http://cogsci.bme.hu/~gkovacs/gyulakovacs/Teaching.html

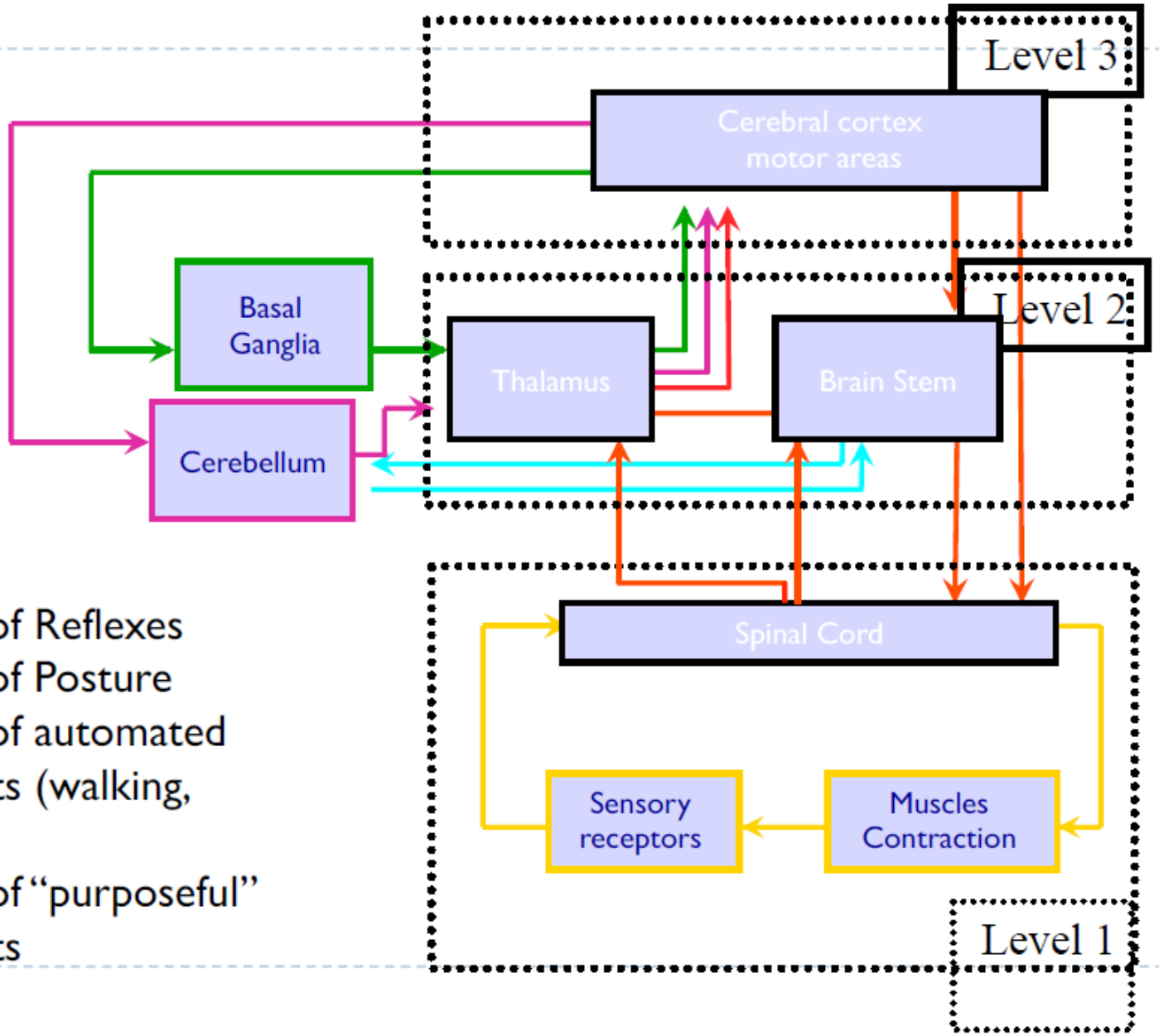
Kognitív idegtudomány

Introduction to neurosciences for MSs.

Motor system 2

Brainstem, Cortex, BG

Organization of the motor system



- Control of Reflexes
- Control of Posture
- Control of automated movements (walking, breathing)
- Control of "purposeful" movements

Motor pathways in the cord

1. voluntary motion pathways
2. postural pathways

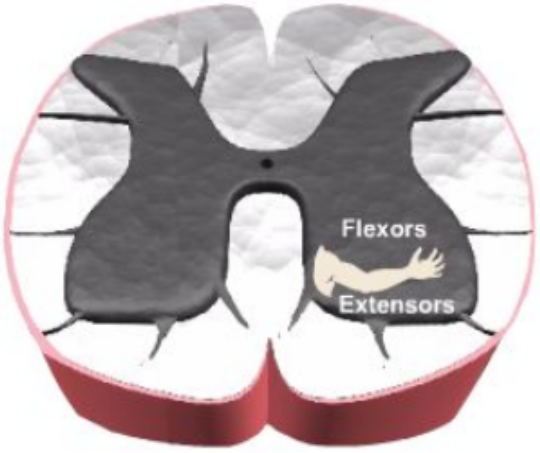
Descending pathways

- automatic reflexes can be modulated, however, by higher levels of the hierarchy
- touching an iron to see if it is hot, your flexor reflex may be hypersensitive or not throwing away the hot pan with the dinner
- Descending motor pathways: multiple regions of the brain innervating alpha motor neurons, gamma motor neurons, and interneurons.
- Topographical organization of the motor neurons in the spinal cord
  - Flexor-extensor rule: motor neurons that innervate flexor muscles are located posteriorly to motor neurons that innervate extensor muscles
  - Proximal-distal rule: motor neurons that

innervate distal muscles (e.g., hand muscles)

are located lateral to motor neurons that

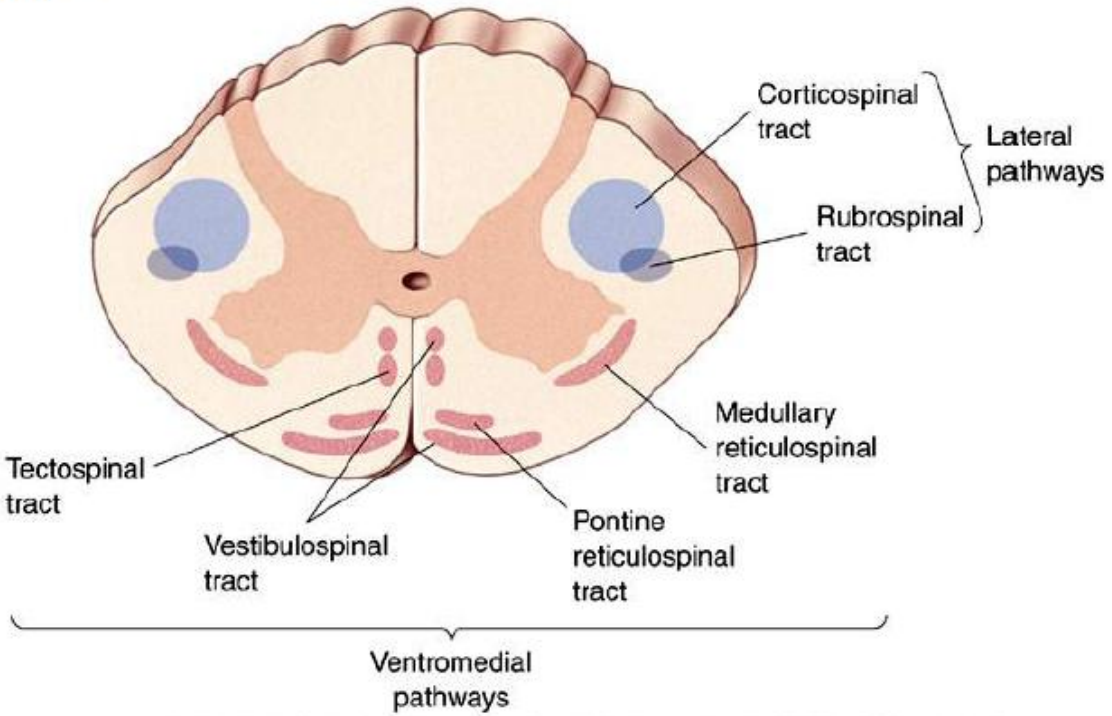
innervate proximal muscles



Descending Control of Movement

Axons from brain descend along two major pathways

- Lateral Pathways
- Ventromedial Pathways

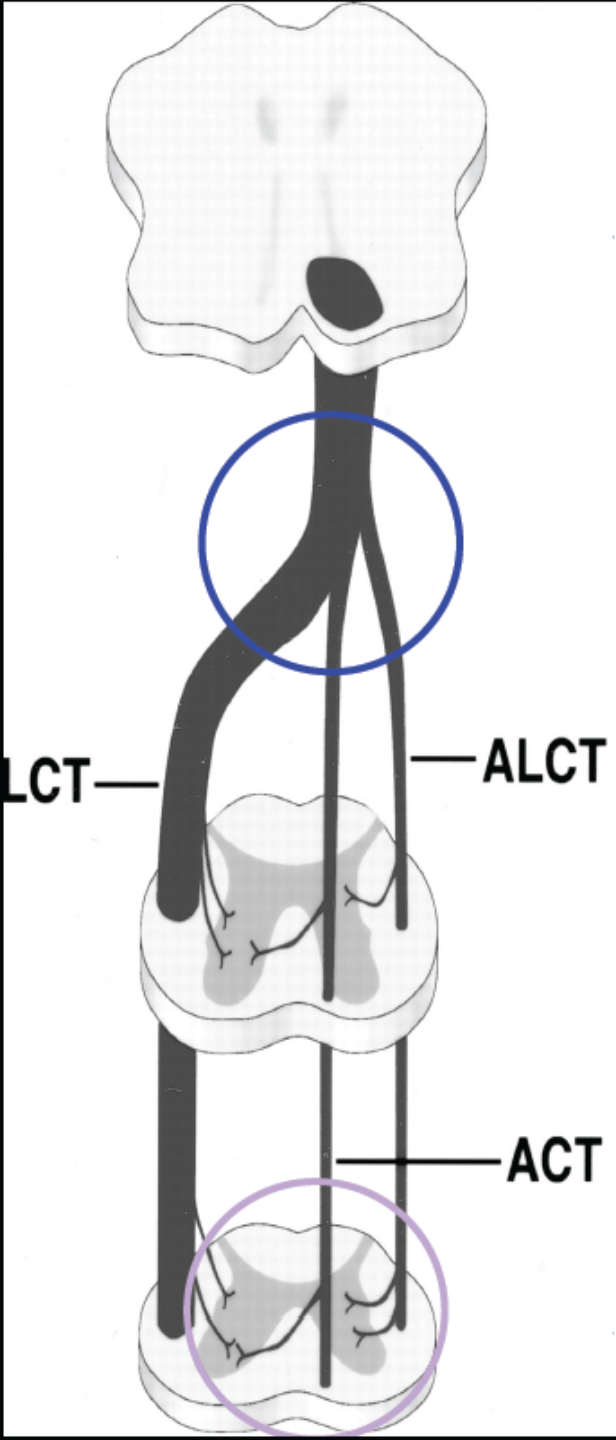


voluntary pathways

- lateral and anterior corticospinal systems,

Corticospinal tracts (pyramidal)

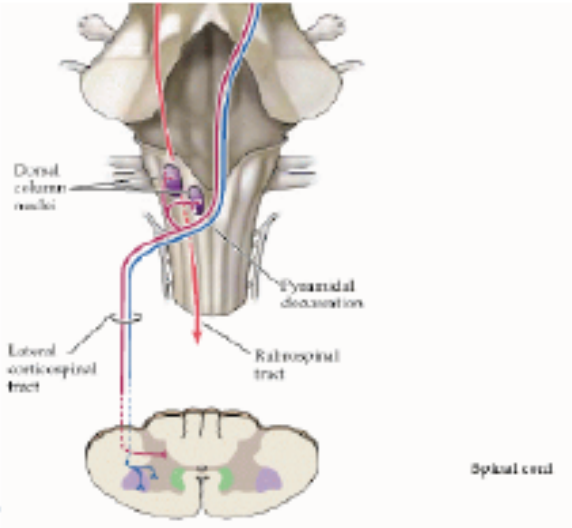
- originates in the motor cortex.
- At the level of the caudal medulla, the corticospinal tract splits into two tracts.
- Approximately 90% of the axons cross over to the contralateral side at the pyramidal decussation, forming the *lateral* corticospinal tract.
- The remaining 10% of the axons that do not cross at the caudal medulla constitute the *anterior* corticospinal tract, as they continue down the spinal cord in the anterior funiculus
- Functions: primary motor pathway, carries motor command about voluntary movements; lateral corticospinal tract: distal musculature (hand) and the anterior corticospinal tract : proximal musculature.

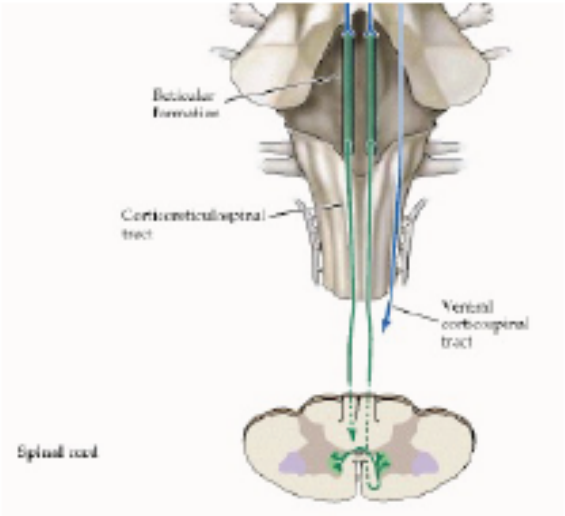


	Lateral CST	Anterior CST
Prop of fibres	Most	Few
Decussation	Pyramidal	Spine
Spinal column	Lateral ant horn	Medial
Connections	Monosynaptic, Ipsilateral	Polysynaptic, Contralateral
Muscles	Distal	Proximal, Axial
Movement type	Fine independent movement	Posture

Dorsolaterals: to distal contralateral limbs
Corticospinal: direct. Decussaition is pyramid at medulla, wrist, hands, fingers, toes
Cortico-rubrospinal. Decussaino at n. Ruber. Arms. Legs.
If you cut : can walk, climb. But cant move fingers independently or release grasp.

Ventromedial: proximal trunk and limb muscles of both sides.
Corticospinal: direct, ipsilateral. Diffuse conn to both sides.
Cortico-brainstem-spinal: indirect.
Tectum, -visual-aud spatial info integration
Retic. Form: common motor programs
Vest.nucleus-balance
Descends bilaterally and diffusely. Posture.
If you cut this: can use elbow, hands, figers, but can not sit or walk.





postural pathways

- do not originate in motor cortex
- maintain an upright posture against gravity, little muscular adjustments that we are not aware of
- three principal pathways in humans:
  - vestibulospinal,
  - tectospinal,
  - reticulospinal pathways
  - rubrospinal system (from the red nucleus) is also sometimes included, but in humans it may be insignificant.

Rubrospinal tract

- originates in the red nucleus of the midbrain.
- cross to the contralateral side of the brain,
- course through the brainstem and the lateral funiculus of the spinal cord.

- Function: an alternative by which voluntary motor commands can be sent to the spinal cord.
- Activation causes excitation of flexor muscles and inhibition of extensor muscles.
- plays a role in movement velocity, as rubrospinal lesions cause a temporary *slowness* in movement
- receives most of its input from the cerebellum,
- plays a role in transmitting learned motor commands from the cerebellum to the musculature.

Vestibulospinal tracts

- originate in 2 of the 4 vestibular nuclei
- Lateral:
- originates in the lateral vestibular nucleus.
- courses through the brainstem and through the anterior funiculus of the spinal cord on the ipsilateral side,
- exiting ipsilaterally at all levels of the spinal cord.
- Medial:
- originates in the medial vestibular nucleus,
- splits immediately and courses bilaterally through the brainstem via the medial longitudinal fasciculus (MLF) and through the anterior funiculus of the spinal cord,
- exiting at or above the T6 vertebra.
- Function: mediate postural adjustments and head movements, they also help the body to maintain balance.

Reticulospinal tracts

Pontine:

originates in the pontine reticular formation,

courses ipsilaterally through the medial longitudinal fasciculus

exits ipsilaterally at all spinal levels.

Medullary:

originates in the medullary reticular formation,

ipsilaterally through the anterior funiculus of the spinal cord

- Function: regulates the sensitivity of flexor responses to ensure that only noxious stimuli elicit the responses. Damage to the reticulospinal tract can cause harmless stimuli, such as gentle touches, to elicit a flexor reflex.

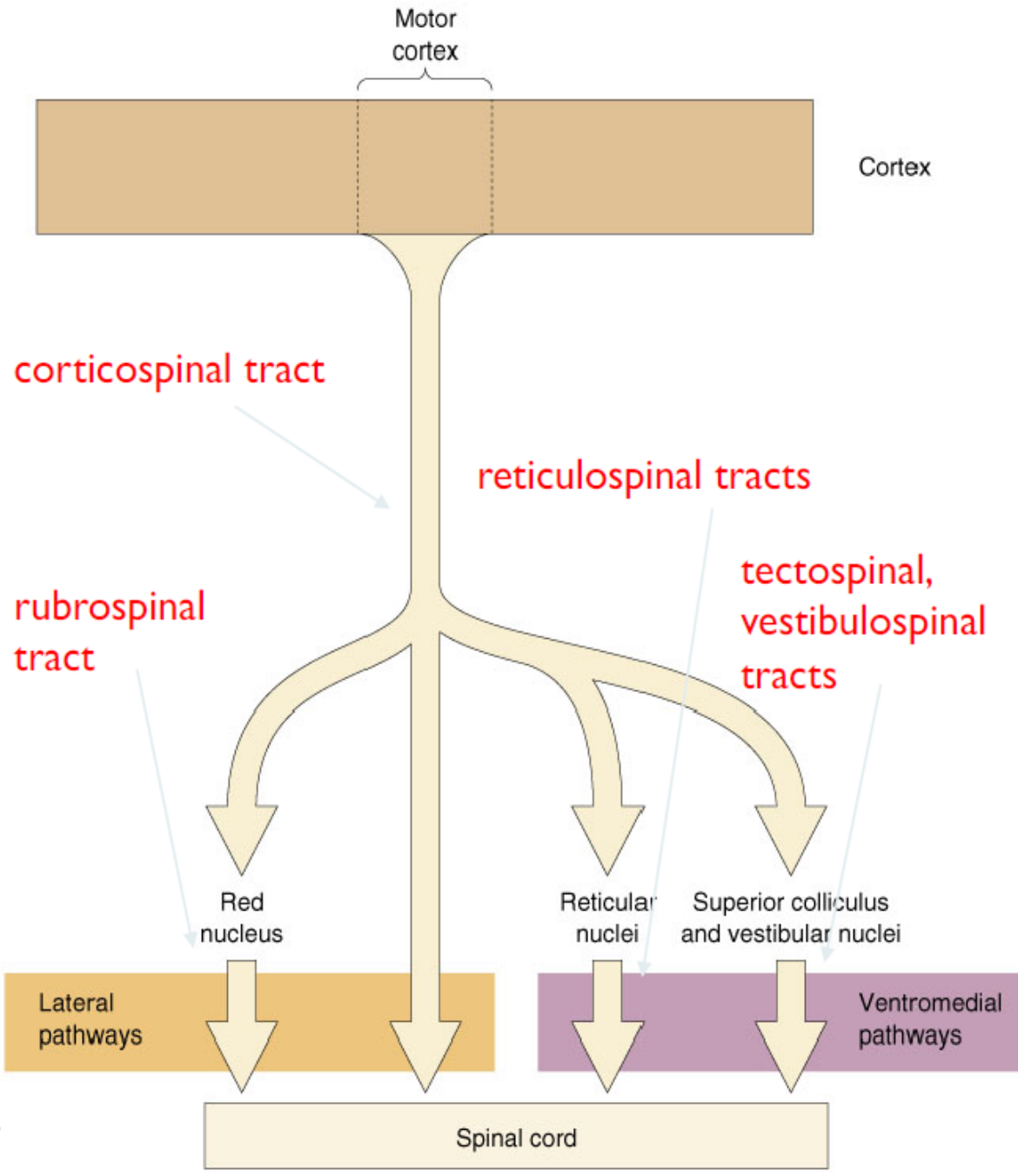
Tectospinal tract

- originates in the deep layers of the superior colliculus
- crosses the midline immediately.
- courses through the pons and medulla,
- courses through the anterior funiculus of the spinal cord,
  - the majority of the fibers terminate in the upper cervical levels.

- Function: Little is known about the function of the tectospinal tract, it is presumably involved in the reflexive turning of the head to orient to visual stimuli.

Summary of the major descending spinal tracts and their points of origin

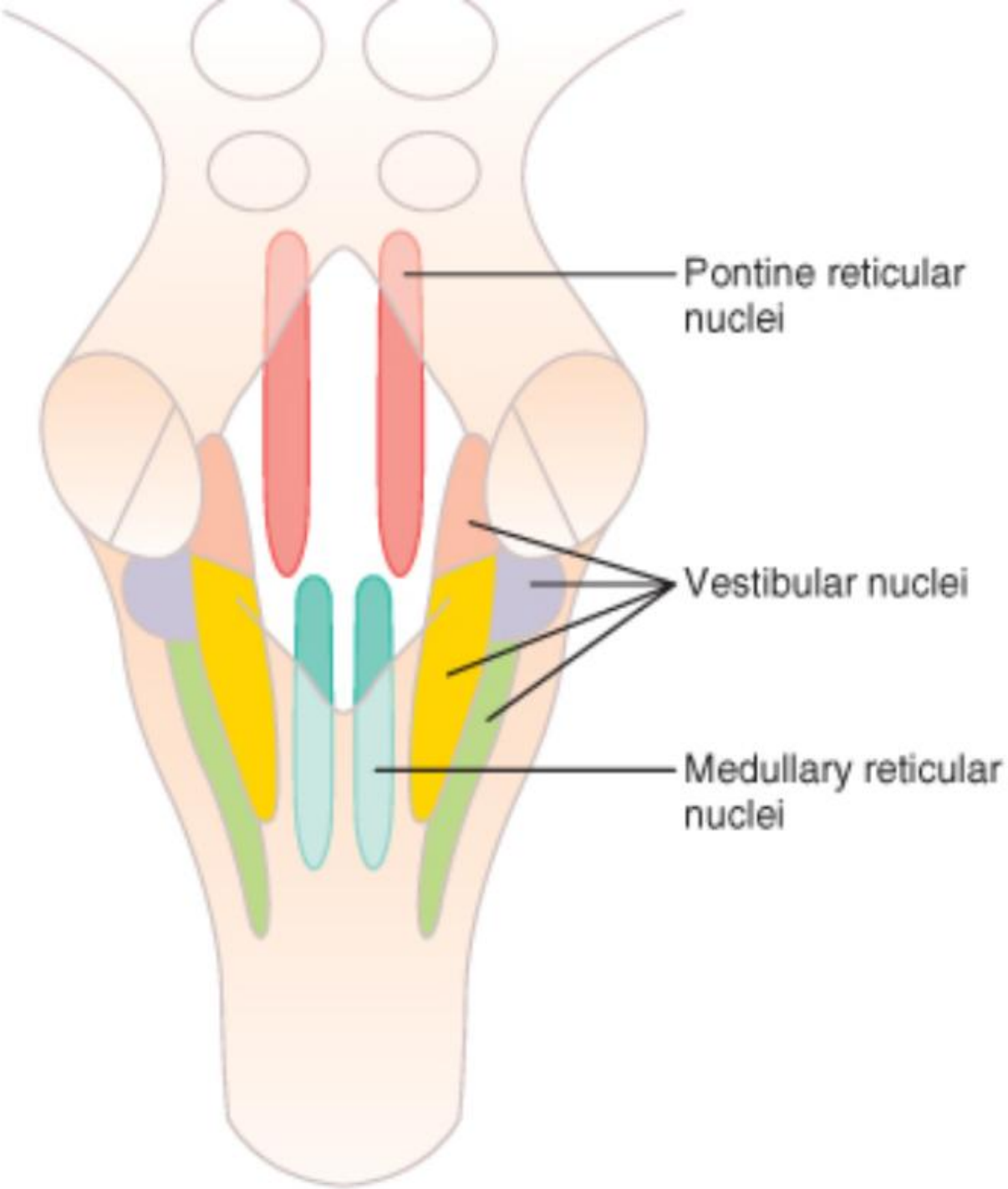
Figure 14.6
A summary of the major descending spinal tracts and their points of origin.



Brain Stem Motor Centers

- Pontine reticular nuclei –
  - *excite* antigravity muscles (muscles of the vertebral column and limb extensor muscles) –
  - pontine reticulospinal tract.
- Medullary reticular nuclei –
  - *inhibit* antigravity muscles –
  - medullary reticulospinal tract.

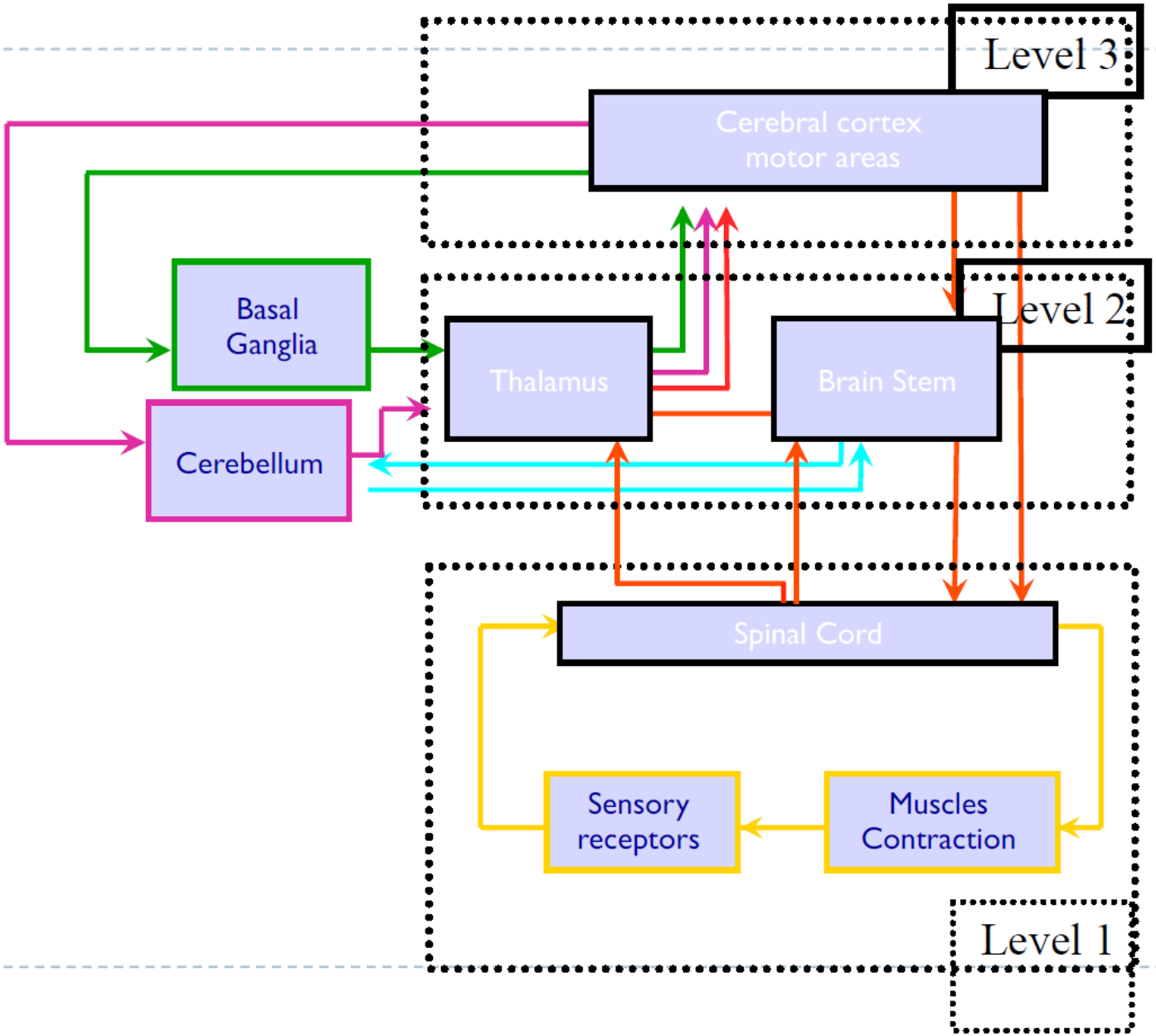
  Pontine & medullary systems balance each other.
- Vestibular nuclei – supplement the excitatory function of the pontine system by integrating vestibular information – lateral and medial vestibulospinal tracts.


Pontine reticular nuclei
Vestibular nuclei
Medullary reticular nuclei

Brainstem reflexes

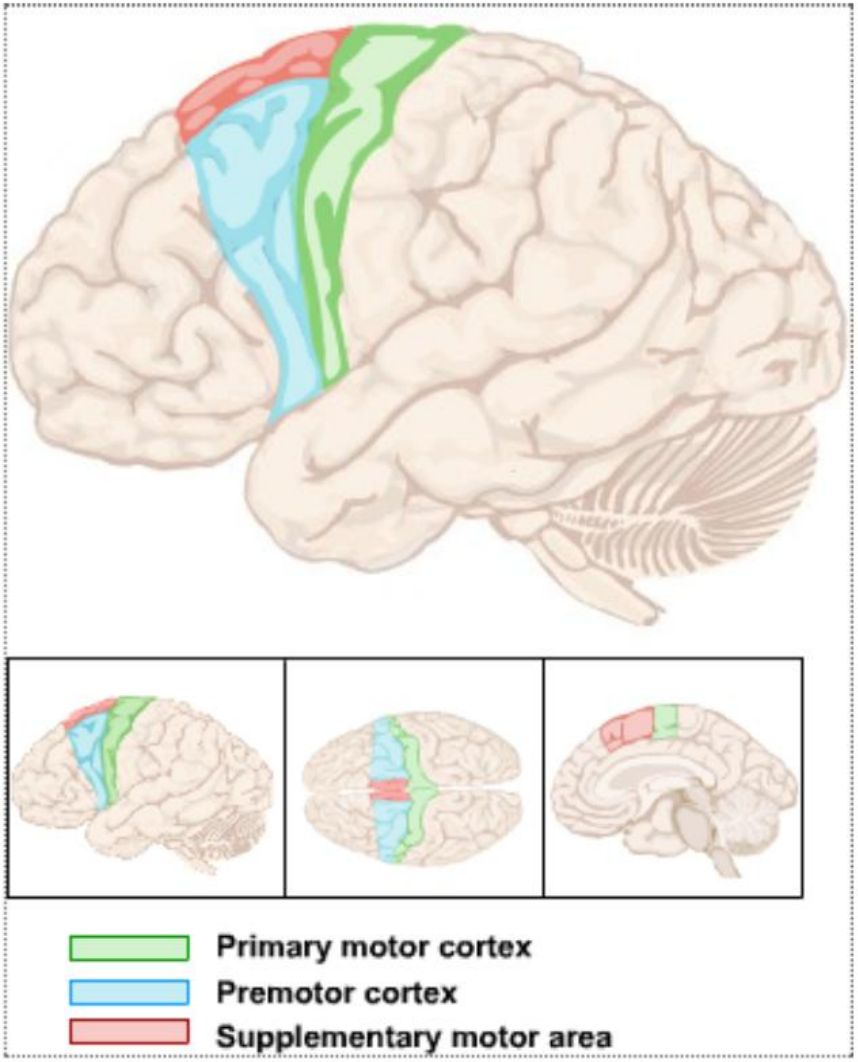
- A. blink reflexes
- B. feeding mechanisms: rhythmic chewing and licking movements
- C. micturition (urination) reflex
- D. gaze control

Organization of the motor system



The motor cortices

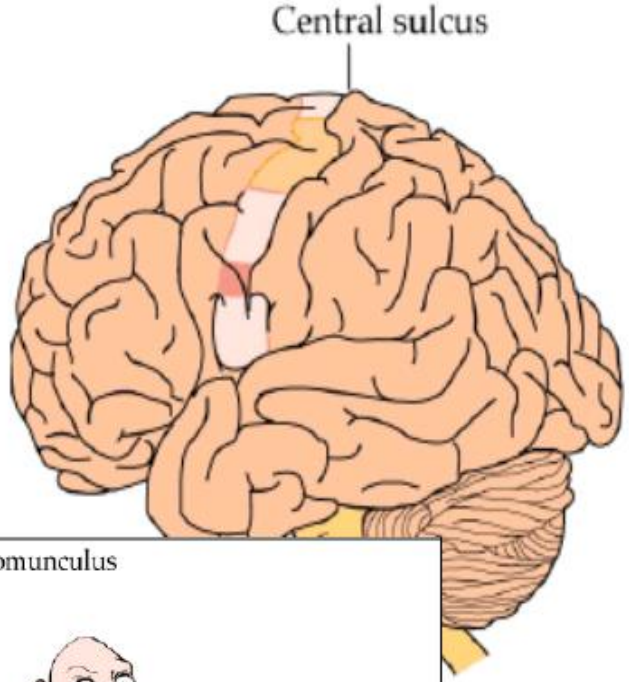
- The **motor cortex** comprises three different areas of the frontal lobe:
  - **primary motor cortex** (Brodmann 4)
  - **premotor cortex**,
  - **supplementary motor area**
  - *Plus :frontal eye-field*
- the premotor cortex and supplementary motor areas encode complex patterns of motor output and that select appropriate motor plans to achieve desired end results.
- Somatotopical organization



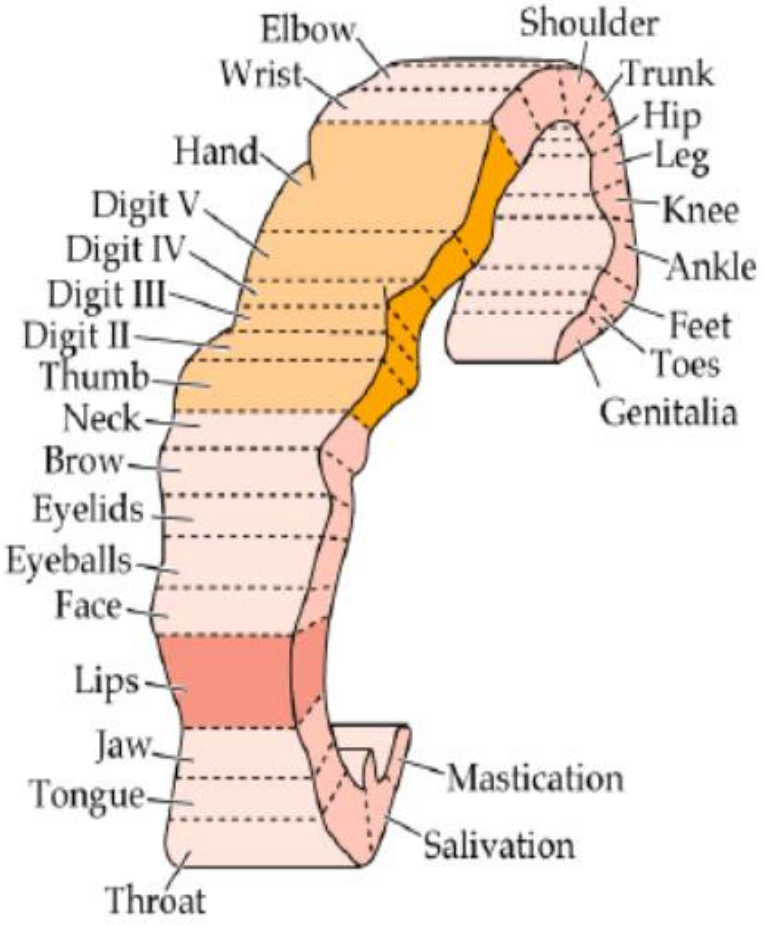
Motor cortices

- Primary motor cortex
- Premotor motor cortex
- Supplementary motor area
- Parietal cortex
- Prefrontal cortex
- Broca's area

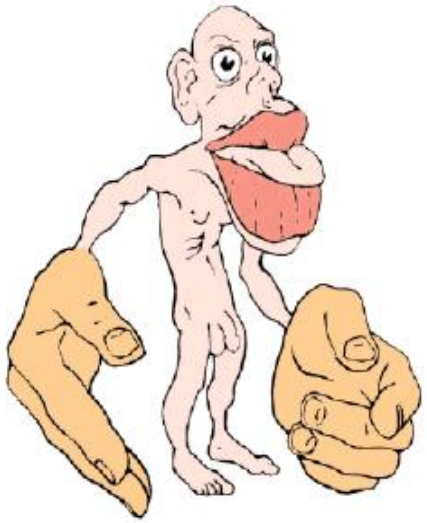
(a) Lateral view of brain showing location of primary motor cortex



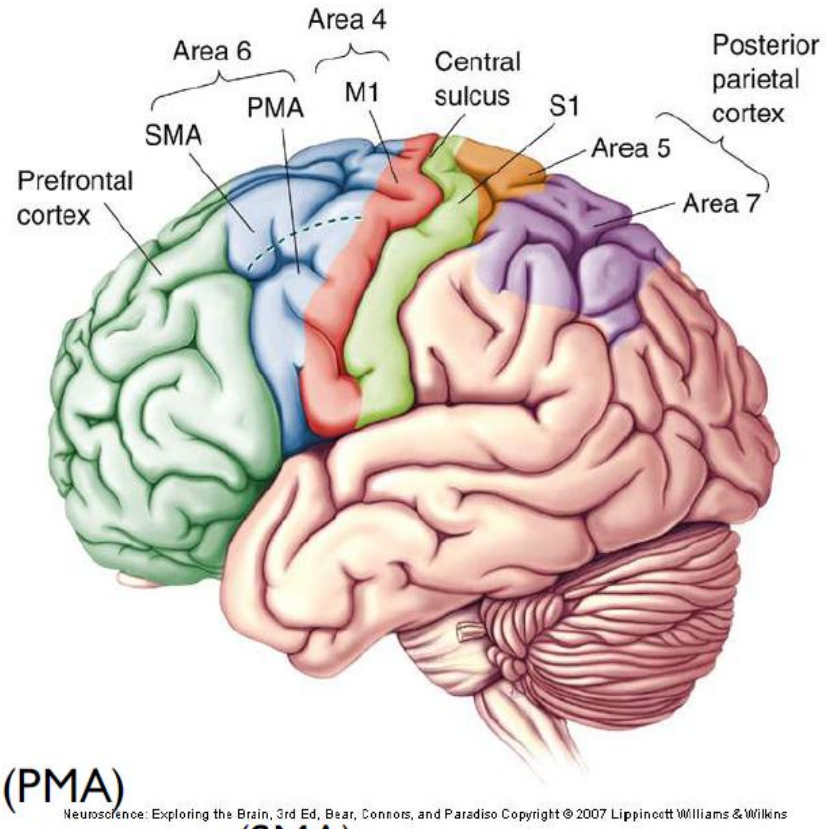
(b) Representation of the body in primary motor cortex



(c) Motor homunculus



Motor cortex



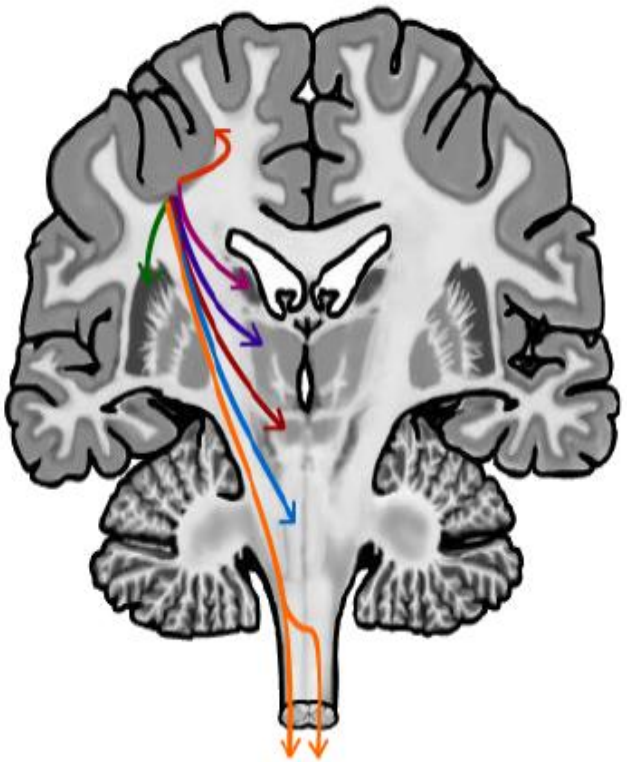
Area 4 = "Primary motor cortex"

Area 6 = "Higher motor area" (Penfield)

- Lateral region → Premotor area (PMA)
- Medial region → Supplementary motor area (SMA)
- Motor maps in PMA and SMA
  - Similar functions; different groups of muscles innervated

Cortical afferents and efferents

- Descending pathways:
  - Corticorubral tract
  - Corticotectal
  - Corticoreticular
- Efferentation of the side loops:
  - Corticostriatal tract (caudate, putamen)
  - Corticopontine tract & corticoolivary (cerebellum)
- Cortico-cortical relations (direct or indirect)
- Bidirectional pathway!!



Primary motor cortex

- Controls individual movements or sequenes of movements
- NOT controls individual muscles directly

- What is encoded by the neurons in the M1?
  1. Relaying the motor command to the alpha motor neurons
  2. Force of the movement (holding a baloon vs holding a bottle)
  3. Direction of the movement
  4. Speed of the movement (bell-shaped curve till we reach something)

Premotor cortex

- Direct links to the primary motor cortex and to the spinal cord as well
- More complex, task-related processing
- motor plans
- What is encoded?
    1. Preparation for the movement:
        1. fire selectively before the movement starts, motor-set neurons
    2. Sensory aspects associated with the motor act:
        1. hearing, seeing somebody' s els acts: mirror neurons
    3. Behavioural context:
        1. full or empty cup (cheap or expensive chinaware)
    4. Correctness/ incorrectness:
        1. activation during the correct actions or movement error trials

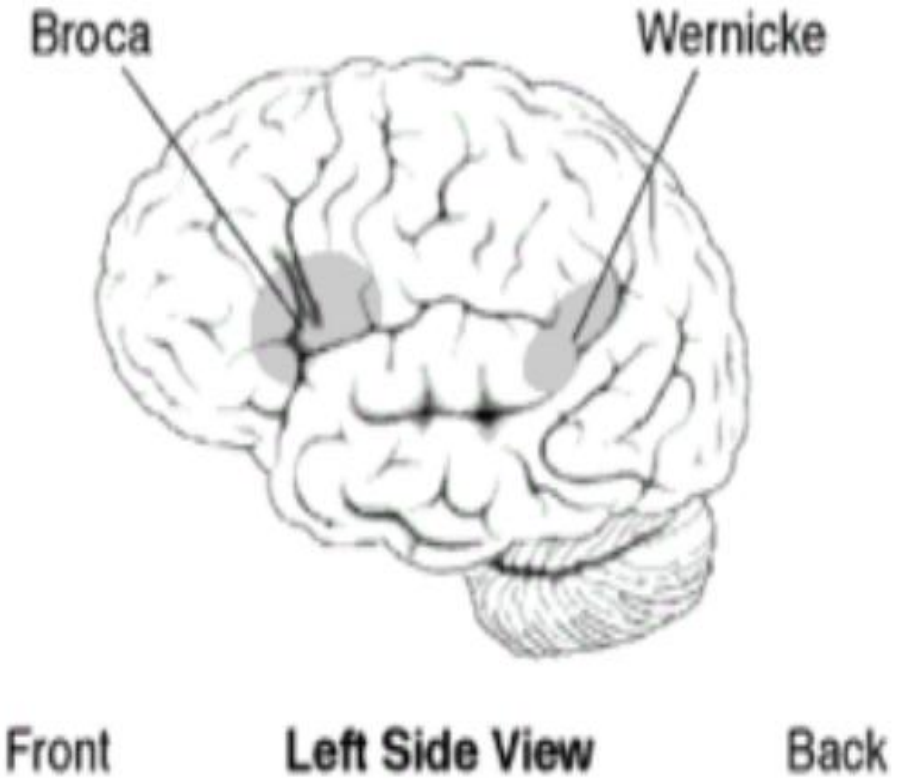
Supplementary motor area

- Programming complex sequences of movements, coordinating bilateral movements
- Selecting motor programs based on memory
- What is encoded?
  1. SMA responds to sequences of movements
  2. Transformation to dynamic information

- Association cortex
- Prefrontal and posterior parietal cortex
- They ensure the adaptibility and appropriateness of the behaviour in a given contex
  1. Posterior pariet. cortex: targeted accurately to objects (spatial relationships), apraxia (inability to make complex, coordinated movements)
  2. Prefrontal cortex: selection of appropriate movements, lack of it: difficulty of executive processing, impulsivity

Broca's area

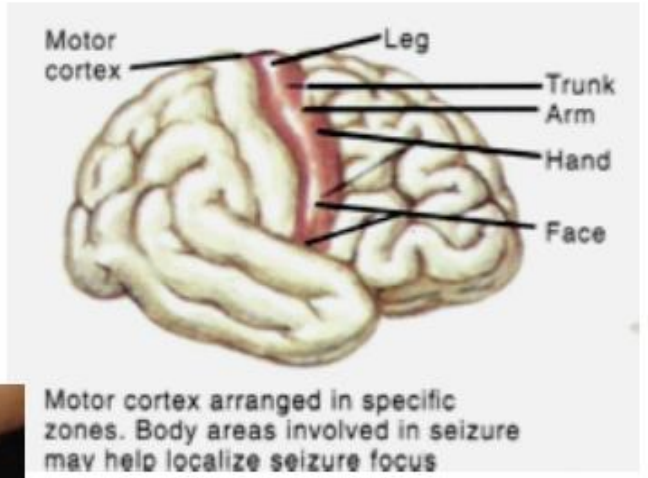

inferior frontal gyrus


Broca
Wernicke
Front
Left Side View
Back

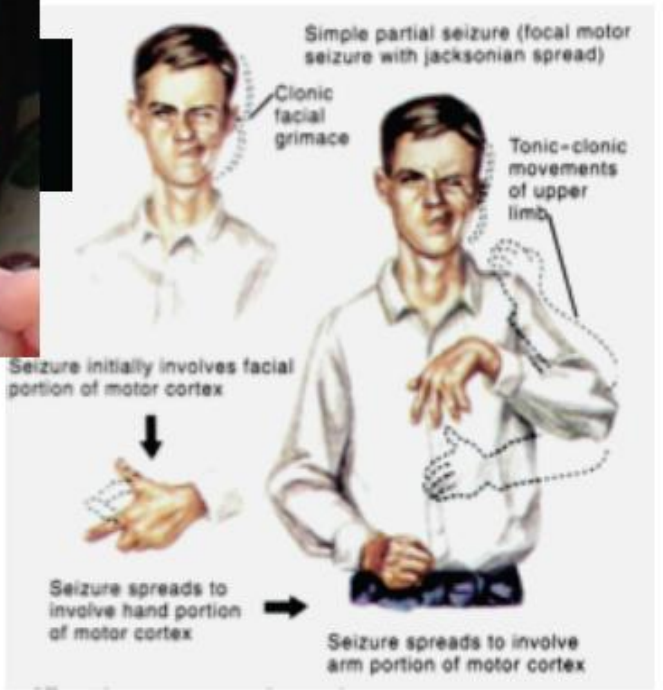
Inputs to Motor Cortex

- Subcortical fibers from other cortical areas: somatosensory, frontal, auditory, visual.
- Subcortical fibers from contralateral cortex through the corpus callosum.
- Somatosensory fibers from thalamic ventrobasal complex.
- Fibers from thalamic VL and ventroanterior nuclei – from cerebellum and basal ganglia.
- Fibers from thalamic intralaminar nuclei – arousal.

- Disturbances of the corticospinal system may be irritative (positive) or paralytic (negative).
  - Irritative (seizures)
    - Jacksonian seizu
      seizures startin
      upper extremit
      proximally
  - Paralytic
    - Weakness – fine movements, skilled movements (distal muscles); no atrophy; presence of Babinski sign and primitive reflexes (upper motor neuron manifestations)



Motor cortex arranged in specific zones. Body areas involved in seizure may help localize seizure focus



CST Lesions

- Common causes of CST lesions include:
  - stroke
  - tumors
  - trauma
- Upper motor neuron (UMN) disease
- Lesions to motor cortex will affect limb muscles contralateral to lesion. Why?

CST Lesions – Positive Signs

- Abnormal responses to stimuli (hyperreflexia) or motor behaviors that emerge as a result of the lesion.
- Primarily due to withdrawal of inhibitory influences or to interneuron connection defects.

CST Lesions – Negative Signs

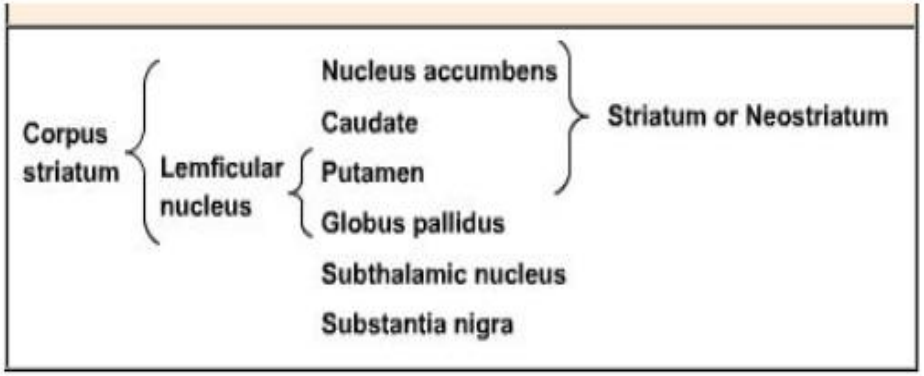
- Loss of the function normally controlled by CST (paralysis), resulting in the inability to initiate fine voluntary movements, or a loss of fractionation (the inability to control individual muscles independently.)
- Primarily due to a loss of connections of CST neurons onto alpha motor neurons.
- Examples: hypotonia (decreased muscle tone), weakness, diminution of movement (paresis).

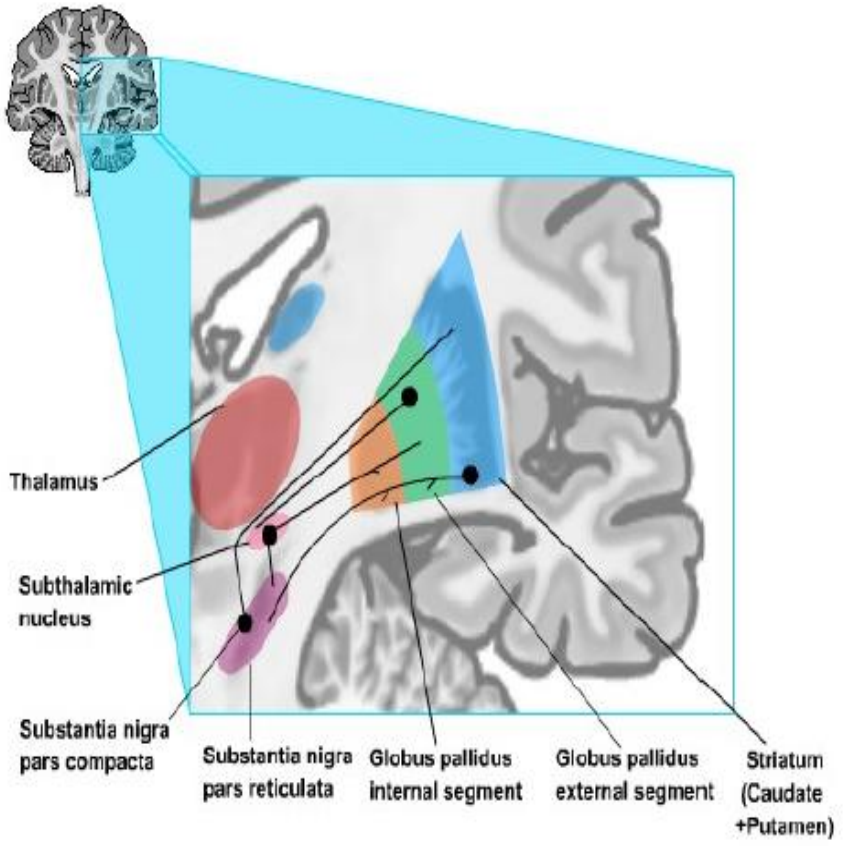
CST Conclusion

- Direct activation of alpha, gamma motor neurons and interneurons.
- Background tonic signals to motor areas of cord.

Basal ganglia

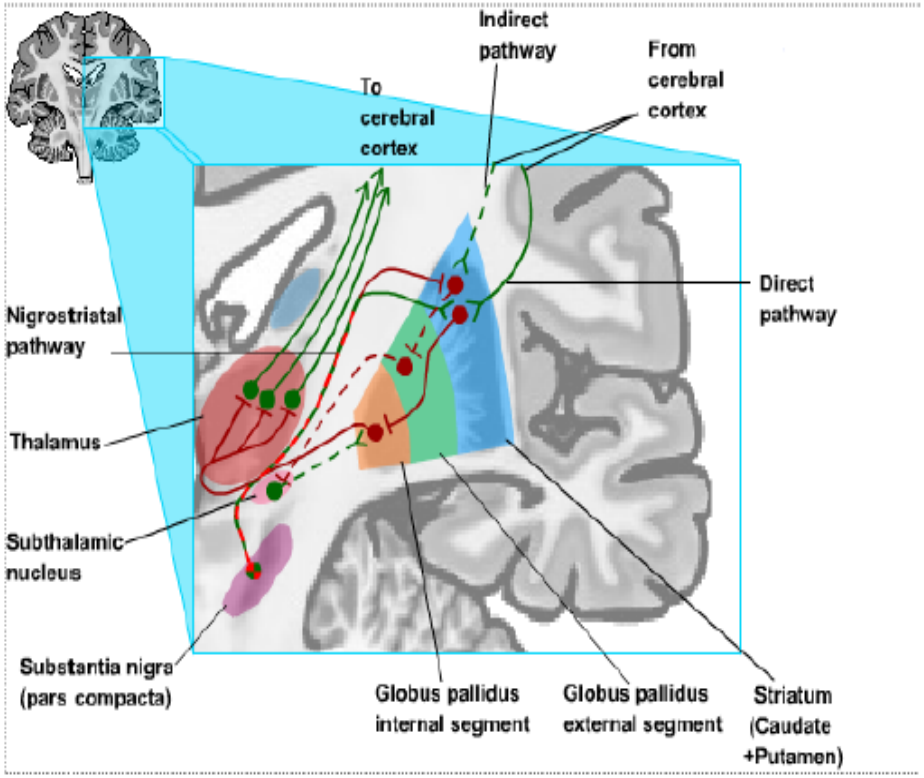
- Side loop in the motor hierarchy
- Elements:





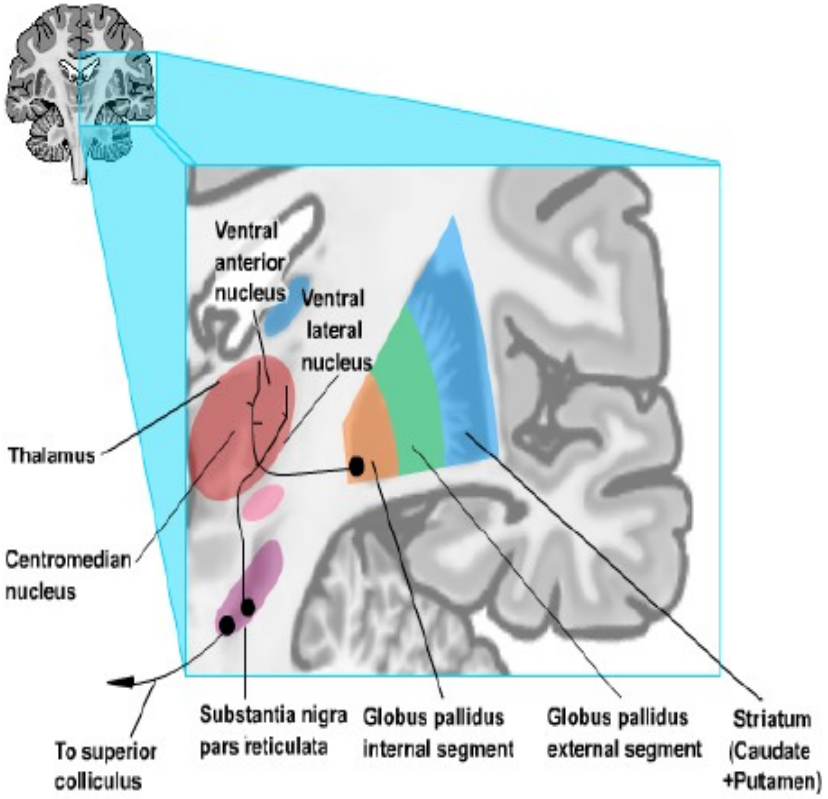
- Globus pallidus: internal (GPint) and external segment (GPext)
- Substantia nigra: pars compacta and pars reticulata (SNr)

Afferentation of the basal ganglia



- Main recipient: striatum
- Caudate:
  - Head:frontal lobe, premotor cortex, supplementary motor cortex
  - Body:pariet. and occipit. lobe,
  - Tail: temporal,
- Putamen: frontal lobe, Ist motor cortex, Ist somatosensory cortex,
- Nucl. accumbens: limbic cortex

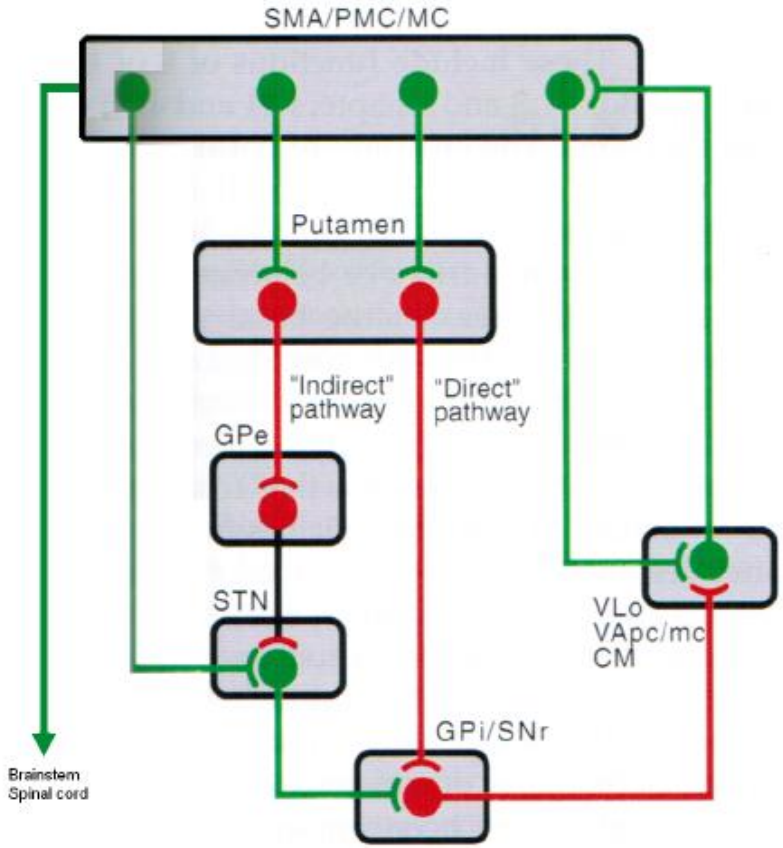
Efferentation of the basal ganglia



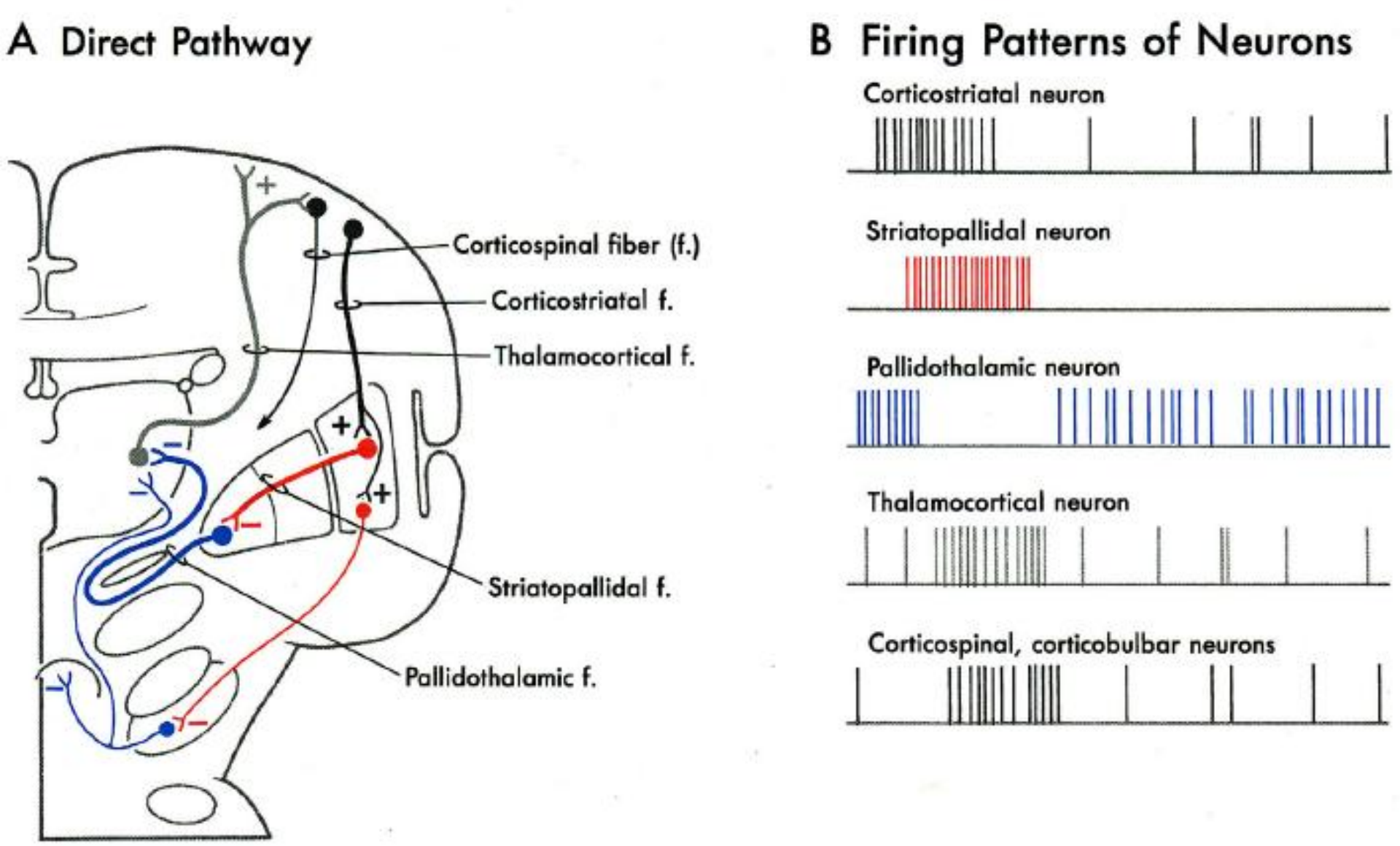
- Major output:
- GPint (GABA)
  thalamus:
  sensorimotor info:
  ventral ant. (VA), VL
  other info: dorsomedial and intralaminar nuclei
- SNr (GABA): superior colliculus (eye movements)

Direct and Indirect Pathways

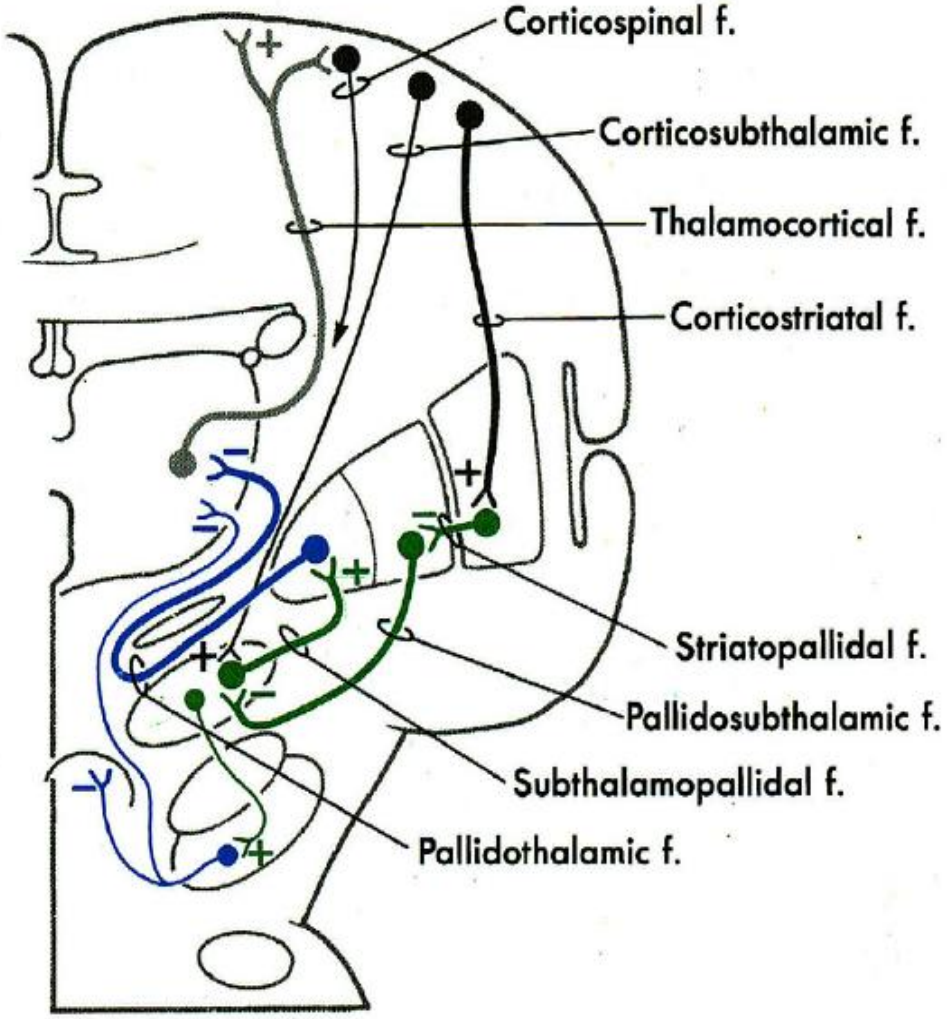
- **Direct pathway**
  - Disinhibits motor thalamus
  - Thus activates thalamo-cortical neurons
  - Activates motor cortex
  - Facilitates movement
- **Indirect pathway**
  - Inhibits motor thalamus
  - Thus inhibits thalamo-cortical neurons
  - Inhibits motor cortex
  - Inhibits movement



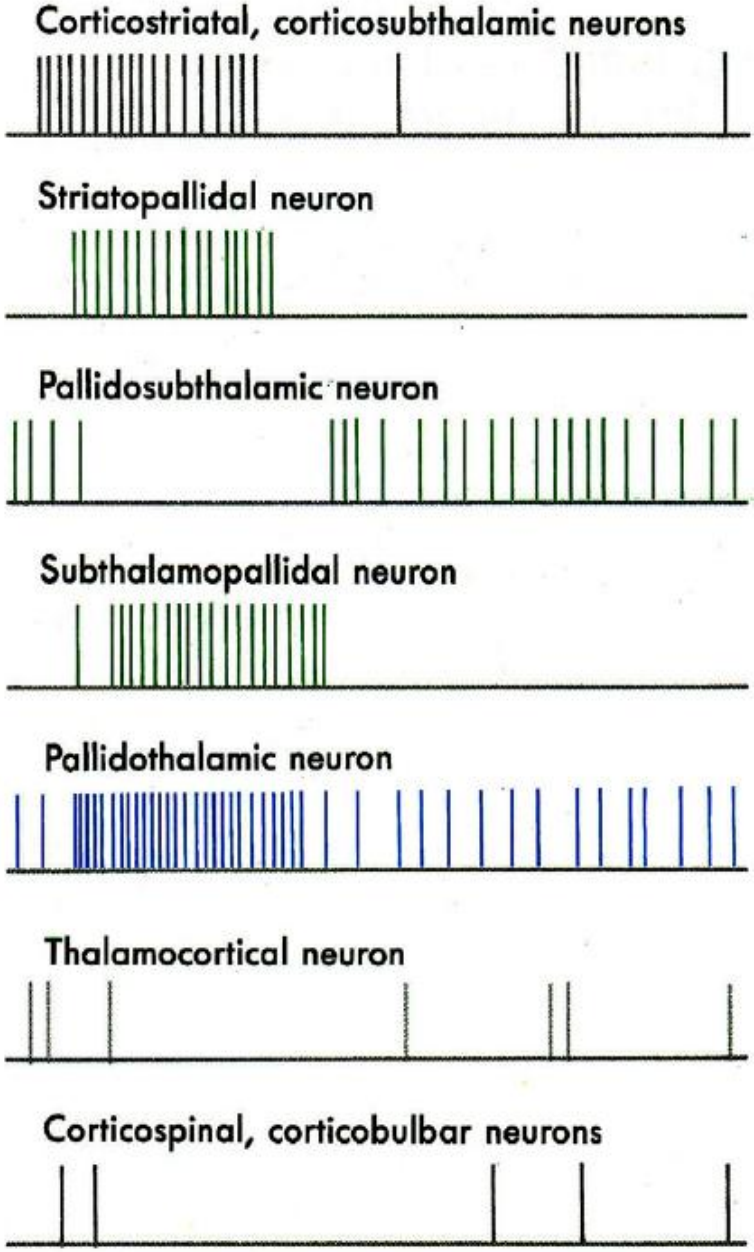
- Indirect Pathway (net "inhibitory") : Putamen -> GPe -> SThN -> GPi/SNr
- Direct Pathway (net "excitatory") : Putamen -> GPi/SNr


A Direct Pathway
Corticospinal fiber (f.)
Corticostriatal f.
Thalamocortical f.
Striatopallidal f.
Pallidothalamic f.
B Firing Patterns of Neurons
Corticostriatal neuron
Striatopallidal neuron
Pallidothalamic neuron
Thalamocortical neuron
Corticospinal, corticobulbar neurons

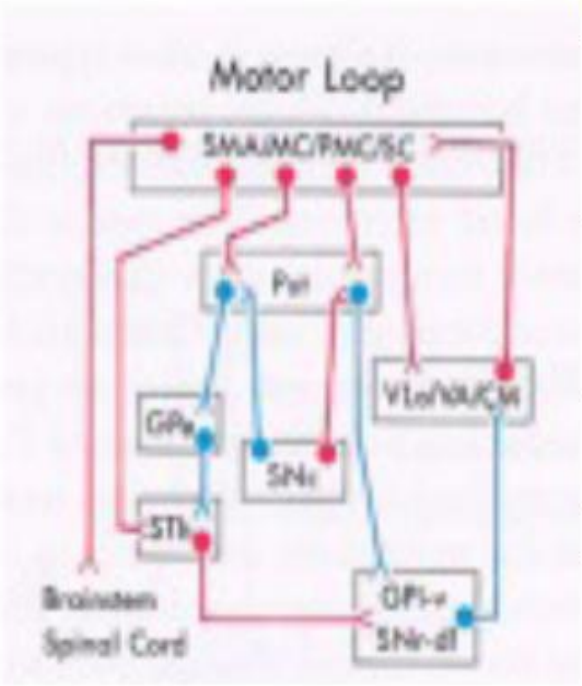
C Indirect Pathway



D Firing Patterns of Neurons



- Cortical Areas
  - SMA
  - M1
  - Premotor cortex
  - Somatosensory cortex
- Putamen
- Globus pallidum
- Substantia Nigra
- Ventral anterior/ centromedial Nn.



Damage:
- Striatum: slow voluntary movements, involuntary posture movements (chorea)
- STN: large-scale contralat involuntary movements (hemiballism)
- GP: slow voluntary movements, involuntary postures
- SNpr: involutary eye movements
- SNpc: Symptoms of Parkinson's Disease (tremor, bradykinesia, akinesia, muscular rigidity, unstable posture)

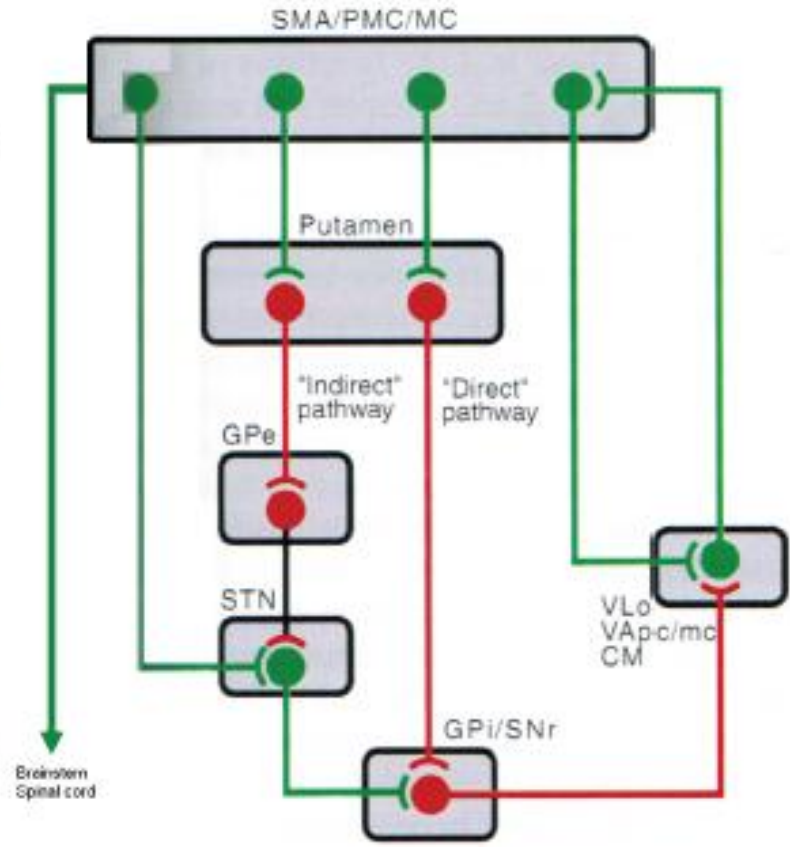
- Input Units: Striatum (Caudatum, Putamen, N. Accumbens) excitatory input from cortex (e.g., M1, SMA, PMC, SC)
- Output Unit: Globus Pallidum Internal (GPi) and Substantia Nigra pars retic. (SNpr) inhibitory ouput to thalamus: ventrolateral nucleus (VLo), ventral anterior (VA)

- Indirect Pathway (net "inhibitory") : Putamen -> GPe -> SThN -> GPi/SNr
- Direct Pathway (net "excitatory") : Putamen -> GPi/SNr

	Direct	Indirect
Pathway	Putamen → (+) GPi, SNr	Putamen → (-) GPe → (-) STN → (+) GPi
Effect on BG output	GPi, SNr inhibited ✗	GPi stimulated ✓
Effect on Thalamus	Stimulated ✓	Inhibited ✗
Effect on movement	Initiated ✓	Inhibited ✗
Malfxning	Parkinson's bradykinesia ✗	Huntington's Chorea ✓

Intrinsic connections

- 5 pathways:
  1. Striatum → pallidum: inhibitory, GABA
  2. Striatum → SNr: inhibitory, GABA
  3. GPext → subthalamic nucl. inhibitory, GABA
  4. Subthalamic nucleus → globus pallidus & SNr: excitatory, GLU
  5. Subst. nigra → striatum: mixed, dopamin



- http://www.dailymotion.com/video/x1j0j5_huntingtons-disease_family
- http://www.dailymotion.com/video/x1iqgs_parkinson-s-disease_news