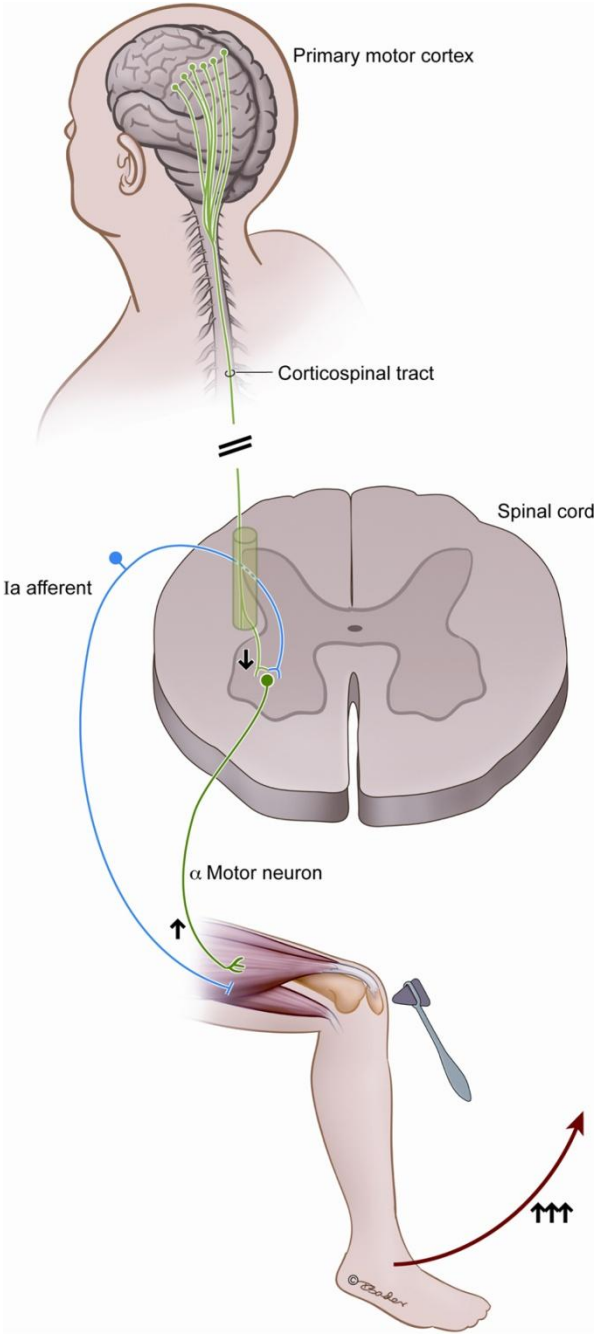
13

Motor system II

Introduction



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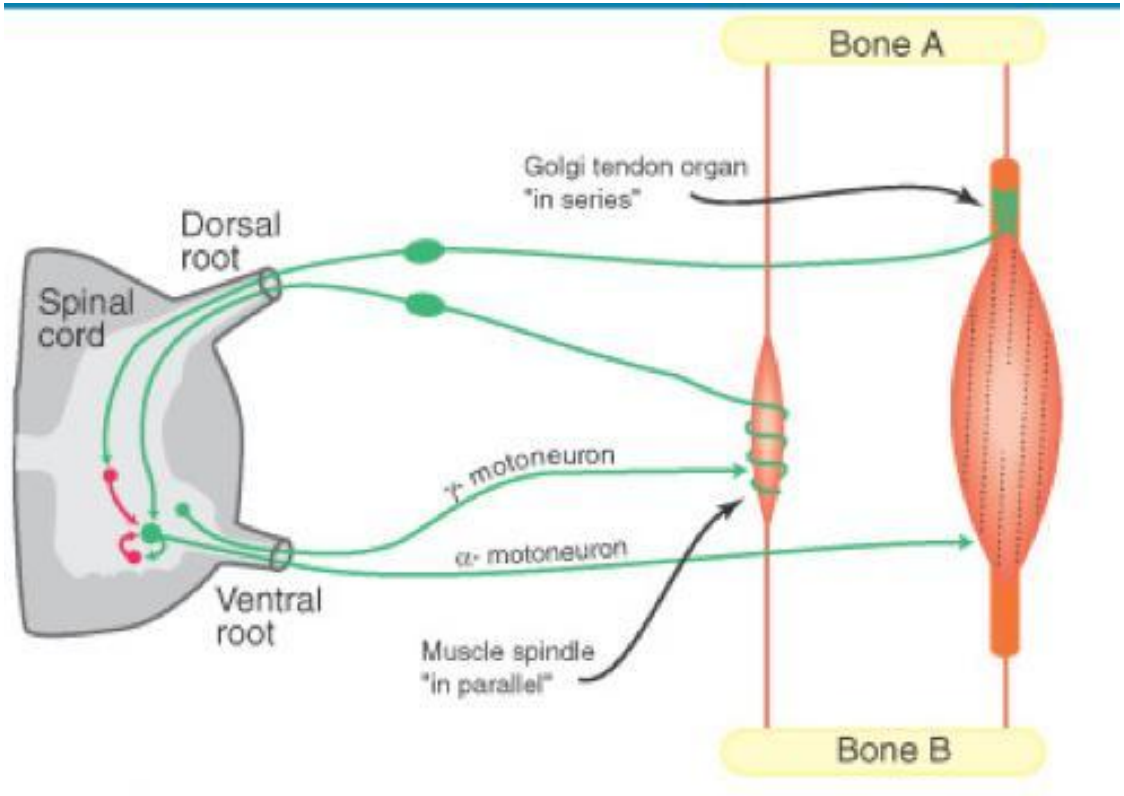
Introduction



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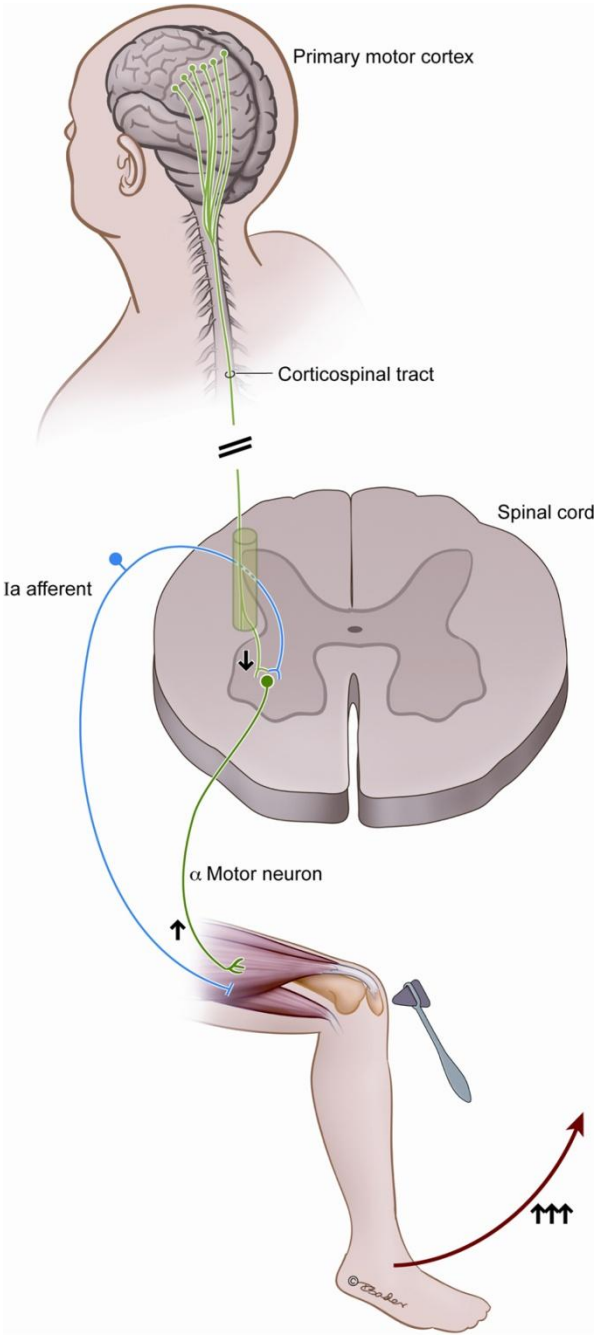

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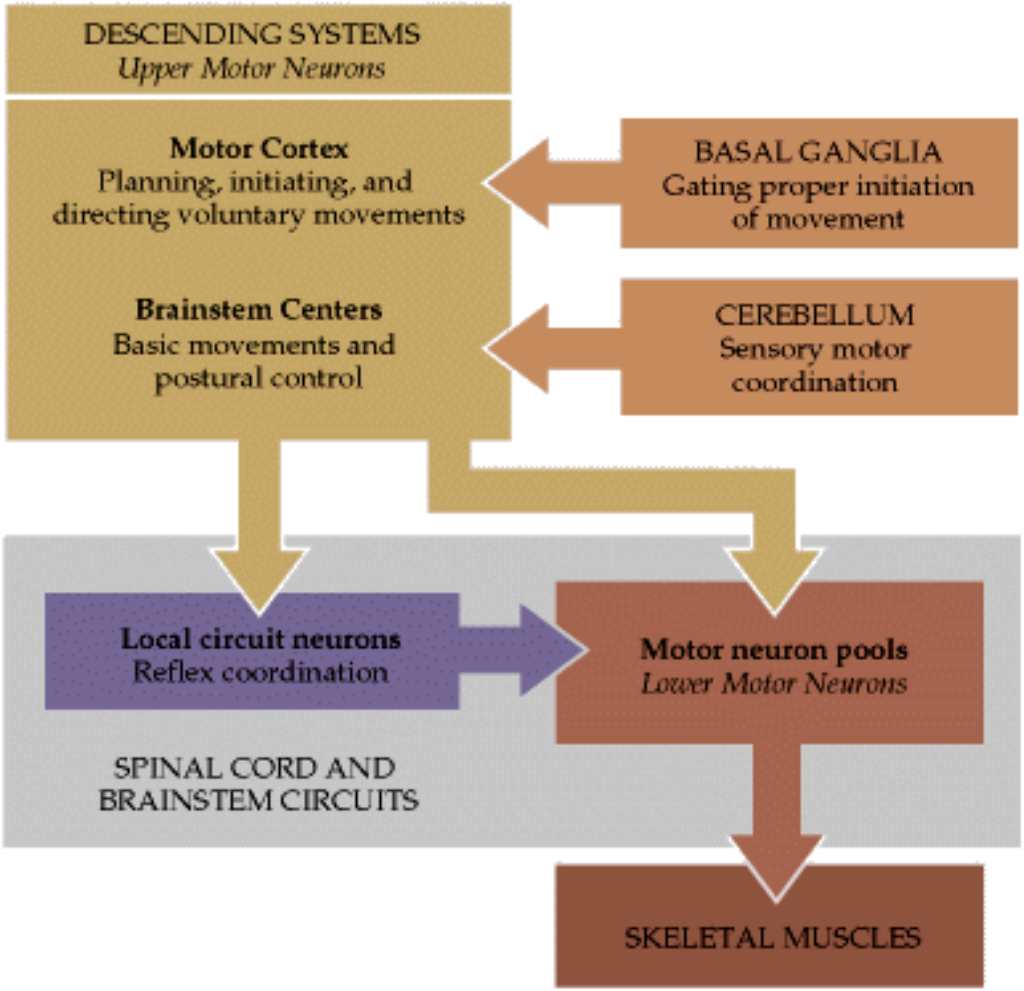
Hierarchic organization of motor system



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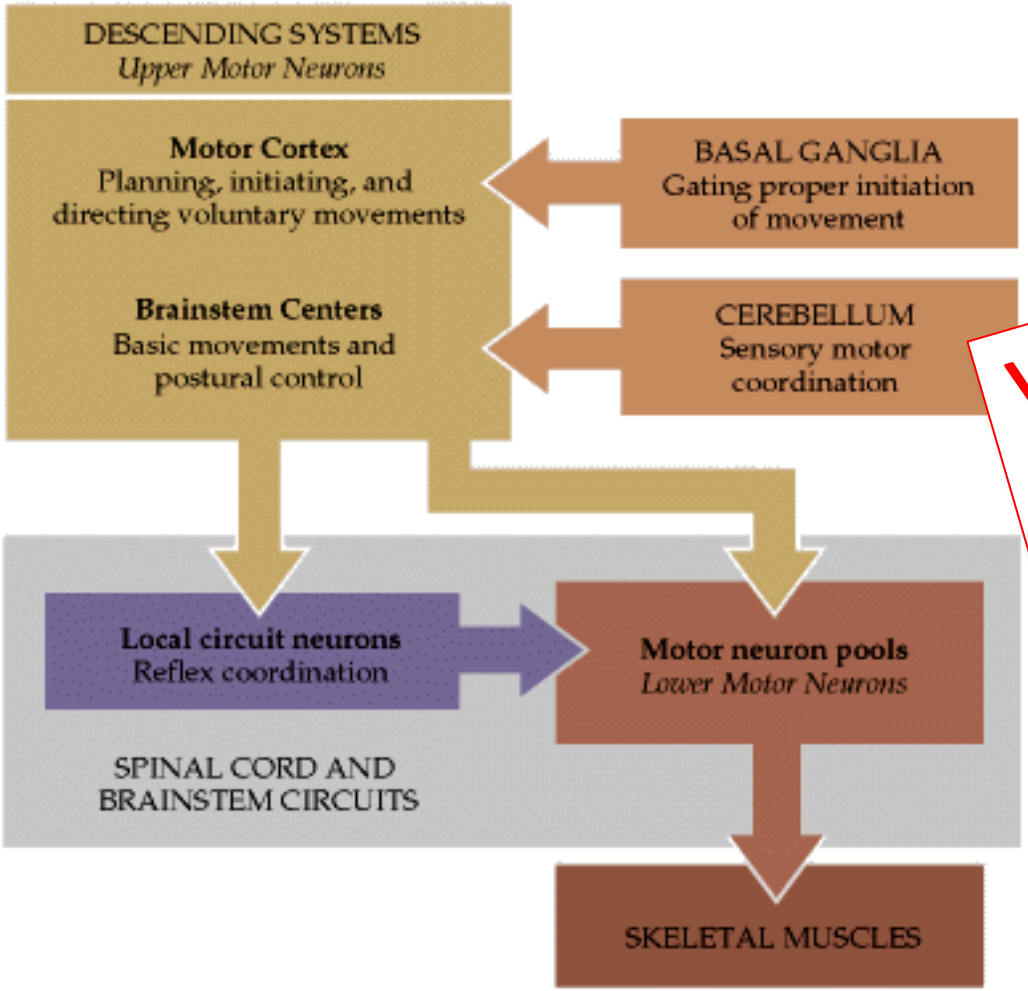
Hierarchic organization of motor system



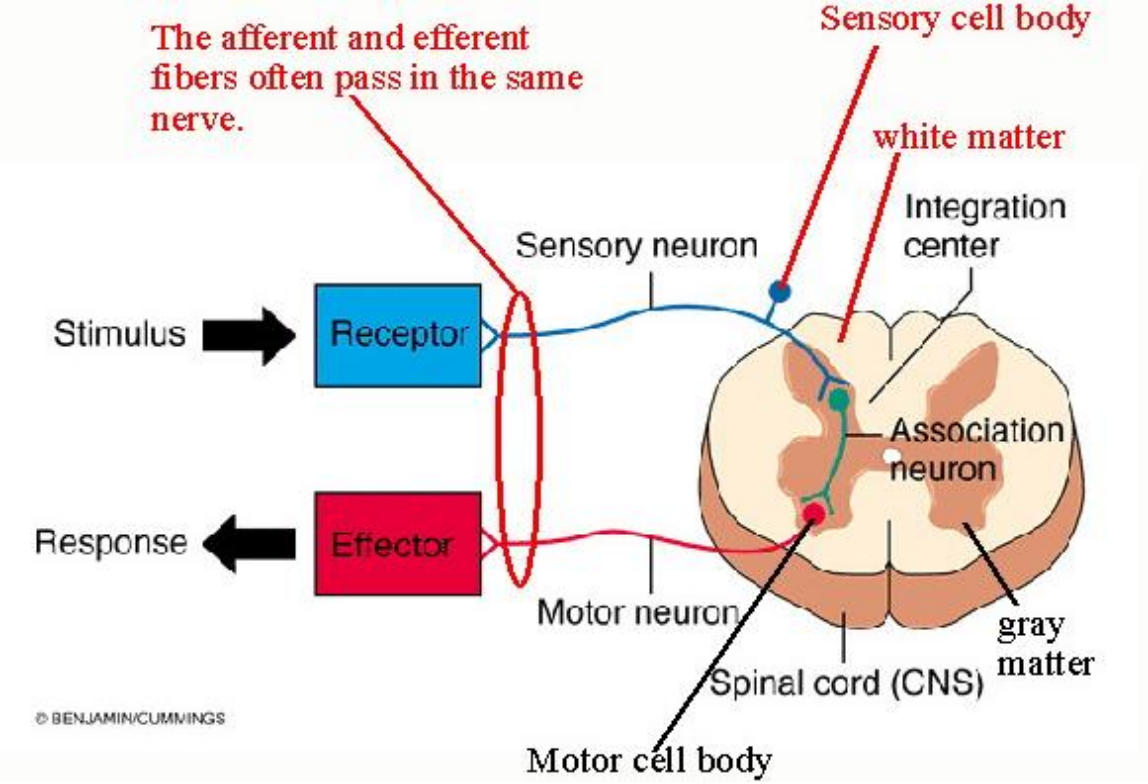
Voluntary movement

Reflex movement

Rhythmic movement

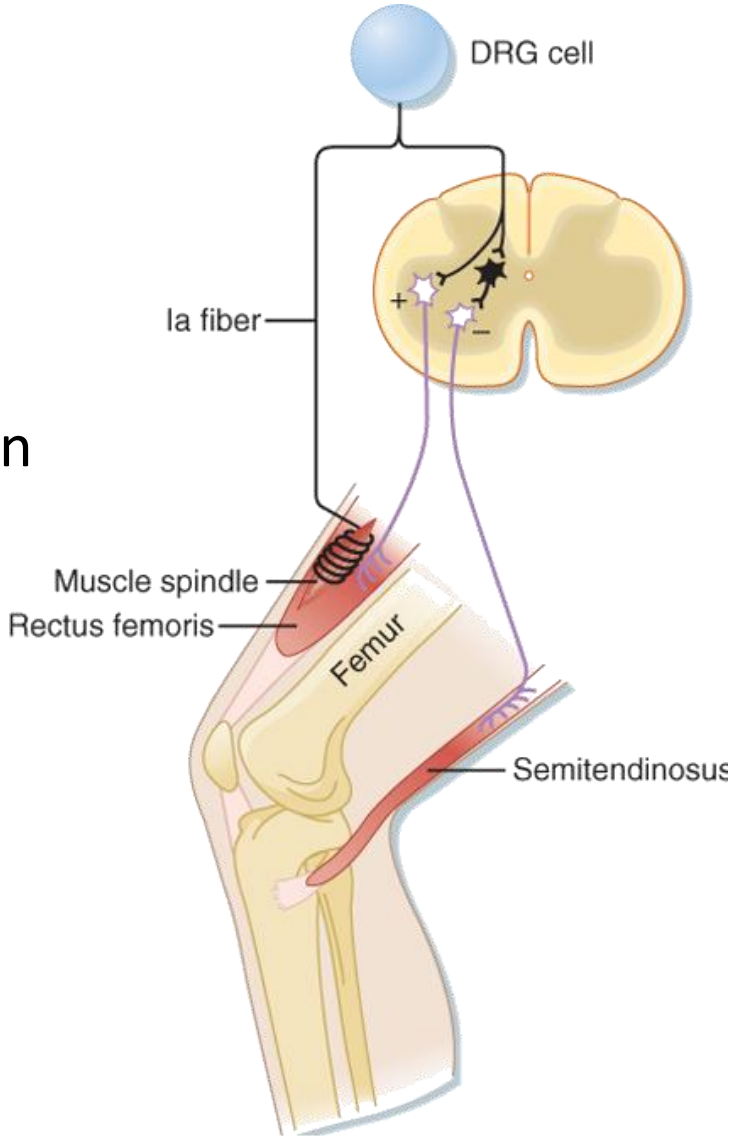
Reflex

- Reflex movement
  - Stereotype (predictable)
  - Involuntary
- Proprioceptive
- Exteroceptive
- Monosynaptic
- Polysynaptic
- Monosegmental
- Polysegmental



Proprioceptive reflex

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



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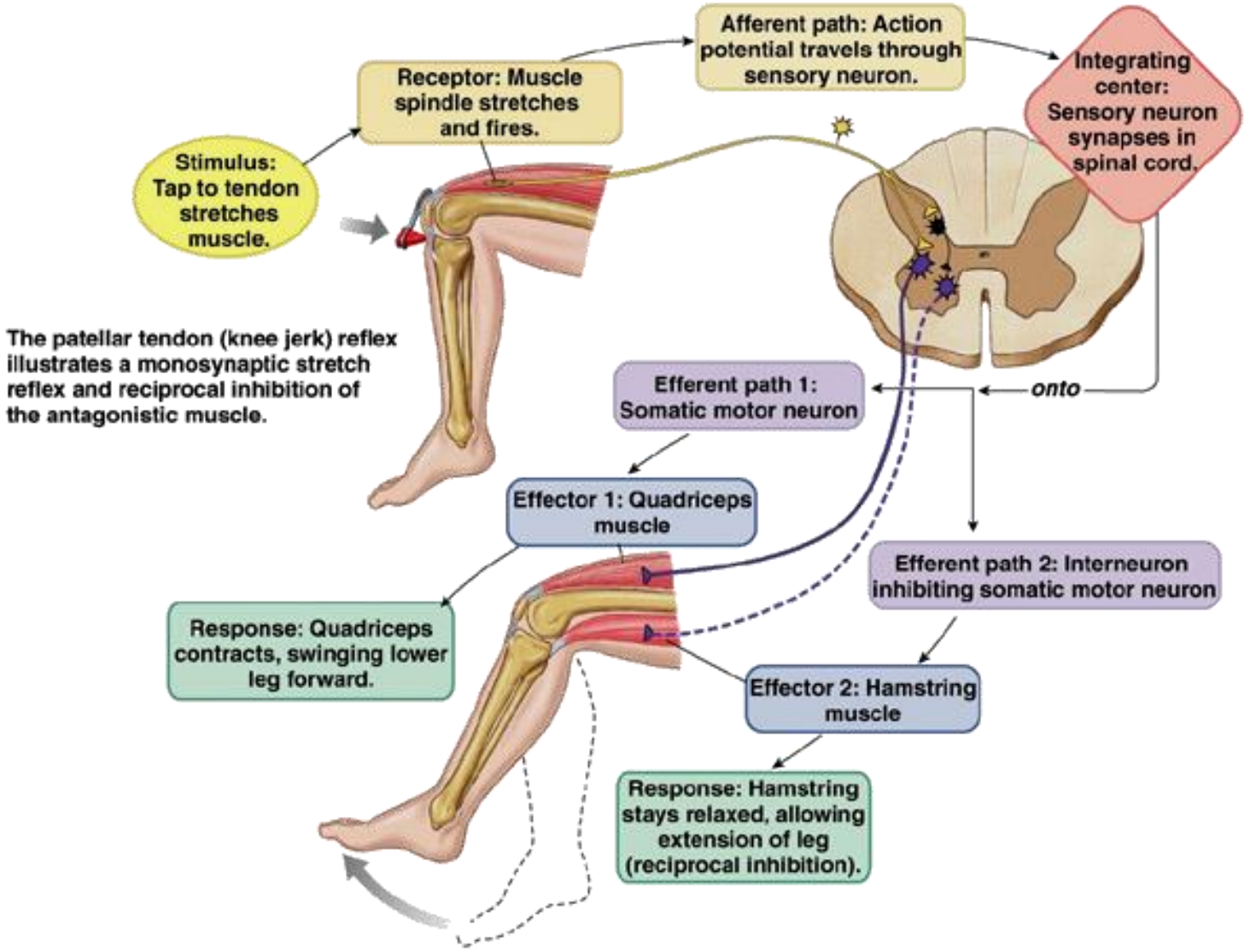
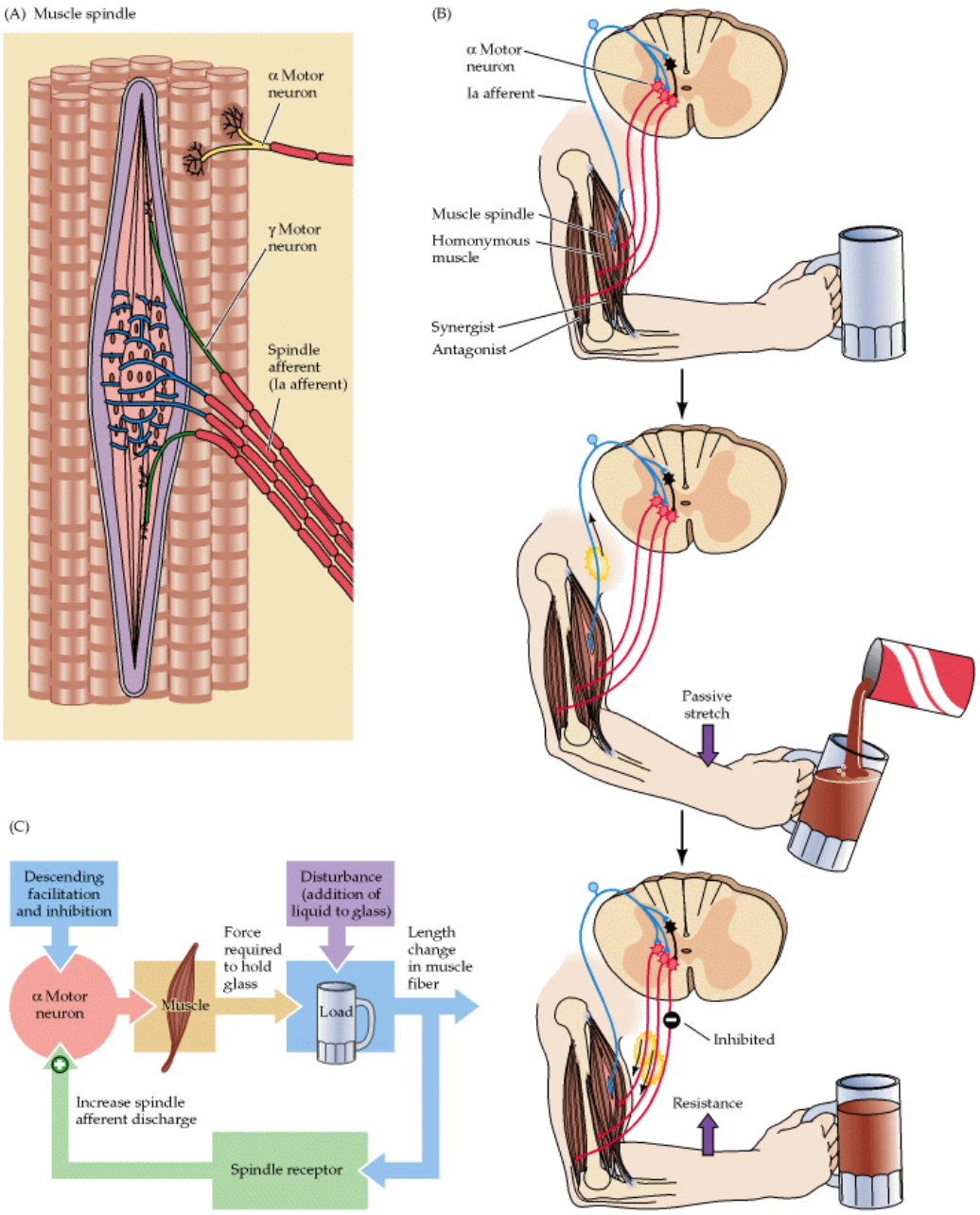
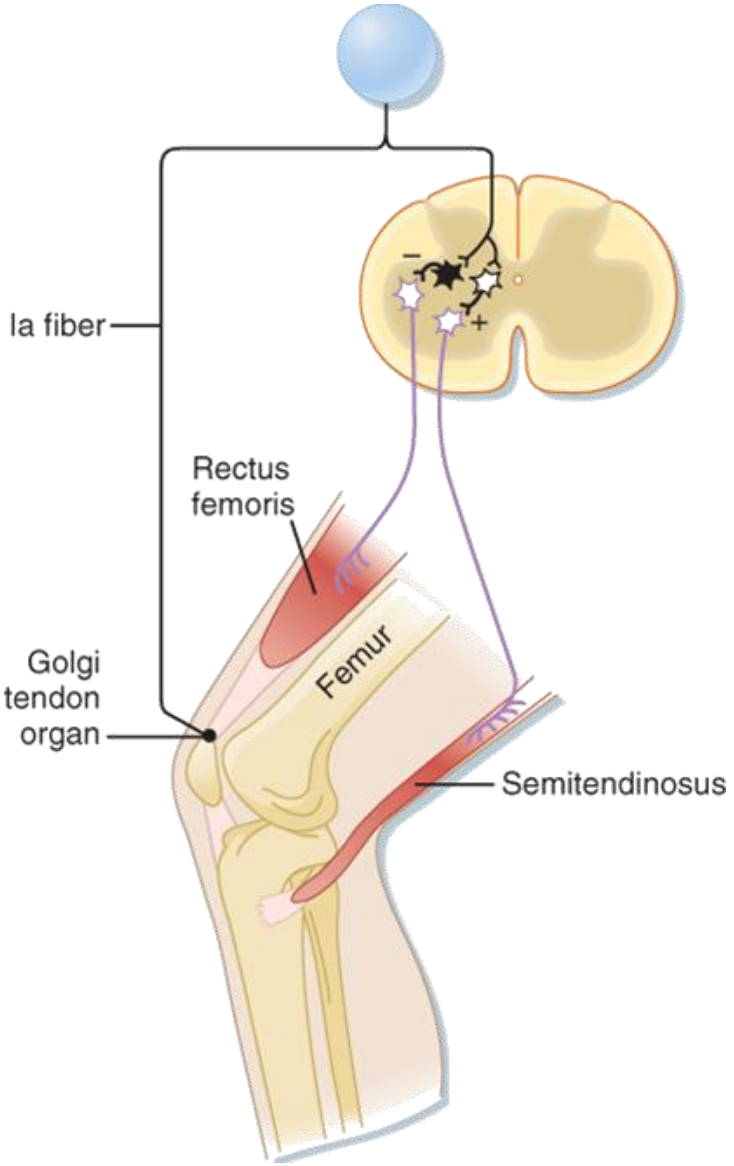


Fig. 13-7


(A) Muscle spindle
α Motor neuron
γ Motor neuron
Spindle afferent (Ia afferent)
(B)
α Motor neuron
Ia afferent
Muscle spindle
Homonymous muscle
Synergist
Antagonist
Passive stretch
Inhibited
Resistance
(C)
Descending facilitation and inhibition
α Motor neuron
Muscle
Force required to hold glass
Disturbance (addition of liquid to glass)
Load
Length change in muscle fiber
Increase spindle afferent discharge
Spindle receptor

Proprioceptive reflex

- Inverse myotatic reflex
  - Monosegmental
  - Disynaptic/polysynaptic
  - Golgi tendon organ
- Homonymous muscle – inhibition
- Antagonist muscle– activation
- Protection against muscle damage caused by extensive force



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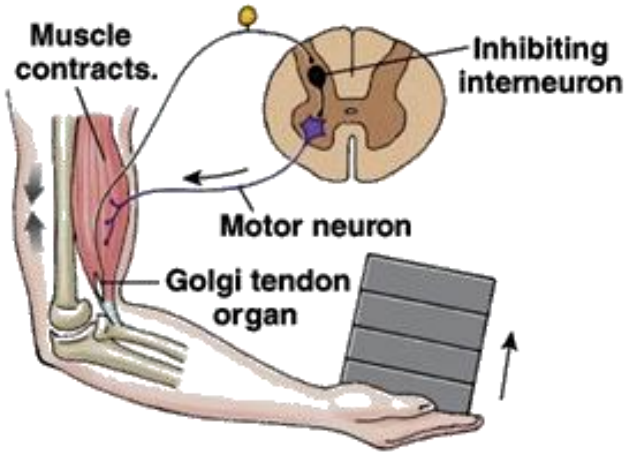
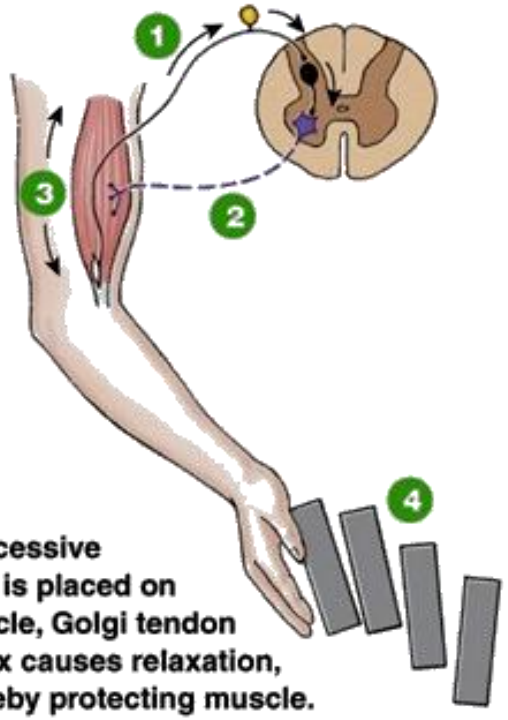
Golgi tendon reflex protects the muscle from excessively heavy loads by causing the muscle to relax and drop the load.



(d) Muscle contraction stretches Golgi tendon organ.



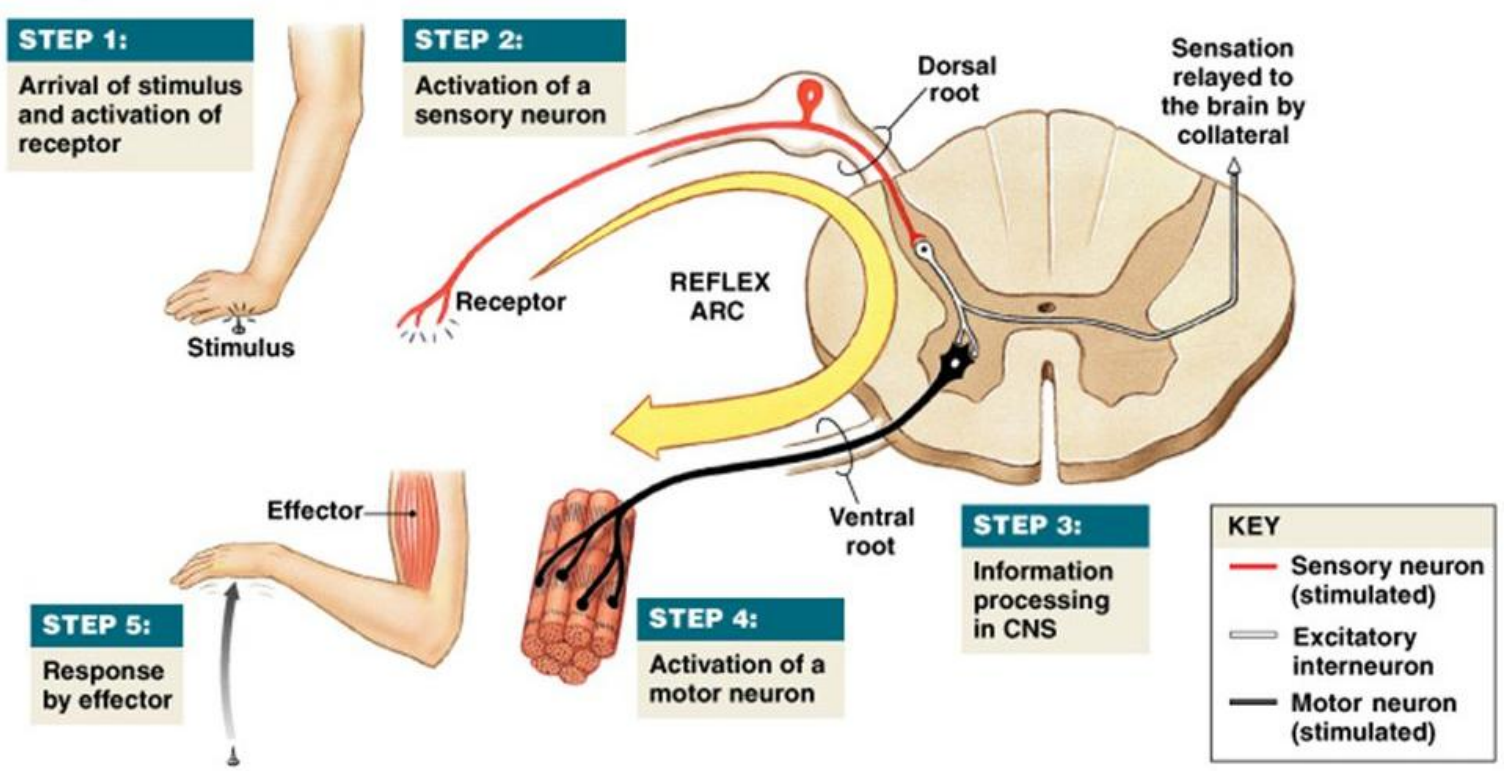
(e) If excessive load is placed on muscle, Golgi tendon reflex causes relaxation, thereby protecting muscle.

1. Neuron from Golgi tendon organ fires.
2. Motor neuron is inhibited.
3. Muscle relaxes.
4. Load is dropped.

Fig. 13-6b

Exteroceptive reflex

- Polysynaptic
- Polysegmental



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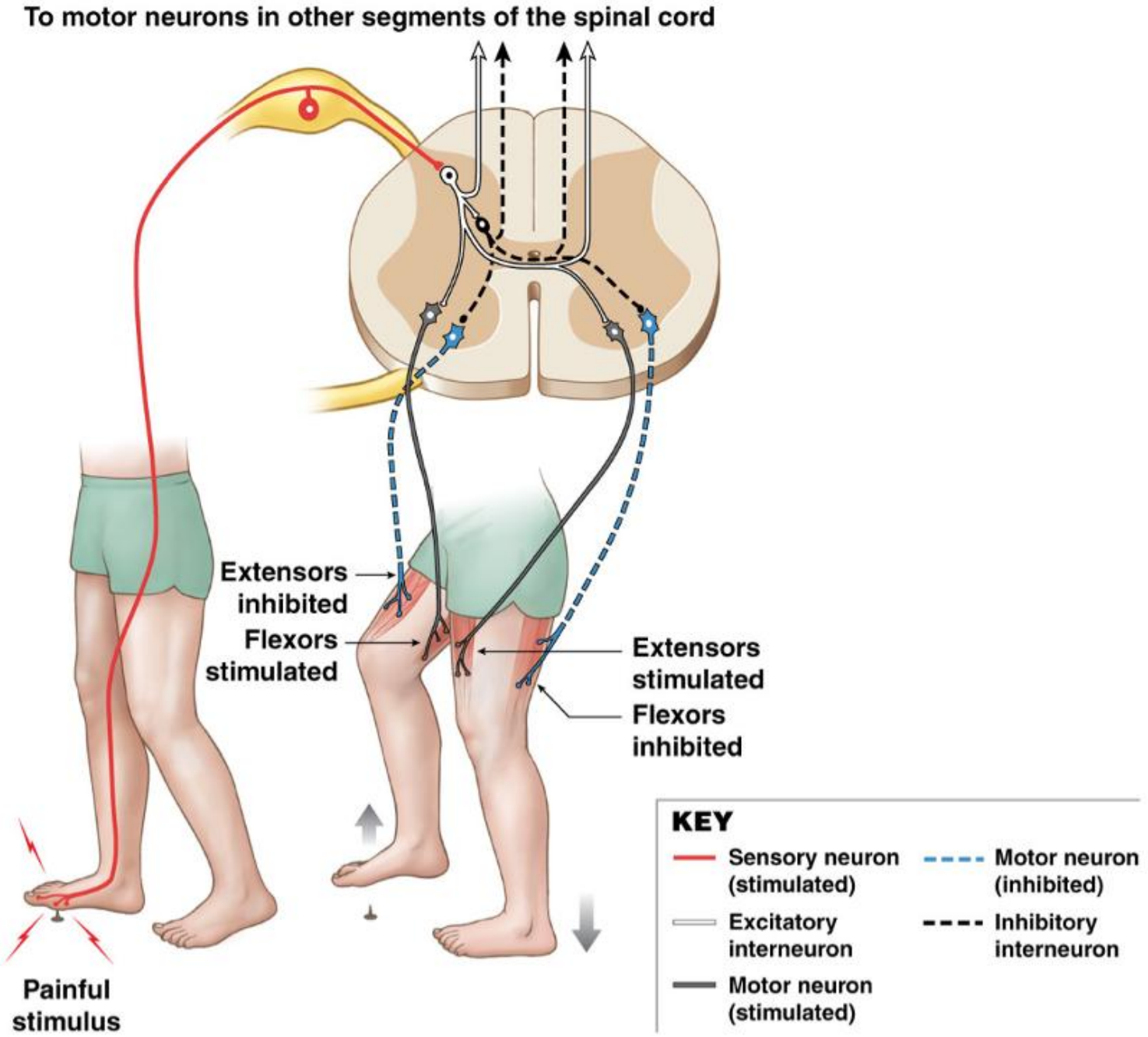

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Subcortical (stem) pathways controlling lower motoneurons

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

Fixed action pattern and rhythmic movement

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

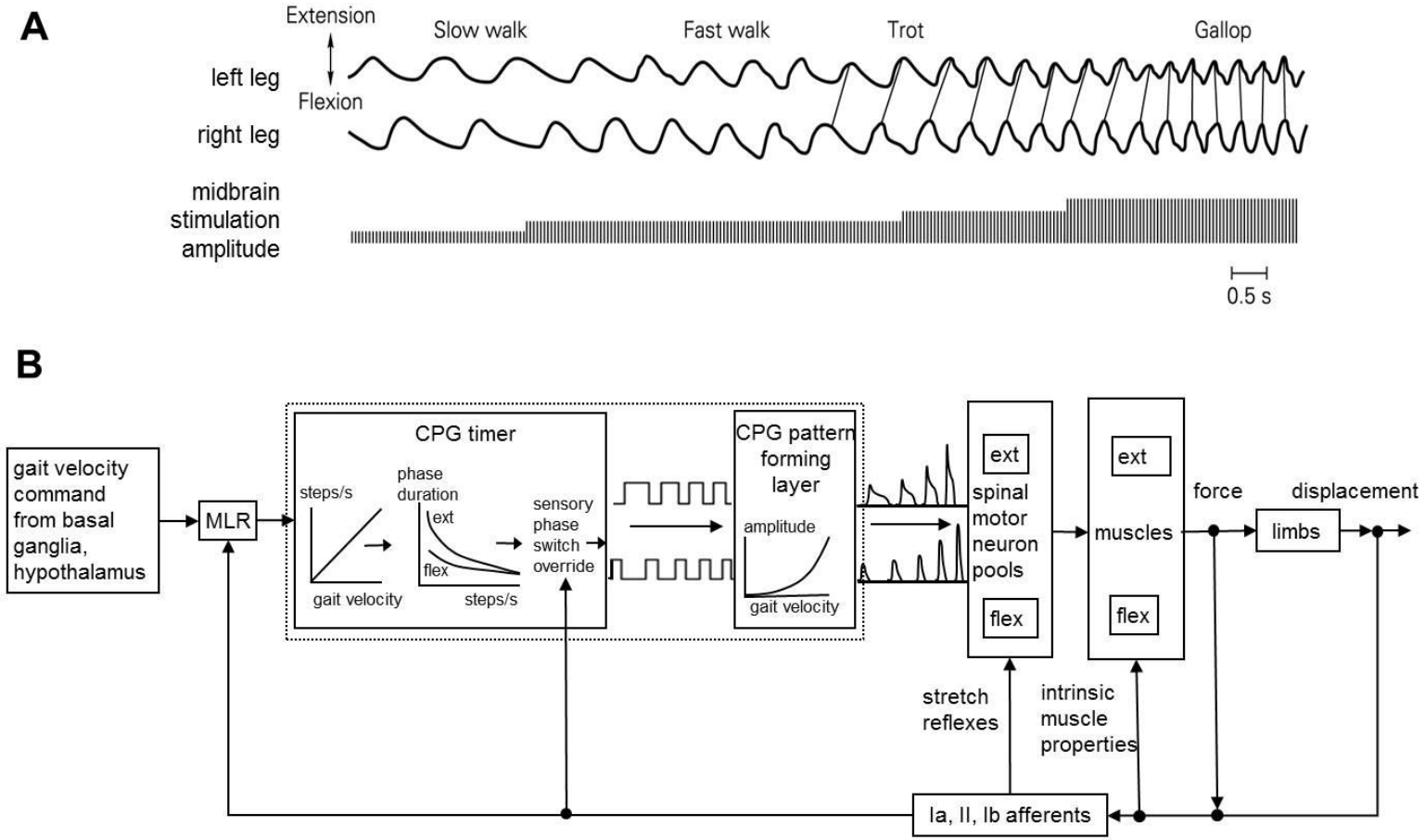


Fig. 1. Neural control of locomotion. A) Increments in the intensity of stimulation of the MLR in the high decerebrate cat increased the cadence (step cycles/sec) of locomotion. Adapted from Shik et al. 1966.[22] B) Schematic of the velocity command hypothesis: a command signal specifying increasing 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 by muscle 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]

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.

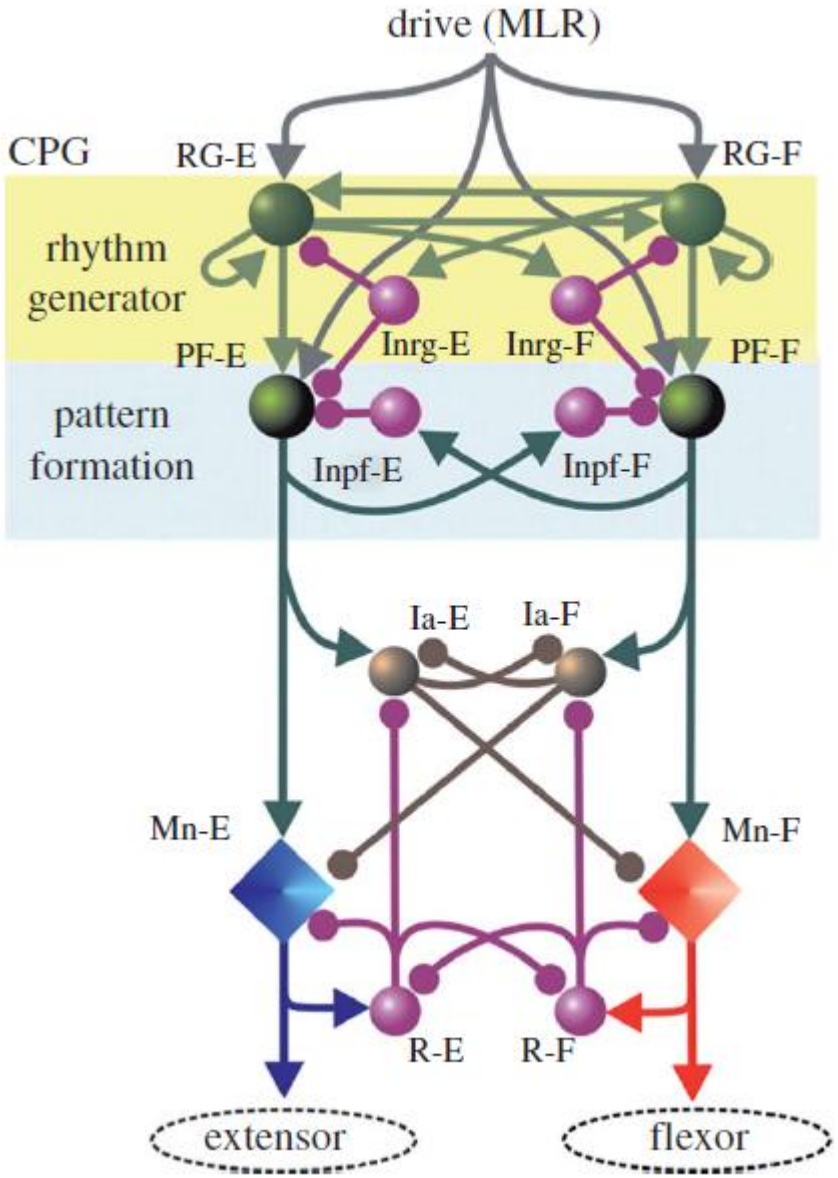


Figure 1. Schematic of model by Rybak & McCrea. The populations of interneurons are indicated by spheres, while the motoneurons are represented by diamonds. This three-layer model consists of a rhythm-generating layer of extensor (RG-E) and flexor (RG-F) interneurons. Both populations have recurrent 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.

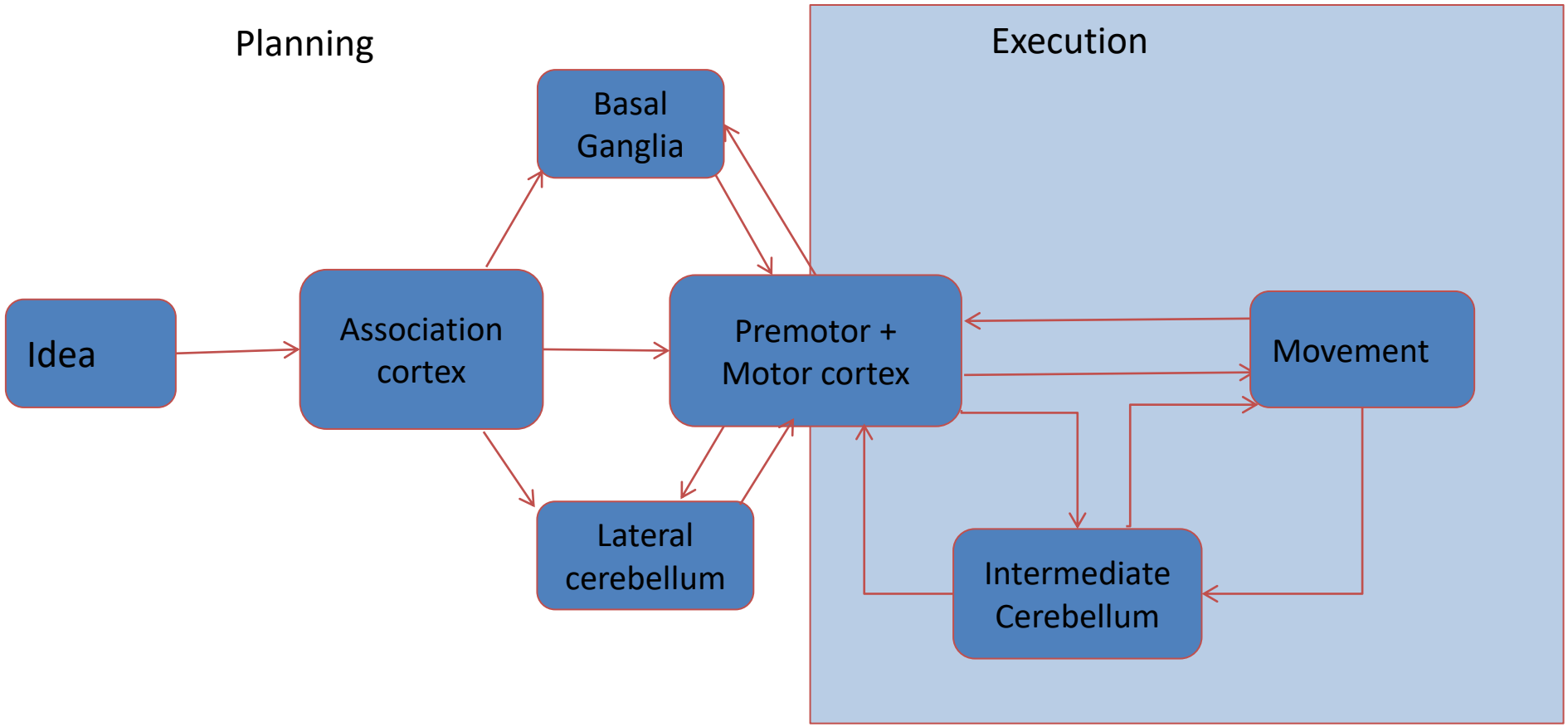
Cortical control of lower motor neuron

Tractus corticospinalis

Tractus corticobulbaris

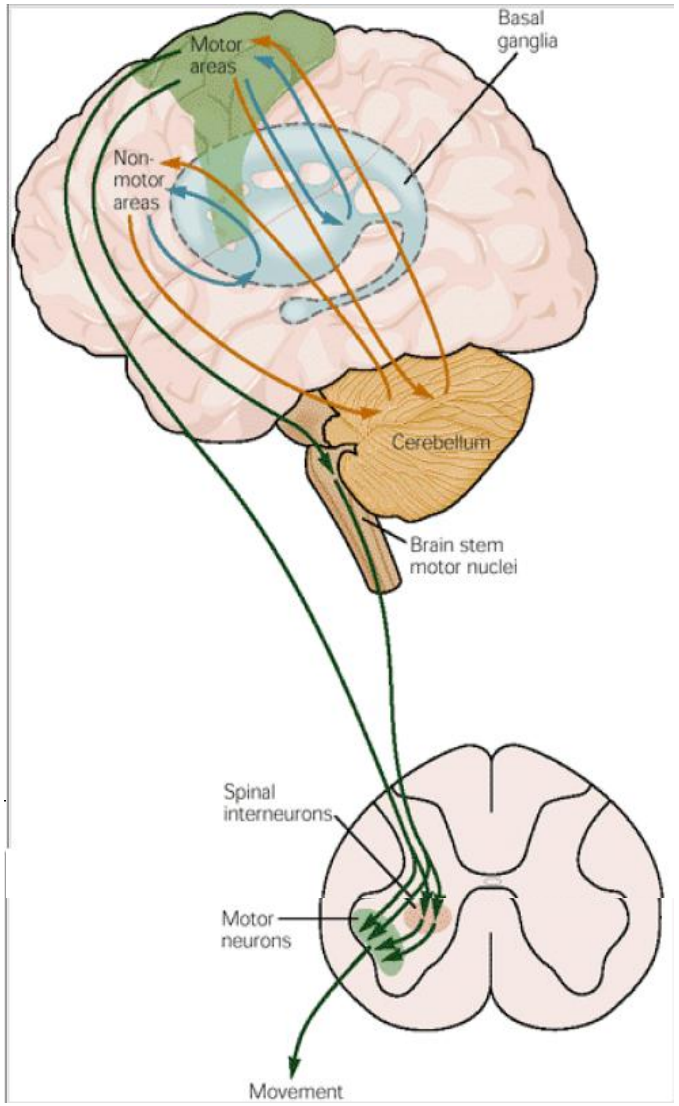
Voluntary motor activity

Voluntary motor activity



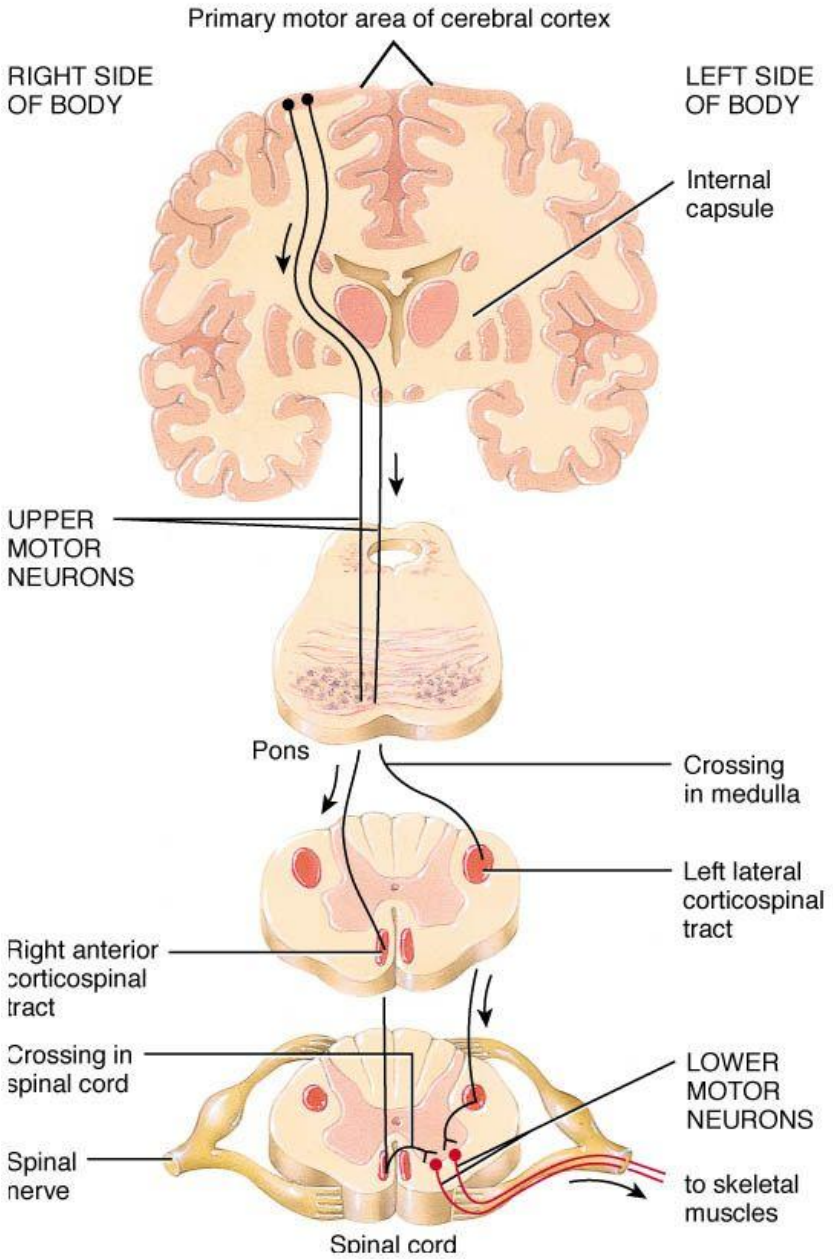
Voluntary motor activity

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



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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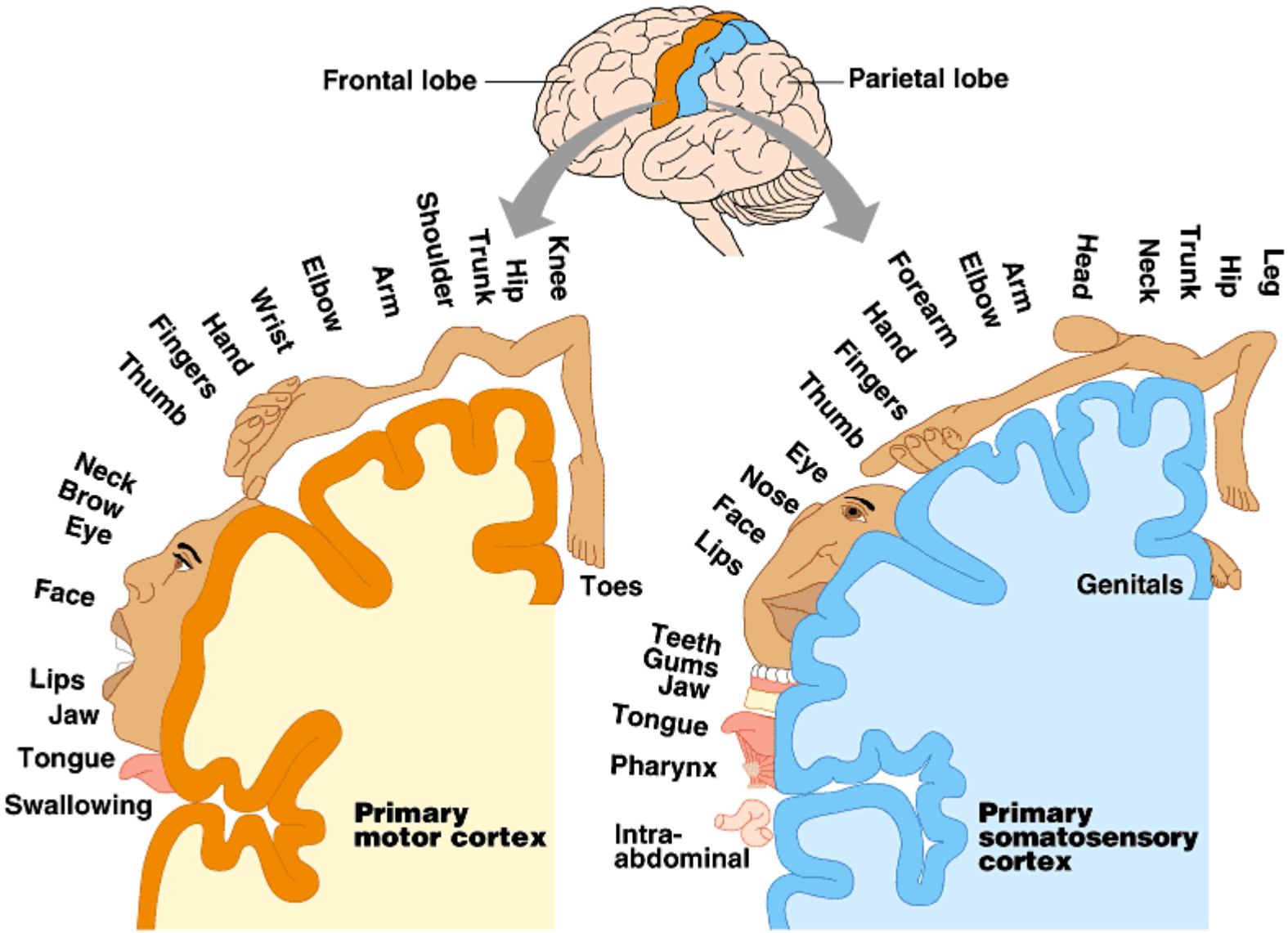
Primary motor cortex



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