General Physiology
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lecture 20
Neuronal Reflexes :Spinal cord reflexes

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Lecture objectives

- Define the reflex.
- Recognize the components of the neuronal reflex arc and the neuronal circuits of spinal cord reflexes (Stretch Reflex , Golgi tendon reflex and withdrawal reflex)
- Identify the types of reflexes (simple and acquired or conditioned reflexes).
- Differentiate between somatic reflexes and autonomic reflexes and give examples
- Learn the clinical significance of reflexes (spinal cord reflexes as an example).

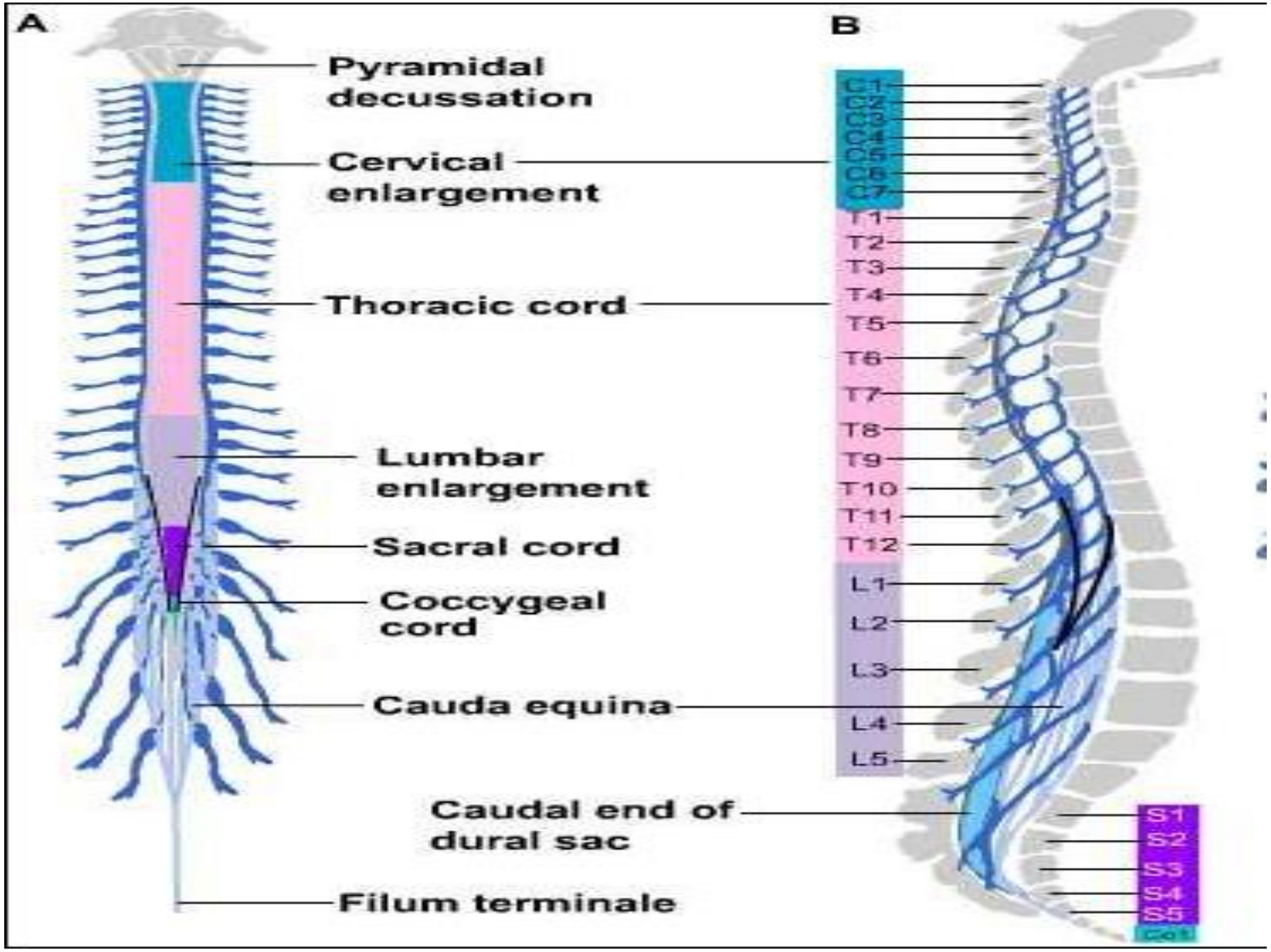
Physiological anatomy of the spinal cord

- The spinal cord extends from the foramen magnum where it is continuous with the medulla to the level of the first or second lumbar vertebrae.
- It is a vital link between the brain and the body, and from the body to the brain.
- The spinal cord is 40 to 50 cm long and 1 cm to 1.5 cm in diameter. Two consecutive rows of nerve roots emerge on each of its sides.
- These nerve roots join distally to form 31 pairs of **spinal nerves**.
- The spinal cord is a cylindrical structure of nervous tissue composed of white and gray matter, is uniformly organized and is divided into four regions: cervical (C), thoracic (T), lumbar (L) and sacral (S),each of which is comprised of several segments.

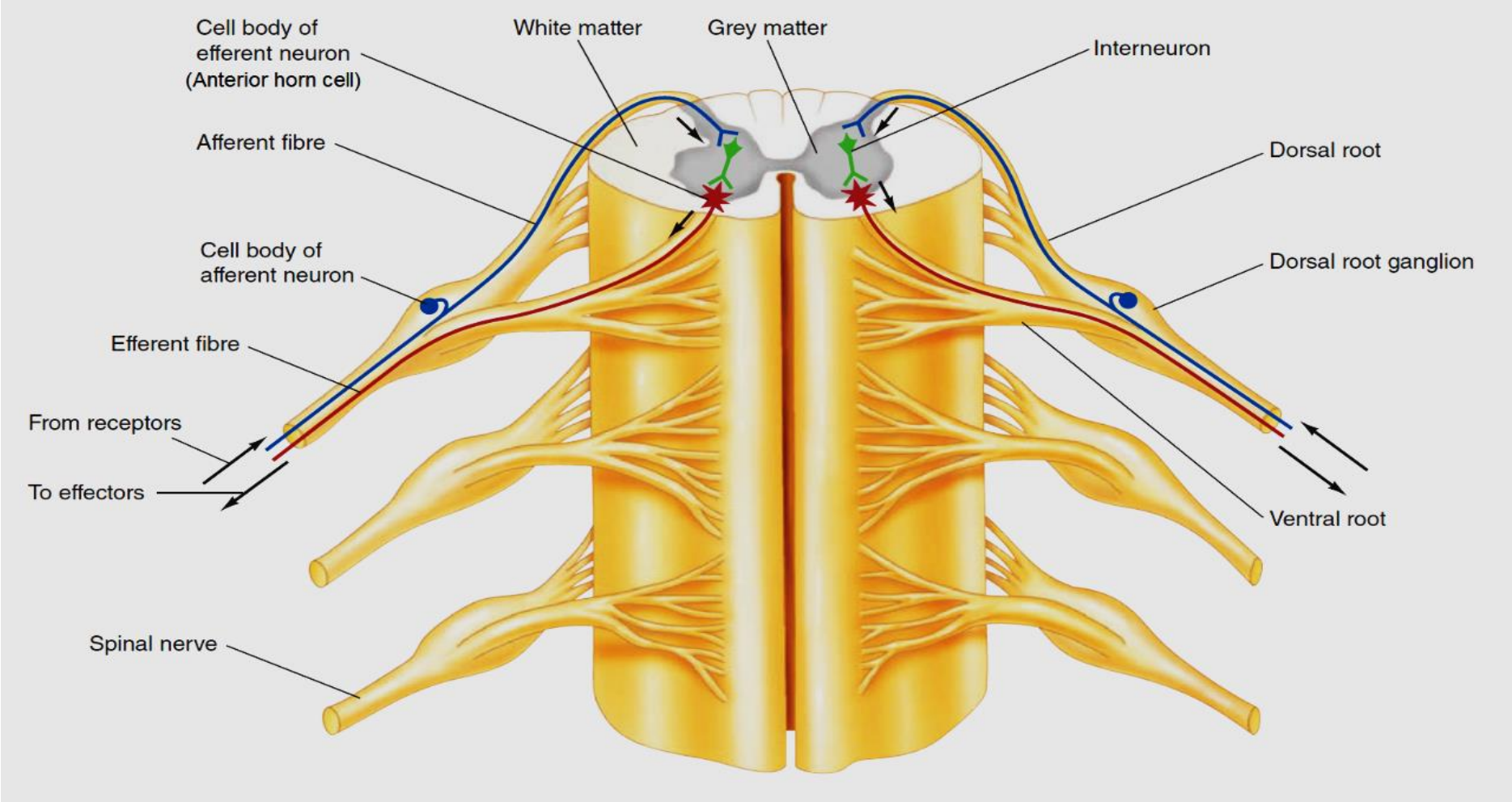
Functions of spinal cord

- **Send sensory signals to the brain.** The nerves also carry signals from different parts of your body to your brain.
- **Regulate body movements**
- Motor neurons in the ventral horn project their axons into the periphery to innervate skeletal and smooth muscles
- Final common pathway which carries motor commands of higher brain centers to skeletal muscles .
- **Control your reflexes.** The nerves in the spinal cord also control some reflex actions without involving your brain
- It contains neurons which mediates autonomic control for most of the visceral functions. For example Micturition reflex

Spinal cord Segments and spinal nerve



Spinal cord and spinal nerves

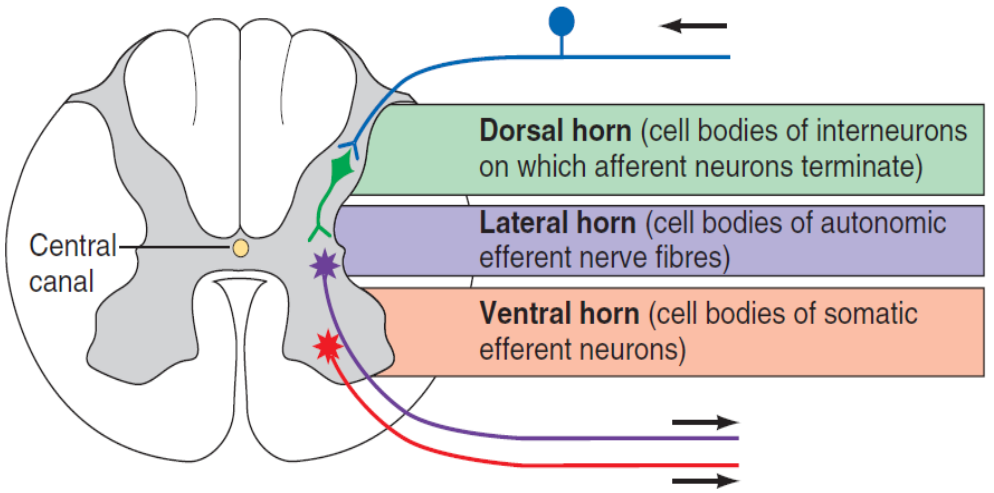


What is a reflex

- A reflex is any response that occurs **automatically** without conscious effort and is part of a biological control system that links stimulus and response.
- There are two types of reflexes:
  1. Simple (basic) reflexes, which are built-in, unlearned responses, such as pulling the hand away from a burning hot object.
  2. Acquired (conditioned) reflexes, which are a result of practice and learning, such as car driving.
- Reflexes can also be classified as
  - Somatic reflexes Associated with somatic structures like Knee jerk reflex
  - Autonomic reflexes Associated with visceral structures innervated by autonomic nervous system GI reflexes, Blood pressure reflexes, Pupil reflex, Micturition reflex etc.

The neuronal component of a reflex arc

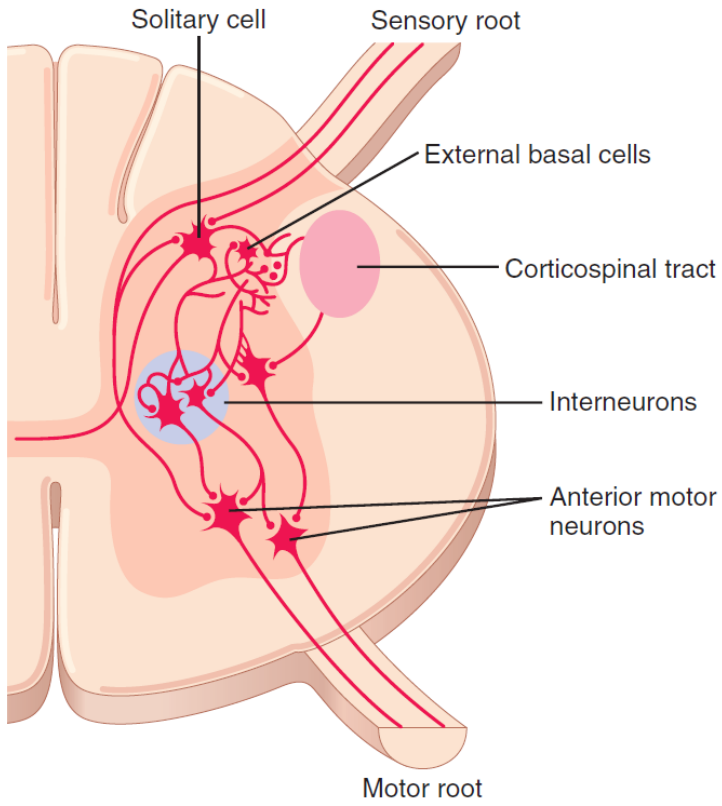
- The **Reflex Arc**: The neural pathway involved in accomplishing reflex activity, which typically includes five basic components:
  1. Receptor
  2. Afferent pathway
  3. Integrating center (part of the CNS)
  4. Efferent pathway
  5. Effector (a muscle or gland)



- The reflex could be a **monosynaptic, bisynaptic,** and **polysynaptic** based on the number of neuronal synapses within the reflex arc.

Organization of the Spinal Cord for Motor Functions

- The cord gray matter is the integrative area for the cord reflexes.
- Sensory signals enter the spinal cord almost entirely through the sensory roots; also known as the posterior or dorsal roots.
- After entering the spinal cord, every sensory signal travels to **two** separate destinations:
  A. One branch of the sensory nerve terminates almost immediately in the **gray matter** of the cord and elicits local segmental spinal cord reflexes and other local effects.
  B. Another branch transmits signals to higher levels of the nervous system; to **higher levels** in the cord itself, to the brain stem, or even to the cerebral cortex.

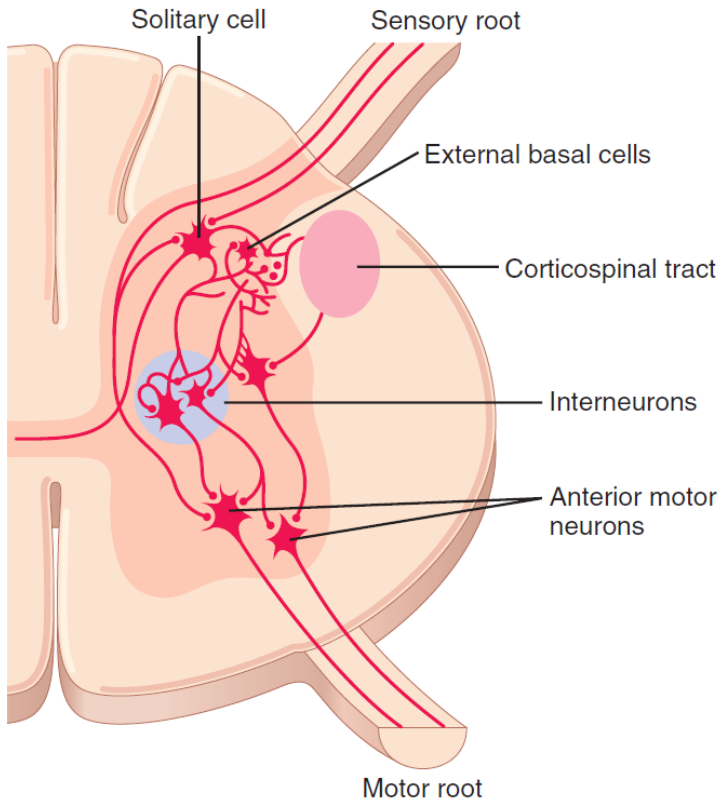


Organization of the Spinal Cord for Motor Functions (cont.):

- Each segment of the spinal cord has several million neurons in its gray matter. these neurons are of two types:
  1. **Anterior motor neurons (large type A fibers):** that are 50-100% larger than most of the other neurons. They give rise to the nerve fibers that leave the spinal cord by way of the anterior roots and directly innervate the skeletal muscle fibers.
  2. **Interneurons:** These cells are about 30 times as numerous as the anterior motor neurons. They are small and highly excitable.

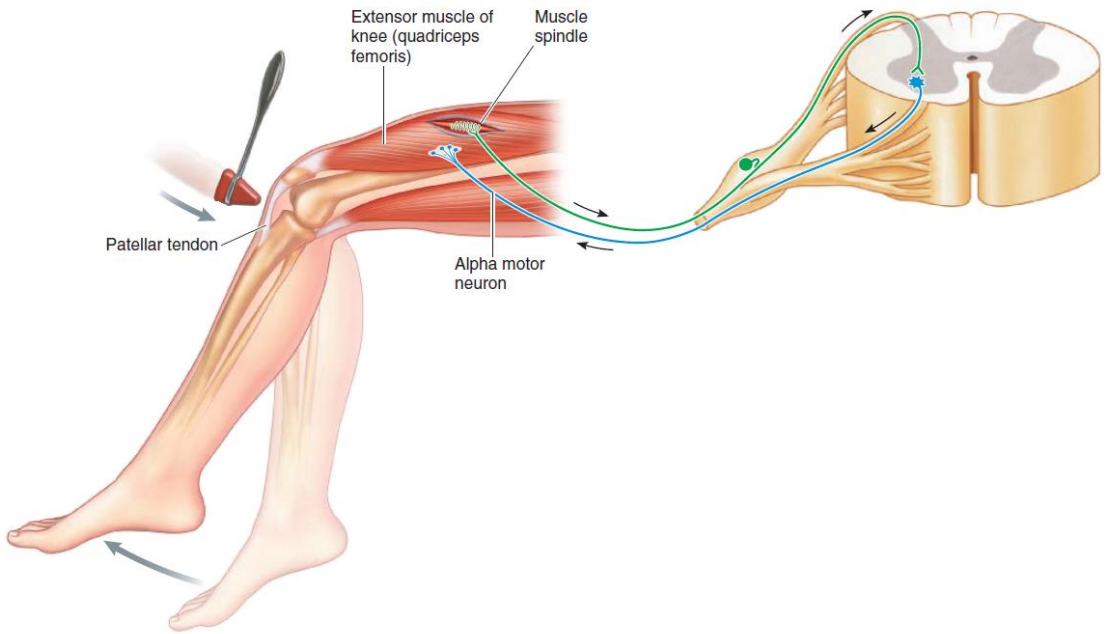
     They have many interconnections with one another, and many of them synapse directly with the anterior motor neurons. Essentially all the different types of neuronal circuits are found in the interneuron pool of cells of the spinal cord, including **diverging, converging, repetitive-discharge, and other types of circuits.**

     Almost all incoming sensory signals from the spinal nerves or motor signals from the brain are transmitted first through interneurons, where they are appropriately processed.



The Stretch Reflex or Myotatic Reflex (monosynaptic reflex)

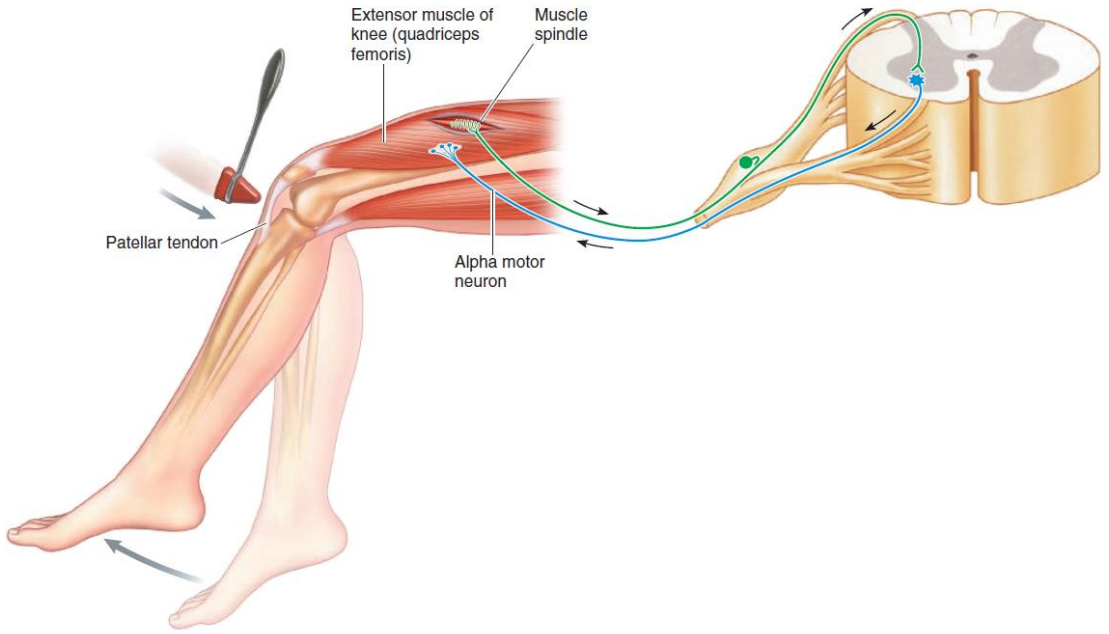
- The afferent neuron originating at a **muscle spindle** in a skeletal muscle. This afferent neuron terminates directly on the efferent neuron supplying the same skeletal muscle.
- The stretch reflex is a **monosynaptic reflex** (one-synapse), because the only synapse in the reflex arc is the one between the afferent neuron and the efferent neuron.
- Whenever a whole muscle is passively stretched, its muscle spindle intrafusal fibers are likewise **stretched** (activated), which increases the firing rate in the afferent nerve fibers whose sensory endings terminate on the stretched spindle fibers.



- The afferent neuron directly synapses on the **alpha motor neuron** that innervates the extrafusal fibers of the **same muscle**, resulting in **contraction** of that muscle.

The Stretch Reflex or Myotatic Reflex (monosynaptic reflex) cont.:

- This stretch reflex serves as a local **negative-feedback** mechanism to resist any passive changes in muscle length so that optimal resting length can be maintained.
- The classic example of the stretch reflex is the **patellar tendon (knee-jerk)** reflex.
- This test is routinely done as a preliminary assessment of nervous system function. It also indicates an appropriate balance of excitatory and inhibitory input to the motor neurons from higher brain levels.

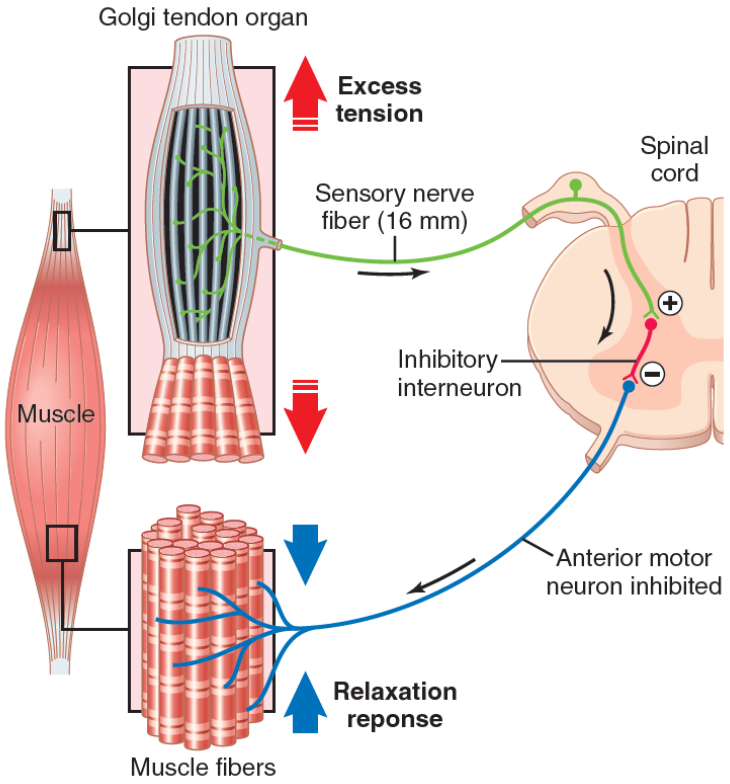


Hypoactive and hyperactive Knee jerk Reflexes Hyperreflexia and hyporeflexia

- Generally speaking lower motor neuron lesions causes a reflexia of hypo-reflexia
- Lesions in anterior horn cells or ventral root of innervation skeletal muscles causes absence of stretch reflexes
- Hypothyroidism cause diminished stretch reflexes (Hyporeflexia)
- Hyperthyroidism cause increase intensity of stretch reflexes (Hyper-refxia)
- Generally speaking Upper motor neurons lesions cause hyperreflxia

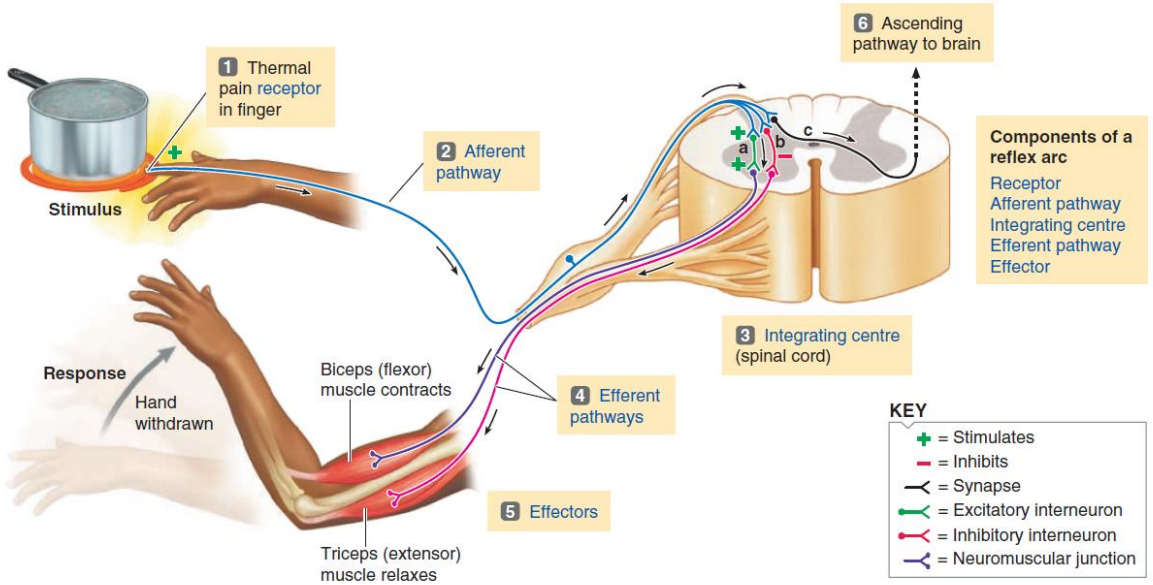
Golgi Tendon Reflex (bisynaptic reflex):

- The Golgi tendon organ is an encapsulated sensory receptor through which muscle tendon fibers pass.
- The major difference in excitation of the Golgi tendon organ versus the muscle spindle is that the spindle detects muscle length and changes in muscle length, whereas the tendon organ detects muscle **tension** as reflected by the tension in itself.
- Golgi tendon organs provide the nervous system with instantaneous information on the degree of tension in each small segment of each muscle.
- Signals from the tendon organ are transmitted through large, rapidly conducting nerve fibers that average 16 micrometers in diameter. The local spinal cord signal excites a **single inhibitory interneuron** that inhibits the anterior motor neuron. This local circuit directly inhibits the individual muscle without affecting adjacent muscles.
- This reflex is **entirely inhibitory**. Thus, this reflex provides a negative feedback mechanism that prevents the development of too much tension on the muscle.
- This effect is called the lengthening reaction; it is probably a **protective mechanism** to prevent tearing of the muscle or avulsion of the tendon from its attachments to the bone.



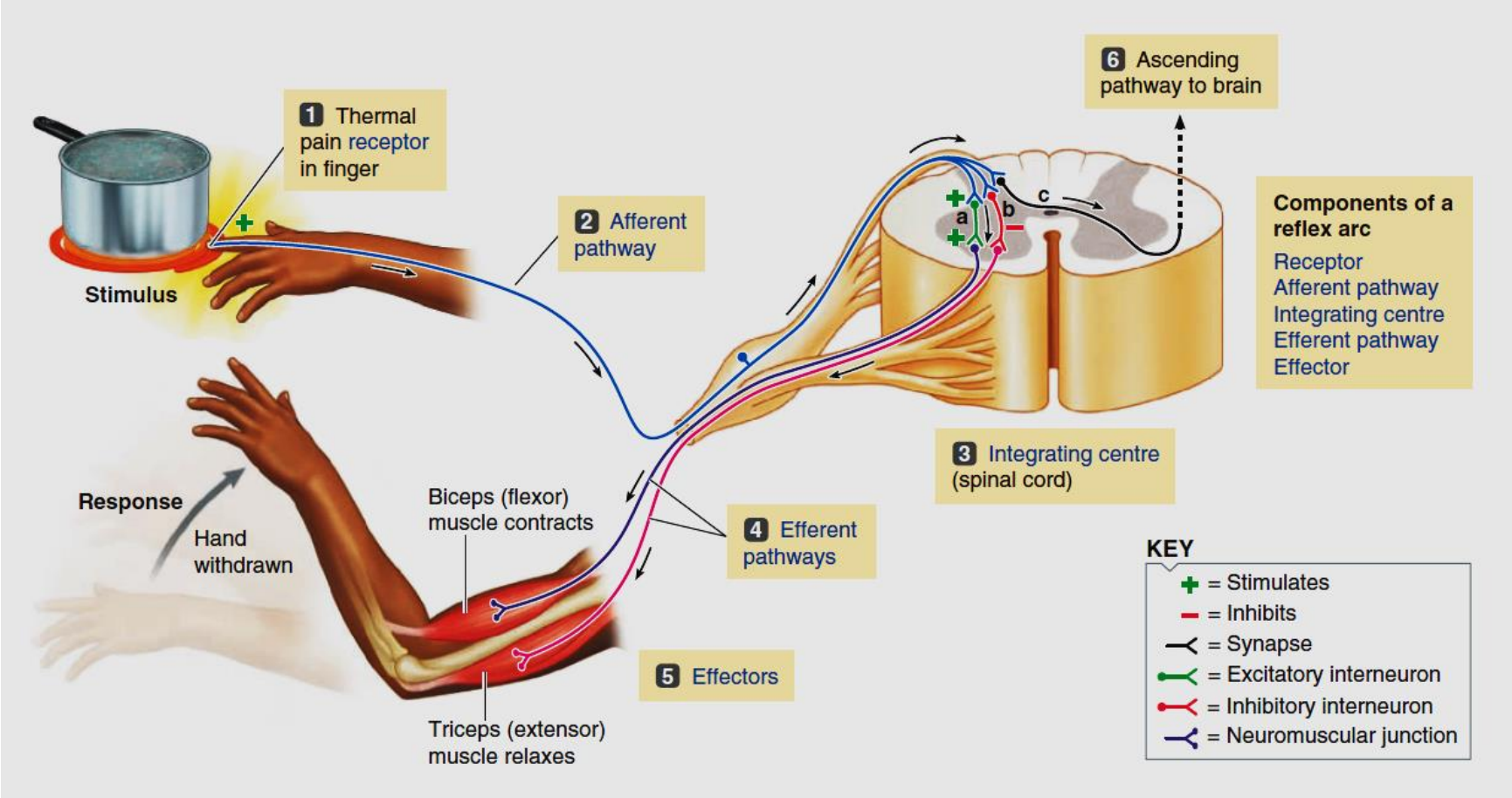
The Withdrawal Reflex (polysynaptic reflex):

- When a painful stimulus affects a limb, a withdrawal reflex is initiated to pull the limb away from the painful stimulus.
- Once the sensory afferent neuron enters the spinal cord, it diverges to synapse with the many different **interneurons**.



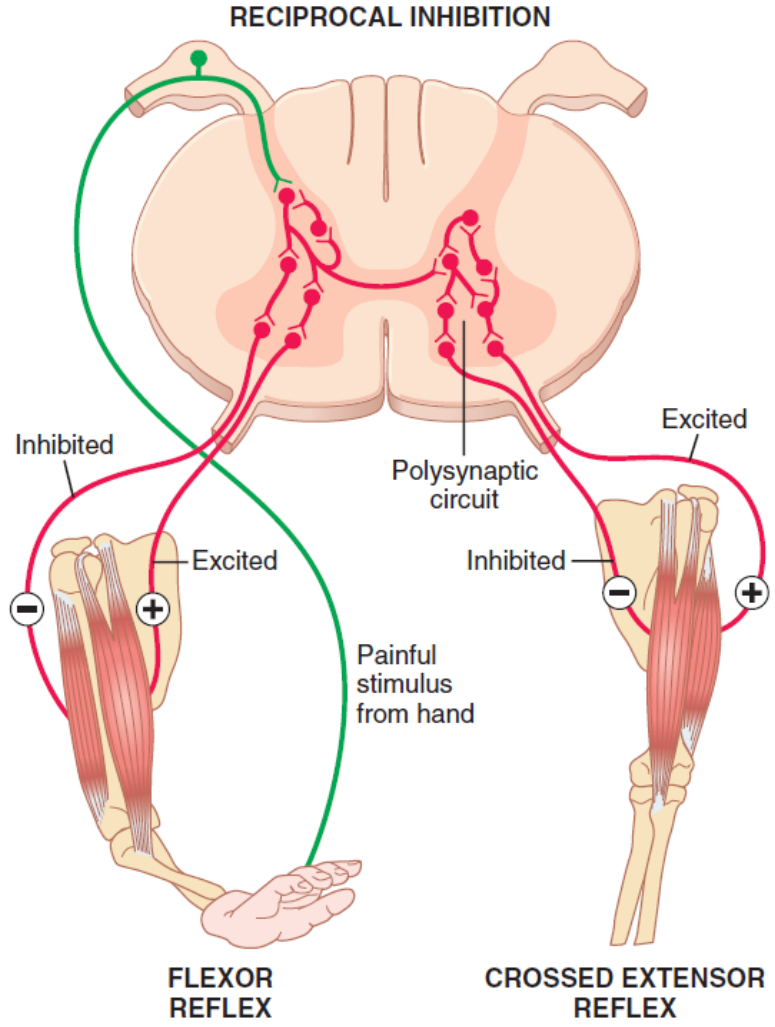
1. Excitatory interneurons that in turn stimulate the efferent motor neurons supplying the flexor muscles to pull the limb away from the painful stimulus.
2. Inhibitory interneurons that in turn inhibit the efferent neurons supplying the extensor muscle to prevent it from contracting. Therefore, built into the withdrawal reflex is inhibition of the muscle that antagonizes (opposes) the desired response. Such type of neuronal connection is known as **reciprocal innervation**.
3. The afferent neuron stimulates still other interneurons that carry the signal up the spinal cord to the brain via an ascending pathway. Only when the impulse reaches the sensory area of the cortex is the person aware of the pain, its location, and the type of stimulus. The information can be stored as memory as well.

The flexor withdrawal reflex neuronal circuit



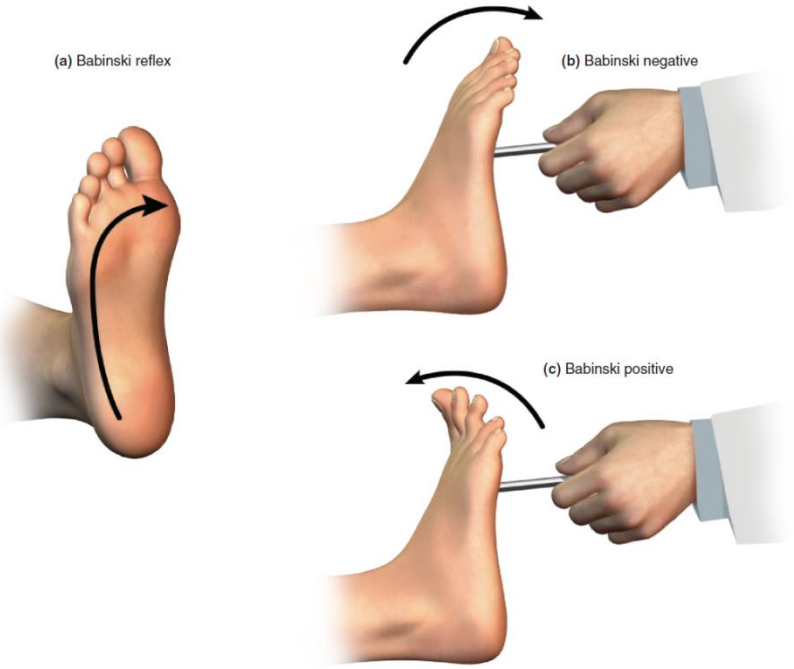
The Withdrawal Reflex (polysynaptic reflex) cont. :

- The withdrawal reflex action is not necessarily limited to motor responses on the same side of the body to which the stimulus is applied.
- Activation of pathways that induce **crossed extensor reflex** of the opposite limb can occur to ensures that the opposite limb will be in a position to bear the weight of the body as the injured limb is withdrawn from the stimulus.
- The brain can modify and **override** the withdrawal reflex by sending IPSPs via descending pathways to the motor neurons supplying the flexors and EPSPs to those supplying the extensor muscles.



The Babinski Reflex (Plantar Reflex):

- Babinski reflex is considered positive (present) when the big toe **dorsiflexes** (straightens) and the other toes fan outward after the lateral portion of the sole of the foot has been stimulated by a sweeping pressure.
- Babinski reflex is positive in **infants**, which is normal up to two years of age. Then this reflex disappears as the child ages and the nervous system develops.
- The presence of positive Babinski reflex after age two is a sign of corticospinal tract **dysfunction**.
- A positive Babinski is commonly associated with diseases such as head injury, meningitis, multiple sclerosis, spinal cord injury, **stroke**, tuberculosis, and rabies.



MCQ

Q. The Knee Jerk reflex :

A. Regulates muscle tension

B. Is attenuated in patient with stroke

C. Is a monosynaptic reflex

D. Is hyperactive in hypothyroid patients

E. Its activity is not affected affected by inputs from higher brain centers