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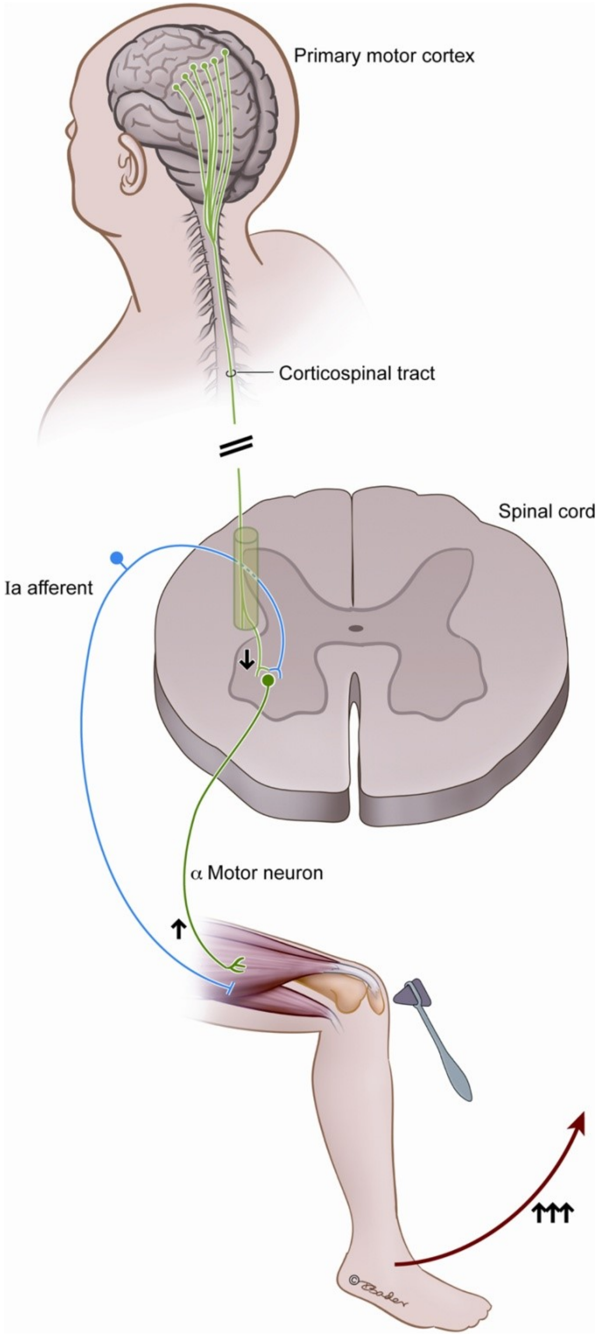
Motor system

Introduction

- Skeletal muscle contraction is initiated by lower motor neuron
- Lower motor neuron is a part of local reflex circuits



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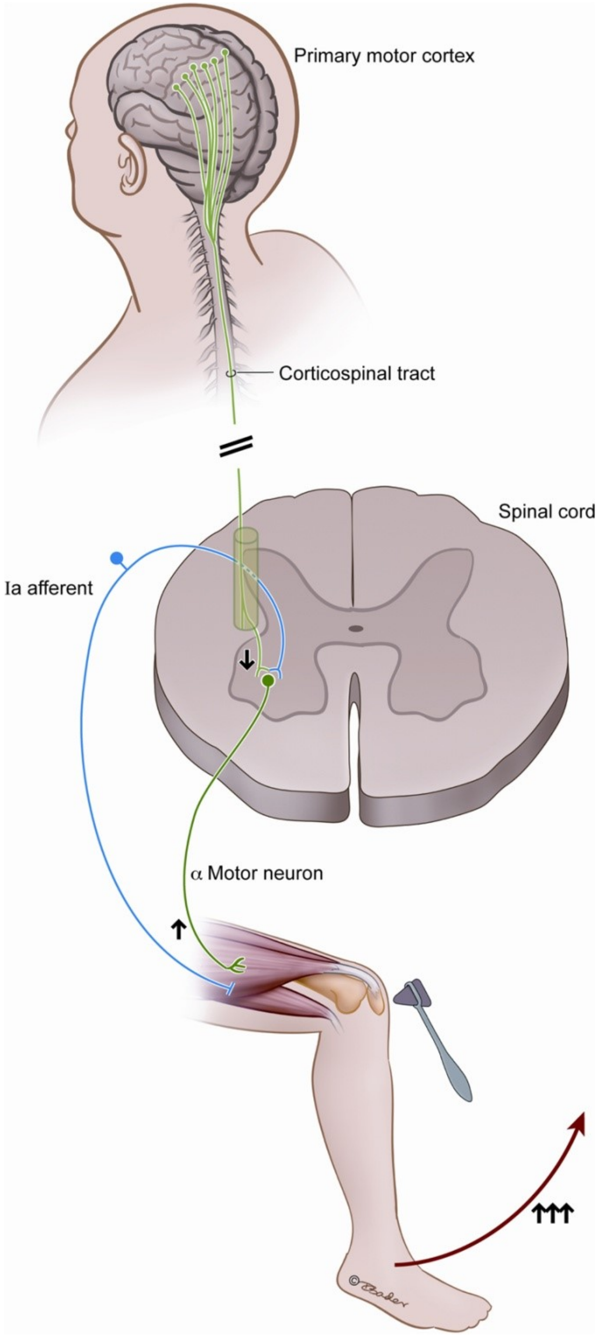
Introduction

- Skeletal muscle contraction is initiated by lower motor neuron
- Lower motor neuron is a part of local reflex circuits
- The information from several sources is integrated in the lower motor neuron
  - Higher levels of CNS
    - ➢Upper motor neuron, tectum, n. ruber, brain stem
  - Proprioception



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Introduction

- Skeletal muscle contraction is initiated l
lower motor neuron
- Lower motor
reflex
- The infc
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  – Highe
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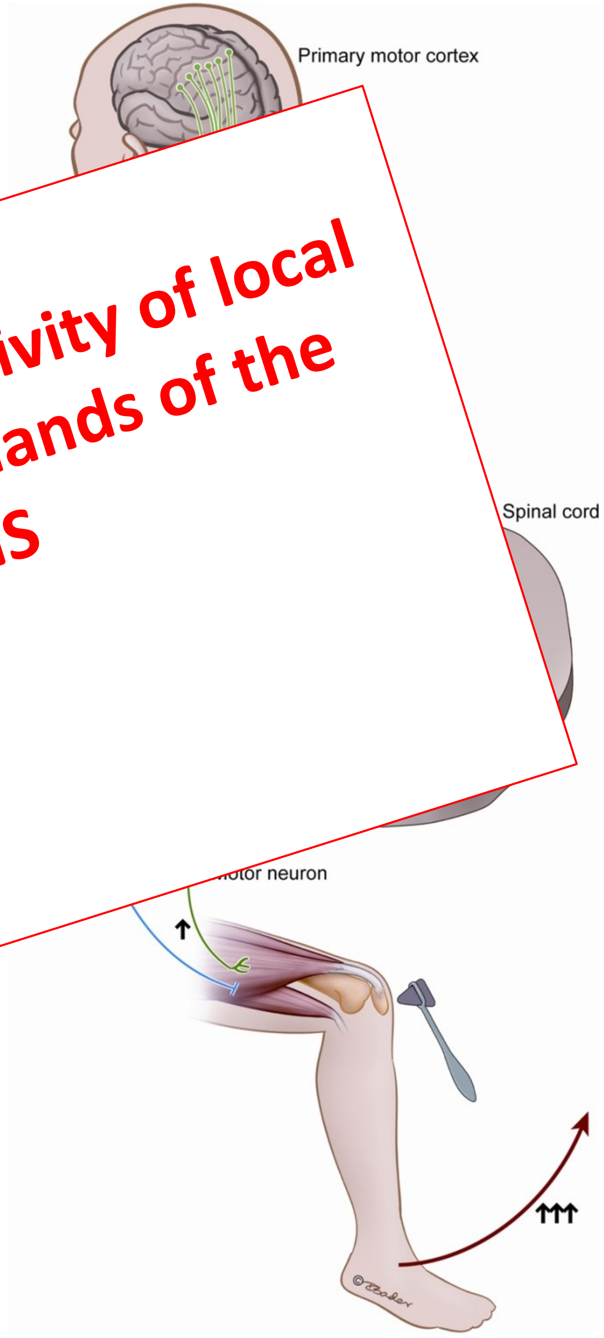
  – Propriocє

Lower motor neuron regulates the activity of local reflex circuits, according to the demands of the higher regions of the CNS



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Introduction

- Skeletal muscle contraction is initiated l lower motor neuron
- Lower motor reflex
- The info integrat
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  - Propriocep

Lower motor neuron regulates the activity of local reflex circuits, according to the demands of the higher regions of the CNS

Proprioception is crucial for the regulation of local circuit activity

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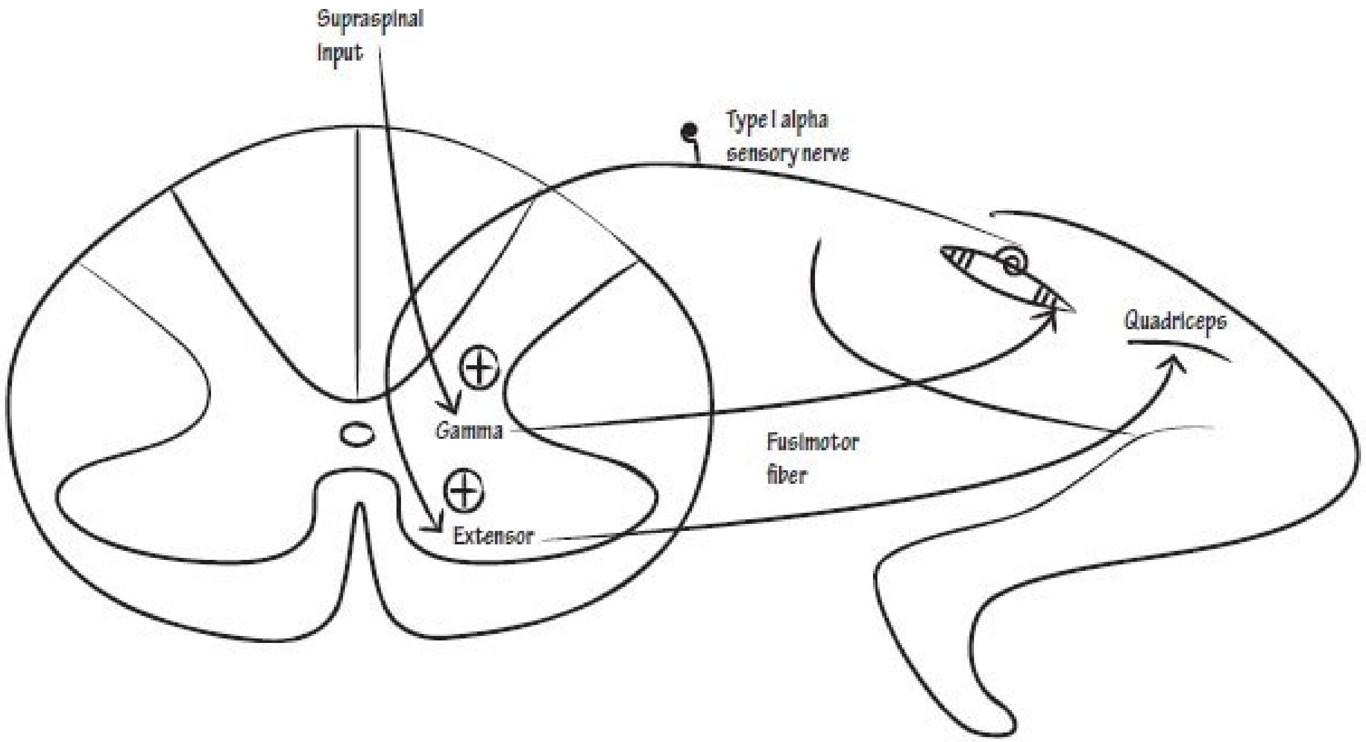
Lower motor neuron

- **α motoneuron**
  - Innervation of contractile elements
  - Extrafusal fibers
  - Muscle contraction

- **γ motoneuron**
  - Innervation of muscle spindles
  - Intrafusal fibers
  - Alignment of muscle spindles
  - Gamma loop

- **β motoneuron**
  - **Both extrafusal and intrafusal fiberrs**



http://epomedicine.com/wp-content/uploads/2016/07/gamma-loop.jpg

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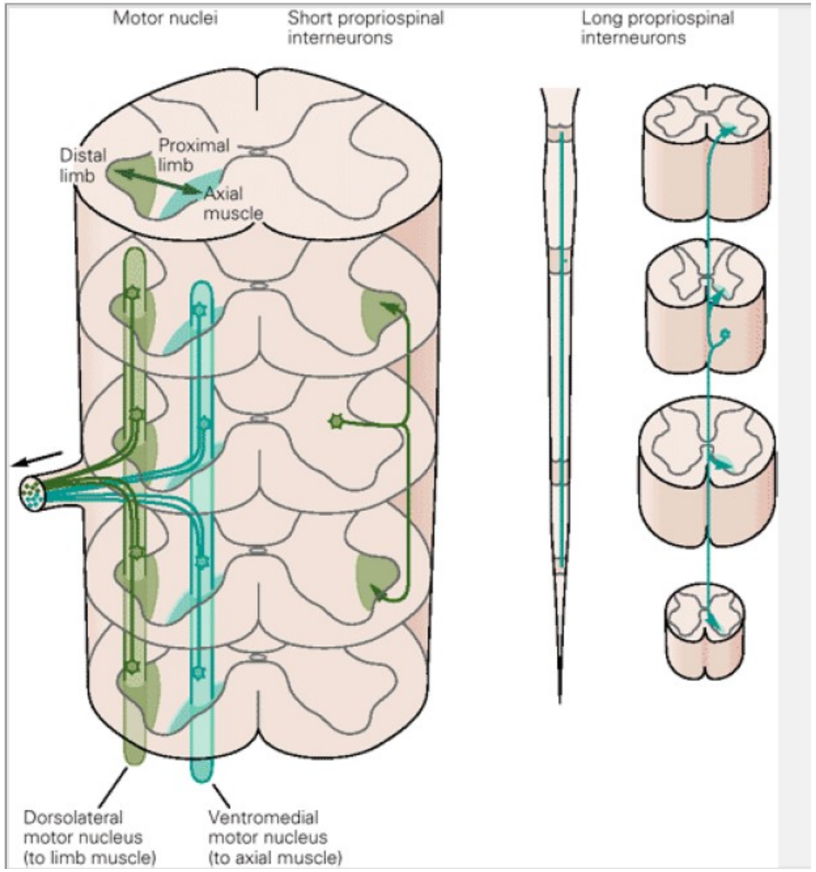
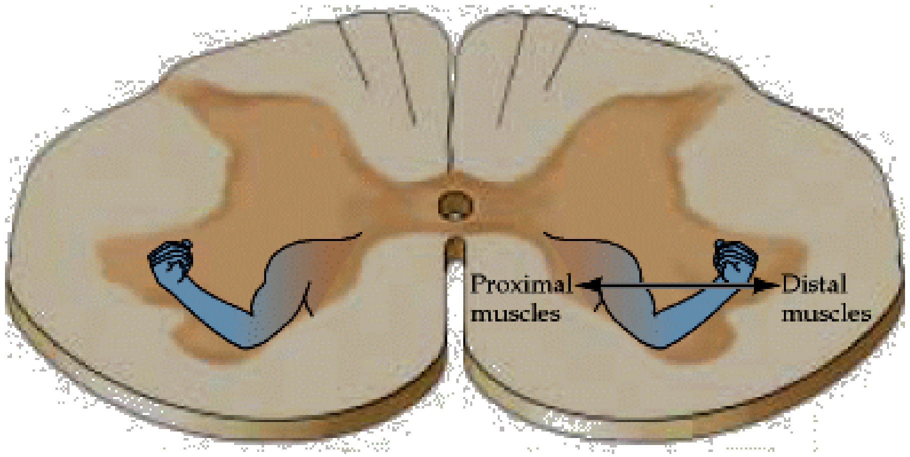
Lower motor neuron

Topography





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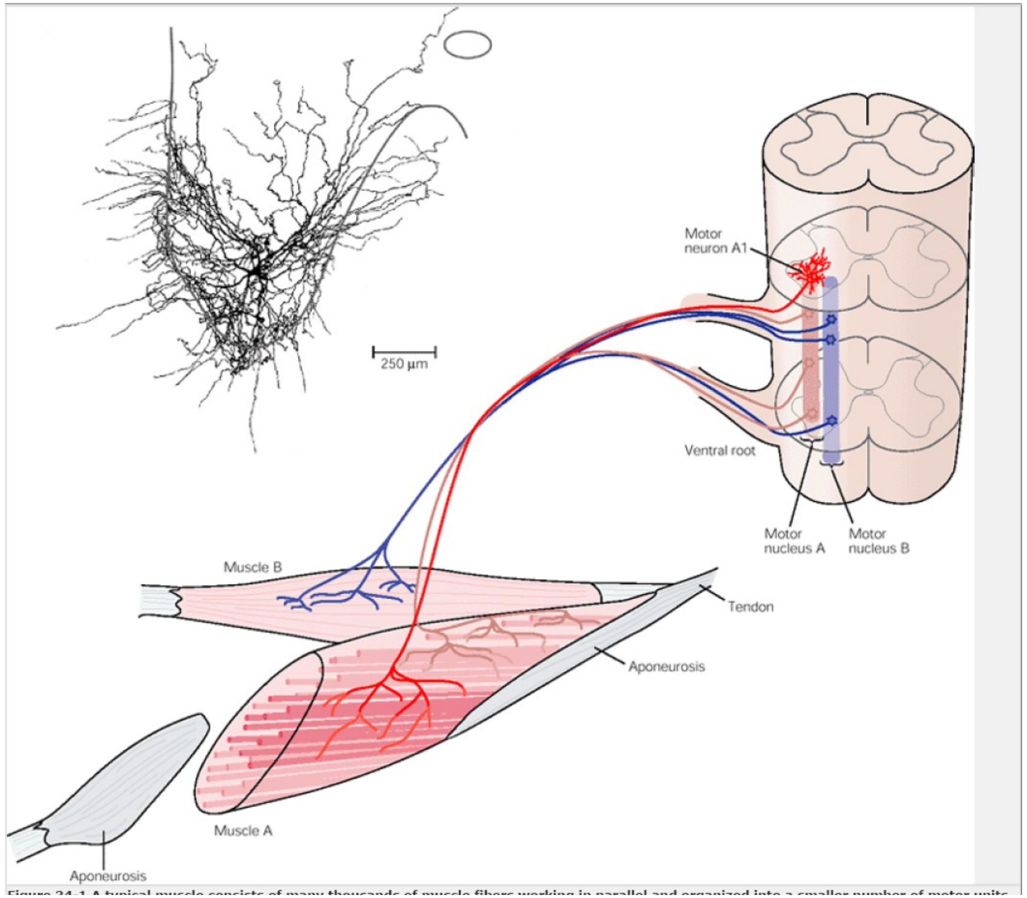
Motor unit

- A typical muscle is innervated by about 100 motoneurons which are localized in motor nucleus
- Each motoneuron innervate from 100 to 1000 muscle fibers and one muscle fiber is innervated by a single motoneuron



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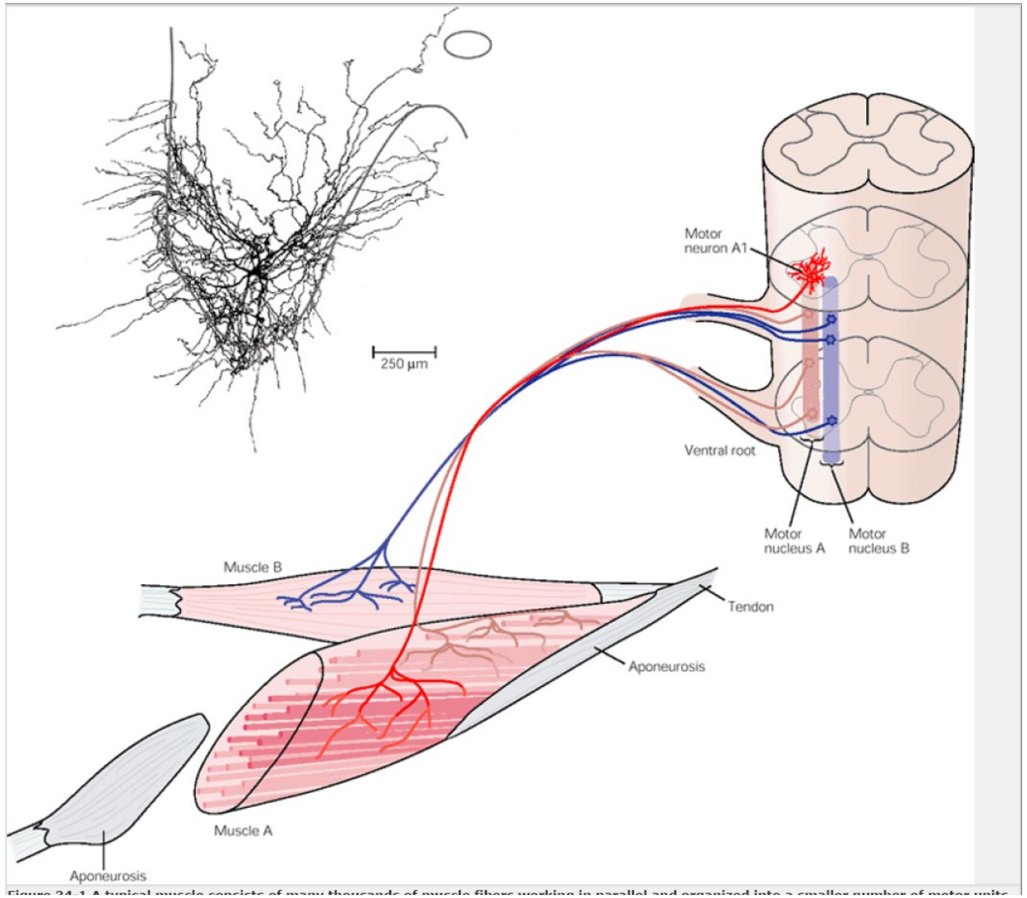
Motor unit

- A typical muscle is innervated by about 100 motoneurons which are localized in motor nucleus
- Each motoneuron innervate from 100 to 1000 muscle fibers and one muscle fiber is innervated by a single motoneuron
- The ensemble of muscle fibers innervated by a single neuron and corresponding motoneuron constitutes the motor unit



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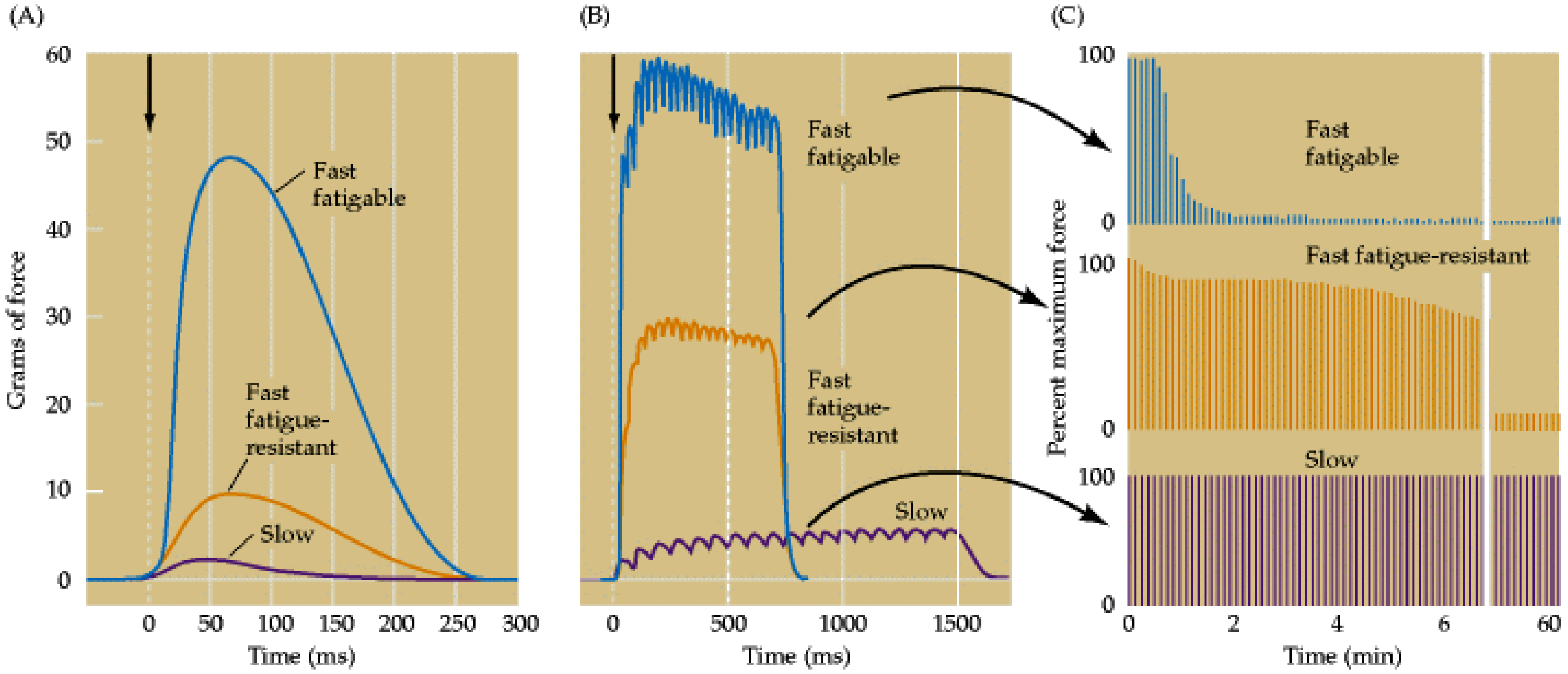
Types of muscle fibers

Fast fibers

- Performance
- Fast fatigue-resistant – normal performance
- Fast fatigable – high performance

Slow fibers

- Endurance
- Fatigue resistant



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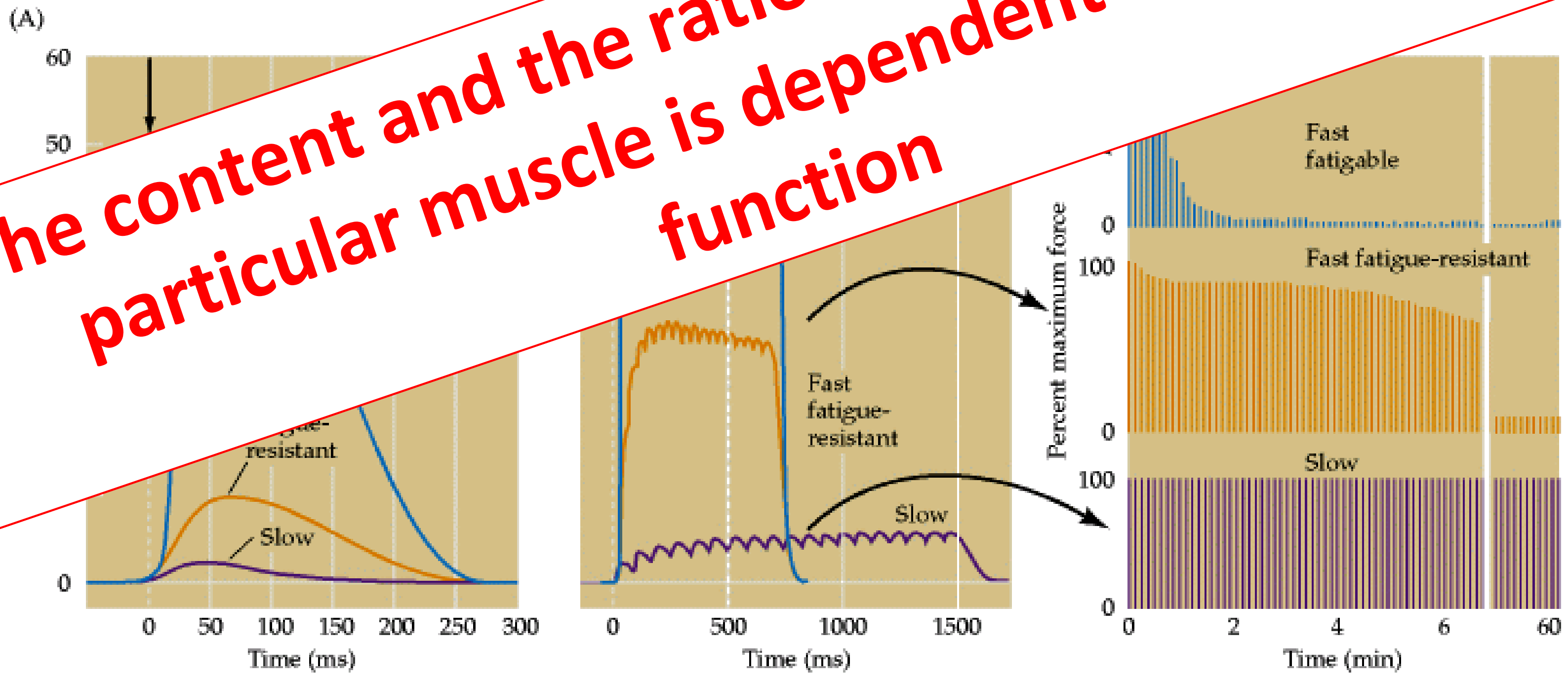
Types of muscle fibers

Fast fibers

- Performance
- Fast fatigue-resistant – normal performance
- Fast fatigable – high performance

Slow fibers

The content and the ratio of fast/slow fibers in particular muscle is dependent on muscle function



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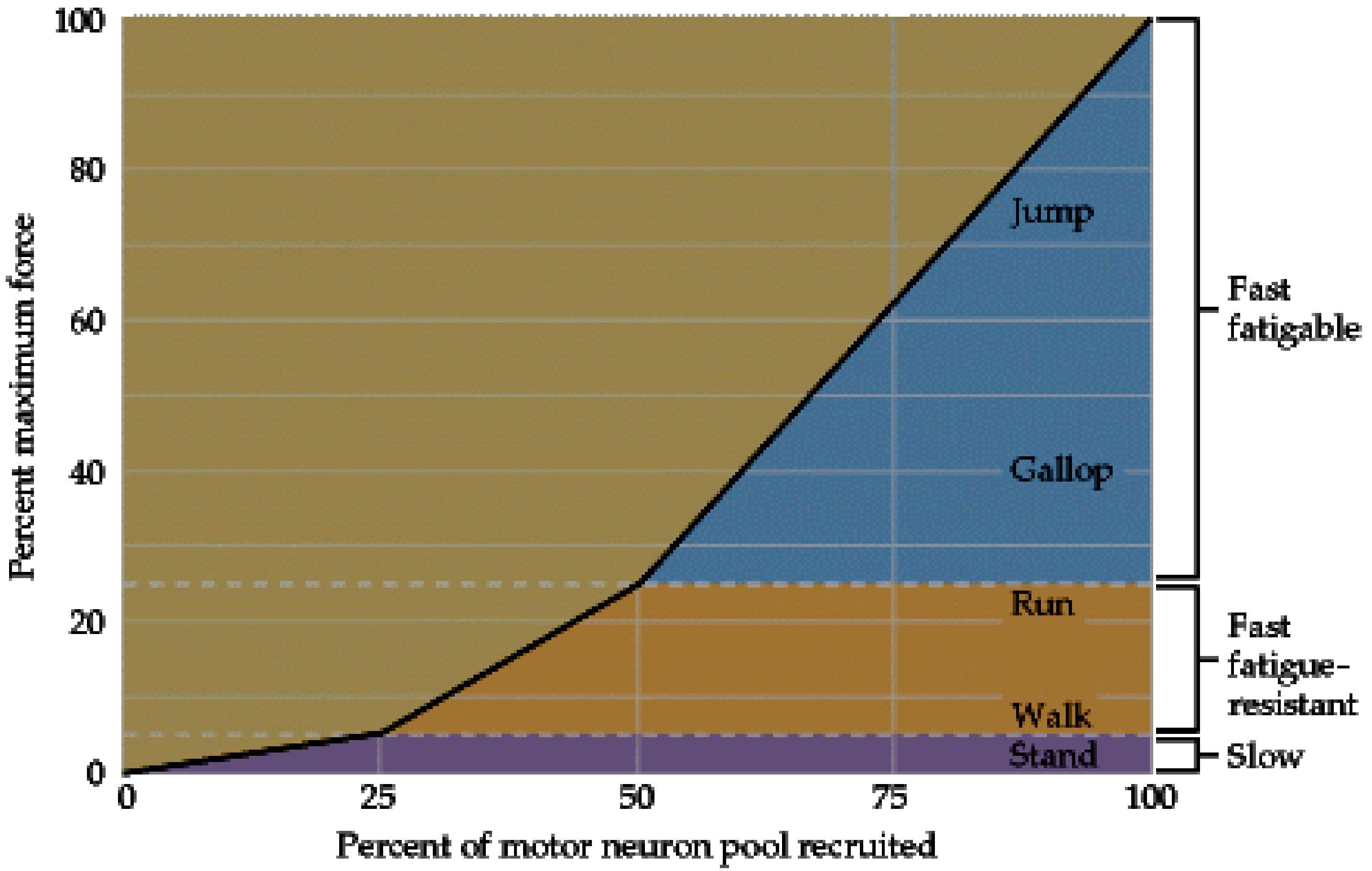
The recruitment of motor neurons

m. gastrocnemius in a cat



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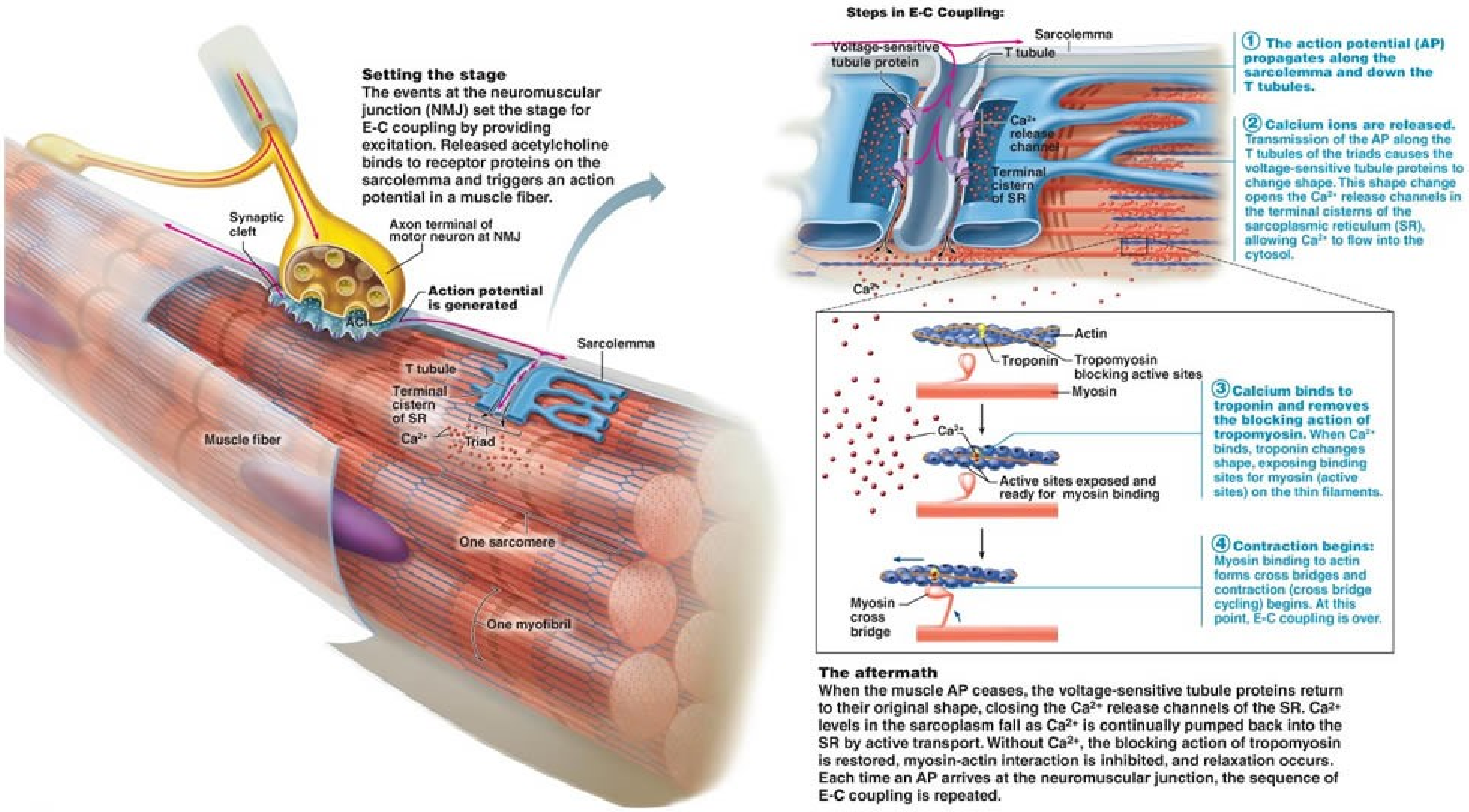
Neuromuscular junction



http://classes.midlandstech.edu/carterp/Courses/bio210/chap09/210_figure_09_11_labeled.jpg

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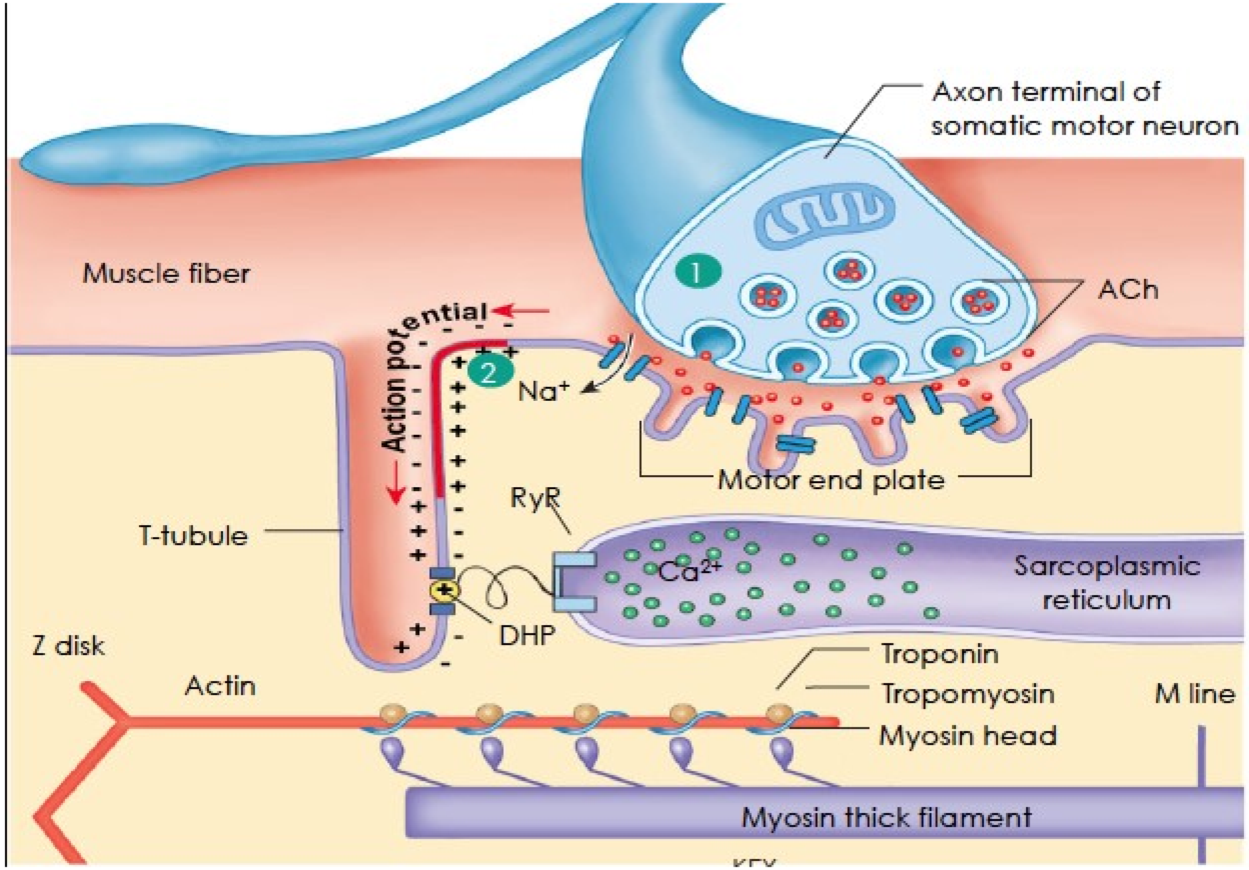
Neuromuscular junction



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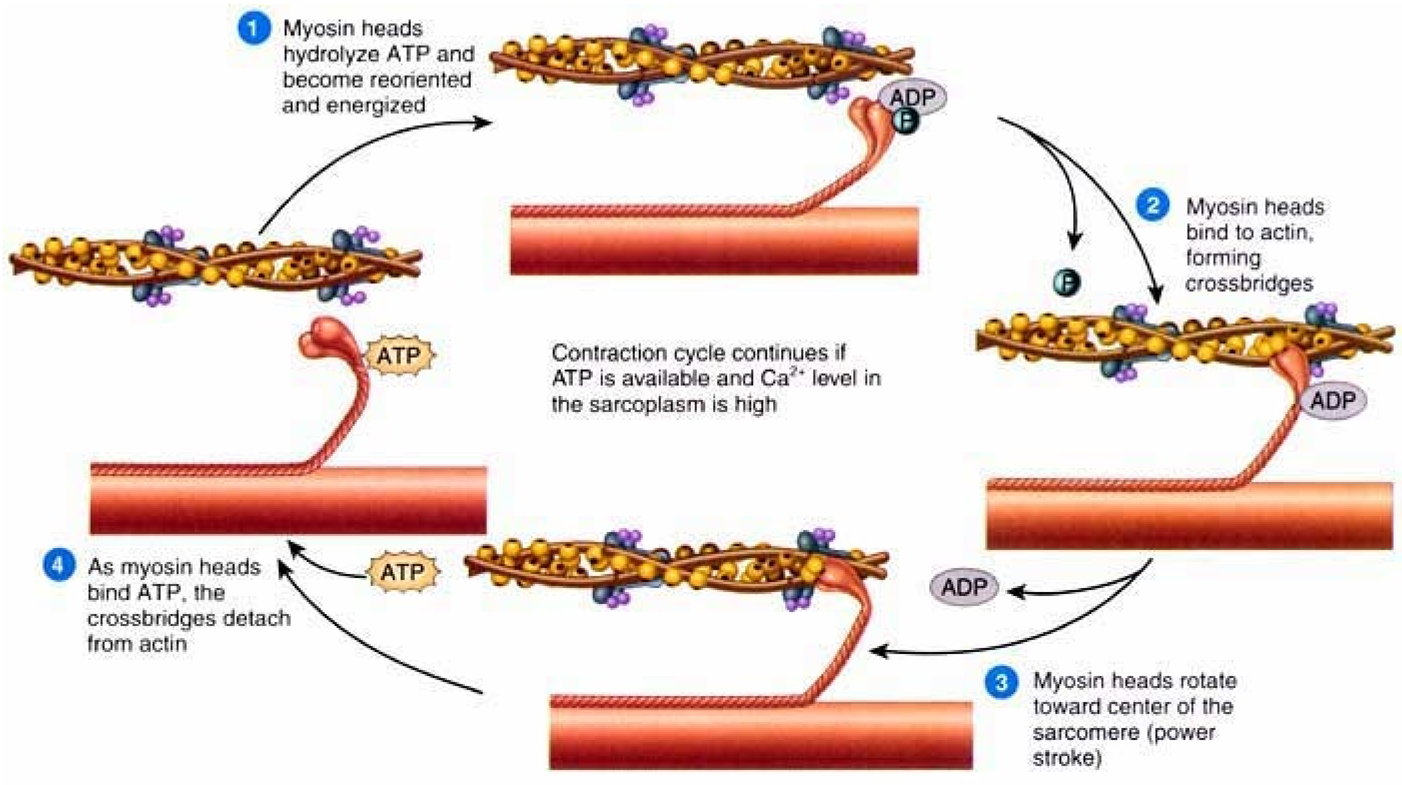
Muscle fibers



http://www.sivabio.50webs.com/mus019.jpg

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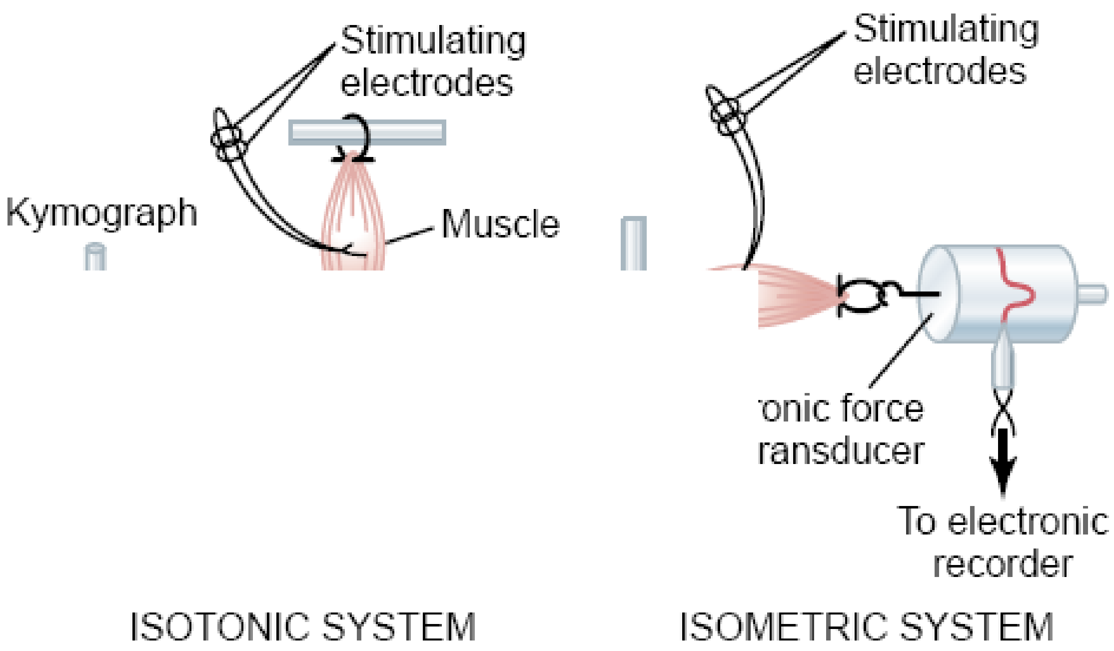
Types of muscle contraction

- Isotonic contraction
  - ➢ Constant tension
  - ➢ Concentric x excentric contraction

- Isometric contraction
  - ➢ Constant length



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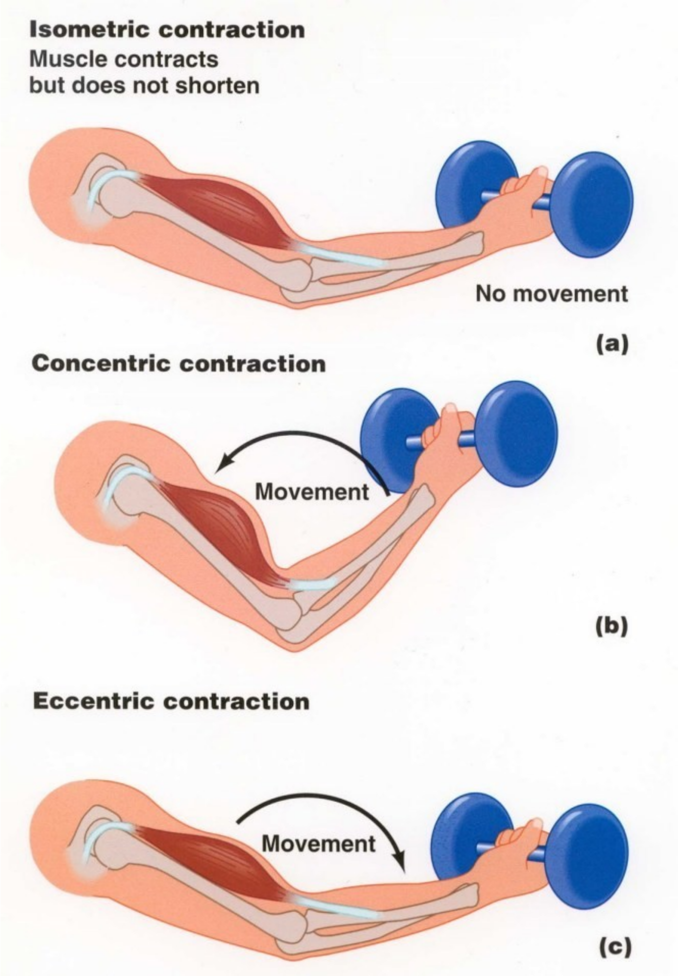

https://i0.wp.com/colebradburn.com/wp-content/uploads/2013/02/contractions.jpg

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Proprioception

- Information about the position of body parts in relation to each other

  (The sum of information about lengths of particular muscles)

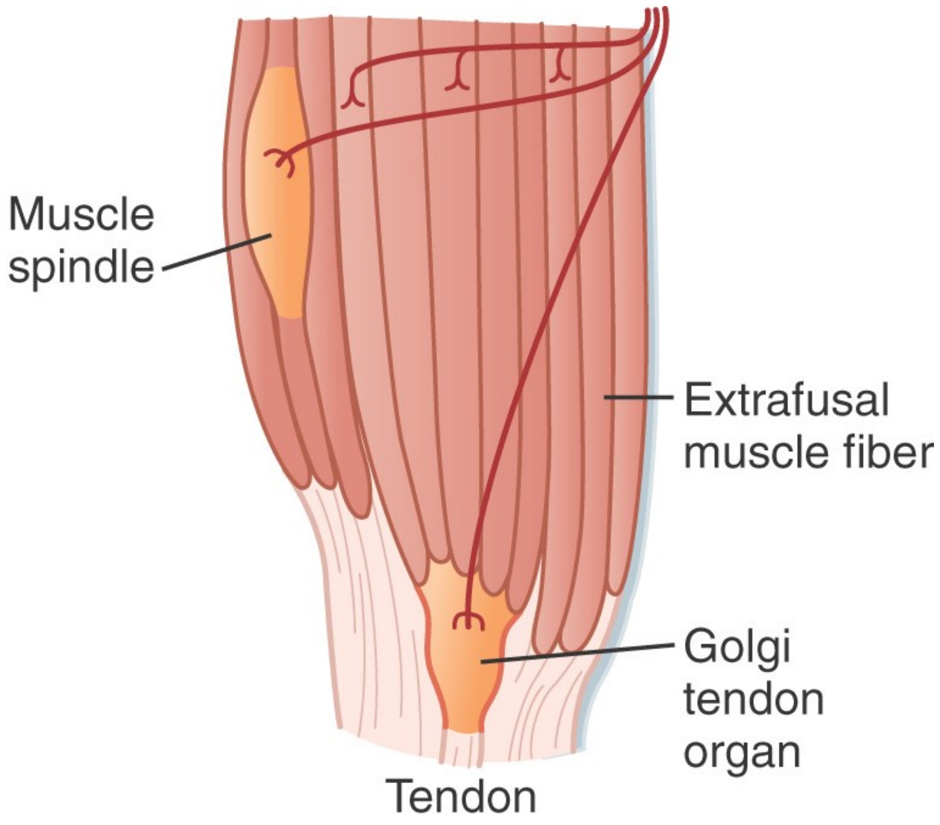
- Information about movement

  (The force and speed of muscle contraction)

- Reflex regulation of muscle activity

- Muscle spindles
  - Lie in parallel with extrafusal muscle fibers

- Golgi tendon organ
  - Arranged in series with extrafusal muscles



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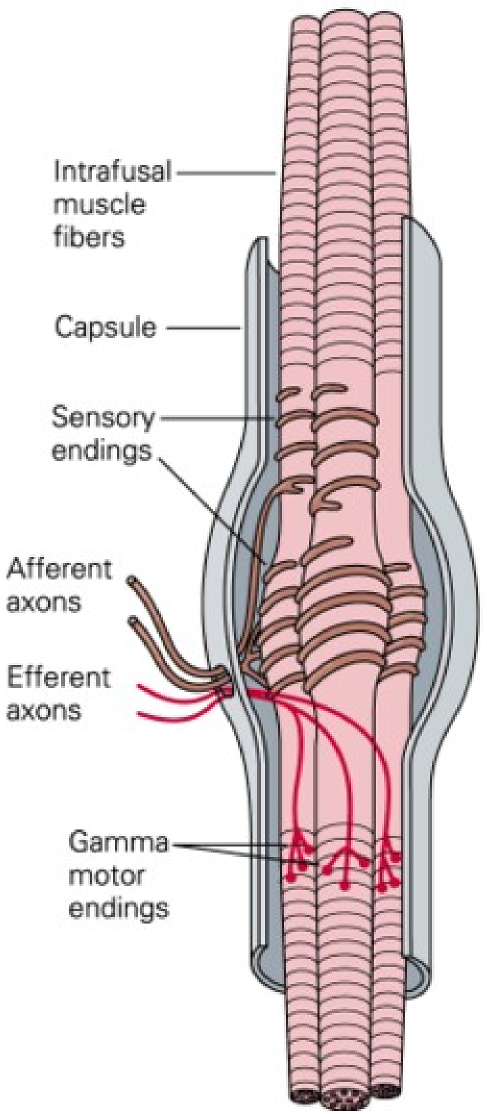
Muscle spindles

- Nno-force generating contractile structures
- The contractility is for spindle length adjustment
- Encapsulated structure filled with a fluid
- Intrafusal fibers
  - Lie in parallel with extrafusal muscle fibers (Stretch/shorten along with extrafusal fibers)
  - Efferent connections (into muscle spindle)
    - γ motoneuron
  - Afferent connections (from muscle spindle)
    - Information about change in muscle length
    - Reflex regulation of the α motoneuron activity



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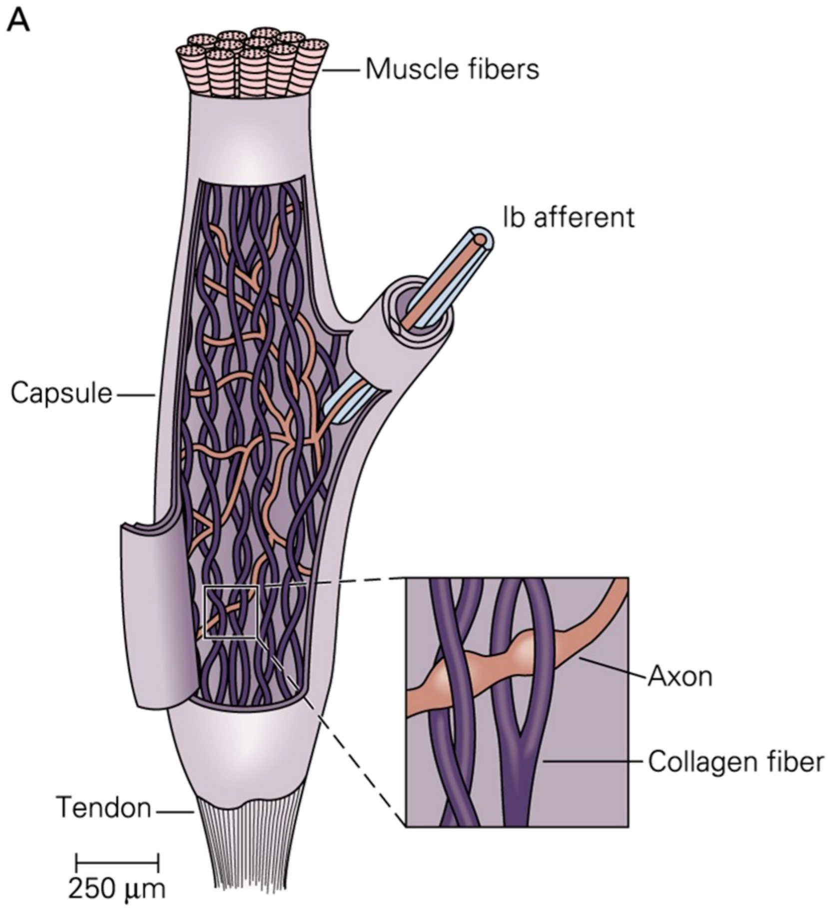
Golgi tendon organs

- Non-contractile encapsulated structures
- Collagen fibers
- Ib (Aα) fibers
- Mechanoreception
- Arranged in series with extrafusal muscles
- Information about changes in tendon tension/force
- Reflex regulation of the α motoneuron activity



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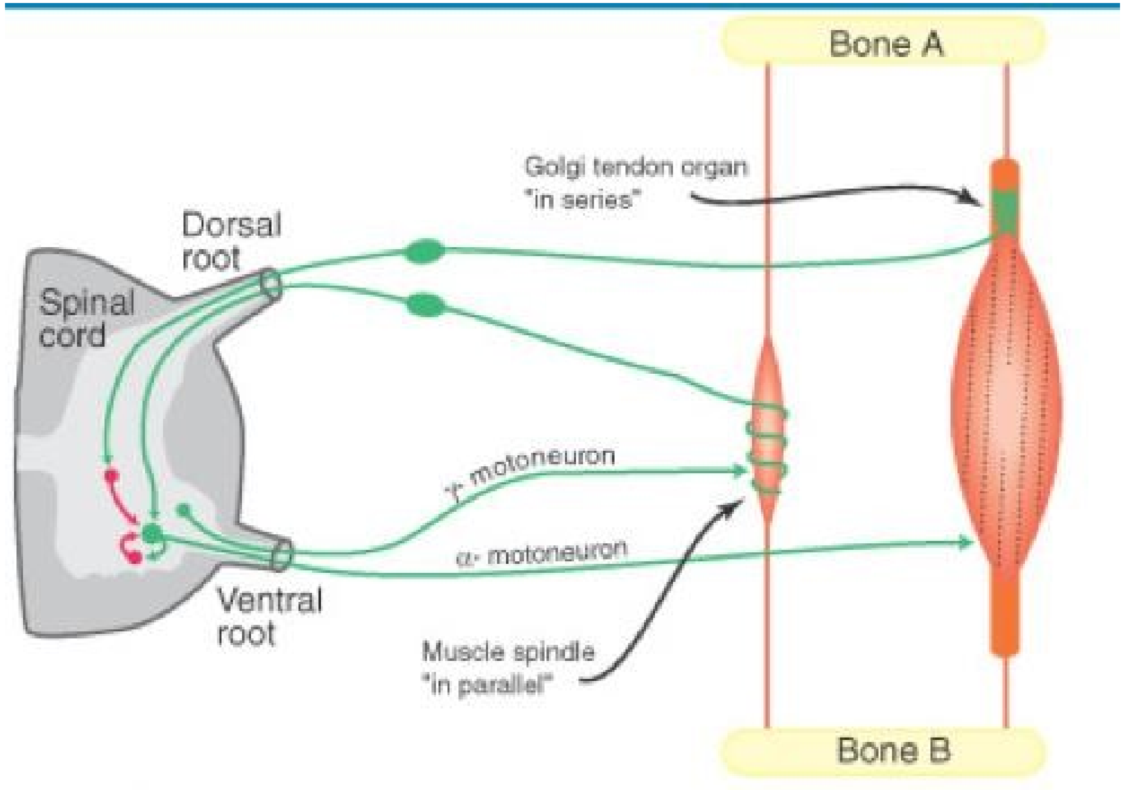
Muscle spindle and Golgi tendon organ



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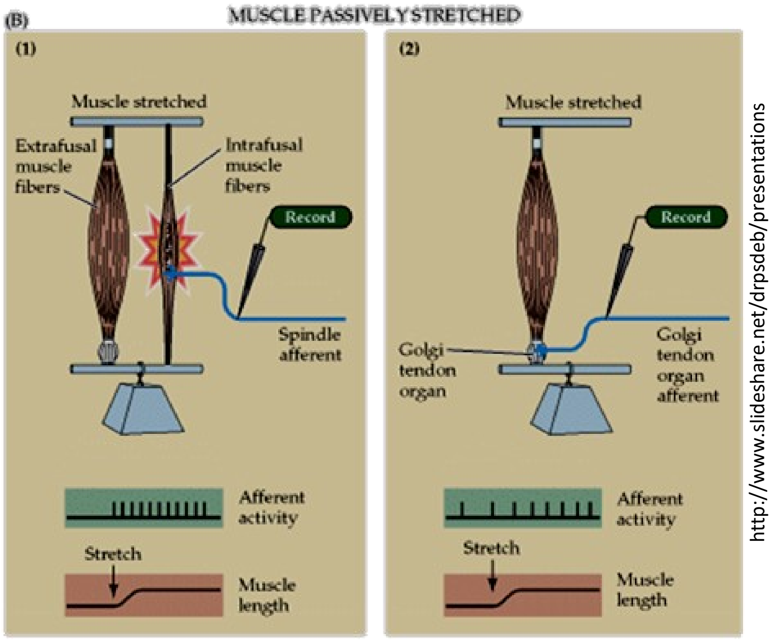
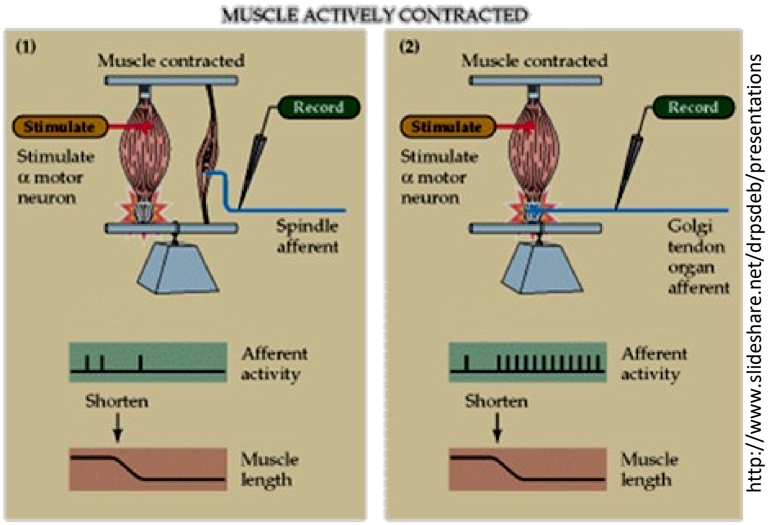
Reaction of muscle spindles and the Golgi tendon organs to muscle fiber stretch/contraction



Stretch (passive)

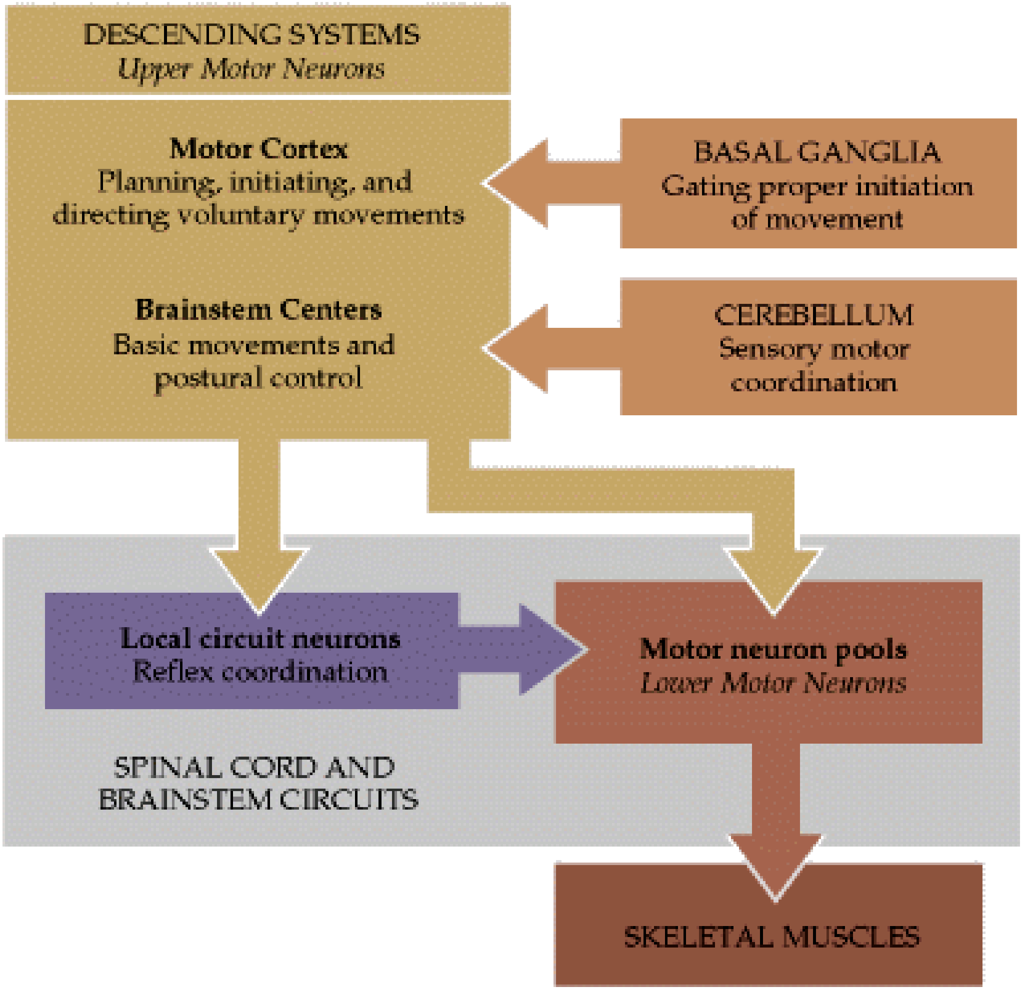
Muscle spindles reaction



Contraction (active)

Golgi tendon organ reaction

Hierarchic organization of motor system



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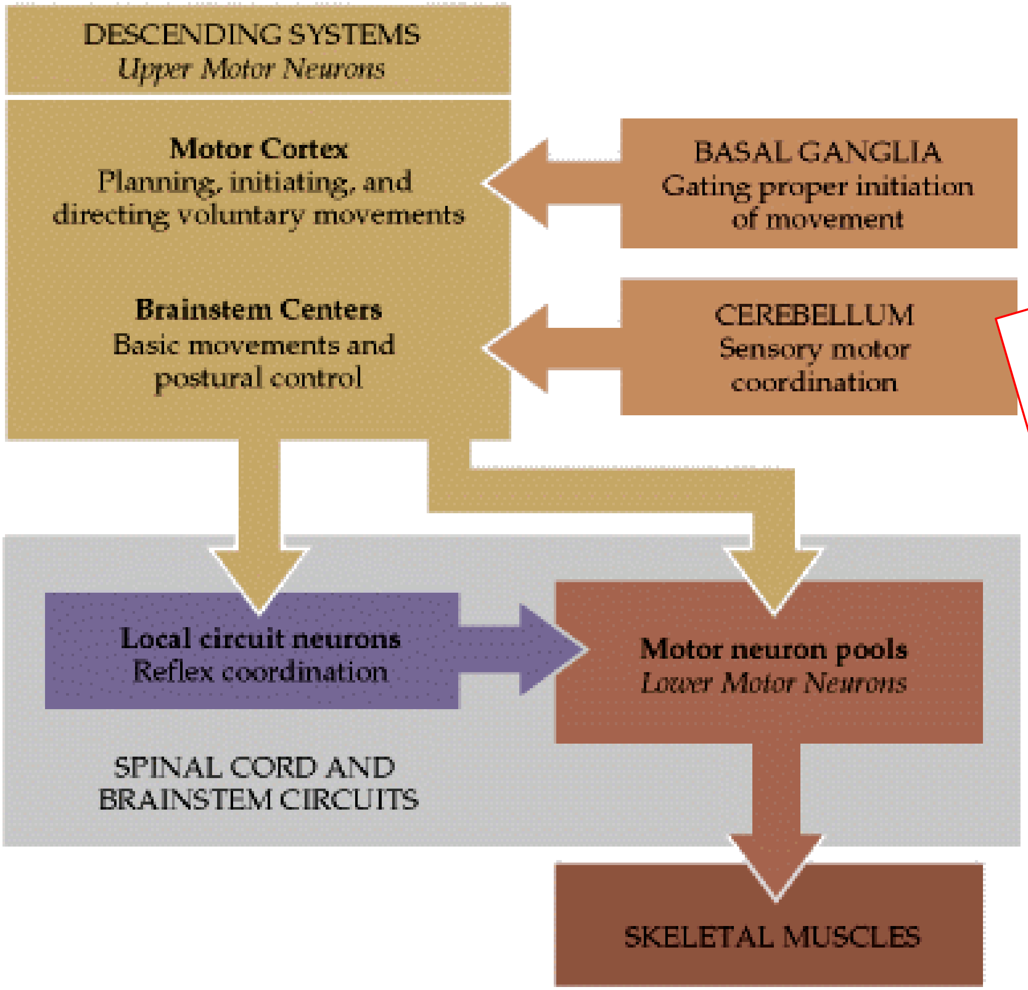
Hierarchic organization of motor system



Reflex movement
Rhythmic movement
Voluntary movement

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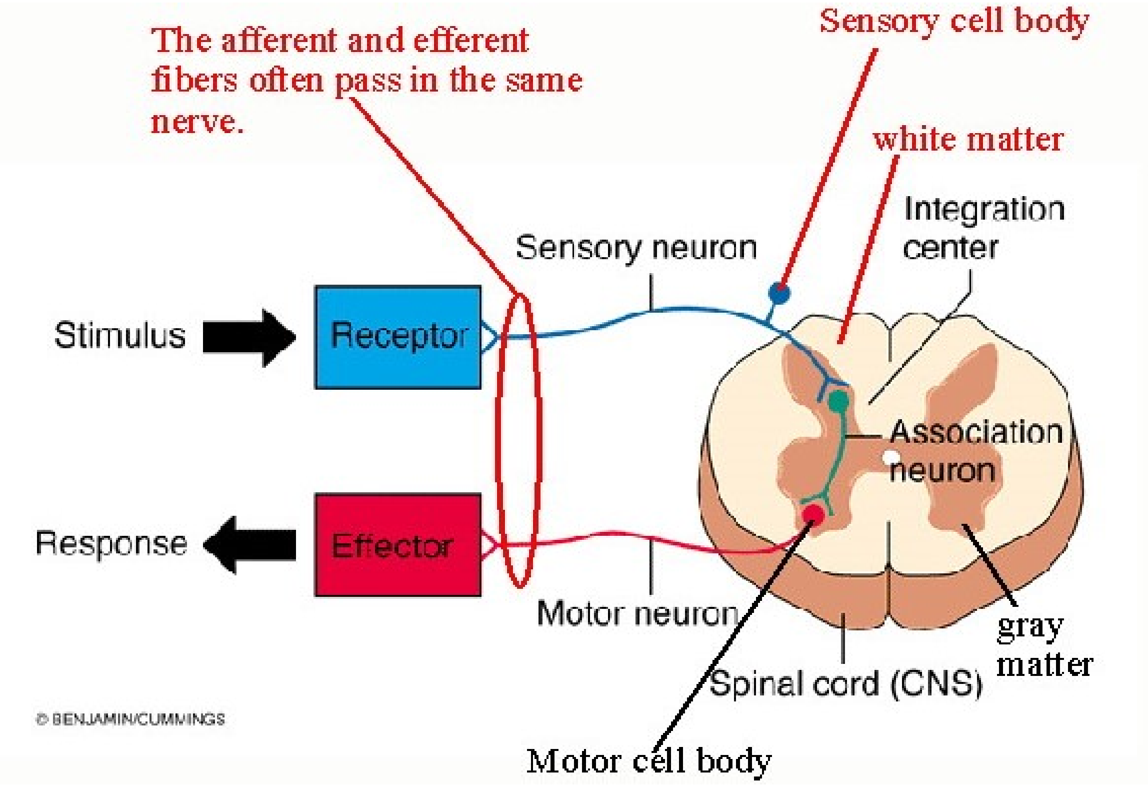
Reflex

- Reflex movement
  - Stereotype (predictable)
  - Involuntary

- Proprioceptive
- Exteroceptive

- Monosynaptic
- Polysynaptic

- Monosegmental
- Polysegmental



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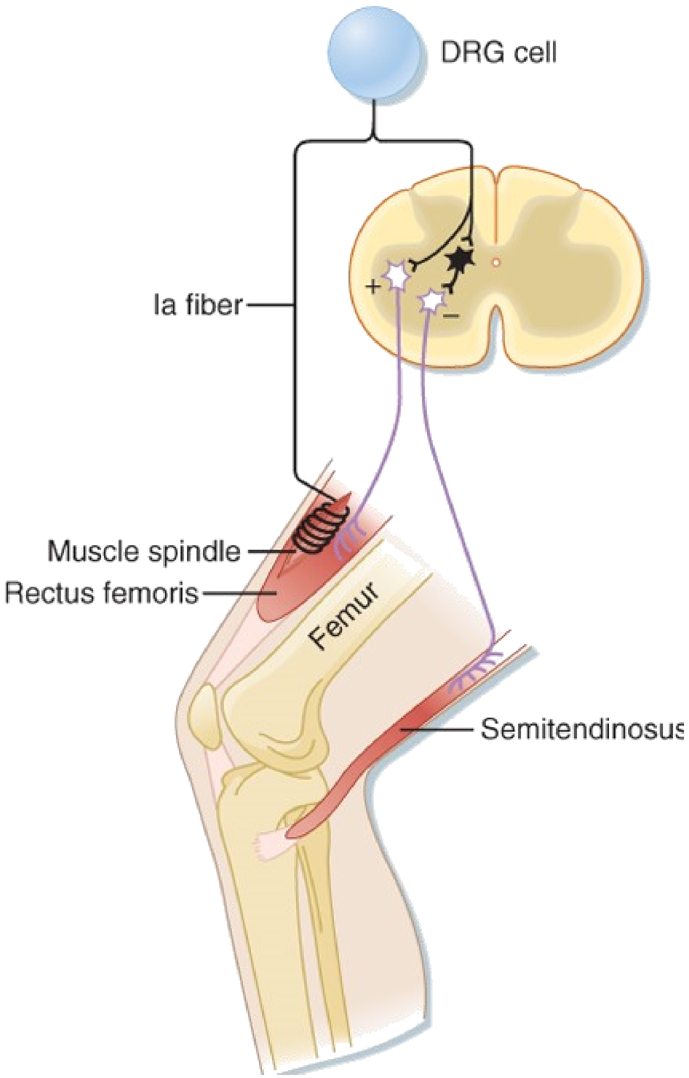
Proprioceptive reflexes

- **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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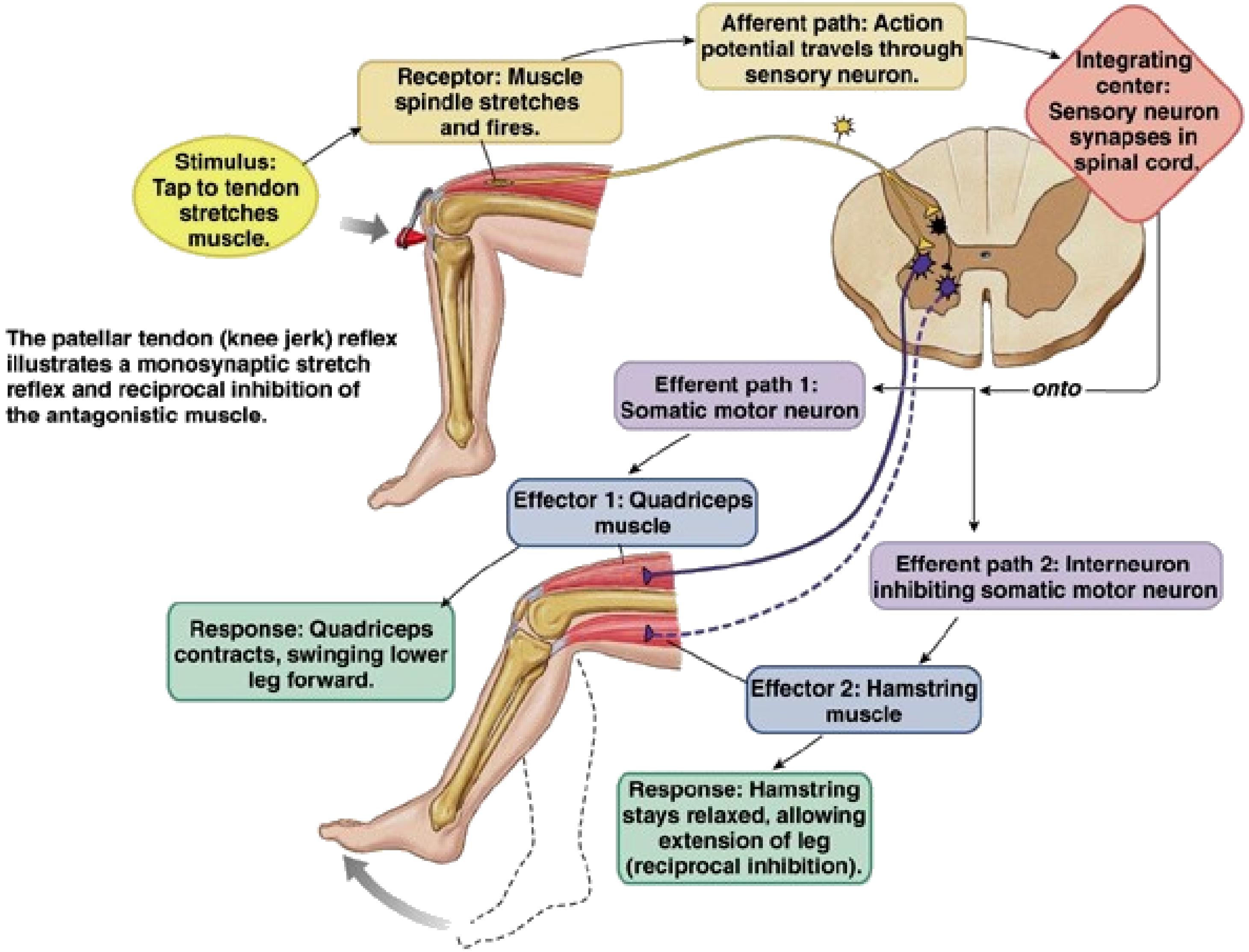

Fig. 13-7

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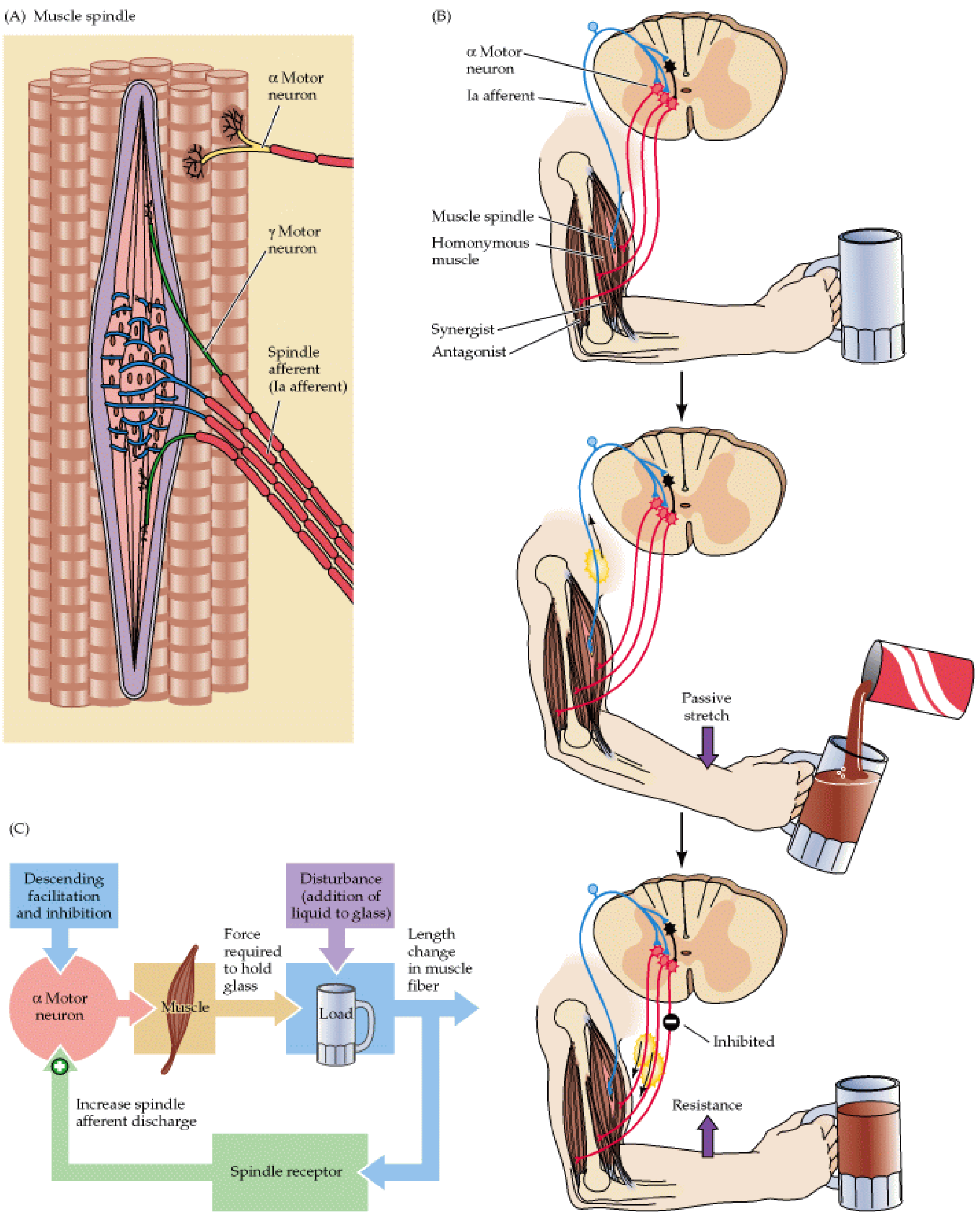

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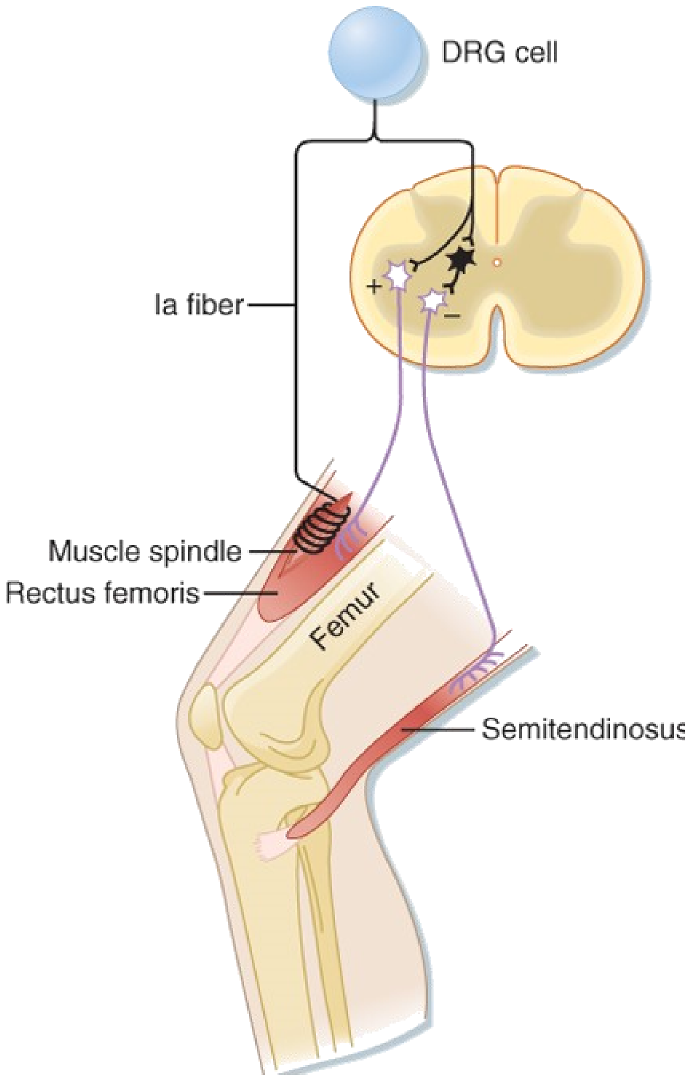
Proprioceptive reflexes

- **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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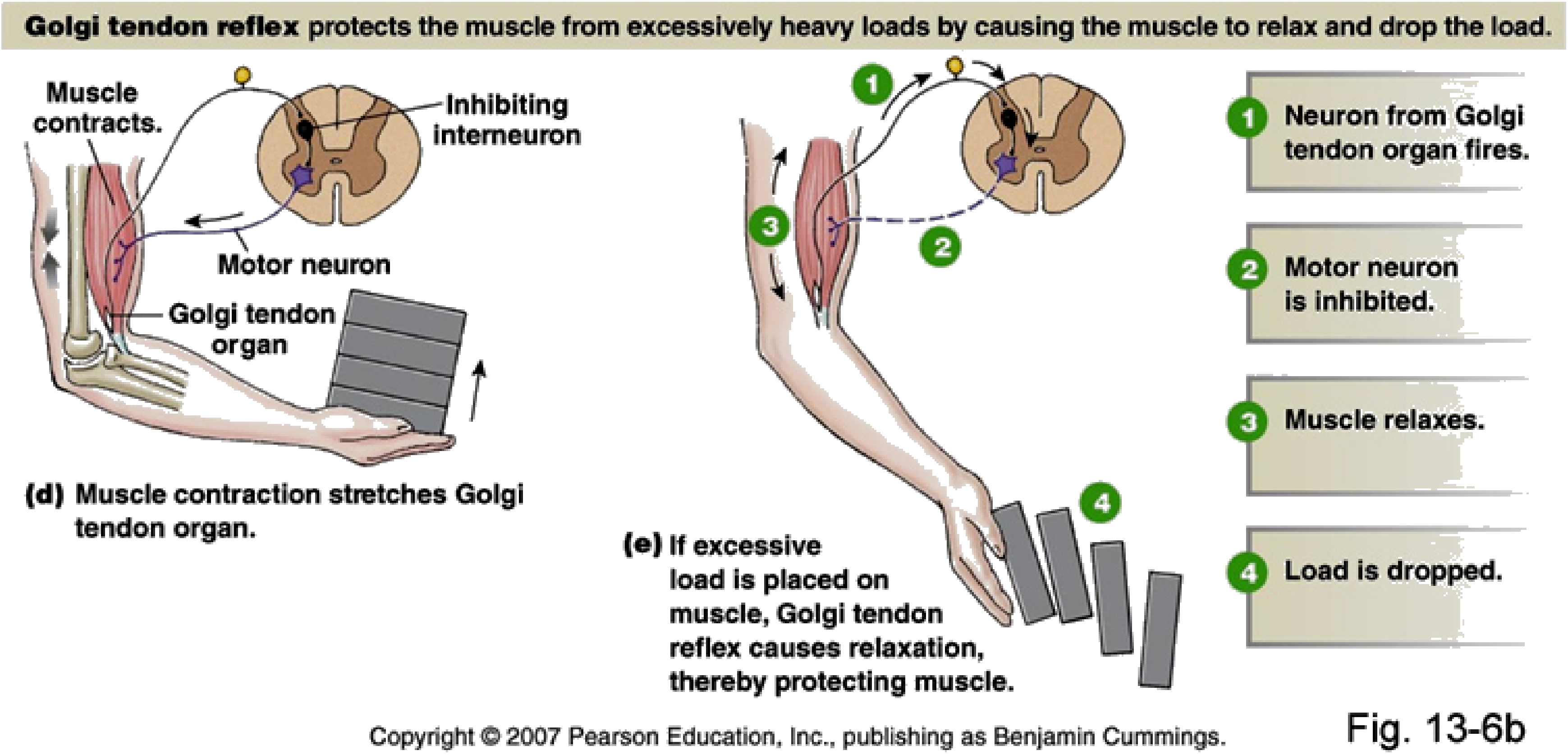

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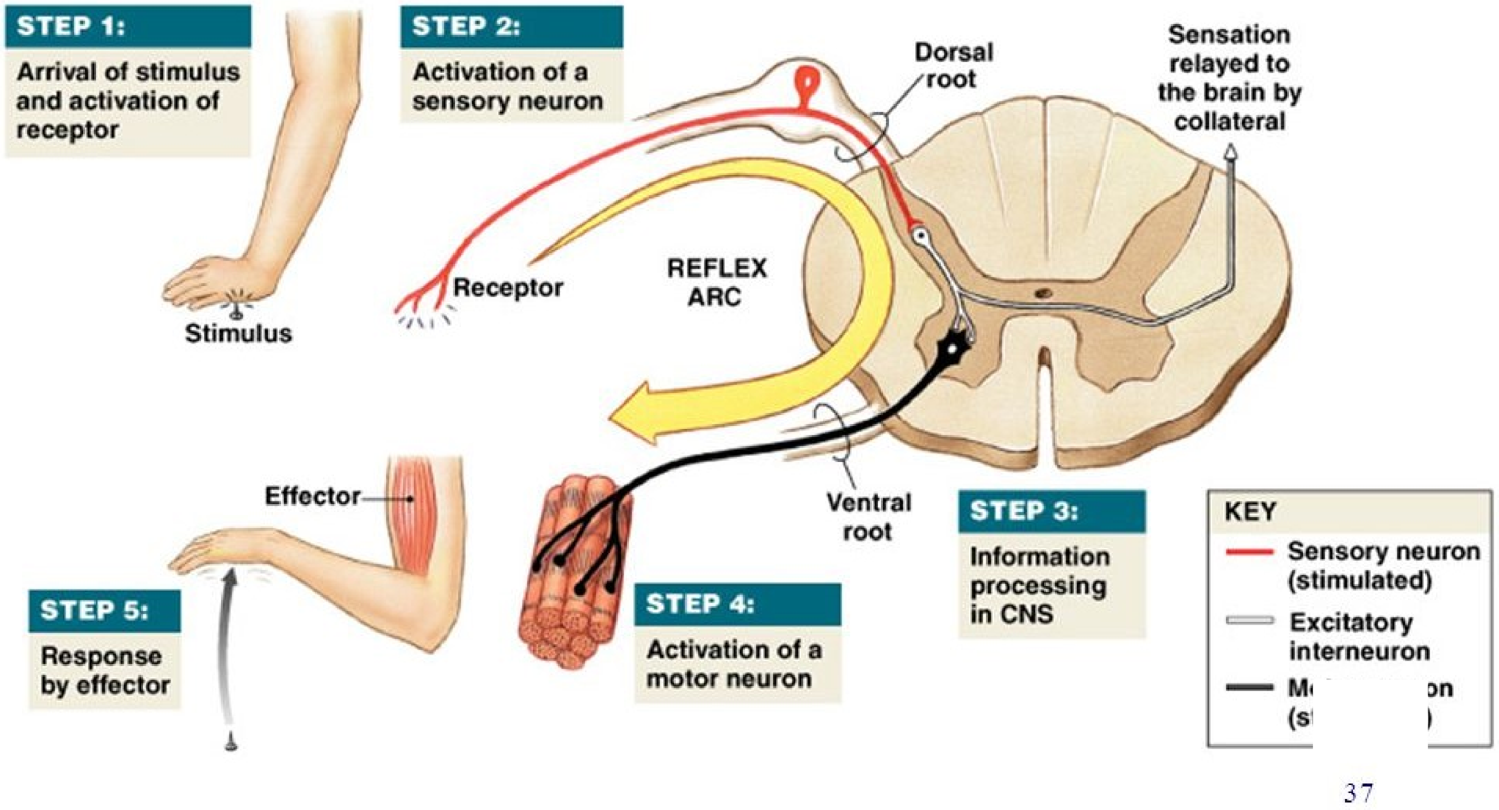
Exteroceptive reflexes

- Polysynaptic
- Polysegmental



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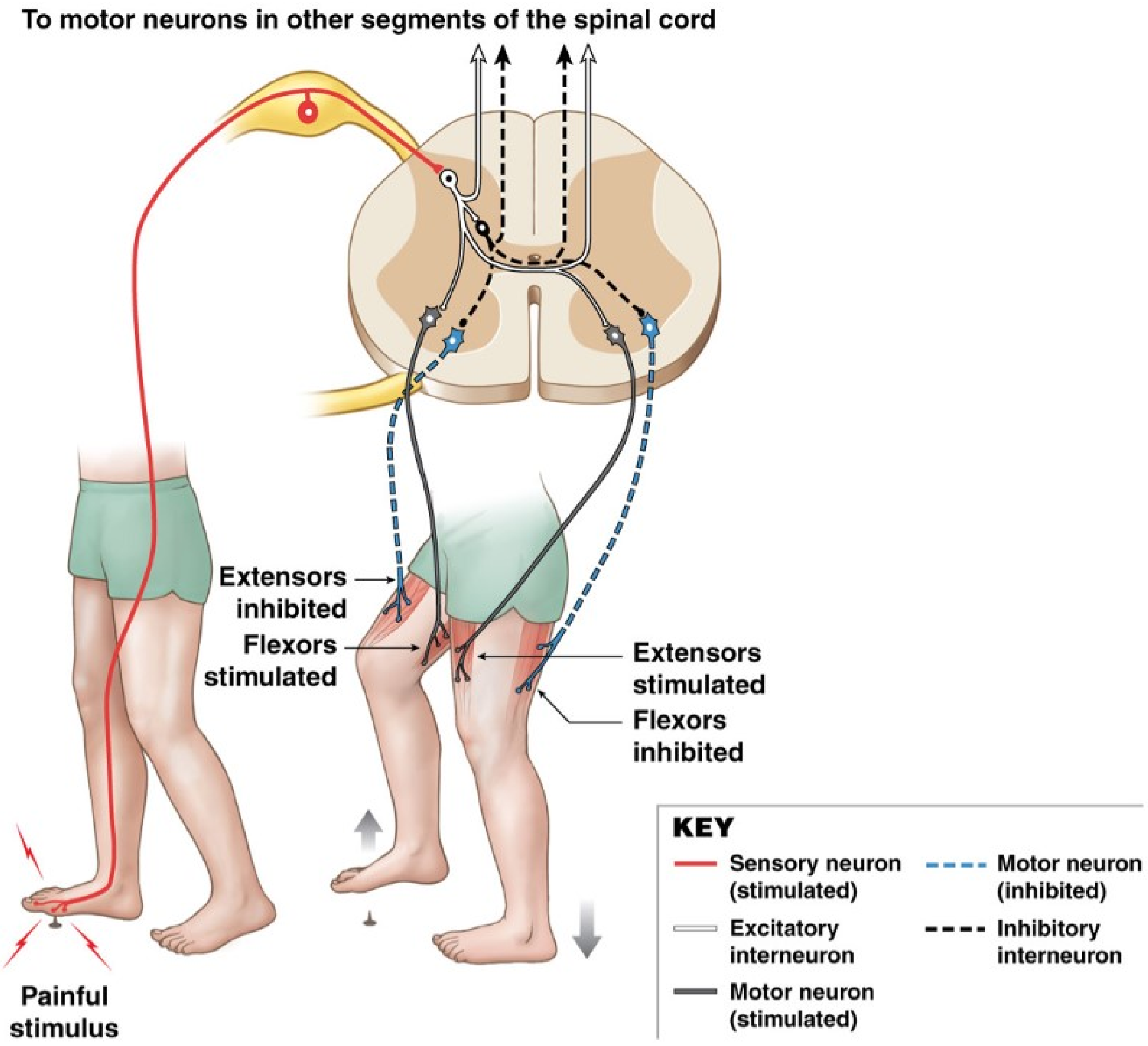
Exteroceptive reflexes

- Polysynaptic
- Polysegmental



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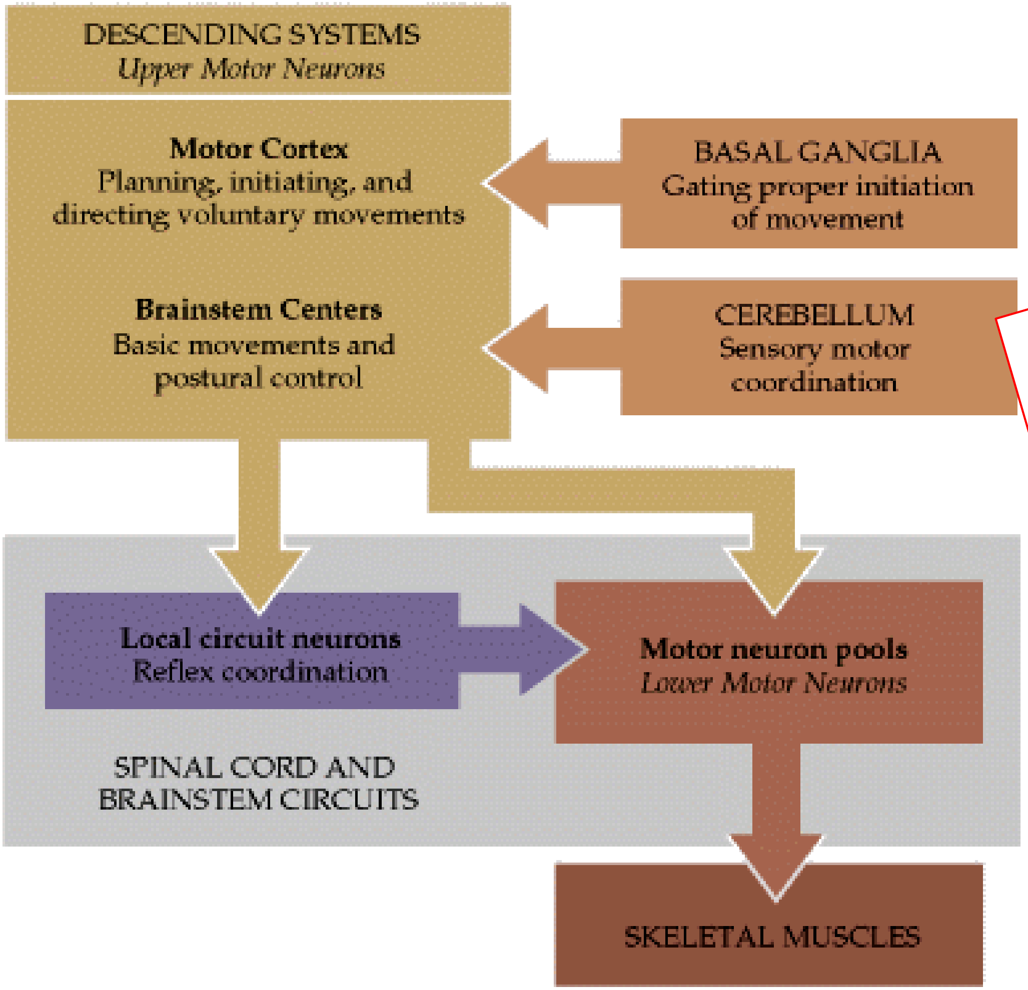
Hierarchic organization of motor system



Reflex movement
Rhythmic movement
Voluntary movement

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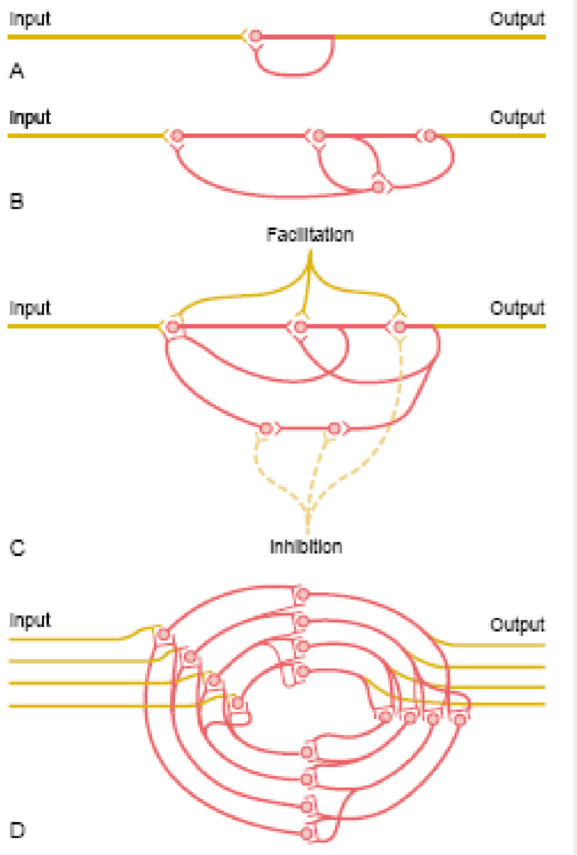
Fixed action pattern and rhythmic movement

- 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)



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Fixed action pattern and rhythmic movement

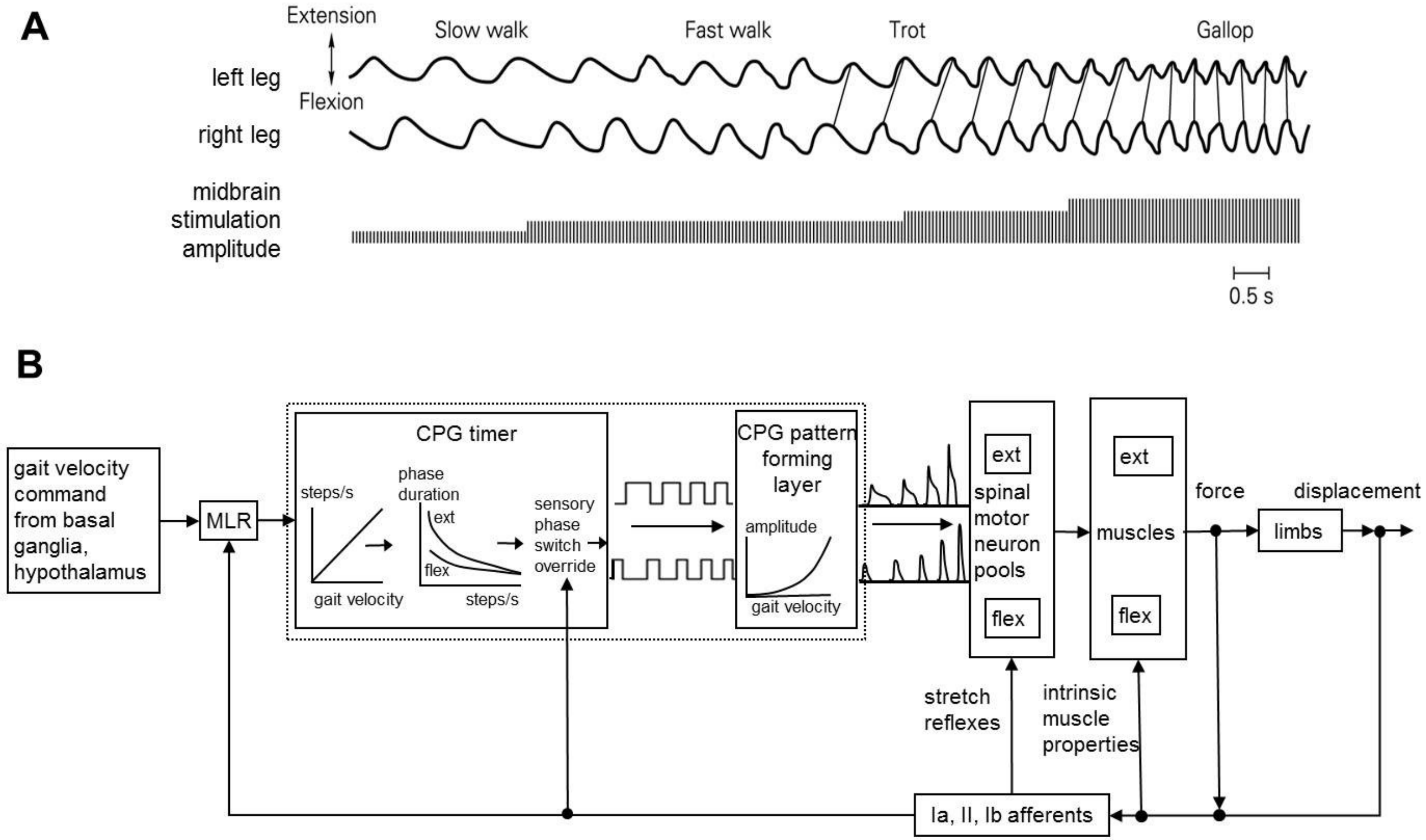


Fig. 1. Neural control of locomotion. A) Increments in the intensity of stimulation of the MLR in the high decerebrate cat increased the cadence (step cycles/sec) of locomotion. Adapted from Shik et al. 1966.[22] B) Schematic of the velocity command hypothesis: a command signal specifying increasing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

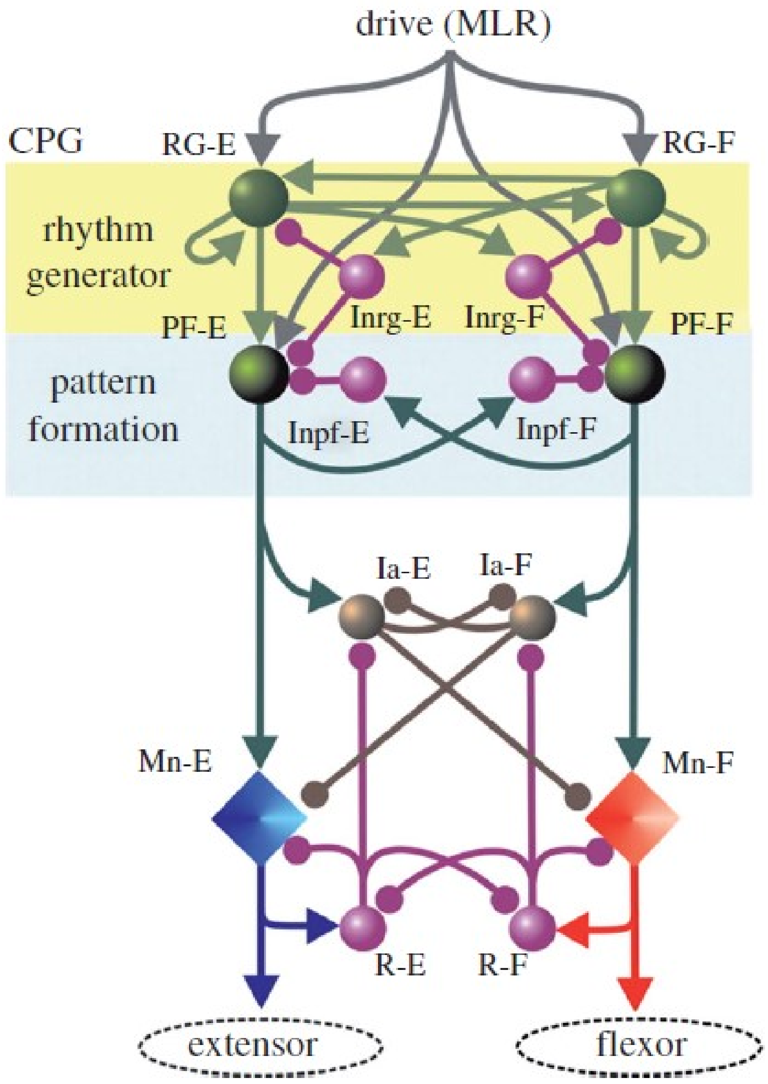
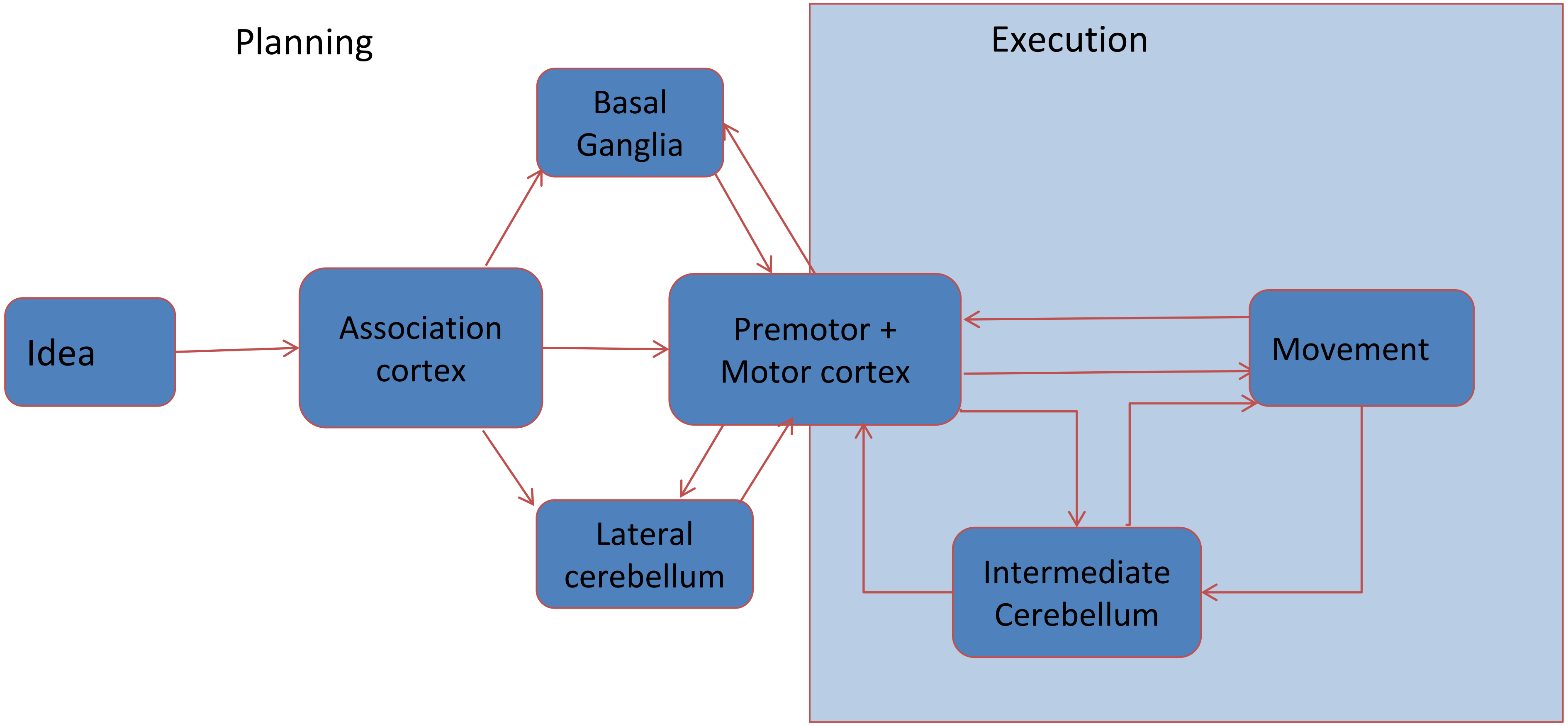


Figure 1. Schematic of model by Rybak & McCrea. The populations of interneurons are indicated by spheres, while the motoneurons are represented by diamonds. This three-layer model consists of a rhythm-generating layer of extensor (RG-E) and flexor (RG-F) interneurons. Both populations have recurrent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

Voluntary motor activity



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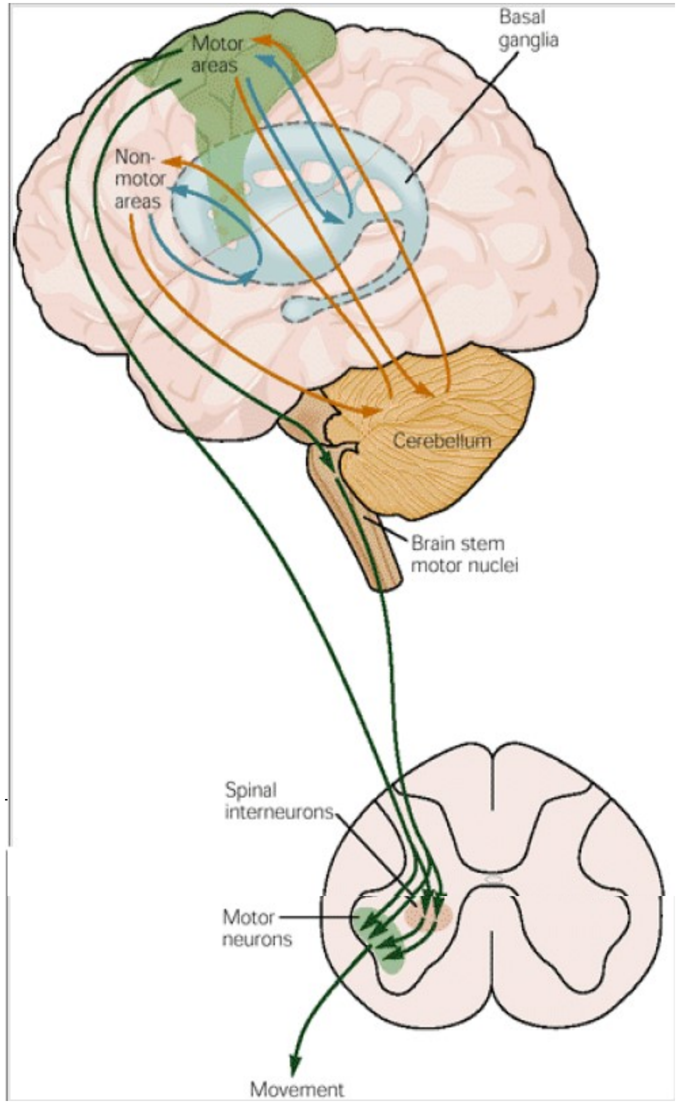
Voluntary motor activity

- 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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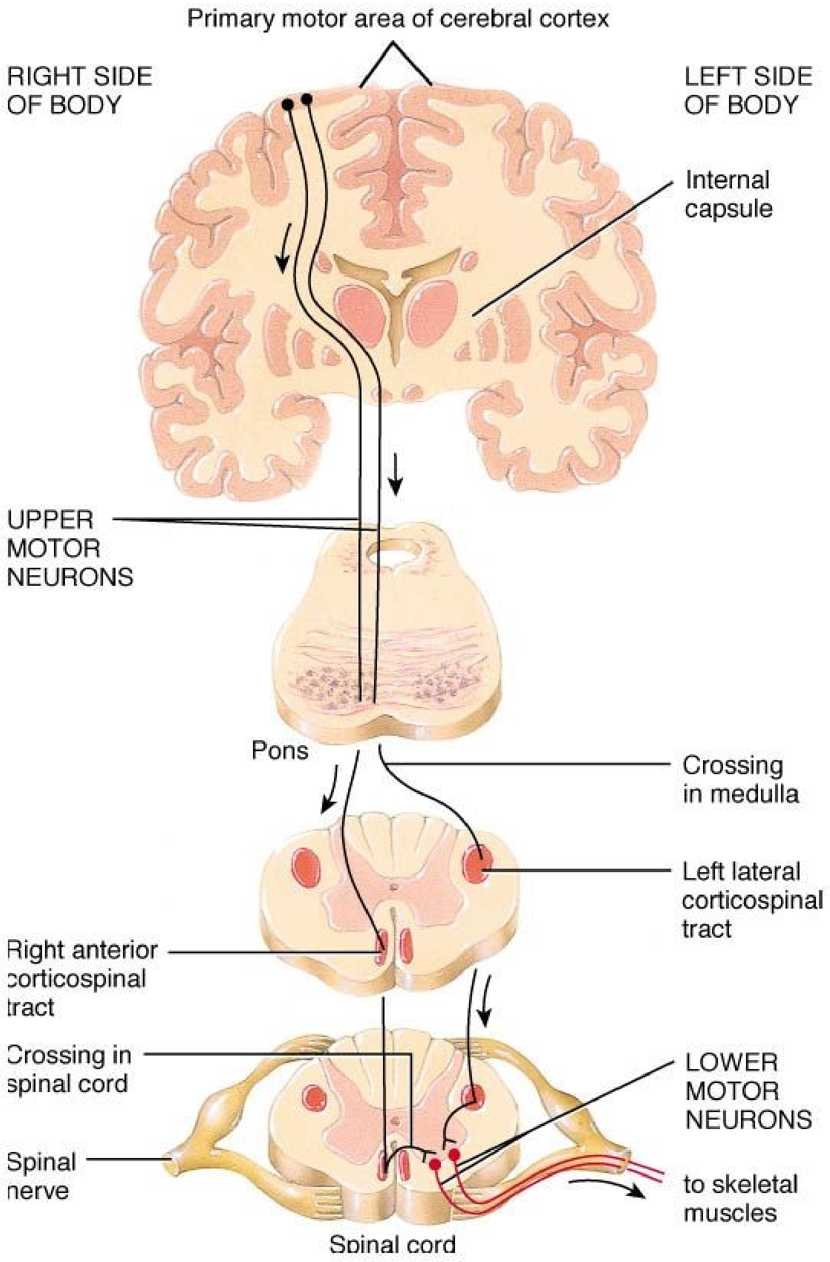
Pyramidal tract

- 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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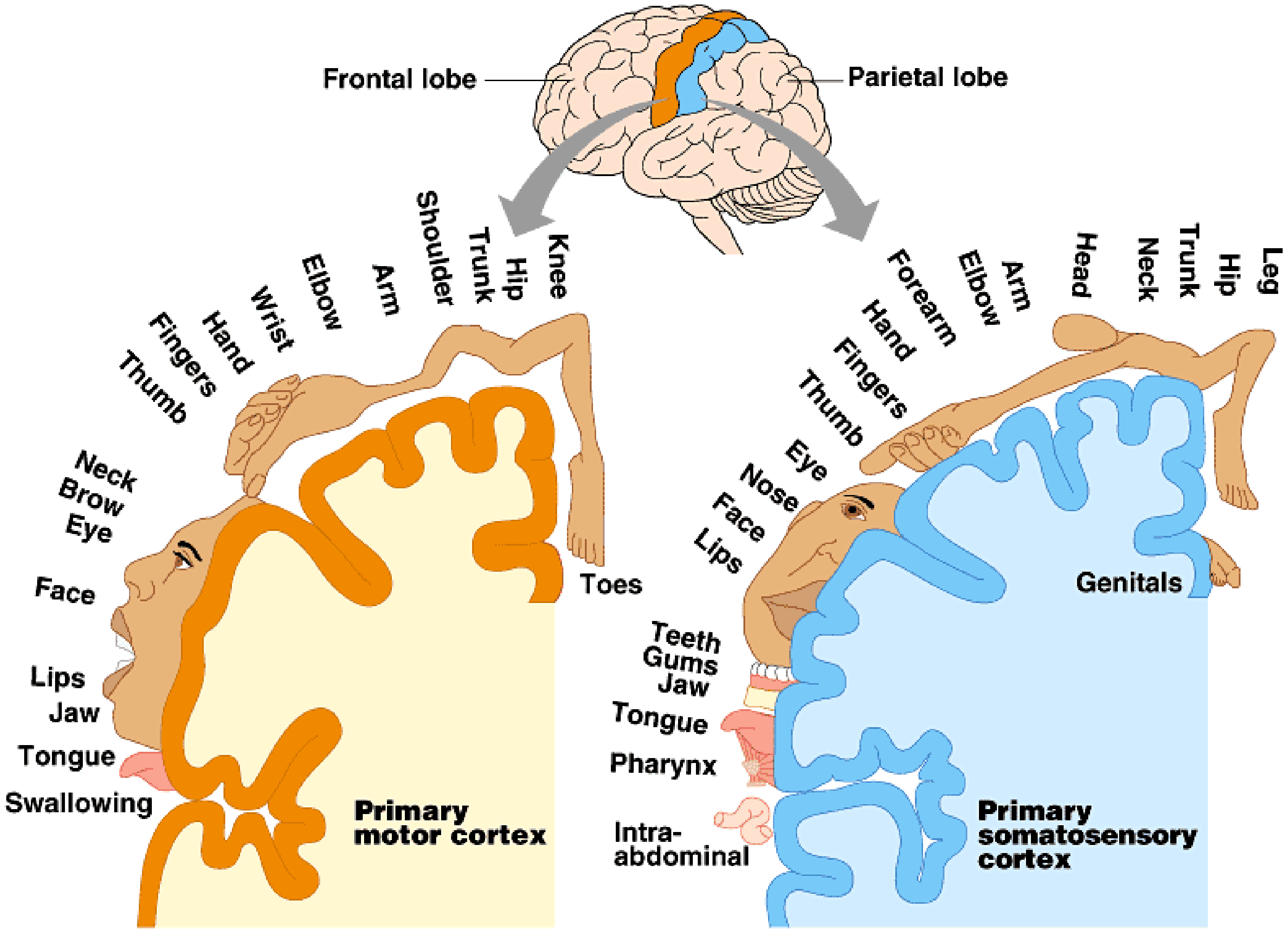
Primary motor cortex



http://www.emunix.emich.edu

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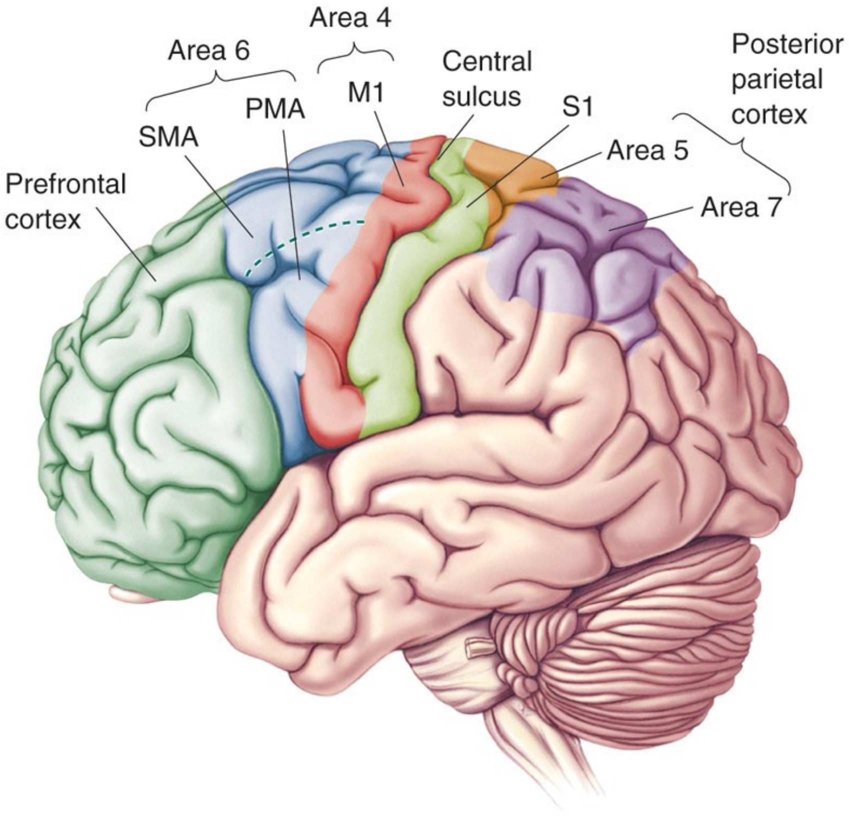
Motor cortex

- 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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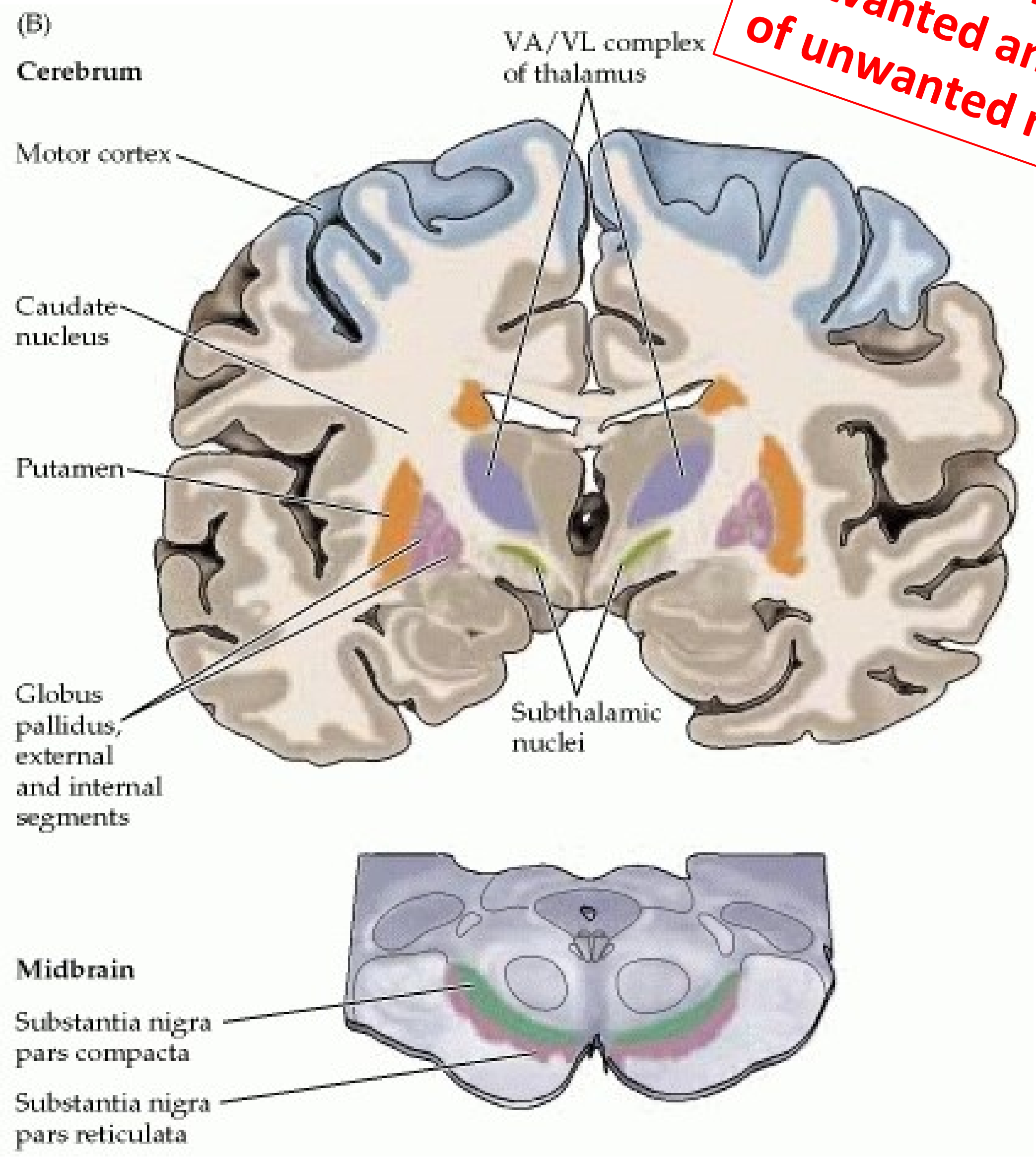
Basal ganglia

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

Motor gating – initiation of wanted and inhibition of unwanted movements



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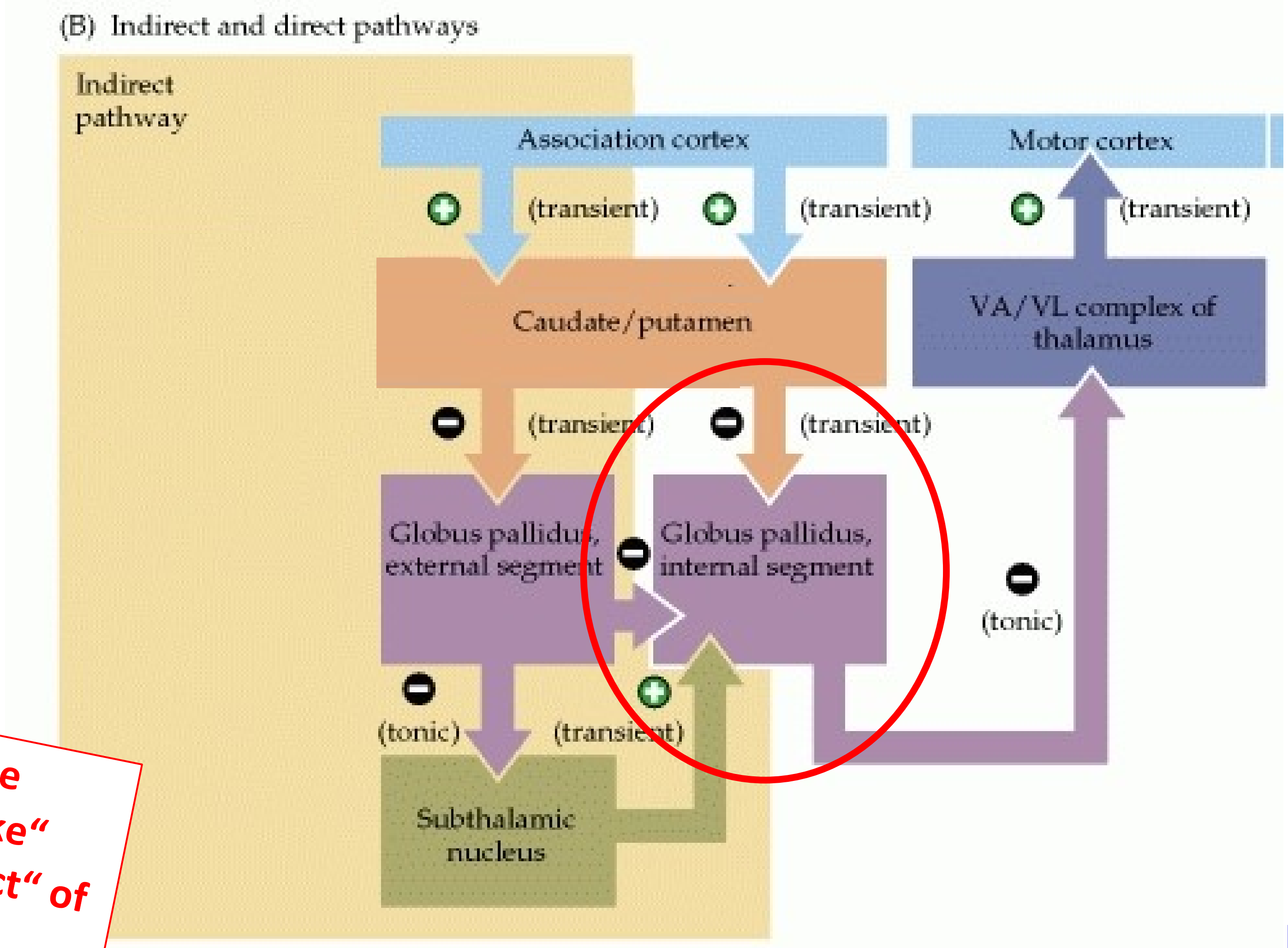
Direct and indirect pathway differences

- Direct pathway
  - ➢ Motor cortex activation
- Indirect pathway
  - ➢ Motor cortex inhibition



http://www.slideshare.net/drpsdeb/presentations

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

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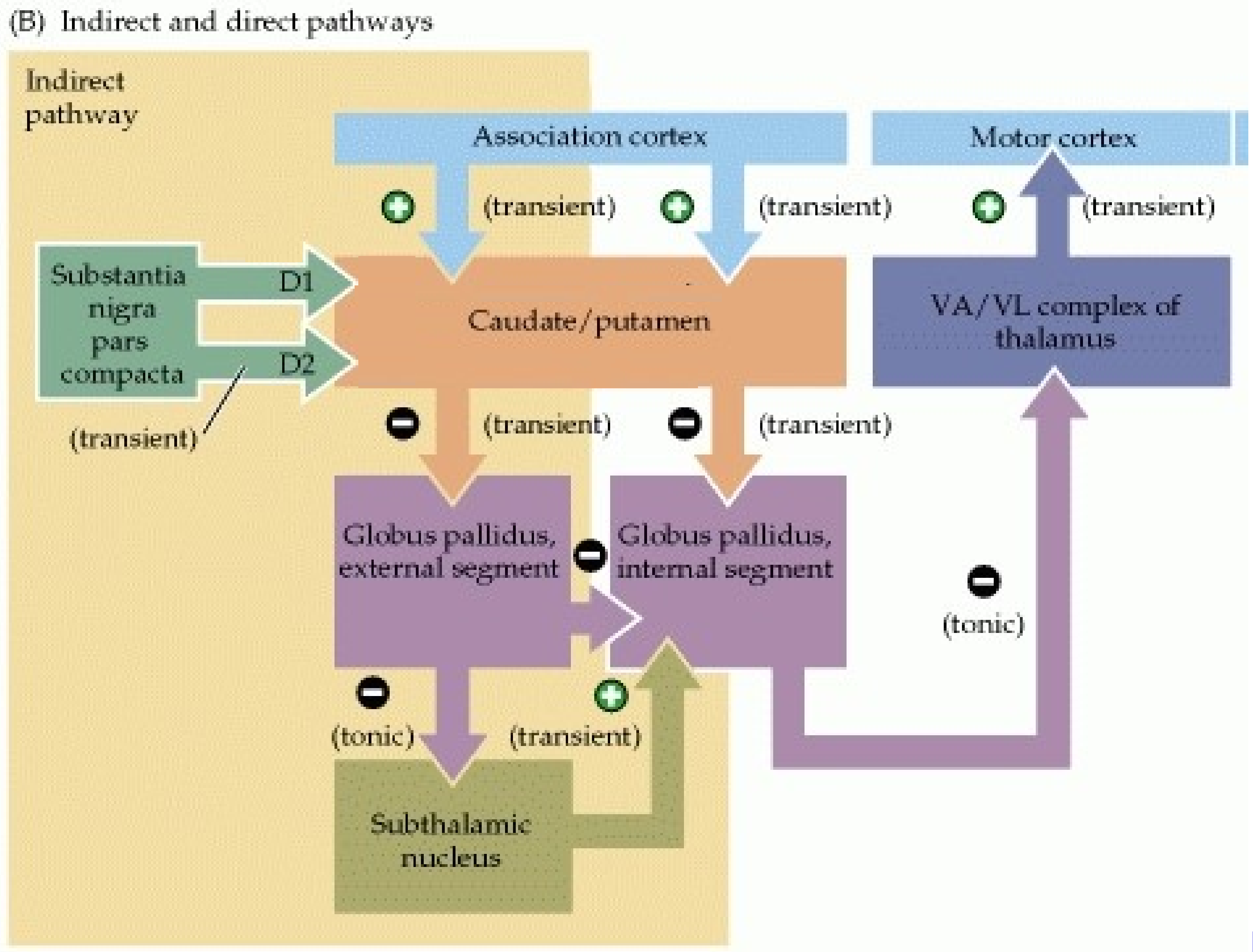
Dopaminergic projections

- Dopaminergic projections are crucial for the function of corpus striatum
- S. nigra pars compacta
- Direct pathway activation
  - D1 receptors
- Indirect pathway inhibition
  - D2 receptors



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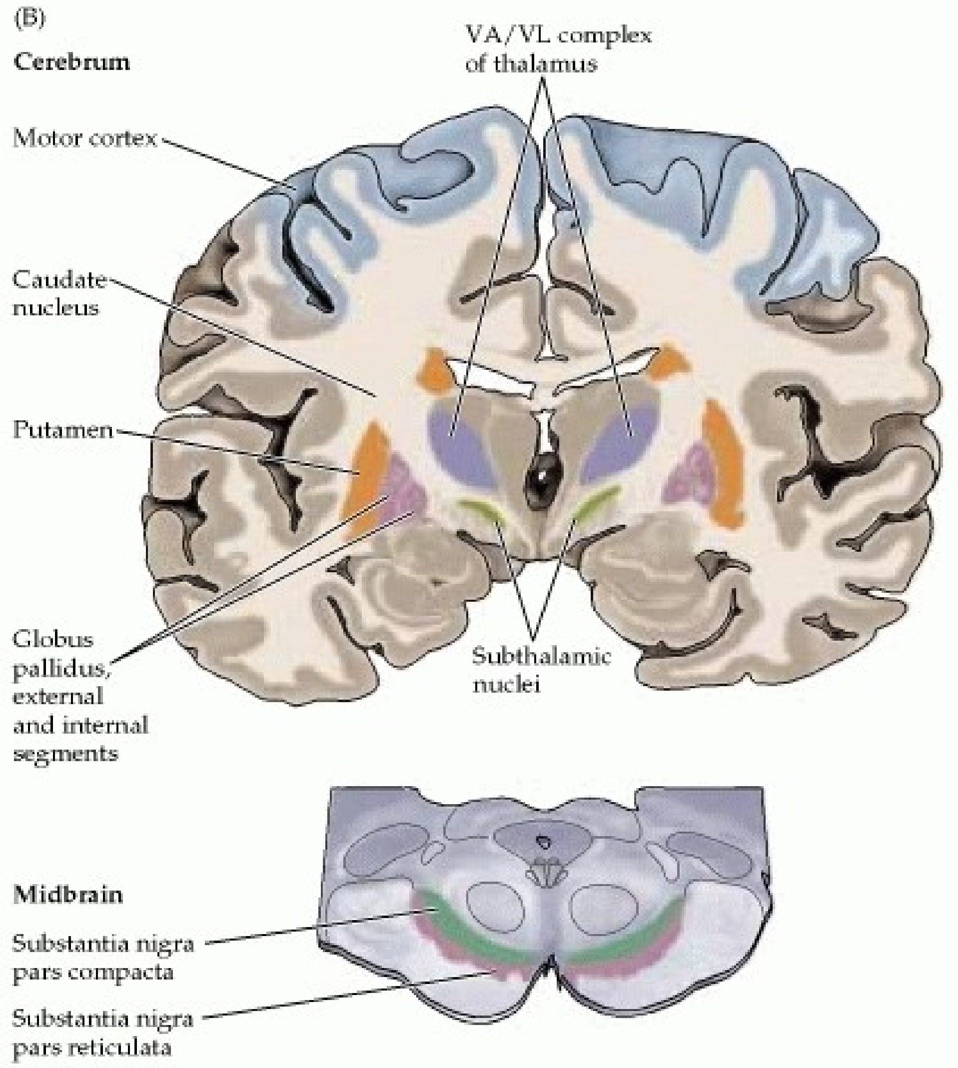
Basal ganglia

- 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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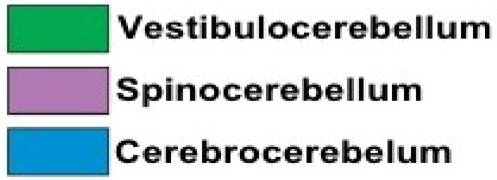
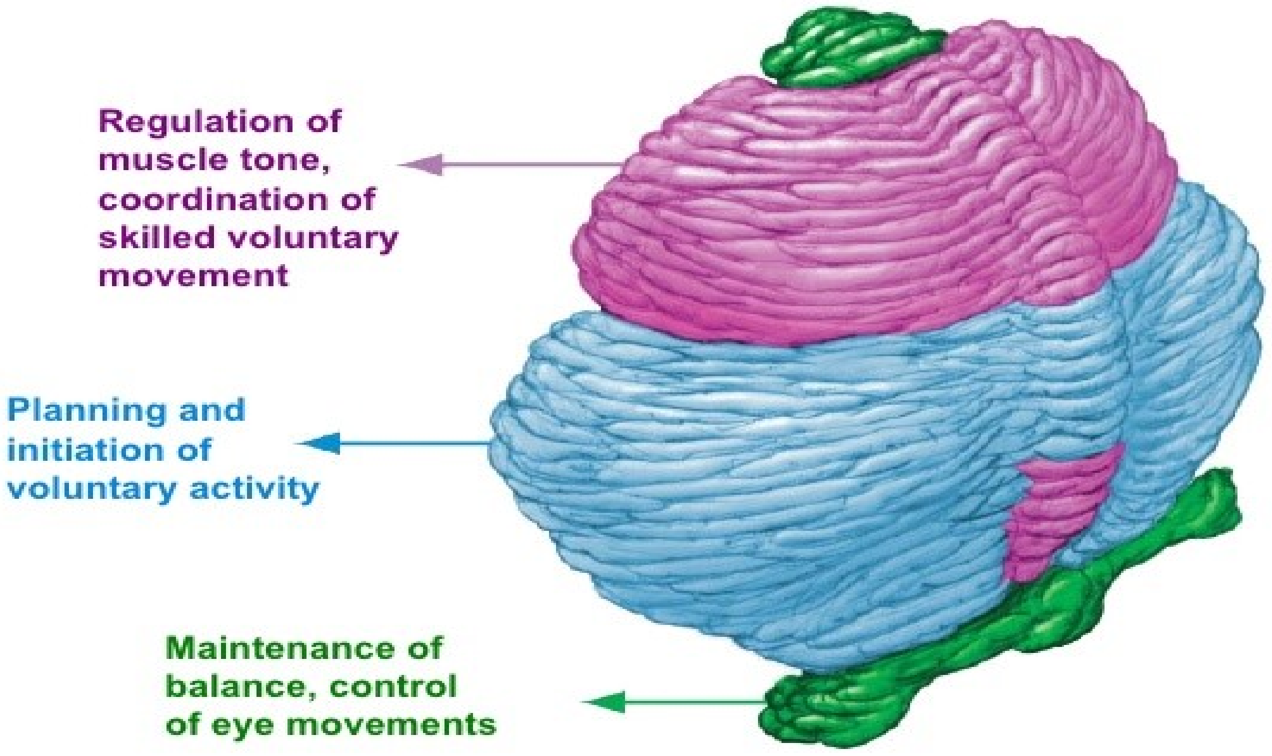
Cerebellum

- 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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