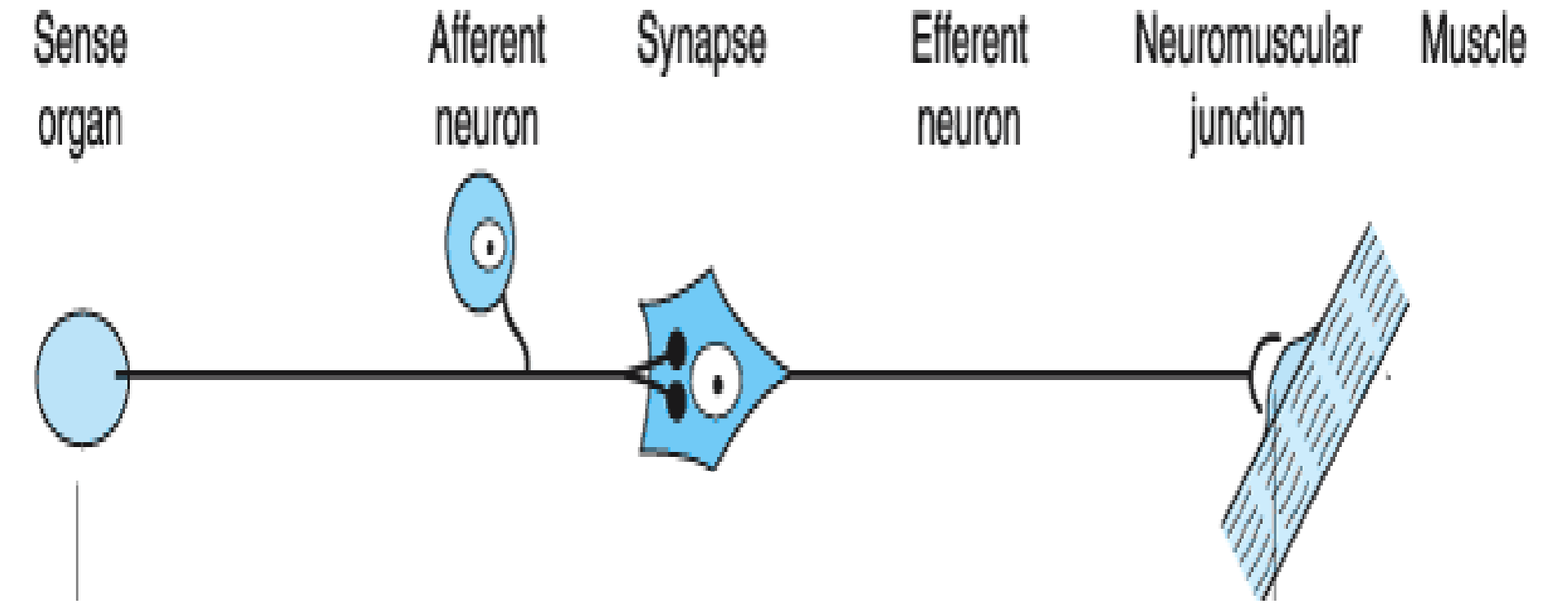
Spinal Reflexes

Dr Renu Raj R

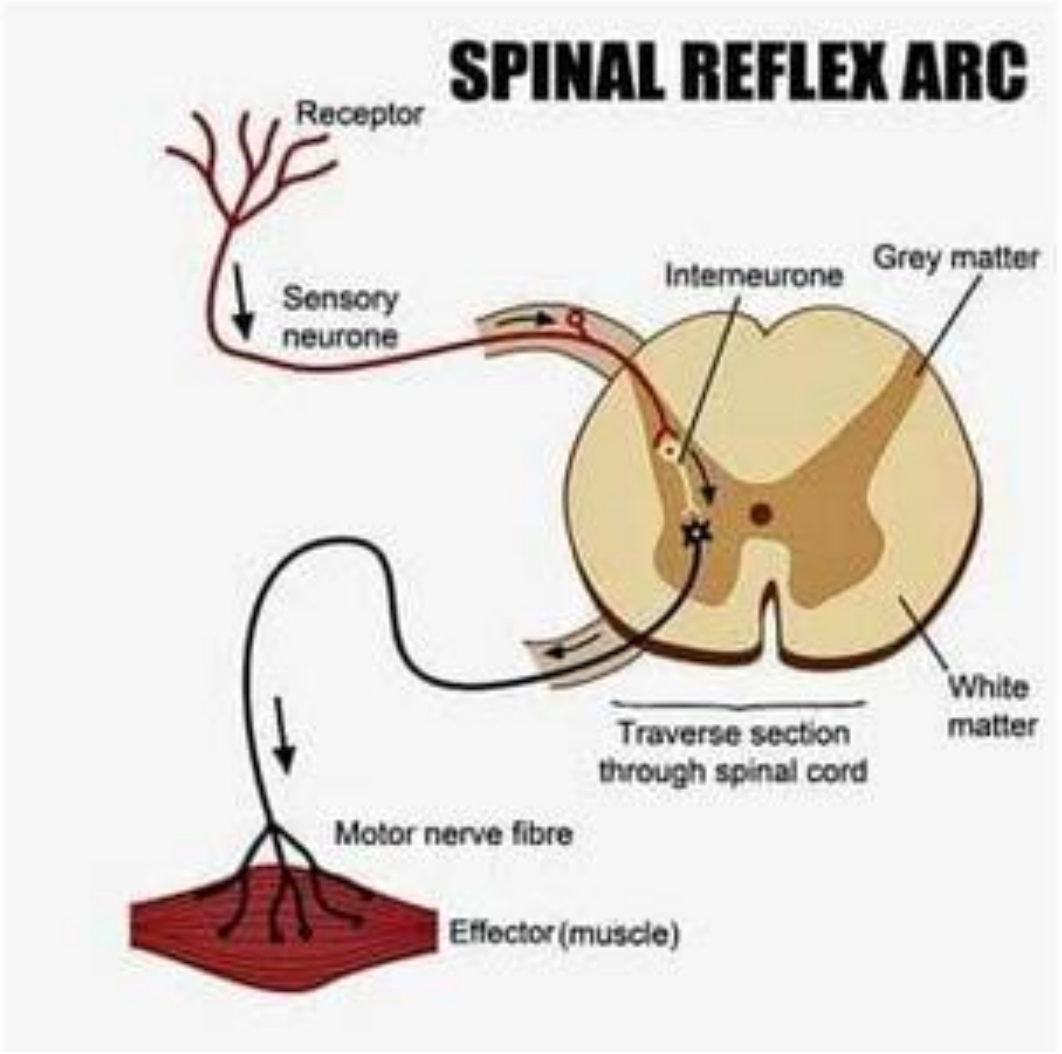
Reflex- definition

- Sudden and involuntary response to a stimulus
- The basic unit of integrated reflex activity is the **reflex arc.**
- This arc consists of
  - receptor
  - afferent neuron
  - Centre (brain / spinal cord)
  - efferent neuron
  - effector organ(muscle/gland)

Reflex arc


Sense organ
Afferent neuron
Synapse
Efferent neuron
Neuromuscular junction
Muscle

Bell–Magendie law



Bell–Magendie law

- The afferent neurons enter via the dorsal roots or cranial nerves and have their cell bodies in the DRG or in the ganglia of the cranial nerves
- The efferent fibers leave via the ventral roots or corresponding motor cranial nerves
- The principle that in the spinal cord the dorsal roots are sensory and the ventral roots are motor is known as the **Bell–Magendie law**

Classification of reflexes

1)Depending on no. of synapses between afferent and efferent neurons

a)Monosynaptic reflex- stretch reflex

b)Bisynaptic reflex- inverse stretch reflex, reciprocal innervation

c)Polysynaptic reflex- withdrawal reflex, superficial reflexes

2)Clinical classification

a) Superficial reflexes – elicited by stimulating skin or mucous membrane

Eg: corneal , conjuctival, abdominal, plantar reflex

b)Deep reflexes – basically stretch reflexes

Elicited by striking tendon of muscle

Eg : knee jerk, ankle jerk

c)Visceral reflexes- defecation reflex, micturition reflex

3) Based on development

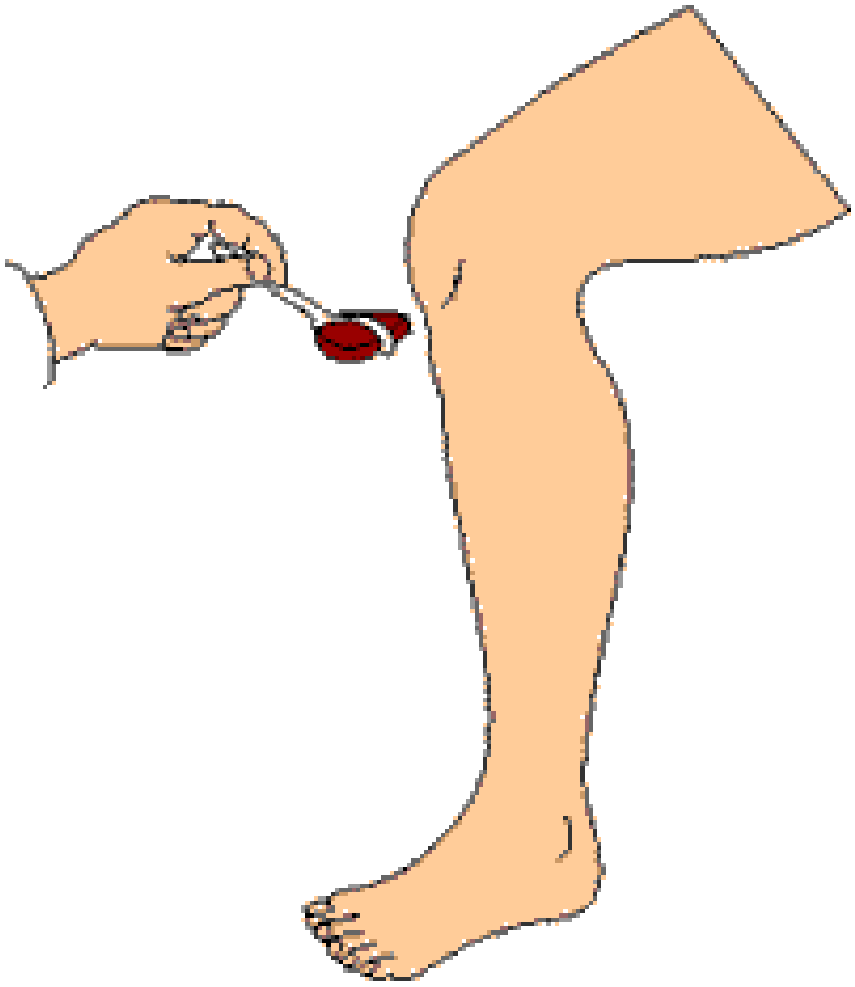
a) Unconditioned / Inborn – present at the time of birth

b)Conditioned/Acquired reflex – develops after birth

–acquired by training or experience

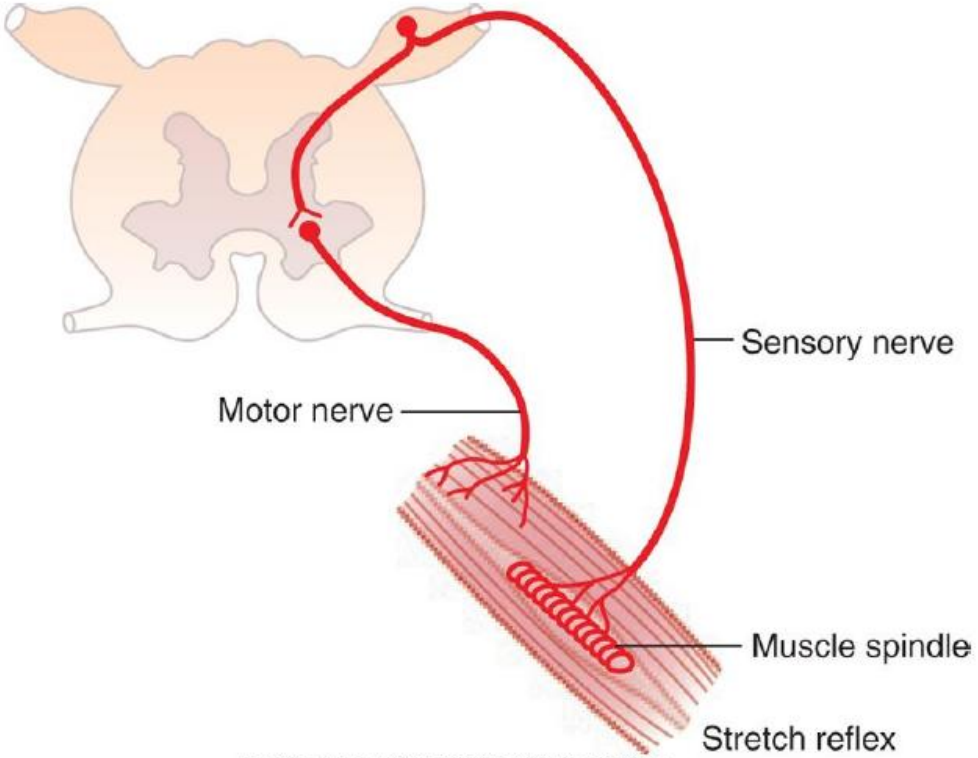
Stretch reflex/Myotactic reflex (Short essay)

- Definition
- Examples
- Reaction time
- Conduction time
- Central delay
- Types
- Function



Stretch reflex

- When a skeletal muscle with an intact nerve supply is stretched, it contracts. This response is called the **stretch reflex**



- Examples of stretch reflex- deep tendon reflexes like knee jerk, ankle jerk, triceps jerk

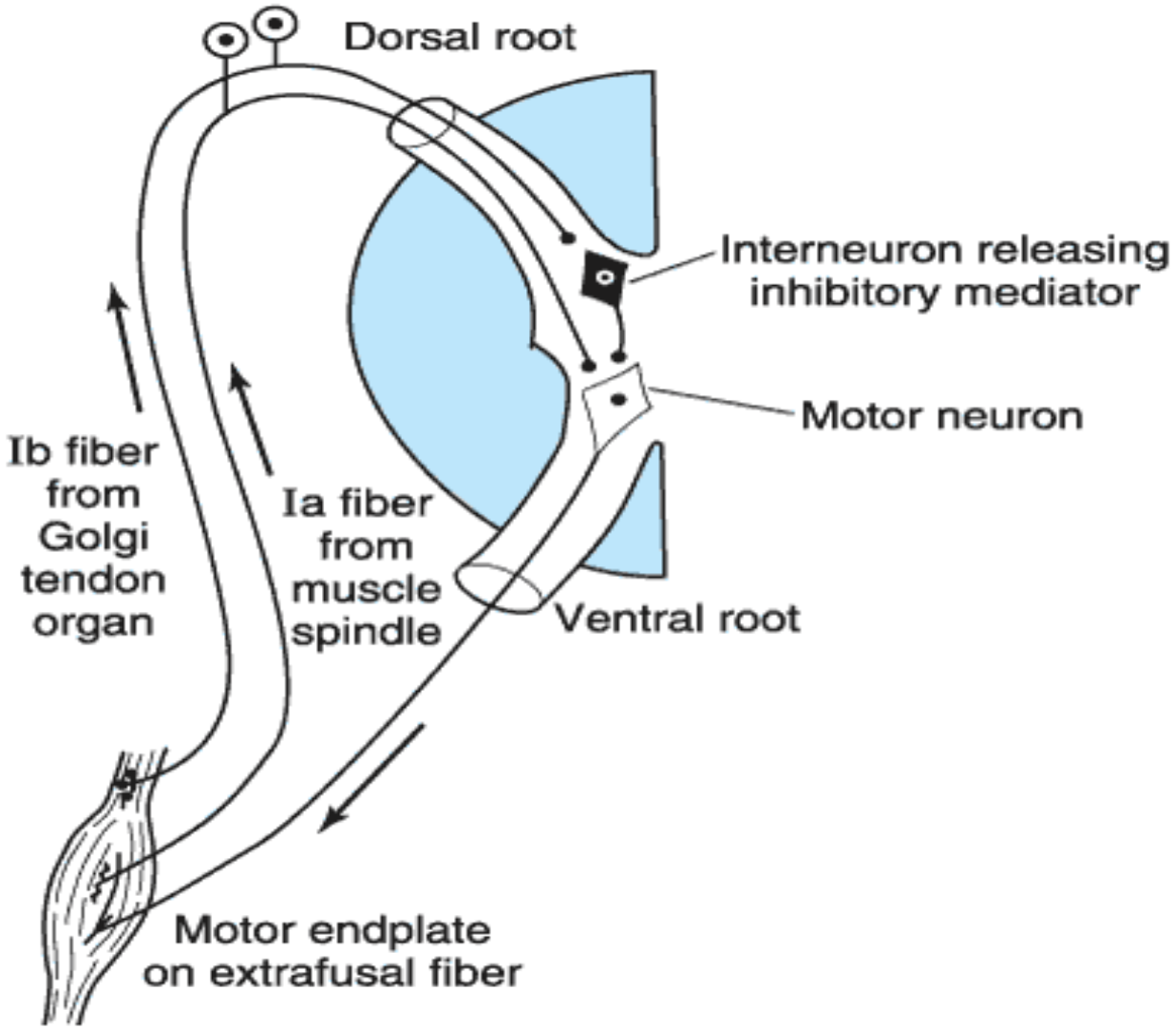
- **Reaction time**
- Time between the application of stimulus and the response
  - For knee jerk , it is 19 – 24 ms

- **Conduction time**
- Time taken for reflex activity to traverse the afferent and efferent nerve fibres

- **Central delay**
- Time taken for the reflex activity to traverse the spinal cord
- **Central delay = reaction time – conduction time**
- 0.6-0.9ms (knee jerk)
  - Minimum synaptic delay – 0.5 ms
  - So 1 synapse could have been traversed
  - So it is a monosynaptic reflex

- Two types of stretch reflexes
- Phasic stretch reflex
- Tonic stretch reflex

Reflex arc



Source: Ganong WF: *Review of Medical Physiology*, 22nd Edition: http://www.accessmedicine.com

Phasic stretch reflex

- By stimulating primary ending of muscle spindle

Reflex arc

- Stimulus – sudden stretch of the muscle
- Sense organ / receptor – primary ending of muscle spindle
- Afferent nerve – group I a fibre
- Centre – spinal cord (alpha motor neuron)
- Efferent nerve – axons of alpha motor neuron
- Effector organ – extrafusal muscle fibres
- Effect- contraction of same muscle

Function of phasic stretch reflex

- Rapid limb movement
- Ensures immediate correction of spinal motor output and helps in the moment- to- moment motor control

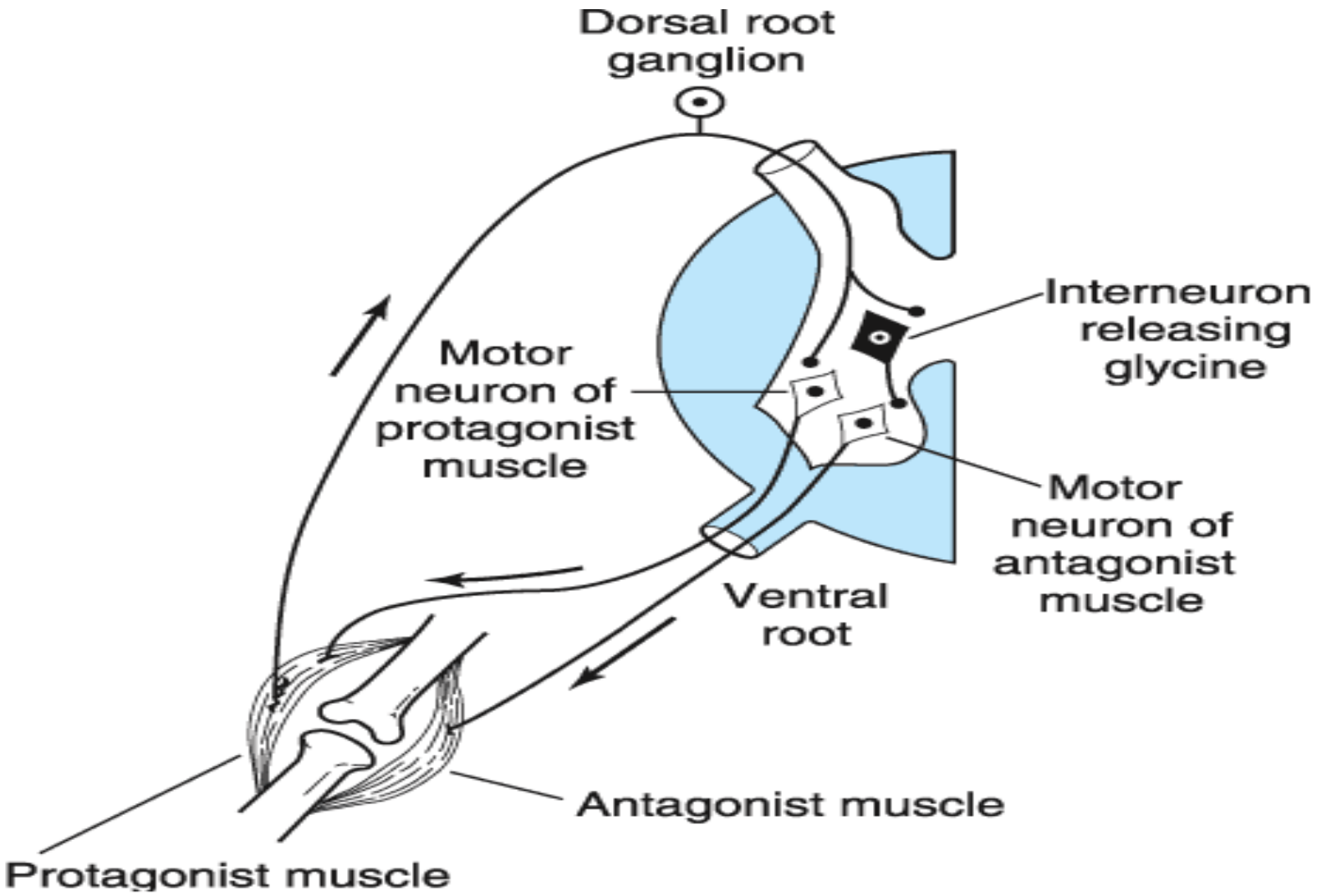
Tonic stretch reflex

- Elicited by sustained stretch of muscle
- Reflex arc
  - Stimulus – sustained stretch of the muscle
  - Sense organ / receptor – both primary and secondary endings of muscle spindle
  - Afferent nerve – group II fibre
  - Centre – spinal cord
  - Efferent nerve – axons of alpha motor neuron
  - Effector organ – extrafusal muscle fibres
  - Effect- contraction of same muscle

Function of tonic stretch reflex

- Maintains the muscle tone (resistance of muscle to stretch)
- Important for regulation of posture

Reciprocal Innervation



Reciprocal Innervation

- When a stretch reflex occurs, the muscles that antagonize the action of the muscle involved (antagonists) relax. This phenomenon is said to be due to **reciprocal innervation**

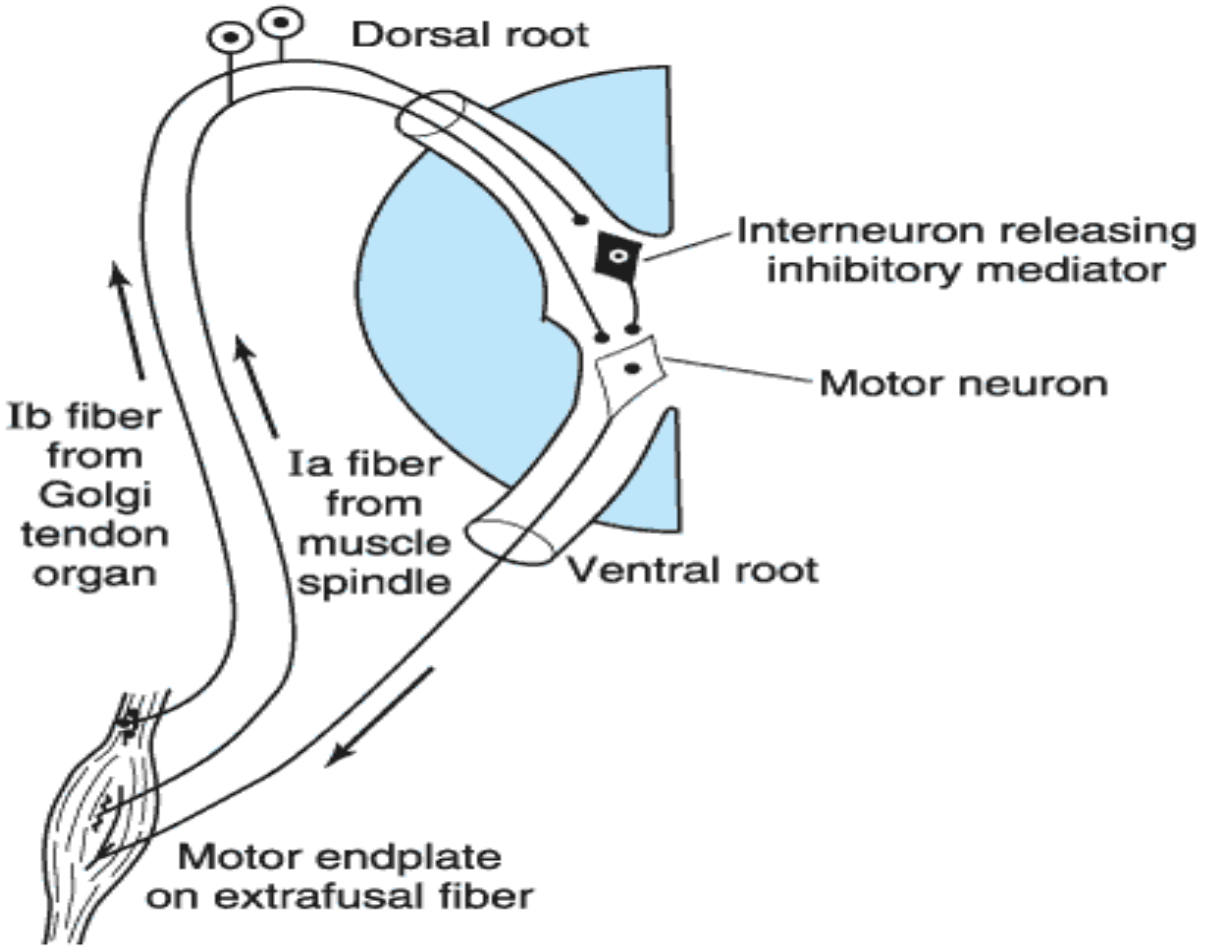
- When we stretch the protagonist muscle, it will contract through the stretch reflex pathway
- At the same time, the afferent neuron give a collateral which synapse with an inhibitory interneuron which inhibit the motor neuron supplying the antagonist muscle producing relaxation of antagonist muscle

Significance of reciprocal innervation

- Stimulation of protagonist and inhibition of antagonist muscle brings about proper joint movements

- Reciprocal innervation plays an important in locomotion

Inverse Stretch Reflex/ Autogenic inhibition/ Bisynaptic reflex/ Disynaptic reflex (Write briefly)



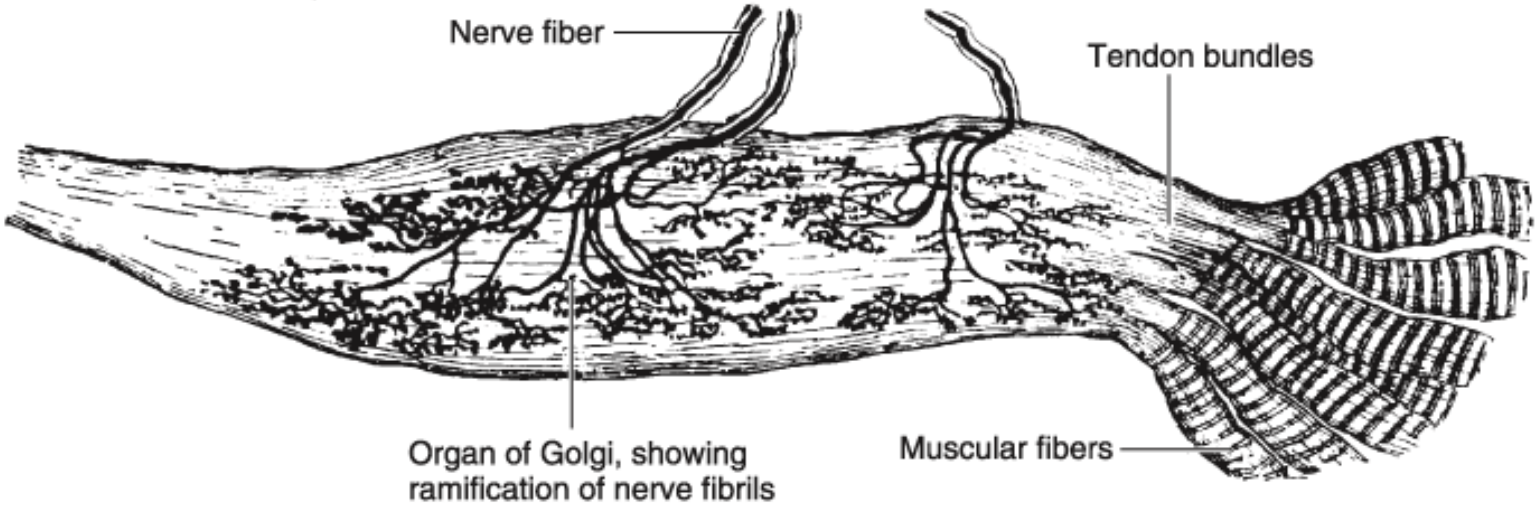
Source: Ganong WF: *Review of Medical Physiology*, 22nd Edition: http://www.accessmedicine.com

Inverse Stretch Reflex

- Up to a point, the harder a muscle is stretched, the stronger is the reflex contraction.
- However, when the tension becomes great enough, contraction suddenly ceases and the muscle relaxes. This relaxation in response to strong stretch is called the **inverse stretch reflex** or **autogenic inhibition**

Reflex arc

- Stimulus- stronger stretch
- Receptor- **Golgi tendon organ**



- Afferent fibre - Ib group of myelinated, rapidly conducting sensory nerve fibers
- Center- spinal cord
  - The Ib fibers enter the spinal cord through dorsal root synapse with an inhibitory interneuron
- Efferent- inhibitory interneuron project to alpha motor neuron supplying same muscle
- Effect- relaxation of the muscle

Functions of inverse stretch reflex

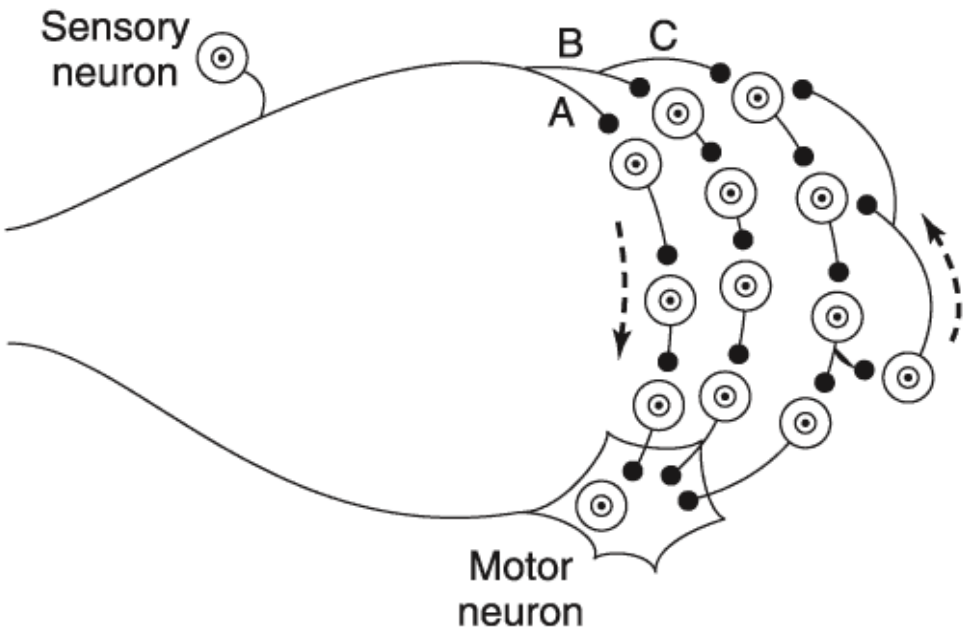
- Golgi tendon organ regulate the muscle force
- Inverse stretch reflex – protective reflex to prevent rupture of the muscle or avulsion of the tendon from its attachments to bone

Physiological significance of stretch reflex and inverse stretch reflex

- Muscle spindle monitors muscle length and GTO monitors muscle tension
- Stretch reflex and inverse stretch reflex by acting together maintain optimal motor response for postural adjustment

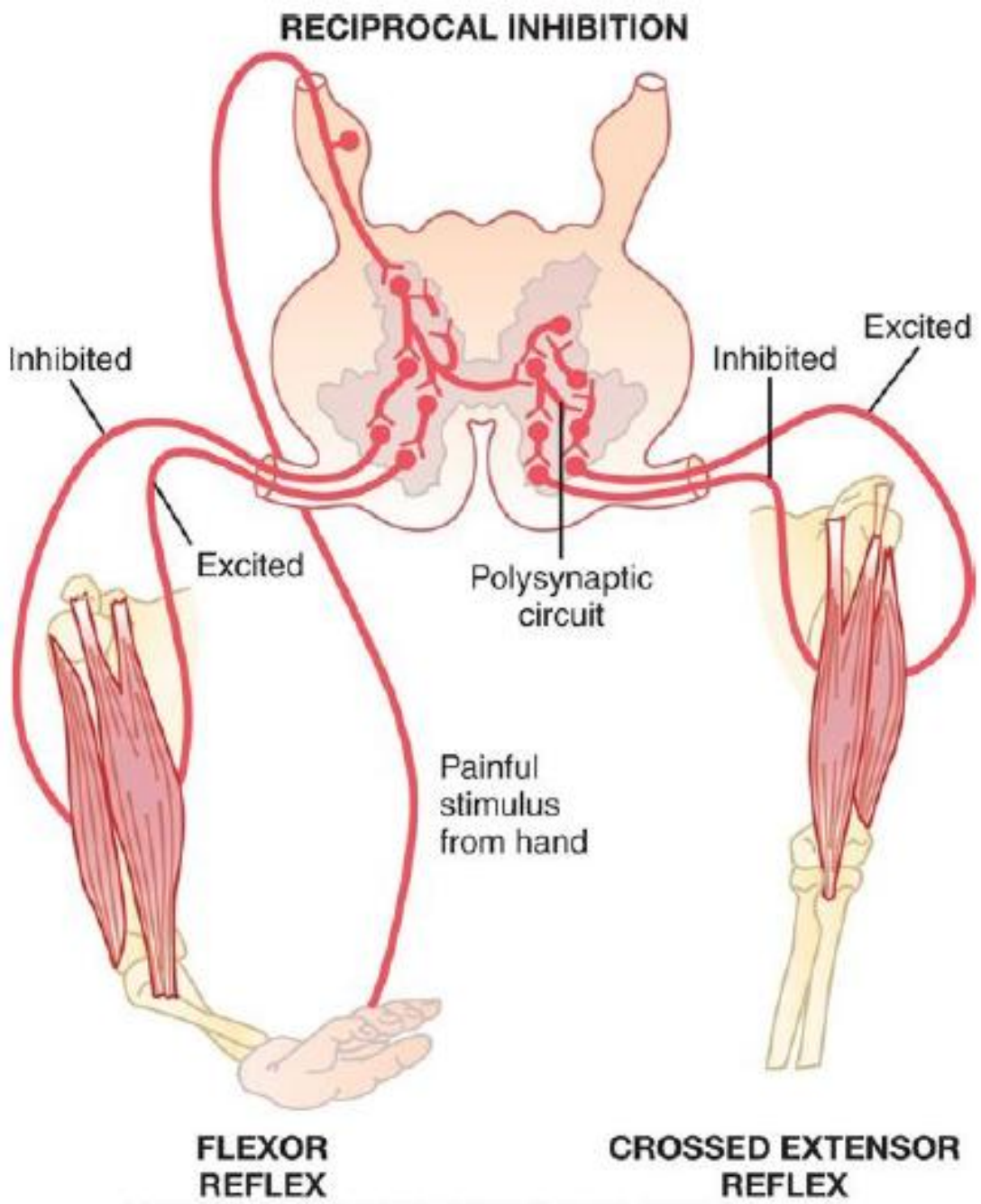
Polysynaptic reflex

- The number of synapses between afferent and efferent neurons vary from 2 to 100s

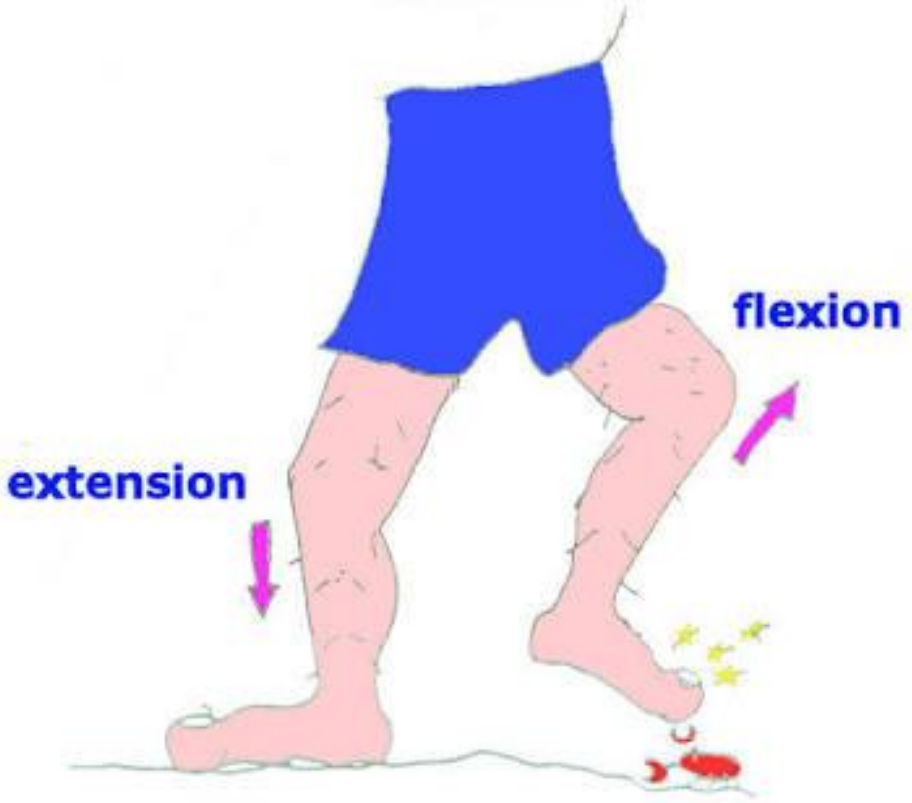


- Because of the synaptic delay at each synapse, activity in the branches with fewer synapses reaches the motor neurons first, followed by activity in the longer pathways →prolonged bombardment of the motor neurons from a single stimulus → prolonged responses.
- Some of the branch pathways turn back on themselves, permitting activity to reverberate
- Such **reverberating circuits** are common in the brain and spinal cord.

Withdrawal reflex (Write briefly)



Flexor reflex and crossed extensor reflex



Withdrawal reflex

- Typical polysynaptic reflex
- Occurs in response to a noxious/ painful stimulation of the skin or subcutaneous tissues and muscle.
- Receptors- nociceptors in skin, muscle, tendon or joint

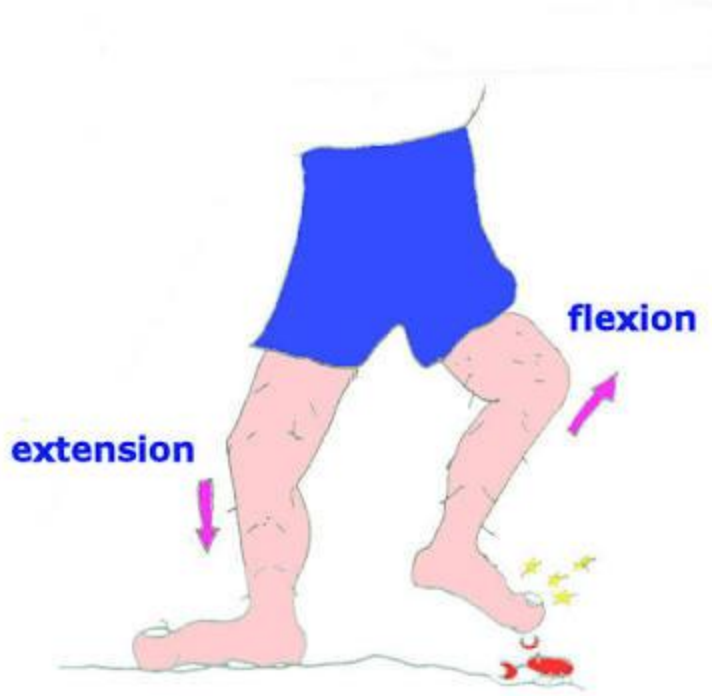
Flexor reflex and crossed extensor reflex

- Mild stimulus - flexor muscle contraction and inhibition of extensor muscles →part stimulated is flexed and withdrawn from the stimulus **(flexor reflex)**

Pathway

- Afferent- Type III and IV somatic afferent
- After entering spinal cord it divides into two branches
- One branch activates a set of interneuron which excites alpha motor neuron supplying flexor muscles of same side
- Another branch activates another set of interneuron which inhibits alpha motor neuron supplying the extensor muscles of same side

- Strong stimulus -not only causes flexion and withdrawal of that limb but also extension of the opposite limb. This is called **crossed extensor response**
- This is due to irradiation of stimulus and recruitment of motor units



- A branch of interneuron (commissural interneuron) excited by afferent crosses the midline to enter the opposite side of ventral horn and terminates on opposite side interneurons
- Commissural interneuron activates interneuron which stimulates motor neuron supplying contralateral extensor muscle and activates interneuron which inhibits motor neuron supplying contralateral flexor muscle

Widespread response

- If the stimulus is very strong
- Impulse irradiate upward and downward in the spinal cord and activate motor neuron supplying muscles of other limb
- Extension of other limb of the same side and flexion of the other limb of opposite side
- Provide postural support and balance for immediate and appropriate withdrawal of body part

Shifting reaction

- Survival value of withdrawal reflex is difficult to demonstrate in normal animals , but can be easily demonstrated in spinal animal (Sherrington)
- When the hind limb of a spinal cat is pinched
  - the stimulated limb is withdrawn
  - the opposite hind limb extends
  - the ipsilateral forelimb extended
  - the contralateral forelimb flexed
- **Shifting reaction**

- This puts the animal in a position to run away from the offending stimulus
- This occurs because of irradiation of stimulus and recruitment of motor units

Significance of withdrawal reflex

1. Withdrawal reflex is a protective reflex
   - Flexion of the stimulated limb gets it away from the source of irritation, and extension of the other limb supports the body.
2. Withdrawal reflex is prepotent ie they block the spinal pathways from any other reflex activity taking place at the moment.
   - This reflex gets priority when we consider other reflexes occurring at that time

3. Local sign- dependence of the exact response on the location of the stimulus is called local sign

- eg :If the medial surface of the limb is stimulated, the response includes some abduction, whereas stimulation of the lateral surface will produce some adduction with flexion.

4. Afterdischarge

- After discharge is the repeated firing due to continued bombardment of motor neurons by impulses arriving by complicated polysynaptic paths
- Lasts for about ms to min after the cessation of stimulus

➢ Mechanisms

1. Reverberating circuits among the interneuronal cells
2. Interneuronal pathways of different length

- Pathway with less number of interneuron stimulates motor neuron first and pathway with more number of interneuron stimulates later

Eg : Withdrawal reflex

- Weak stimulus- 1 quick flexion movement
- A strong stimulus causes prolonged flexion

→This prolonged response is due to prolonged, repeated firing of the motor neurons.

- After the painful stimulus is removed, the crossed extensor reflex has an even longer period of afterdischarge than does the flexor reflex

Properties of reflexes

1. Adequate stimulus
2. Final common pathway
3. Reaction time
4. One way conduction
5. Summation
6. Occlusion
7. Subliminal fringe
8. Habituation
9. Sensitization
10. Facilitation
11. Inhibition
12. Fractionation
13. Irradiation of stimulus
14. Recruitment of motor units
15. Central excitatory and inhibitory state

1. Adequate stimulus

- The stimulus that triggers a reflex is generally very precise. This stimulus is called the **adequate stimulus** for the particular reflex.
- It should be adequate in terms of strength and duration
- Eg: Scratch reflex in dog is initiated only by multiple linear touch stimuli
- If multiple stimuli are widely separated, reflex is not initiated

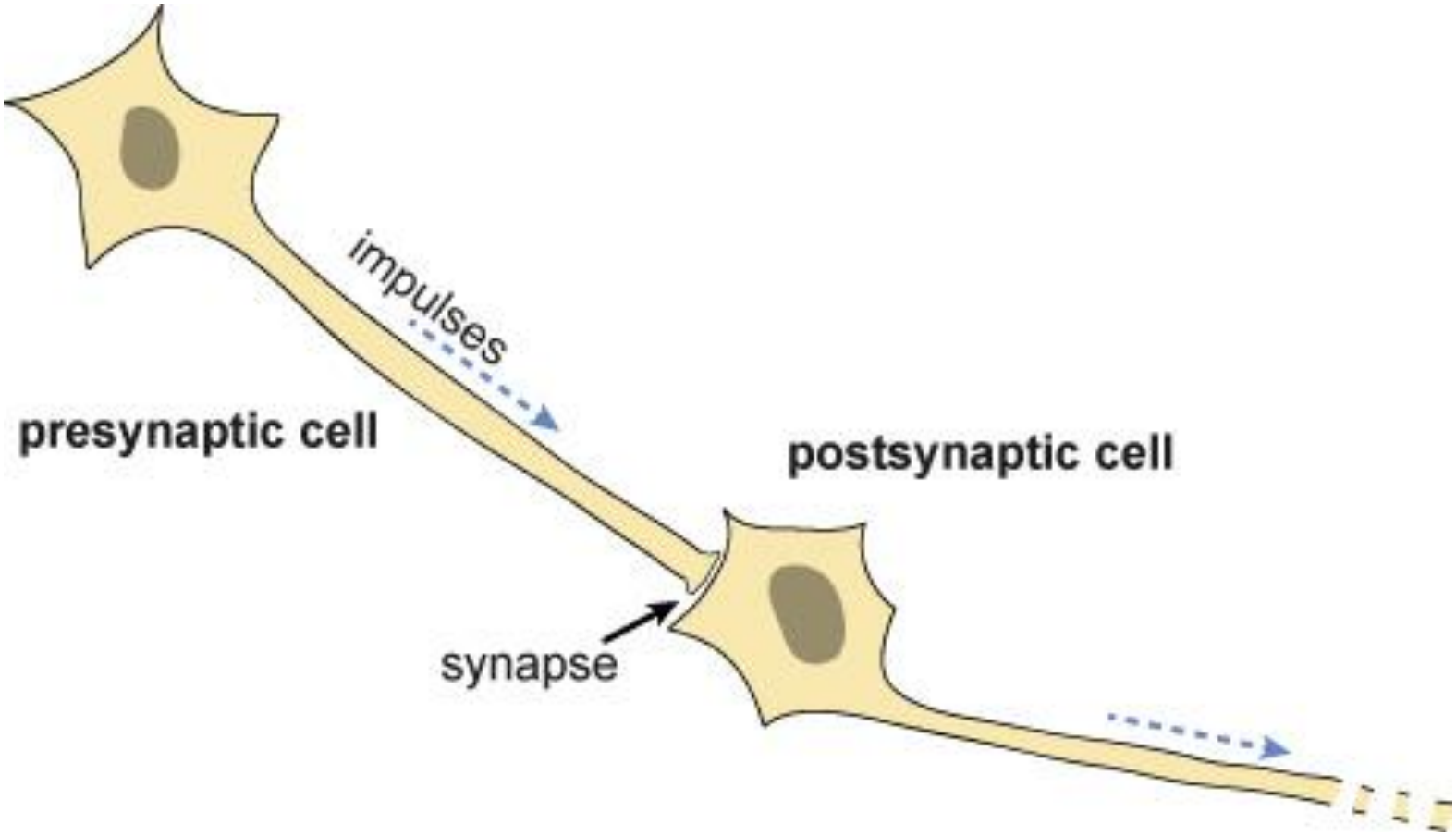
2. Final Common Path

- The alpha motor neurons that supply the extrafusal fibers in skeletal muscles are the efferent side of many reflex arcs.
- All neural influences affecting muscular contraction ultimately funnel through them to the muscles, and they are therefore called the **final common paths**

3. Reaction time

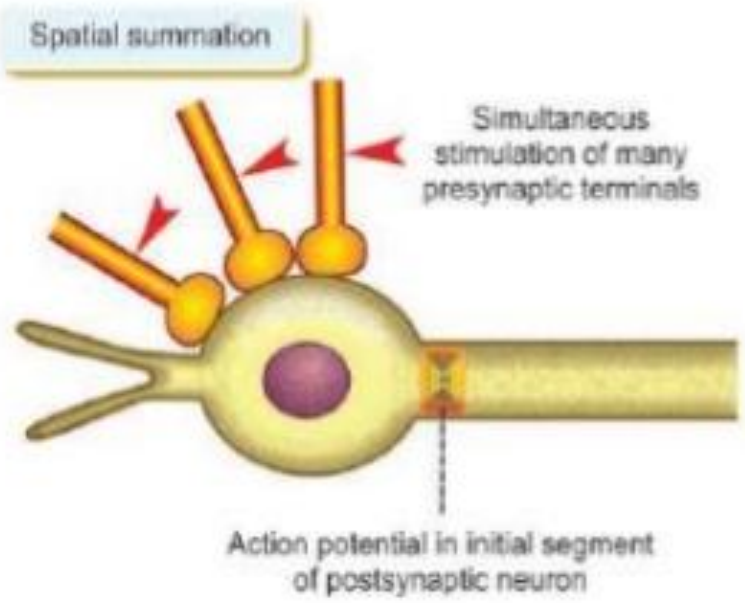
- **Reaction time** - time between the application of stimulus and the response

4. One way conduction

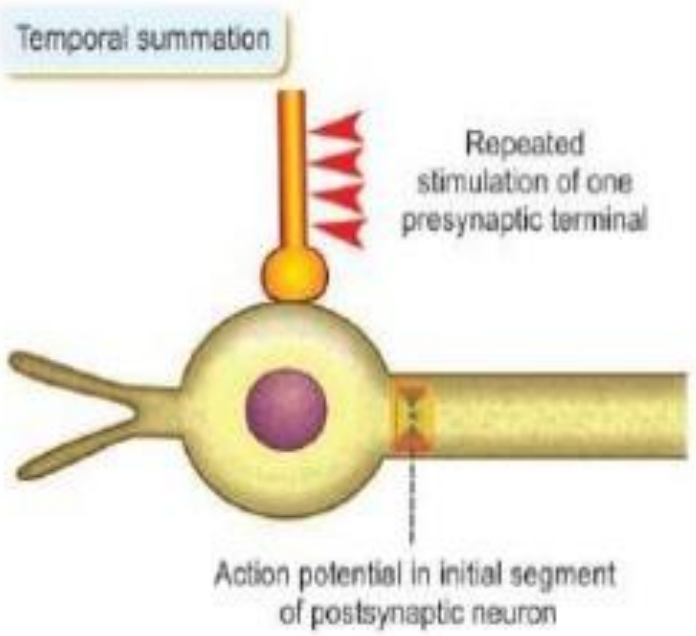


5. Summation

- **SPATIAL SUMMATION**



- **TEMPORAL SUMMATION**



6. Occlusion

- Response to simultaneous stimulation of 2 presynaptic neurons < sum total of response obtained when they are stimulated separately
- Decrease in response since pre synaptic fibres overlap and share post synaptic neurons

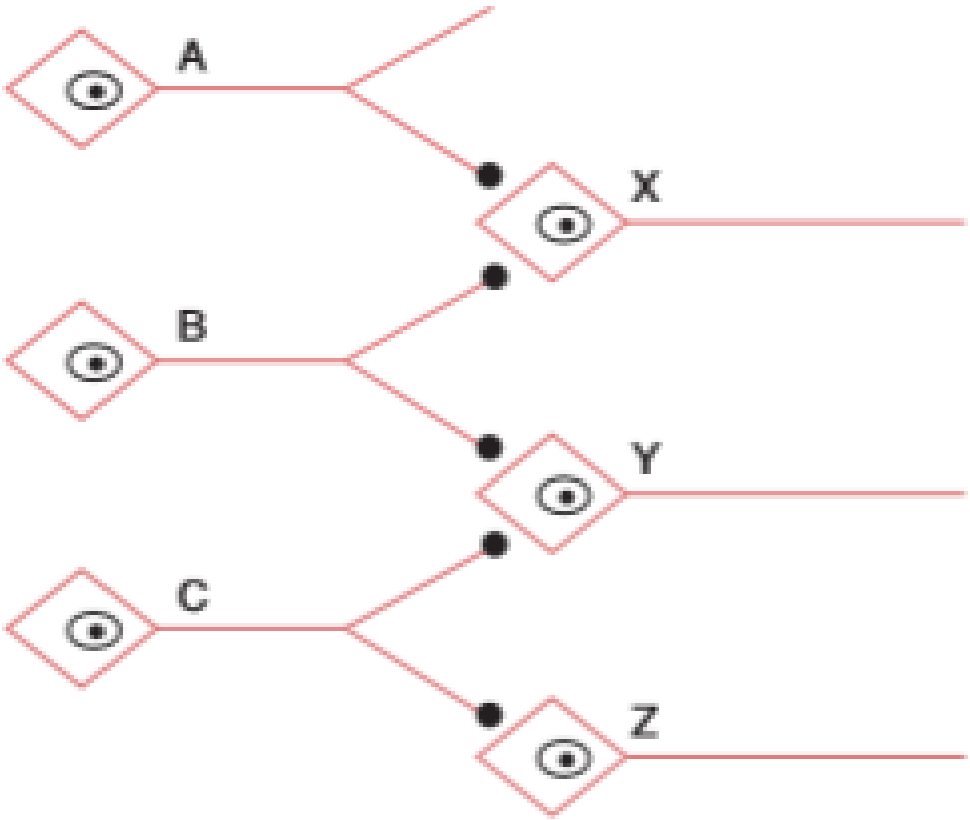


FIGURE 6–12 **Simple nerve net.** Neurons A, B, and C have excitatory endings on neurons X, Y, and Z.

7. Subliminal fringe

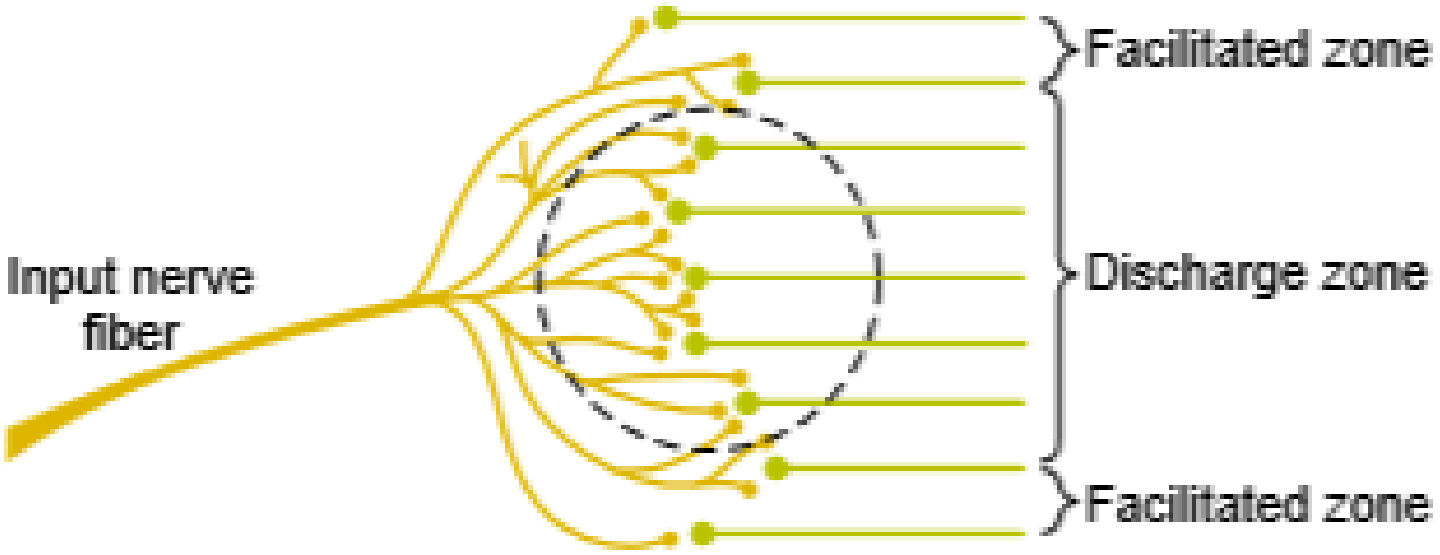


Figure 46–10

"Discharge" and "facilitated" zones of a neuronal pool.

8. Habituation

- With experience reflexes can be modified
- Physiological basis of learning and memory

9. Sensitization

- When stimulus is applied repeatedly decreased response of target neuron occurs

10. Facilitation

- Activities in single afferent fiber may not excite target motor neuron
- When many afferent neurons projecting on a single motor neuron are stimulated simultaneously the motor neuron is activated

11. Inhibition

- Decrease in activity of target neuron
- Reciprocal inhibition
- Renshaw cell inhibition

12. Fractionation

- When a muscle is stimulated directly or through the motor nerve, the magnitude of contraction is greater than stimulating the sensory nerve

- This indicates that the afferent inputs **fractionate** the motor neuron pool

13. Irradiation of stimulus and 14. Recruitment of motor units

- Strong stimuli generate activity in the interneuron pool → spread of excitatory impulses up and down the spinal cord to more and more motor neurons is called **irradiation of the stimulus,** and the increase in the number of active motor units is called **recruitment of motor units.**

15. Central excitatory and inhibitory state

- **Central excitatory state -** have been used to describe prolonged states in which excitatory influences exceed inhibitory influences
- If inhibitory state dominates, it is called **central inhibitory state**
- Prolonged changes in excitability is possible because of activity in reverberating circuits or prolonged effects of synaptic mediators.

- When the central excitatory state is marked, excitatory impulses irradiate not only to many somatic areas of the spinal cord but also to autonomic areas.
- In paraplegic humans a mild noxious stimulus may cause prolonged withdrawal-extension patterns in all four limbs, urination, defecation, sweating, and blood pressure fluctuations **(mass reflex).**

Muscle tone

- Resistance of the muscle to stretch (clinically examined by doing passive movement)
- Because muscles are in a state of slight contraction in the body at rest (due to muscle spindle)
- Increased muscle tone- hypertonic muscle or spastic
  - Resistance of muscle to stretch is increases due to hyperactive stretch reflex due to increased gamma motor neuron discharge
- Decreased muscle tone- hypotonic muscle or flaccid
  - Due to motor neuron damage or when discharge of gamma motor neuron is decreased

Clasp knife phenomenon (Give reason)

- When a hypertonic muscle as seen in UMN paralysis is stretched muscle contracts and on continued stretch muscle relaxes
- High resistance of muscle followed by sudden collapse
- Resembles the closing/opening of clasp knife
- Physiologically it is called lengthening reaction as the response occurs due to lengthening of muscle
- Physiological basis
  - As muscle tone is more, resistance against flexion of limb is more
  - But when flexion is continued inverse stretch reflex is activated and relaxes the muscle and resistance to flexion suddenly disappears

Clonus (Give reason)

- Regular rhythmic contraction of muscle subjected to a sudden and maintained stretch
- Eg: ankle clonus
- Dorsiflexion of foot and maintaining it in that position results in rhythmic plantar flexion of ankle
- Seen in UMN lesion where spindles are hyperactive
- Physiological basis
  - When muscle is stretched it contracts
  - Contraction of muscle stops the spindle discharge and muscle relaxes
  - Maintained stretch stimulates the spindle again and the process is repeated