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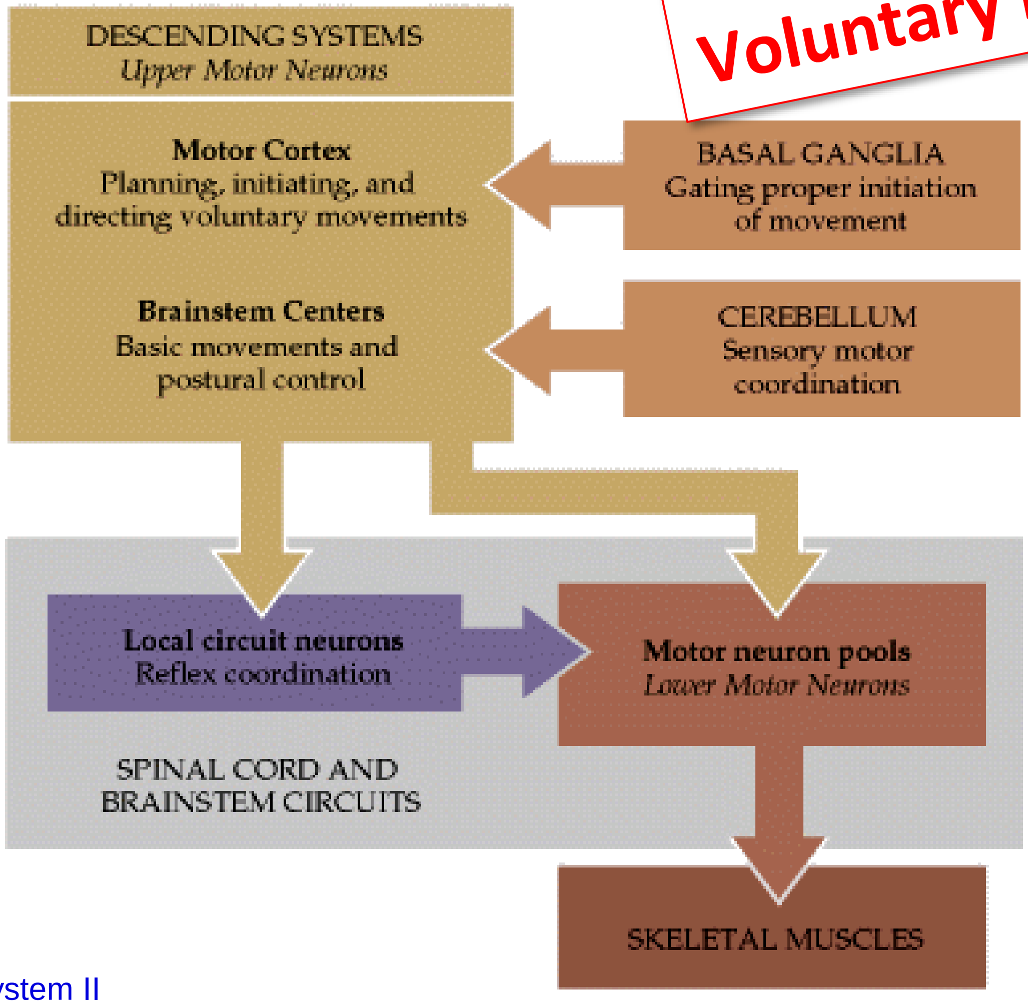
Motor system II

Introduction

Reflex movement
Rhythmic movement
Voluntary movement



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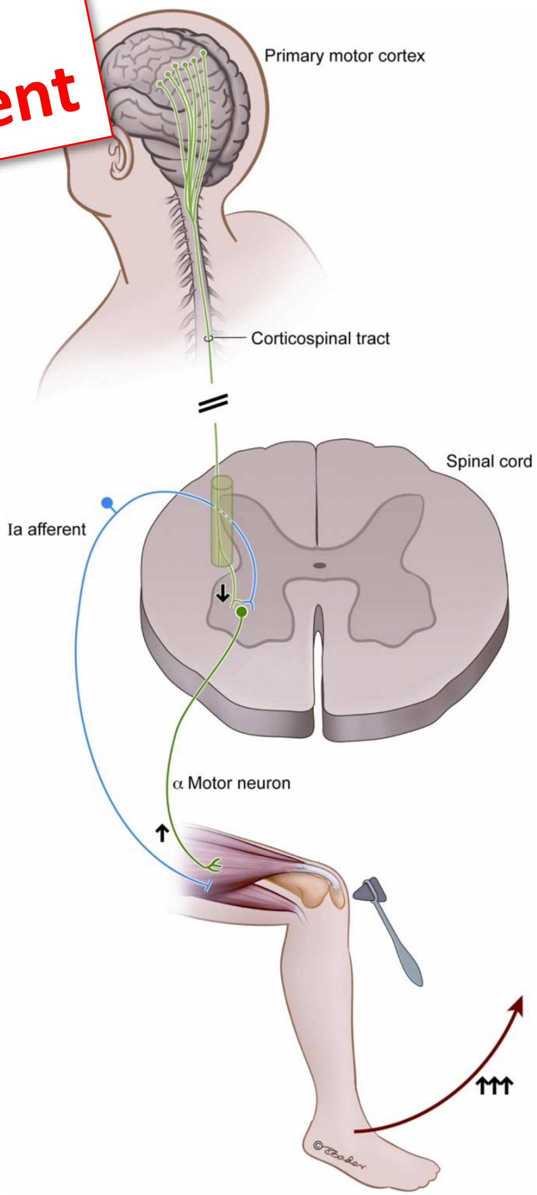

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Subcortical (stem) pathways controlling lower motoneurons

Medial system

- Axial muscle control
- Tr. Vestibulospinalis
  - Reflex control of balance and postural control
- Tr. Reticulospinalis
  - Muscle tone regulation (postural control)
- Tr. Tectospinalis
  - Coordination of head and eyes movements

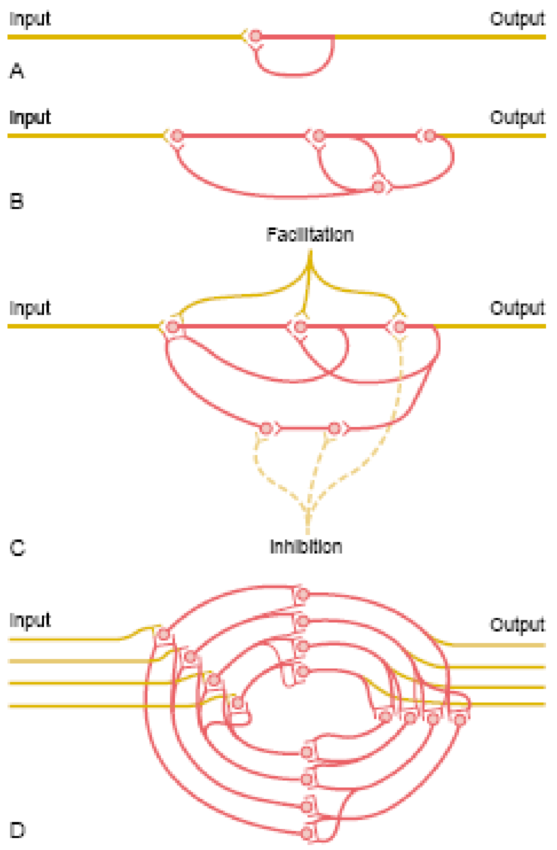
Lateral system

- Distal muscle control
- „Reflex“ control of the limbs
- Replaced by tr. corticospinalis

- Tr. Rubrospinalis
- Tr. Rubrobulbaris

Fixed action pattern and rhythmic movement

- Fixed action pattern (e.g. Swallowing)
  - Neuronal networks for complex motor activity
- Central pattern generator (e.g. Walking, breathing)
  - Neuronal networks generating rhythmic activity
  - „Spontaneously repeated fixed action patterns“
  - No need of feedback



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Fixed action pattern and rhythmic movement

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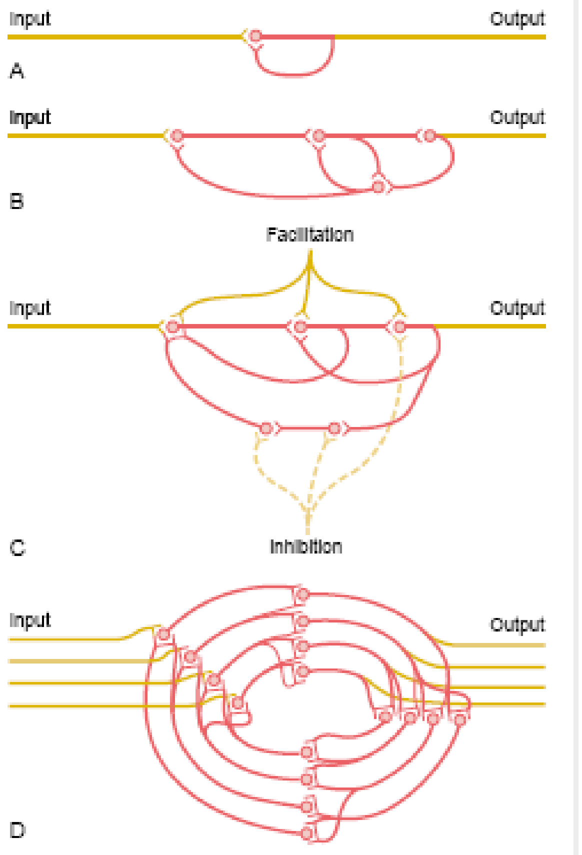
  - Neuronal networks for complex motor activity
- Central pattern generator (e.g. Walking, breathing)
  - Neuronal networks generating rhythmic activity
  - „Spontaneously repeated fixed action patterns“
  - No need of feedback
- Localization
  - Walking – brain stem, lower thoracic and upper lumbar spinal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



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Fixed action pattern and rhythmic movement

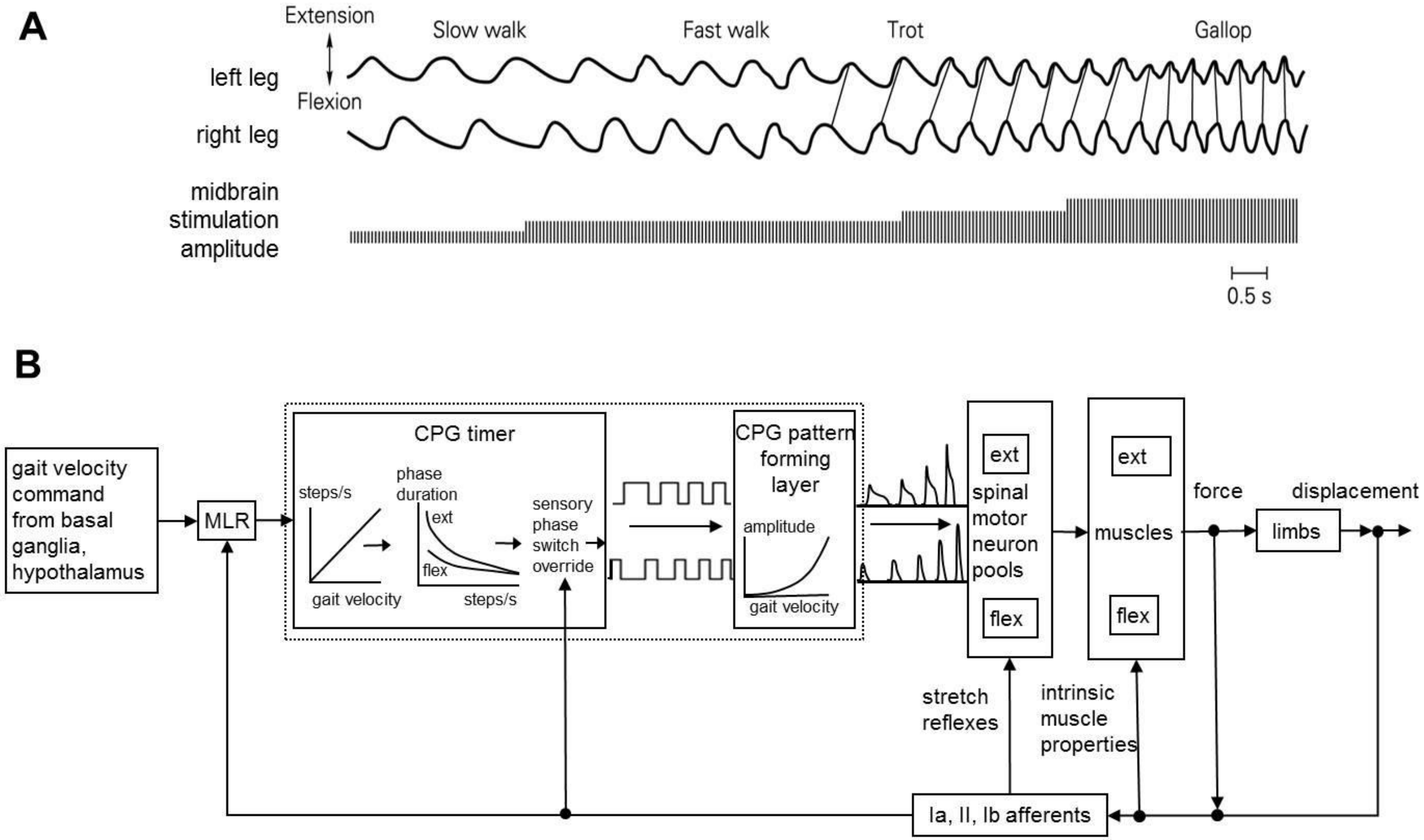

Fig. 1. Neural control of locomotion. A) Increments in the intensity of stimulation of the MLR in the high decerebrate cat increased the cadence (step cycles/sec) of locomotion. Adapted from Shik et al. 1966.[22] B) Schematic of the velocity command hypothesis: a command signal specifying increasing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

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

Fixed action pattern and rhythmic movement

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

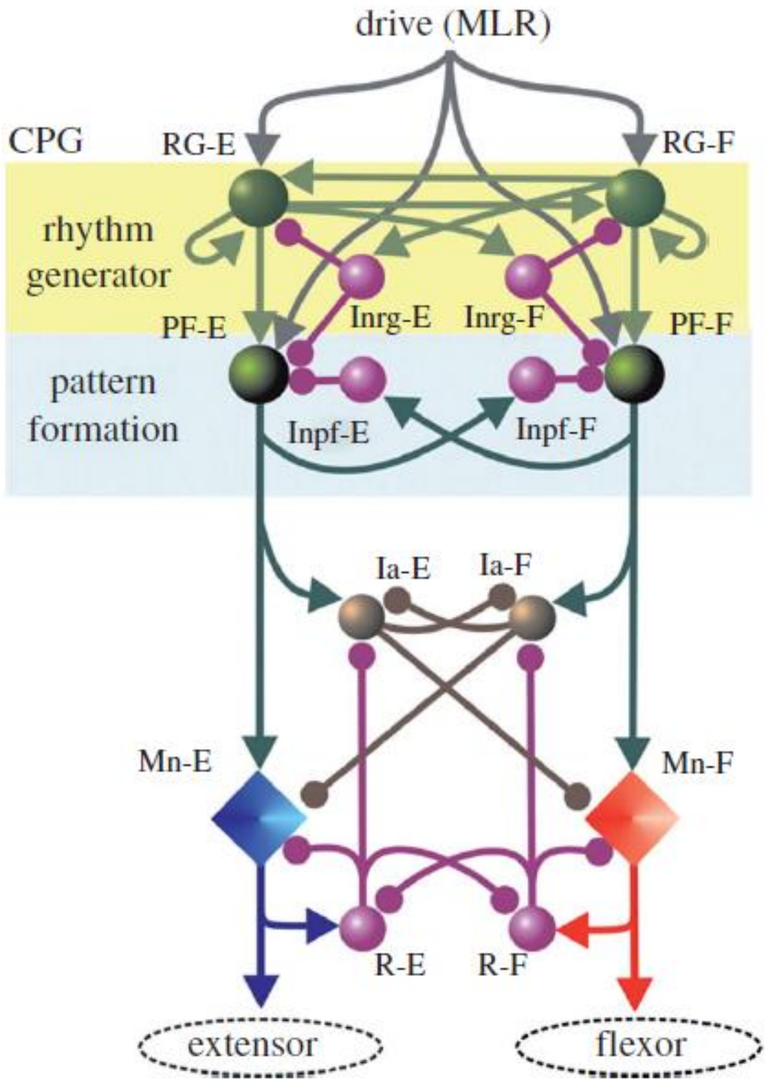

Figure 1. Schematic of model by Rybak & McCrea. The populations of interneurons are indicated by spheres, while the motoneurons are represented by diamonds. This three-layer model consists of a rhythm-generating layer of extensor (RG-E) and flexor (RG-F) interneurons. Both populations have recurrent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

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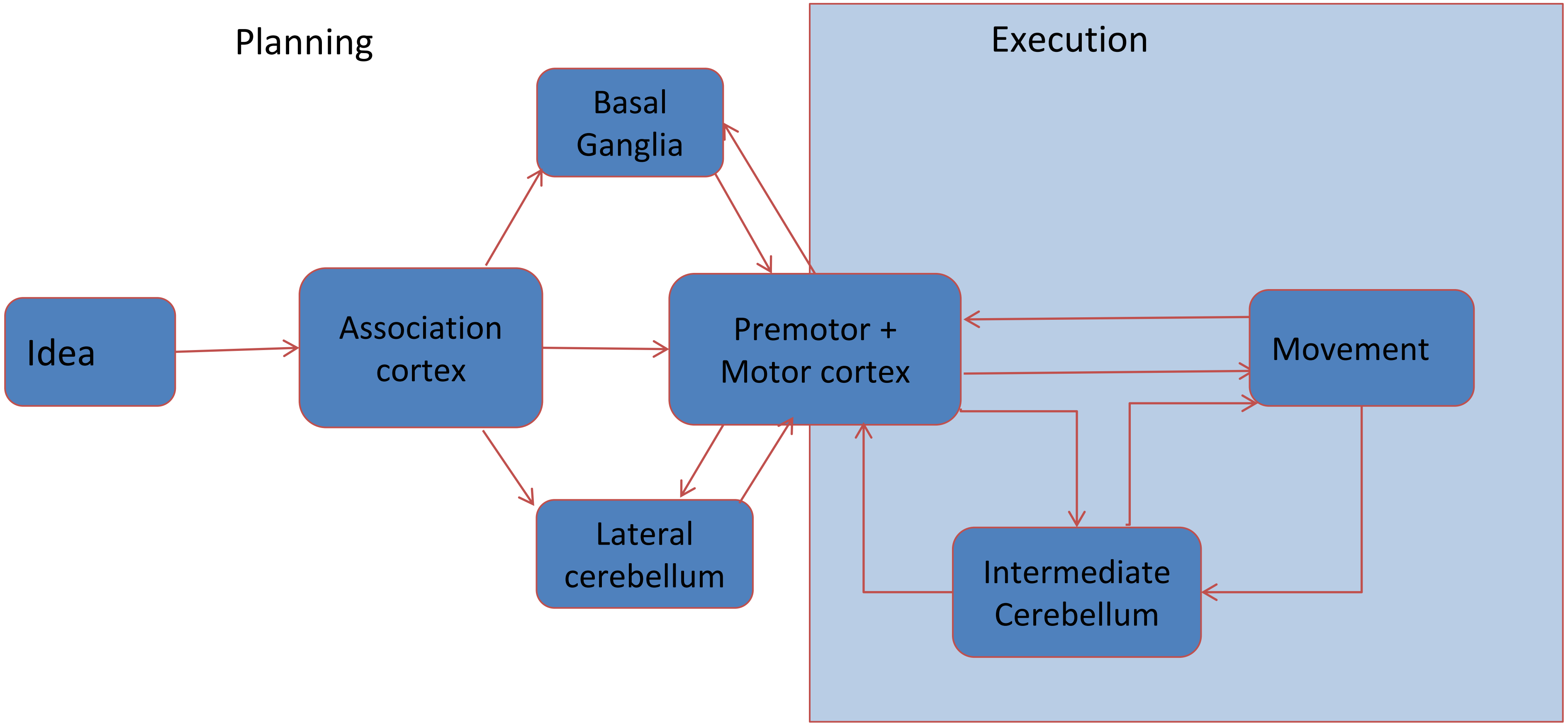
Cortical control of lower motor neuron

Tractus corticospinalis

Tractus corticobulbaris

Voluntary motor activity

Voluntary motor activity



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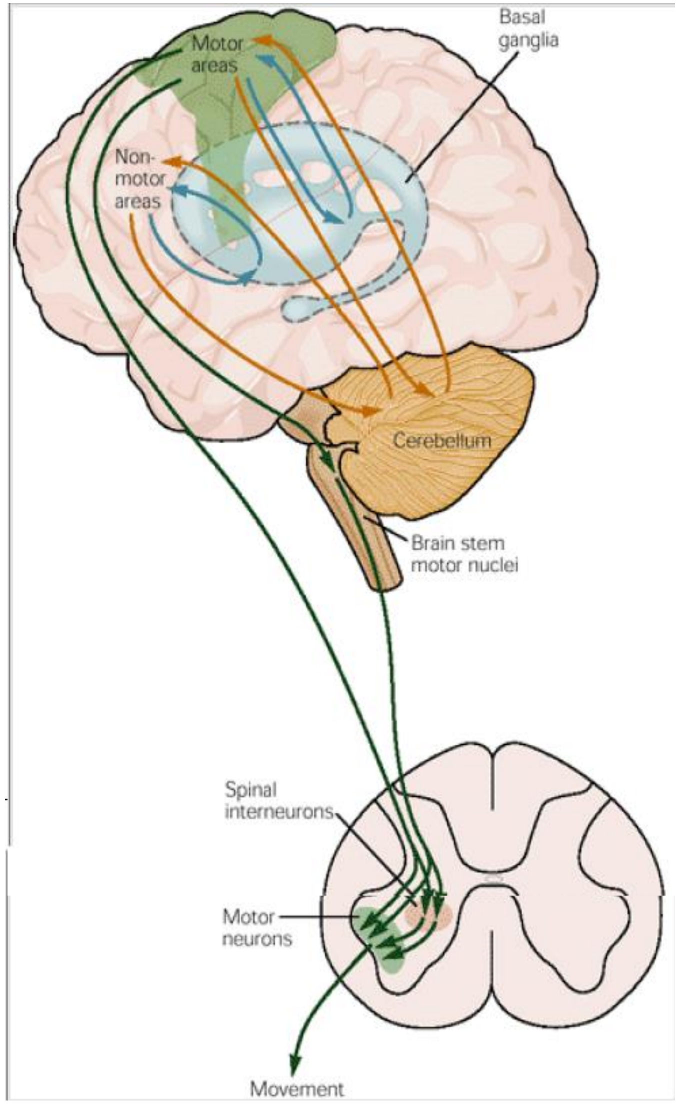
Voluntary motor activity

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



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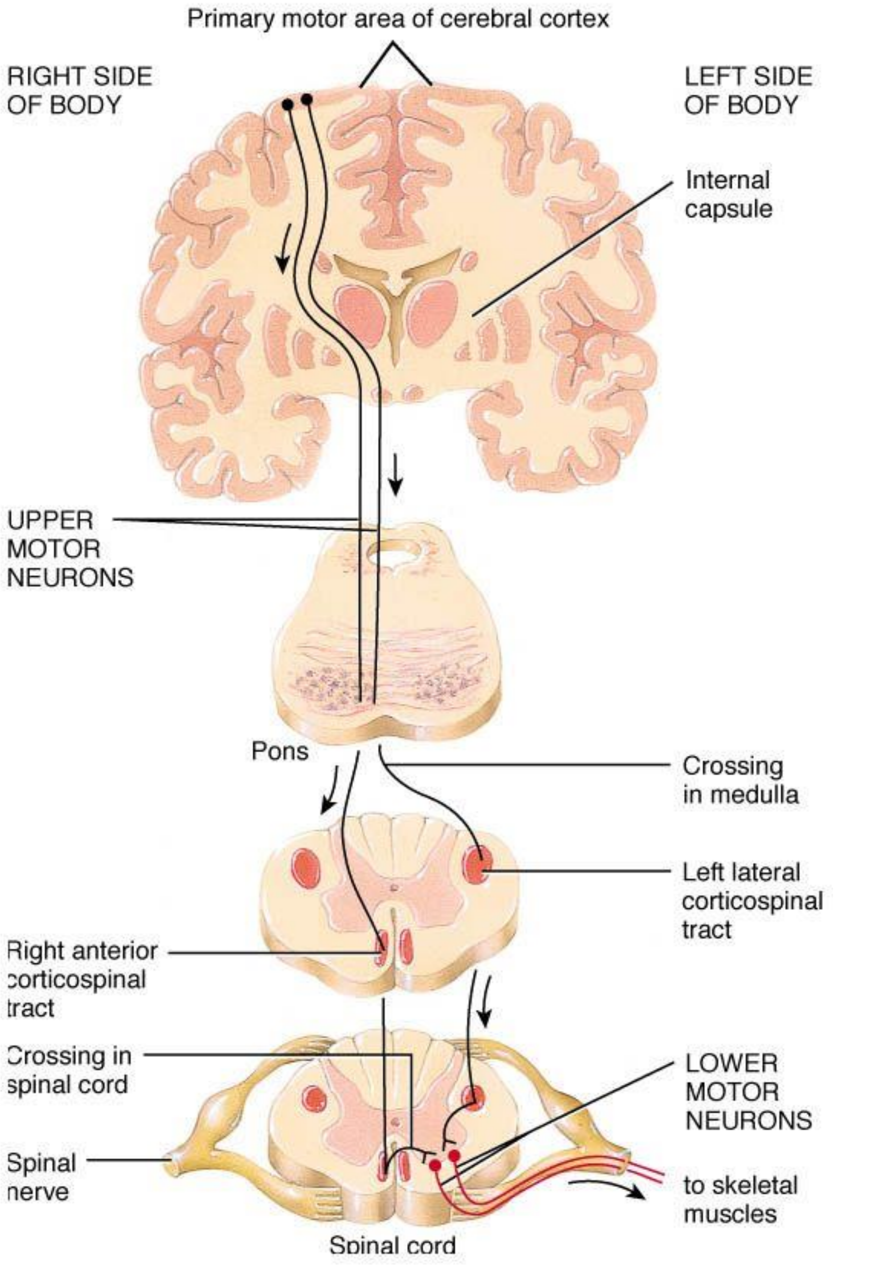
Pyramidal tract

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



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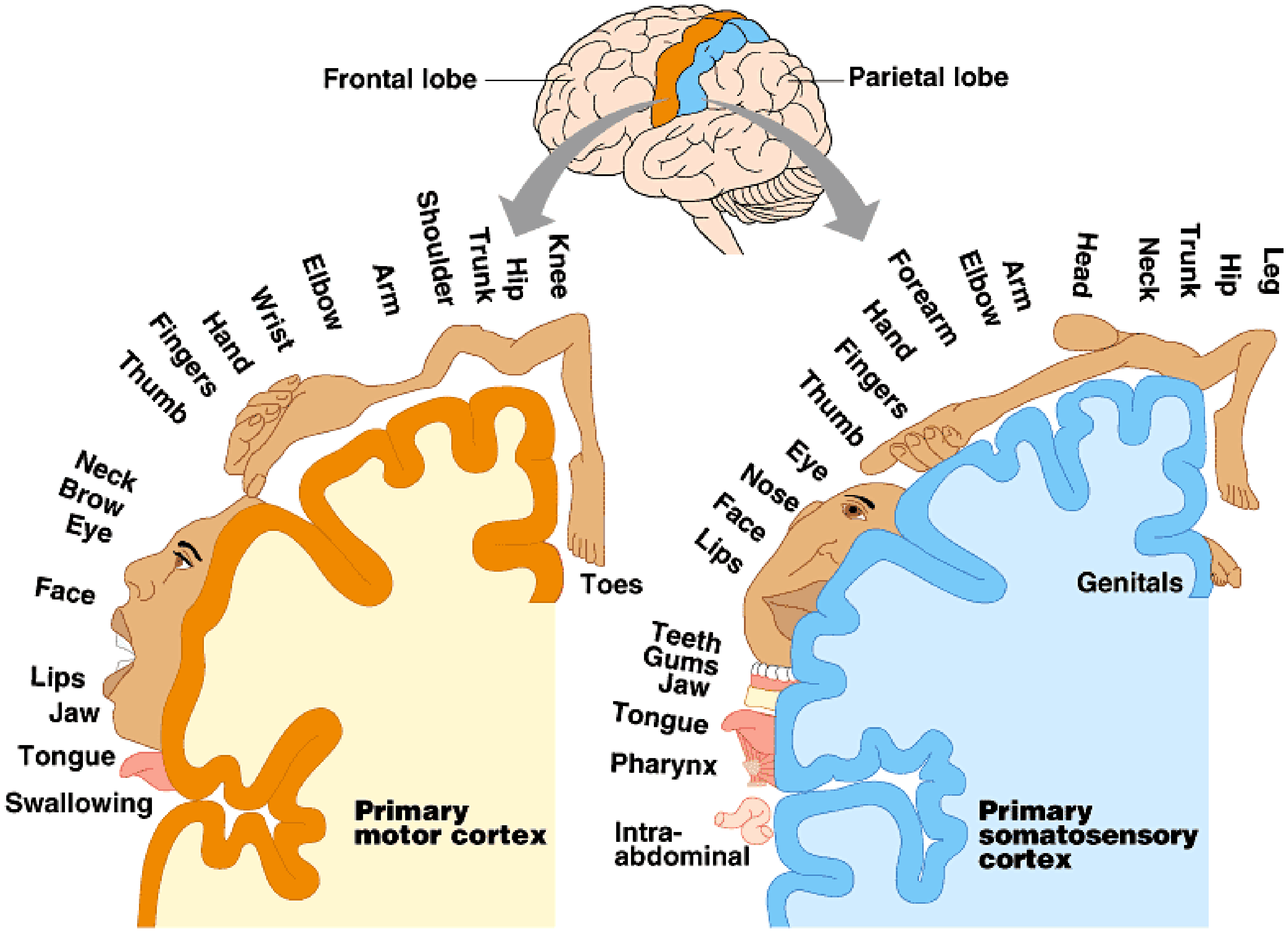
Primary motor cortex



http://www.emunix.emich.edu

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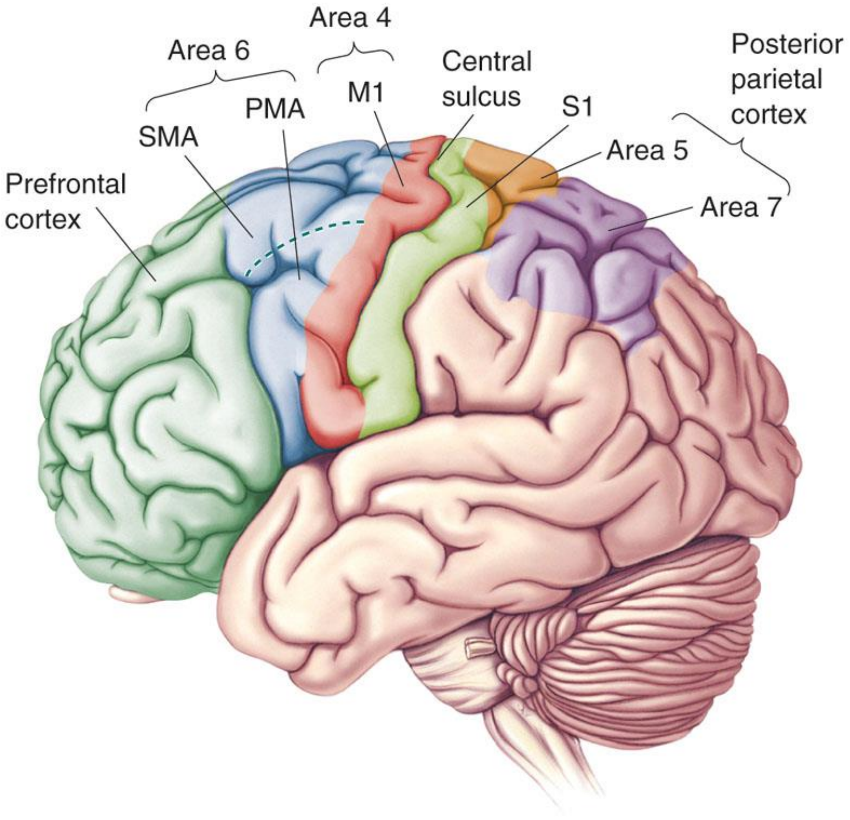
Motor cortex

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



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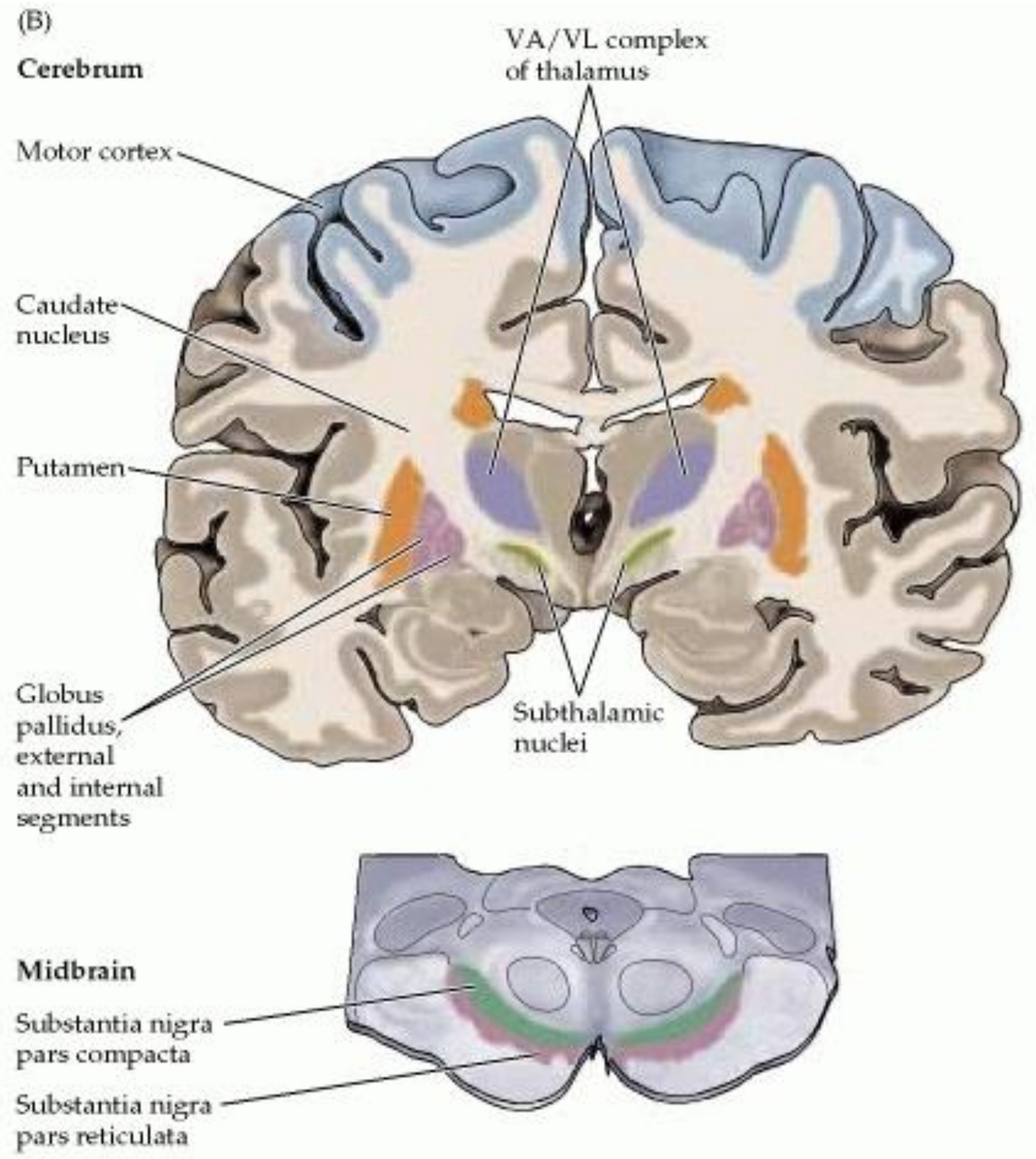
Basal ganglia

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



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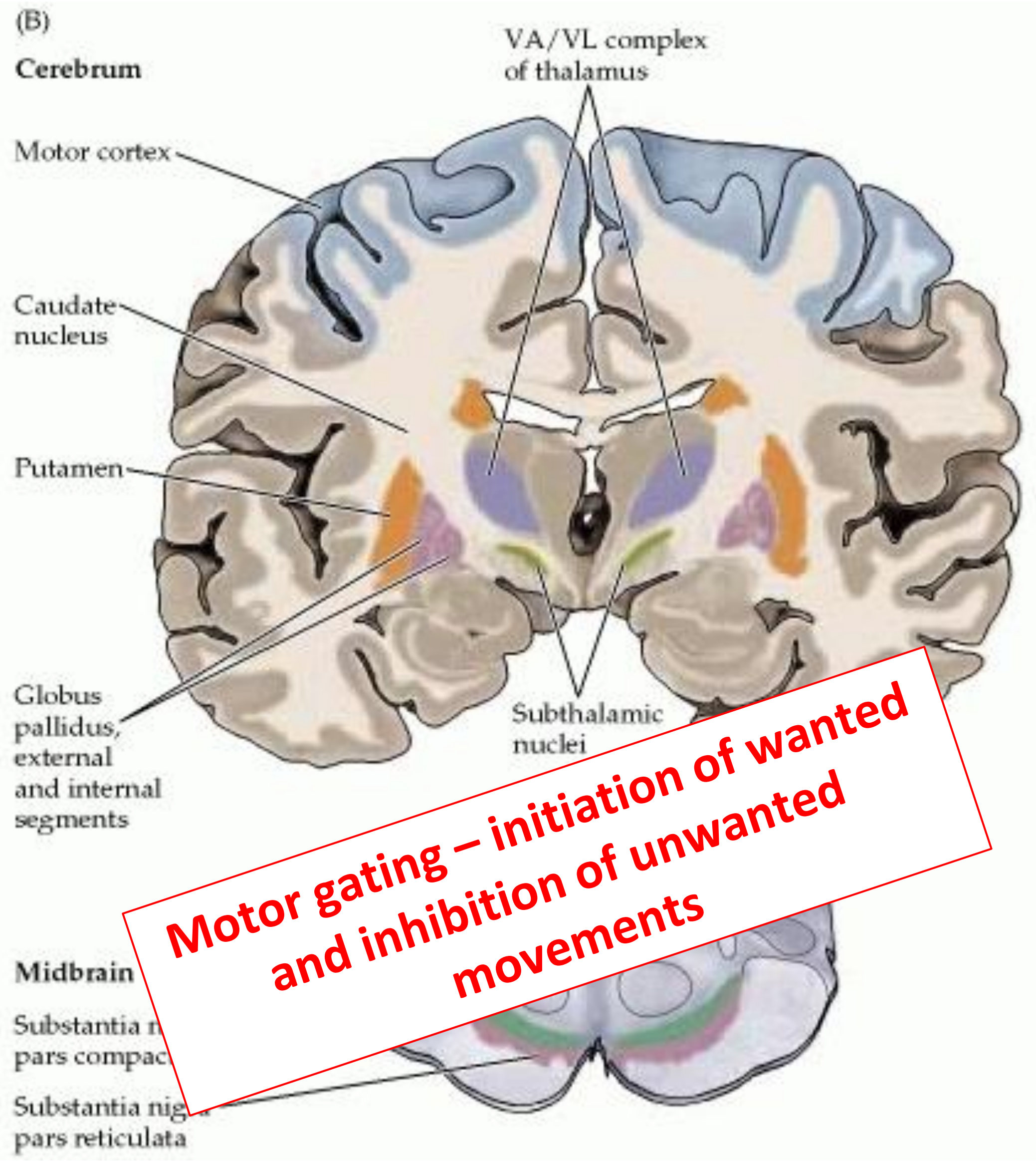

Motor gating – initiation of wanted and inhibition of unwanted movements

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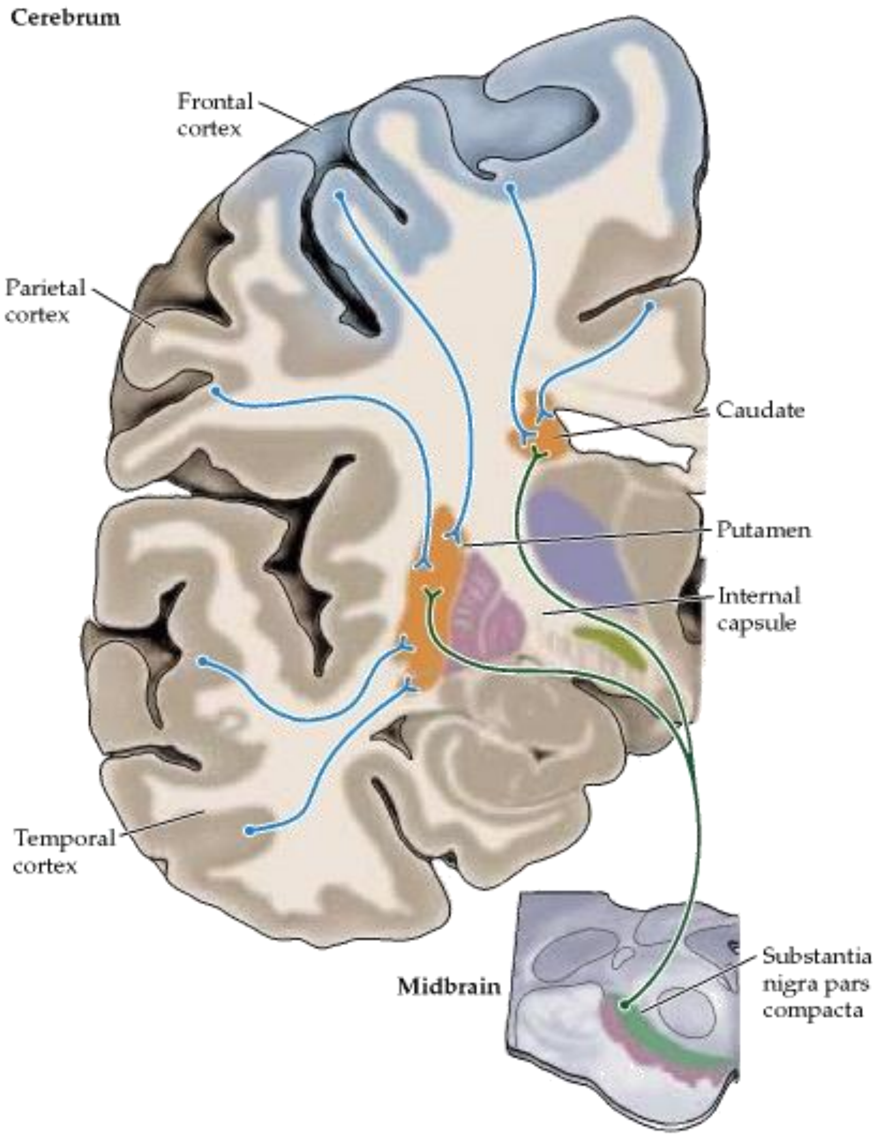
Basal ganglia - inputs

Corpus striatum

- Connections from all cortical areas with two exceptions – primary visual and primary auditory cortex
- The most of connections from
  - Frontal and parietal association areas
  - Motor areas



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Basal ganglia

Motor control realized by two circuits

- ✓ **Direct pathway**

  Motor cortex activation

- ✓ **Indirect pathway**

  Motor cortex inhibition

Direct pathway

Cortex

↓

Corpus striatum

↓

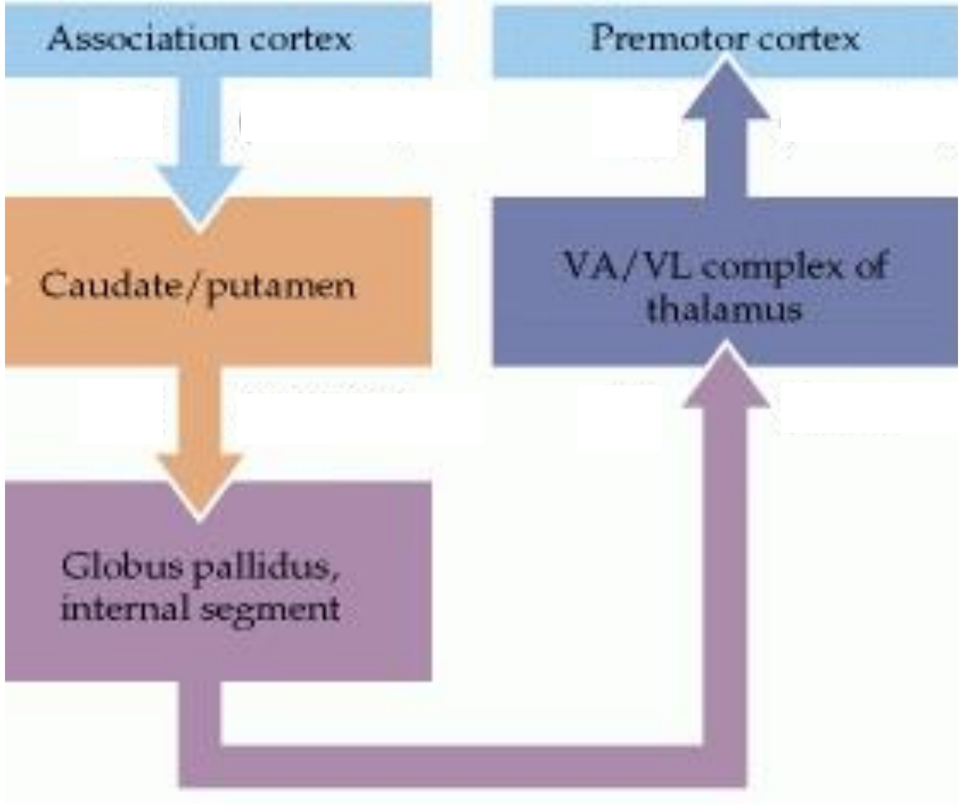
Globus pallidus internus (Gpi)

↓

Thalamus

↓

Cortex



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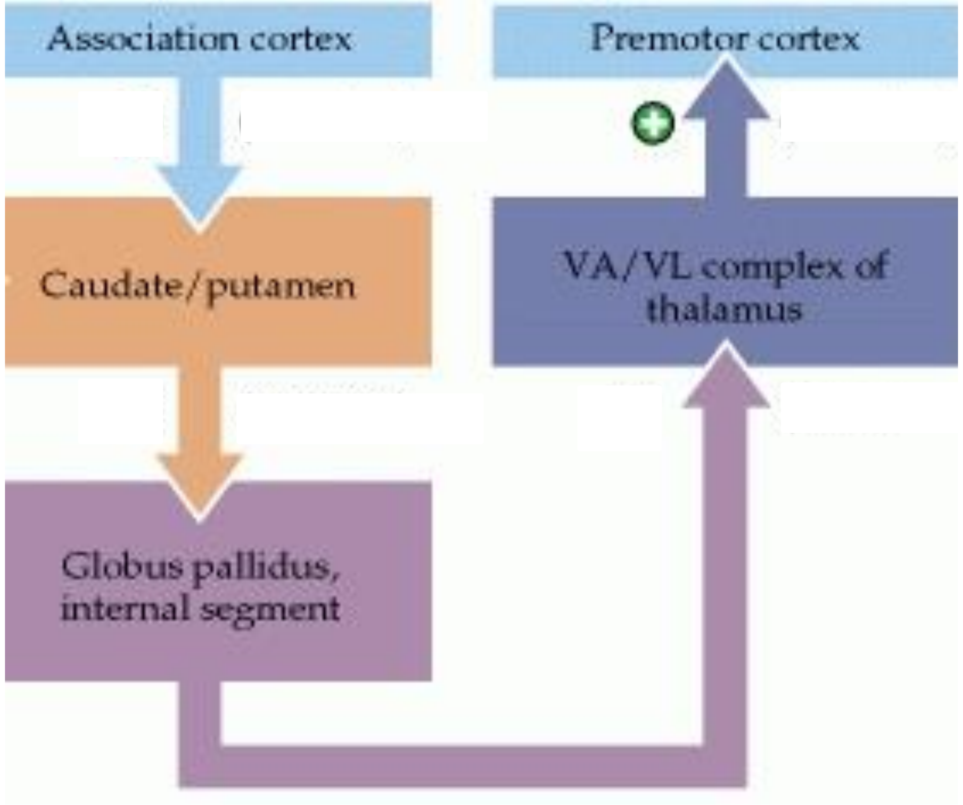
Direct pathway

- Thalamic motor nuclei activate motor cortex



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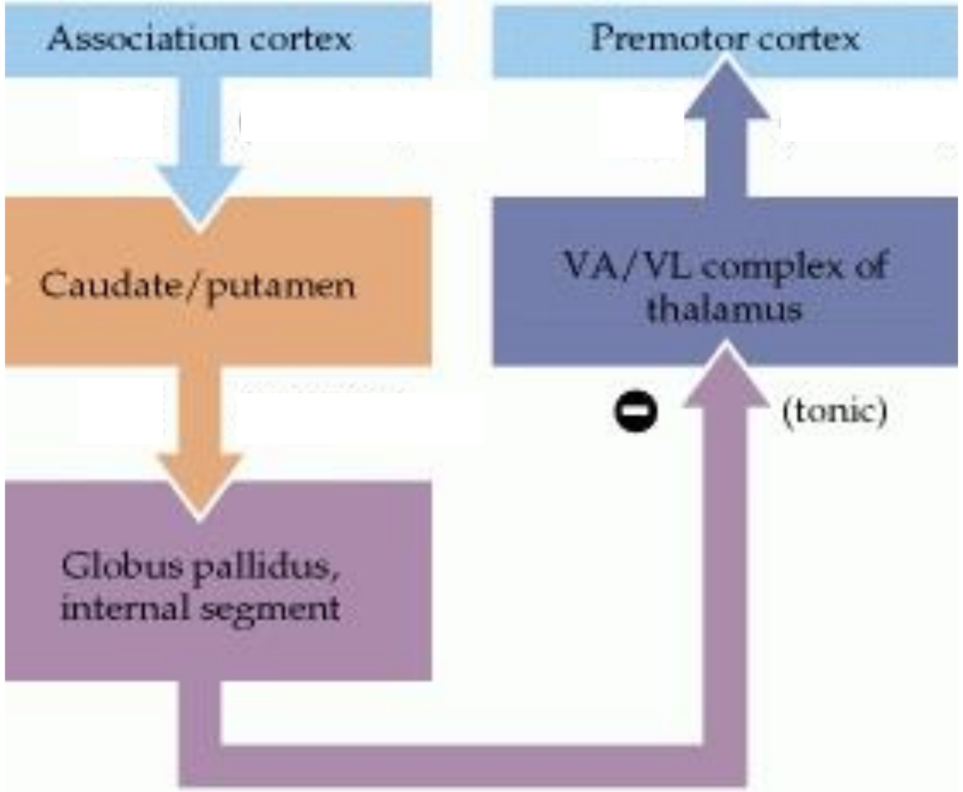
Direct pathway

- Thalamic motor nuclei activate motor cortex
- Tonic inhibitions of thalamic motor nuclei by GPi



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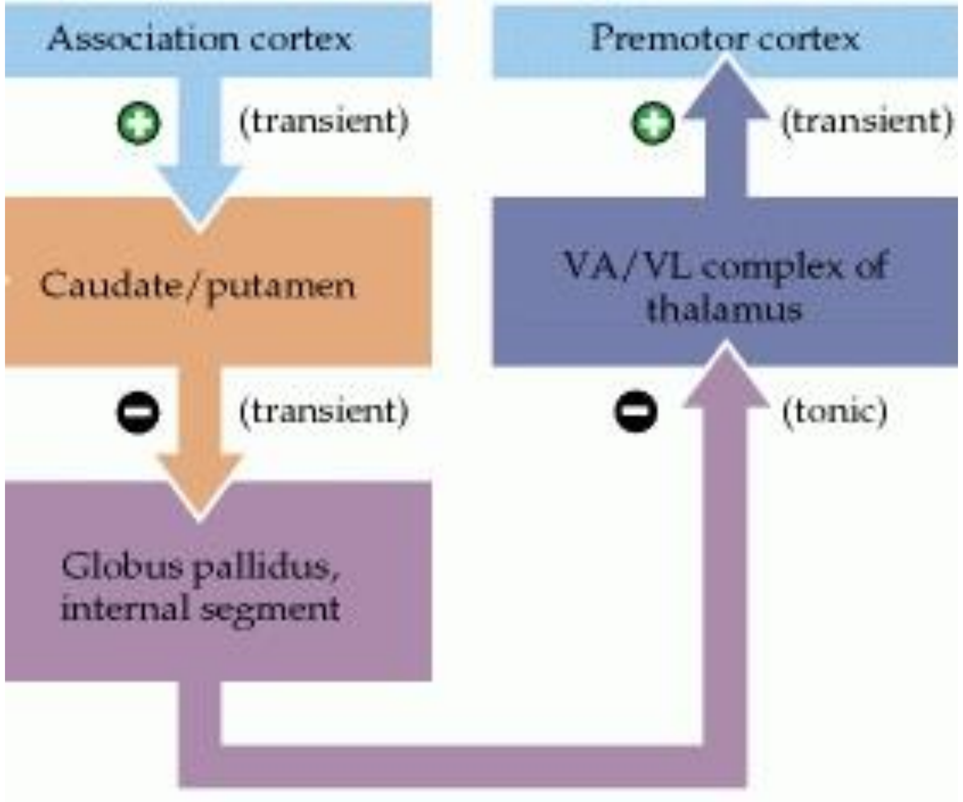
Direct pathway

- Thalamic motor nuclei activate motor cortex
- Tonic inhibitions of thalamic motor nuclei by GPi
- Activated corpus striatum transiently inhibits Gpi, resulting in transient disinhibition of thalamic motor nuclei



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Indirect pathway

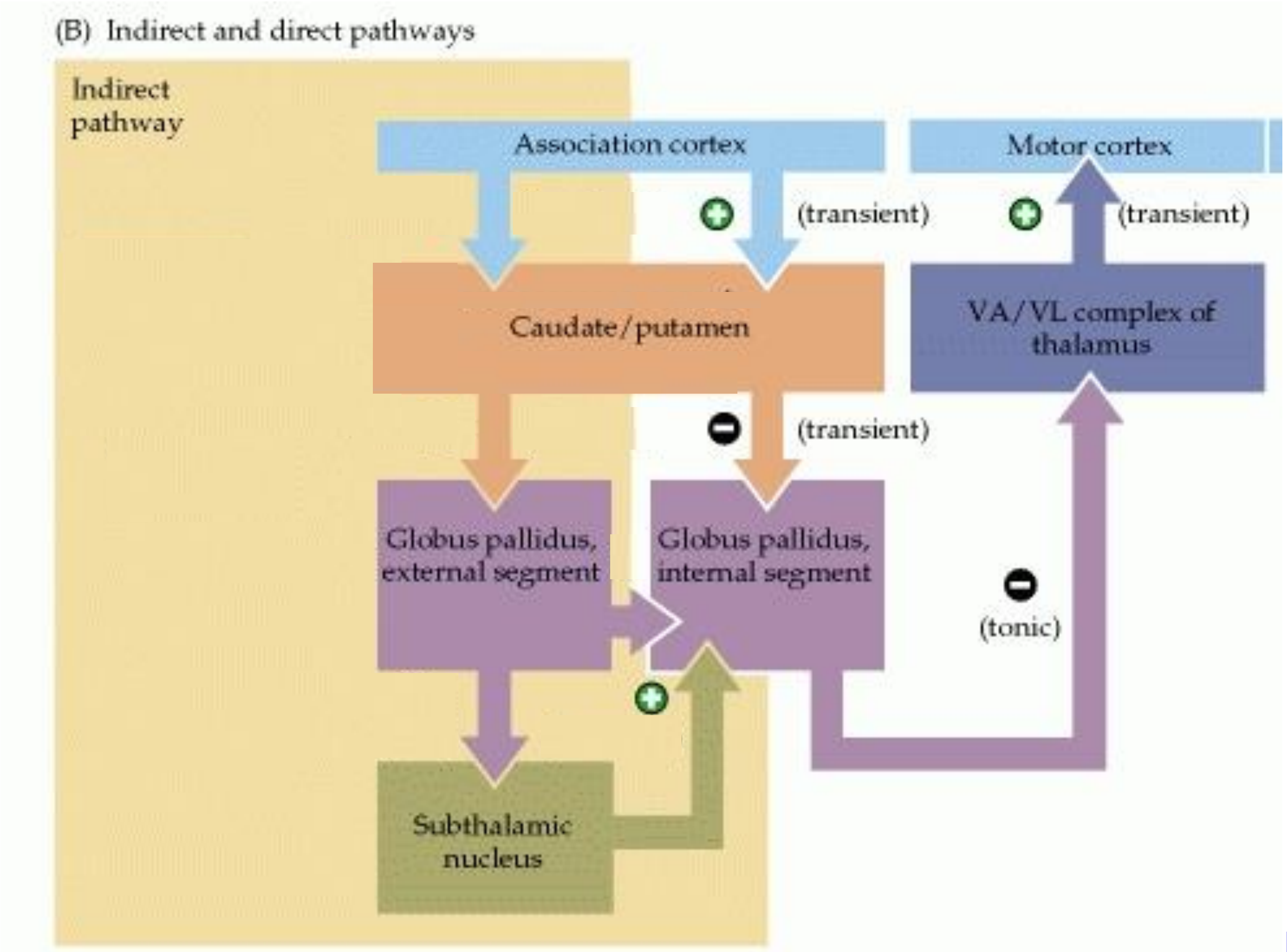
Kortex

Corpus striatum

Globus pallidus externus (GPe)

Nucleus subthalamicus (NS)

GPi



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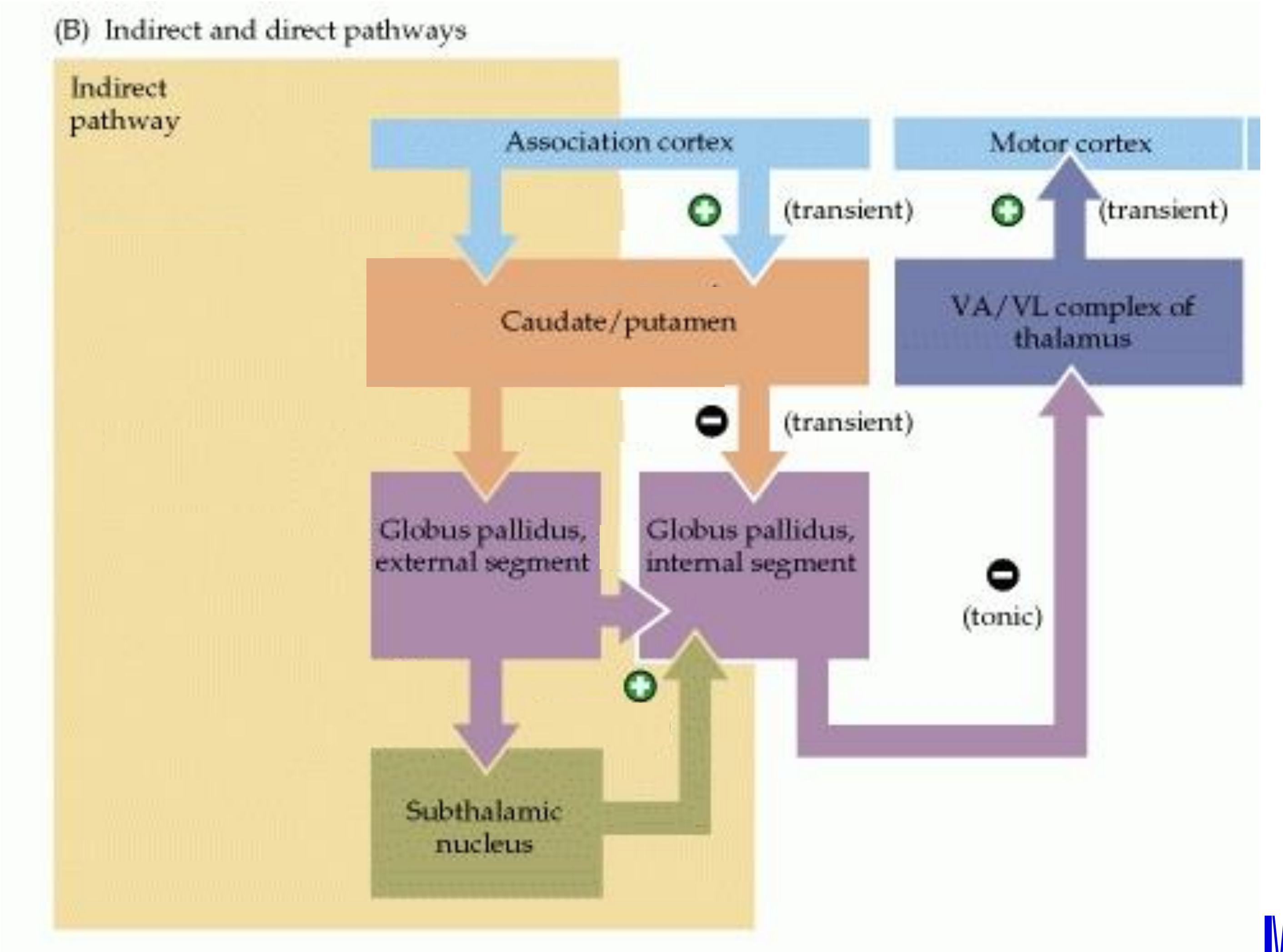
Indirect pathway

- NS activates GPi



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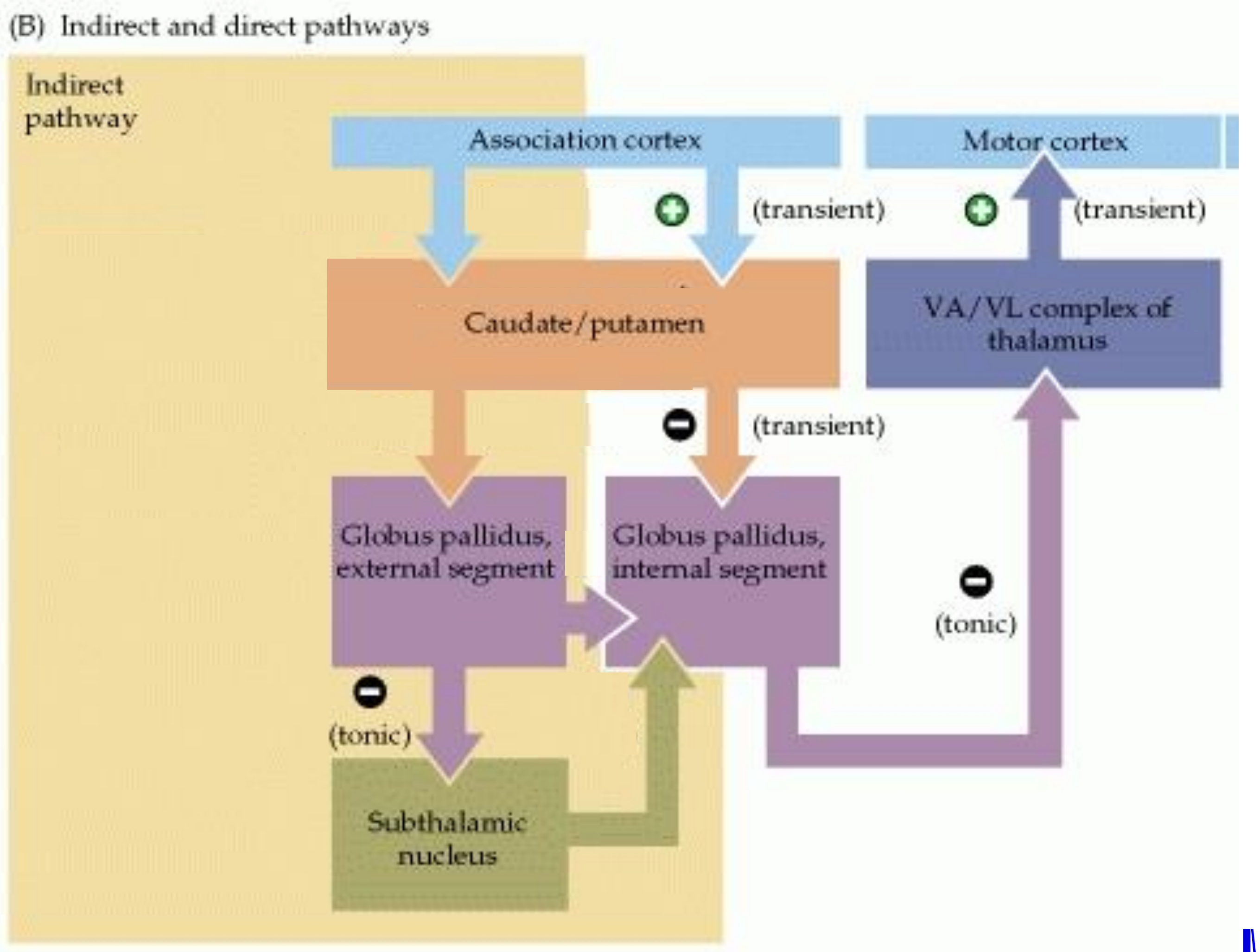
Indirect pathway

- NS activates GPi
- GPe tonically inhibits NS



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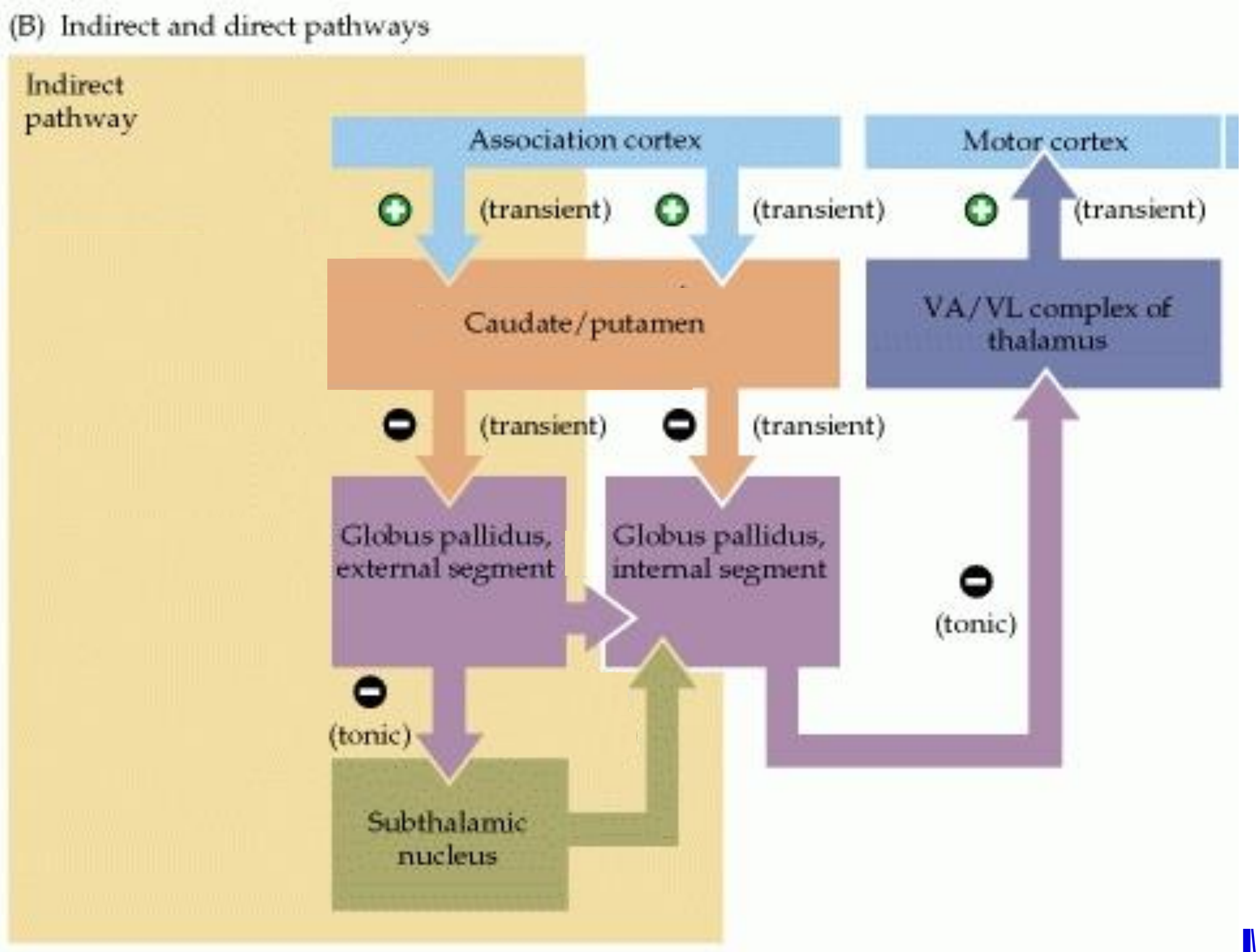
Indirect pathway

- NS activates GPi
- GPe tonically inhibits NS
- Corpus striatum transiently inhibits GPe



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Indirect pathway

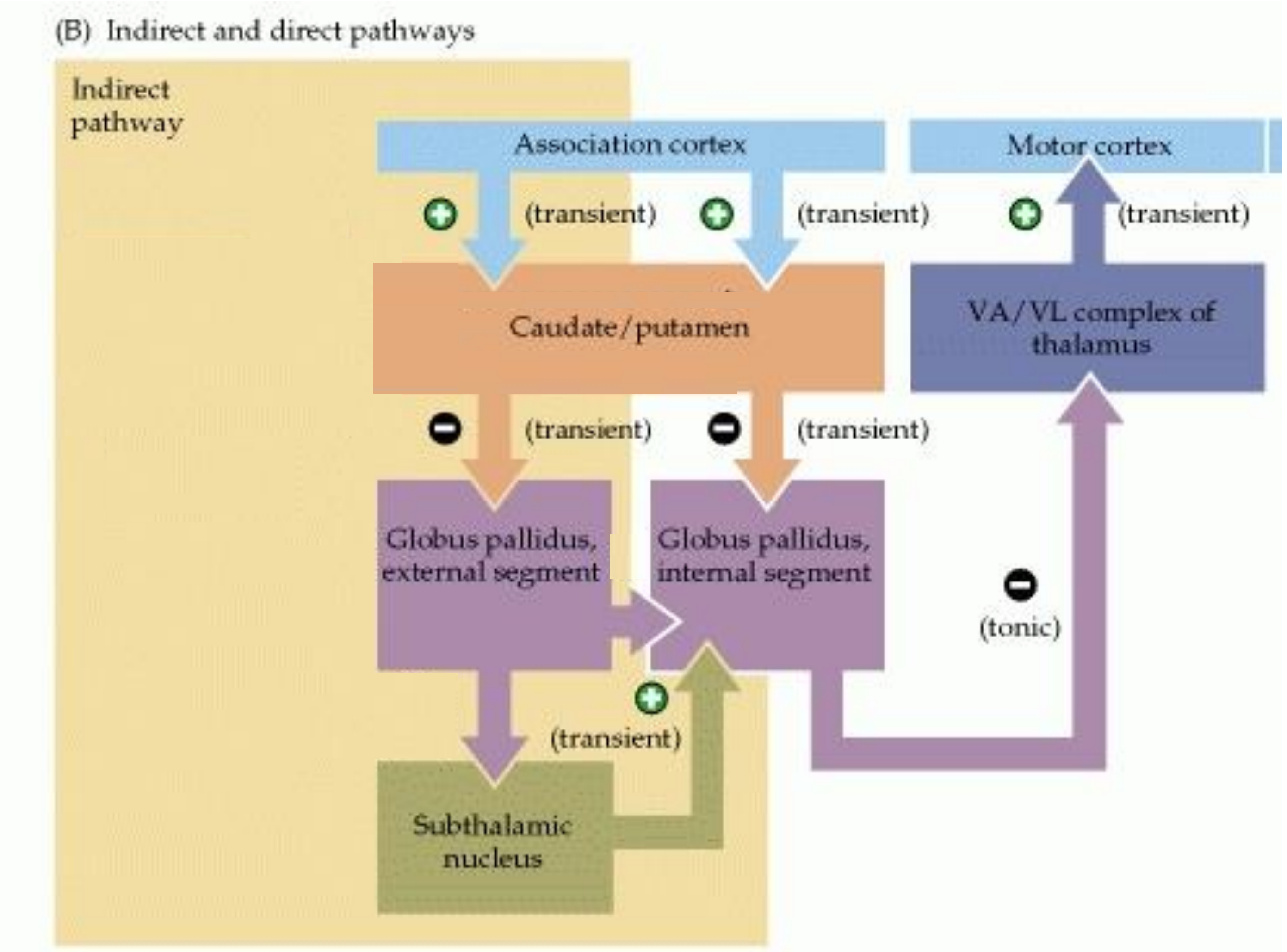
- NS activates GPi
- GPe tonically inhibits NS
- Corpus striatum transiently inhibits GPe

↓

NS disinhibition

↓

Gpi activation



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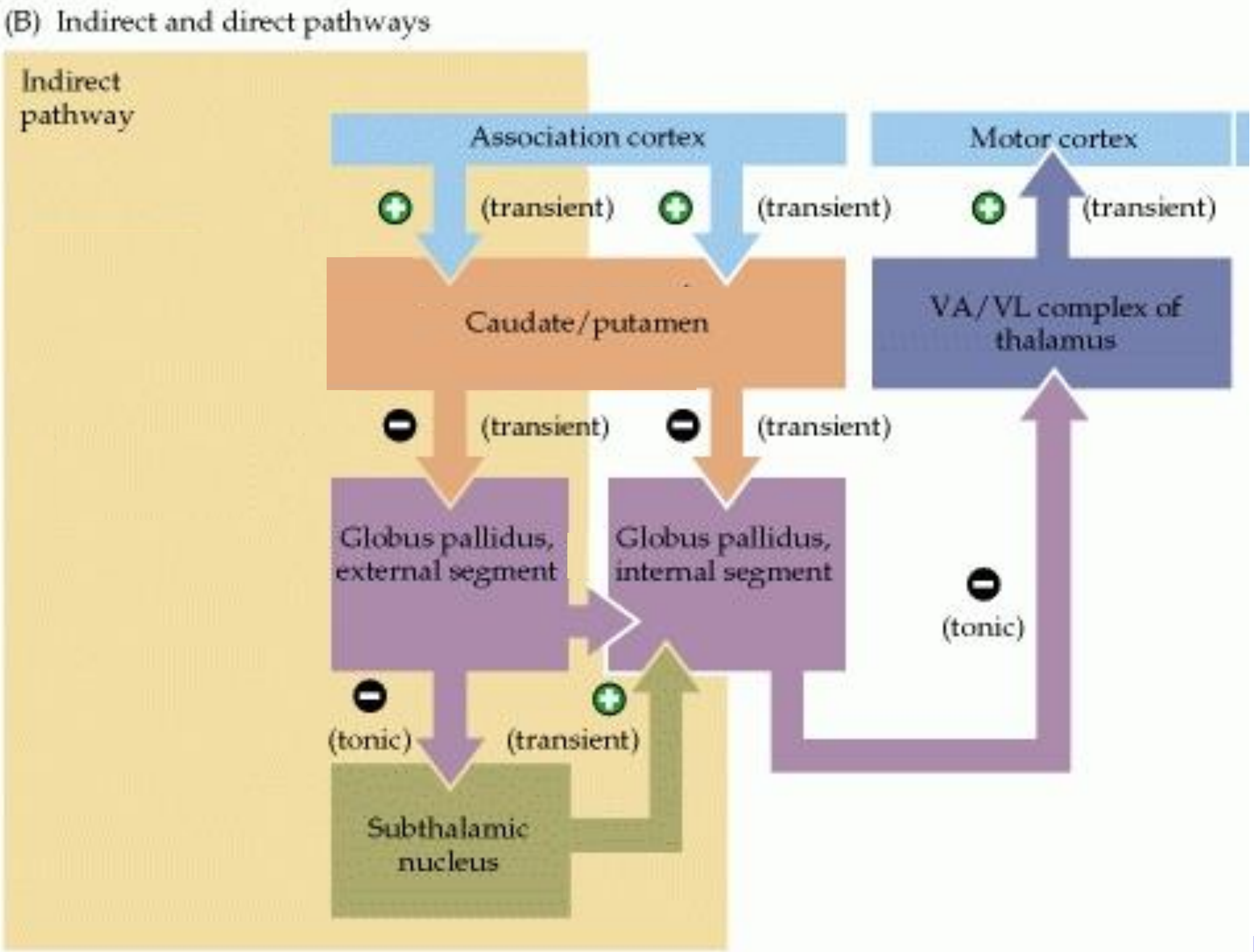
↓

NS disinhibition

↓

Gpi activation



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Indirect pathway

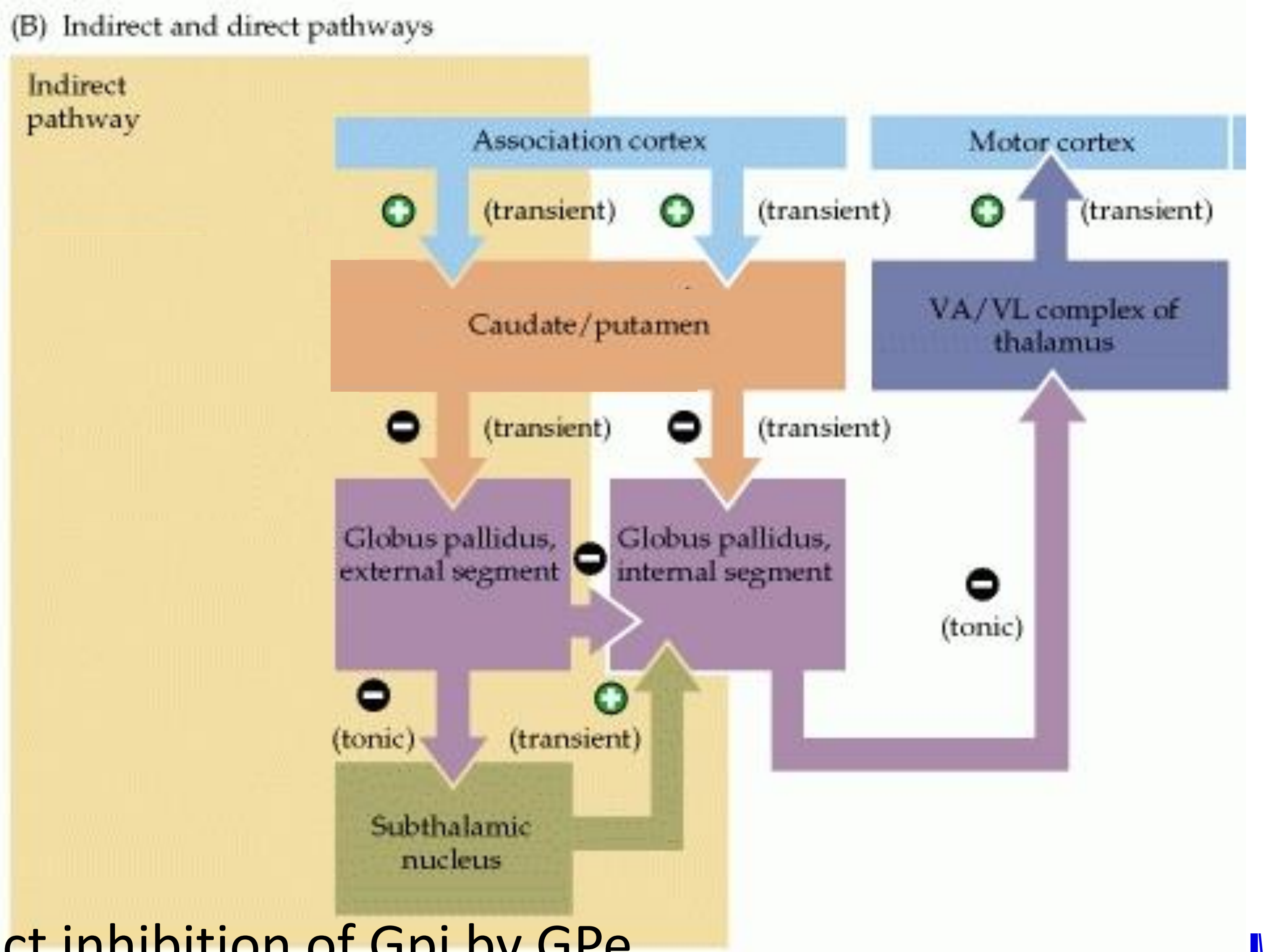
- NS activates GPi
- GPe tonically inhibits NS
- Corpus striatum transiently inhibits GPe

  ↓

  NS disinhibition

  ↓

  Gpi activation



- Less important is a direct inhibition of Gpi by GPe

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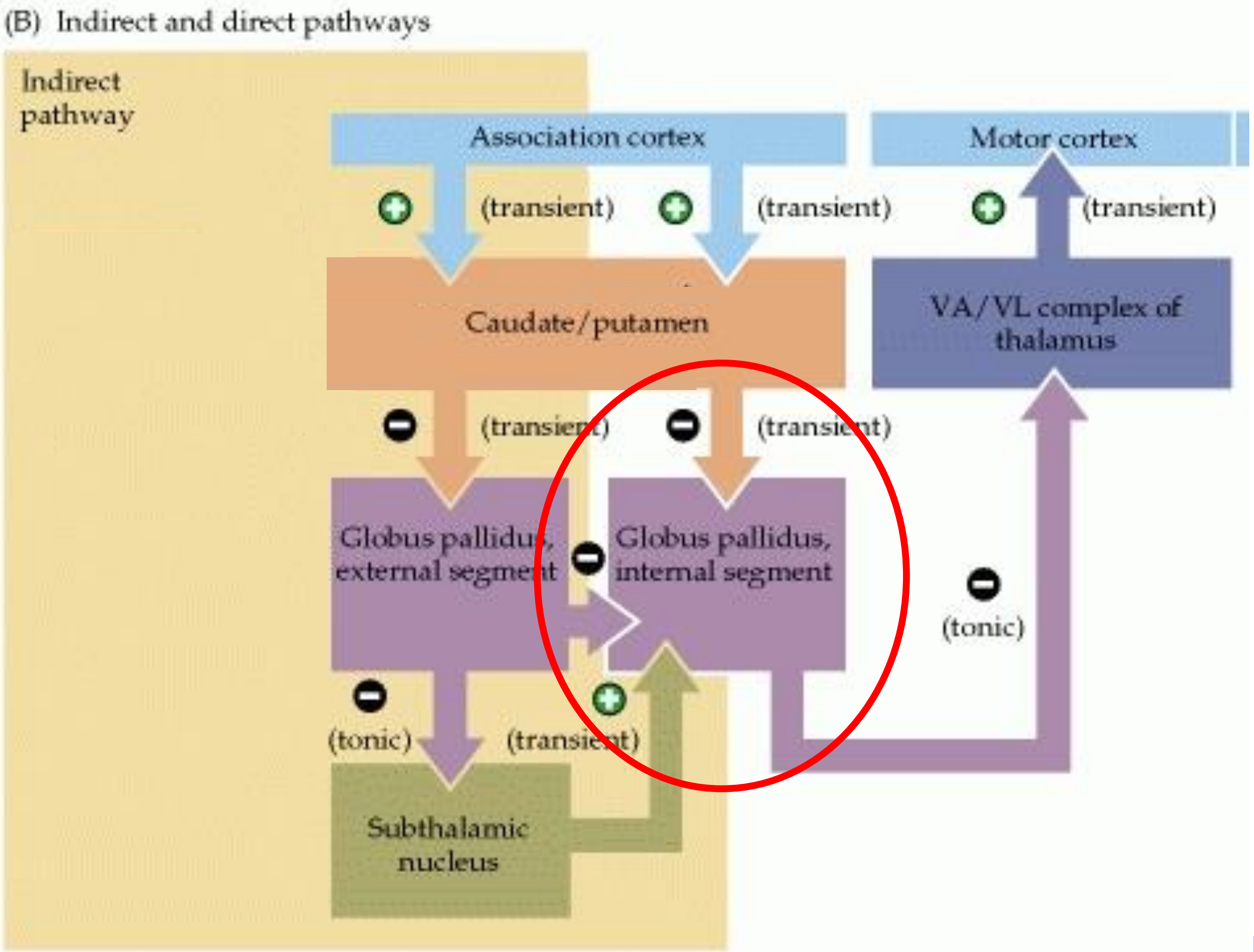
Direct and indirect pathway differences

- Direct pathway
  - ➢ Motor cortex activation

- Indirect pathway
  - ➢ Motor cortex inhibition



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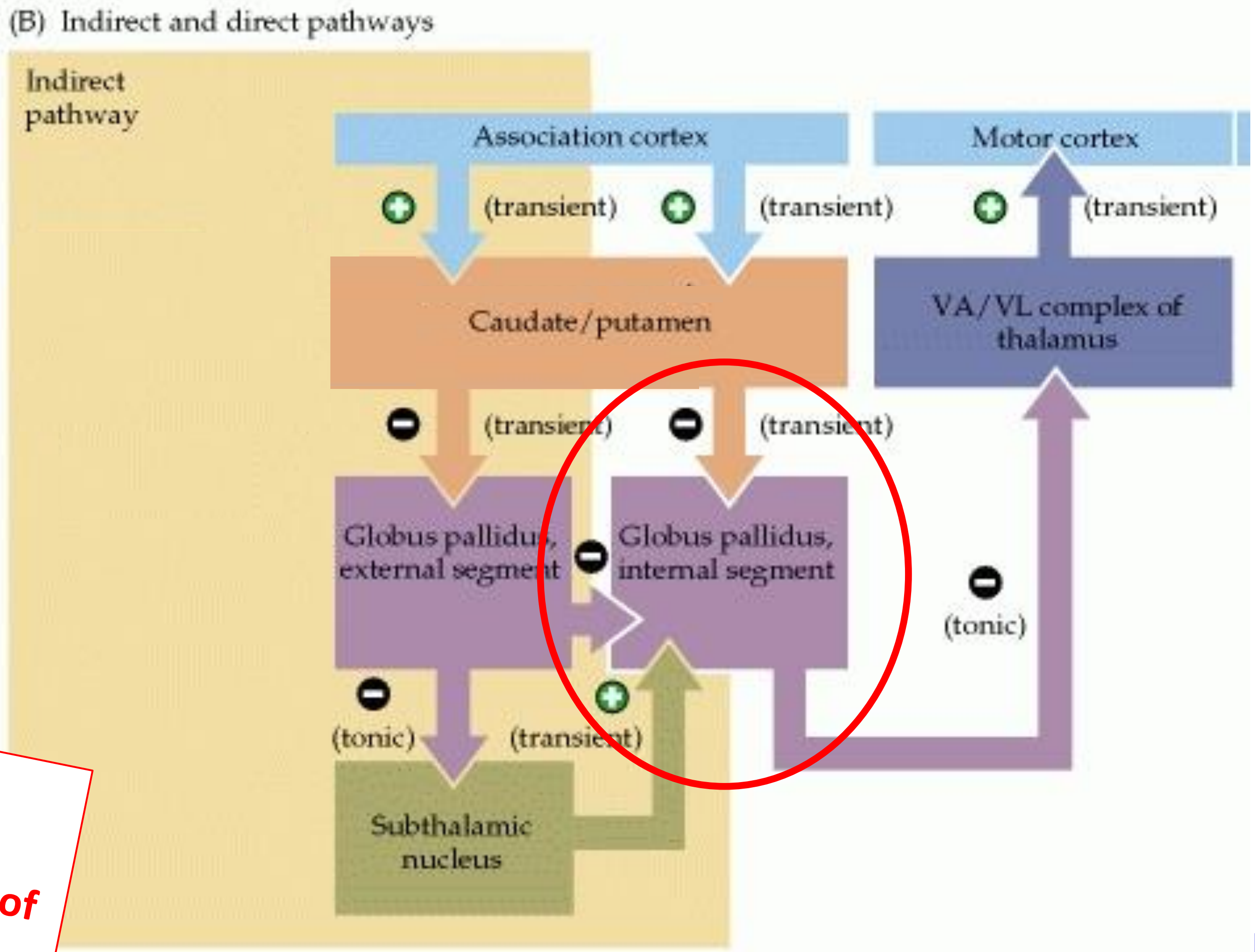
Direct and indirect pathway differences

- Direct pathway
  - Motor cortex activation

- Indirect pathway
  - Motor cortex inhibition

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



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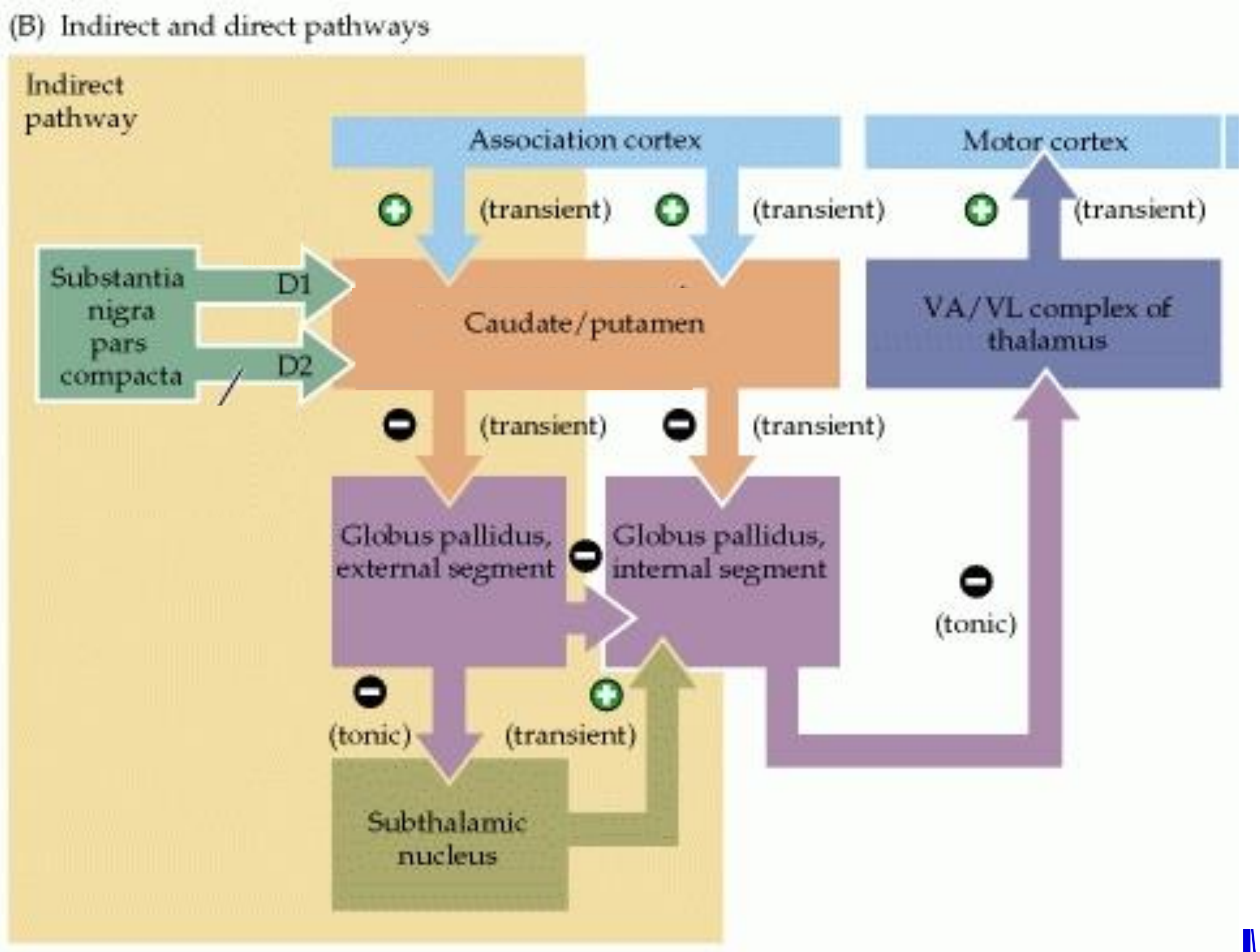
Dopaminergic projections

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



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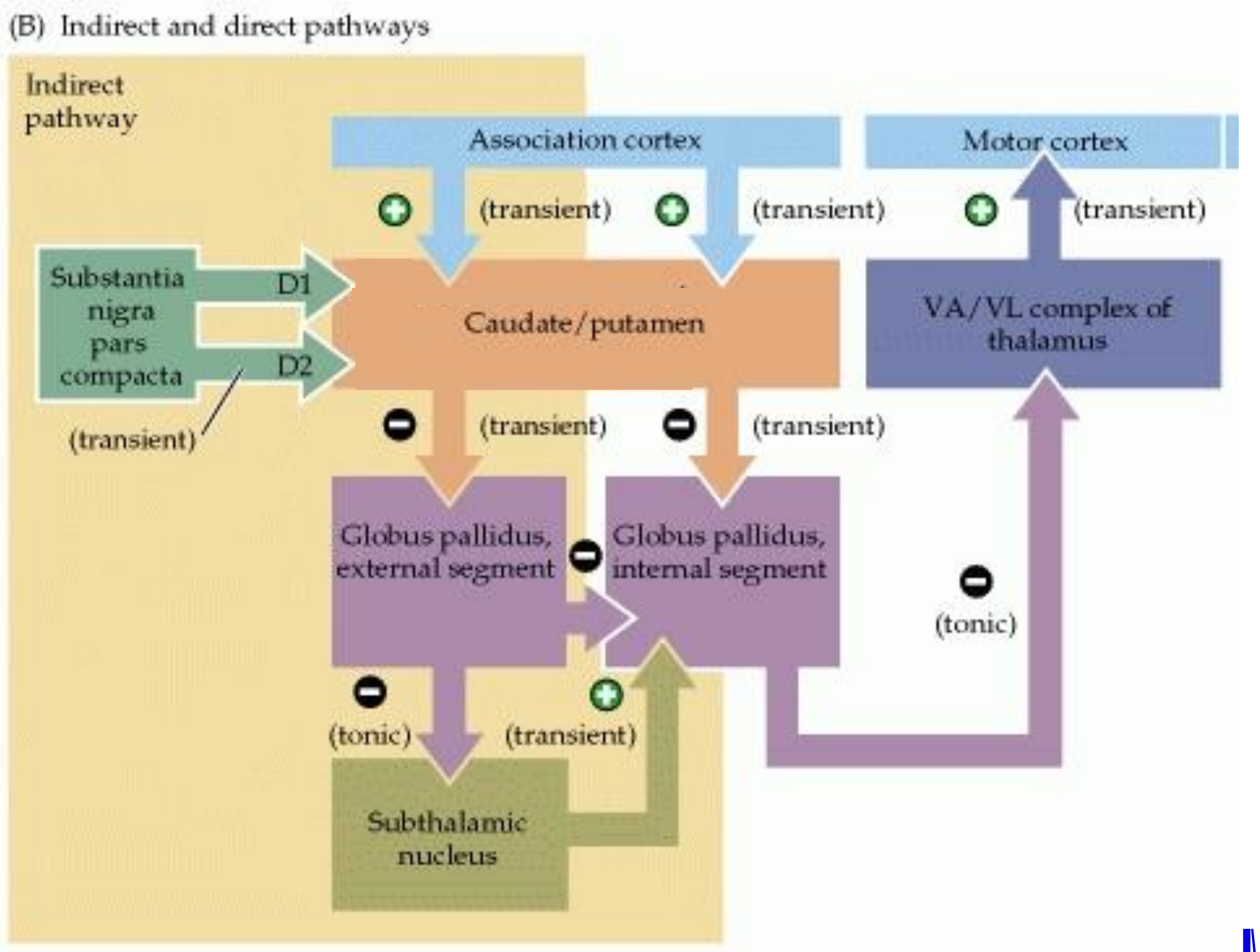
Dopaminergic projections

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

- Direct pathway activation
  - D1 receptors

- Indirect pathway inhibition
  - D2 receptors



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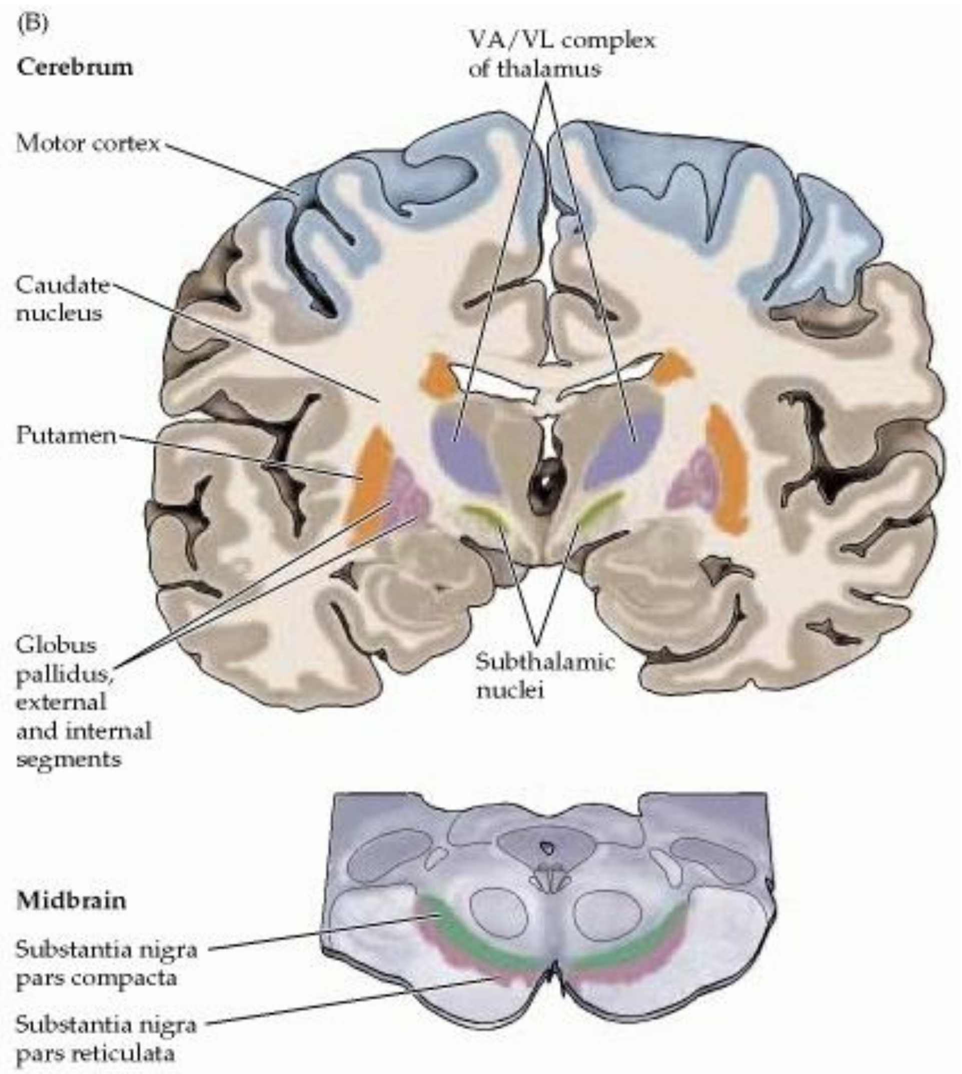
Basal ganglia

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



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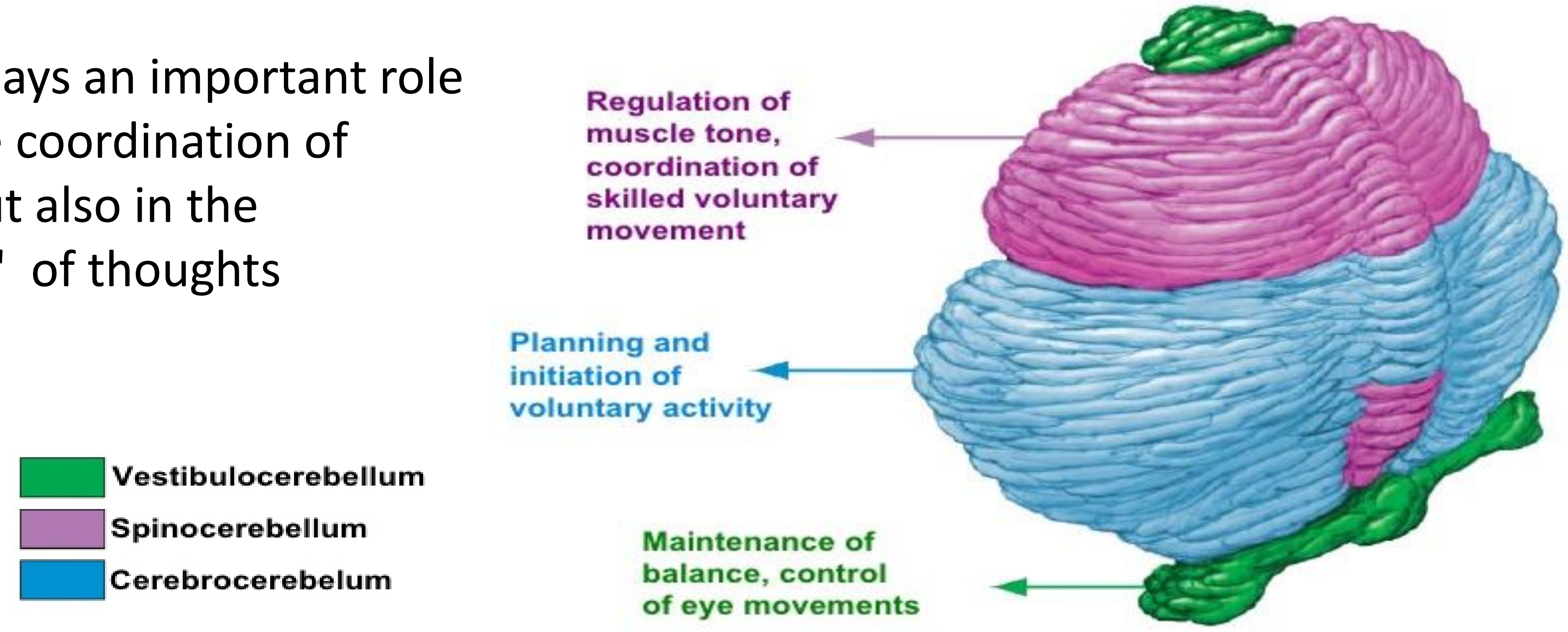
Cerebellum

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



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

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80. Hierarchic organization of motor system – reflex vs. voluntary motor activity

- Hierarchy of movement
  - Reflex – economical, uniform, protective, fast
  - Rhytmic – economical solution for complex uniform actions (breathing, walking…)
  - Voluntary – non-economical, unique, relatively slow
- Classification and description of reflexes
- Fixed action pattern and rhythmic movement (definition and examples)
- Voluntary motor control
  - Overview of structures involved in planning and execution of voluntary motor activity
  - Motor cortex organization (primary, premotor and supplementray motro cortex…)
  - Brief description of pyramidal tract

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81. The basic functions of basal ganglia

- Brief description of basal ganglia function (loops, motor, non-motor)
- Overview of basal ganglia nuclei and the conncetions
- Description of direct and indirect pathway

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