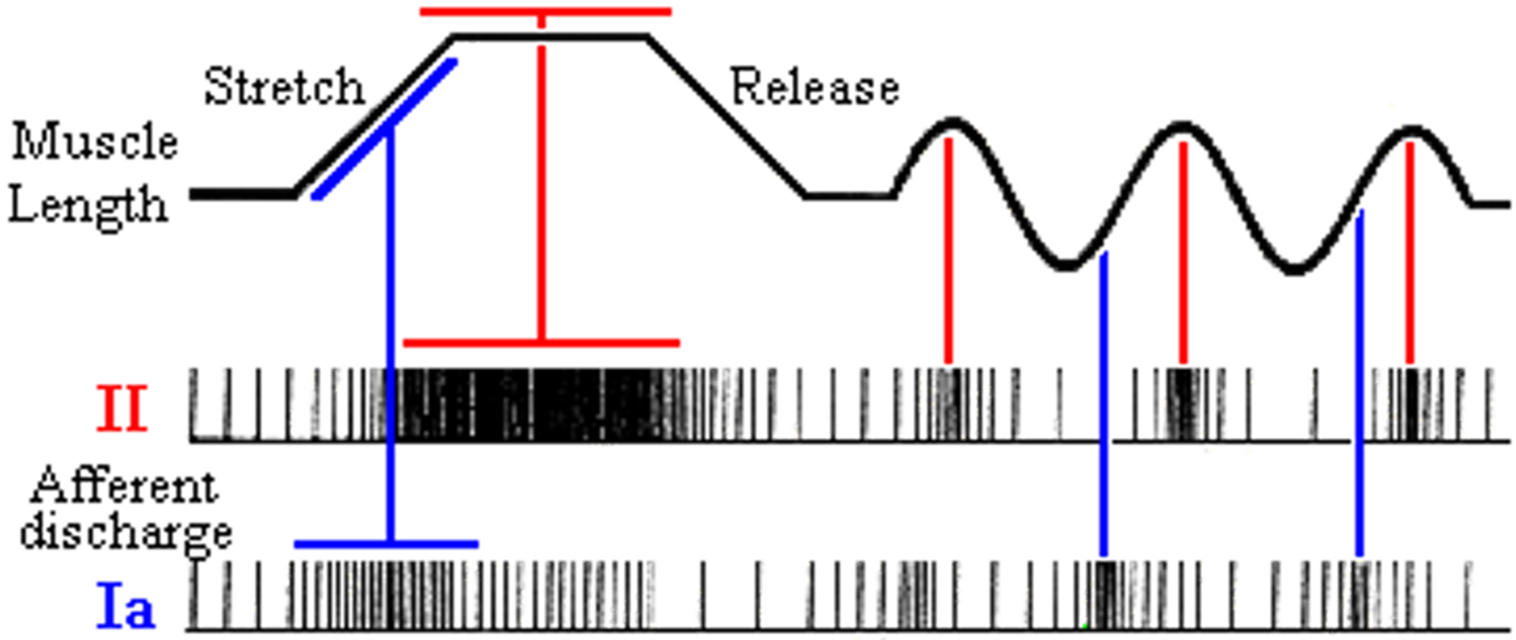
BMD ENG 301
Quantitative Systems Physiology
(Nervous System)

Spinal Reflex Circuits (cont’d)

Professor Malcolm MacIver

Proprioceptor Activity

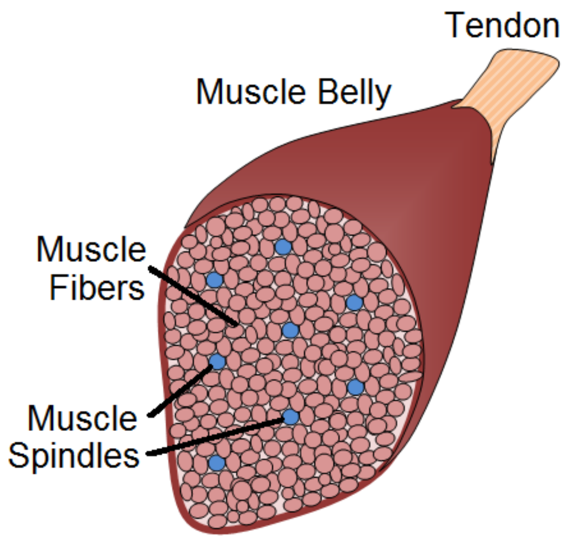
Functions

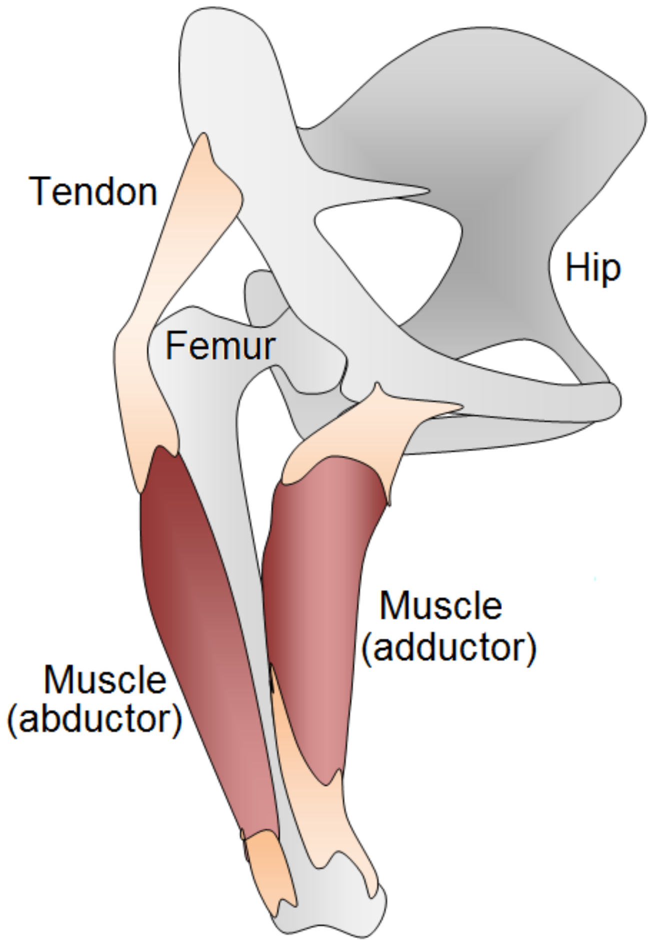


Types of Neurons

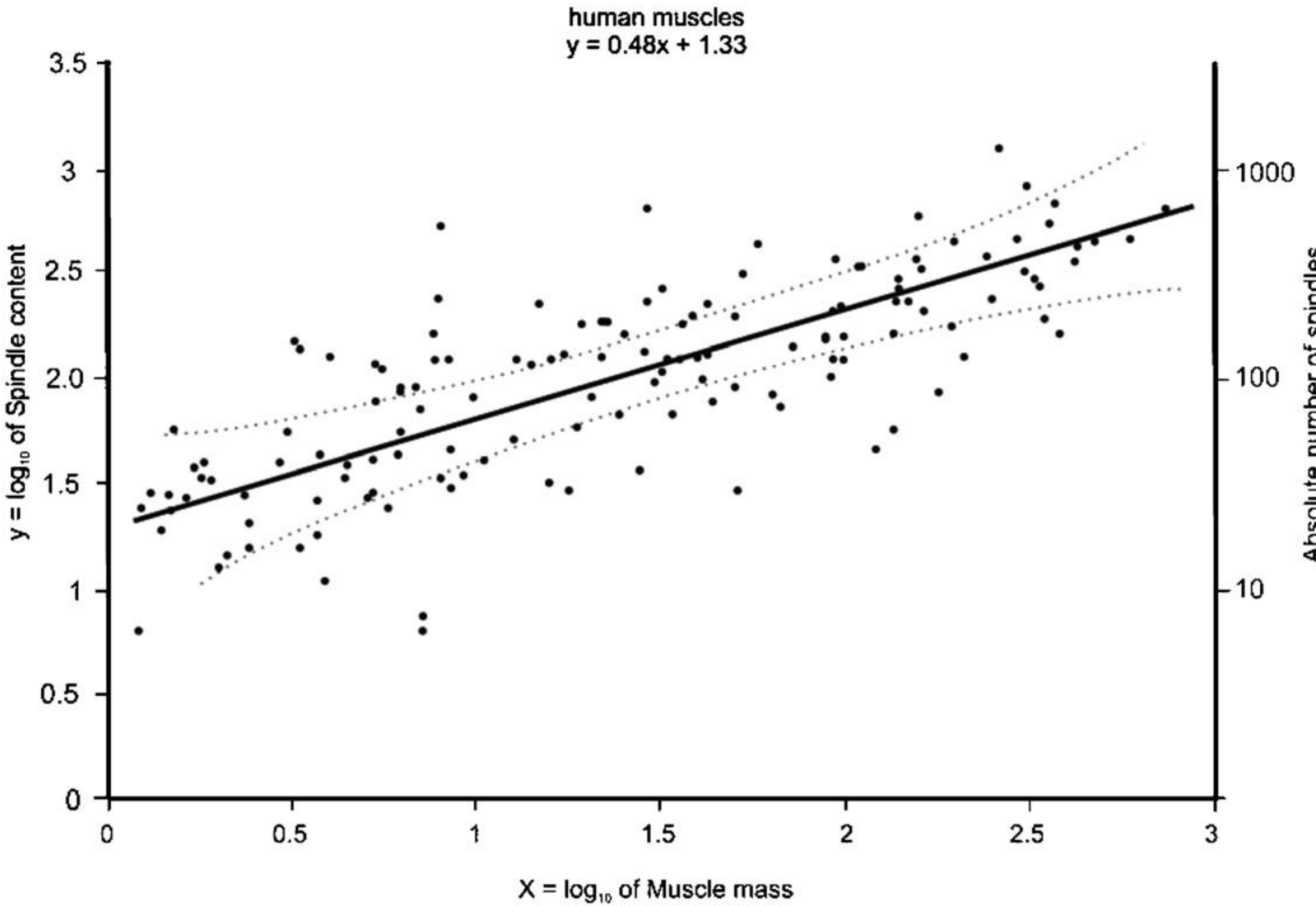
Type	**Axon Diameter (μm)**	**Signal Speed (ms^{-1})**	**Soma Location**	**Innervate**	
Ia sensory	13-20	70-120	Dorsal root ganglion	Nuclear bag fibers	Very fast
II sensory	6-12	30-70	Dorsal root ganglion	Nuclear bag and nuclear chain fibers	Fast, second most highly myelinated axon type
γ motor	5-8	4-24	Ventral horn	Intrafusal fibers	Small and slower conduction
α motor	13-20	80-120	Ventral horn	Muscle fibers	Very fast

- Found in almost all muscles
- From 10 to over a 1000 spindles in each muscle
- Number of spindles roughly proportional to size of muscle
- Do not run the length of the muscle
  - except for short muscles

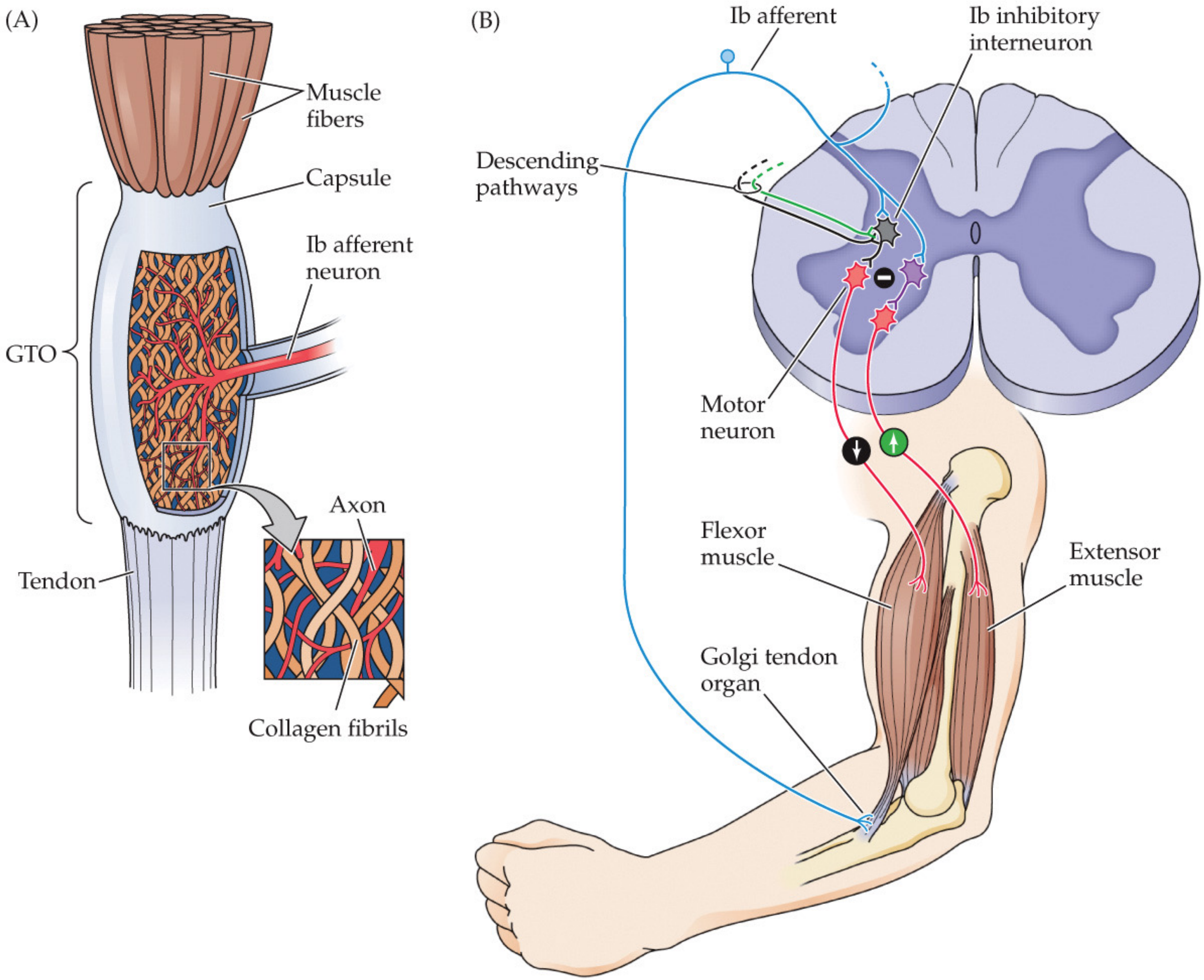




Number of Spindles



Negative feedback regulation of muscle tension by Golgi tendon organs



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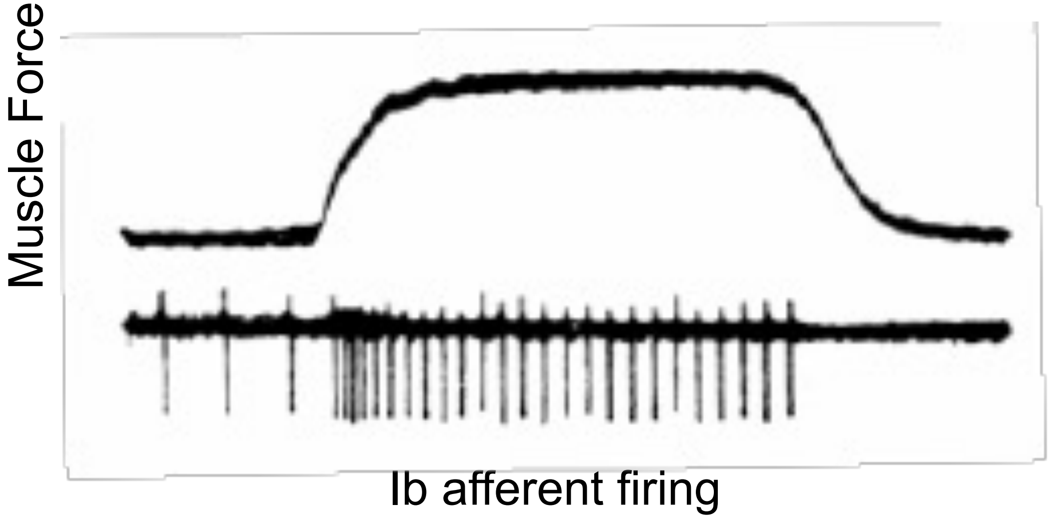
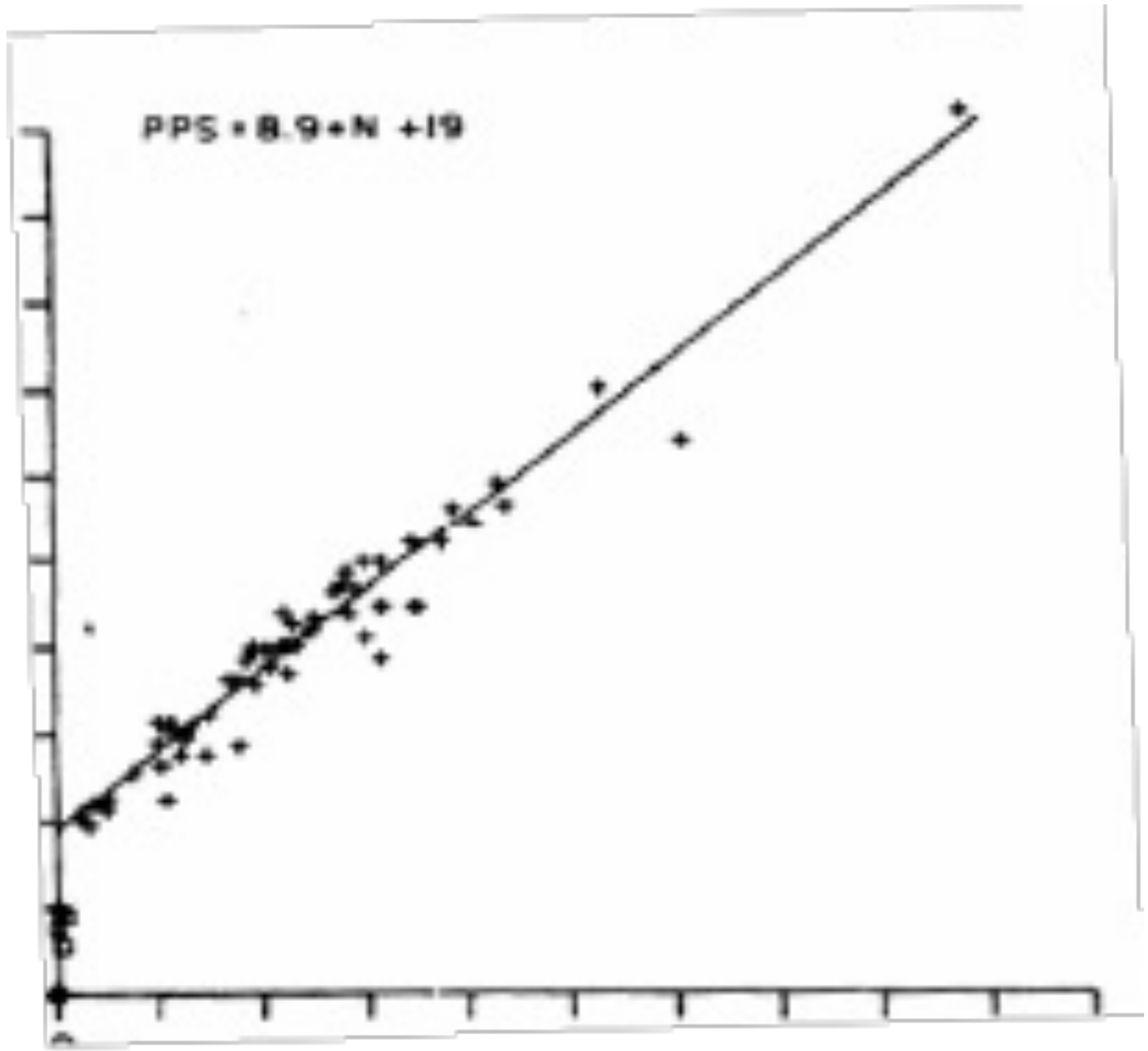
Ib afferent encodes force



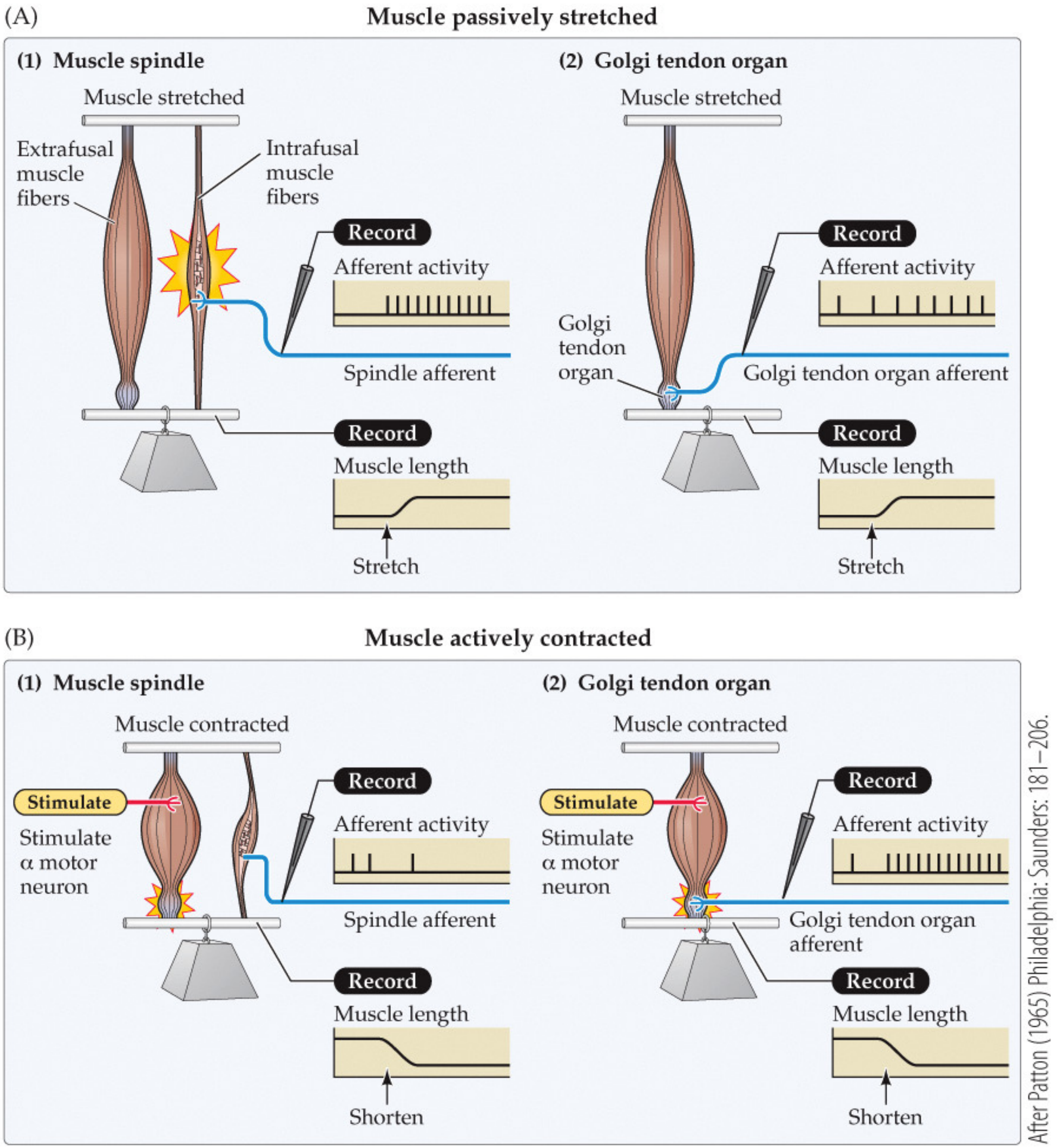
Ib afferent encodes force

Ib afferent firing rate



Muscle force

Spindle Sensor	GTO Sensor
Length and ΔL/dt	Force
Ia and II afferents	Ib afferent
Ia afferent provides <u>direct</u> excitatory drive to alpha motor neurons innervating homonymous and synergist muscles	Ib afferent provides inhibitory drive to alpha motor neurons innervating homonymous muscle <u>through interneurons</u>
Ia afferent provides inhibitory drive to alpha motor neurons innervating antagonist muscle <u>through interneurons</u>	Ib afferent provides excitatory drive to alpha motor neurons innervating antagonist muscle <u>through interneurons</u>
	Ib afferent has widespread connections in the spinal cord
Spindle arranged in parallel with the extrafusal fibers	GTO arranged in series with the extrafusal fibers



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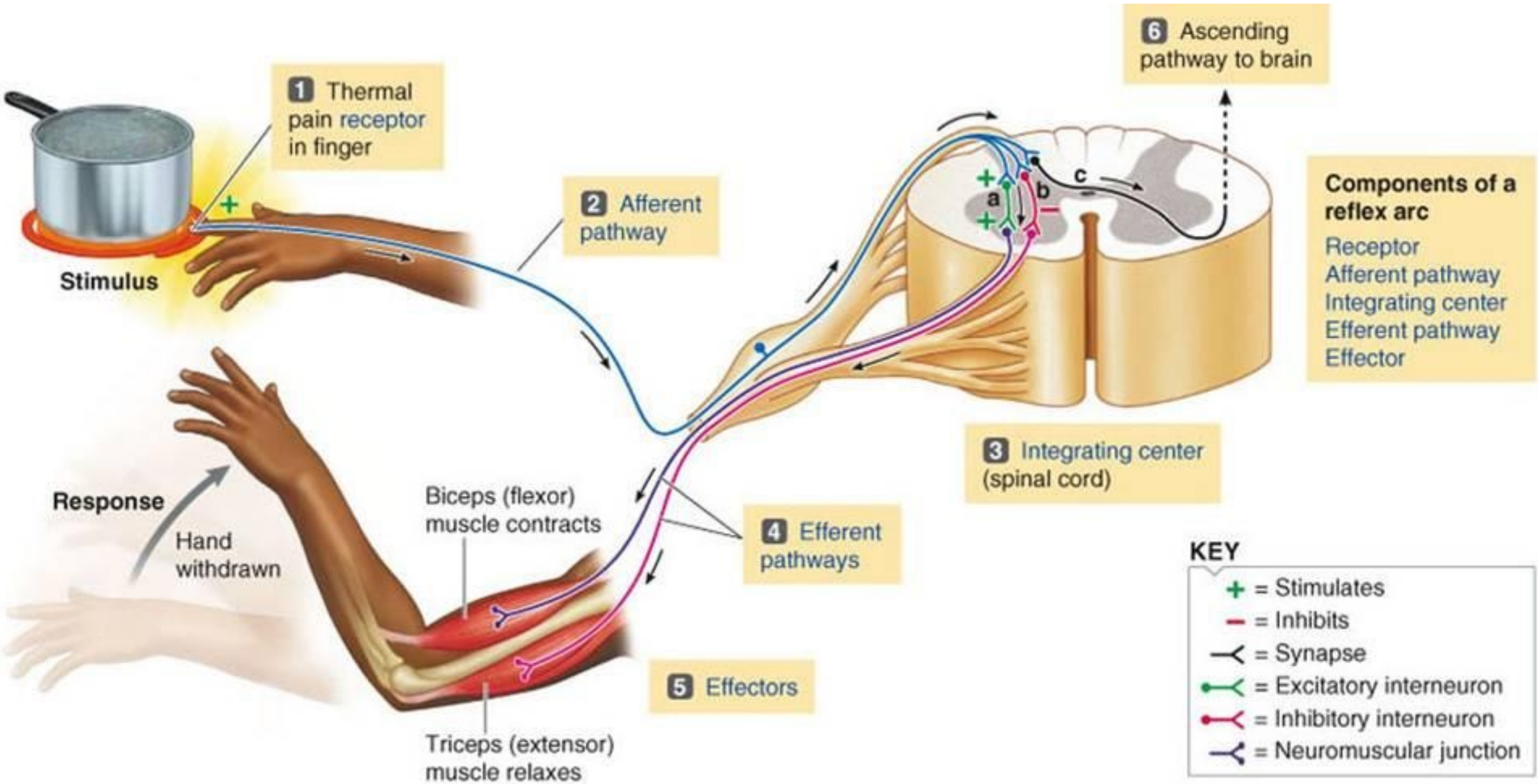
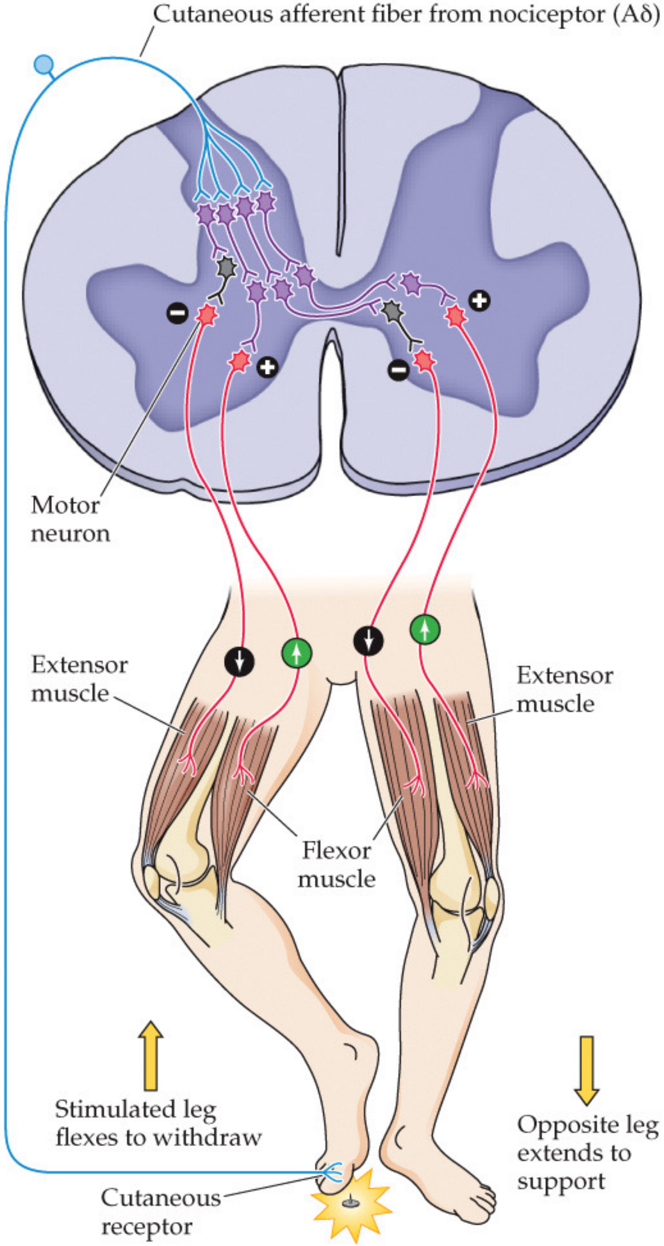
Flexor Reflex



Spinal cord circuitry for the flexion–crossed extension reflex



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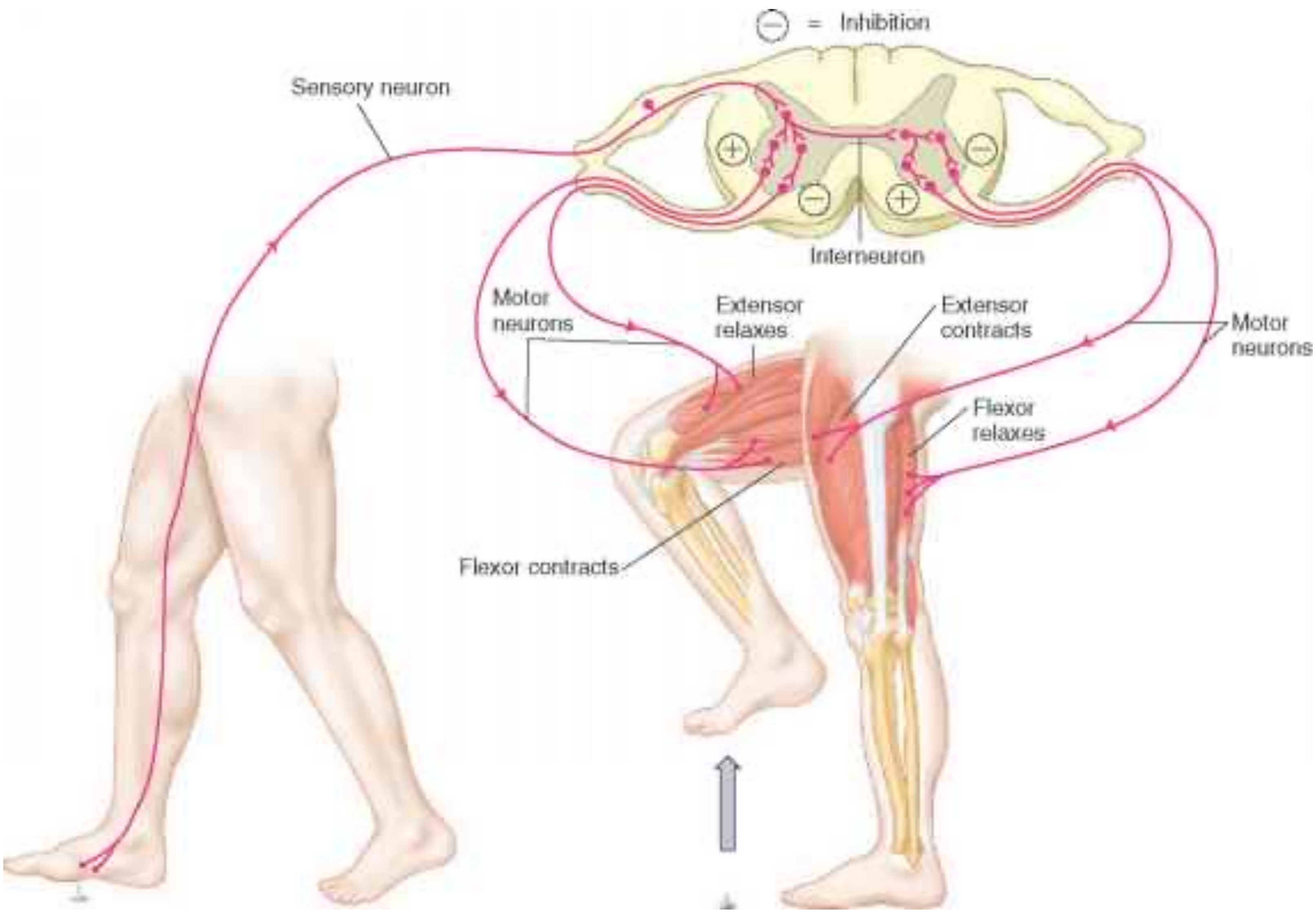
Withdrawal + Crossed Extension Reflexes



Reflexes

Reflex	Afferent	Detects	Mode of Action	Function
Stretch (Myotatic)	Ia from spindle (70-120 ms^{-1})	Phasic stretch of muscle	Contraction of homonymous muscle, relaxation of antagonist muscle	Adjust a motor action for unpredicted perturbation
"Inverse" Myotatic	Ib from GTO (70-120 ms^{-1})	Active stretch of tendon	Contraction of antagonist muscle, relaxation of homonymous muscle (BUT not really the exact opposite of the myotatic action)	Control of muscle force/stiffness (prevent overstretch)
Group II	II from spindle (30-70 ms^{-1})	Steady stretch of muscle	Complex	Posture
Flexor	II, III, IV from cutaneous nerve endings (0.5-70 ms^{-1})	Harmful stimulus	Ipsilateral flexion and contralateral extension	Withdraw limb from harm

Doc cam

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Locomotion

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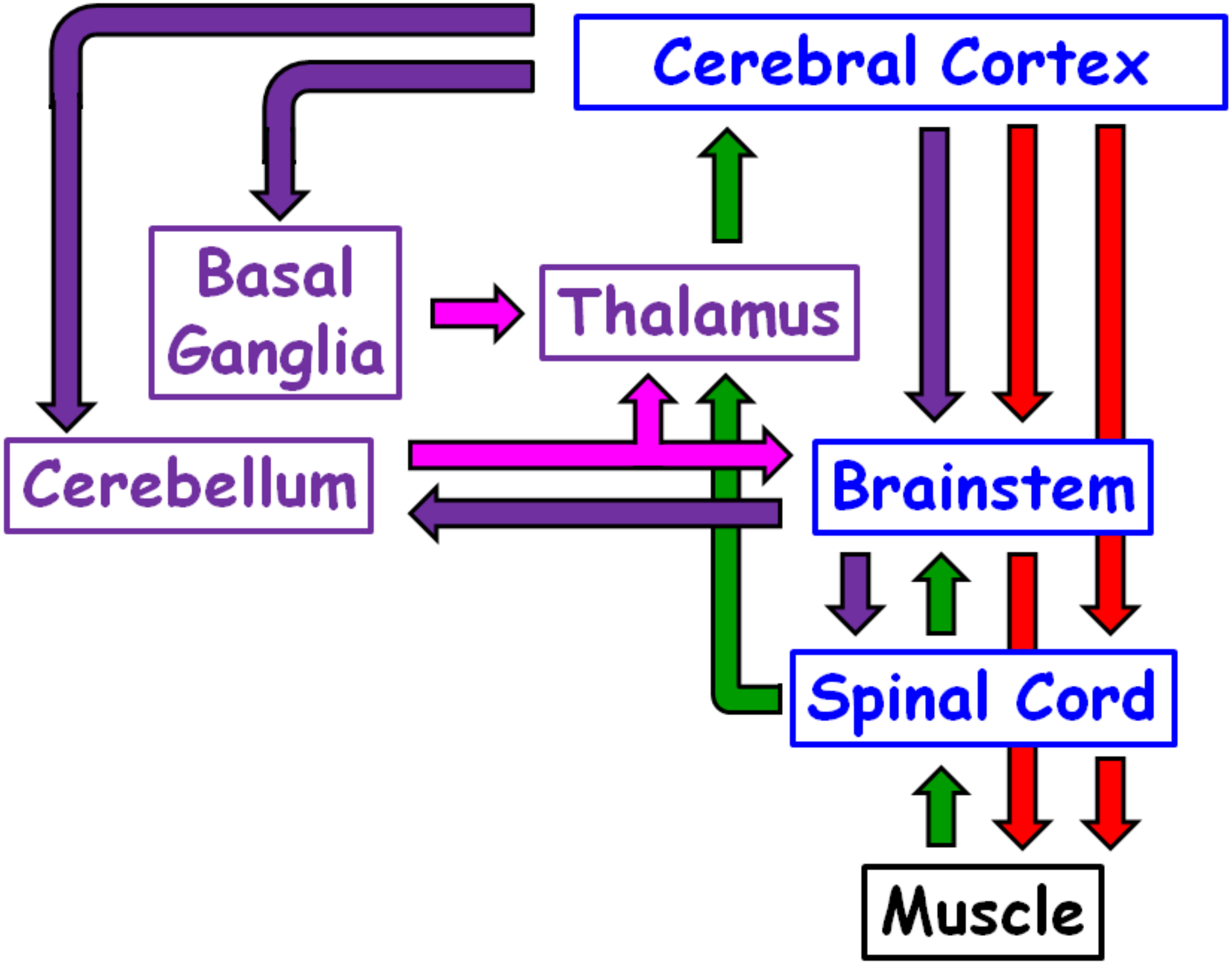
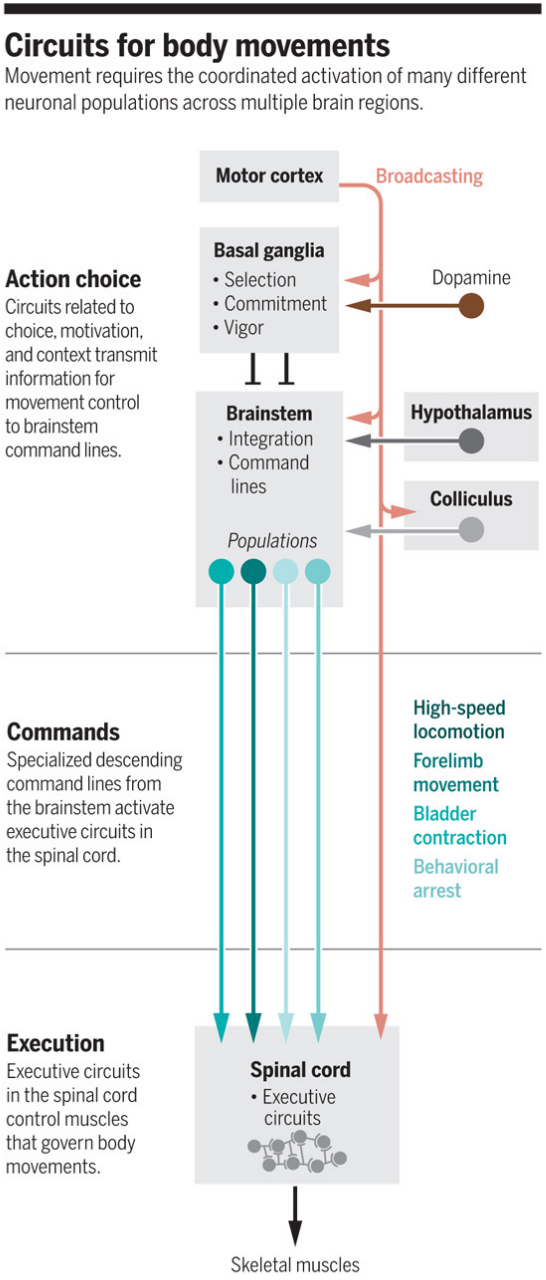
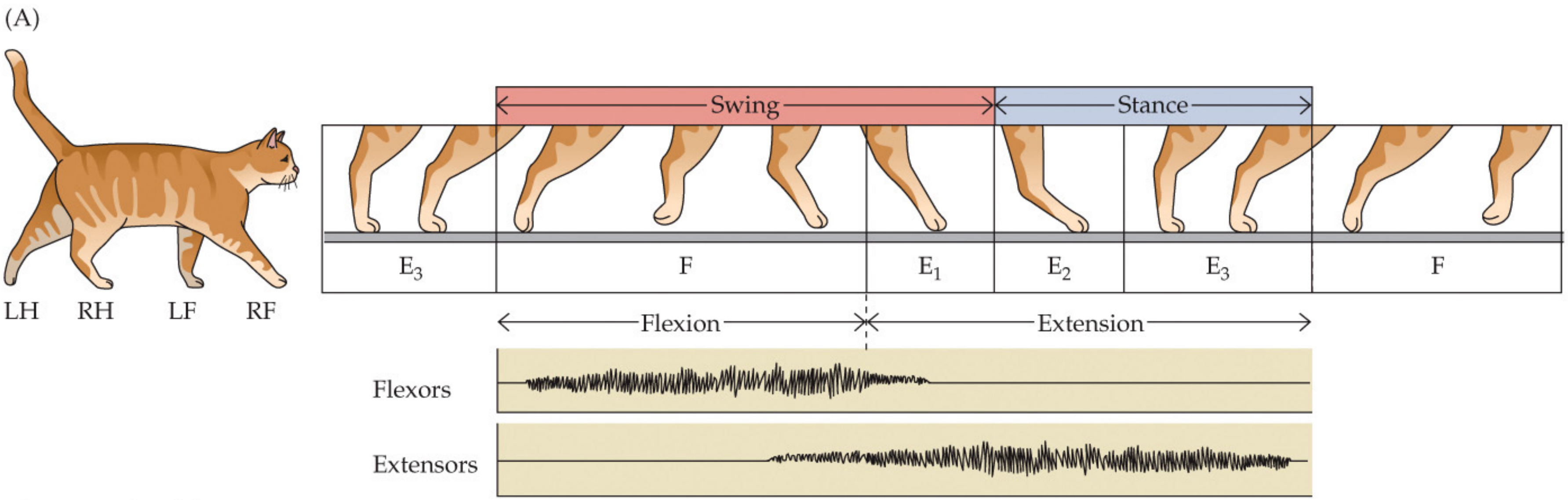
Organization of the motor system (body only)



Motor control is distributed



The mammalian cycle of locomotion is organized by central pattern generators in the spinal cord



After Pearson (1976) *Sci. Amer.* 235: 72–86.

***NEUROSCIENCE 6e*, Figure 16.15 (Part 1)**

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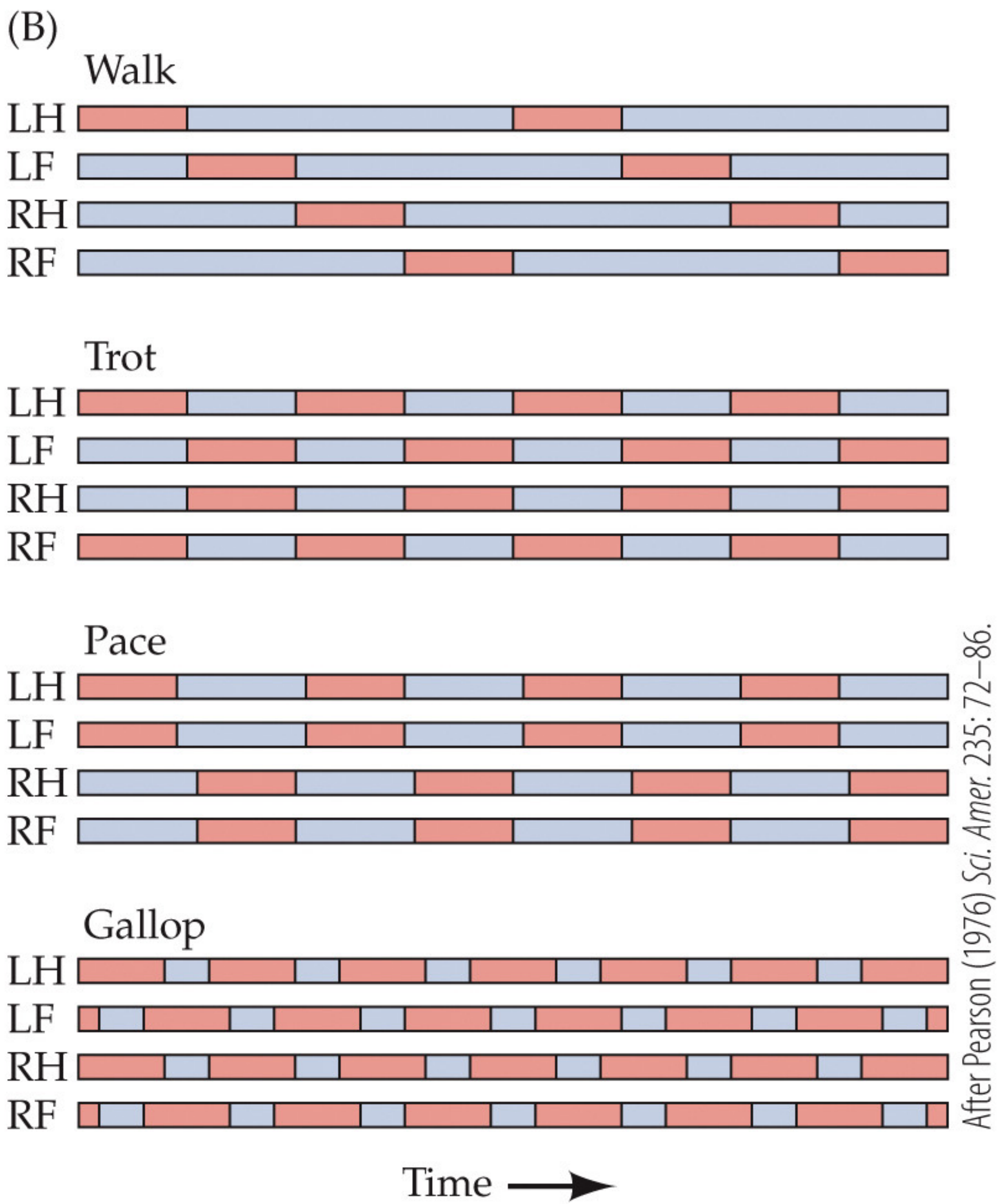
The mammalian cycle of locomotion is organized by central pattern generators in the spinal cord



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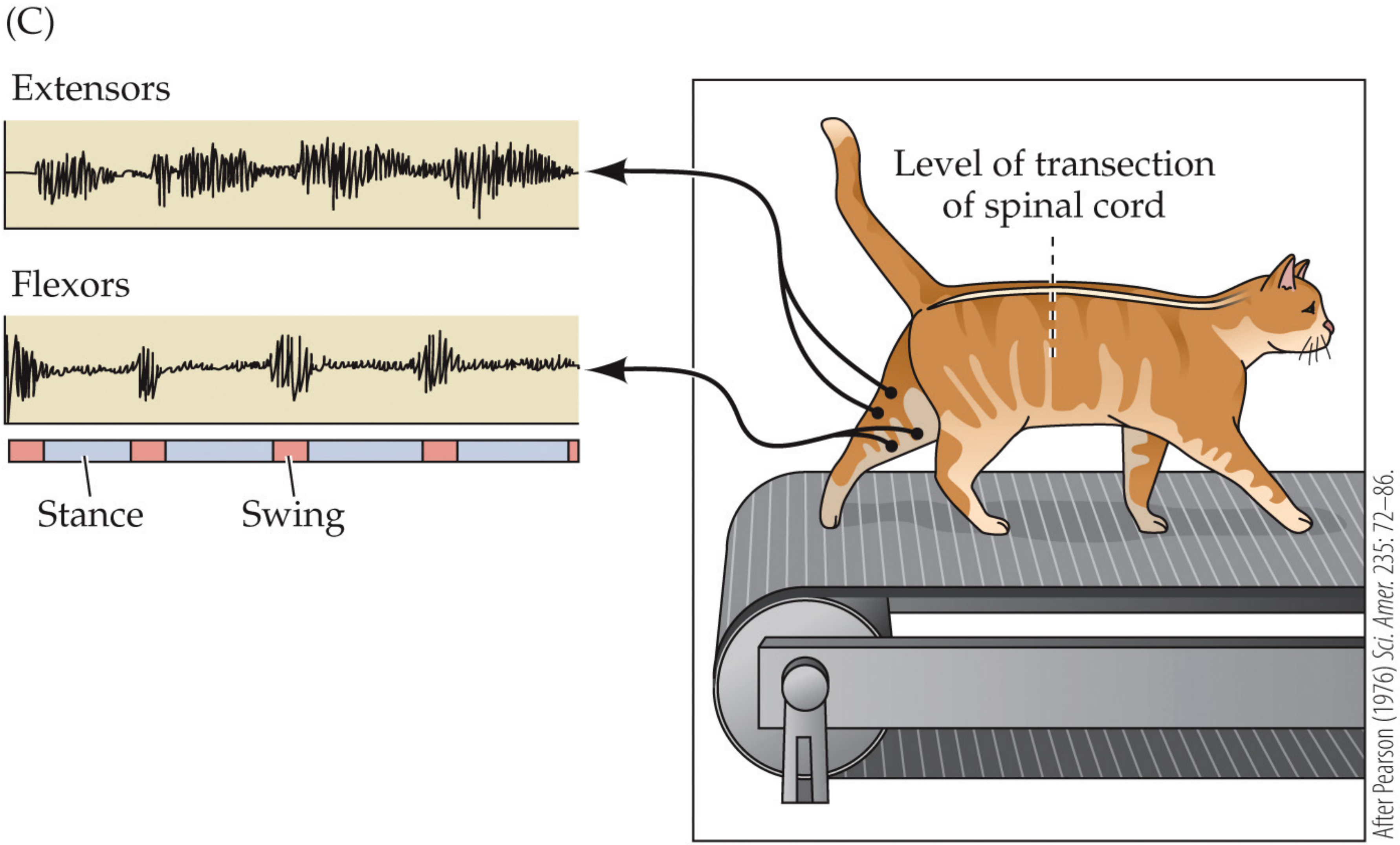
The mammalian cycle of locomotion is organized by central pattern generators in the spinal cord



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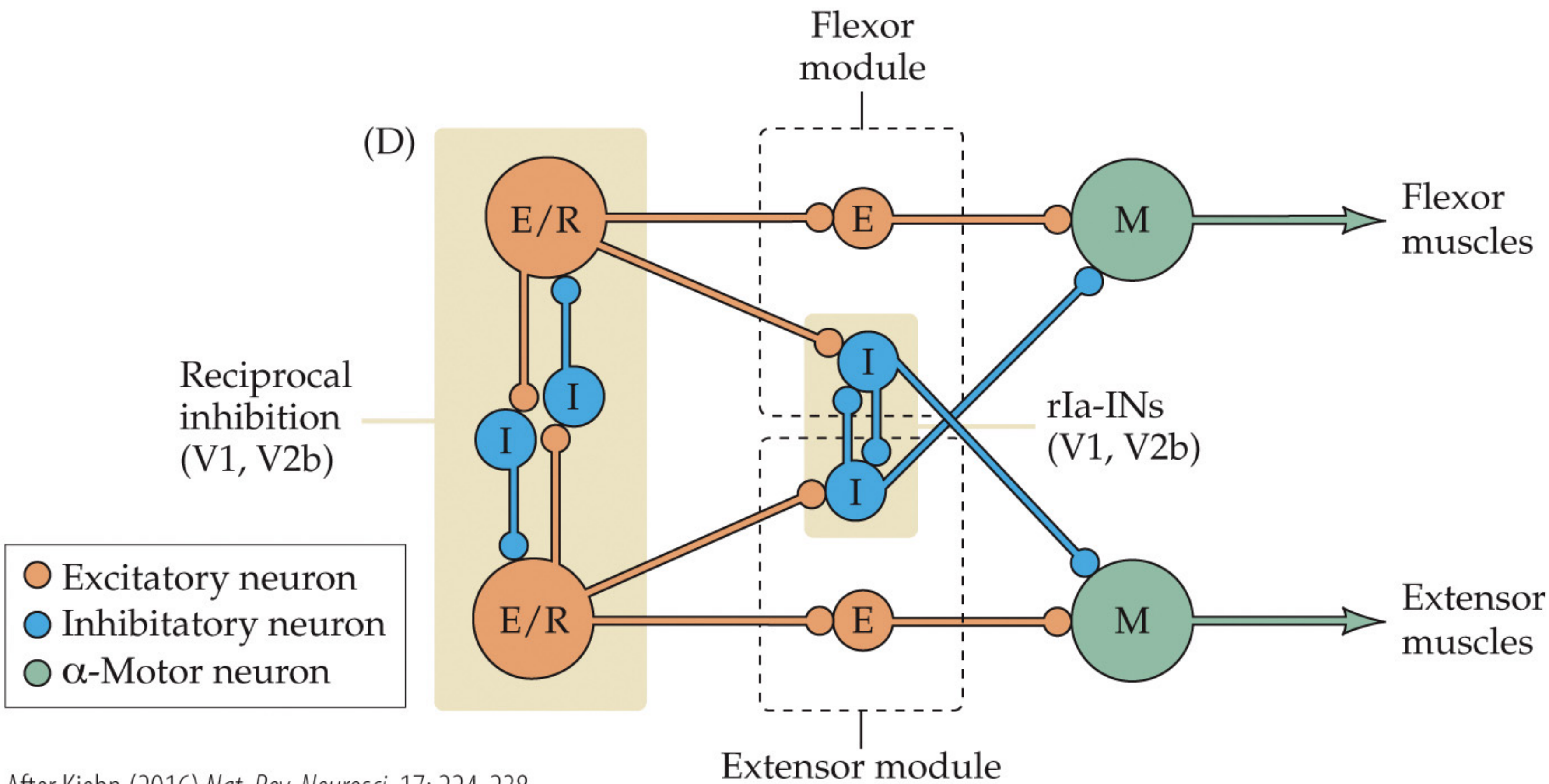
Doc cam

Central pattern generator in the spinal cord



After Kiehn (2016) *Nat. Rev. Neurosci.* 17: 224-238.

***NEUROSCIENCE 6e*, Figure 16.15 (Part 4)**

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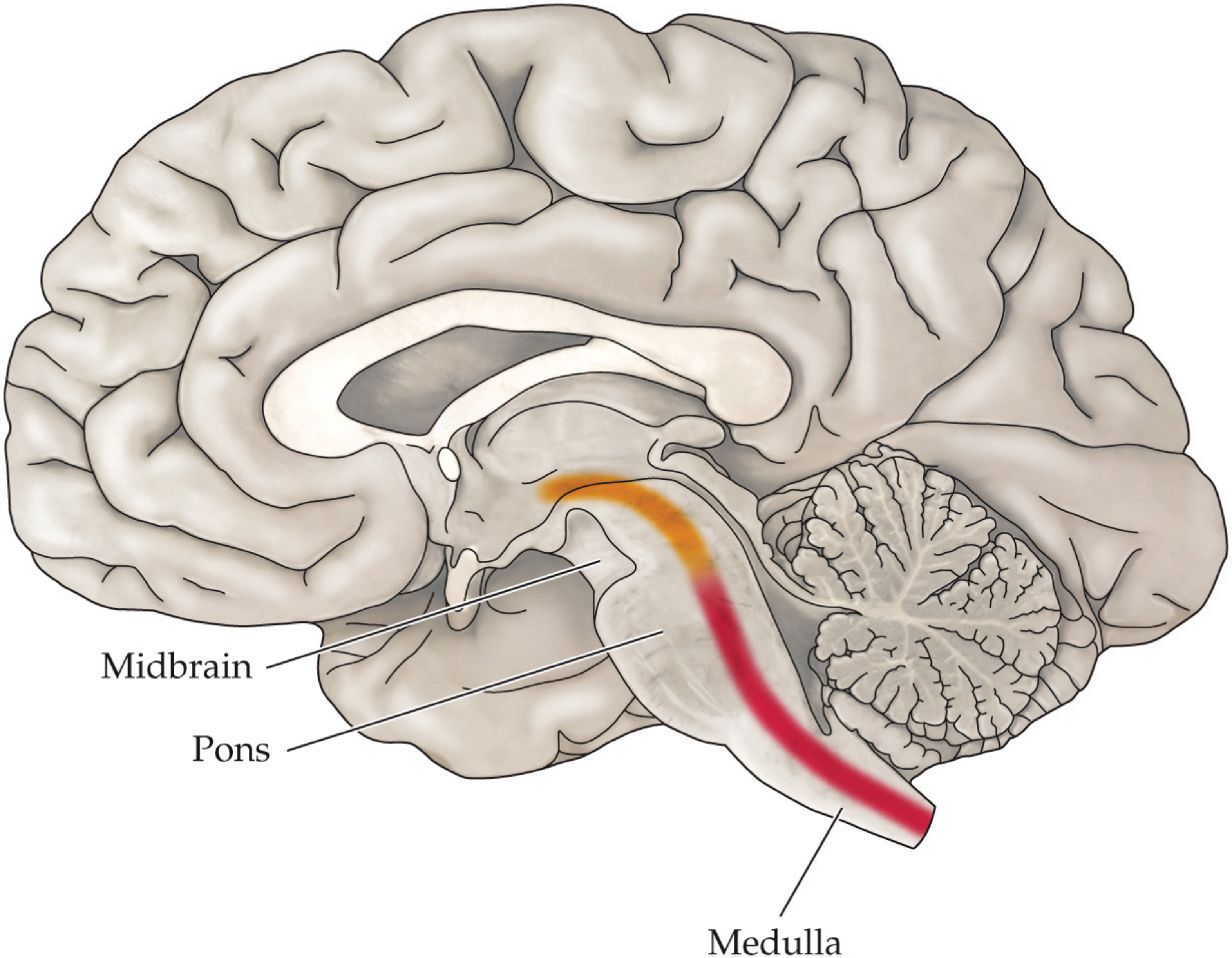
The reticular formation



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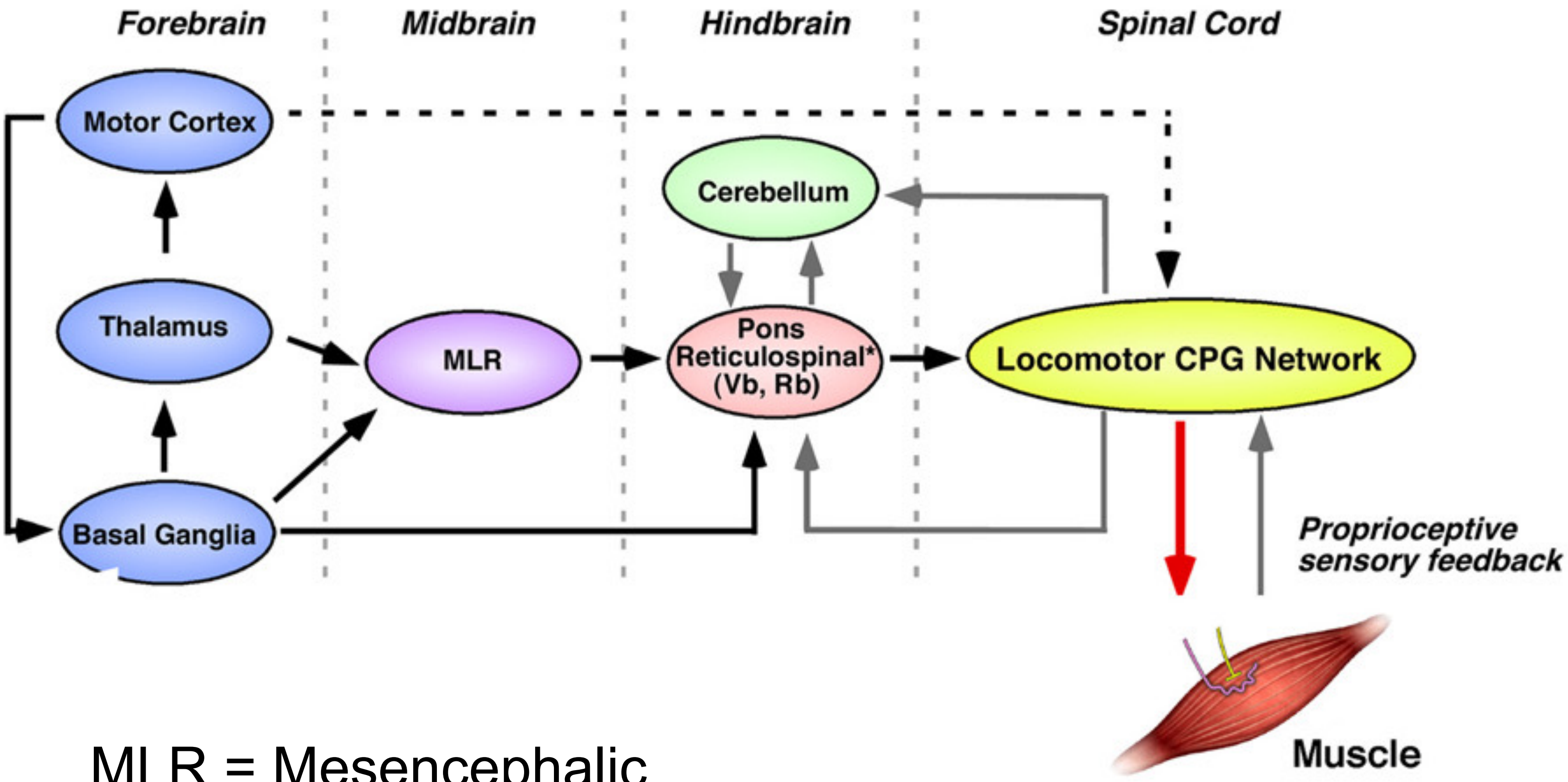
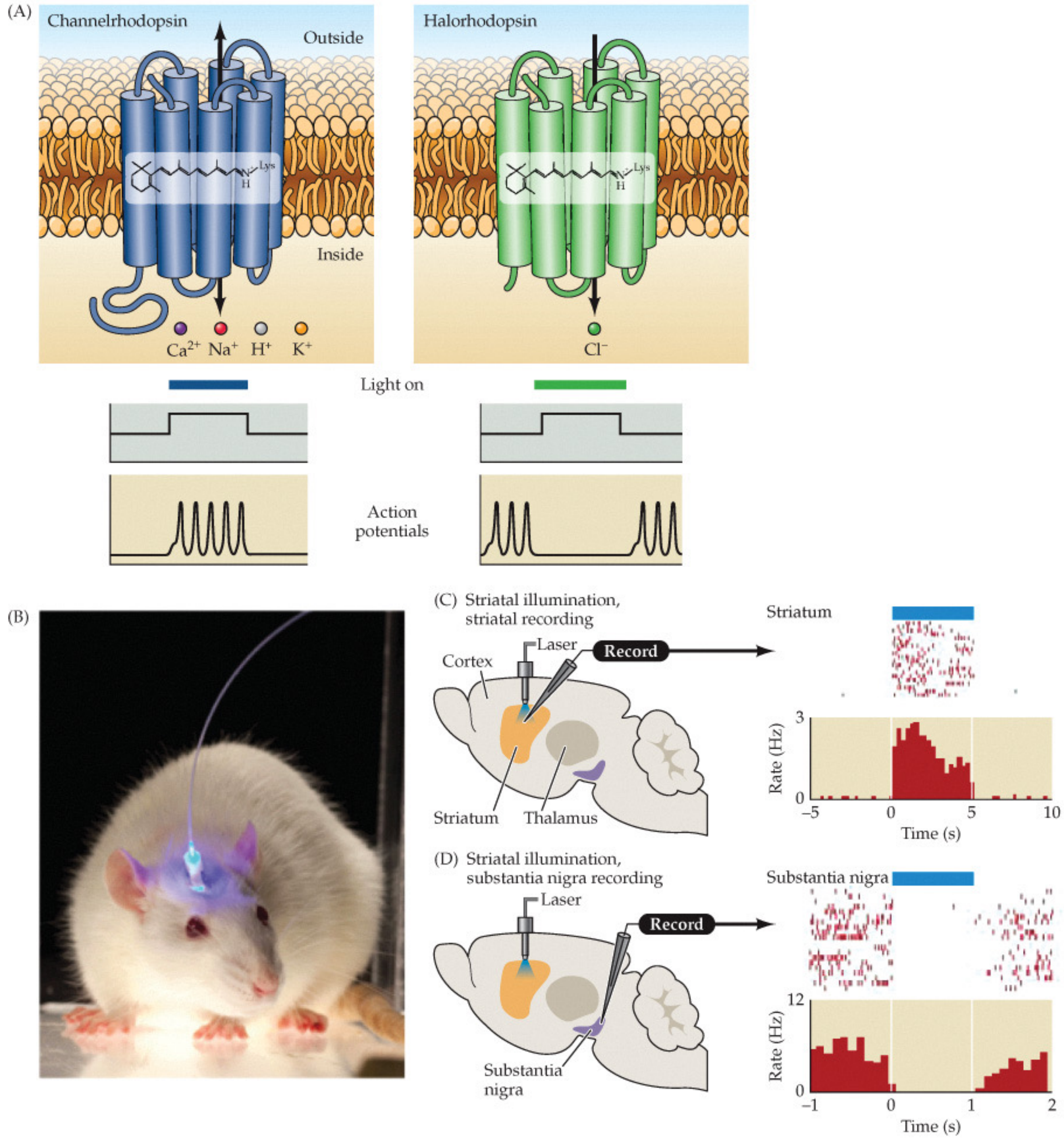


MLR = Mesencephalic locomotor region

Optogenetic methods used to control electrical activity in nerve cells



A from Zhang et al. (2011) *Cell* 147(7): 1446–1457. B © John B. Carnett/Getty Images. C,D from Kravitz et al. (2010) *Nature* 466: 622–626.

***NEUROSCIENCE 6e*, Figure 1.11**
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Courtesy Cris Neil, U. Oregon