Stretch Reflex

منعكس الشد

and Golgi Tendon Reflex

منعكس قولجي الوتري

Dr. Taha Sadig Ahmed,

• Objectives

- At the end of this lecture the student should :
- (1) be able to describe a stretch reflex .
- (2) be able to explain what is muscle tone
- (3) describe the structure , innervations and function of the muscle spindle .
- (4) explain what is meant by static and dynamic stretch reflex .
- (5) describe the spinal and supraspinal regulation of the stretch reflex .
- (6) describe the inverse stretch reflex and its function

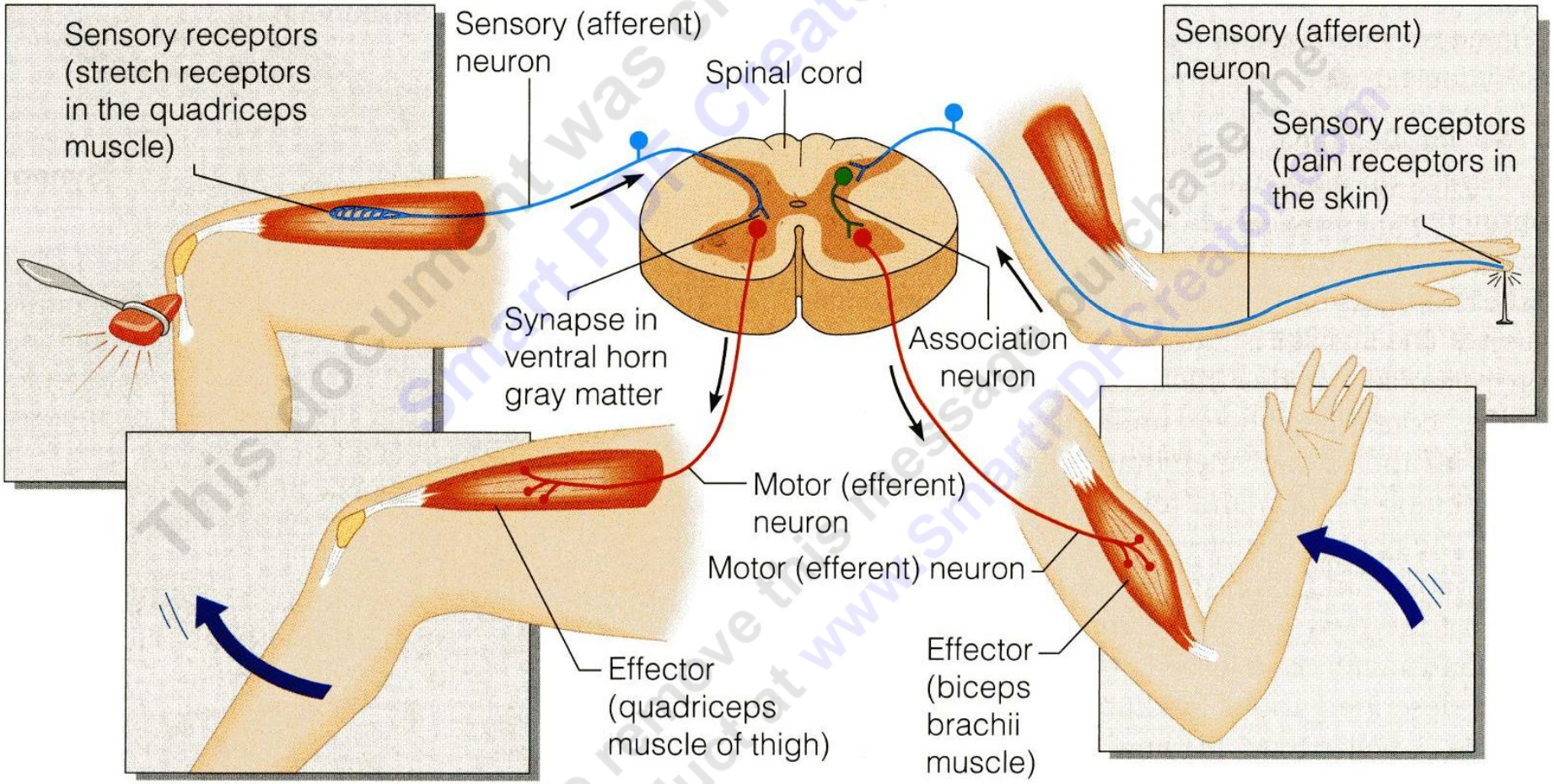
Reference Book

- Ganong's Review of Medical Physiology , 23rd edition . Barrett KE, Barman SM, Boitano S, Brooks HL , edotors . Mc Graw Hill, Boston 2010 .
- Pages 157-165 .

What is the Stretch Reflex ?

- It is reflex contraction of muscle resulting from stimulation of the muscle spindle (which is the receptor that is located inside the muscle & detects changes in muscle length + rate of change in muscle length) .
- Elicitation of the reflex is by tapping on the muscle tendon , which leads to stretching of muscle → stimulation of the muscle receptor → spindle afferents excite the alpha motoneuron → muscle contraction .
- In case of dynamic stretch reflex we get a jerk , & in case of static stretch reflex we get a more sustained contraction .

The knee jerk and biceps jerk are two examples of the stretch reflex



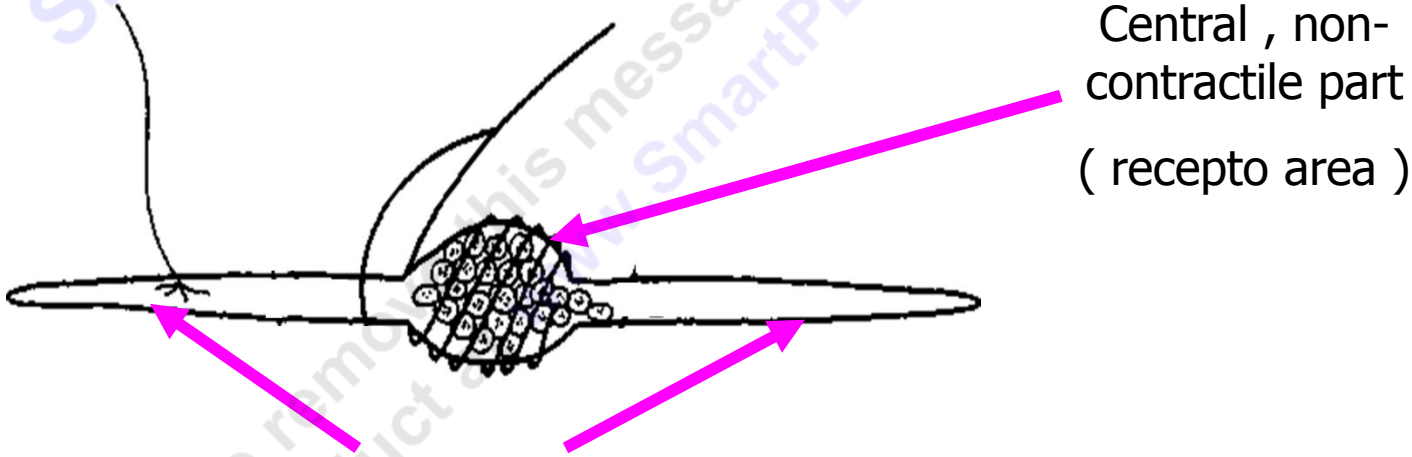
Functions of the Stretch Reflex

- Production & modulation { from moment to moment } of muscle tone .
- Muscle tone is the resistance of muscle to stretch
- It is produced by co-activation of alpha & gamma motoneurons .
- Its degree is regulated & maintained mainly by the tonic { continuous } discharge of gamma efferents .

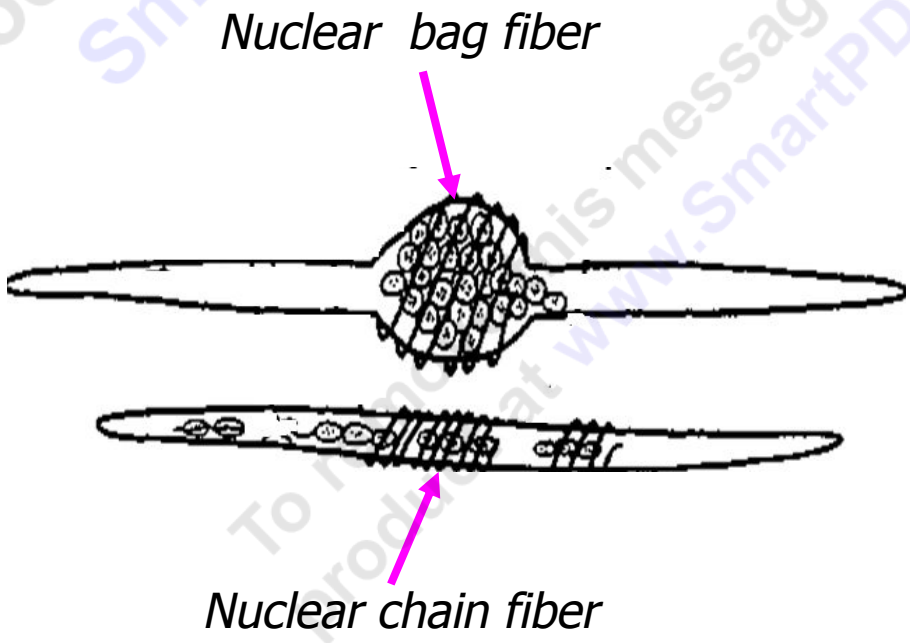
The Muscle Spindle

المغزل العضلي

- Each spindle consists of 3-12 Intrafusal Fibres.
- They lie parallel to the large Extrafusal Fibres (which constitute the muscle bulk) and are attached to them or to the tendon.
- Each intrafusal fibre consists of :
- (1) Central non-contractile area (receptor area),
- (2) Peripheral contractile parts on either side of the central receptor area



- There are two types of intrafusal fibers:
  - Nuclear bag fibers : contain many nuclei in a dilated central area (" bag ") . Typically there are 2 nuclear bag fibers per spindle .
  - Nuclear chain fibers : thinner and shorter than nuclear bag fibers , and have one line of nuclei spread in a chain along the receptor area . There are 4 – 9 nuclear chain fibers per spindle



Sensory (Afferent) Innervation of the Muscle Spindle

Spindle afferents :

The receptor area of the intrafusal fibers is innervated by 2 types of sensory endings:

A/ Primary (Annulospiral) Endings (Afferents)

(1) Are the terminations of rapidly-conducting group Ia fibers

(2) Encircle the receptor areas of BOTH nuclear bag and nuclear chain fibres (carry information rate of change in length ($^{dL}/_{dt}$)from Nuclear Bag ; & information about absolute change in length (dL) from Nuclear Chain) , because Nuclear Chain can not detect $^{dL/dt}$)

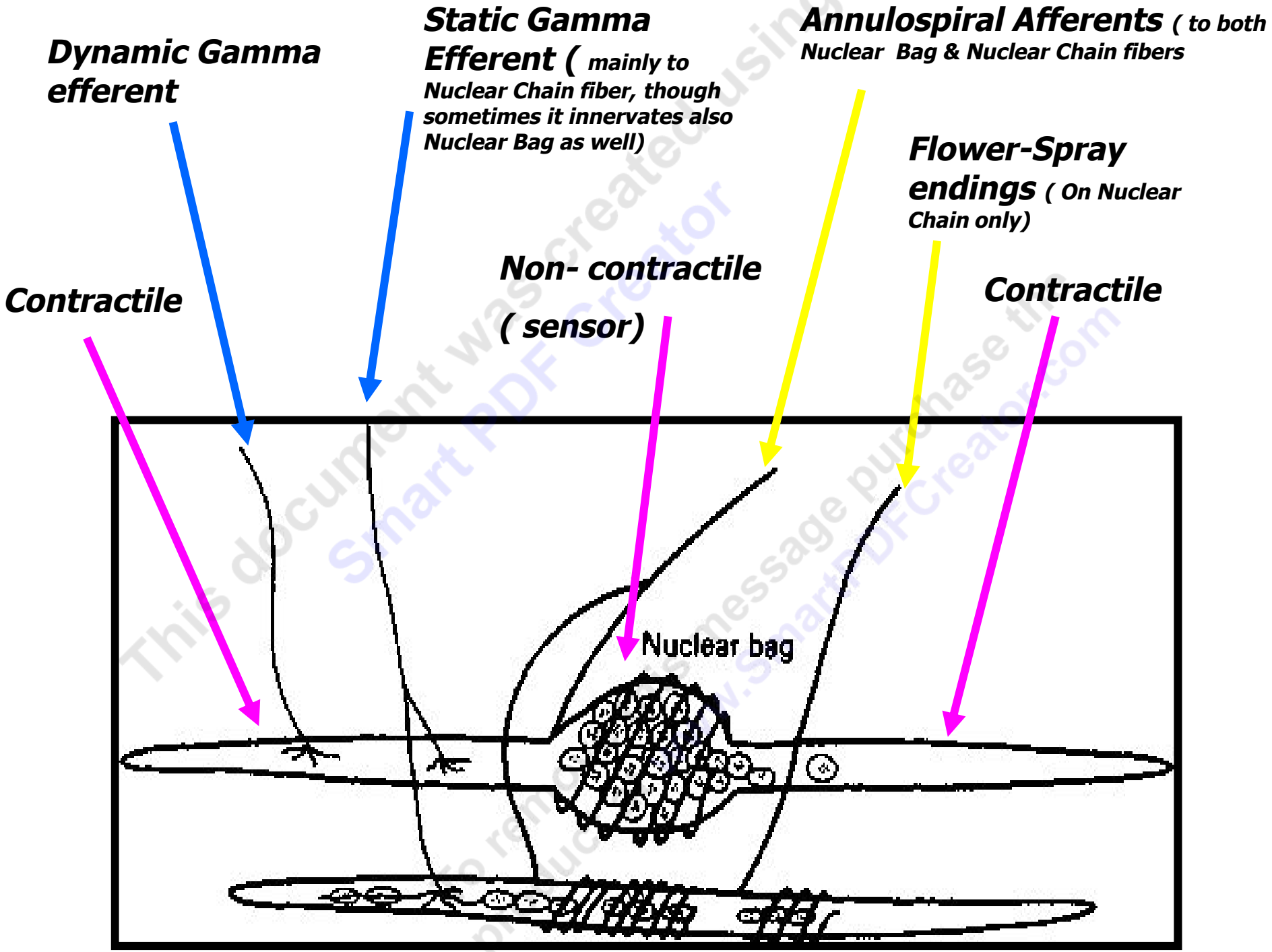
(3) Measure

(i) the rate of change in muscle length (information coming from nuclear bag fibers

- ✓ This response is called the Dynamic response of the receptor (because it is mainly about dL & $^{dL}/_{dt}$)
- ✓ The Dynamic Response occurs mainly when the muscle is suddenly stretched

(ii) the absolute) change in muscle length , dL (information coming from nuclear chain fibers) .

- ✓ This res101010ponse is called the Static Response .
- ✓ The Static Response occurs mainly with maintained muscle stretch


Dynamic Gamma efferent
Static Gamma Efferent (mainly to Nuclear Chain fiber, though sometimes it innervates also Nuclear Bag as well)
Annulospiral Afferents (to both Nuclear Bag & Nuclear Chain fibers
Flower-Spray endings (On Nuclear Chain only)
Contractile
Non- contractile (sensor)
Contractile
Nuclear bag

- ✓ Thus the primary (annulospiral) ending responds (sends afferent impulses to the spinal center of the reflex) both when →

(i) The muscle is suddenly stretched

(Dynamic Response) + also when

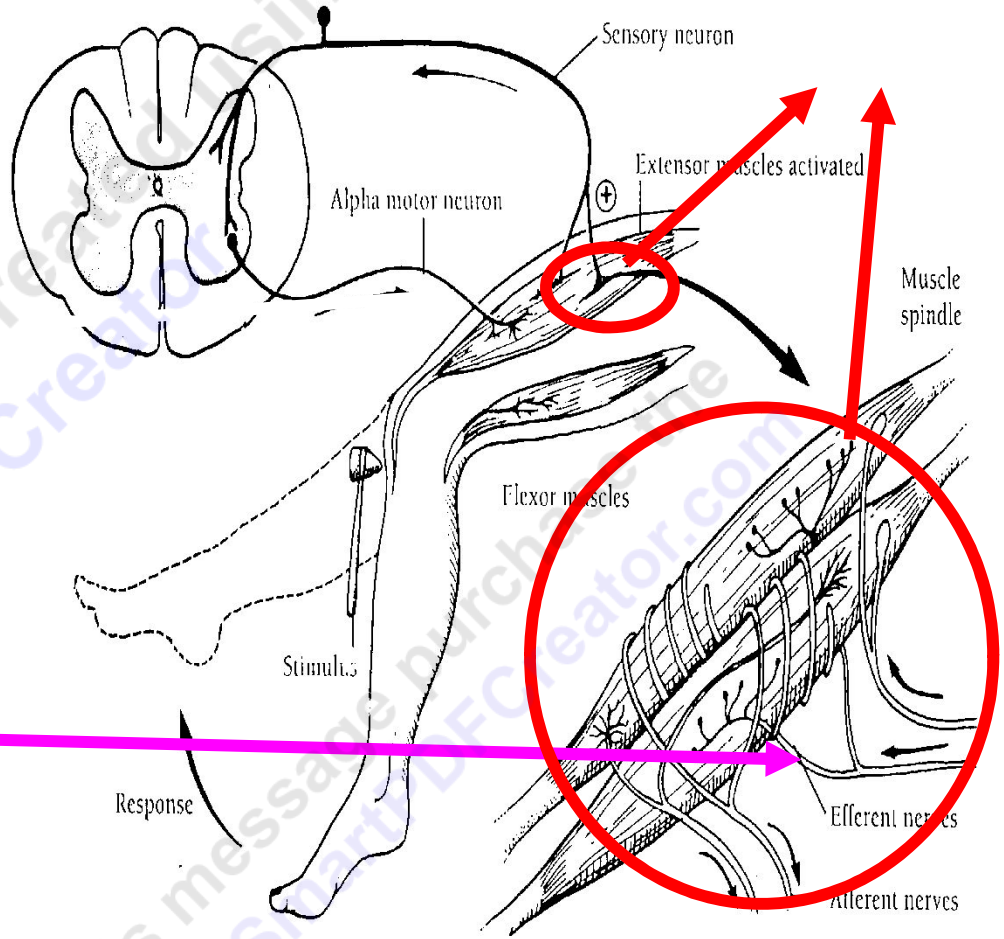
(i) The muscle is subjected to maintained stretch (Static Response)

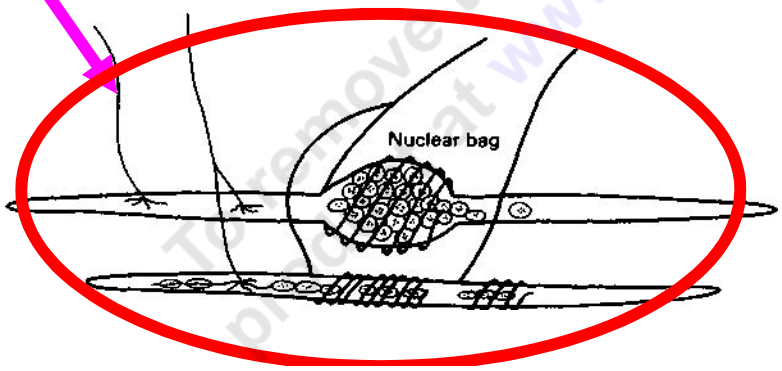
B/ Secondary (Flower-spray) Afferents

- ✓ Innervate ONLY the nuclear chain receptor
- ✓ Discharge at an increased rate throughout the period during which the muscle is being stretched , directly proportion to the degree of stretch (measure only muscle length , Static Response).

Alpha motor neuron to Extrafusal Fibers

Gamma motor neuron to Intrafusal Fibers (inside the muscle spindle)

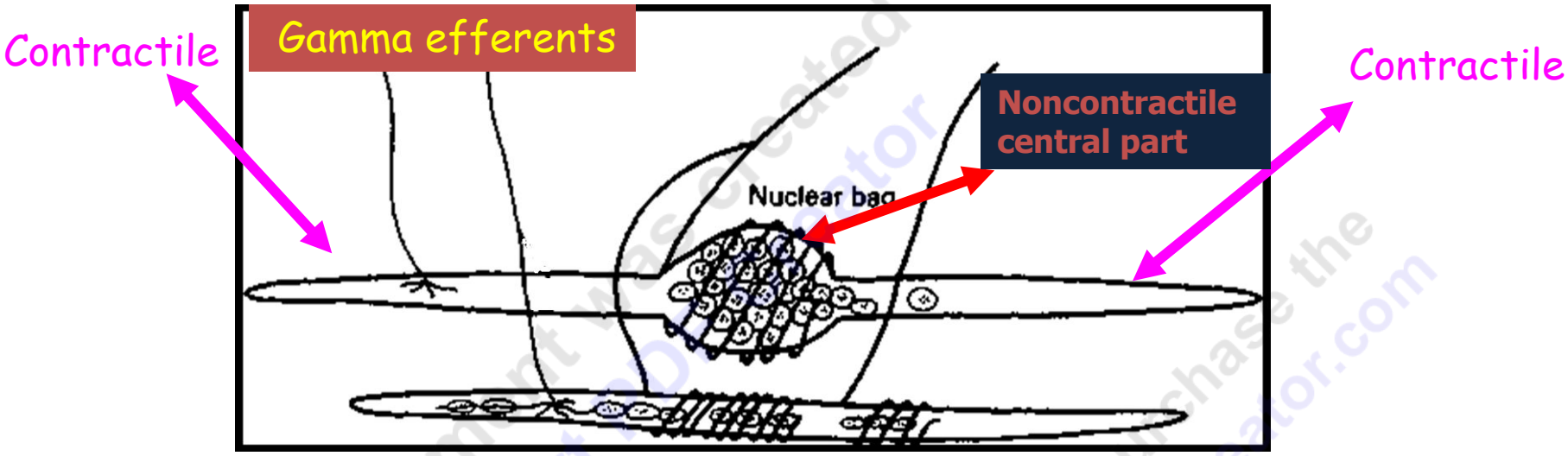




Remember that :

- Nuclear bag fibres are supplied by primary endings only → responsible for the dynamic response (e.g. in case of knee-jerk)
- Nuclear chain fibres are supplied by both primary and secondary endings → responsible mainly for the static response (and to a much lesser extent , dynamic response) .

Motor innervations of the muscle spindle



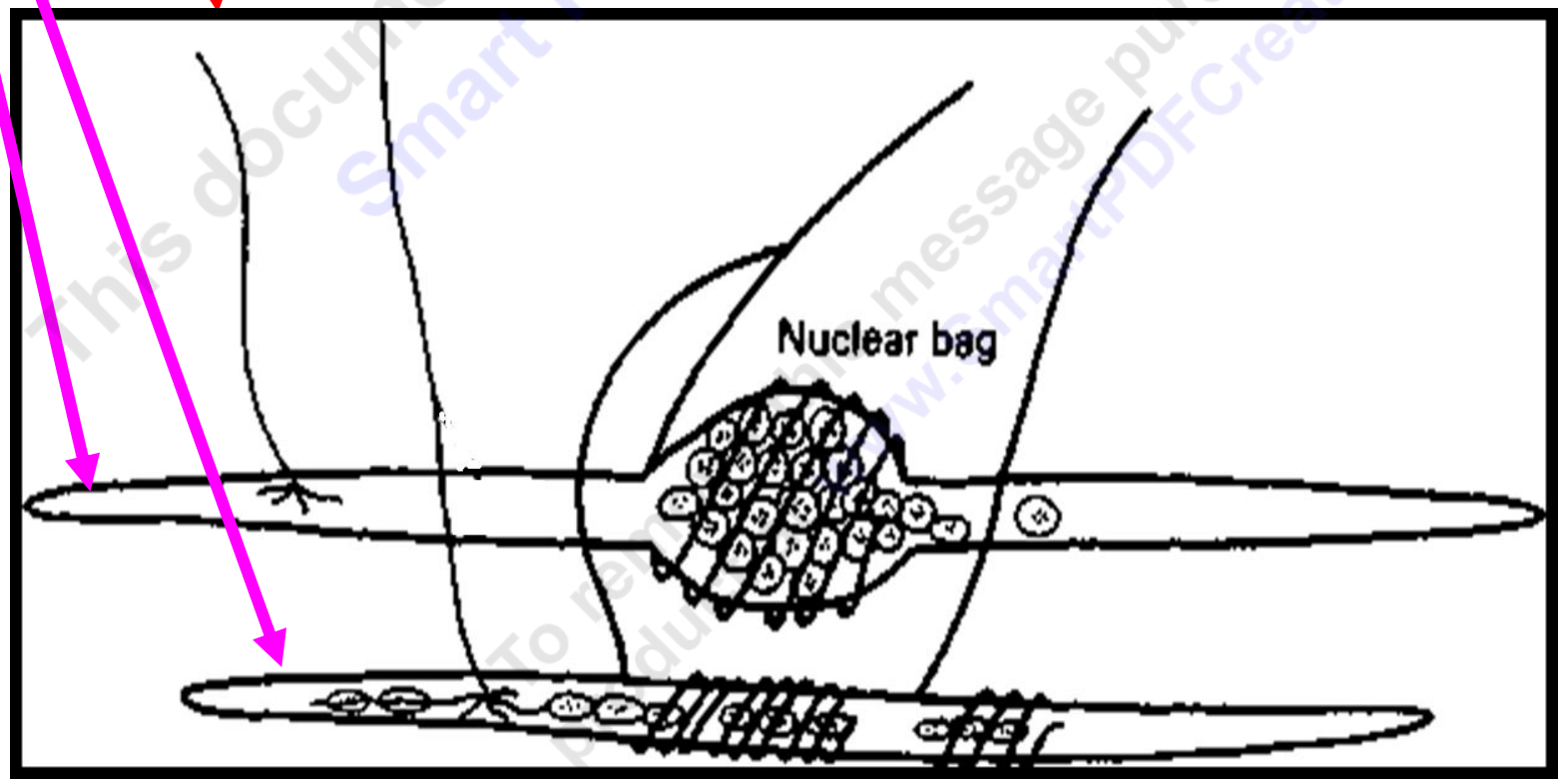
- Whereas motor innervation of extrafusal fibers is by Alpha Motoneurons , motor supply to the Muscle Spindle is by Gamma Efferents (Motoneurons)
- Gamma Efferents cause contraction of the peripheral ends of the intrafusal fiber →leading to stretching & stimulation of the middle , receptor part of the intrafusal fiber
- This leads to action potentials in the spindle afferents (annulospiral & flower-spray) → leading to stimulation of Alpha Motoneuron → contraction of the extrafusal fibers .

Types of Gamma Efferents

Dynamic Gamma efferents
end mainly on the nuclear bag fibres

Static Gamma efferents
end mainly on nuclear chain fibres

Contractile



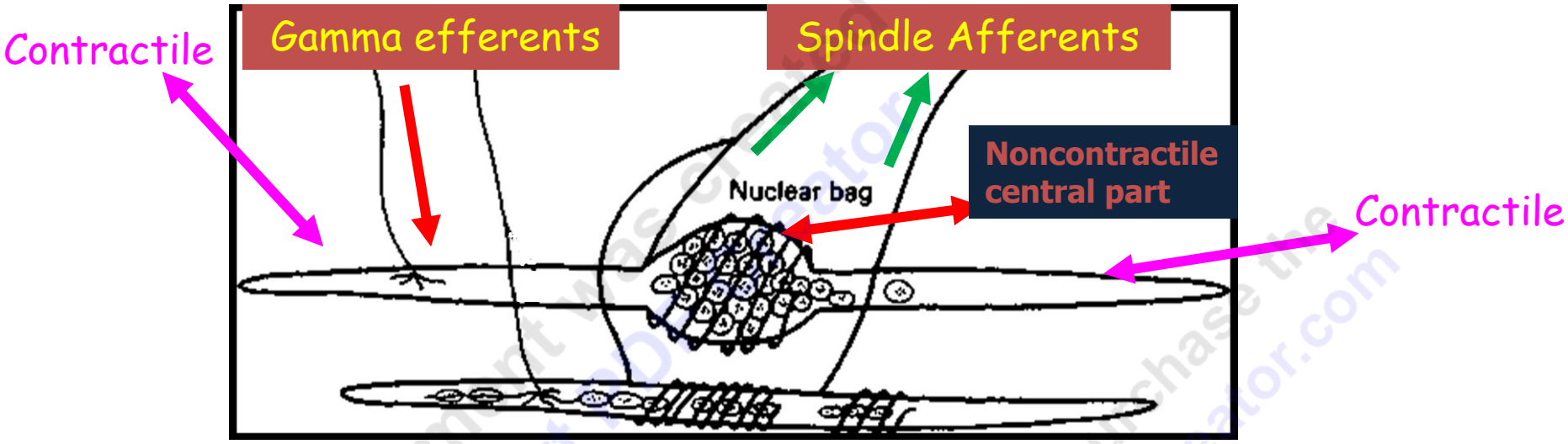
There are 2 mechanisms to stimulate the receptor :

- (I) First mechanism : By stretching the whole muscle , or , alternatively →
- (II) Second mechanism : By stimulating Gamma Efferents (at the same muscle length , without need to stretch the muscle extrafusal fibers)

- (I) First mechanism :

- Stretching the muscle bulk (extrafusal fibers) also stretches the receptor (muscle spindle , because the muscle spindle intrafusal fibers lie in parallel with the extrafusal fibers of the muscle bulk) →
- stretch receptor →
- AP discharges in the spindle afferents (annulospiral or flower-spray) →
- These monosynapse on Alpha Motoneuron , stimulating it →
- APs motor discharges from Alpha Motoneurons to Extrafusal muscle fibers → contraction of muscle bulk .

(II) Second mechanism :



- Gamma efferent discharge →
- cause contraction of peripheral ends of intrafusal fiber →
- stretching the receptor , thereby stimulating it →
- afferent discharges in annulospiral or flower-spray fibers →
- stimulation of Alpha Motoneuron →
- extrafusalmuscle fiber (whole muscle) contraction .

Dynamic stretch reflex

- ✓ Sudden (phasic) rapid stretch of a muscle → causes synchronous متزامن strong burst of excitatory discharges in Annulospiral Afferents to the Alpha Motoneuron →
- ✓ This causes the latter to send strong Synchronous motor excitatory impulses to Extrafusal Fibers →
- ✓ Causesing sudeden , jerky (brief) muscle contraction (jerky movement)
- ✓ As the muscle shortens → the spindle becomes lax → and ceases to discharge → no more stimulation of alpha motoneuron → no more excitatory impulses from alpha motoneuron to the extrafusal fibers → muscle relaxes
  - This is the basis of Tendon Jerks (dynamic stretch reflexes) .

Static stretch reflex

- Maintained (tonic) stretch of muscle →
- Impulses from muscle spindle travel through spindle afferents to alpha motor neuron , stimulating it to produce →
- Asynchronous motor excitatory impulses to Extrafusal Fibers →
- Causing sustained (continuous) contraction of the muscle as long as it is stretched
- The Static Stretch Reflex is the basis of **Muscle Tone**

Higher Control
(Supraspinal Control)
of the Stretch Reflex

(i.e., control on Gamma Efferent Discharge (Activity)

Higher control on Gamma Efferent Discharge → and hence on the Stretch Reflex and → Degree Muscle Tone

Summary of Factors Influencing/Modulating Gamma Efferent Activity (& hence the Stretch Reflex)

Enhances

A/ Supraspinal influences :

(1) Cortical (motor area 4) :
(voluntary , conscious + limbic → fear/apprehension , and anxiety , pain)

(2) Brainstem mechanisms :
(i) Vestibular nucleus
(ii) Pontine Reticular Formation

(3) Neocerebellum

B/ Largely spinal mechanisms :
related to noxious (painful) stimuli .

Inhibits

A/Supraspinal :

(1) Cortical (motor area 6)
(voluntary , conscious , mostly) .

(2) Extrapyramidal & Brainstem mechanisms :
(i)Basal ganglia ,
(ii) Red Nucleus .
(iii) Medullary Reticular formation .

(3) Paleocerebellum)

B/ Largely spinal mechanisms :
1. Excessive muscle stretch
(stimulation of Golgi tendon organ).
2. Muscle contraction

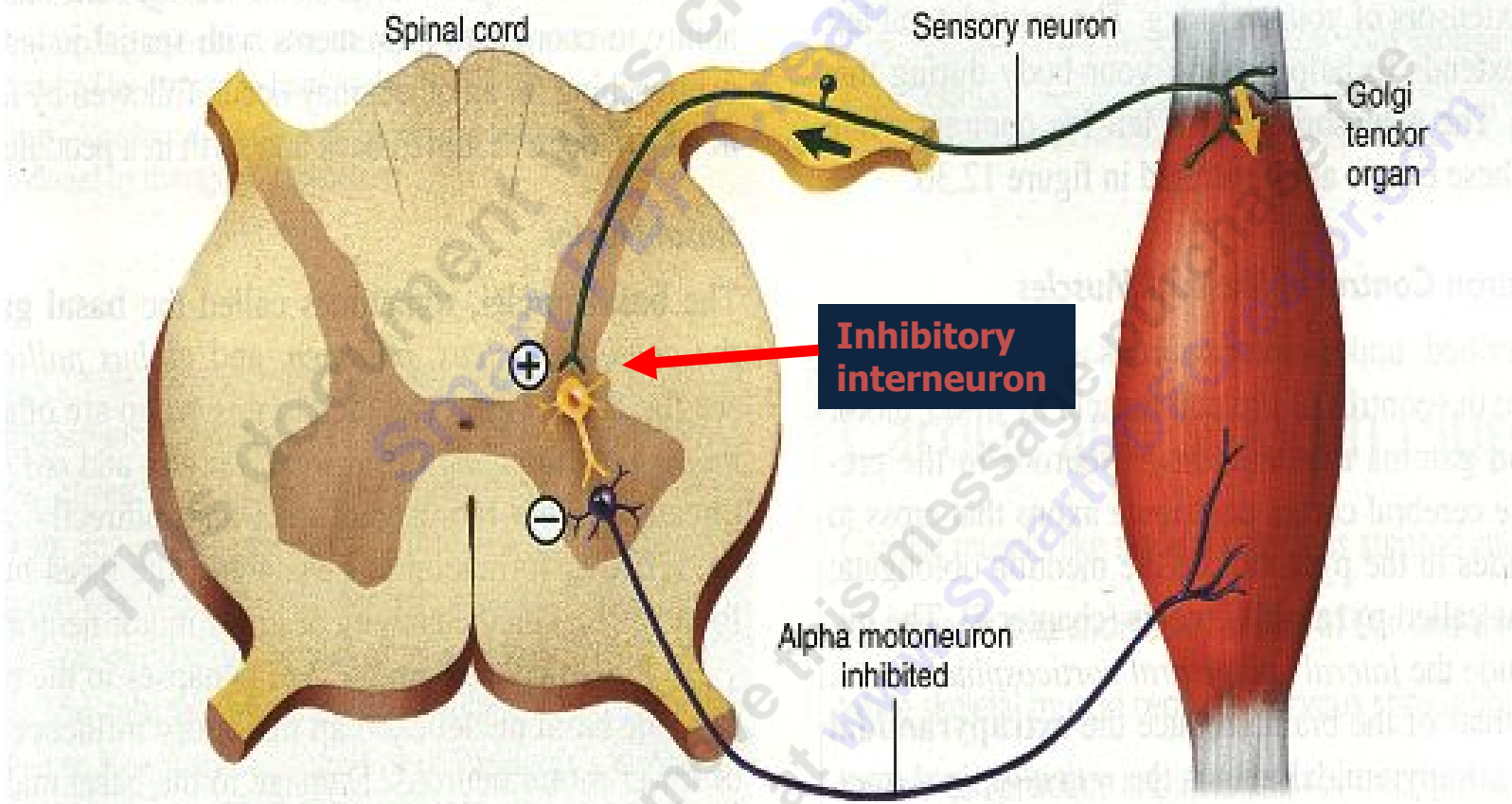
The cerebellum.

- Cerebellar cortex exerts an inhibitory influence on the stretch reflex.
- Deep cerebellar nuclei (DCN) are excitatory via lateral vestibular nuclei.
- However , cerebellar lesions in humans are characterized by hypotonia, due to deep cerebellar nuclei invovement .

The Golgi tendon reflex (inverse stretch reflex

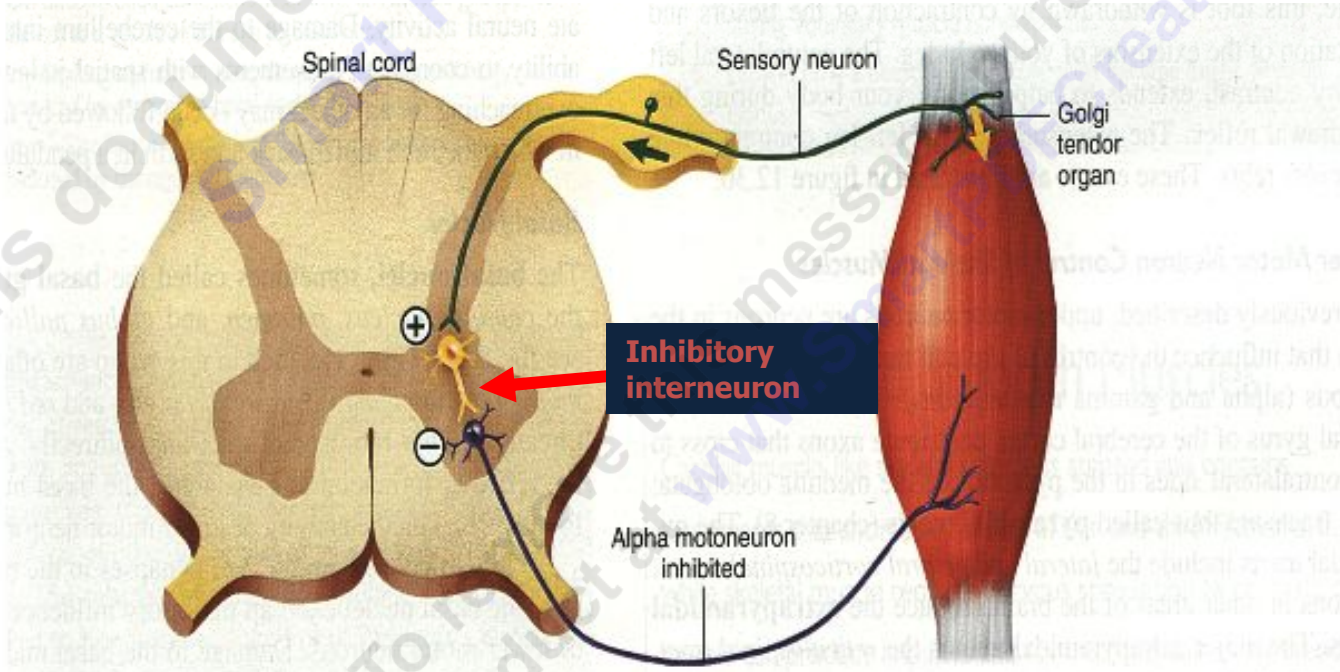
منعكس قولجي الوتري ، منعكس الوتر

(Although it is a deep reflex , but it is polysynaptic)



The action of the Golgi tendon organ. An increase in muscle tension stimulates the activity of sensory nerve endings in the Golgi organ. This sensory input stimulates an interneuron, which in turn inhibits the activity of a motor neuron innervating that muscle.

- When muscle is excessively stretched → it contracts strongly and pulls on the tendon → excessive tension is coveyed/transferred to the tendon → this stimulates Golgi Organ in the tendon →
- it sends afferent impulses via the fast Aα fibers →
- excitation of inhibitory interneuron in spinal cord →
- inhibition of alpha motor neuron → muscle relaxation
- This reflex protects muscle from rupture by excessive stretch & tension.



The action of the Golgi tendon organ. An increase in muscle tension stimulates the activity of sensory nerve endings in the Golgi organ. This sensory input stimulates an interneuron, which in turn inhibits the activity of a motor neuron innervating that muscle.

END