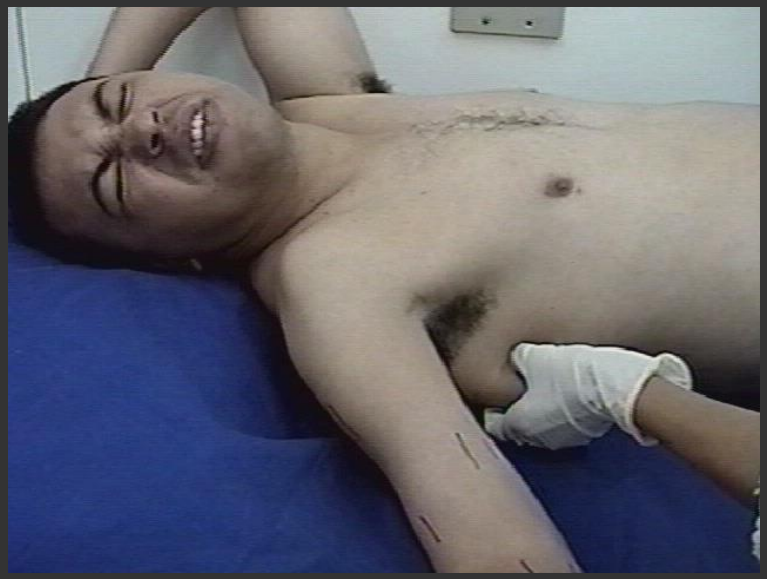
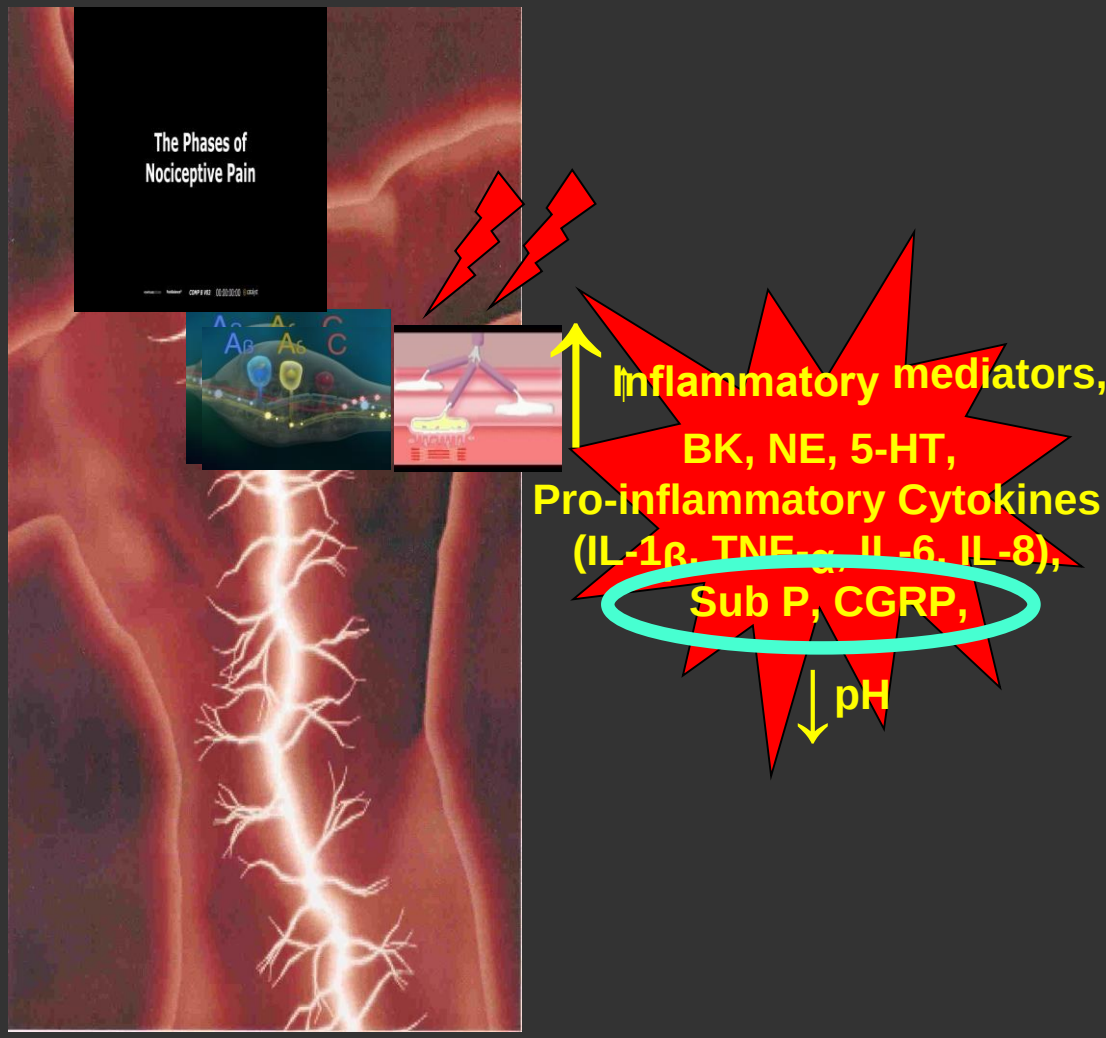
Chronic Musculoskeletal Pain, Myofascial Trigger Points and Central Sensitization:

Integrating Advancements in the Pain Sciences with Objective Physical Findings and Treatment Strategies

Myofascial Trigger Points, Sensitization, Neurogenic Inflammation and *Neuro*-musculo-skeletal Pain

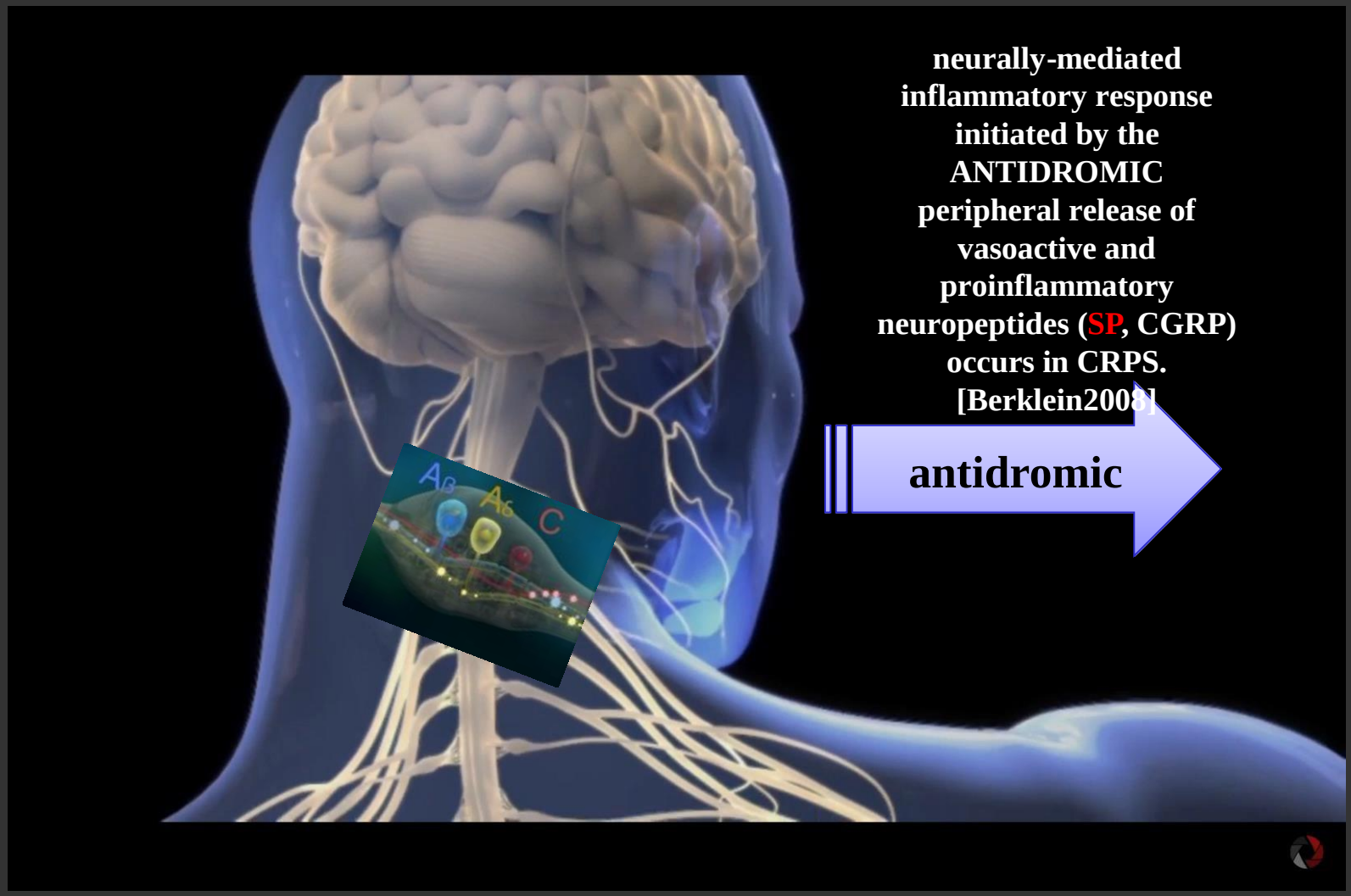


Courtesy Marta Imamura



From Peripheral to Central Sensitization and *Back*!

Neurogenic Inflammation in CRPS



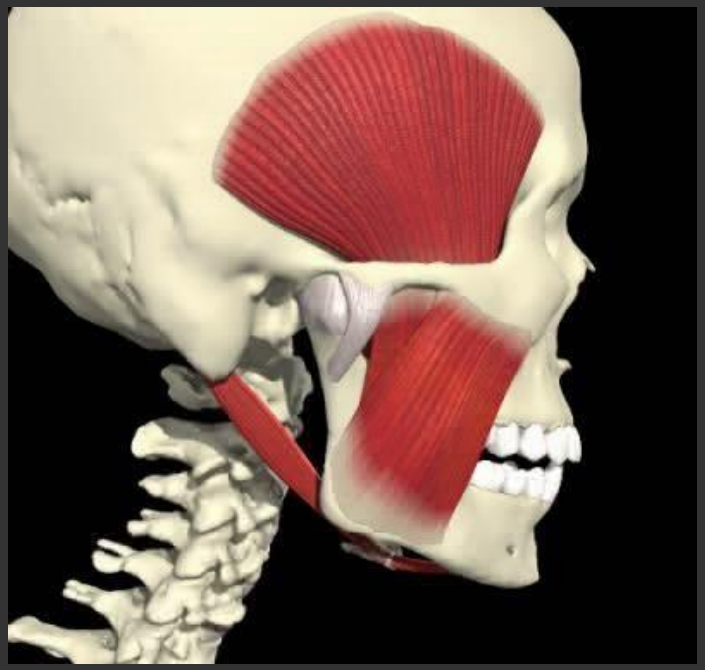
Myofascial Pain Syndrome

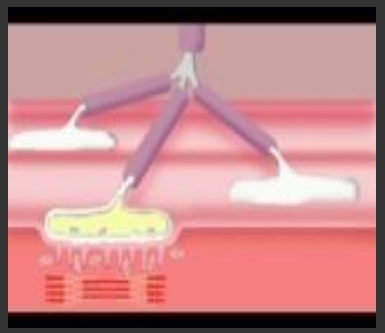
Myofascial Pain Syndrome – a pain condition that may be acute or - more commonly - chronic and involves the muscle and its surrounding connective tissue (e.g., the fascia)

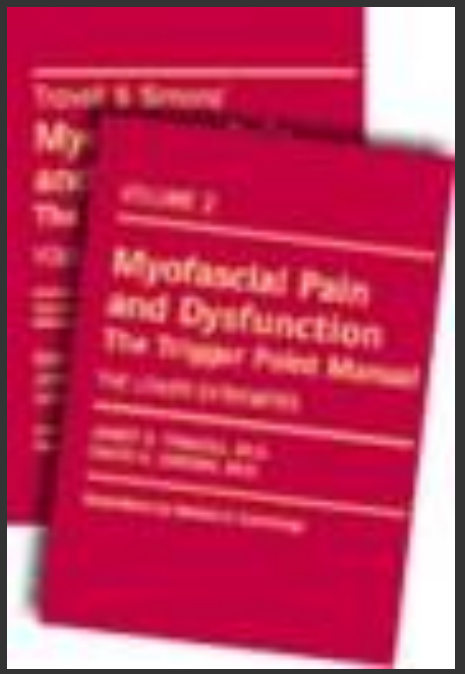
Travell and Simons – Myofascial Trigger Points (MTrPs) are central to the Dx of MPS

- MTrPs commonly found in asymptomatic individuals (i.e., Latent MTrPs)
- Some nodules are not tender to palpation (i.e., non-tender nodules)

MTrPs are sufficient but are they necessary??

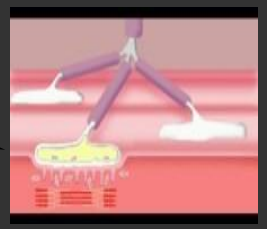


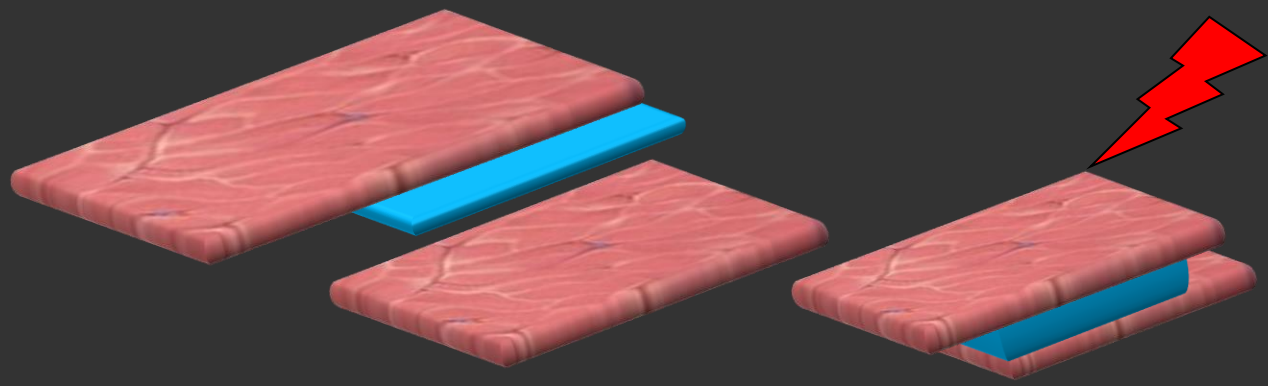




Myofascial Pain Syndrome

- What is the role of the muscle?
- What is the role of the MTrP?
- What happens when a MTrP becomes *active* (i.e., spontaneously painful?)
- What is the role of the nervous system and brain?
- What is the role of the fascia?



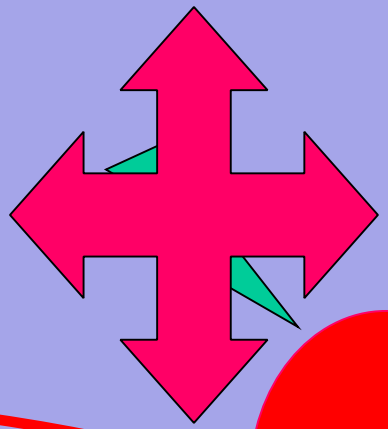


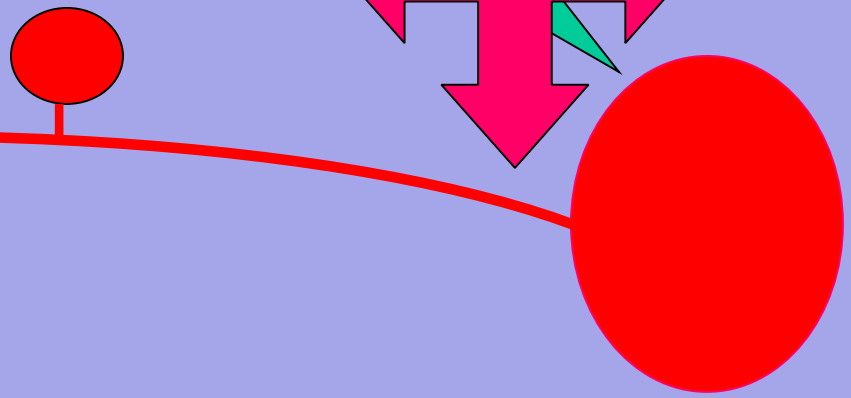
How Many Noxious Stimuli are Needed to Induce Spontaneous Discharge of the Dorsal Horn Neuron?

Stimulation

"Wind Up"

Extracellular recording





Receptive field

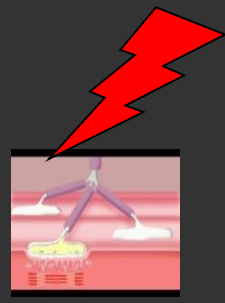
Spontaneous discharge activity after 150 stimuli

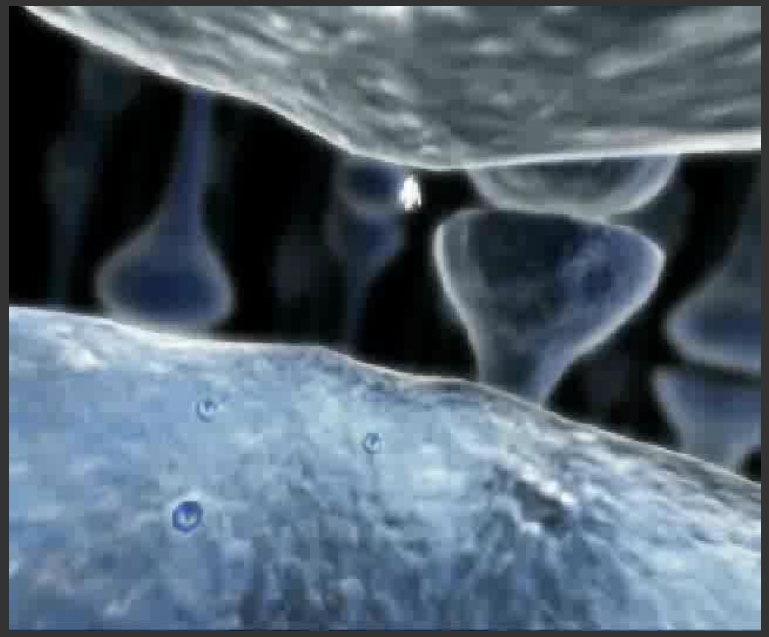
Zieglgansberger W. *Scand J Rheum*
2000;29 113:19-23

Wind-up and Central Sensitization are induced by Persistent Nociceptive Bombardment

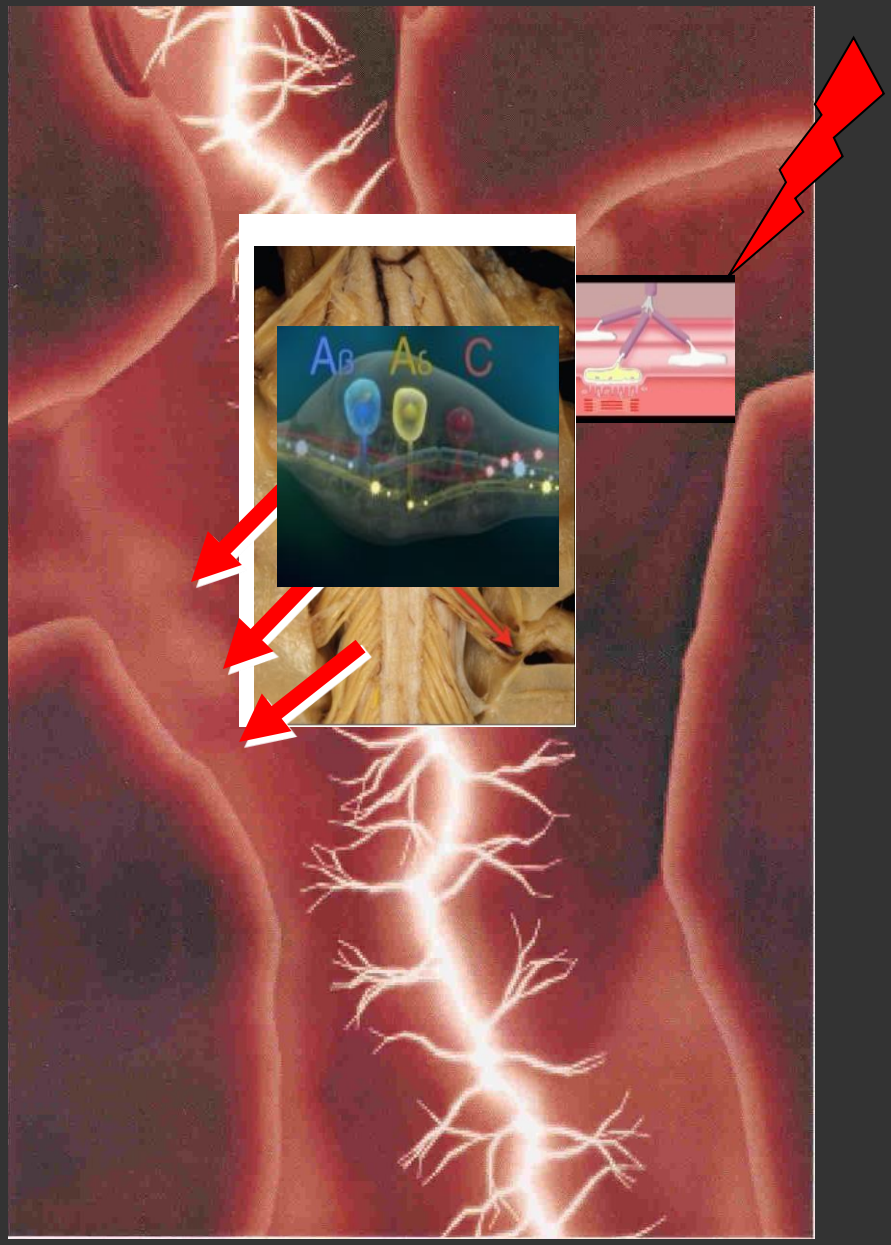
“MTrPs are not merely a peripheral phenomenon - the input from MTrPs leads to hyperexcitability of central neurons that manifests in allodynia, hyperalgesia and pain referral” Mense, S. *Journal of Musculoskeletal Pain*, 2010

“These central changes are mainly based on an increase in the synaptic efficacy of central connections induced by nociceptive input.” Mense, S. *Journal of Musculoskeletal Pain*, 2010

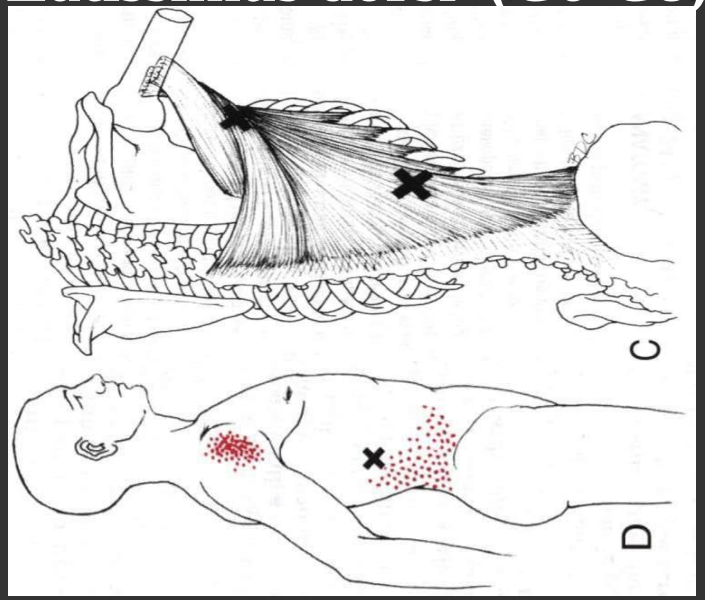




Active MTrP Bomardment *Sensitizes* the Spinal Segment, Resulting in Expansion of the Receptive Field of Pain



Latissimus dorsi (C6-C8)



Zimmermann, Sem Arth. Rheu. 18:22, 1989

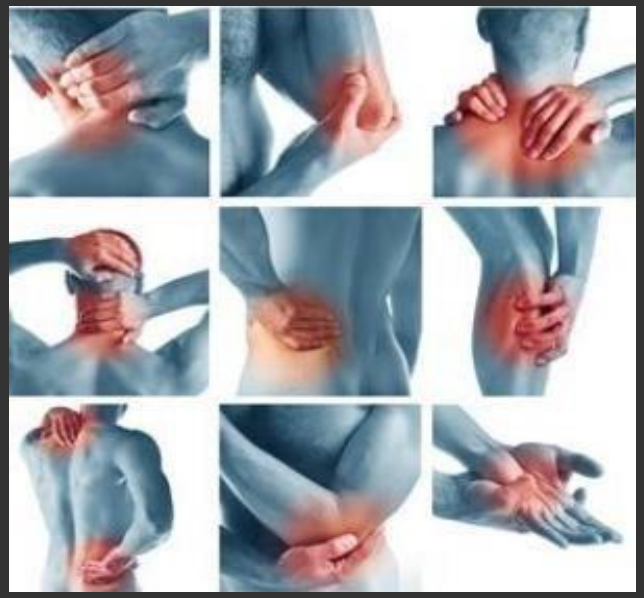
The Sensation of Pain Depends upon the Balance of Sensitizing and Desensitizing Actions

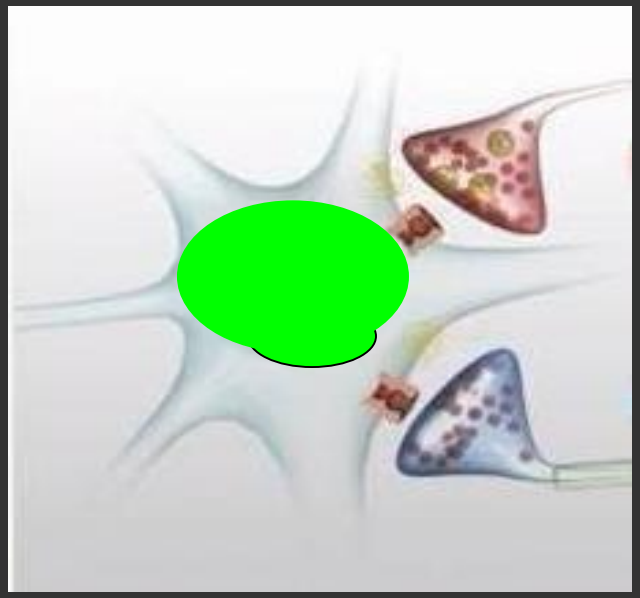
Sensitized Dorsal Horn Neurons Demonstrate:

1) *Increased responsiveness* to external stimuli

2) *Spread of excitation* to spinal segments that do not normally receive input from the damaged muscle

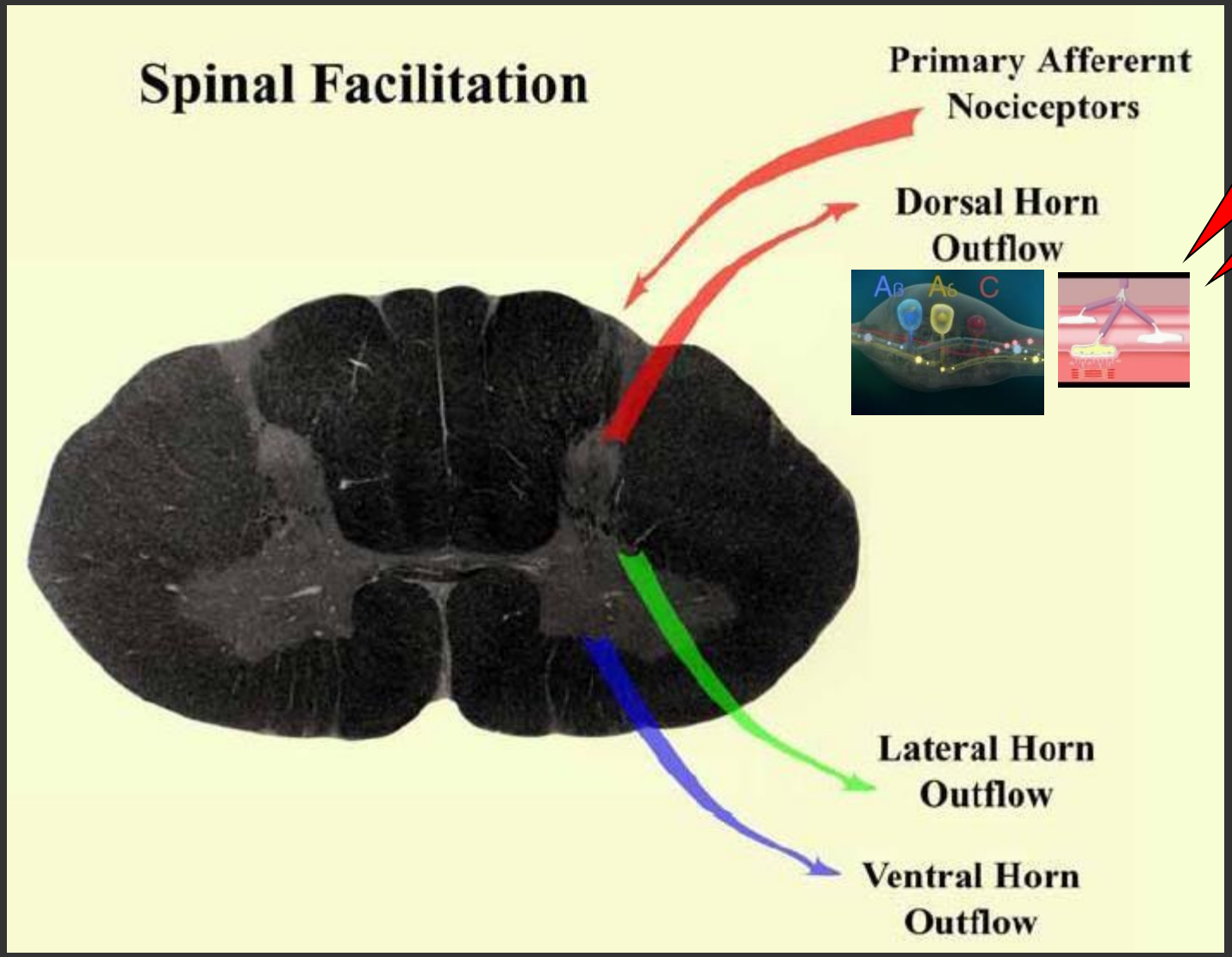
3) *Increased background* activity





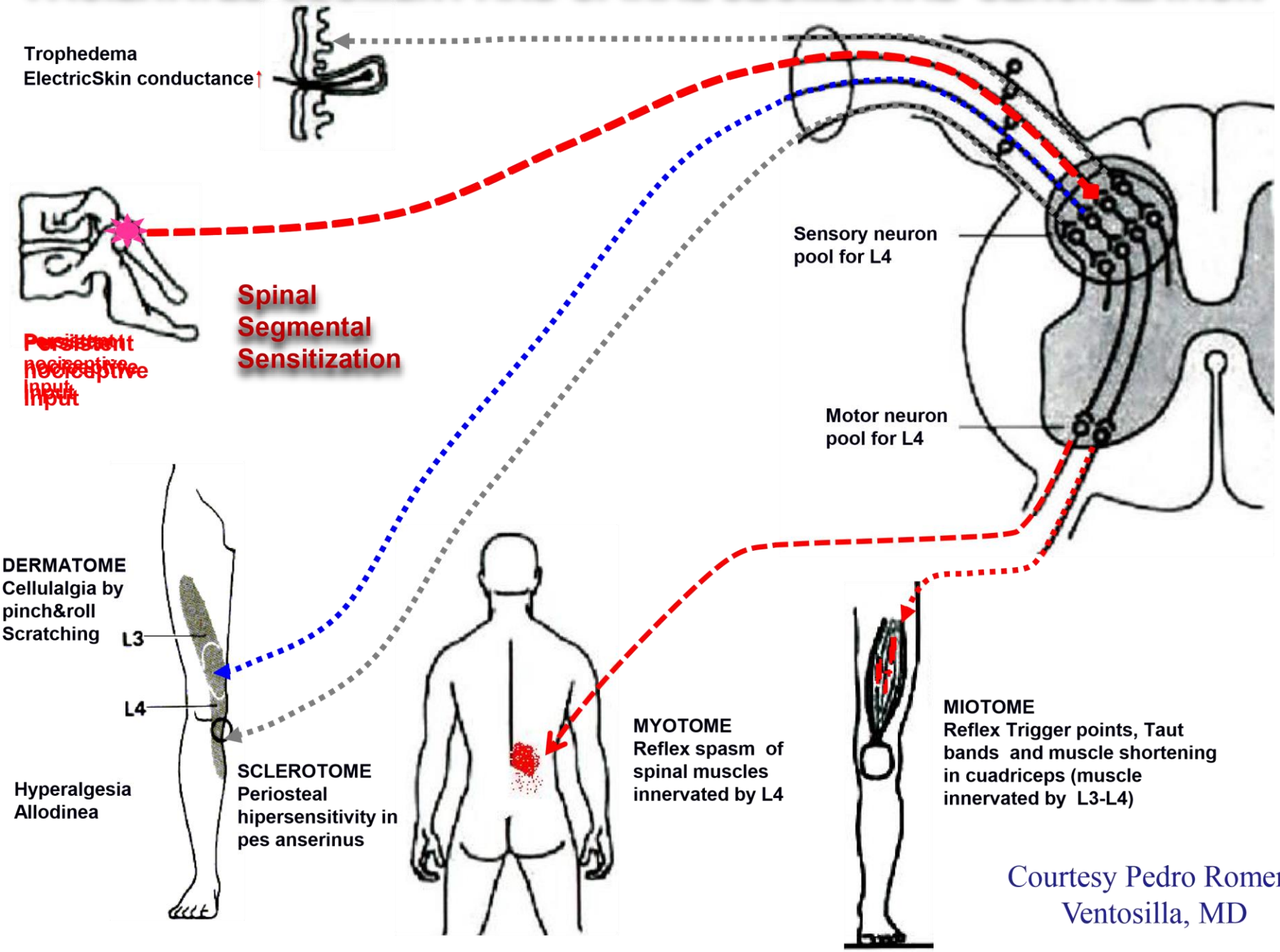
Excitatory tonus via Nociceptors

Inhibitory tonus via Mechanoreceptors



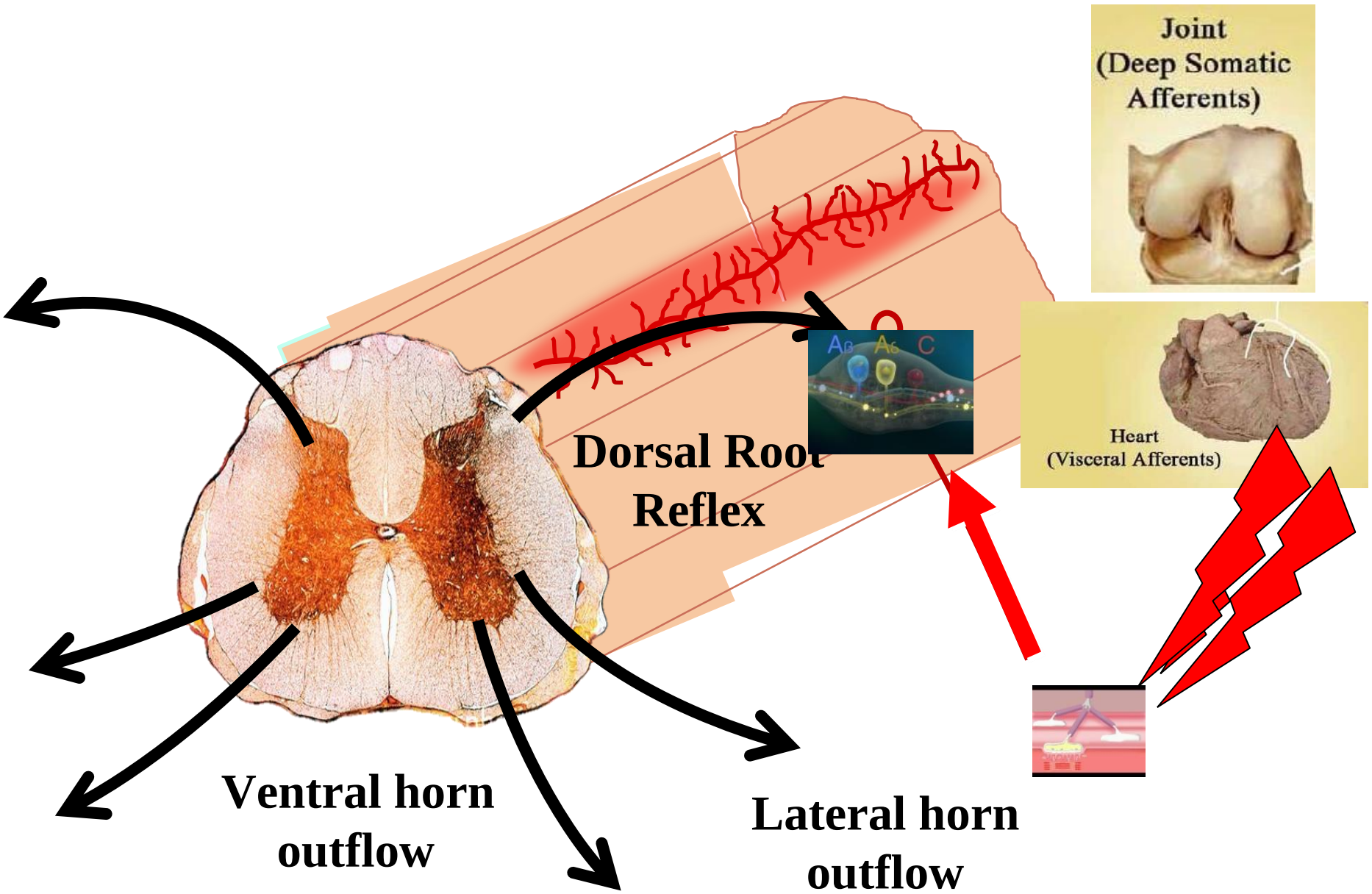
Courtesy Frank Willard,

FACILITATED SEGMENT AND SPINAL SEGMENTAL SENSITIZATION



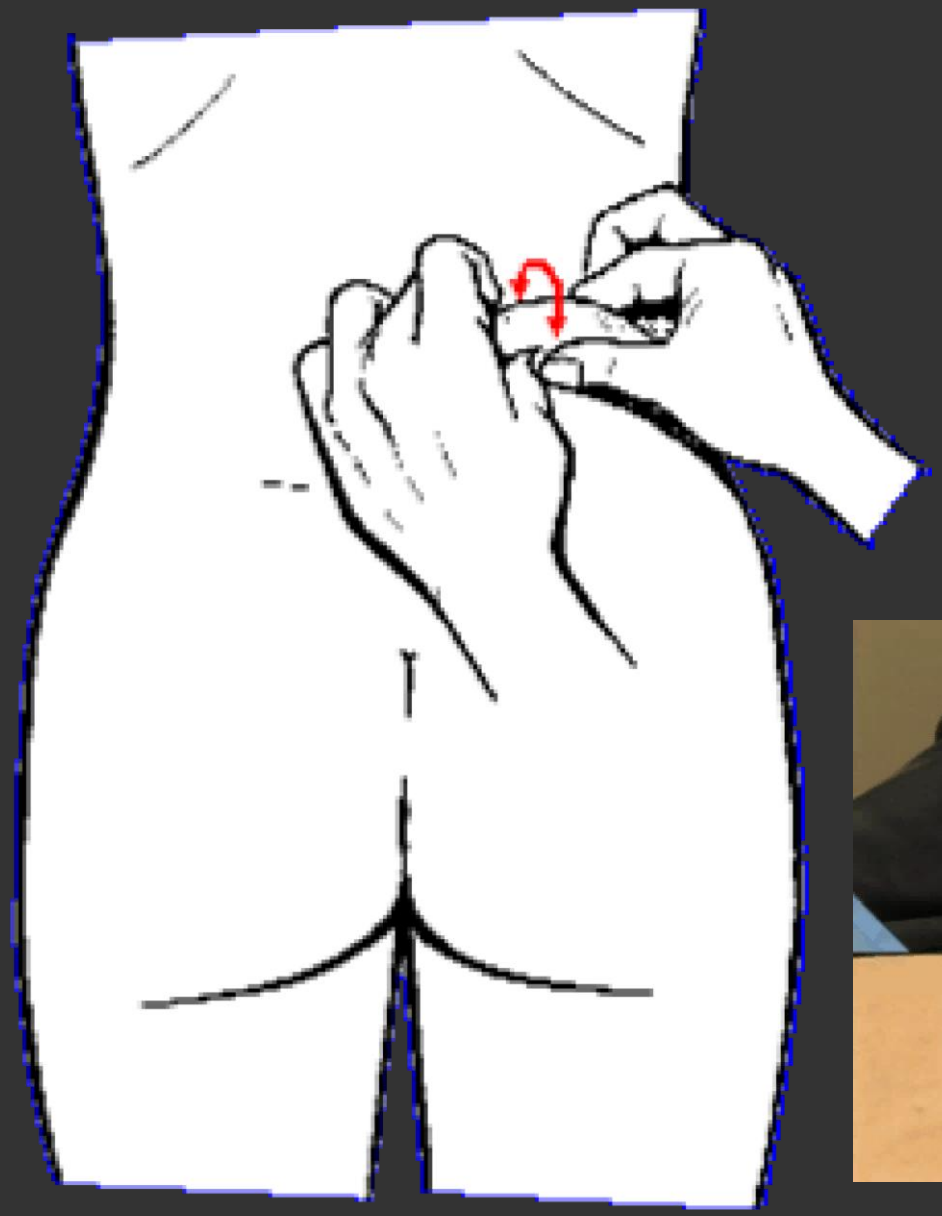
Courtesy Pedro Romero Ventosilla, MD

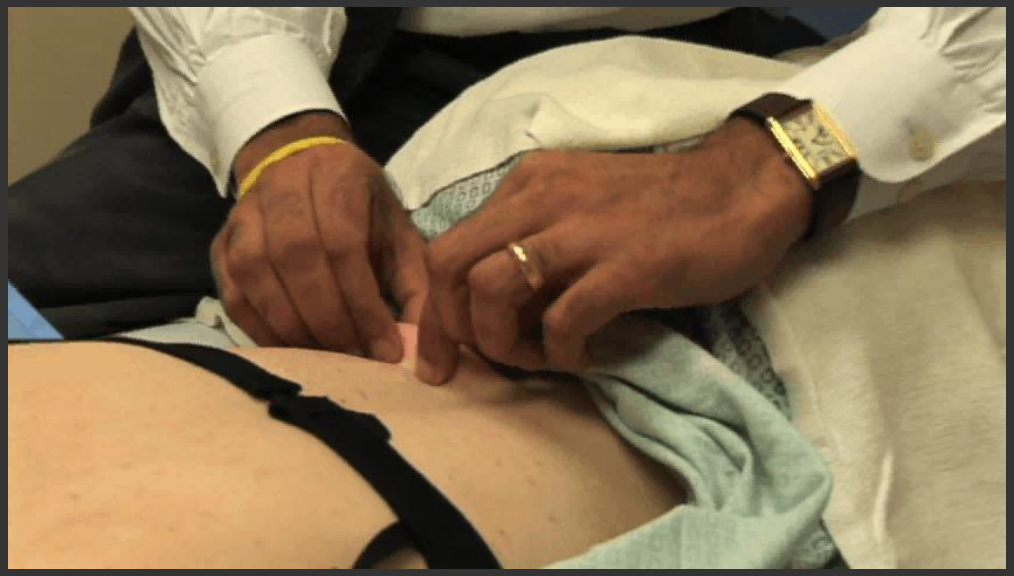
Sensitized Dorsal Horn Neurons Demonstrate


Joint
(Deep Somatic
Afferents)
Heart
(Visceral Afferents)
Dorsal Root
Reflex
Ventral horn
outflow
Lateral horn
outflow

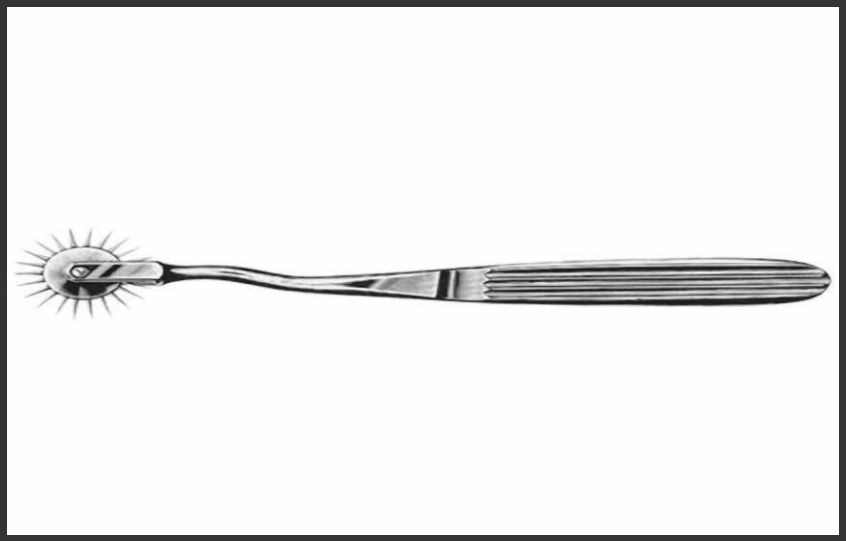
Extra-Segmental Spread!

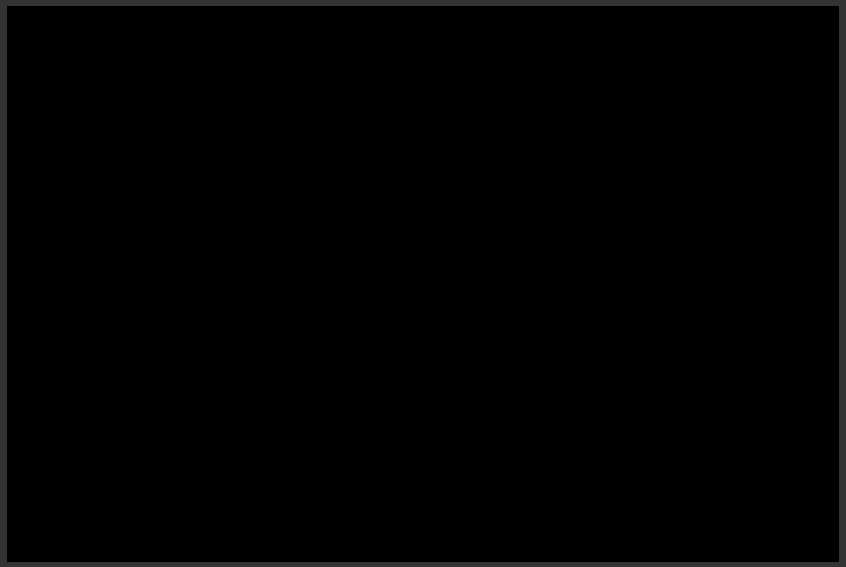
PINCH & ROLL: Allodynia

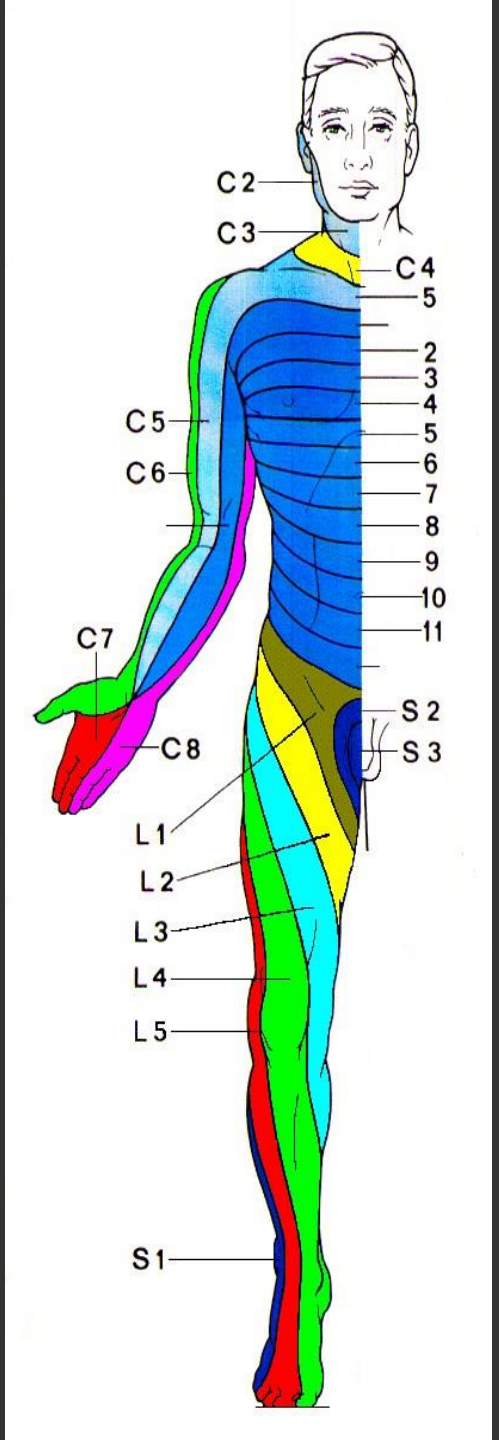




Waternberg pinwheel: Hyperalgesia







Chronic Pain and and Spinal Segmental Sensitization

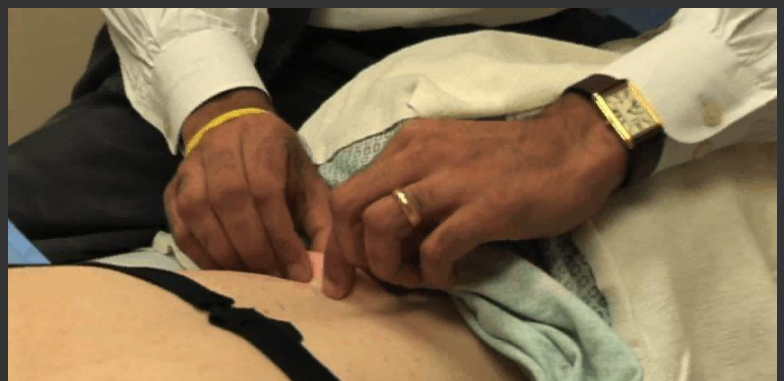
“The future of pain management will require the development of diagnostic methods that permit us to identify the mechanisms of pain in an individual patient and treatments that target those mechanisms.” Clifford Woolf, MD, PhD

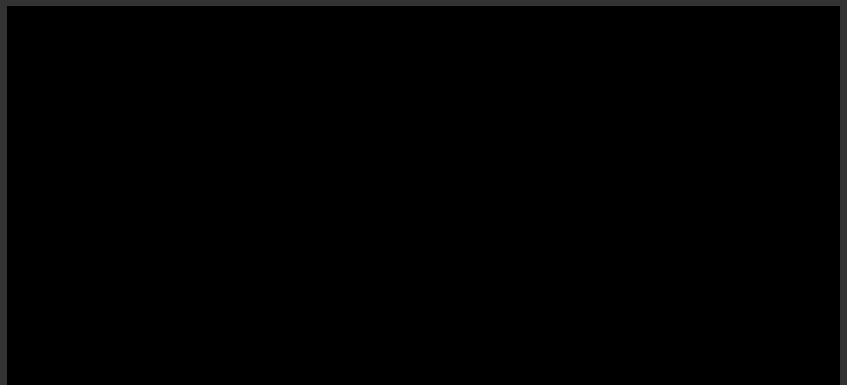
Chronic Myofascial Pain and the Sensitized Segment

There are *objective*, *reproducible* physical manifestations of sensitization in chronic neuro-musculoskeletal pain

We will practice the application of *quantitative* and *objective* techniques to determine the affected dermatomes, myotomes and sclerotomes involved in chronic pain

We shall discuss, apply and practice how to develop a treatment algorithm (e.g., needling techniques, physical modalities, etc.) that desensitizes the involved segments, eliminates chronic MTrPs and alleviate neuro-musculoskeletal pain

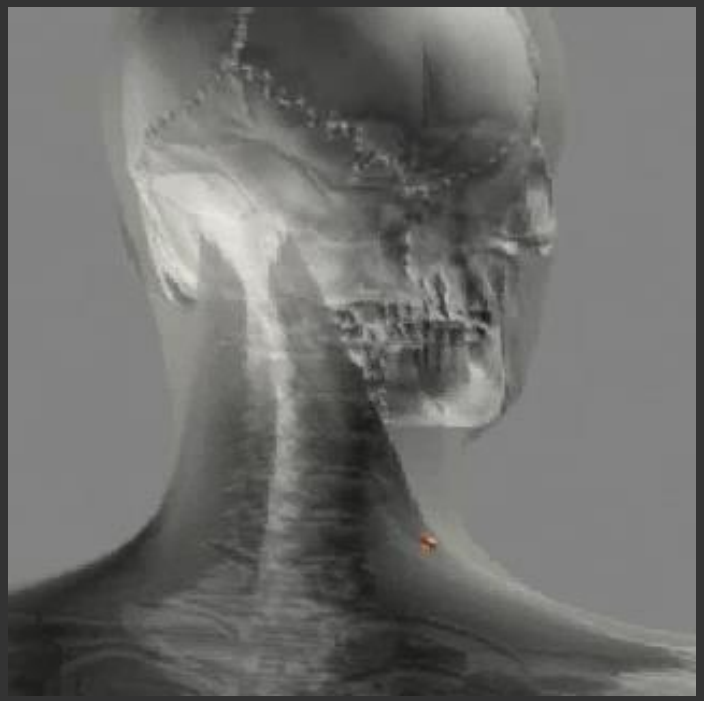


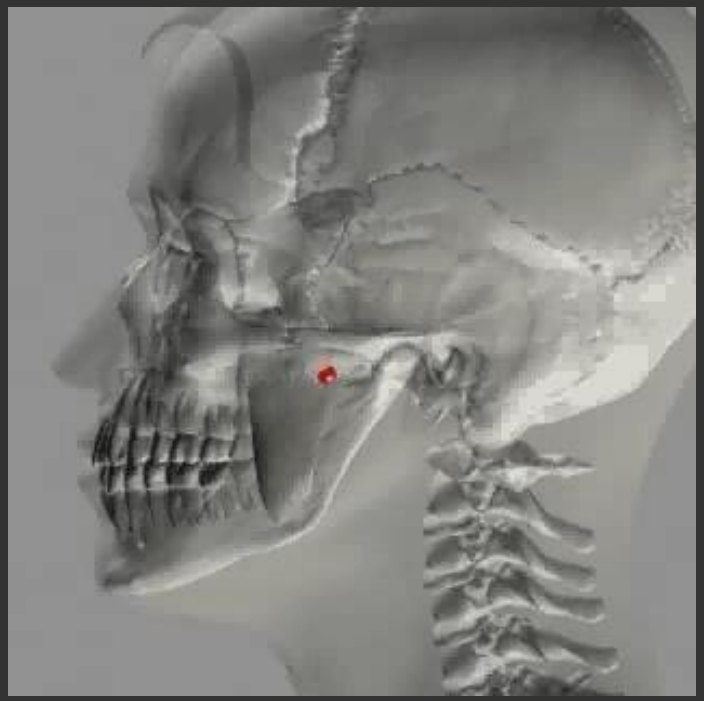


Myofascial Trigger Points and Referred Pain

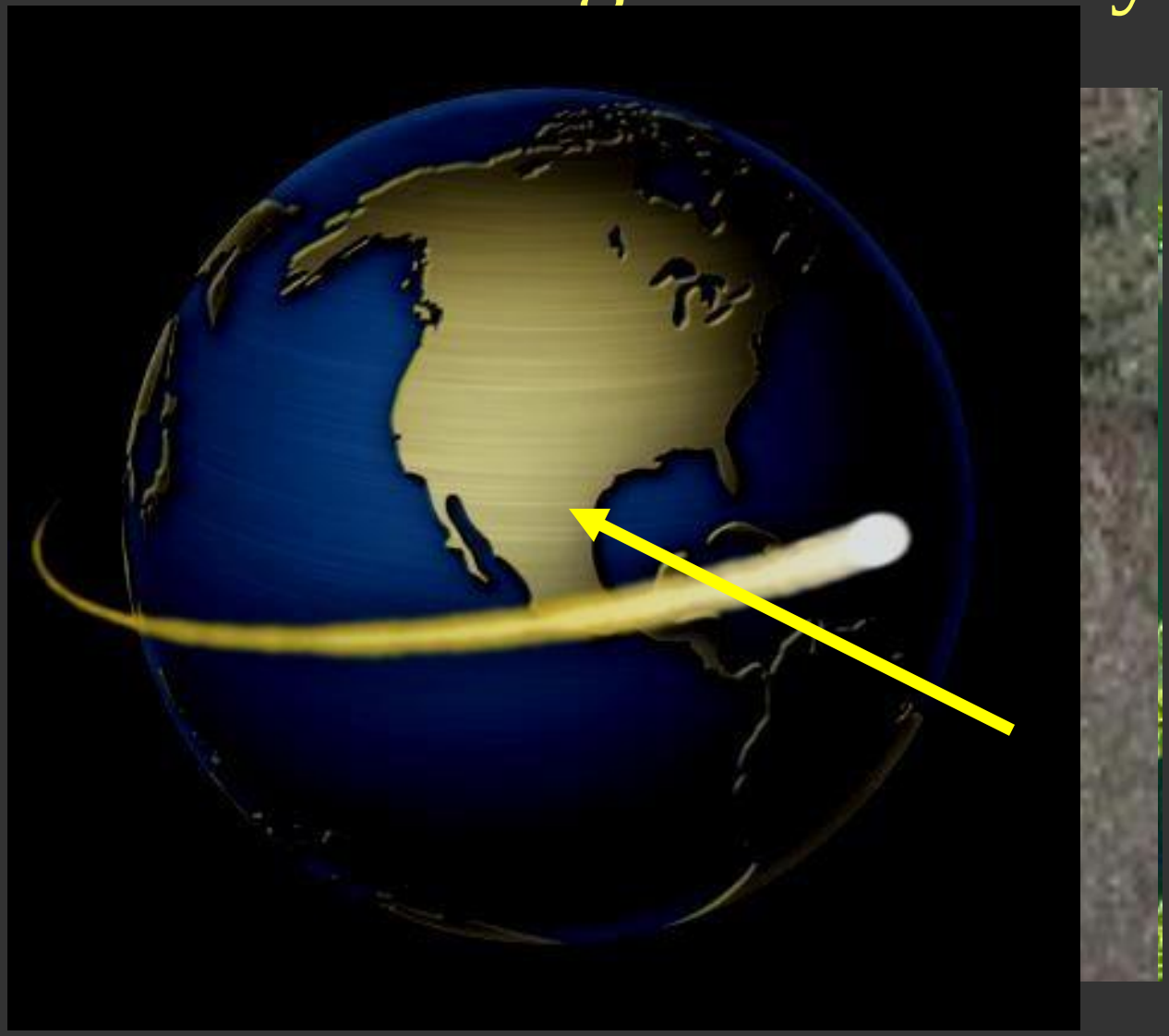
It is essential to learn how to palpate the muscle, identify active MTrPs and also how to recognize common pain referral patterns

However, it is also critical to understand that active MTrPs in different muscles can have overlapping pain referral patterns making accurate diagnosis challenging, *especially* when there is central sensitization!





Thank You
Dr. Kettner and Logan University!

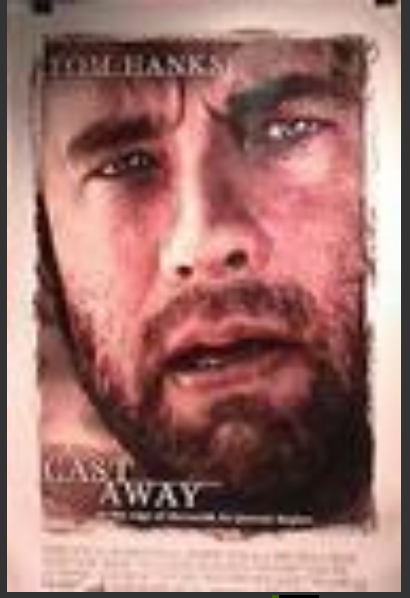


Nothing to Disclose

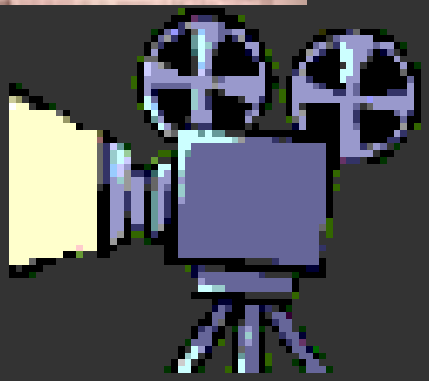
I Love My Job!


TOM CRUISE
JACK NICHOLSON
DEMI MOORE
A FEW GOOD MEN


5 ACADEMY AWARDS
BEST DIRECTOR 1998: Steven Spielberg
saving private ryan


TOM HANKS
CAST AWAY

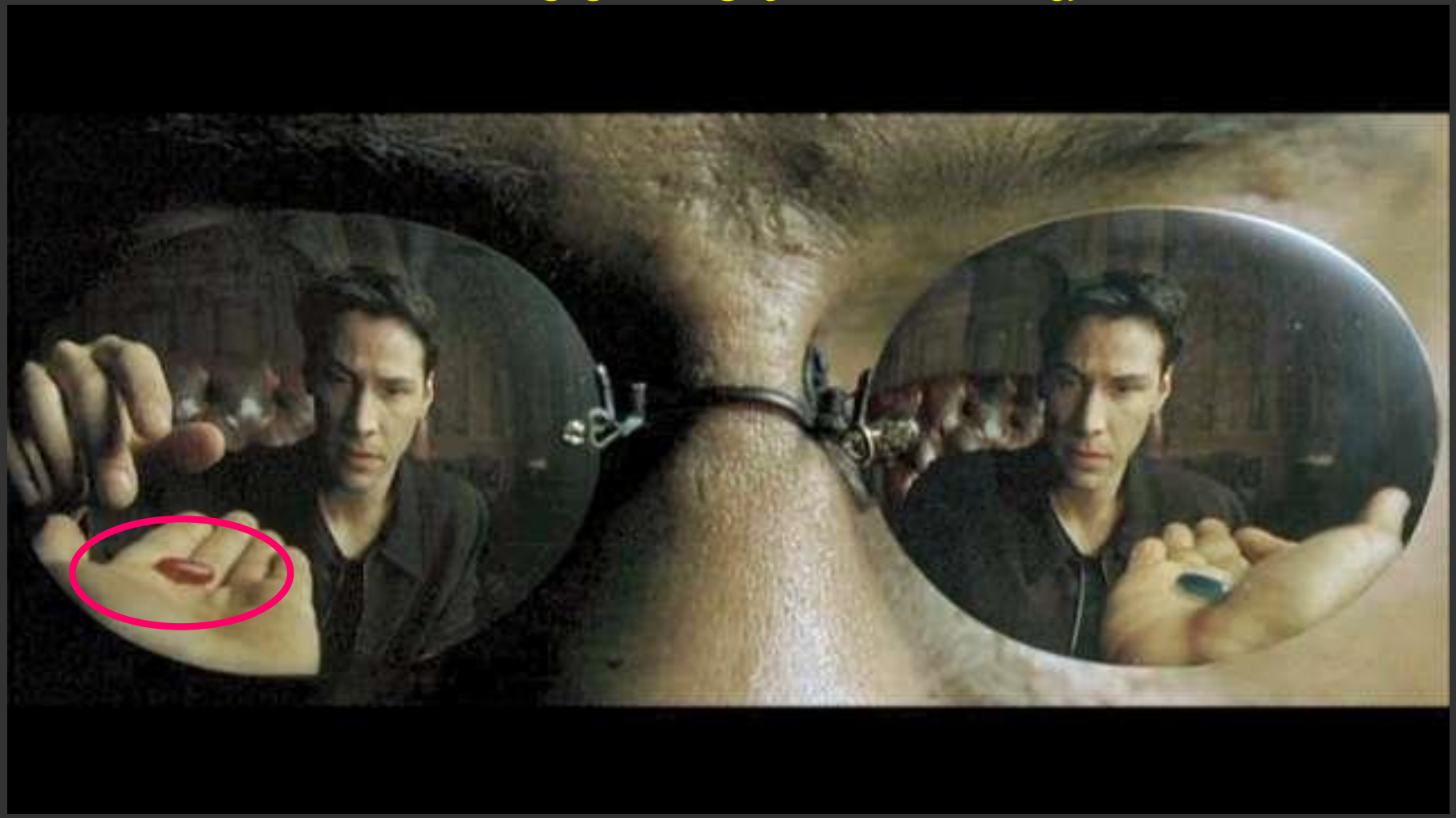

M A T R I X

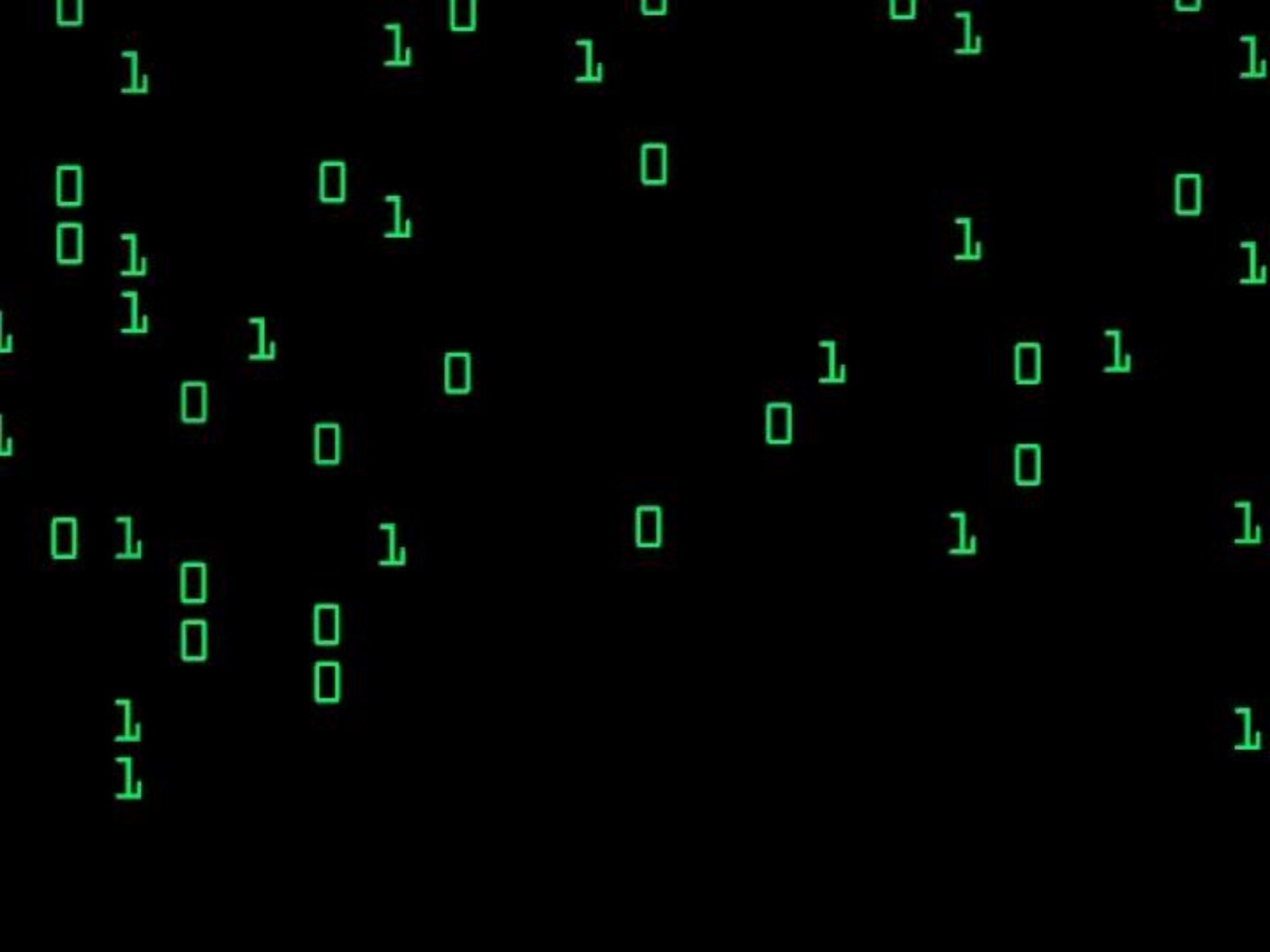



SEAN CONNERY
THE HUNT FOR RED OCTOBER
ALEC BALDWIN

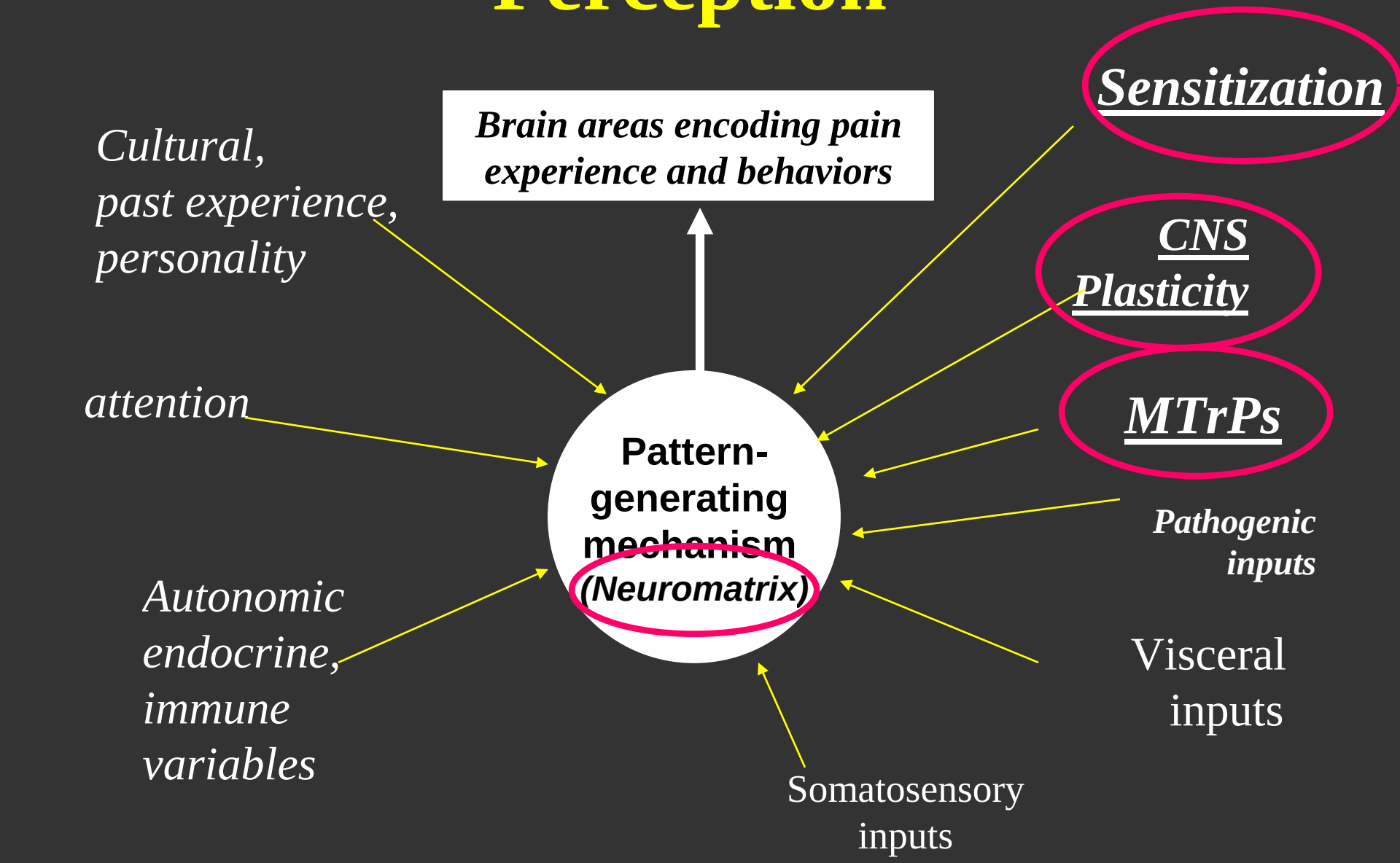

ENEMY AT THE GATES

“Free Your Mind”



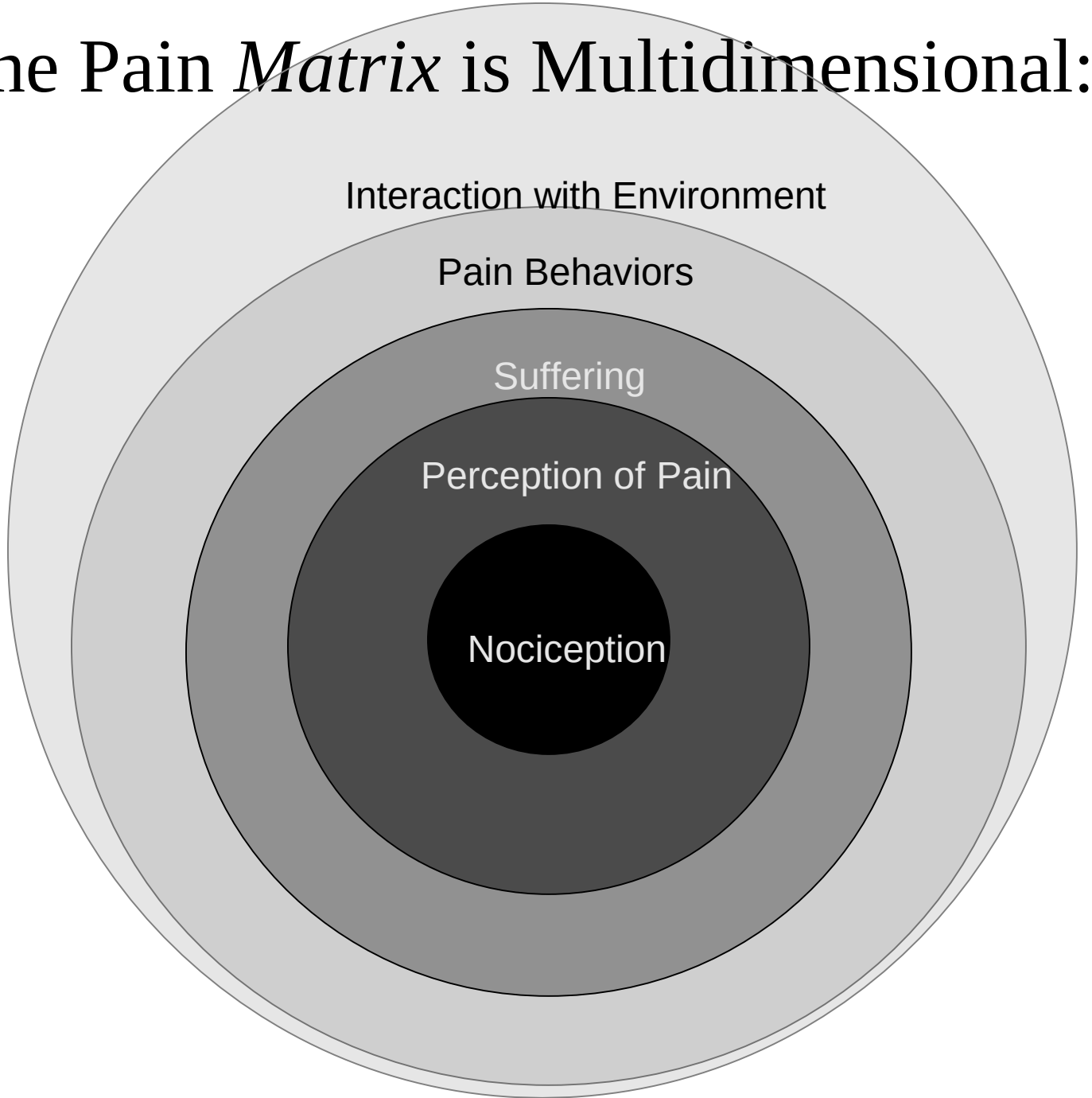


Perception



Melzack, Trends Neurosci 1990; 13:88-92

The Pain *Matrix* is Multidimensional:



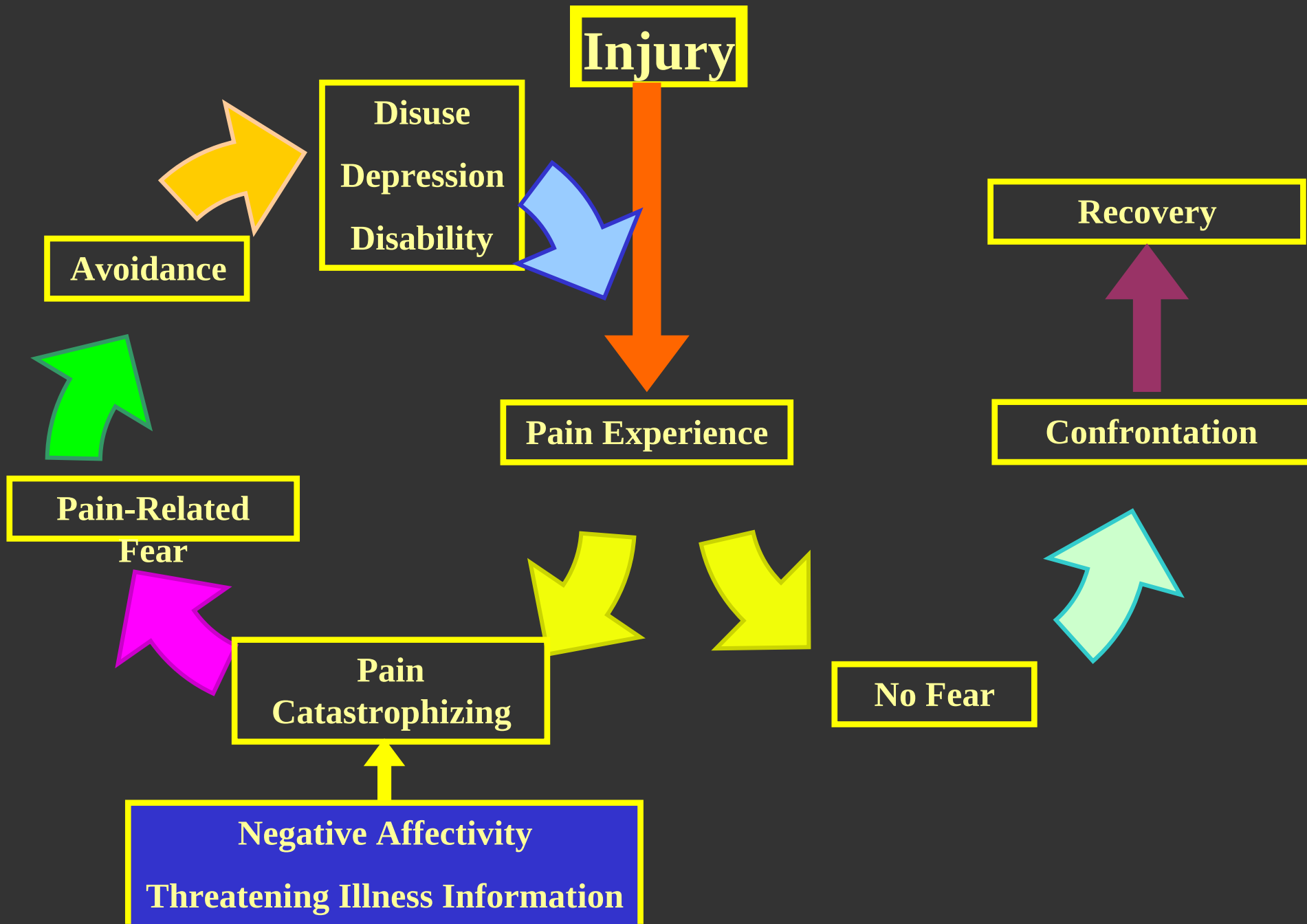
Perception

- “Perception of pain is thus generated by the output of the neuromatrix as a function of sensory inputs that feed into it, together with information from the regions of the brain involved in affective and cognitive activities.”
- “Pain behaviors can be generated or perpetuated by previously conditioned cues in the environment or by the expectation of pain and suffering.”
- “The output of the neuromatrix can be modified by various forms of treatment that change the inputs, or influence the neuromatrix”

Melzack, Trends Neurosci 1990; 13:88-92

Chronic Pain and Suffering: A Unique Perceptual Experience

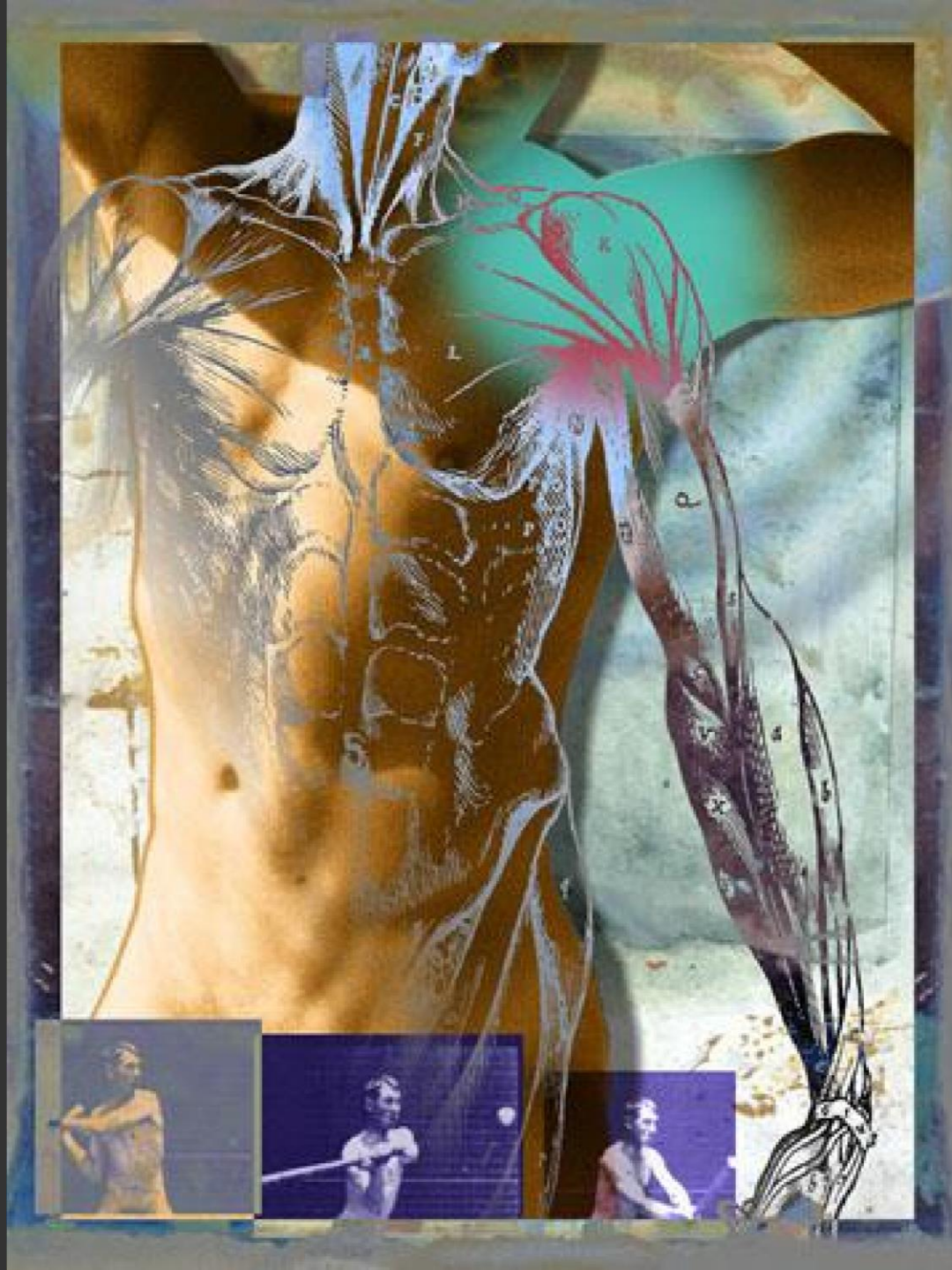
Can we identify the pain mechanism(s)?*Mal*-Adaptive Neuroplastic ty


Injury
Disuse
Depression
Disability
Avoidance
Pain Experience
Recovery
Confrontation
Pain-Related Fear
Pain Catastrophizing
No Fear
Negative Affectivity
Threatening Illness Information

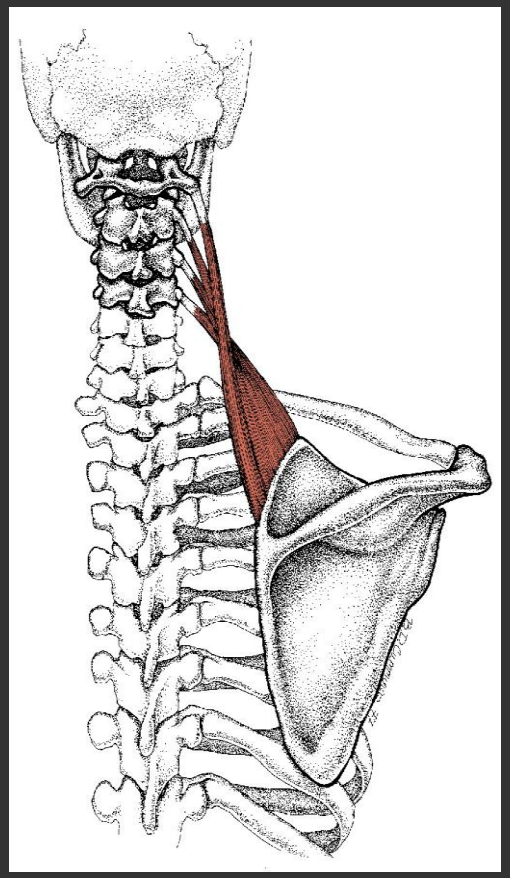
Technological Advancements:

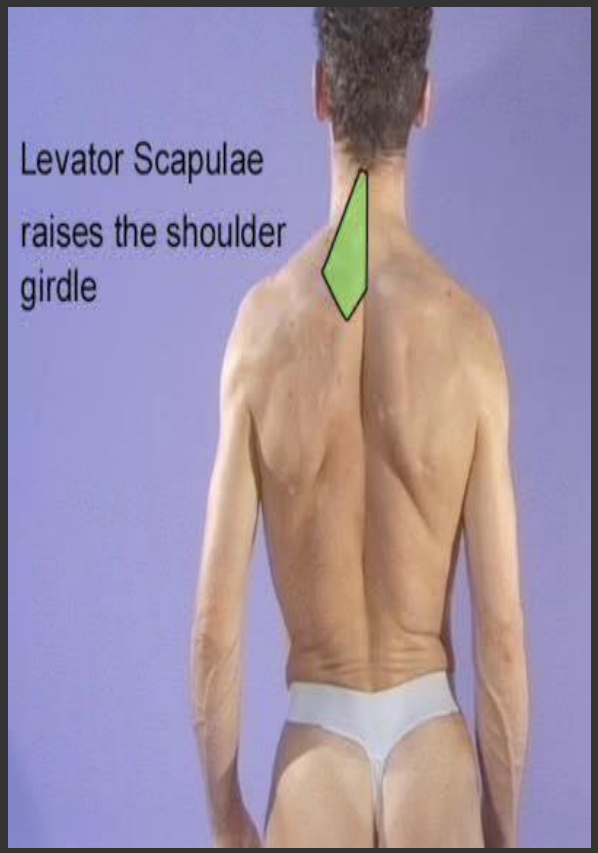
New and Abnormal Sodium Channels Migrate to Sites of Nerve Damage

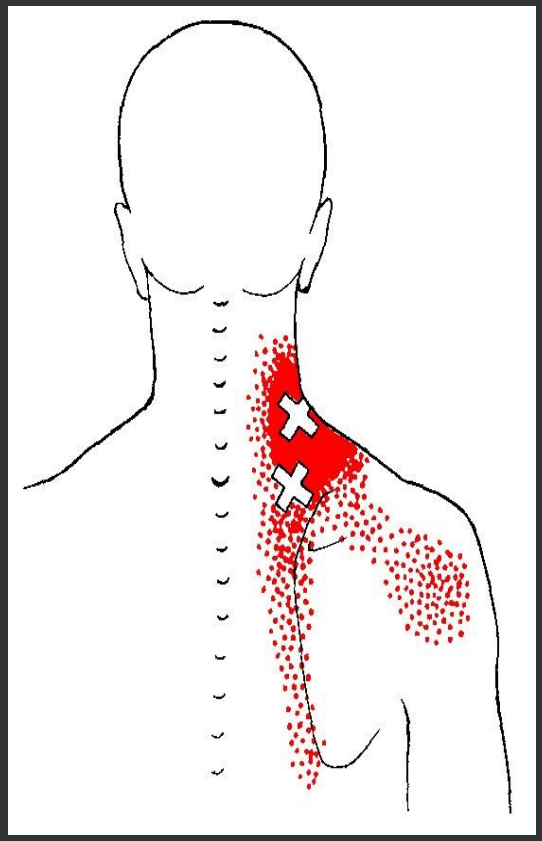
What about *Chronic* Musculoskeletal Pain?



Can we identify the pain mechanism(s) in *chronic* myofascial pain?







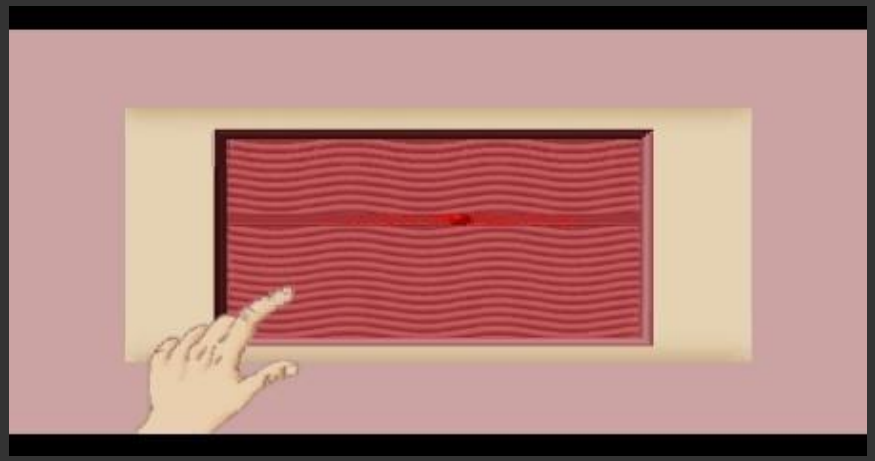
Travell JG, Simons DG. Myofascial pain and dysfunction: the trigger point manual. Baltimore: Williams & Wilkins; 1992.

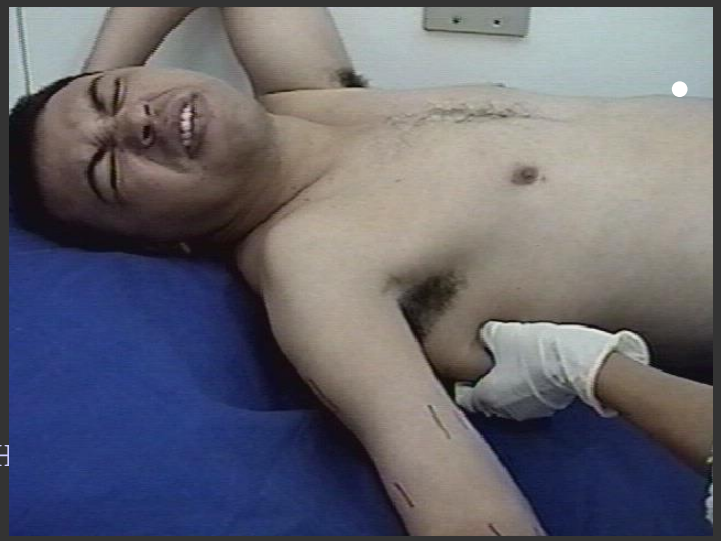
Myofascial Conundrum

- Myofascial trigger points (MTrPs) are a very common, complex and *overlooked cause* of non-articular musculoskeletal pain whose pathophysiology is unknown
- *Why?* Because the diagnostic criteria are imprecise and the full impact of MPS on life activity and function is not fully understood
- Furthermore, there are currently no accepted criteria (e.g., biomarkers, electrodiagnostic, imaging, etc.) for diagnosing MTrPs or for assessing the clinical outcome of treatments

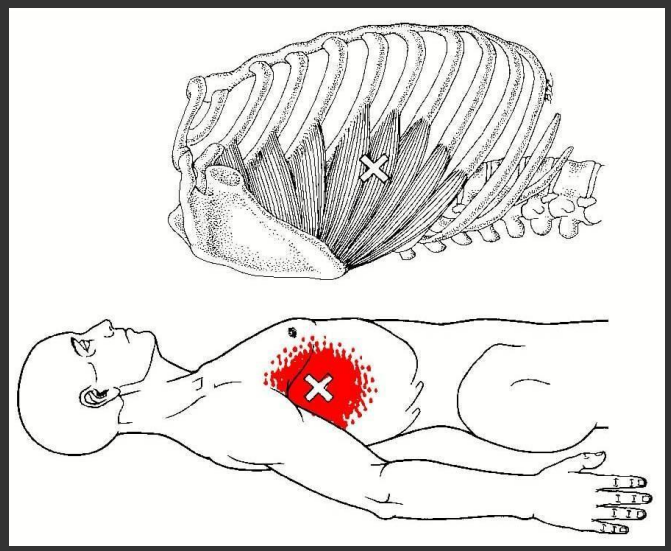
Myofascial Pain and MTrPs: A Clinical Diagnosis

- **Palpation of a taut band**
- **Hard, palpable, exquisitely tender nodule (a myofascial trigger point) in the taut band**





- **Reproduction of the person's symptomatic pain**

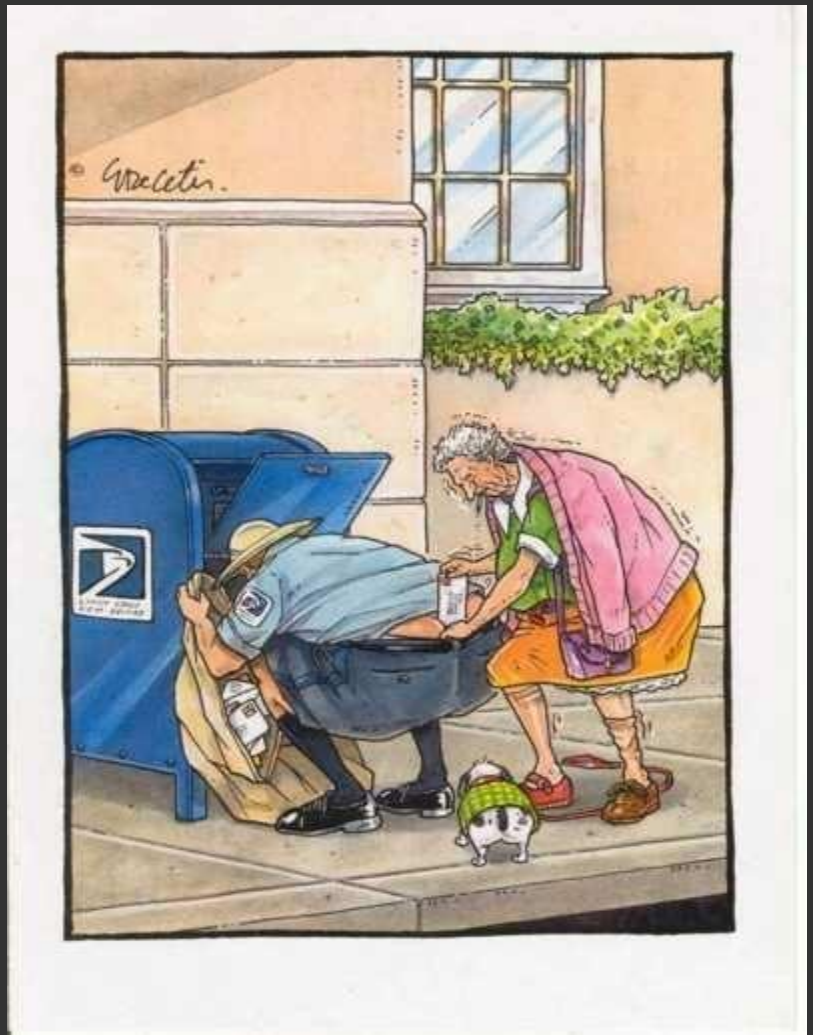


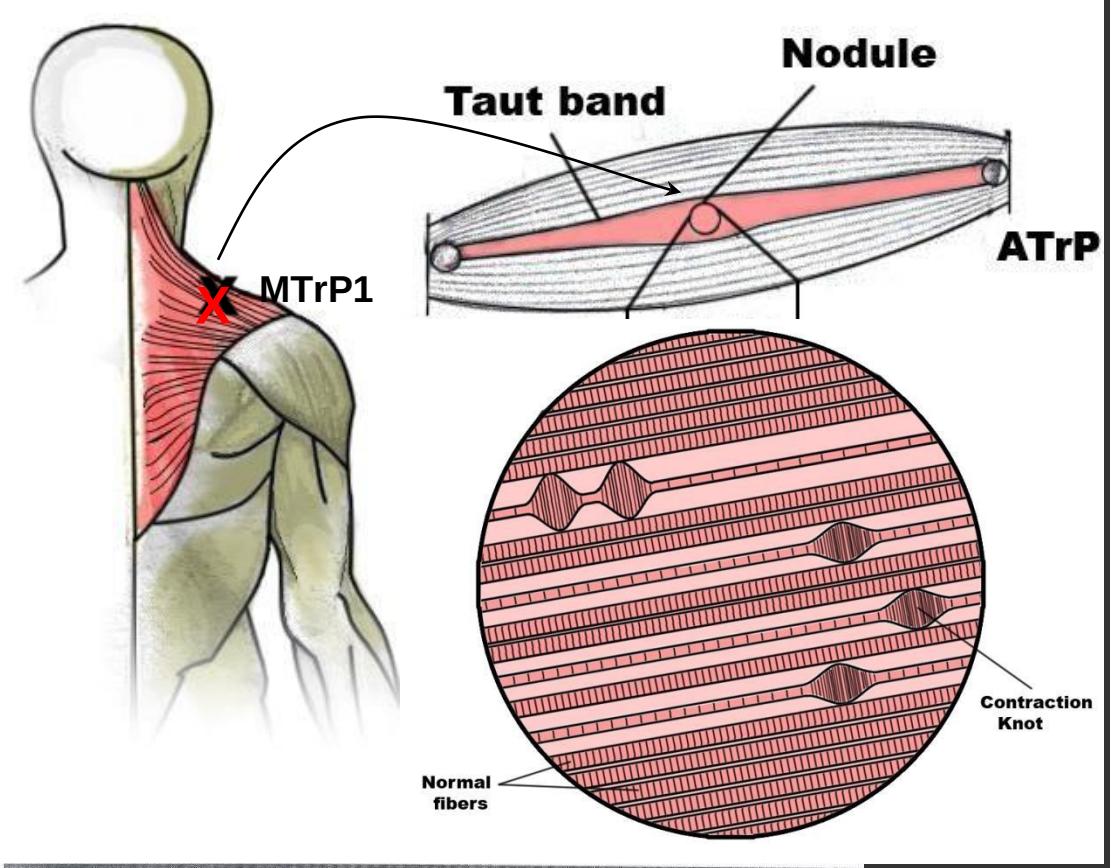
Courtesy Marta Imamura, MD

Palpation, Palpation, Palpation

- Careful palpation of the surface of the body reveals distinct differences in the quality and density of the underlying tissue. Many of these areas or points will be tender:

- A Shi points in Traditional Chinese Medicine
- Kori in Japanese system
- Myogeloses in German system

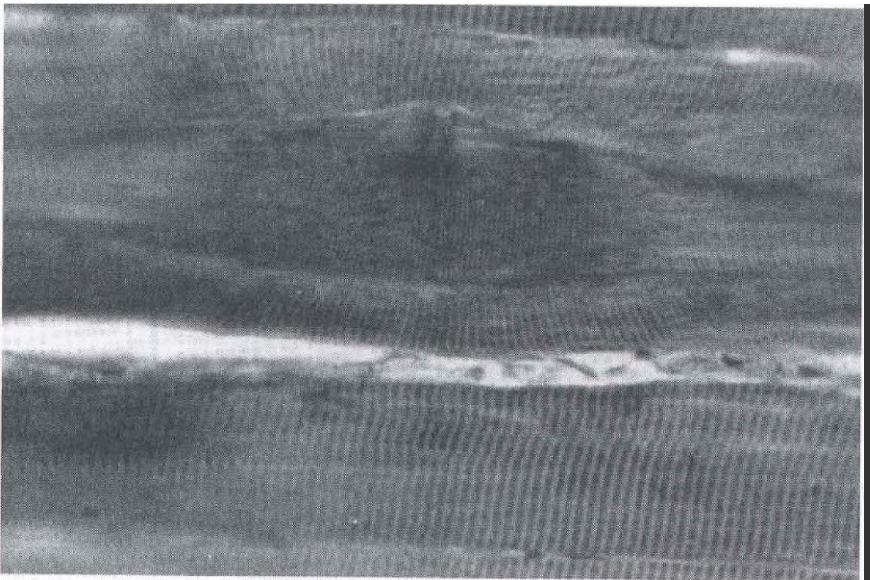




Trigger Point – Hard palpable nodules in *taut* bands of skeletal muscle.

Active – spontaneous pain or other abnormal sensory symptoms

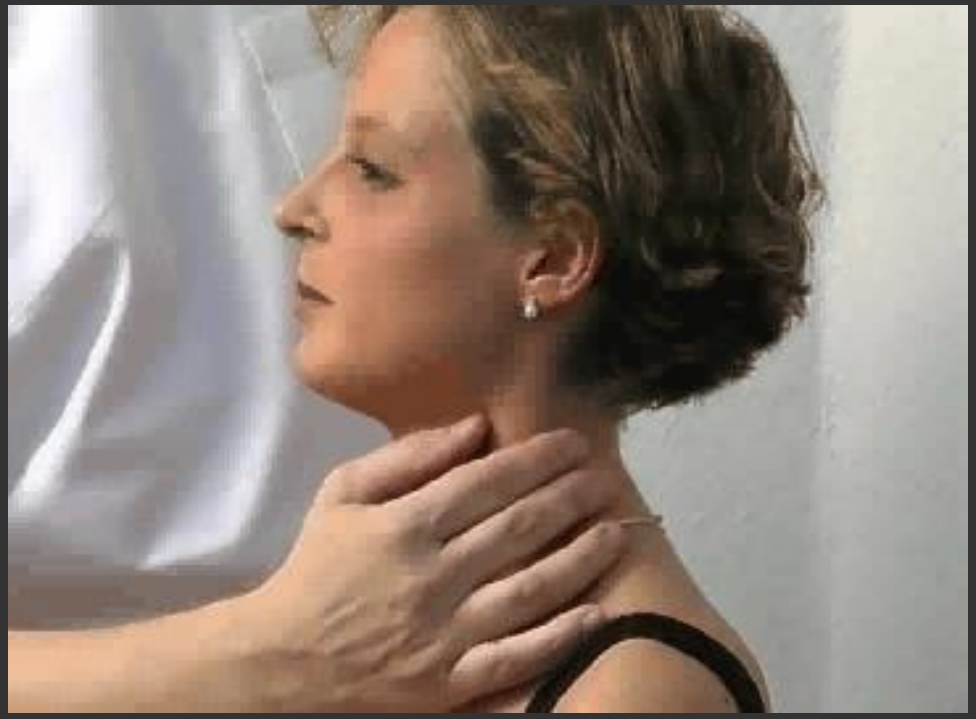
Latent – no spontaneous pain, but show all the other characteristics of active MTrPs



The Trigger Point Manual.
Simons, Travell and Simons, 1999

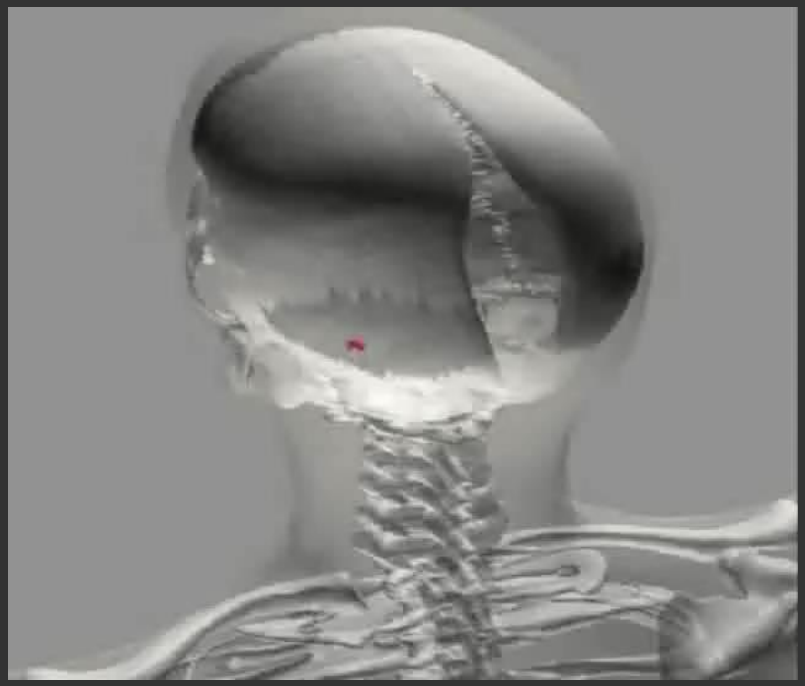
Myofascial Trigger Point: Hypercontracted Sarcomeres in a Taut Band of Muscle

Active MTrPs can only be diagnosed by systematic palpation

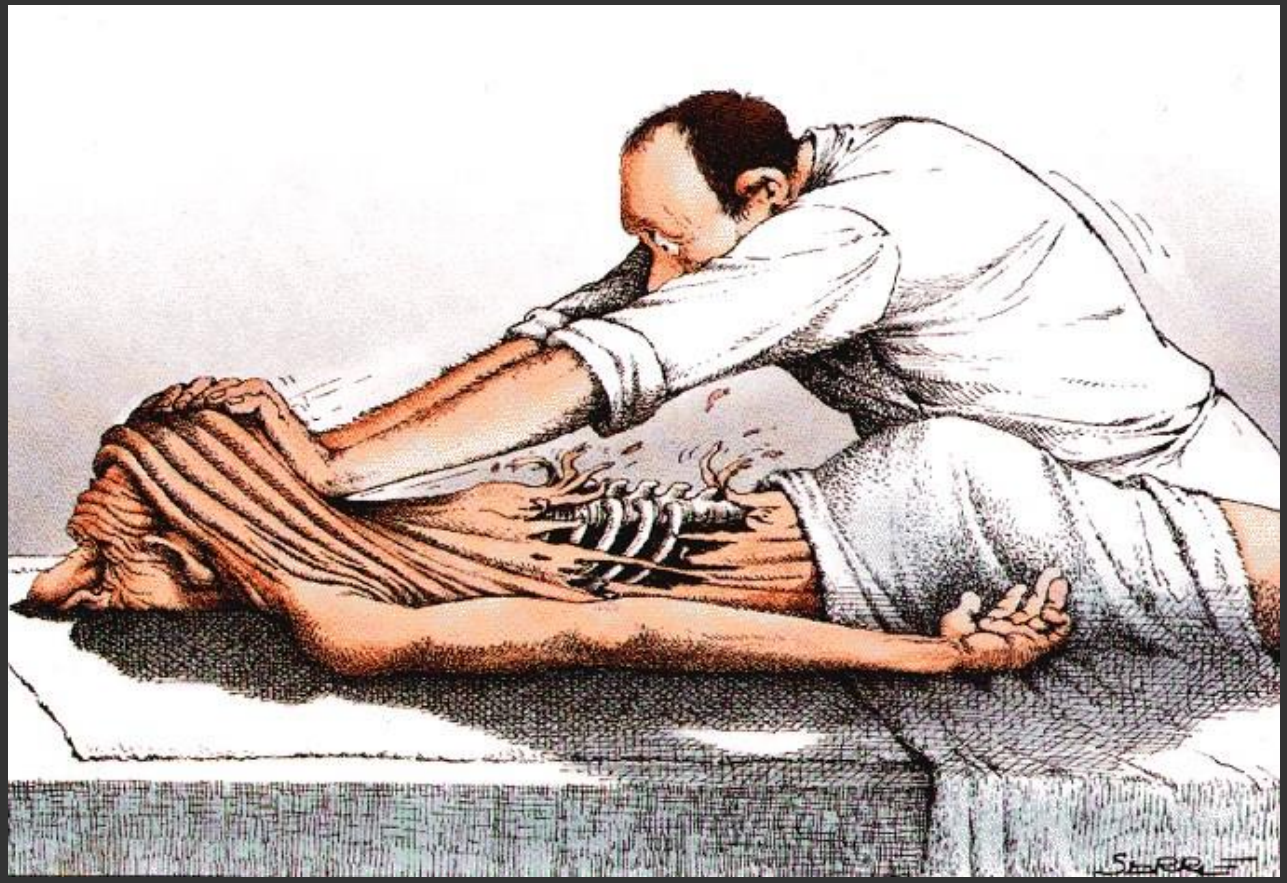


Hans-Werner Weisskircher
www.trigger-point.com

Apply *Firm* Pressure

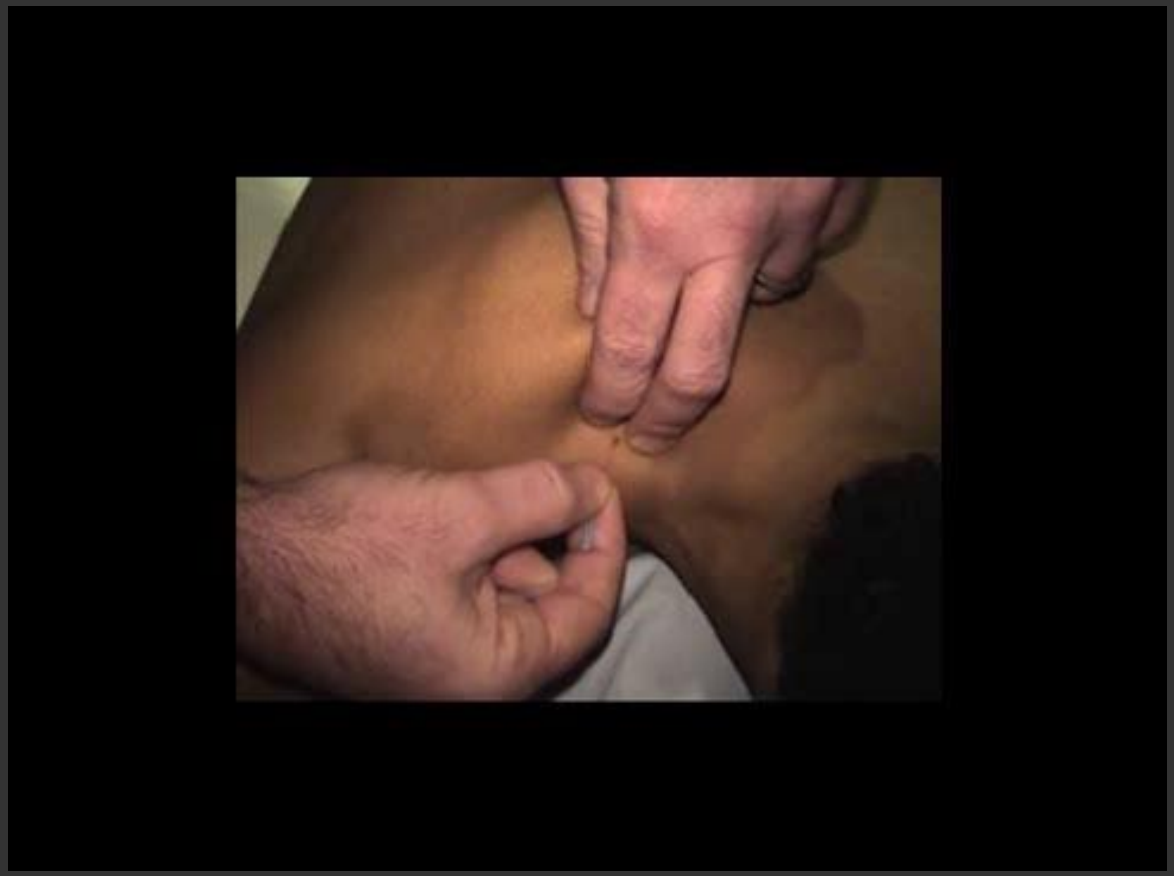


Manual Therapy



Trigger Point Injections and Dry Needling: Proper Technique to Elicit Local Twitch Responses is Essential

Hong CZ *Arch Phys Med Rehab* **1994;73:256**



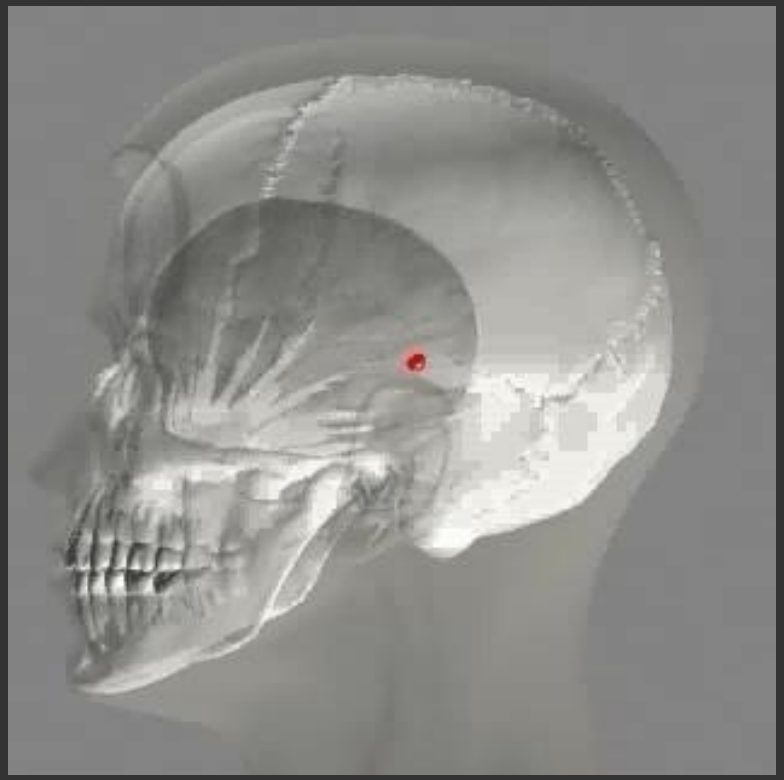
Courtesy Joseph Audette, MD

How do dry needling and injection techniques work for MPS?

What is the pathophysiology of myofascial pain?

UNKNOWN

Matrix of Myofascial Pain



Physical Finding and Symptom Cluster without Demonstrable Pathology

Hans-Werner Weisskircher
www.trigger-point.com

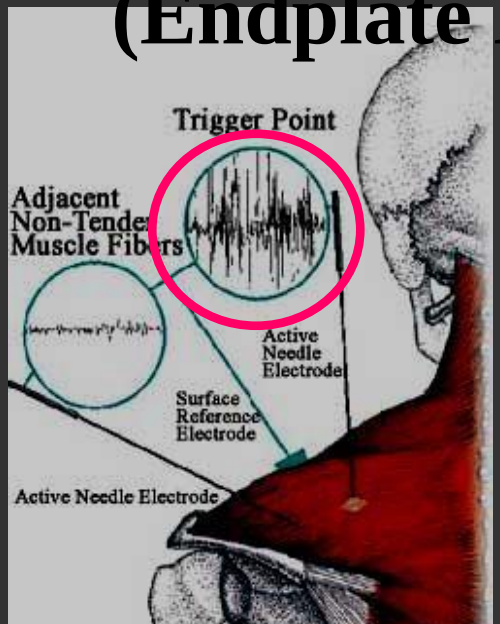
Simons' Integrated Hypothesis

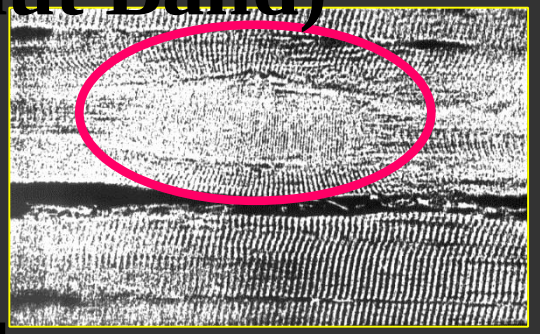
Pathophysiology

Histopathology

Increased Miniature Endplate Potentials (Endplate Noise)

Increased Fiber Tension (Taut Band)

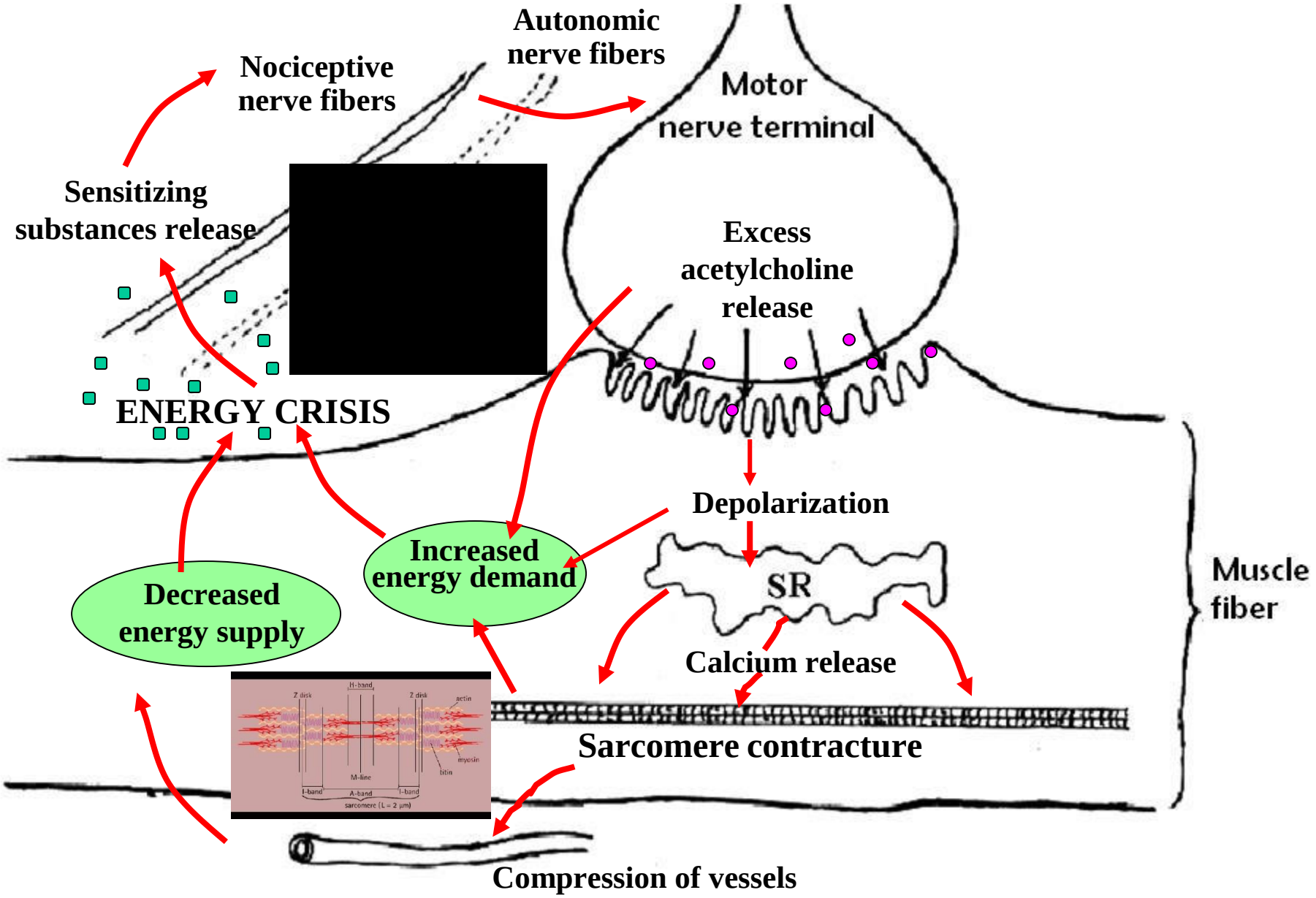




Histochemistry

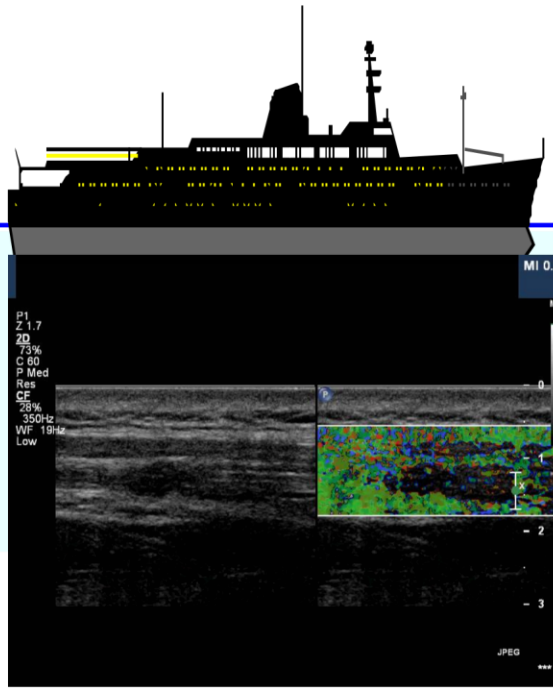
Release of Sensitizing Substances? (Pain)

Simons' Integrated Hypothesis


Autonomic nerve fibers
Nociceptive nerve fibers
Motor nerve terminal
Sensitizing substances release
Excess acetylcholine release
ENERGY CRISIS
Depolarization
Increased energy demand
Decreased energy supply
SR
Muscle fiber
Calcium release
Sarcomere contracture
Compression of vessels

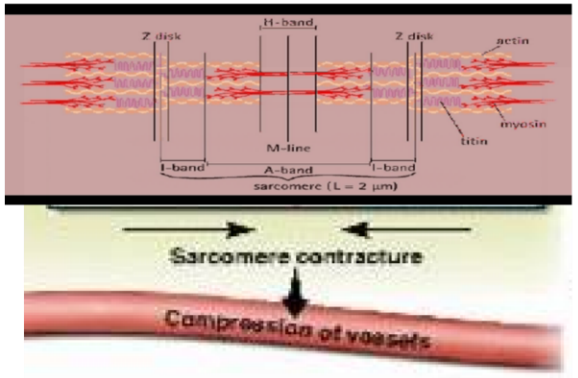
Is Simons' Hypothesis about the

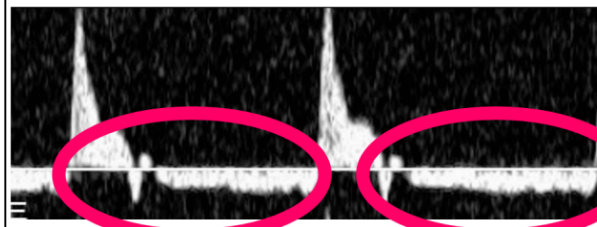
Biochemical Milieu, Viscoelastic Properties and



Clinical findings

Underlying milieu?





Ischemia/Hypoxia associated with MTrPs Correct?

Myofascial Trigger Points:

Doors are Opening Worldwide

Courtesy Jan Dommerholt

Exploring the Matrix of Myofascial Pain

1) Measured the local biochemical milieu of MTrPs *in vivo* (e.g., inflammatory mediators, neuropeptides, cytokines, catecholamines, etc.)
2) Developed a repeatable and reliable diagnostic imaging method for evaluating the nature of MTrPs and surrounding soft tissue (e.g., viscoelastic properties, vasculature, etc.)

Biochemical Data Validate the Clinical Findings!

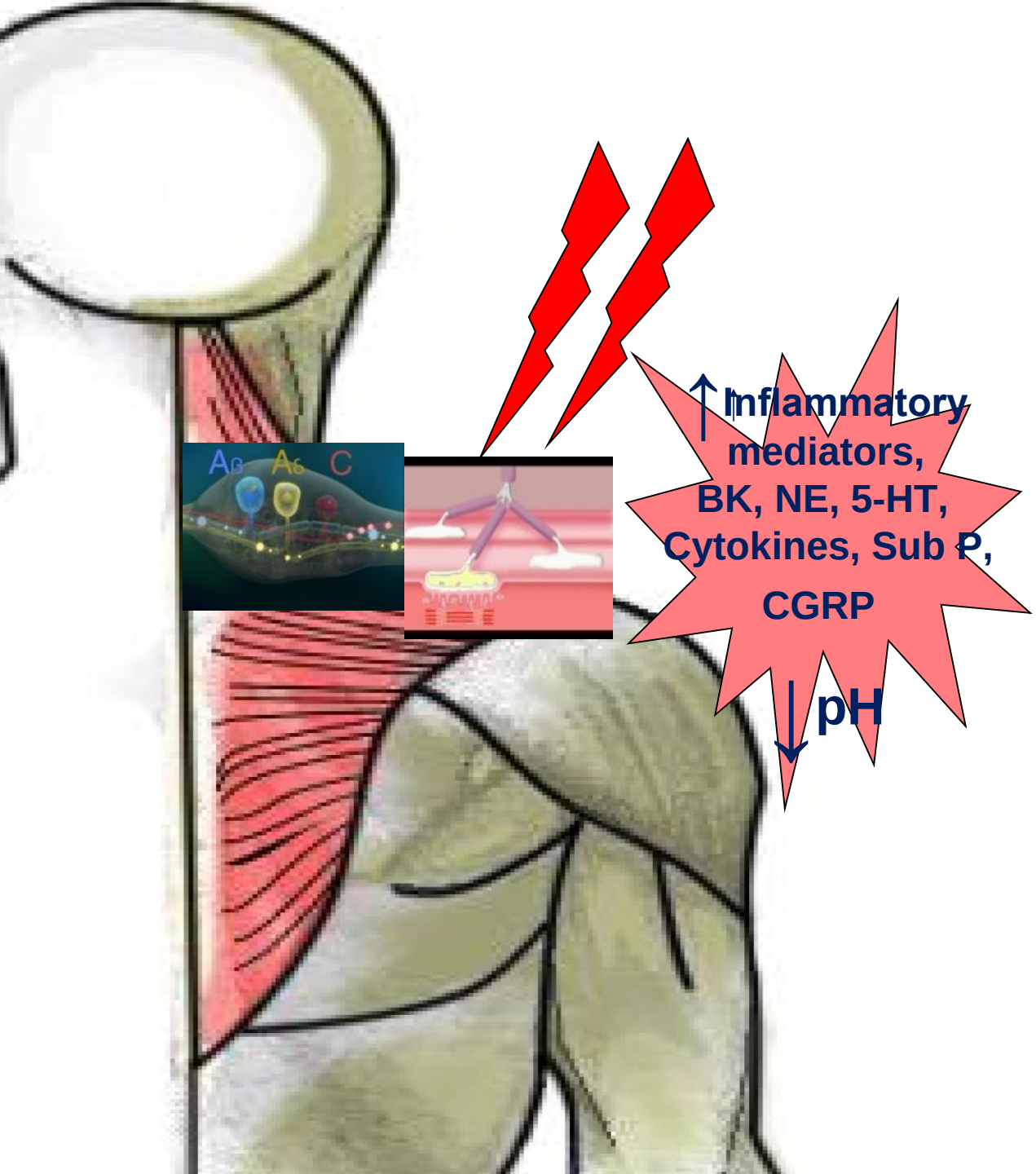
Using Travell and Simons' criteria and digital palpation, we have demonstrated and confirmed that objective biochemical data validate the diagnostic distinction clinicians make among *active* myofascial trigger points (MTrPs), latent MTrPs and uninvolved muscle

Shah et. al. *J of App Physiol*. 2005

Shah et. al. *Archives of PM&R*. 2008

Sensitization:

Hallmark in Transition from Acute to Chronic Pain



Question

Peripheral Sensitization is exacerbated by all of the following mechanisms except

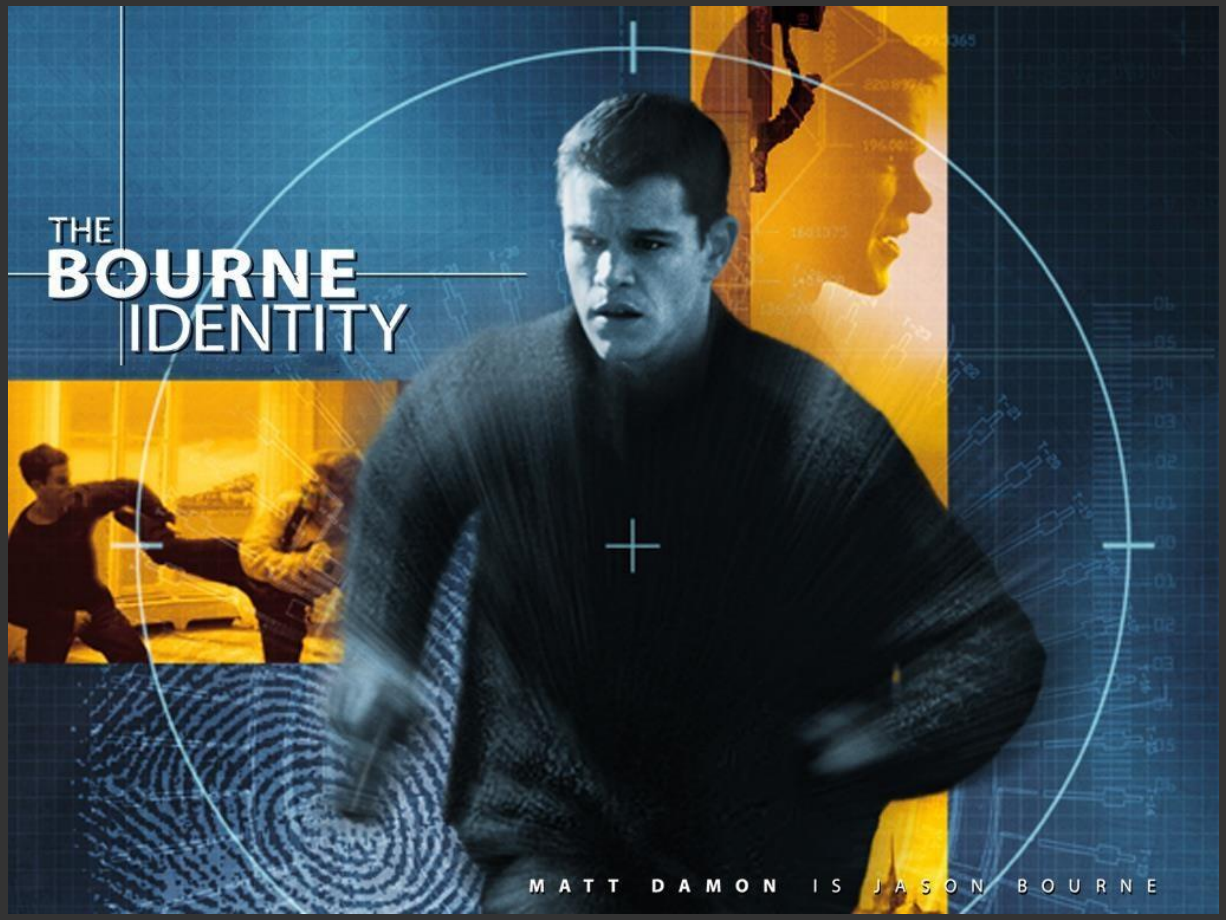
A. Lowered pH in the periphery

B. Elevated bradykinin in the periphery

C. Lowered substance P levels in the periphery

D. Elevated serotonin in the periphery

Can you name the motion picture?



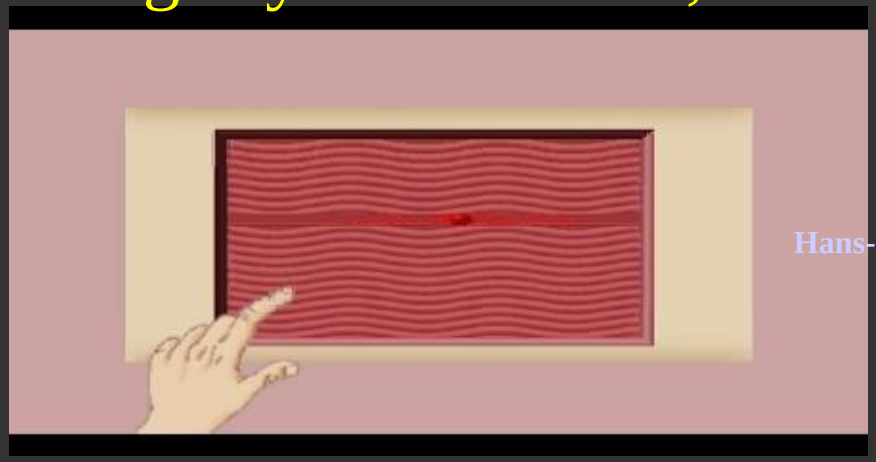
Can you name the motion picture?

Now *That* is Central Sensitization!

Controversies about MTrPs and Myofascial Pain

- What is the etiology and pathophysiology?
- What is the mechanism by which pain state begins, evolves and persists?
- How does a tender nodule progress to a myofascial pain syndrome?
- No consensus about which soft tissues are involved
- The physical findings are not always discernable
- No consensus about objective measures for therapeutic outcomes

Although Digital Palpation of MTrPs is the Gold Standard for Diagnosing Myofascial Pain, it Does Not:



Hans-Werner Weisskircher www.trigger-point.com

- Provide a reliable and sensitive method of diagnosis and measurement of treatment efficacy
- Provide quantitative comparisons of the tissue properties before and after treatment

- Objectively discriminate between superficial and deep MTrPs or describe the surrounding milieu

Novel Applications of Ultrasound Technology to Visualize and Characterize Myofascial Trigger Points and Surrounding Tissue:

A New Direction to Address an Old Controversy

Controversy over Myofascial Pain and MTrPs

"Everyone has trigger points"

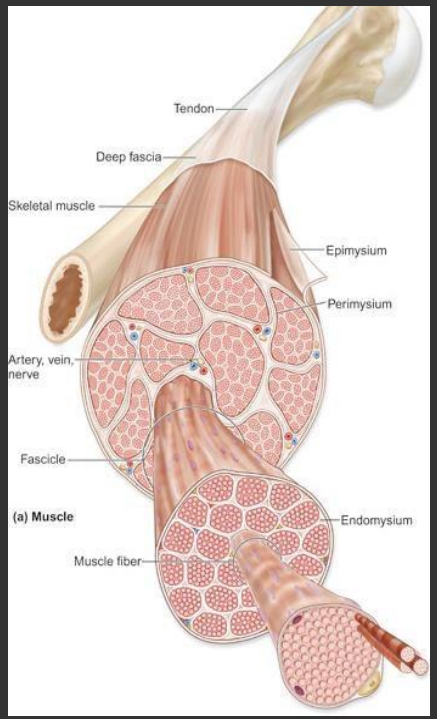
"That's your opinion. I can't find them"

"I don't *believe* they exist"

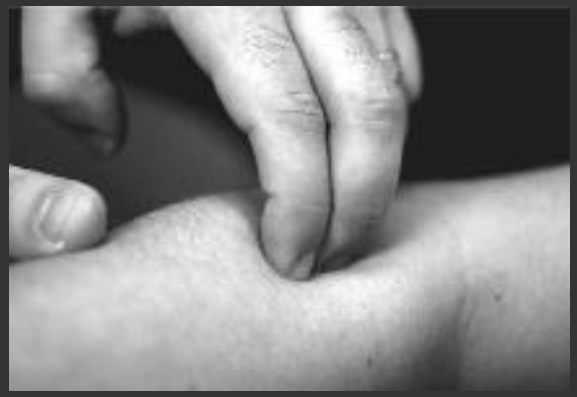
The Soft Tissue Neighborhood of Muscle & Fascia

Interrelationships between soft tissue structure, mechanical properties, and vascular physiology are implicated in myofascial pain

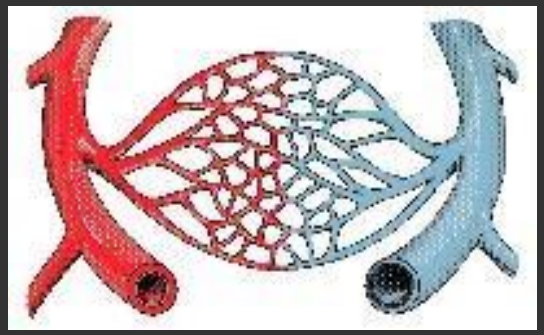
Microstructure and composition



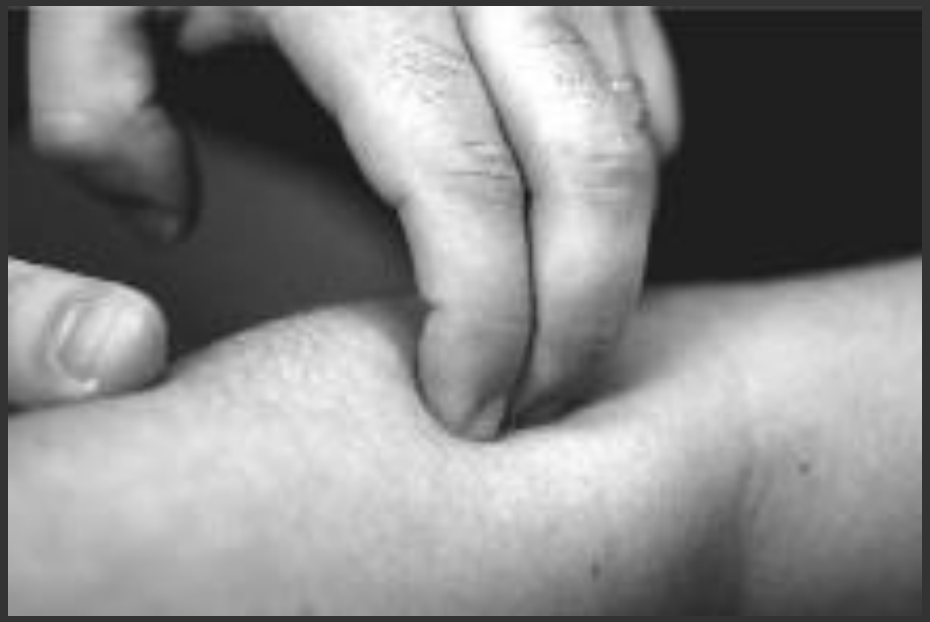
Mechanical (viscoelastic) tissue properties

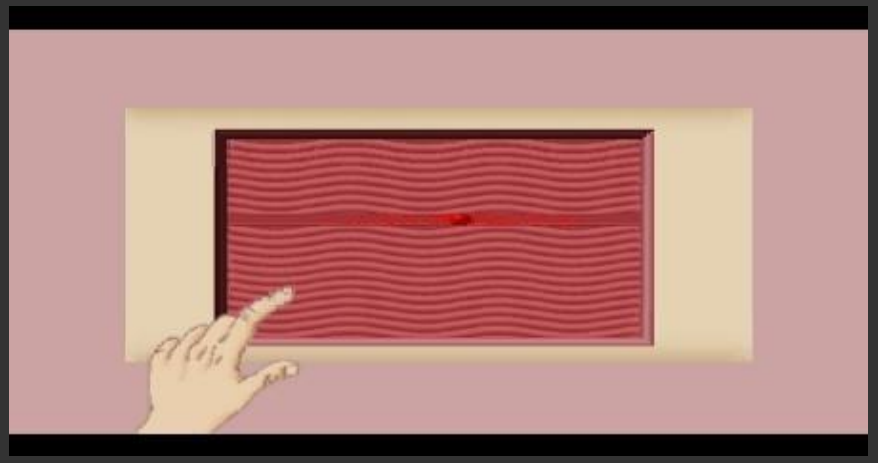


Vascular environment



What happens when you palpate the soft tissue?

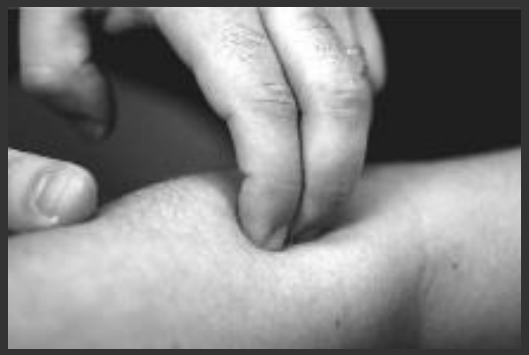


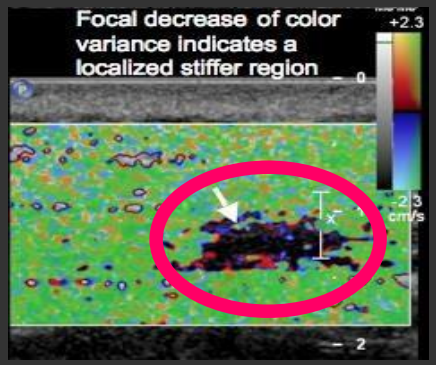


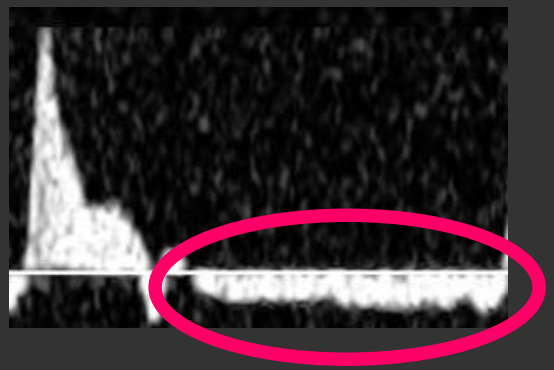
You are estimating the mechanical properties of the soft tissue in response to your perturbation/deformation

Lack of Consensus on the Diagnostic Criteria, including the Relationship between MTrP and MPS

- The lack of objective clinical outcome measures has been a barrier to critical evaluation of the efficacy of therapeutic methods like manual therapies, dry needling, acupuncture, etc.
- Ultrasound imaging can be used to visualize MTrPs and for objective clinical assessment in conjunction with digital palpation
- MTrPs are stiffer than surrounding tissue; *active* MTrPs have a larger surface area than latent MTrPs and *active* MTrPs can be distinguished from latent MTrPs by their unique blood flow waveform characteristics





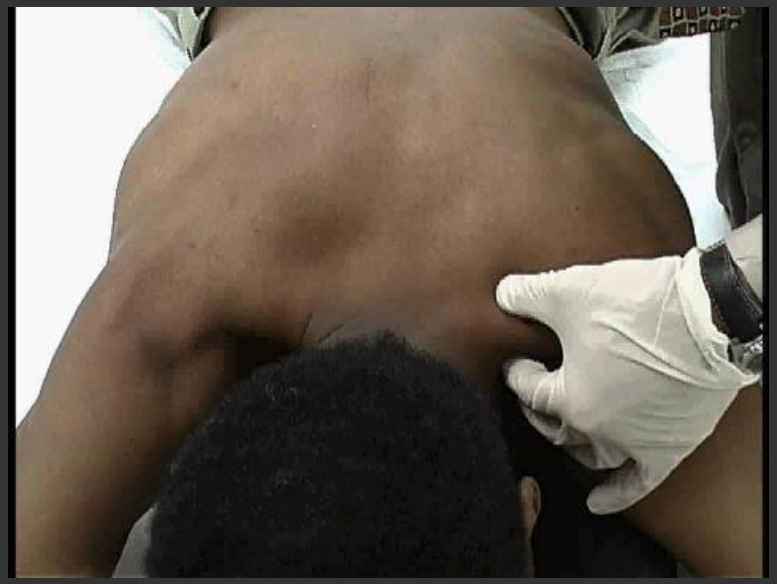


Sikdar et. al. *Archives of PM&R*. 2009

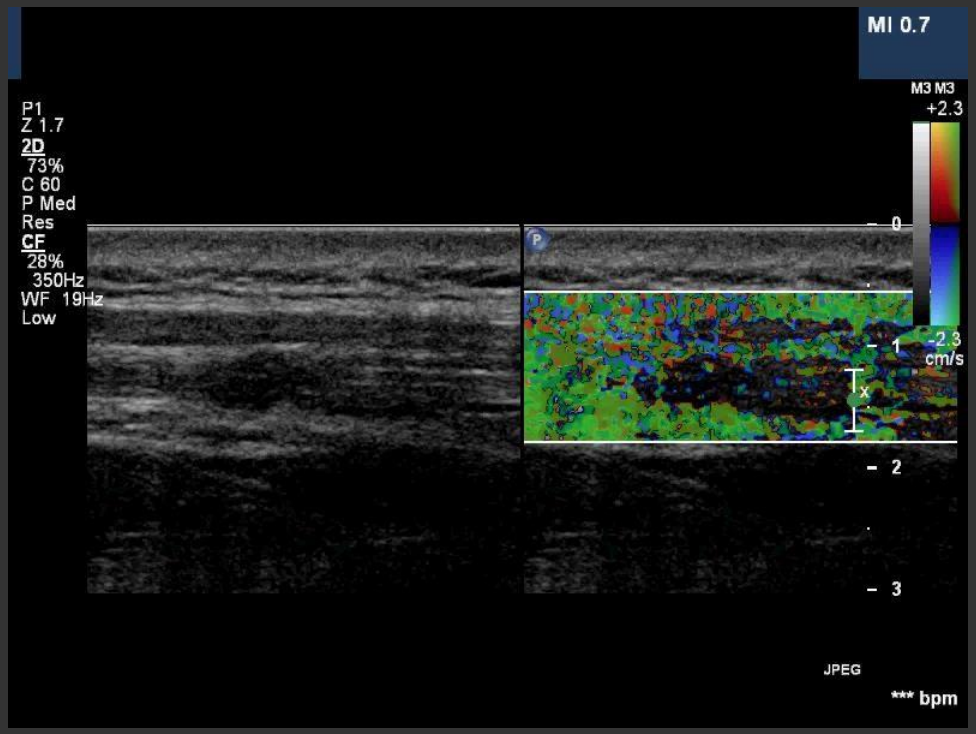
Ballyns et. al. *J Ultrasound Med* 2011

The MTrP is a Unique Physical Finding in MPS

- We are able to "*exploit*" the physical properties of the MTrP and its adjacent milieu and describe it more objectively
- This provides a useful starting point to investigate the patho-physiology of MPS and its relationship to established mechanisms of muscle pain

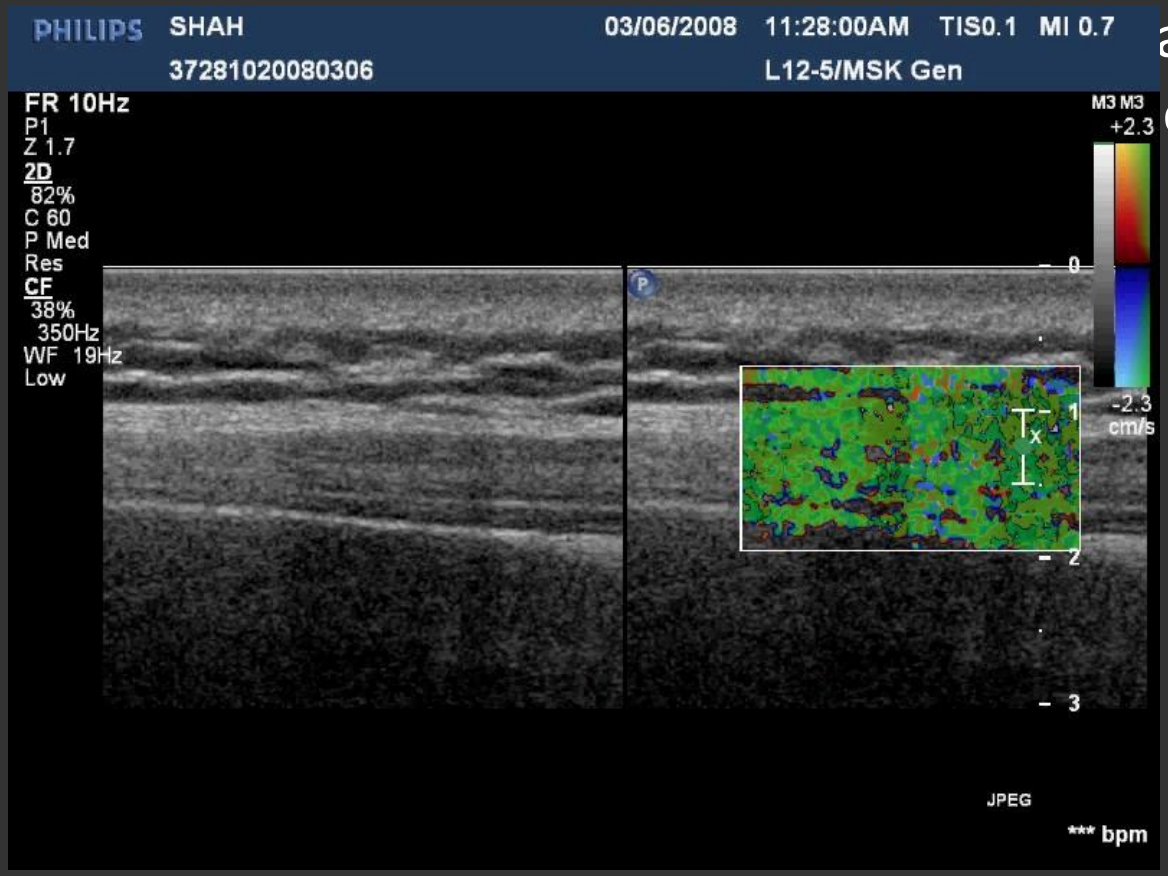


Courtesy Bryan O'Neill



Sikdar et. al. *Archives of PM&R*. 2009

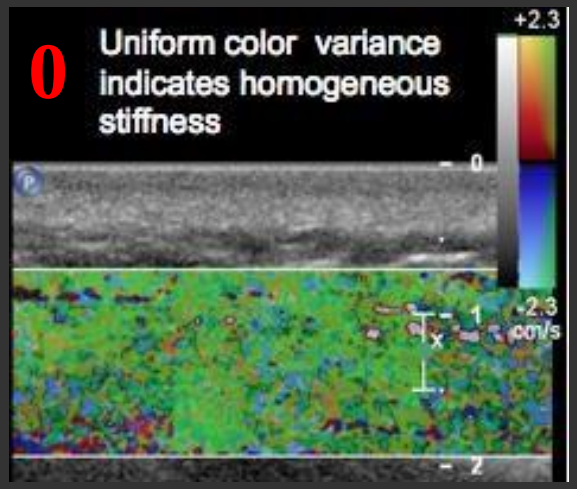
Vibration Sonoelastography of Uninvolved Muscle

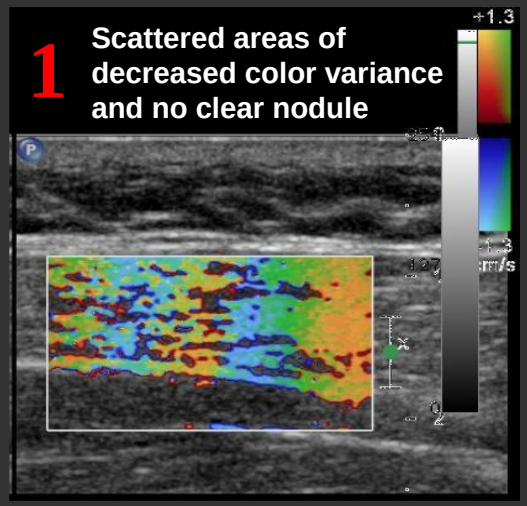


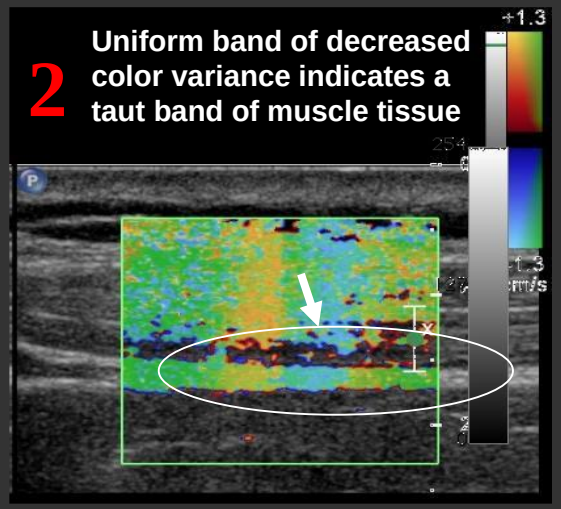
ance

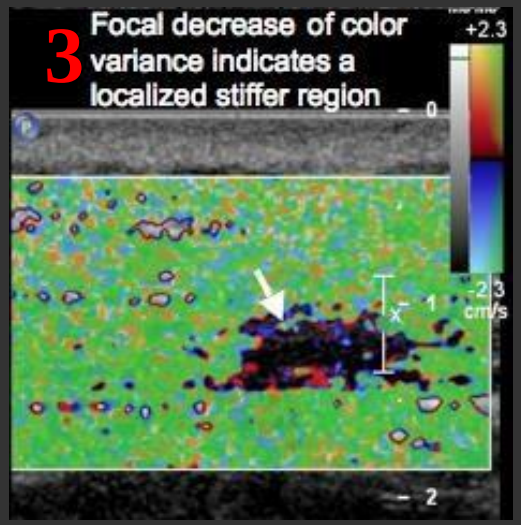
eous

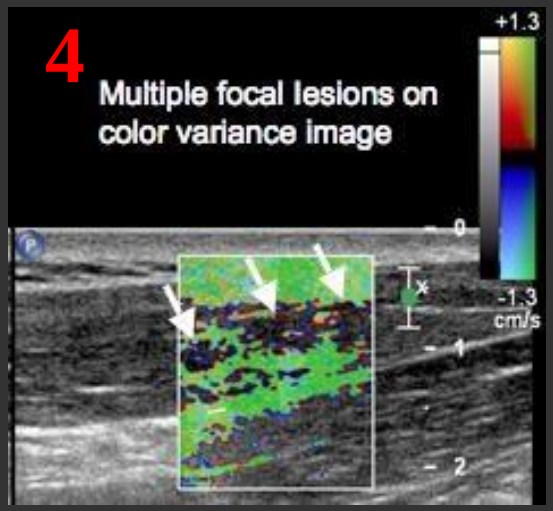
Spectrum of Sonoelastography Images









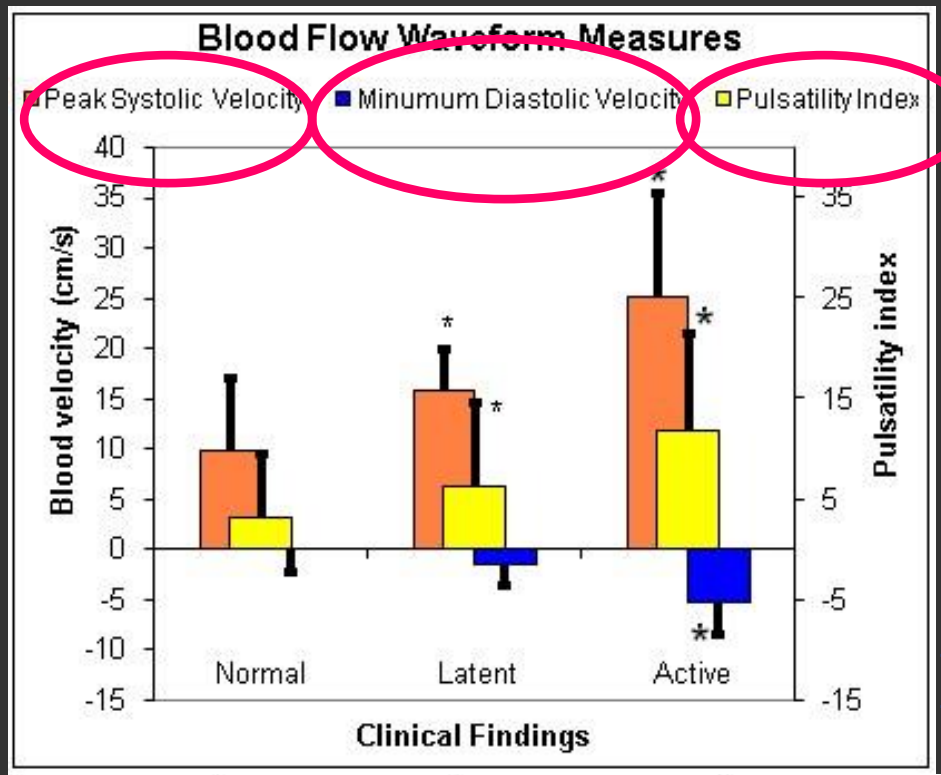


Sikdar et al. *IEEE Ultrasonics Sym.*, 2010

Imaging Advantages:

1) Objective Dx test – Quantify size and # of MTrPs
2) Objective description of natural history of MFP
3) Identify MTrPs in deeper tissue beyond palpation
4) Objective outcome measure to evaluate tissue changes in response to treatment

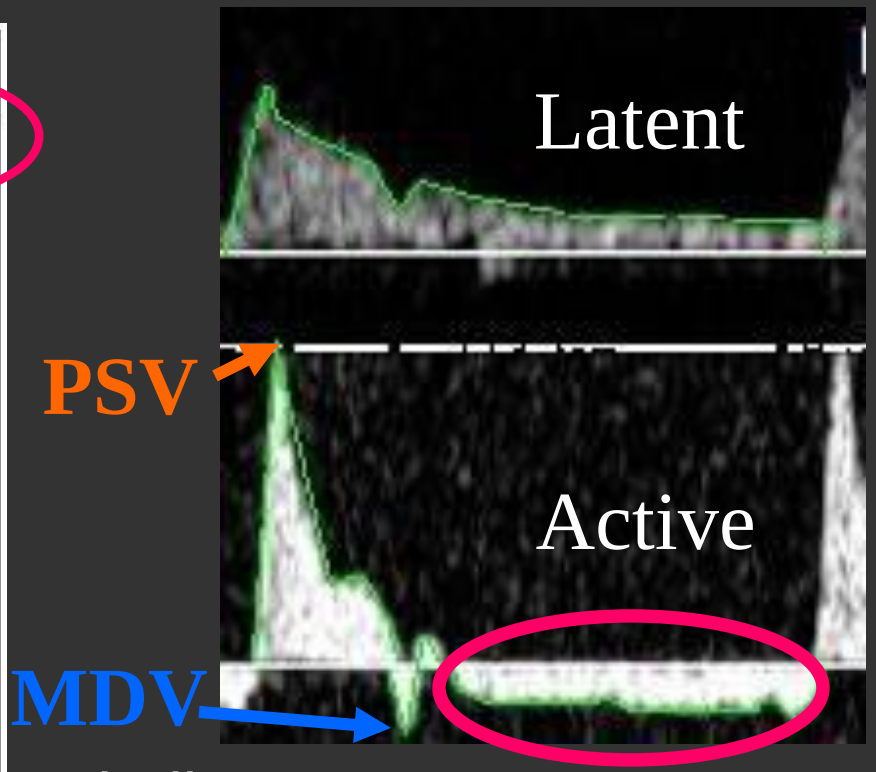
Quantitative Blood Flow Measures



	Peak Systolic Velocity	Minimum Diastolic Velocity	Pulsatility Index
Normal vs. Latent	p=0.18	p=0.667	p=0.147
Normal vs. Active	p=0.006*	p=0.04*	p=0.03*
Latent vs. Active	p=0.04*	p=0.043*	p=0.32

*p<0.05 for a two-sided Mann-Whitney U-test

Sikdar et al. *IEEE EMBC.*, 2010

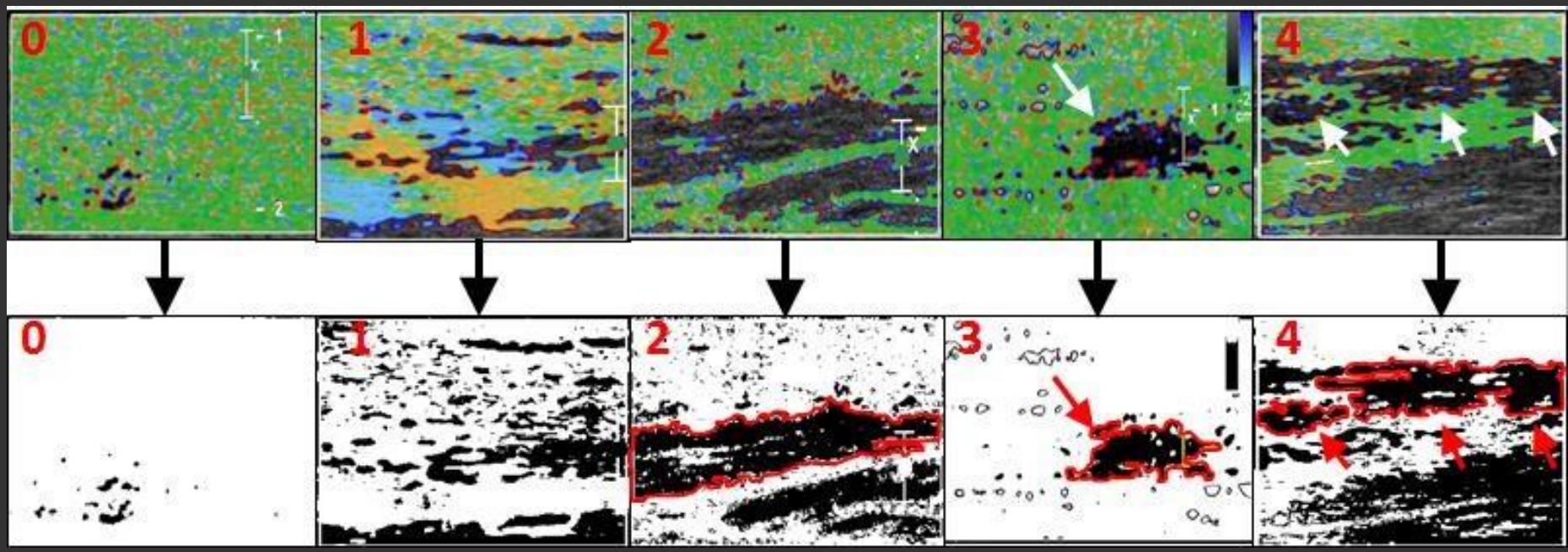


Findings:

1) *Active* MTrPs had more pulsatile flow with higher systolic and negative diastolic flow velocities

2) Compared to latent sites, A***ctive*** MTrPs display an increase in downstream vascular resistance and a more highly compliant local vascular environment

Trigger Point Area Measured by Importing Elastographic Images into Image J

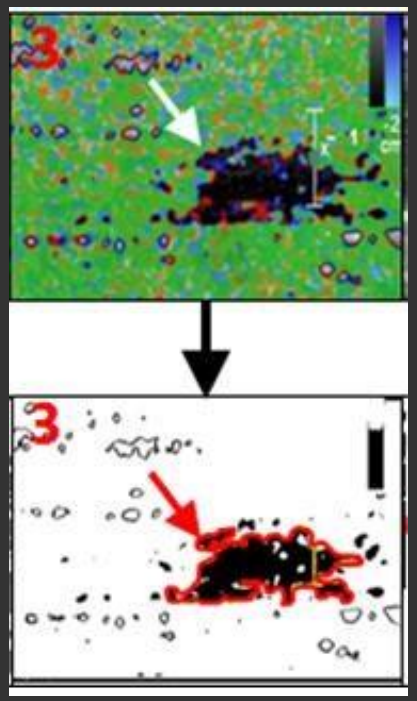


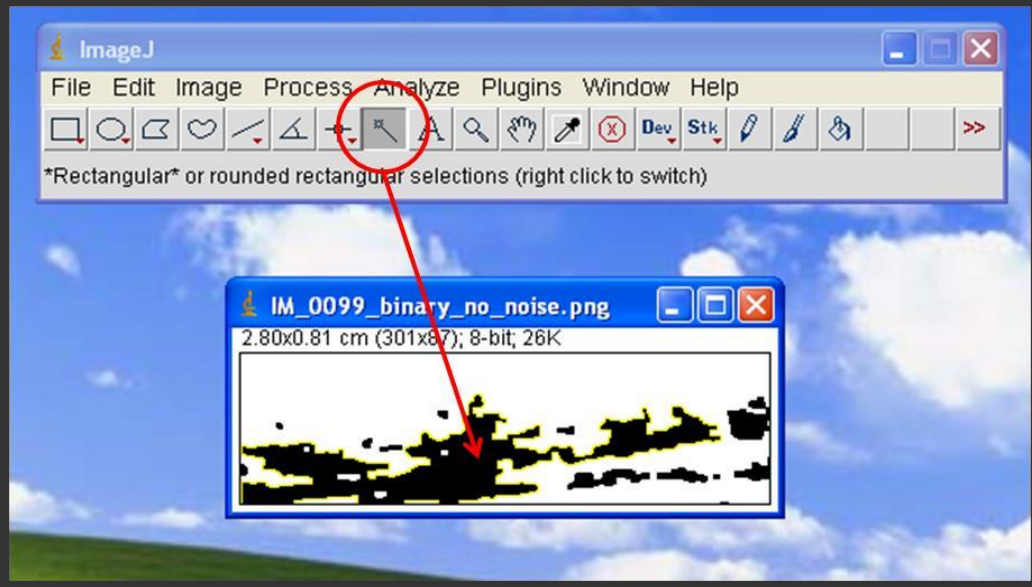
Measuring Trigger Point Surface Area

1) **Make the US image binary (black and white)**

2) **The tracing tool selects the black area that is evident in the color variance**

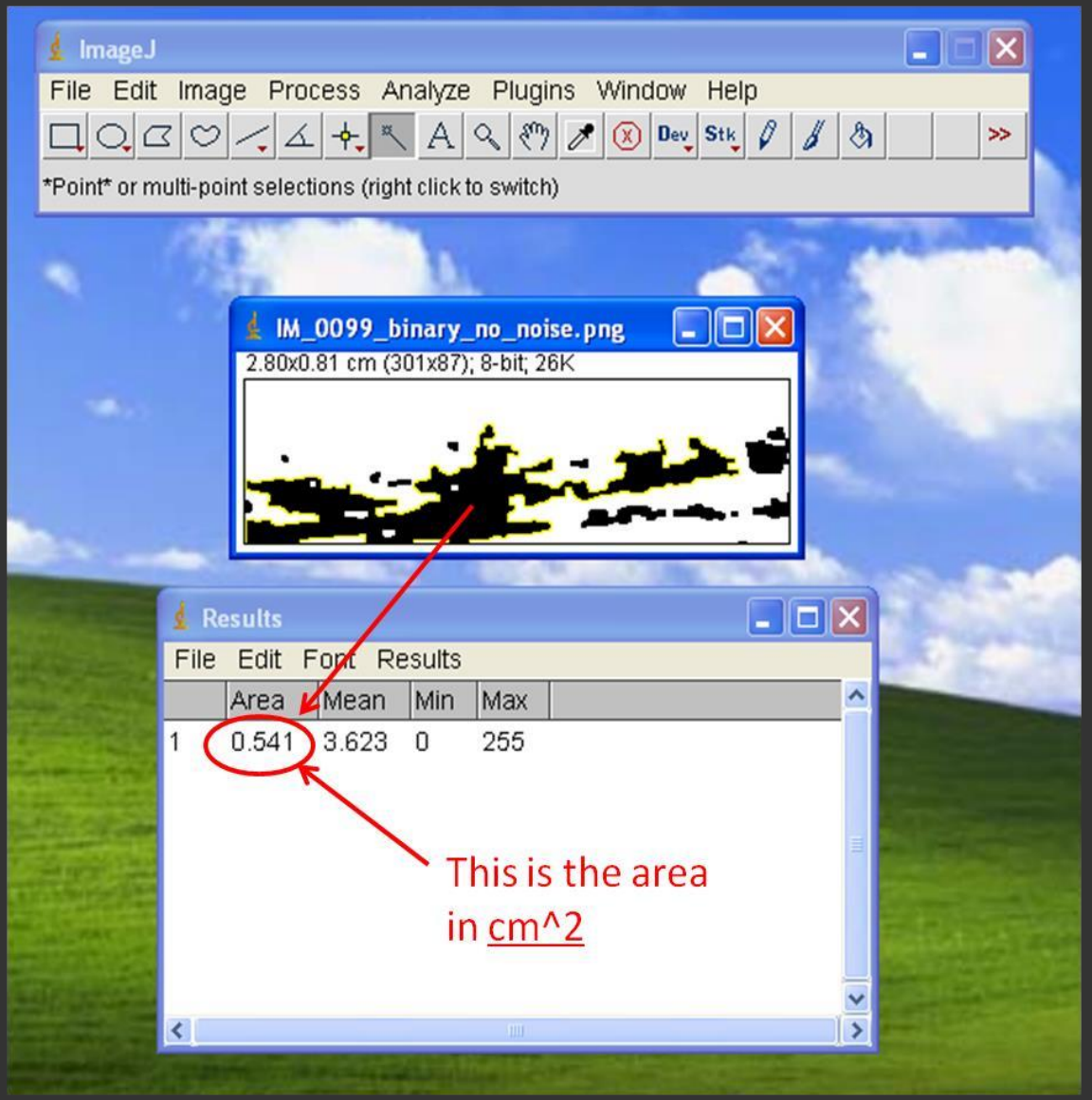
3) **The program recognizes the contiguous border and is able to select it as an individual entity**





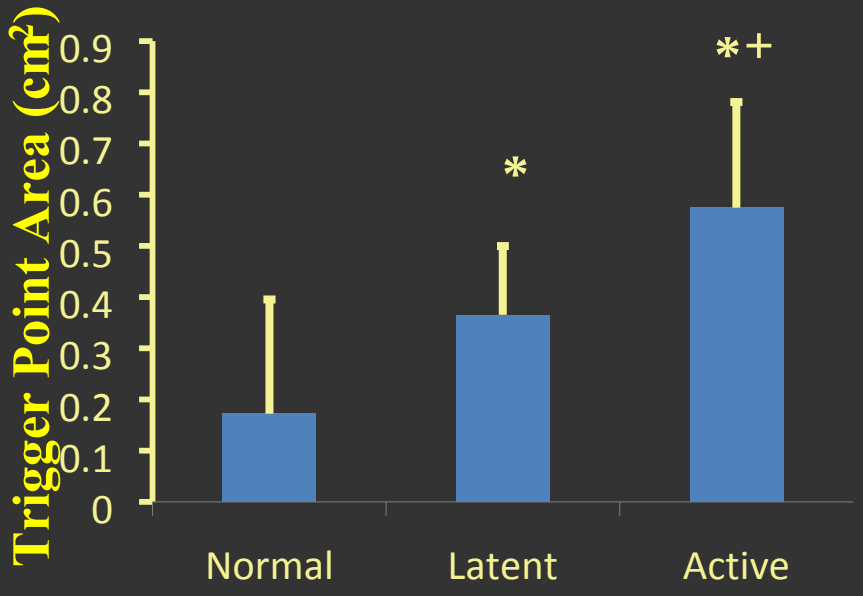
Measuring Trigger Point Surface Area

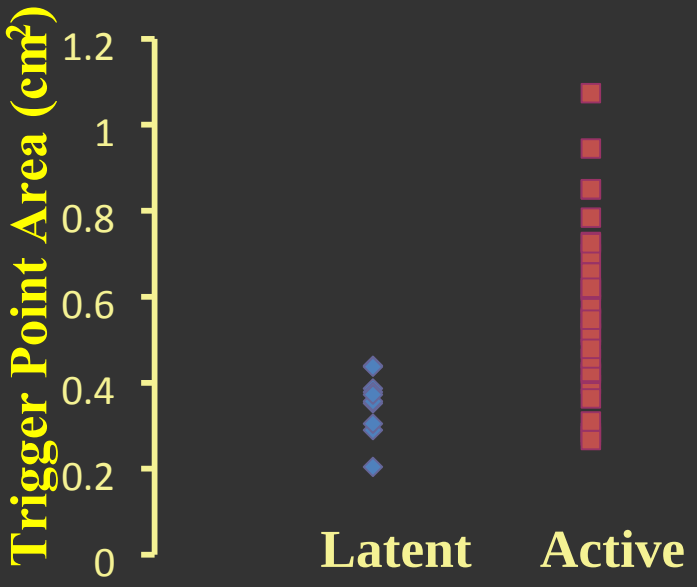
4) **Program is able to count each individual pixel to calculate a measurement of surface area**



Trigger Point Area

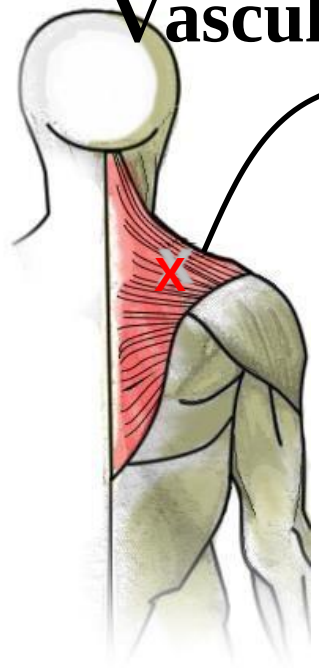
N=44 subjects with cervical pain
169 muscle sites

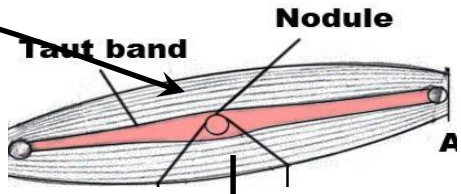


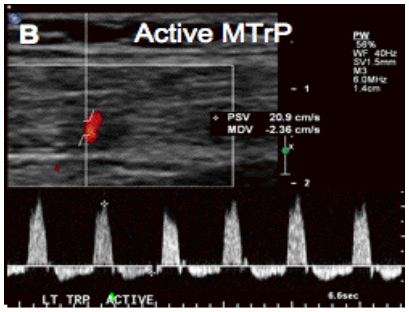


Ballyns et al., *J Ultrasound Med*, 2011

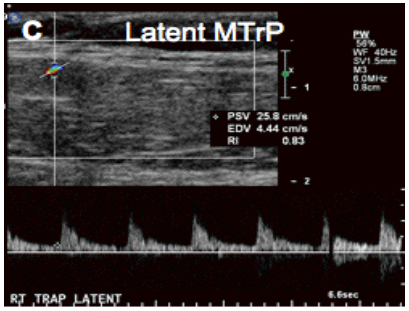
Vascular Remodeling in the Neighborhood of the MTrP



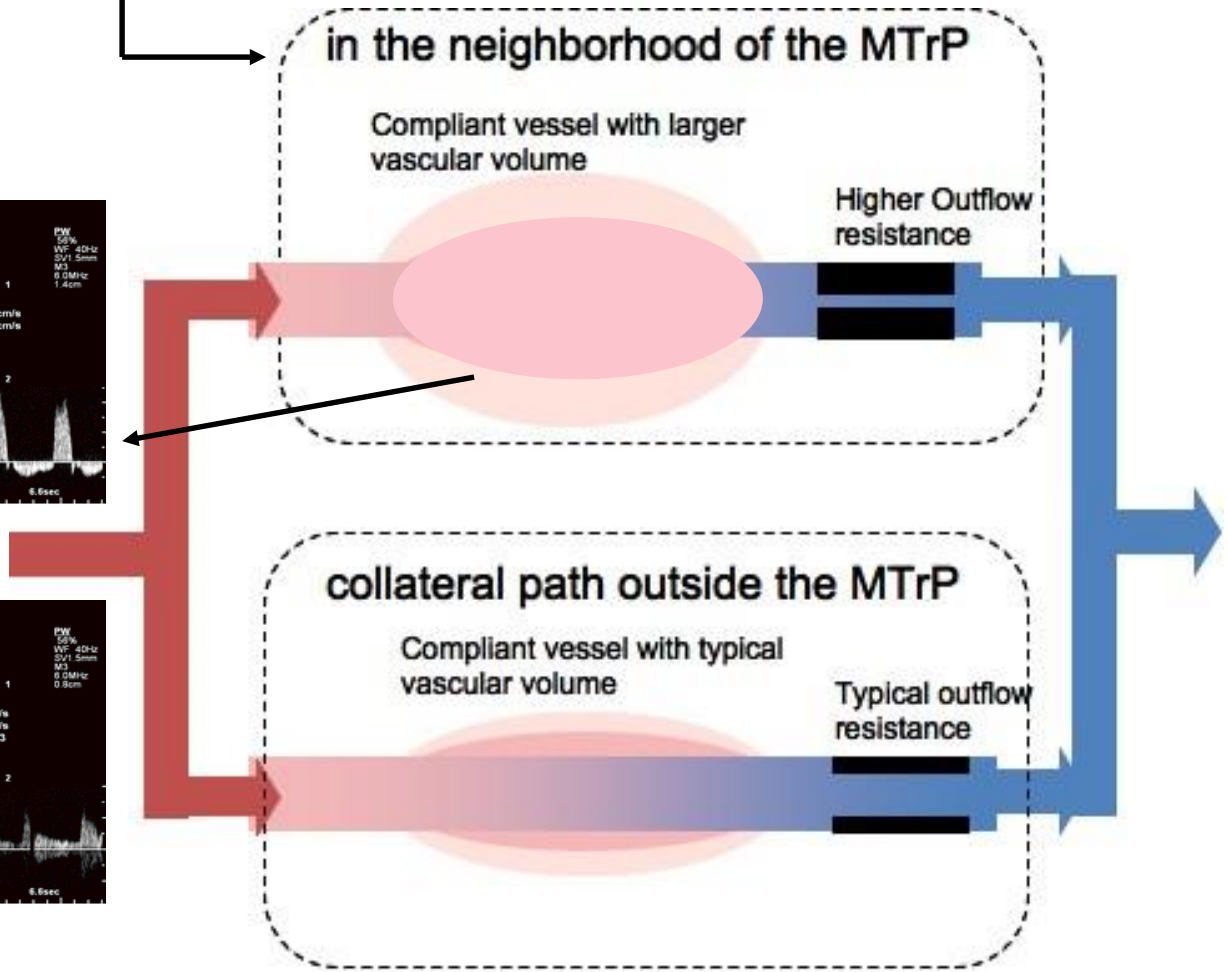




Reversal



No Reversal



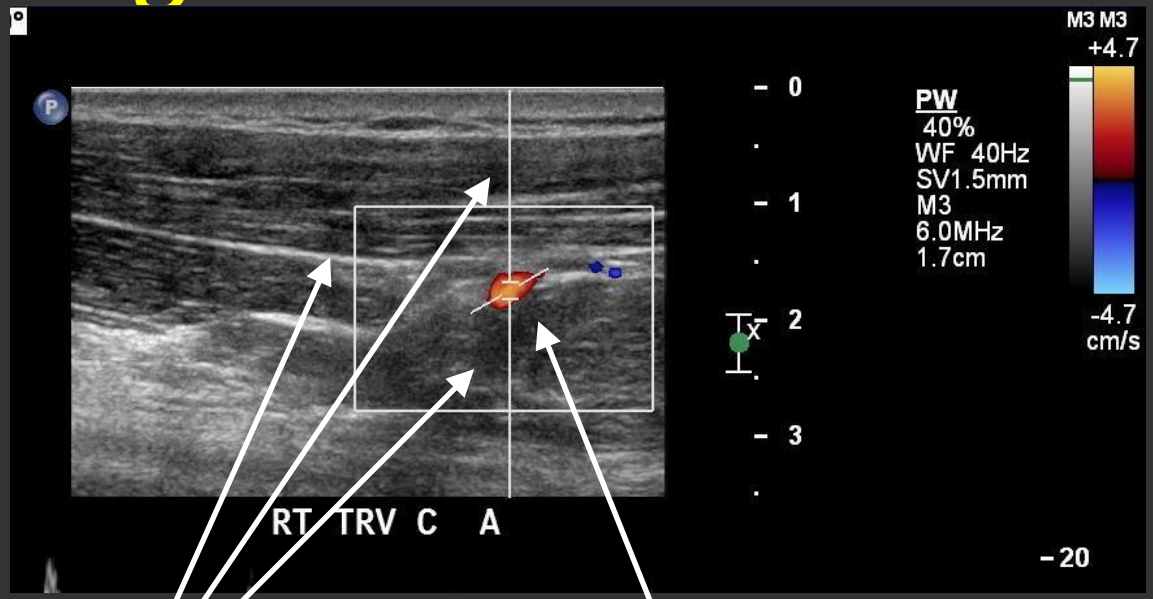
Vascular Remodeling: In the Neighborhood of the MTrP

Mechanisms of Vascular Remodeling

1. Vascular Redesign
2. Development of New Blood Vessels

   “Neo-vascularization”

Vascular Remodeling: In the Neighborhood of the MTrP



Hypoechoic Regions

Large Blood Vessel

Vascular Remodeling: In the Neighborhood of the MTrP

Angiogenesis

- Local Environmental Cues
- Role of IL-8?

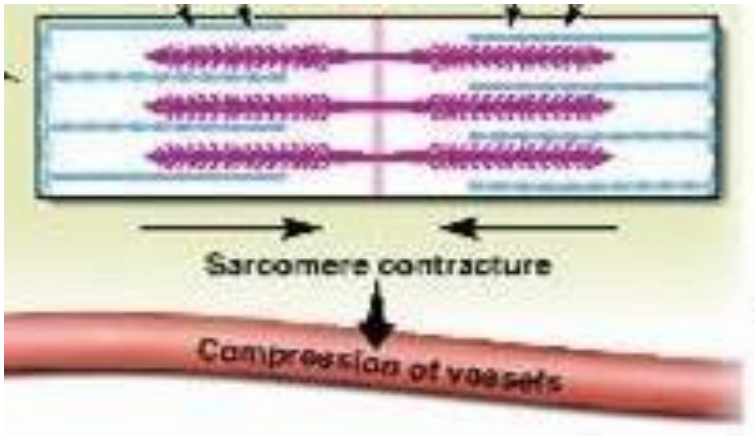
***Neo*-vascularization**

[redacted] → Cascade of Cytokines (**IL–8**) → **Angiogenesis** → **New Blood Vessels in the MTrP Region**

Cascade of Cytokines (**IL–8**) → Hypernociception

Observations

- MTrPs exhibit different echogenecity compared to surrounding muscle
- Vibration sonoelastography shows differences in relative stiffness between MTrPs and normal (uninvolved) muscle
- Blood flow waveform characteristics can be used to differentiate ***Active*** and Latent MTrPs
- Retrograde flow in diastole (indicating a very high resistance vascular bed and



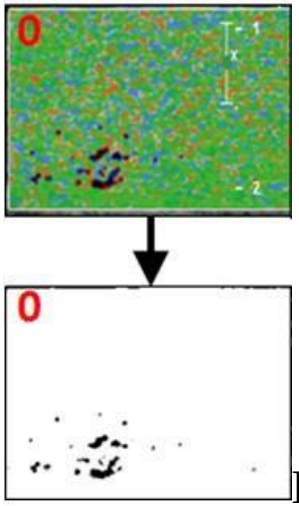
possible blood vessel compression) is associated with ***Active*** MTrPs

Sikdar S, Shah JP, Gebreab T, Yen R, Gilliams E, Danoff J, Gerber L. Applications of Ultrasound Technology to Visualize and Characterize Myofascial Trigger Point and Surrounding Soft Tissue. *Arch. Phys. Med. Rehabil.*, 2009

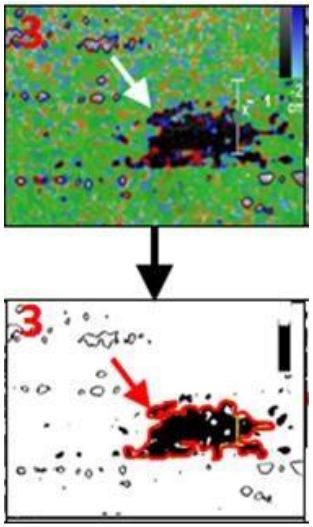
Observations

- Vibration sonoelastography is an effective method for measuring MTrP size and was excellent for distinguishing the site type
- Sonographic techniques can play a role in:

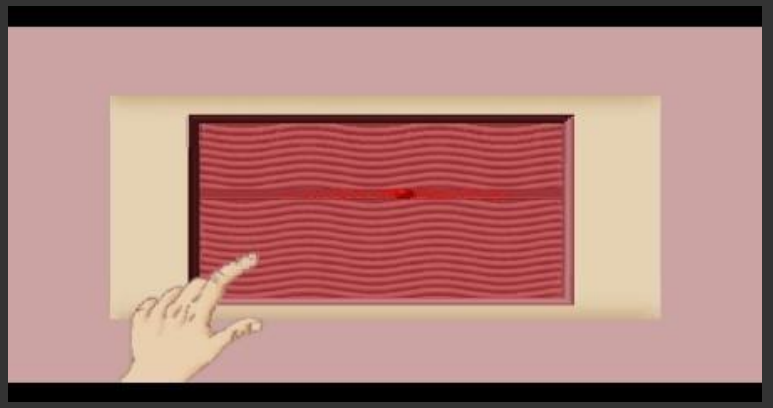
- Objectively identifying active vs. latent MTrPs
- Developing outcome measures after therapeutic intervention
- Better describing the complex environment surrounding MTrPs

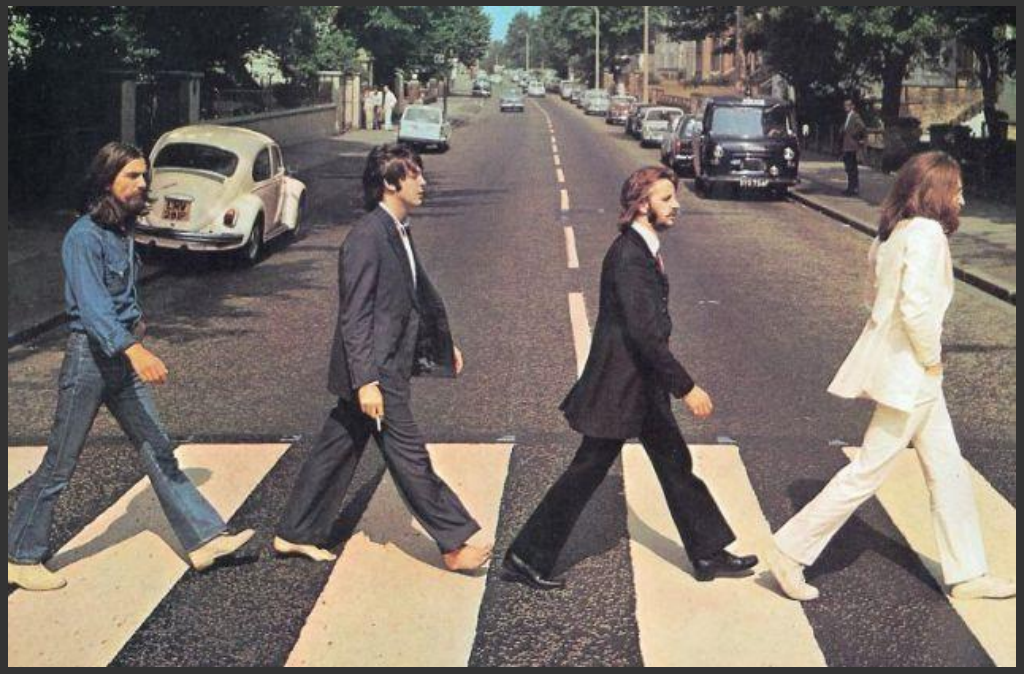


Ballyns et al., *J* *Ultrasound Med*, 2011



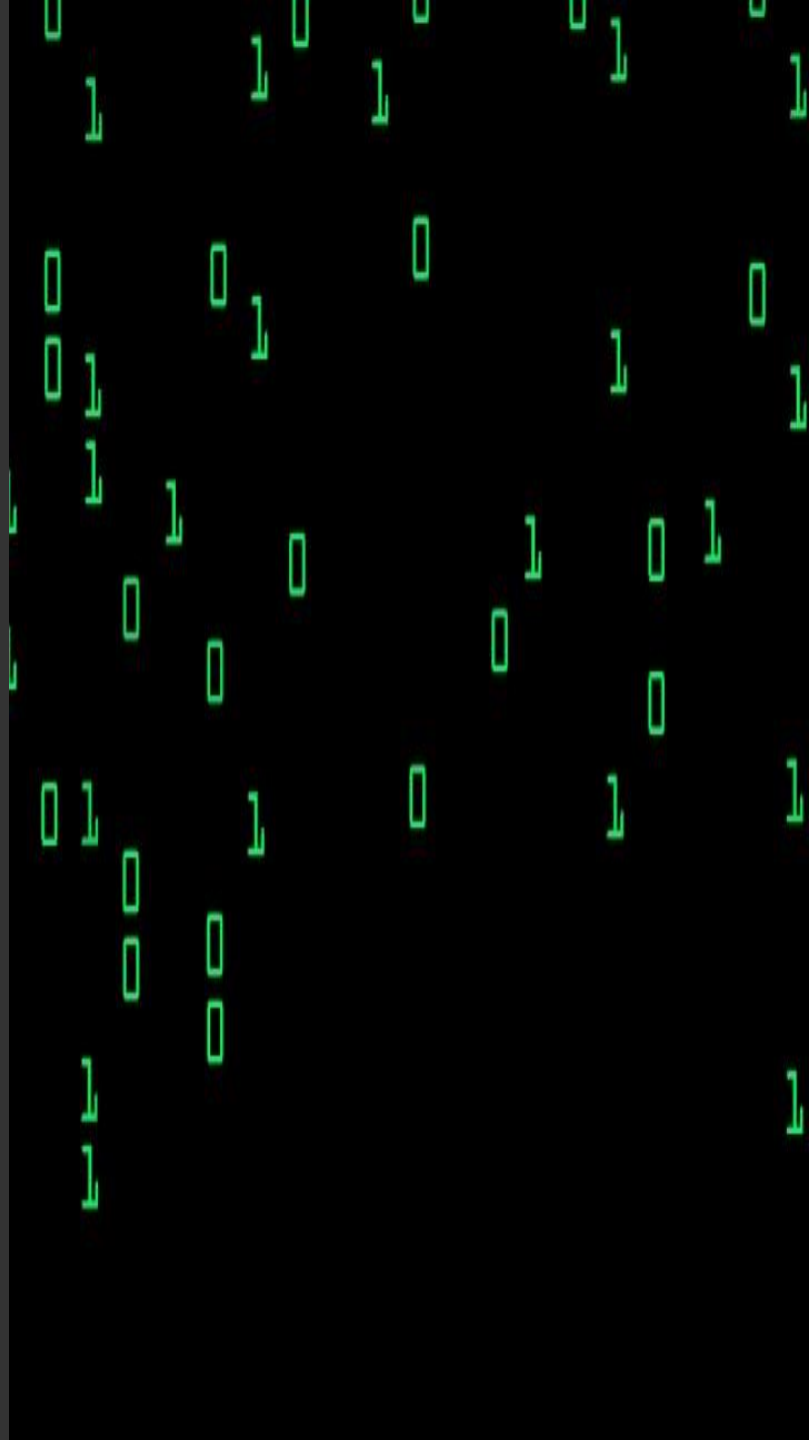
What do MTrPs and Yoko Ono have in Common?





They both cause *Tension* in the Band!

The Dynamic Role of Sensitization in Neuro-musculoskeletal Pain: *Enter the Matrix*



Nociceptors

- Activation:
  - Mechanical stress
  - Thermal stress
  - **Chemical irritation**

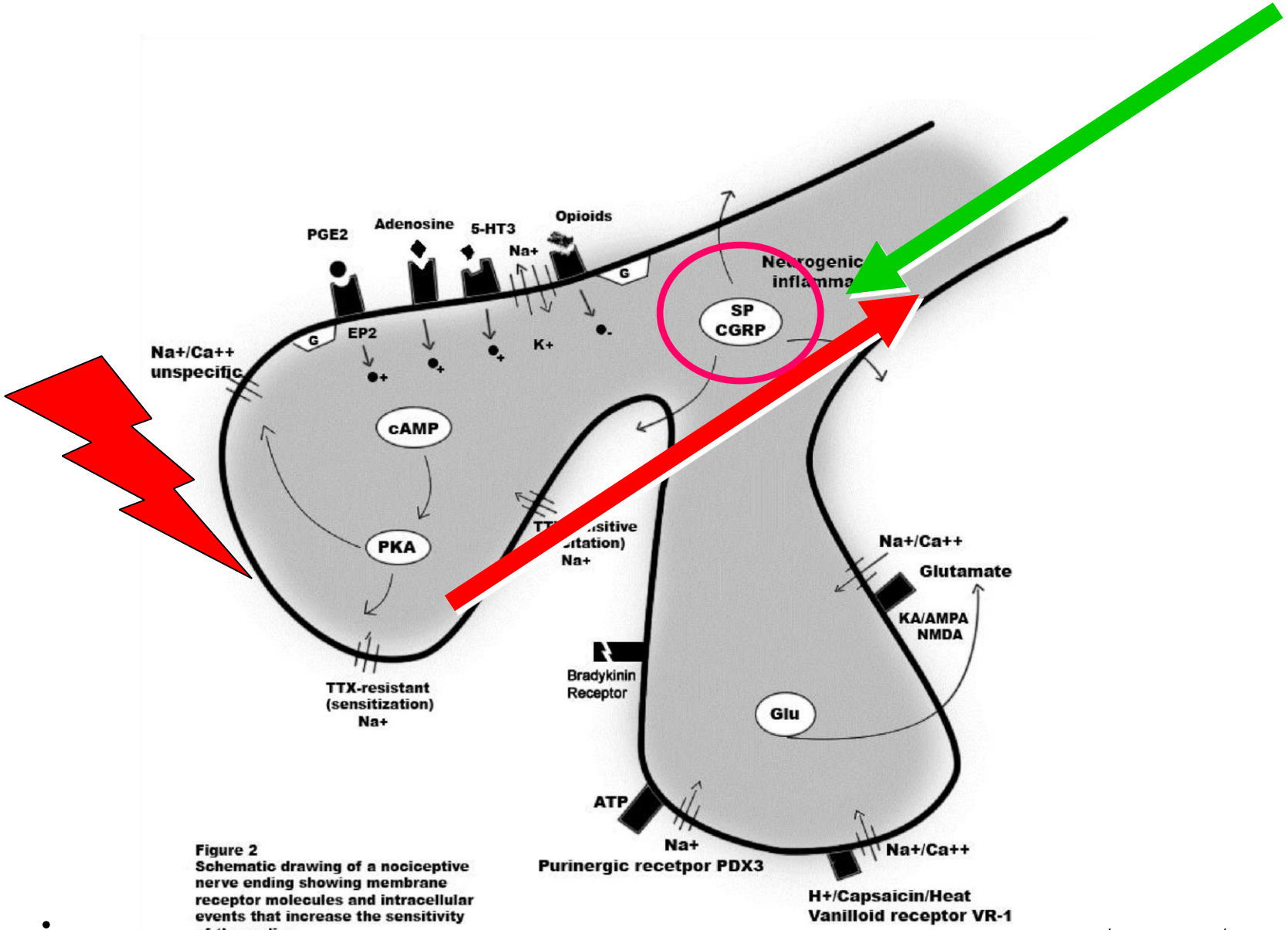


Figure 2
Schematic drawing of a nociceptive nerve ending showing membrane receptor molecules and intracellular events that increase the sensitivity of the ending.

Adapted from
Mense, S. *The Pathogenesis of Muscle Pain.* Current Pain and Headache Reports 2003

Nocicep tructures

Muscle Pain

Peripheral Mechanisms Underlying Sensitization

Muscle Nociception – Binding of Substances to Matched Chemoreceptors

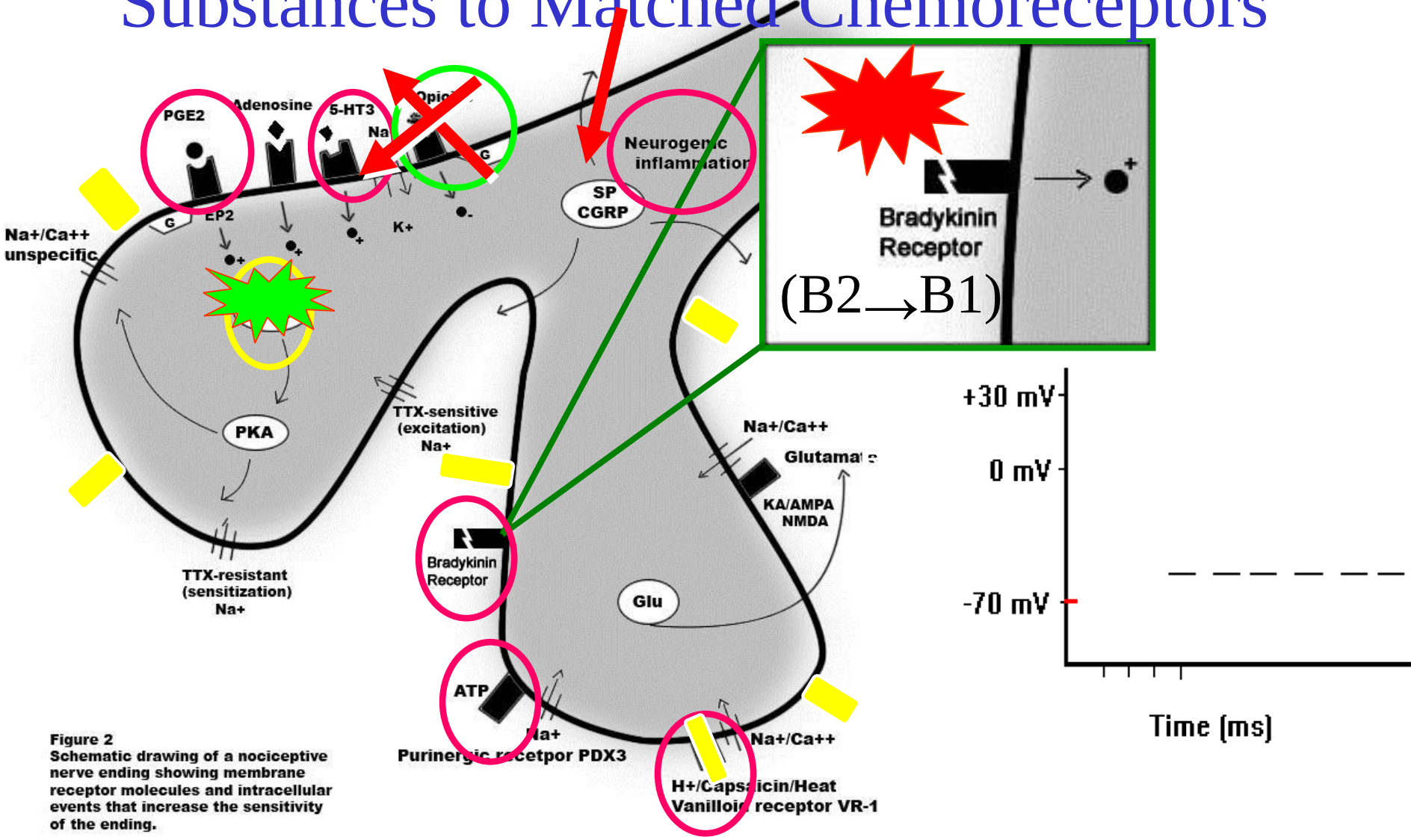
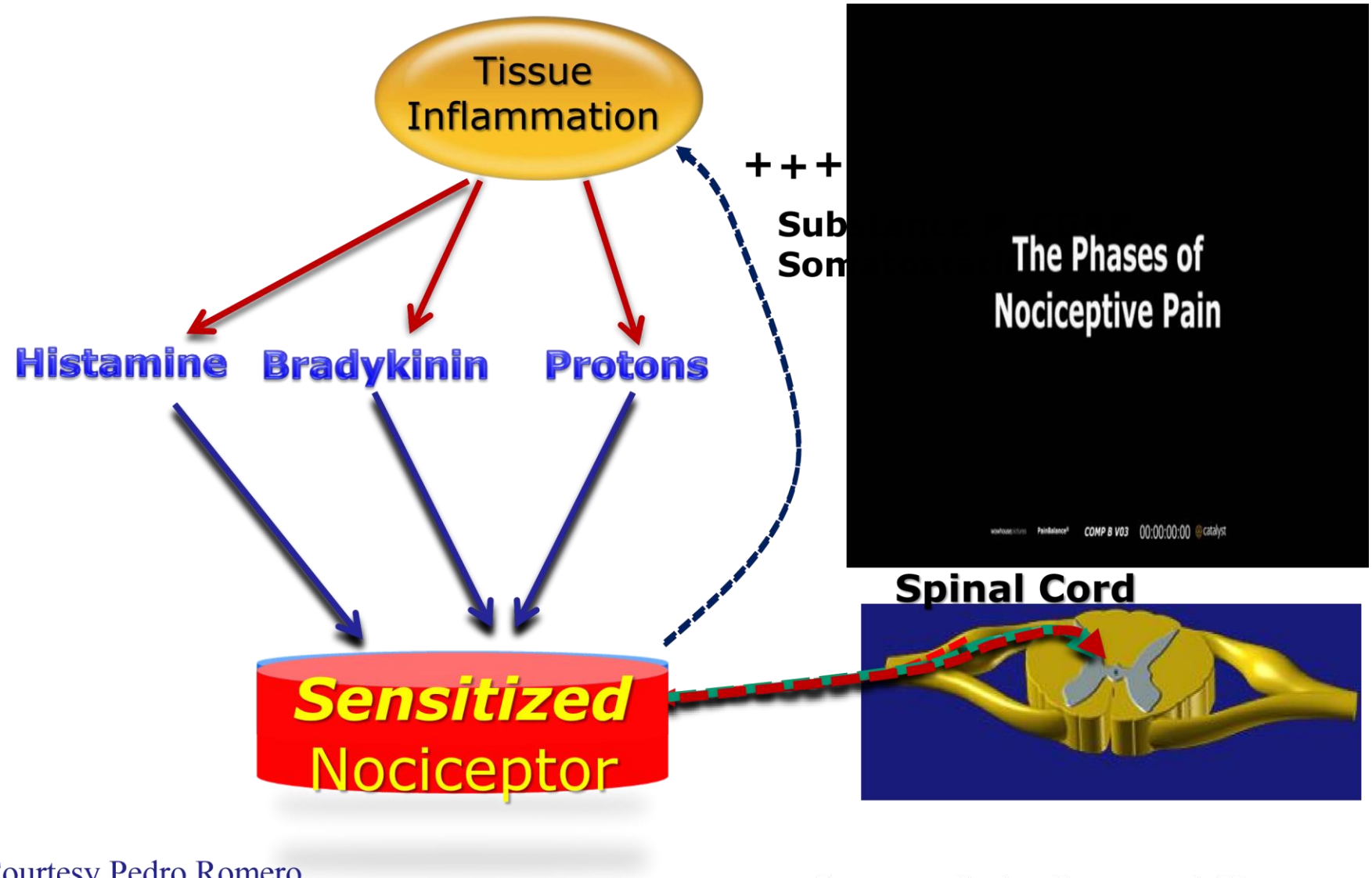


Figure 2
Schematic drawing of a nociceptive nerve ending showing membrane receptor molecules and intracellular events that increase the sensitivity of the ending.

Adapted from
Mense, S. *The Pathogenesis of Muscle Pain.* Current Pain and Headache Reports 2003

Neurogenic Inflammatory Cycle



Courtesy Pedro Romero Ventosilla, MD

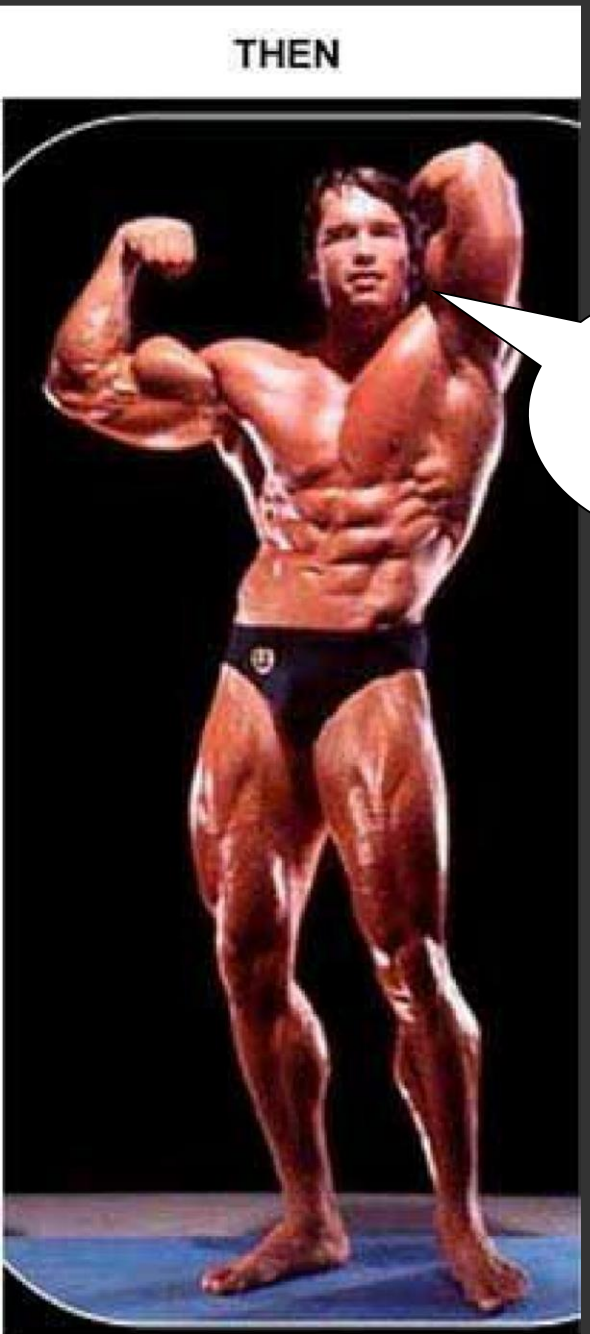
Courtesy Pedro Romero, MD

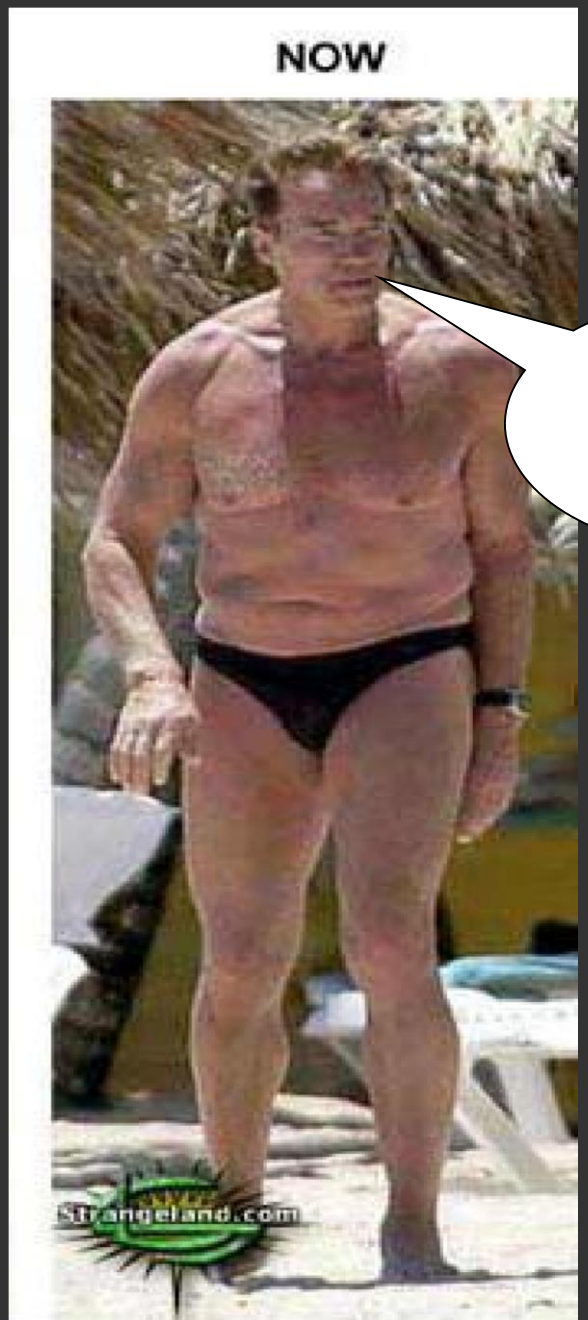
Communication of Critical Information is in Two Opposite Directions Simultaneously

Unique Neurobiology of Muscle Pain

Muscle pain is NOT skin pain

Muscle Pain is often Overlooked





Unique Characteristics of Muscle Pain

- *Aching, cramping* pain, difficult to localize and *referred* to deep and distant somatic tissues
- Muscle pain *activates unique cortical* structures

  Svensson P et al. Cerebral processing of acute skin and muscle pain in humans. J Neurophysiology July 1997; 78: 450-460.

- *Inhibited* more strongly by descending pain-modulating pathways

  XianMin Y, Mense S. Response Properties and descending control of rat dorsal horn neurons with deep receptive fields. *Neuroscience 1990; 39:823-831.*

- *muscle*

  effective *neuroplastic*

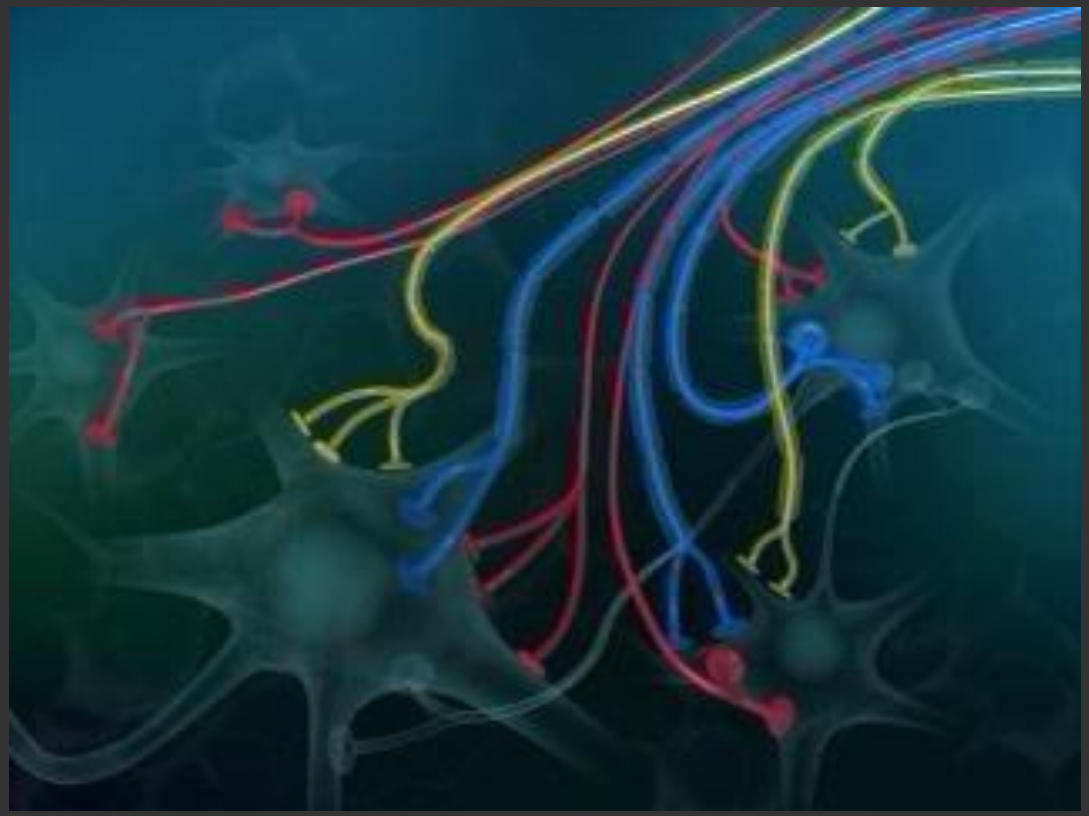
  Wall PD, Woolf CJ. *J Physiol* 1984 Nov;356:443-458.

Powerful Descending Inhibition on Muscle Pain

Fields HL, Basbaum AI: Central nervous system mechanisms of pain modualtion. In *Textbook of Pain*; 1999:309-329.

Activation of Muscle nociceptors is much more Effective at Inducing Neuroplastic Changes:

2nd Messenger Cascades, Induction of *Immediate Early Genes* and Protein Synthesis, Excitotoxicity and Cell Death



Activity Dependent Plasticity

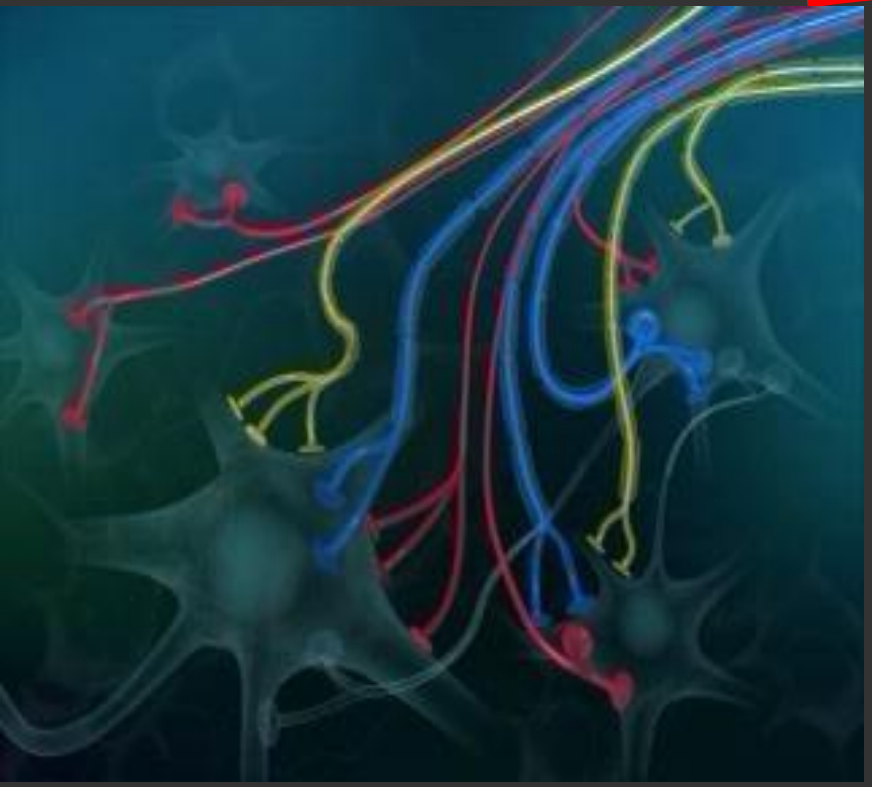
Wall PD, Woolf CJ. Muscle but not cutaneous C-afferent input produces prolonged increases in the excitability of the flexion reflex in the rat. *J Physiol*. 1984 Nov;356:443-58.

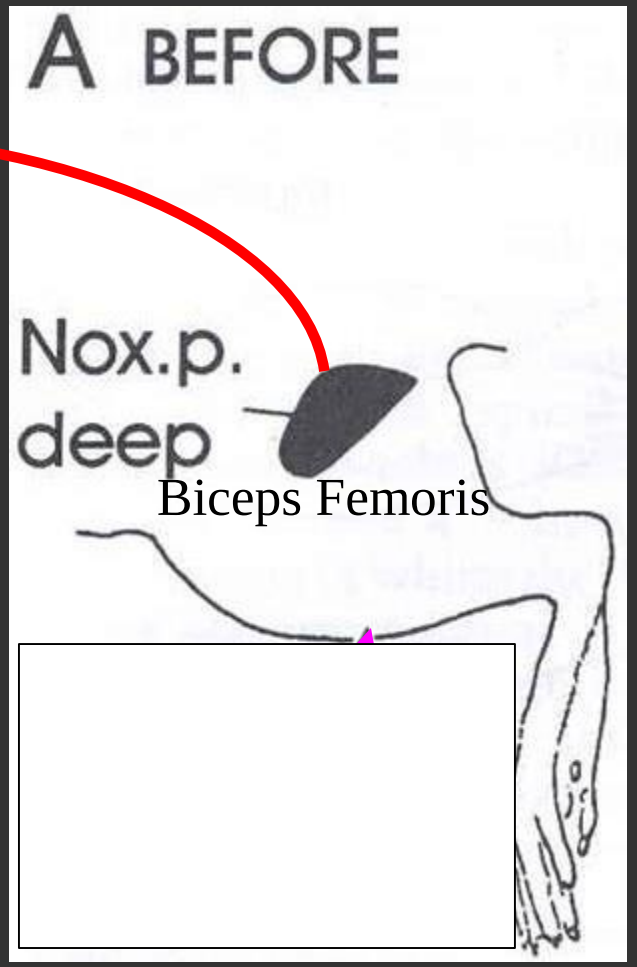
Muscle Pain

Spinal Mechanisms Underlying Expansion of the Receptive Field of Pain

Expansion of Receptive Field by a Painful Muscle Stimulus

Courtesy Jan Dommerholt

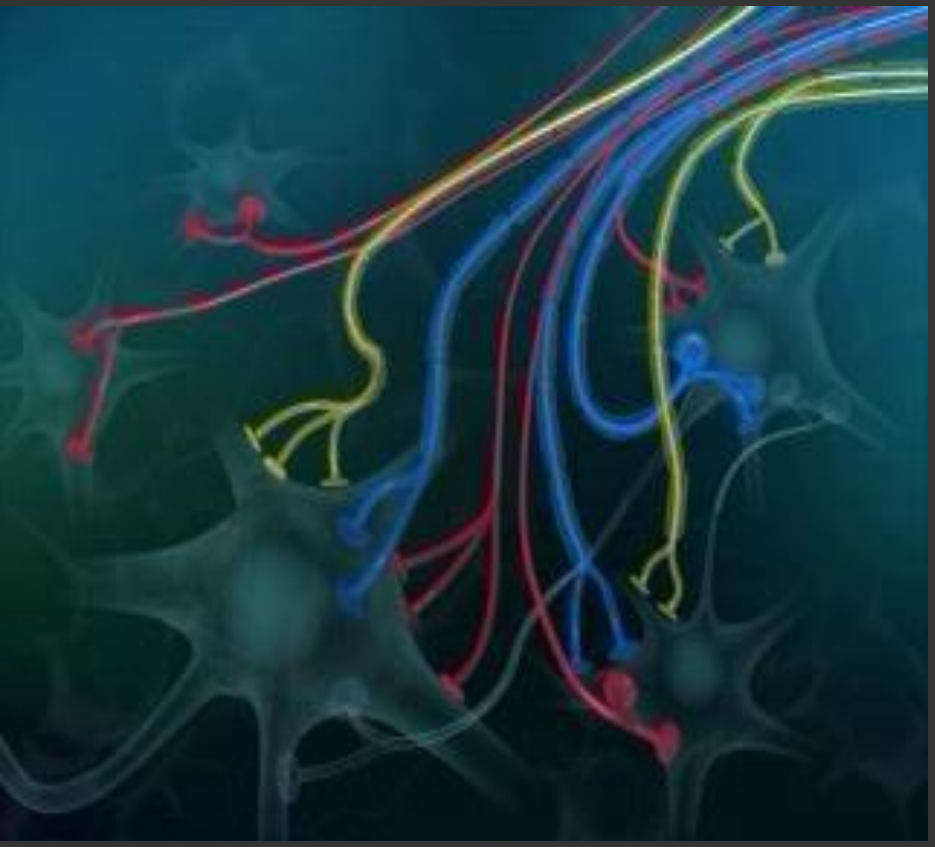


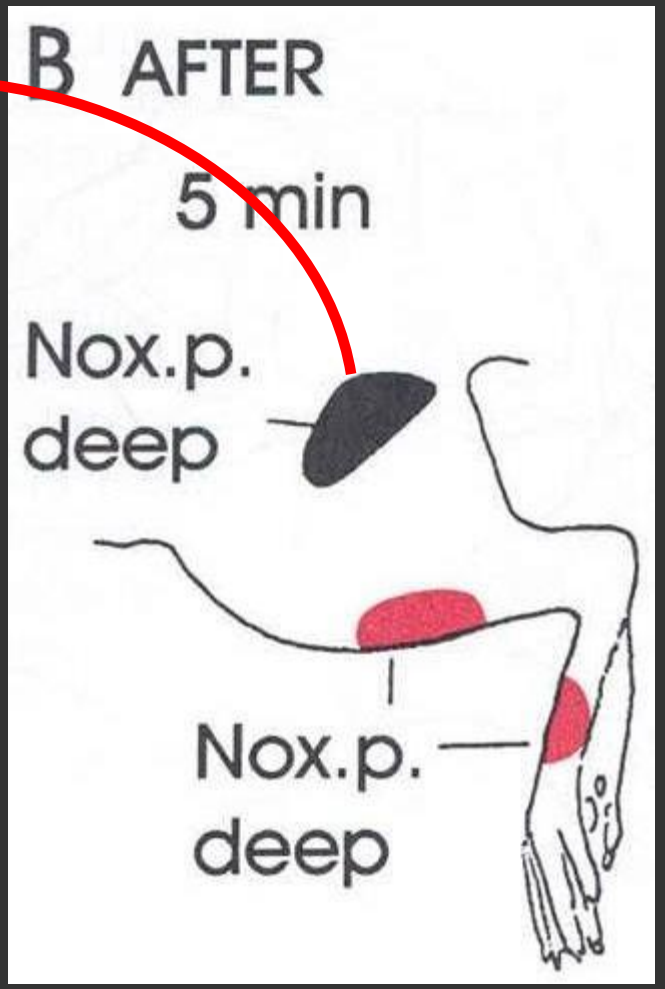


Selected neuron responds only to deep pressure in biceps femoris muscle

Hoheisel U, Mense S, Simons DG. Appearance of new receptive fields in rat dorsal horn neurons following noxious stimulation of skeletal muscle: a model for referral of muscle pain? *Neurosci lett* 153:9-12, 1993

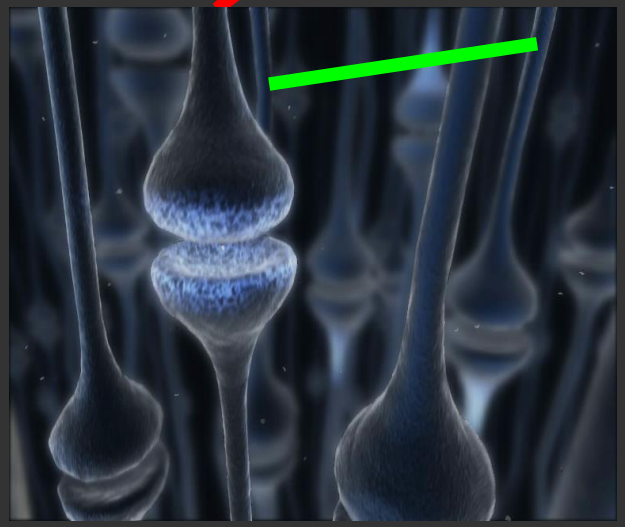
Painful Muscle Stimulus

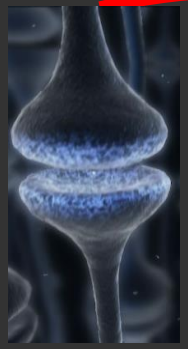


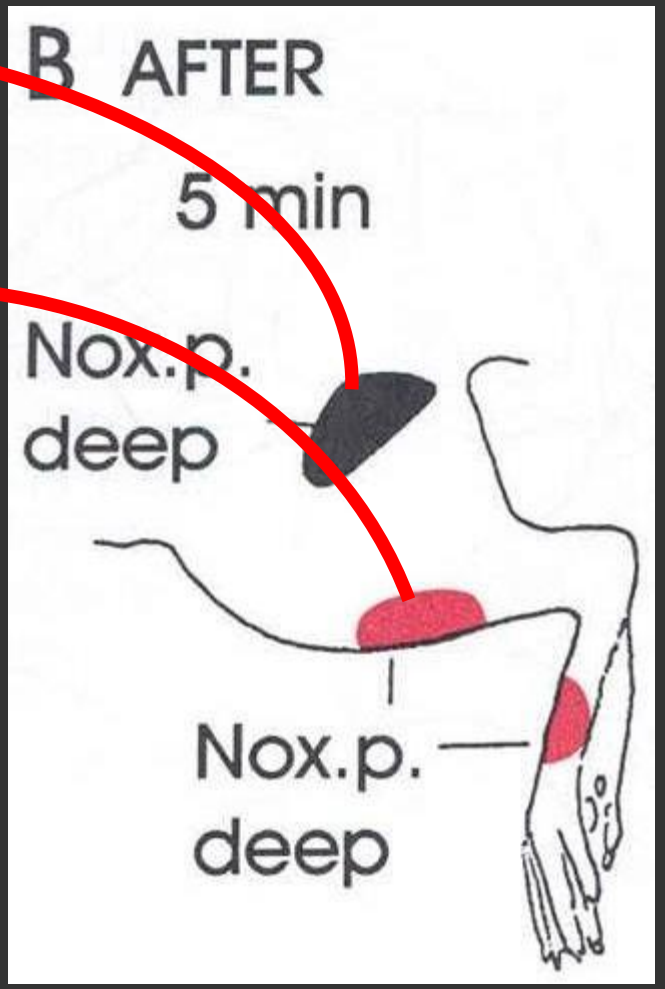


5 min after BK injection in TA, the selected neuron can now be excited by additional RF's located in deep muscle that normally have high threshold

Painful Muscle Stimulus

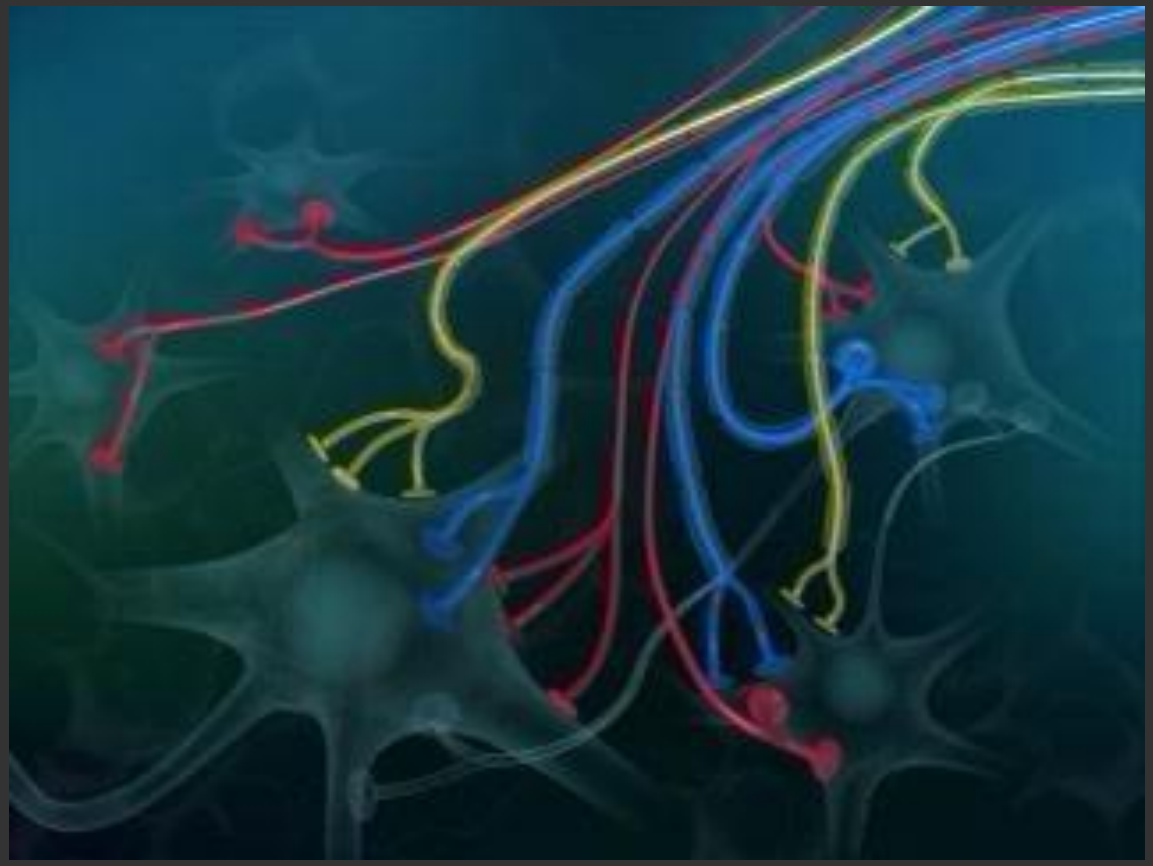


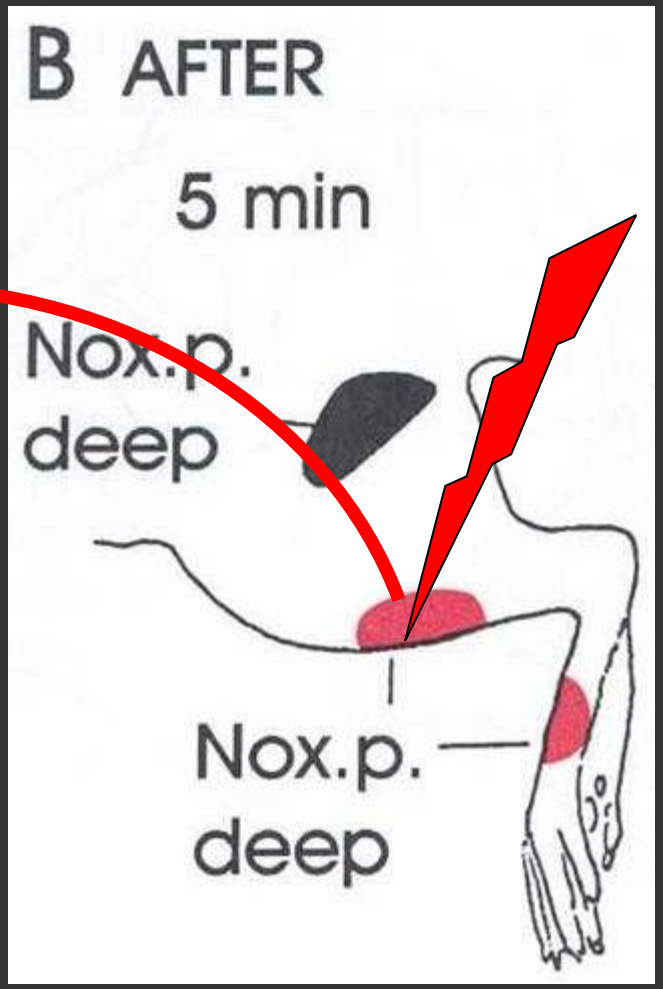




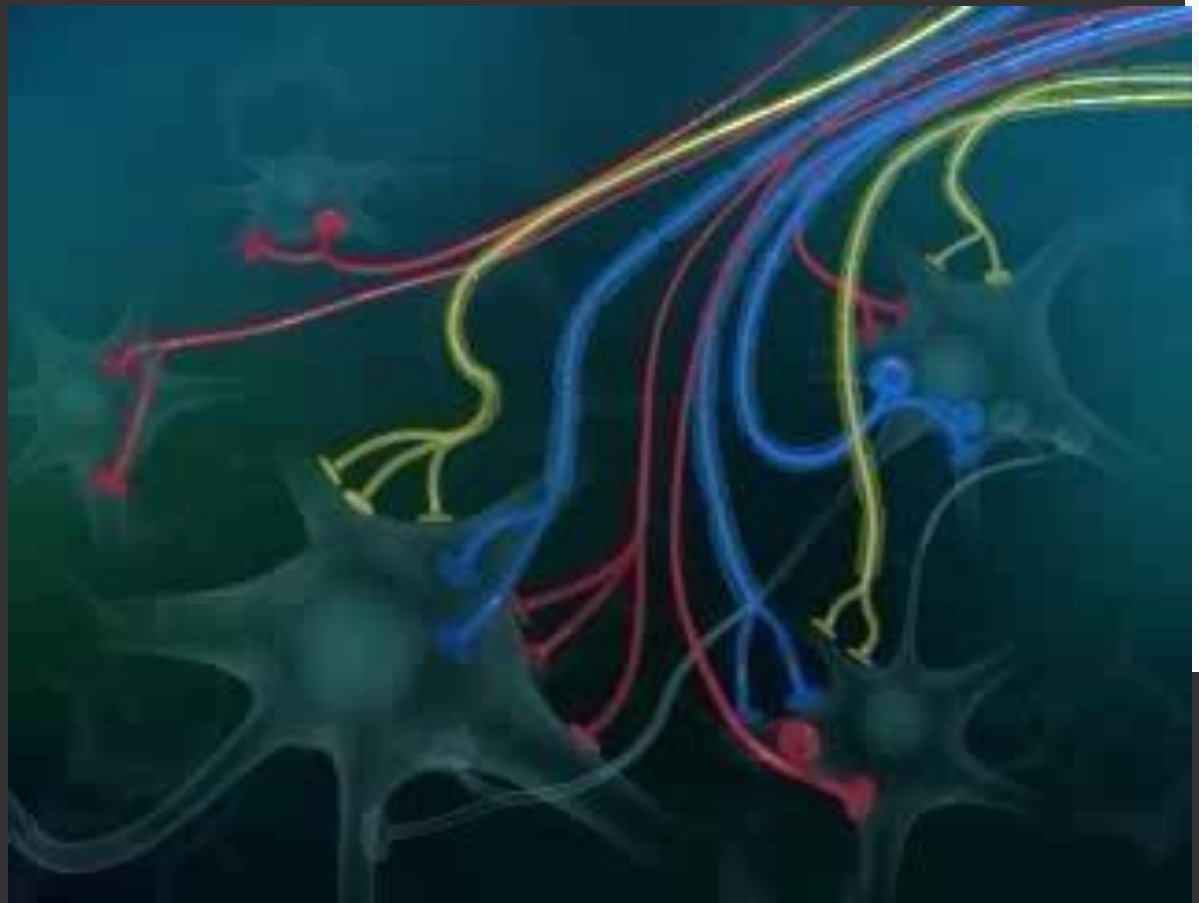
153:9-12, 1993

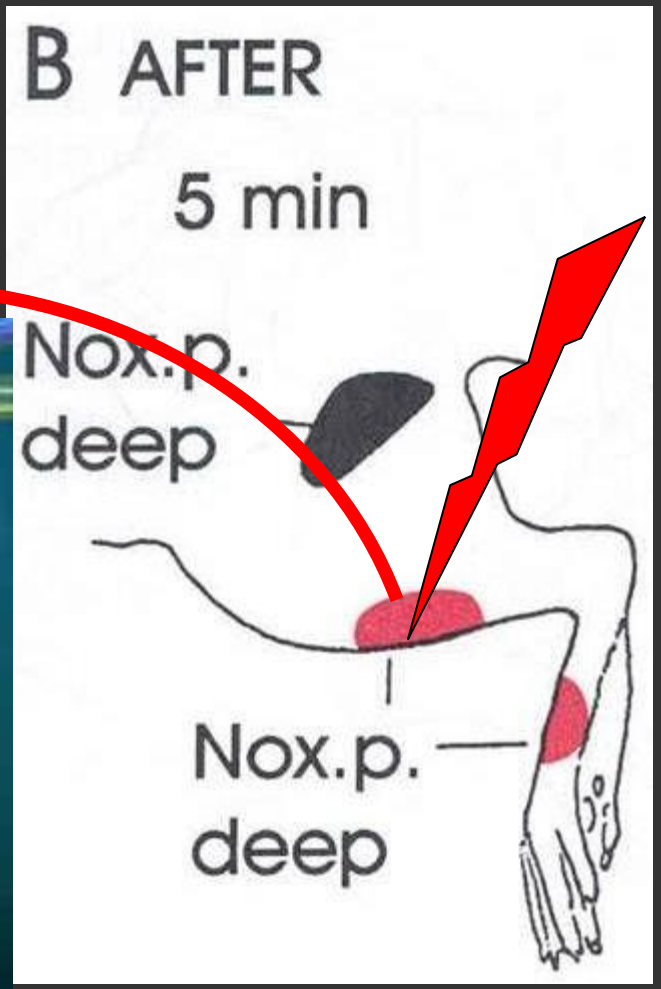
Painful Muscle Stimulus



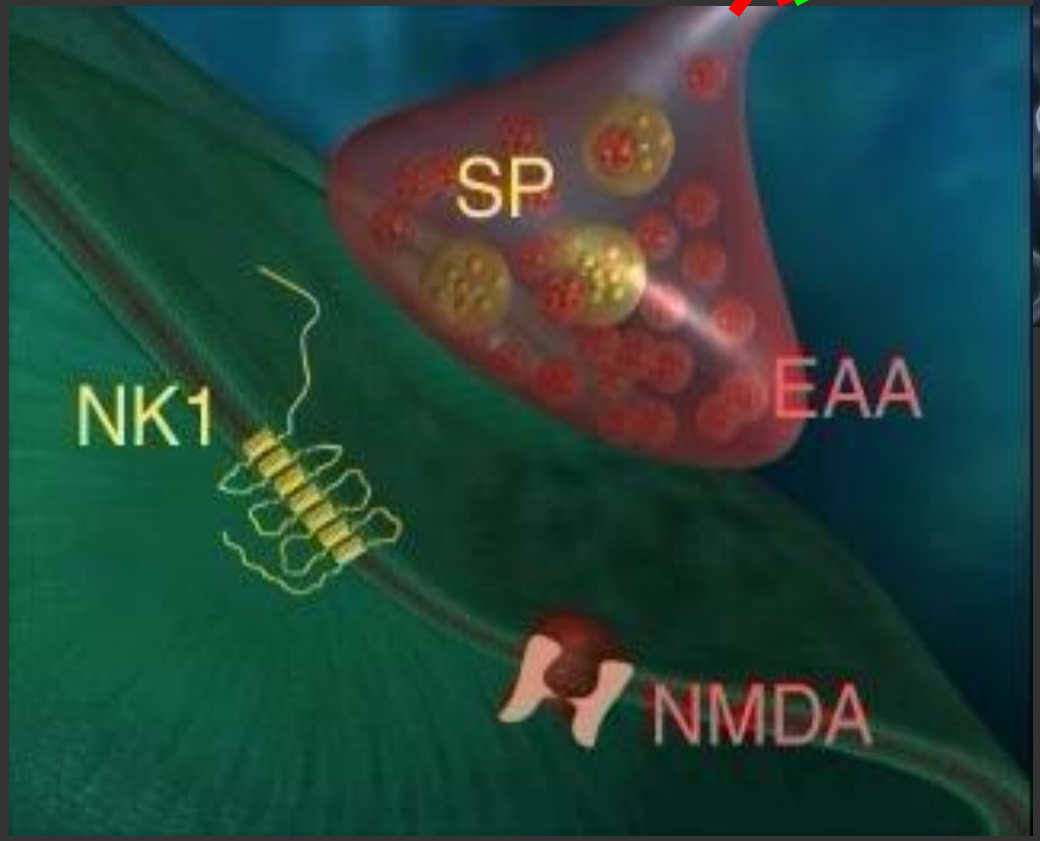


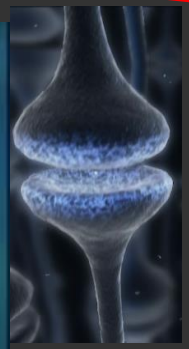
Painful Muscle Stimulus

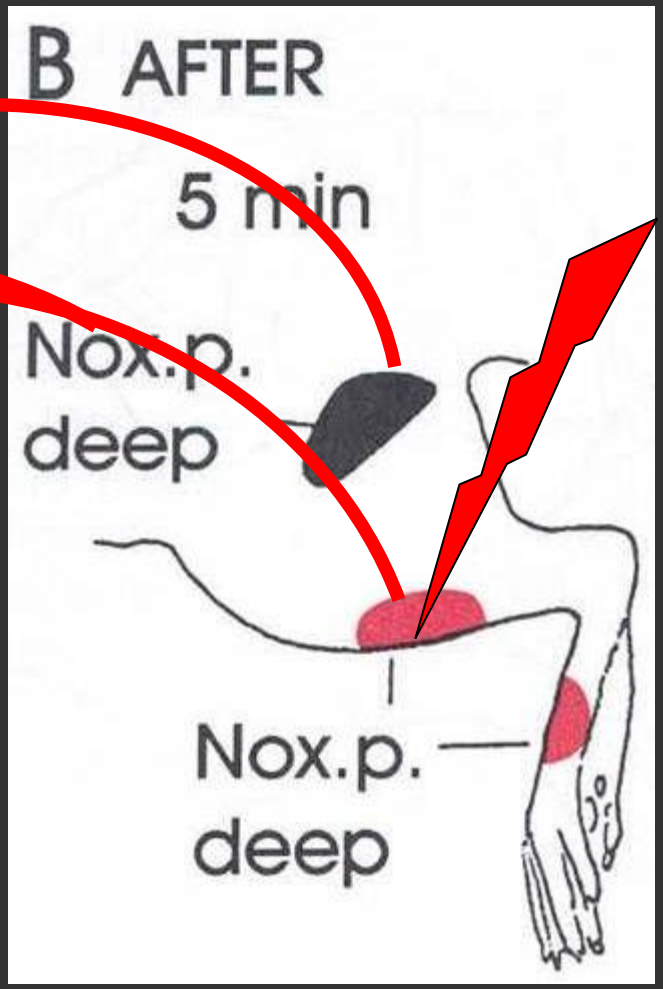




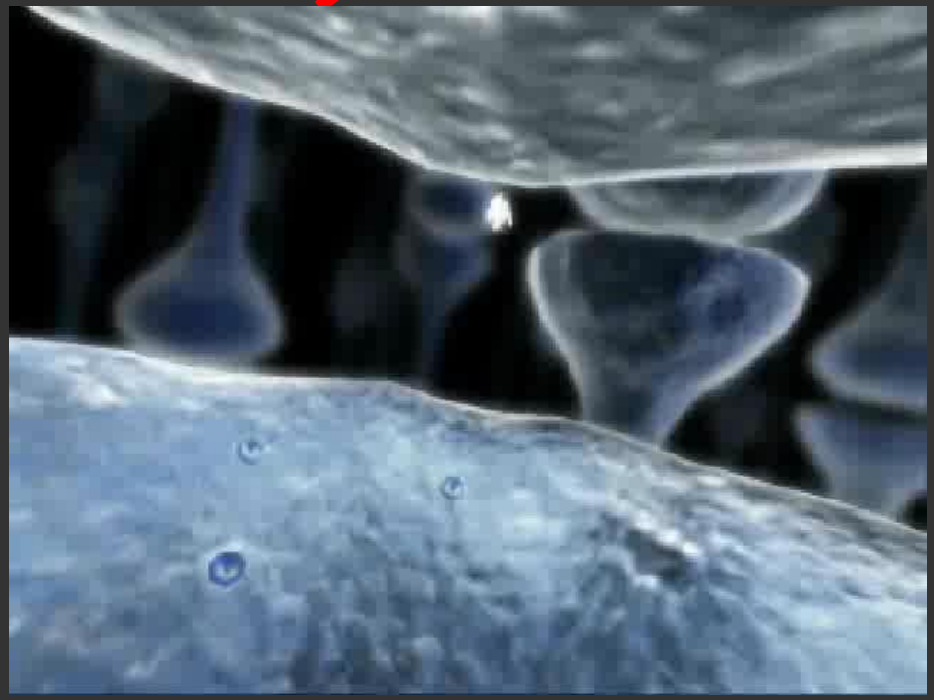
Painful Muscle Stimulus Opens Ineffective Synapses

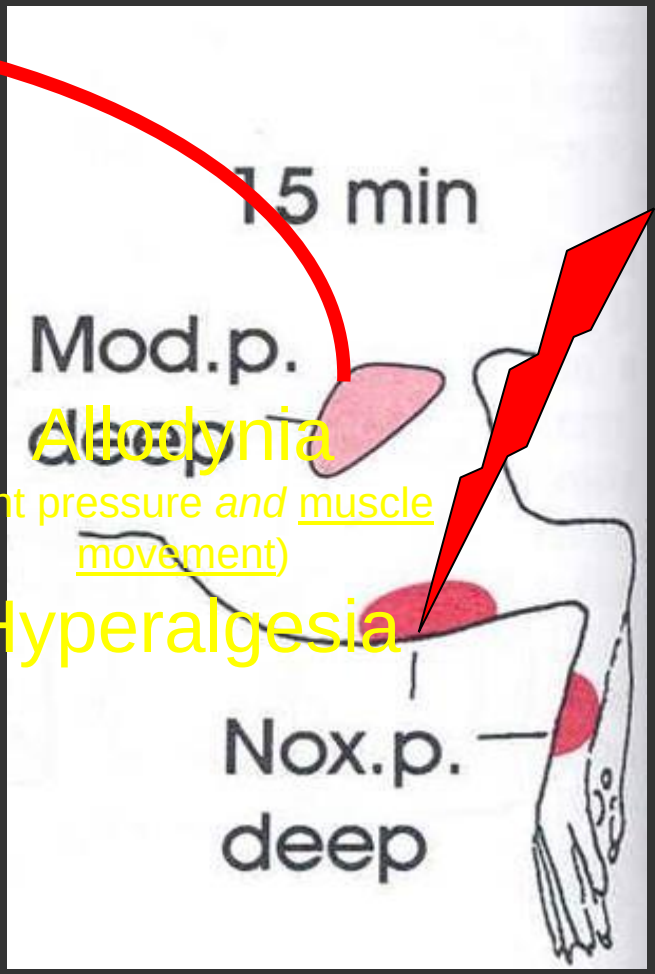






Expansion of Receptive Field by a Painful Muscle Stimulus





Allodynia

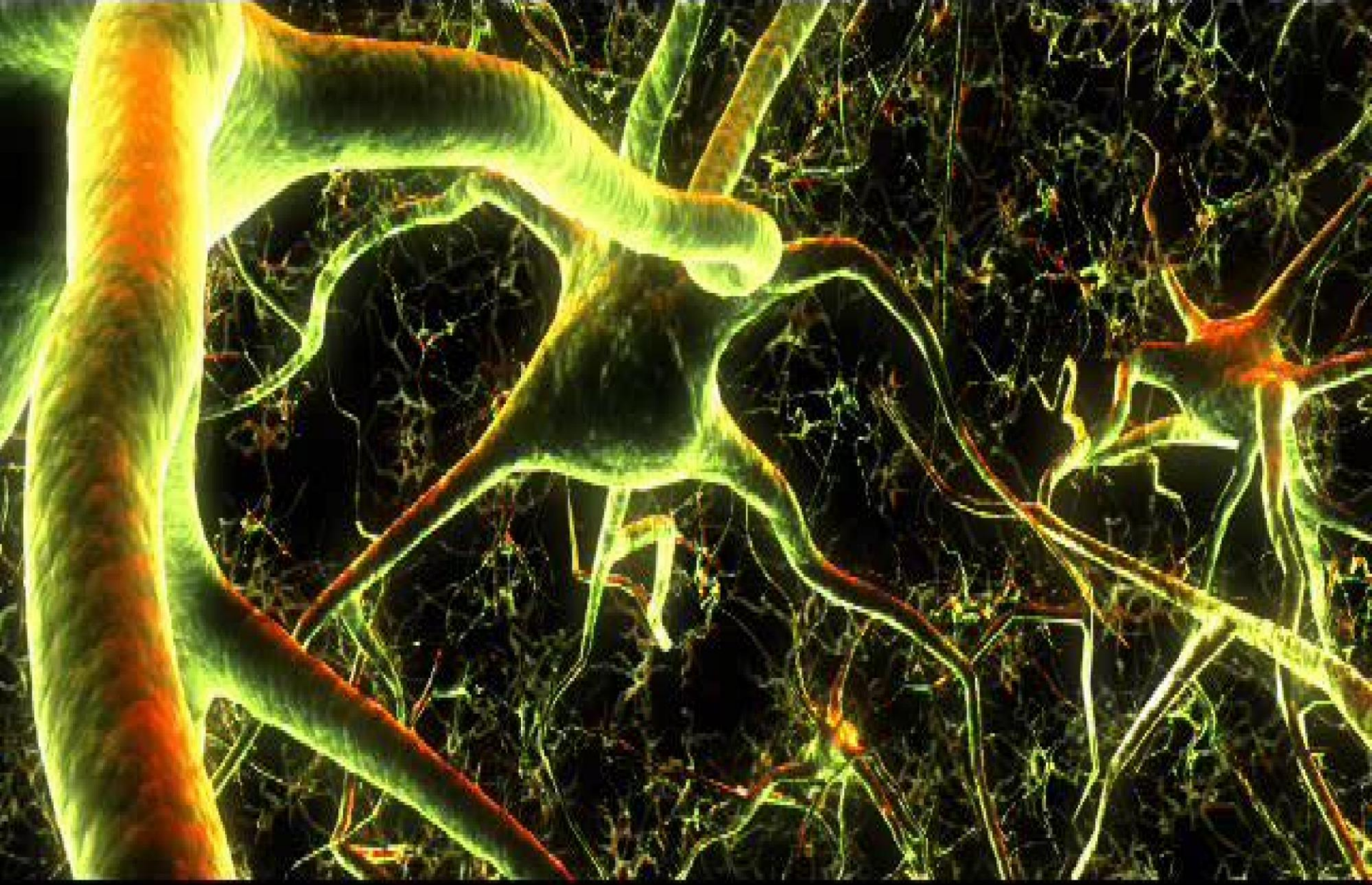
(light pressure *and* muscle movement)

Hyperalgesia

15 min after BK injection in the TA the selectedneuron responds to moderate (*innocuous*) pressure in its original receptive field - biceps femoris

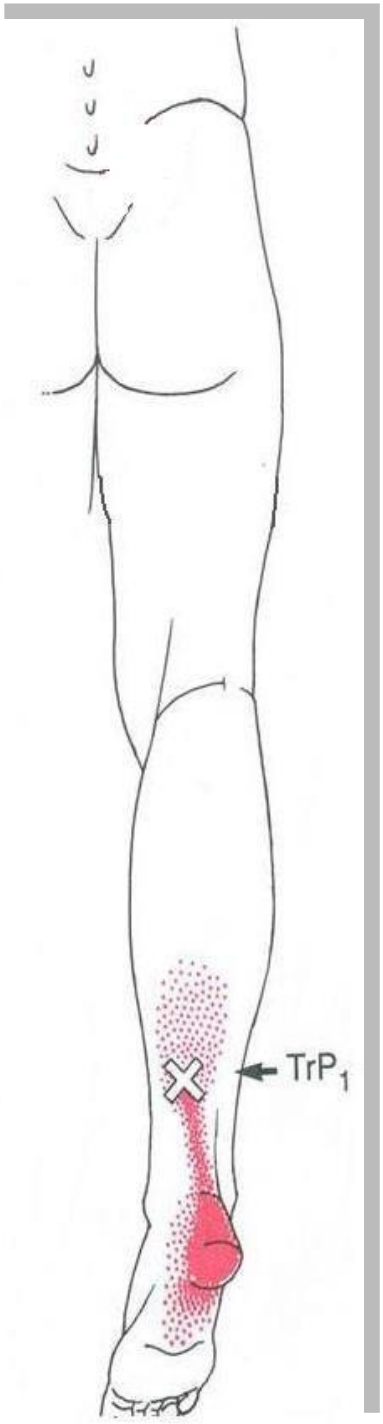
Hoheisel U, Mense S, Simons DG

Neurosci lett 153:9-12, 1993

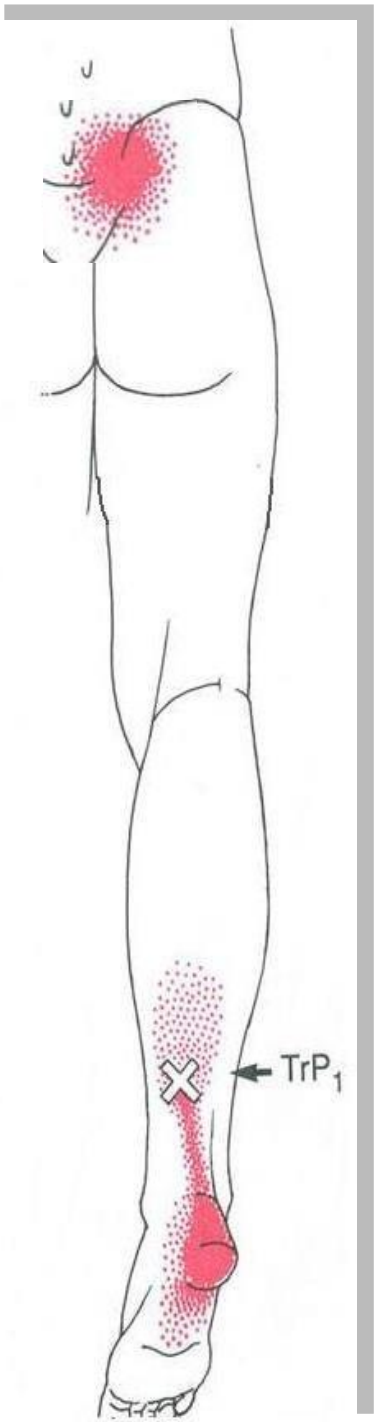


Ineffective Synapses can become Effective Synapses

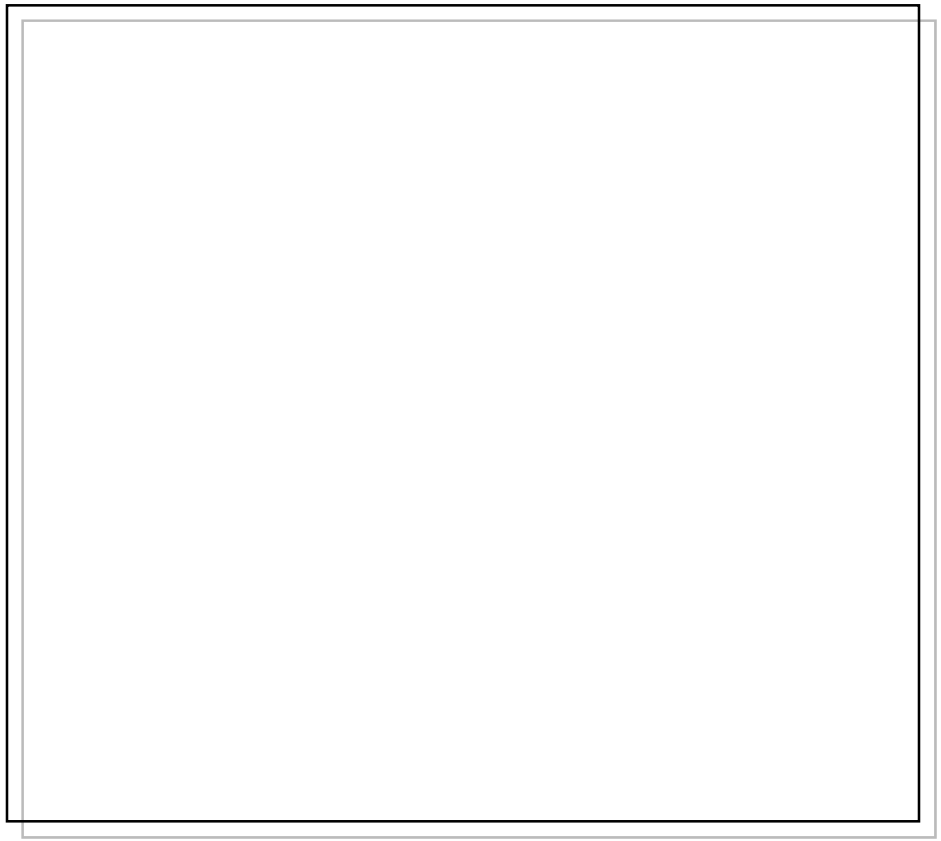
Pain begins in Calf, Heel and Foot



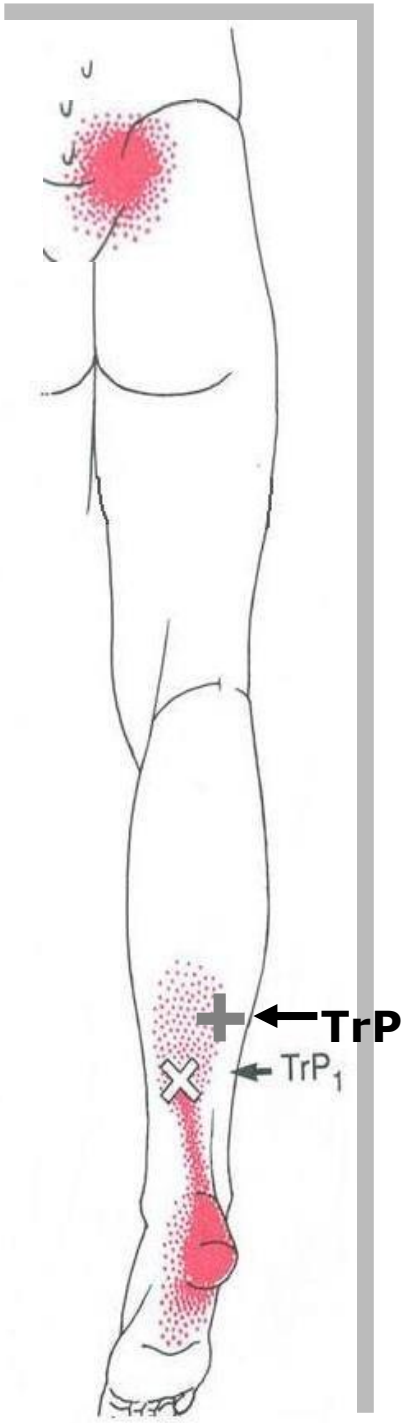
Then Develops Pain in SI



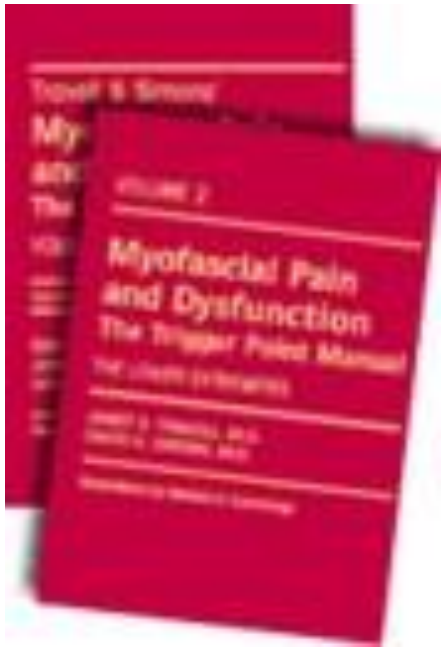
Joint too



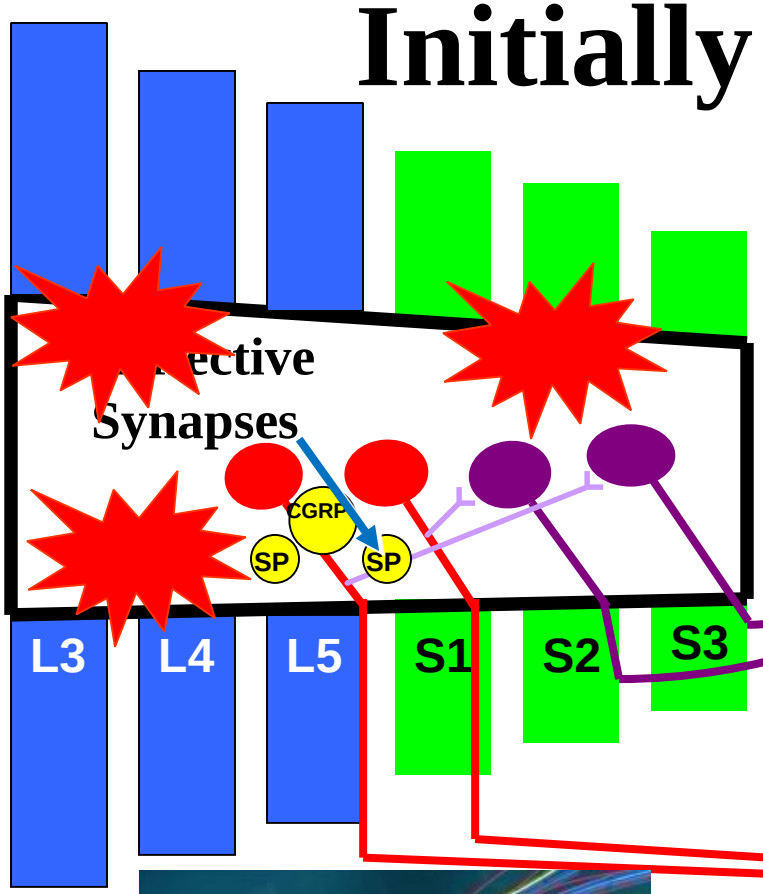
Then Develops Pain in SI

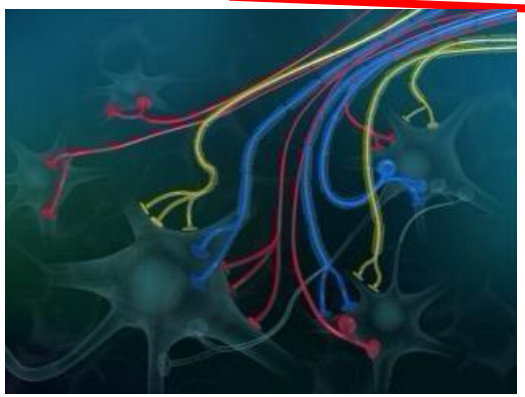


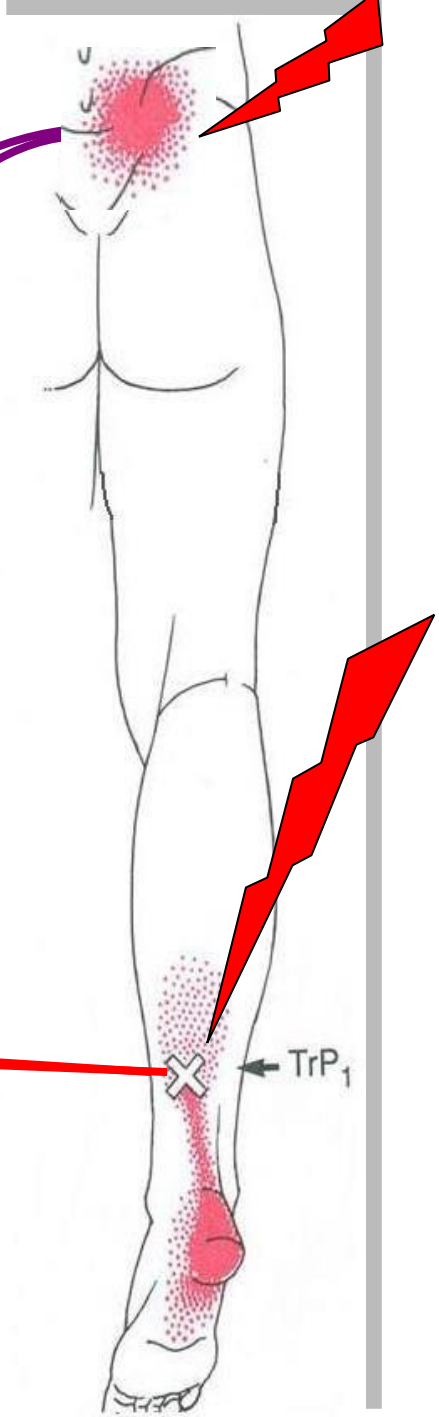
Joint too



Neuron for SI Joint is Initially Inactive

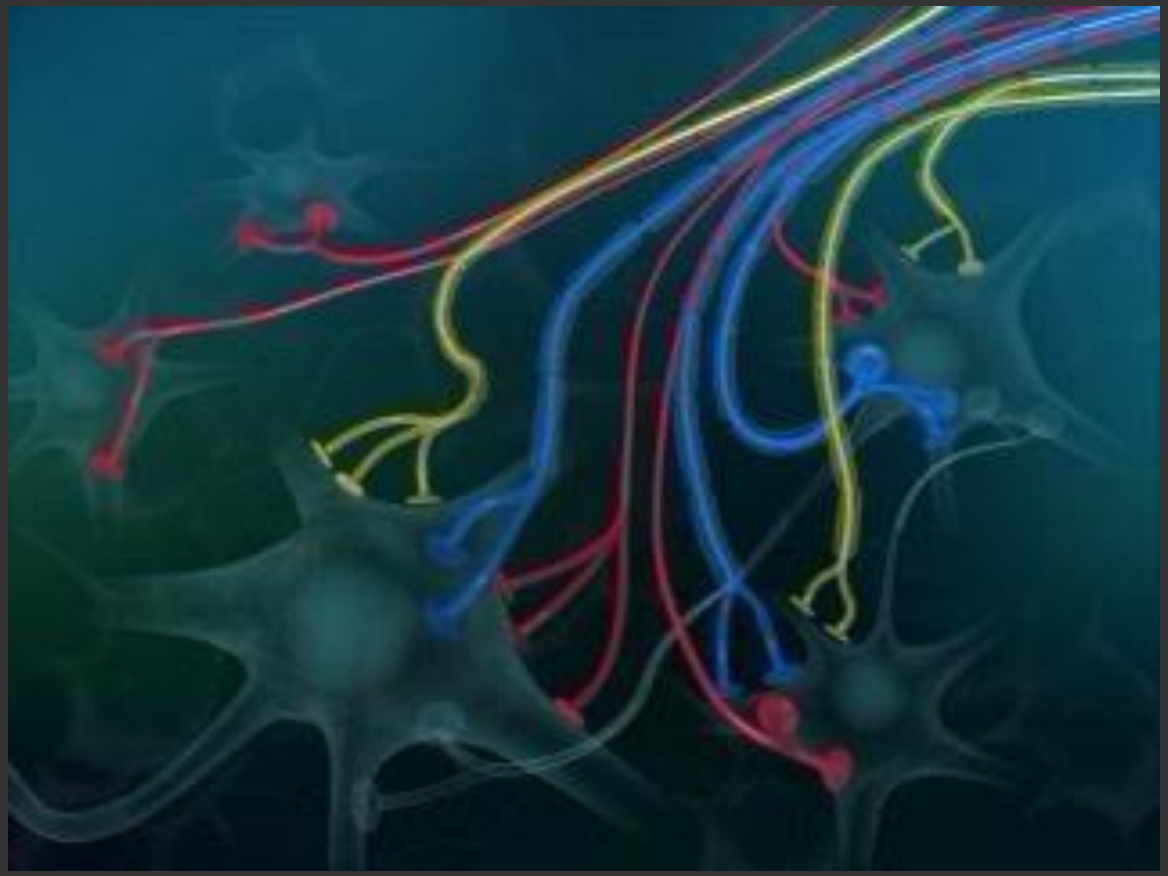


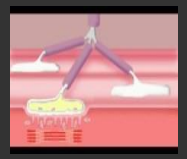




Active MTrPs and Central Sensitization

Wide Dynamic Range Neuron





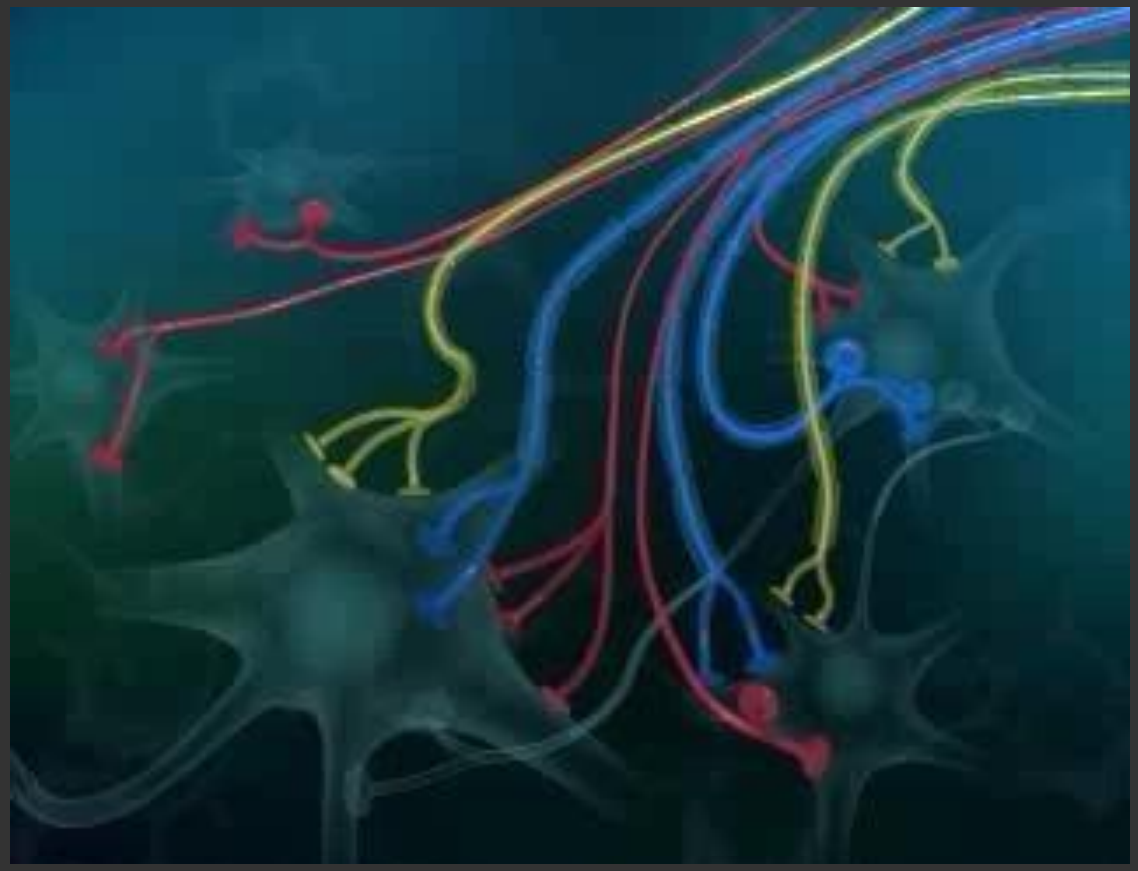
Clinical Hallmarks of Central Sensitization:

1) Allodynia
2) Hyperalgesia
3)Expansion of the Receptive Field of Pain
4)Pain with Muscle Movement

Prolonged Activation of Wide Dynamic Range Neurons

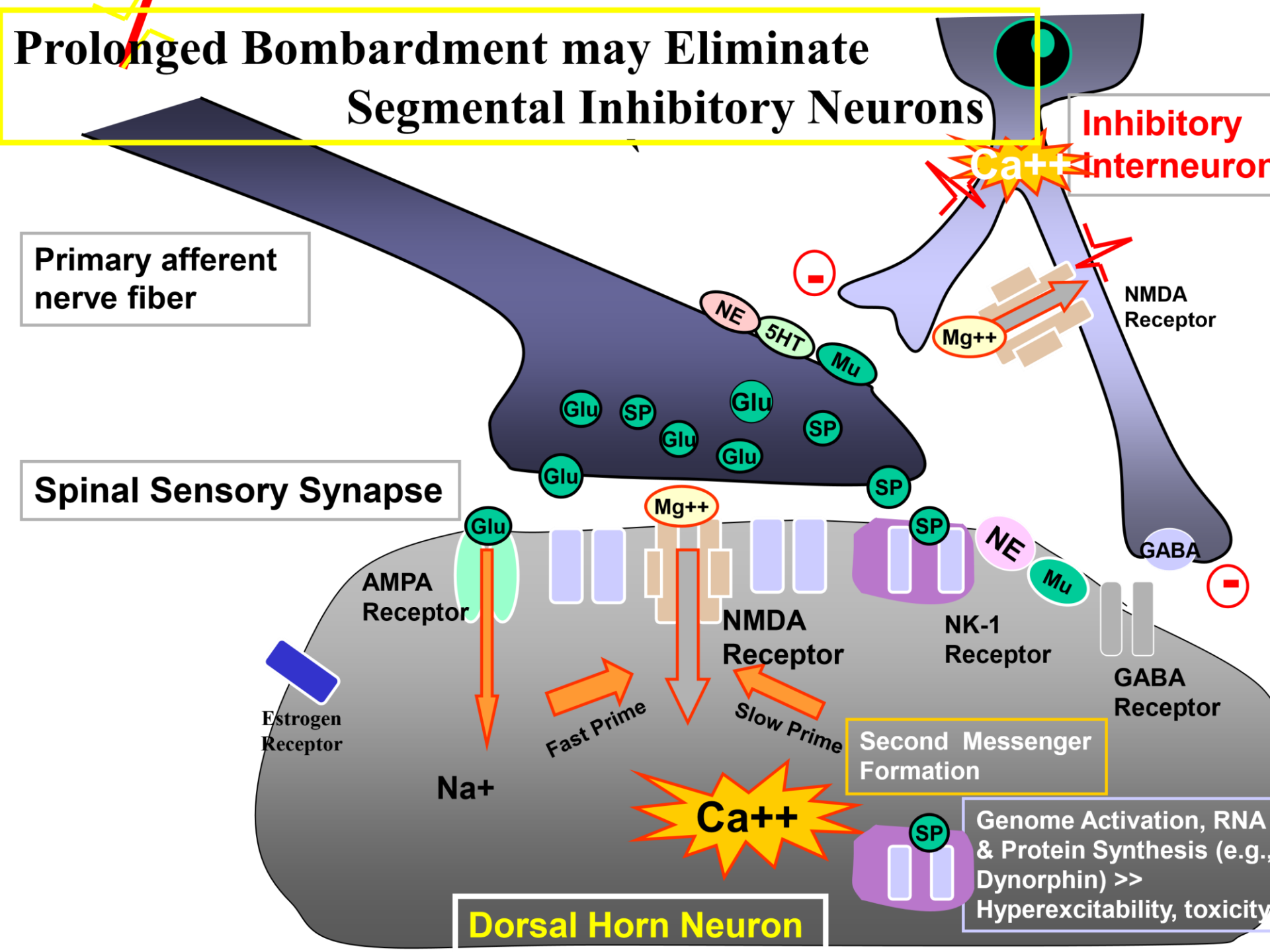
Central Sensitization, Dysfunction or loss of Inhibitory Neurons and Creation of Facilitated Segments

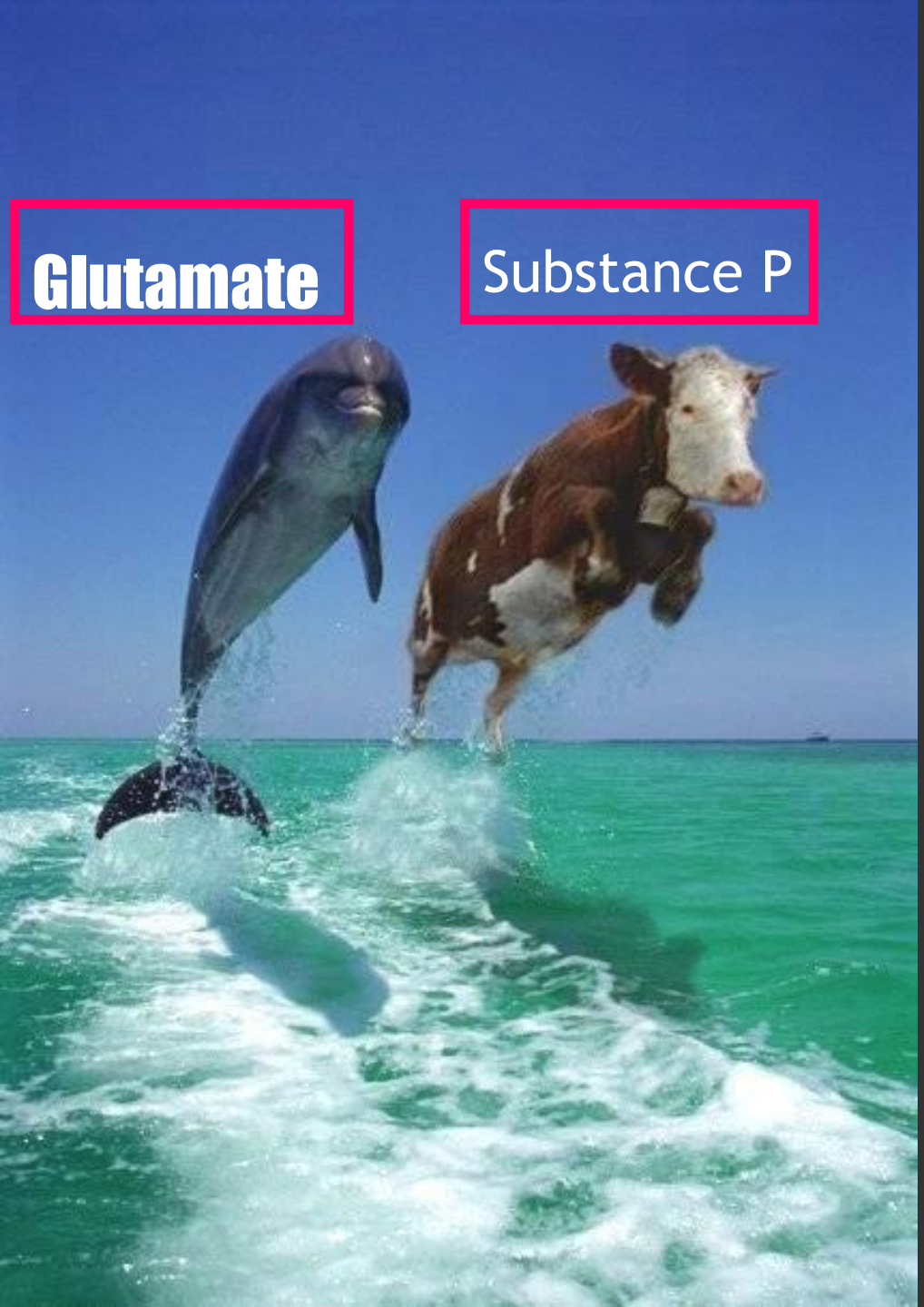
Wide Dynamic Range Neuron



Activity-Dependent Neuroplasticity

Prolonged Bombardment may Eliminate Segmental Inhibitory Neurons

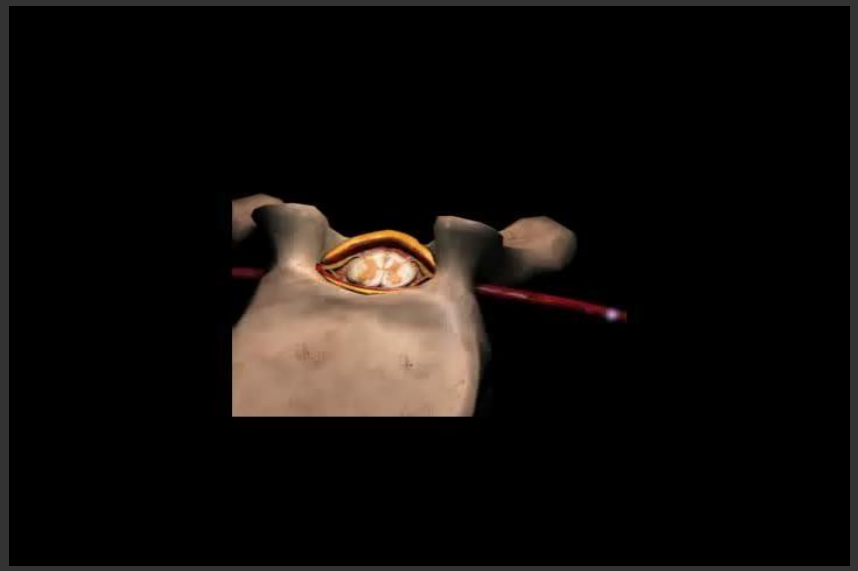




Nociceptive Bombardment causes

Central Sensitization and Neuroplastic

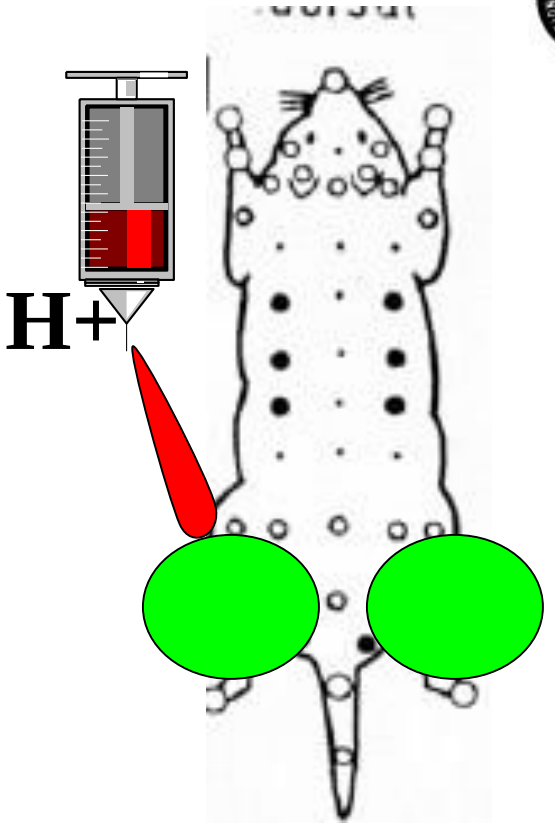
Changes in Dorsal Horn Neurons



Biochemical and *Non-neuronal* Considerations of Sensitization

UNILATERAL INTRAMUSCULAR INJECTIONS OF ACIDIC SALINE PRODUCE A BILATERAL, LONG-LASTING HYPERALGESIA

K.A. SLUKA, PhD,[1,3] A. KALRA,[1] and S.A. MOORE, MD, PhD[2,3]



PAIN

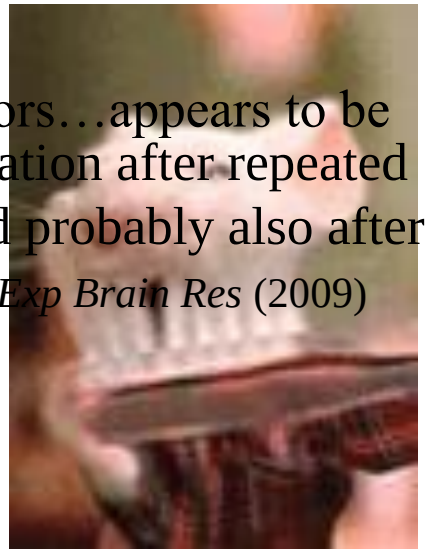
Pain 106 (2003) 229–239

www.elsevier.com/locate/pain

Chronic hyperalgesia induced by repeated acid injections in muscle is abolished by the loss of ASIC3, but not ASIC1

Kathleen A. Sluka[a,b,*], Margaret P. Price[c], Nicole M. Breese[d], Cheryl L. Stucky[d], John A. Wemmie[b,e,f], Michael J. Welsh[b,c]

"…activation of ASIC3 receptors…appears to be essential for the central sensitization after repeated injections of acidic solutions and probably also after other muscle lesions. Mense S. *Exp Brain Res* (2009)



METABOLIC ACTIVITY CHANGES IN THE RAT SPINAL CORD DURING ADJUVANT MONOARTHRITIS

J. SCHADRACK,*†‡ F. L. NETO,*‡§ A. ABLEITNER,* J. M. CASTRO-LOPES,§ F. WILLOCH,*‖ P. BARTENSTEIN,‖ W. ZIEGLGÄNSBERGER* and T. R. TÖLLE¶

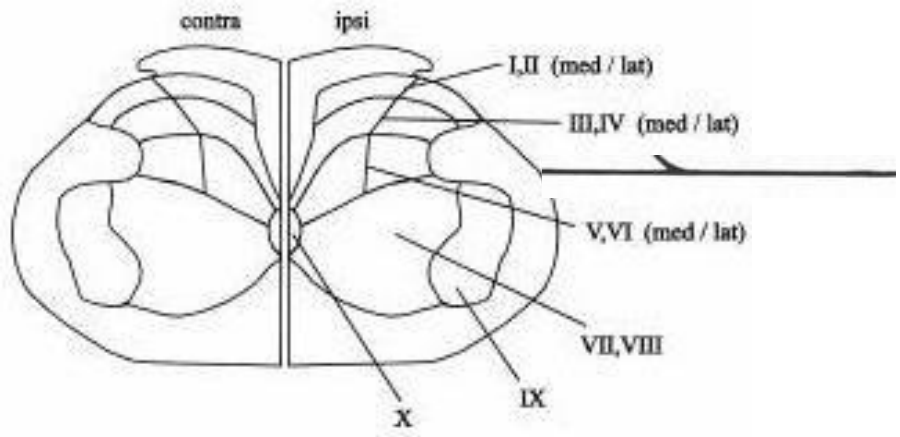
Complete Freunds Adjuvant versus saline in tibio tarsal joint

2- deoxyglucose technique:

Neuroscience Vol. 94, No. 2, pp. 595–605, 1999

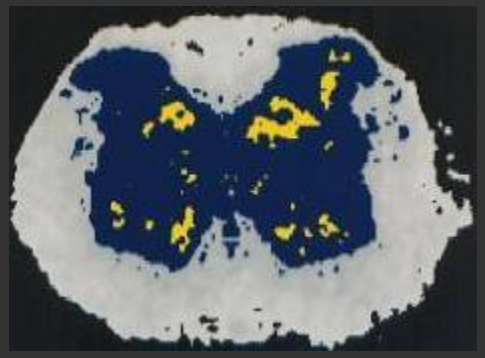
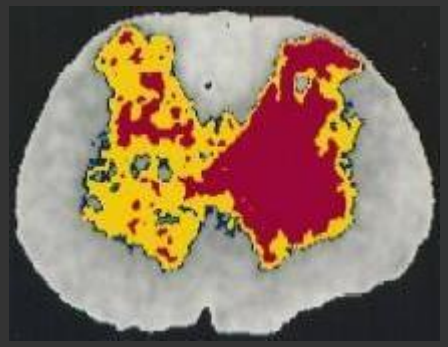
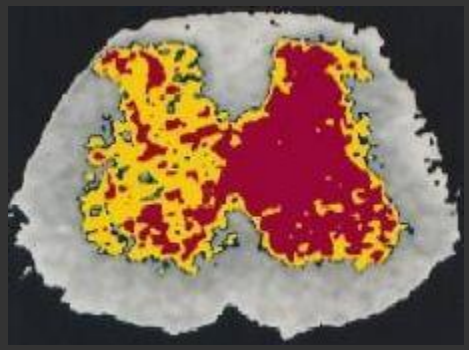
0306-4522/99 $20.00+0.00

Spinal

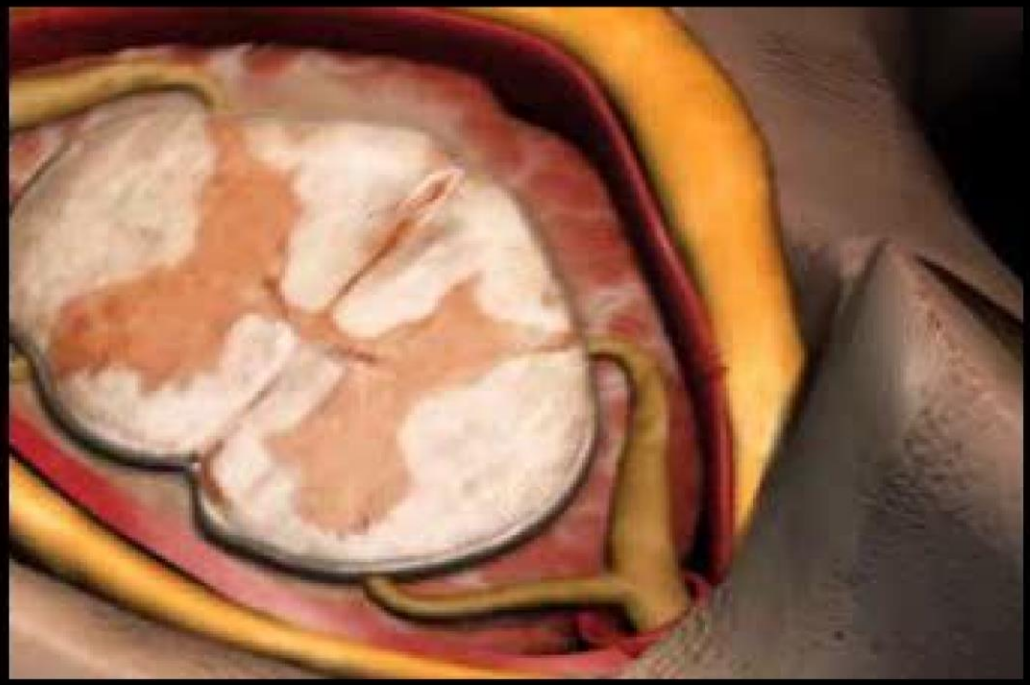


Metabolic Activity

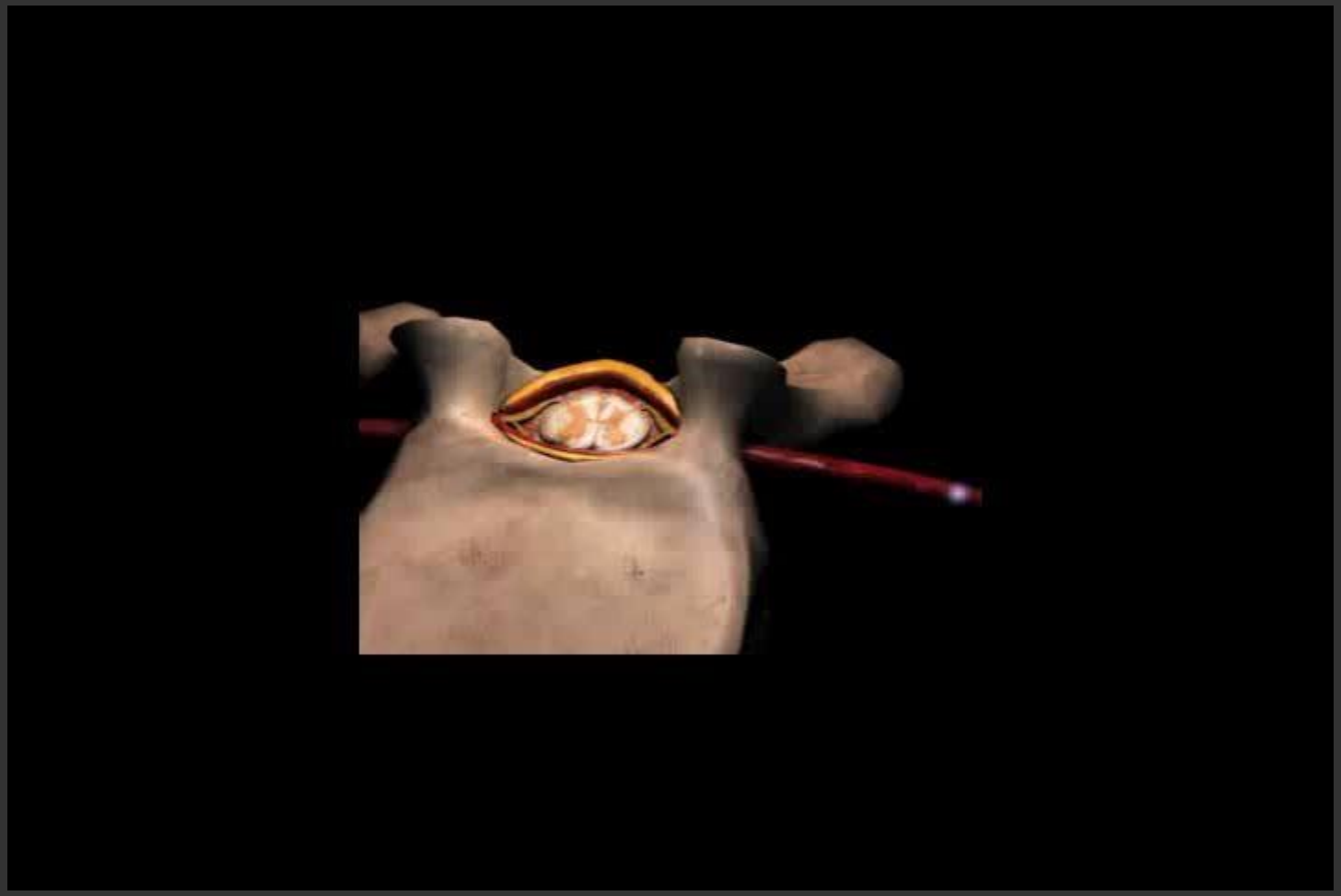
Spinal Metabolic Activity during Monoarthritis

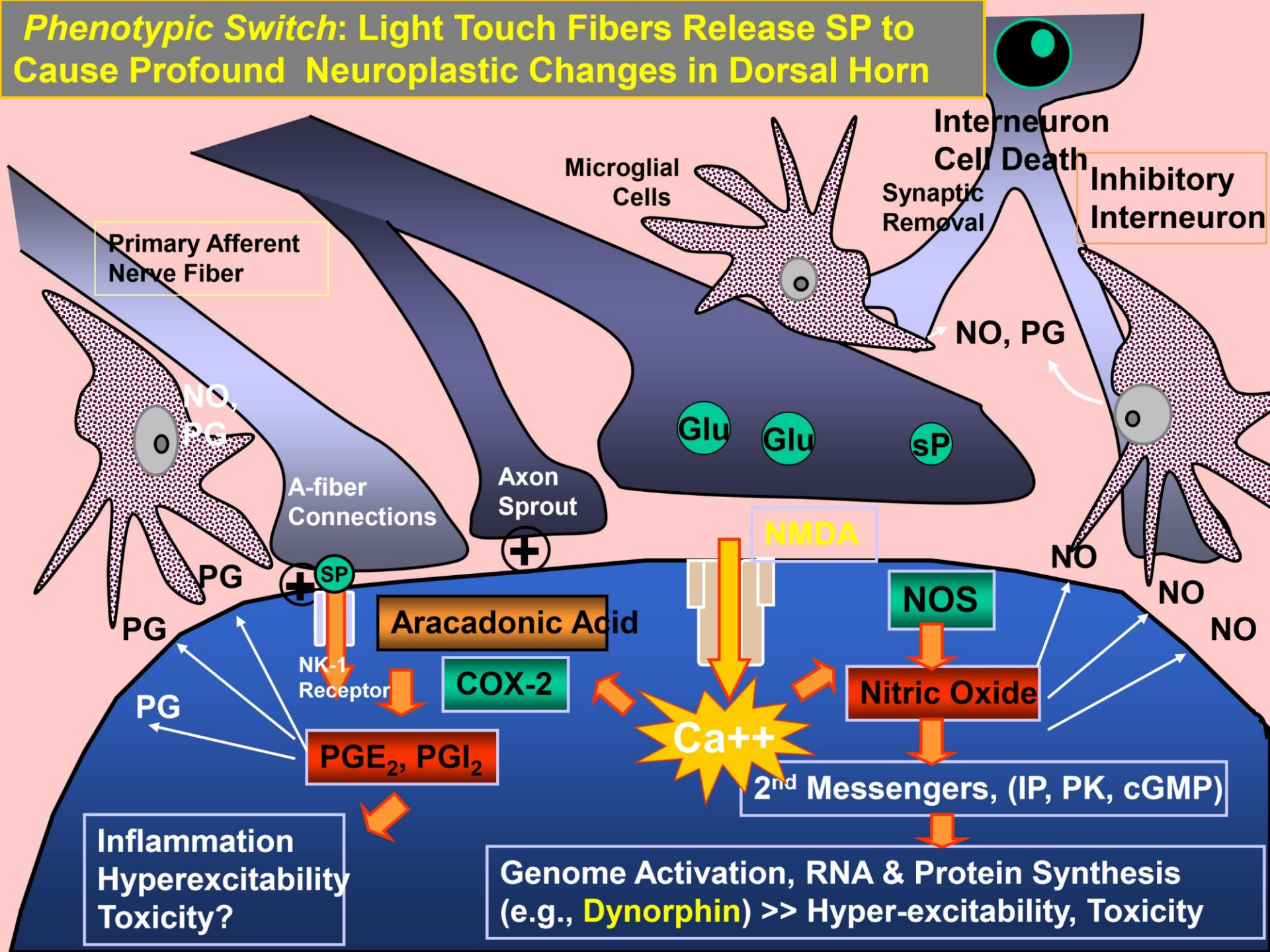
	L2-L3	L4-L5
Saline		
CFA		

“Seizure” of Dorsal Horn Neurons

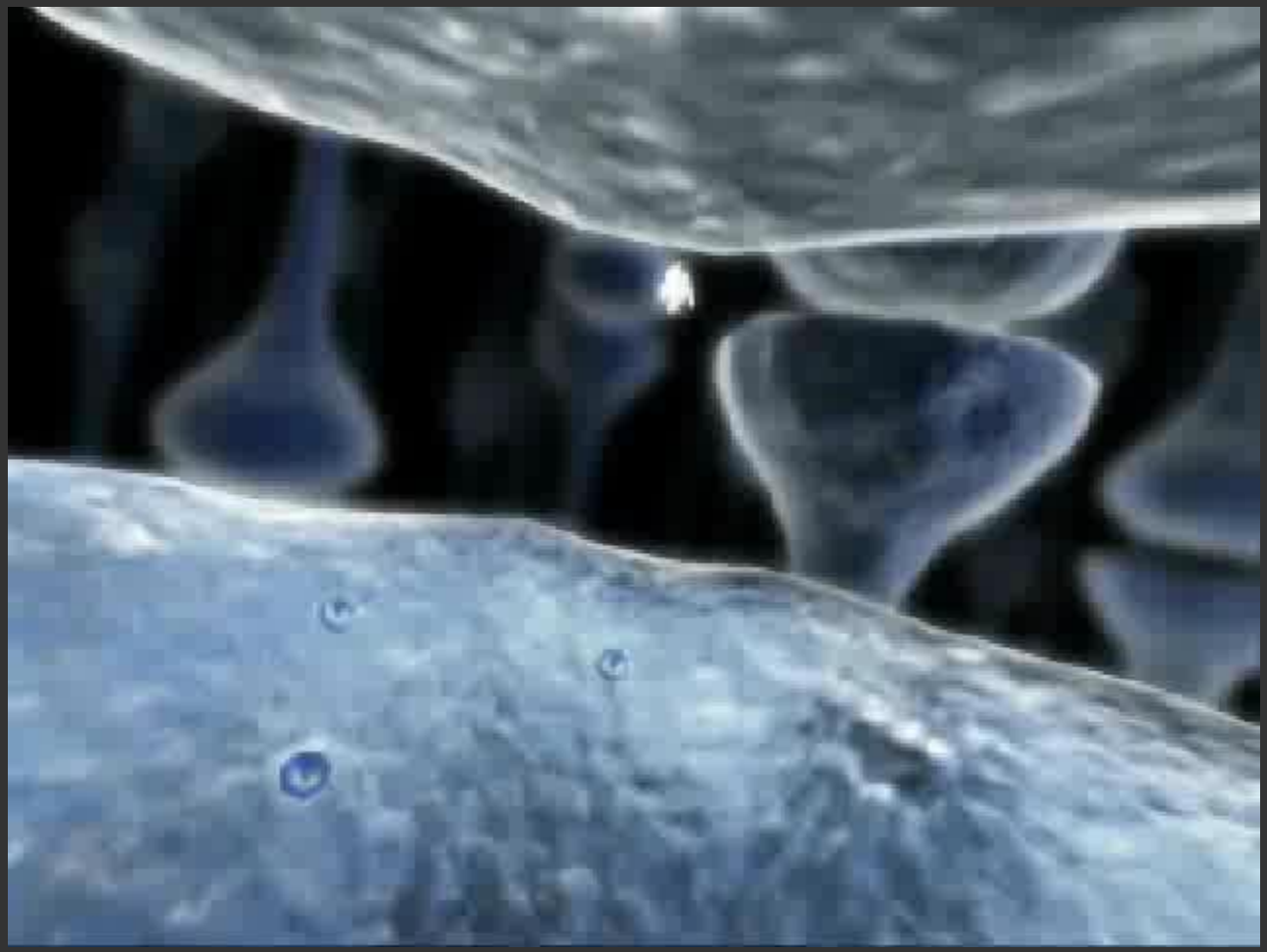


Phenotypic Switch: Light Touch Fibers Activate WDR Neurons




Phenotypic Switch: Light Touch Fibers Release SP to Cause Profound Neuroplastic Changes in Dorsal Horn
Interneuron Cell Death
Microglial Cells
Synaptic Removal
Inhibitory Interneuron
Primary Afferent Nerve Fiber
NO, PG
NO, PG
Glu
Glu
sP
A-fiber Connections
Axon Sprout
NMDA
SP
PG
PG
PG
NO
NO
NO
Aracadonic Acid
NOS
NK-1 Receptor
COX-2
Nitric Oxide
Ca++
PGE2, PGI2
2nd Messengers, (IP, PK, cGMP)
Inflammation Hyperexcitability Toxicity?
Genome Activation, RNA & Protein Synthesis (e.g., Dynorphin) >> Hyper-excitability, Toxicity

So…theoretically, activation of Light Touch Fibers may Open Previously Ineffective Synaptic Connections



Substances *Dynamically* Modulating Dorsal Horn Neurons

Dynorphin

Met Leu-systemenkepalin

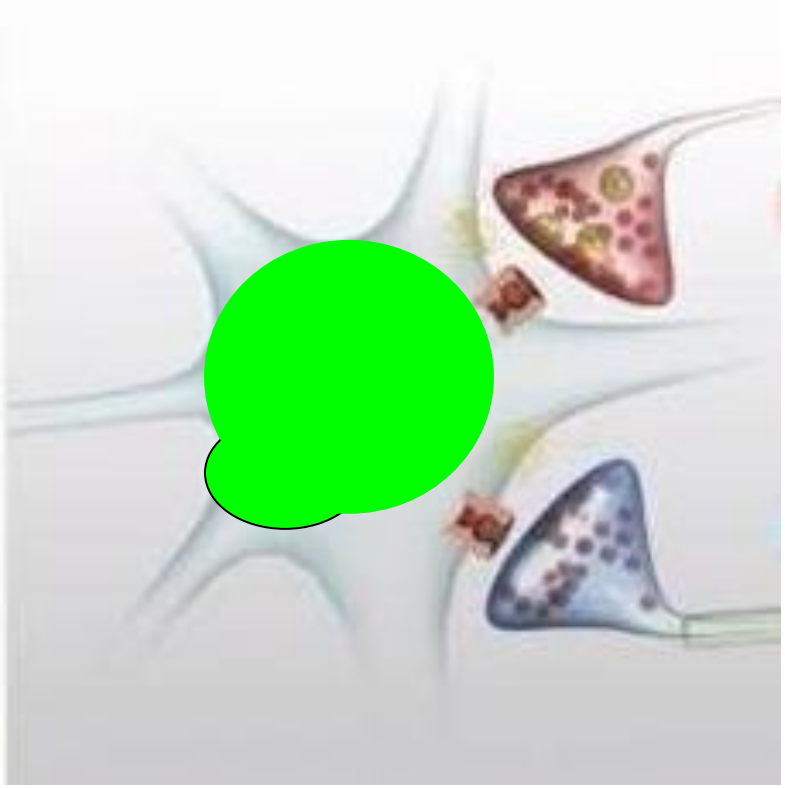
Immune

NeurotrophinsSP

NeurosteroidsGalanin

CytokinesVIP

Glia and



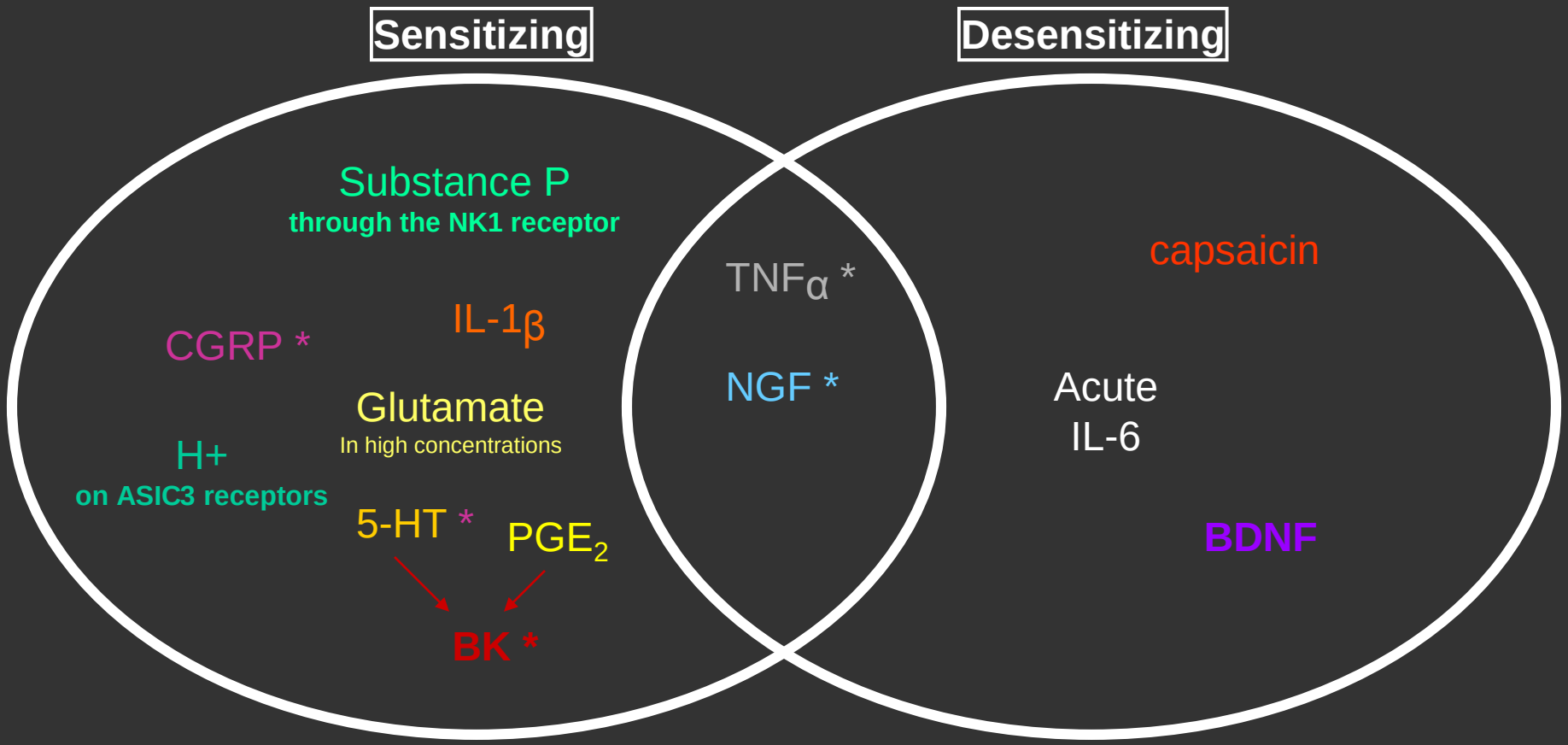
AstrocytesNPY

SOM

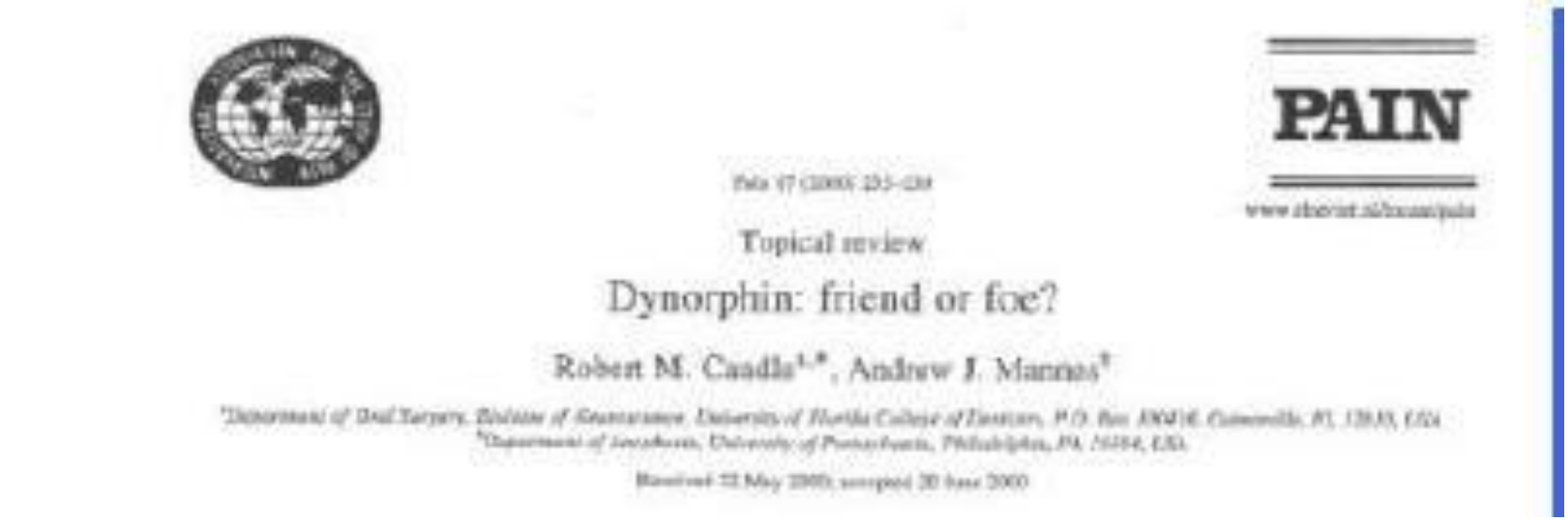
GABA, Glycine, Glutamate, ACh, DA, 5-

HT, Nitric Oxide

Biochemicals and Sensitization



- * NGF works later (not acute)
- * TNFα plays a dual role (also related to acute vs. later phase sensitization)
- * PGE_2 and Serotonin (5-HT) work to augment Bradykinin (BK) induced sensitization
- * CGRP and 5-HT increase vasodilation and extravasation increasing other local sensitizing substances



PAIN

Topical review

Dynorphin: friend or foe?

Robert M. Caudle[a,*], Andrew J. Mannes[b]

- Dynorphin activates opioid receptors but does not produce analgesia in the absence of injury
- Dynorphin activates NMDA receptors
- "…spinal dynorphin *first* preserves the animal through opiod receptors and then preserves the limb through NMDA receptors"

- Pathological damage may occur when dynorphin's animal and limb protective functions do not reduce nociceptive input and neuronal barrage

Glia: A *Non-neuronal* Contributor to Chronic Pain

Traditional views of pathological pain (i.e., that it's exclusively neuronal) are changing

Glia are activated in *every* clinically relevant model of chronic pain

Spinal glial cells are important factors in *muscle pain*, sensitization and hyperalgesia

Suppressing glial activation and/or glial pro-inflammatory cytokines suppresses pain in *every* animal model of pain

Journal of Bodywork and Movement Therapies (2008) 12, 371–384

ELSEVIER

Journal of
Bodywork and
Movement Therapies

www.elsevier.com/jbmt

MYOFASCIAL PAIN RESEARCH

Uncovering the biochemical milieu of myofascial trigger points using in vivo microdialysis: An application of muscle pain concepts to myofascial pain syndrome

Jay P. Shah, MD*, Elizabeth A. Gilliams, BA

Rehabilitation Medicine Department, Clinical Center, National Institutes of Health, 10 Center Drive, Room 1-1469, MSC 1604, Bethesda, MD 20892-1604 USA

Question

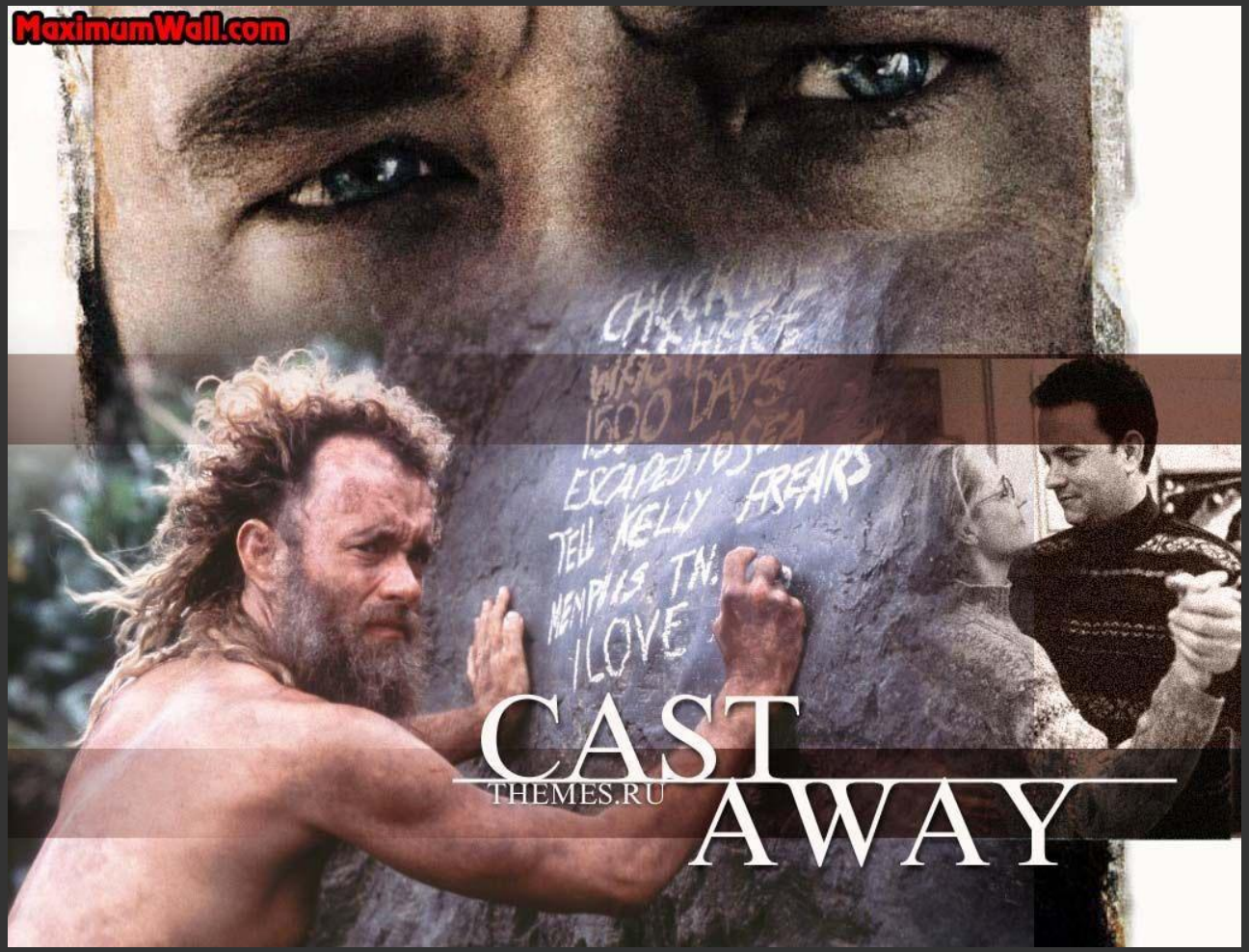
1. All of the following are main changes found in sensitized dorsal horn neurons *except:*

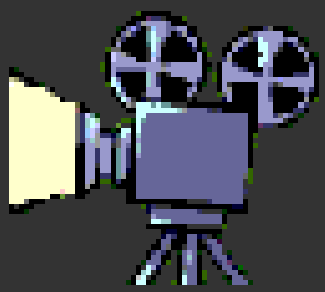
A) Increased responsiveness to external stimuli

B) Spread of excitation to spinal segments that do not normally receive input from the damaged muscle

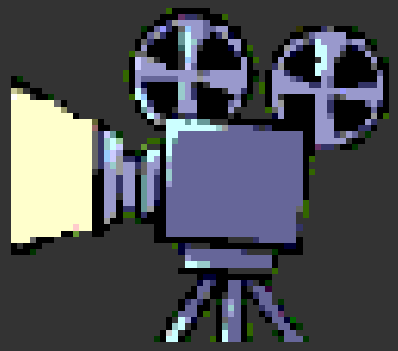
C) Decreased background activity

Can you name the motion picture?





Can you name the motion picture?



Can you name the motion picture?

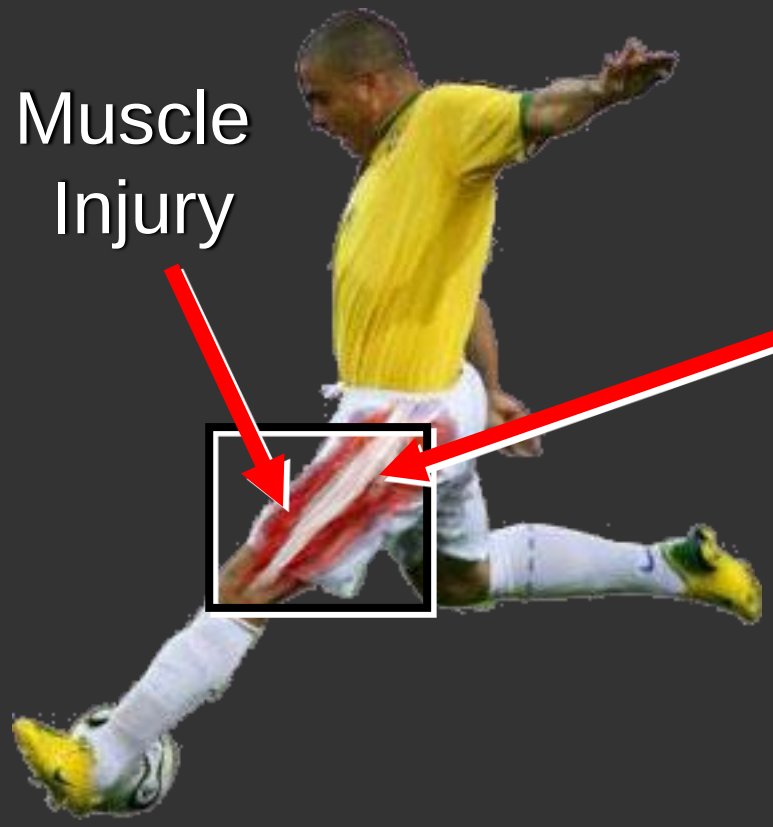
Myofascial Trigger Points and the Unique Neurobiology of Muscle Pain:

From Peripheral to Central Sensitization

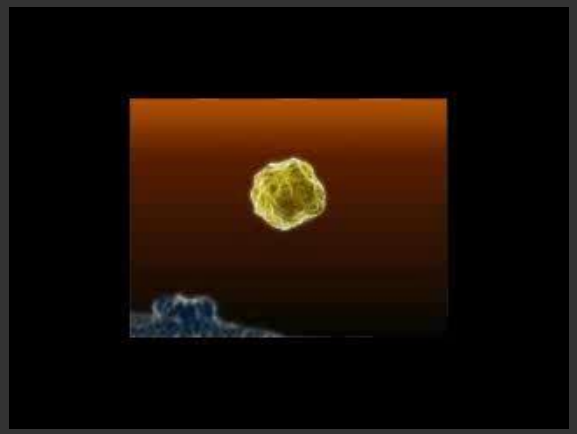
Muscle Injury and Pain

Courtesy Marta Imamura

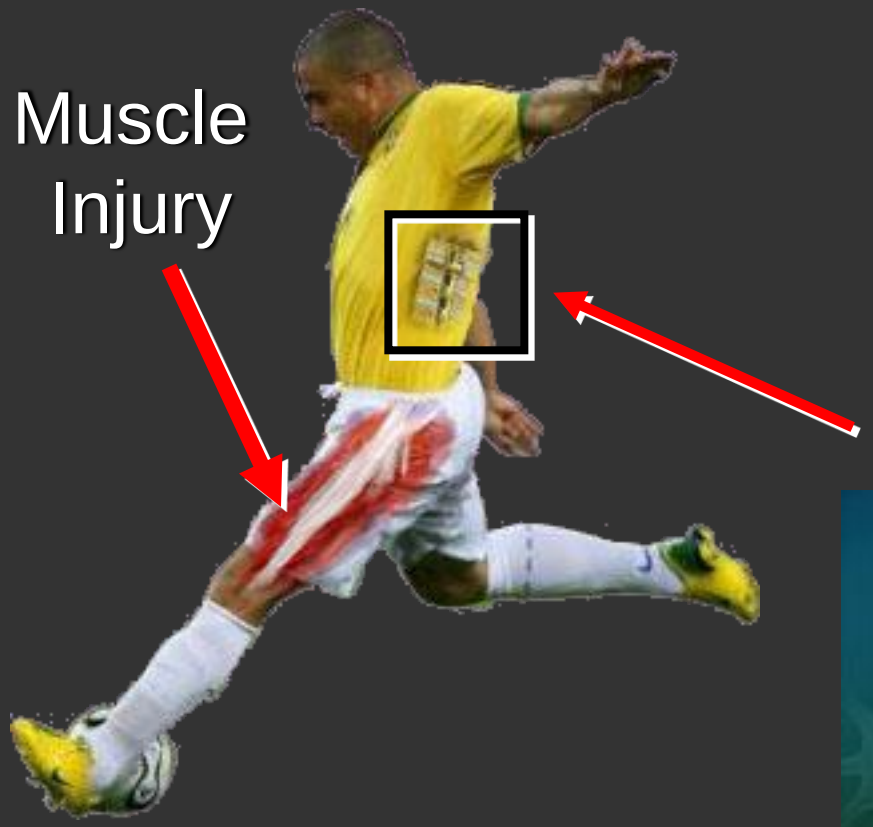
Muscle Pain, Inflammation, and Sensitization

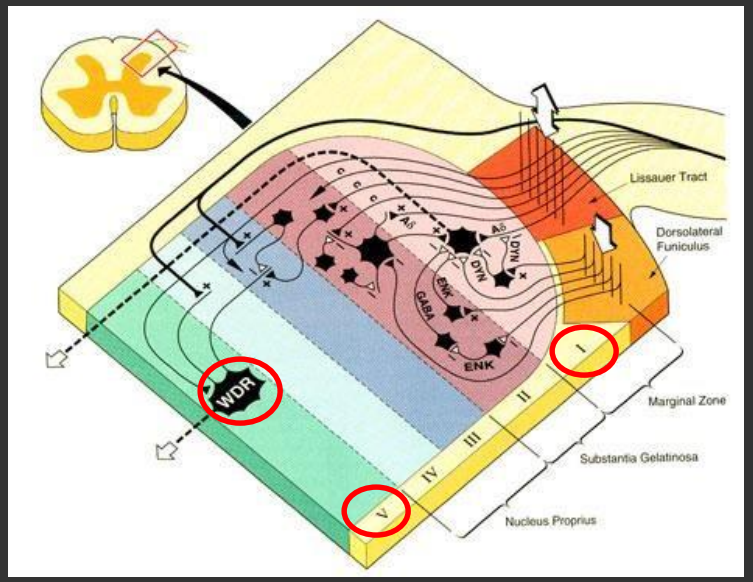


Release of Inflammatory mediators, Neuropeptides and Cytokines



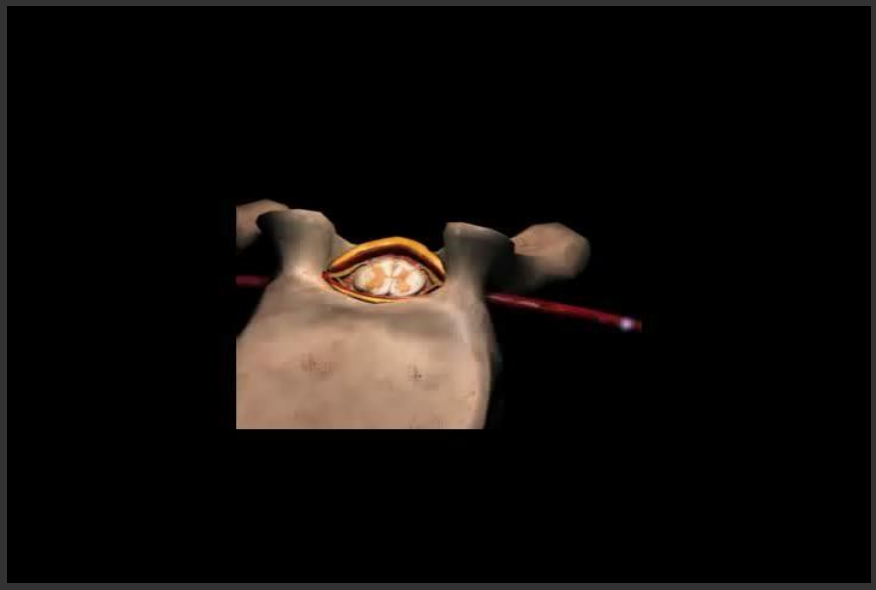
Muscle Pain, Inflammation, and Sensitization





Muscle Pain, Inflammation, and Sensitization

… expansion of the receptive field of pain and referral of pain



Muscle Pain, Inflammation, and Sensitization

Limbic System → Increase: Fear, Anxiety, Stress

Pain Perception and the Human Brain

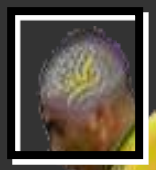
Niddam et al. found increased limbic system activity in upper trapezius myofascial pain syndrome

Descending Pain Pathway

Emotions

Hormones

Limbic System



Peri-Acqueductal Gray

Muscle re-injury, after premature return to sports or something else?

Rostral Ventral Medulla:

ON/OFF Cells

Supr

's.

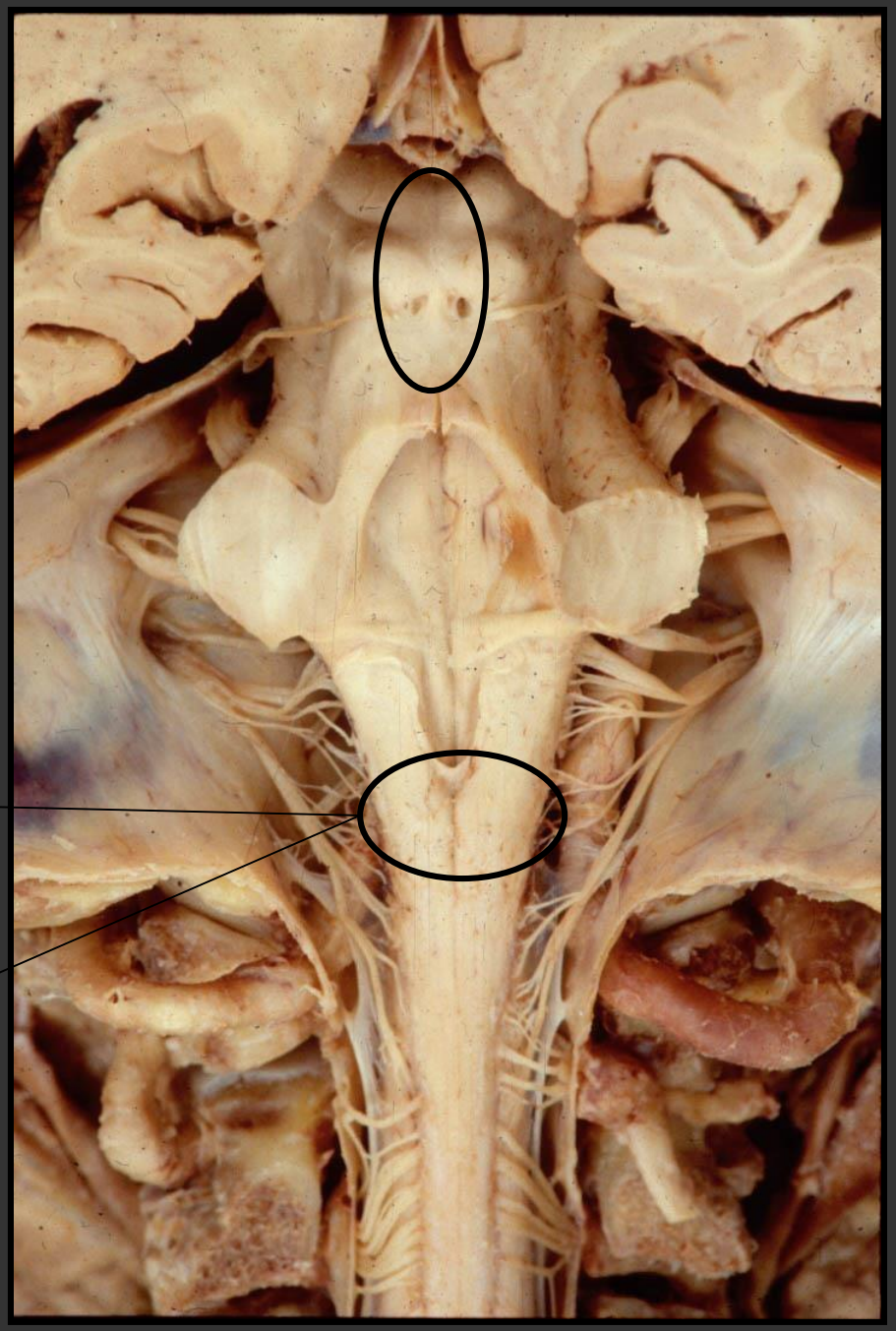
Lamina I / V

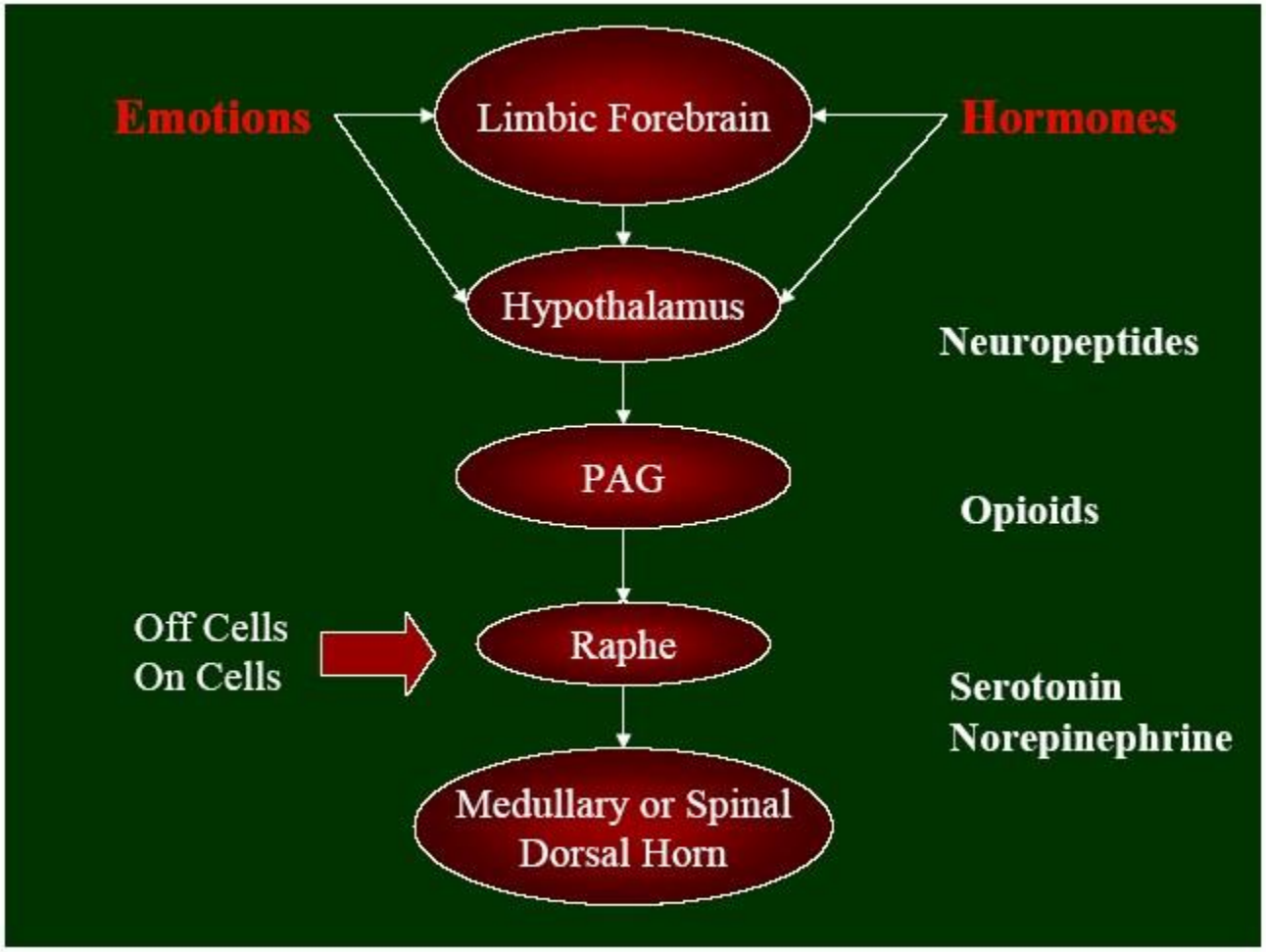
Periaqueductal Gray
Raphe Nuclei

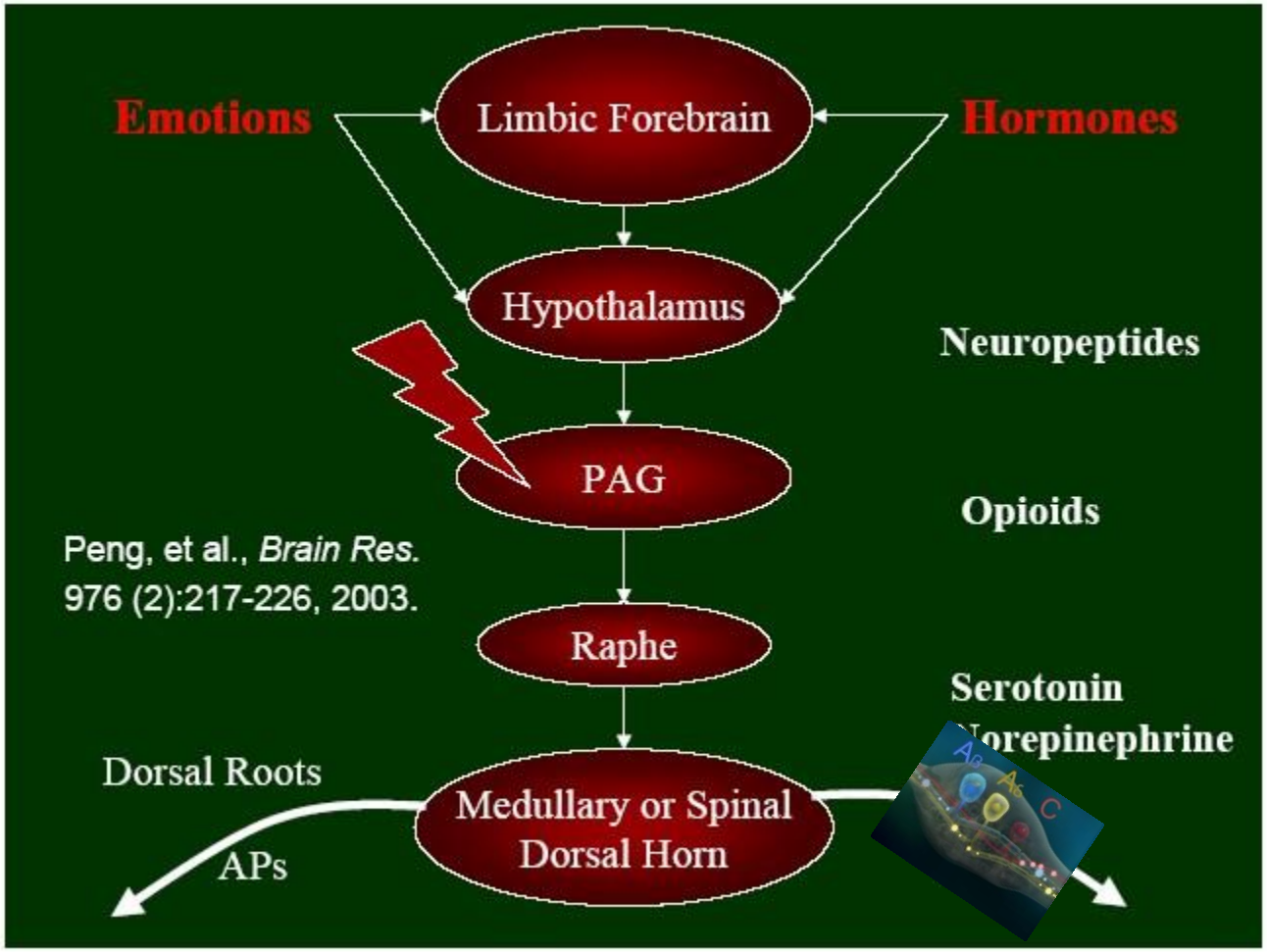
- Descending projections to the spinal cord gray matter

“Off Cells”

“On Cells”

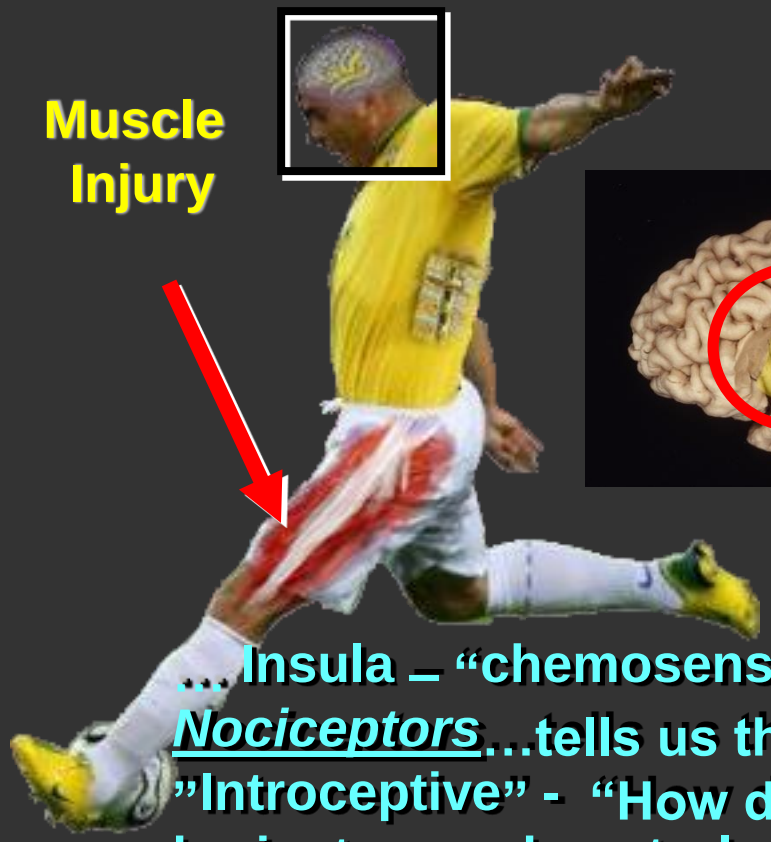


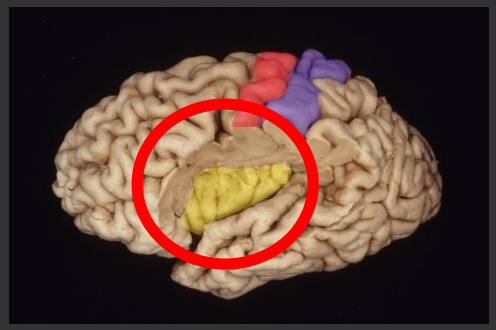

Emotions
Limbic Forebrain
Hormones
Hypothalamus
Neuropeptides
PAG
Opioids
Off Cells
On Cells
Raphe
Serotonin
Norepinephrine
Medullary or Spinal
Dorsal Horn

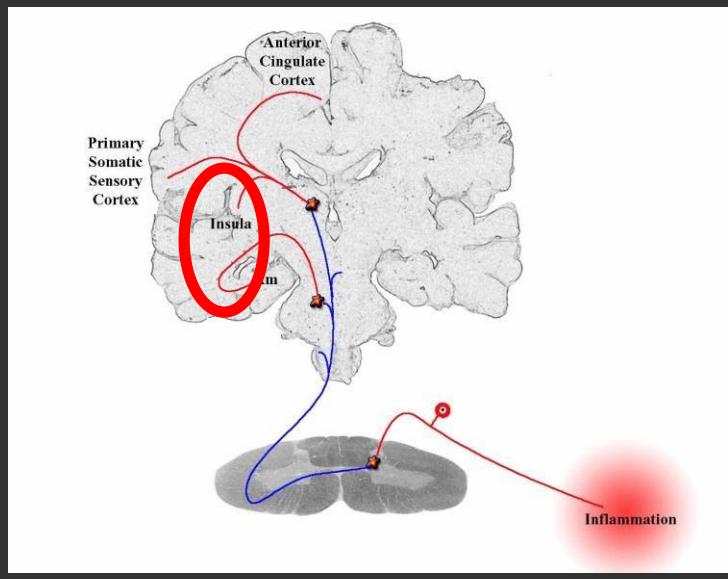

Emotions
Limbic Forebrain
Hormones
Hypothalamus
Neuropeptides
PAG
Opioids
Peng, et al., Brain Res. 976 (2):217-226, 2003.
Raphe
Serotonin
Norepinephrine
Dorsal Roots
Medullary or Spinal Dorsal Horn
APs

Muscle Pain and the CNS

Muscle Injury

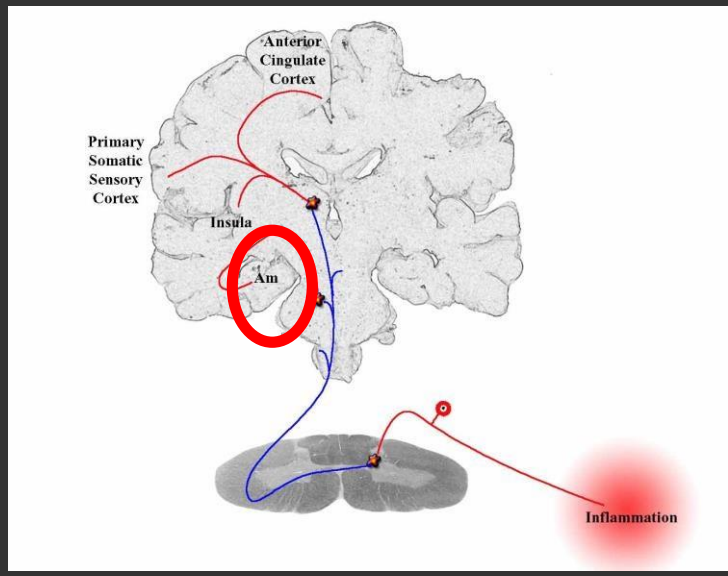






…Insula – "chemosenstive" map of the body activated by ***Nociceptors***…tells us the status of the tissues right now - "Introceptive" - "How do you feel?" It has big projection to the brainstem and controls the descending autonomic system to regulate the tissues via homeostasis

Muscle Pain and the CNS

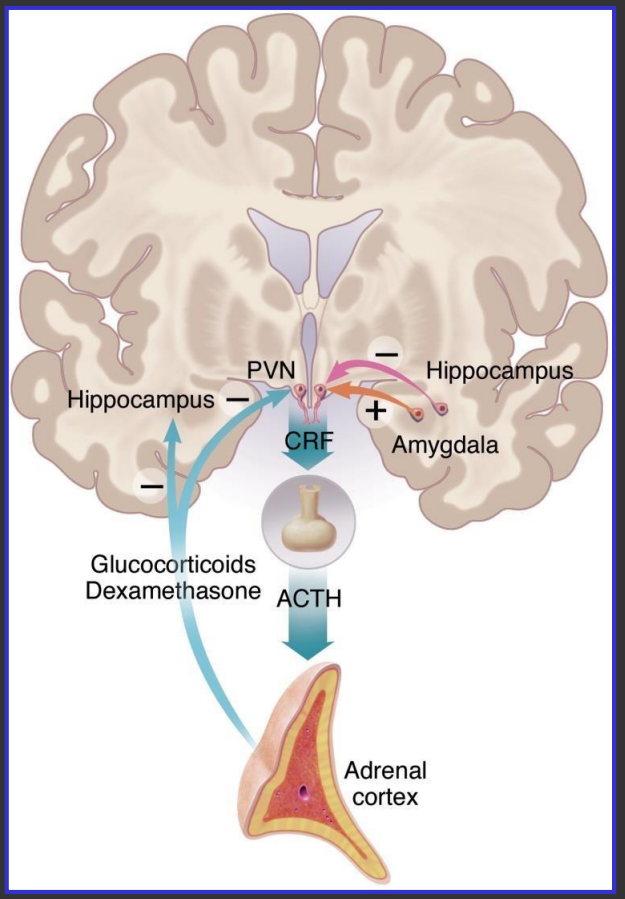


Amydgala – Big target of the Nociceptors…Can be sensitized and facilitated, especially to fear memories associated with traumatic events. Activates the ANS through the midbrain and the HPA axis through the hypothalamus, secreting NE and cortisol : Acute - arousal, vigilance; Chronic – hyper-arousal

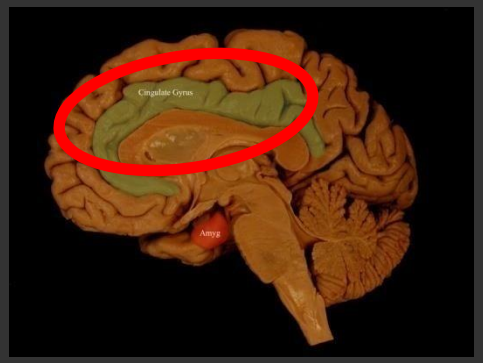
and the HPA axis through the hypothalamus, secreting NE and cortisol : Acute - arousal, vigilance; Chronic – hyper-arousal and vigilance, obsession, anxiety, depression

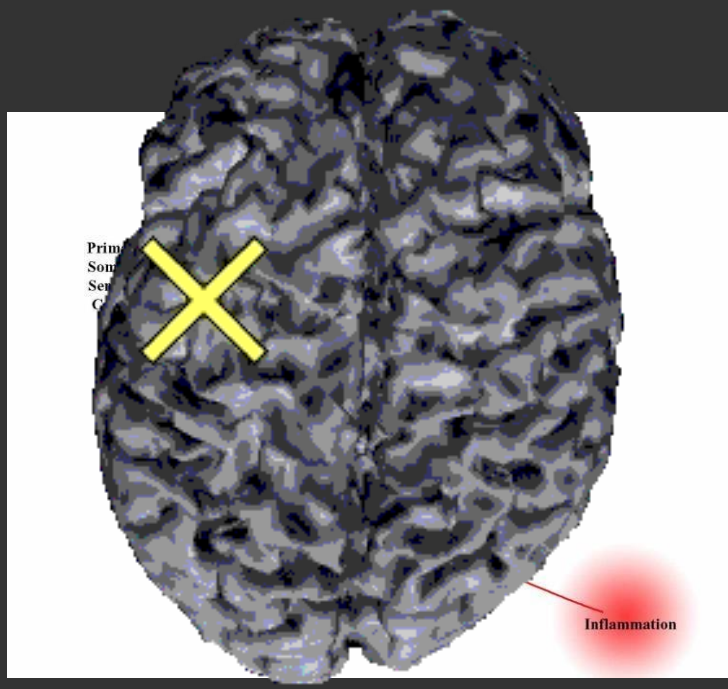
Hippocampus

Exercise has *neuro-regenerative* effects on Hippocampus!



Muscle Pain and the CNS





Pain in the brain is a network, not one individual site

Anterior Cingulate Gyrus – Affective Component of pain; activated even by *suggestion* of pain; closely connected to amygdala

Myofascial Pain Syndrome:

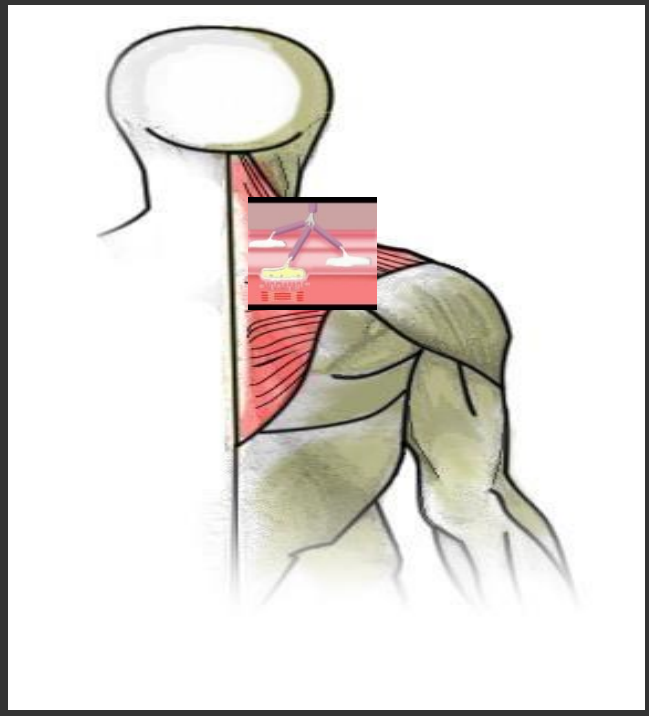
4) We need a more comprehensive and systematic evaluation to distinguish people with MPS from those without

The Usefulness of the Cervical Range of Motion Device in the Ocular Motility Examination

Arch Ophthalmol. 2000;118(7):946-950. doi:10-1001/pubs.Ophthalmol.-ISSN-0003-9950-118-7-ecs90244

JTech Medical© Commander Digital Algometer

http://www.jtechmedical.com/solutions/commander/algometer



A Systematic Comparison b/w Subjects with no Pain and Pain associated with Active MTrPs

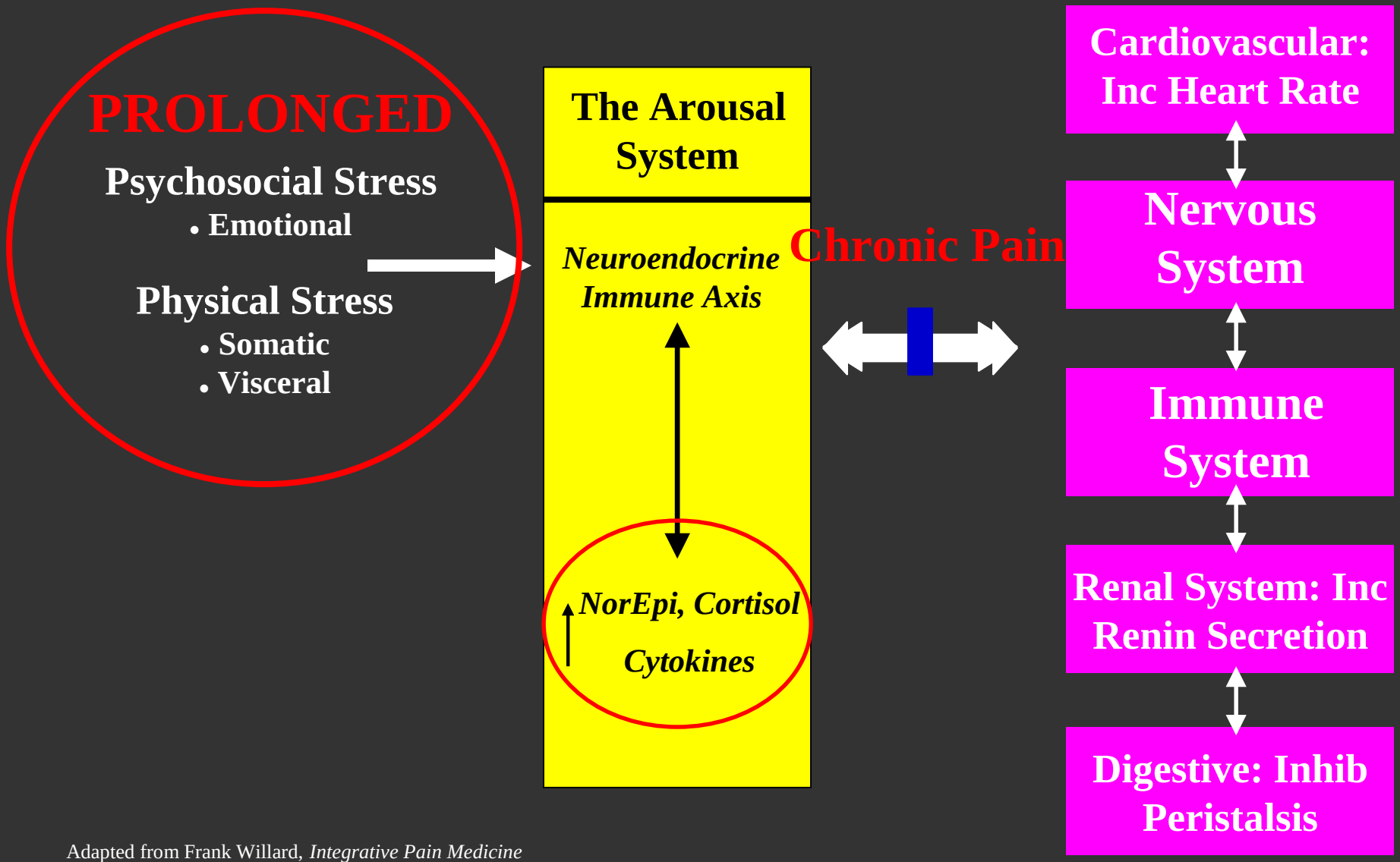
A combination of objective measures (soft tissue palpation, CROM, algometry) and self-reports (SF-36, Profile of Mood States [POMS], Brief Pain Inventory [BPI], Oswestry Disability Scale) successfully distinguished subjects with cervical pain (due to *Active* MTrPs in upper trapezius) from subjects with no pain

Compared to no pain group, the group with cervical pain secondary to *Active* MTrPs had:

1) Lower PPT ($p<0.01$)
2) Poorer health Status ($p<0.001$)
3) More depression, fatigue, tension, confusion and mood disturbance ($p<0.001$)
4) Greater disability ($p<0.0001$)

- Gerber L et al. *PMR* 2013

Allostasis: "Stability Through Change"



Adapted from Frank Willard, *Integrative Pain Medicine*

"Since no (Medical) Specialty Claims Skeletal Muscle as it's Organ, it is Often Overlooked"

David G. Simons, MD

1922-2010

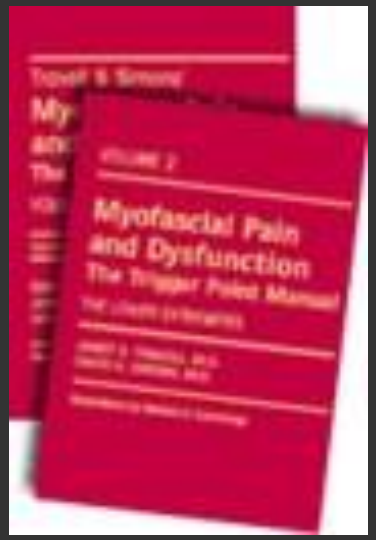
MANHIGH Project

Muscle – The "Orphan Organ"

- NO specialty claims muscle as its organ
  - Muscle is ½ of the body
- No organized emphasis on muscle pain (MTrP) research or student training
- Clinicians focus primarily on treating the SYMPTOMS of myogenic pain, not the CAUSE of the pain (MTrPs)

Muscle Palpation is a Learned Skill _ Start Early!

Travell and Simons' Trigger Point Manual



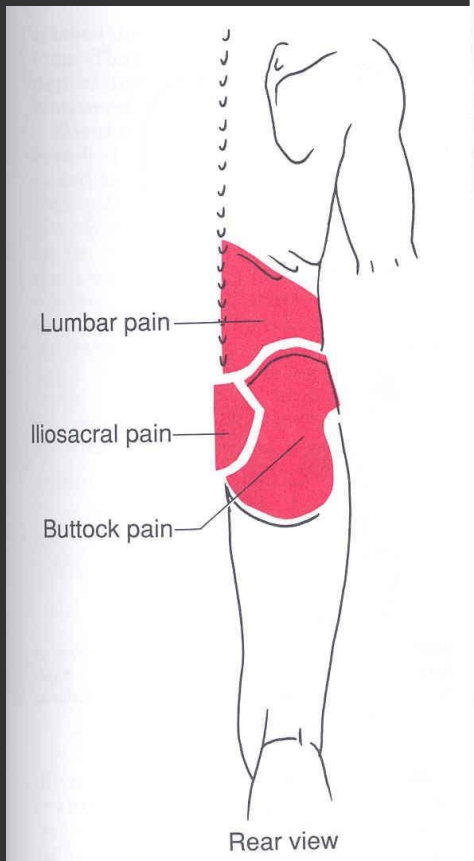


Figure 3.1. Designated areas *(red)* within the low torso region where patients may describe myofasc pain. The pain may be referred to each designated

PAIN GUIDE

ABDOMINAL PAIN

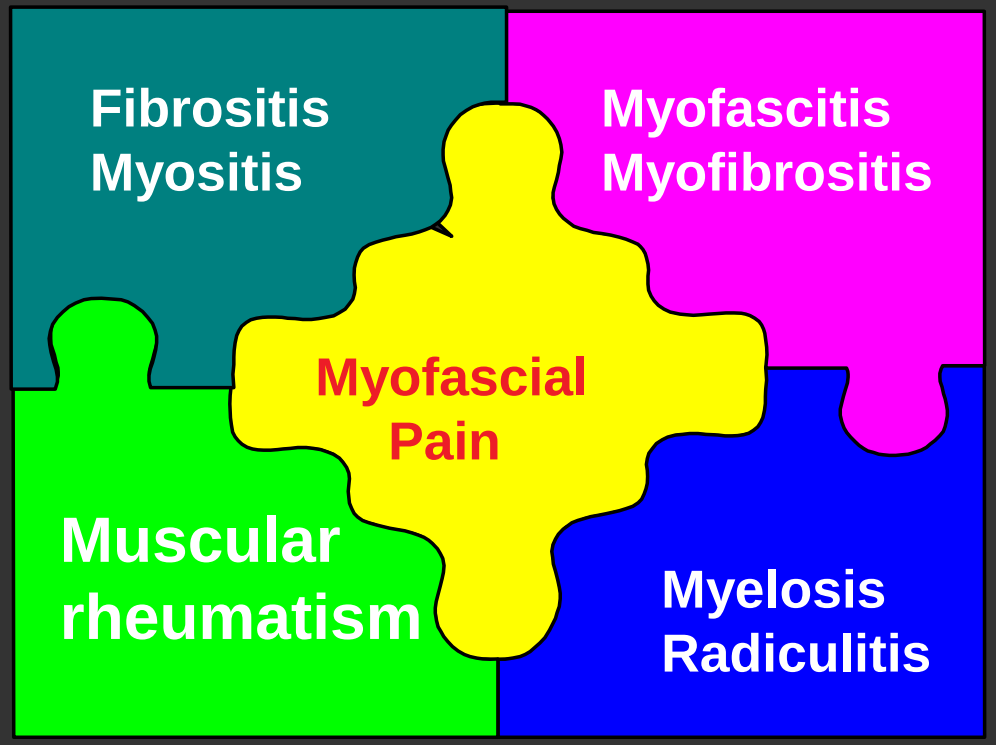
Rectus abdominis (49.2*B*, p. 664)[9]
Obliquus externus abdominis (49.1*C*, p. 662)[9]
Iliocostalis thoracis (48.1*B*, p. 638)[9]
Multifidi (48.2*B*, p. 639)[9]
Quadratus lumborum (4.1*A*, p. 30)
Pyramidalis (49.2*D*, p. 664)[9]

BUTTOCK PAIN

Gluteus medius (8.1 TrP_1 and TrP_2, p. 151)
Quadratus lumborum (4.1*A* and 4.1*B*, p. 30)
Gluteus maximus (7.1*A*, *B*, and *C*, p. 133)
Iliocostalis lumborum (48.1*C*, p. 638)[9]
Longissimus thoracis (48.1*D*, p. 638)[9]
Semitendinosus and semimembranosus (16.1*A*, p. 317)
Piriformis (10.1, p. 188)
Gluteus minimus (9.1, p. 169 and 9.2, p. 169)
Rectus abdominis (49.2*A*, p. 664)[9]
Soleus (22.1 TrP_3, p. 429)

Myofascial Pain Syndrome (MPS)

Historical and Regional Confusion



"Poking around at night on the muscles over my shoulder blade, trying to give some "do-ityourself" massage, I was astonished to touch some spots that intensified, or reproduced my pain, as though I had turned on an electric switch. It was my first introduction to the enigmatic trigger area. No nerve existed, I knew, to connect those tiny spots directly with my arm. I was baffled, but I did not discard the observation on the grounds that I could not

explain it”

Travell, J. *Office Hours: Day and Night* (1968)

THE MYOFASCIAL GENESIS OF PAIN

JANET TRAVELL AND SEYMOUR H. RINZLER*

Cornell University Medical College and Beth Israel Hospital, New York

Trigger Areas in Myofascial Structures Can Maintain Pain Cycles Indefinitely

THE TRIGGER AREA

Data are drawn from about 1000 patients with (1) pain syndromes and (2) myofascial trigger areas.

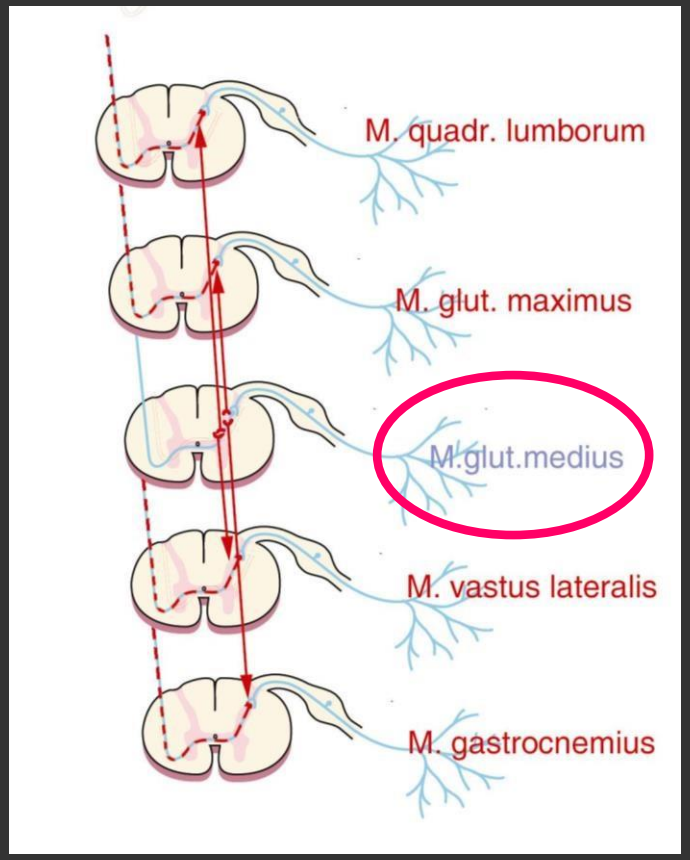
The trigger area is a small hypersensitive region from which impulses bombard the central nervous system and give rise to *referred*

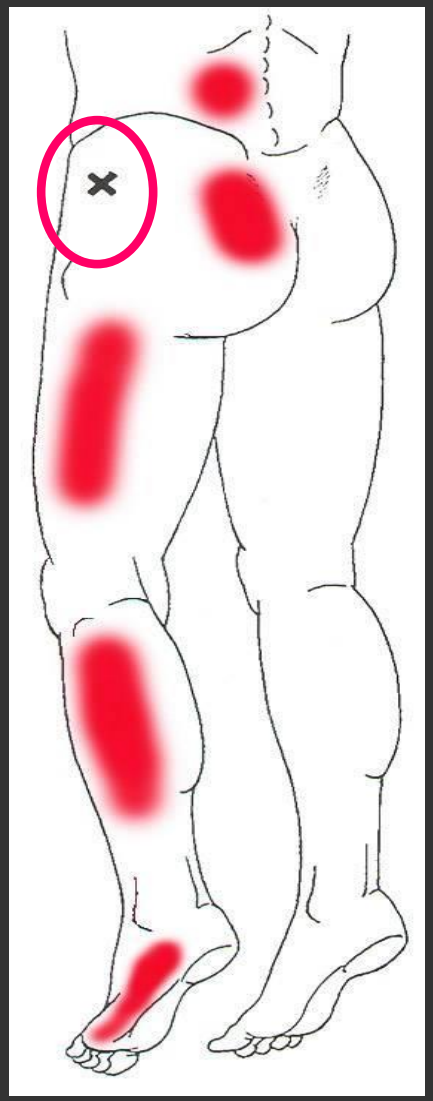
may be accompanied
other autonomic effect
zone of pain.

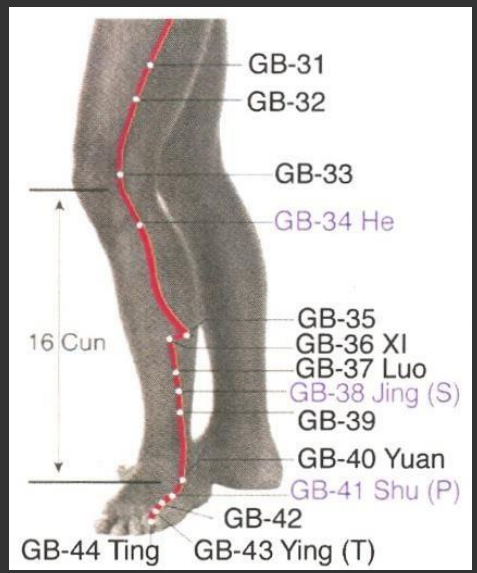
A trigger area at a
to a similar distributio
person as in another.

This constancy of p
pulses concerned in th

Opening of Previously Ineffective Synapses







Active trigger point at the gluteus minimus muscle

↓

Enlargement of receptive field by sensitization (mostly peripheral)

↓

Persistent nociceptive input to 2nd order neuron at the dorsal horn

↓

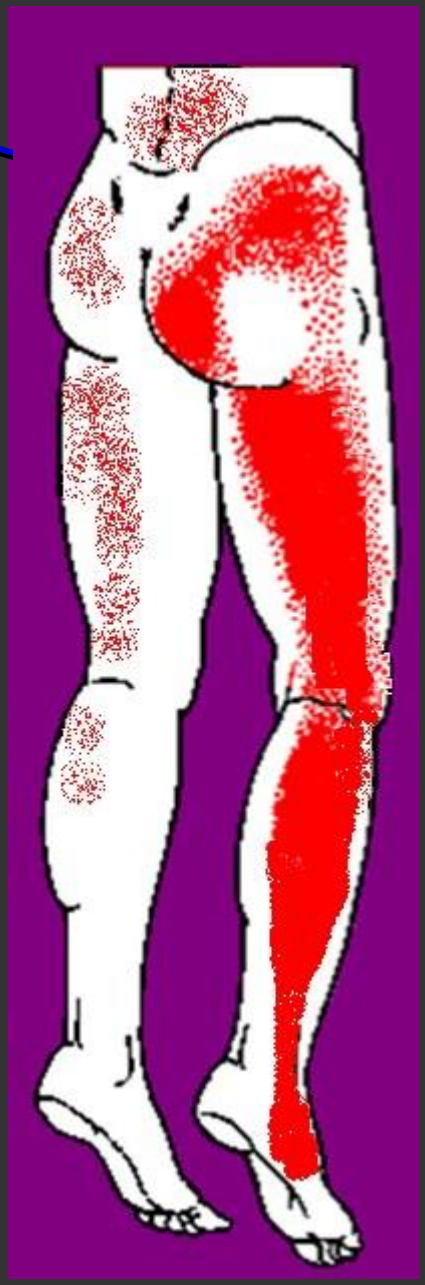
Central Sensitization
Spinal Segmental
Sensitization

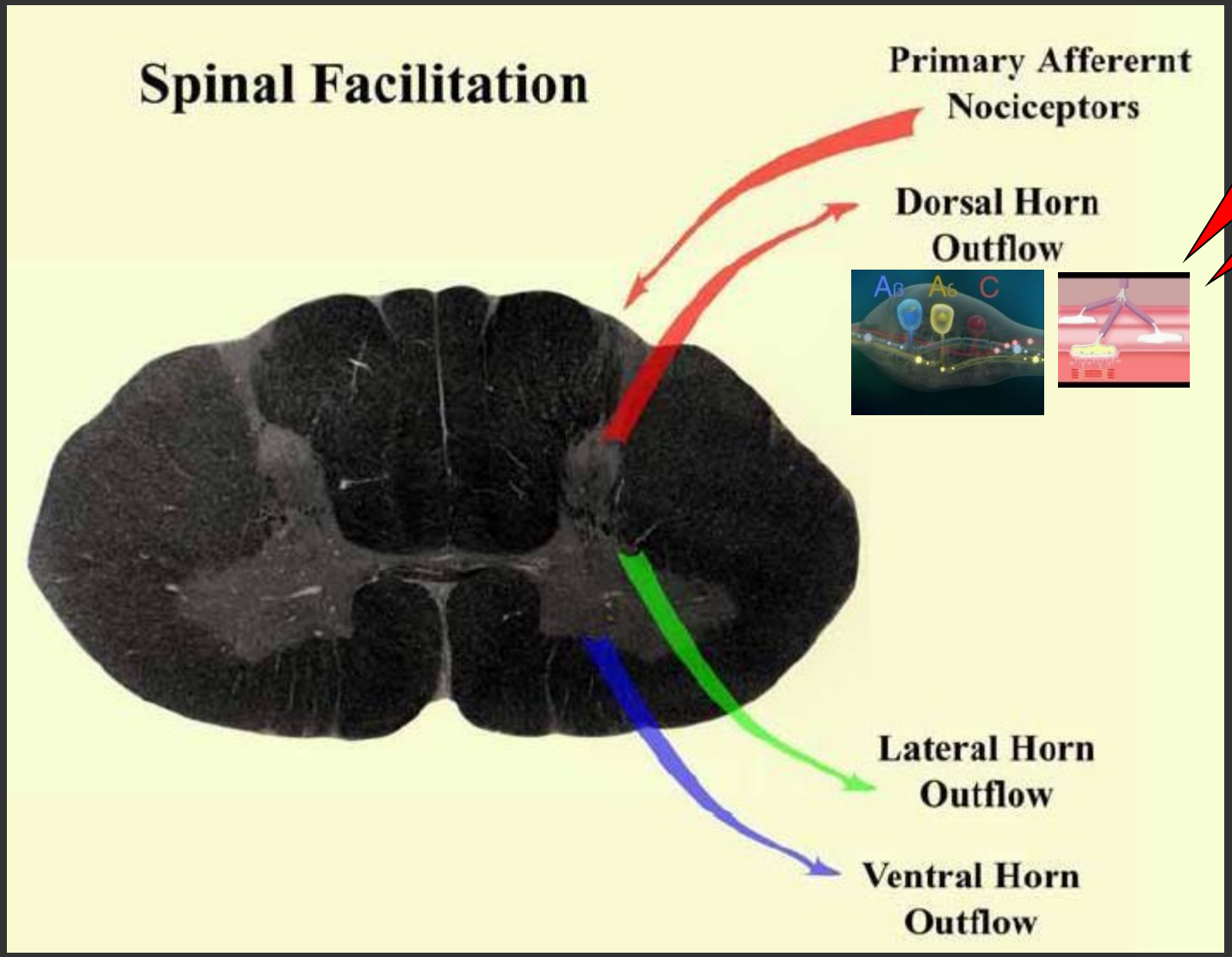
↓

Spontaneus pain at S1 spinal level
Dermatome, myotome, sclerotome manifestations

↓

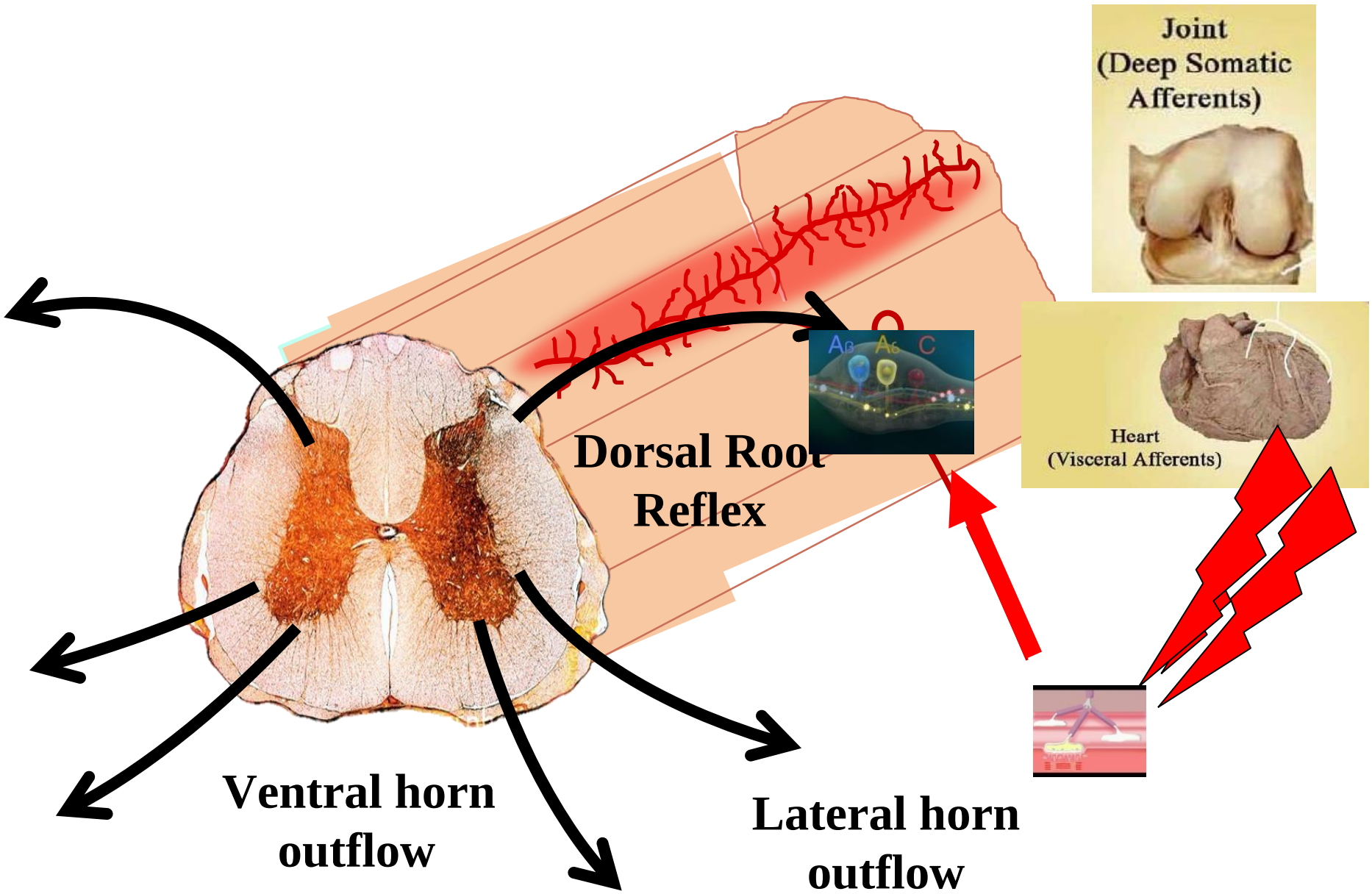
Spread of sensitization to other dorsal horn levels and to contralateral side





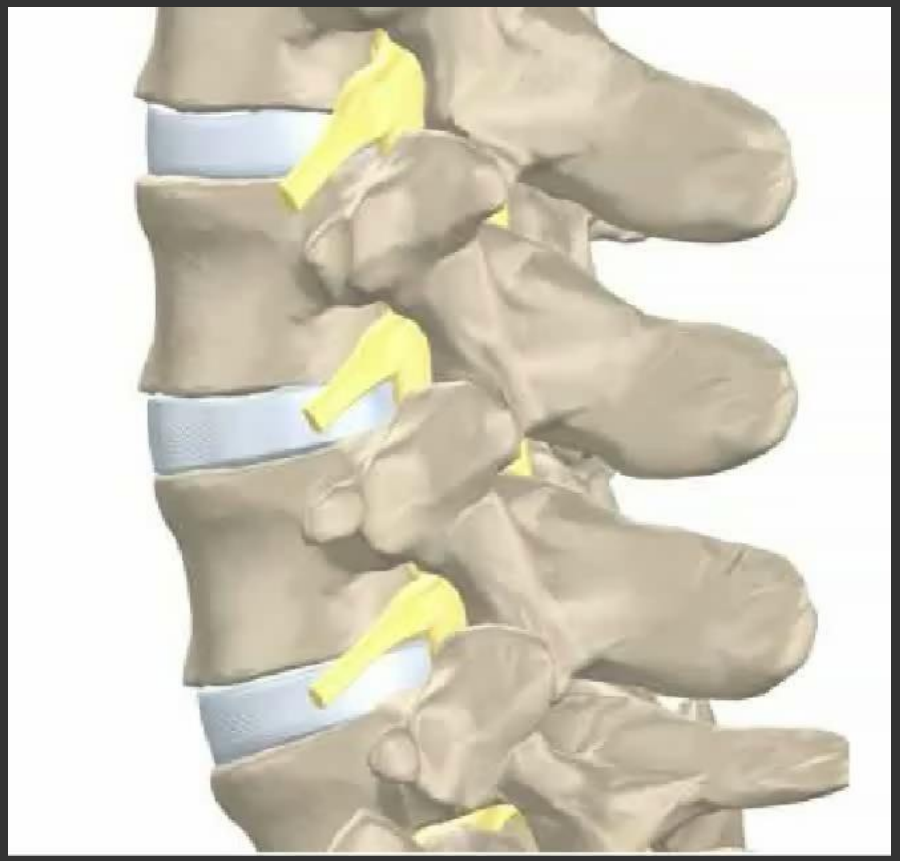
Courtesy Frank Willard,

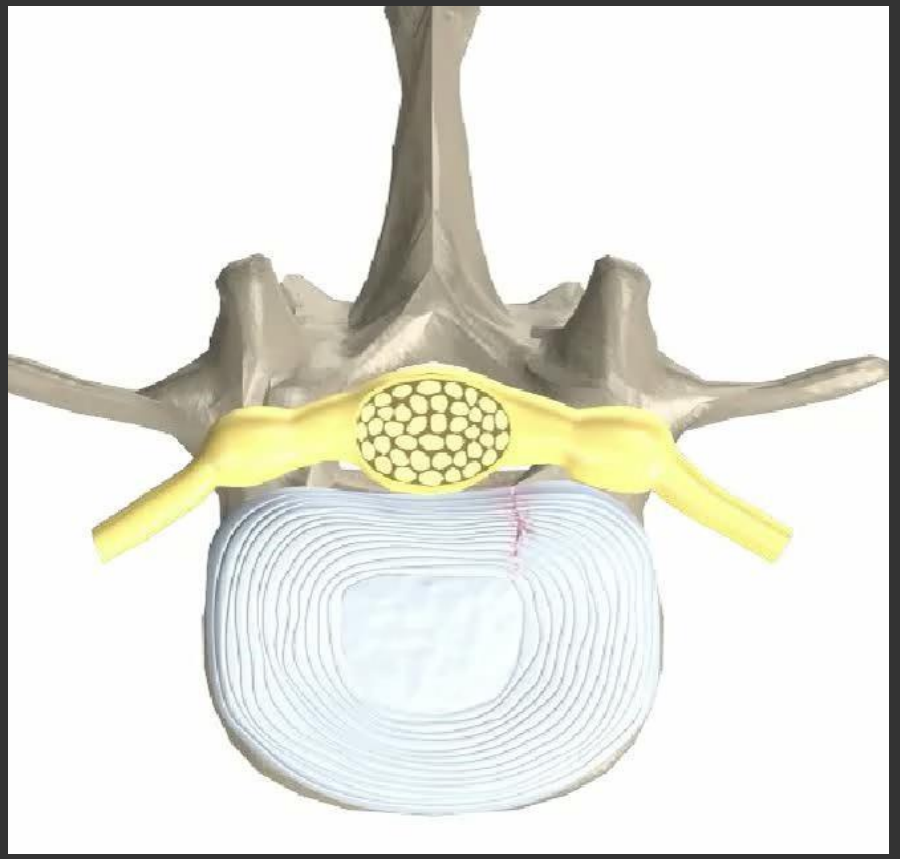
Sensitized Dorsal Horn Neurons Demonstrate


Joint
(Deep Somatic
Afferents)
Heart
(Visceral Afferents)
Dorsal Root
Reflex
Ventral horn
outflow
Lateral horn
outflow

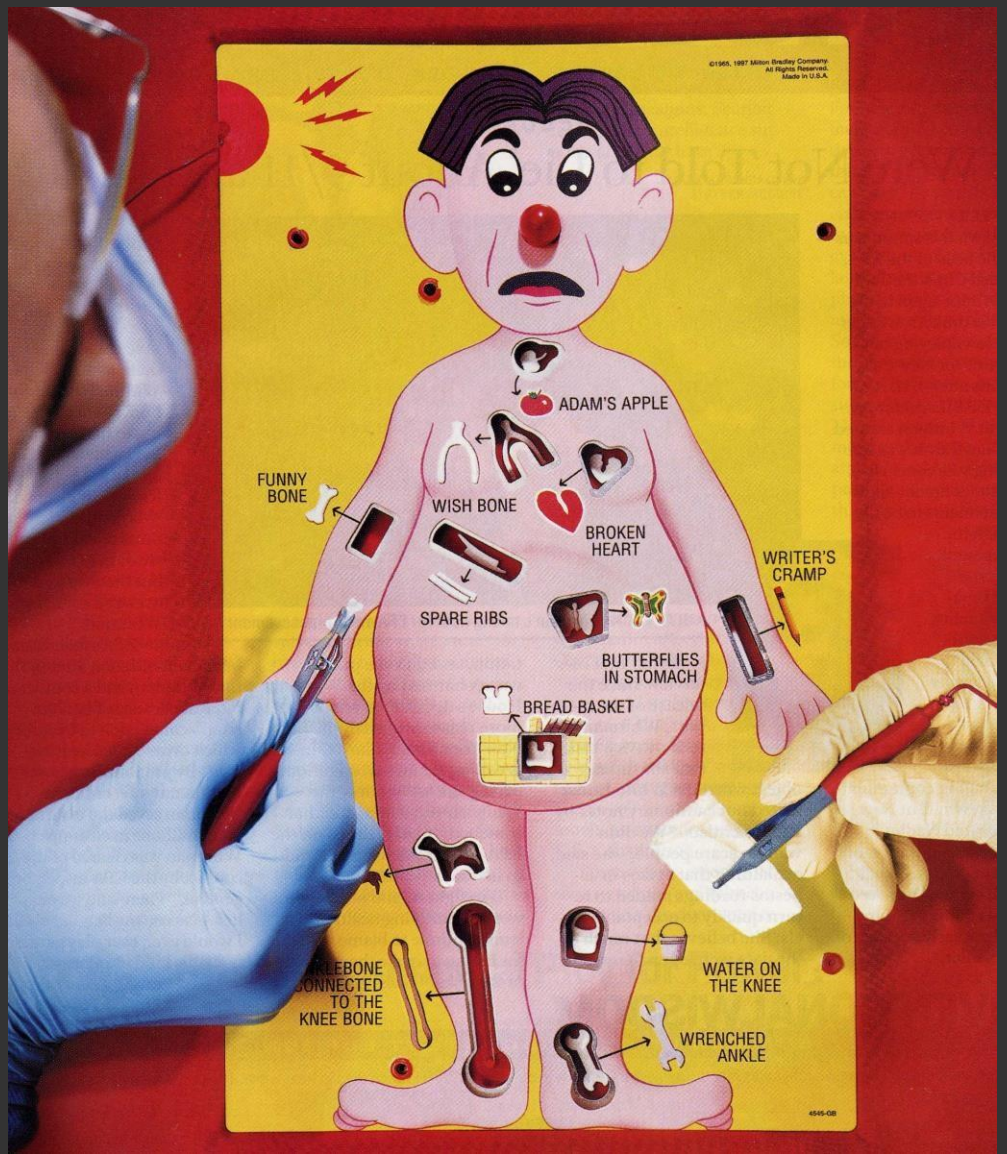
Extra-Segmental Spread!

Low Back Pain and Paraspinal Muscle Spasms

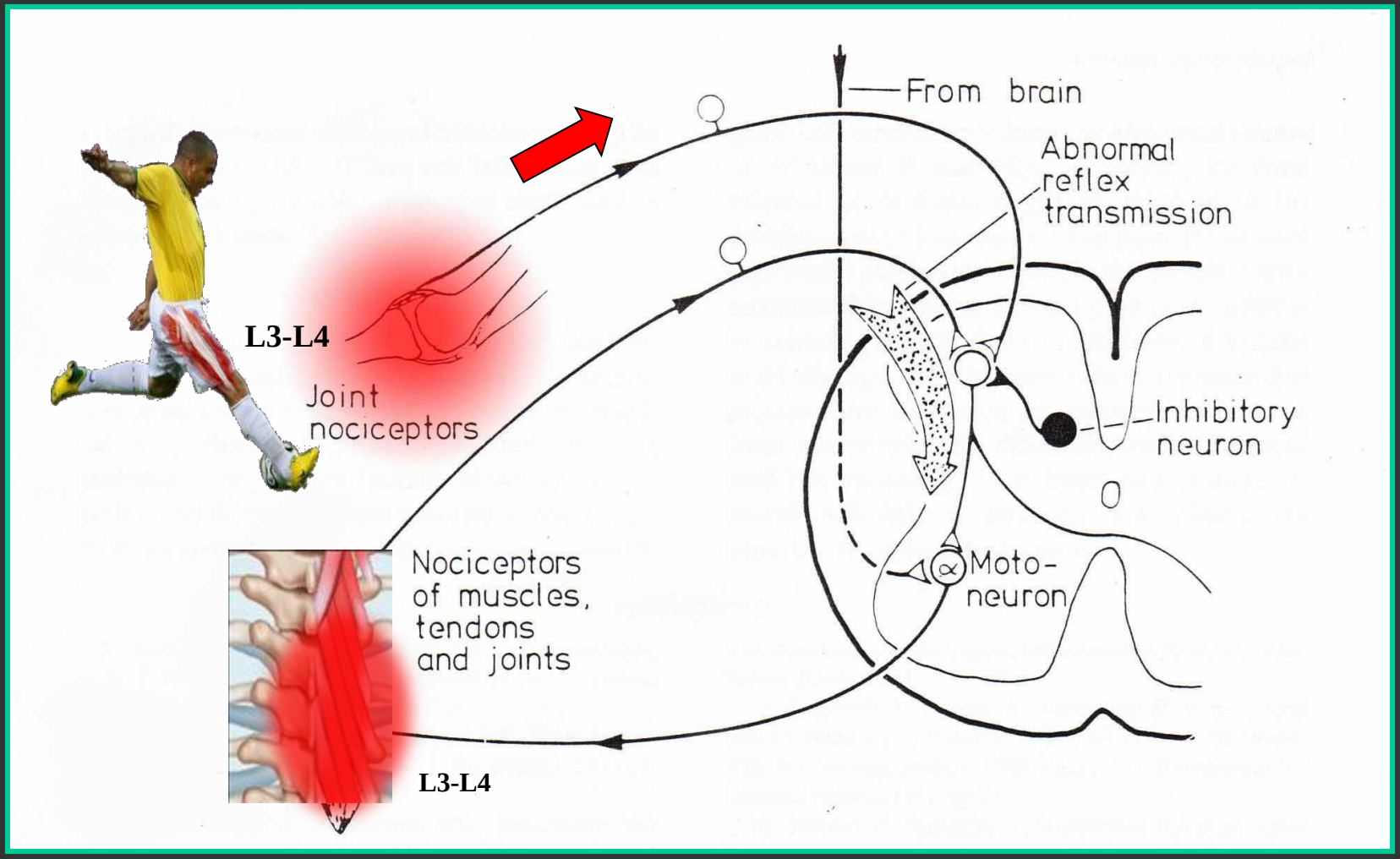




Beyond the Medical Model of Chronic Pain…

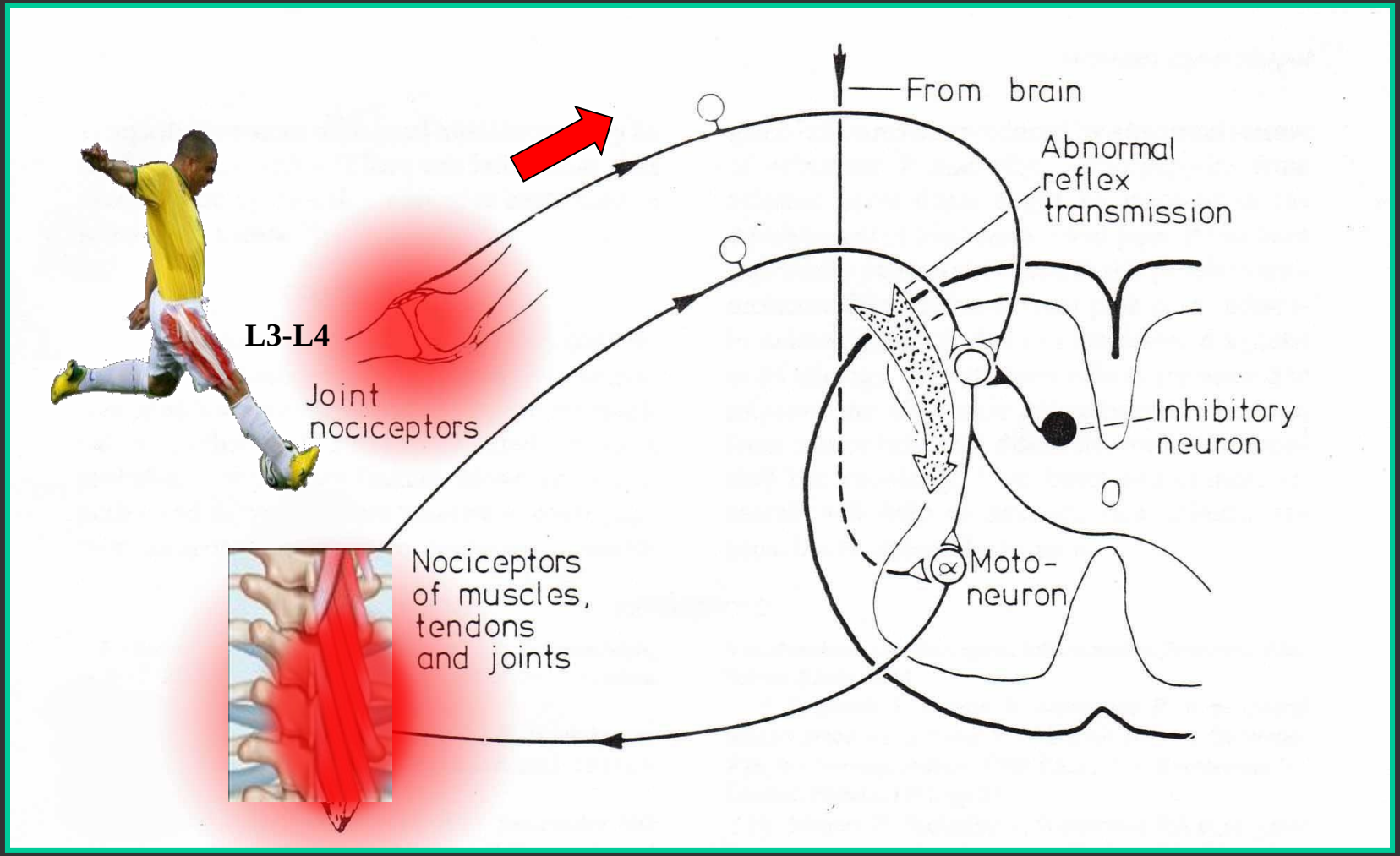


Spinal Facilitation - Application



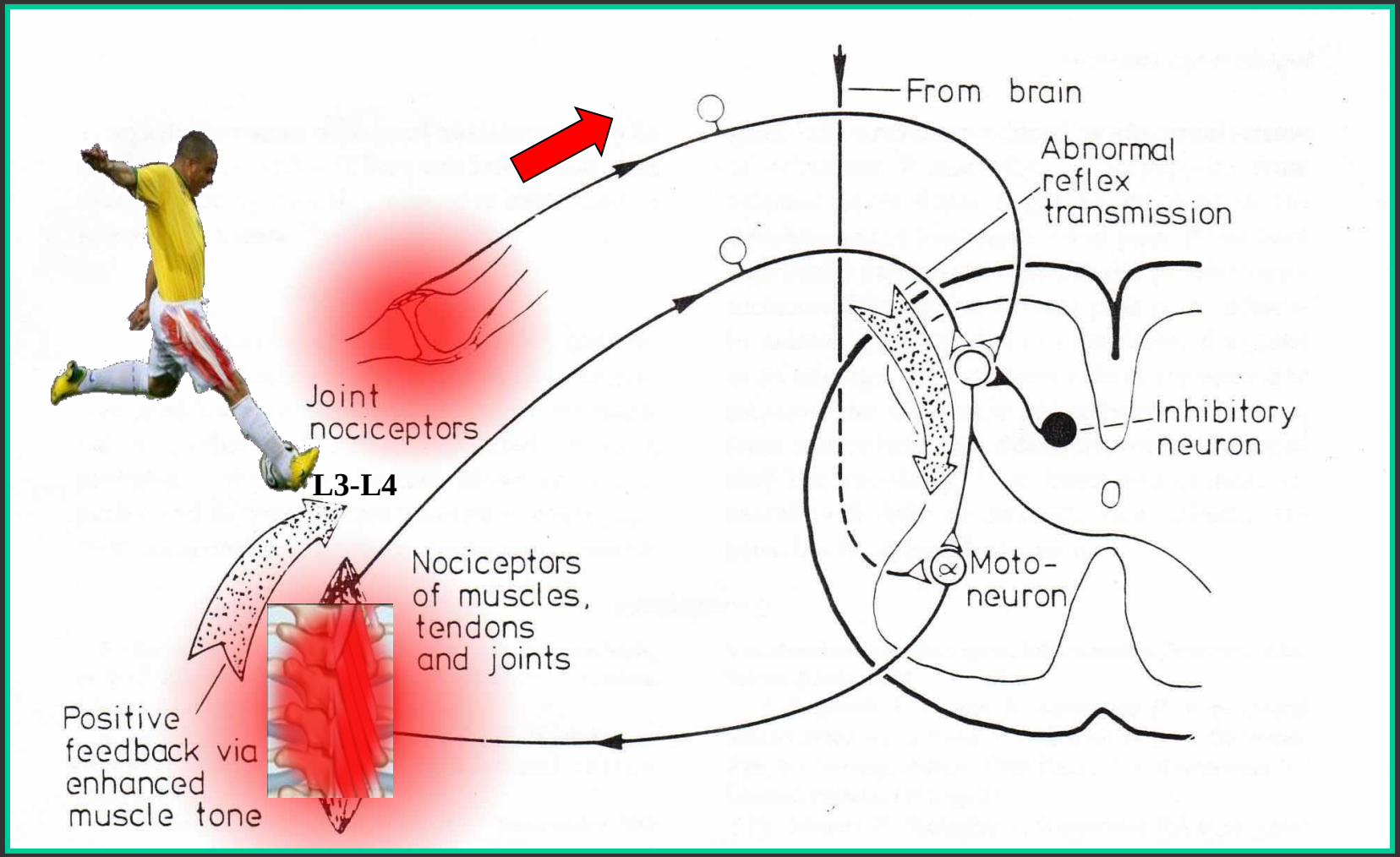
Zimmermann, M. Pain mechanisms and mediators in osteoarthritis Sem Arth. Rheu. 18:22, 1989

Spinal Facilitation - Application

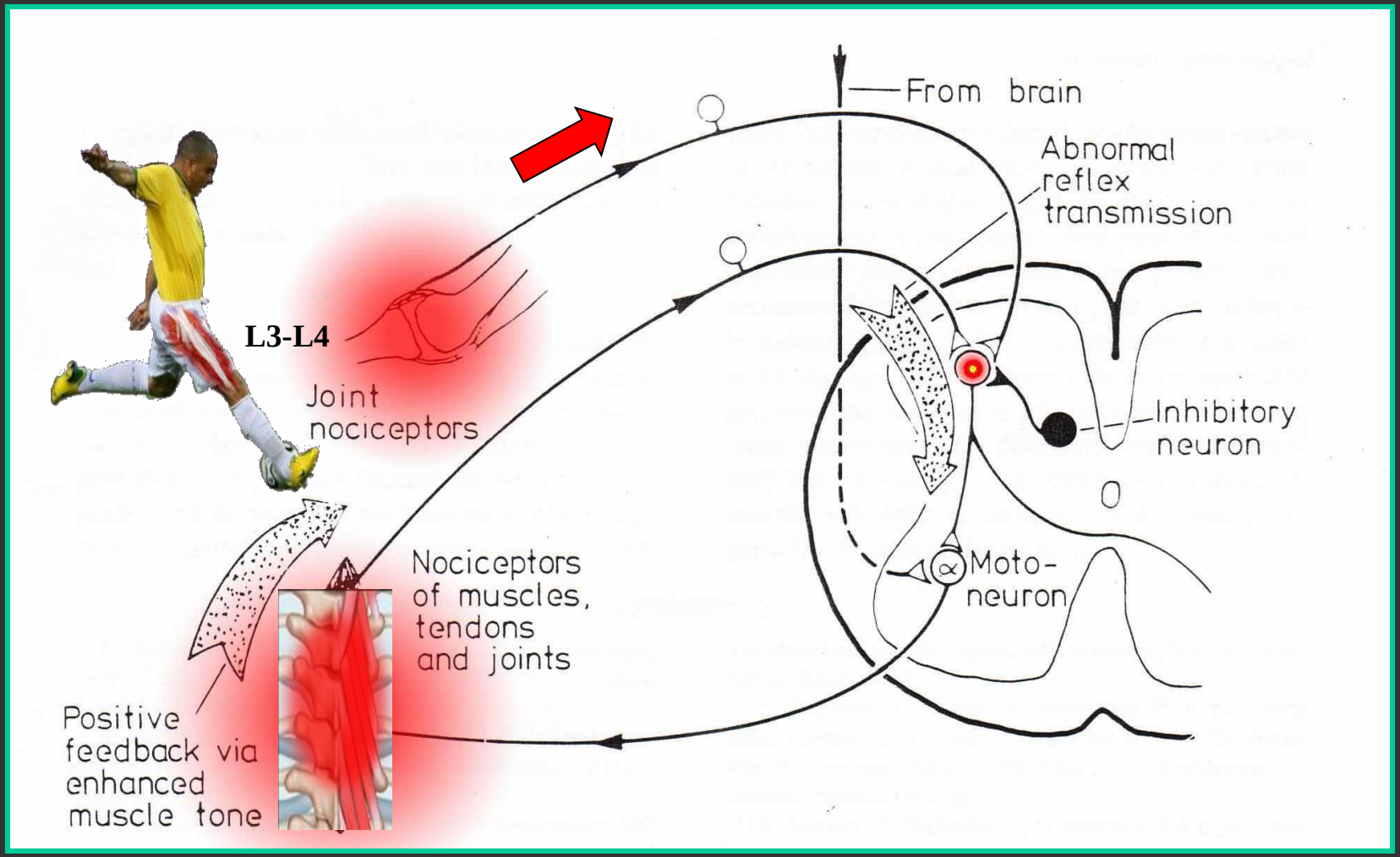


. 18:22, 1989

Spinal Facilitation - Application

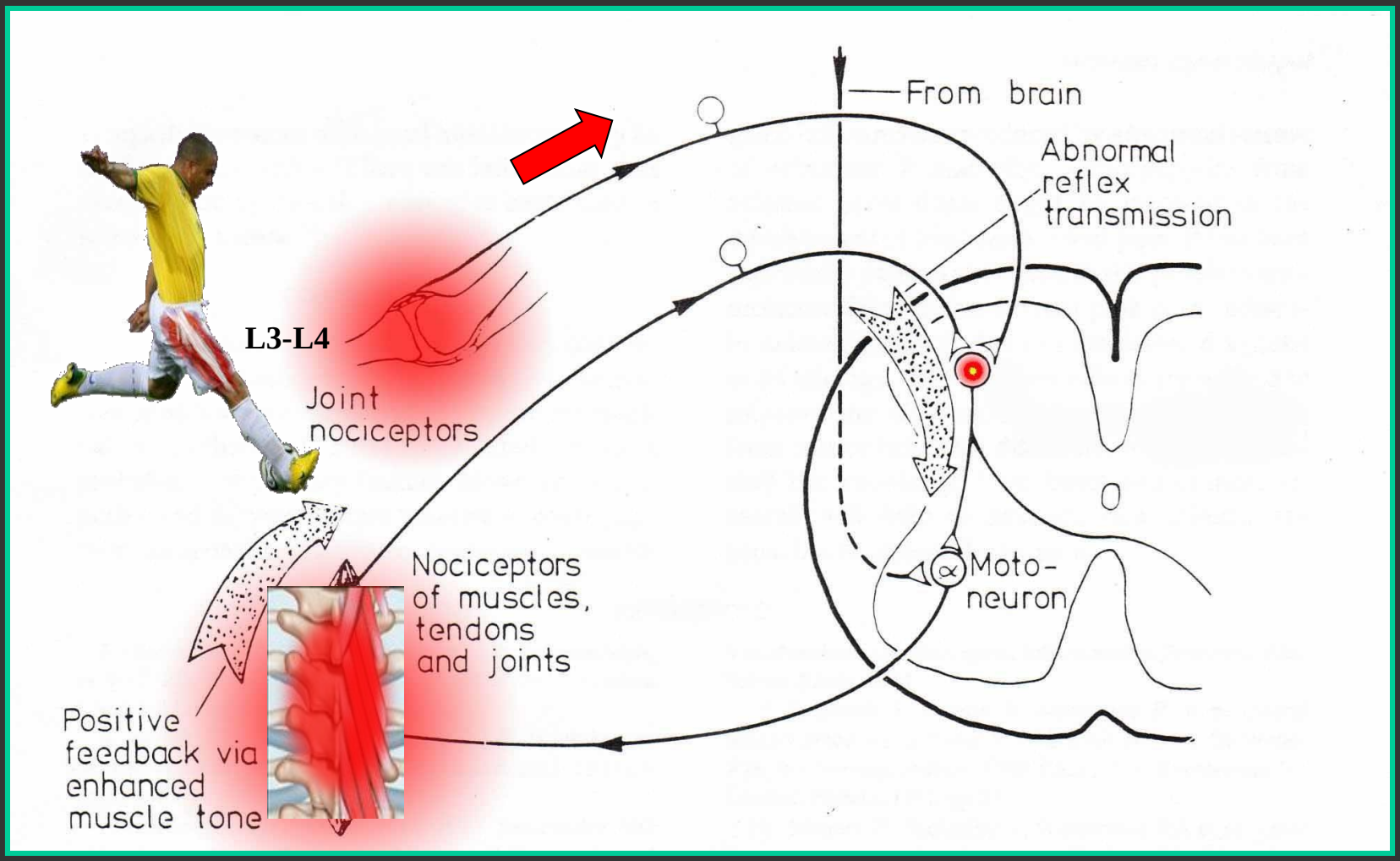


Spinal Facilitation - Application

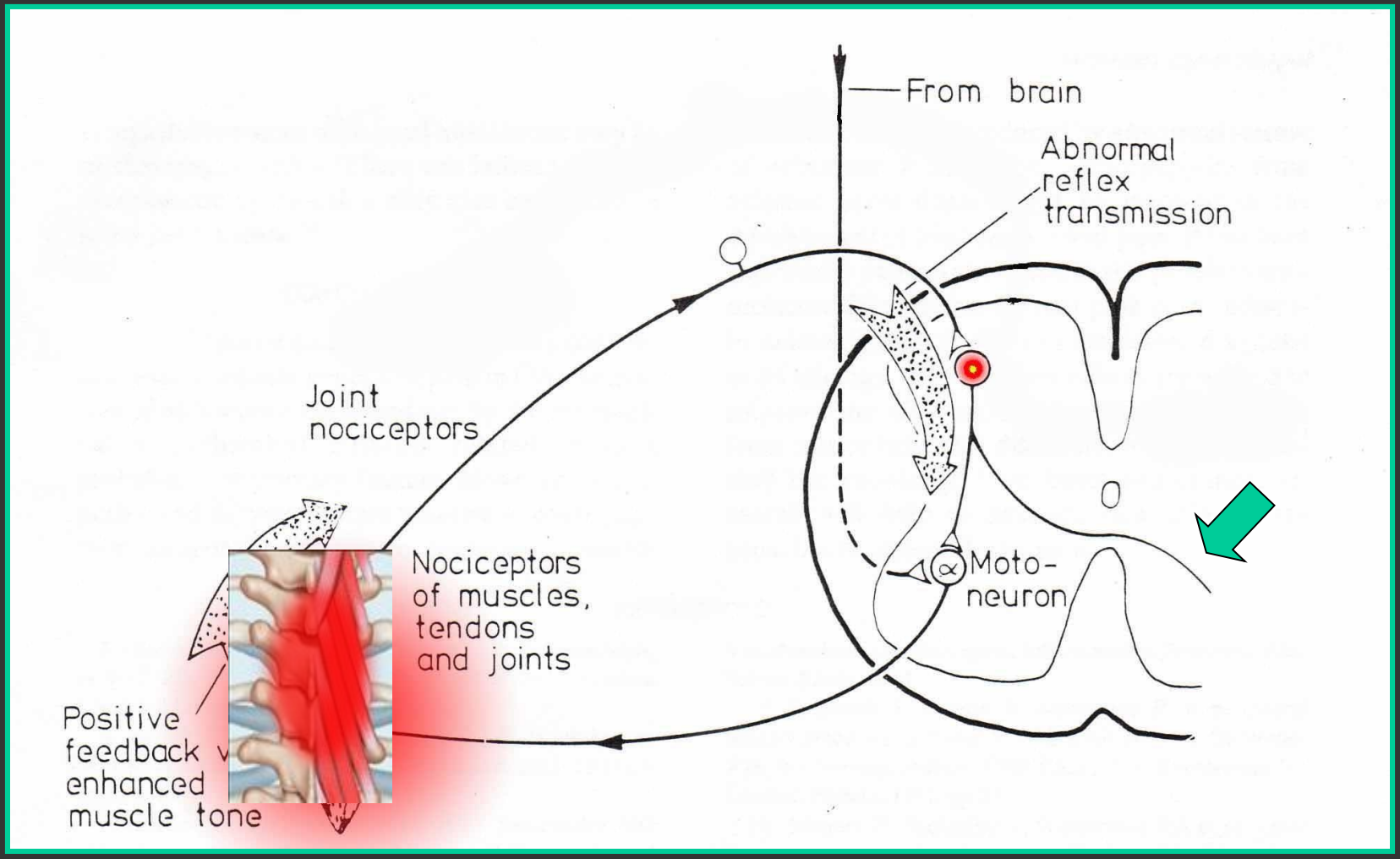


. 18:22, 1989

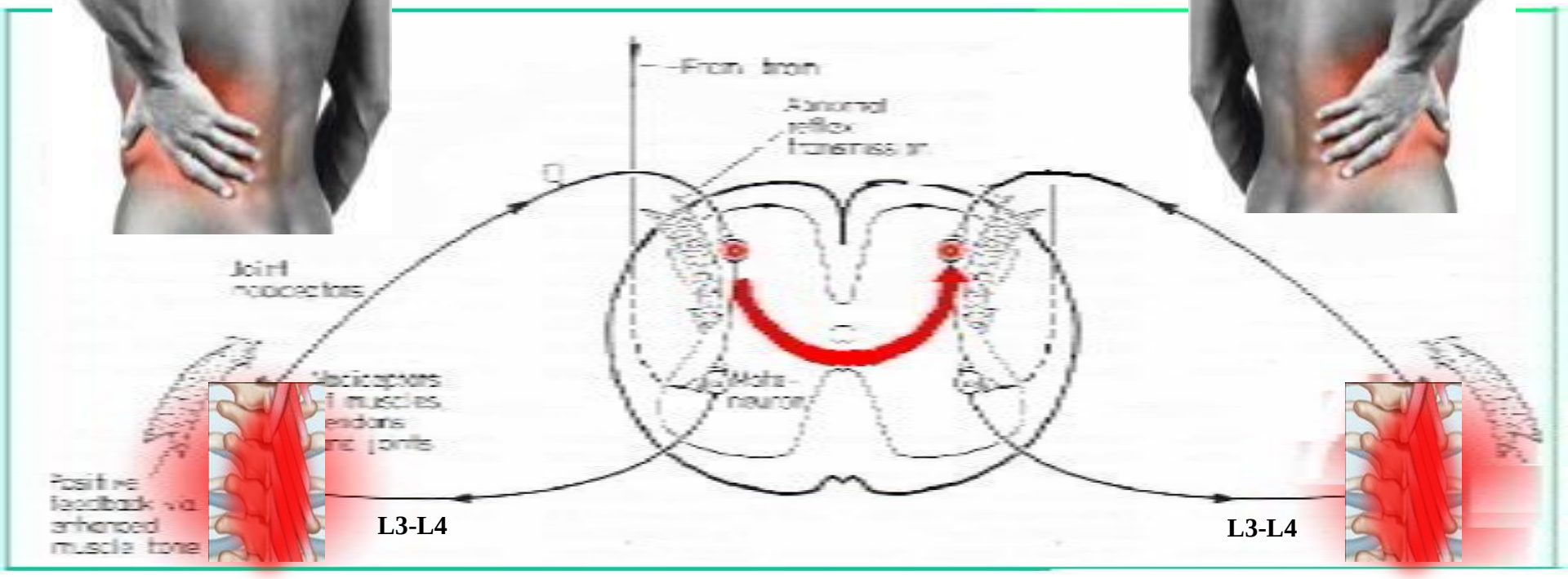
Spinal Facilitation - Application



Spinal Facilitation - Application

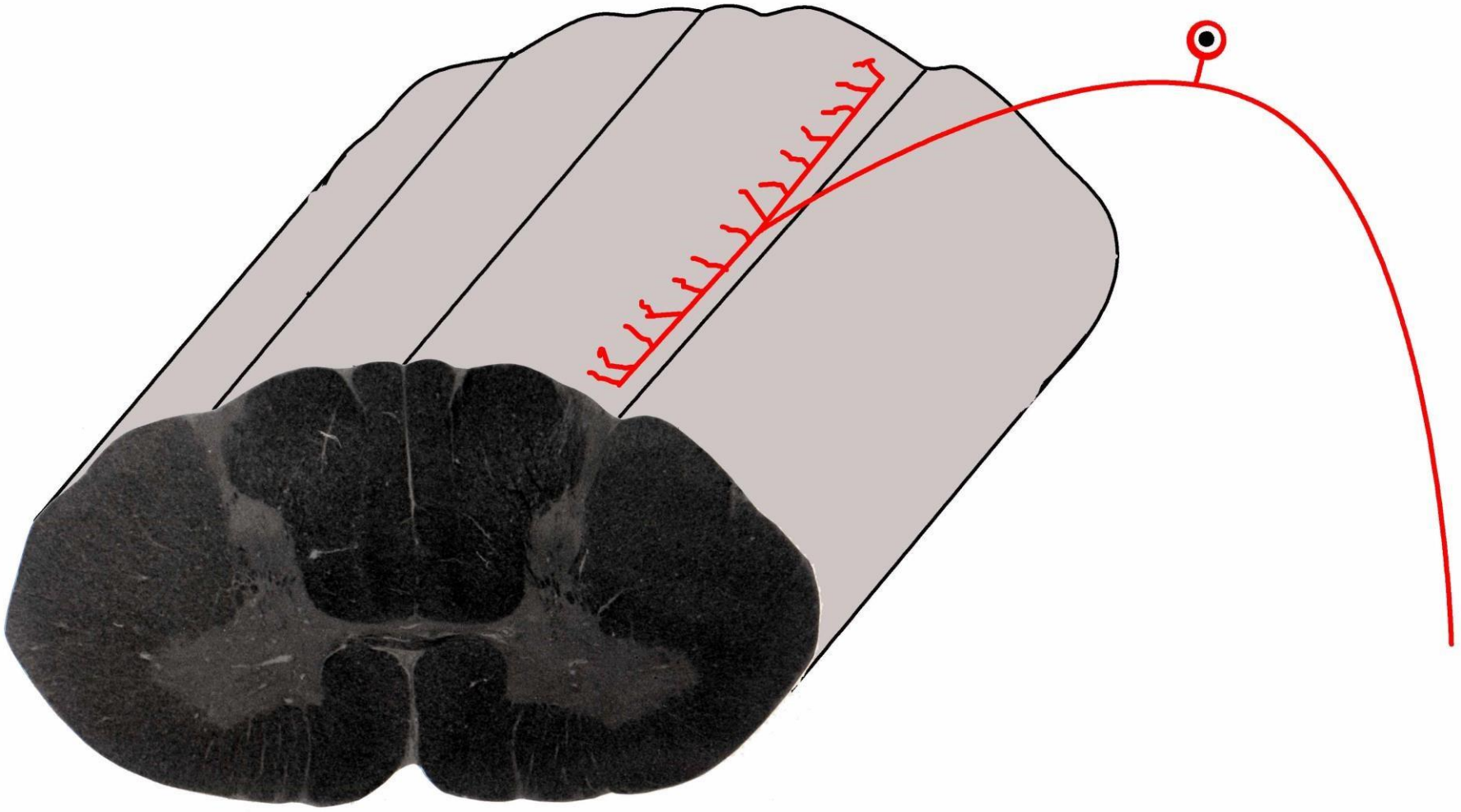


. 18:22, 1989



Zimmermann, Sem. Arth. Rheu. 18:22, 1989

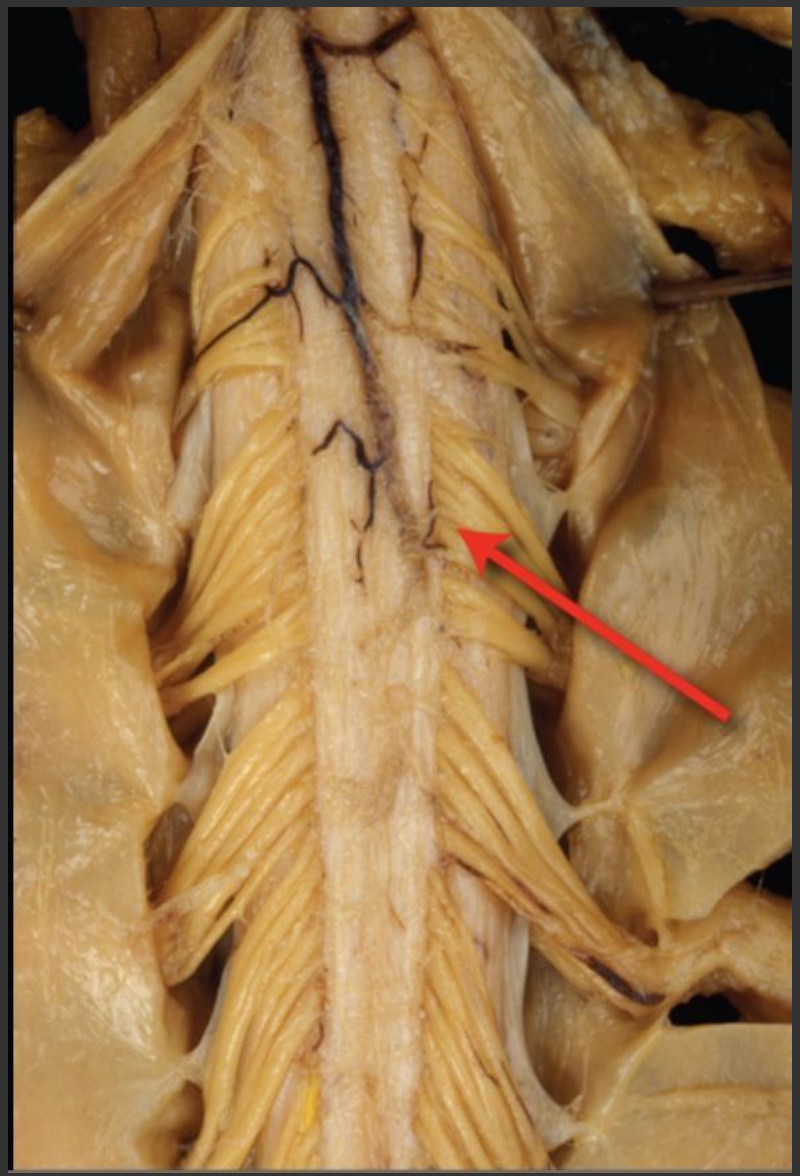
Pain Spreads to Contralateral Side



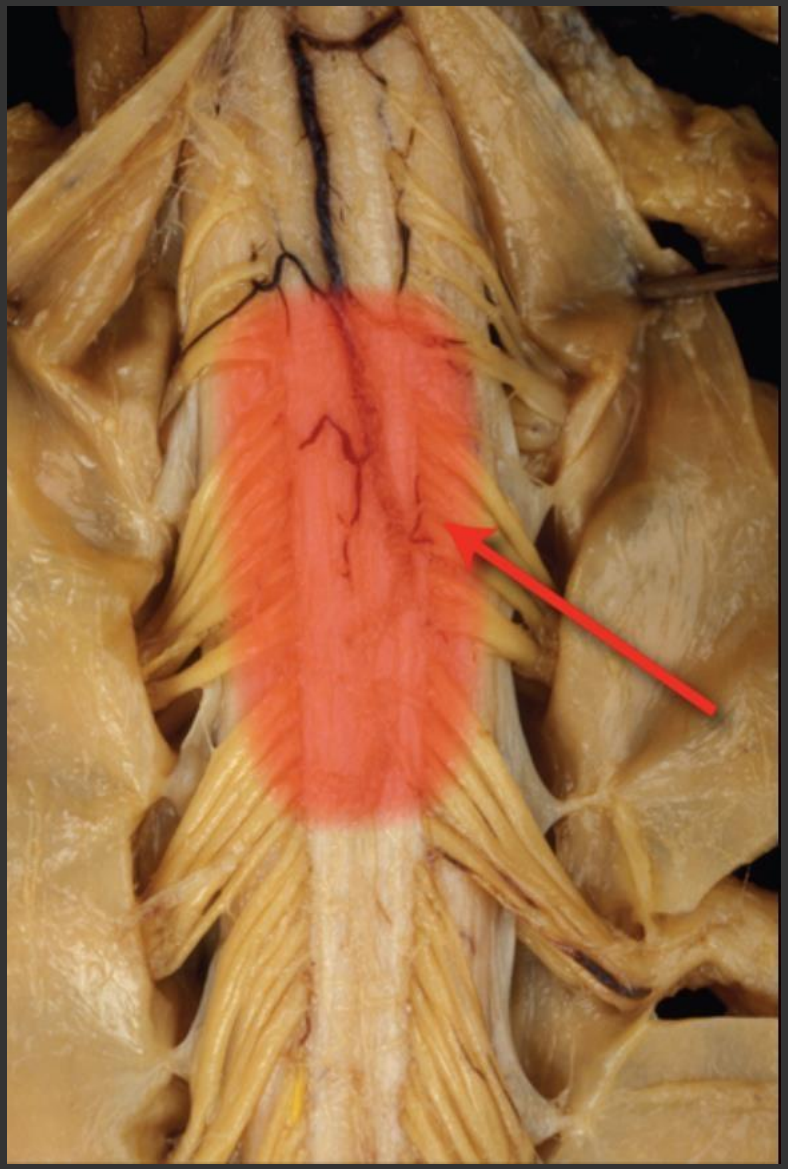
Spinal Facilitation - *Mechanisms*

- The nociceptors can be *sensitized*
- They, in turn, can *sensitize* the dorsal horn neuron, which can do permanent damage, creating an *uninhibited* segment
- That segment can be invaded from distant sites above and below the original segmental level of input

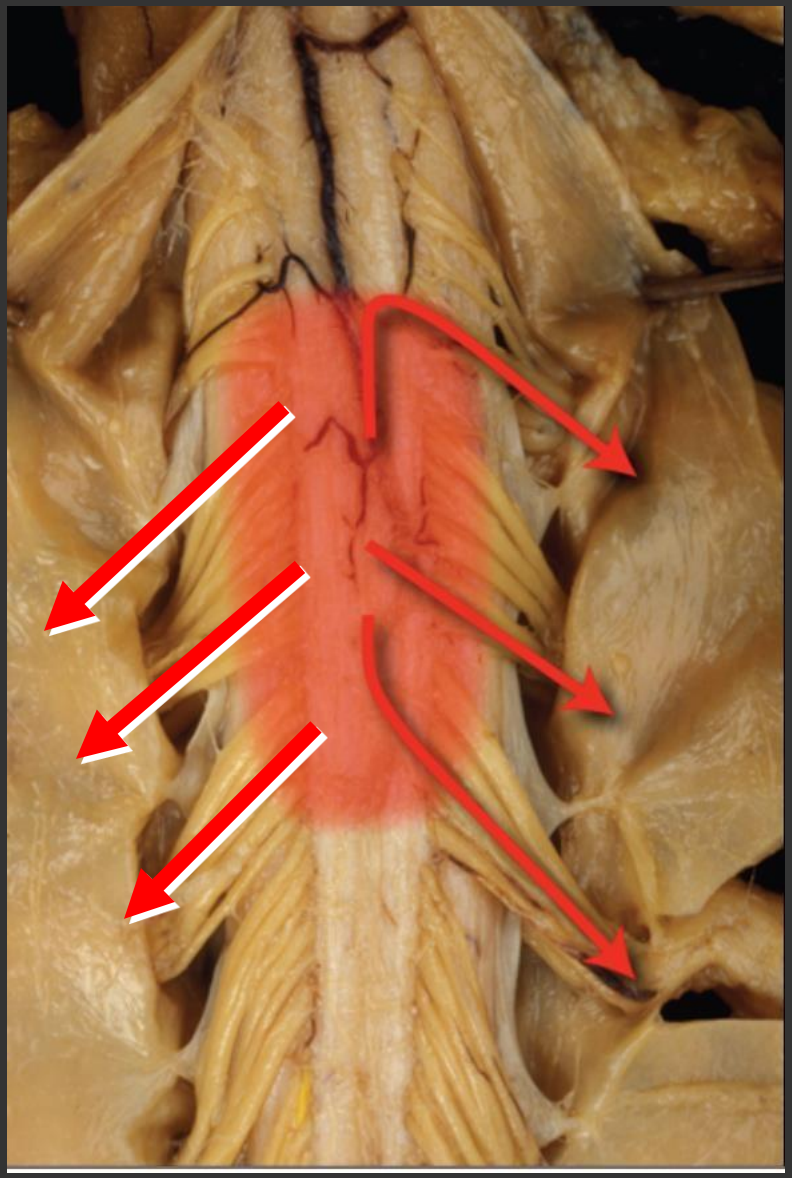
Creation of a Dorsal Root Reflex following initial C-fiber activity



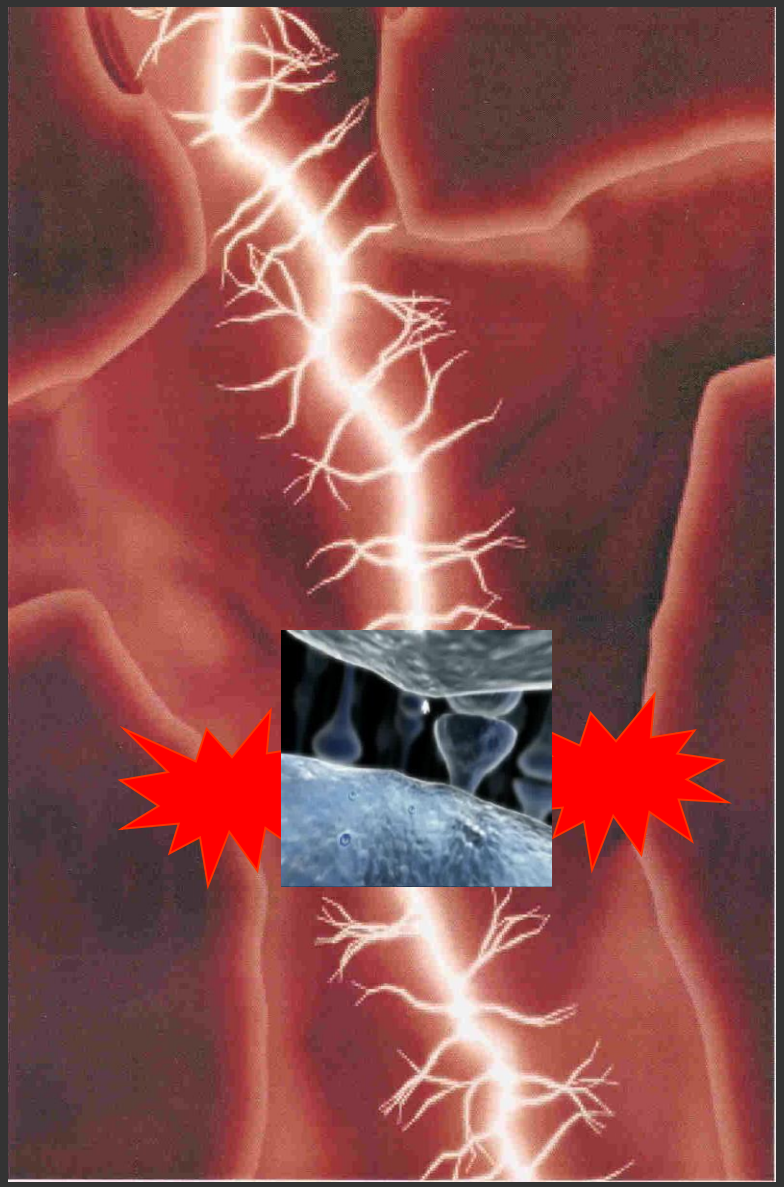
Creation of a Dorsal Root Reflex following initial C-fiber activity

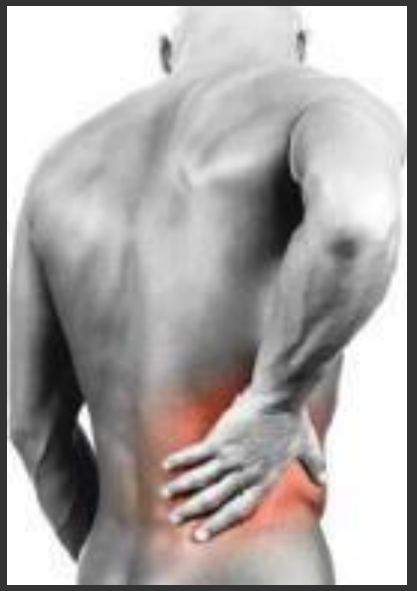


Dorsal Root Reflexes and mirror-image pain

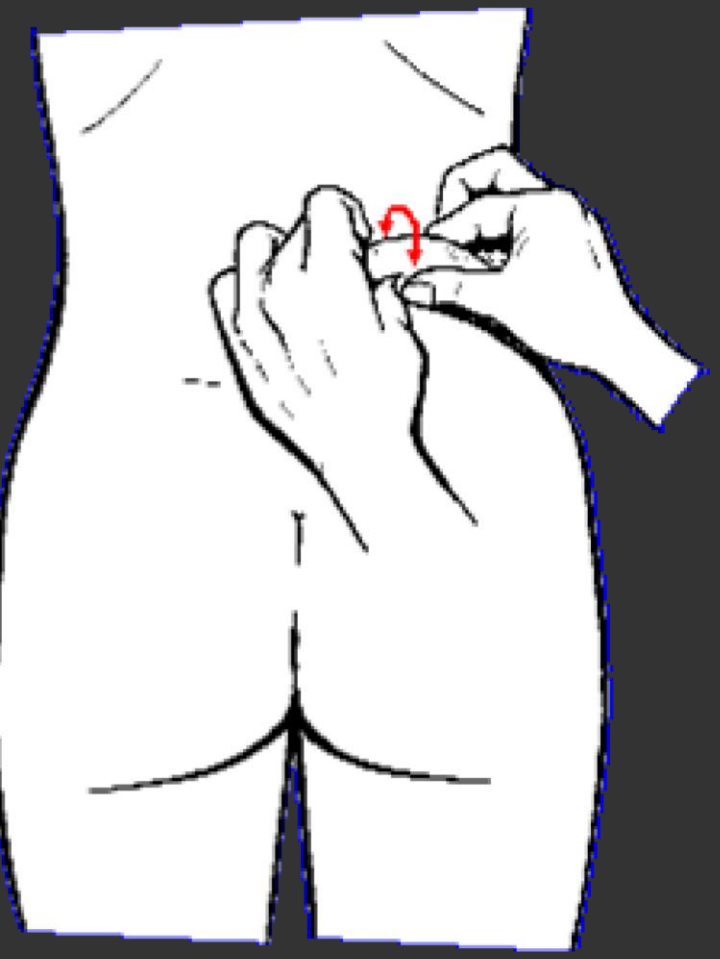


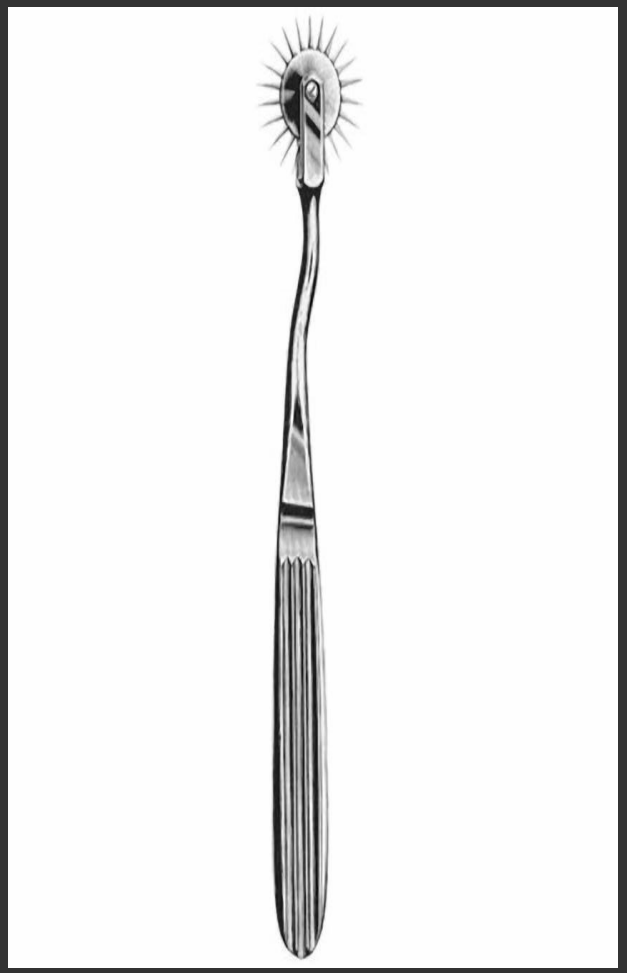
Segmental Sensitization, Spinal Facilitation and Mirror-Image Pain

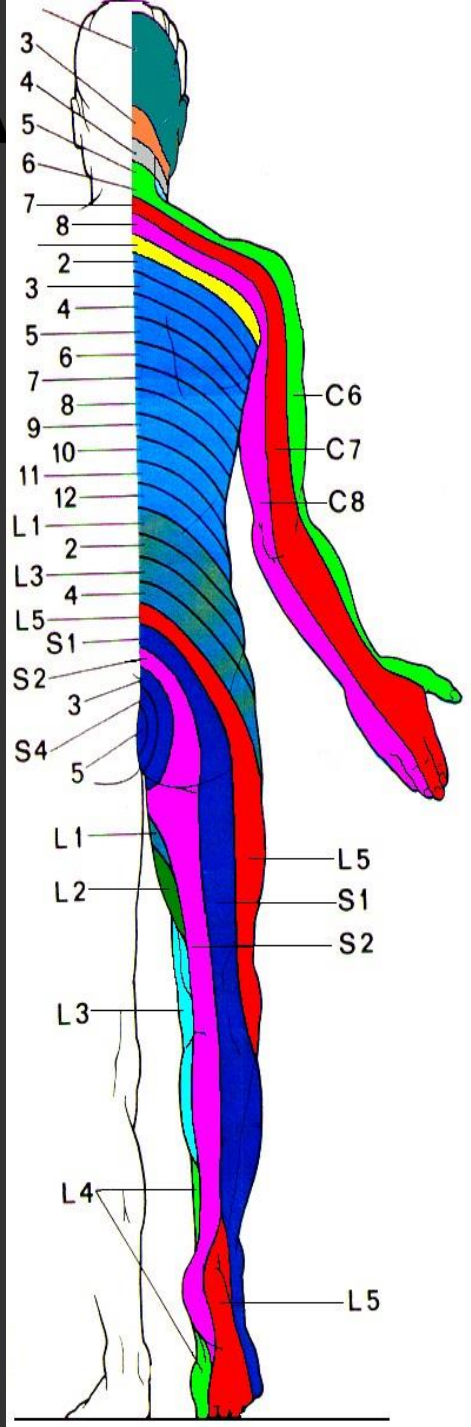




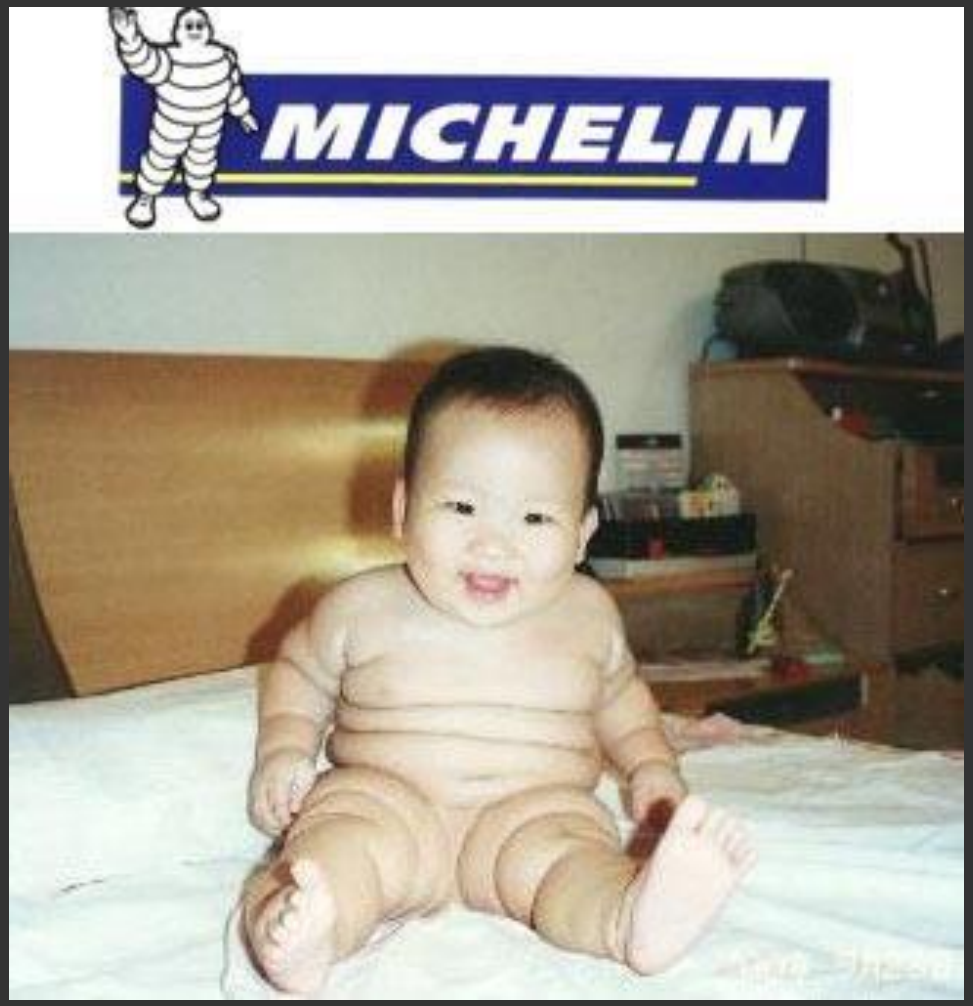
ALLODYNIA & HYPERALGESIA







Of course, in some people it's very easy to palpate the soft tissue…



Dynamic interaction

– Exacerbation of local inflammation by neuropeptide release

Sensitization

– Activity-dependent plasticity

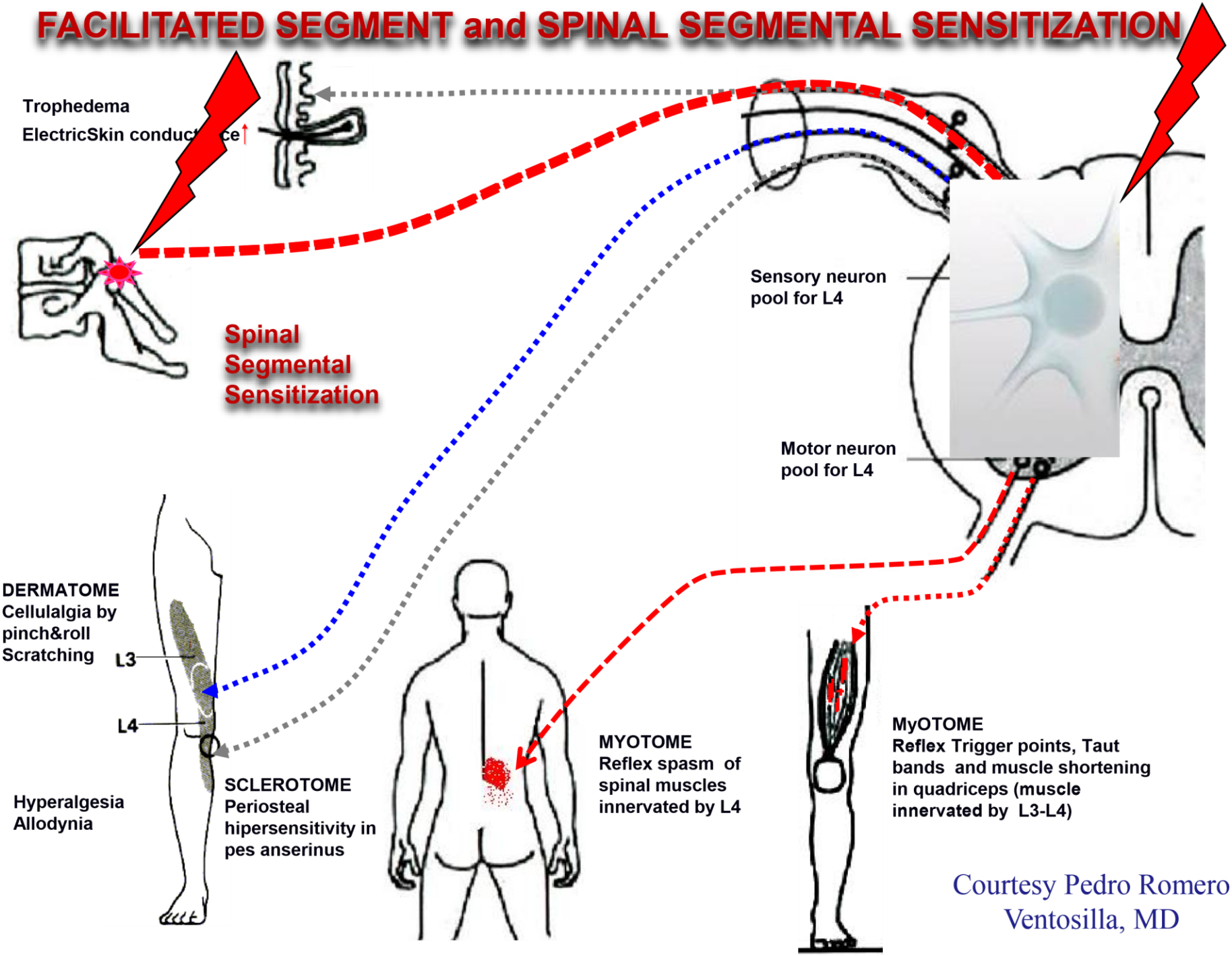
spinal facilitation

“Afferent Drive”

Activity Dependent plasticity

- After initiation, the afferent drive is not necessary to sustain the spinal facilitation
  - M. F. Anderson and B. J. Winterson. *Brain Res.* 678:140-150, 1995.

FACILITATED SEGMENT and SPINAL SEGMENTAL SENSITIZATION



Courtesy Pedro Romero Ventosilla, MD

Current Prevailing Theory for MTrP Formation
Integrated Hypothesis

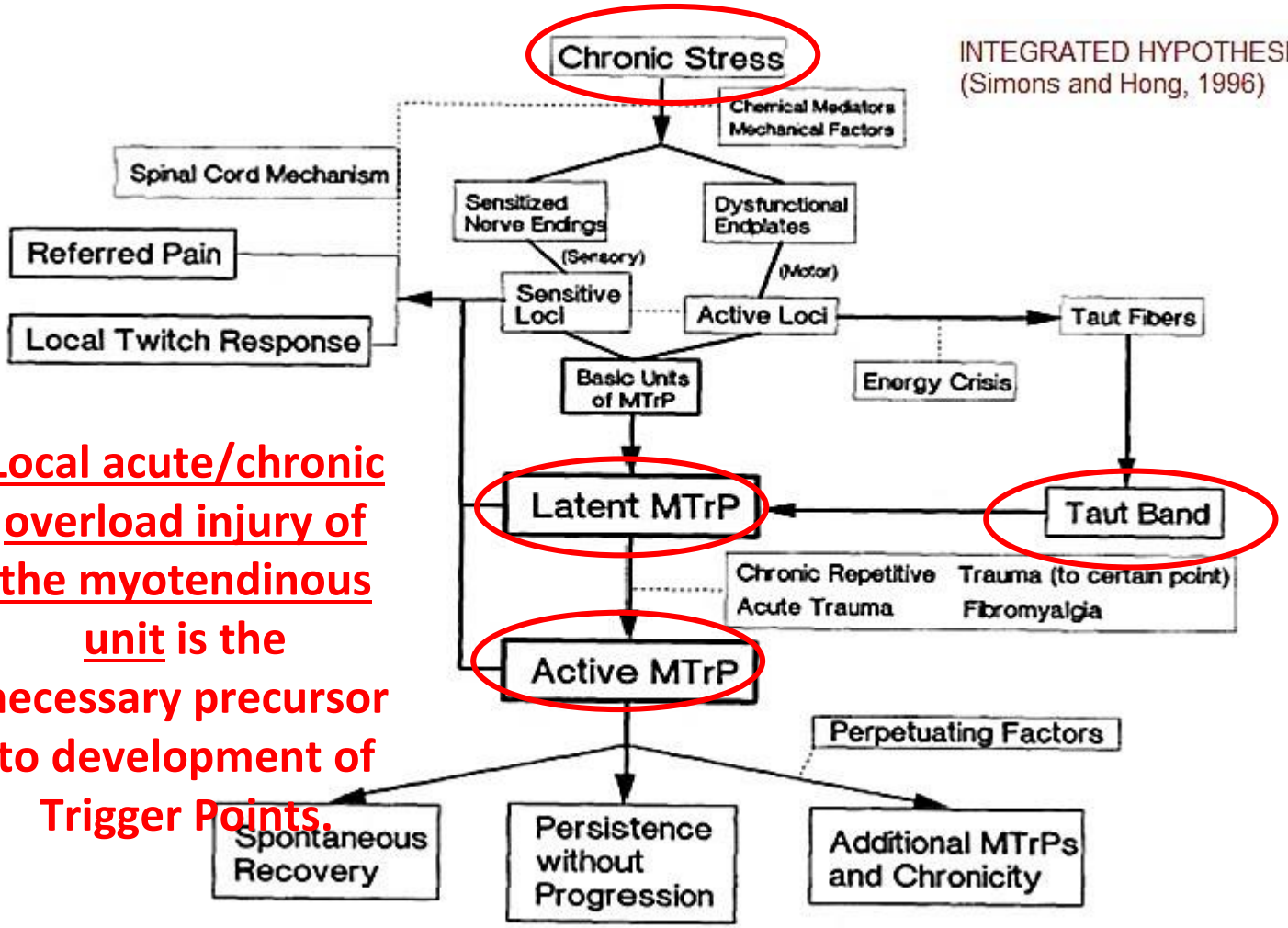
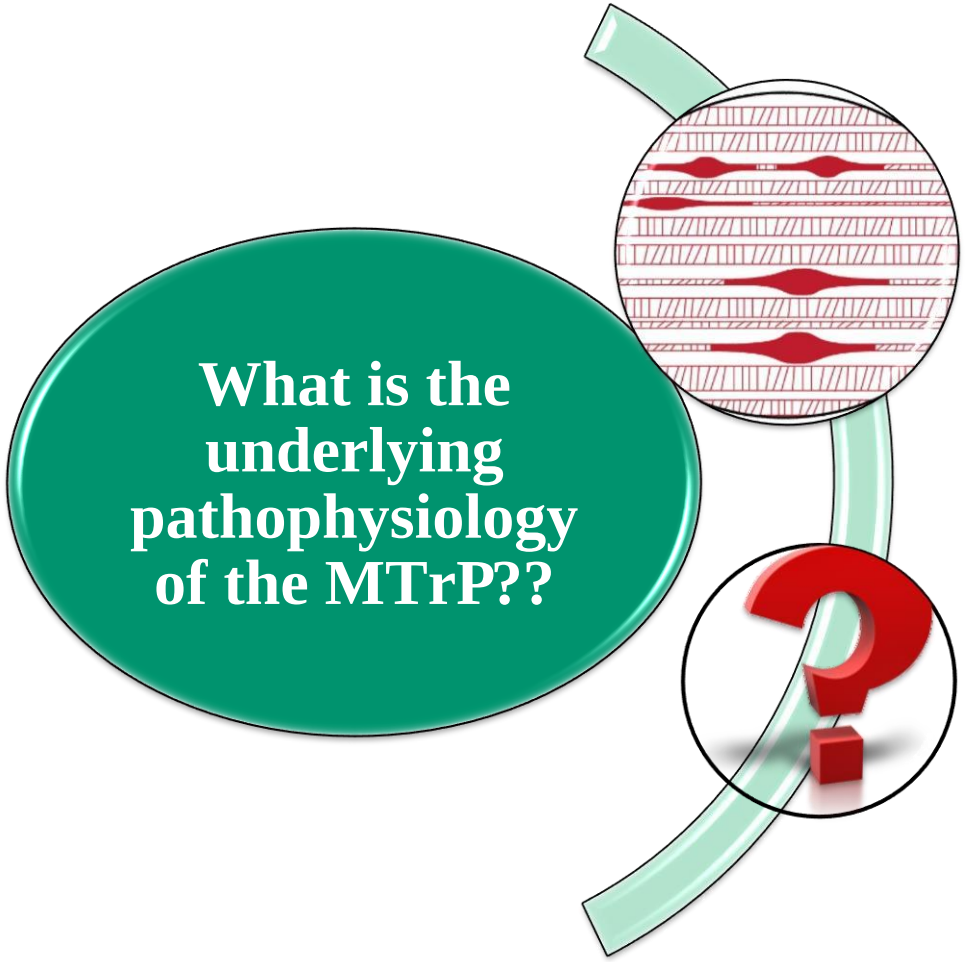


Fig 2. A proposed pathogenesis of MTrPs.

Local acute/chronic overload injury of the myotendinous unit is the necessary precursor to development of Trigger Points.

Myofascial Pain Central Outstanding Question



"Is the MTrP the **primarypathology** in Myofascial Pain Syndrome (MPS) or is MPS a clinical manifestation of an underlying physiologic mechanism?"

Is the MTrP the "Cause or Effect"?

Courtesy John Srbely, DC PhD

Several clinical observations have emerged to challenge the local injury mechanism of the Integrated Hypothesis.

Courtesy John Srbely, DC PhD

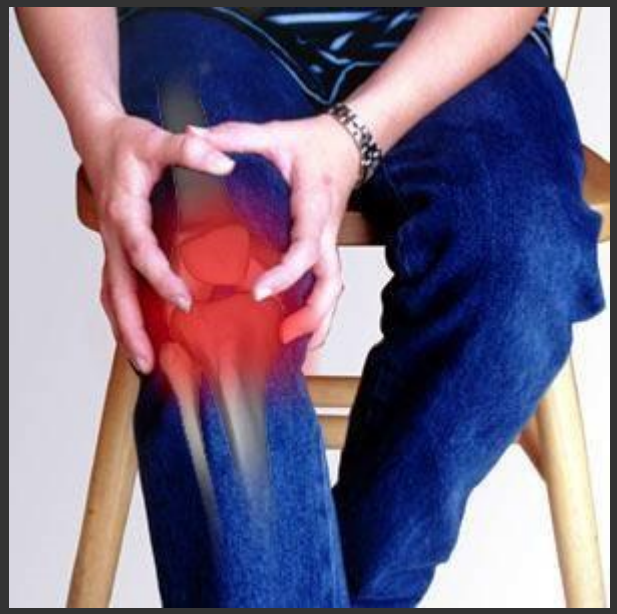
Mechanical overload injury of the myotendinous unit leads to:

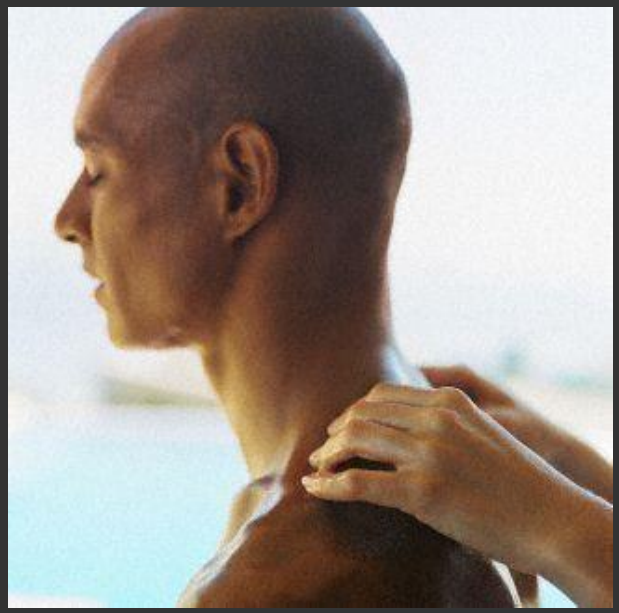
- “acute pain”
- sharp and welllocalized
- pressure on muscle induces a withdrawal reflex

Courtesy John Srbely, DC PhD

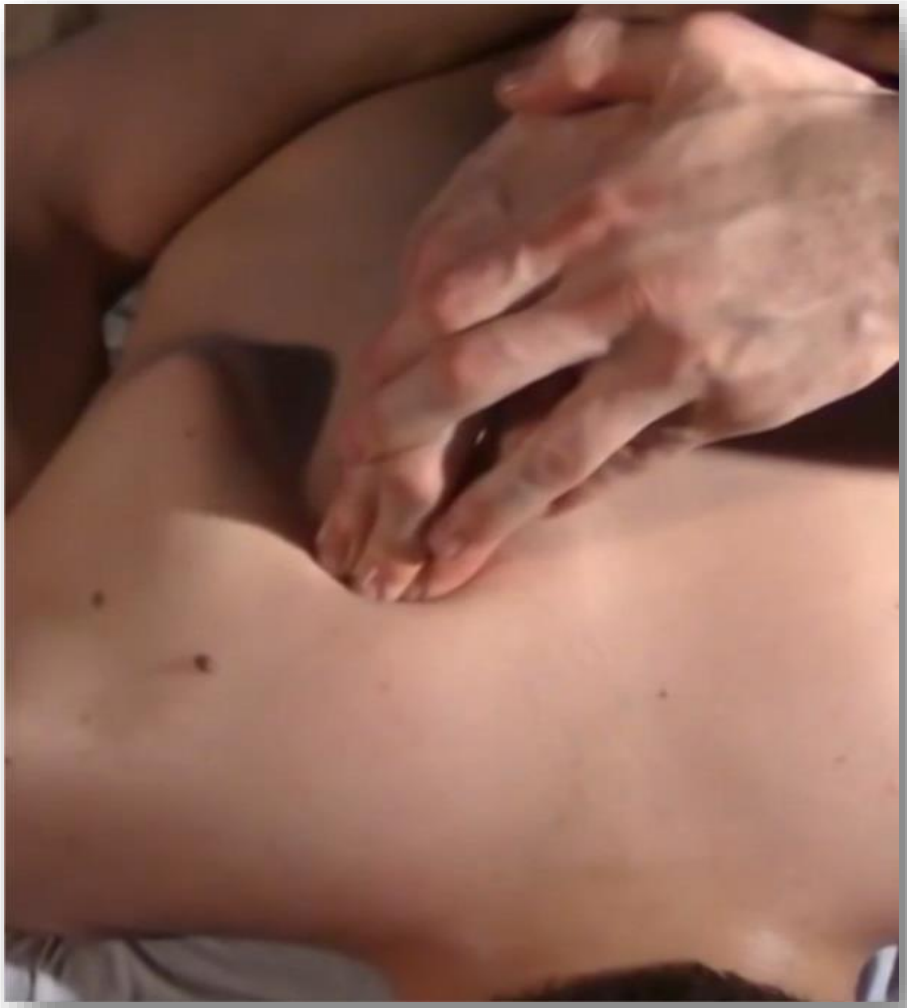
Courtesy John Srbely, DC PhD

Pressure on a MTrP does NOT induce a withdrawal reflex.





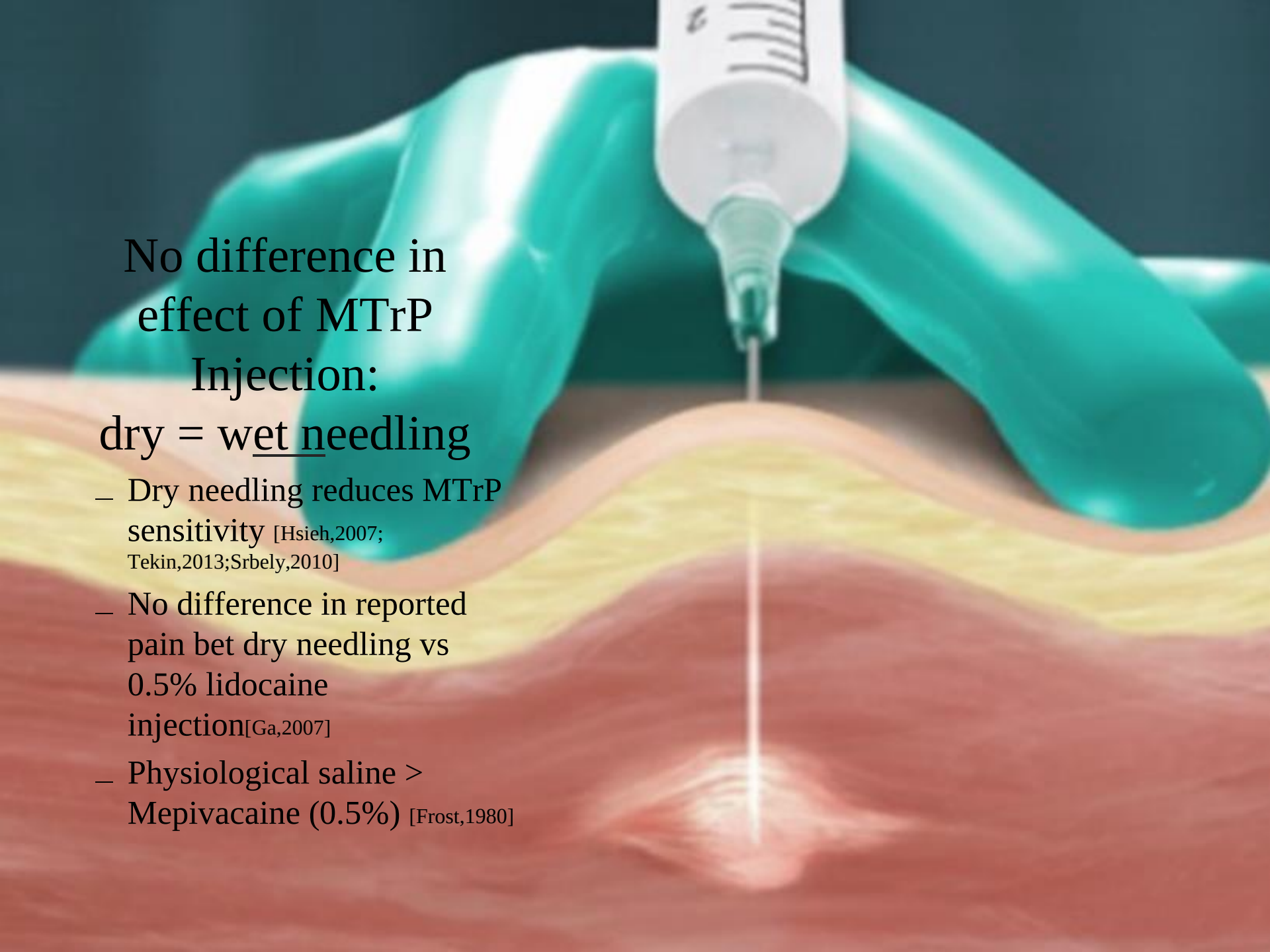
The myofascial trigger point region does not behave like a local injury



- NO withdrawal reflex
- Pain character:
  - Deep, achy
  - Often diffuse, poorly localized
- "good pain"
- "more pressure"
- Gradually decreasing pain with sustained pressure

Courtesy John Srbely, DC PhD

Courtesy John Srbely, DC PhD

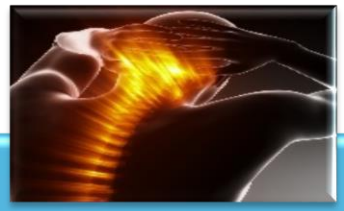


No difference in effect of MTrP Injection: dry = wet needling

- Dry needling reduces MTrP sensitivity [Hsieh,2007; Tekin,2013;Srbely,2010]
- No difference in reported pain bet dry needling vs 0.5% lidocaine injection[Ga,2007]
- Physiological saline > Mepivacaine (0.5%) [Frost,1980]

MTrPs are observed with a number of musculoskeletal and nonmusculoskeletal pain syndromes, *in absence of injury* to affected muscle.

- **Disc pathology (Hsueh, 1998)**
- **Tendonitis (Wang, 2006)**
- **Craniomandibular dyfunction (Dommerholt, 2006)**
- **Carpal tunnel sx (Skubick, 1993)**
- **Computer related disorders (Treaster, 2006)**
- **Spinal dysfunction (Fruth, 2006)**



- **Post herpetic neuralgia (Weiner, 2006)**
- **Complex regional pain syndrome (Dommerholt, 2004)**
- **Phantom pain (Kem, 2006**
- **Migraine (Calandre 2006)**
- **Tension type headache (Fernandez-de-las-Penas, 2005, 2006)**
- **Radiculopathy (Rosomoff, 1989)**
- **Joint dysfunction (Bajaj, 2001)**

Courtesy John Srbely, DC PhD

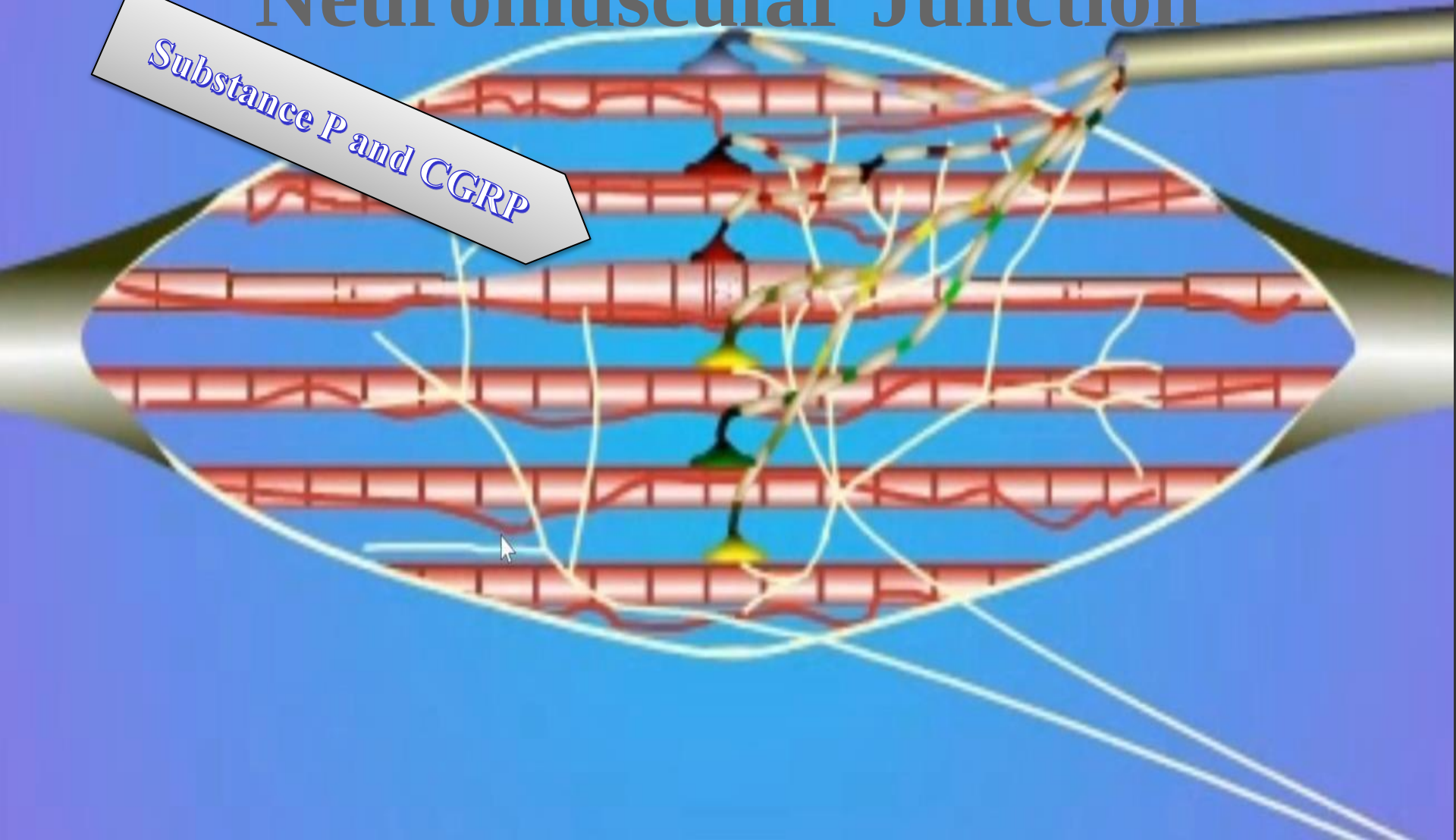
Courtesy John Srbely, DC PhD

- **Internal Cystitis/bladde syndrome (Fitz 2012)**
- **Pelvic pain syn (Anderson, Wi**

MTrP region has unique biochemical milieu

1. Shah, 2005, 2008
2. Delagdo,2003
3. Payan, 1987

Substance P and CGRP: Act on Neuromuscular Junction



So what other pathophysiologic mechanism(s) might contribute to the pathophysiology of MTrPs??

NEUROGENIC HYPOTHESIS

Myofascial Trigger Points

(Myofascial Pain Syndrome) are the physiologic expression within

Srbely, J. Z., Dickey, J. P., Bent, L. R., Lee, D., & Lowerison, M. (2010). Capsaicin-induced central sensitization evokes segmental increases in trigger point sensitivity in humans. *The Journal of Pain*, *11*(7), 636-

Current Prevailing Theory for MTrP Formation

Integrated Hypothesis

Courtesy John Srbely, DC PhD

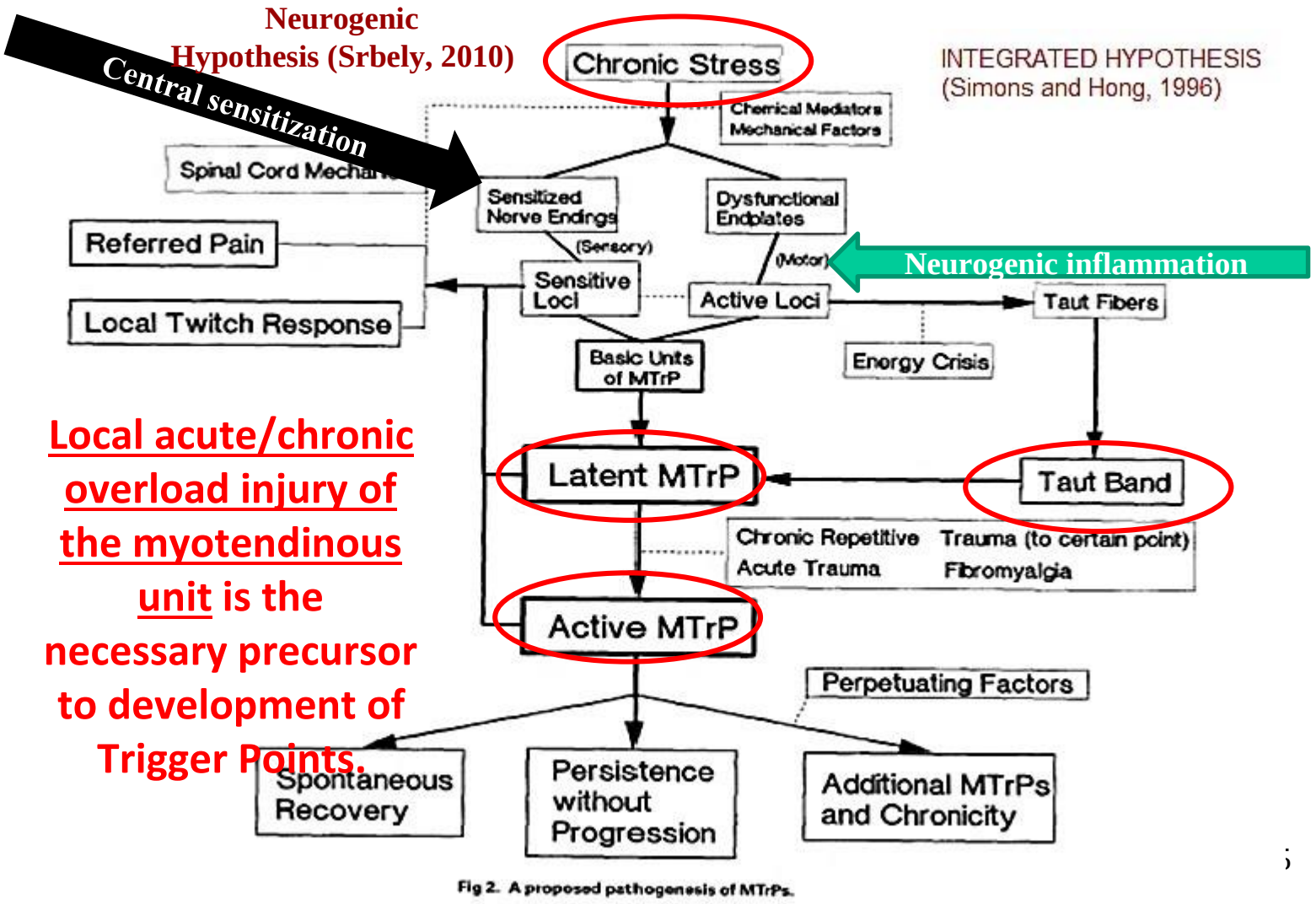
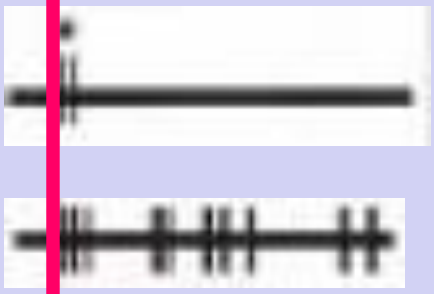


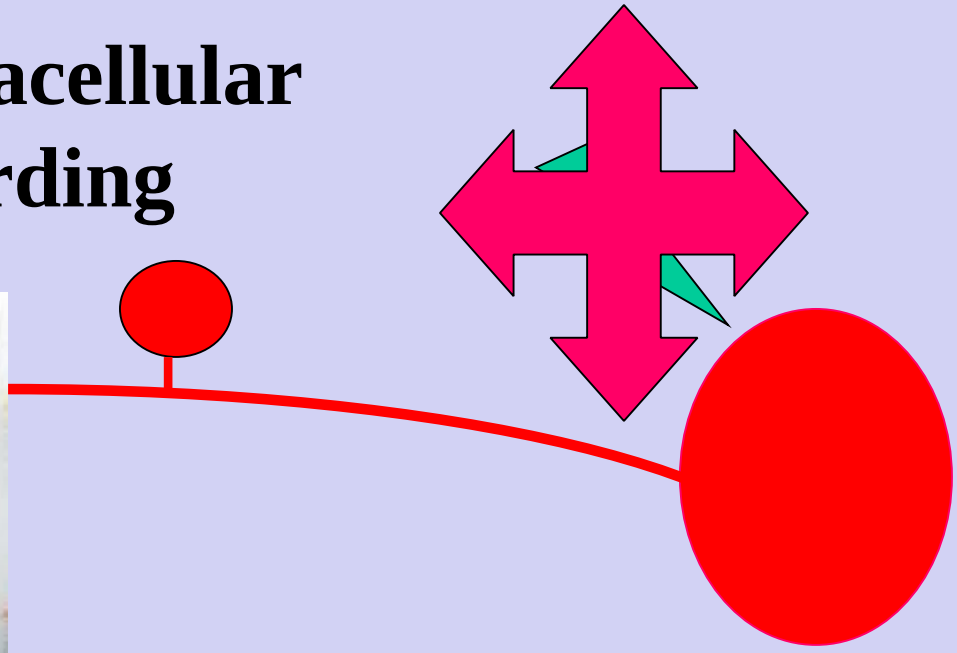
Fig 2. A proposed pathogenesis of MTrPs.

Stimulation

"Wind Up"



Extracellular recording

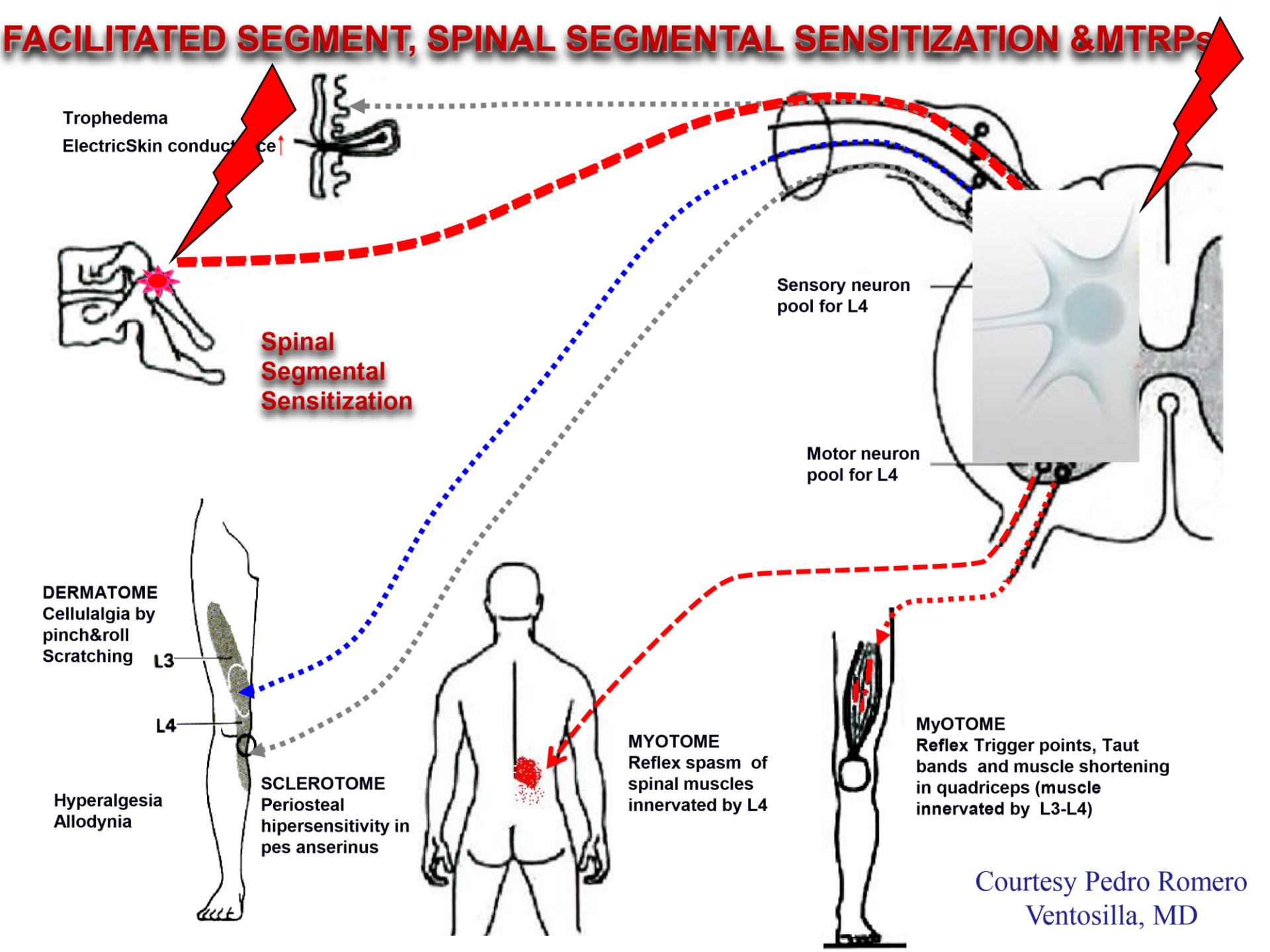


Receptive field

Spontaneous discharge activity after 150 stimuli

Zieglgansberger W. *Scand J Rheum*
2000;29 113:19-23

FACILITATED SEGMENT, SPINAL SEGMENTAL SENSITIZATION &MTRPs



Courtesy Pedro Romero Ventosilla, MD

Question

The Anterior Cingulate Cortex has what function in pain processing?

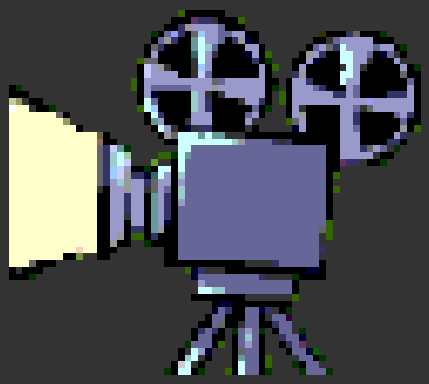
A. Process the emotional or affective response to pain

B. Responds to the anticipation of pain

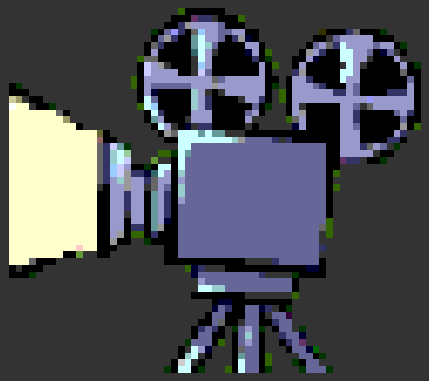
C. Is part of the limbic system

D. All of the above

Can you name the motion picture?



Can you name the motion picture?

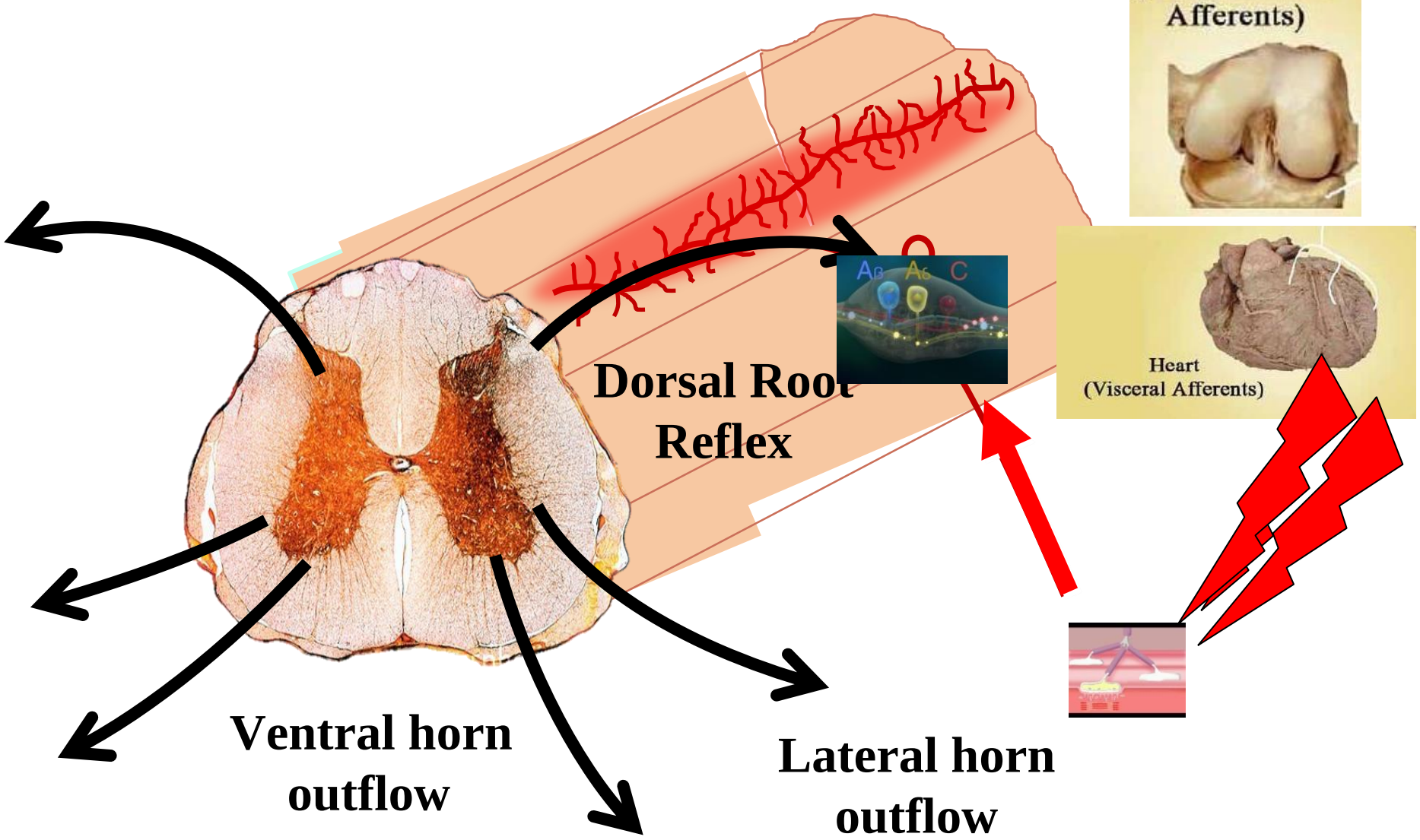


Spinal Facilitation, Somatovisceral/Viscerosomatic Reflexes and *Neuro*-musculoskeletal Pain

Principle of Divergence in Facilitated Segment

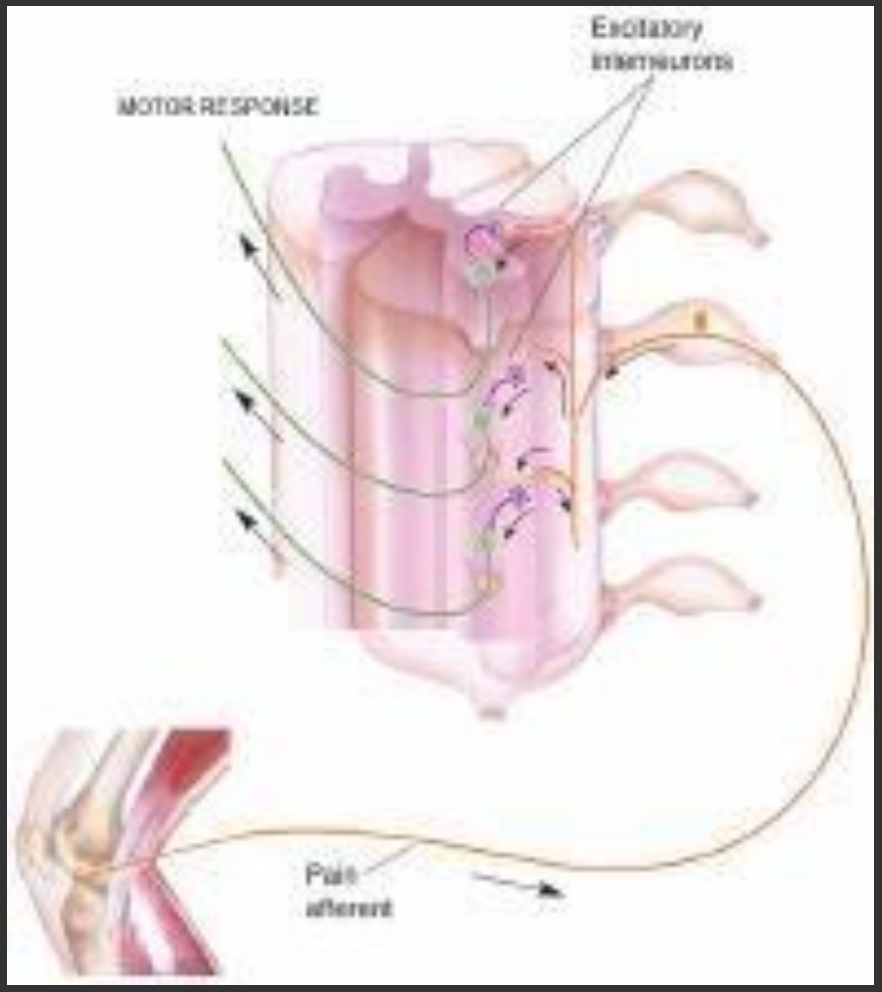
- Dorsal horn wide dynamic range neuron is the epicenter of the process of central facilitation seen in chronic pain states
- Facilitated segment can become malignant with spread segmentally *up and down* as well as *contra-laterally* in the cord
- Described as changes in receptive field in animal models
- The retrograde neurosecretory properties of nociceptors and opening of previously ineffective connections are the most likely explanation

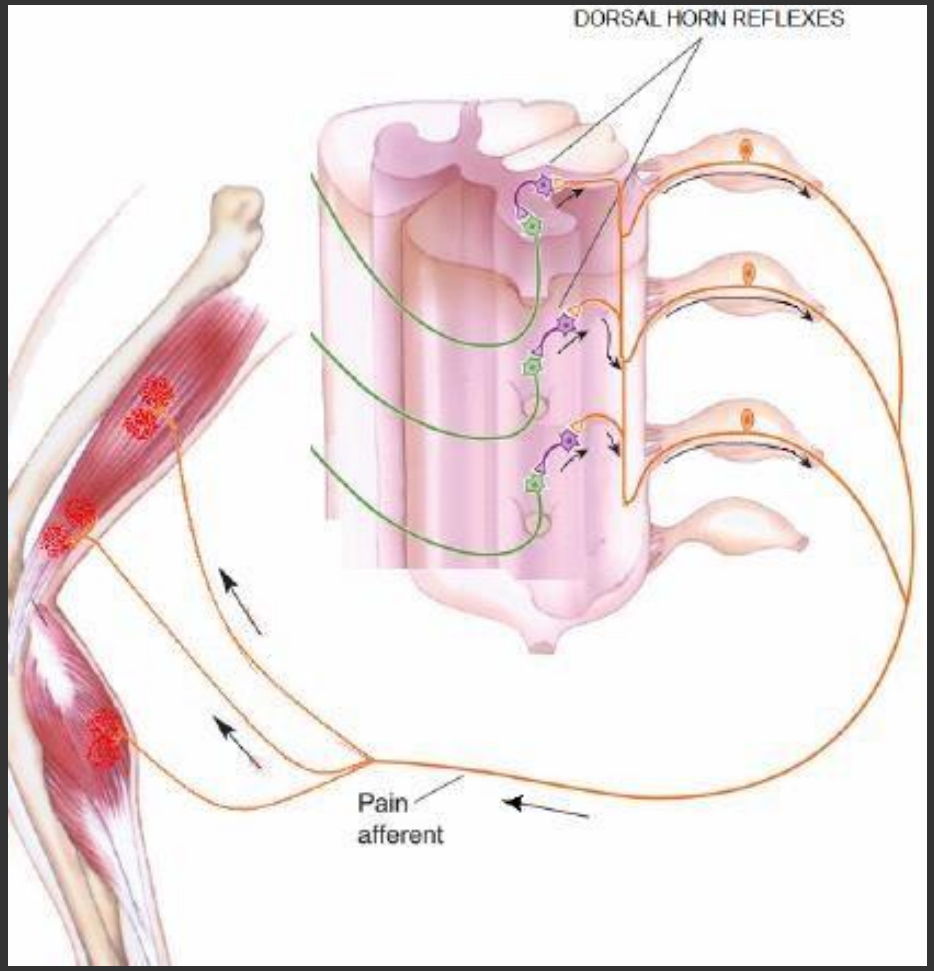
Sensitized Dorsal Horn Neurons Demon


Joint
(Deep Somatic
Afferents)
Heart
(Visceral Afferents)
Dorsal Root
Reflex
Ventral horn
outflow
Lateral horn
outflow

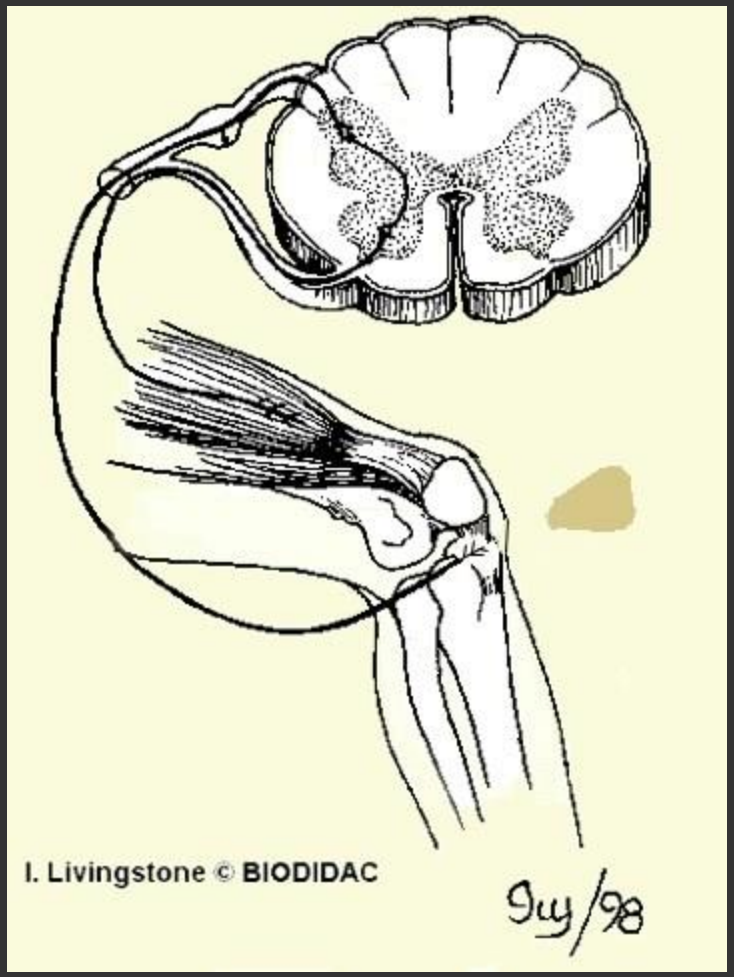
Segmental Spread!

Dorsal Horn Reflex causes Peptide Release

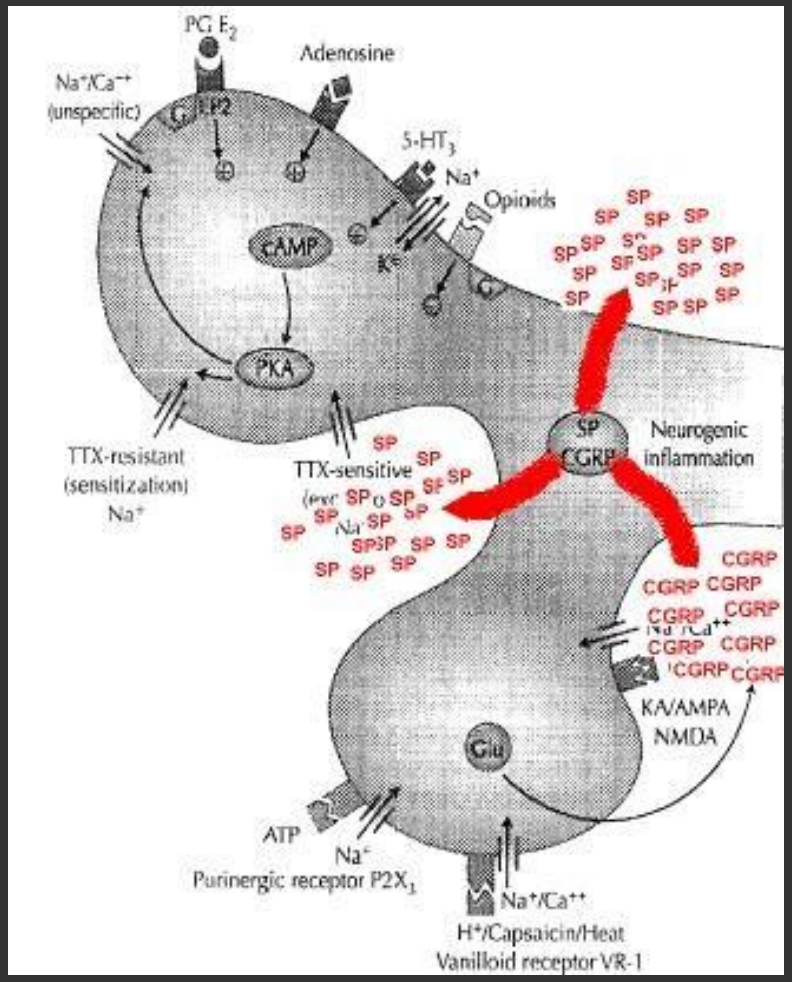


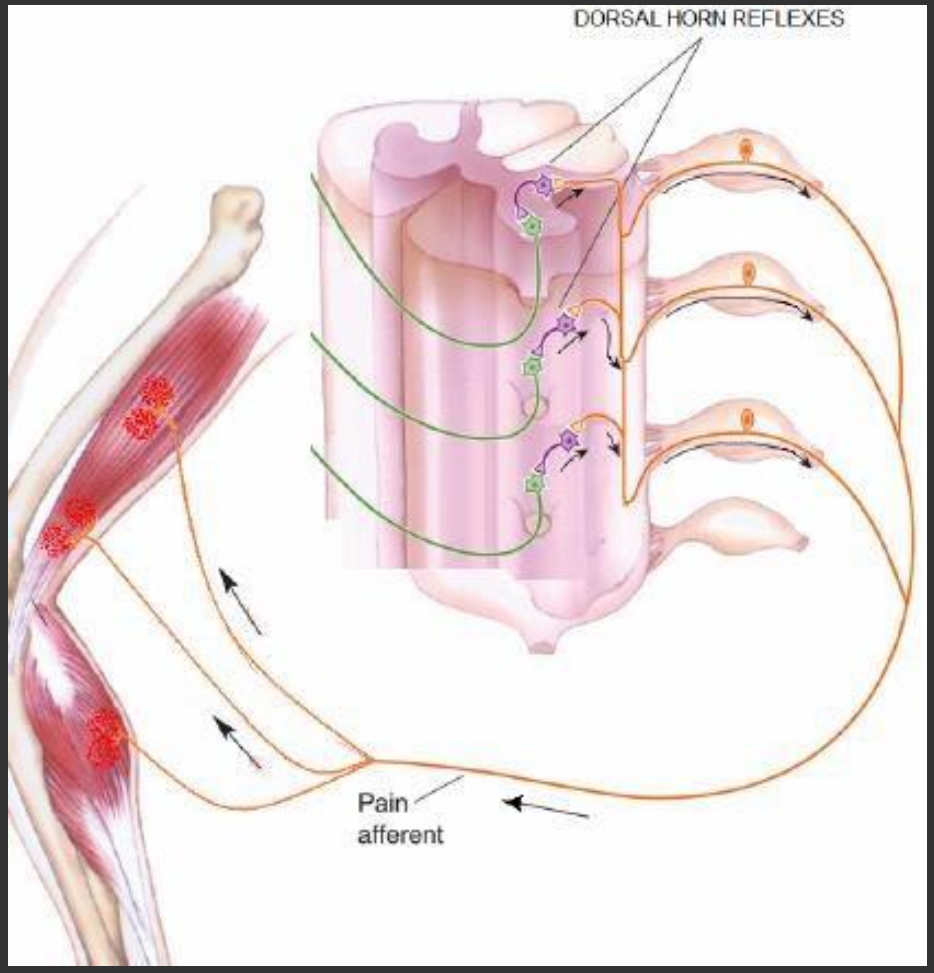


Somato-Visceral and Viscero-Somatic Interactions are Reflexes



Peptide Release will Cause Tenderness





Are Myofascial Trigger Points a Primary Problem or a Secondary Consequence?

Somatic Dysfunction

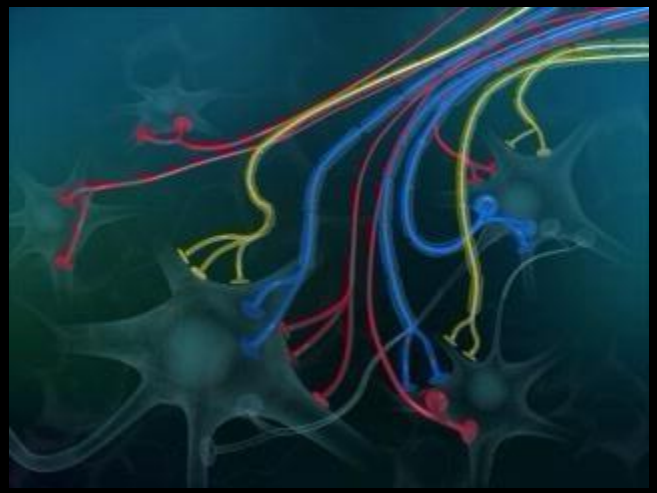
Visceral Dysfunction

Somatic Dysfunction

PANs

Visceral Dysfunction

Afferent Drive



Somatic Dysfunction

PANs

Visceral Dysfunction

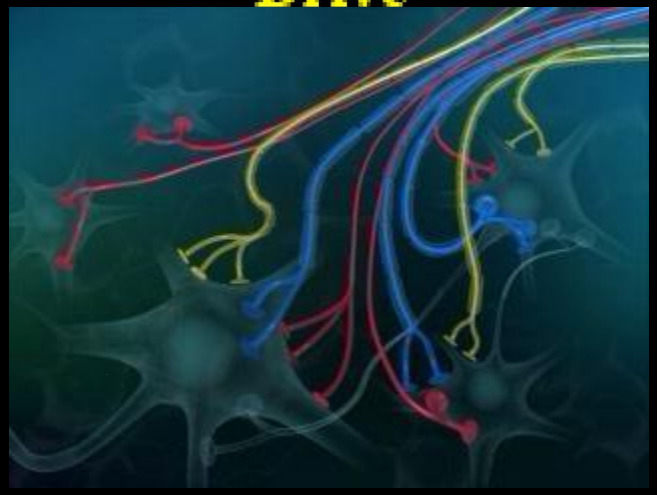
Afferent Drive

Sacral

Lumbar

Thoracic

Cervical



COPD

PID

Reflux

Spinal Facilitation

Manual Therapy, Dry Needling

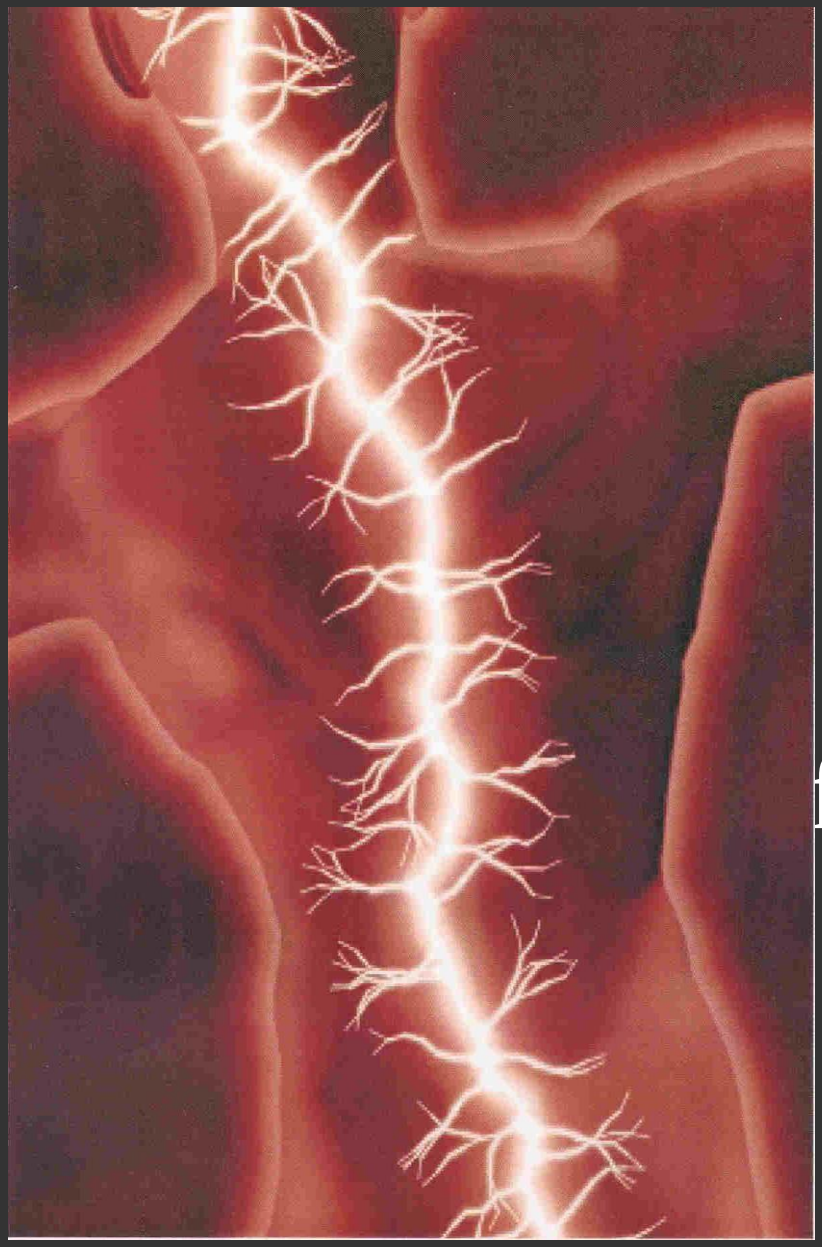
Manual Therapy, Dry Needling

Muscle Tone

Fascia: Visceral and Vascular Tone

Hormonal Adaption

Perception Well-being



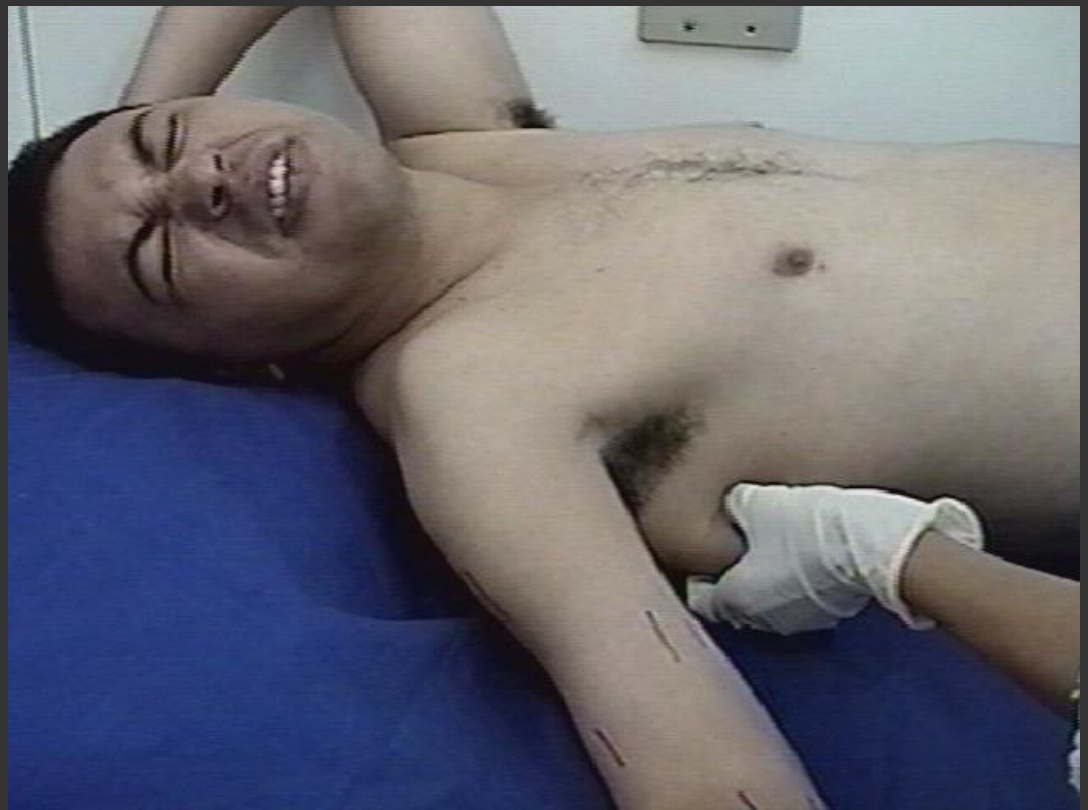
Clinical Diagnosis of a Sensitized Segment Using Surface Anatomy and Palpation: Relevance for Chronic Myofascial Pain

ALGORITHM

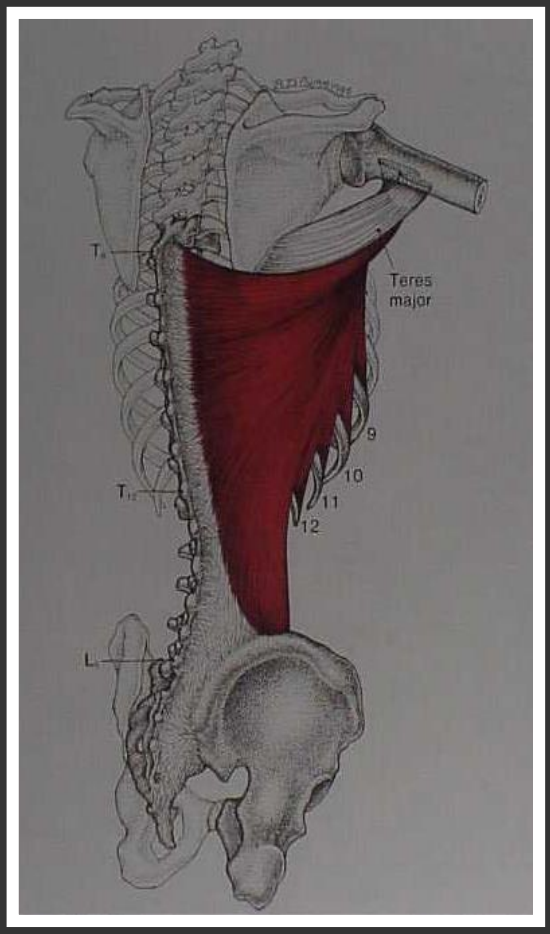
- Phase I: Identify the immediate cause of pain
- Phase II: Diagnosis of Spinal Segmental Sensitization
- Phase III: Treatment
- Phase IV: Diagnosis and removal of perpetuating and etiological factors

IMMEDIATE CAUSE OF PAIN

1. Point with one finger where the pain is most intense
2. Find point of maximum tenderness
3. Reproduction of pain



Latissimus dorsi (C6-C8)

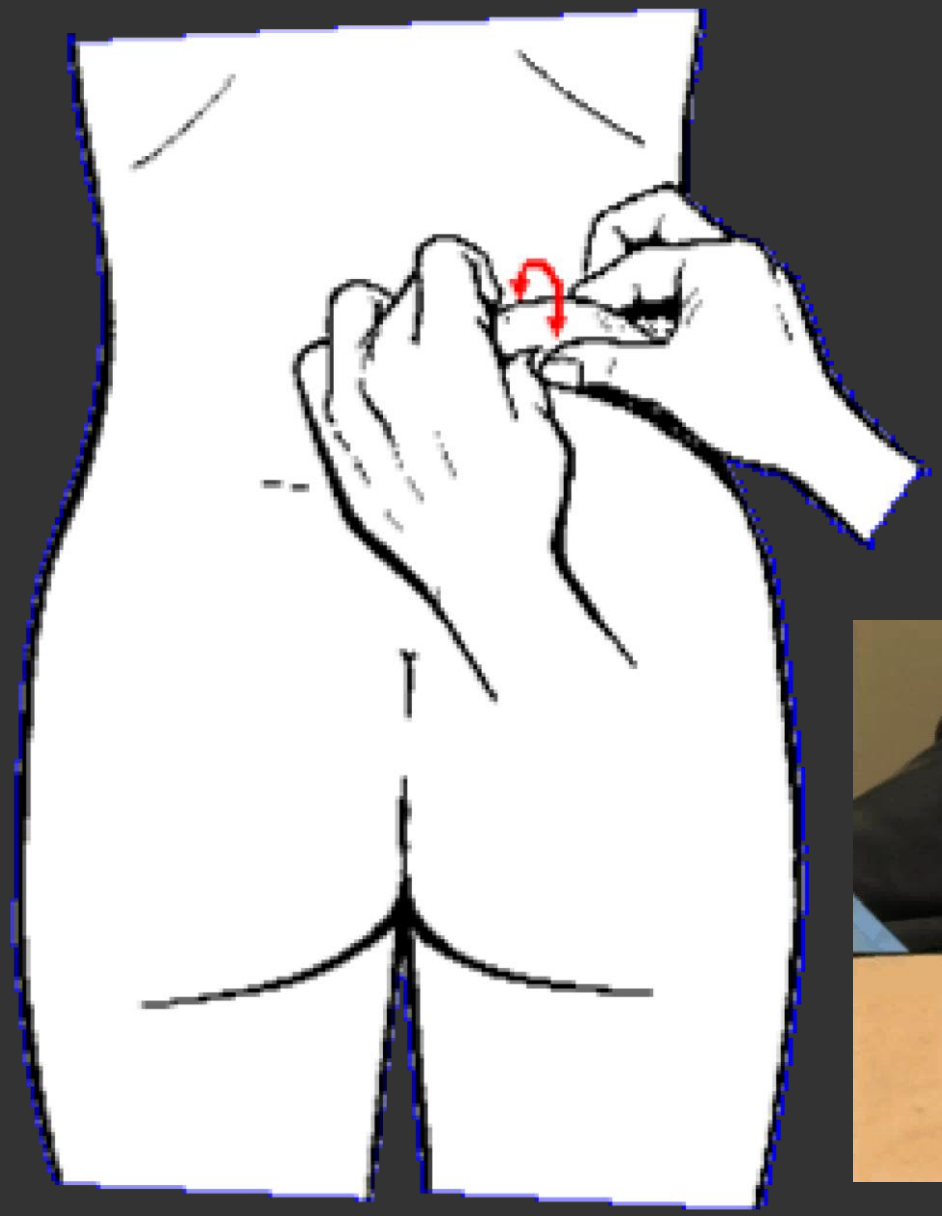


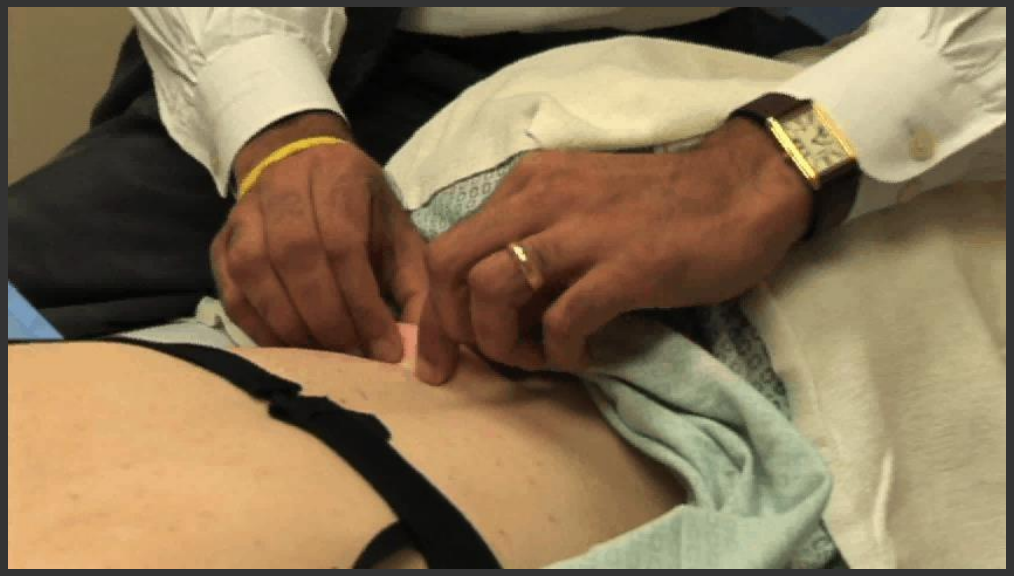
Courtesy Marta Imamura

PHASE II

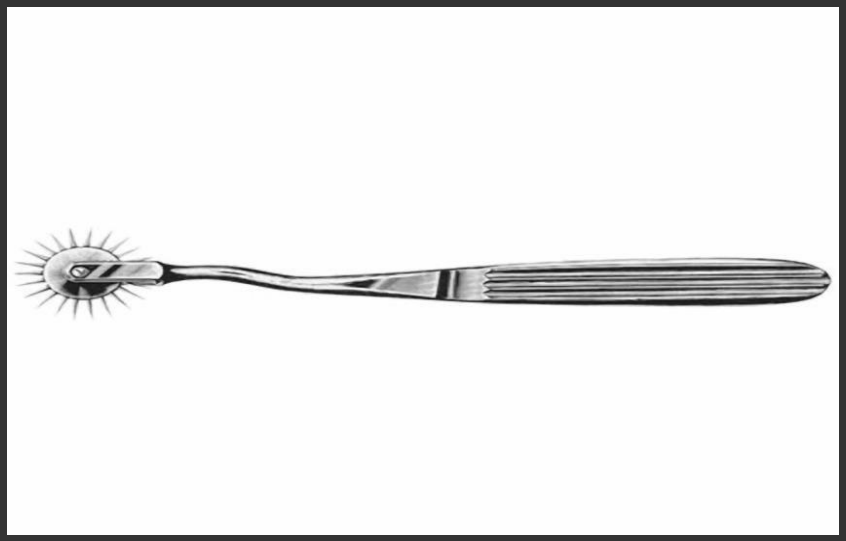
DIAGNOSIS OF SPINAL SEGMENTAL SENSITIZATION

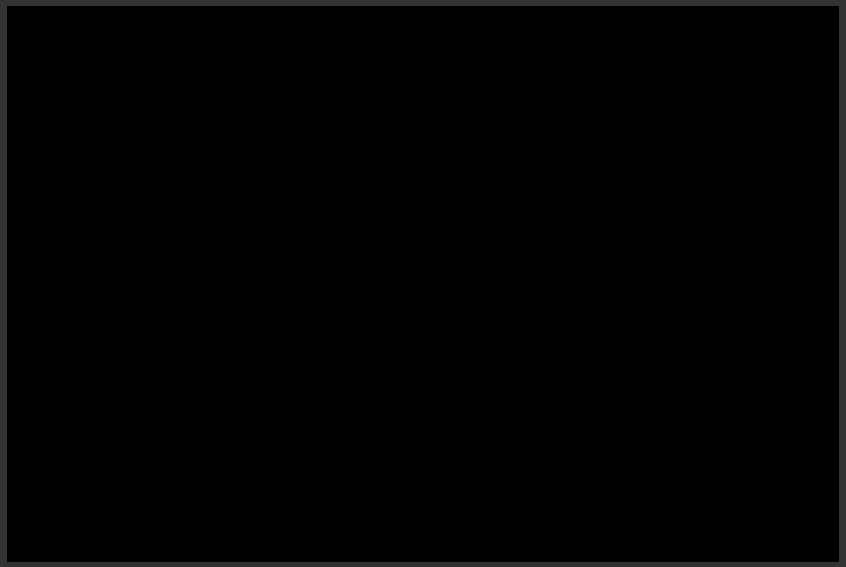
PINCH & ROLL: Allodynia

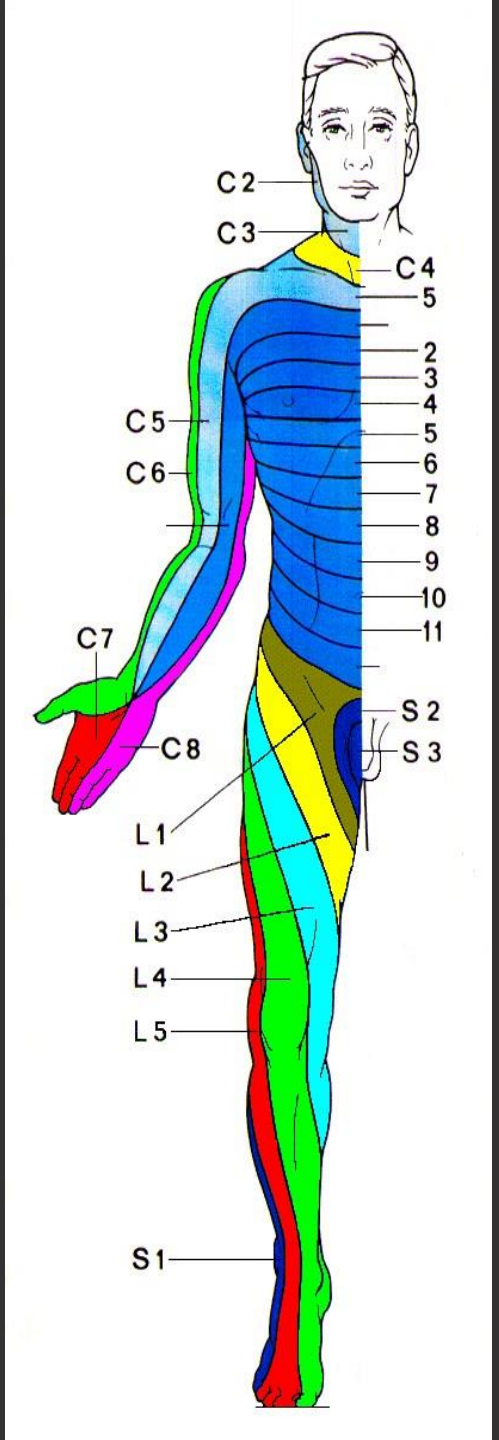




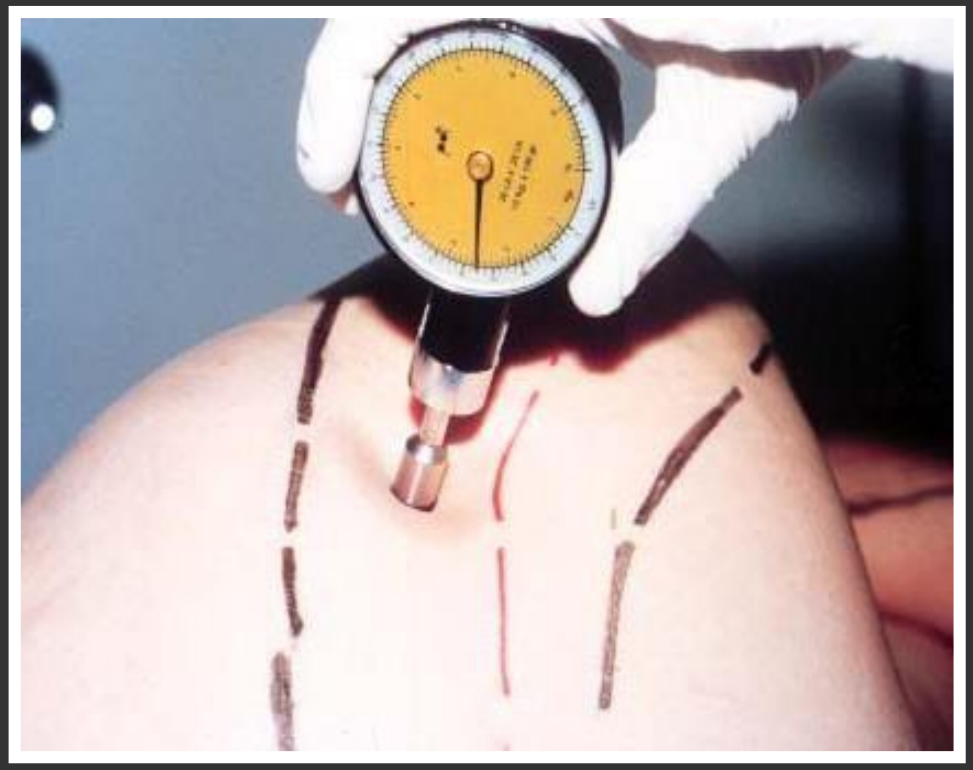
Waternberg pinwheel: Hyperalgesia





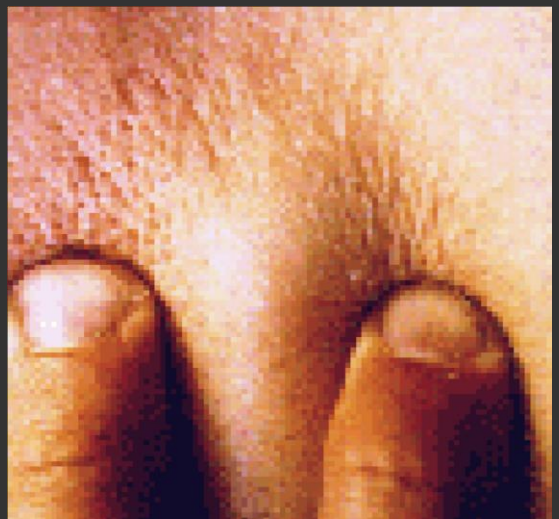


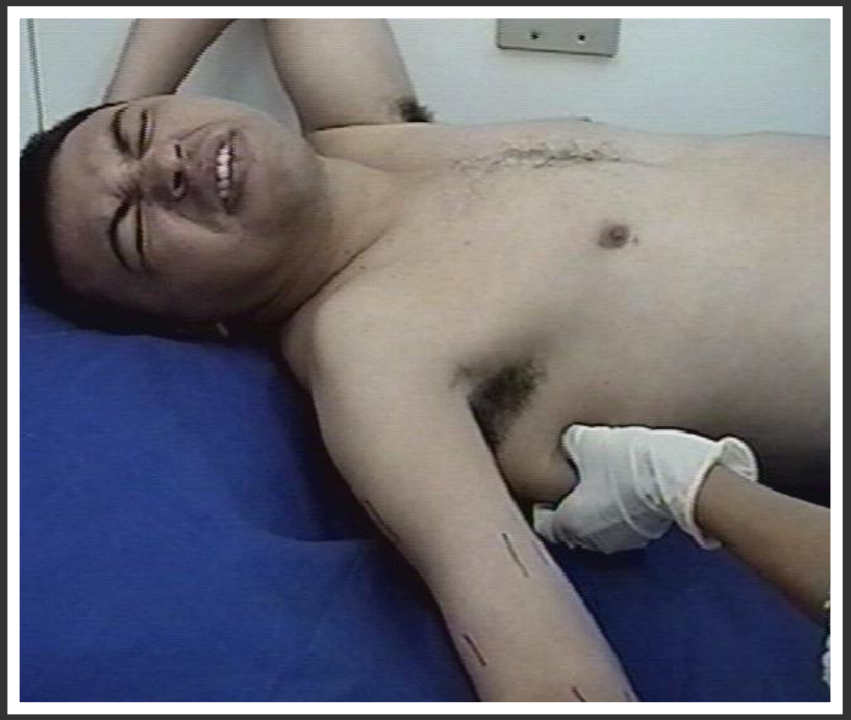
ALGOMETRY



Fischer, A.A. Pain 30: 115-126, 1987
Standard values, validity and reproducibility.

Signs of SSS

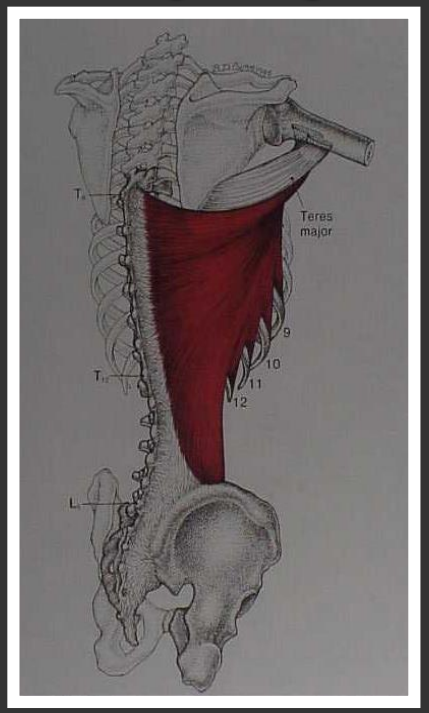




MOTOR

MYOTOME

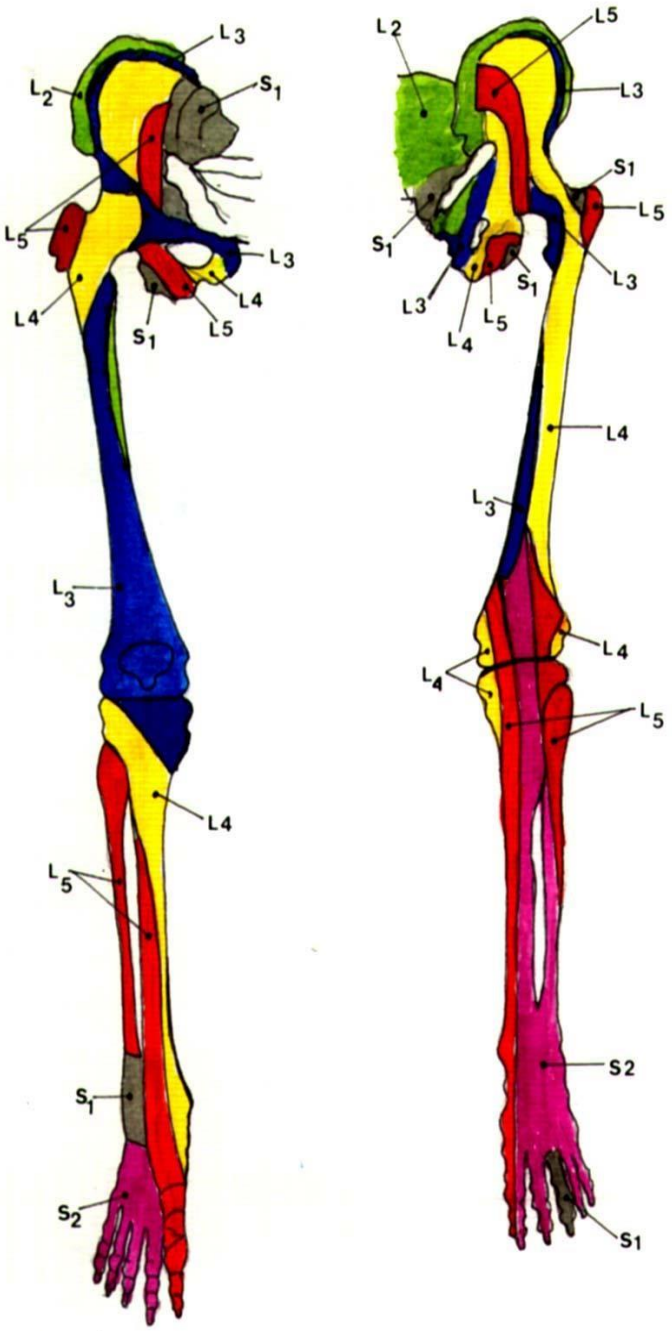
Latissimus dorsi (C_6-C_8)



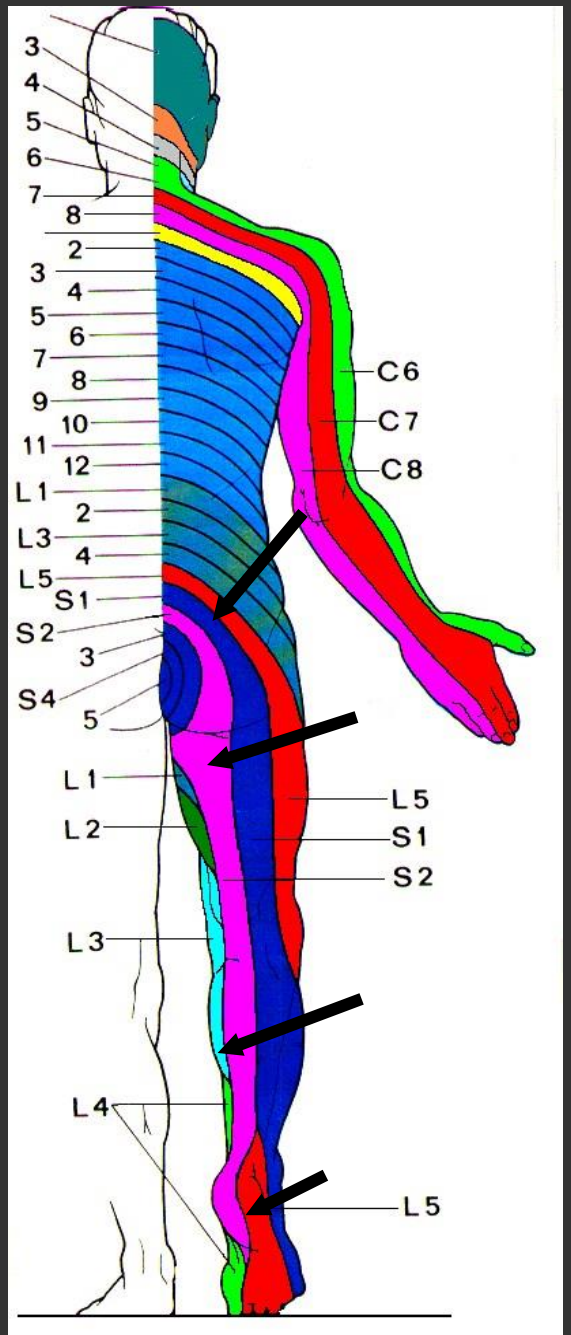
- Point tenderness
- Algometry
- Reduced threshold to muscle palpation

SCLEROTOME

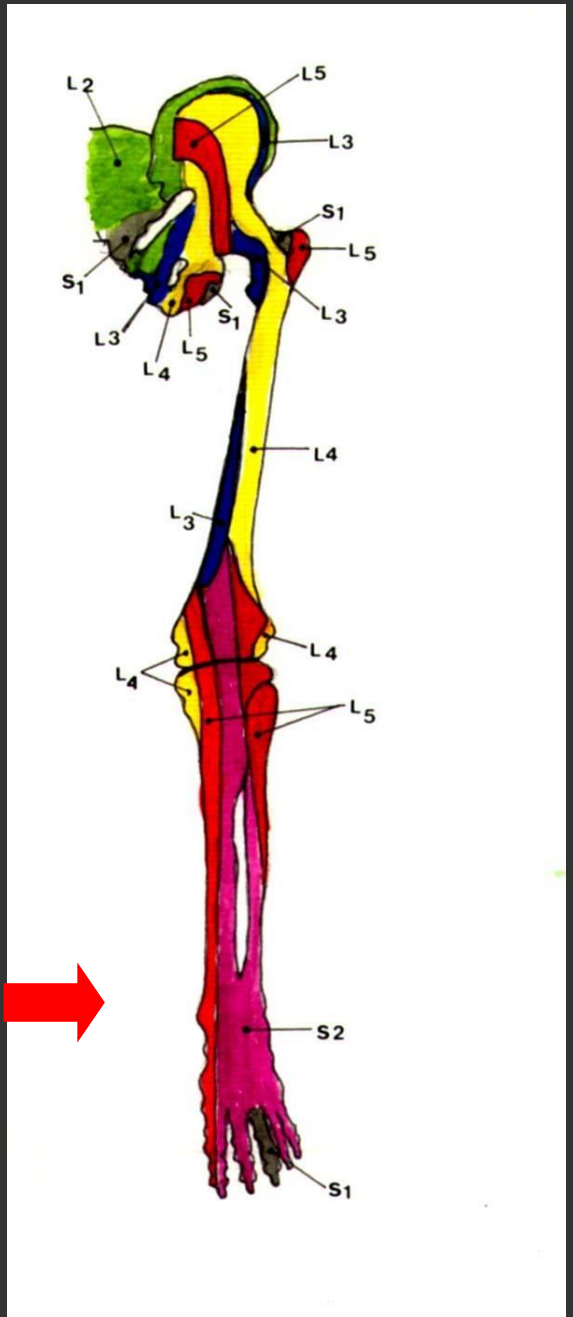
- Supraspinous lig
- L4: pes anserinus
- L5: Major trocanter
- S1: SIJ
- S2: Plantar fascia



Dermatome



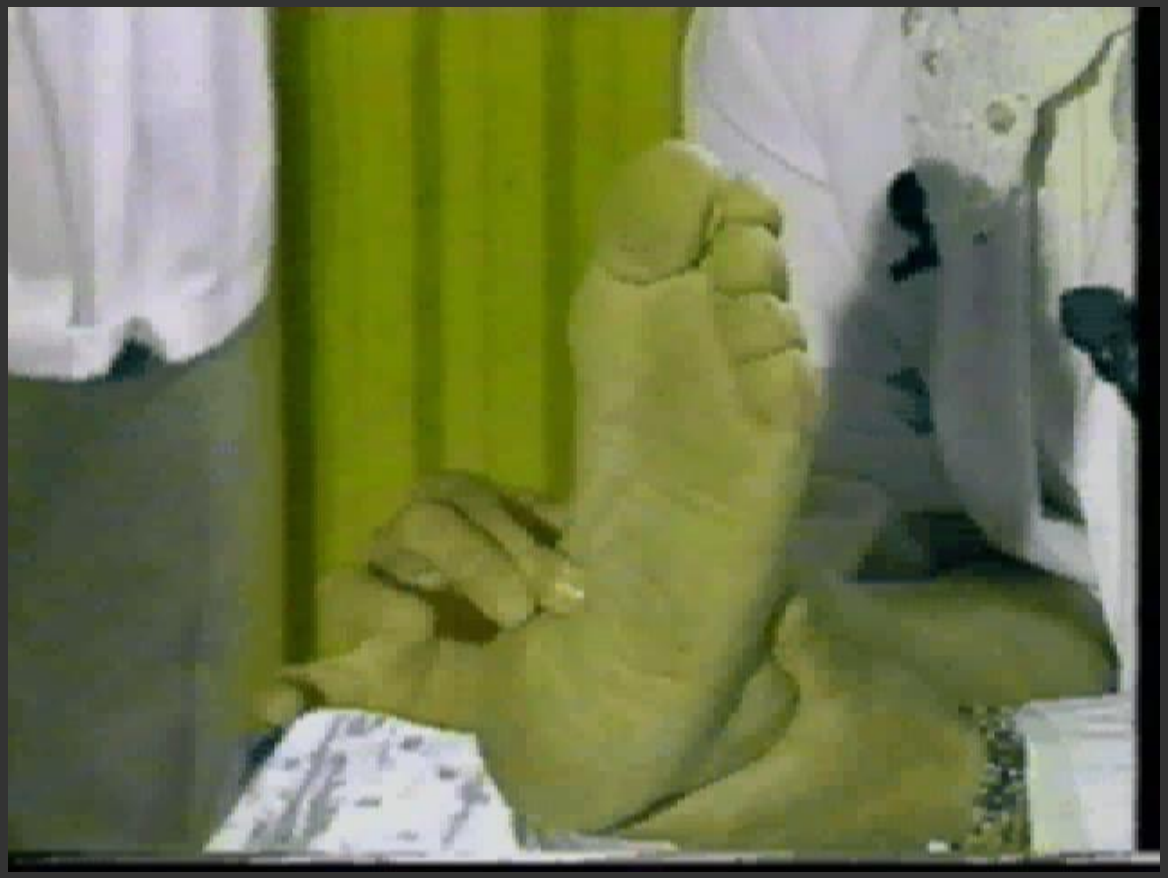
Sclerotome



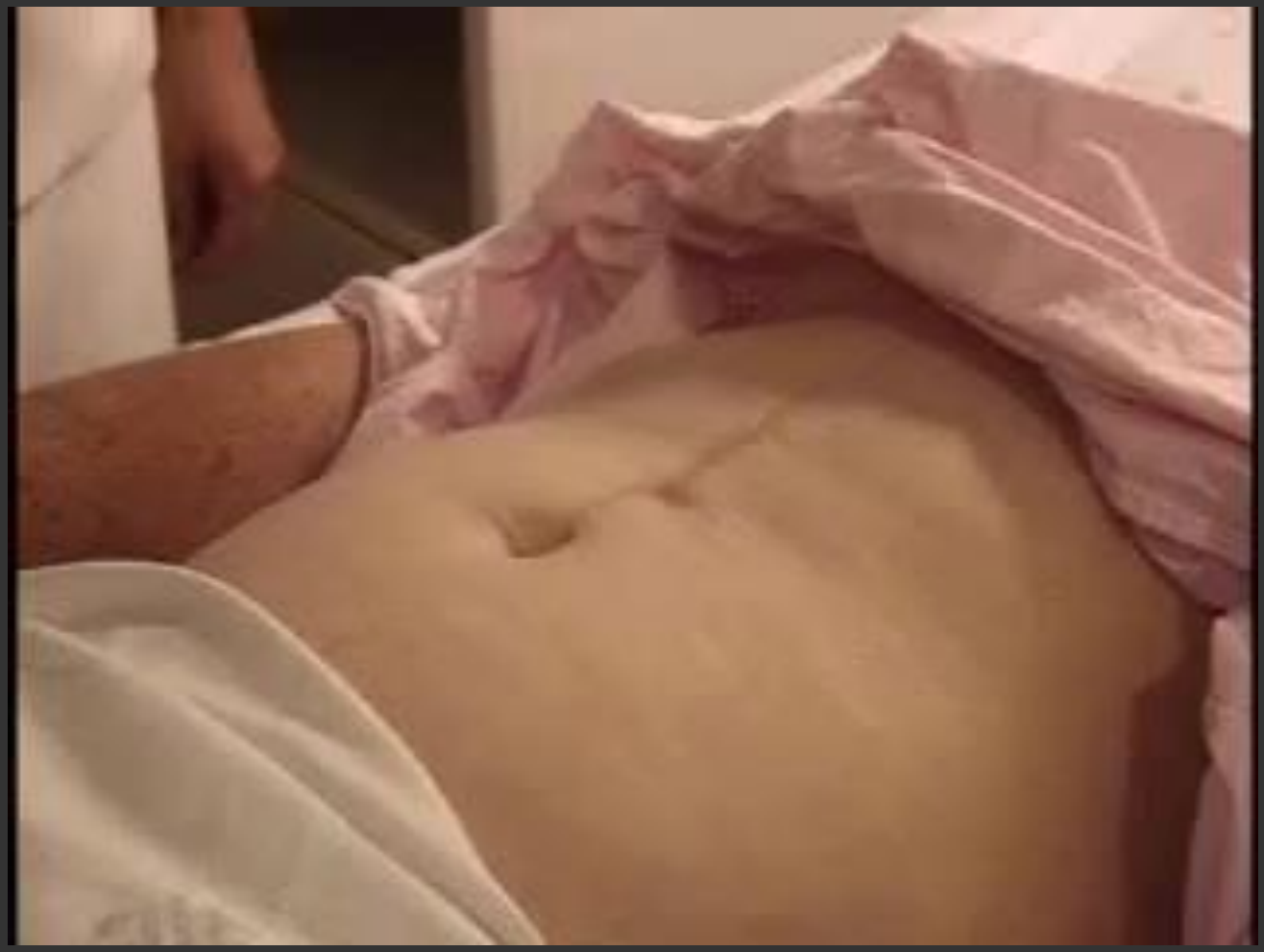
SCLEROTOME

- Supraspinous ligaments
- C5: subacromial bicipital tendinitis
- C6: lateral epicondylitis
- C8: medial epicondylitis

?Plantar Fasciitis?

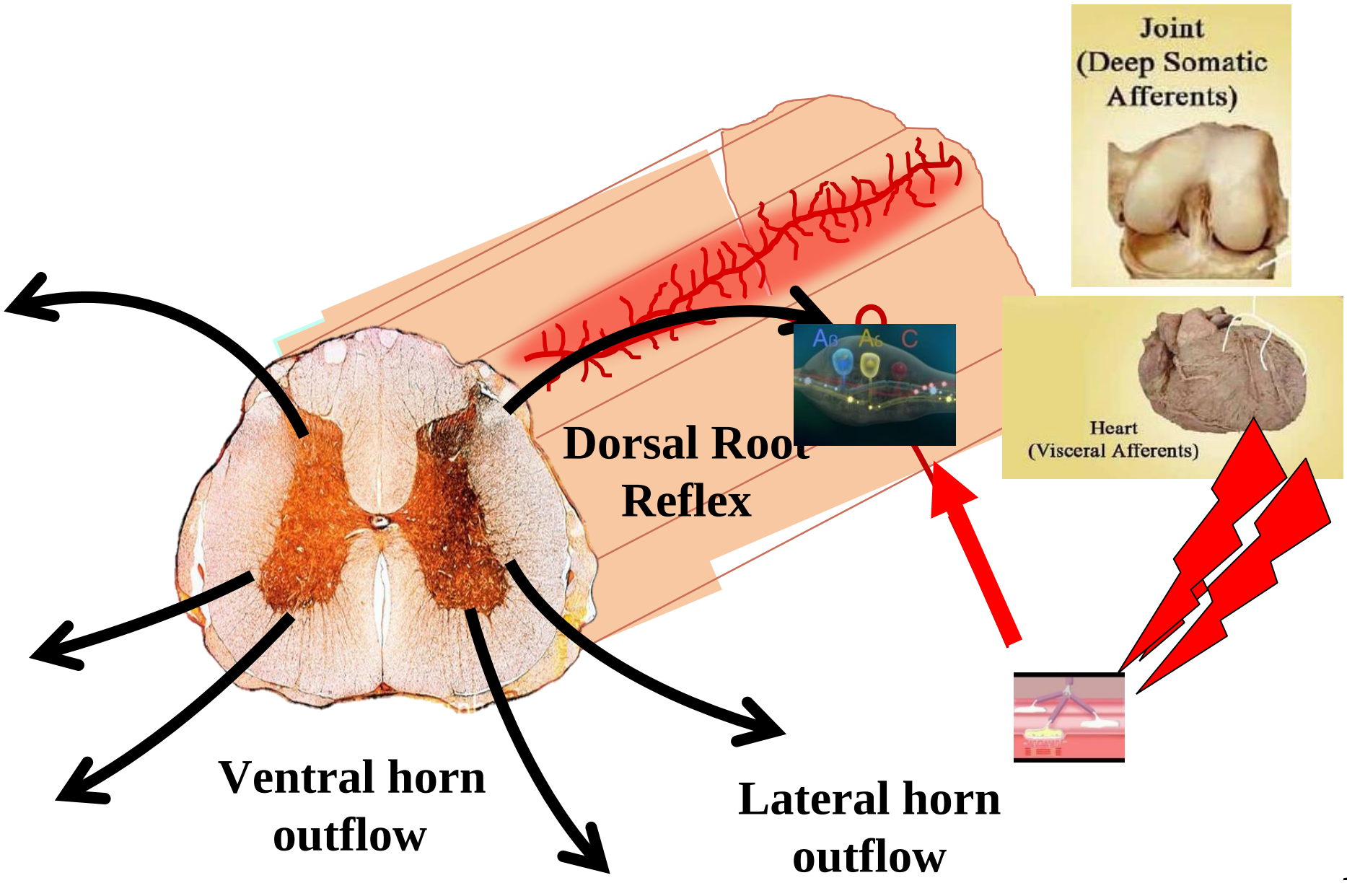


Courtesy Marta Imamura



Courtesy Marta Imamura

Sensitized Dorsal Horn Neurons Demons


Joint
(Deep Somatic
Afferents)
Heart
(Visceral Afferents)
Dorsal Root
Reflex
Ventral horn
outflow
Lateral horn
outflow

Segmental Spread!

Neuro-modulating the Pain Matrix:

Dry Needling, Injection, Acupuncture and Electrical Stimulation Techniques for *Desensitizing* the Sensitized Segment and Deactivating Chronic MTrPs

Neuro-modulating the Pain Matrix:

Concentrate on the sensitized segment (central) and the related structure (peripheral) corresponding to the immediate cause of pain

SEGMENTAL DESENSITIZATION

MODALITIES:

- Electrical Stimulation
- Dry Needling
- Electroacupuncture
- TENS
- Spray and Stretch

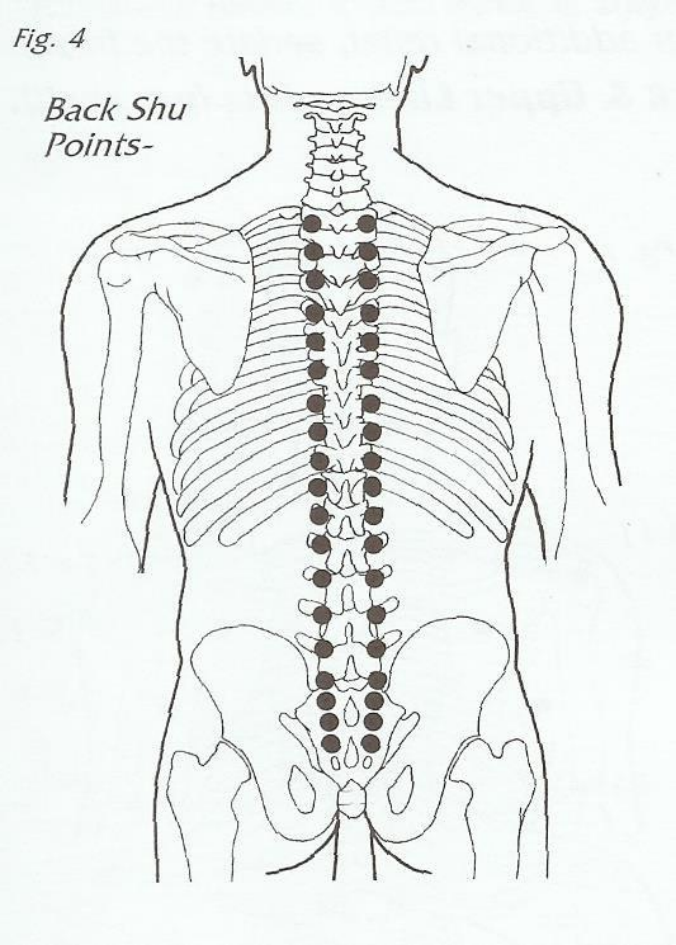
Electrical Stimulation

SEGMENTAL DESESITIZATION

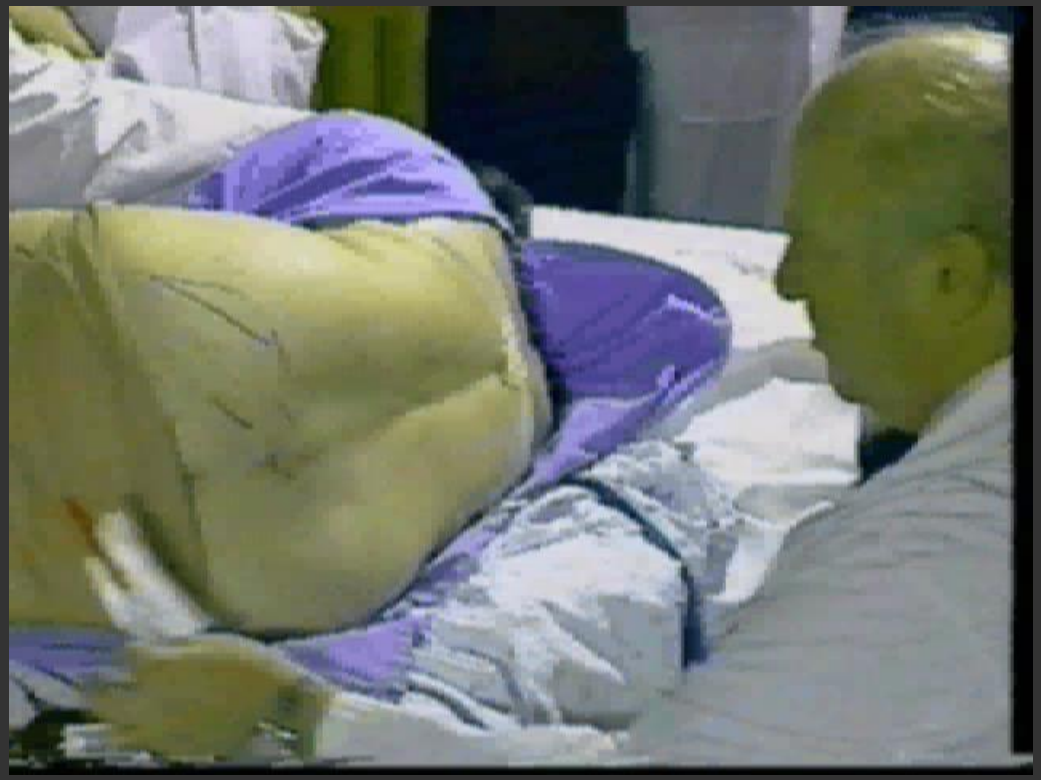
PRO-STIM:

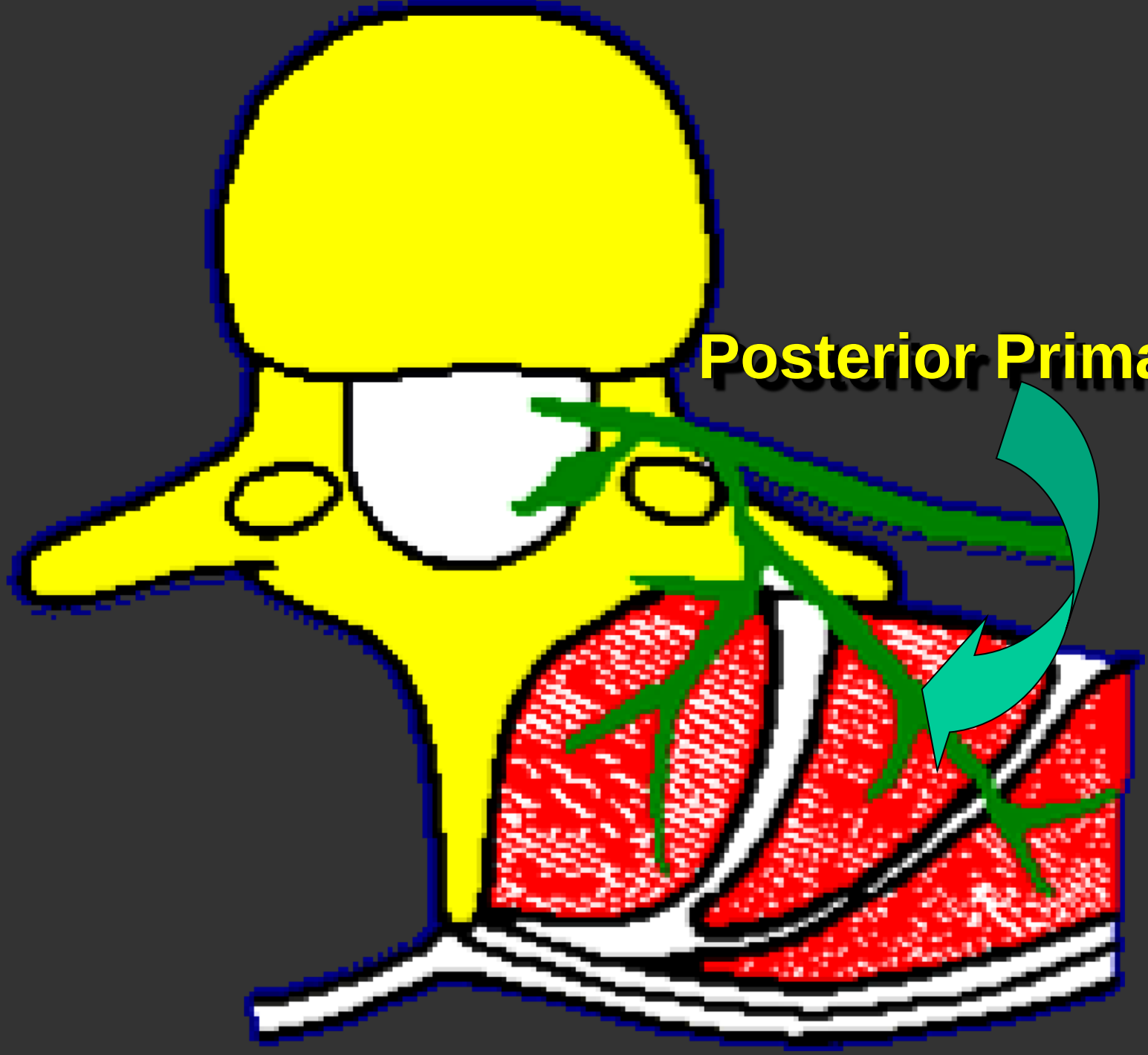
- Square waveform pulses
- Parameters vary with skin impedance
- 1.5Hz
- 6 _ 400 microamps
- Max peak pulse width: 330msec

Point Stimulation



?Plantar Fasciitis?



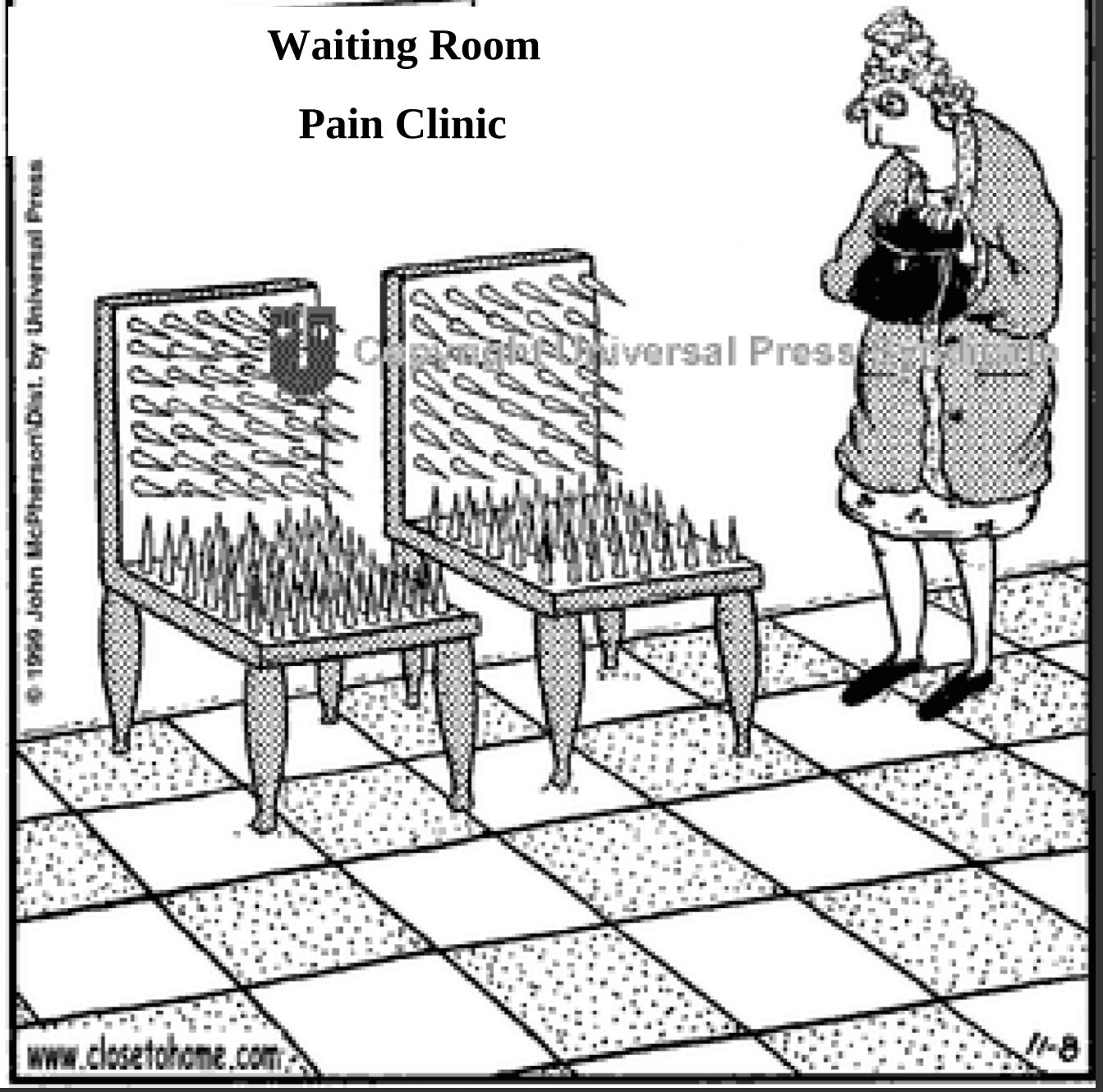

Posterior Primary Ram

We Must Deactivate MTrPs that could Re-sensitize the Dorsal Horn

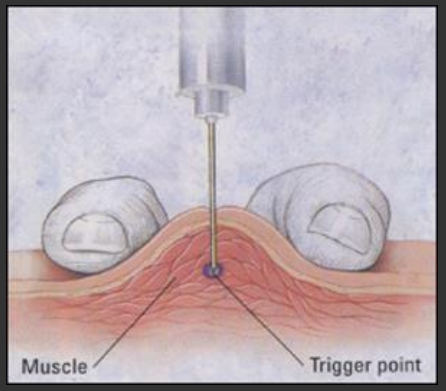
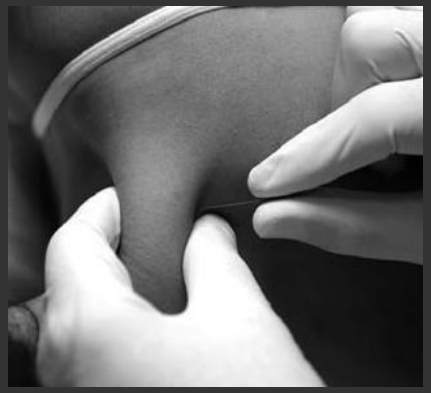
Some clinicians start dry needling right away…

Waiting Room

Pain Clinic

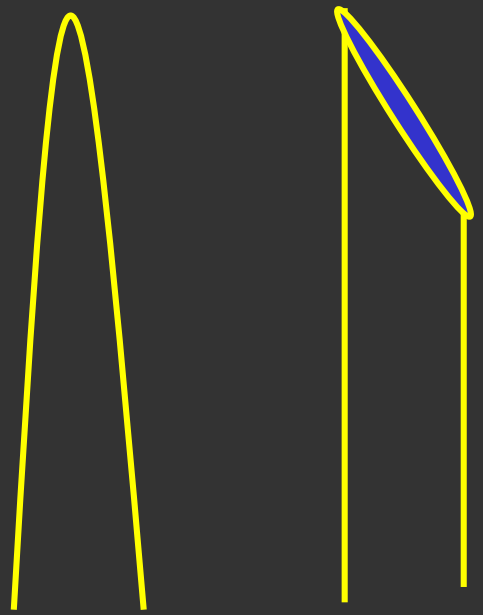


Needling

Injection	Dry Needling
	
Use of syringe	Use of solid filament
Delivery of pharmacologic agents	Mechanical stimulation of the TrP
Mechanism of action based in that of the drug delivered	Activate pain inhibitory system, stretch connective tissue, increase blood flow, relaxation of muscle fibers

Comparison of Needle Tips

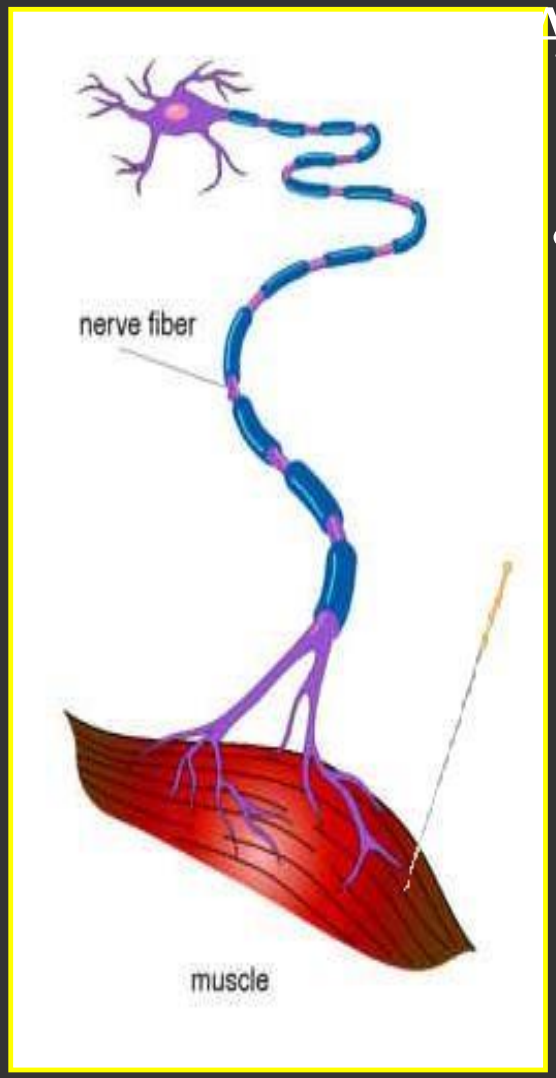
Rounded acupuncture needle tip pushes cells aside rather than piercing them



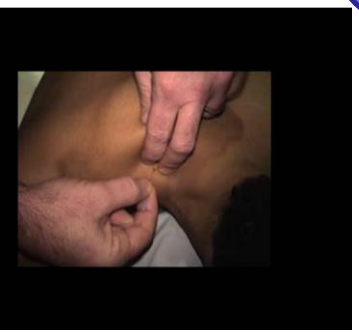
Sharp beveled hypodermic needle tip acts like a miniature scalpel capable of piercing, cutting and tearing cells

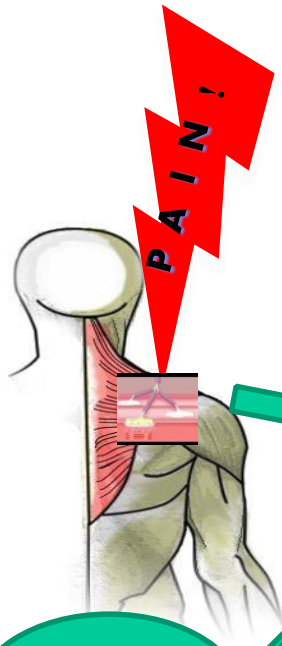
Courtesy Terry Phillips

Possible Dry Needling Mechanisms



- Activate pain inhibitory system
  - Via Aδ and Aβ nerve fibers
- Stretch connective tissue
  - Fibroblast stretch via mechanical stimulation
- Increase blood flow
  - By releasing vasodilatory biochemicals
- Relax muscle fibers
  - Reduce overlap between actin and myosin filaments; interrupt motor end-plates





INCREASE IN BLOOD FLOW

Release of SP and CGRP

Local Microtrauma

Needle Insertion

Mechanical Stimulation

Activation of Aδ fibers

Activation of Aβ fibers

LTR

SEA

Inhibition of C-fibers

Segmental Inhibition (gate control)

Placebo Effect?!

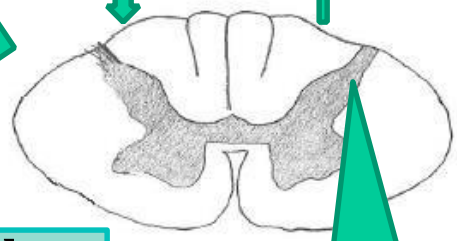
PAIN MATRIX

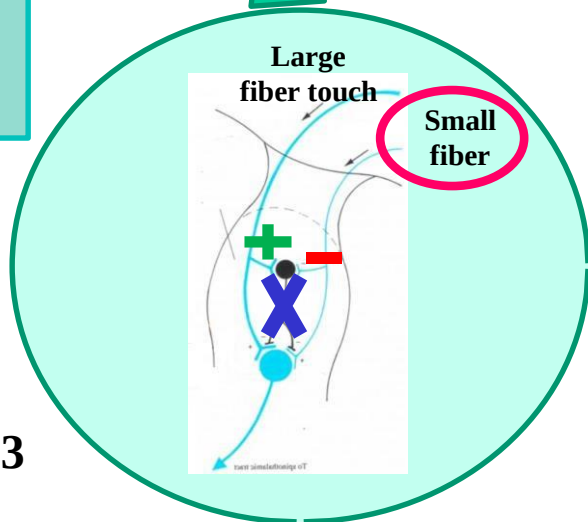
SUPRASPINAL SITES

PAG

RVM

Ascending Pain Pathways





Overview of Pot[illegible]ry Needling Physiological Effects

Adapted from Caigne et al., 2013

3 Week Dry Needling Treatment for Chronic Cervical MPS

- The goal of this study was to assess the effect of a commonly used intervention (dry needling) to elicit a change in MTrP status
- The primary outcomes, change in level of pain and status of the MTrP were used to power the study
- Currently, assessments of patients with MPS rely upon self-reports that use descriptors of the pain, its frequency and its intensity
- These measures are valid; however, their sensitivity to change and the variation of interpretation by individual patients makes quantification difficult

3 Week Dry Needling Treatment for Chronic Cervical MPS

- A significant number of subjects experienced a change in MTrP status from active to latent or active to resolved (i.e., no palpable nodule)
- After Tx, the size of the A-MTrP decreased along with reduction in pain
- MTrPs that do not respond to treatment remain large and people with A-MTrPs unresponsive to Tx experience greater pain than responders

Gerber et. al. *PMR*. 2015

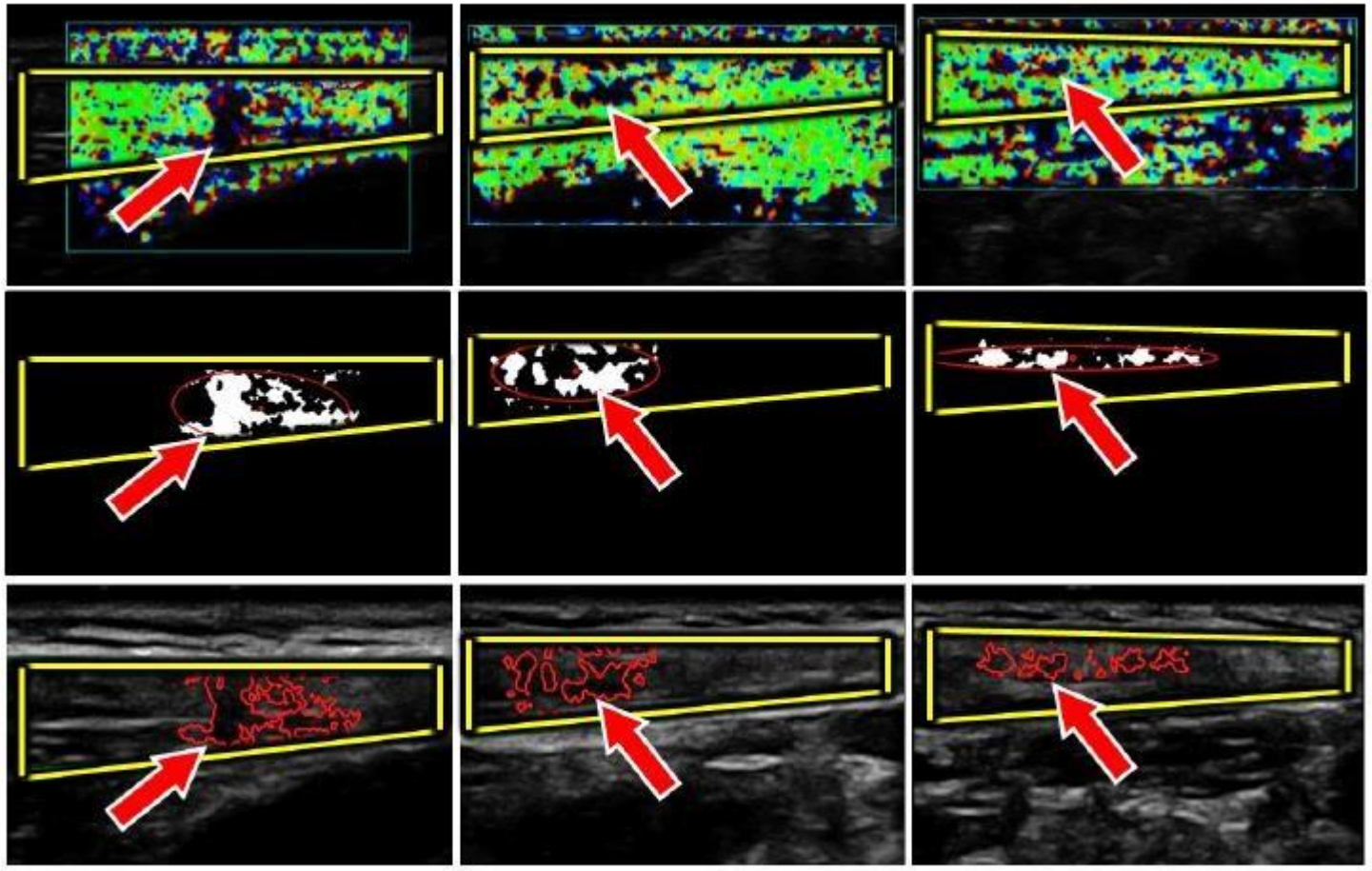
Dry Needling Decreases Pain of Chronic Cervical MPS and Improves Patient Outcomes through 6 weeks after Treatment

Significant improvements were found at 6 weeks after Tx compared to baseline in:

Gerber et. al. *PMR*. 2016

Ultrasound elastography can be used to quantify muscle tissue changes after dry needling treatment

Figure 3



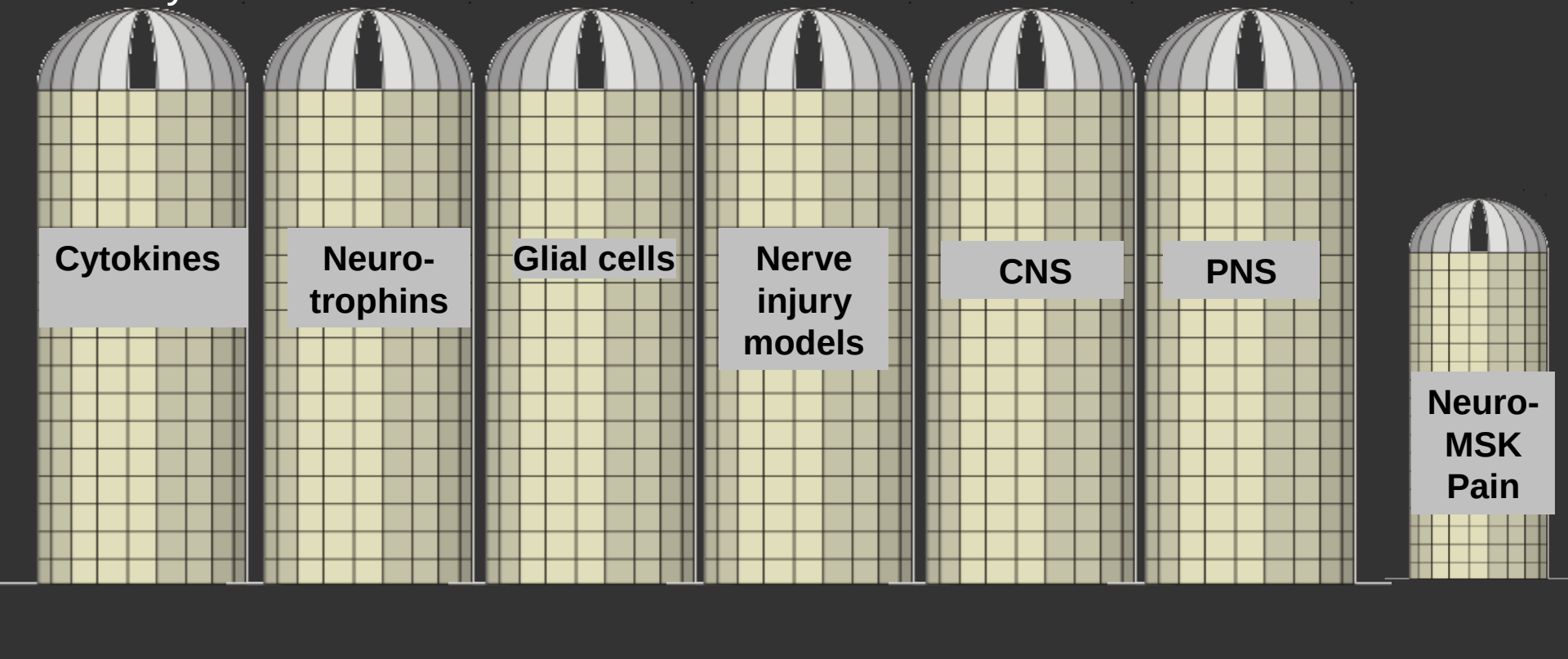
Turo et. al. *J Ultrasound in Medicine*. 2015

Mechanisms of Chronic Pain

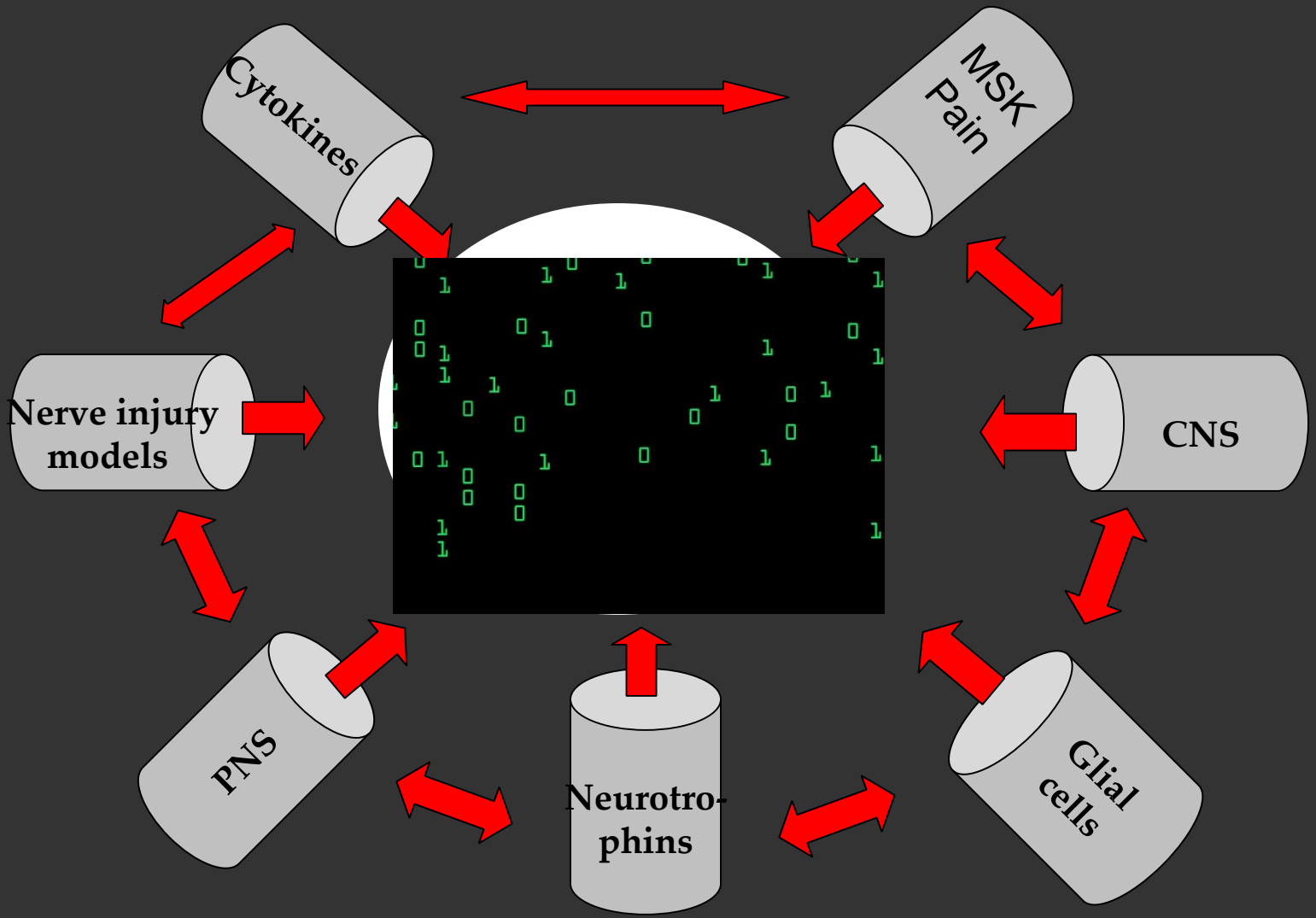
- Silos of knowledge

- Impressive, detailed and convincing mechanisms in animal models

- Need big picture integration to understand pathophysiology of Neuro-musculoskeletal pain and effects of treatment on these systems



Neuromatrix



Integrated Neuromuscular Theory:

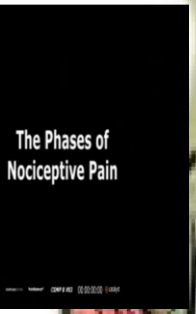
Central

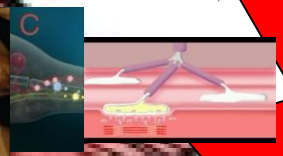
Peripheral

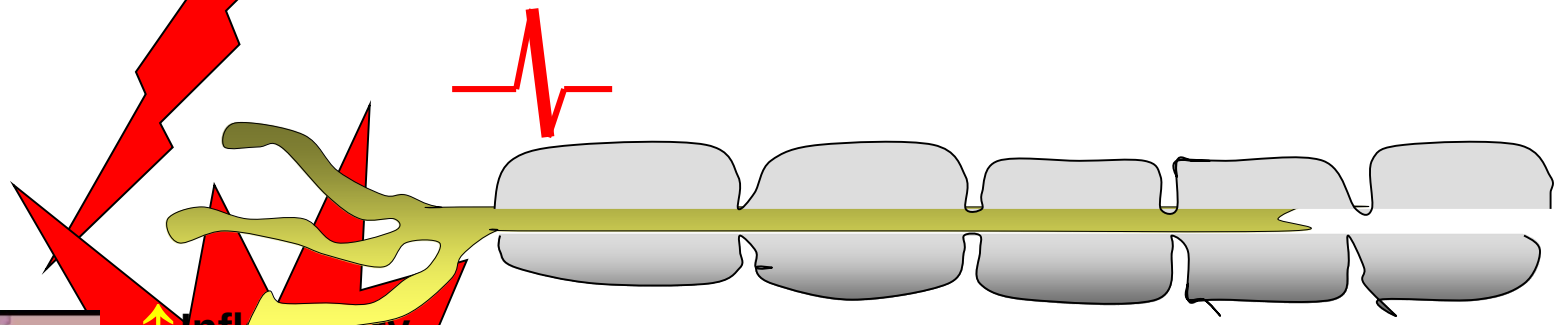
Peripheral

Central

Integrated Neuromuscular Theory:
Central to Peripheral Sensitization

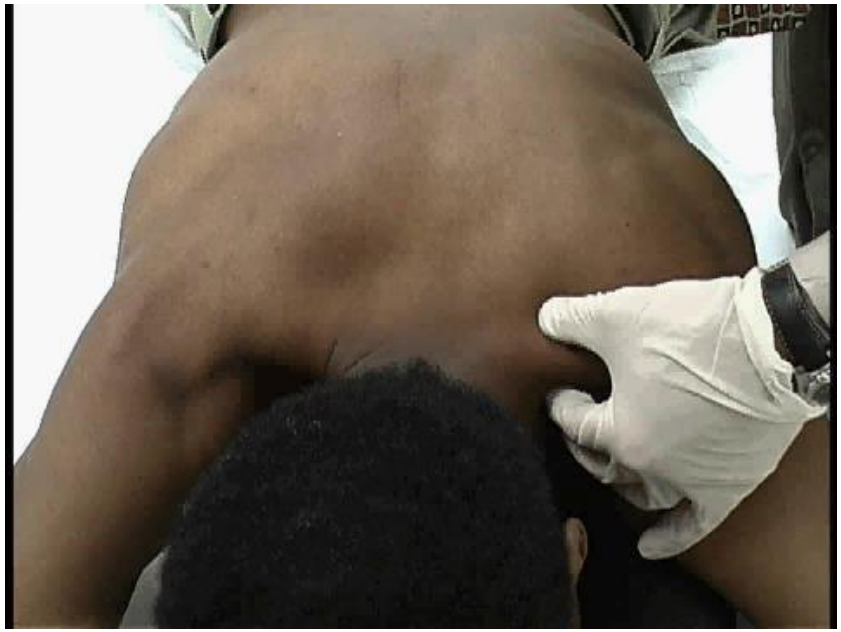






↑Inflammatory Mediators, BK, NE, SP, Serotonin, Cytokines

↓pH

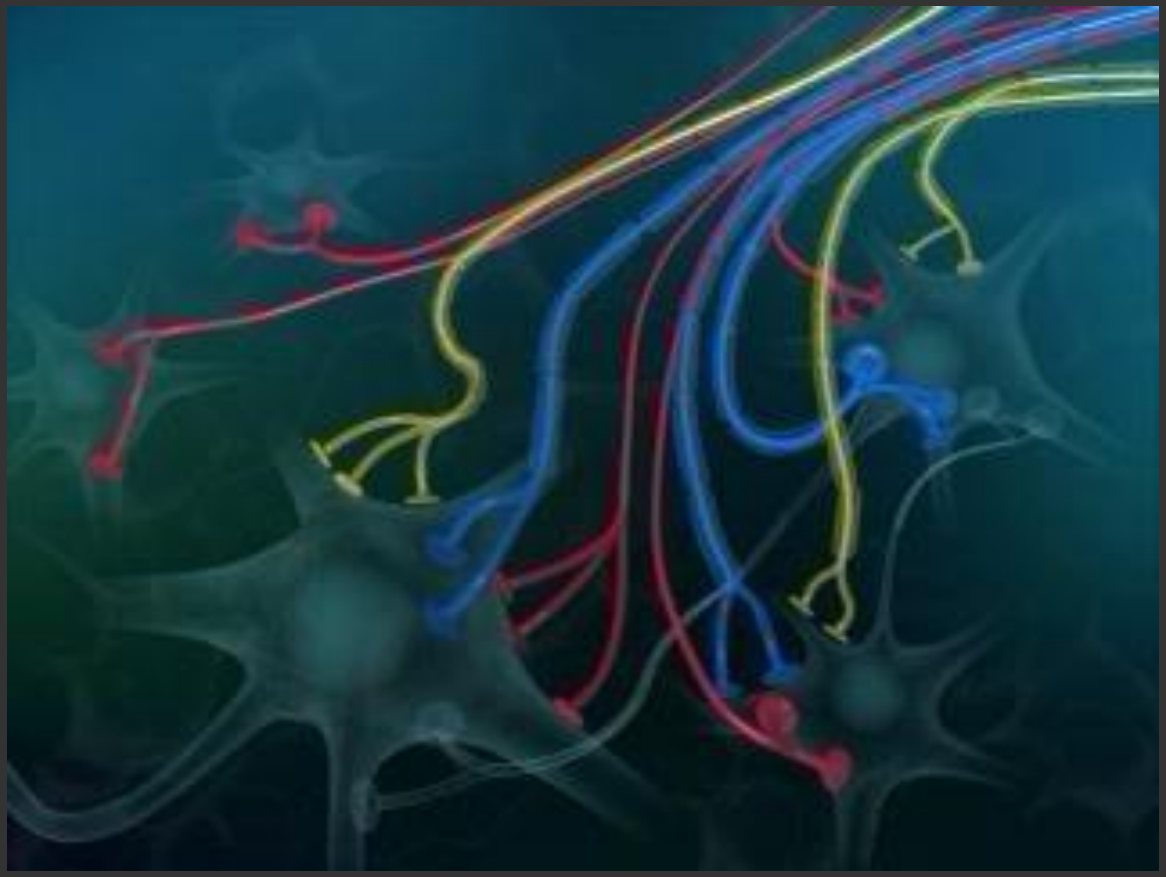


Integrated Neuromuscular Theory

Integrated Neuromuscular Theory

Integrated Neuromuscular Theory

Integrated Neuromuscular Theory

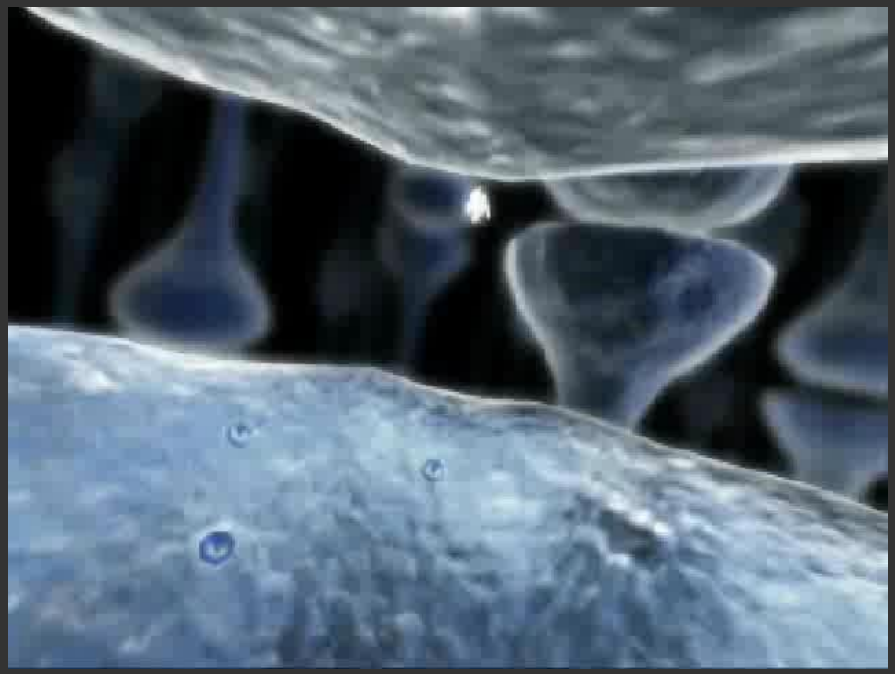


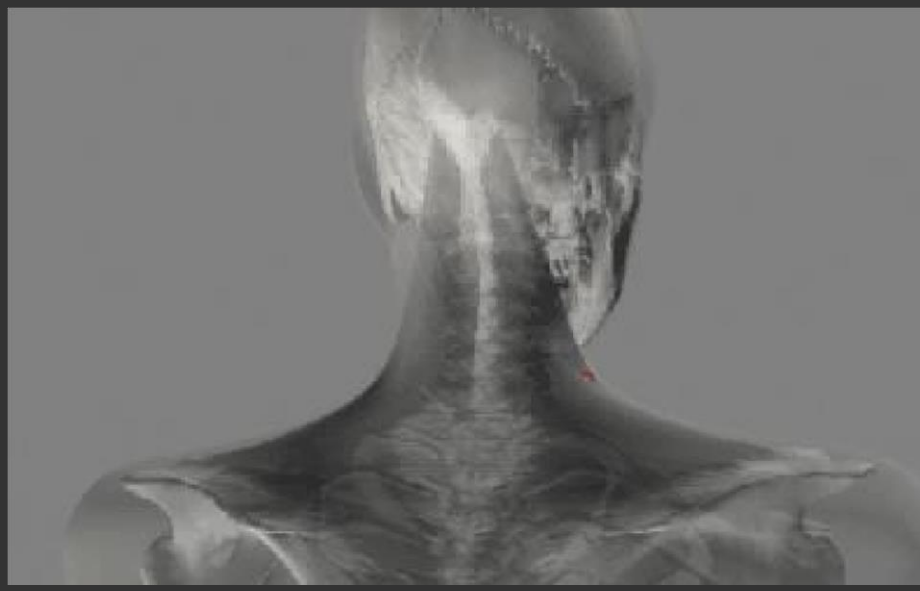
Active MTrPs function as dynamic foci of peripheral nociception that can initiate, accentuate, and maintain central sensitization

Courtesy of Jan Dommerholt

Integrated Neuromuscular Theory

…which will open previously ineffective connections - resulting in new receptive fields and referral of pain





Hans-Werner Weisskircher
www.trigger-point.com

Trigger Point Needling:
Deactivation of Peripheral Nociceptive Foci

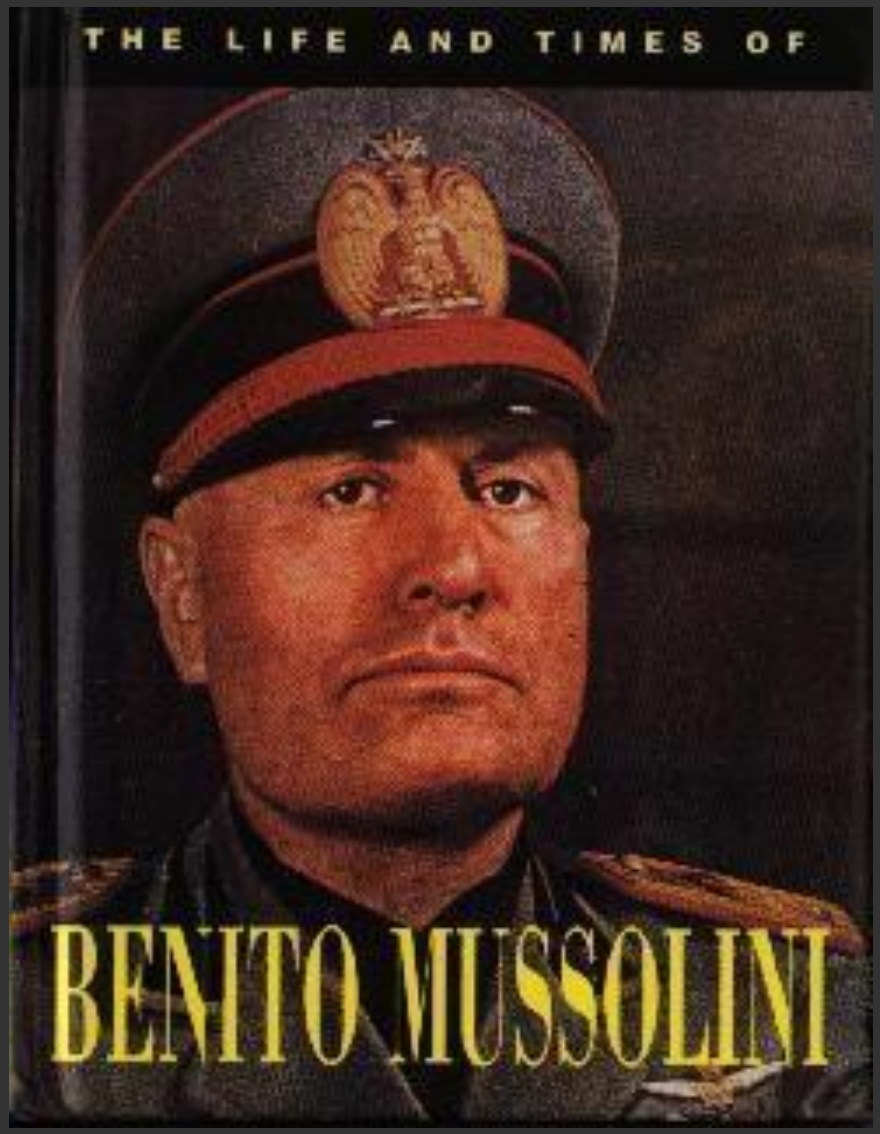
TrP

TrP

TrP

TrP

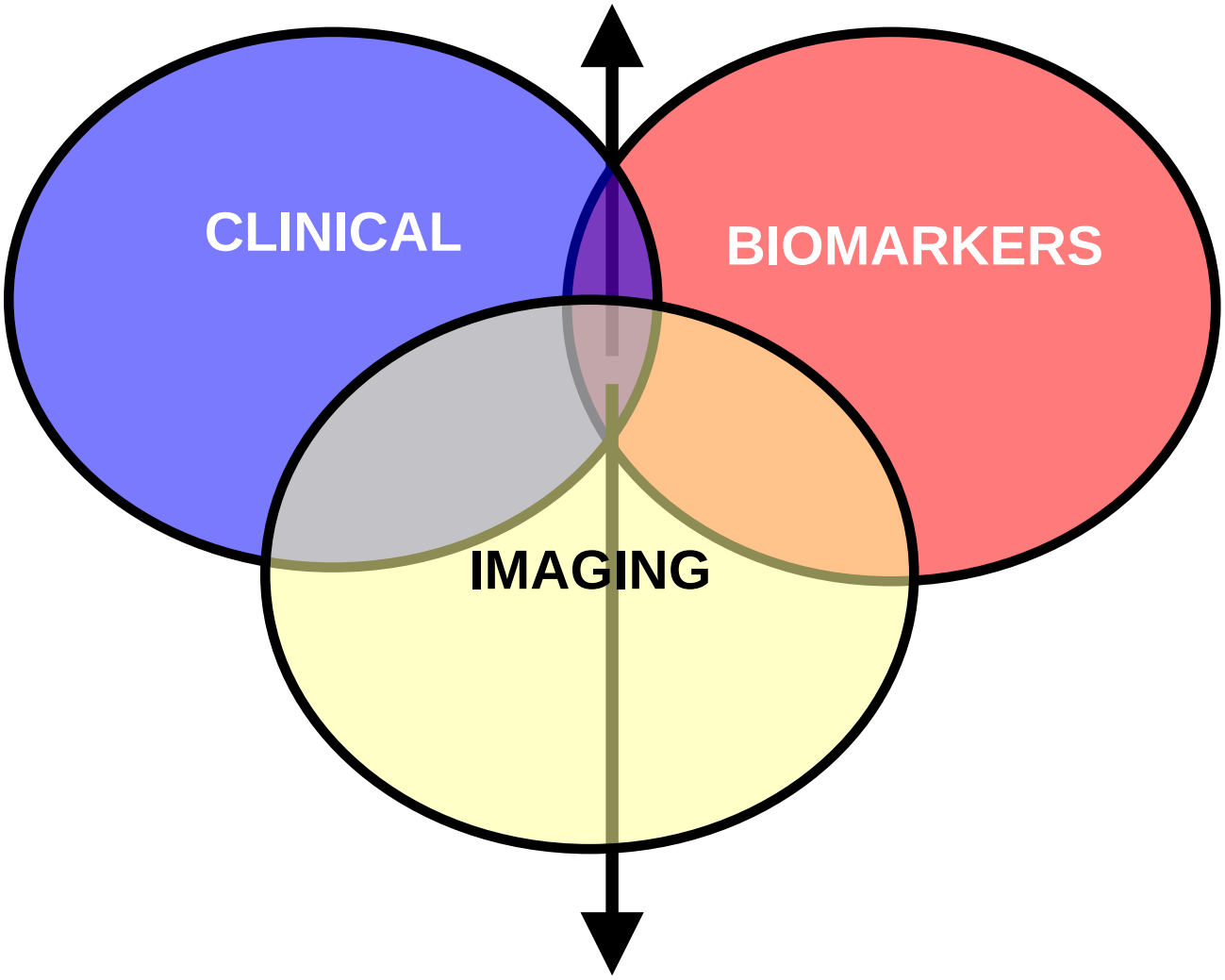
“I’m NOT a Myofascist!”



“I’m a Myo-fascia-nado”

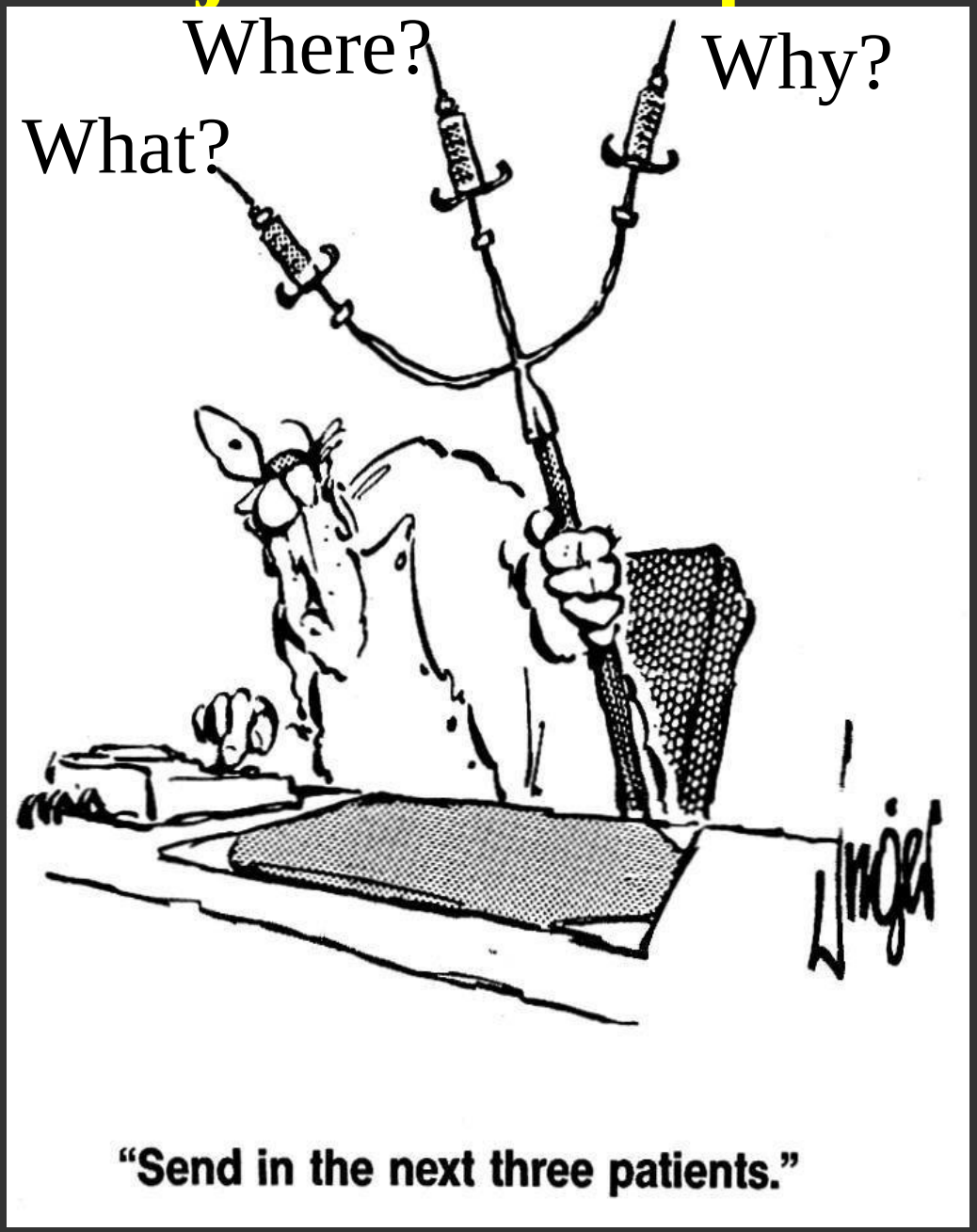
Preliminary Concepts Enabling Model Development

Mechanism-Based Diagnostic Criteria


CLINICAL
BIOMARKERS
IMAGING

Identify Treatment Targets and Objective Outcome Measures

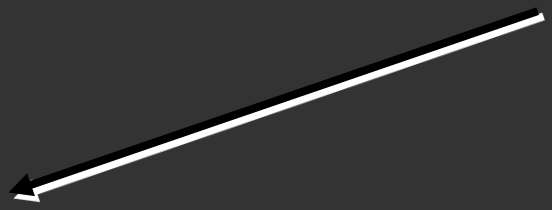
Injection Therapies



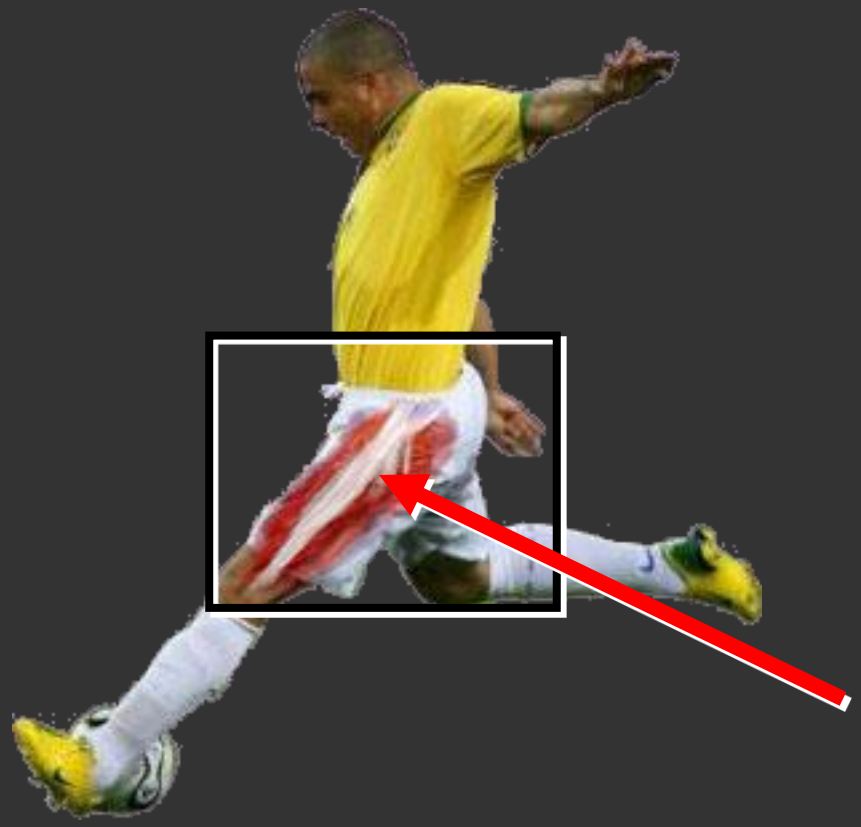
Mgmt of Neuro-musculoskeletal Pain and Sensitization

- **Diagnosis and workup**
  - ✓ Consider referral patterns of common MTrPs
  - ✓ Rule out other causes of pain by physical exam, imaging and laboratory tests, etc.
  - ✓ Palpate the muscle for active MTrPs

Mgmt of Neuro-musculoskeletal Pain and Sensitization

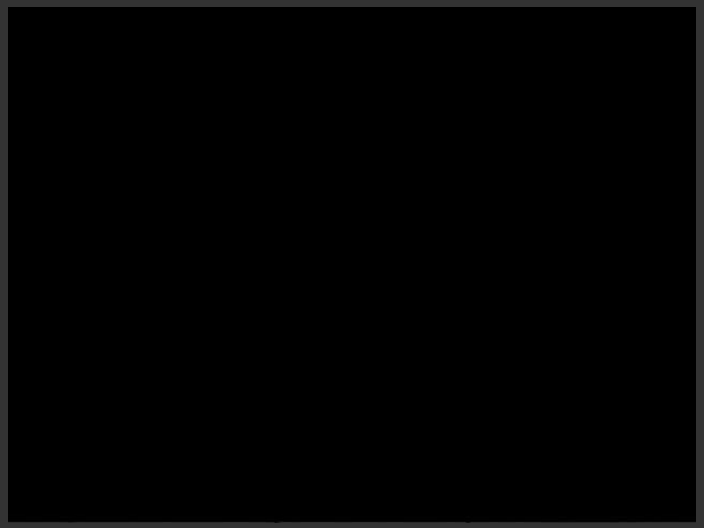


Mgmt of Neuro-musculoskeletal Pain and Sensitization

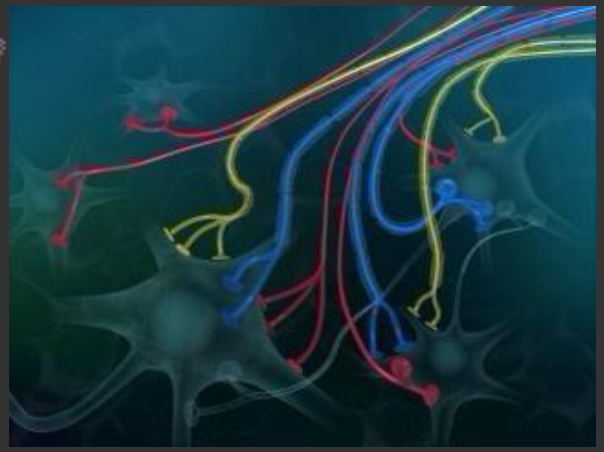


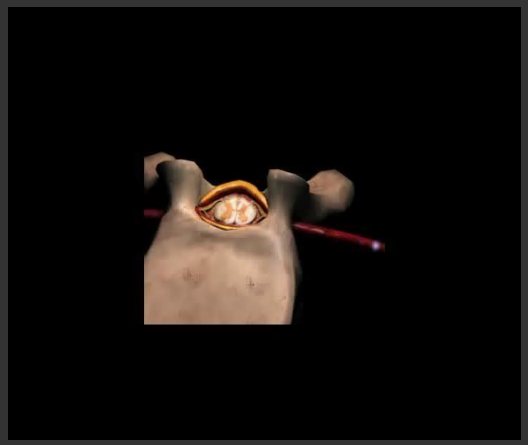
Modulation of the acidic pH, neuropeptides and pro-inflammatory cytokine cascade in the muscle

- Treatment that targets peripheral structures



Mgmt of Neuro-musculoskeletal Pain and Sensitization





Modulation of the dysfunctional, hyperexcitable dorsal horn neurons that cause allodynia, hyperalgesia and expanded pain referral patterns

- Treatment that desensitizes the dorsal horn of the spinal cord

Mgmt of Neuro-musculoskeletal Pain and Sensitization

Correction of fear avoidance behaviors, catastrophizing, and depression

- Treatments such as behavioral management, relaxation, coping skills, cognitive retraining, etc.

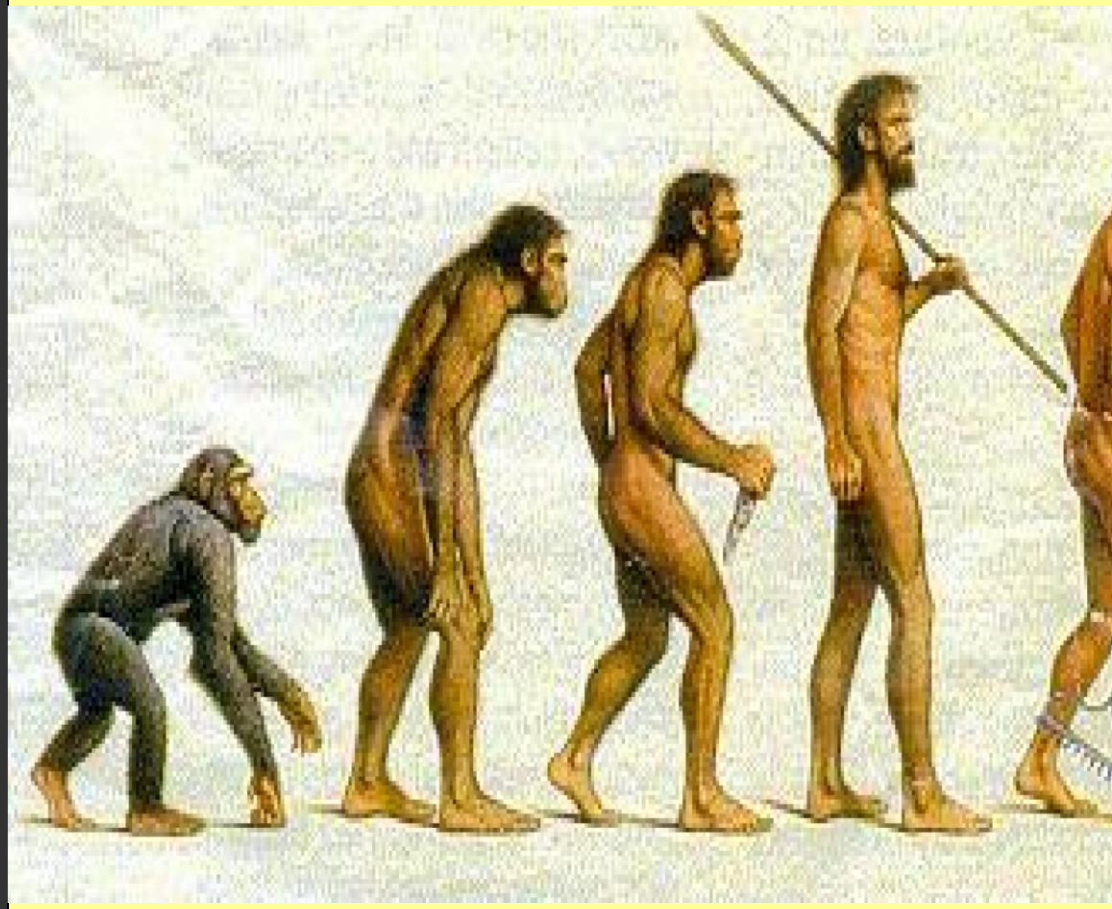
Address Perpetuating Factors

- Poor Body Mechanics
- Poor Posture

Forward Head Posture

Hans-Werner
Weisskircher
www.trigger-point.com

Progress?



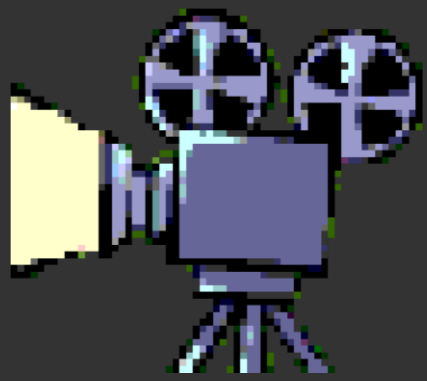
Forward Head Posture

Post Treatment Flexibility Exercises

Aerobic Conditioning

Self Massage Techniques

Can you name the motion picture?



Arigato!

Efharisto!

Gamsahabnida!

Grazie!

Thank You!

Obrigado!

Tak, Takk,Tack!

Teshekur ederim!

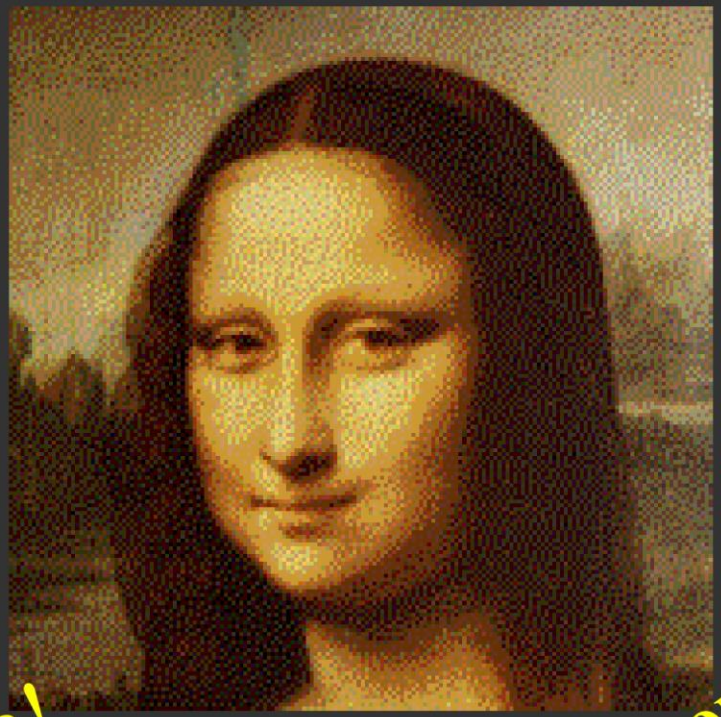
Dekuju!

THANK YOU!

Xie Xie!

Spasiba!

Merci!



Chok-ran!

Dhanyavaad!

Hvala!

Cam On!

Khop Khun Mak Kha!

Shokriya!

Toda!

Dankeschön!

Mamnun!