- Descending motor pathways
    - Corticospinal: lateral funiculus into the lateral horn of the grey matter. Control voluntary movement
    - Rubrospinal: lateral funiculus into lateral horn of grey matter. Control fine tuned movement.
    - Reticulospinal: Ventral (pontine), lateral (medullary) funiculus into the ventral horn, controls antigravity and posture
    - Vestibulospinal and tectospinal: medial funiculus to around central canal, control head movement and posture

- Motor cortex of the cerebrum: cell sorted into Brodmann areas in a cytotectonic manner. Anterior to posterior:
    - Prefrontal cortex
    - Premotor cortex (PMC): Brodmann area 6 planning of movement, receive input from VA
        - Supplementary motor area (SMA)
        - Premotor area (PMA): recieve input from Brodmann area 5 & 7
    - Primary motor cortex (M1): Brodmann area 4, Precentral gyrus, initiate movement, receive input from VL
    - Central sulcus
    - Primary somatosensory cortex (S1): receive somatic sensory input
    - Posterior parietal cortex: Brodmann area 5 & 7, vision input, project to PMA
        - Brodmann area 5: perceive the positional infomation of the perceived object, project to PMAd
        - Brodmann area 7: perceive the property of the object. Project to PMAv

Movement control: signalling hierachy in the brain:

- Prefrontal cortex: Strategic planning of further future movements, signalling into the Brodmann area 5 and 7.
- Brodmann area 5&7: Visual dorsal and ventral stream:
    - Brodmann area 5: positional infomation of the object to the dorsal PMA
    - Brodmann area 7: property infomation of the object to the ventral PMA
- PMC plan based on visual cues: PMA controls spontaneous movements, SMA control movement planning and mental rehearsal (experimental evidence: PET scan of brain when performing task/imaginery task)
- PMA and SMA and S1 input into the M1, initiate movement.

Order for threshold of producing movement:

M1 < PM < SMA < S1 < Area 5 < Area 7 < Prefrontal

Thalamocortical pathway: thalamus is the integrating center for sensory infomation

- Ventral Anterior nucleus project to the PMC
- Ventral Lateral nucleus project to the M1

Corticospinal pathway: M1 - internal capsule - Medulla - Spinal cord

- M1: Lower limbs are more medial (closer to the longitudinal fissure), upper limbs & face more temporal
- Internal capsule: Rostral innervations are more medial, lower limbs more lateral, some cranial nerves leave in the brainstem
- Medulla: Majority of corticospinal tract decussate at the mudullary pyramids: produce lateral corticospinal tract and anterior corticospinal tract
- Spinal cord: Lateral corticospinal tract in the lateral funiculus, anterior corticospinal tract lateral to the ventral fissure
    - Lateral spinocortical tract cross at the medullary pyramid, anterior spinocortical tract corss in the spinal cord.

Convergence and divergence:

- Multiple pyramidal neurons in the M1 cortex can innervate a single downstream motor neuron: Convergence
- Each pyramidal neuron can innervate multiple downstream motor neuron pool / interneuron pool: divergence

Muscle tension coding

- Some M1 neuron firing rates correlate with the force being generated (Static)
- Some M1 neuron's firing rate correspond to the differential force (rate) generated (Dynamic)
- Most neurons firing pattern comprised of both.
- Population coding: firing pattern of a group of neuron can correspond to the direction of movement

Cerebellum: Contain 50% of the total neurons

Cerebellar nucleus supraspinal control:

- Pyramidal cells receive input from climbing fibres (inferior olive) and mossy fibre(affarent copy and sensory input) via granular cells:
    - Mossy fibre:
        - Spinal sensory signal: somatosensory, nociception, proprioception
        - Vestibular system: balance, head movement.
        - Pontine nuclei: auditory, visual signal from the cerebral cortex, efference copy.
    - Climbing fibre: inpur from inferior olive: modulate cerebellar model.

- Pyramidal cells in cortex send output signal via nucleus below the cortex in the cerebellum
    - Medial cortex - fastigial nucleus - vestibular nuclei - vestibulospinal tract - balance, posture, eye movement
    - Intermediate cortex - Globus/Enboliform interposed nucleus - Red nucleus - rubrospinal tract - ongoing movement
    - Lateral cortex - dentate nucleus - thalamus - corticospinal tract - M1 - voluntary movements.

Cerebellar control of movement:

- Receive efference copy from the mossy fibre
- Error correction input from the climbing fibre from inferior olives
- Cerebellum act as a predictive controller, efference copy prediction of outcome is compared with input information,
- cerebellum send output signal to influence ongoing movement if actual outcome contrast with predicted movement.
- Cerebellum update model if predicted outcome differ from actual outcome.

Cerebellar leision: Leision results in ataxia: loss of coordination and control of agonist antagonist musle pairs, results in slurred speech, tremour of movement, deteriorating motor skills, intention tremor.

Experiment: Monkey's ability to bring a lever back to a fixed postition deteriorate after cooling the cerebellum nuclei.

Basal Ganglia

Components: Thalamus nuclei, Striatum(Caudate+Putamen), Globus Pallidus (Medial and lateral), Substantia Nigra (Pars compacta + pars reticulata), subthalamic nucleus.

Basal ganglion circuitry: direct + indirect pathyway converge on the thalamus then to the SMA.

Direct: cortex —> striatum —x GPi/SNr —x thalamus —> cortex

Indirect: cortex —> striatum —x GPe —x subthalamic nucleus —> GPi/SNr —x thalamus —> cortex

Substantia Nigra compacta produce dopamine, excite D1 receptor in direct striatal cells, inhibit D2-indirect striatal cells.

Putamen neurons project to the SMA

Caudate neurons project to the prefrontal cortex