CNS
Doctor 2021

Physiology

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Neurophysiology

Spinal cord

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Functions of the spinal cord

Nerve impulse propagation:

The white matter tracts in the spinal cord are highways for nerve impulse propagation.

Sensory input travels along these tracts toward the brain, and motor output travels from the brain along these tracts toward skeletal muscles and other effector tissues.

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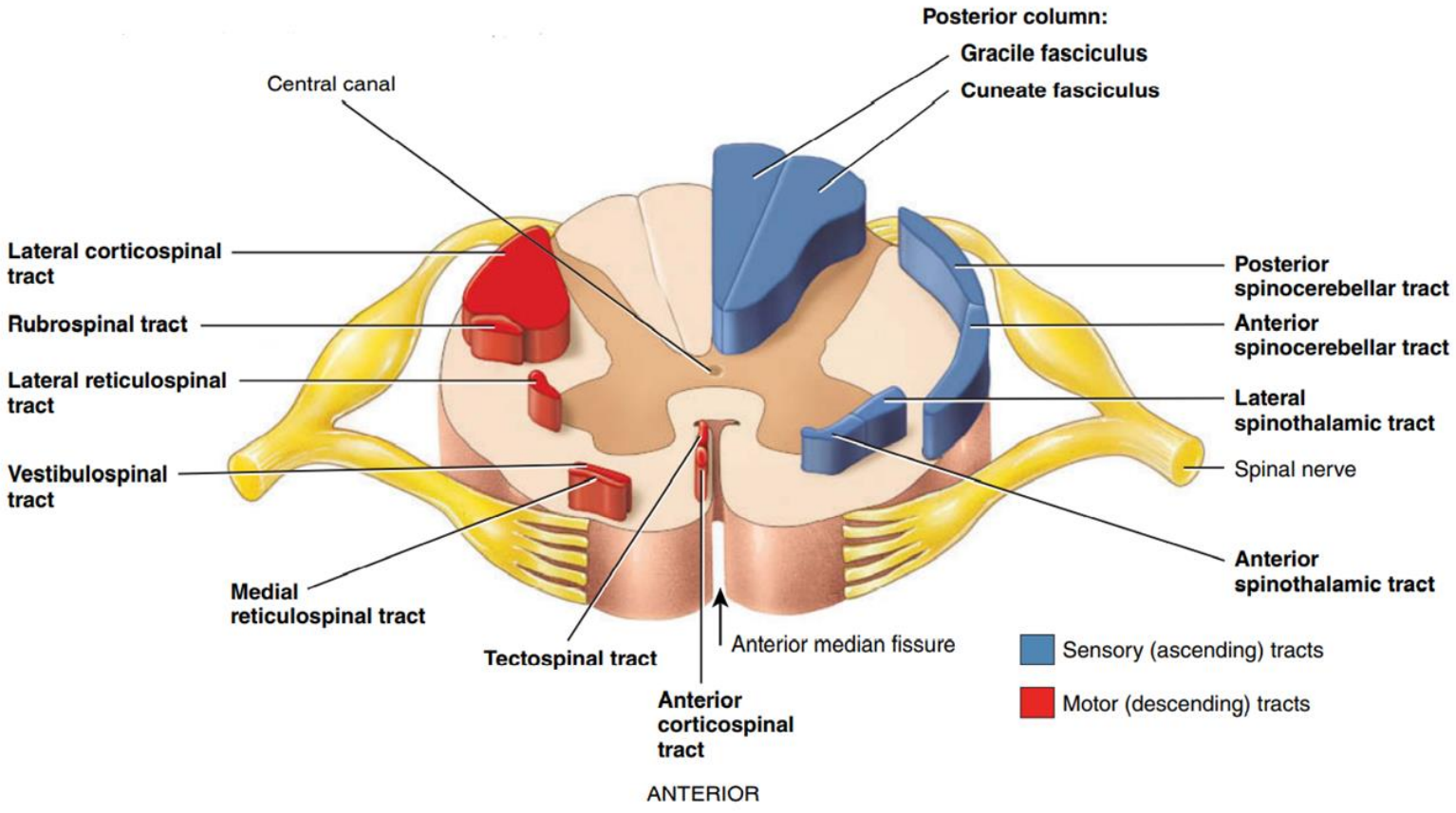
Tracts in the spinal cord

Signals are transmitted through tracts located in the white matter of the spinal cord up to the higher centers in the CNS. These tracts can be either sensory(ascending) or motor(descending)



Functions of the spinal cord

Integration of information: By processing information, making decisions about certain information

The gray matter of the spinal cord receives and integrates incoming and outgoing information mainly for some reflexes.

Spinal Reflexes take place within the gray matter of spinal cord that contains the cell bodies of neurons

A reflex is a fast, involuntary, unplanned sequence of actions that occurs in response to a particular stimulus.

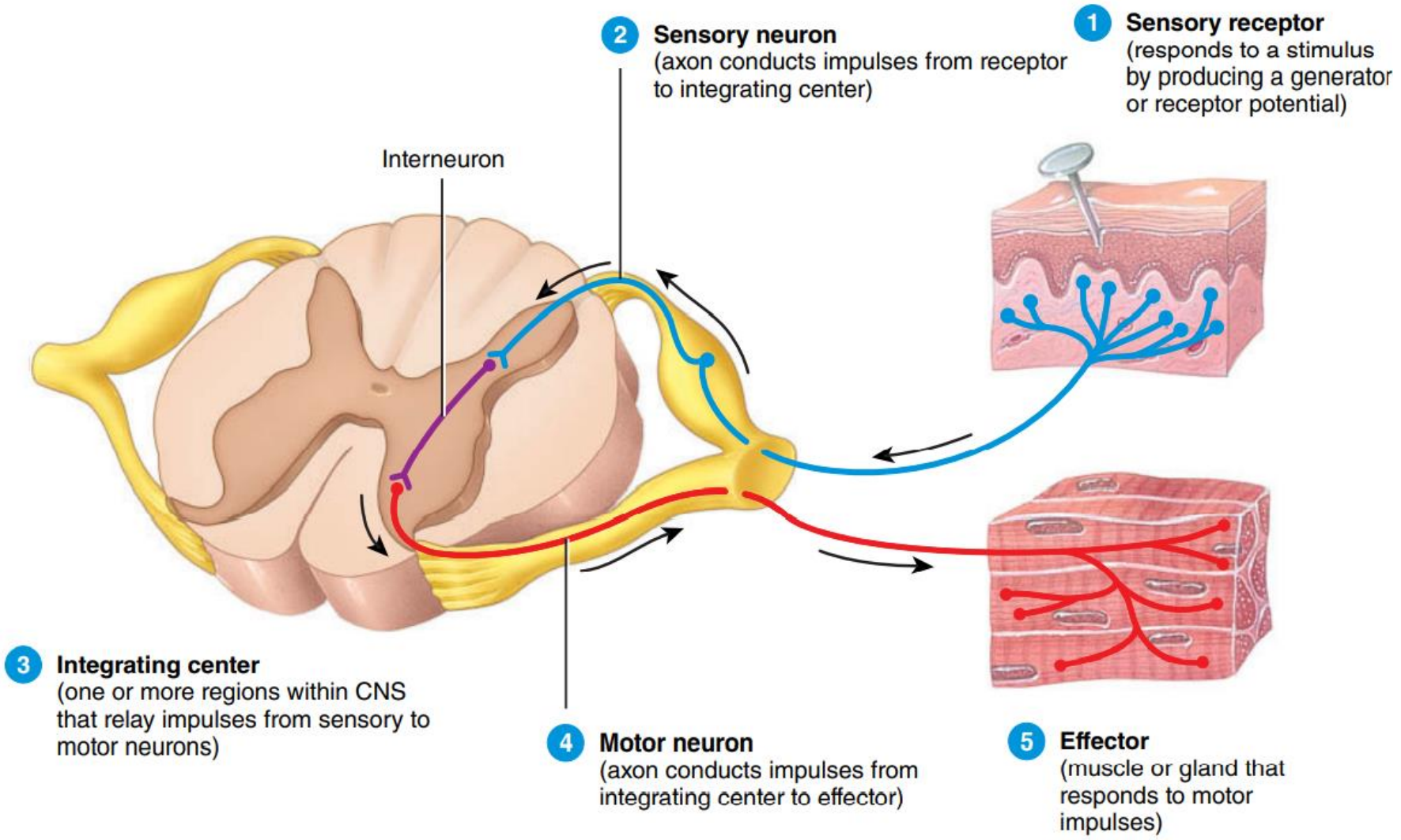
Reflex arc

- The pathway followed by nerve impulses that produce a reflex is a **reflex arc** (reflex circuit).

- A reflex arc includes <u>five functional components.</u>

  1. Sensory receptor
  2. Sensory neuron
  3. integrative center
  4. Motor neuron
  5. Effector (as skeletal muscle in next slide)

Components of the reflex arc



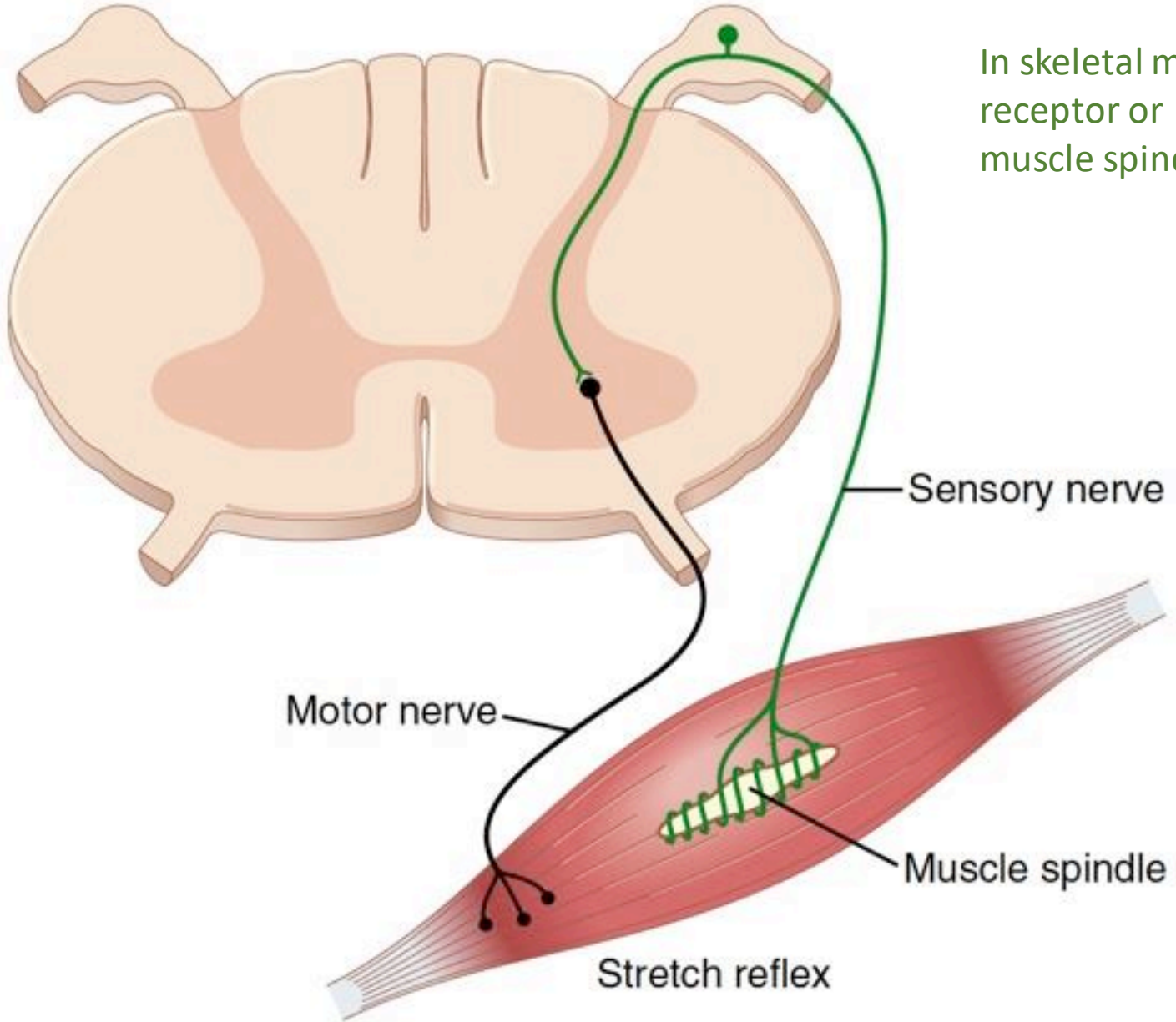
Sensory receptors in muscles

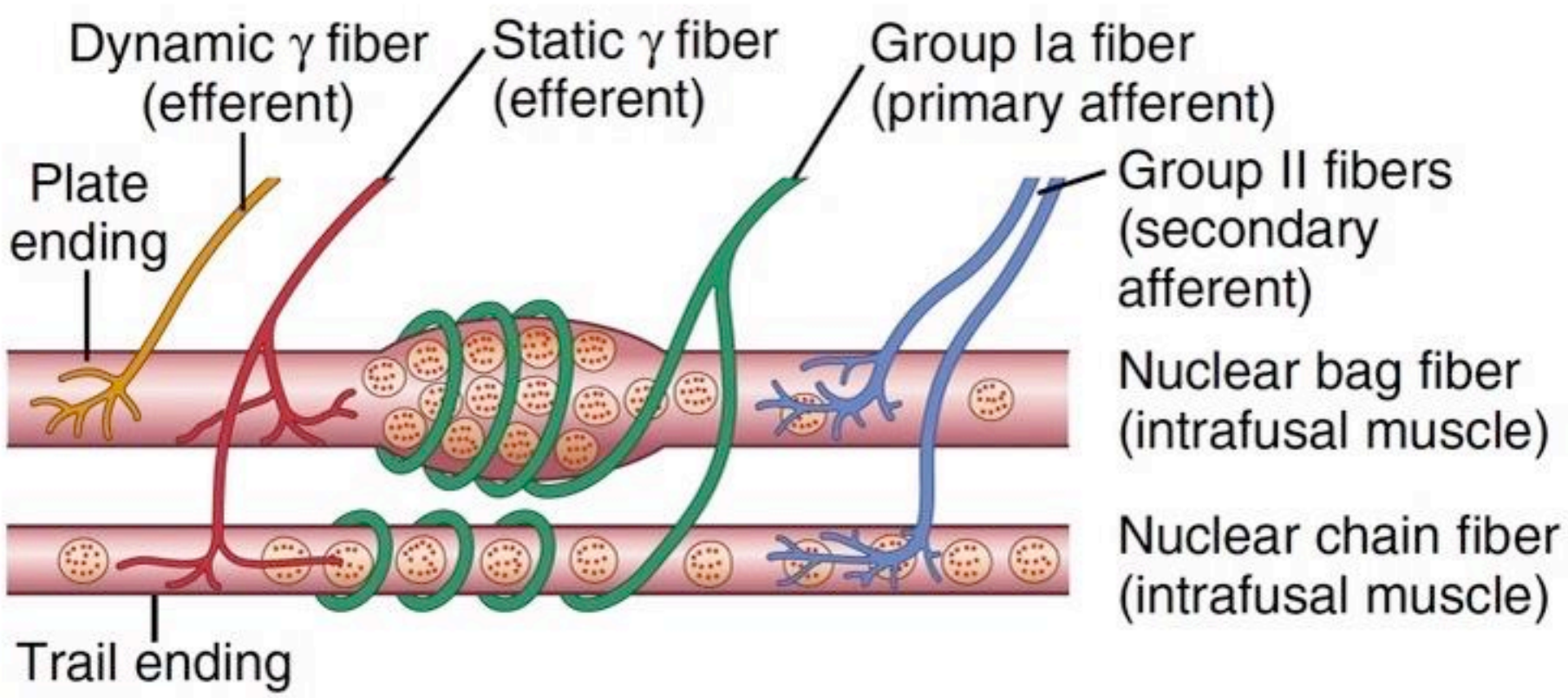
- the muscles and their tendons are supplied abundantly with two special types of sensory receptors:
- (1) muscle spindles, which are distributed throughout the belly of the muscle and send information to the nervous system about muscle length or rate of change of length.
- (2) Golgi tendon organs, which are located in the muscle tendons and transmit information about tendon tension or rate of change of tension.

Motor innervation of muscle fibers

- Aα motor nerve fibers innervate the large skeletal muscle fibers (motor unit).
- type A gamma (Aγ) motor nerve fibers either static or dynamic, go to small, special skeletal muscle fibers called intrafusal fibers.
- They constitute the middle of the muscle spindle, which helps control basic muscle “tone” which means there are always some sort of activation to these skeletal muscle fibers and mainly this is the role of static fibers, while dynamic fibers mostly respond to sudden changes in muscle length
- Interneurons are present in all areas of the cord gray matter.

In skeletal muscle, we have sensory receptor or proprioceptor which is muscle spindle





-these intrafusal fibers can be categorized into either nuclear bag or nuclear chain fibers. So the muscle spindle respond to any stimulus of changing muscle length either stretching or unstretching of the muscle either way, these information will go through the sensory neurons as primary (1a) and secondary(2) afferent fibers.Change in the muscle length can occur suddenly and this dynamic change will activate group 1a fibers which are more responsive to the change in the rate of the contraction

-Skeletal muscle fibers can be extrafusal or intrafusal muscle fibers, and these intrafusal muscle fibers are very tiny small muscle fibers with special structure that in the center of these fibers there are no or almost very little actin and myosin so no contraction in this part

-in peripheral part of these intrafusal muscle fibers they do have actin and myosin so it can contract

Muscle spindle

- Normally, when there is some degree of gamma nerve excitation, the muscle spindles emit sensory nerve impulses continuously.
- Stretching the muscle spindles increases the rate of firing, whereas shortening the spindle decreases the rate of firing.
- Thus, the spindles can send to the spinal cord either positive signals (increased numbers of impulses to indicate stretch of a muscle) or negative signals (reduced numbers of impulses) to indicate that the muscle is unstretched.

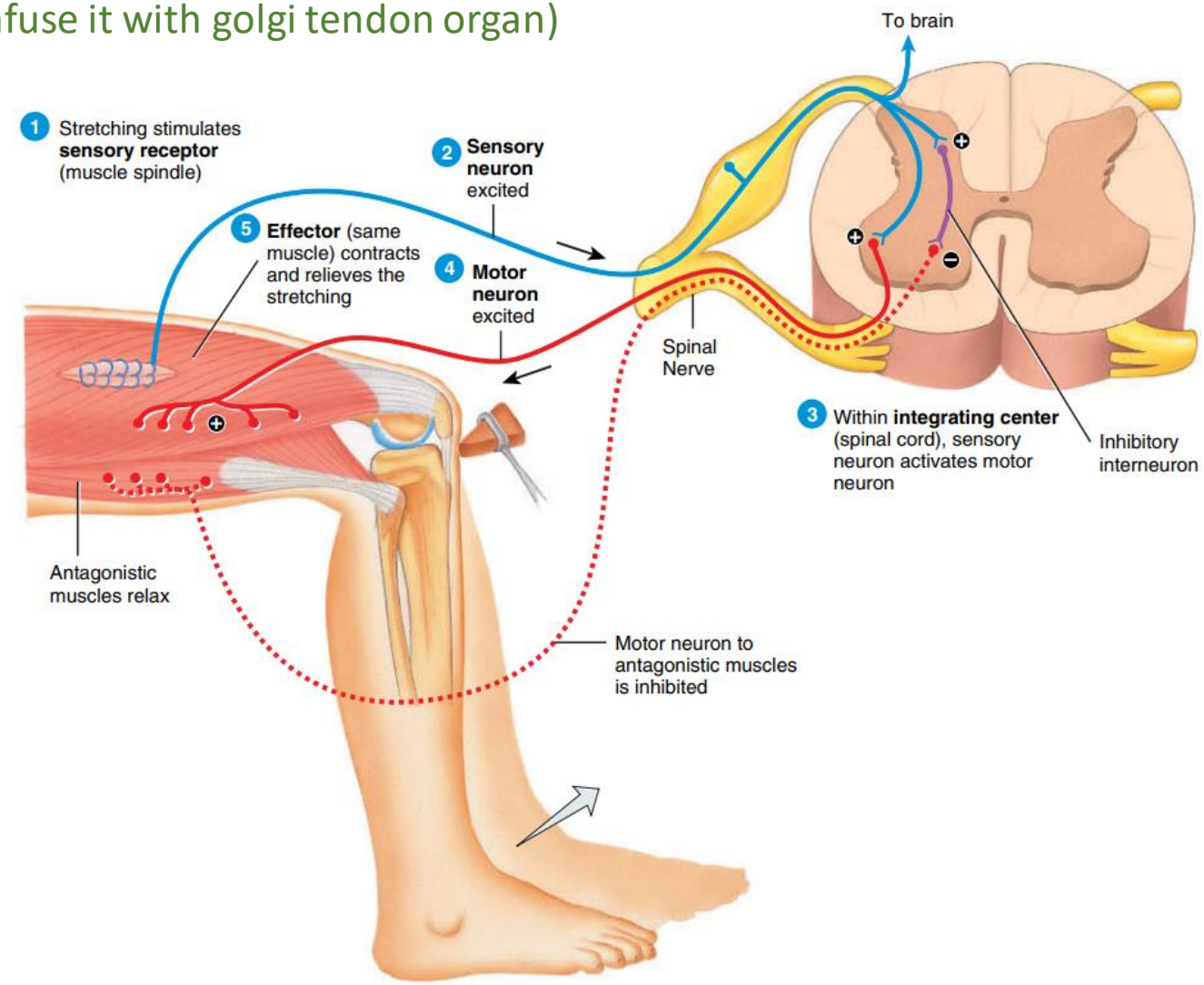
When the patient come to your clinic you will ask him/her to set unsupported the leg, then you hit the patellar tendon with hammer, that will cause stretching in extensors of the knee which will activate the muscle spindle and then the signal will go through the sensory neuron 1a mainly that will go to the anterior horn of the gray matter then synapse with anterior motor neuron (alpha) that will activate and cause contraction in the muscle that stretched

Stretch reflex arc

The simplest manifestation of the muscle spindle function is muscle stretch reflex or a deep tendon reflex (don't confuse it with golgi tendon organ)

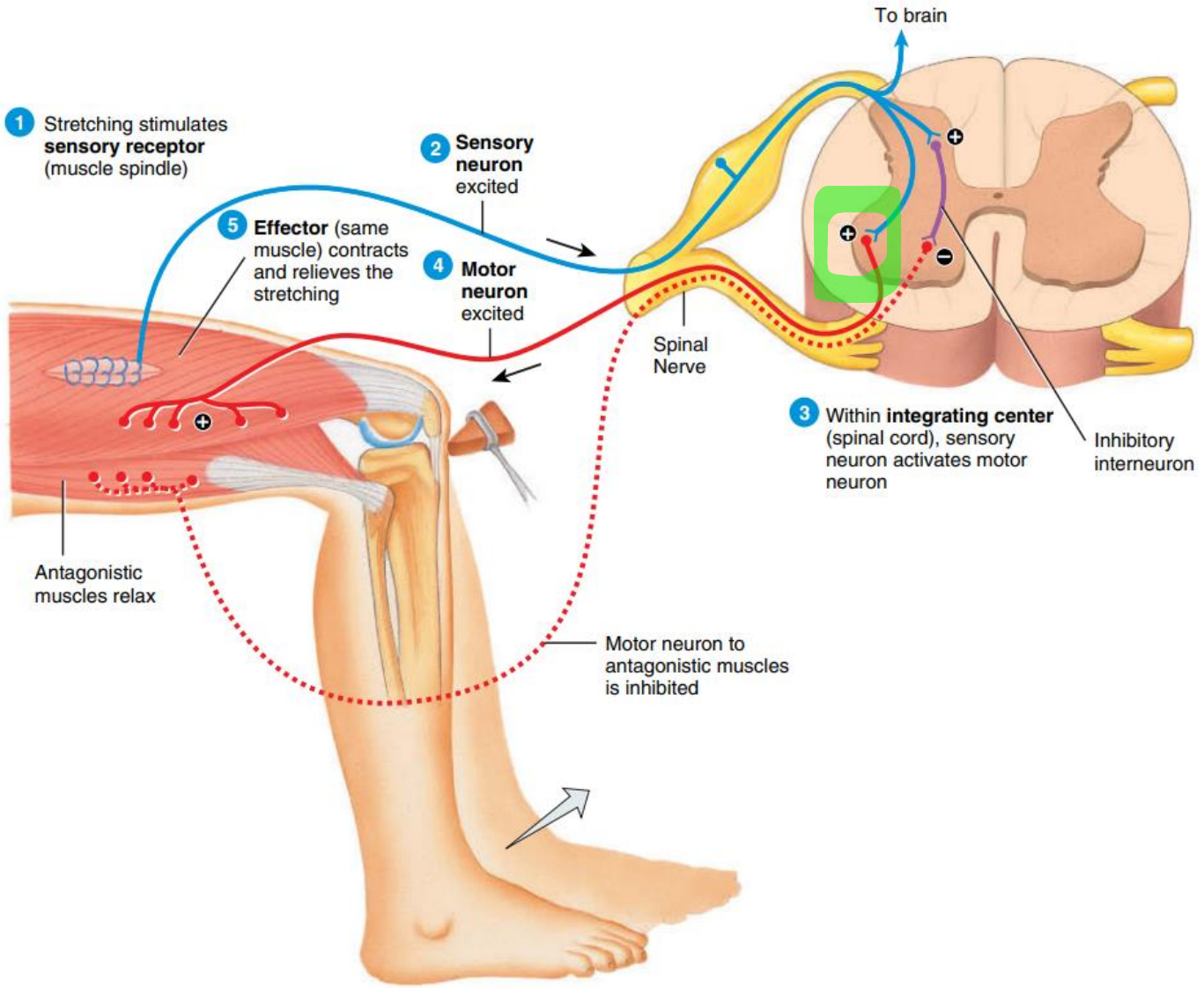
Stretch

Spindle



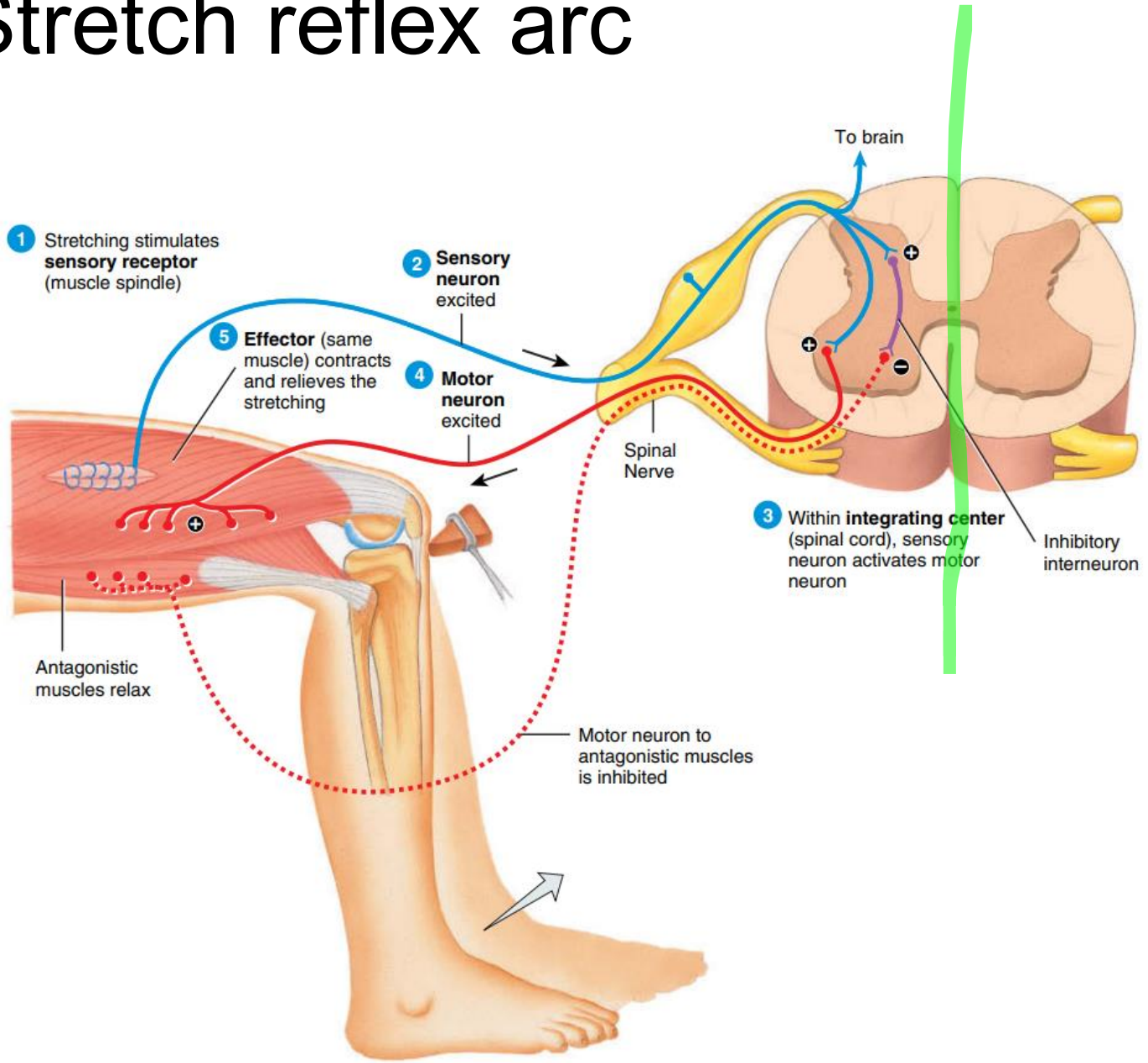
Stretch reflex arc

Monosynaptic



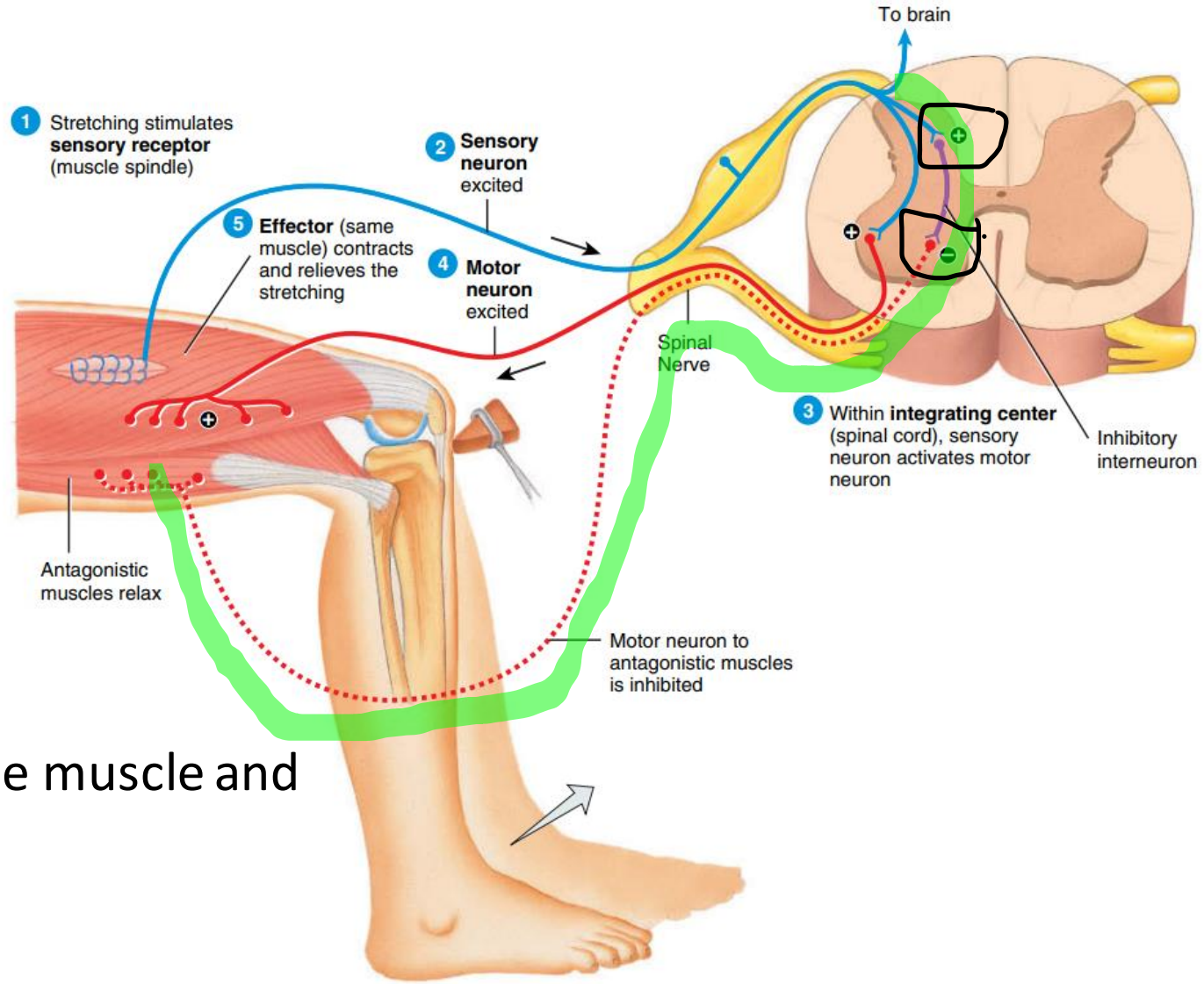
Stretch reflex arc

Ipsilateral



Stretch reflex arc

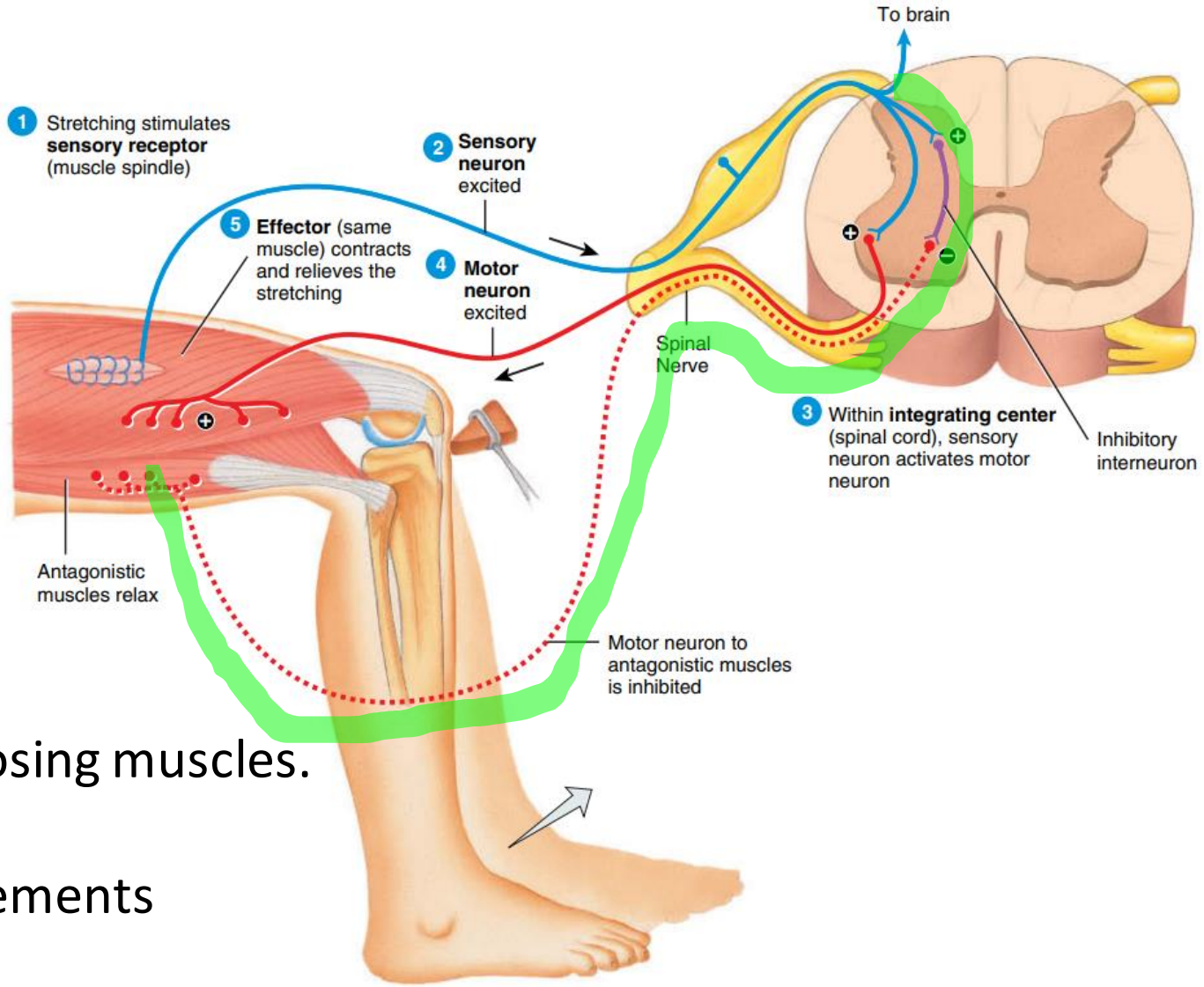
Reciprocal innervation



Simultaneous contraction of one muscle and relaxation of its antagonist.

Stretch reflex arc

Reciprocal innervation



Prevents conflict between opposing muscles.

Vital in coordinating body movements

Muscle stretch reflex

- The stretch reflex can be divided into two components:
- The **dynamic stretch reflex** is elicited by potent dynamic signals transmitted from the primary sensory endings of the muscle spindles, caused by rapid stretch or unstretch.
- That is, when a muscle is suddenly stretched or unstretched, a strong signal is transmitted to the spinal cord, which causes an instantaneous strong reflex contraction (or decrease in contraction) of the same muscle from which the signal originated.
- Thus, the reflex functions to oppose sudden changes in muscle length.

Muscle stretch reflex

- The dynamic stretch reflex is over within a fraction of a second after the muscle has been stretched (or unstretched) to its new length, but then a weaker **static stretch reflex** continues for a prolonged period thereafter.

- This reflex is elicited by the continuous static receptor signals transmitted by both primary and secondary endings.

- The importance of the static stretch reflex is that it causes the degree of muscle contraction to remain reasonably constant, except when the person's nervous system specifically wills otherwise.

Role of muscle spindle in voluntary movements

- Whenever signals are transmitted from the motor cortex or from any other area of the brain to the alpha motor neurons, in most instances the gamma motor neurons are stimulated simultaneously, an effect called c**oactivation of the alpha and gamma motor neurons.**

- This effect causes both the extrafusal skeletal muscle fibers and the muscle spindle intrafusal muscle fibers to contract at the same time.

- coactivation keeps the muscle spindle reflex from opposing the muscle contraction.

Role of muscle spindle in voluntary movements

- The gamma efferent system is excited specifically by signals from the bulboreticular facilitatory region of the brain stem and, secondarily, by impulses transmitted into the bulboreticular area from the following: (1) the cerebellum; (2) the basal ganglia; and (3) the cerebral cortex.

Clinical significance of stretch reflex

- The muscle jerks are used by neurologists to assess the degree of facilitation of spinal cord centers.
- When large numbers of facilitatory impulses are being transmitted from the upper regions of the central nervous system into the cord, the muscle jerks are greatly exaggerated.
- Conversely, if the facilitatory impulses are depressed or abrogated, the muscle jerks are considerably weakened or absent.
- These reflexes are used most frequently in determining the presence or absence of muscle spasticity caused by lesions in the motor areas of the brain or diseases that excite the bulboreticular facilitatory area of the brain stem.

Significance of stretch reflex

- Because the stimulus for the stretch reflex is stretching of muscle, this reflex **helps avert injury by preventing overstretching of muscles.**

Stretch reflex

- The stretch reflex can also **help maintain posture**.

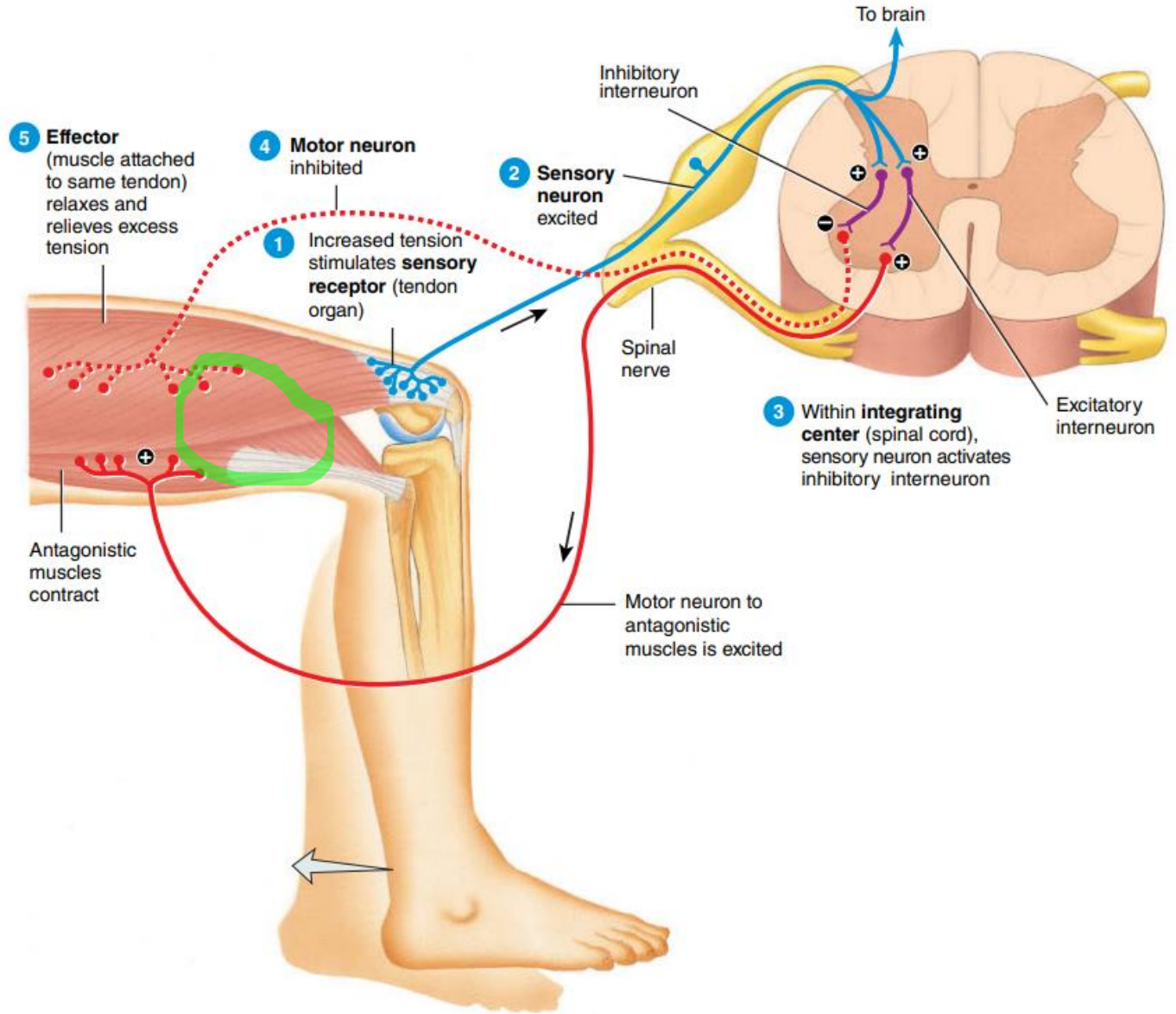
- For example, if a standing person begins to lean forward, the gastrocnemius and other calf muscles are stretched. Consequently, stretch reflexes are initiated in these muscles, which cause them to contract and reestablish the body's upright posture.

Activation of golgi tendon organ by increasing the tension will activate the sensory neuron that will go to the gray matter synapse on interneuron (inhibitory) then synapse on anterior motor neuron resulting in relaxation of this muscle, so by this will decrease the tension in this muscle and prevent bulging the tendon or injury to the tendon and muscle by the increased tension

Tendon reflex

Tension

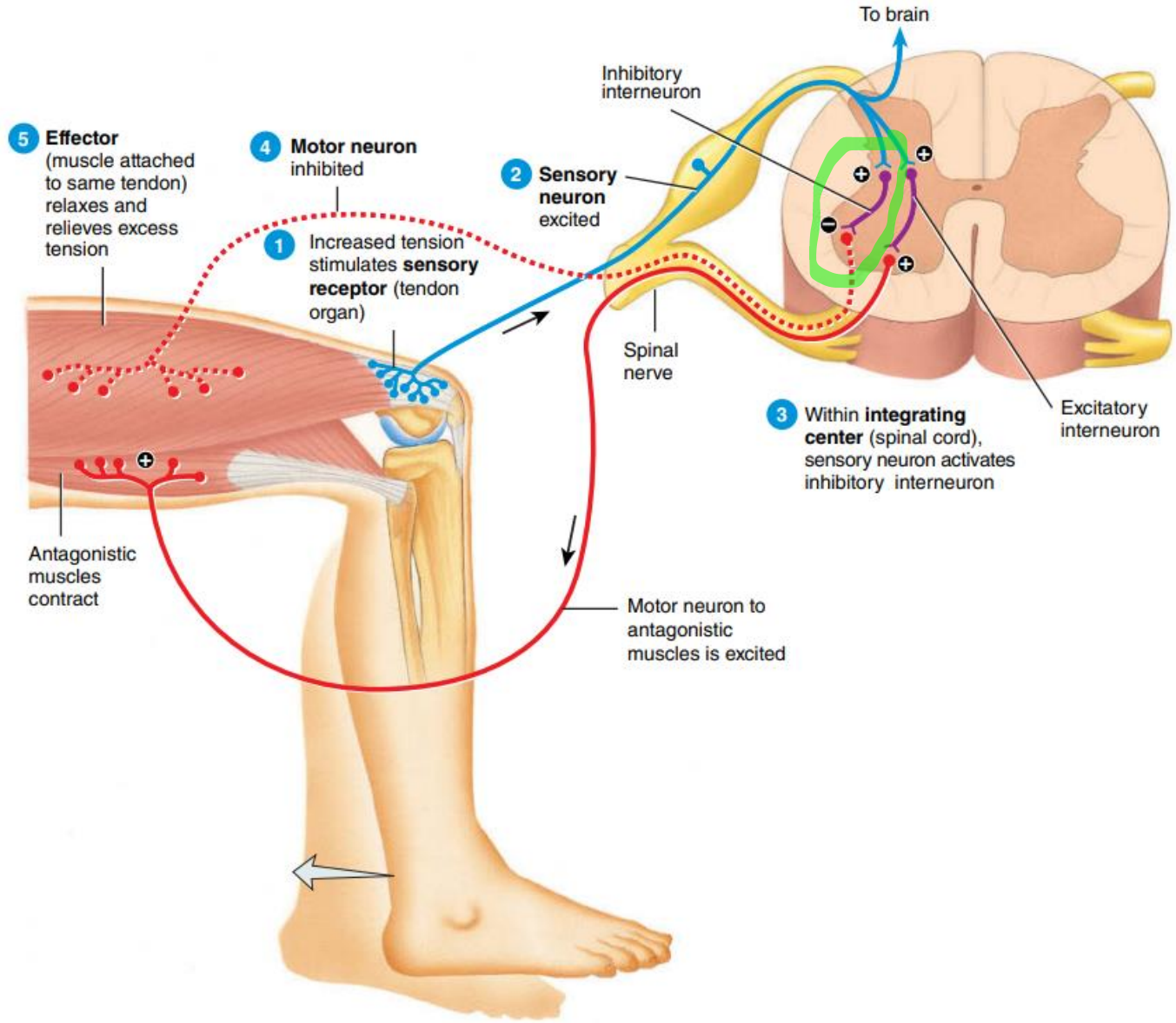
Tendon organ (Golgi)



Tendon reflex

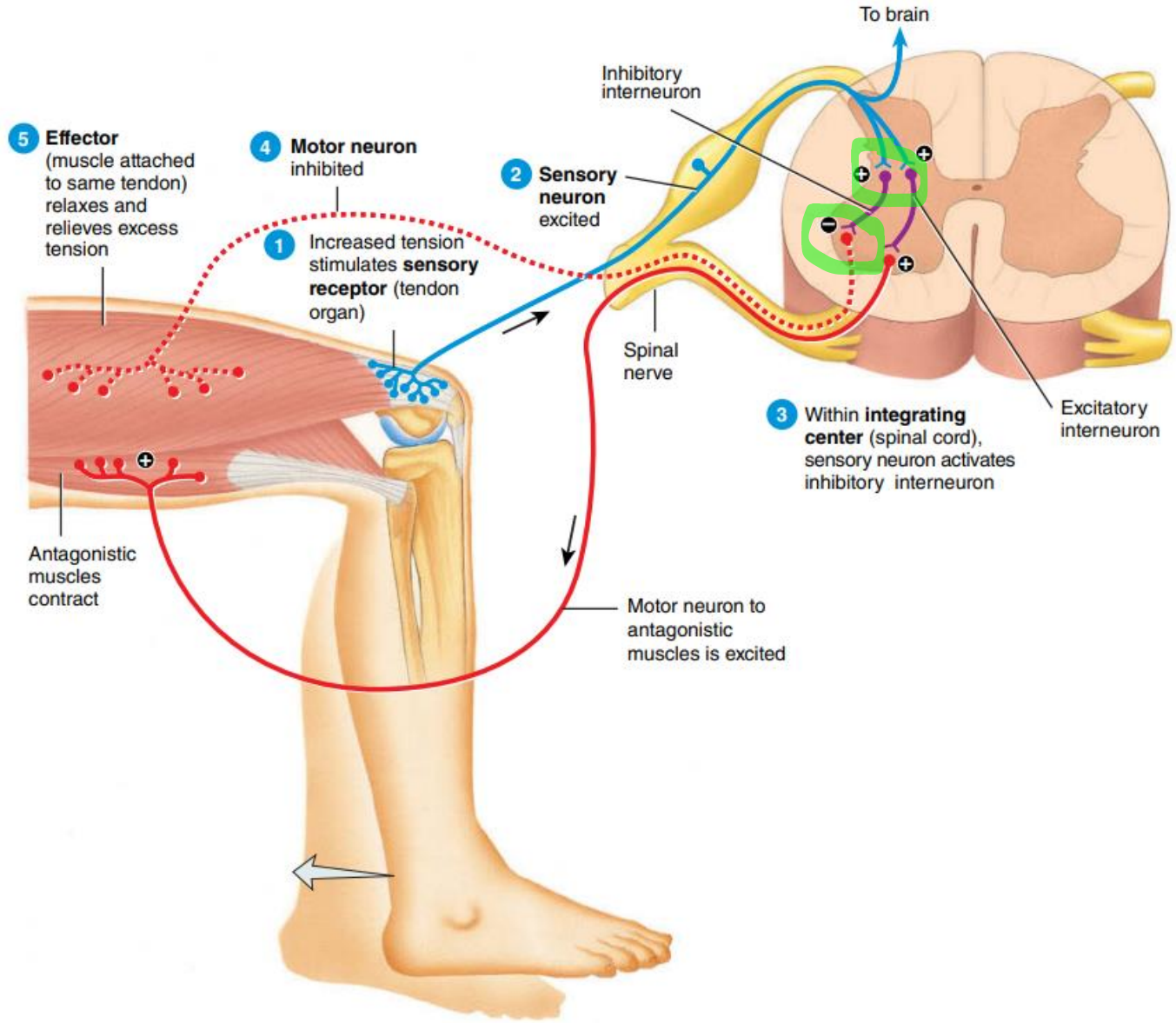
Sensory neuron activates inhibitory interneuron

Muscle relaxes
Less tension



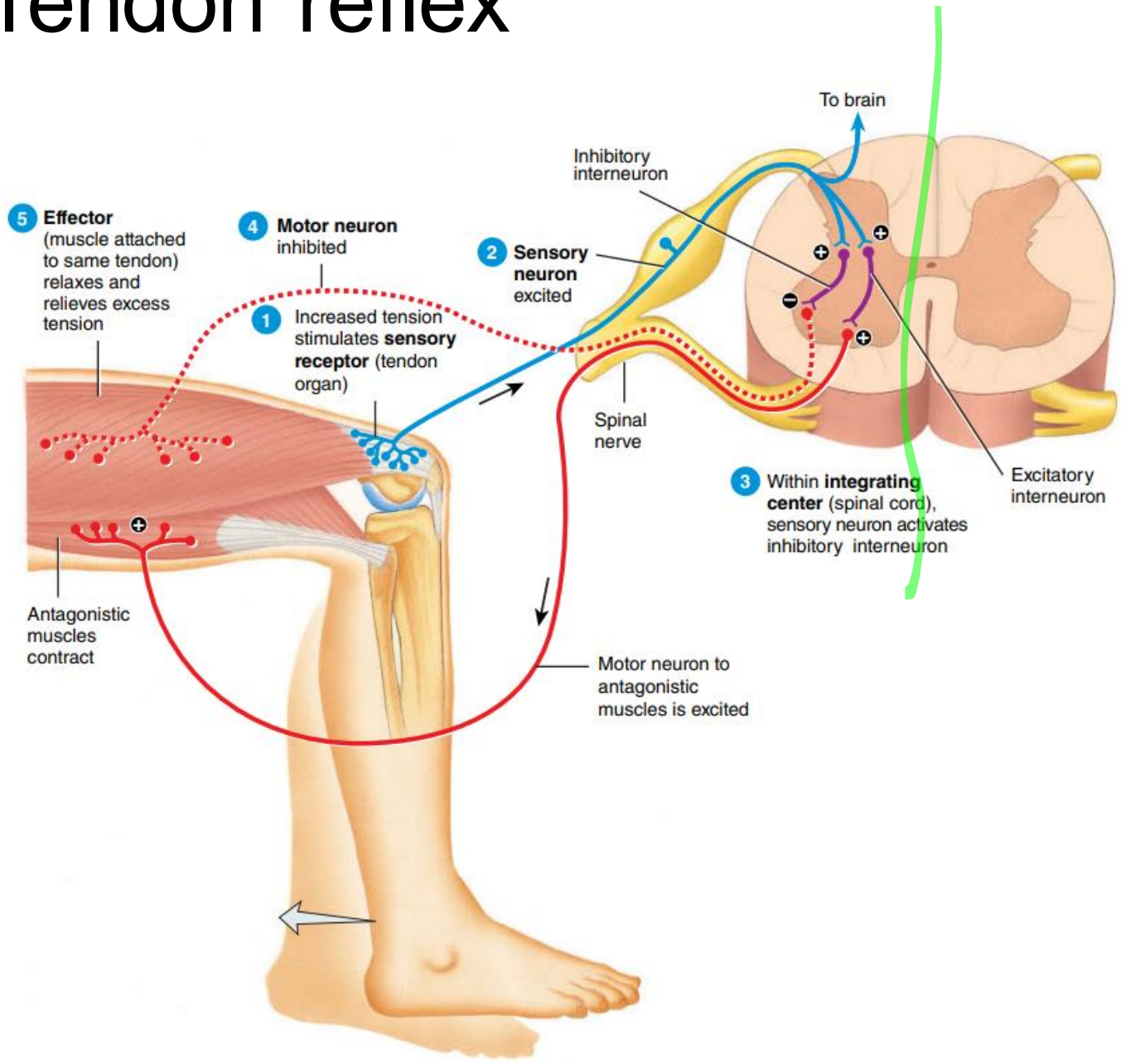
Tendon reflex

Polysynaptic



Tendon reflex

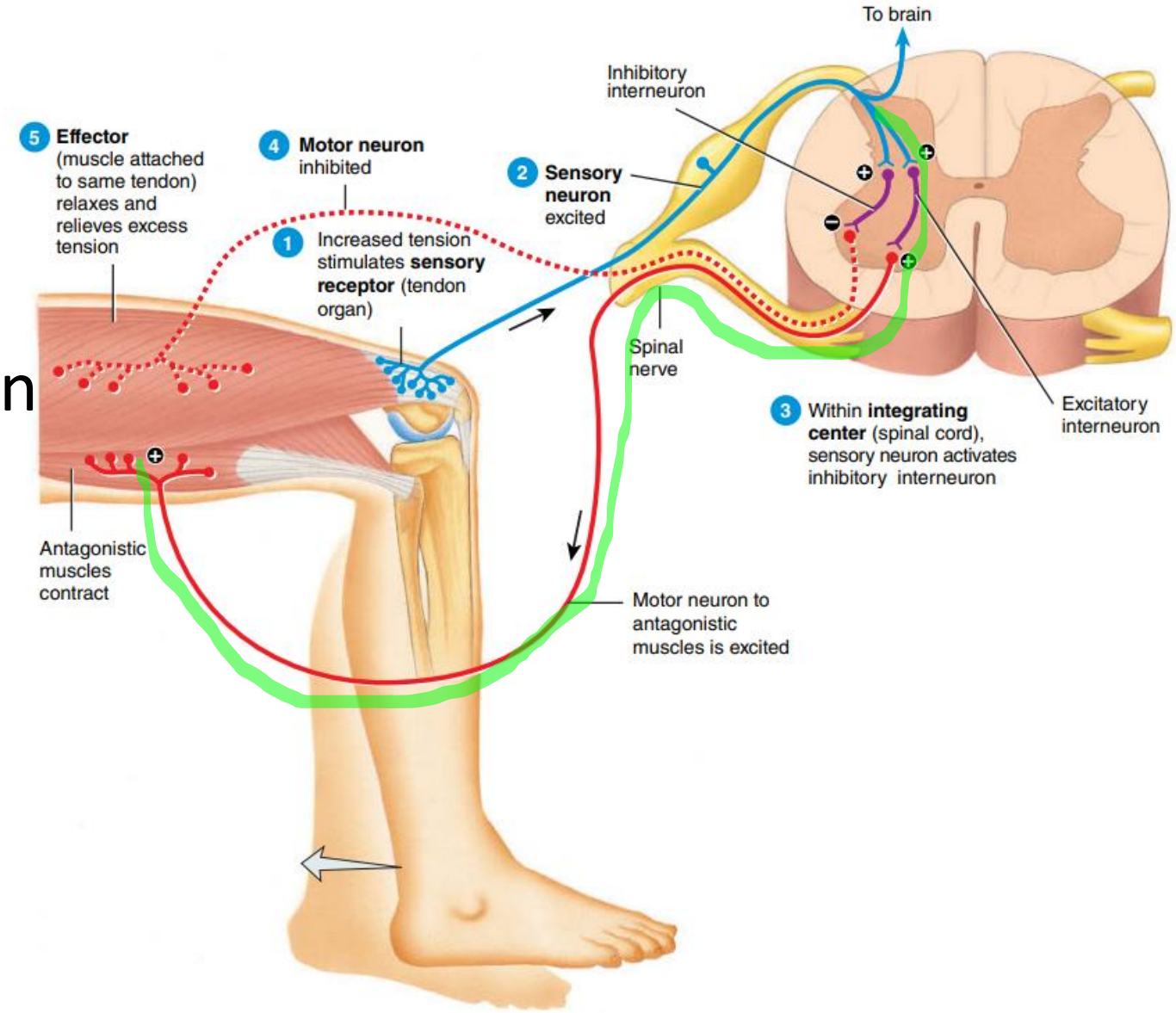
Ipsilateral



Just like what we explain in stretch reflex, in the tendon reflex there is also reciprocal innervation which means there is a branch going to the antagonist muscle but here the antagonistic muscle will be activated and contracted since the another is relaxed

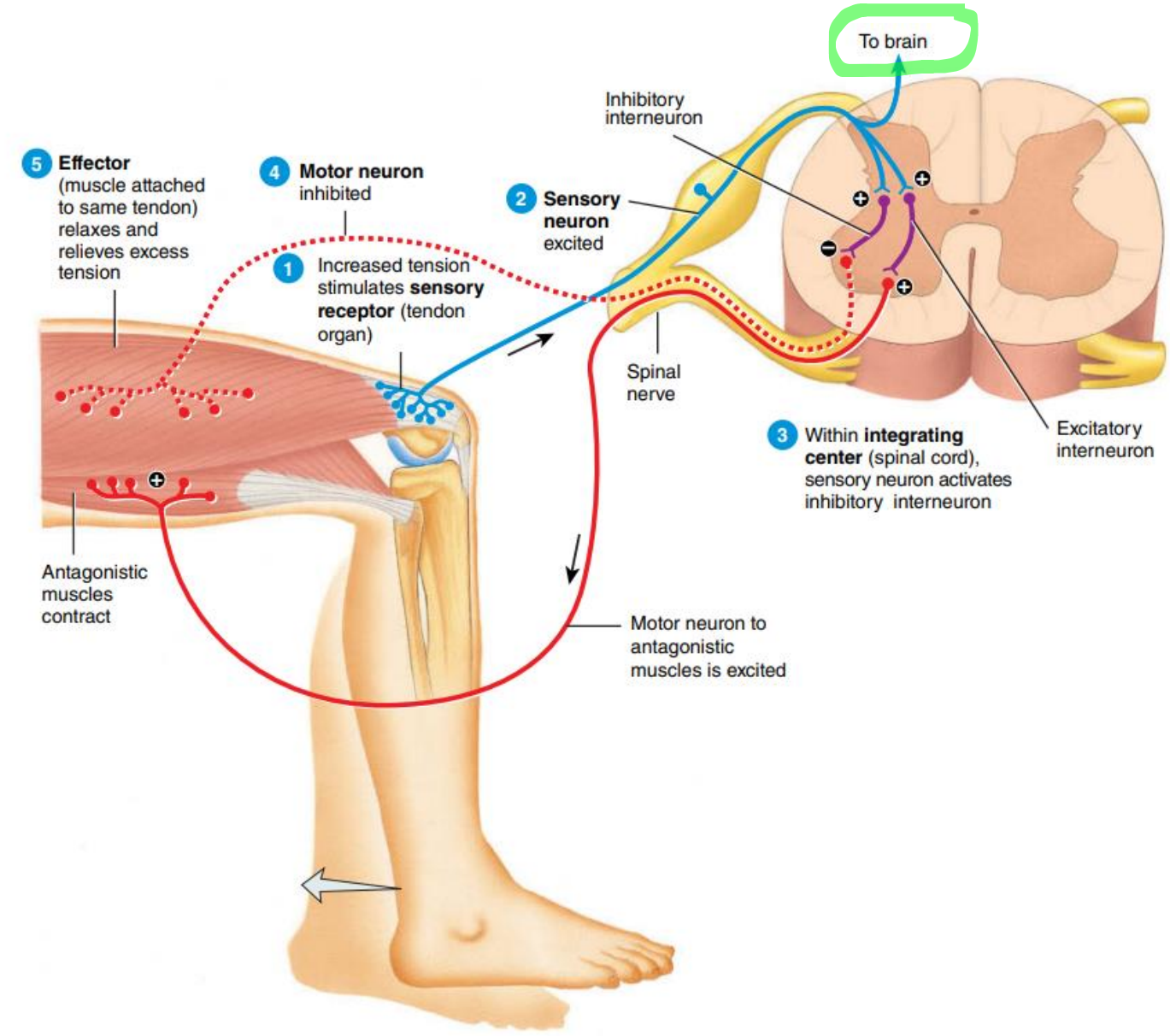
Tendon reflex

Reciprocal innervation



It has dynamic and static reflexes as stretch reflex. Static tendon reflex that is for prolonged time and always informing the CNS (cerebral cortex, motor area , cerebellum and reticular formation) about the situation of the tension as well as the stretch in the case of stretch reflex

Tendon reflex



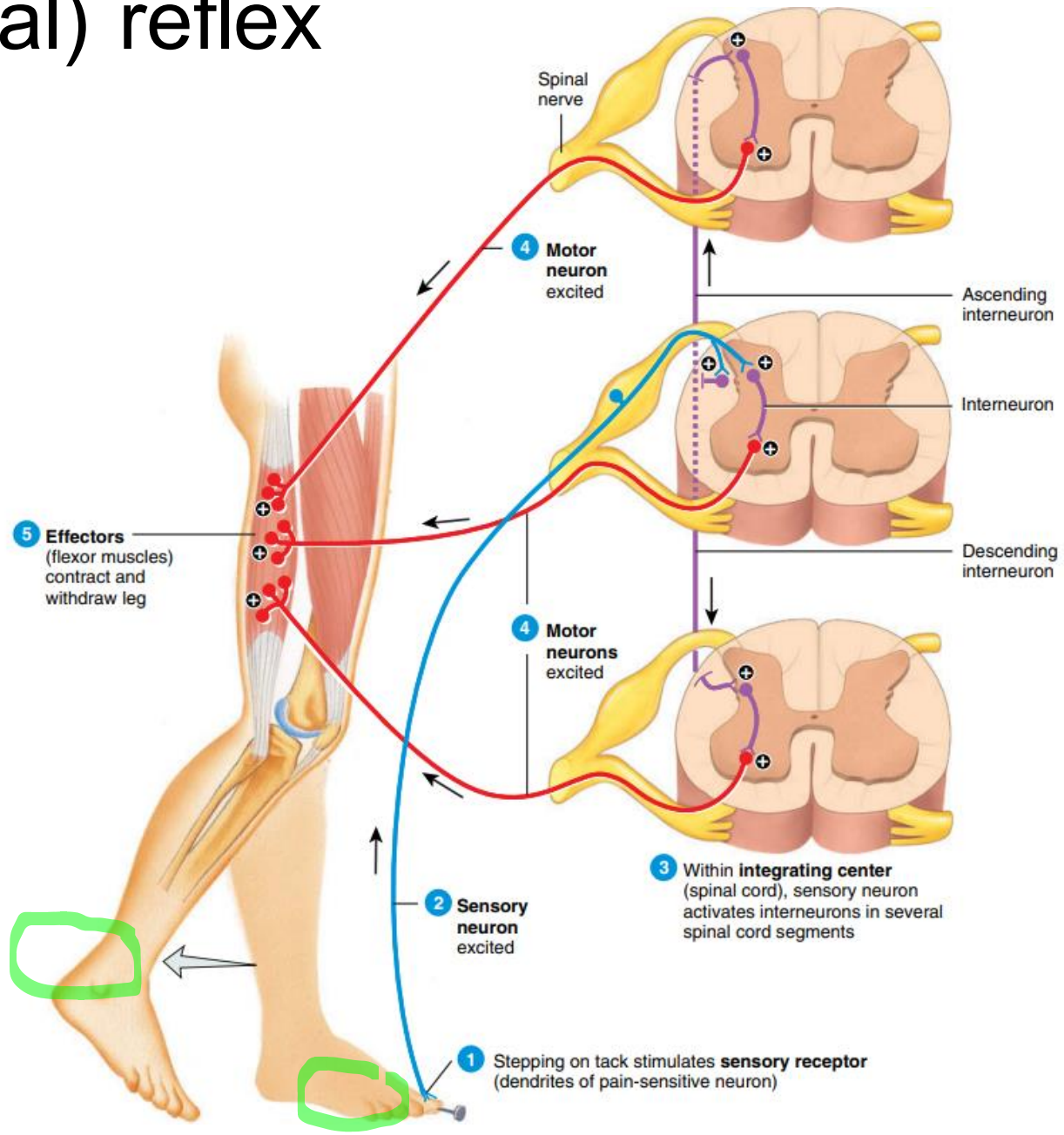
Flexor (withdrawal) reflex

Spinal reflexes aren't only stimulated by proprioceptive signals, they maybe stimulated with any other cutaneous signal for example flexor reflex. You may flex your arm or leg and withdraw them from light touch but most importantly from pain

-pain stimulus activating nocicepter will cause flexion or withdrawal from this signal

Pain

Withdrawal

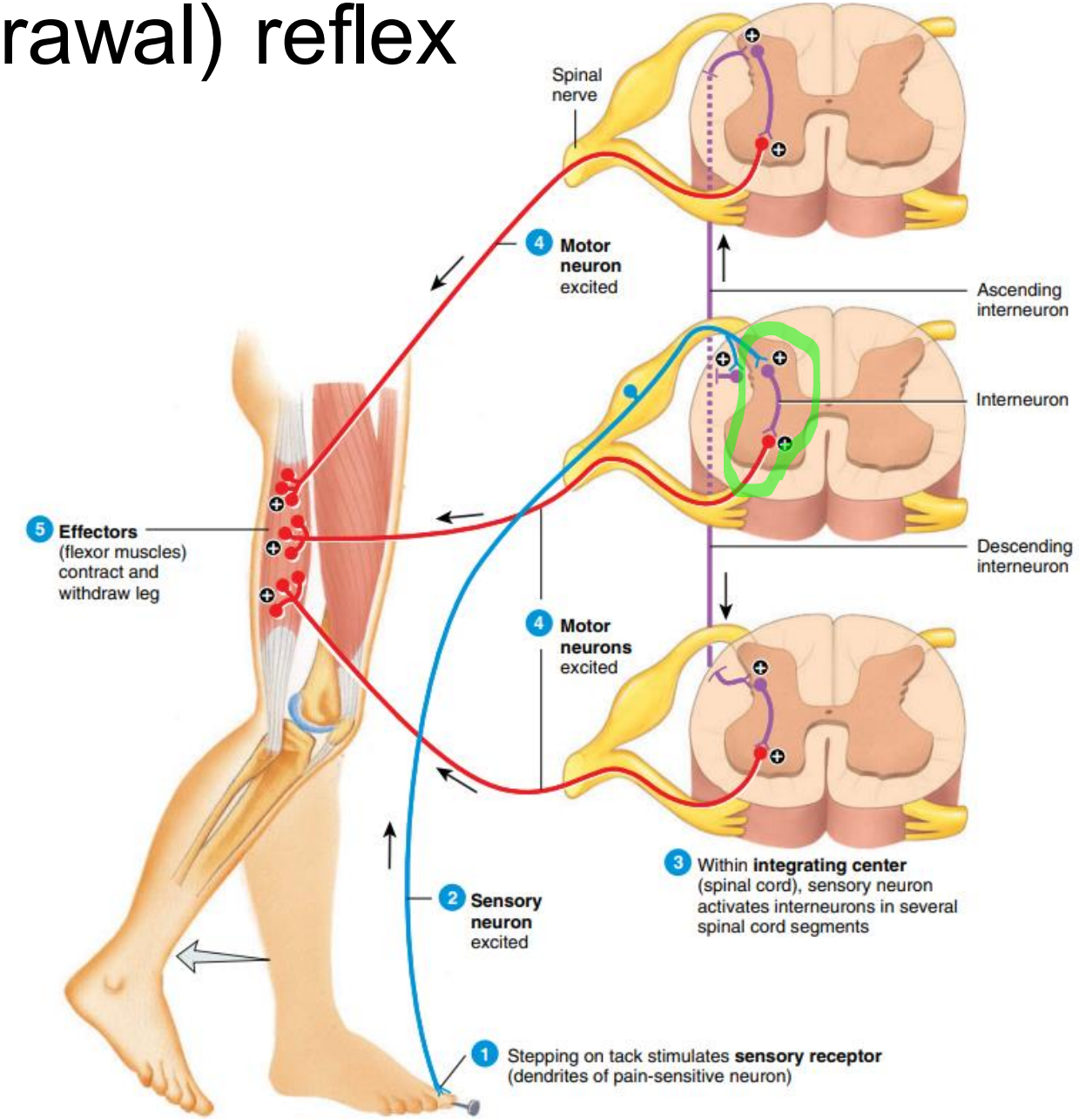


Flexor (withdrawal) reflex

This reflex look more complex than the previous two reflexes because it involves different types of neuronal circuits such as the divergent circuit, reciprocal circuit and after-discharge circuit

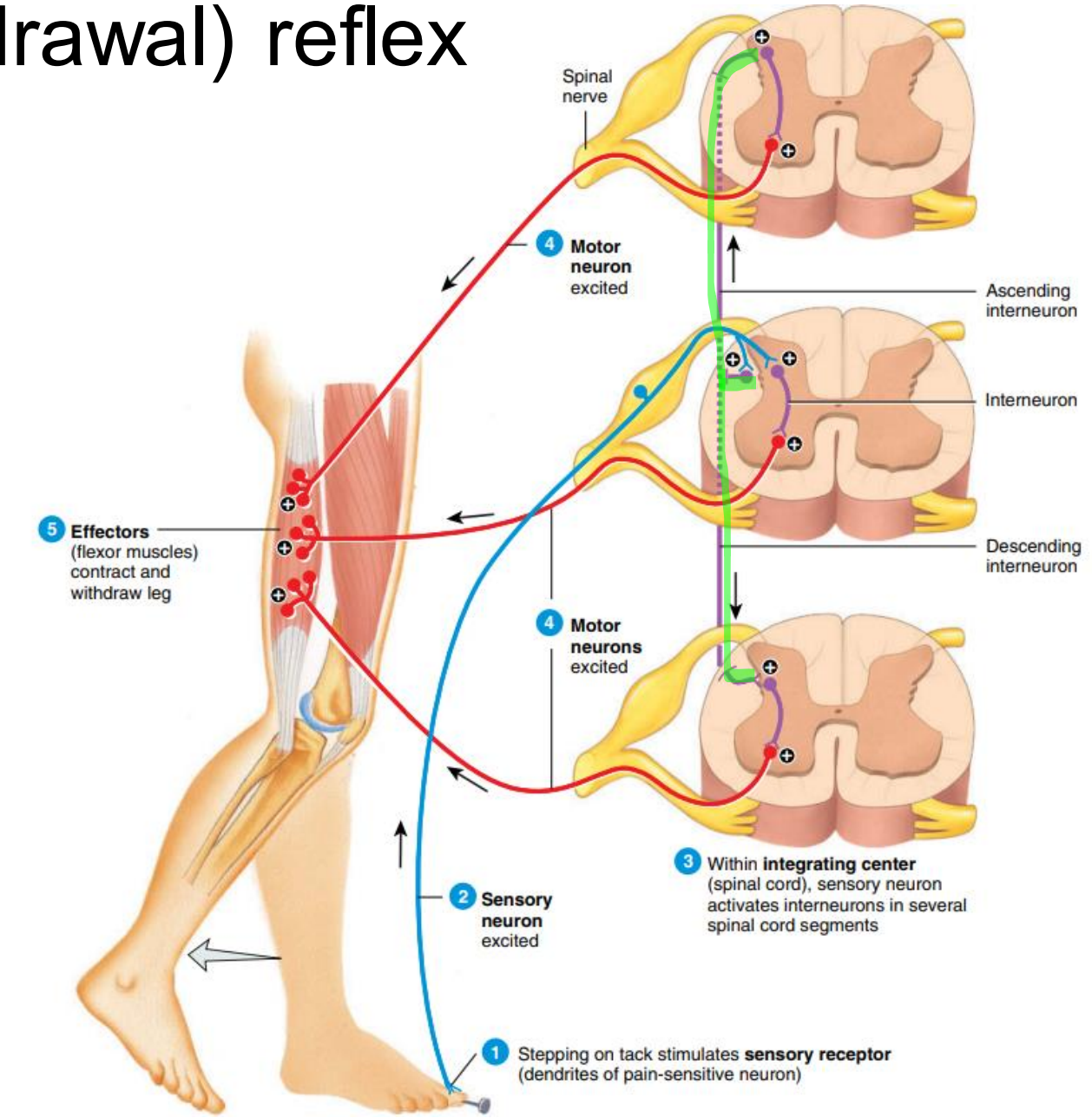
Polysynaptic

The after-discharge circuit plays an important role to keep this kind of withdrawal from the signal to prolong time until the CNS figure out what to do with this painful signal



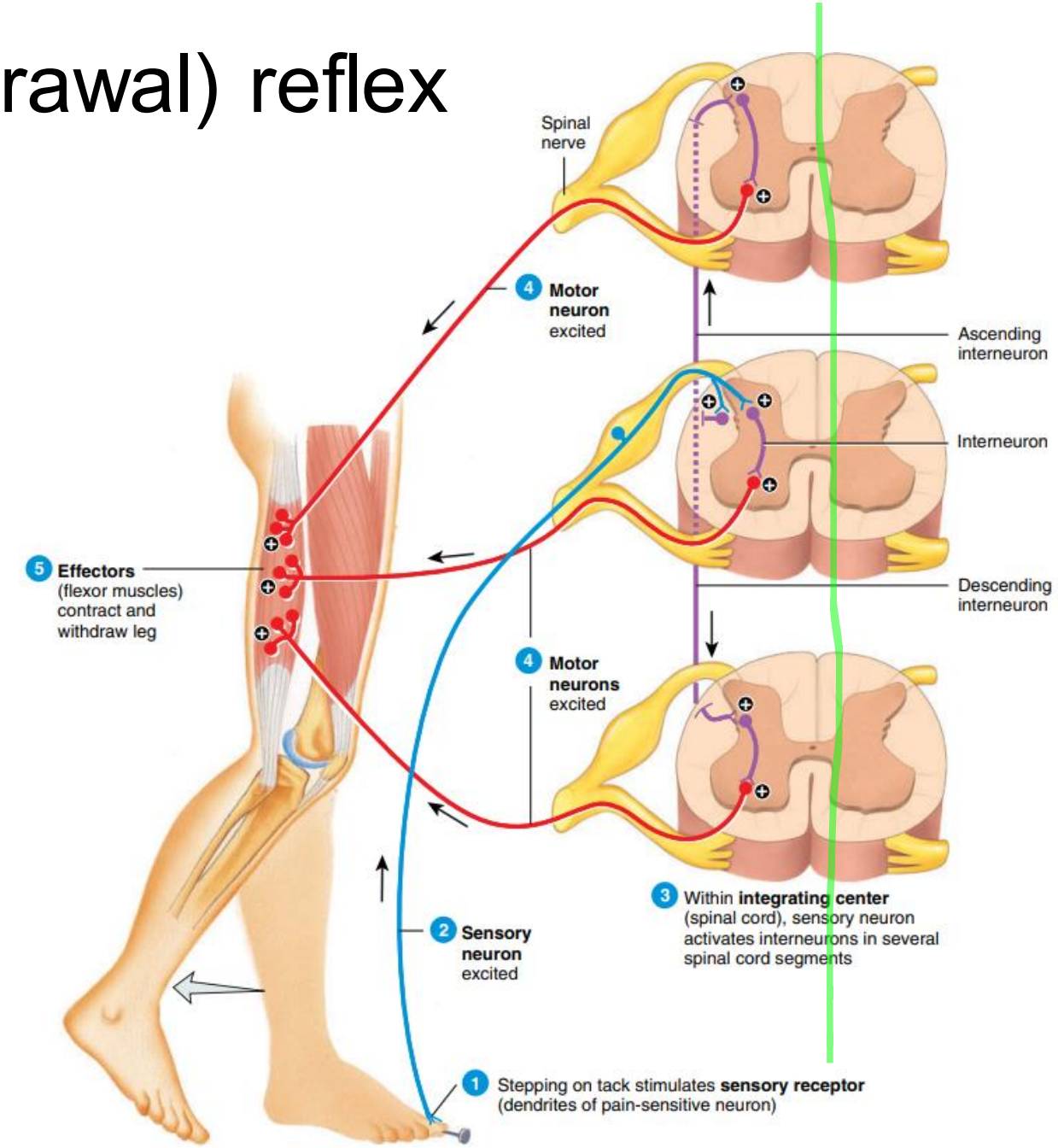
Flexor (withdrawal) reflex

Intersegmental



Flexor (withdrawal) reflex

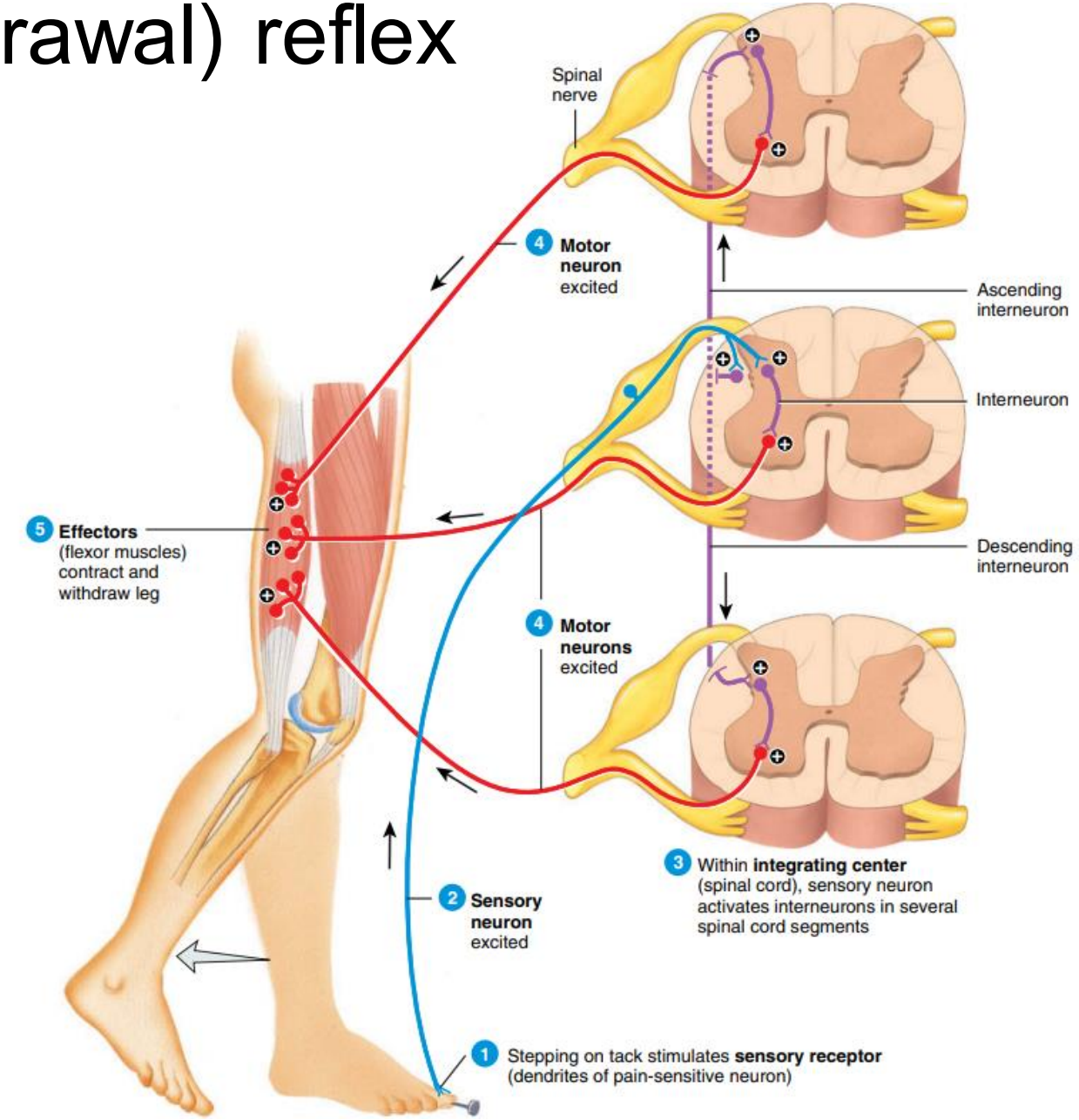
Ipsilateral



Flexor (withdrawal) reflex

Initiates
crossed
extensor reflex

Which will affect the opposite limb

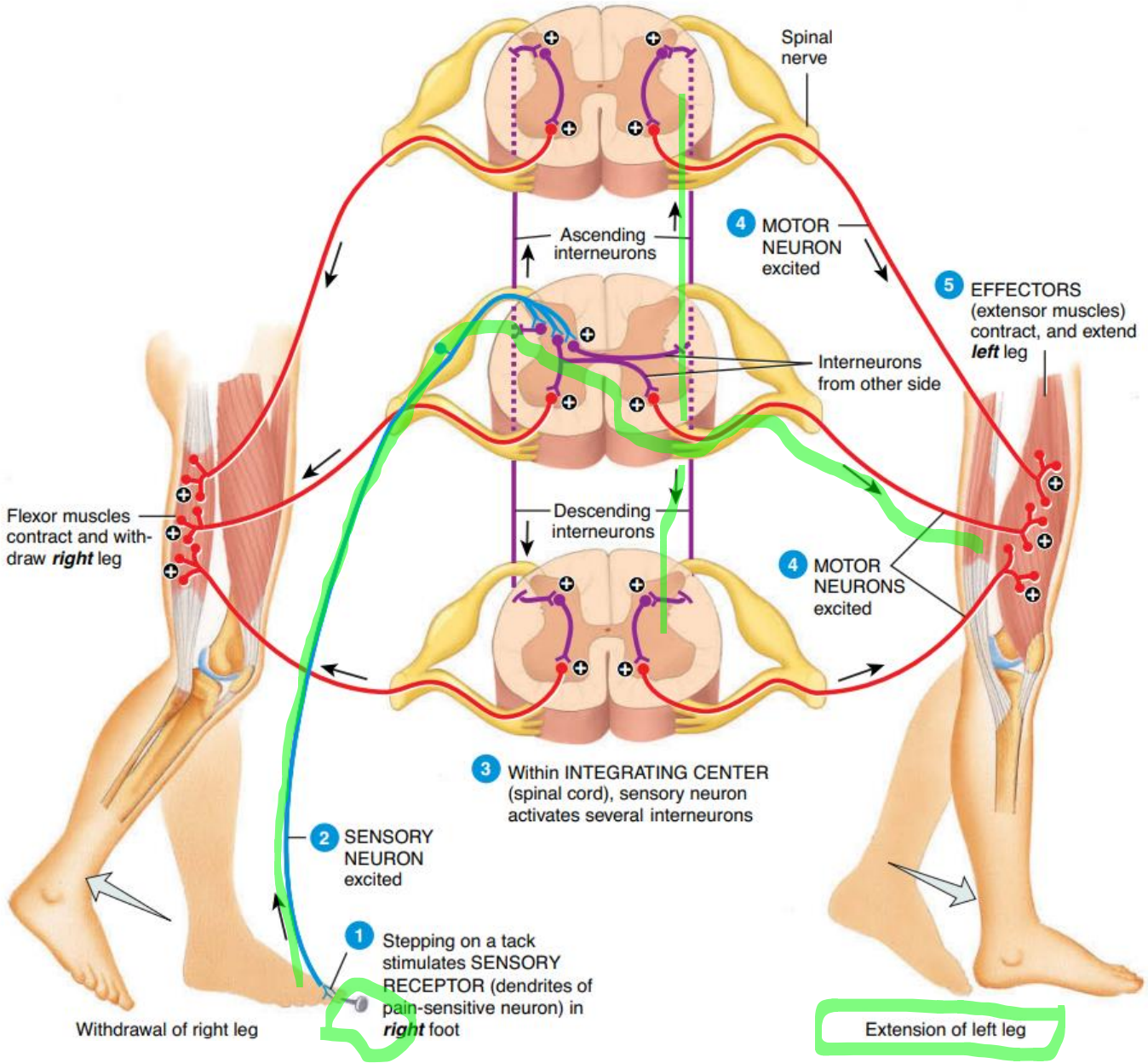


Crossed extensor reflex

Contralateral reflex arc

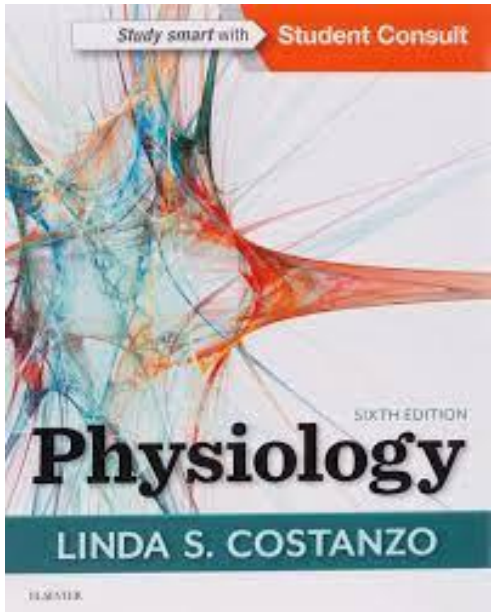
Maintain balance

A signal on one side will activate a flexor reflex, will also activate a contralateral extensor reflex to maintain balance in case of lower limb and get away from painful stimulus for the upper limb -it's complex, intersegmental reflex and has many interneurons



Thank you

References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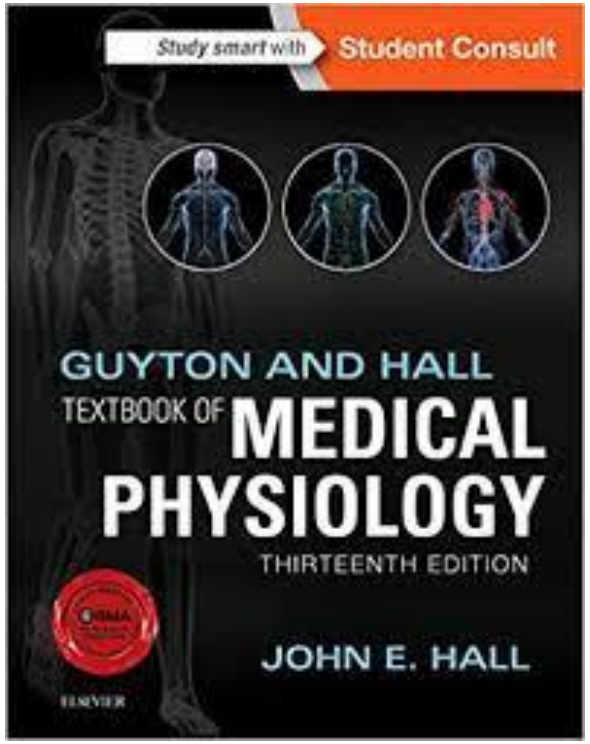
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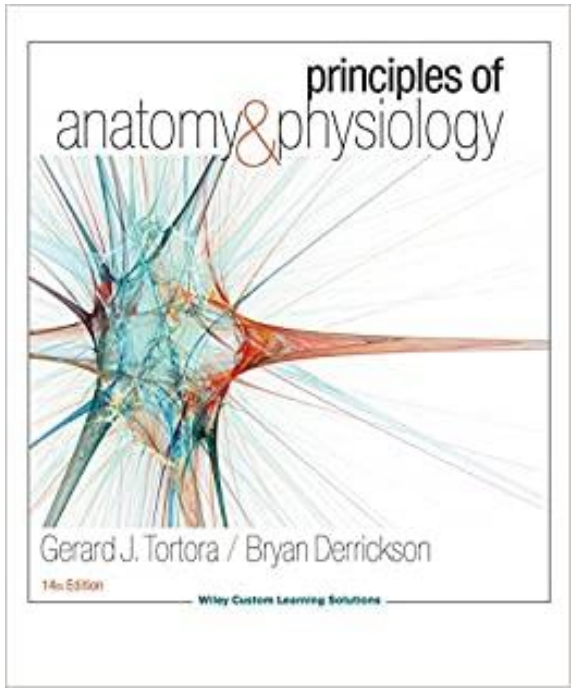
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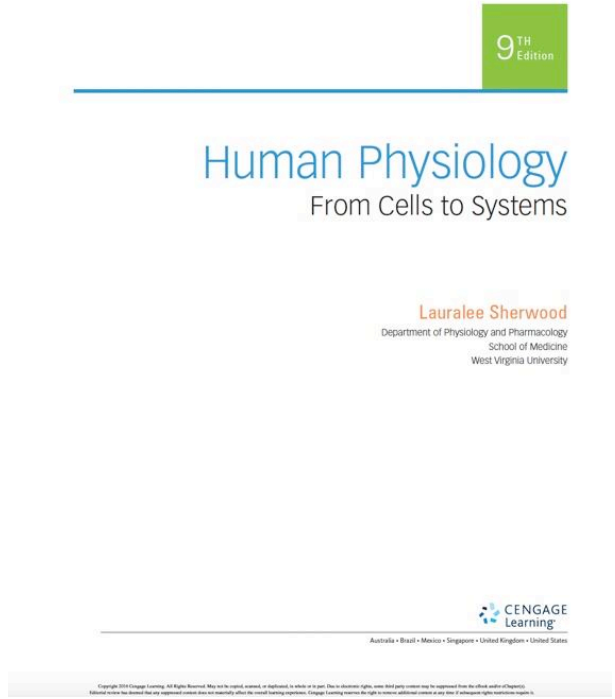
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