60. Visceral sensation - stimuli, receptors, their distribution. Draw and describe a simple scheme illustrating position, localization and connections of neurons that convey viscerosensory information to subcortical and cortical structures. Three examples of visceral information use in body function control

Visceral sensations are those from the viscera of the body, one usually refers specifically to sensation from the internal organs. This is a part of the ANS.

→ The receptors for pain and the other sensory modalities present in viscera are similar to those in skin but there are differences in their distribution. There are no proprioceptors in viscera and few temperature/touch receptors. Often, the only sensory receptors are of pain.

There are some specialized visceral sensory receptors:

- Osmoreceptors : found in hypothalamus
- Baroreceptors : detect BP and participates in regulation of CO. Found in carotid sinus.
- Chemoreceptors : detect CO_2 level in blood. Present in carotid body in carotid artery.

Pain receptors are distributed in periosteum, arterial wall, joint surfaces, and surface of viscera.

Stimuli which excite the visceral receptor include:

→ Ischemia: causes pain due to the formation of acidic metabolic end products (lack of O_2 → anaerobic glycolysis → lactic acid) or tissue degenerative products.

→ Chemical stimuli: damaging substances that leak from GIT into peritoneal cavity in case of stomach ulcers.

→ Spasm of hollow organs: spasm of GIT, gall bladder, bile duct, uterus causes pain due to mechanical stimulation of pain endings.

→ Distension of hollow organs: overfilling (for example by gas) causes stretch and pain.

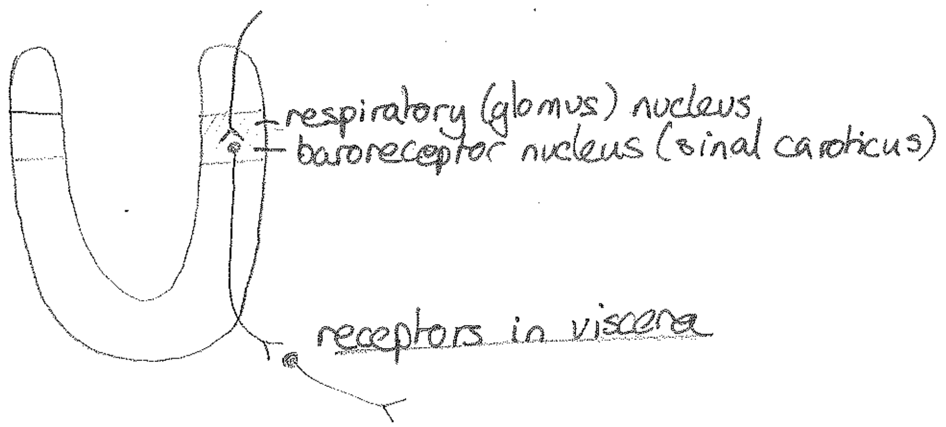
Sensations from thorax and abdomen are transmitted by 2 pathways:

① Visceral pathway - pain is transmitted via pain nerve fibres and pain is referred to surface areas of the body. Fibres are C-type transmitting slow pain. Pain located at a distance from the painful organ.

② Parietal pathway - sensation is conducted directly into local nerves from parietal peritoneum, pleura or pericardium. These sensations are usually located directly over the painful area.

Axons of viscerosensation are present inside nerves of parasympathetic/sympathetic system.

The Ist order neuron of visceral sensation is located in ggl. inf. n. IX others in ggl. inf. n. X. They are pseudounipolar nerves. Their peripheral branch terminate on sensors located in wall of viscera; baroreceptors, chemoreceptors. All central branches from Ist terminate on ncl. solitarius (main nucleus for viscerosensation) contains IInd order neurons of this pathway.



Sympathetic pathways

Visceral organs → Prevertebral ggl. → Ncl. proprius → VPL ncl. thalamus → Viscero-sensory cortex

(61). Nociception and pain, stimuli, receptors, physiological significance. Classification of pain, nerve fibres. Pain perception. Referred pain. Draw and describe scheme of ascending pathways for the nociceptive information in spinal system. Describe structures for endogenous analgesic system and its functional significance.

Pain is primarily a warning signal to the organism; it is often accompanied by withdrawal from a noxious stimuli, but not all noxious stimuli that activate nociceptors are necessarily experienced as pain.
All perception involves an abstraction and elaboration of sensory inputs. Pain is more than a sensory experience of danger.

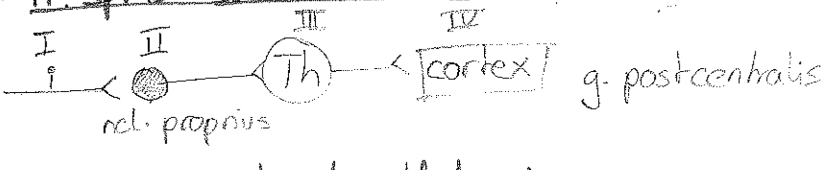
Nocisensors - activated by mechanic, thermal or chemical stimuli, factors released by damaged tissue.

Nociceptive afferent axons
Aδ - thin myelinated 5-30 m/s transmission - thermal + mechanical nocisensor - sharp, localized pain.
C - unmyelinated axons, 0.5-2 m/s transmission - polymodal nocisensors mechanical stimuli of high intensity, chemical and extreme thermal and cooling stimuli - diffusion, dull pain

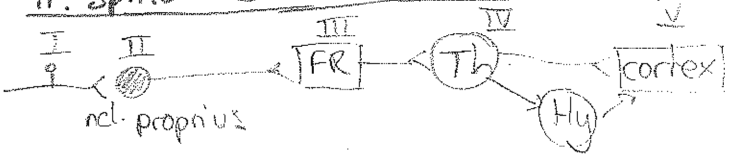
- Lateral pain system - tr. spinothalamicus lat. → it is associated with sharp, suddenly felt, and discriminating aspects of pain (called phasic pain)
- Medial pain system - spinoreticulothalamic and trigeminoreticulo thalamic pathways → it is involved in persistent and diffuse unpleasant feelings for some time after injury has ceased; through the limbic system it is influenced with affect and motivation

Aδ
sharp pain

- Tr. spinothalamicus lat.

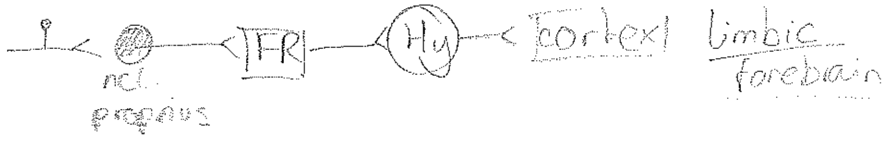


- Tr. spino-reticulo-thalamicus



C
· diffusional pain
· autonomic and reflex answers to pain stimuli
· emotional reaction to pain

- Tr. spino-mesencephalicus - emotional expression of pain

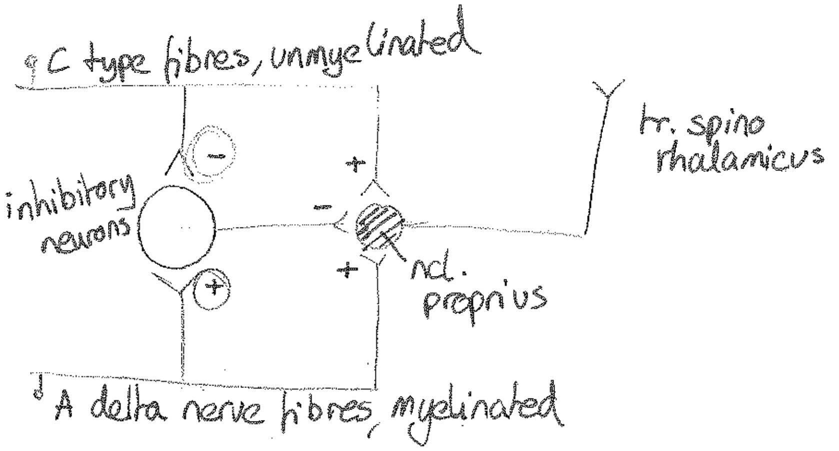


Segmental antinociception (analgesic system) Spinal and supraspinal levels

Sensory modulation - gate control of sensory transmission from first to other order neurons is subject to gating.

Gating of the spinothalamic response to C-fibres activity can be induced by stimulation of mechanoreceptors.

- projection neuron is activated by both types of fibres
- myelinated axons also activate inhibitory interneurons
- activity of myelinated axons results in reduction of projection
- base for transcutaneous electrical nerve stimulation



- action of myelinated Aδ fibres modulates inhibition/activation of inhib neurons to stop action of tr spinothalamicus

Supraspinal antinociception

Hypothalamus → releasing of opiate peptides - PAG → ncl. raphe magnus = stress-induced analgesia an organism's response to an emergency is a reduction in responsivity of pain.

Ncl. raphe magnus → raphespinal tract - serotonin - PAG-stimulation → stimulus-induced analgesia

- Referred pain - pain that arises from nociceptors in deep visceral structures but is felt at sites on the body surface

(62). ...same... Draw and describe scheme of ascending pathways for the nociceptive information in trigeminal system. ...same...

Pain pathway in trigeminal system:

tr. trigemino-reticulo-thalamicus - diffusional, worse localized pain

tr. trigemino-thalamicus ventralis - sharp, localized pain

63. Encoding of auditory stimuli - frequency and intensity. Structure and functions of the inner and outer cochlear hair cells, mechanisms of stimulation. Function of basilar membrane. Draw and describe scheme of position, localization and connections of neurons for pathways that convey auditory information to the cortex.

Frequency :

Intensity :

Inner hair cells

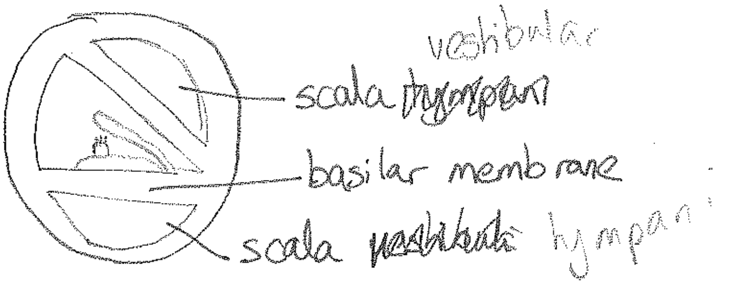
- located in inner part of Organ of Corti
- Its stereocilia are arranged in semicircles and by height. Displacement towards the largest stereocilia causes depolarization and displacement away causes hyperpolarization
- Stereocilia are connected to each other via tip links that transmit force to an elastic gating spring, which in turn opens the cation channel → MECHANOTRANSDUCTION → very fast
- Depolarization : rapid influx of K^+ which causes Ca^{2+} channels to open. Calcium influx causes neurotransmitter-filled vesicles to fuse with the basal membrane and release glutamate.
- Inner cells are responsible for hearing while outer cells amplify signals processed by inner hair cells.

Outer hair cells

- When outer hair cells are depolarized, their cell bodies actively contract and when they are depolarized their length increases.
- Contraction of outer hair cells influence the movement of the basilar membrane in that particular segment, increasing the fluid displacement around the inner hair cells, this amplifies the magnitude of K^+ influx into the inner hair cells increasing the signal to the cochlear nerve.

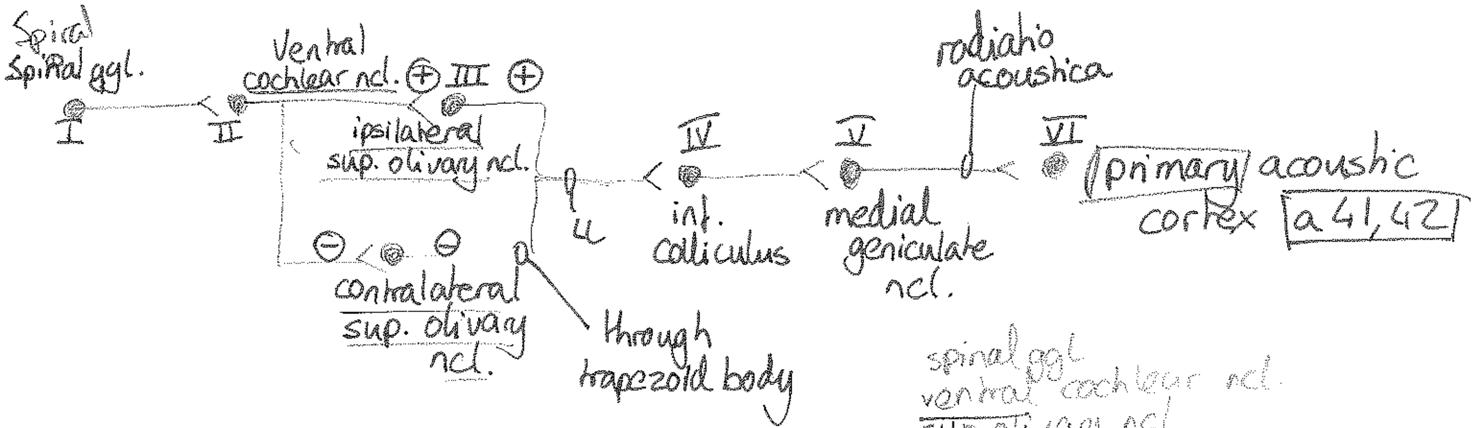
Basilar membrane

- Where the inner and outer hair cells sit on.
- When the perilymph in the scala vestibuli is displaced by some stimuli from outside, the basilar membrane moves causing inner + outer cells to depolarize.
- Frequency of a sound has a place on the basilar membrane where it is displaced the most, the amplitude of the displacement results in the loudness.



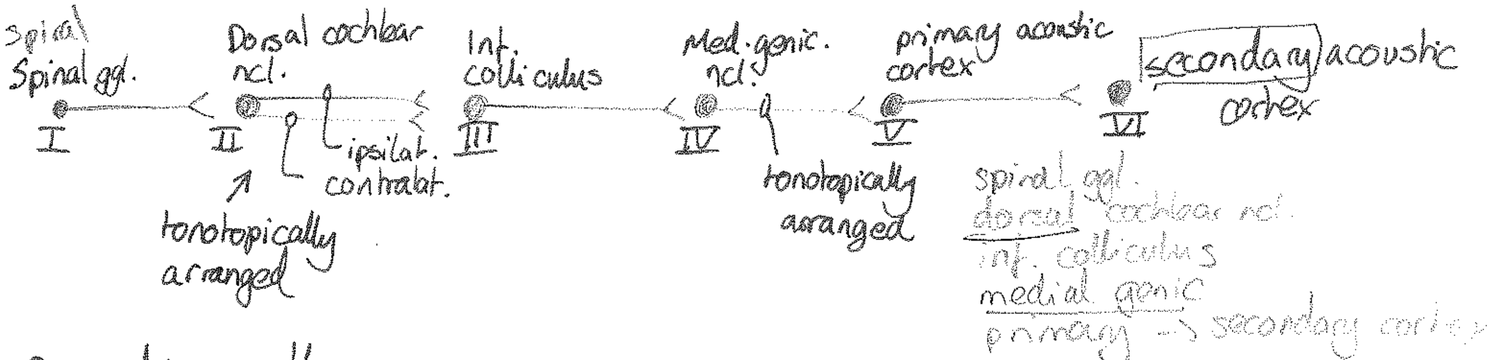
1) Intensity of sound and lag for detection of hearing

Ncl. cochlearis ventralis



spinal ggl.
ventral cochlear ncl.
sup. olivary ncl.
inf. colliculus
medial geniculate → primary cortex

2) Frequency (pitch)



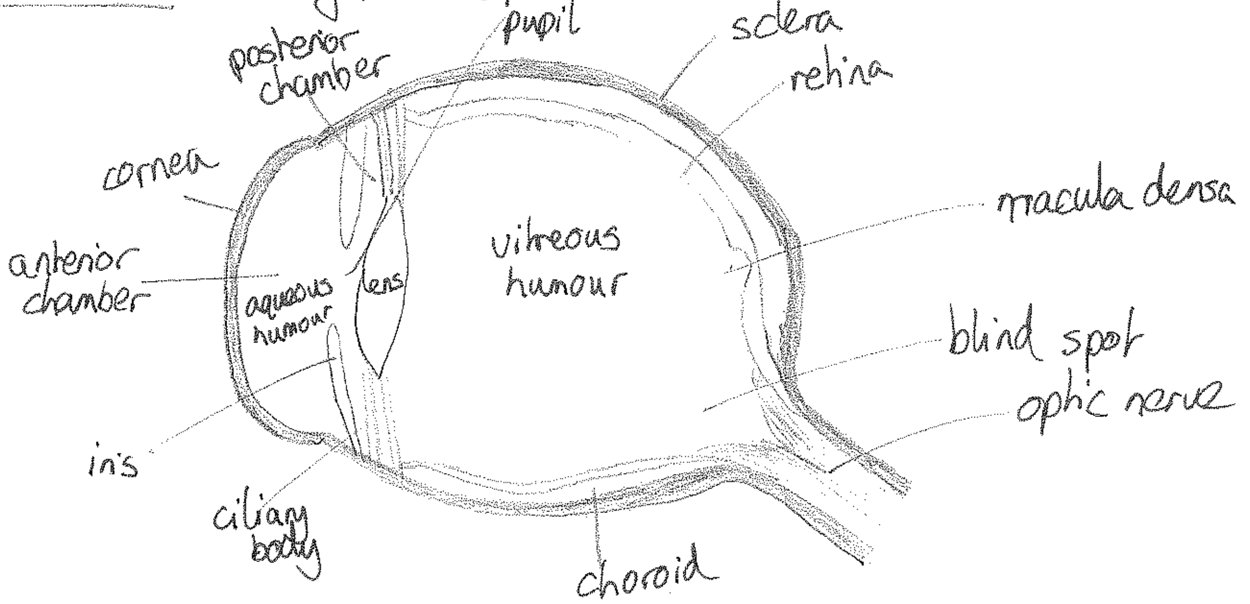
Descending pathways:

1) from auditory cortex and ncll. (such as sup. olivary ncl.) – tr. olivocochlearis
→ outer hair cells – rise of sensitivity

2) from auditory cortex – supression of extreme inputs, vigilance

64. Optical system of the eye. Common defects of the image-forming mechanism. Adaptation to different light intensities. Accomodation. Photopic and scotopic vision. Draw and describe simple scheme of pathways for mydriatic and miotic pupillary reflexes and accomodation.

Each eye is composed of 3 layers: an external layer consisting of sclera and cornea; a middle layer consisting of choroid, ciliary body (which produces aqueous humour) and an inner layer of nervous tissue, the retina, which consists of an outer pigment epithelium and an inner retina proper. The photosensitive retina proper is part of the CNS and communicates with the cerebrum through the optic nerve and extends forward to ora serrata.



Before forming an image, the ray of light must pass through 4 optical environments on its path to the retina - the cornea, the aqueous humour, the lens and the vitreous body - each of which contributes to the refraction of the light beam. Due to this diminished and inverted images of the outside world are formed in the retina. By projecting the inverted image through visual pathways to the centre of vision in the cerebral cortex, we realize the images in their correct position.

- Changes in the refractive power of the lens are referred to as accomodation. The curvature of the lens is changed with help of m. ciliaris depending on distance of object we observe. When viewing distant objects, lens is made thin and flat and has least refractive power. For near vision, the lens become thick and rounder and has the most refractive power. These changes result from activity of ciliary muscle surrounding the lens.

→ the automatic focusing of optical system is made possible by accomodation.

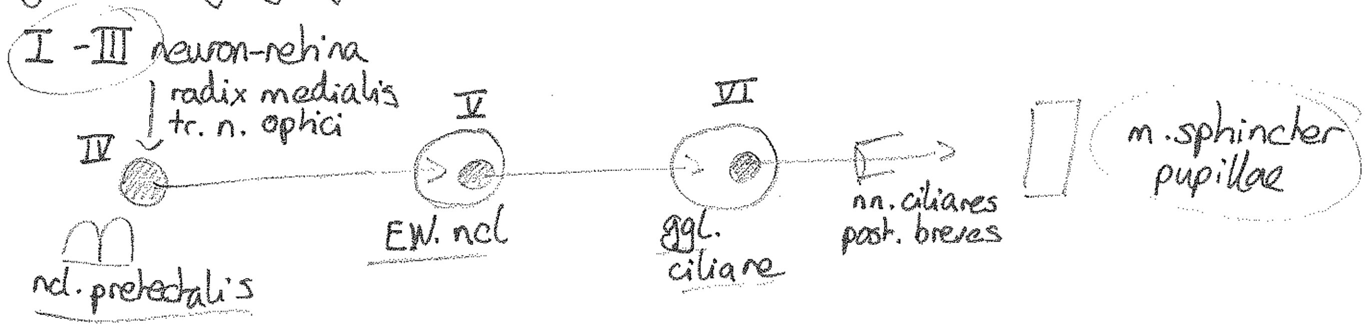
The cones provide for vision under high intensity of light. They enable us to see details of shape and colour. They take over during adaptation to light. This adaptation is fast, it takes 20-60 seconds. The vision of an eye adjusted to light is called photopic.

The rods provide for non-colour vision and become active at very low intensities of light. They play a role during adaptation to dark. This adaptation is slower it takes aprox. 40-60 seconds to reach max. adaptation. The vision of an eye adopted to dark is called scotopic.

• Mydriatic and miotic pupillary reflexes (adaptation to diff. light intensities)

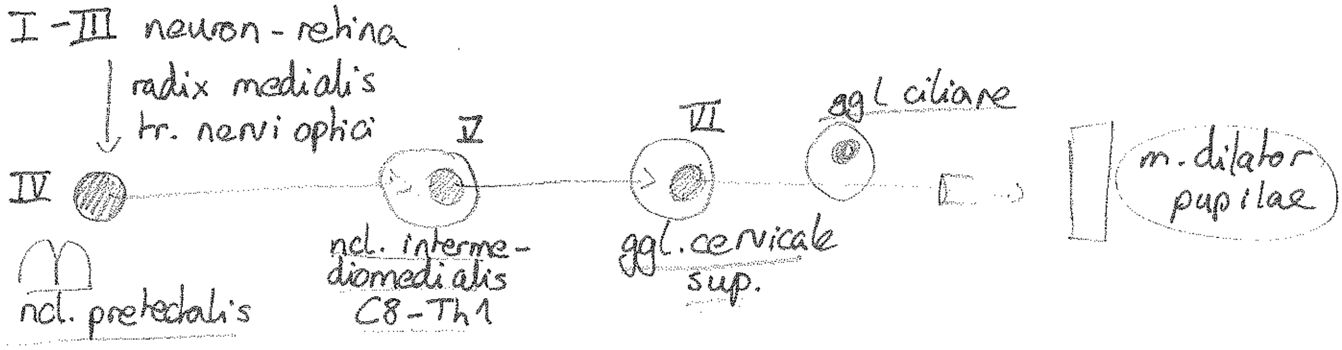
Miosis - pupils constrict

When light is shone into eyes, the pupils constrict. When light impinges on the retina, a few of the resulting impulses pass from the optic nerves to the pretectal nuclei. From here, secondary impulses pass to the E.W. ncl and back through parasympathetic nerves to constrict the sphincter of the pupil. The function of this light reflex is to help the eye to adapt extremely rapidly to changing light conditions.

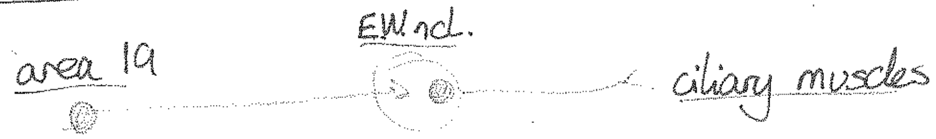


Mydriasis - pupils dilat

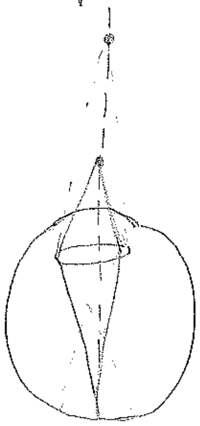
Refers to the dilation of pupils for instance in low light conditions or under sympathetic stimulation.



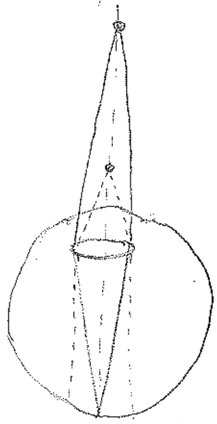
Accomodation



Accomodation to near point



Accomodation to far point



Common defects of image-forming mechanism

- Myopia (shortsightedness) - condition where the light that comes in does not directly focus on the retina but in front of it. This causes image that one sees when looking at a distant object to be out of focus but in focus when looking at a close object. Can be corrected by lenses (concave) (or negative) or by refractive surgery.
- Hyperopia (farsightedness) - defect caused when eyeball is too short or lens does not become round enough, causing difficulty focusing on near objects. As an object moves toward the eye, the eye must increase its optical power to keep the image in focus on retina. If power is insufficient (in hyperopia) the image will be blurred. The image focuses at a point behind the retina.
- Astigmatism - optical defect in which vision is blurred due to the inability of the optics of the eye to focus a point object into a sharp focused image on the retina. This may be due to an irregular curvature of cornea or lens.

cones - light rods - dark

Photopic and scotopic vision

The rods and cones have different properties. The rods have very low spatial resolution but are extremely sensitive to light. The cones have very high spatial resolution but are much less sensitive to light. The range of illuminance over which the rods and cones operate is therefore different.

At the lowest levels of light, only the rods are activated. Such rod-mediated perception is called scotopic vision. As illumination increases, cones become more and more dominant is determining what is seen, and they are the major determina[nt] of perception under relatively bright conditions such as normal indoor lightning or sunlight. The contributions of rods to vision drops out in so called photopic vision because their response to light saturates (the membrane potential of individual rods no longer varies as a function of illumination because all of the membrane channels are closed).

Mesotopic vision occurs in levels of light at which both rods and cones contribute - at twilight for example.

(65). Vision – analysis of colour. Information processing in the retina. Mechanisms of colour vision. Receptive fields of retinal ganglion neurons and neurons in corresponding visual pathway. Draw and describe scheme of position, localization and connections of neurons for pathways that convey this visual information to the cortex. Describe arrangement of primary visual cortex, mention other visual cortices for colour analysis.

The perception of colour in humans is based on 3 types of cones, each containing a variant of visual pigment iodopsin which have a different sensitivity to light of different wavelengths, and for the reason are referred to as "red" (long), "green" (medium), "blue" (short). The 3 visual pigments are formed from binding retinal to 3 distinct opsin proteins.

Although the visual pigments are designated as red, green or blue, their absorption spectra overlap. For this reason, the brain's perception of intermediate hues depends on the differential stimulation of 2 or more classes of cones. (For example, when both red and green cones are stimulated we may see yellow or orange depending on which class is more strongly stimulated). This is called trichromatic vision.

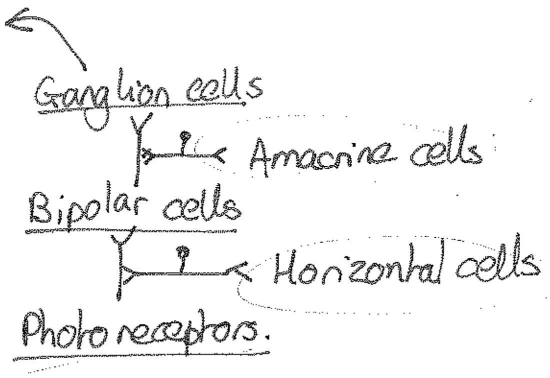
Dichromacy (colour blindness) is a hereditary and sex-linked colour vision defect predominantly affecting males. It occurs when one of the cone pigments is missing and colour is reduced to 2 dimensions. It most often results in the inability to differentiate between red and green.

The processing of visual information begins in the retina, where rods and cones synapse with bipolar cells. In the dark, rods and cones are depolarized and continually release the neurotransmitter glutamate at these synapses. Some bipolar cells depolarize in response to glutamate whereas others hyperpolarize. Which of the 2 responses a bipolar cell exhibits depends on the type of glutamate receptors present on its surface. When light strikes the rods and cones, they hyperpolarize, shutting off their release of glutamate.

In addition to bipolar cells, information processing in the retina requires 3 other types of neurons – ganglion, horizontal and amacrine cells. In the retina there are vertical connections between the photoreceptors, bipolar cells and ganglionar cells.

Horizontal connections are maintained by horizontal and amacrine cells. The processes of horizontal cells enable lateral connections between photoreceptors and bipolar cells. They carry signals from one rod or cone to other photoreceptors and to several bipolar cells. When an illuminated rod or cone stimulates a horizontal cell, the horizontal cell inhibits more distant photoreceptors and bipolar cells that are not illuminated. The result is that the light spot appears even lighter and the dark surroundings even darker. This form of integration, called lateral inhibition sharpens edges and enhances contrast of the image.

The process of amacrine cells are postsynaptic to bipolar cells terminals and presynaptic the dendrites of ganglion cells. So the horizontal and amacrine cells function in neural pathways that integrate visual information before it is sent to the brain



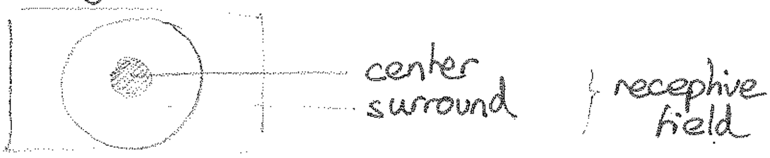
Receptive fields of retinal ganglion neurons

Each ganglion cell responds to stimulation of a small circular patch of the retina, which defines the cell's receptive field. In other words: each single ganglion cell receives information from an array of rods and cones, each of which responds to light coming from a particular location.

There are 2 classes of ganglion cells, "on center off surround" and "off center on surround". Turning on a spot of light in the receptive field centre of an "on centre off surround" ganglion cell produces a burst of APs. The same stimulus to the center of the receptive field of an "off centre on surround" ganglion cell reduces the rate of dischage. When stimulus is applied to the surrounding of an "on centre off surrounding" cell the rate of discharge ~~increases~~ decreases.

The fewer rods or cones that supply a single ganglion cell, the smaller the receptive field. A smaller receptive field results in a sharper image, because the information about where light hit the retina is more precise. The ganglion cells of the fovea have very small receptive field (1 cone -> 1 ganglion) (while in periphery maybe 100 rods -> 1 ganglion cell) so visual acuity in the fovea is high.

small field -> sharper
1 cone -> 1 ganglion



Pathways that convey visual information

Ganglion cells can be divided in 3 types:

- G_c type P – cca 80%, small receptive field, detection of form, depth + colour
- G_c type M – cca 10%, large receptive field, detection of movement
- G_c type non-P or M – cca 10%, projection to ncl. colliculi sup.

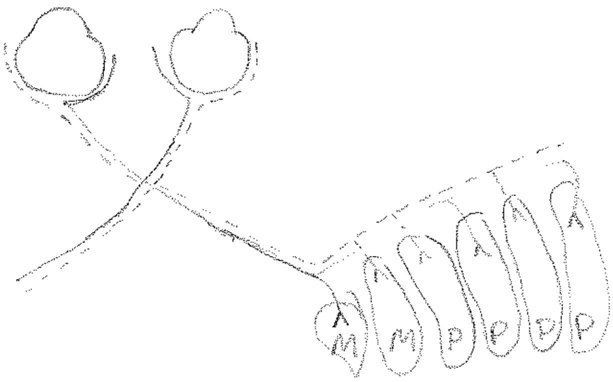
Ganglionic cell axons exit the retina through the optic disc (optic papilla) where they form the optic chiasma where fibres from the nasal hemiretina of each side cross to the contralateral optic tract. Once past the optic chiasma axons form the optic tract. Thus, the optic tract, unlike the optic nerve, contain fibres from both eyes.

One of the major targets of the axons (90%) in the optic tract, is the lateral geniculate nucleus of the thalamus. These neurons send their axons to the cerebral cortex via the internal capsule called radiatio optica and terminate in the primary visual cortex (a.17).

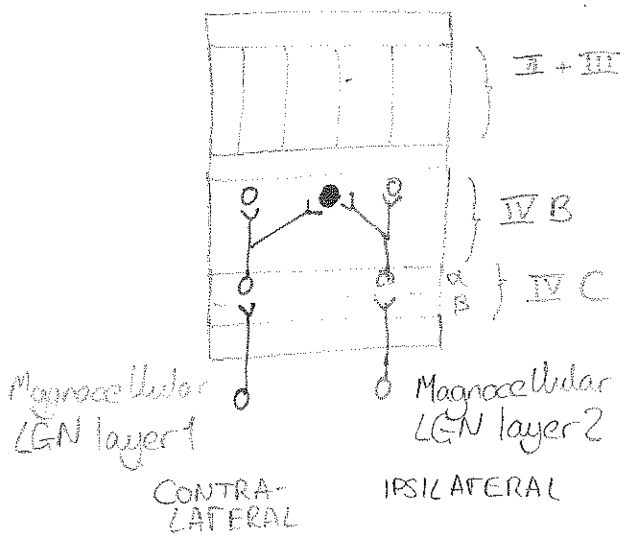
Other axons (10%) go to:

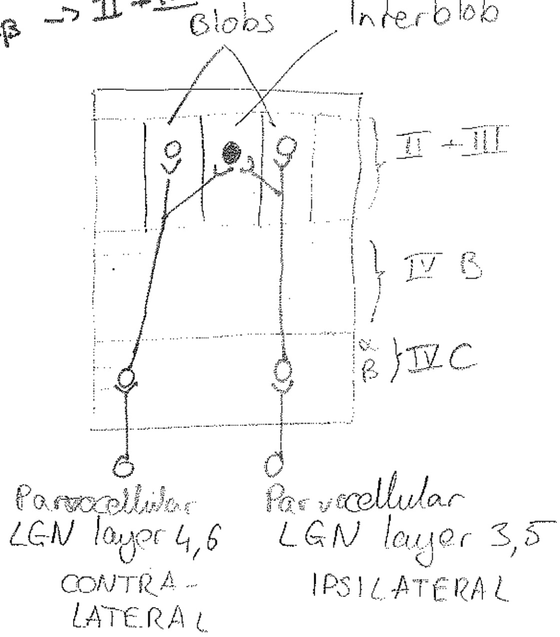
- tectum - reflexes for persuit and saccadic eye movements
- hypothalamus - suprachiasmatic ncl - circadian rhythm
- pulvinar thalami - coordination of visual and ss perception.

Although the lateral geniculate nucleus receives input from both eyes, the axons terminate in separate layers, so that individual geniculate neurons are monoocular.



1st neuron - rods + cones
2nd neuron - bipolar cells
3rd neuron - ganglionar cells
4th neuron - ncl. corpori n. geniculati lateralis
5th neuron - primary visual cortex → 4Cβ → II + III





67. Vision - detection of motion, functional significance. Information processing in the retina. Characteristic properties of receptive fields of neurons in corresponding visual pathway. Draw and describe scheme of position, localization and connections of neurons for pathways that convey this visual information to the cortex. Describe arrangement of primary visual cortex, mention other visual cortices for motion analysis.

Motion perception is based on visual, vestibular and proprioceptive inputs.

1) First order motion perception - the perception of motion of an object that differs in contrast with its background.

2) Second order motion perception - the perception of motion by looking at the contrast and texture of the moving object.

The visual system puts these 2 motion perceptions together into a 2D image. And together with binocular and monocular cues a depth perception is created and a 3D image is formed.

M type ganglion cell
- 10%.
- large receptive area
- connect with magnocellular layers of lateral geniculate nucleus of the thalamus.

Photoreceptors → Bipolar cells → Ganglion cells → Lateral geniculate nucleus

a5 + a7 somatosensory ← a17 4β ← a17 $4C\alpha$ ← (Lateral geniculate nucleus)

68. Sense of balance – description of stimuli and receptor cells. Detection of head position due to gravity. Detection of angular and linear acceleration. Draw and describe a simple scheme illustrating position, localization and connections of neurons that convey vestibular information to BS. Nystagmus

Maculae – sensory organs of the utricle and saccule for detecting orientation of the head in respect to gravity.

Located on the inside surface of the utricle and saccule is a small sensory area called macula. The macula of the utricle lies mainly in the horizontal plane on the inferior surface of the utricle and plays an important role in determining orientation of the head when the head is upright. Conversely, the macula of the saccule is located mainly in a vertical plane and signals head orientation when lying down

Each macula is covered by a gelatinous layer in which many small calcium carbonate crystals called statoconia are embedded. Also in the macula are thousands of hair cells; these project cilia up into the gelatinous layer. The bases and sides of the hair cells synapse with sensory endings with sensory endings of the vestibular nerve. The weight of the statoconia bends the cilia in the direction of gravitational pull.

Each hair cell has 50–70 stereocilia plus one large kinocilium. The kinocilium is always located to one side and the cilia become shorter. Tip links connect the tips of stereocilia to next and finally to kinocilium. A mechanically gated cation channel is located at one or both ends of each tip link and is normally open part of the time. Deflecting the hair bundle toward the kinocilium stretches the tip links, increasing the probability of channel opening. The resulting inward cation current depolarizes the hair cells causing the opening of voltage-gated Ca^{2+} channels and increased release of transmitter onto the nerve endings (VIII C.N.). The excitatory transmitter (probably glutamate) causes increased firing frequency in the nerve fibre. Deflecting the hair bundle in the opposite direction decreases the tension on the tip links, the transduction channels close cation current stops transmitter release and firing rate diminishes. Under normal resting conditions the nerve fibres leading from the hair cell transmit continuous nerve impulses at a rate of about 100/sec. When the stereocilia are bent toward the kinocilium the impulse traffic increases often to several hundreds per second; conversely, bending the cilia away from the kinocilium decreases the impulse traffic often turning it off completely.

The 3 semicircular ducts in each vestibular apparatus, known as the anterior, posterior and lateral are arranged at right angles to one another so that they represent 3 planes in space. Each duct has an enlargement at one of its ends called the ampulla and the ducts and ampulla are filled with endolymph. Flow of this endolymph through one of the ducts and through its ampulla excites the sensory organ of ampulla. In each ampulla there is a crista ampullaris. On top of there it is a loose gelatinous mass, the cupula.

Into the cupula are projected hundreds of cilia from hair cells located on the ampullary crest. When a person's head begins to turn in any direction, the inertia of the fluid in the duct causes the fluid to remain stationary while the semicircular ducts rotate with the head. This bends the cupula to one or the other side. The kinocilia of these hair cells are all oriented in the same direction in the cupula and bending the cupula in that direction causes depolarization of the hair cells whereas bending in the opposite direction hyperpolarize the cell.

Responses to angular and linear acceleration

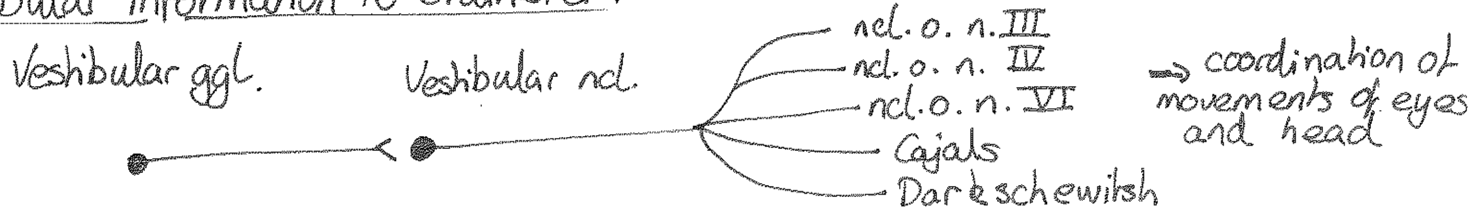
It is specially important that the hair cells are all oriented in different directions in the macullae of the utricles and saccules so that with different positions of the head, different hair cells become stimulated. These "patterns" of stimulation of the different hair cells apprise the brain of the position of the head with respect to the pull of gravity. In turn, the vestibular, cerebellar and reticular motor nerve systems of the brain excite appropriate postural muscles to maintain proper equilibrium.

When the body is suddenly accelerated the statoconia which have greater mass inertia than the surrounding fluid fall backward on the hair cell cilia, and the information of disequilibrium is sent to the nervous centers.

When the head suddenly begins to rotate in any direction (angular acceleration) the endolymph in the semicircular ducts, because of its inertia, tends to remain stationary while the semicircular ducts turn.

This causes the fluid to flow in the ducts in the direction opposite to head rotation → detection of rotation.

Vestibular information to brainstem



Nystagmus: form of involuntary eye movement that is part of the vestibulo-ocular reflex (VOR), characterized by alternating smooth pursuit in one direction and saccadic movement in other direction.

69. Control of posture - functions of postural system. Describe corresponding muscle groups, essential afferent information, reflexes and CNS structures. Proprioceptive pathway from the lower extremity (q. 71), scheme and its description

To maintain body in an upright, balanced position, it needs some postural control or adjustment

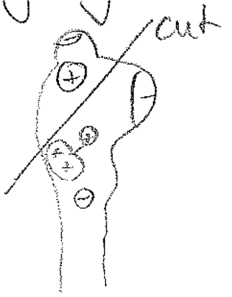
Postural control includes: - static reflexes
- phasic (dynamic) reflexes

Static reflexes involve sustained contraction of muscles
Phasic reflexes involve transient movements, short-term movements

Posture is controlled by motor centers in brainstem, ex. ncl. ruber, vestibular nuclei + reticular formation
Inputs are received from labyrinth organs and propriosensors in muscles. Also, input from skin receptors, eyes, ears also play a role in posture control

Descending tracts to spinal cord from ncl. ruber and reticular formation in medulla oblongata (tr. rubrospinalis + tr. reticulospinalis lat.) have an inhibitory effect on α + γ motor neurons of extensor muscles and excitatory effect on flexor muscles.
On the other hand, Deiter's nucleus + reticular formation in pons inhibit flexors // excite α + γ of extensors.

Normally there is an equal distribution of inhibitory/stimulating neurons to flexor/extensor muscles but if we make a cut, it'll not be equal anymore.
Ex: a transection of brainstem below ncl. ruber will lead to decerebrate rigidity because effect of Deiter's nucleus predominates.



Decerebrate rigidity develops as soon as bs is transected. Patient will form a posture like this then die:

Decortical rigidity develops when transection is made above ncl. ruber. This results patient to lie with crooked arms as in picture

If the head of a decerebrate patient is turned to the side, the limb of one side becomes extended and the limb on the other side becomes flexed. This response is called the tonic neck reflex. It's initiated by stretch of the proprioceptors in upper part of neck.

70. Voluntary movements of upper extremities. Essential afferent information. Draw and describe a simple scheme of motor pathways that control voluntary movements of upper extremity. Scheme and description of corresponding proprioceptive pathways. Praxis and apraxis. Electromyography.

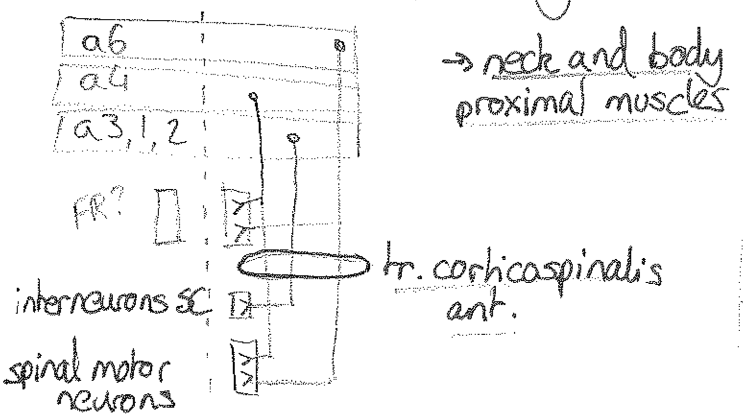
Propriocephon = perception of position of parts of the body; serves for many reflexes in the body and are crucial for motor functions.

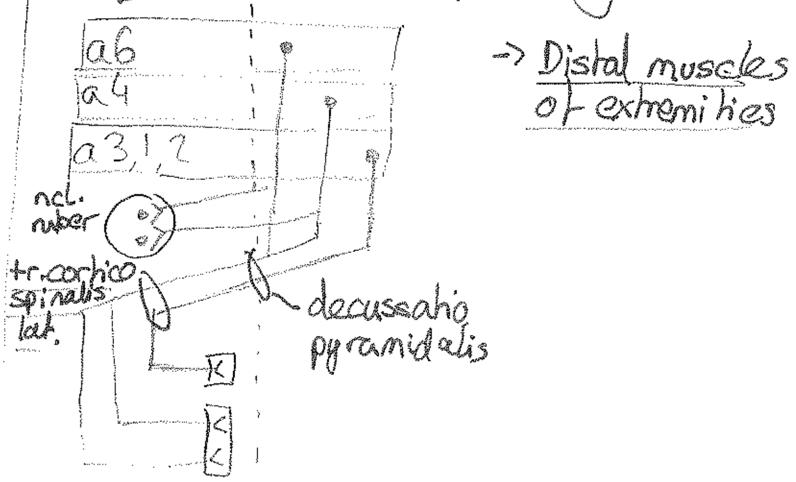
Receptors (proprioceptors) for propriocephon are located in joints + muscles. The muscles are supplied with 2 important types of encapsulated proprioceptors: muscle spindles and Golgi tendon organs. Muscle spindles are said to be the most important proprioceptors.

The receptors in joints and their capsules are free nerve endings, endings equivalent to Golgi tendon organs in ligaments and Ruffini endings as well as a few Pacinian corpuscles (rapidly adapting).

· Motor path that controls voluntary movement of upper extremity

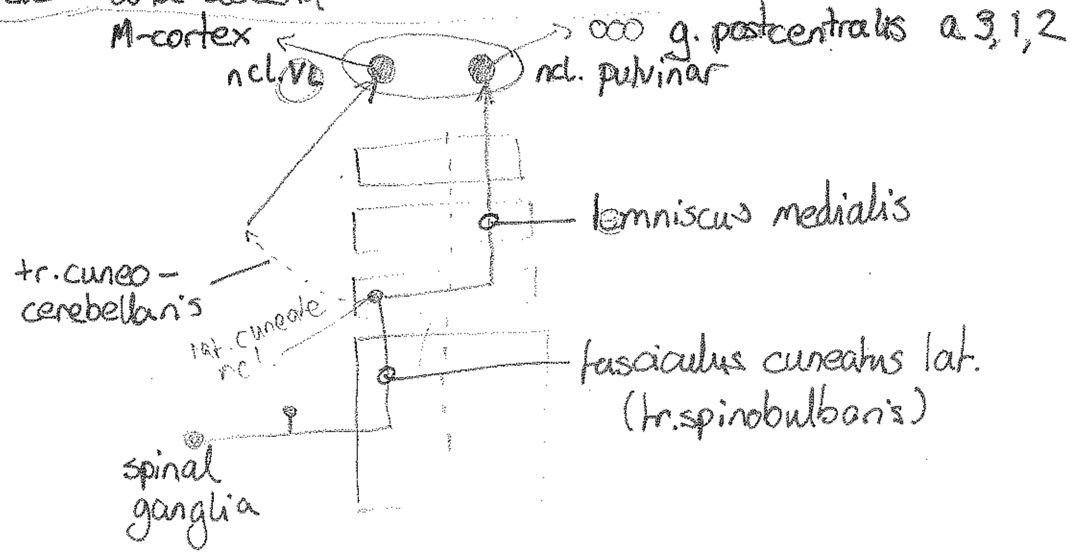
Medial cortical pathway | Lateral cortical pathway





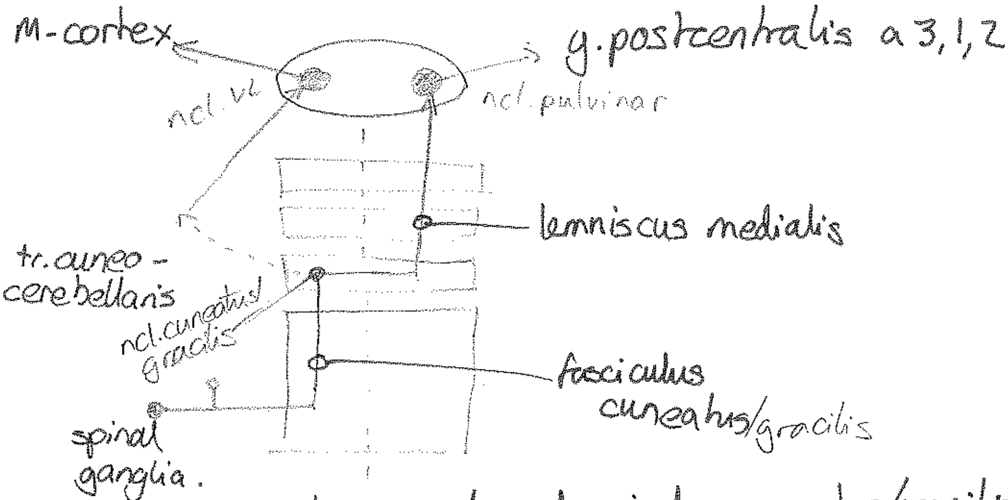
(+ describe)

⇒ Pathway for kinesthetic propriocephon from C-Th spinal cord segments
Exactly where the proprioceptive axons synapse depends on wether they originate in legs or arms. Fibres from arms enter at cervical and thoracic levels and ascend to caudal medulla.



→ Kinetic proprioceptive fibres enter spinal cord and ascend in fasciculus cuneatus to the caudal medulla
→ Synapse in lateral cuneate nucleus
→ Secondary axons ascend in lemniscus medialis (tr. bulbothalamicus) to posterior nucleus of thalamus or via cuneocerebellar tract to cerebellum
→ From thalamus, fibres from ncl. pulvinar project to gyrus postcentralis (a 3, 1, 2
→ Fibres from cerebellum are terminated in nucleus ventral lateralis thalami and from here they go to motor cortex

⇒ Static proprioception



→ Enter spinal cord and ascend in fasciculus cuneatus/gracilis to caudal medulla
→ Synapse in ncl. cuneatus /gracilis
→ 2nd axons ascend in lemniscus medialis to post. thalamus or to cerebellum via tr. bulbocerebellaris
→ From ncl. pulvinar → gyrus postcentralis
→ From cerebellum → ncl. VL → motor cortex

Apraxia - loss of ability to carry out learned purposeful movements, despite having desire and physical ability to perform movement. It is a disorder of motor planning. Caused by damage to specific areas of cerebrum.

Praxis - ability to interact successfully with the physical environment to plan, organize and carry out a sequence of familiar actions. Broad term which includes:
- Ideation – thought of planning idea in mind
- Motor planning – planning for action
- Execution – actually doing the activity/action

• Electromyography - technique for evaluating and recording the electrical activity produced by skeletal muscles. An electromyograph detects the electrical potential generated by muscle cells when they are electrically or neurologically activated. The electrical source is the muscle membrane potential of -90mV.
→ Muscle at rest is normally electrically inactive
→ When the muscle is voluntarily contracted, APs begin to appear; as the strength of the muscle contraction is increased more and more muscle fibres will produce APs.

71. Control of locomotion. Spinal pattern generators, basic stepping pattern and its modulation by afferent information. Describe function of main CNS structures involved in locomotion. Scheme and description of proprioceptive pathways from the lower extremity.

Spinal pattern generators
- neural network that produces rhythmic (or stepping) patterned outputs without the need for sensory feedback
- forward flexion of the limb is followed about a second later by backward extension. The flexion occurs again and the cycle is repeated over and over
- the oscillation backwards and forwards between flexor and extensor muscles can occur even after sensory nerves are cut, and it seems to result mainly from mutual inhibition currents within the matrix; oscillating between the neurons controlling against antagonist muscles.

Modulation by afferent information
- selects appropriate afferent info according to external requirement. e.g. positive support reaction - pressure on the sole of the foot causes appropriate extension of leg muscles to keep leg upright

Main CNS structures in locomotion.

Cerebellum - ensures smooth coordinated movements of voluntary muscles
- it receives info concerning:
  - position of body - proprioceptive info from spinocerebellar and cuneocerebellar tract
  - muscle tone and activity of spinal reflex arcs (spinocerebellar and cuneocerebellar)
  - position of head (vestibular information)
  - cortical activity
- it controls upper motor units: ✓ cortex ✓ brainstem

Basal ganglia - ensure that movements are planned and executed precisely. They encode for decision to move, direction of movement, amplitude of movement, motor expression of motion.
- The thalamus is under tonic inhibition. The tonic inhibition is modulated through the influence of direct and indirect pathways on the thalamus.
- Through the BG circuitry and its influence on the motor system each movement becomes efficient and target oriented.
- Receive input from widespread cortical areas (limbic system)

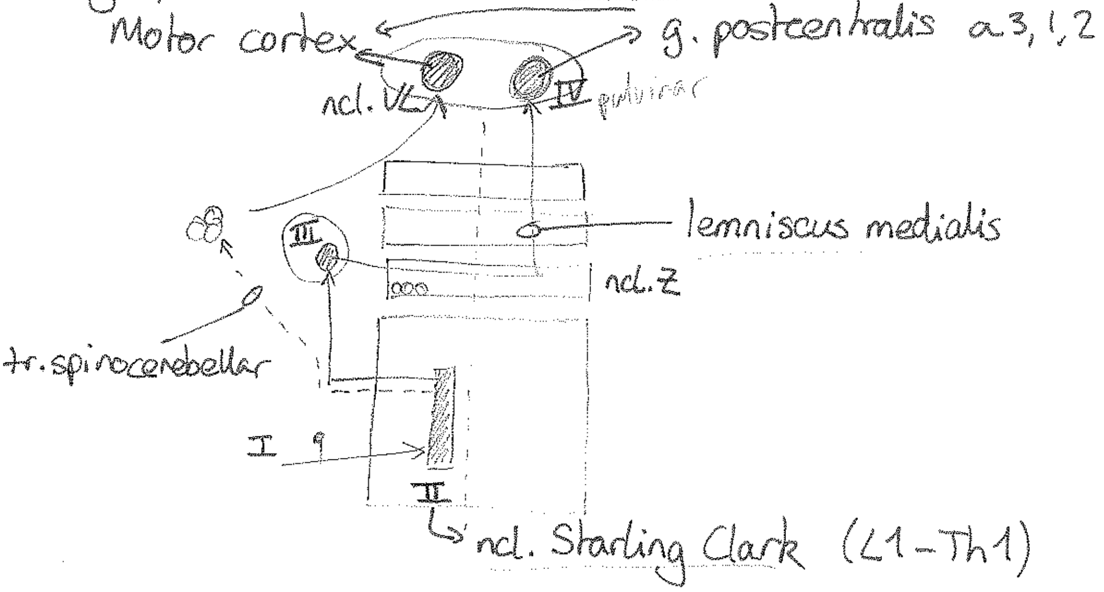
Direct effectors on lower motor neurons

- Vestibular nuclei – postural and movement adjustments
- Reticular formation – acts on α motor neurons, supplying trunk and proximal limb muscles to influence locomotion and postural control and through influences on γ motor neurons modulates muscle tone.

Red nucleus

1) Relay station – station for information going from cerebellum to thalamus
 – plays a significant role as an integrator of information through these connections with the cerebral cortex, cerebellum and thalamus.
2) Receives descending inputs and gives efferents to lower motor units.

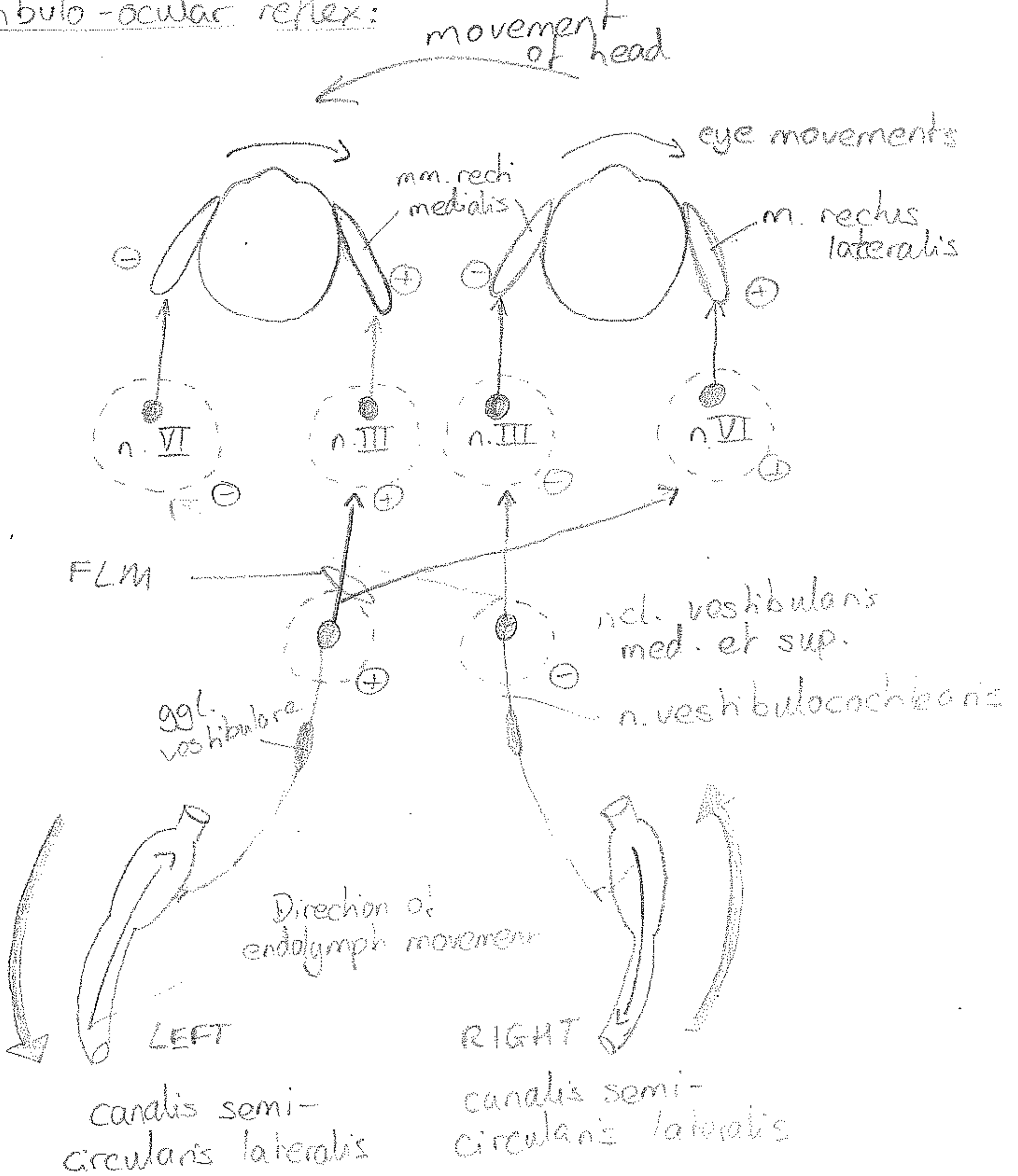
Pathways for kinesthetic proprioception from L-S spinal cord



(72). Eye movements – basic types and their function, eliciting stimuli. Draw and describe simple block scheme of pathways for the vestibulo-ocular reflex.

- Saccades are rapid eye movements that redirect gaze to an object of interest and result in the projection of that object onto the fovea. They orient our gaze in the visual environment.
- Smooth pursuit is used when tracking a slowly (slow pursuit) moving object. The aim is to keep that object on the fovea of both eyes. Smooth pursuit stabilizes and holds the image on the retina during movement of the object itself, or the person.
- Vergent movements – both eyes remain upon an object from diff. positions.

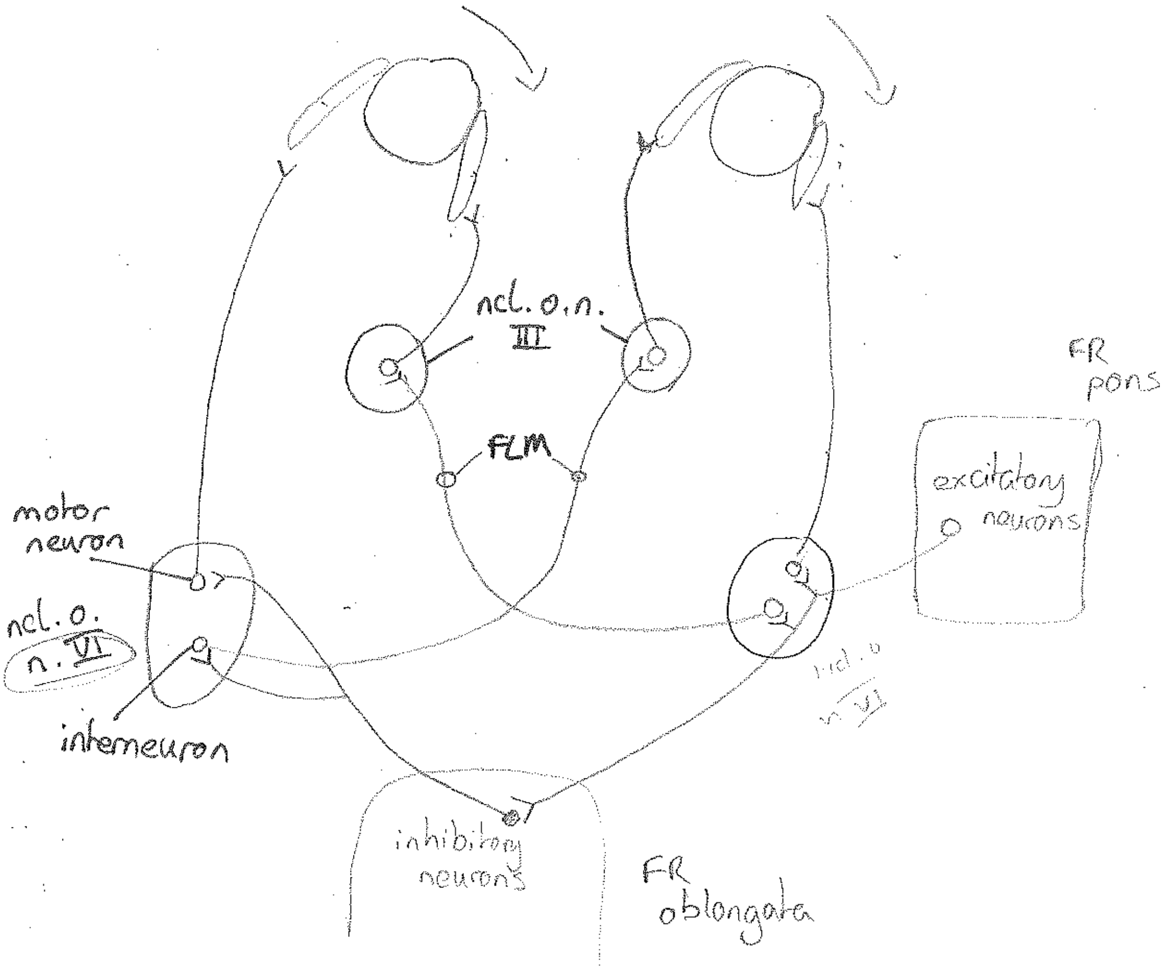
Vestibulo-ocular reflex:



VOR: reflex eye movement that stabilizes images on retina during head movement by producing eye movement in opposite direction to preserve image on visual field.

73. Eye movements - basic types and their function, eliciting stimuli. Draw and describe simple block scheme of pathways for slow eye movements.

(same as q. 72)



(74). Eye movements – basic types and their function, eliciting stimuli. Describe CNS structures involved in control of saccadic eye movements. Electrooculography.

+ other eye movements

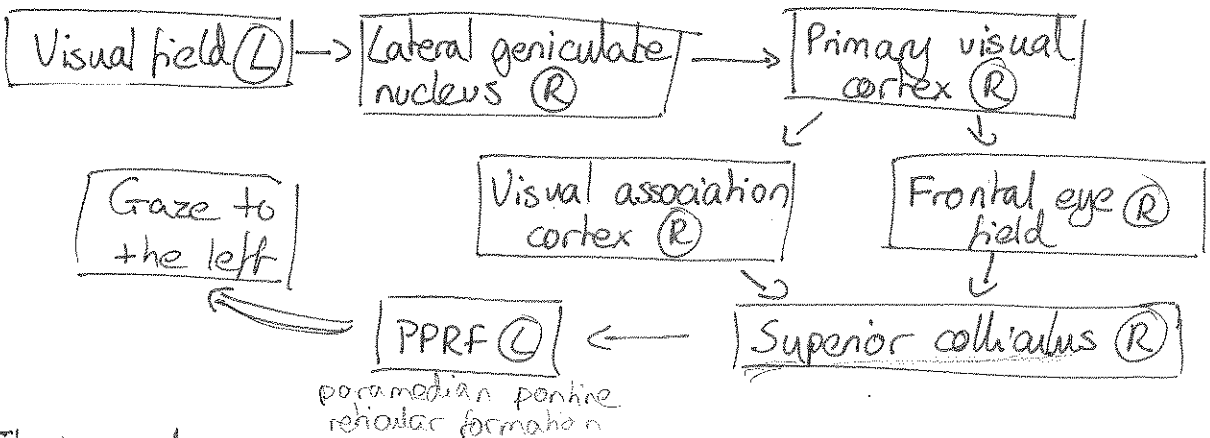
Saccades are rapid eye movements that redirect gaze to an object of interest and result in the projection of that object onto the fovea. They orient our gaze in the visual environment.

There are 2 types of saccades: Reflex vs voluntary

1) Reflexive – can have input from cerebellum or basal ganglia
   a) when an object may be detected in the left visual field, it activates the right lateral geniculate nucleus and through it to right sup. colliculus
   b) neurons in a specific area of the visual map in the sup. colliculus are activated the deeper areas.
   c) from here, input goes to the left (contralateral) pontine reticular formation which inactivates horizontal gaze to the left, to the exact position from where the stimulus came.

2) Volitional – voluntary eye movements that are independent of a visual stimulus. Frontal eye field sends input to the paramedian pontine reticular formation (PPRF) for volitional saccades (area on middle frontal gyrus).

Three types: antisaccades – look away from stimulus
memory saccades – remember where something was + look there.
predictive saccade – eye directed to plane where target is predicted to be.



Electrooculography

- Method of assessment of the eye movements employing the measurement of potential difference between the cornea and retina (cornea ⊕; retina ⊖)
- The potential difference is an electric dipole oriented in parallel with the optical axis of the eye. Any eye movement changes the orientation of the dipole.
- The vector of the dipole is measured by surface electrodes.

75. Language and speech - modern concept of organization. CNS structures engaged in spoken and written language. Target muscle groups and corresponding motor pathways. Function of hemispheres in different aspects of language. Aphasia.

Areas of the cerebral cortex are necessary for speech.

1) Broca's area is located partly in the posterior lateral prefrontal cortex and partly in the premotor area. It is here that motor patterns for exposing individual words or even short phrases are initiated and executed.

2) Wernicke's area lies behind the primary auditory center in the posterior part of the superior gyrus of the temporal lobe. It is the sensory area for interpretation of language; it is closely related with both the primary and secondary hearing areas of the temporal lobe.

3) Auditory cortex

4) Visual cortex

· Hearing and speaking pathway

1) Reception in the primary auditory area of the sound signals that encode the words
2) Interpretation of the words in Wernicke's area
3) Determination of the thoughts and words to be spoken (Wernicke's area)
4) Transmission via fasciculus arcuatus from Wernicke's to Broca's area
5) Activation of the skilled motor programs in Broca's area for control of word formation
6) Transmission of appropriate signals into the motor cortex to control the speech muscle.
7) Transmission by corticobulbar and corticospinal tract to target muscles.

· Target muscle groups

- ARTICULATION - muscular movements of the mouth, tongue, larynx, vocal cords and so forth that are responsible for the intonation, timing and rapid changes in intensities of the sequential sounds.
- The facial and laryngeal regions of the motor cortex activate these muscles and the cerebellum, basal ganglia and sensory cortex to help control the sequences and intensities of muscle contraction.

Hemispheres

- 95% of humans have Broca's and Wernicke's area on the left hemisphere, therefore the left side is responsible for the understanding and speech
- Right hemisphere has got an analogous area to Wernicke's area which understands the emotional colour of speech

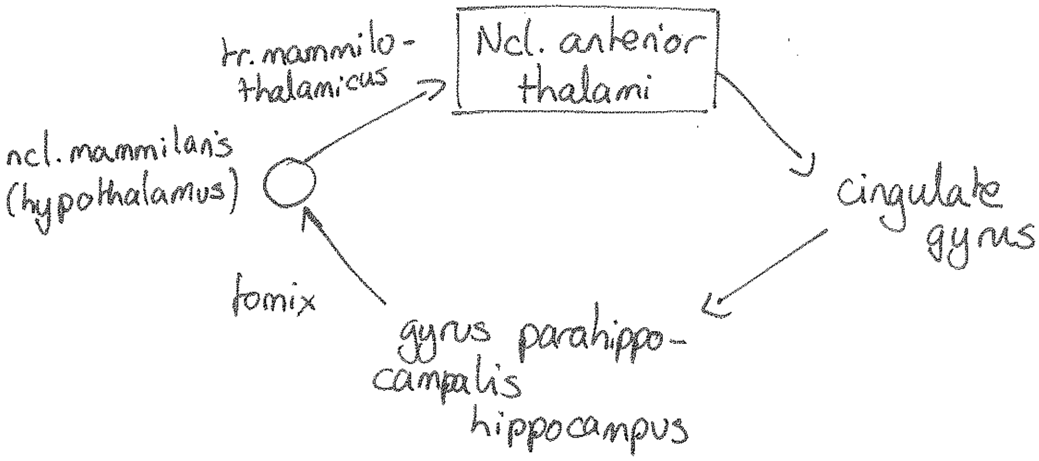
LEFT	RIGHT
· understanding and speech	· emotional coloring of language
· writing	· spatial abilities
· speech	· rudimentary speech

Aphasia - language disorder which ranges from having difficulty remembering words to being completely unable to speak, read or write.

- Wernicke's aphasia - words understood, thoughts cannot be interpreted.
- Motor aphasia - capable of deciding what to say but cannot make the vocal system emit words instead of noises.

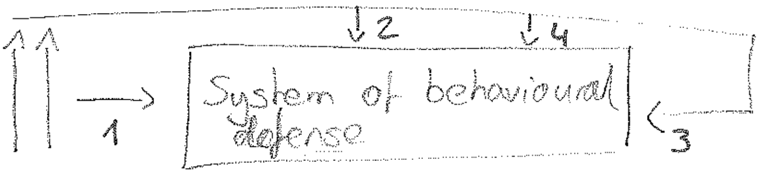
76. Central system of emotion and stress - major structures of limbic forebrain including amygdala. Projections of the limbic forebrain to effector systems. Components of defensive response. Assessment of capabilities to cope with threat in relation to corresponding behaviour.

James Papez first proposed that specific brain circuits are devoted to emotional and expression.



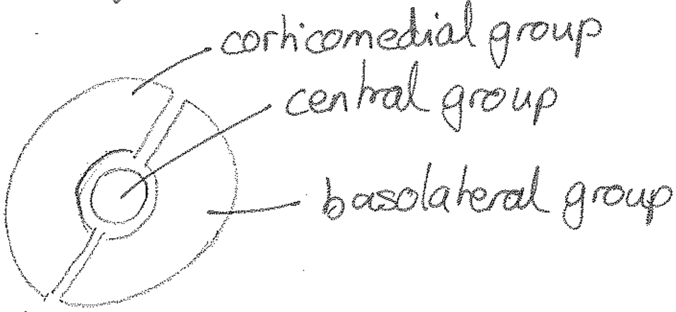
However the circuit has later been enlarged to include parts of the orbital and medial prefrontal cortex, ventral parts of the basal ganglia, the mediodorsal nucleus of the thalamus, septal area and the amygdala.

The amygdala is an essential structure for the experience of fear and defense reaction. Inputs to this system are illustrated in the scheme:



1. Input without cortical analysis
2. Fast cortical analysis
3. Context evaluation
4. Higher order information which arise in the brain.

- The amygdala is divided into 3 major functional and anatomical subdivisions, each of which has a unique set of connections with other parts of the brain.



The corticomedial group – connections with olfactory bulb + cortex

The basolateral group – connections with cerebral cortex, especially the orbitofrontal

The central group – connections with hypothalamus and brainstem

↓

Amygdala → Hypothalamus → Sympathetic activation → Tachycardia, paleness, pupil dilation, increased BP

Amygdala → Central grey → Cessation behaviour → Freezing, hypoalgesia

Amygdala → Trigeminal facial motor ncll. → Mouth opens, jaw movements → Facial expression of fear.

Components of defensive response:

- Behavioural – posture, face
- Vegetative – sympathetic
- Endocrine – catecholamine, cortisol
- Emotional – experiential

Some crucial steps in evoking defense response are firstly the assessment of the sensory inputs (in this situation a threat or a menace). Then we access the capabilities to cope with the threat. If control is evident or probable, then we have active forms of defense behaviour which could be: indignation, anger, rage. There is activation of ANS. Hormones which are involved are: noradrenaline, testosterone, oxytocin, adrenaline.

On the other hand, if we think we have no control of the threat situation, there will be inactive defense reaction. This means: anxiety and feeling of hopelessness. There is also here an activation of the ANS. Hormones which are involved are ADTH, cortisol.

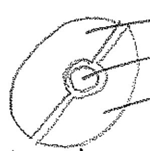
77. Central system of emotion and stress - major structures and pathways of limbic forebrain including amygdala. Sensory afferent inputs to the limbic forebrain, information processing and modification of information meaning. Linkage of psychological stress to organ pathology.

Afferents to the limbic forebrain enter mainly the hippocampal formation, cingulate cortex, amygdala.

The major input to the hippocampal formation is from the entorhinal cortex via a projection called the perforant pathway. This pathway includes information from the cingulate gyrus, olfactory bulb, basolateral amygdala, visual, auditory and taste association cortices. Hippocampus has therefore access to many types of sensory info.

The cingulate cortex receives input from premotor, prefrontal areas and from visual, auditory, somatosensory association cortices (cingulate gyrus also projects to most cortical areas from which it receives input). The cingulate gyrus is therefore not only an integral part of the Papez circuit but also an important conduit through which a wide range of information can reach the limbic system.

The amygdala receives information from both subcortical and cortical structures. The amygdala is divided into 3 functionally and anatomically different groups.



Basolateral group receives inputs from the thalamus, prefrontal cortex, cingulate and parahippocampal gyri, temporal lobe and insular cortex and the subiculum. These fibres supply a wide range of somatosensory, viscerosensory and visceral information to the amygdaloid complex. Corticomedial cell groups receives olfactory input, fibres from hypothalamus and thalamus.

Cortical group receives ascending input from nuclei in brain stem known to be involved in visceral functions (parabrachial, solitary ncl., PAG).

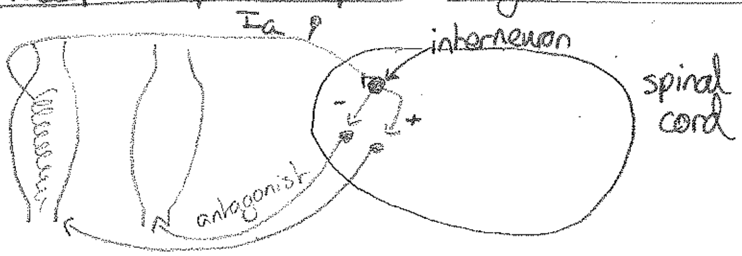
Information processing

- Emotional significance of inputs from various cortical areas is assessed primarily in the basolateral nucleus.
- Efferents from there to the hypothalamus activate the appropriate visceral and motor responses.
- At the same time, the amygdala sends outputs via the dorsomedial nucleus of the thalamus to the orbitofrontal cortex, which mediates the conscious perception of emotions.
- Thus the amygdala is involved in linking perception with visceral and behavioural responses and with memory.

→ If prolonged exposure to stress, this keeps the hypothalamus releasing hormones which can lead to organ pathology.

(78.) Reflexes in motor control. Myotatic and Golgi tendon reflexes and their functional involvements. Draw and describe scheme of these reflex arches. Supraspinal influences on reflexes. Task specific reflex reversal. Evaluation of reflexes in clinical practice, examples. H reflex.

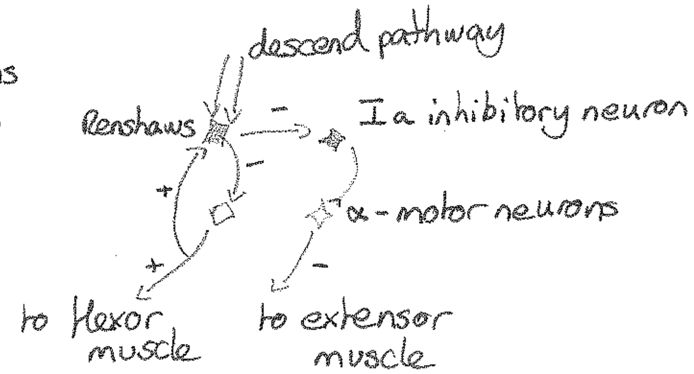
Propriaceptive spinal reflex = myotatic reflex



γ motorneurons innervate the muscle spindles. Afferentation is carried in Ia fibres to spinal cord, where they stimulate α-neurons to cause contraction in synergist muscle or in the same muscle.
The Ia fibres can also stimulate interneurons which then inactivate the α-motor neurons which innervate the antagonist muscle thus making it relax.

Renshaws cells

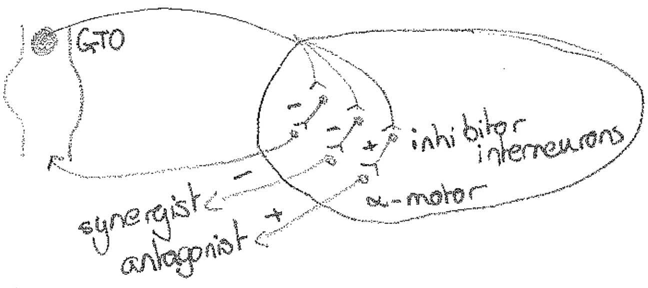
Are a type of inhibitory interneurons in anterior horn. They receive axons from a motor neuron and inhibit it, it is like a self-inhibition.
Renshaws also have contact with Ia-inhibition neuron. Renshaws will inhibit it so that the antagonist muscle can contract. Renshaw cells are also under control of descending pathways which can stimulate/inhibit it.



→ This myotatic reflex can be tested, for example by testing the knee jerk reflex. It's used to test if spinal segments are intact in L2-L4.
By hitting tendon you passively stretch the muscle and this stimulate stretch in muscle spindle. Ia will thus stimulate α-motorneurons which will cause contraction of quadriceps.

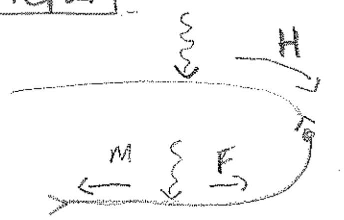
Golgi tendon organ reflex

Golgi are also encapsulated by c.t. capsule; but inside we have clusters of collagen fibres and between them are dendritic zones of IIb fibres.
Golge are innervated by Ib afferent fibres. They follow the spinal nerves and end on inhibitory ~~motor~~neurons in spinal cord, which in turn inhibit the α-neurons.
Thus ↑activity of Ib lead to ↓activity of α-neurons of some muscle fibre.



This reflex is used to protect muscles from tearing when exposed to heavy weights.

H reflex



Electrical stimulation of nerve. (M) arrives first. (F) arrives later.
With increased stimulation it disappears.

79. Learning and memory - nondeclarative + declarative memory, corresponding CNS structures in humans. Hippocampal formation. Cellular mechanisms of habituation and sensitization. Neurophysiological mechanisms of memory storage - long term potentiation and depression. Memory impairments.

There are 2 types of long-term memory, declarative and nondeclarative

- Declarative - memories of events or facts that are accessible to consciousness and can be expressed explicitly

[Declarative] → Episodic memory (events) - ability to learn/store info about everyday life - including time/places etc
→ Semantic memory (facts) - knowledge of facts that have been learned but of which source of original information is not known e.g. knowing apples + bananas are fruits

CNS: ↓ Requires hippocampus and associated and associated cortical areas (entorhinal cortex, parahippocampal gyrus) and widespread neocortical association areas (that send inputs to entorhinal cortex)

- Nondeclarative - involves memories that manifest as subconscious behavioral or physiological responses to events or stimuli.
  → Includes forms of learning that occur during performance of a task.
  e.g. driving, swimming, riding bicycle

CNS: depend on striatum (caudate nucleus + putamen), motor areas of cortex + cerebellum

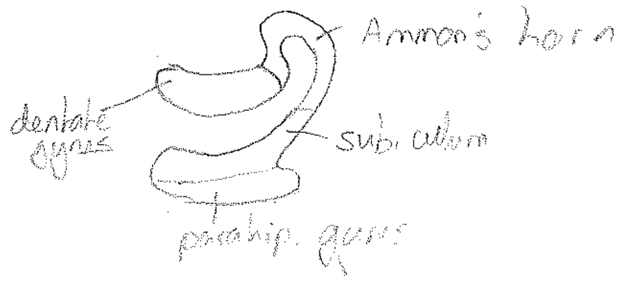
- emotional memory + conditioned reflexes are also a form of nondeclarative memory

emotional memory ↓ change in behaviour toward stimuli due to experience, depends on amygdala.

conditioned reflexes ↓ when a stimulus is associated to an action e.g. a dog hearing a bell knowing it is time to eat
∴ depends on cerebellum

Hippocampal formation

Elongated portion of cortex folded on the medial side of the temporal lobe, occupying the floor of the inferior or temporal horn of the lateral ventricle.
Consists of:
1) subiculum - transition zone of cortex, continuous with the hippocampus on one side and parahippocampal gyrus on the other
2) Ammon's horn - hippocampus proper, consists of gray matter with an expanded anterior end and the parahippocampal gyrus on the other side.
3) Fimbria - fornix
4) Dentate gyrus



Function:

- Most important role of hippocampus in humans is its ability of learning and the formation of new memories + storage of memories
- As part of the limbic system and in view of its extensive connections with the hypothalamus and other limbic structures (amygdala, mam bodies, association cortex), hippocampus plays a role in visceral and endocrine function and in the expression of emotions + emotional behaviour.

Habituation/Sensitization

Long-term potentiation + depression

LTP - a long lasting strengthening of a post-synaptic nerve cell to stimulation across a synapse that occurs with repeated stimulation
→ this allows for aid in learning and long-term memory due to strong and repeated stimulation.

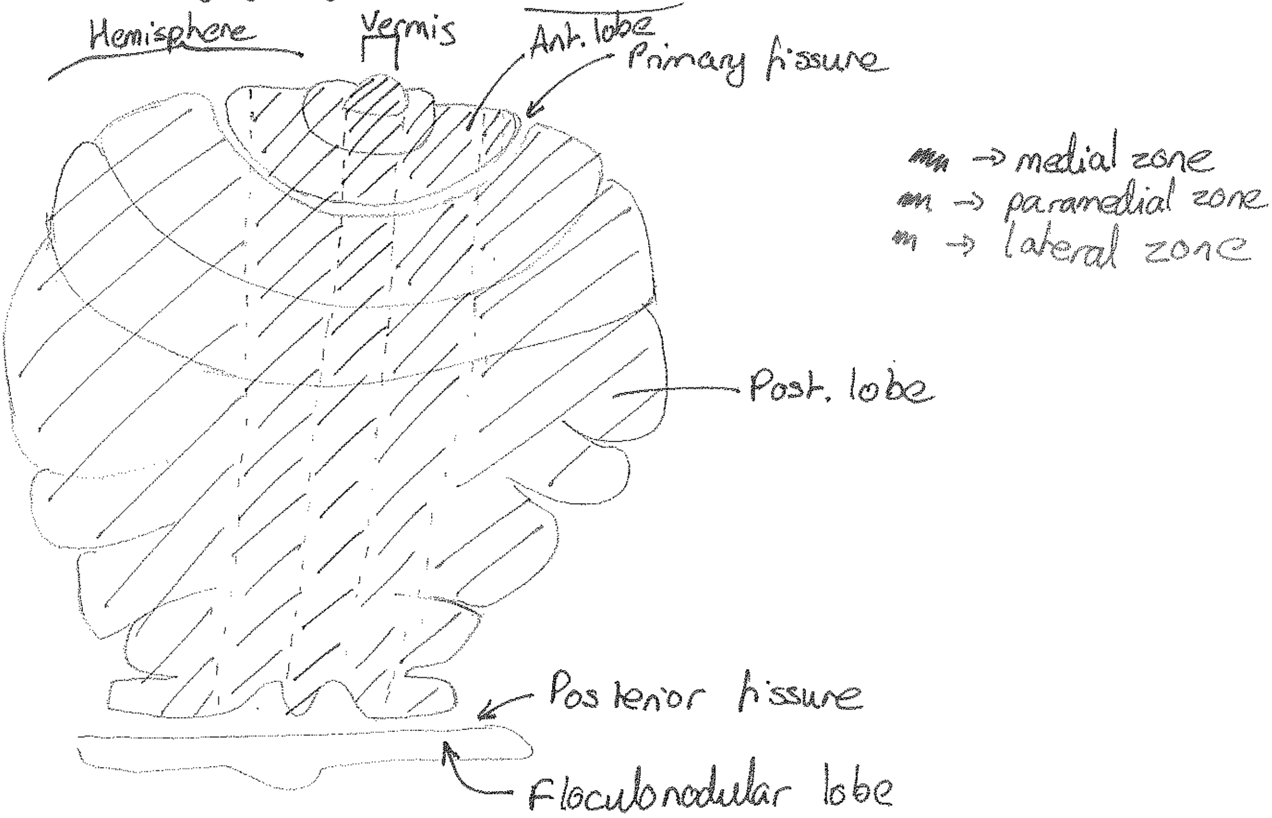
LTD - activity dependent reduction in efficiency of neuronal synapses lasting hours or longer. Occurs on hippocampus and cerebellum. Results from a decrease in postsynaptic receptor density or a decrease in presynaptic neurotransmitter release.
Cerebellar LTD is important for motor learning, hipocampal LTD is important for cleavage of old neurons.

Memory impairments

1) Anterograde amnesia - loss of ability to create new memories after the event that caused amnesia, leading to a partial or complete inability to recall recent past while long term memories from before event remain intact. occurs when there's damage to hippocampus and nearby subcortical regions.
2) Retrograde amnesia - loss of access to events that occur or information that was learnt before onset of disease

80. Structural-functional compartments of the cerebellum (horizontal and longitudinal divisions). Connections of the spinal cerebellum (median and paramedian zones) and their functional involvements. Cerebellum and learning. Effects of cerebellar lesions - examples.

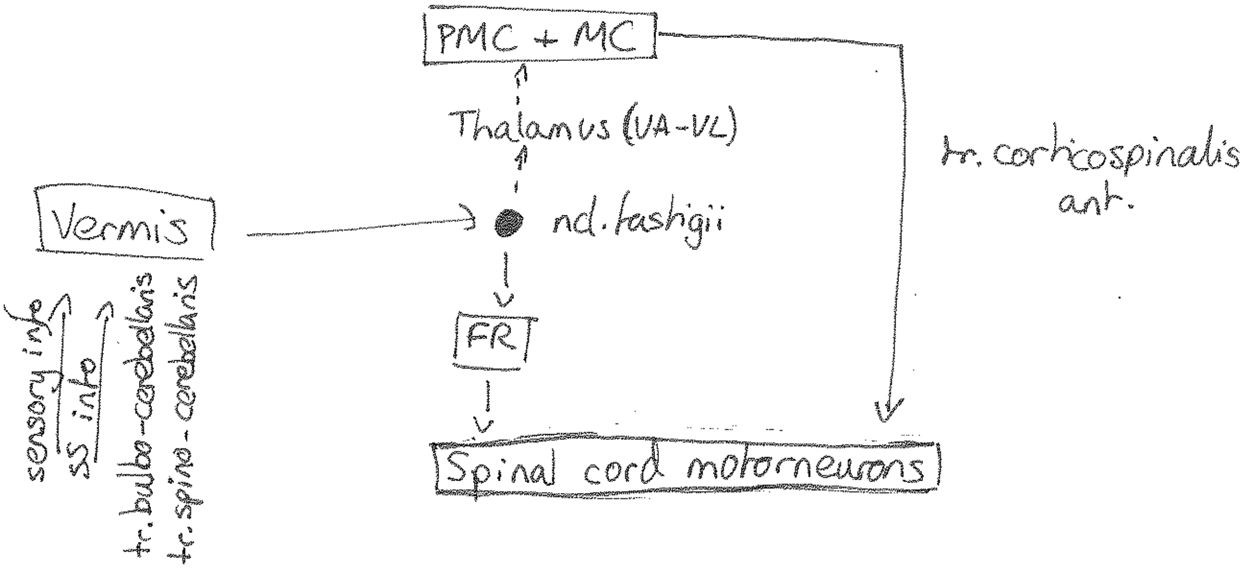
The cerebellum is located in the posterior cranial fossa, separated from the cerebrum by the tentorium cerebri. It lies over the 4th ventricle. The cerebellum has a right and a left hemisphere and a midline structure called vermis. The cerebellum is divided into 3 lobes:



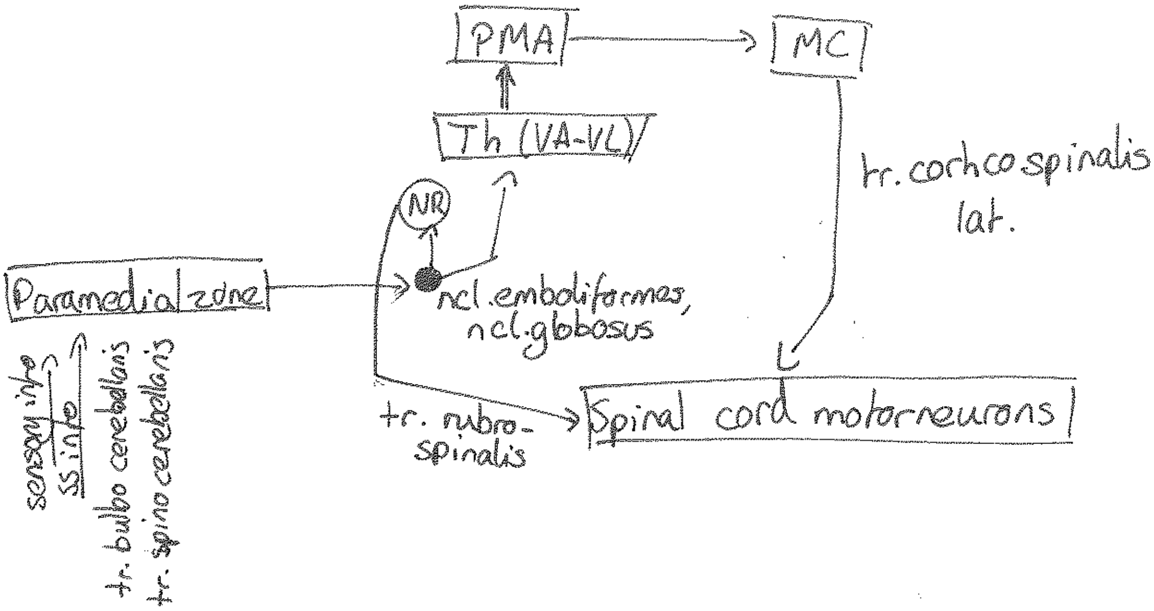
Gray matter (cortex + ncll.) and white matter (including peduculi cerebellares)

- Medial zone - cortex covering vermis + ncll. fastigii
- Paramedial zone - paramedial cortex + ncll. emboliformes et globosi
- Lateral zone - lateral cortex + ncl. dentatus

Connections of spinal cerebellum - medial zone



Connections of spinal cerebellum – paramedial zone



Cerebellar lesions

Patients with cerebellar lesions exhibit persistent errors in movement. These movement errors are always on the same side of the body as the damage to the cerebellum.

Cerebellar lesions lead first and foremost to a lack of coordination of ongoing movements.

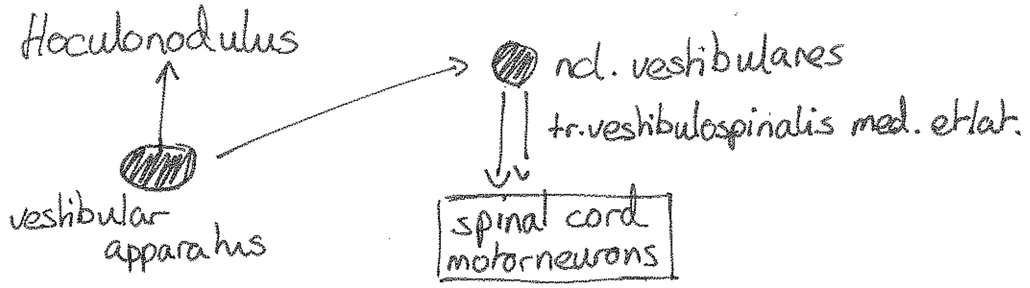
→ Damage to vestibulocerebellum impairs the ability to stand upright and maintain the direction of gaze. The eyes have difficulty maintaining fixation, they drift from the target and then jump back with a corrective saccade.

→ Patients with damage to the spinocerebellum have difficulty controlling walking movements. They also have difficulty performing rapid alternating movements → dysdiachokinesia. Over and under reaching may also occur → dysmetria. During the movement, tremors – called intention tremors – accompany over due to disruption of the mechanism for detecting and correcting movement errors.

→ Lesions of cerebro cerebellum produce impairments in highly skilled sequences of learned movements such as speech or playing a musical instrument.

81. Structural-functional compartments of the cerebellum (horizontal and longitudinal divisions). Connections of the vestibular cerebellum, the pontocerebellum and their functional involvements. Cerebellum and learning. Effects of cerebellar lesions – examples.

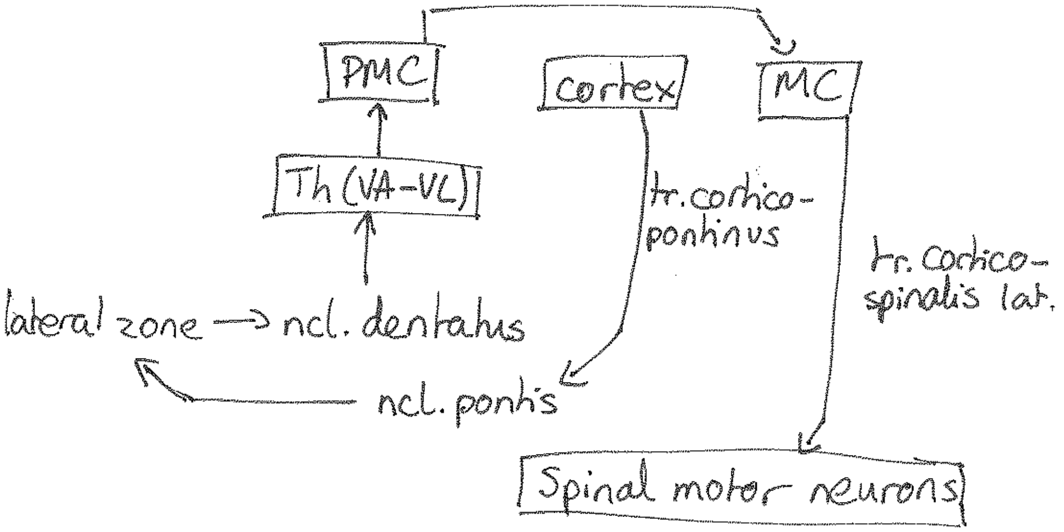
Connections of vestibular cerebellum



Functions:

- basic significance for maintenance of balance – tr. vestibulospinales
- influence to lower motorneurons for axial muscles
- role during control of eye movement and their coordination with movement of head.

Pontocerebellum



→ Control of motor planning
→ Control of target movement
→ non-motor function (cognition)
→ solution of problem
→ linguistics phrasing

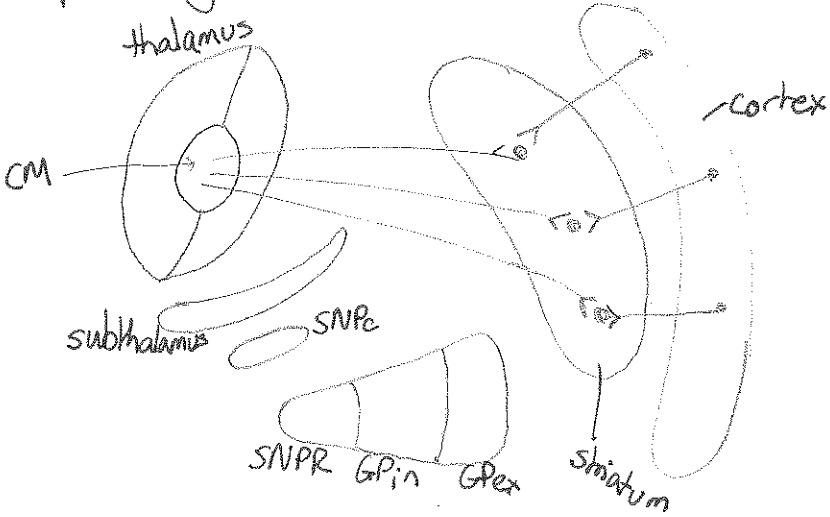
(82). The basal ganglia, their afferent, efferent and basic internal connections. Four basic functional loops of the basal ganglia. Role of the basal ganglia in motor control. Examples of the basal ganglia impairments in humans.

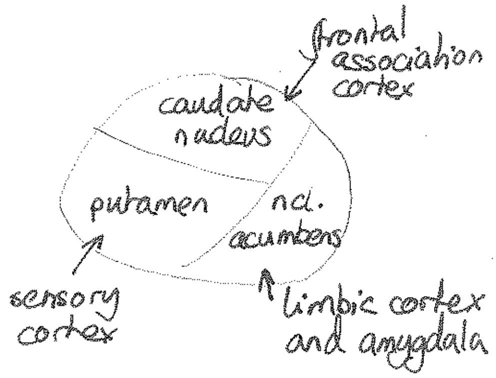
Basal ganglia – group of nuclei of varied origin that act as cohesive functional unit

- Striatum
  - ncl. caudatus – dorsal striatum
  - putamen
  - ncl. accumbens – ventral striatum
- Globus pallidus
  - lateral seg.
  - medial seg.
- Substantia nigra
  - pars reticularis
  - pars compacta

Afferentation of basal ganglia

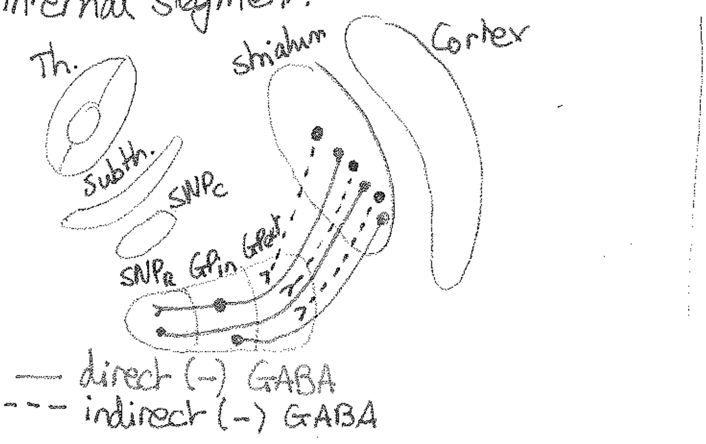
Afferents from the cortex (via corticostriate tract) and thalamus (ncl. centromedianus) reach the striatum. They make excitatory (glutamate or aspartate) connections and terminate somatotopically. Substantia nigra pars compacta also sends afferents to the striatum (via nigrostriatal tract). They use dopamine as neurotransmitter which is excitatory at some synapses and inhibitory at others (Dopaminergic projection, final effect according to D_1 or D_2 receptors)
↳ excit. ↳ inhib.

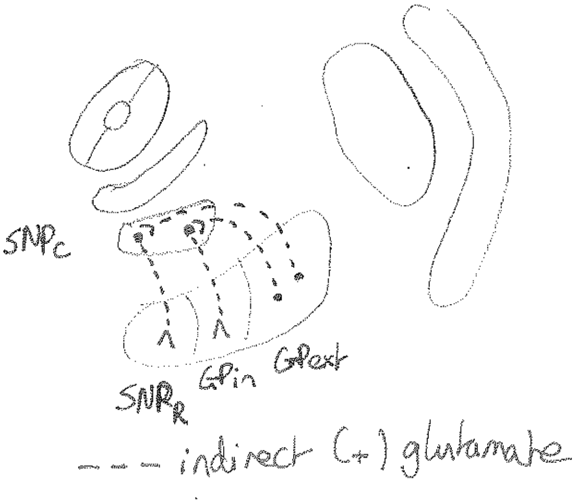




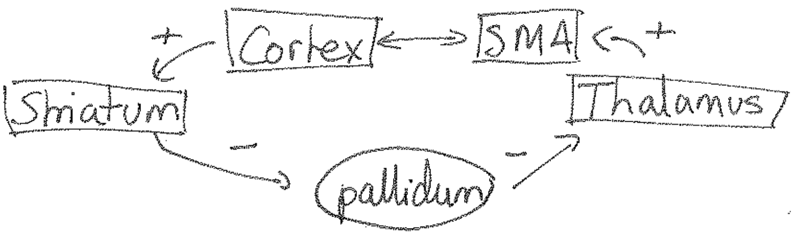
Intrinsic connections of basal ganglia

Connections between striatum and pallidum (and SNP_R). Can be direct or indirect. In striatum we have 2 different neurons. Neurons with direct connection with internal segment and neurons with indirect connection with internal segment.



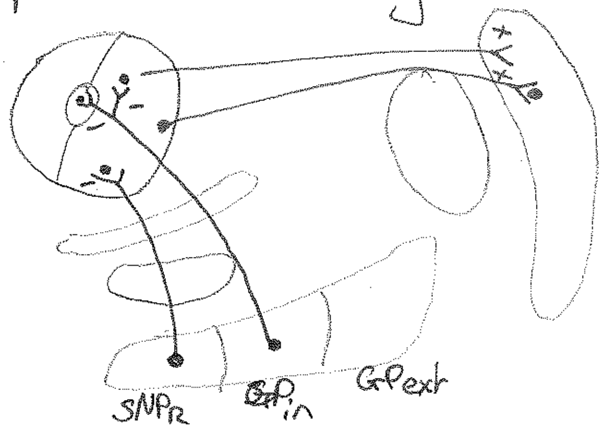


General connections of BG



Efferentation of basal ganglia

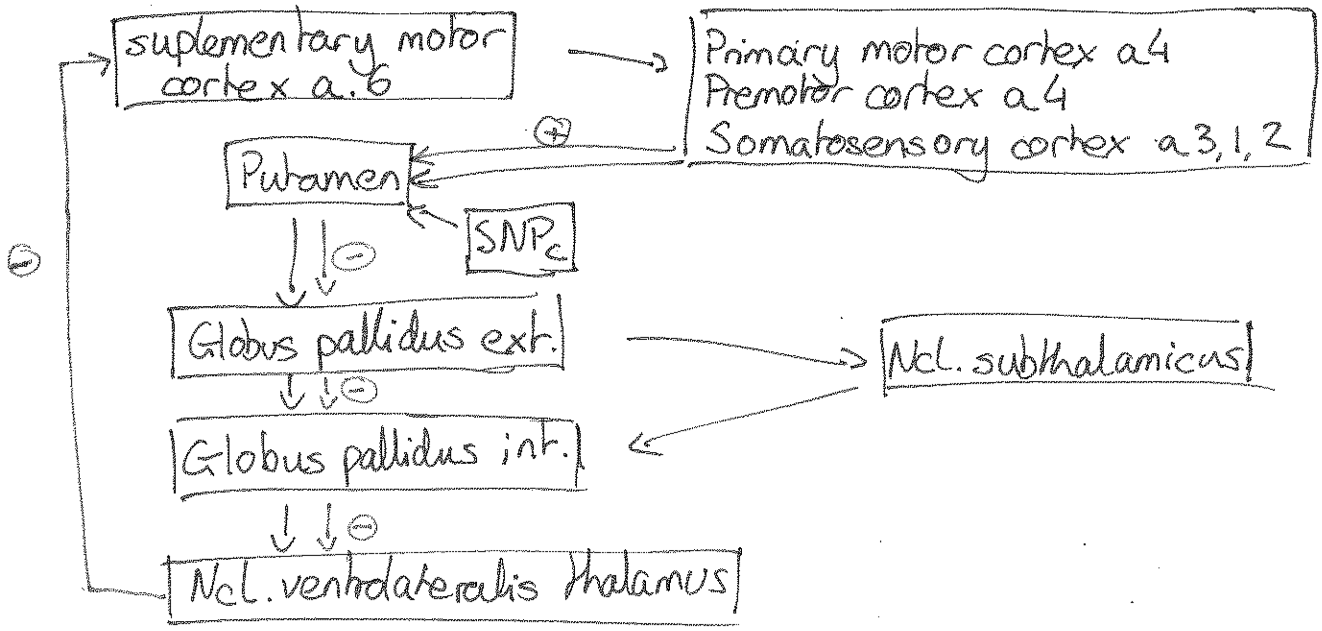
The output nuclei of the basal ganglia are globus pallidus, substantia nigra pars reticularis. They have inhibitory connections with thalamus (VL + VA).



Four basic loops of the basal ganglia
- → sensory-motor loop
- → association (prefrontal) loop
- → limbic loop
- → oculomotor loop.

Sensory-motor loop

Function: control of movement and their perception.



Association (prefrontal) loop — Function: space memory

Prefrontal cortex a9,10

↓

Ncl. caudatus ← Premotor cortex a6; Parietal cortex a7

Globus pallidus int.
SNPR

Ncl. ventrolateralis thalamus

Limbic loop — Function: motor expression of emotion, aggressive or submissive attitude, gesture, laugh.

Cingulary (a24), medial orbitofrontal cortex (a10,11)

↓

Ventral striatum (ncl. acumbens)
Ncl. caudatus
← Amygdala

↓

Ventral pallidum, SNPR

→ Ncl. VA
Ncl. medialis dorsalis

↑ (to Cingulary, medial orbitofrontal cortex)

Oculomotor loop

Frontal visual field (a8)

Prefrontal cortex (a9,10)
Parietal cortex (a7)

Ncl. caudatus

Globus pallidus int.

Ncl. colliculi sup.

SNPR

Ncl. ventrolateralis
Ncl. dorsomedialis

Role of basal ganglia in motor control

→ Efferent neurons from lateral globus pallidus and substantia nigra is the major pathway linking basal ganglia and upper motor neurons (cortex-brainstem)

→ Axons from SNPR → upper motor neurons in sup. colliculus → eye movements.

Disease of the basal ganglia in humans - motor consequences

Since the basal ganglia constitute an accessory motor system that functions in close association with the cerebral cortex and corticospinal motor control system, damage to them will cause movement disorders.

Lesions in the GP frequently lead to spontaneous and often continuous writhing movements of a hand, arm, neck or face - movements called athetosis.

Lesion in subthalamus often leads to sudden failing movements of an entire limb, a condition called hemiballisms.

Multiple small lesions in the putamen lead to flickering movements in hands, face and other parts of body called chorea.

Lesions of substantia nigra lead to rigidity, akinesia and tremors in Parkinson's disease.

Finally, the Huntington's disease is a hereditary disorder that usually begins causing symptoms at age 30/40. Characterized at first by flicking movements in individual muscles and then progressive severe distortional movements of entire body. In addition, severe dementia develops along with motor dysfunction.

Notes written by Carlos Castro and Catarina Carvalho Bastos, 2012/13.
Has information from Liliana Amaral's notes on Neuroscience.