HUMAN PHYSIOLOGY (normal)

LECTURE 3. General Physiology of Central Nervous System. The Physiology of Spinal Cord

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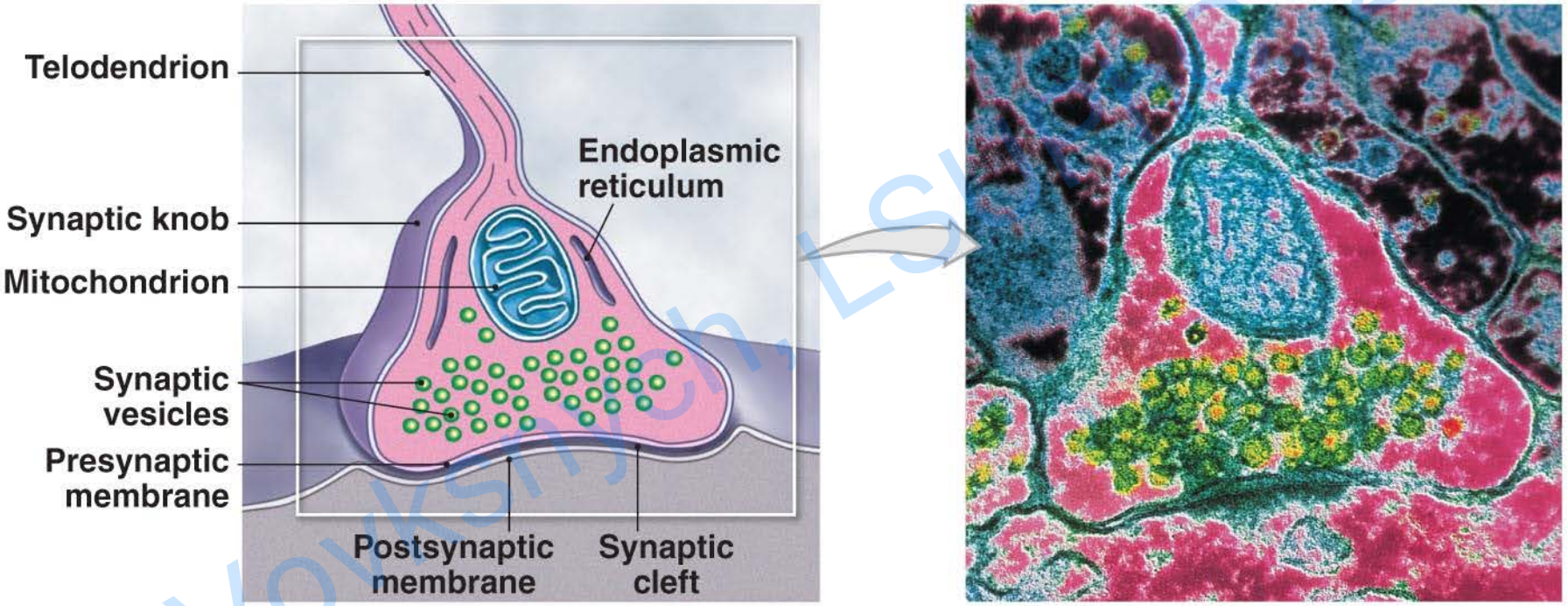
Mechanism of Neurons Interaction



Structure of the chemical synapse

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Synapses and Neurotransmitters

Two **Classes of Synapses** based on different action of the Neurotransmitters

- **Excitatory neurotransmitters**
  - Cause depolarization of postsynaptic membranes
  - Promote action potentials
- **Inhibitory neurotransmitters**
  - Cause hyperpolarization of postsynaptic membranes
  - Suppress action potentials

- **Synaptic Delay**
  - Between the arrival of action potential at synaptic knob and effect on postsynaptic membrane
  - Typical value - 0.2–0.5 msec
  - Fewer synapses mean faster response
  - Reflexes may involve only one synapse

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Neurotransmitters

At least **50 neurotransmitters,** the most important:

- Acetylcholine (ACh) – usually excitatory
- Norepinephrine (NE) - excitatory effect
- Dopamine - may be excitatory or inhibitory
- Serotonin - affects attention and emotional states
- Gamma aminobutyric acid (GABA)- inhibitory effect

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Information Processing in CNS

Postsynaptic Potentials

- Graded potentials developed in a postsynaptic cell in response to neurotransmitters

Two Types of Postsynaptic Potentials

- Excitatory postsynaptic potential (EPSP)
  - Graded **depolarization** of postsynaptic membrane
- Inhibitory postsynaptic potential (IPSP)
  - Graded **hyperpolarization** of postsynaptic membrane

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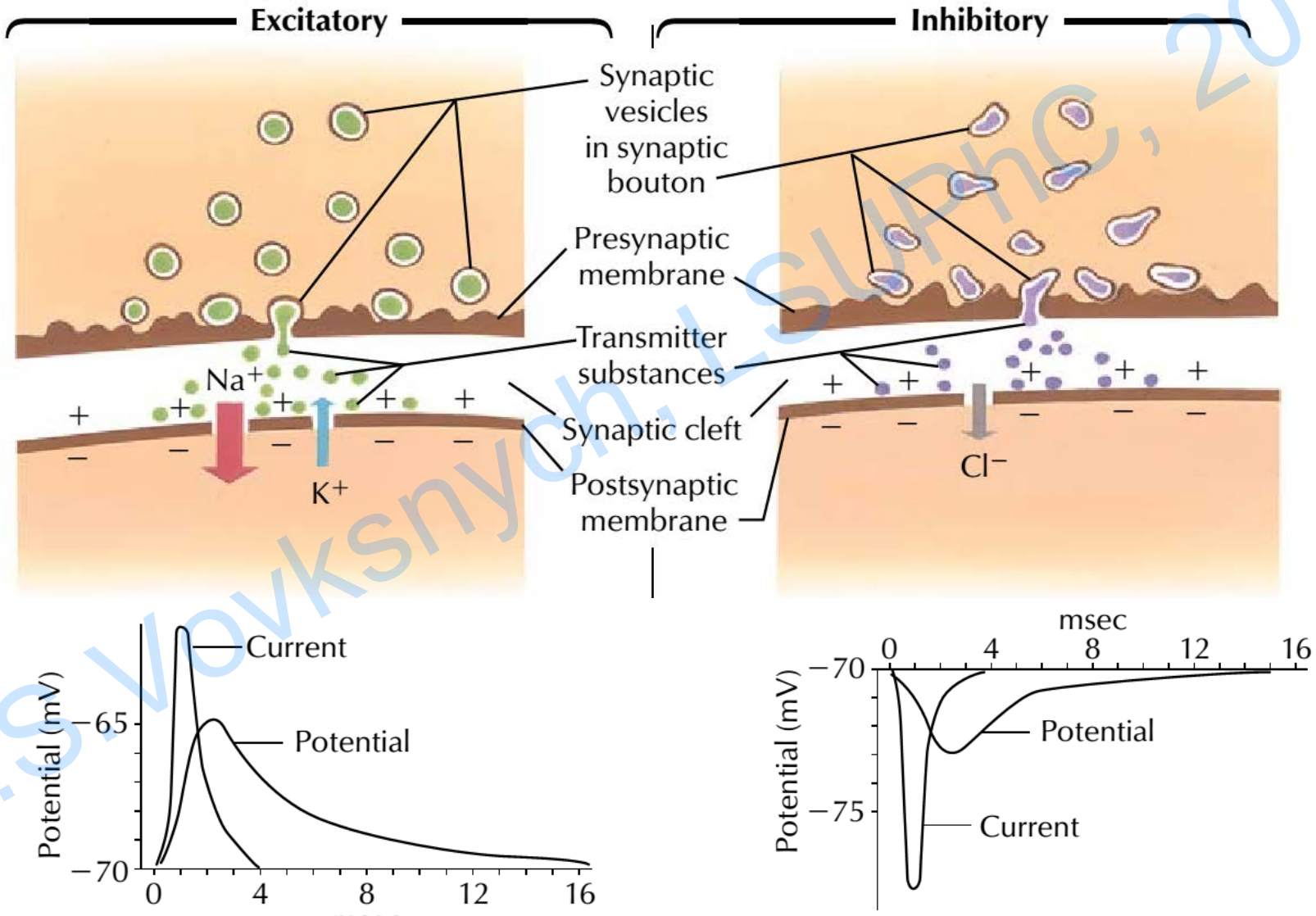
Two Types of Postsynaptic Potentials



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Information Processing in CNS

Inhibition

- A neuron that receives many IPSPs is inhibited from producing an action potential, because the stimulation needed to reach threshold is increased

Excitation

- To trigger an action potential the number of EPSP is needed
- EPSPs (and IPSPs) combine through summation:
- temporal summation
- spatial summation

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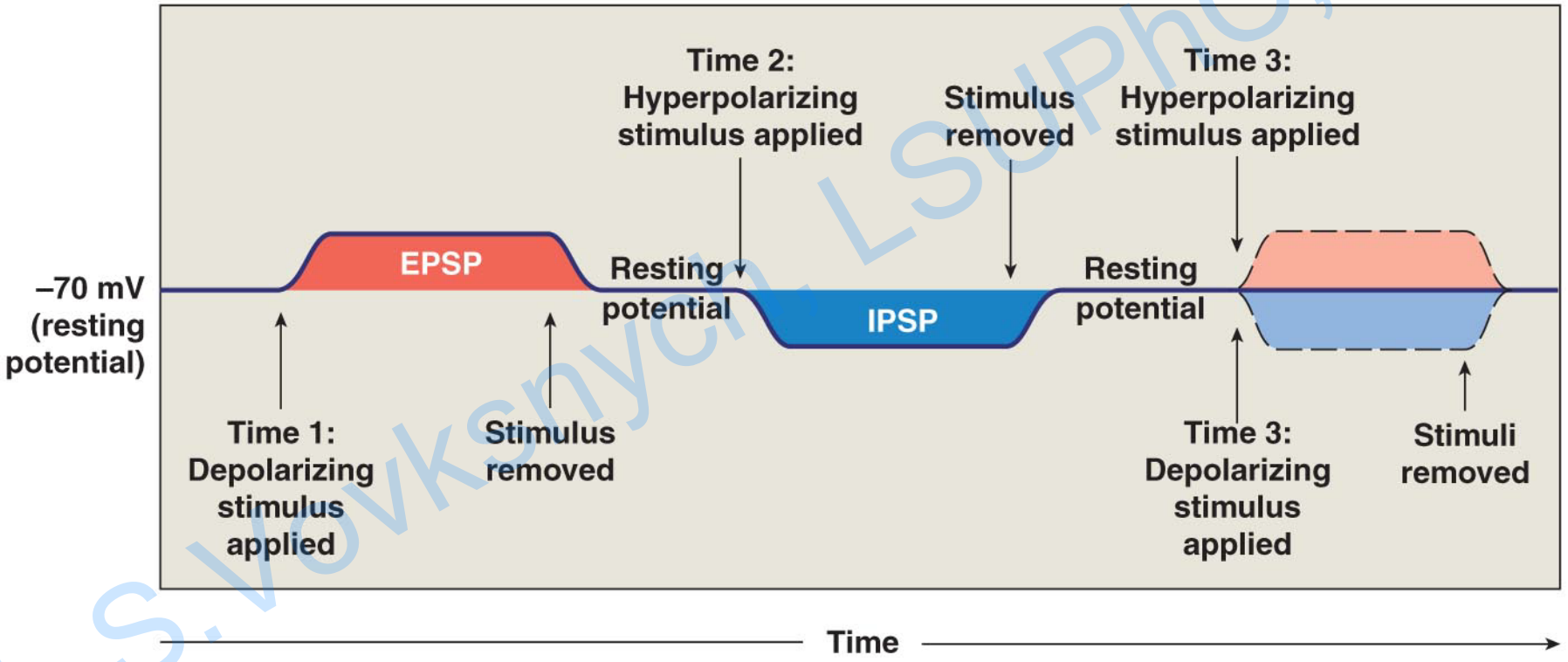
Information Processing in CNS



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Neurons

Sensory neurons

- About 10 million
- Deliver information to CNS

Motor neurons

- About 1/2 million
- Deliver commands to peripheral effectors

Interneurons

- About 20 billion
- Interpret, plan, and coordinate signals in and out

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Neural Circuits in CNS

Divergence
- Spreads stimulation to many neurons or neuronal pools in CNS

Convergence
- Brings input from many sources to single neuron

Serial processing
- Moves information in single line

Parallel processing
- Moves same information along several paths simultaneously

Reverberation
- Positive feedback mechanism
- Functions until inhibited

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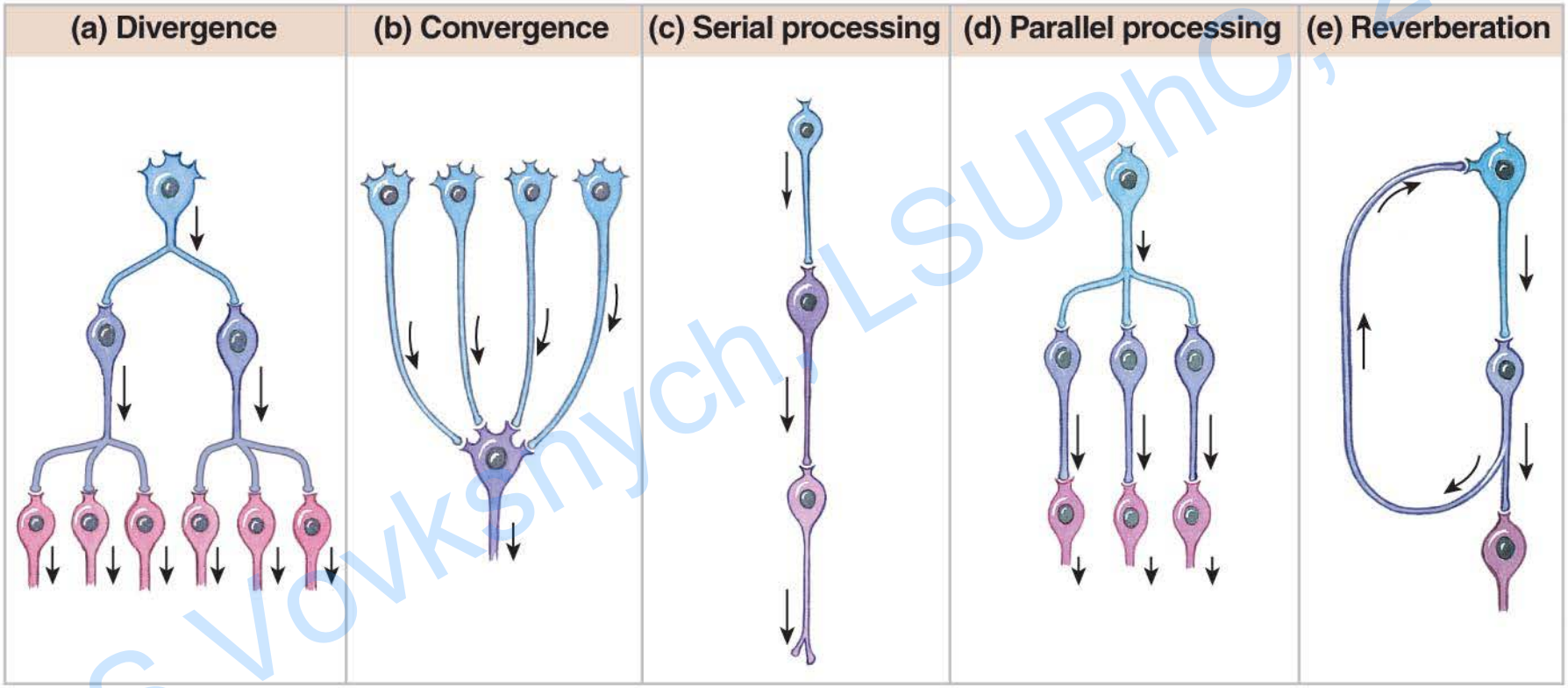
Neural Circuits in CNS



The Organization of Neuronal Pools

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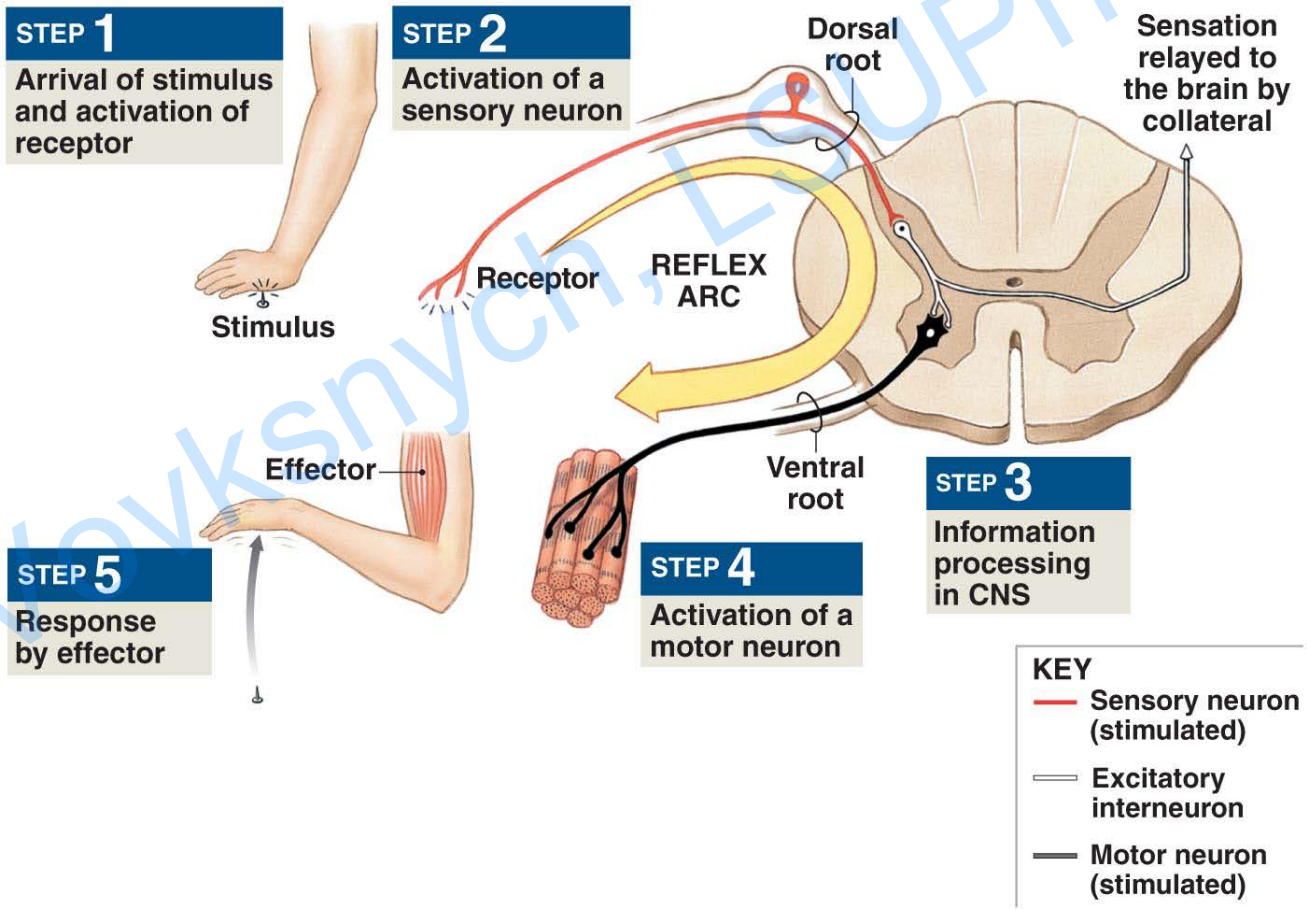
Reflexes

Reflex, or **reflex action**, is an mediated by CNS reaction in response to a stimulus influence



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Reflex Arc

Reflex arc is the nervous pathway for a reflex action

A **simple reflex arc** includes five components:

- **Receptor** - receives the stimulus. When receptor is stimulated, impulses are generated in afferent nerve
- **Afferent** or **sensory nerve** transmits sensory impulses from the receptor (via **sensor neuron** or group of neurons) to center
- **Reflex center** receives the sensory impulses via afferent nerve fibers and in turn, it generates appropriate motor impulses. Center (one neuron or group of **interneurons**) is located in the brain or spinal cord
- **Efferent** or **motor nerve** transmits motor impulses from the center (**efferent neuron**) to the effector organ
- **Effector organ** is the structure such as muscle or gland where the activity occurs in response to stimulus

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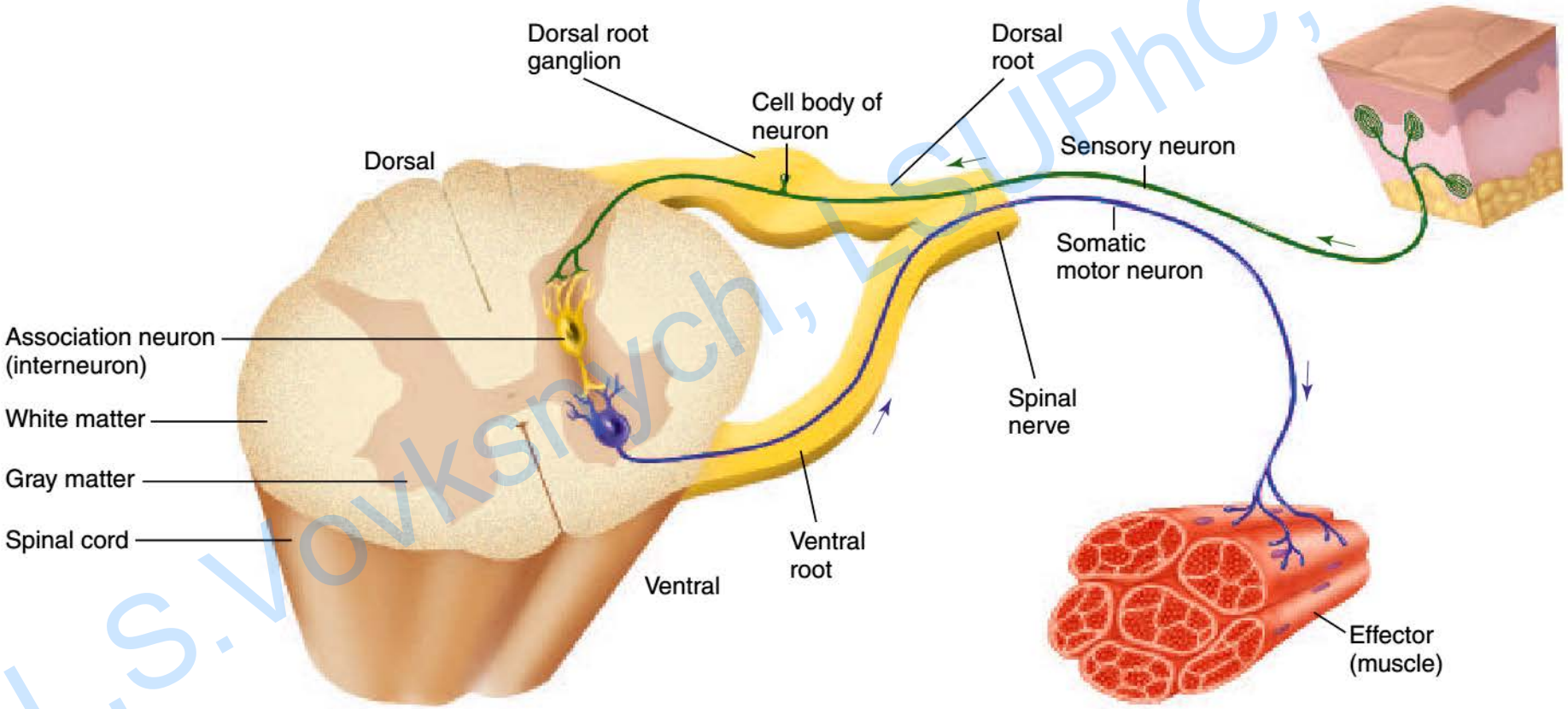
Reflex Arc



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Classification of Reflexes

Reflexes are classified by some different methods

- How reflex was **developed**
- Where the **reflex center** is localized
- What is the **functional significance** of the reflex
- How many **synapses** are in the reflex arc
- What is the **response**
- Where the receptors are **localized**

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Classification of Reflexes

Development

- **Inborn** (**Innate)** reflexes - **unconditioned** reflexes are the natural reflexes, which are present since the time of birth
- **Conditioned** or **acquired** reflexes are the reflexes that are developed after conditioning or training

Reflex center localization

- **Spinal** reflexes - having their center in the spinal cord
- **Bulbar** or **medullary** reflexes - have their center in medulla oblongata
- **Midbrain** reflexes - have their center in **midbrain.**
- **Cortical** reflexes - have their center in cerebral cortex

Functional Significance

- **Protective** reflexes
- **Postural** reflexes
- **Digestive** reflexes etc.

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Classification of Reflexes

Number of Synapses

- Monosynaptic reflexes - only one synapse in the reflex arc
- Polysynaptic reflexes - more than one synapse in the reflex arc

Response

- **Somatic** reflexes are the reflexes, for which the reflex arc is formed by somatic nerve fibers (involve the participation of skeletal muscles).
- **Visceral** or **autonomic** reflexes are the reflexes, for which at least a part of reflex arc is formed by autonomic nerve fibers. Involve the smooth and cardiac muscles, glands

Receptors localization

- **Superficial** reflexes are the reflexes, which are elicited from the surface of the body (mucus membrane reflexes and skin reflexes)
- **Deep** reflexes are elicited from deeper structures beneath the skin like tendon
- **Visceral** reflexes are the reflexes arising from visceral organs

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Functions of Spinal Cord

White matter – **conductive** function

- **Short tracts (pathways)**- connect different parts of spinal cord itself
- **Long tracts** (**projection tracts) -** connect the spinal cord with other parts of CNS
  - **Ascending tracts**, which carry sensory impulses from the spinal cord to brain
  - **Descending** tracts, which carry motor impulses from brain to the spinal cord
-

Gray matter – **reflex** function

- **Monosynaptic** reflexes
- **Polysynaptic** reflexes
- **Intersegmental** reflexes

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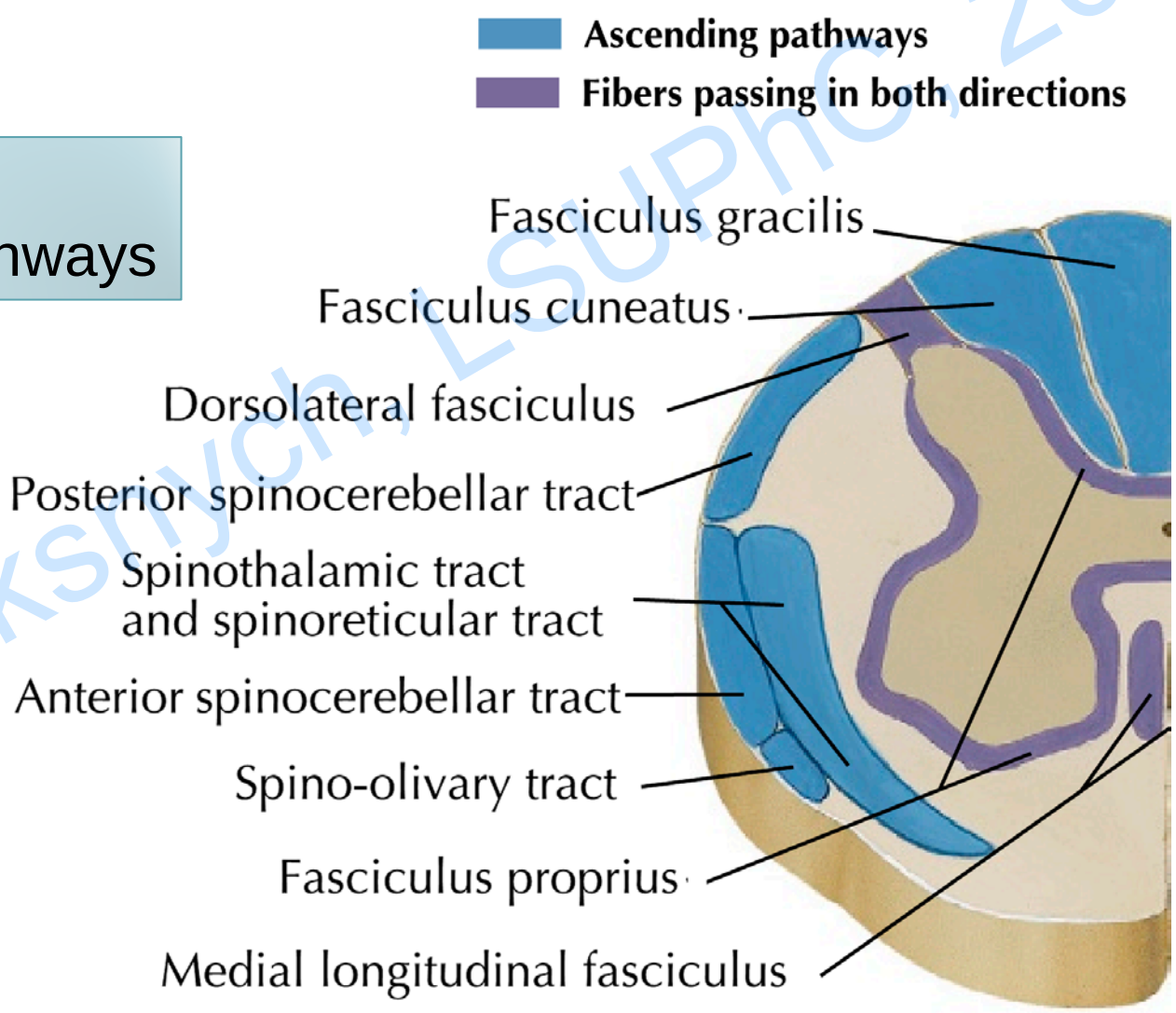
Long Tracts (Pathways)

The main Ascending Pathways



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Ascending Tracts of Spinal Cord

Column	Tract	Origin	Coarse	Termination	Function
Posterior white column	Fasciculus gracilis	Posterior ganglion	Uncrossed fibers No synapse in spinal cord	Nucleus gracilis in Medulla oblongata	Tactile sensation Vibratory sensation Conscious kinesthetic sensation
	Fasciculus cuneatus	Posterior ganglion	Uncrossed fibers No synapse in spinal cord	Nucleus gracilis in Medulla oblongata	

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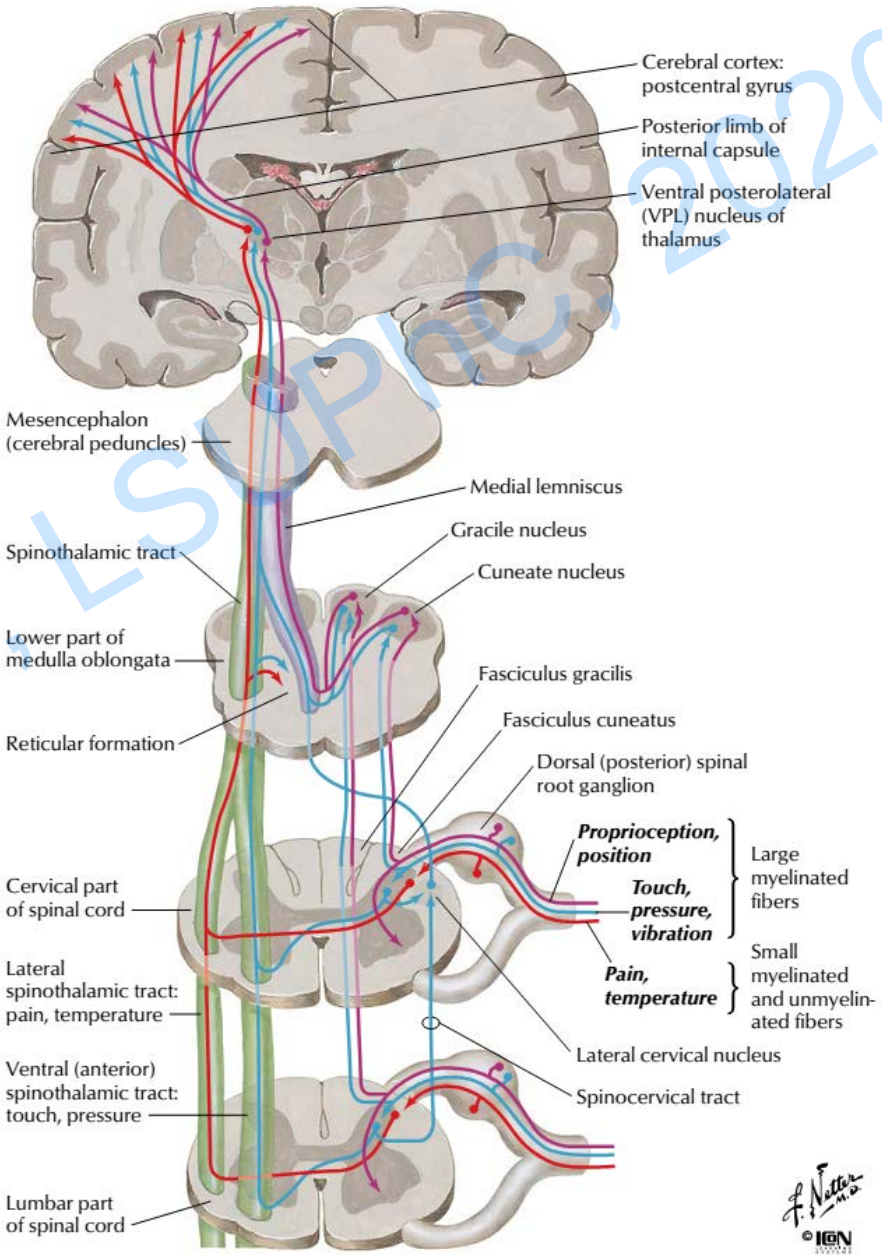
Ascending Tracts

Fasciculus gracilis
Fasciculus cuneatus
Spinothalamic tracts



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Ascending Tracts of Spinal Cord

Column	Tract	Origin	Coarse	Termination	Function
Lateral and Anterior	Anterior spinothalamic tract	Chief sensory nucleus	Crossing in spinal cord Forms spinal lemniscus	Ventral postero-lateral nucleus of thalamus	Crude touch sensation
	Lateral spinothalamic tract	Substantia gelatinosa			Pain and temperature sensation
	Ventral spinocerebellar tract	Marginal nucleus	Crossing in spinal cord	Anterior lobe of cerebellum	Sub-conscious kinesthetic sensations
	Dorsal spinocerebellar tract	Clarke nucleus	Uncrossed fibers		
	Spino-olivary tract	Non-specific	Uncrossed fibers	Olivary nucleus	Proprio-ception

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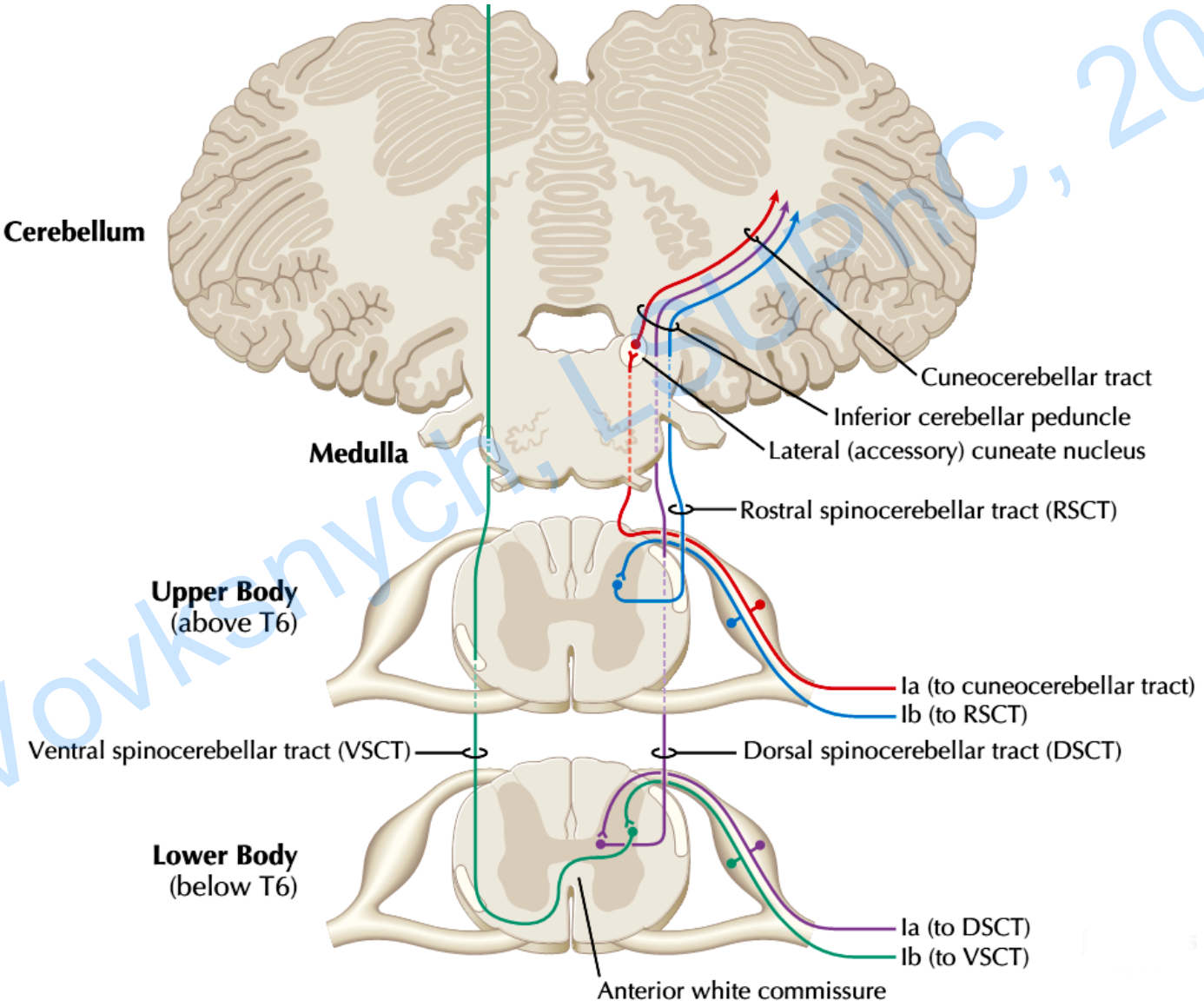
Spinocerebellar tracts



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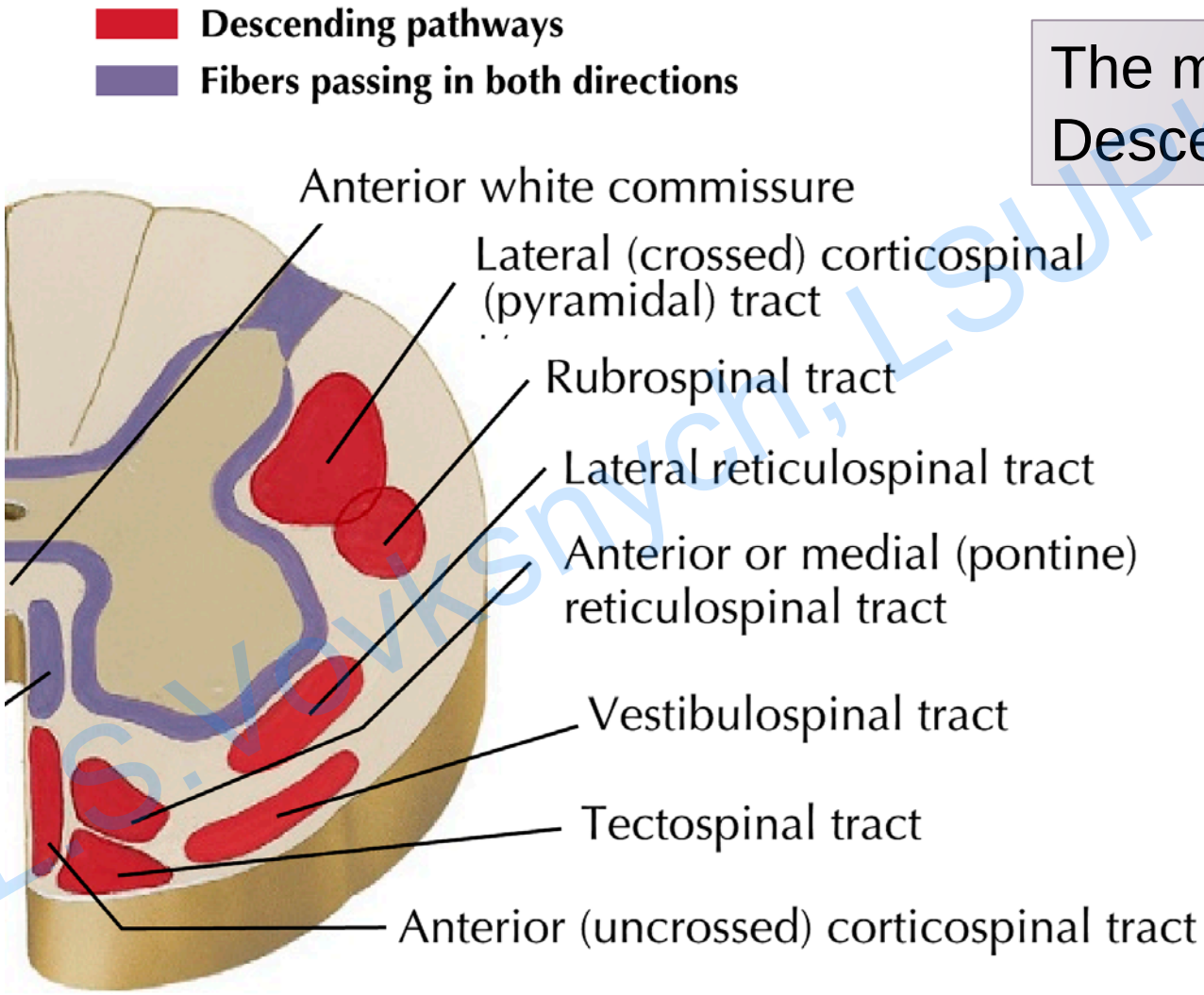
Long Tracts (Pathways)



The main Descending Pathways

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Pyramidal Tracts

Tract	Origin	Coarse	Termination	Function
Anterior corticospinal tract	Betz cells and other cells of motor area	Anterior white column Uncrossed fibers	Motoneurons	Control of voluntary movements
Lateral corticospinal tract		Lateral white column Crossed fibers	Motoneurons	

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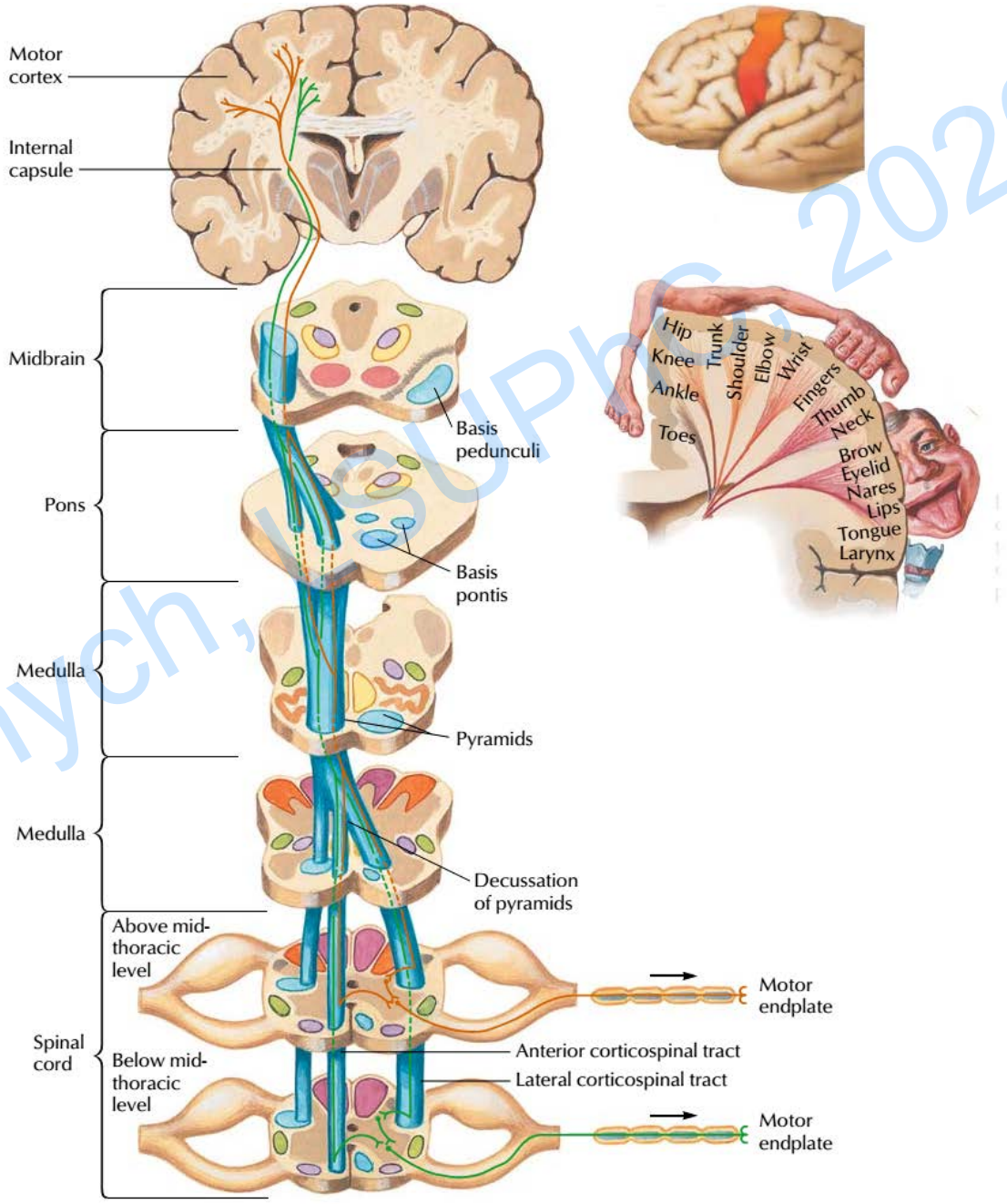
Pyramidal Tracts



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Extrapyramidal Tracts

Tract	Origin	Coarse	Function
Vestibulospinal tracts	Medial and lateral vestibular nucleus	Anterior and lateral white column Uncrossed fibers	Maintenance of muscle tone and posture
Reticulospinal tract	Reticular formation of pons and medulla	Lateral white Fasciculus Mostly uncrossed	Coordination of movements and muscle tone
Tectospinal tract	Superior colliculus	Anterior white column Crossed fibers	Control of movement of head in response to visual and auditory impulses
Rubrospinal tract	Red nucleus	Lateral white column Crossed fibers	Maintenance of muscle tone

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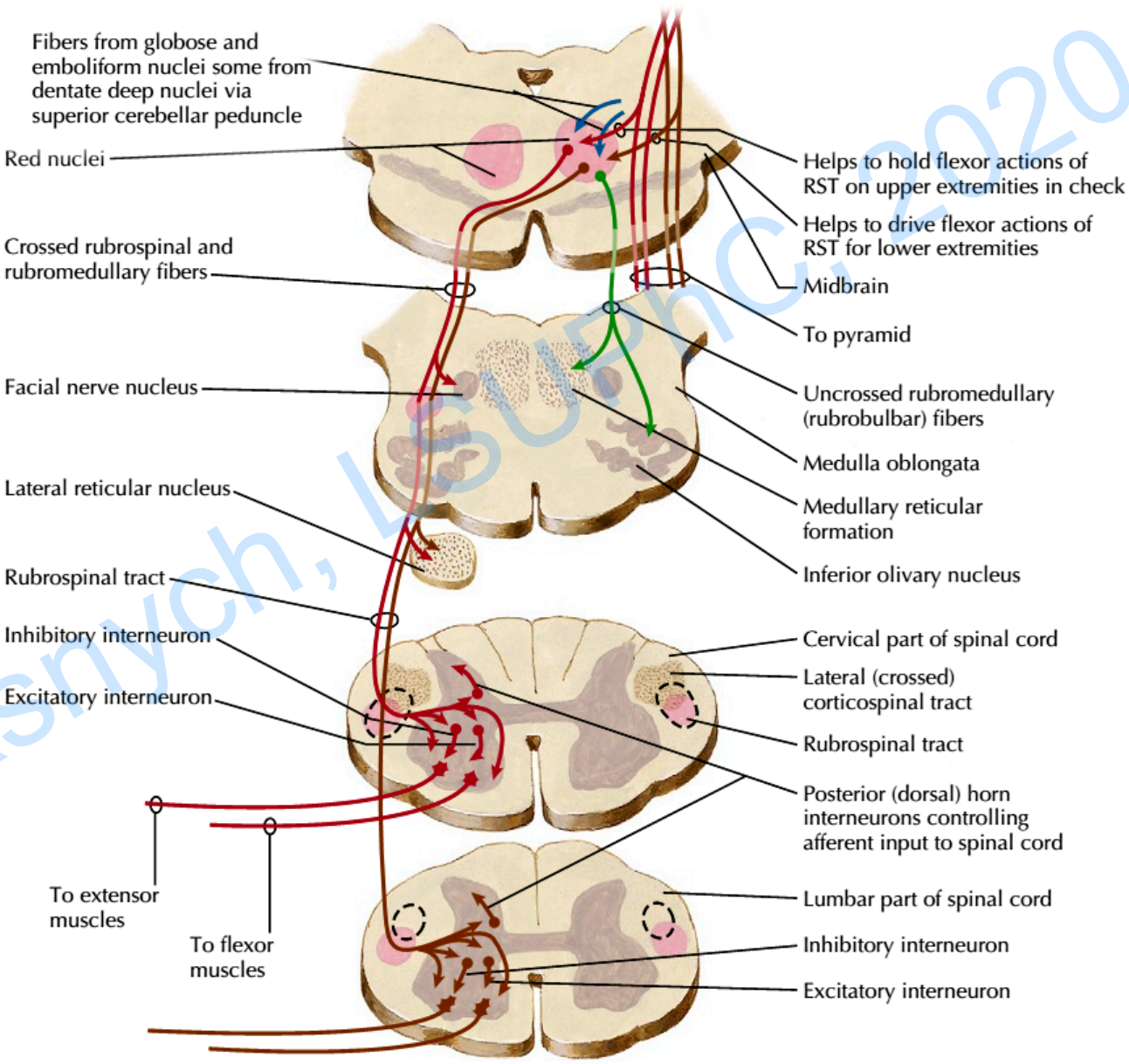
Rubrospinal tract



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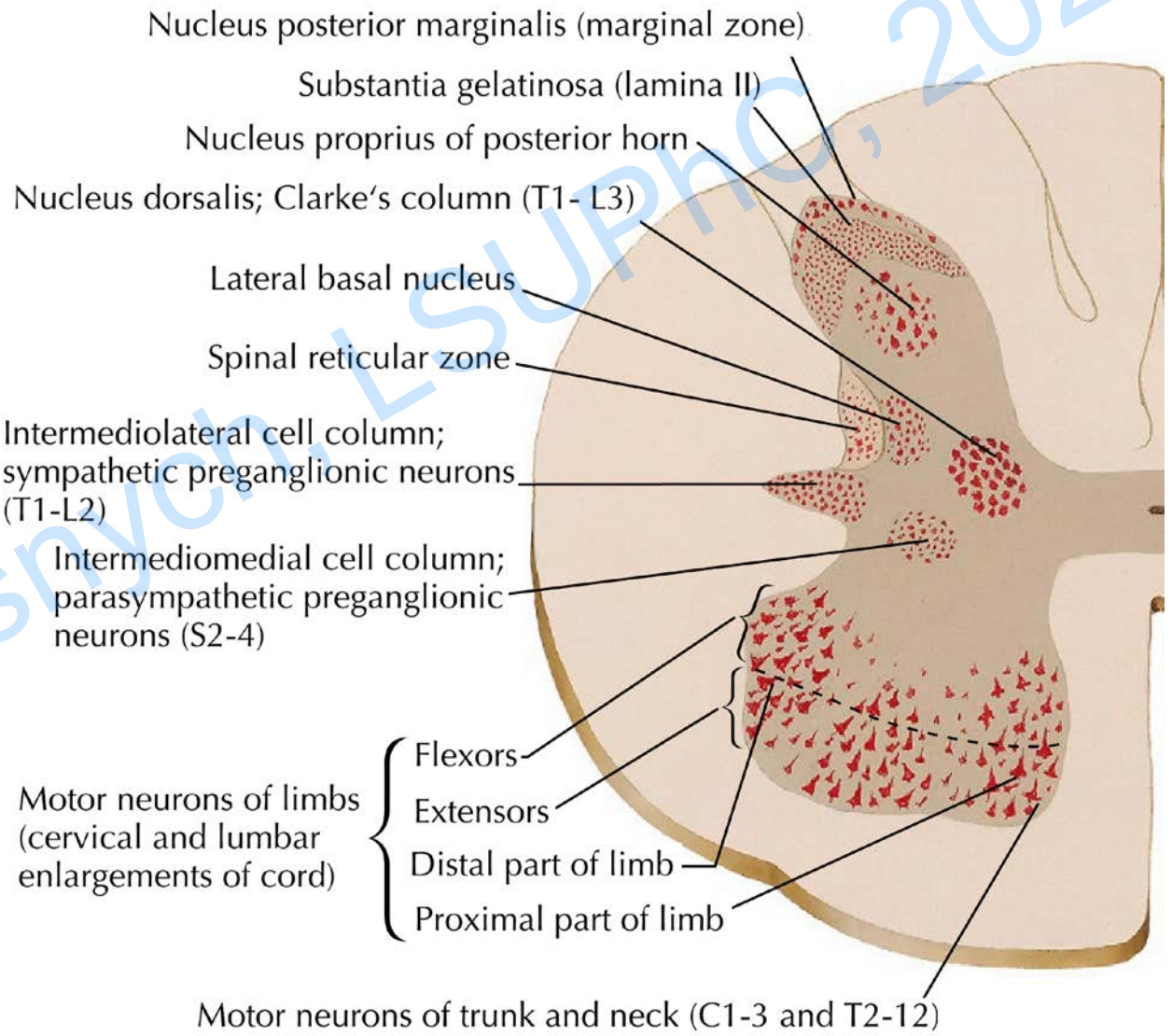
Grey Matter of Spinal Cord

Reflexes

- **Visceral (ANS)**
- **Motor (SNS)**

Three types of **motor** neurons in anterior grey horn:

- **Alpha motor neurons**
- **Gamma motor neurons**
- **Renshaw cells** - inhibitory neurons



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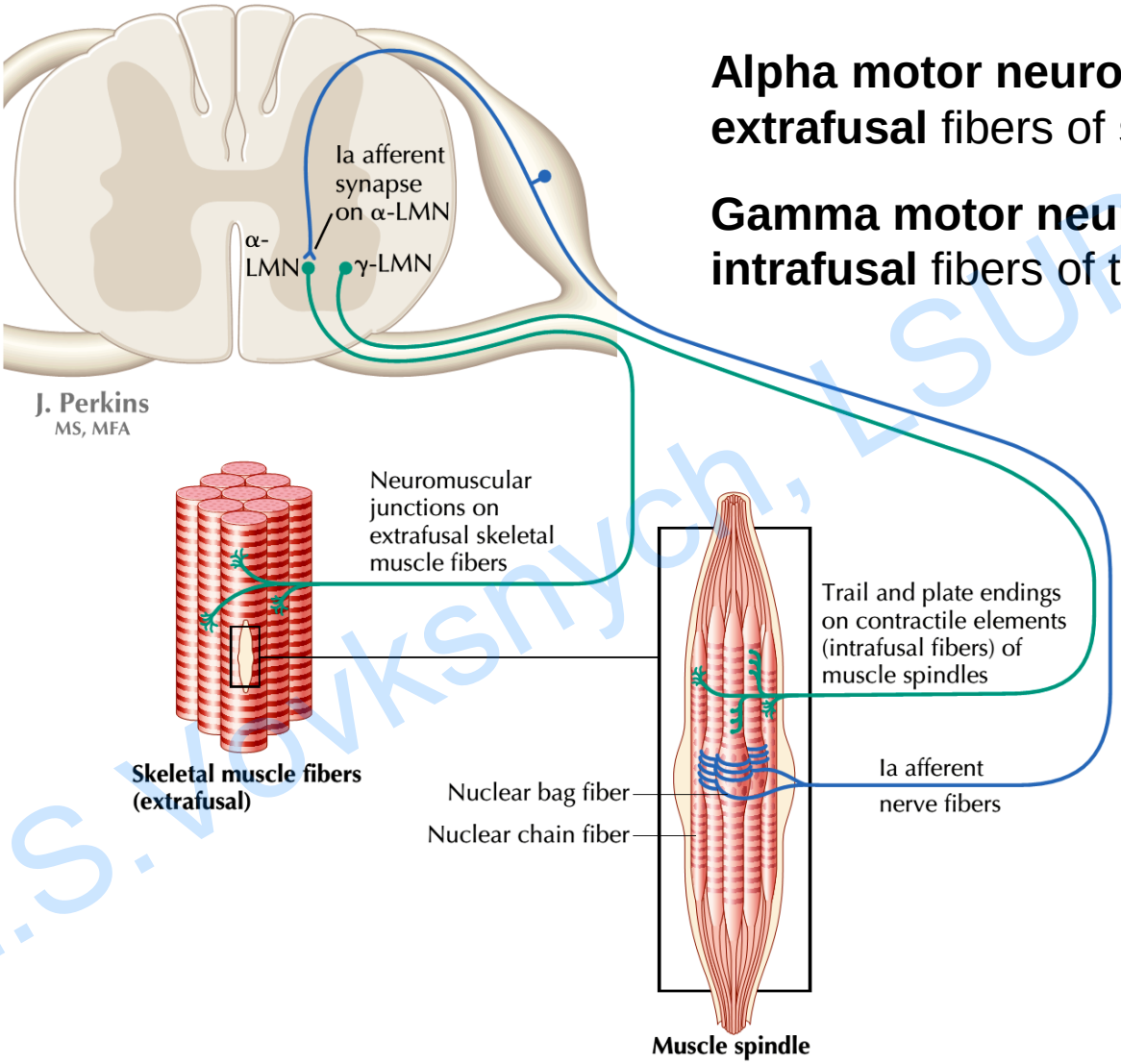
Motoneurons of Spinal Cord



Alpha motor neurons – innervate **extrafusal** fibers of **skeletal muscles**

Gamma motor neurons send axons to **intrafusal** fibers of the **muscle spindle**

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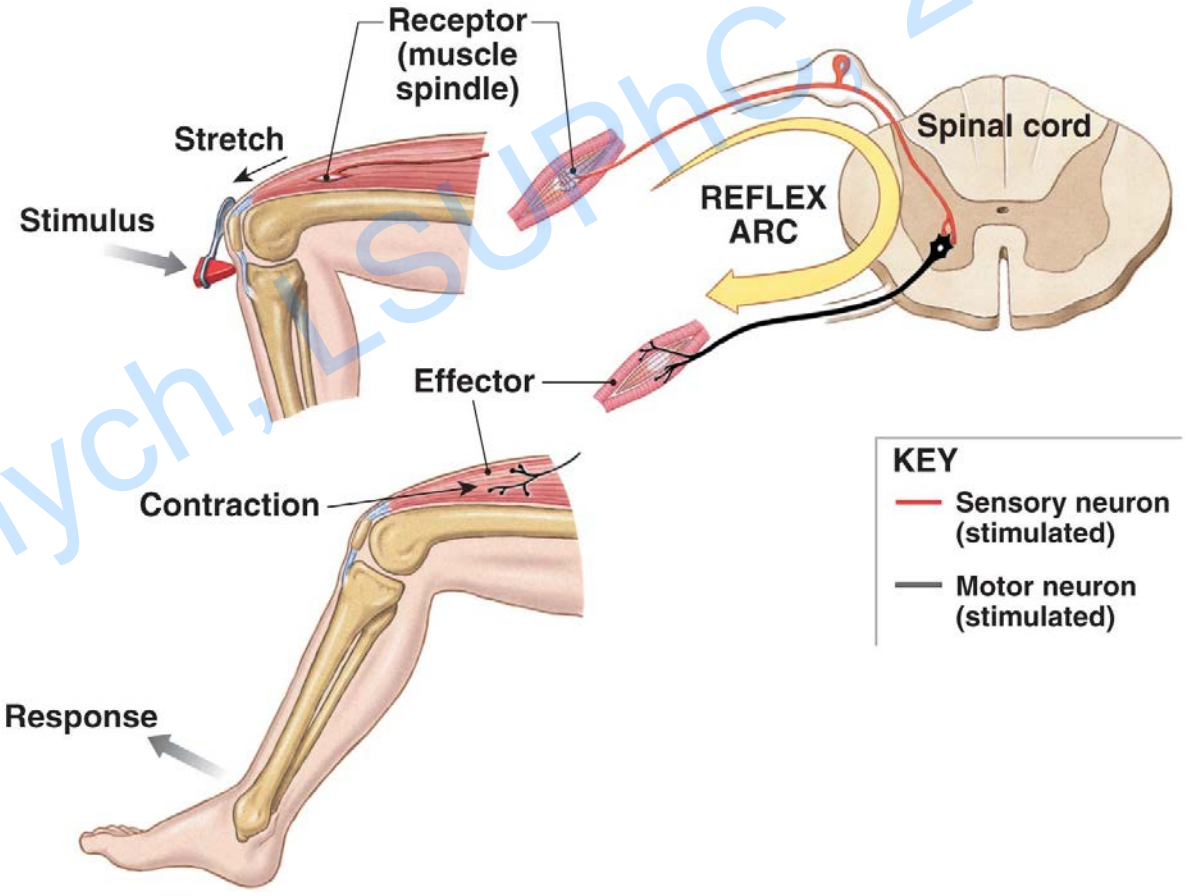
Stretch Reflex

- **Monosynaptic**
- Completed in 20–40 msec
- Receptor is muscle spindle
- Stretched muscle responds by contracting
- Maintain the muscle length (posture)



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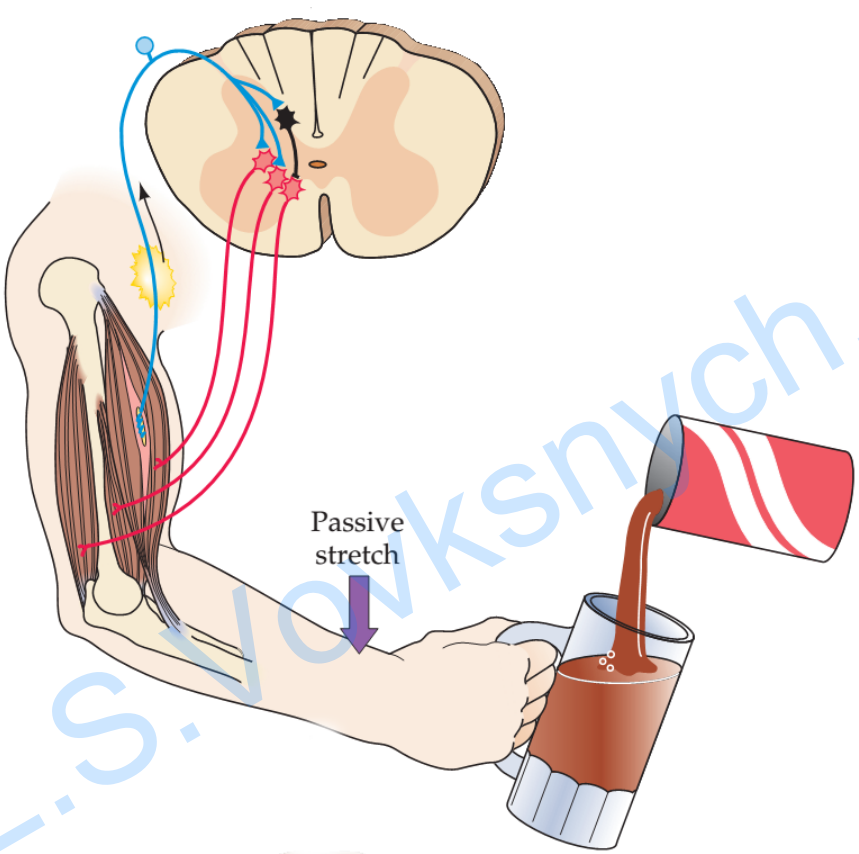
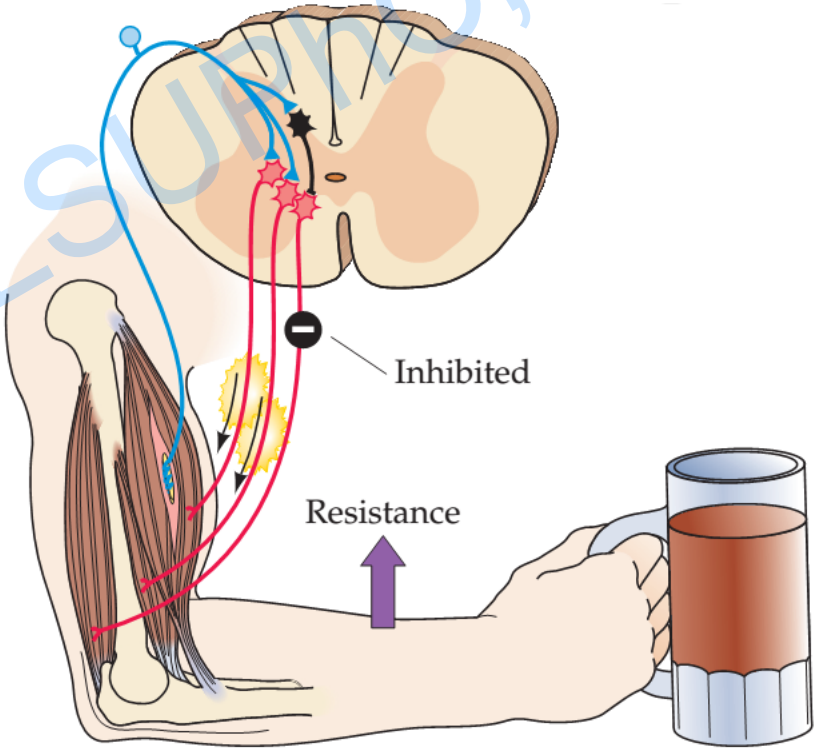
Stretch Reflex





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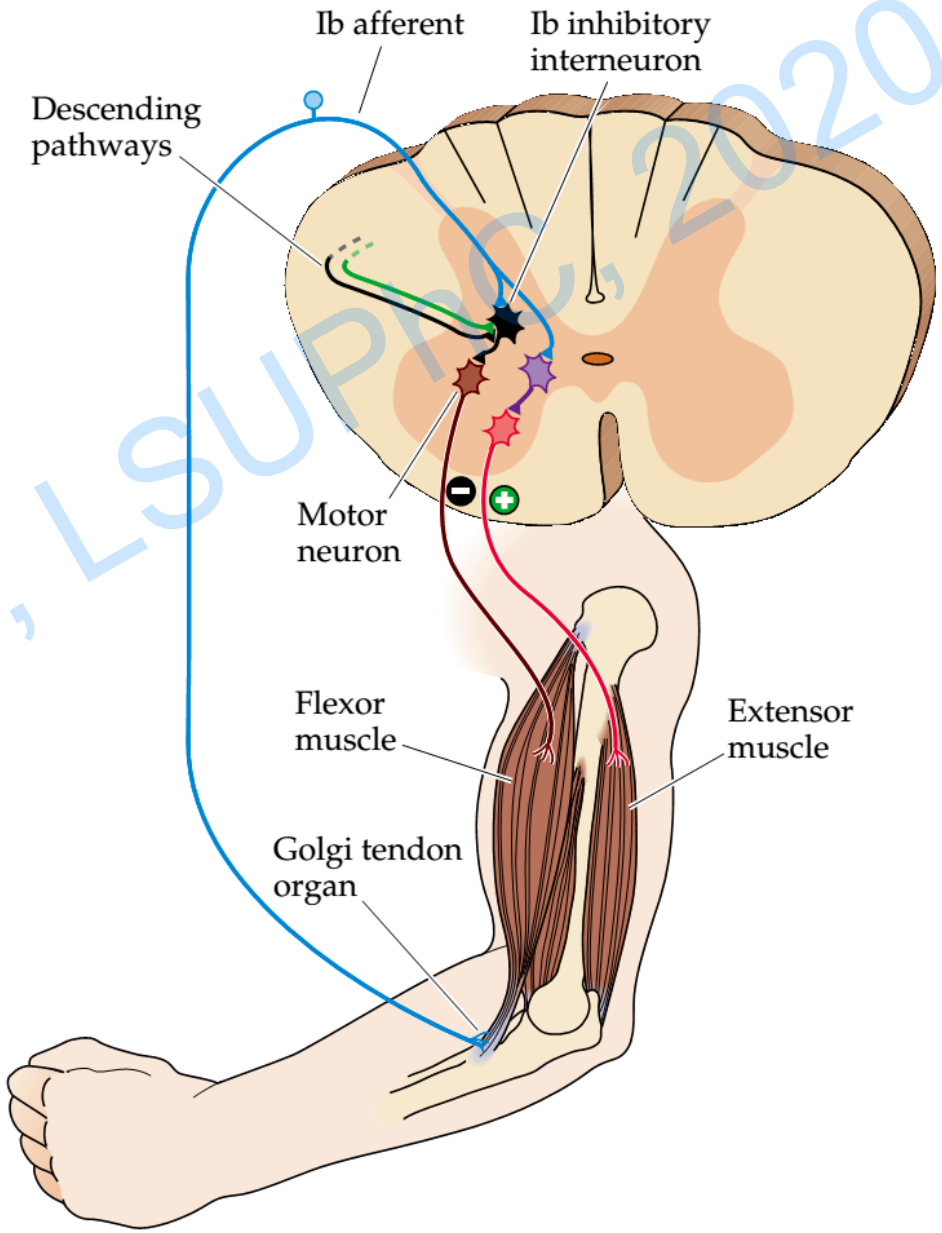
The Tendon Reflex

- **Polysynaptic**
- Prevents skeletal muscles from developing too much tension and tearing or breaking tendons
- The Ib afferents from tendon organs contact inhibitory interneurons that decrease the activity of α motor neurons innervating the same muscle.



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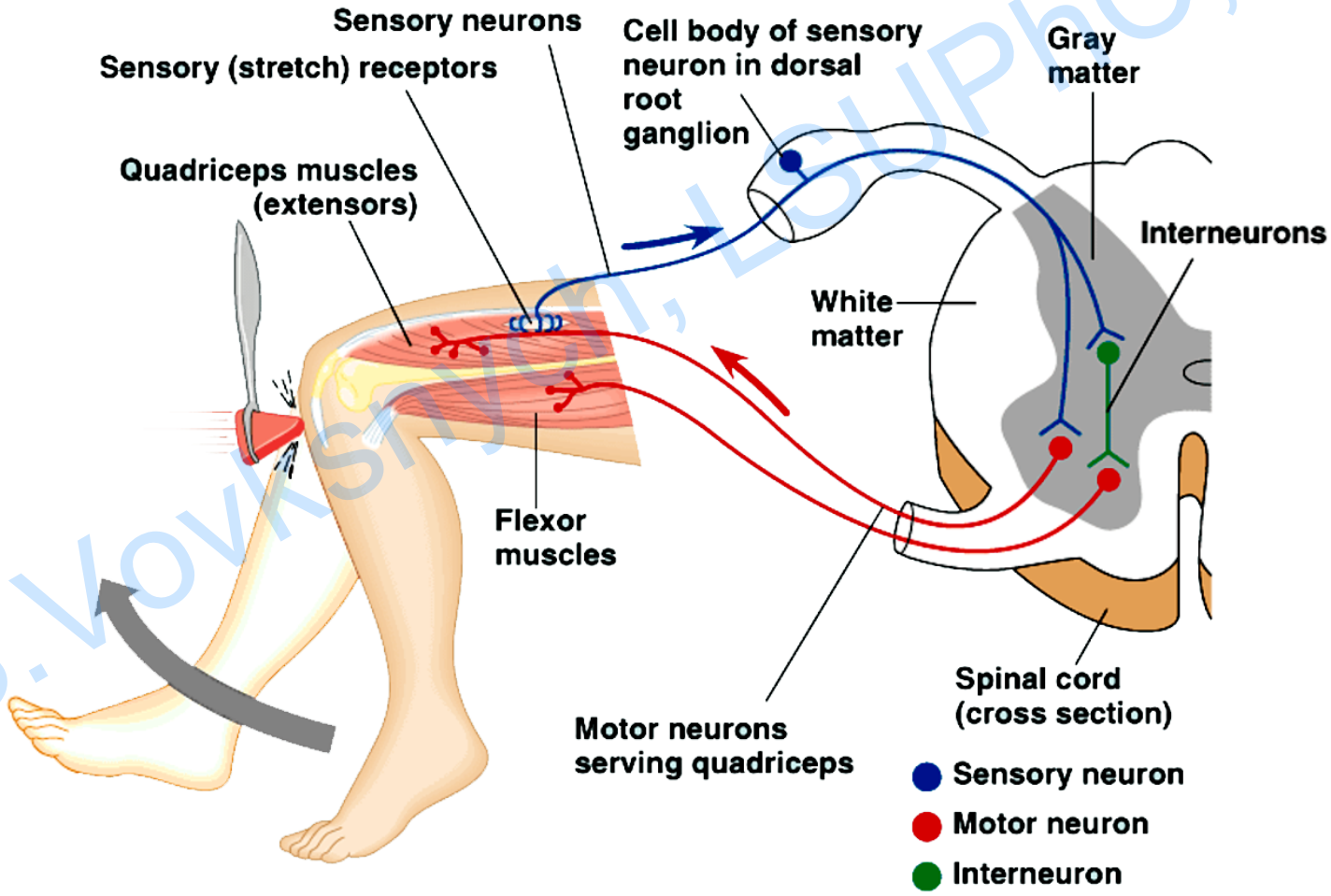
Reciprocal Inhibition

The stretch reflex of antagonistic (extensor) muscle must be inhibited (reciprocal inhibition) by interneurons in spinal cord



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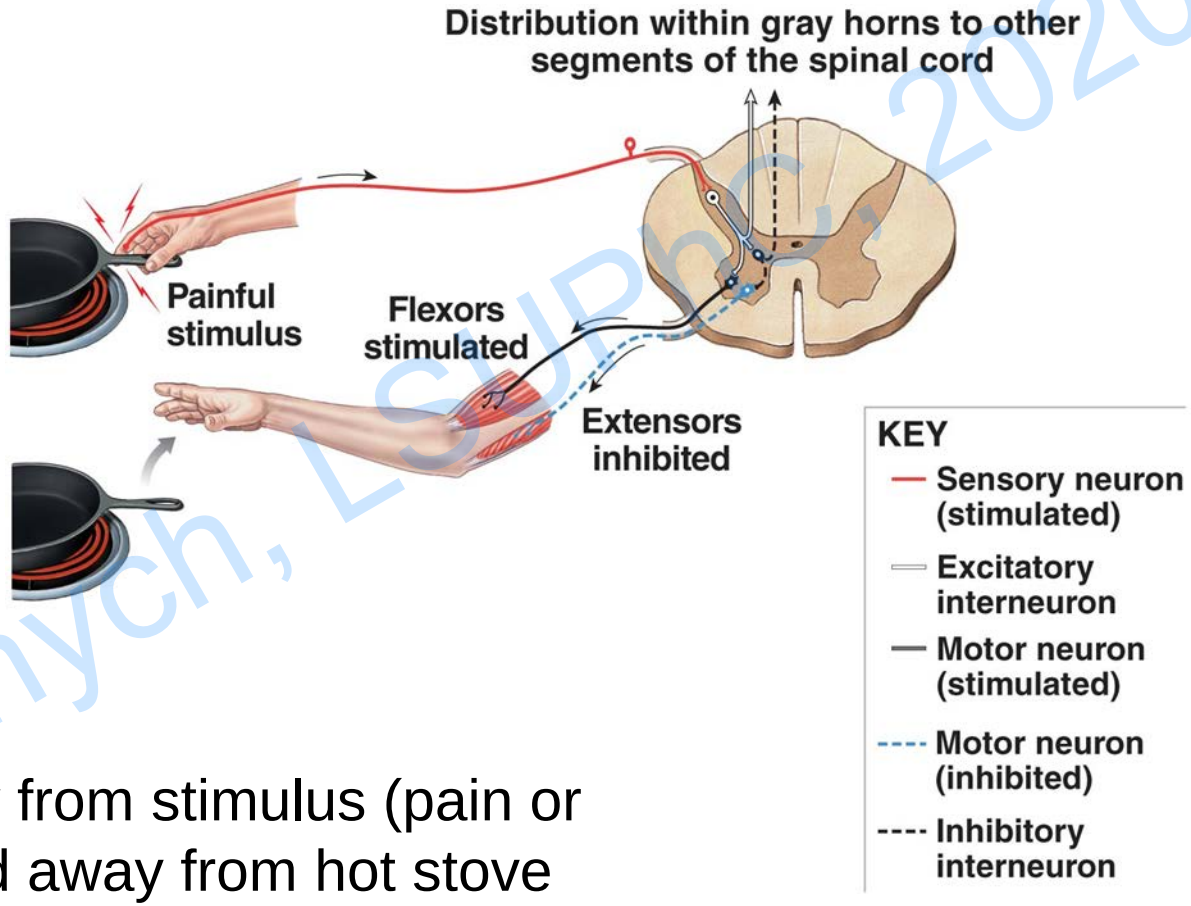
Withdrawal Reflexes



- **Polysynaptic**
- Move body part away from stimulus (pain or pressure) - pulls hand away from hot stove
- Strength and extent of response depends on intensity and location of stimulus

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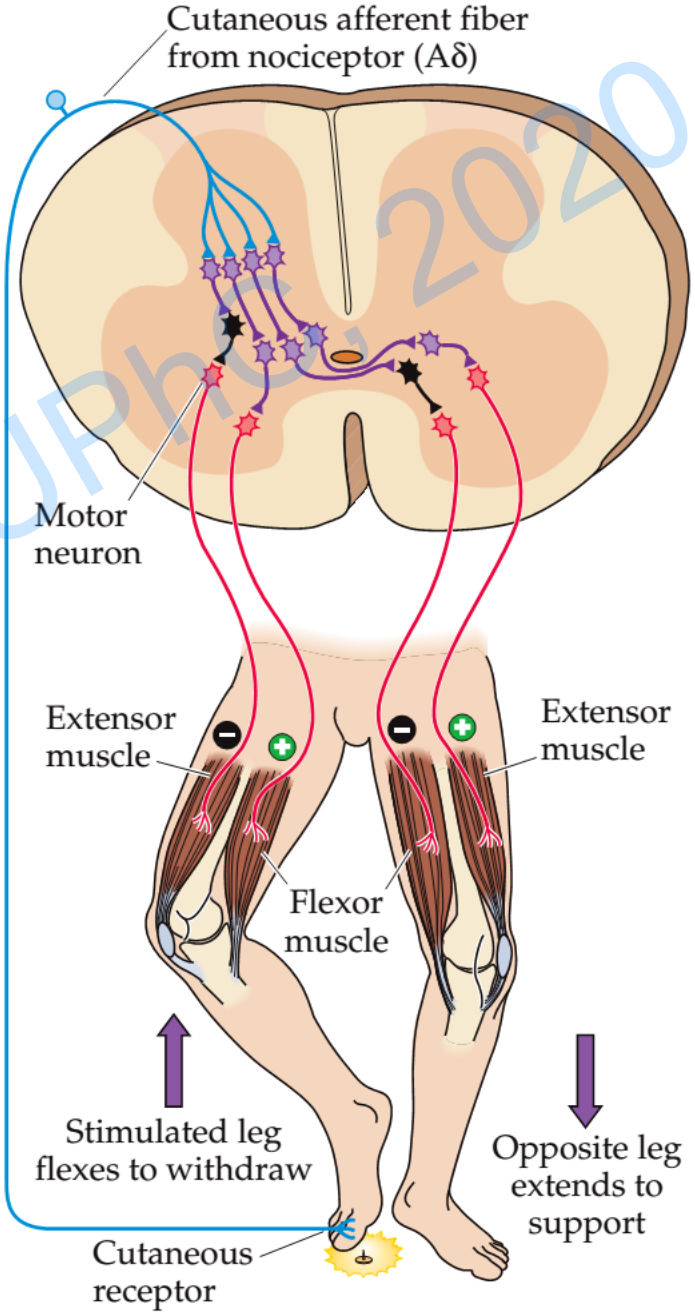
Crossed Extensor Reflex

- Involve a contralateral reflex arc
- Occur on side opposite to stimulus
- Occur simultaneously, coordinated with flexor reflex
- For example, flexor reflex causes leg to pull up, crossed extensor reflex straightens other leg, to receive body weight



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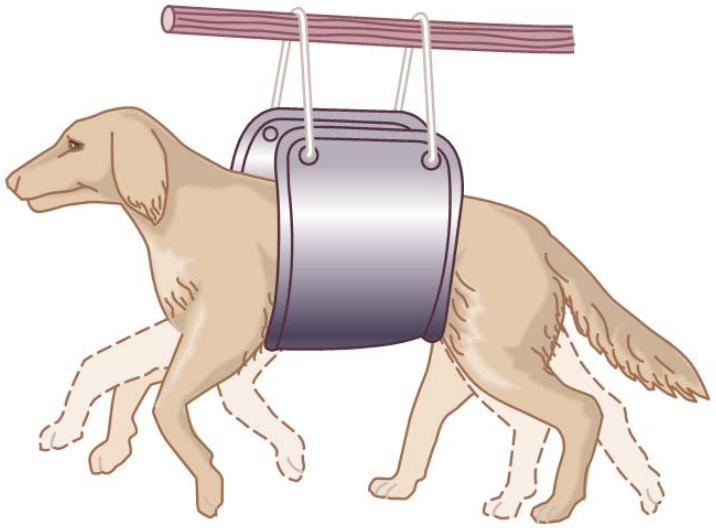
Postural and Locomotive Reflexes of the Spinal Cord

- Positive Supportive Reaction - pressure on the footpad causes the limb to extend against the pressure
- Cord “Righting” Reflexes - incoordinate movements trying to raise itself

  Rhythmical Stepping Movements of a Single Limb.
- Reciprocal Stepping of Opposite Limbs.
- Diagonal Stepping of All Four Limbs
- Galloping Reflex
- Scratch Reflex



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Spinal cord injury

Spinal cord **injury** leads to either temporary or permanent **dysfunction**. Dysfunction of spinal cord occurs because of:

- **Direct injury** due to bullet firing or accidents (on road, in working place, during communal violence, etc.)
- **Compression** by bone fragments, hematoma or disk material
- **Ischemia** due to rupture of spinal arteries

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Spinal cord injury

Dysfunction of spinal cord is classified into four types:

- Complete transection
- Incomplete transection
- Hemisection
- Diseases of spinal cord

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Spinal cord injury

Complete transection causes immediate loss of sensation and voluntary movement below the level of lesion

Then the effects (symptoms) of complete transection of spinal cord start appearing. Effects occur in three stages:

- Stage of **spinal shock** (lasts for about 3 weeks)
- Stage of **reflex activity**
- Stage of **reflex failure**

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Stage of Spinal Shock

- Paralysis of limbs
  - injury at cervical region - paralysis of all the four limbs (quadriplegia or tetraplegia)
  - injury at the other segments - paralysis of lower limbs (paraplegia)
- Loss of reflexes
- Loss of sensations
- Effect on visceral organs (urinary bladder and rectum)
- Heart rate is decreased
- Venous return is very much decreased
- Effect on blood pressure

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Stages of reflex activity and failure

Stage of reflex activity

- First, the functional activities return to smooth muscles
- Next, the sympathetic tone to blood vessels returns
- Lastly, after another 3 months, the tone in skeletal muscle returns (to flexor muscles first), the muscles remain hypotonic, limbs cannot support weight of the body
- Flexor and extensor reflexes appear

Stage of Reflex Failure

- Failure of reflex function develops.
- The reflexes become more difficult to elicit.
- The threshold for stimulus increases.
- The muscles become extremely flaccid and undergo wasting.

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