Muscle receptors and spinal reflexes

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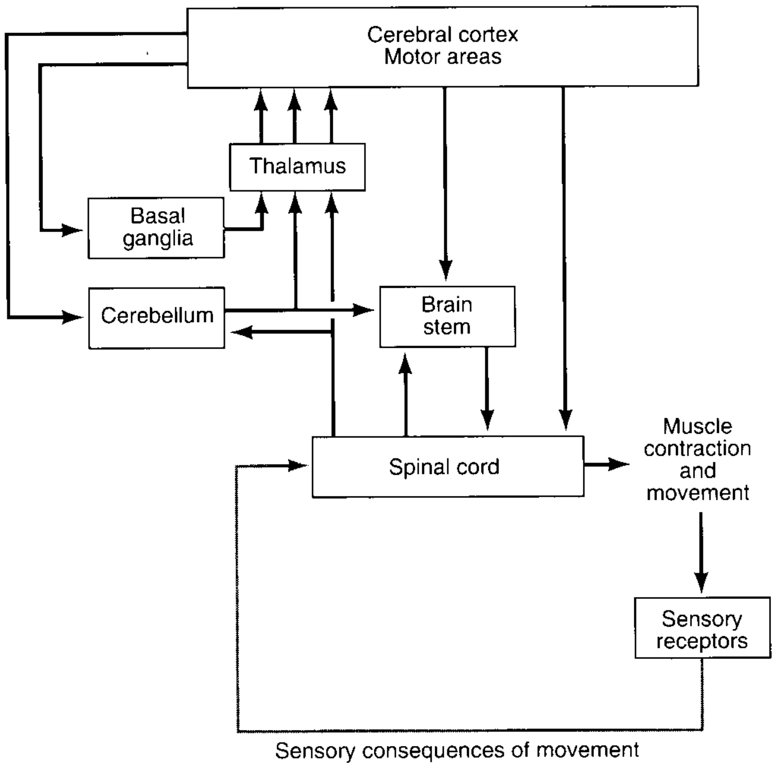
- Essential Neuroscience (second edition, Siegel A, Sapru HN; Chapter 9, pages 158-162; chapter 15, pages 261-263)
- Principles of neural science, (fourth edition, Kandel ER et al; chapter 34 and chapter 36)

HUMAN MOTOR SYSTEM



Motor unit

- A motor unit consists of a single motor neuron and the muscle fibers it innervates
- The number of muscle fibers innervated by one motor neuron is called *innervation ratio (it is roughly proportional to the size of the muscle; in extraocullar muscles the ratio is about 10; in hand muscles it is about 100 in the large gastrocnemius muscle is about 2000 fibers innervated by single motor neuron*

- Nervous system force the grade of muscle contraction in **two ways**:
- 1) it can vary the number of motoneurons activated - the more that are activated, the higher the force the muscle will produce- *recruitment*
- 2) it can vary the rate of action potentials in a motor neuron - the higher the rate of firing, the greater the force that muscle will produce - *rate modulation*

Muscle receptors

- They sense different features of the state of the muscle

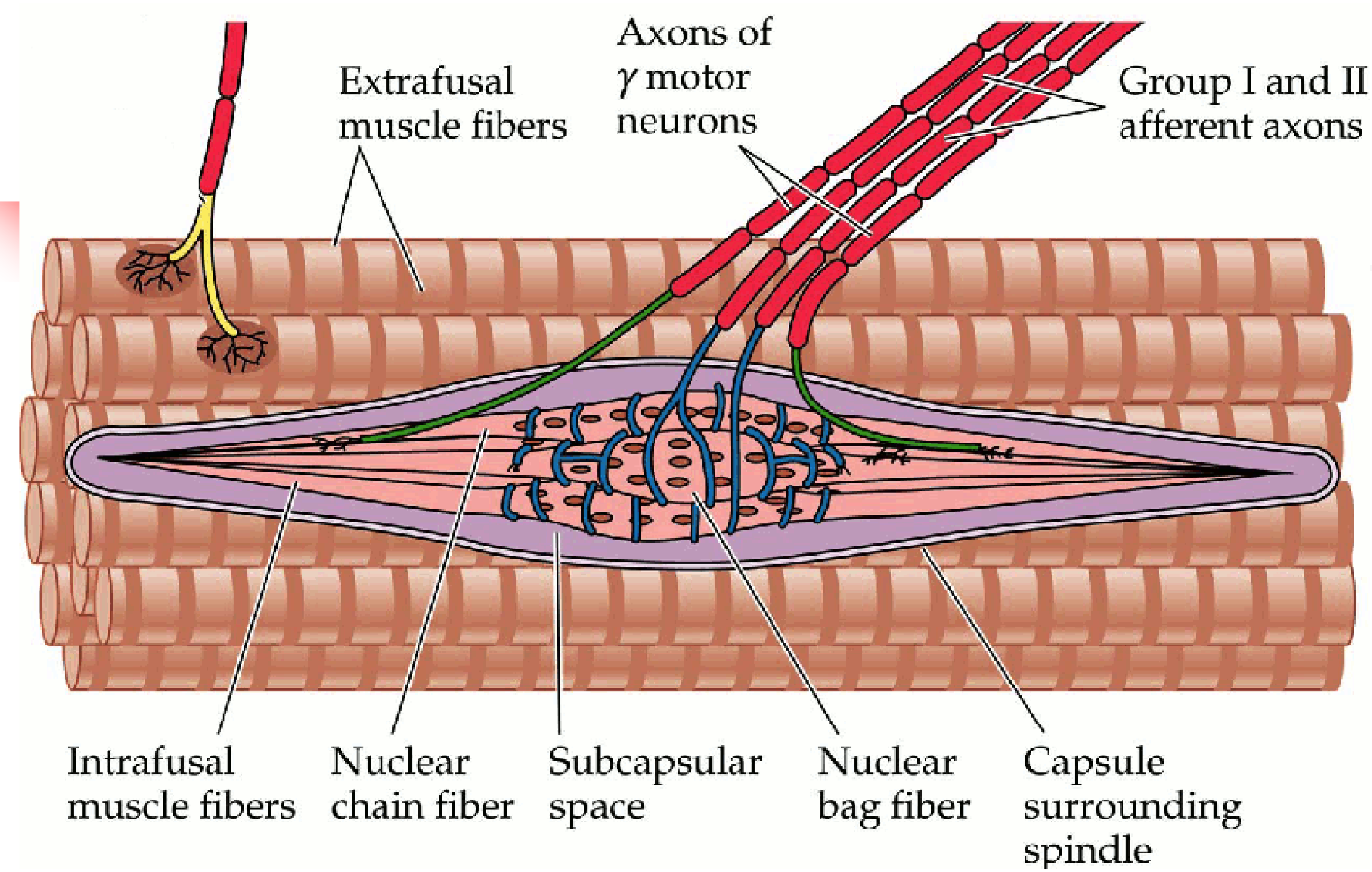
Muscle spindles within the fleshy portions of the muscle, in parallel with the sceletal muscle fibers; they are innervated by **group Ia** and **group II afferent fibers**

Golgi tendon organs at the junction between muscle fibers and tendon, in a series to a group of sceletal muscles; they are innervated by **group Ib afferent fibers**

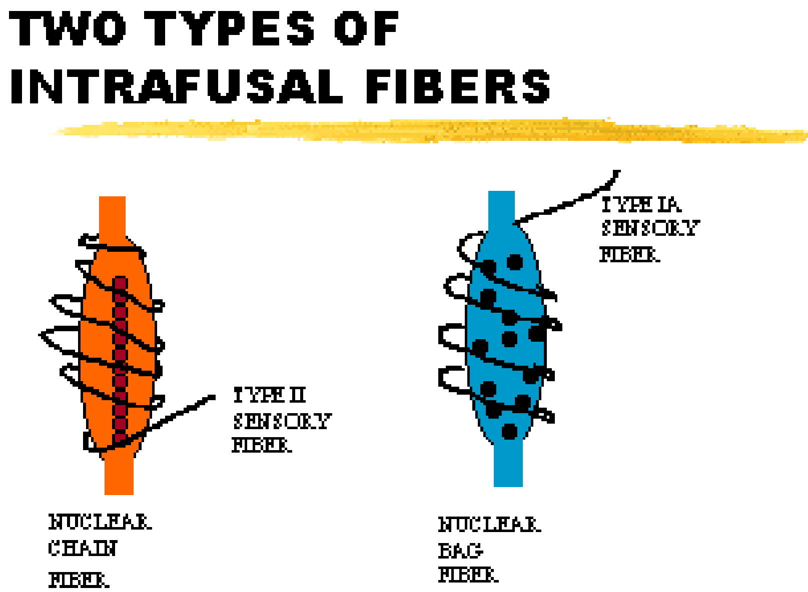
Muscle spindles

- Respond to **STRECH** of specialized muscle fibers
- Fusiform, spindle-like shape
- Range in length form 4 to 10 mm
- They have three main components:

1. A group of specialized (intrafusal) muscle fibers
2. Sensory terminals in the intrafusal muscle fibers
3. Motor terminals that regulate the sensitivity of the spindle.


Extrafusal muscle fibers
Axons of γ motor neurons
Group I and II afferent axons
Intrafusal muscle fibers
Nuclear chain fiber
Subcapsular space
Nuclear bag fiber
Capsule surrounding spindle

- The specialized muscle fibers of the spindle are called **INTRAFUSAL** (distinguish from skeletal muscle fibers-extrafusal)
- Intrafusal fibers do not contribute to muscle contraction
- The central parts of the intrafusal fibers are essentially no contractile; **ONLY THE POLAR REGIONS ARE ACTIVELY CONTRACT**



Short and slender

Thicker in diameter
There are two types **dynamic and static**

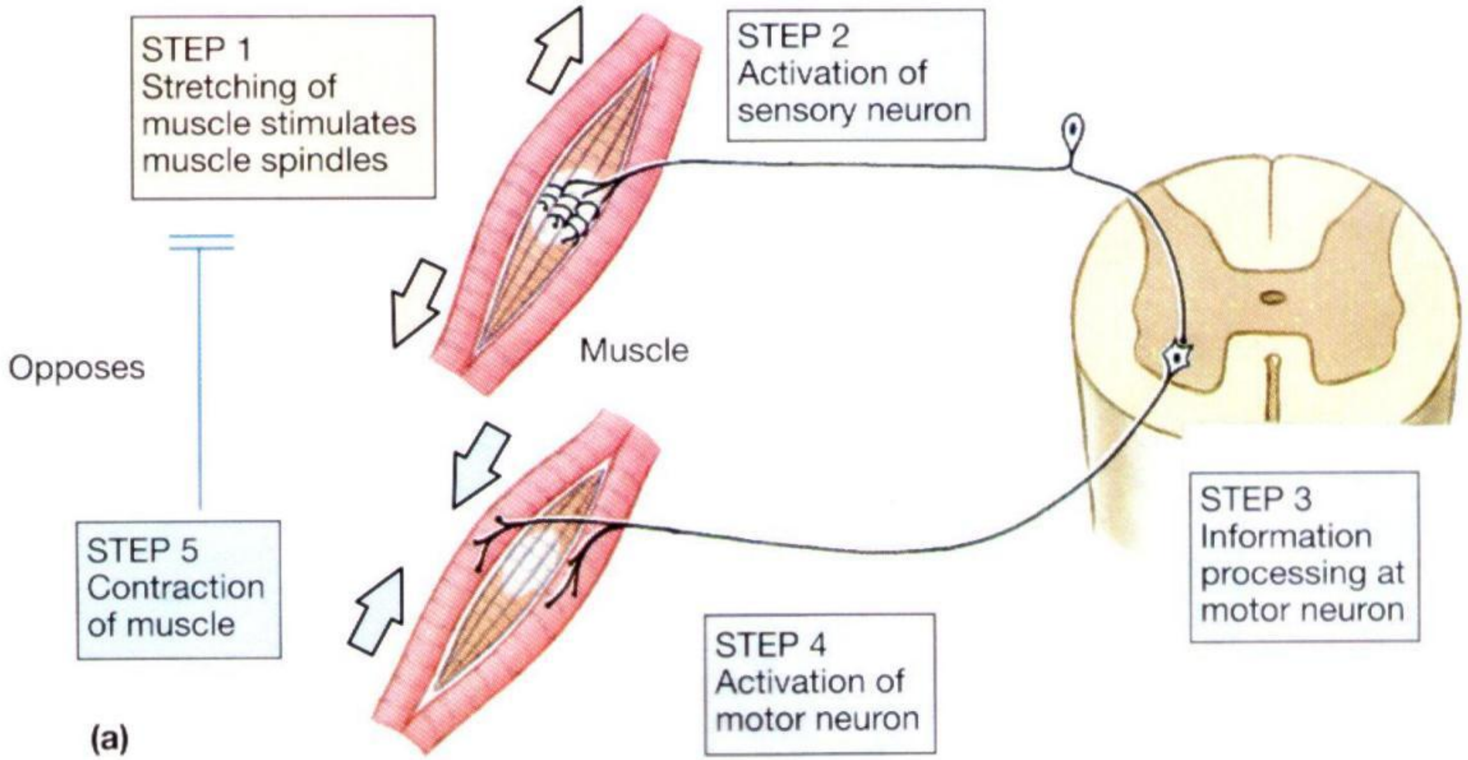
5:1 ratio

What kind of stimulus exerts generation of action potential in Ia or type II muscle spindle afferents?

STRETCHING

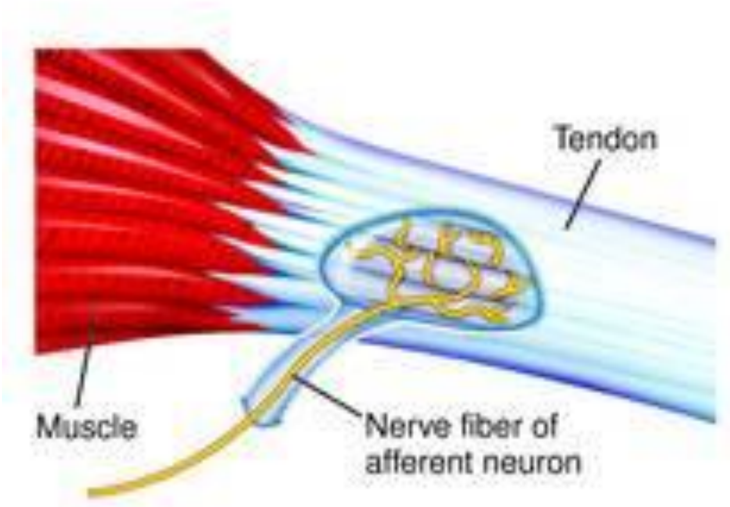
- When intrafusal fibers are stretched, referred to as loading the spindle, the sensory ending increase firing rate
- WHY IS THAT?

- Because stretching of the spindle lengthens the central region of the intrafusal fibers around which the afferent fibers are entwined
- Ia fibers (primary) ***are more sensitive to the rate of change of length than are*** type II fibers (secondary)

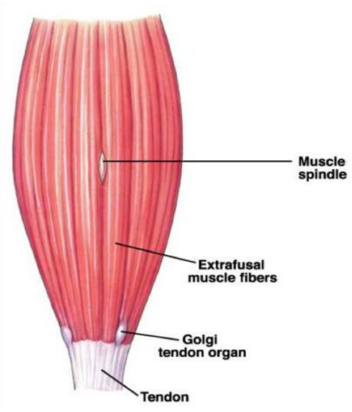

STEP 1
Stretching of muscle stimulates muscle spindles
STEP 2
Activation of sensory neuron
Muscle
Opposes
STEP 3
Information processing at motor neuron
STEP 4
Activation of motor neuron
STEP 5
Contraction of muscle
(a)

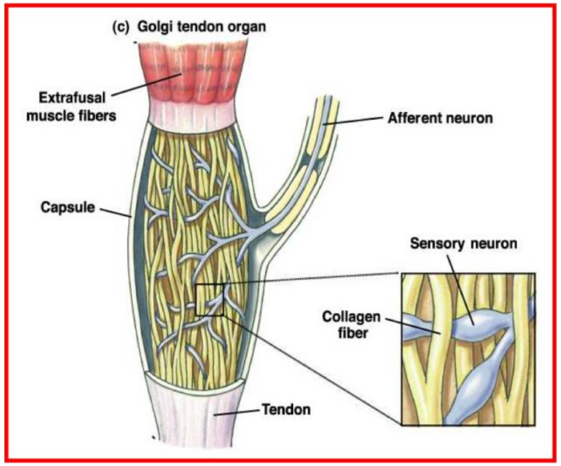
Golgi tendon organ

- Are sensitive to change in tension
- Are slender encapsulate structures about 1 mm long and 0.1 mm in diameter
- They are located at junction of muscle and tendon, and is attached to the muscle fibers by collagen fibers

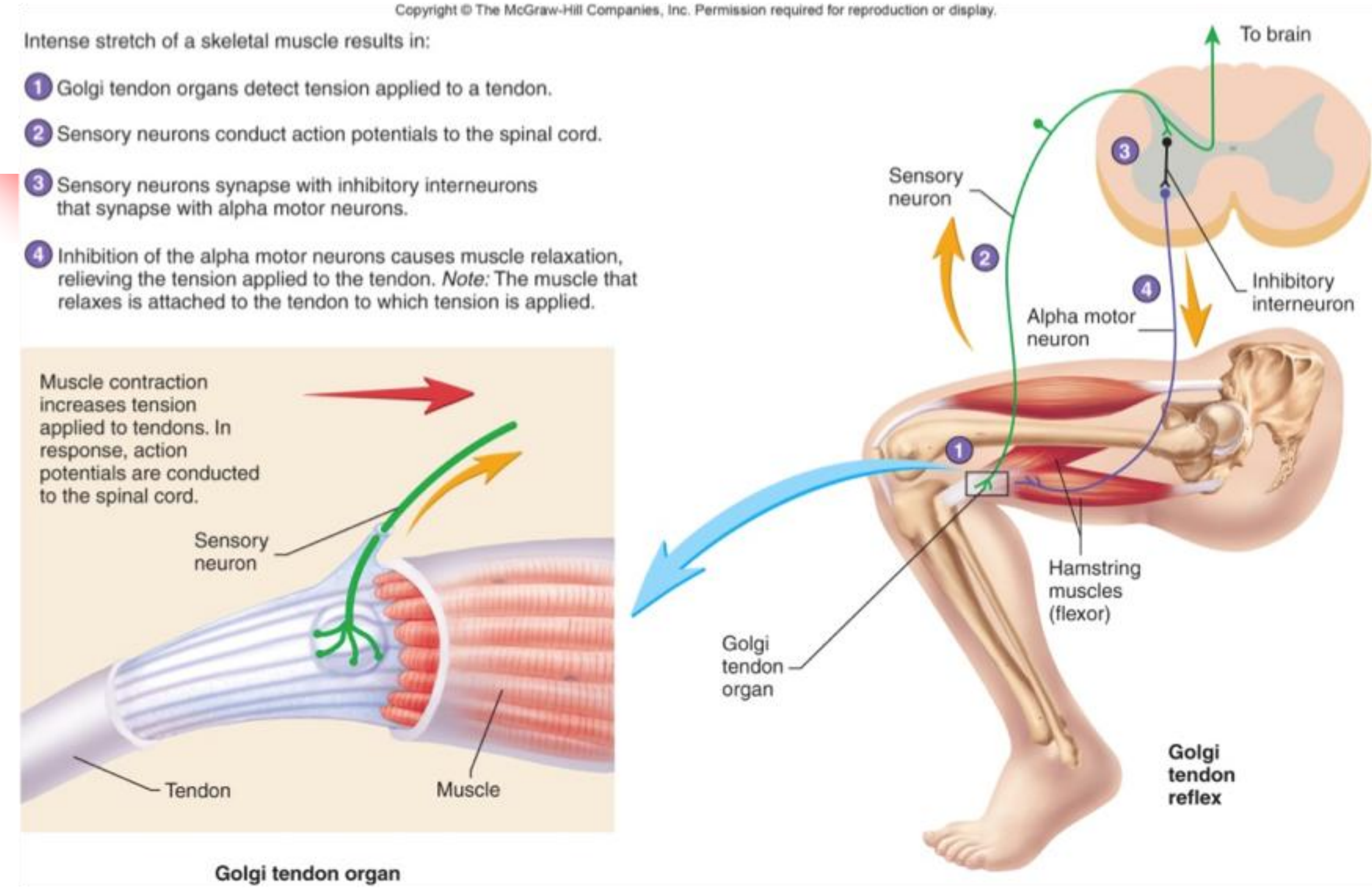

Tendon
Muscle
Nerve fiber of
afferent neuron

- A single Ib afferent axon enters the capsule and branches into many unmyelinated endings that wrap around and between collagen fibers.





- When the ***CONTRACTION*** of the muscle happens than the afferent axon is compressed by the collagen fibers and the action potential generates



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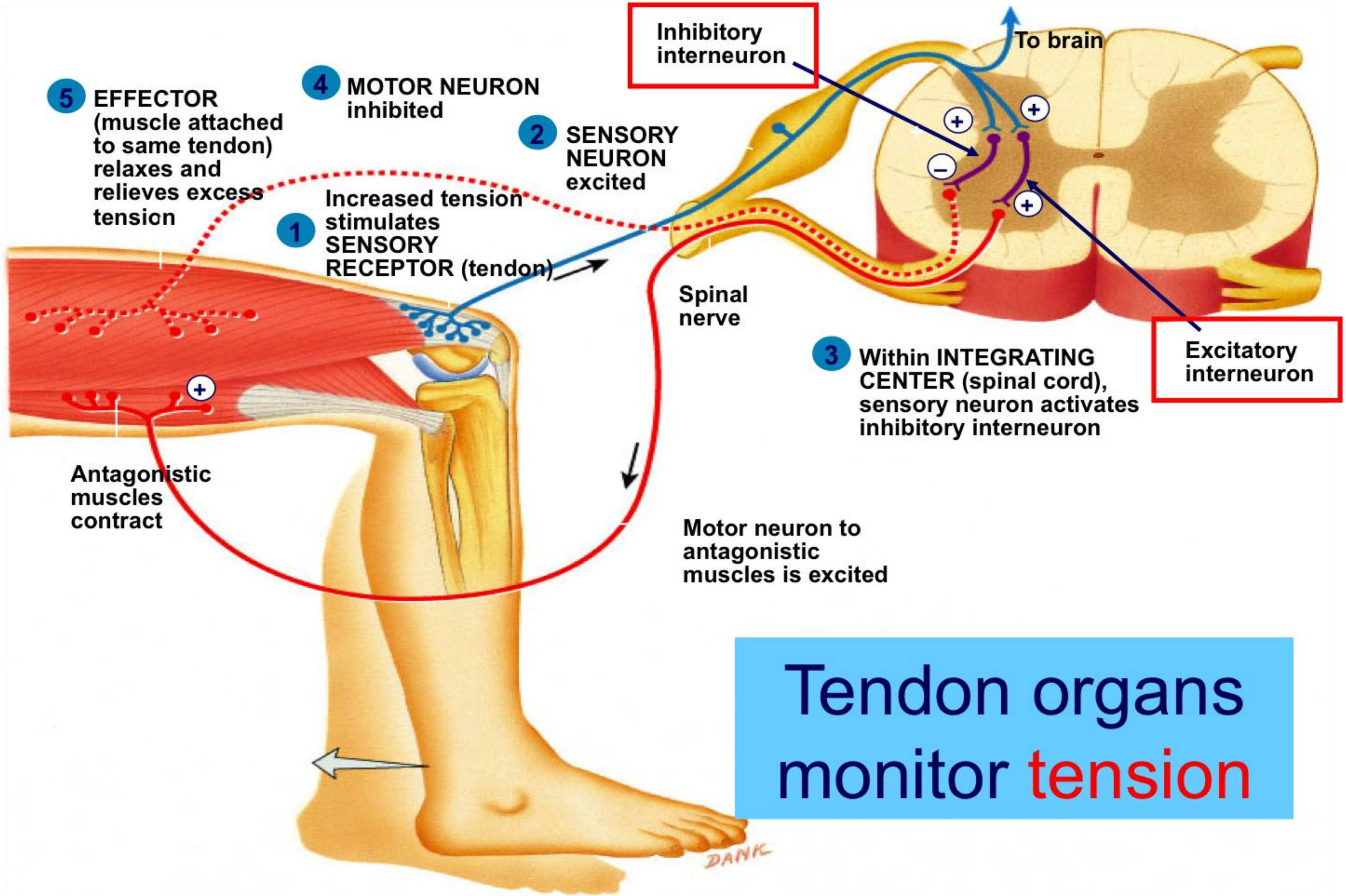
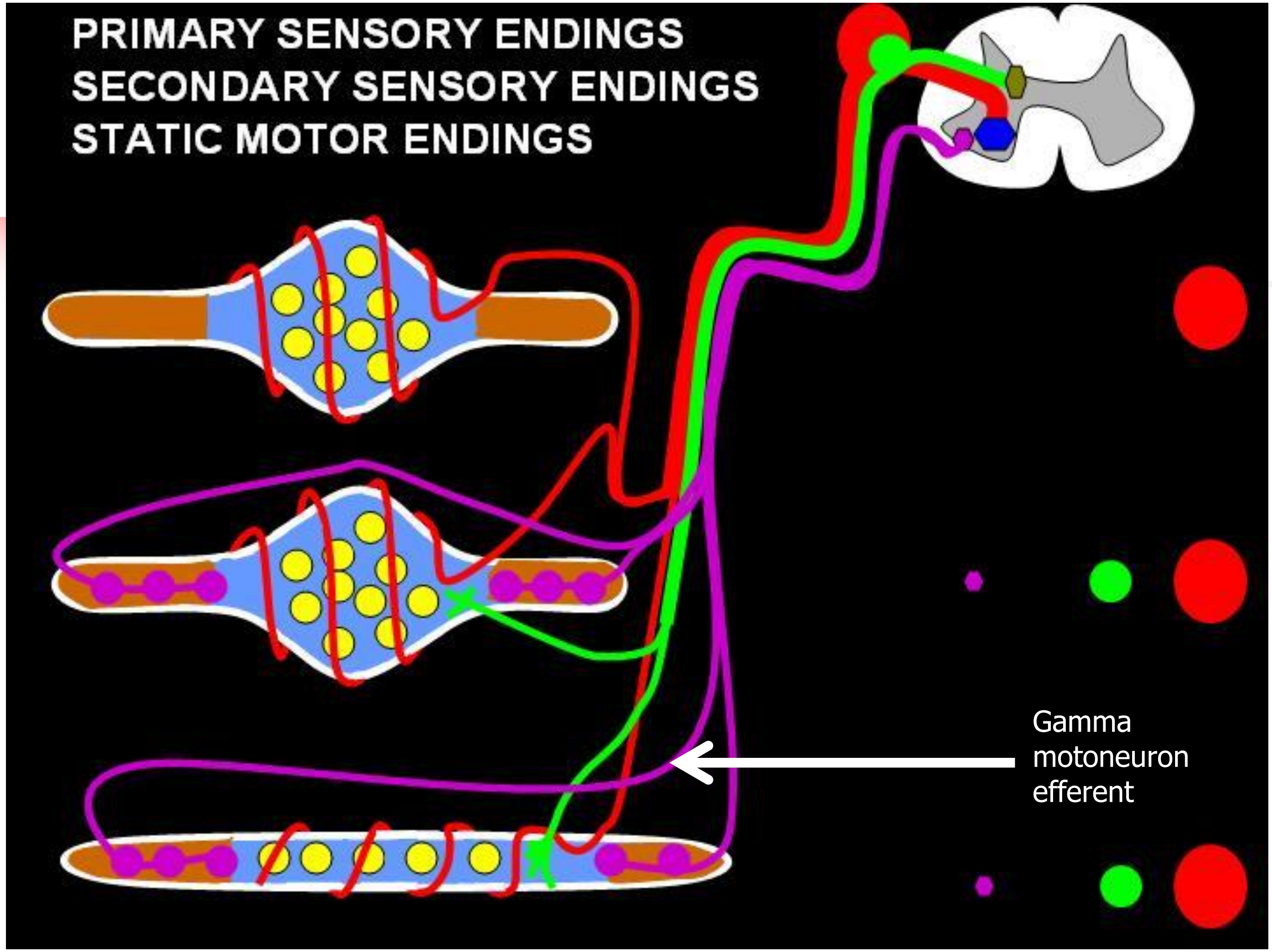
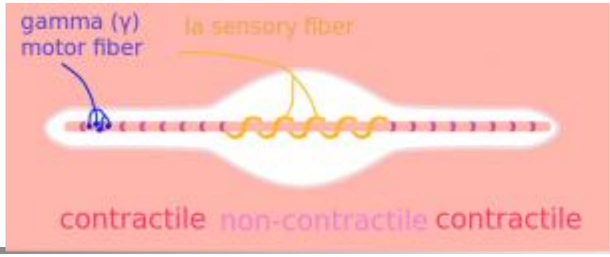
Intense stretch of a skeletal muscle results in:
1 Golgi tendon organs detect tension applied to a tendon.
2 Sensory neurons conduct action potentials to the spinal cord.
3 Sensory neurons synapse with inhibitory interneurons that synapse with alpha motor neurons.
4 Inhibition of the alpha motor neurons causes muscle relaxation, relieving the tension applied to the tendon. Note: The muscle that relaxes is attached to the tendon to which tension is applied.
Muscle contraction increases tension applied to tendons. In response, action potentials are conducted to the spinal cord.
Sensory neuron
Tendon
Muscle
Golgi tendon organ
To brain
Sensory neuron
Inhibitory interneuron
Alpha motor neuron
Hamstring muscles (flexor)
Golgi tendon organ
Golgi tendon reflex

Tendon organs monitor tension



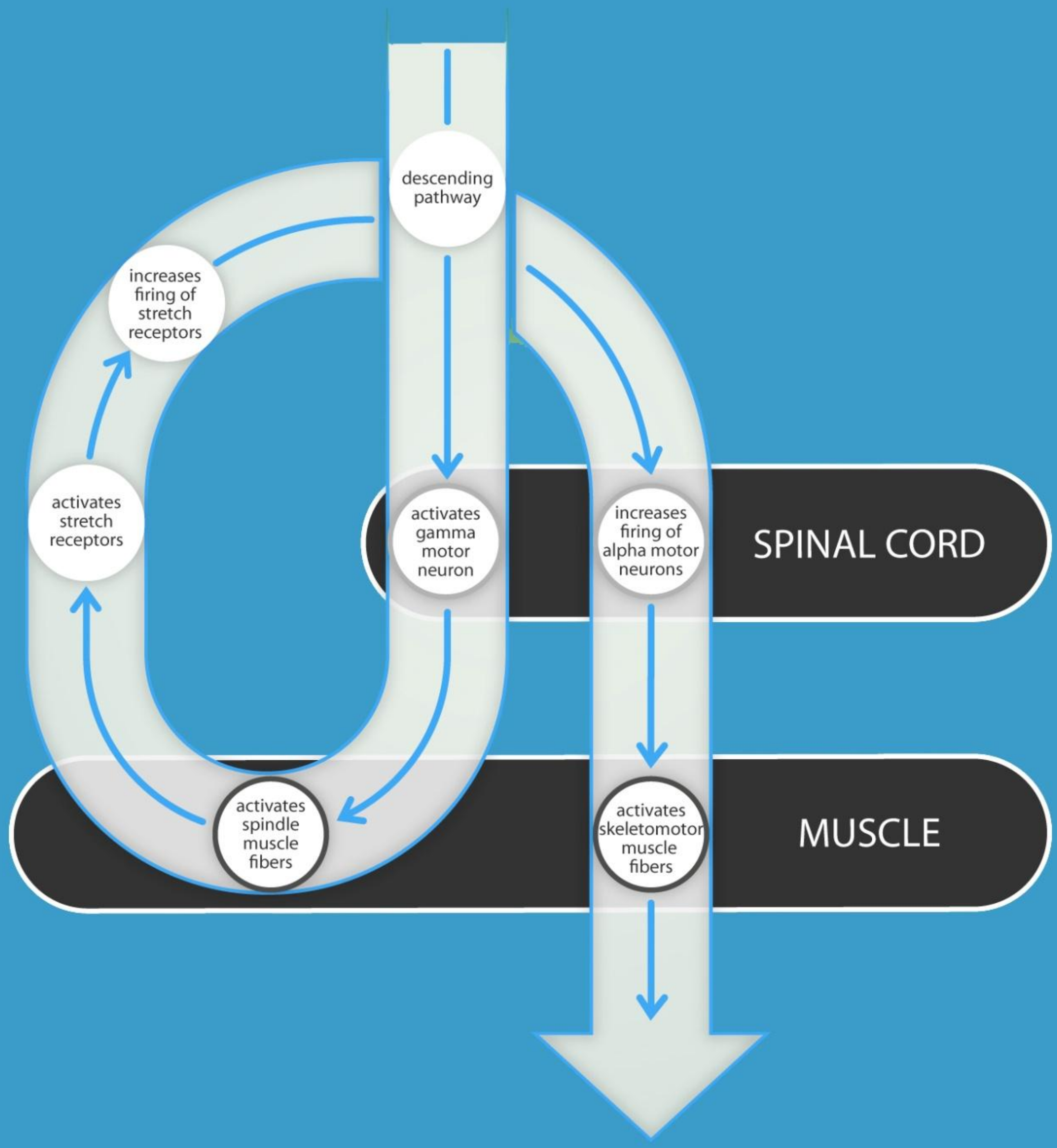
- The central nervous sytem controls sensitivity of the muscle spindles through the gamma motor neurons
- Gamma motoneurons innervate the polar regions of the intrafusal fibers, where the contractile elements are located


PRIMARY SENSORY ENDINGS
SECONDARY SENSORY ENDINGS
STATIC MOTOR ENDINGS
Gamma
motoneuron
efferent



- Activation of gamma motoneuron causes contraction and shortening of the polar regions, which in turn stretches the central region from both ends
- This action increases the firing rate of the sensory endings and also makes the afferent endings ***MORE SENSITIVE TO STRECH OF THE INTRAFUSAL FIBRES***

THE ALPHA-GAMMA LOOP



SPINAL REFLEXES

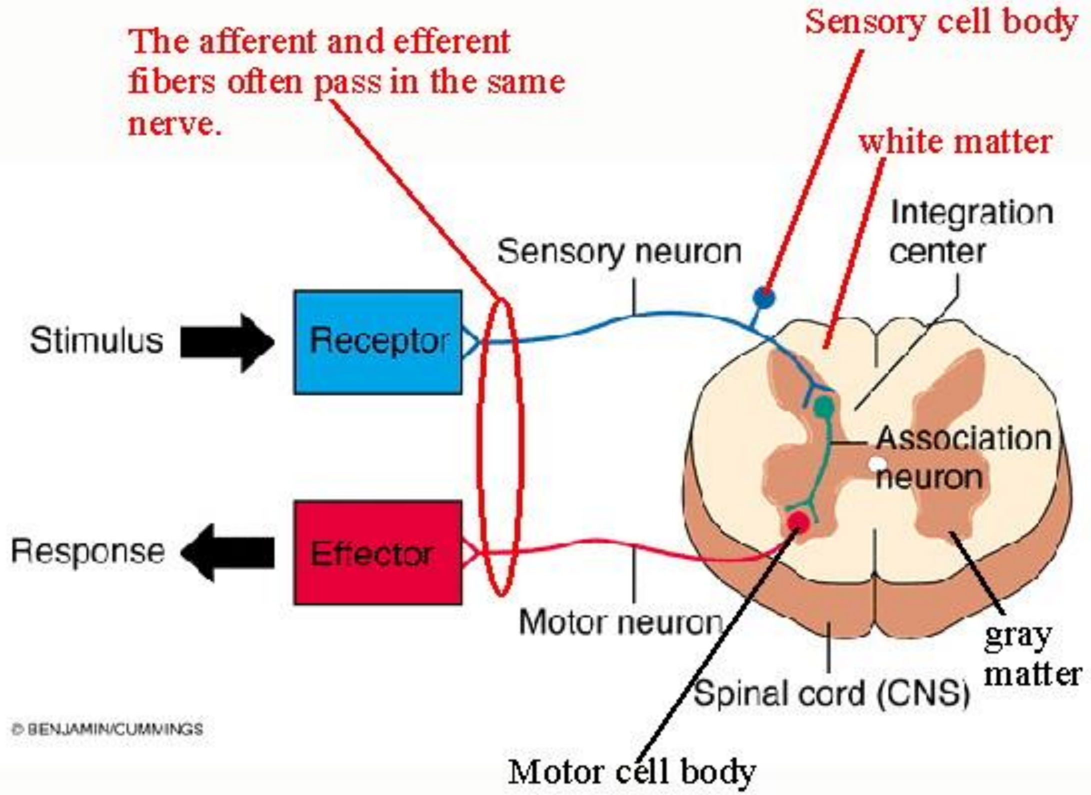
"There's nothing wrong with your reflexes ..."

- Is the most elementary form of motor coordination
- Reflex action is stereotyped response to a specific sensory stimulus
- The **locus** of the stimulus determines which muscle will contract to produce the reflex response
- The **strength** of the stimulus determines the amplitude of the response; reflexes are graded in intensity

- Neural circuitry responsible for a spinal reflex is entirely contained within the spinal cord, and receives sensory information from muscles, joints, and skin directly
- Spinal reflexes have an essential role in all voluntary action movement

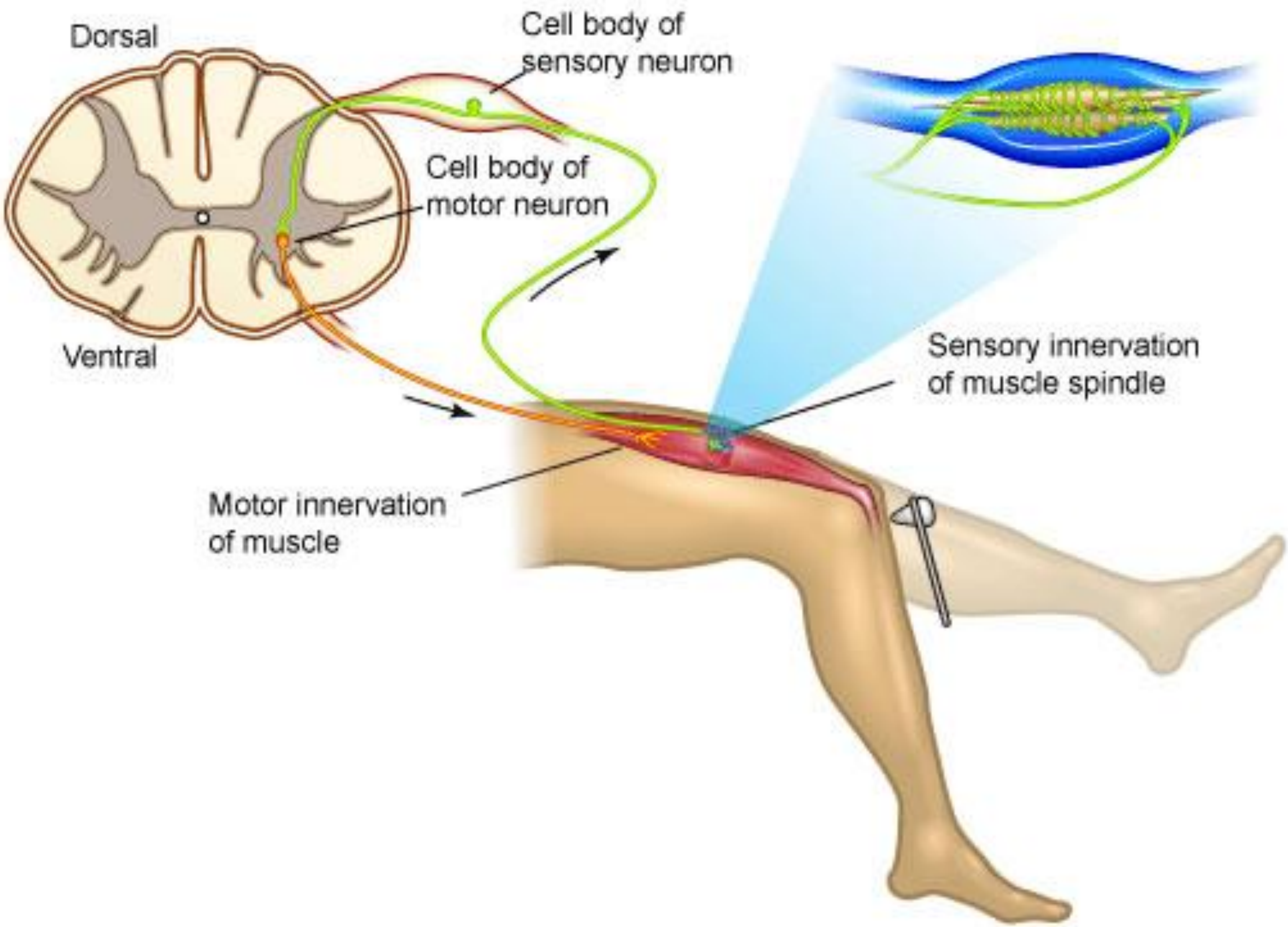
- Since reflexes are recruited by higher brain centers to generate more complex motor behavior, understanding of how they are organized is essential for understanding of complex motor sequences

A Reflex Arc Shows How Neuron Types Work Together.

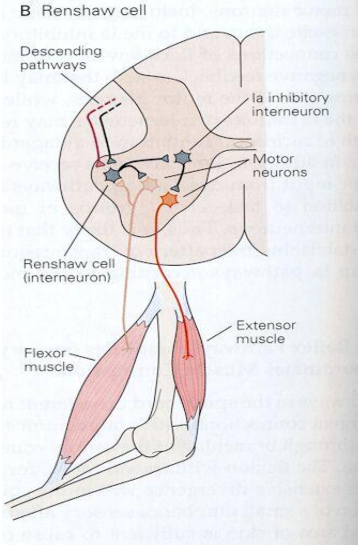


Stretch reflex

- This reflex consists of contractions of a muscle that occurs when that muscle is lengthened
- The stretch reflex depends only on the monosynaptic connections between primary afferent fibers from muscle spindles and motor neurons innervating the same muscle

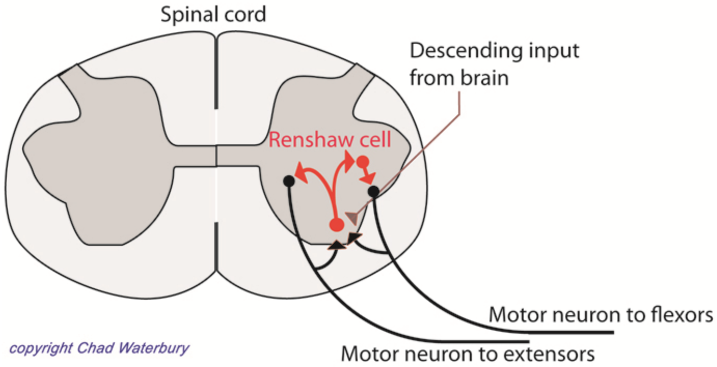

Dorsal
Cell body of
sensory neuron
Cell body of
motor neuron
Ventral
Sensory innervation
of muscle spindle
Motor innervation
of muscle

- Branches of the Ia afferent excite motor neurons innervating the homonymous muscle, and also those innervating synergist muscle (muscle that control the same joint and has a similar mechanical action)
- Each Ia afferent makes excitatory connections to all motor neurons of the homonymous muscle and up to 60% for some synergists
- Other branches excites interneuron's that inhibit antagonist motor neurons (reciprocal inhibition)



Interneurons

- Ia
- Ib
- Renshaw cells (produces recurrent inhibition of motor neurons; they are excited by collaterals from motor neurons and then inhibit those same motor neurons; regulates excitability and firing rate of motor neurons; also sends collaterals to Ia interneuron and synergist motor neuron)



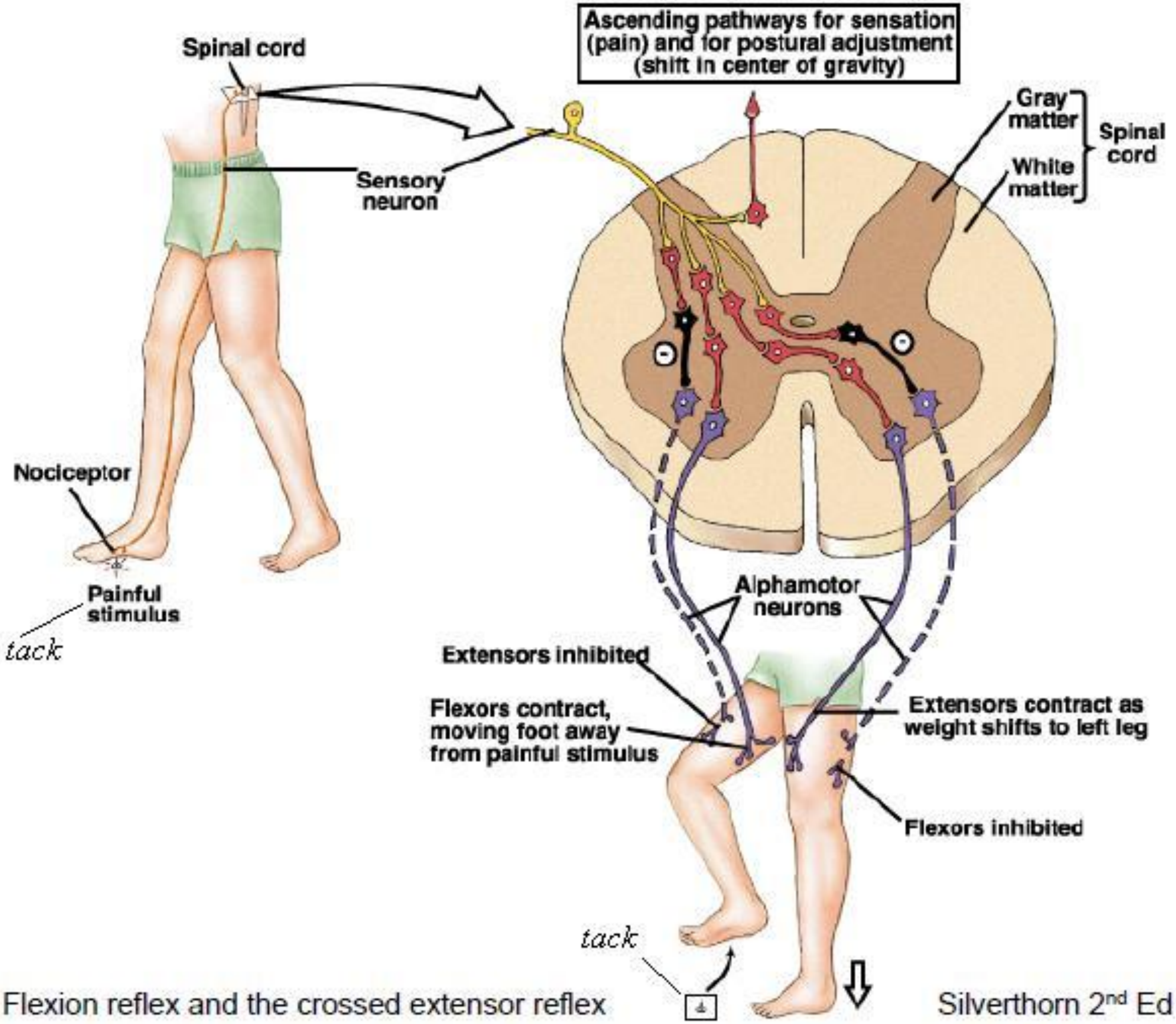
- Homonymous motor neurons are influenced by a second type of inhibitory interneuron's, the *Ib inhibitory interneuron*, which receives inputs from the Golgi tendon organ
- These inputs provide negative feedback mechanisms for regulating muscle tension, parallel to the negative feedback from the muscle spindles that regulates muscle length
- Outcome is to decrease muscle tension

- Testing the strength of the stretch reflex, by trapping the muscle or its tendon with the reflex hammer, is useful in clinical diagnosis
- **Absent or weak (hypoactive)** stretch reflex often indicate a disorder of one or more components of the reflex circuit, or lesions of the central nervous system

- **Hyperactive stretch reflex** always result from central lesions that lead to increased excitatory input to motor neurons; they are often associated with disorders of tone, such as spasticity and rigidity

Flexion (Withdrawal reflex) Reflex

- Flexion reflexes serve protective and postural functions and are initiated by stimulation of the skin
- They involve movement of entire limbs
- Certain type of reflexes consists of rhythmic movements (maintaining the standing posture of the animal)
- The main features of walking movements are controlled by the spinal cord



Flexion reflex and the crossed extensor reflex

Silverthorn 2nd Ed

Descending pathways involved in reflex control

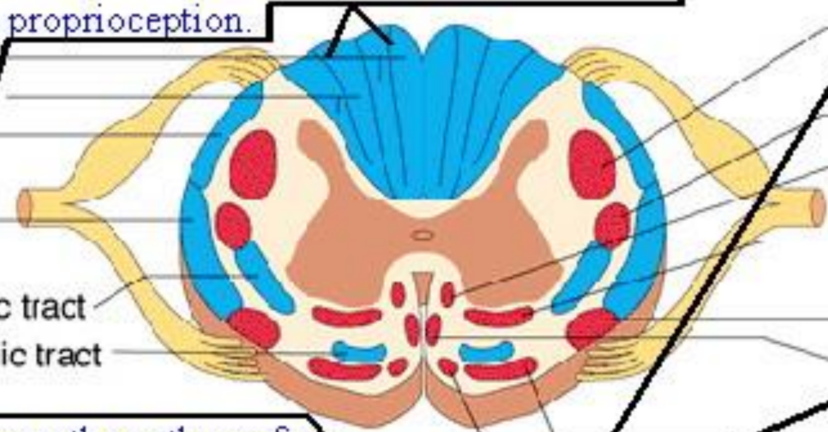
Motor system	Tract	Distribution	Principal effects on motor neurons	
			Excitatory to:	*Inhibitory to:*
Medial	Lateral vestibulospinal	Ipsilateral	Axial and proximal limb extensors	Axial and proximal limb flexors
	Medial vestibulospinal	Bilateral	Axial ipsilateral	Axial contralateral
	Pontine (medial) reticulospinal	Ipsilateral	Axial and proximal limb extensors	Proximal limb flexors
	Medullary (lateral) reticulospinal	Bilateral	Proximal limb flexors	Axial and proximal limb extensors
Lateral	Corticospinal	Largely contralateral	Distal limb flexors	Distal limb extensors
	Rubrospinal	Bilateral	Distal limb flexors	Distal limb extensors

The Spinal Tracts

sensory tracts
Ascending tracts

motor tracts
Descending tracts

Often called the posterior white columns. Carry discriminative touch and conscious proprioception.



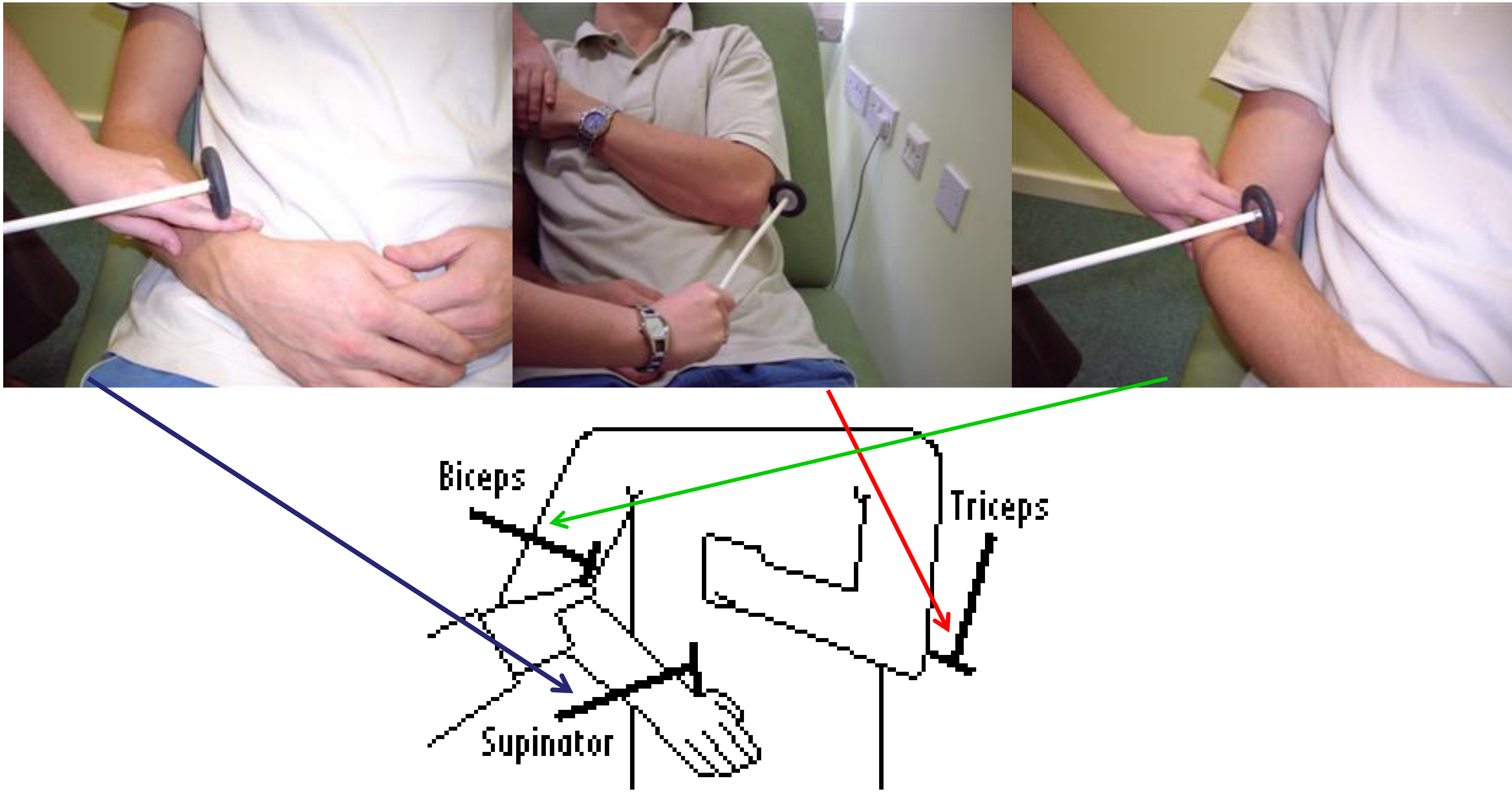
Lead to the thalamus, the pathway for crude touch, pain, temperature, pressure.

From the spinal cord to the cerebellum. Carry subconscious proprioceptive stimuli. Proprioception is "body sense" and "muscle sense", the perception of body position and muscle position necessary for coordinating movements.

These tracts come from a variety of locations in the brain, as a group are termed the "extra-pyramidal tracts", and are generally associated with balance and muscle tone.

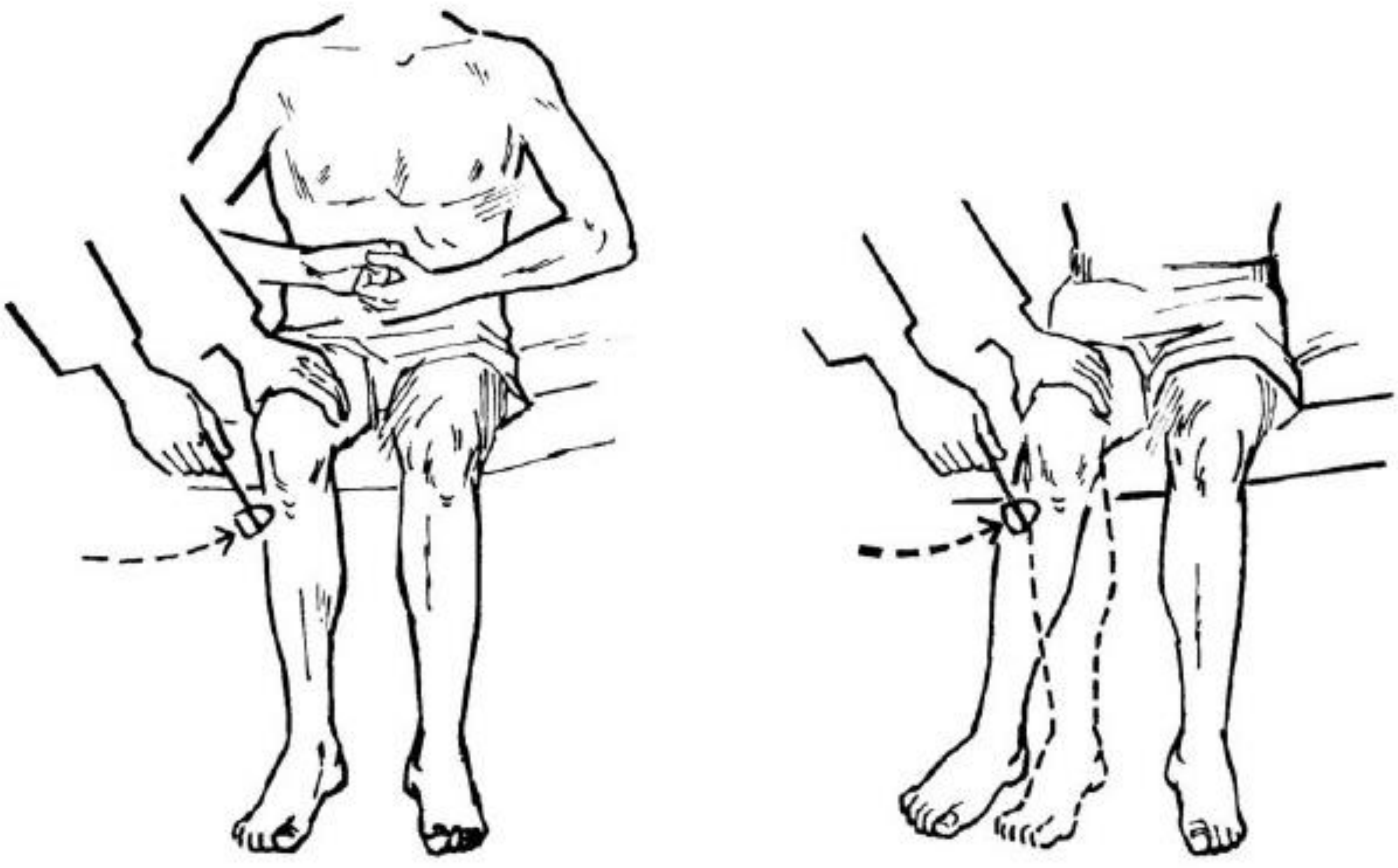
The corticospinal tracts carry voluntary motor stimuli from the cerebral cortex to motor neurons in the spinal cord. They are also called the "pyramidal tracts" because some of them cross in the pyramids of the medulla.

REFLEX EXAMINATION IN CLINICAL PRACTICE



UPPER EXTREMITIES REFLEXES EXAMINATION

Patelar reflex



Plantar reflex

EXAMINATION TIP

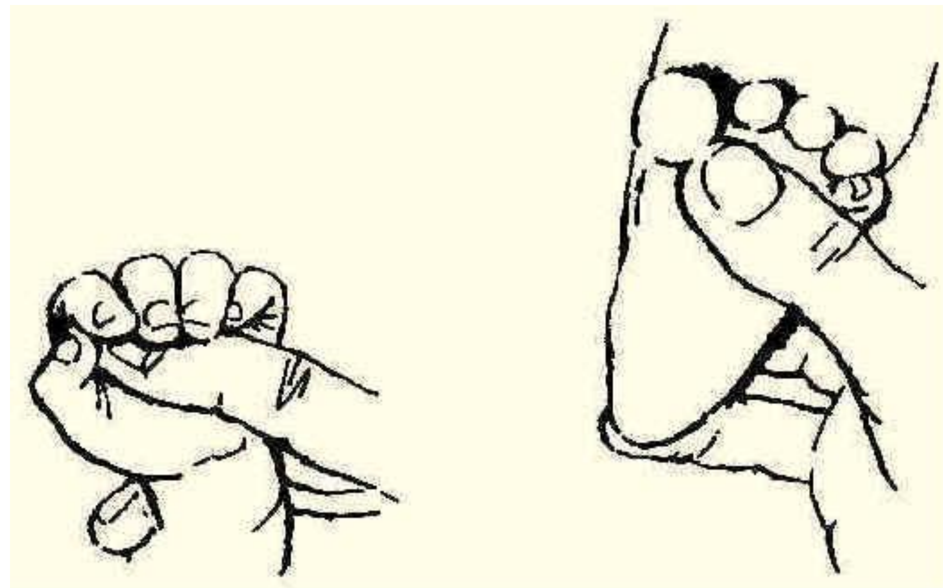
How to elicit Babinski's reflex

To elicit Babinski's reflex, stroke the lateral aspect of the sole of the patient's foot with your thumbnail or another moderately sharp object. Normally, this elicits flexion of all toes (a negative Babinski's reflex), as shown below in the left illustration. With a positive Babinski's reflex, the great toe dorsiflexes and the other toes fan out, as shown in the right illustration.

NORMAL TOE FLEXION

POSITIVE BABINSKI'S REFLEX

PRIMITIVE REFLEXES



Moro reflex (3-4 month)

Grasp reflex (5-6 month)

SEEKING REFLEX (3-4 MONTH)

WALKING REFLEX (AROUND 2 MONTH)

PATELAR REFLEX, BABINSKI (6 MONTH-2 YEAR)