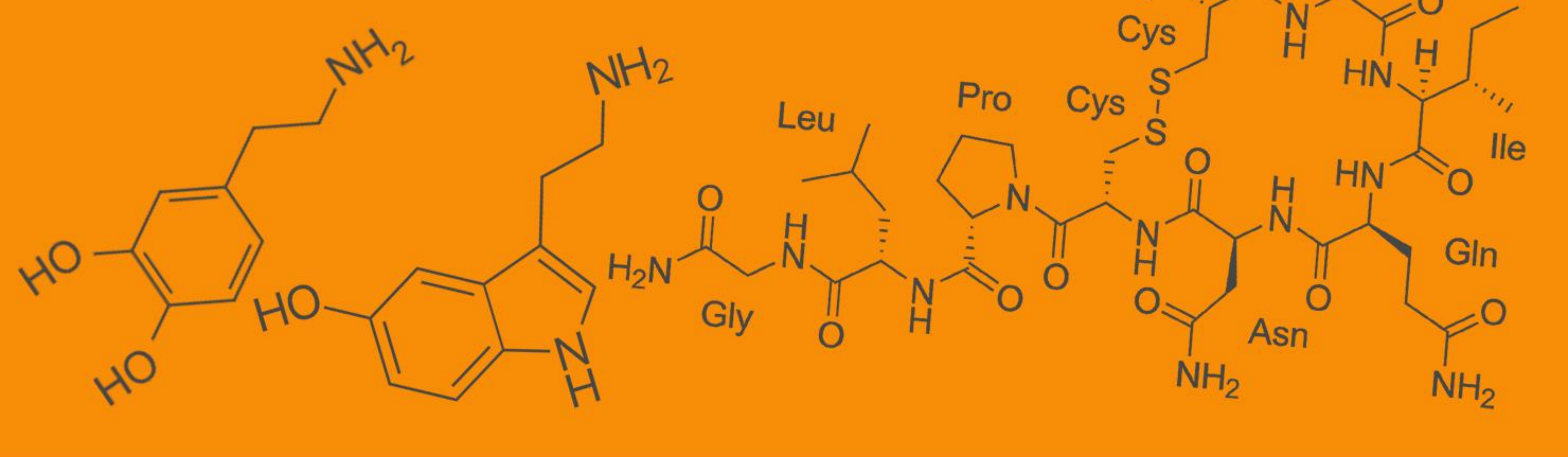


MEDICINE438's

CNS PHYSIOLOGY

LECTURE I: Spinal Cord Functions and Reflexes

EDITING FILE GSLIDES

IMPORTANT | MALE SLIDES | EXTRA | FEMALE SLIDES | LECTURER'S NOTES

OBJECTIVES

- Appreciate the two-way traffic along the spinal cord.
- Describe the organization of the spinal cord for motor functions (AHC, Interneurons & neuronal pool).
- Describe the physiological role of the spinal cord in spinal reflexes & reflex arc components.
- Classify reflexes into superficial & deep, monosynaptic & polysynaptic.
- Describe withdrawal reflex and crossed extensor reflex.
- Recognize the general properties of spinal cord reflexes.

BOX 1-1: GUYTON AND HALL

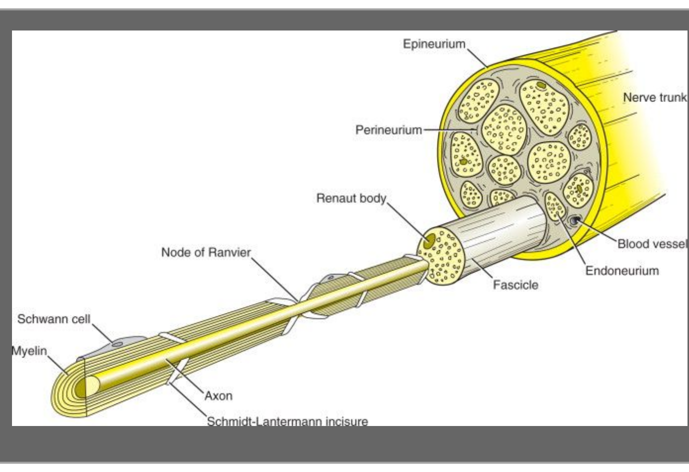
Sensory stimulus are received by receptors, which are of five basic types: (1) Mechanoreceptors, which detects compression or stretching of tissues. (2) Thermoreceptors, for heat. (3) Electromagnetic receptors, for light sensation. (4) Pain receptors (nociceptors) for pain sensation. (5) Chemoreceptors for chemical changes.

- All of those receptors share one feature in common, a change of membrane potential to propagate the signal.
- The signals then are transmitted through sensory nerves to two separate destinations (1) One branch of the sensory nerve terminates in the grey horn and initiates reflexes and other effects. (2) Another branch transmits signals to higher levels of the cord itself, the brain stem or the cerebral cortex.
- Skeletal muscles are made of fibers that extend throughout the length of the muscle, each fiber is made of numerous myofibrils which contain 3000 actin and 1500 myosin for contraction, between those myofibrils is the cytoplasm, mitochondria and sarcoplasmic reticulum.

BOX 1-2: EXTRACURRICULAR: HISTOLOGY

Fibers are packed inside a nerve by multiple connective tissue layers.

- Epineurium: Dense connective tissue surrounding the whole nerve filling in between nerve fascicles.
- Perineurium: Flattened cells surrounding each tract.
- Endoneurium: Fine connective tissue between individual nerve fibers.



HIGHER BRAIN OR CORTICAL LEVEL	Control all lower centers, thought processes, memory. All are conscious
LOWER BRAIN OR SUBCORTICAL LEVEL	Subconscious activities of the body are controlled in the lower areas of the Brain; the medulla, pons, mesencephalon, hypothalamus, thalamus, cerebellum, and basal ganglia. subconscious
SPINAL CORD LEVEL	1. Walking reflexes 2. Withdrawal reflexes 3. Antigravity reflexes 4. Reflexes that control of blood vessels gastrointestinal, urinary/defecation. All are reflexes without thinking

Table 1-1

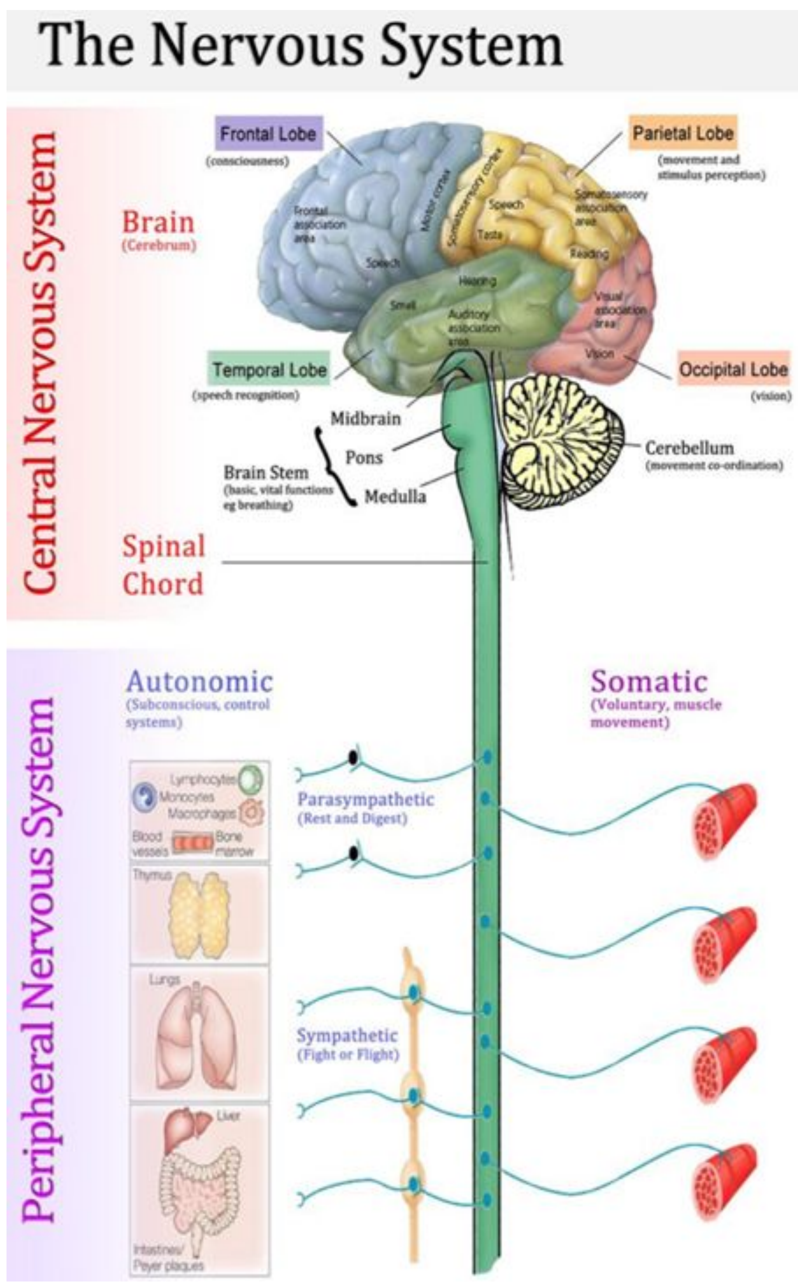
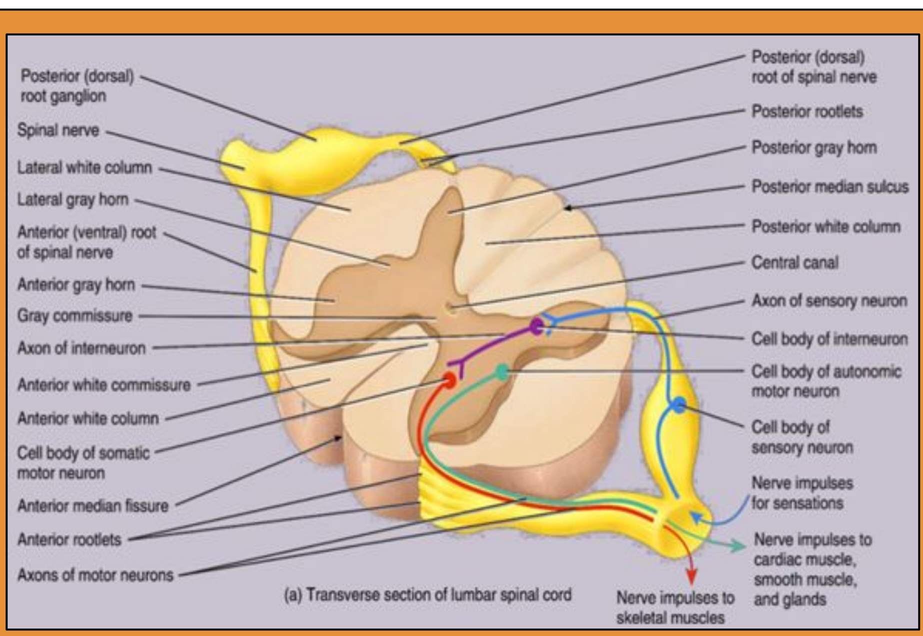
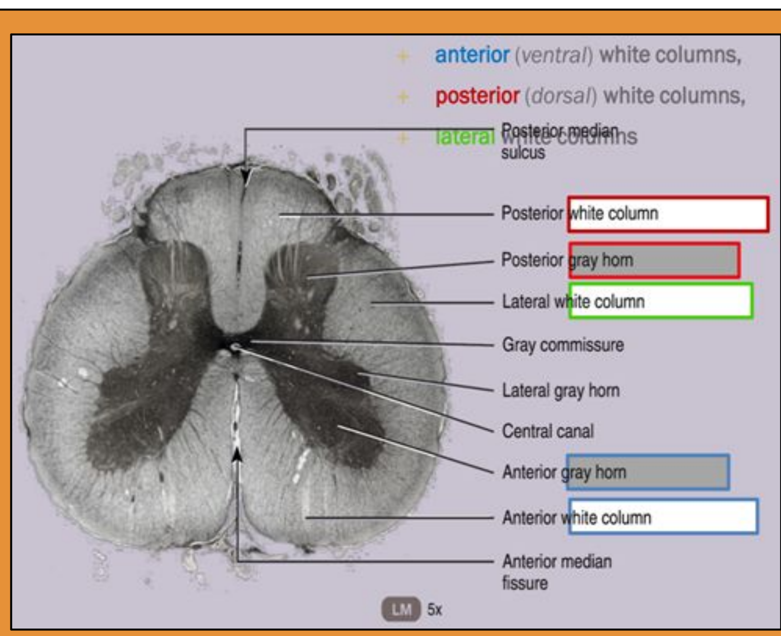


Figure 1-1





GREY MATTER	WHITE MATTER
- In the grey matter of the spinal cord and brain, clusters of neuronal cell bodies from functional groups called **nuclei.** - **Sensory nuclei** receive input from receptors via sensory neurons. - **Motor nuclei** provide output to effector tissue via motor neurons. FEATURES: 1. The posterior grey horn contains axons of sensory neurons and cell bodies of **interneurons.** 2. The ***lateral*** *grey horn* contains cell bodies of autonomic **motor neurons.** 3. The ***anterior*** *grey horn* contains cell bodies of somatic **motor neurons.**	- Each column in turn contains distinct bundles of **axons** having a common origin or destination and carrying similar information. - These bundles, which may extend long distances up or down the spinal cord, are called **tracts.** - **Sensory (Ascending) Tracts** consists of axons that conduct **nerve impulses** toward the brain. - Tracts consists of axons that carry nerve impulses from the brain are called *Motor (Descending) Tracts.* - **Sensory** and **motor** tracts of the spinal cord are continuous with sensory and motor tracts in the brain.

Table 1-2

FUNCTIONS OF THE SPINAL CORD

1. Gateway and Conduction Pathway for All Tracts.

The two-way traffic along the spinal cord:

A. **Sensory signal**s from receptors enter the cord through the **sensory** *(posterior)* roots, then every sensory signal travels to two separate destinations:

1. One branch of the sensory nerve terminates in the **gray matter** of the cord and elicits local segmental cord reflexes

2. Another branch transmits signals to **higher levels in the cord**, or to the **brain stem**, or even to the **cerebral cortex** through spinal **ascending sensory tracts** as:

i. Dorsal Column Tracts (Gracile & Cuneate)
ii. Lateral & Anterior Spinothalamic Tract
iii. Spinocerebellar Tracts

FUNCTIONS OF THE SPINAL CORD

1. Gateway and Conduction Pathway for All Tracts. (cont...)

B. Motor signals & brain motor commands pass through descending motor tracts & then to spinal efferent motor nerves to skeletal muscles to execute motor functions.

2. Center of spinal cord reflexes (somatic & autonomic).
3. Gateway for pain control systems.

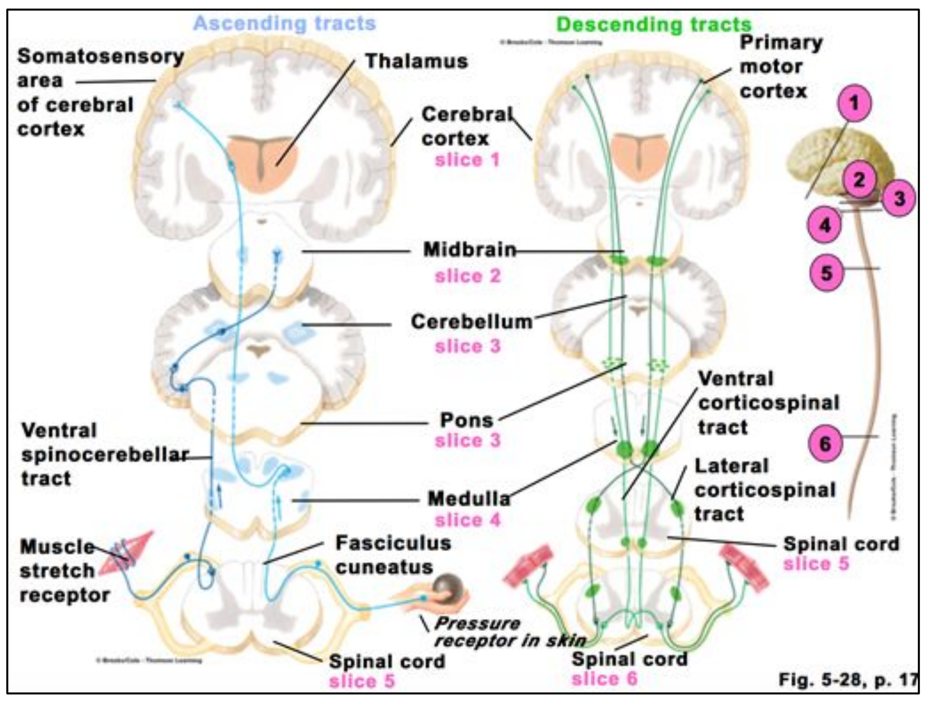


Figure 1-2

BOX 1-3: GANONG'S MEDICAL PHYSIOLOGY

TABLE 4–1 Types of mammalian nerve fibers.

Fiber Type	Function	Fiber Diameter (μm)	Conduction Velocity (m/s)	Spike Duration (ms)	Absolute Refractory Period (ms)
Aα	Proprioception; somatic motor	12–20	70–120		
Aβ	Touch, pressure	5–12	30–70	0.4–0.5	0.4–1
Aγ	Motor to muscle spindles	3–6	15–30		
Aδ	Pain, temperature	2–5	12–30		
B	Preganglionic autonomic	< 3	3–15	1.2	1.2
C, Dorsal root	Pain, temperature	0.4–1.2	0.5–2	2	2
C, Sympathetic	Postganglionic sympathetic	0.3–1.3	0.7–2.3	2	2

Classification of mammalian nerve fibers according to velocity of conduction, and their respective functions.

THE ORGANIZATION OF THE SPINAL CORD FOR MOTOR FUNCTIONS (ANTERIOR HORN CELLS & INTERNEURONS & NEURONAL POOLS)

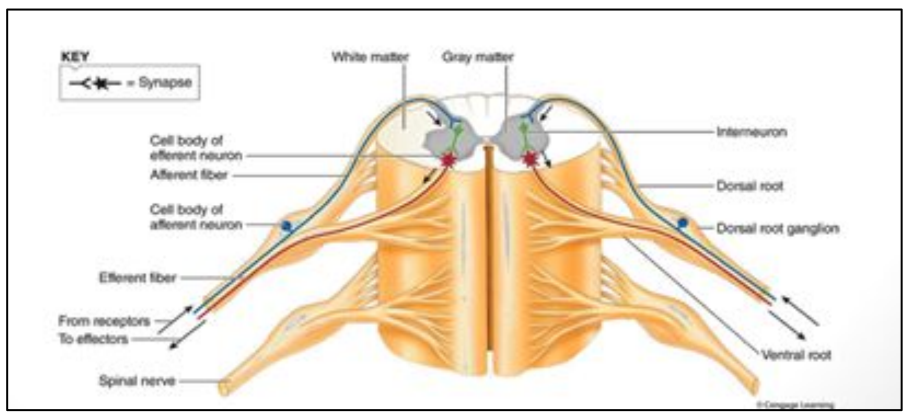
Located in each segment of the anterior horns of the cord gray matter, several thousand neurons that are 50 to 100 percent larger than others neurons. They give rise to the nerve fibers that leave the cord in the ventral roots and directly innervate the skeletal muscle fibers.

1. Alpha Motor Neurons

- They give rise to large type A alpha (Aa) (refer to BOX 1-3) motor nerve fibers.
- 14 micrometers in diameter.
- Innervate the large skeletal muscle fibers called extrafusal fibers.

2. Gamma Motor Neurons

- Smaller gamma motor neurons, along with alpha motor neurons.
- They transmit impulses through much smaller type A gamma motor nerve fibers.
- 5 micrometer in diameter.
- Go to special skeletal muscle fibers called intrafusal fibers.



What is the motor unit?

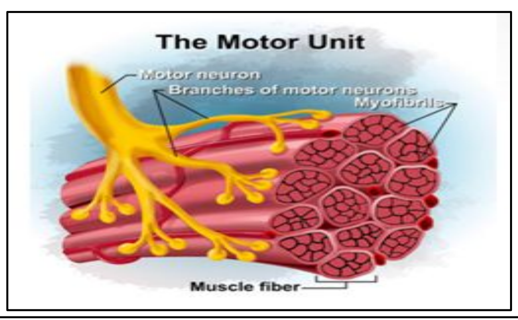


Table 1-3

SPINAL REFLEXES

What is a reflex?

- Functional unit of **CNS**, rapid, predictable, <u>automatic</u> (involuntary) response to a stimulus that involve spinal neurons only.
- Example: pinprick causes withdrawal.

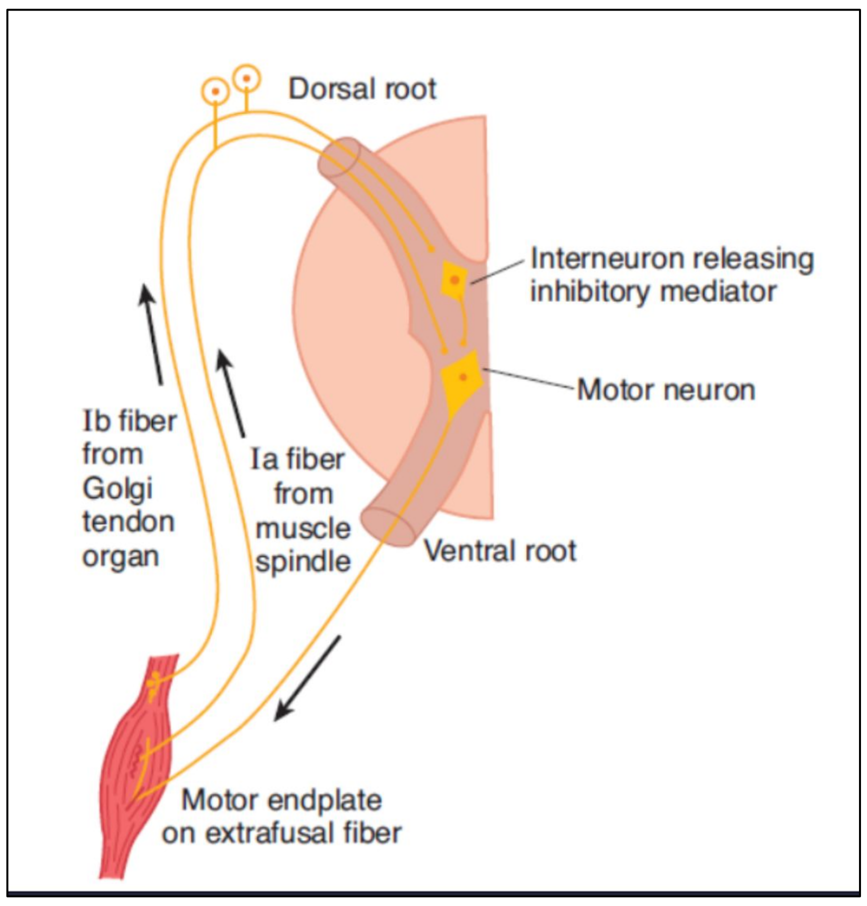


Figure 1-3

REFLEX ARC

Reflex arc is the pathway followed by nerve impulses that produce a reflex is a reflex arc (reflex circuit).

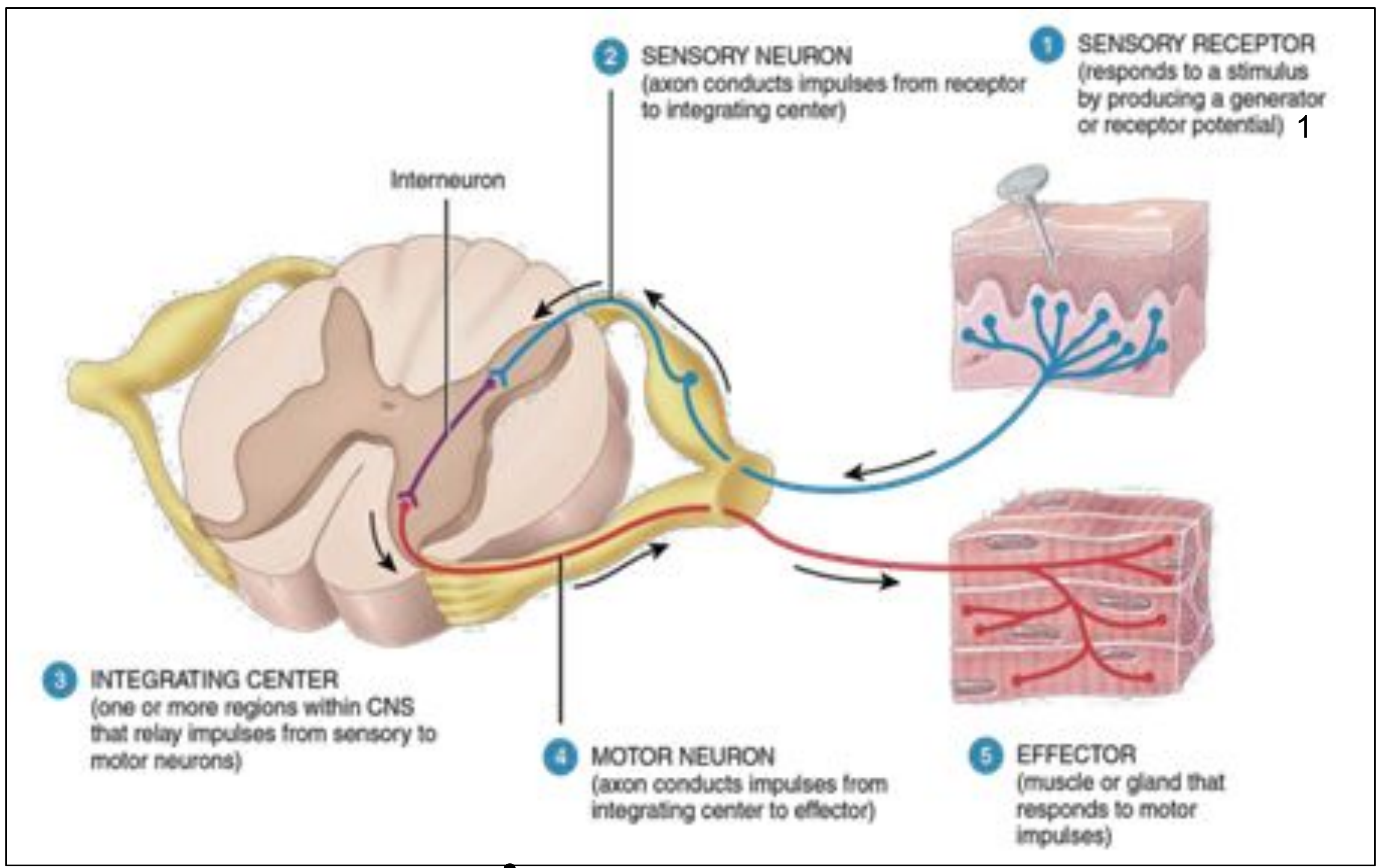


Figure 1-4

INCLUDES FIVE FUNCTIONAL COMPONENTS

1. SENSORY RECEPTOR

- It responds to a specific stimulus - A change in the internal or external environment- by producing a graded potential called a *generator* (or receptor) potential.
- If the **generator potential** reaches the *threshold* level of depolarization, it will trigger one or more nerve impulses in the **sensory neuron.**

2. SENSORY NEURON

- The **nerve impulses** propagate from the **sensory recepto**r along the axon of the sensory neuron to the axon terminals, which are located in the grey matter of the spinal cord or brain stem.
- Relay neurons send **nerve impulses** to the area of the brain that allows conscious awareness that the reflex has occurred. Or it send to motor neuron or interneuron.

3. INTEGRATING CENTRE

- In the simplest type of reflex, the integrating centre is a single synapse between a **sensory neuron** and a **motor neuron** termed **monosynaptic reflex ARC (no interneurons)**.
- More often, the integrating center consists of one or more **interneurons** which may relay impulses to other interneurons as well as to a **motor neuron which is termed a polysynaptic reflex ARC.**

FOOTNOTES

1. Guyton and Hall: *All sensory receptors in the body have one feature in common, their stimulation lead to change in membrane potential*, this is called receptor potential or generator potential.

Interneurons & Interneuron Pool

- **Interneurons** are present in the **gray matter** in the **dorsal horns**, the **anterior horns**, and the **intermediate areas** between them.
- **30 times** as numerous as the **anterior motor neurons**, small and highly excitable, often exhibiting spontaneous activity.
- Different types of **neuronal circuits** are found in the **interneuron pool** (parallel and reverberating circuits).
- Have *diverging*, *converging*, and *repetitive-discharge*.
- They are (excitatory or inhibitory).

Renshaw Cells

- Small **interneurons** located in the **anterior horns** of the spinal cord, in close association with the **motor neurons.**
- **AHCs** axon leaves the body of the neuron, sends collateral branches to adjacent **Renshaw cells.**
- These are inhibitory cells that transmit inhibitory signals to the surrounding motor neurons by **lateral inhibition**[1]**.**
- This **lateral inhibition** helps to focus or sharpen the signals from each motor neuron.

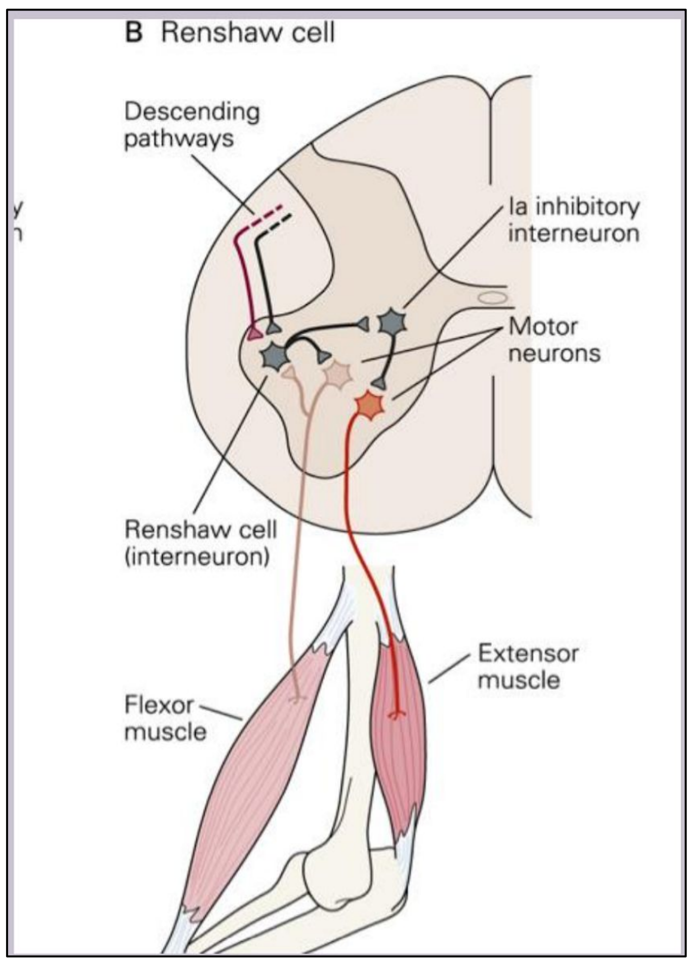


Figure 1-5

4. MOTOR NEURON (Efferent Neurons)

- Impulses triggered by the integrating center propagate out of the **CNS** along motor axons to the part of the body that will respond, and the cell bodies of these axons are located in **the anterior horn** of the spinal cord grey matter and they are of two types:

A. Alpha motor neurons:
Large cells, with large myelinated fibres (axons) form 70%of **ventral root** supply ***extra*fusal** muscle fibres (2/3 Of **Skeletal muscle** fibers).

B. Gamma Motor Neurons:
Smaller cells-with thinner axons form 30% of **ventral root**-supply ***intra*fusal** muscle fibres (muscle spindles=1/3 Of skeletal muscle fibers).

5. EFFECTOR

- The part of the body that responds to the motor **nerve impulse**, such as a muscle is the effector.
- Its action is called a **reflex.**
- If the effector is **skeletal muscle**, the reflex is a **somatic** reflex. If the effector is **smooth muscle**, or a **gland**, the reflex is an **autonomic (visceral)** reflex.

FOOTNOTES

1. Guyton and Hall: Lateral inhibition means that *a stimulation of a motor neuron tend to have an inhibitory effect on an adjacent motor neuron.*

THE GENERAL PROPERTIES OF REFLEXES AND THEIR NEURONAL POOLS

1. Convergence	2. Divergence	3. Reverberating Circuits
4. Recruitment	5. Central Delay	6. After-Discharge
7. Minimal Synaptic Delay	8. IRRADIATION	9. Reflex Time

Table 1-4

Sensory afferent enter spinal cord via dorsal (posterior) root, as they enter the neuronal pool undergo:

1. CONVERGENCE:

- Signals from multiple inputs unit to excite a single neuron.
- Multiple action potentials converging on the neuron provide enough spatial summation to bring the neuron to the threshold required for discharge.
- (multiple stimuli summate & collect together at the same time)

2. DIVERGENCE

- Help to spread a single stimulus to a wide area of the spinal cord (amplification of signal).
- It is important for weak signals to excite far greater numbers of nerve fibers leaving the pool.

BOX 1-4: ENCYCLOPEDIA OF NEUROSCIENCE

To better visualize divergence, a signal from a preganglionic fiber can excite many different cell bodies in a ganglion to perform a function. The same case can happen with convergence, where each ganglionic neuron receives an input from several preganglionic fibers, this can help to ensure an action potential gets initiated.

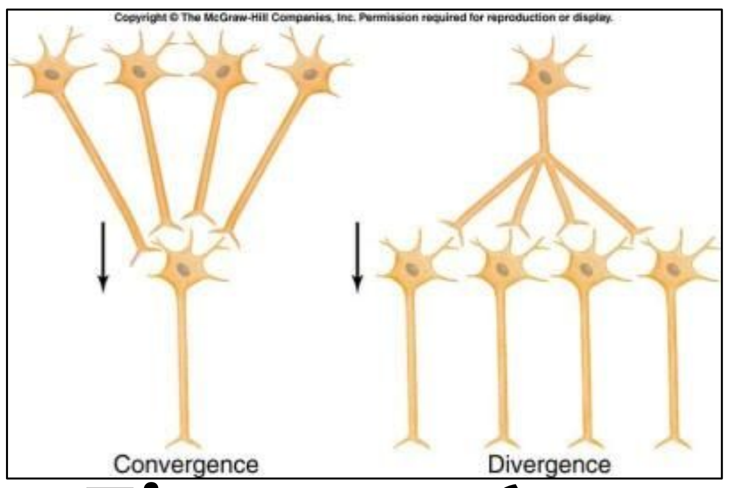


Figure 1-6

DIVERGENCE AND CONVERGENCE

- Output from one neuron onto many.
- Each **postsynaptic** neuron receives input from the same **presynaptic** neuron, but may react to it differently.
- In a **divergent** neural circuit, the axon of one neuron branches to send information to multiple target neurons.
- **Divergent** output allows the same signal to reach many different neurons.

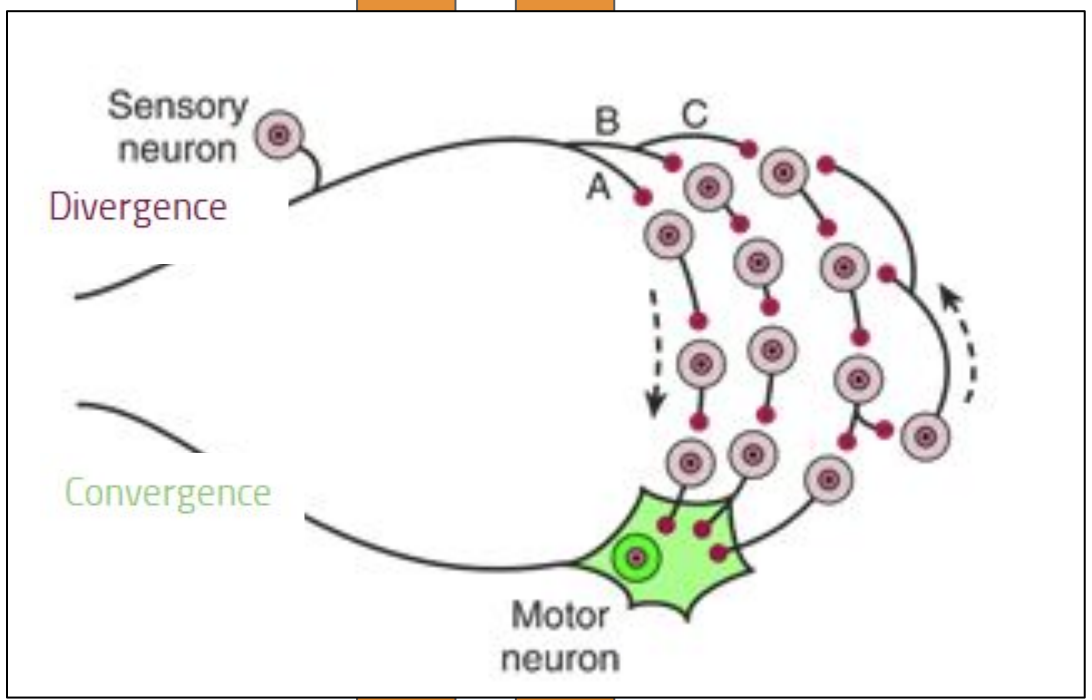


Figure 1-7

DIVERGENCE

- A. **Divergence** within a pathway to cause amplification of the signal.
- B. **Divergence** into multiple tracts to transmit the signal to separate areas.

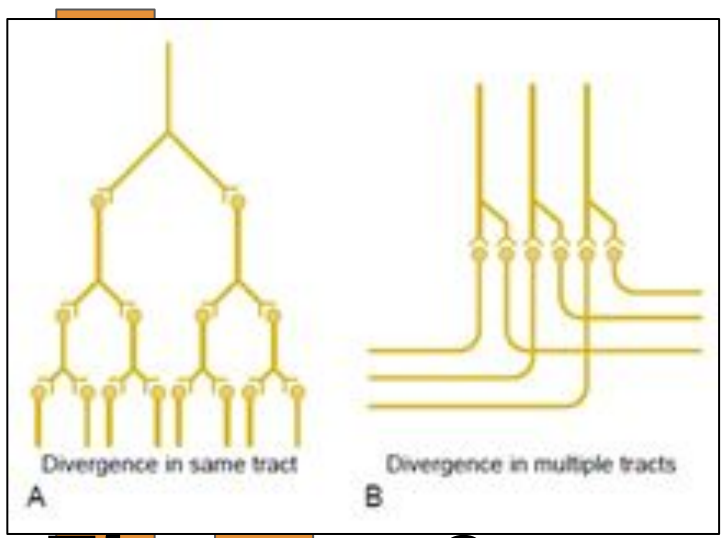


Figure 1-8

CONVERGENCE

- Convergence of multiple input fibers onto a single neuron.

A. Multiple input fibers from a single source.
B. Input fibers from multiple separate sources.

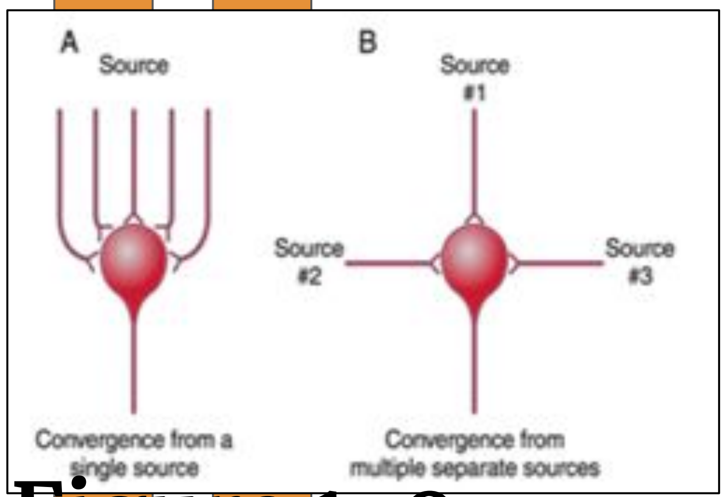


Figure 1-9

RECIPROCAL INHIBITION CIRCUITS

- Stimulation of flexors muscle accompanied by inhibition of extensors through inhibitory interneurons , the neuronal circuit that causes this reciprocal relation is called reciprocal innervation.

- Reflex contraction of an agonist muscle is accompanied by inhibition of the antagonist.

- The input fibre directly excites the excitatory output pathway, but it stimulates an intermediate inhibitory neuron (neuron 2), which secretes a different type of transmitter substance to inhibit the second output pathway from the pool. (3)
- Value/ preventing over activity in many parts of the spinal cord.

- Reciprocal inhibition is required with the monosynaptic reflex. It's important that you refer to **Box 1-6.**

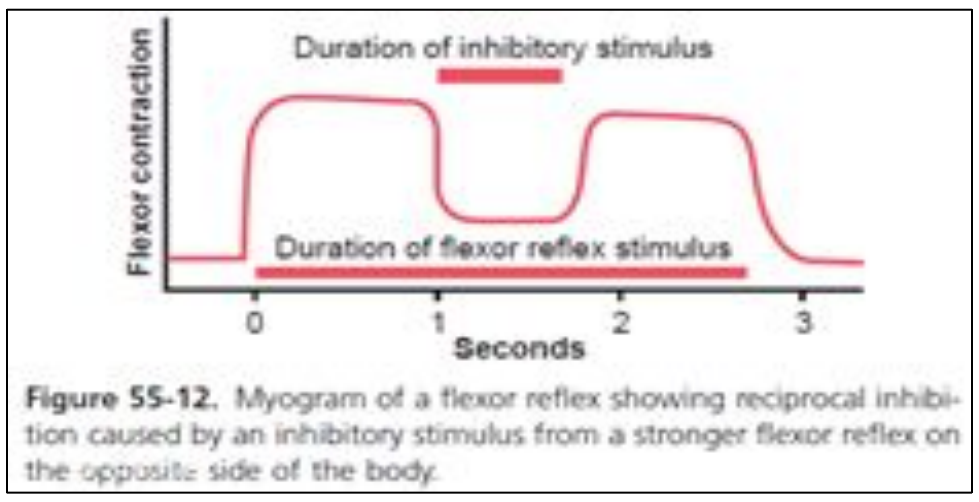


Figure 1-10

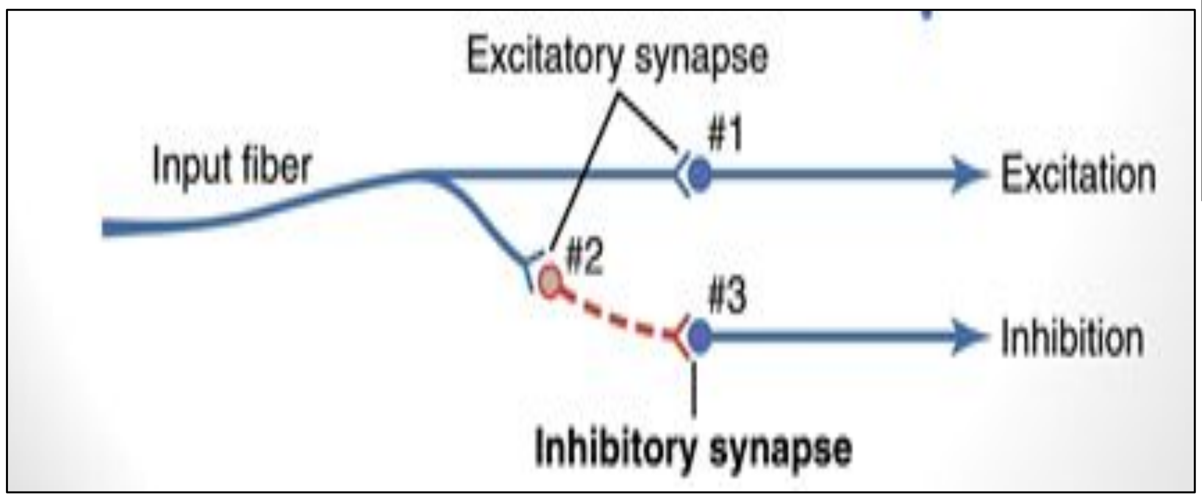


Figure 1-11

NEURONAL POOL CIRCUITS

1. PARALLEL

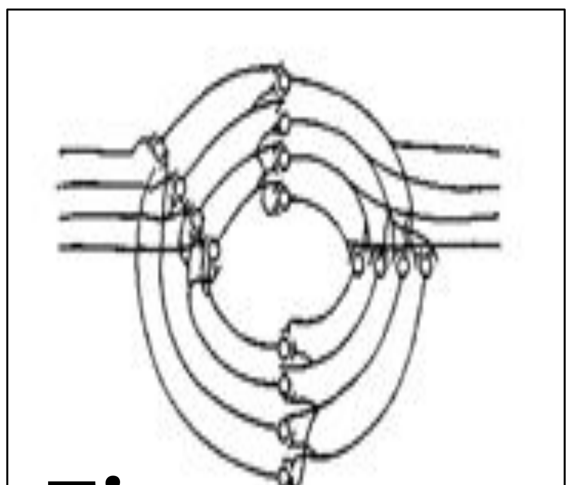


Figure 1-12

2. REVERBERATING

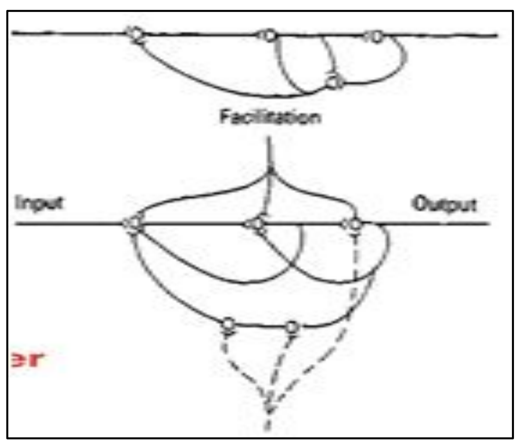


Figure 1-13

PARALLEL vs. REVERBERATING

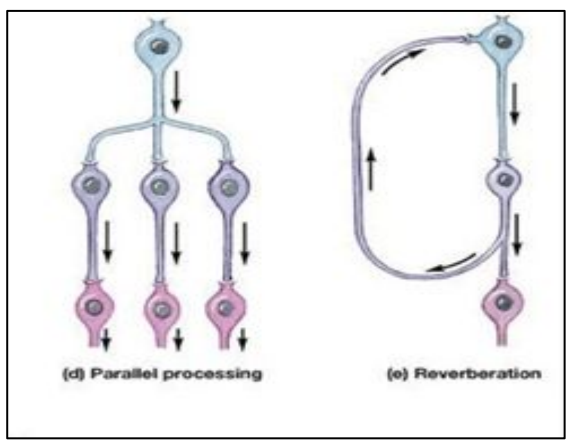


Figure 1-14

BOX 1-5: GUYTON AND HALL

For instance, at the same time that an excitatory signal is transmitted to cause forward movement of the leg an inhibitory signal is also transmitted by a different neuron to inhibit the muscles of the back of the leg so that they will not oppose the forward movement, as seen in **Figure 1-11.** The input fiber excites the forward movement through an excitatory synapse but also inhibits through a different type of transmitter to cause inhibition. An anterior motor horn synapses with an inhibitory interneuron before leaving the spinal cord to sharpen the signal by lateral inhibition.

BOX 1-6: GANONG'S MEDICAL PHYSIOLOGY

It should be noted that a monosynaptic reflex like stretch reflex is monosynaptic, that is, the sensory signal causes direct stimulation for contraction of a certain muscle. However, a collateral from the sensory axon must synapse with an interneuron to inhibit antagonist muscle. Hence, the reflex is monosynaptic, but the whole process is bisynaptic.

- Parallel circuits: afferent and efferent are parallel to each other (input parallel to output.)

3. REVERBERATORY (OSCILLATORY) CIRCUIT

- A more complex circuits in which both facilitatory and inhibitory fibers involved on the reverberating circuit.
- A facilitatory signal enhances the intensity and frequency of reverberation, whereas an inhibitory signal depresses or stops the reverberation.
- Most reverberating pathways are constituted of many parallel fibers.
- Circuit may discharge repetitively for a long time called long term potentiation and causes signal prolongation (Allow prolonged discharge of the same motor neurons by a single stimulus).

REVERBERATORY (OSCILLATORY) CIRCUIT

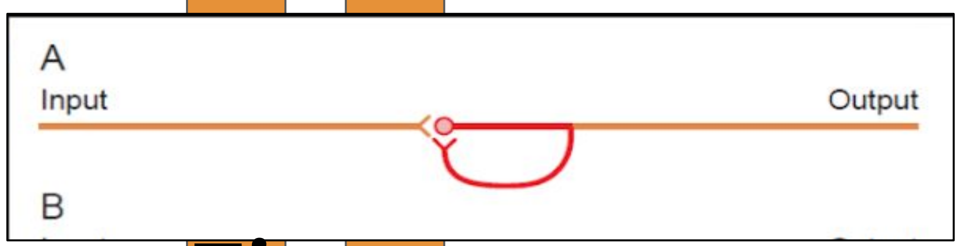


Figure 1-15

Figure 1-15: The simplest reverberatory circuits involves only a single neuron. The output neuron sends a collateral nerve fiber back to its own dendrites or soma to re-stimulate the input neuron itself.

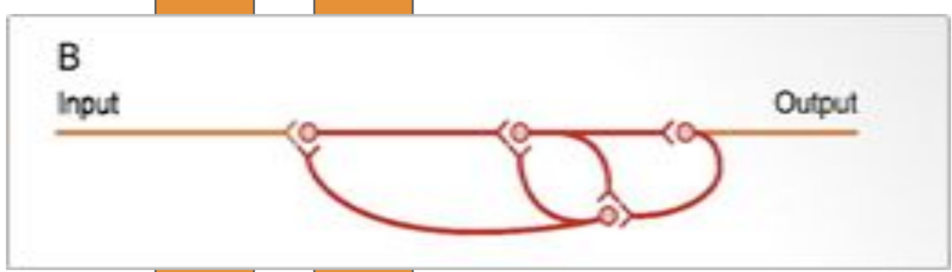


Figure 1-16

Figure 1-16: shows a few additional neurons in the feedback circuit, which causes a longer delay between initial discharge and the feedback signal.

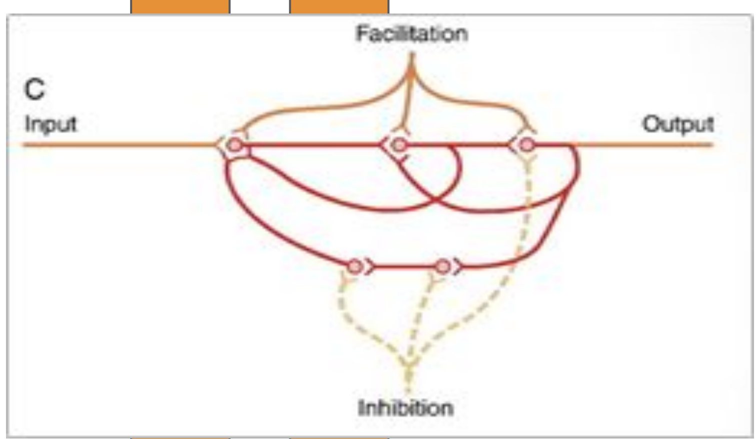


Figure 1-17

Figure 1-17: Shows a still more complex system in which both facilitatory and inhibitory fibers interact in the reverberating circuit.
- A facilitatory signal enhances the intensity and frequency of reverberation.
- An inhibitory signal depresses or stops the revelation.

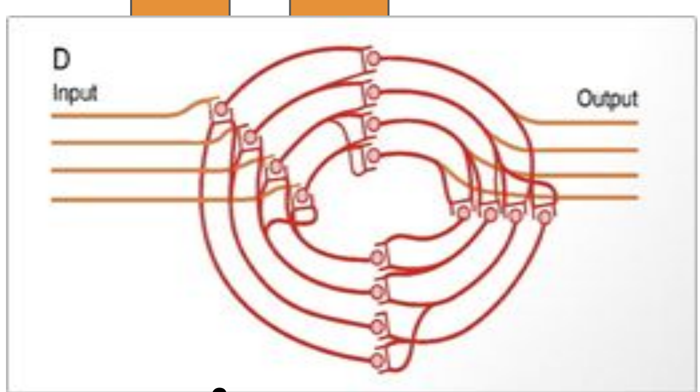


Figure 1-18

Figure 1-18: shows that most reverberating pathways are constituted of many parallel fibers.

4.. AFTER-DISCHARGE

A prolonged maintained output discharge of AHCs called after discharge, lasting a few milliseconds or many minutes after the incoming signal is over.
(cont...)
Occurs due to the following:

1. **Synaptic (short-term) After-discharge:** When excitatory synapses discharge on the surfaces of dendrites or soma of a neuron, a **postsynaptic electrical potential (PSP)** develops in the neuron and lasts for milliseconds. It can continue to excite the neuron, causing it to transmit a series of repetitive discharges, this cause *maintained reflex action* & response continue for some time after cessation of stimulus).

Lecturer's notes: For example, in Scratch reflex, postsynaptic electrical potential continue to excite the neuron. That's why when you scratch once, you still feel the urge to scratch more.

2. **Reverberating circuits (prolonged):** Presence of reverberating circuit restimulate AHCs.

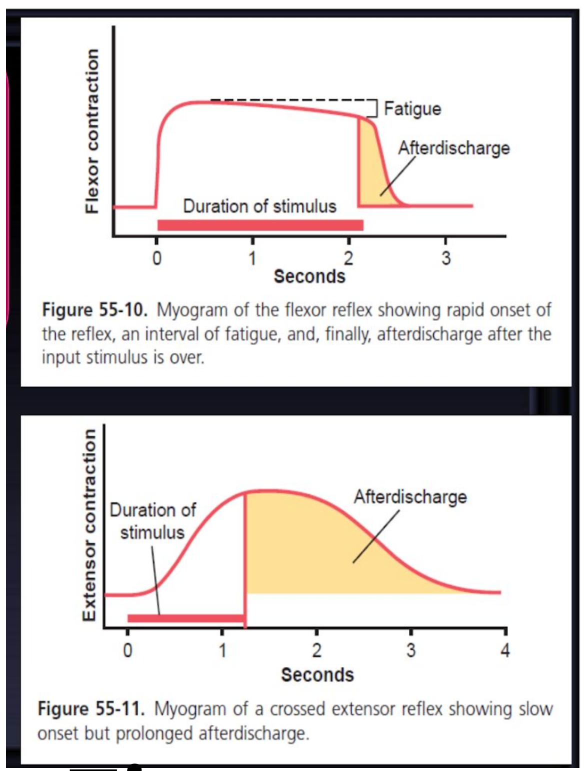


Figure 1-19

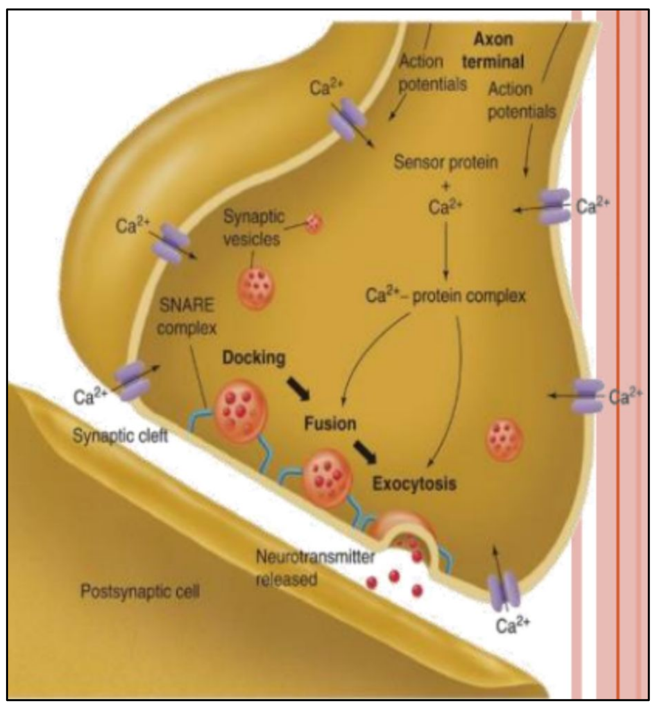


Figure 1-20

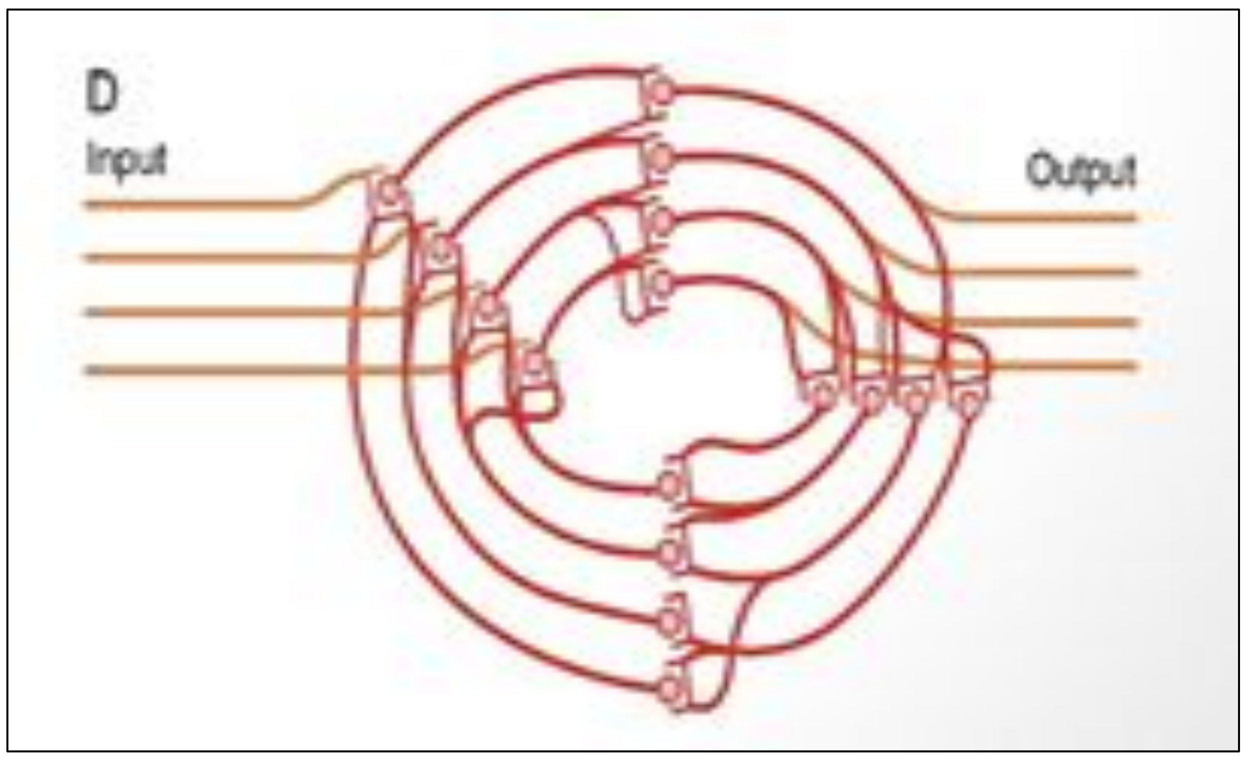


Figure 1-21

5. SYNAPTIC DELAY (CENTRAL DELAY)

Is the time of reflex to pass through neurons of the spinal cord.

- The minimal period of time required for transmission of a neuronal signal from a presynaptic neuron to a postsynaptic neuron, is **synaptic delay.**
- Equals 0.5 ms/synapse (it is long in polysynaptic Reflex)
- It is >2 ms in the withdrawal R (polysynaptic reflex).
- Number of synapses in a reflex = central delay/0.5ms
- For knee jerk it equals 0.6 msc = one synapse

BOX 1-7: GUYTON AND HALL

An afterdischarge simply means a prolongation of an output signal long after the input signal stops. One can see this with long-acting neurotransmitters. Also, one of the way to achieve after-discharge is by a reverberatory circuit, which is caused by a positive feedback to re-excite the input of the neuron.

6. REACTION (REFLEX) TIME REFLEX TIME = CENTRAL DELAY + TIME SPENT IN CONDUCTION OF IMPULSES ALONG THE AFFERENT AND EFFERENT NERVES.

The time between the application of the stimulus and the response is called the **reaction time.**

- In humans, the **reaction time** for a stretch reflex such as the knee jerk is 19-24 ms.
- The conduction velocities of the afferent and efferent fiber types are known and the distance from muscle to the spinal cord can be measured
- This is responsible for most of the reaction time.

7. RECRUITMENT

Gradual activation of more number of motor neurons (AHCS) on stimulation of afferent nerve in a reflex arc by maintained, repetitive stimulus.

- Can cause: Different *conduction velocities* of afferents.
- Different number of **interneurons** with short & long pathways to the **motor neurons (AHCs).**

8. IRRADIATION

Spread of impulses up & down to different segments and motor neurons in the S.C.

- A strong stimulus in sensory afferent irradiate to many segments of S.C due to divergence.
- The extent of the response in a reflex depends on the intensity of the stimulus.

9. "LOCAL SIGN" PATTERN OF WITHDRAWAL

The pattern of withdrawal that results when the flexor reflex is elicited depends on which sensory nerve is stimulated.

- Thus, a pain stimulus on the inward side of the arm elicits not only contraction of the flexor muscles of the arm but also contraction of abductor muscles to pull the arm outward. This is called the principle of **"local sign"**.

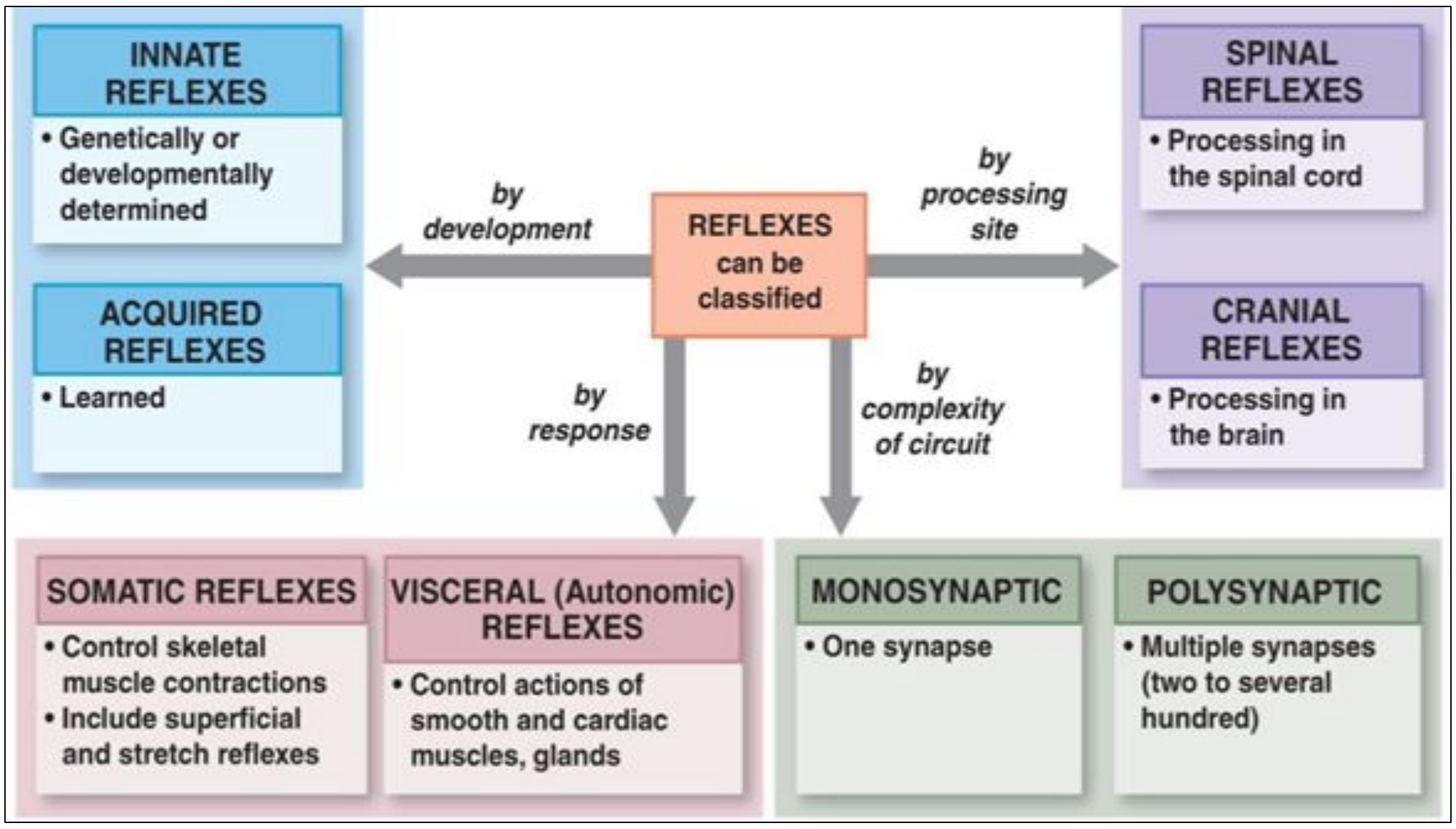


Figure 1-22 Showing classification of reflexes.

A

SOMATIC REFLEXES INTEGRATED IN THE SPINAL CORD			
STRETCH	FLEXOR	EXTENSOR	RHYTHMIC
Maintain muscle tone	Withdrawal	Standing, posture, stepping	Walking, stretching

B

AUTONOMIC (VISCERAL) RELFEXES INTEGRATED IN THE SPINAL CORD	
VASOMOTOR	MICTORITIUON & DEFECATION
Vascular tone	Bladder & bowel

Table 1-5

TYPES OF SPINAL REFLEXES

ACCORDING TO NUMBER OF NEURONS

1. **POLYSYNAPTIC Sensory axon** *(afferent)* synapse with one or more **interneuron.**
   - These reflexes are mediated by the spinal cord, but influenced by higher centers
   - **Examples:** Withdrawal, abdominal reflexes, visceral and plantar reflex.

2. **MONOSYNAPTIC Sensory axon** *(afferent)* synapse directly with anterior horn cell.
   Examples: Stretch reflex

Monosynaptic reflex as a knee reflex:
- In the simplest type of reflex, the **integrating center** is a single synapse between a **sensory neuron** and **a motor neuron.**
- When a **reflex ARC** consists of only two neurons in an animal **(one sensory** and **one motor neuron)** it is defined as **monosynaptic.**
- Reciprocal inhibition is required with the monosynaptic reflex

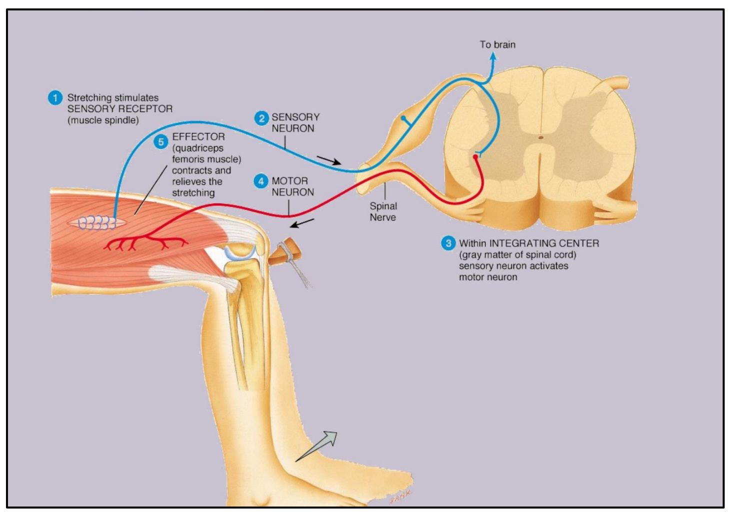


Figure 1-23

Table 1-5

ACCORDING TO RECEPTOR SITE

1. **DEEP REFLEXES (Figure 1-24)** by stimulation of receptors deep in muscle and tendons.
   A. Stretch Reflexes (Tendon jerks), they are **monosynaptic**.
   - The receptor for all these is the muscle spindle (is located deep within the muscle itself.
   - **Examples:** knee-jerk (patellar reflex) and ankle jerk.

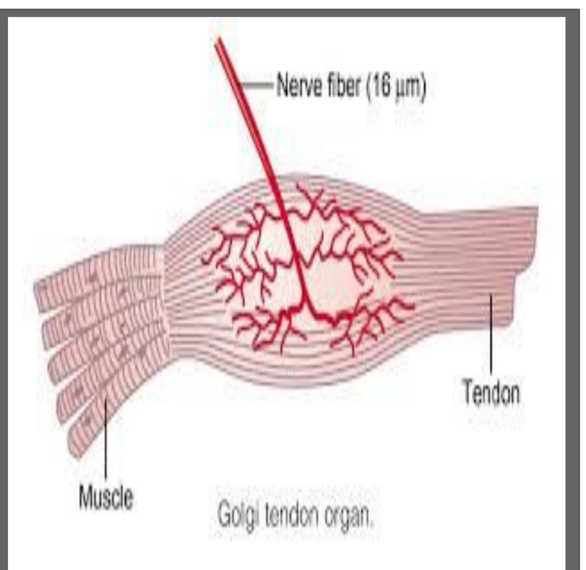
   B. INVERSE STRETCH REFLEX (GOLGI TENDON ORGAN REFLEX) **Polysynaptic:** The receptor is called Golgi Tendon Organ (refer to **Box 3-5**, from Guyton and Hall) present deep in the muscle tendon.
   - Also there are: Extensor standing, posture, stepping, rhythmic walking, scratching.

2. **SUPERFICIAL REFLEXES (Figure 1-25)** are **polysynaptic** reflexes, the receptors are superficial in the skin or mucous.
   - **Examples:** Withdrawal, abdominal reflexes and plantar reflex

3. **VISCERAL** Are the reflexes where at least one part of the reflex arc is autonomic nerve. by stimulation of receptors in the viscera.
   - All autonomic reflexes are polysynaptic with at least one synapse in the CNS and another in autonomic ganglia.
   Examples: As Micturition, defecation, pupillary reflex and carotid sinus reflex.

BOX 1-8: GUYTON AND HALL

Proper function of muscles requires contact between muscle and nervous system, this is can be done by sensory receptors termed "slow adapting receptors", and they are of two types: (1) muscle spindles, present on the belly of the muscle and provide information about muscle length, it's connective tissue surrounding intrafusal muscle fibers, those fibers provide spindles with information about contraction of larger fibers, extrafusal fibers (2) **Golgi tendon organs**, which are located in the muscle tendons and provide information about tendon tension or rate of change of tension.



Golgi tendon organ.

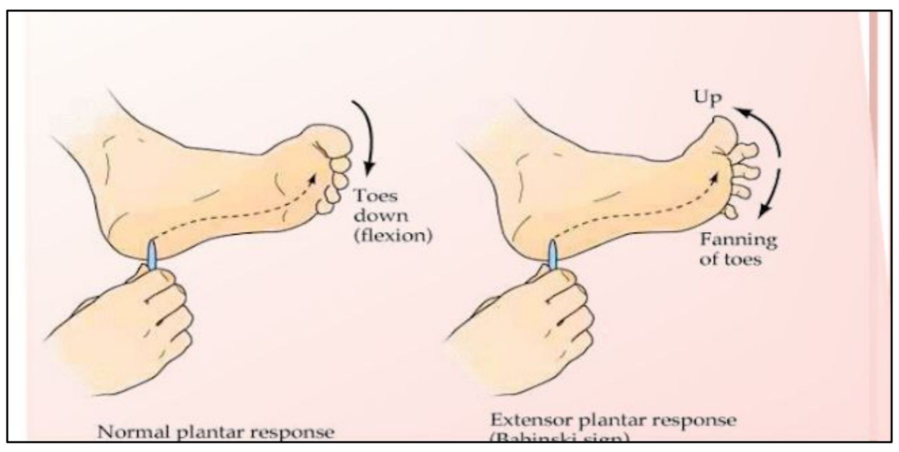


Figure 1-24

WITHDRAWAL REFLEX (FLEXOR REFLEX) (NOCICEPTIVE[1] REFLEX)

- A superficial polysynaptic reflex.
- In the spinal[1] or decerebrate[2] animal, almost any type of cutaneous sensory stimulus from a limb is likely to cause the flexor muscles of the limb to contract, thereby with drawing the limb from the stimulating object. This reflex is called the flexor reflex.
- Stimulation of pain receptors of hand (a pin- prick, heat, or a wound) → impulses to SC in A delta or C fibres → interneurons pool → motor neurons → stimulate hand flexor muscles → move the hand away from the injurious stimulus.

CHARACTERIZED BY

1. DIVERGING CIRCUITS To spread the reflex to the necessary muscles for withdrawal.

.

2. RECIPROCAL INHIBITION CIRCUITS Circuits to inhibit the antagonist muscles.
- Stimulation of flexors muscle accompanied by inhibition of extensors through inhibitory interneurons.

3. RECRUITMENT Gradual activation of more number of motor neurons (AHCS) on stimulation of afferent nerve in a reflex arc by maintained, repetitive stimulus.
- Can cause:
- A. Different *conduction velocities* of afferents.
- B. Different number of **interneurons** with short & long pathways to the **motor neurons (AHCs).**

Motor unit recruitment: If a repetitive & stronger stimulus is maintained, there will be gradual increase in the force of the muscle contraction until the maximum force is reached, due to gradual recruitment/activation of more and more motor neurons.

4. AFTER-DISCHARGE CIRCUITS Circuits to cause afterdischarge lasting many fractions of a second after the stimulus is over.
- The duration of after-discharge depends on the intensity of the **sensory stimulus** that elicited the reflex.
- **Cause:** Presence of reverberating circuit restimulate AHCs.
- **Value:** prolong the protective response of reflex.

5. IRRADIATION Spread of impulses up & down to different segments and motor neurons in the S.C.
- A strong stimulus in sensory afferent irradiate to many segments of S.C due to divergence.
- The extent of the response in a reflex depends on the intensity of the stimulus.
- The more intense the stimulus → greater spread of activity in the spinal cord → involving more & more motor neurons → more response.
- Weak stimulus → irradiates to small number of neurons, so it causes weak flexion of limb.
- Strong stimulus → irradiates to large number of neurons, so it causes withdrawal of affected limb & extension of opposite limb. (as in crossed extensor reflex).

FOOTNOTES

1. In a spinal animal the spinal cord is transected, frequently in the neck, yet most of the spinal cord remains functional!
2. In a decerebrate animal, the brain stem (superior continuation of the spinal cord) is cut in the middle or the lower part of the midbrain.

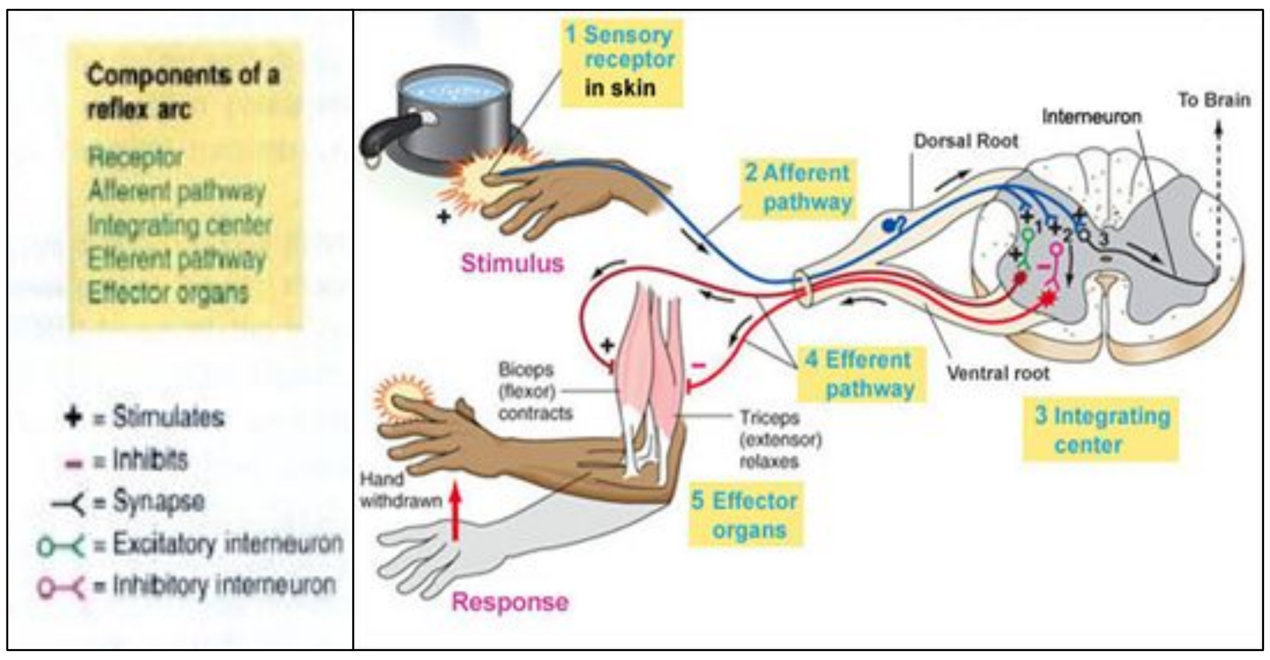


Figure 1-25

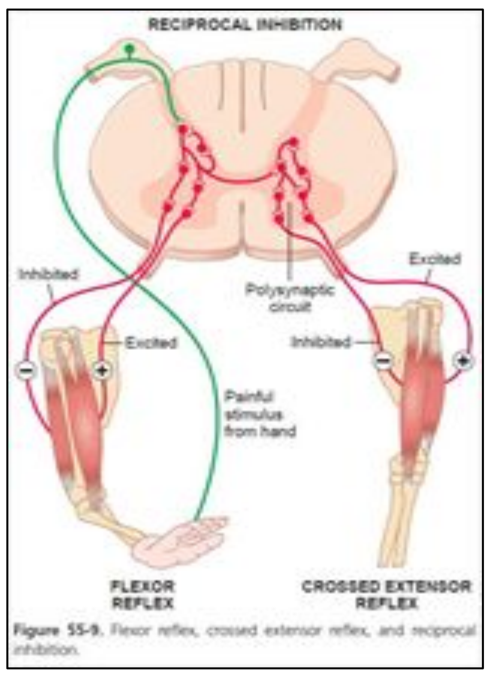


Figure 1-26

THE WITHDRAWAL REFLEX

REFLEX	Flexor reflex or withdrawal reflex	
CLINICAL TEST/STIMULUS	Sharp painful stimulus (stepping on nail)	
RESPONSE	Limb is rapidly withdrawn	
SENSORY RECEPTOR	Cutaneous skin and pain receptors	
SYNAPSES INVOLVED	Polysynaptic (via interneuron)	
EFFECTS ON MUSCLE	Contracts flexor muscle	
OTHER EFFECTS	Relaxes (-) extensor muscle of same limb	Reverse effect on opposite limb (crossed extensor reflex)
FUNCTION	Protective - withdrawal from painful stimulus	Cross extensor aids in maintaining posture when opposing leg is lifted

Table 1-10

CROSSED EXTENSOR REFLEX

Crossed extensor reflex supporting the body weight against gravity while pushing the body away from the injurious agent by withdrawal reflex and it includes two main actions.

- Flexion and withdrawal of the stimulated limb.
- Extension of the opposite limb.

It Occurs with strong stimulus only. Why?

1. Signals from sensory neurons as it activates withdrawal reflex in the stimulated limb, cross to the opposite side of the cord by irradiation & divergence to excite excitatory interneurons to activate motor neurons of extensor muscles neurons & send collaterals to inhibitory interneurons to inhibit motor neurons of the flexors (all in the other limb).

2. It does not begin until 200 to 500 milliseconds after onset of the initial pain stimulus, because many interneurons are involved in the circuit between the incoming sensory neuron and the motor neurons of the opposite side of the cord.

3. After the painful stimulus is removed, the crossed extensor reflex has an even longer period of afterdischarge, results from reverberating circuits. This of benefit in holding the pained area of the body away from the painful object & support balance.

- Mostly in the lower limb to support balance.
- **Reciprocal innervations occurs also in crossed extensor reflex. How?**

1. Flexors in the opposite limb are inhibited while extensors are excited
2. The crossed extensor reflex supporting the body weight against gravity.

PRESENT ONLY IN FEMALE SLIDES

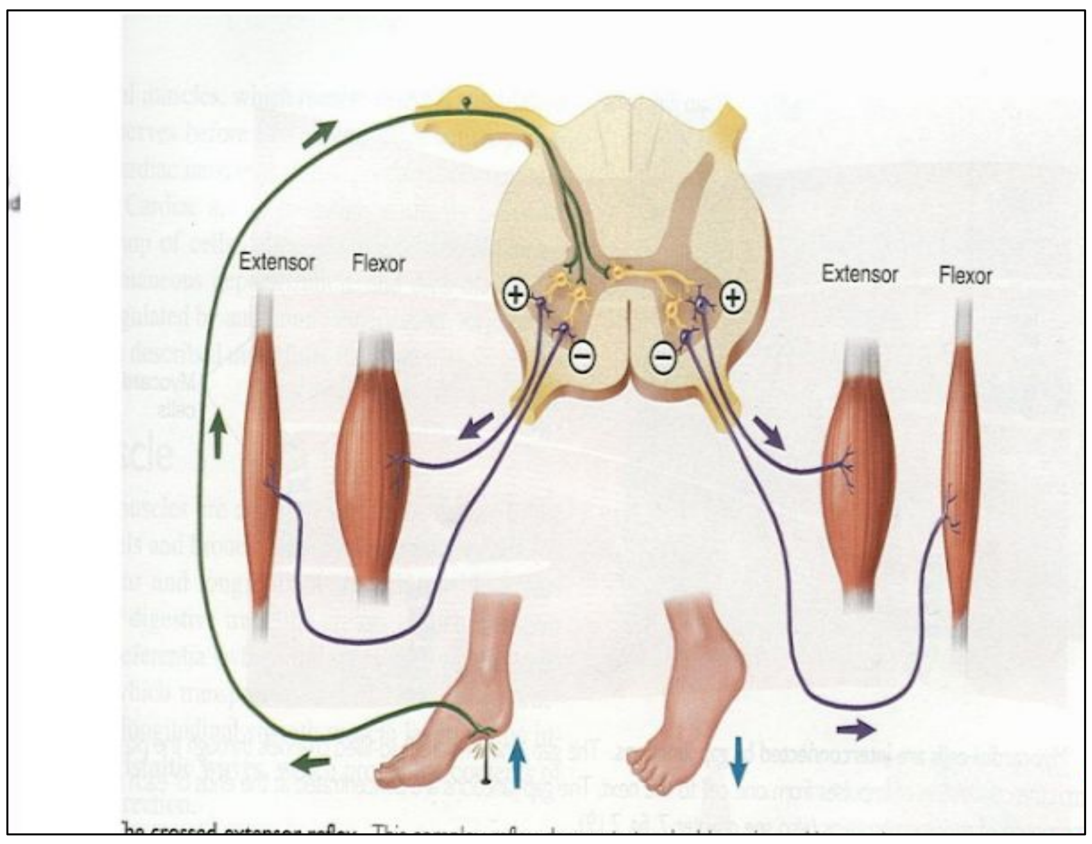


Figure 1-27

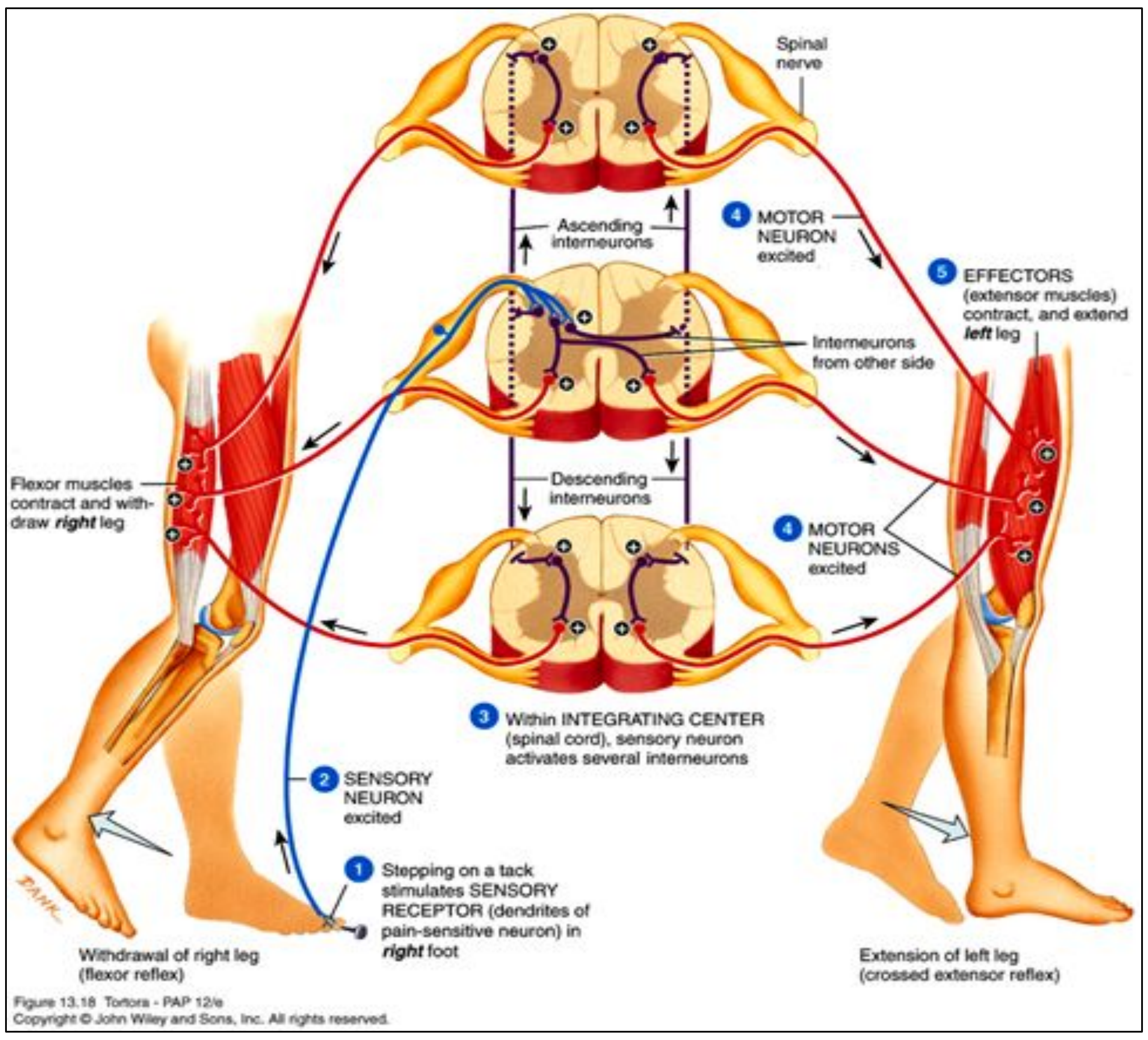


Figure 1-28

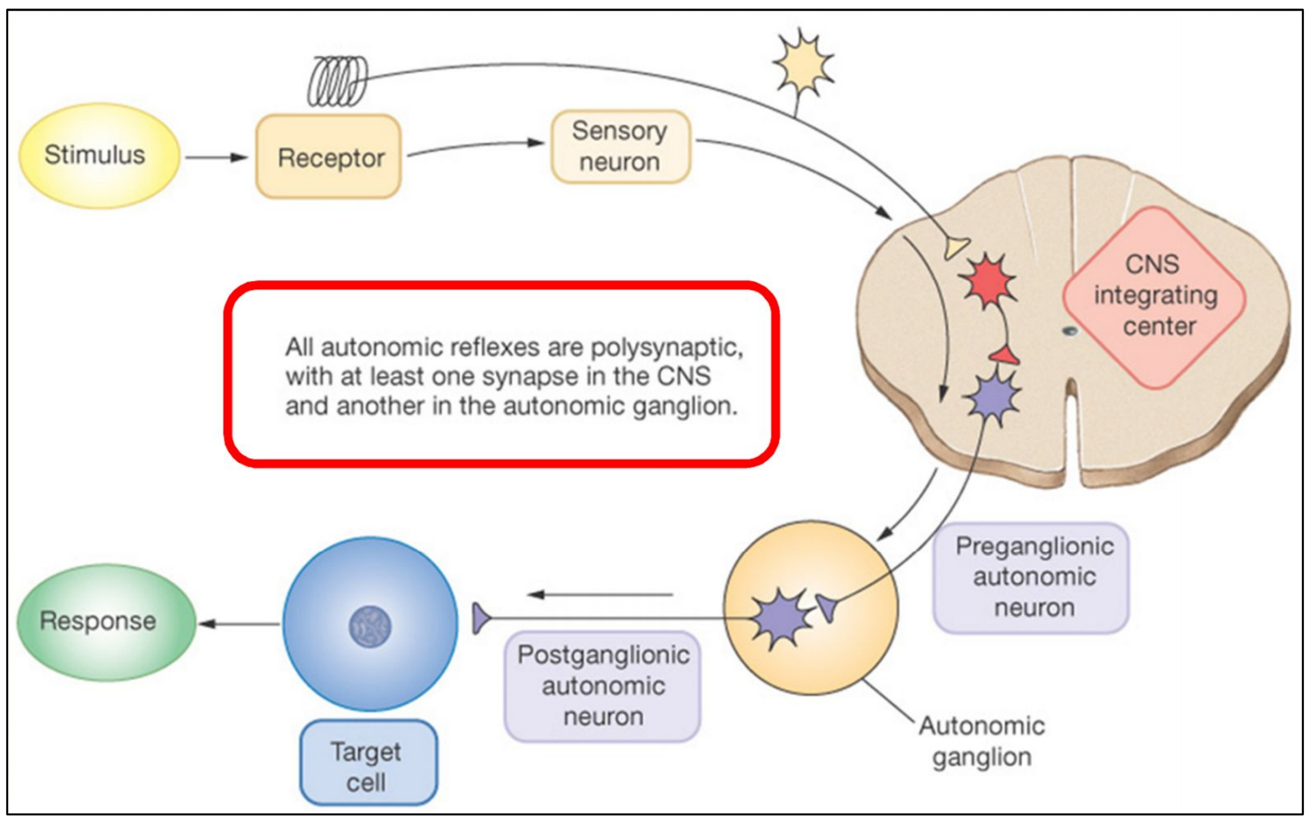


Figure 1-29

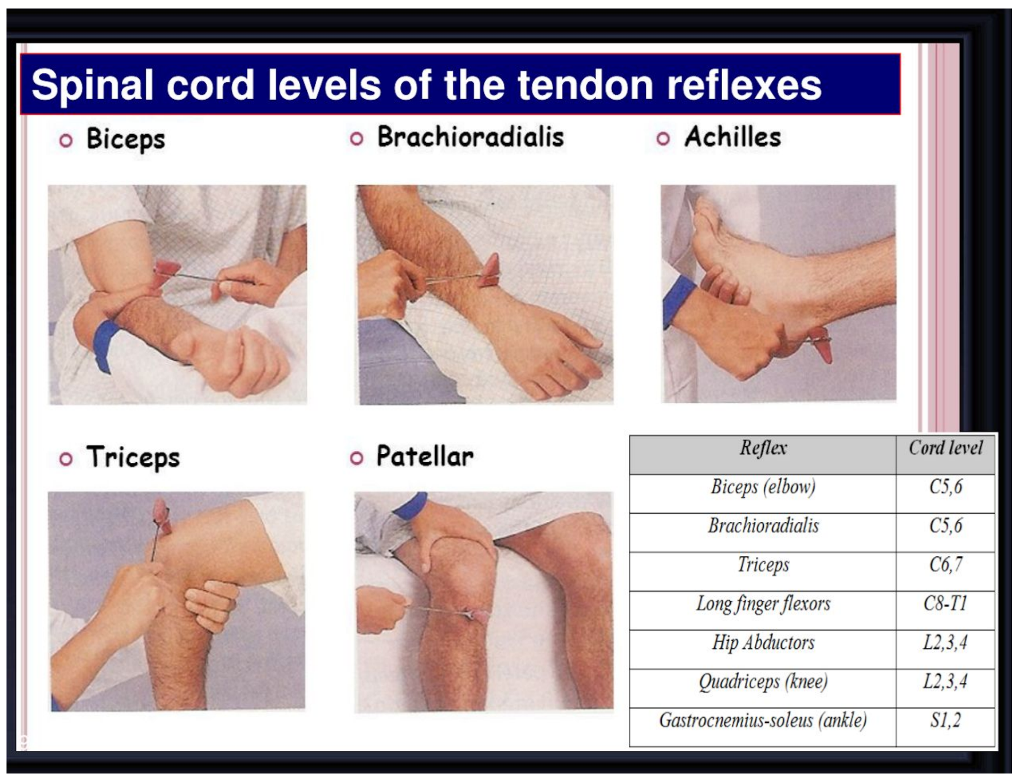


Figure 1-30

REFLEX OF POSTURE AND LOCOMOTION

- Positive Supportive Reaction.
- Cord "Righting" Reflexes.

STEPPING AND WALKING MOVEMENTS

- Rhythmical Stepping Movements of a Single Limb.
- Reciprocal Stepping of Opposite Limbs.
- Diagonal Stepping of All Four Limbs—"Mark Time" Reflex.
- Galloping reflex.

STRETCH REFLEX

1. Position sense that allows the paw to find the exact point of irritation on the surface of the body.
1. A to-and-fro scratching movement.

SPINAL CORD REFLEXES THAT CAUSE MUSCLE SPASM

- Muscle Spasm Resulting From a Broken Bone.
- Abdominal Muscle Spasm in Persons with Peritonitis.
- Muscle Cramps.

SEGMENTAL AUTONOMIC REFLEXES ARE INTEGRATED IN THE SPINAL CORD

1. Changes in vascular tone resulting from changes in local skin heat.
2. Sweating, which results from localized heat on the surface of the body.
3. Intestinointestinal reflexes that control some motor functions of the gut.
4. Peritoneointestinal reflexes that inhibit gastrointestinal motility in response to peritoneal irritation.
5. Evacuation reflexes for emptying the full bladder.

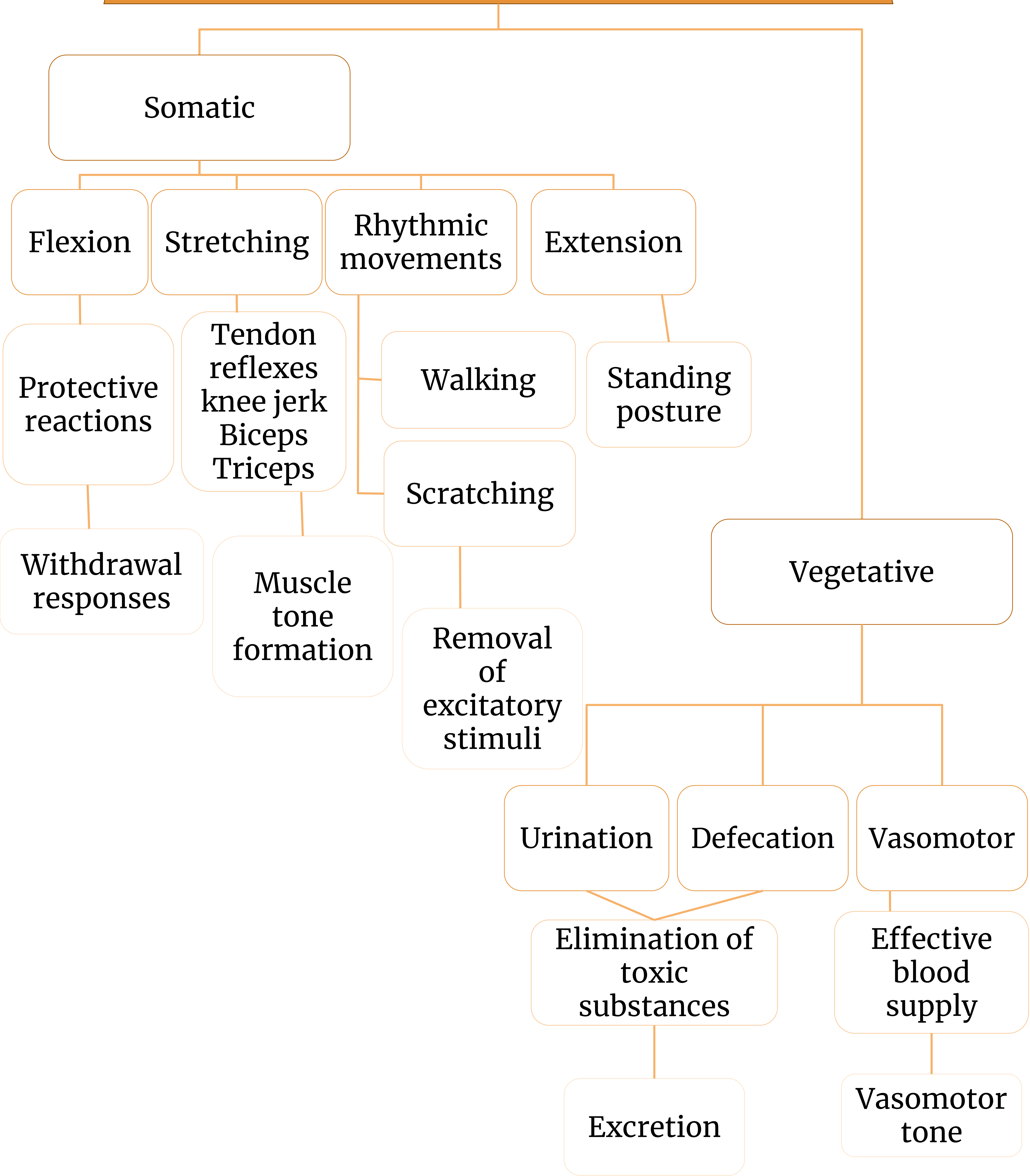
MASS REFLEX

In a spinal animal or human being, sometimes the spinal cord suddenly becomes excessively active, causing massive discharge in large portions of the cord by painful stimulus.

PRESENT ONLY IN MALE SLIDES

Table 1-11

SUMMARY: SPINAL CORD REFLEXES



SUMMARY

- All autonomic and superficial reflex are polysynaptic.
- All tendon jerks are monosynaptic reflex.
- Reciprocal inhibition is not a monosynaptic effect.
- Renshaw cells are inhibitory cells that transmit inhibitory signals to the surrounding motor neurons By Lateral inhibition(helps to focus or sharpen the signals from each excited motor neuron.
- Renshaw cells Allow transmission of the primary signal in the desired direction & suppressing the tendency for signals to spread laterally.
- Alpha motor neurons are large cells, with large myelinated fibres (axons) form 70% of ventral root supply extrafusal muscle fibres (2/3 Of Skeletal muscle fibers).
- Gamma Motor Neurons are smaller cells-with thinner axons form 30% of ventral root-supply intrafusal muscle fibres (muscle spindles=1/3 Of skeletal muscle fibers).
- long term potentiation In reverberatory circuit is the output neuron sends a collateral nerve fiber back to its own dendrites or soma to re-stimulate the input neuron itself & so the circuit may discharge repetitively for a long time.
- Most reverberating pathways are constituted of many parallel fibers.
- Withdrawal reflex is superficial polysynaptic reflex That is stimulated by pain receptors of hand >> impulses to SC in A delta or C fibres >> interneurons pool >> motor neurons >> stimulate hand flexor muscles >> move the hand away from the injurious stimulus.
- In irradiation The extent of the response in a reflex depends on the intensity of the stimulus.
- Crossed extensor reflex supports the body weight against gravity while pushing the body away from the injurious agent by withdrawal R. Then in result of reverberating circuit; the crossed extensor reflex has an even longer period of afterdischarge.

QUIZ

1. Which of the following controls the subconscious activities of the nervous system:
A) Subcortical level
B) Spinal cord level
C) Higher brain level
D) Peripheral nervous system

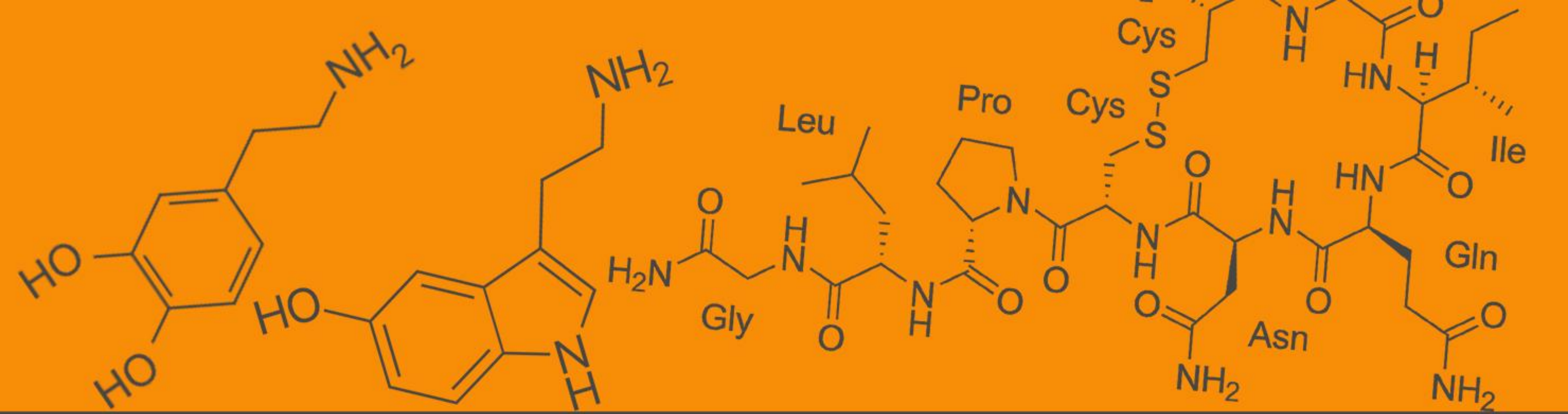
2. Which of the following is contained within the muscle spindle:
A) Intrafusal muscle fibers
B) Extrafusal fibers
C) Visceral muscles
D) Smooth muscles

3. Choose the correct sentence:
A) Intrafusal fibers are contractile throughout its length
B) Muscle spindles function primarily to increase the strength of contraction.
C) Renshaw cells are excitatory interneurons.
D) Extrafusal fibers are highly contractile muscle fibers

4. Golgi tendon organs are located in:
A) Tendons of muscle fibers.
B) Belly of muscle fibers
C) Gap junctions.
D) Muscle spindle

5. In a visit to a clinician the knee jerk reflex was tested to test the efficacy of spinal cord reflexes, the mechanical stimulation caused contraction of quadriceps femoris muscle, which of the following is responsible for initiation of this response:
A) Stretching of the muscle spindle
B) Tension sensed by golgi tendon organ
C) Innate ability of skeletal muscles to contract upon stimulus without spinal cord involvement
D) None of the above.

ANSWER KEY: A, A, D, A, A



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REFERENCES

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- Ganong's Review of Medical Physiology