golgi tendon organ

  ➢ Homonymous muscle – inhibition
  ➢ Antagonist muscle– activation

✓ Protection against muscle damage caused by extensive force



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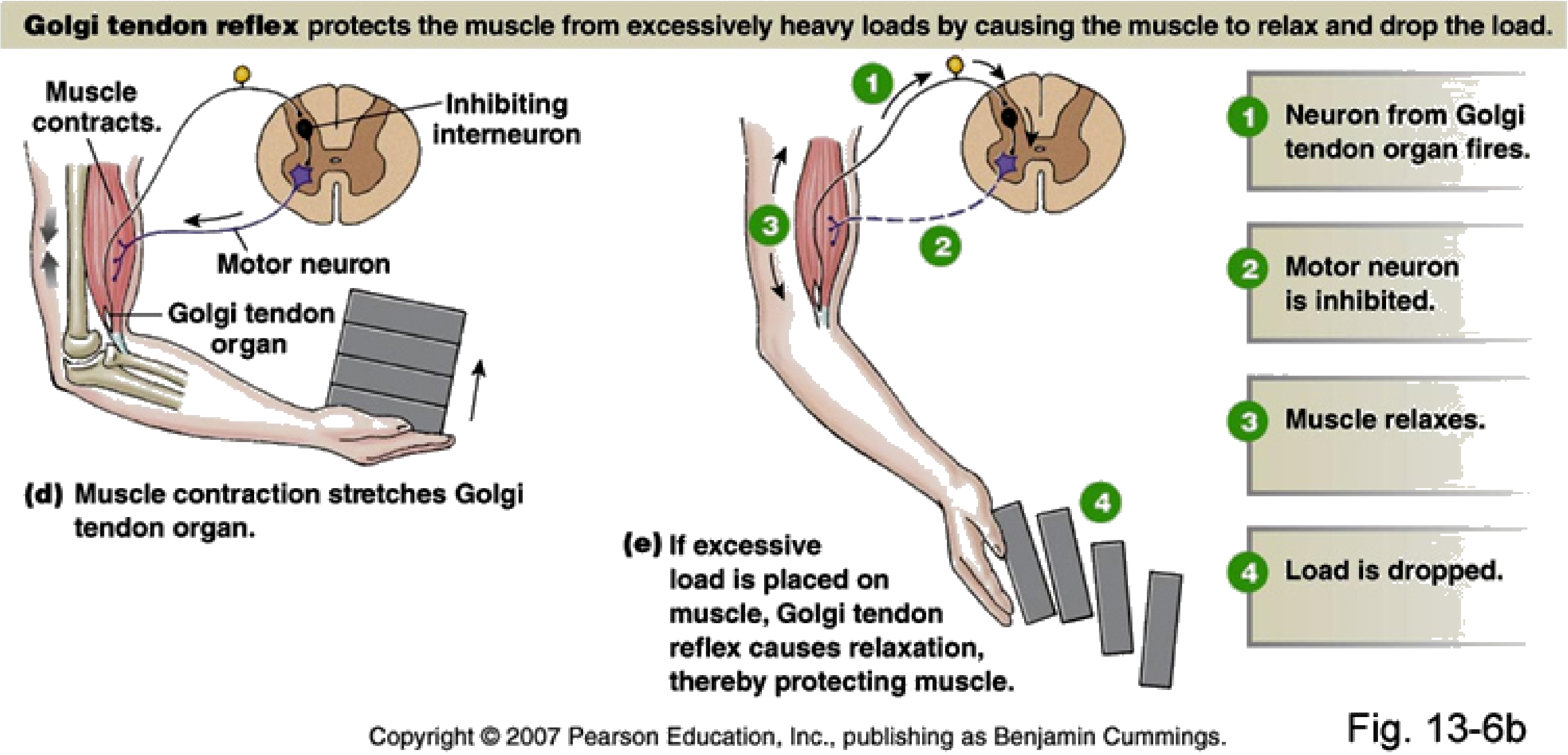

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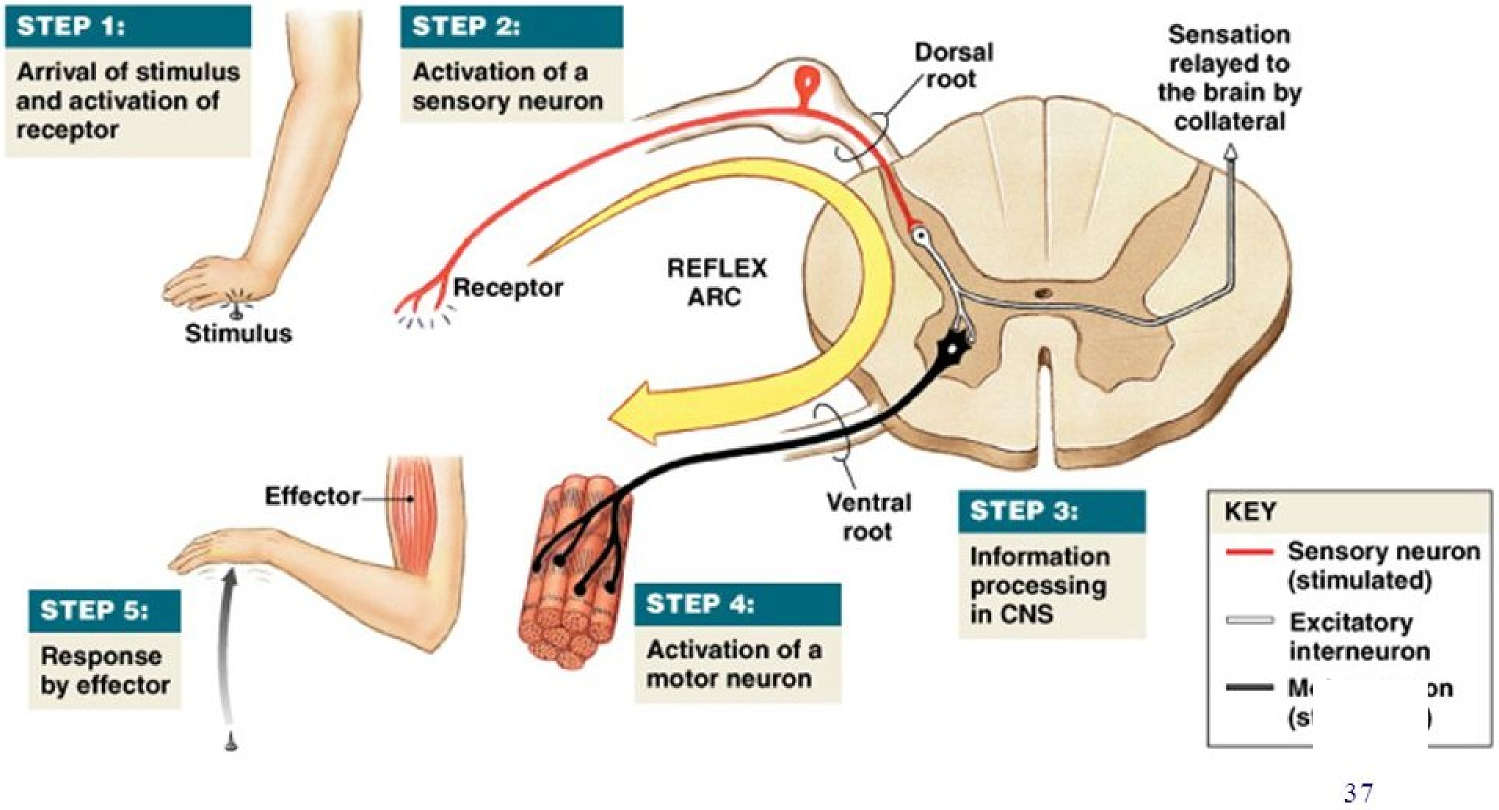
Exteroceptive reflexes

- Polysynaptic
- Polysegmental



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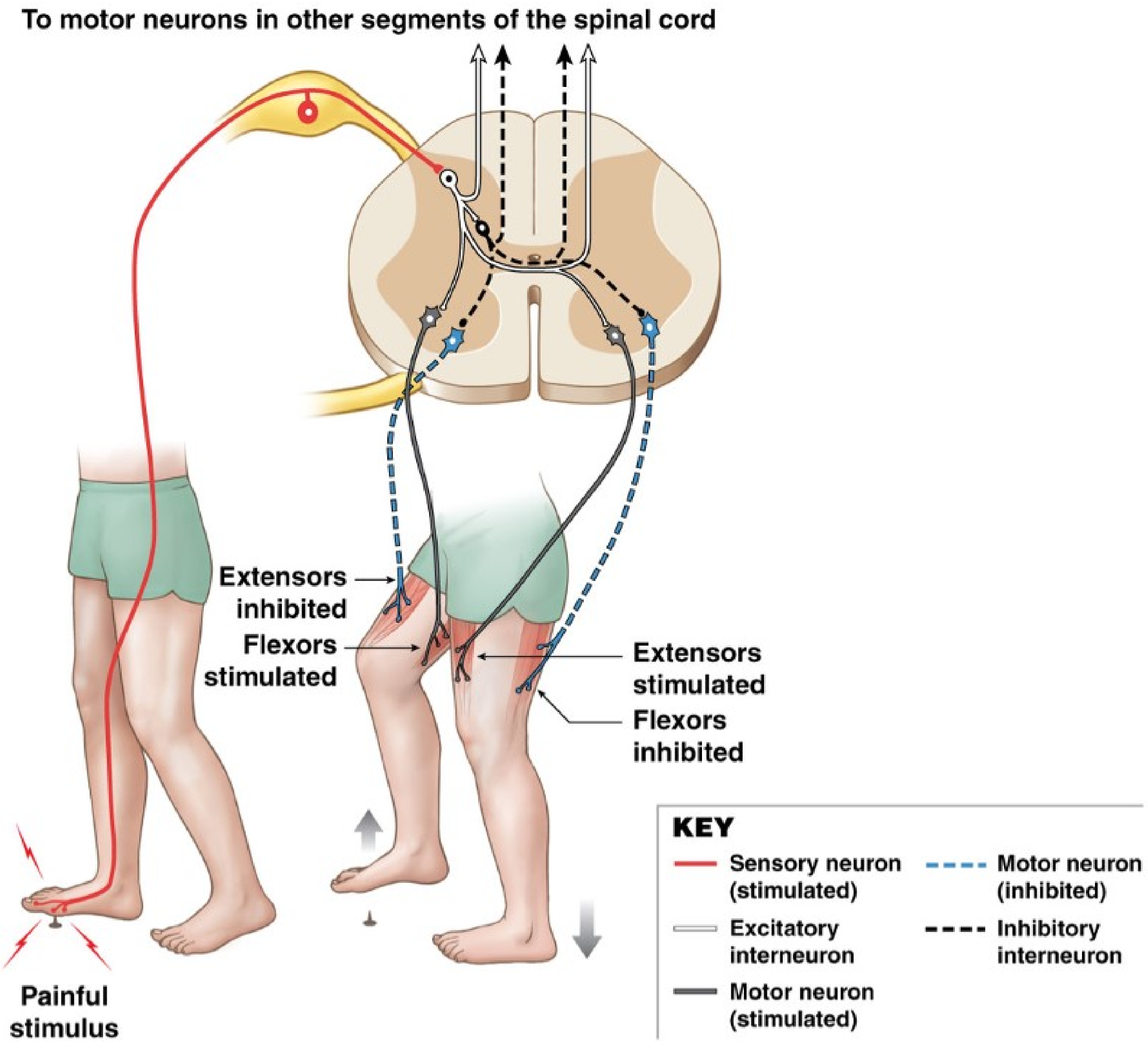
Exteroceptive reflexes

- Polysynaptic
- Polysegmental



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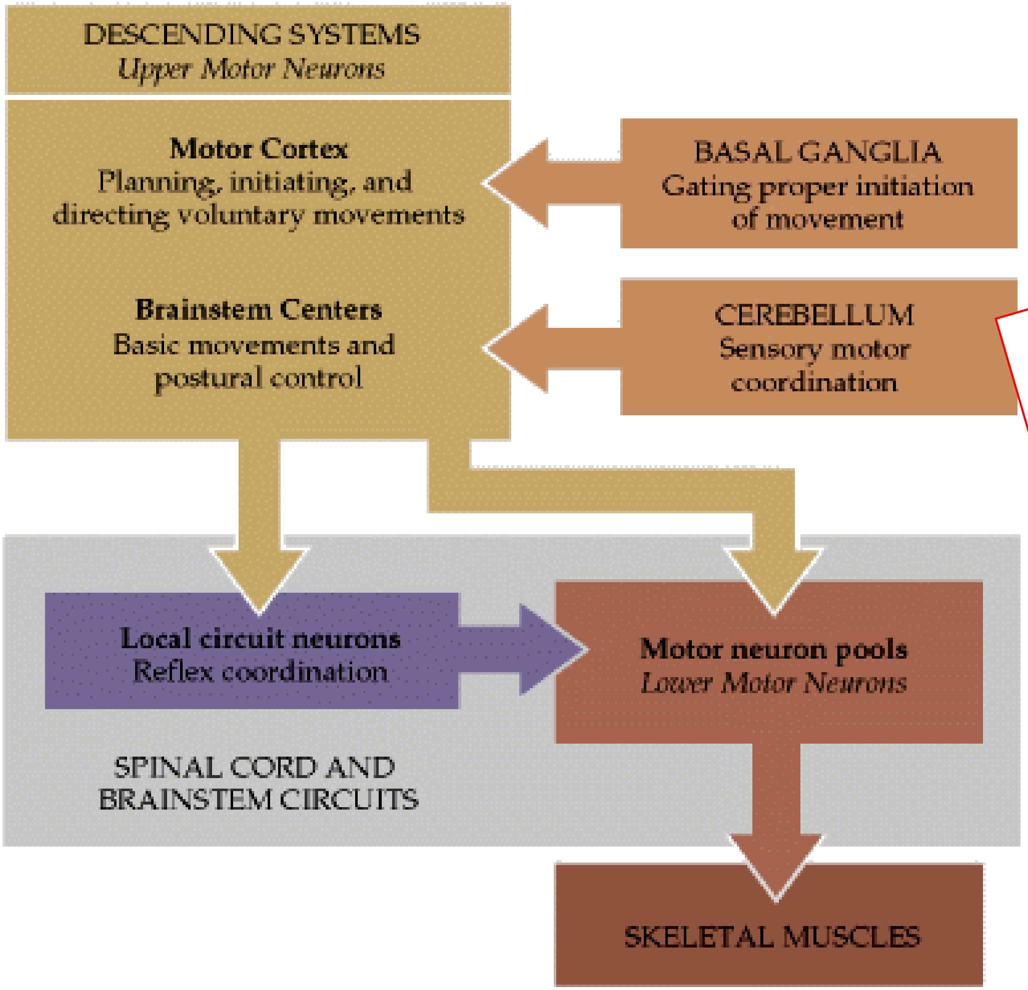
Hierarchic organization of motor system



Reflex movement
Rhythmic movement
Voluntary movement

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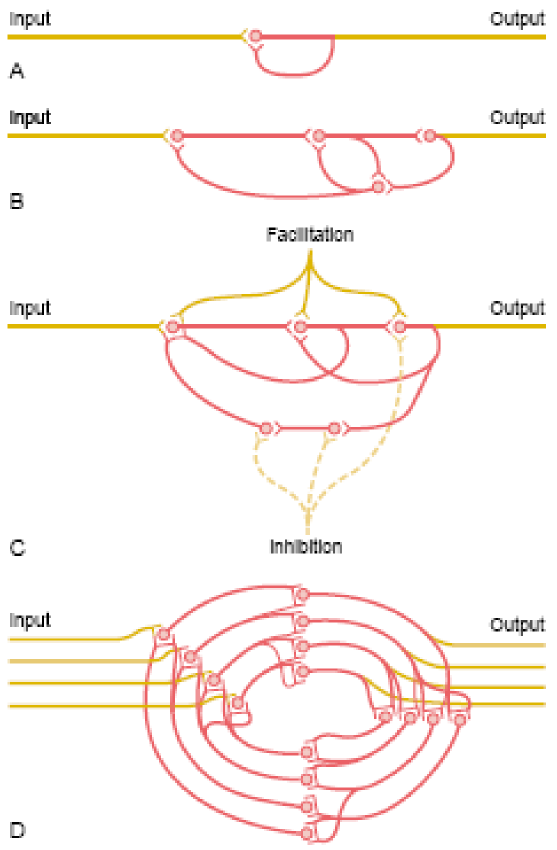
Fixed action pattern and rhythmic movement

- Fixed action pattern (e.g. Swallowing)
  - Neuronal networks for complex motor activity
- Central pattern generator (e.g. Walking, breathing)
  - Neuronal networks generating rhythmic activity
  - „Spontaneously repeated fixed action patterns“
  - No need of feedback
- Localization
  - Walking – brain stem, lower thoracic and upper lumbar spinal cord
  - Breathing – brain stem
  - Swallowing - medulla oblongata/brain stem
- Variously expressed voluntary control
  - Walking (full control)
  - Breathing (partial control)
  - Swallowing (limited control)



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Fixed action pattern and rhythmic movement

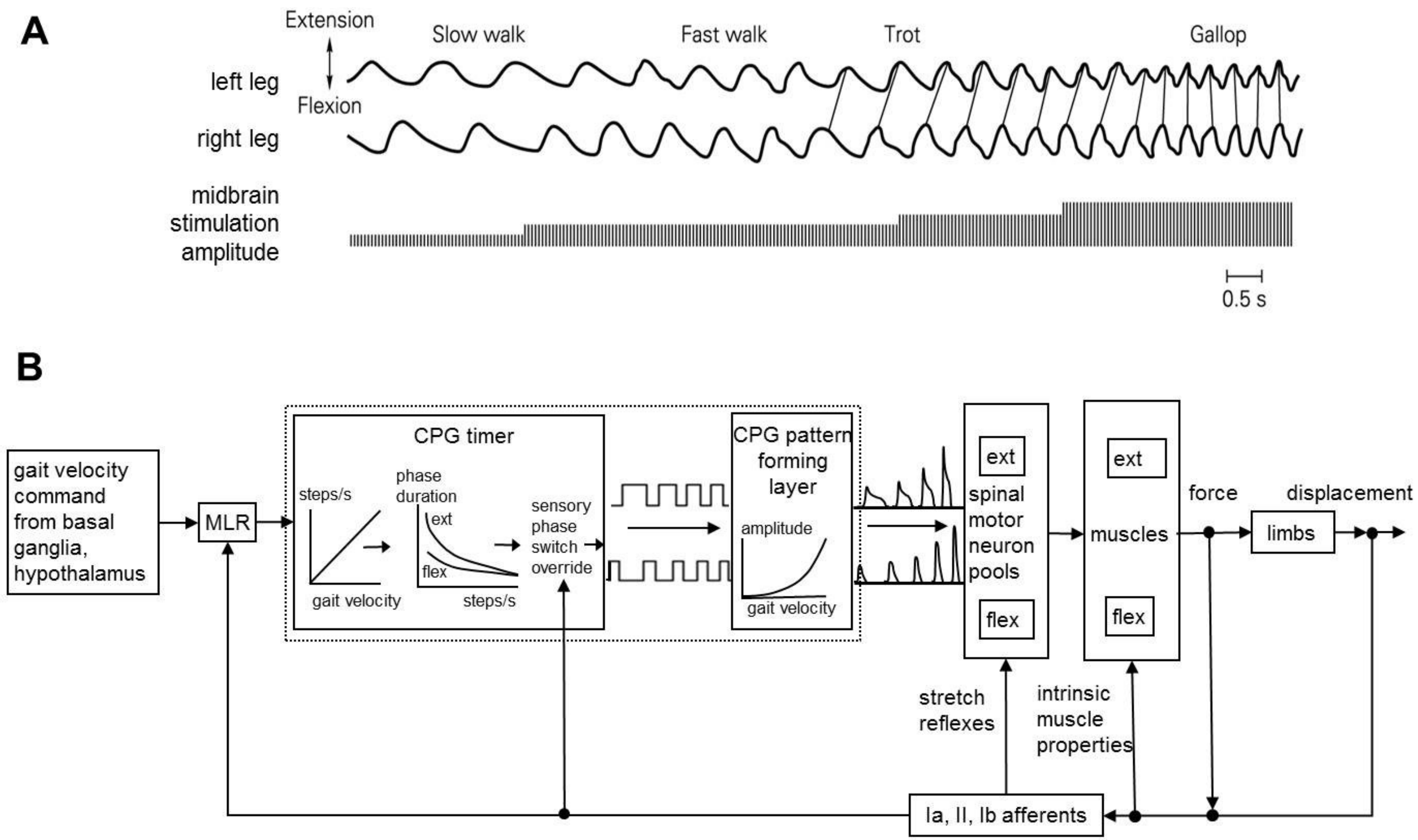

Fig. 1. Neural control of locomotion. A) Increments in the intensity of stimulation of the MLR in the high decerebrate cat increased the cadence (step cycles/sec) of locomotion. Adapted from Shik et al. 1966.[22] B) Schematic of the velocity command hypothesis: a command signal specifying increasing body velocity descends from deep brain nuclei via the MLR to the spinal cord and drives the timing element of the spinal locomotor CPG to generate cycles of increasing cadence. Extensor phase durations change more than flexor phase durations. The command signal also drives the pattern formation layer to generate cyclical activation of flexor and extensor motoneurons. Loading of the activated muscles (e.g. supporting the moving body mass) is resisted by the muscles' intrinsic spring-like properties. This is equivalent to displacement feedback. Force and displacement sensed bymuscle spindle and Golgi tendon organ afferents reflexly activate motoneurons. A key role of these afferents is to adjust the timing of phase transitions, presumably by influencing or overriding the CPG timer. Adapted from Prochazka & Ellaway 2012.[23]

https://en.wikipedia.org/wiki/Central_pattern_generator

Fixed action pattern and rhythmic movement

Whelan PJ. Shining light into the black box of spinal locomotor networks. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*. 2010;365:2383–2395.

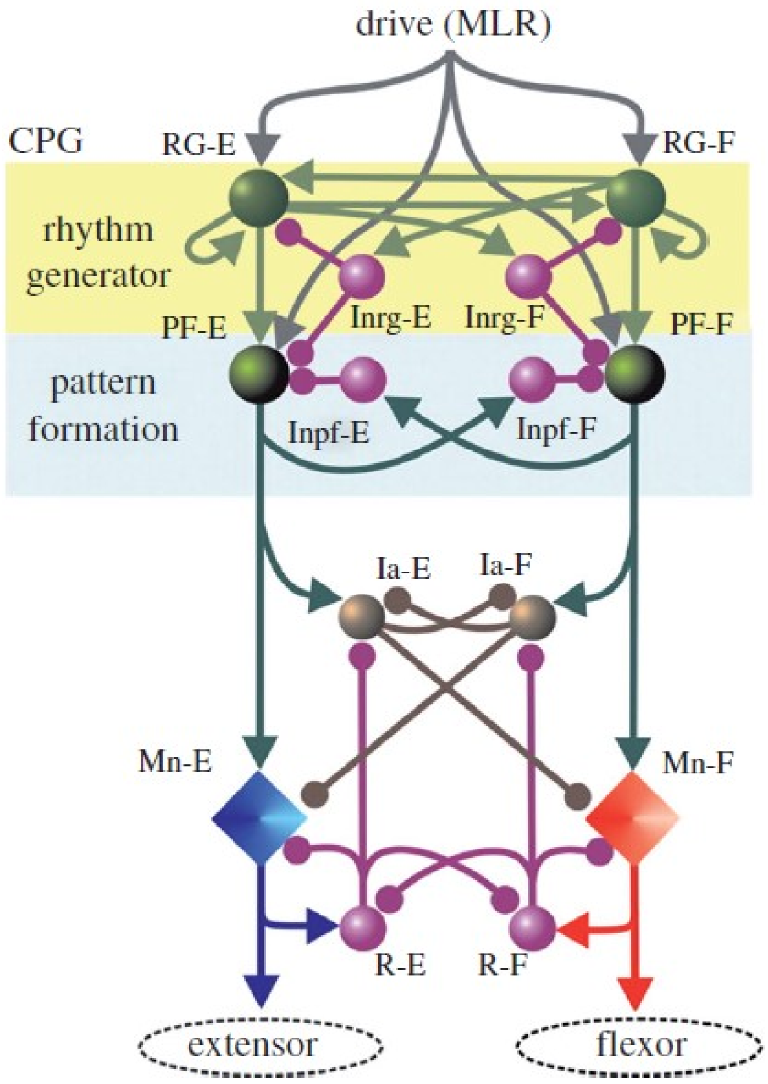

Figure 1. Schematic of model by Rybak & McCrea. The populations of interneurons are indicated by spheres, while the motoneurons are represented by diamonds. This three-layer model consists of a rhythm-generating layer of extensor (RG-E) and flexor (RG-F) interneurons. Both populations have recurrent excitatory connections (see also figure 2). These interneurons in turn receive mutually inhibitory input (Inrg cells). The drive projects to a pattern formation layer (PF), which acts through mutually inhibitory connections (Inpf cells) to sculpt the pattern, which is then output to the extensor and flexor motoneurons. The final output of the motoneurons is modulated by a final layer of Ia inhibitory interneurons (Ia-E, Ia-F) and Renshaw cells (R-E, R-F). Arrows indicate excitatory drive, while the filled circles indicate inhibitory drive. Reproduced with permission.

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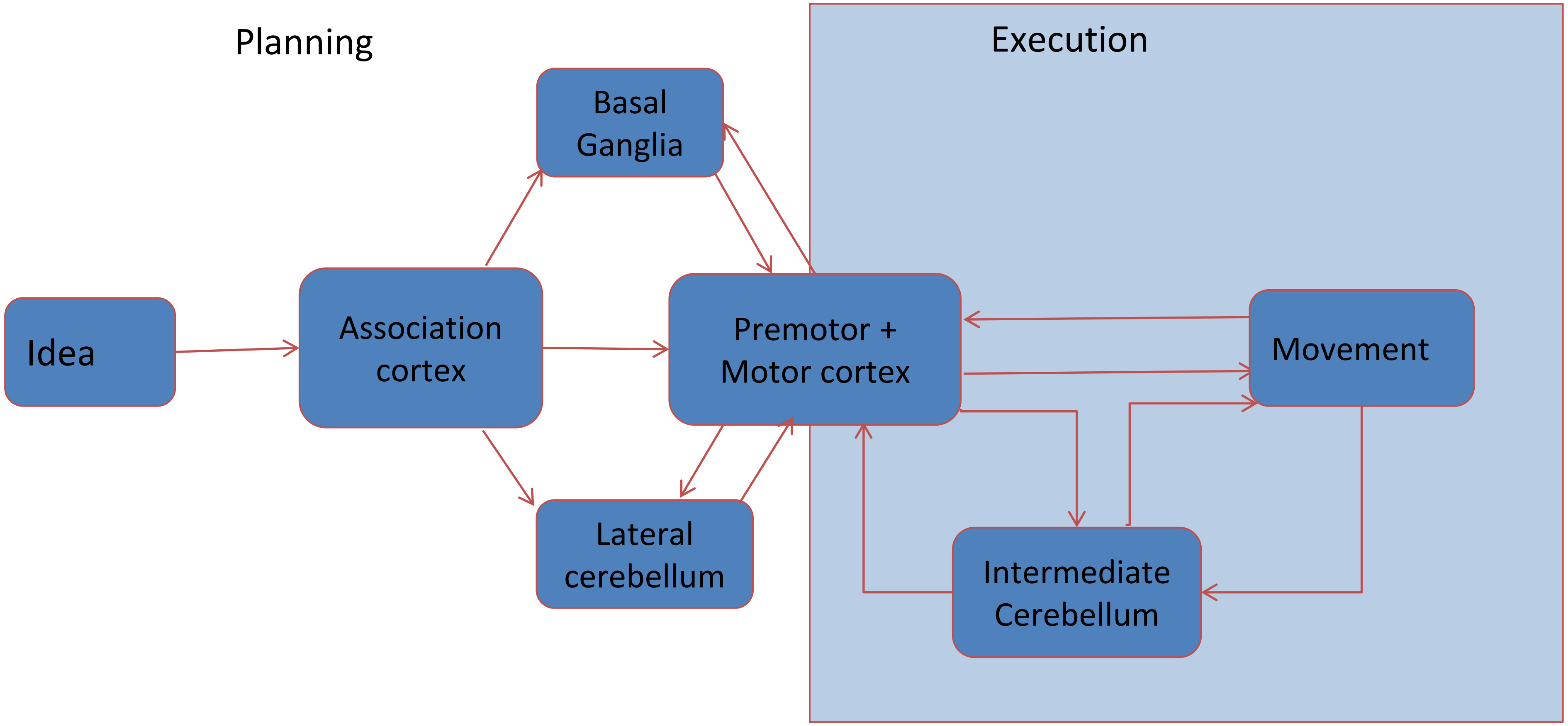
Voluntary motor activity



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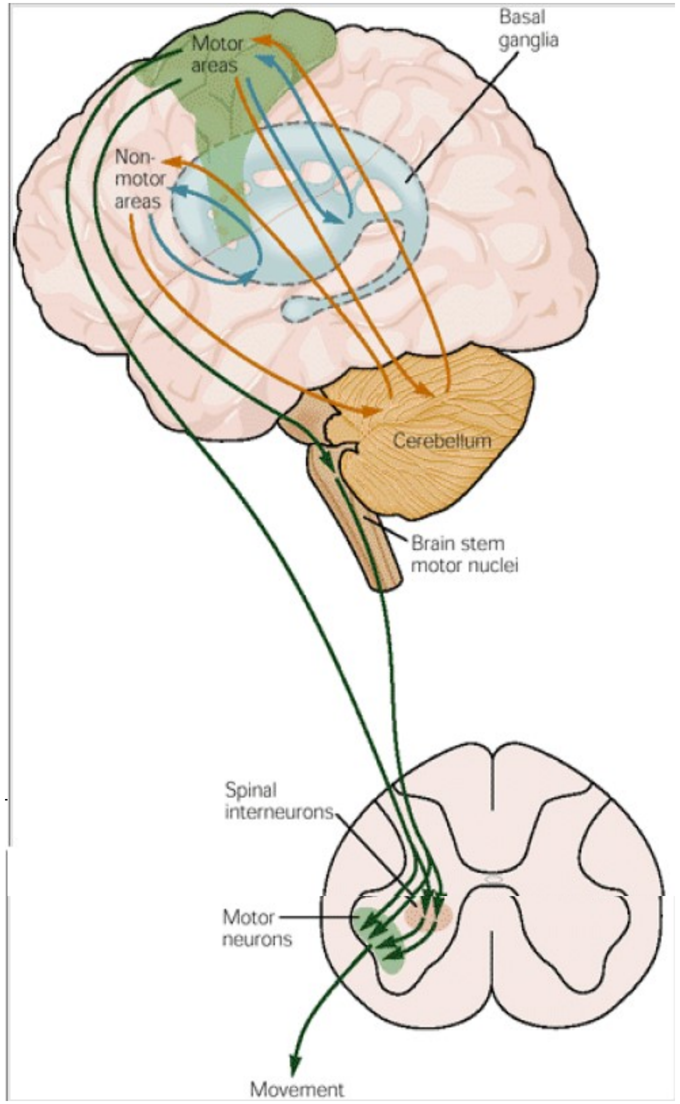
Voluntary motor activity

- Result of cooperation of upper and lower motor neuron
- Basal ganglia
  - Motor gating – initiation of wanted and inhibition of unwanted movements
- Cerebellum
  - Movement coordination



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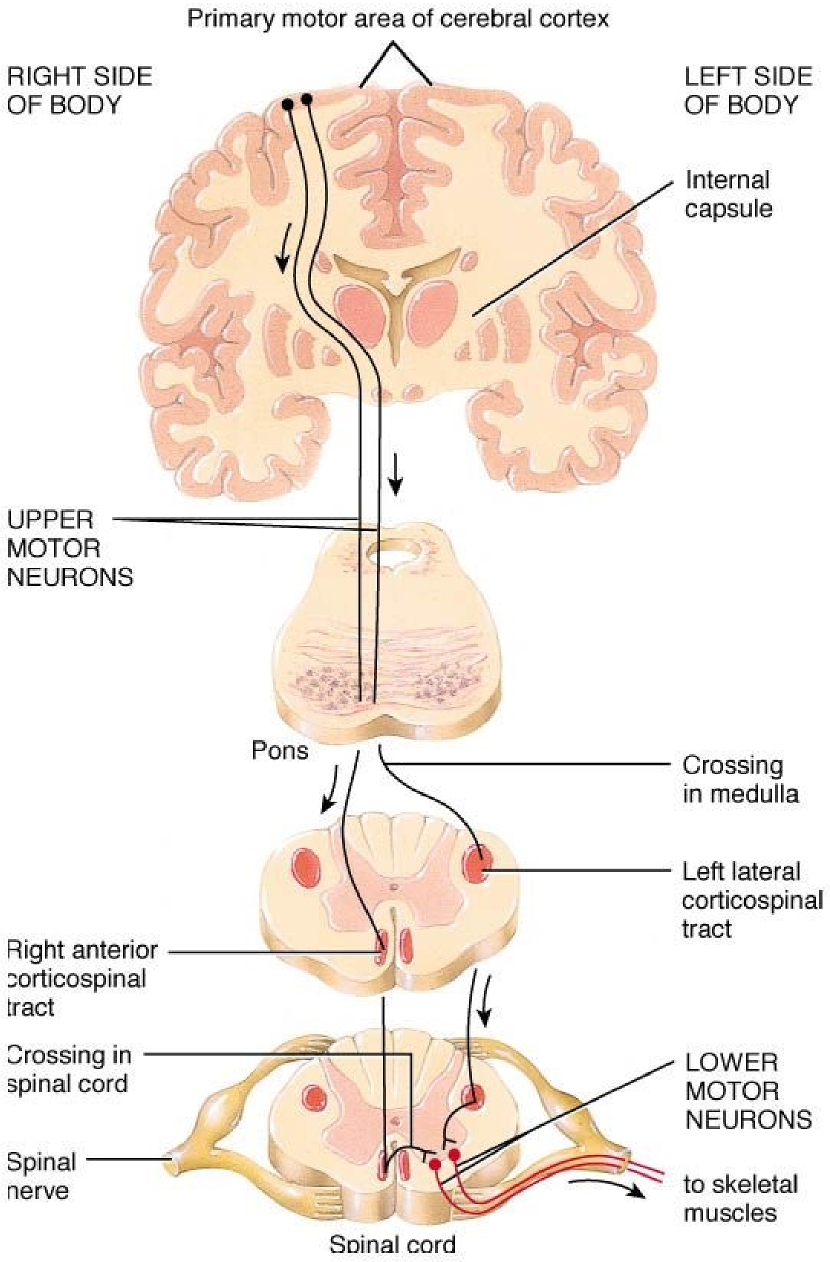
Pyramidal tract

- Upper motor neuron
  - Primary motor cortex
- Lower motor neuron
  - Anterior horn of spinal cord
- Tractus corticospinalis lateralis
  - 90% of fibers
- Tractus corticospinalis anterior
  - 10% of fibers
  - Cervical and upper thoracic segments
- Tractus corticobulbaris



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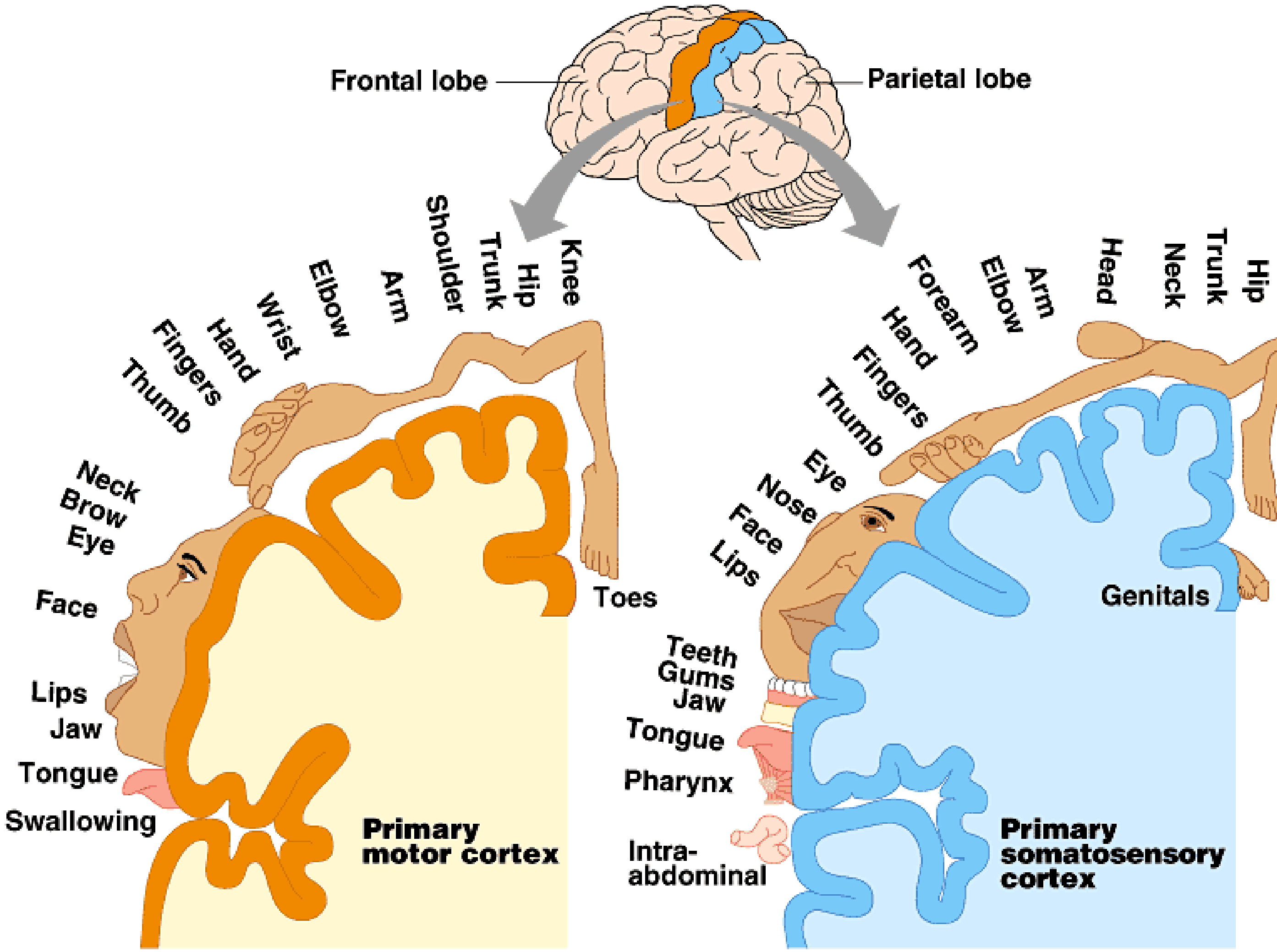
Primary motor cortex



http://www.emunix.emich.edu

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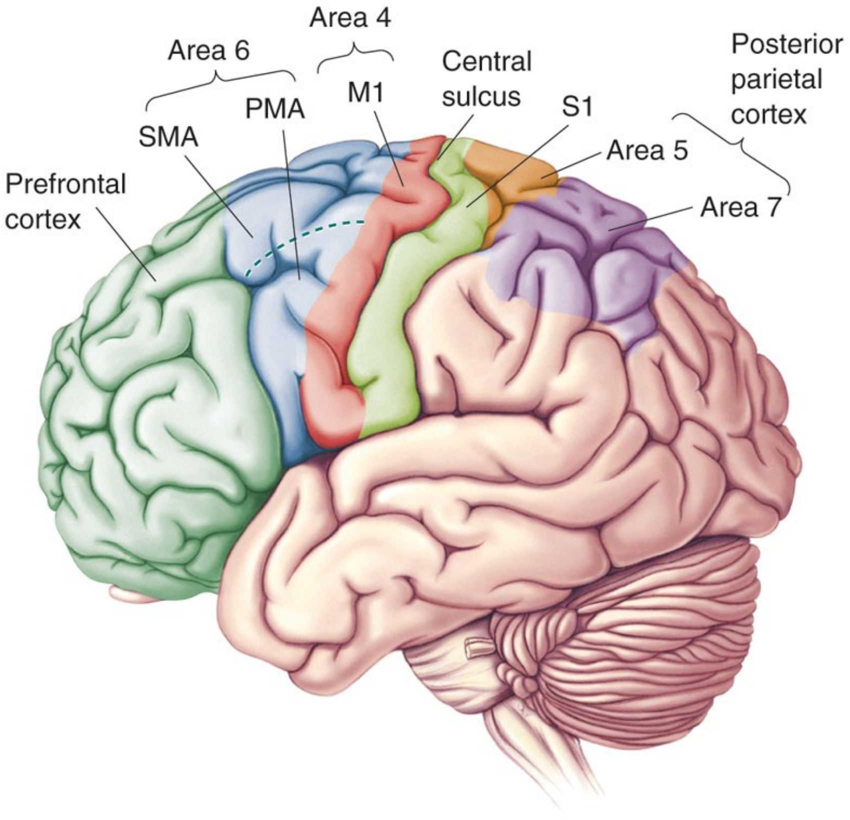
Motor cortex

- Primary motor cortex (area 4)
  - Somatotopic organization
  - Control of lower motor neuron
- Premotor cortex (area 6 laterally)
  - Preparation of strategy of movement
    - Sensor motor transformation
    - Movement patterns selection
- Supplementary motor cortex (area 6 medially)
  - Involved in planning of complex movements
    - Movement of both limbs
    - Complex motion sequences
  - Activated also by complex movement rehearsal



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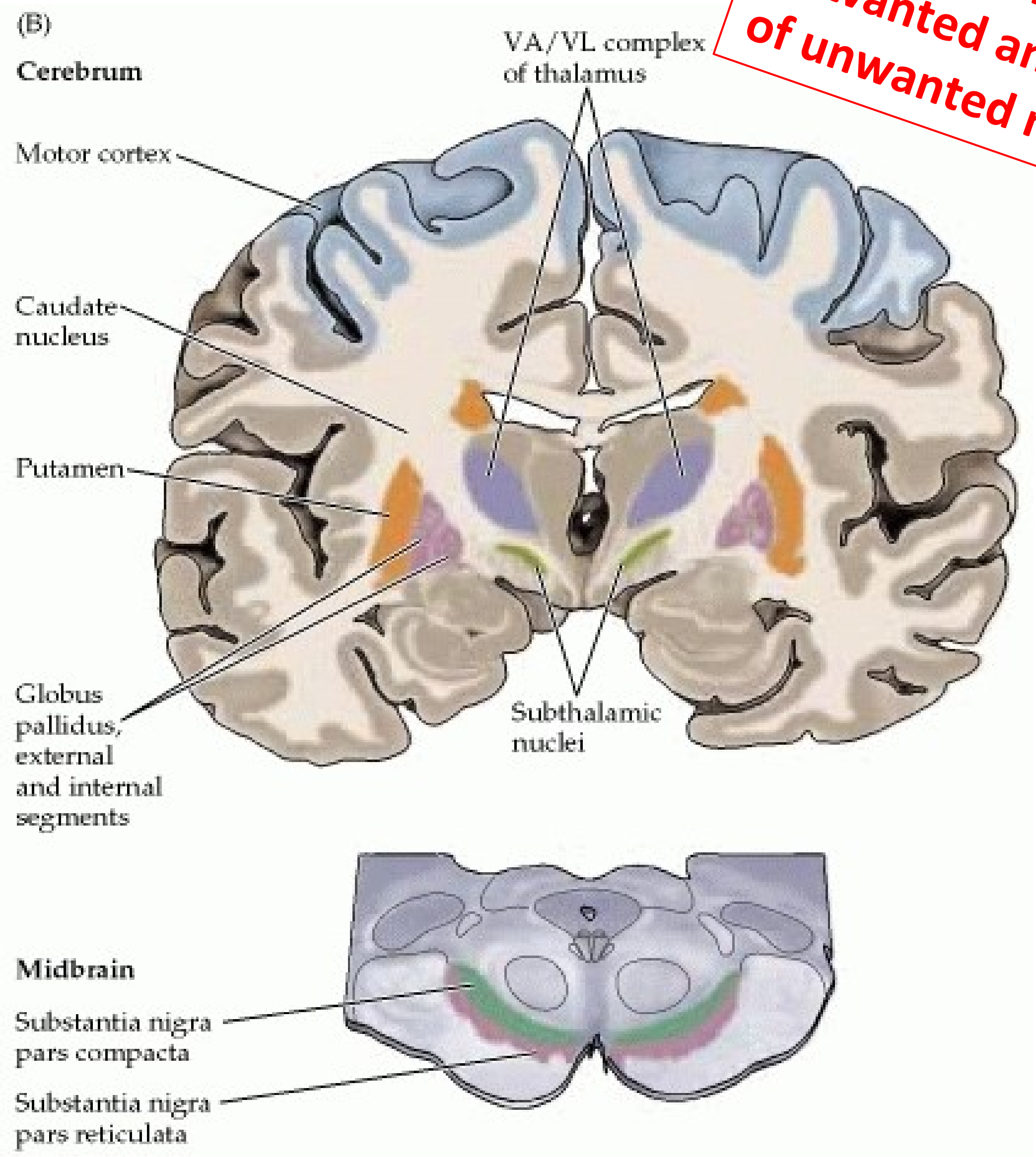
Basal ganglia

- Corpus striatum
  - Nucleus caudatus
  - Putamen
- Globus pallidus (Pallidum)
  - Externum
  - Internum
- Nucleus subthalamicus
- Substantia nigra
  - Pars compacta
  - Pars reticulata
- Thalamic motor nuclei

Motor gating – initiation of wanted and inhibition of unwanted movements



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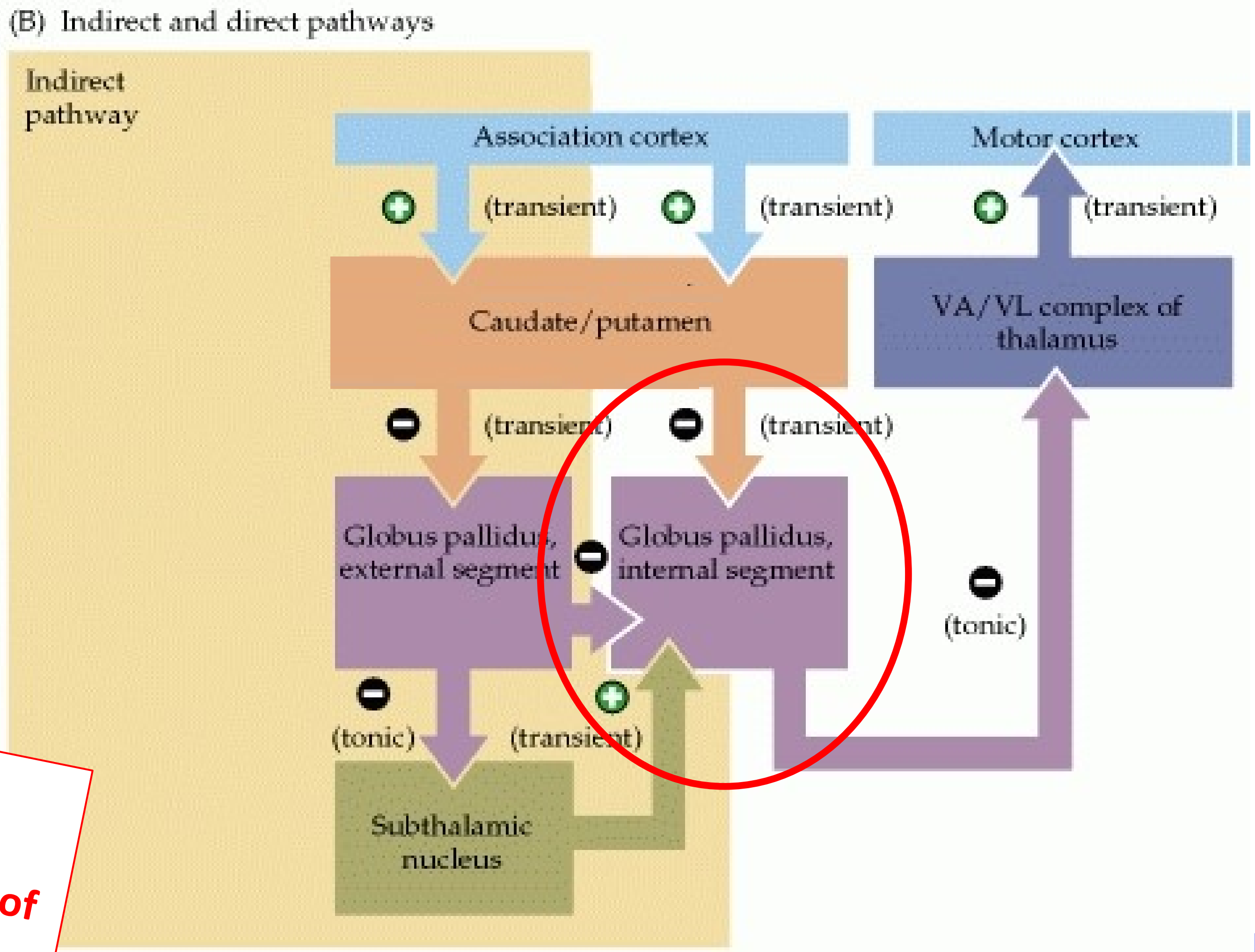
Direct and indirect pathway differences

- Direct pathway
  - Motor cortex activation

- Indirect pathway
  - Motor cortex inhibition

Indirect pathway may be considered as a „handbrake“ regulating „acceleration effect“ of the direct pathway



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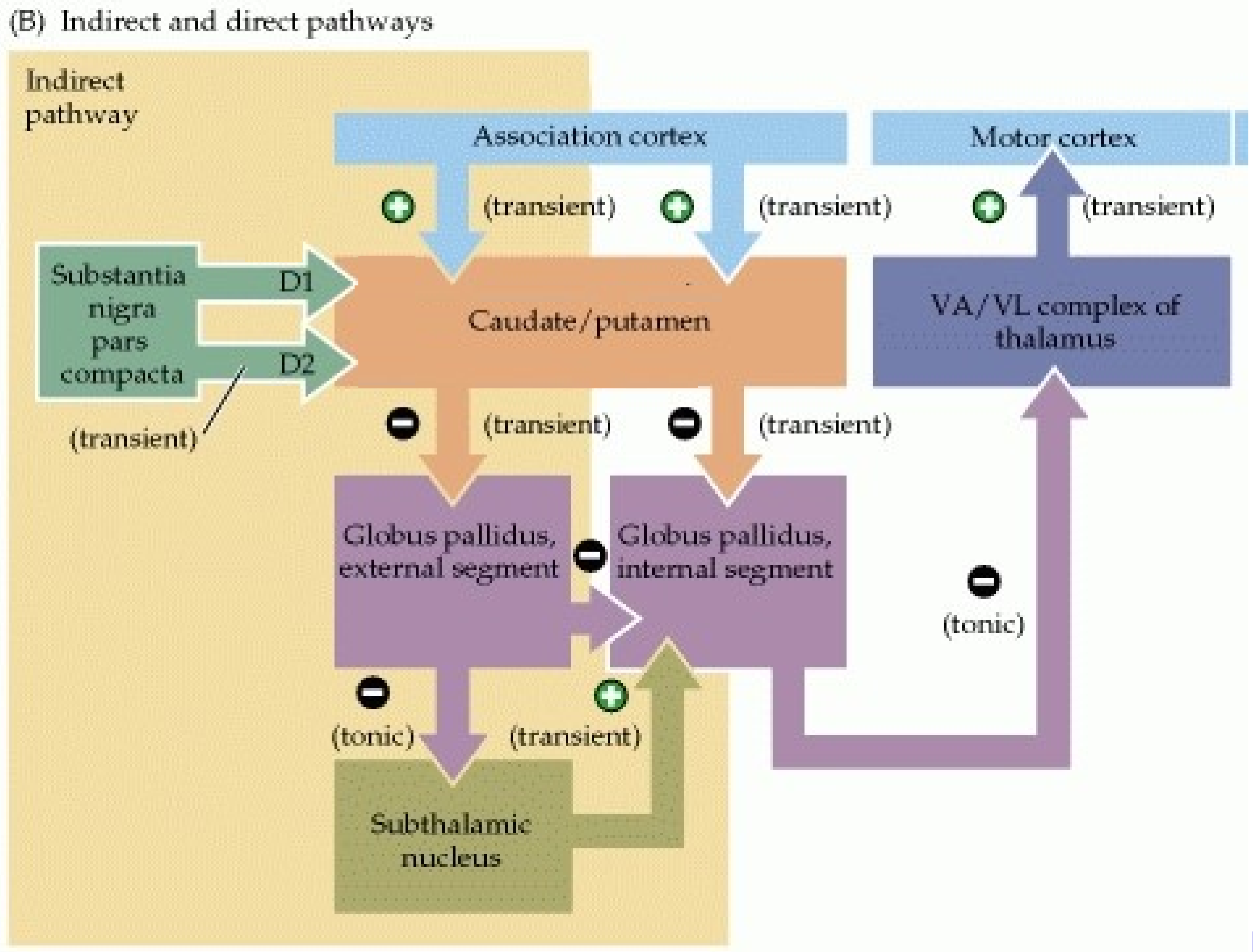
Dopaminergic projections

- Dopaminergic projections are crucial for the function of corpus striatum
- S. nigra pars compacta

- Direct pathway activation
  - ➢ D1 receptors

- Indirect pathway inhibition
  - ➢ D2 receptors



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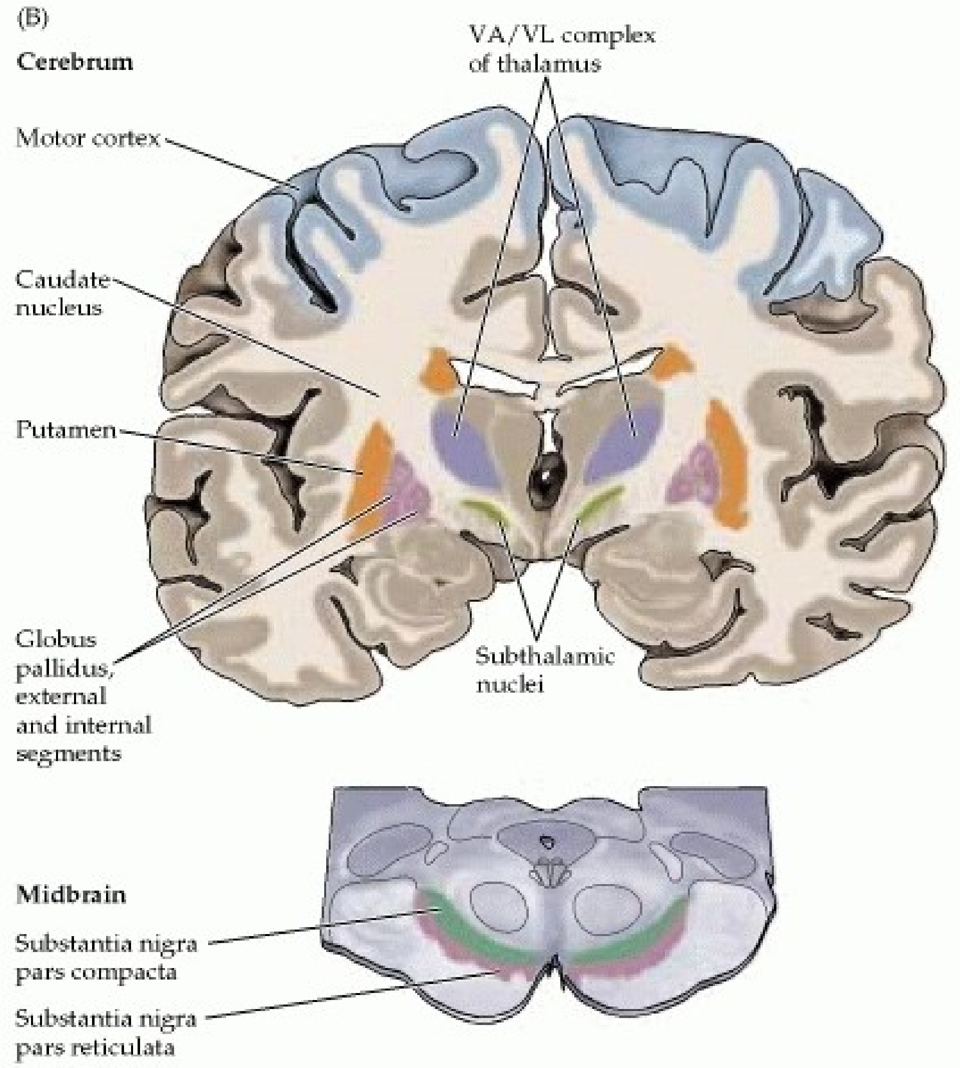
Basal ganglia

- Beside motor loop there are other loops associated with other thalamic nuclei
- „Gating“ of the other sort of information
- Association loop
- Limbic loop
- Basal ganglia play an important role in information processing in general and this is crucial for thinking process
- Connections of corpus striatum are plastic what allows learning and this was very important during evolution



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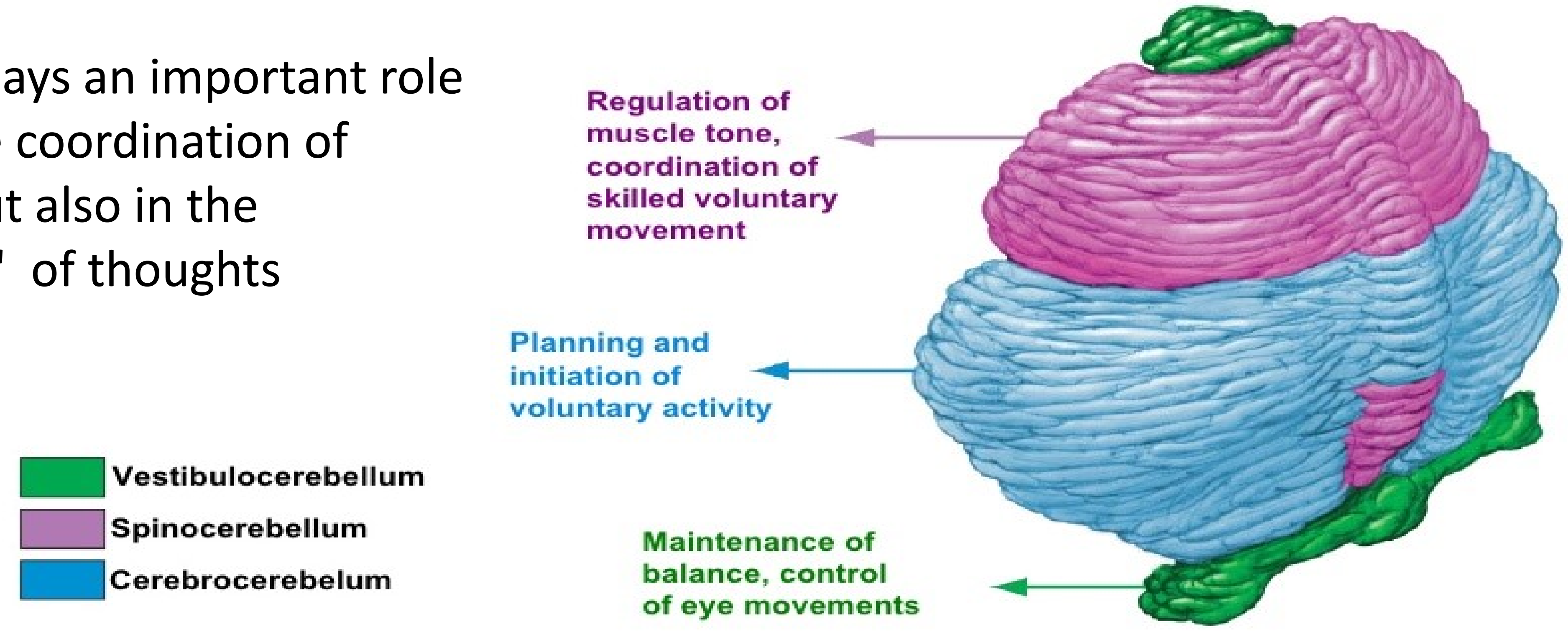
Cerebellum

- Coordination
- Cerebellum plays an important role not only in the coordination of movement, but also in the "coordination" of thoughts



http://www.slideshare.net/HarshshaH103/cerebellum-its-function-and-releveance-in-psychiatry

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