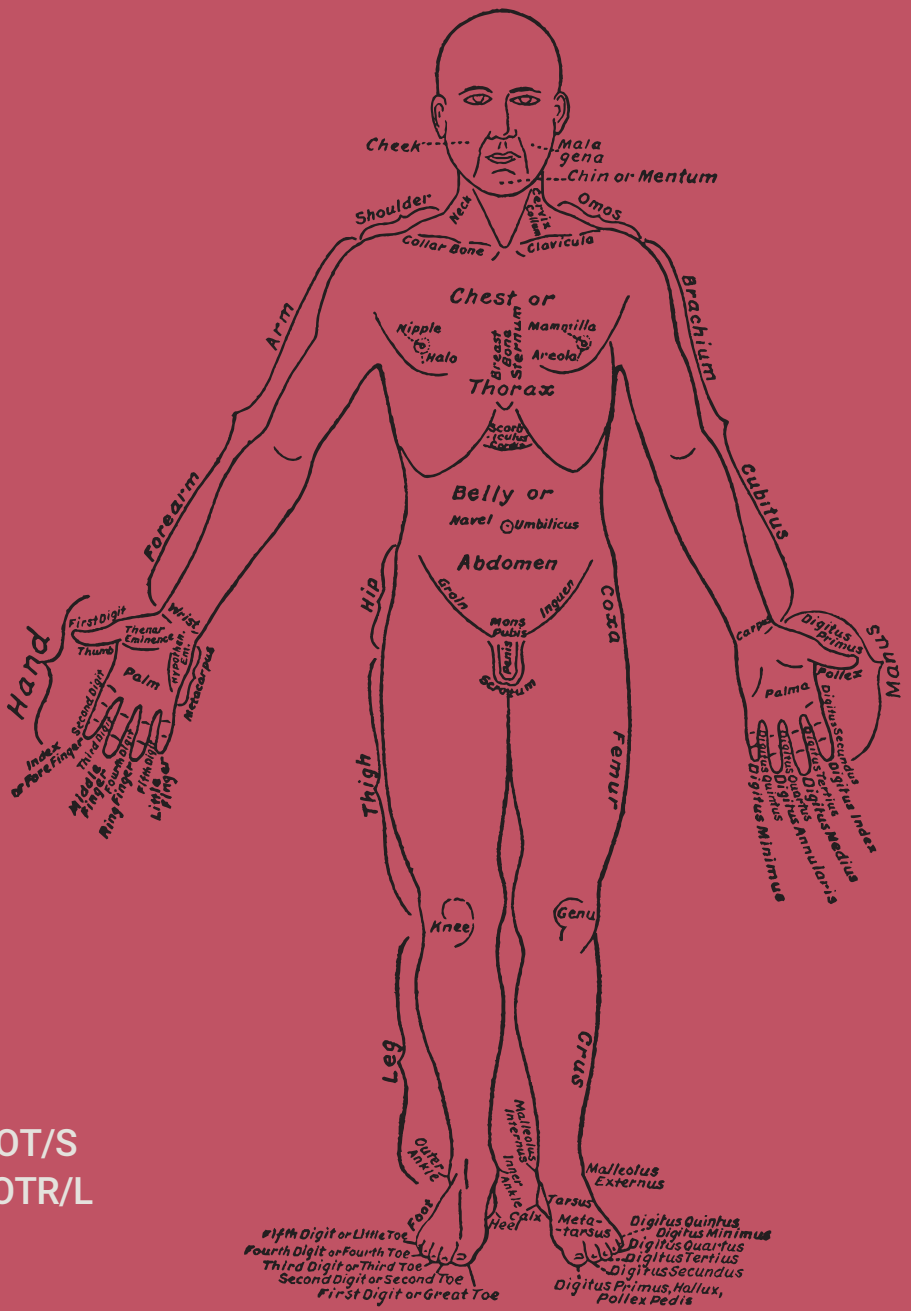
Sensation, Sensibility and "Neurohacking"



By: Justine Ramos, OT/S
Janet Brooks, EdD, OTR/L

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Note: These resources are meant to be a guide to your learning that can better facilitate your knowledge of the Hand and UE and should always be used alongside your lectures and readings.

Sensation, Sensibility and "Neurohacking"

Lecture by: Amy Orroth OTR/L, CHT
Outline and Study Materials by: Justine Ramos, OT/s and Janet Brooks, EdD, OTR/L

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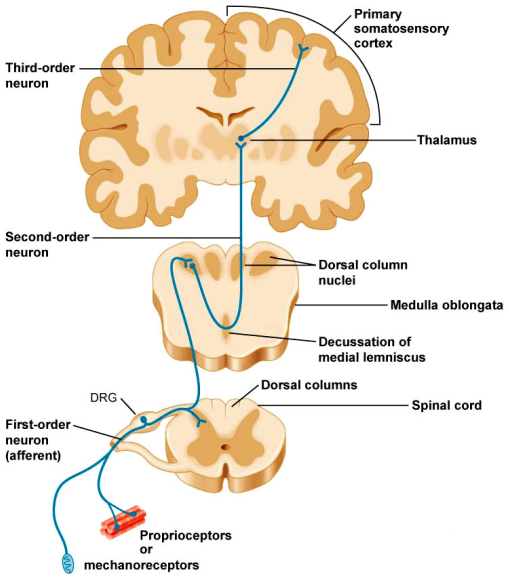
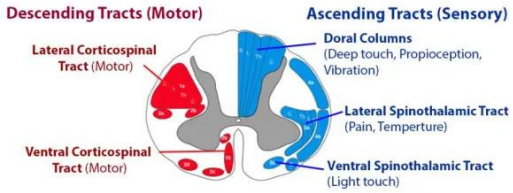
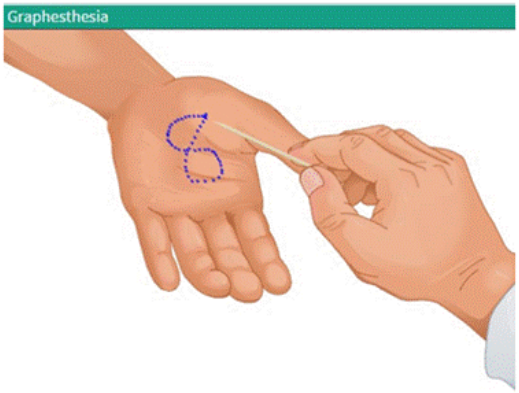
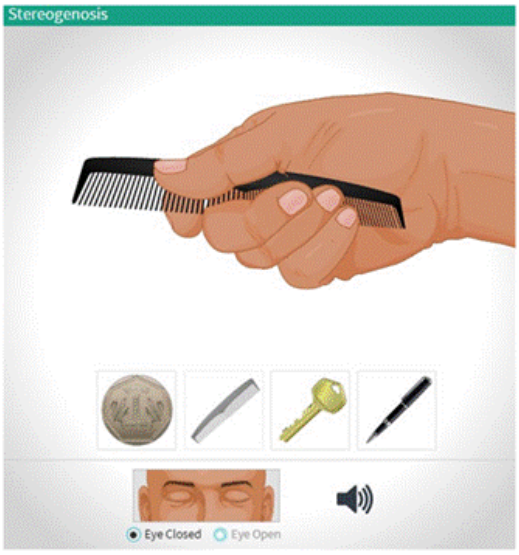
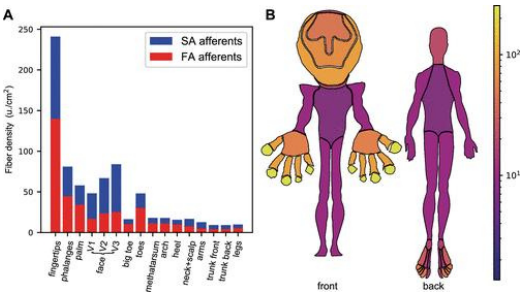
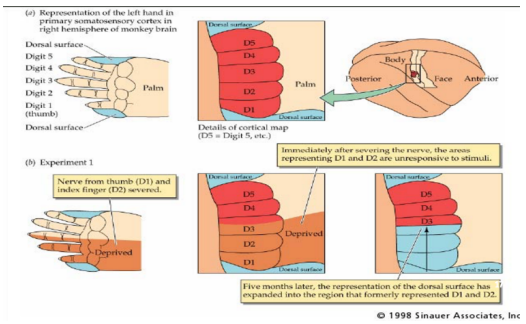
Sensation 101 Terms [For best viewing, please use this link]

Sensation	is the activation of impulses along the afferent nerves where they become an abstraction of the neural pattern on the somatosensory cortex. can be conscious and unconscious	
Touch-pressure threshold detection	the ability to perceive increasing or decreasing levels of light touch to deep pressure that correlates to detection, recognition and discrimination.	
Epicritic sensation	accurate discrimination/ recognition between small degrees of sensation - includes two point discrimination, localization, proprioception, temperature (Functional)	
Sensibility	is the conscious appreciation and interpretation of the sensory stimulus on the receptive field and the interpretation of the experience within the person - mind, body, and emotion it is a learned experience...continuously	

	reconstructed	
Proprioception	Your body's position in space (joint position sense)	
Kinesthesia	Awareness of your body's position in movement	
Graphesthesia	ability to recognize writing on the skin	
Stereognosis	ability to ID various objects of varying size, shape or texture	
Tactile Gnosis	ability to ID different objects	

Protective Sensation	sustain an injury without recognition of trauma	
Threshold	stimulus necessary for mechanical deformation	
Innervation Density	number of end-organ receptors in an area of the skin, joint, or muscle which are activated • Relates to functional discrimination • many small receptive fields associated with discrimination	
Receptive Fields	specific areas on the somatosensory cortex that correlate to the distal end organs	

Peripheral Nerve Classification and Mechanoreceptors [For best viewing, please use this link]

Group A: Myelinated	
A-delta (2-5 um)	correlated with sticking pain and temperature
A-beta (10-15 um)	correlated with touch , heavily myelinated
A-alpha (15-20 um)	motor fibers

Group C: Unmyelinated (small, 1-2 um)	correlated with burning pain

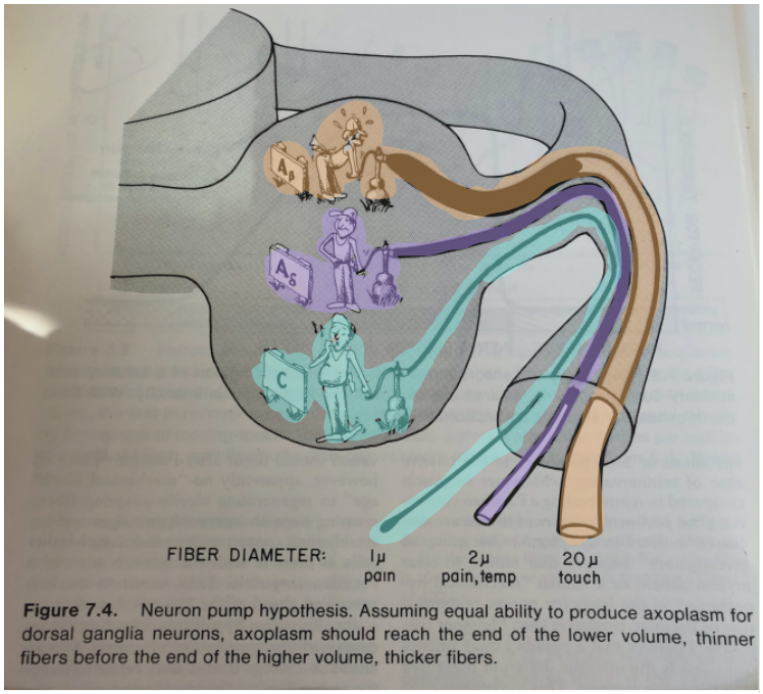
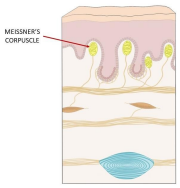
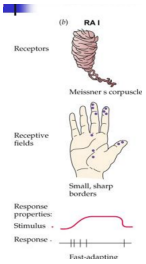
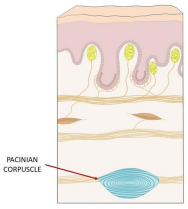
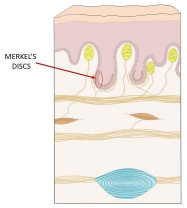


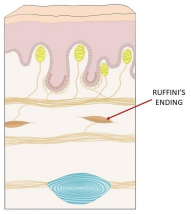
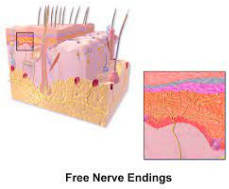
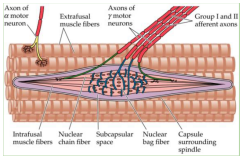
Figure 7.4. Neuron pump hypothesis. Assuming equal ability to produce axoplasm for dorsal ganglia neurons, axoplasm should reach the end of the lower volume, thinner fibers before the end of the higher volume, thicker fibers.

Cutaneous Mechanoreceptors Properties

Type of Mechanoreceptor	What it detects	How it activates/ Response frequency	How it changes based on intensity changes	Etc.
Slow Adapting	detects the info such as size and shape of objects	continue to discharge/keeps responding to constant stim	increase frequency in response to increased stim intensity	• Constant touch • Pressure • Weber test/static two point discrimination and Semmes Weinstein measures innervation density of slow adapting fibers
Quickly (Rapidly) Adapting	detects movement. moving touch	activated when stimulus is first encountered , fall silent if stimulus remains present fire briefly/cease firing	no change in impulse pattern with intensity change	Moving two point discrimination measures the innervation density of the fibers

Cutaneous Mechanoreceptors

Types	Receptive Field/ Dermal Layer	Provides CNS information regarding:	Reactive to...	Image	Image 2
Meissner's corpuscles **(Rapidly Conducting)**	Small receptive field (2-4mm) dermal layer	Localized change Moving touch (tactile gnosis), texture, or if item is sliding past the skin/ important for maintaining grip ex: tapping	low frequency vibration – 30cps fluttering sensations		
Pacinian corpuscles **(Rapidly Conducting)**	large receptive field dermal layer	Distributed change Moving touch and joint acceleration/ deceleration vibration from items when contacted or grasped: tool use ex: vibration	vibration (256 cps) –deep touch Sensitive to compressive not tensile forces		
Merkel's disks (Merkel-cell Neurite Complex) **(Slowly adapting mechanoreceptor)**	Small receptive field (2-4mm) base epidermis/folds dense in finger tips	Localized static stimuli Perceives constant touch/pressure Encodes fine spatial details/discriminative such as shape and texture	static touch		

Ruffini's ending **(Slowly adapting mechanoreceptor)**	large receptive field dermal layer	Distributed static stimuli Important to signaling movement and pressure, skin stretch-bending your finger stimulucutaneous tension ex: indentation	during motion		
Free Nerve Endings **(Rapidly conducting mechanoreceptor)**	small receptive field epidermis, located all over the body	pain and temperature	Increase in sensitivity with repeated stimulation, Injury, inflammation and infection		
Golgi-like Receptor **(Rapidly conducting mechanoreceptor)**	In joint, muscles – spray ending Similar to Ruffini ending	extreme motion	extremes of motion Silent in the immobile joint/muscle		

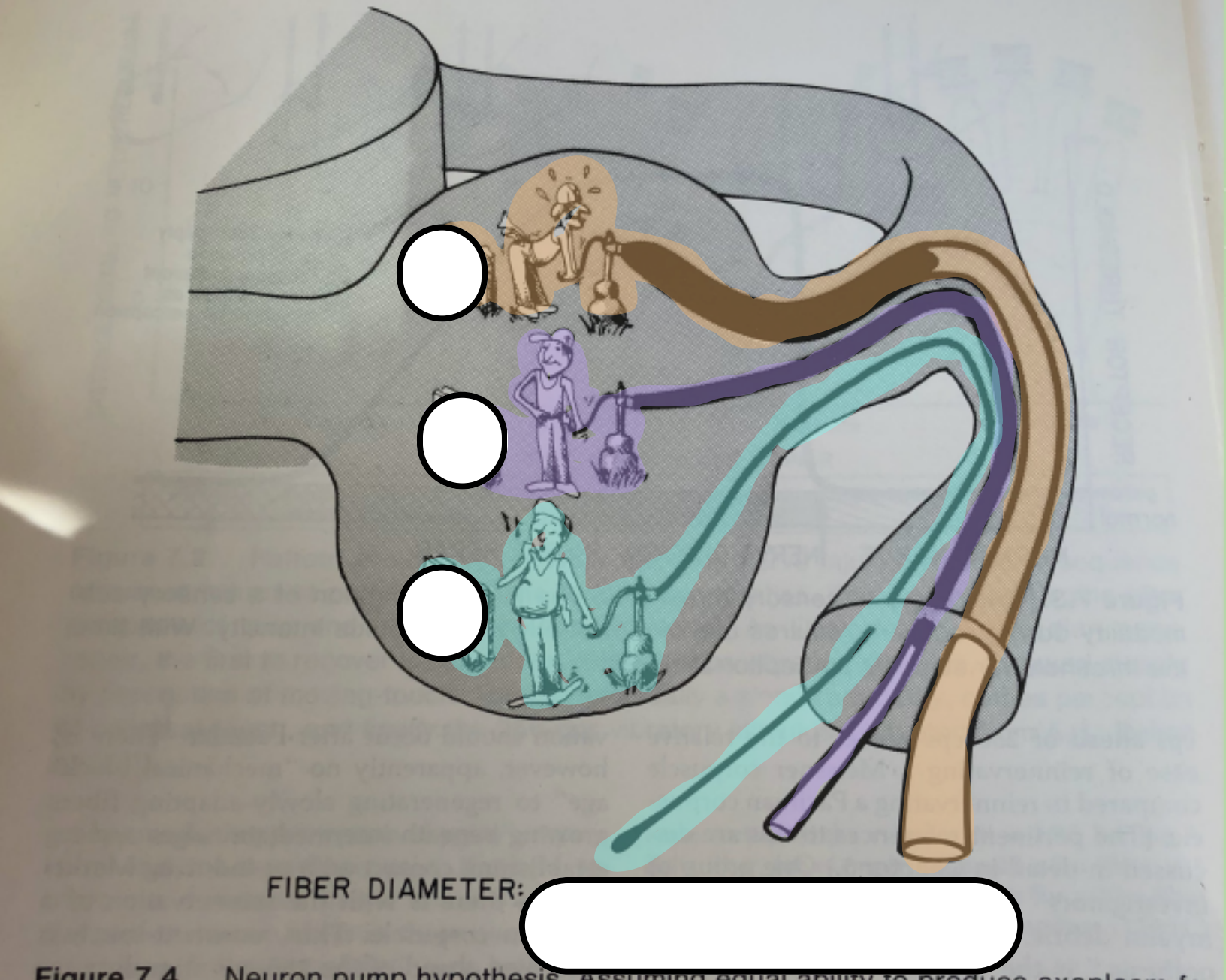


Figure 7.4. Neuron pump hypothesis. Assuming equal ability to produce axoplasm for dorsal ganglia neurons, axoplasm should reach the end of the lower volume, thinner fibers before the end of the higher volume, thicker fibers.

Label each of the nerve fibers and the sensation they detect

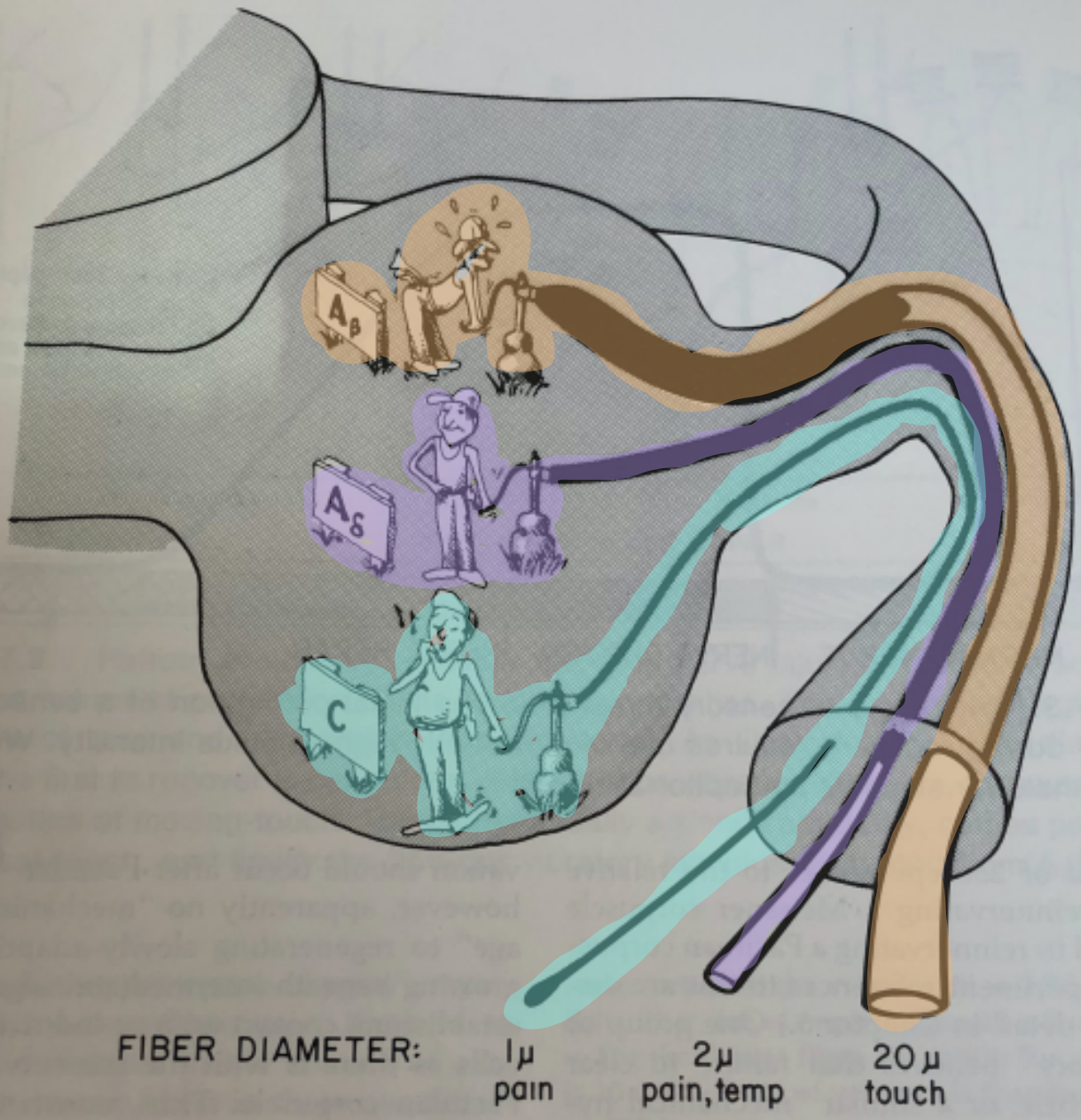
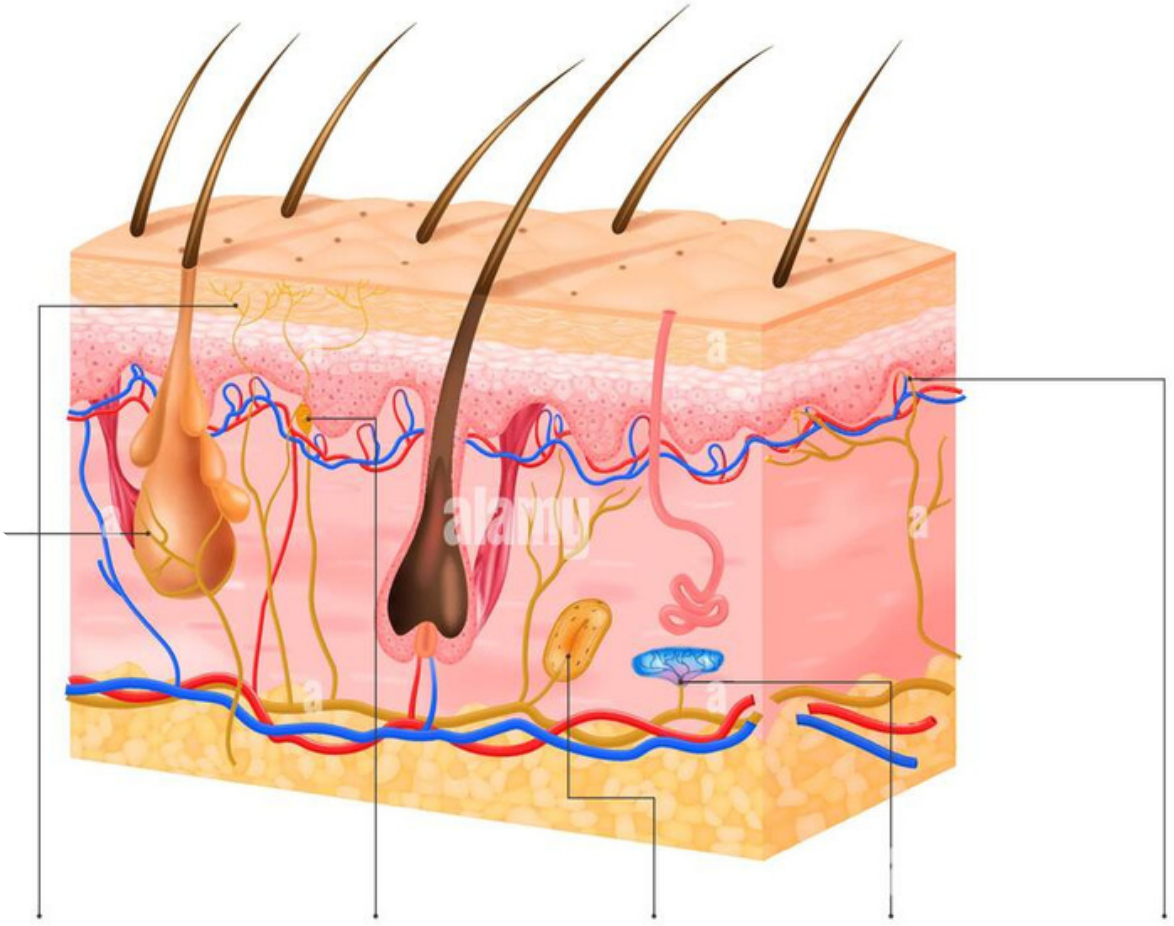
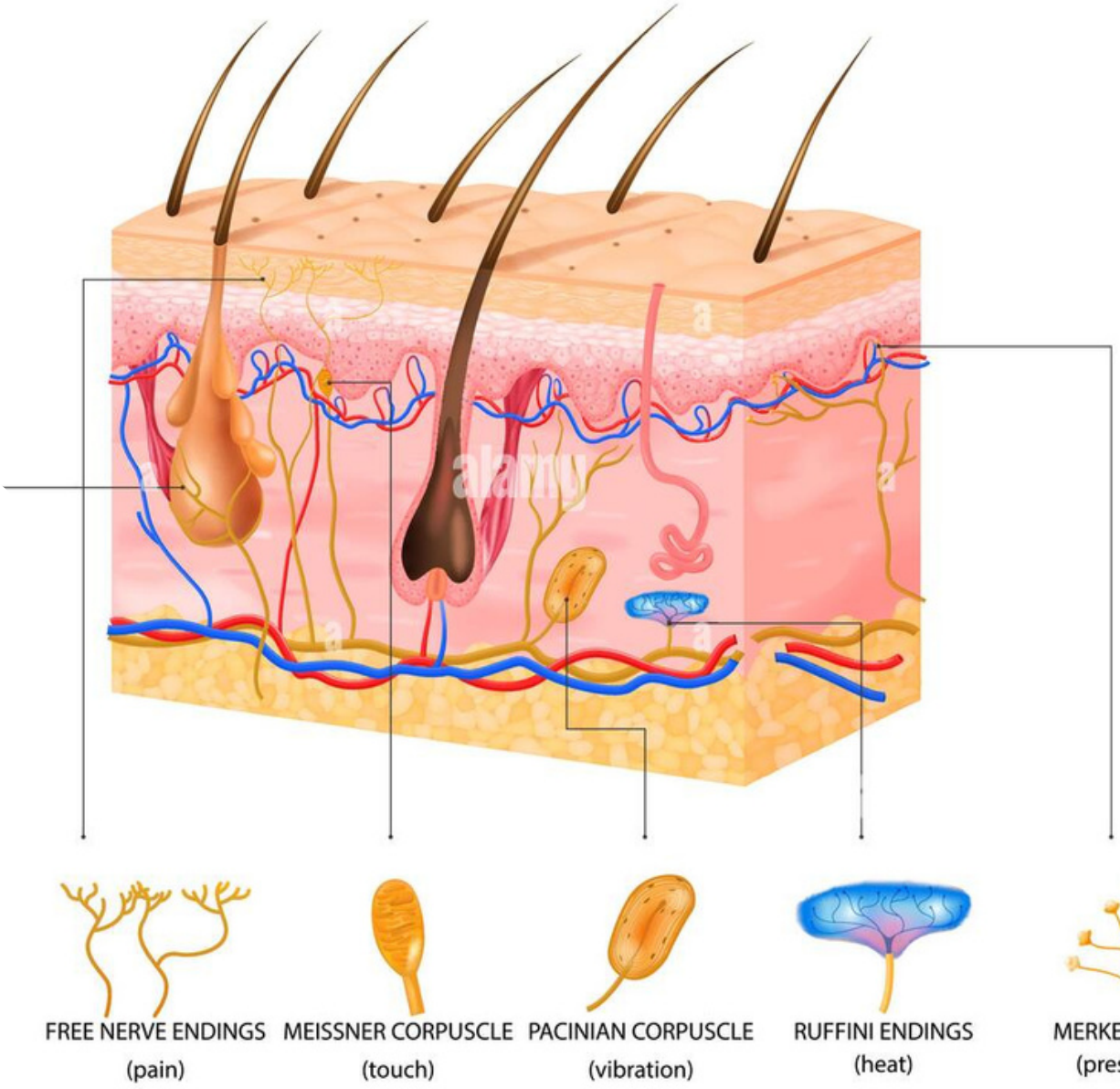


Figure 7.4. Neuron pump hypothesis. Assuming equal ability to produce axoplasm for dorsal ganglia neurons, axoplasm should reach the end of the lower volume, thinner fibers before the end of the higher volume, thicker fibers.

Identify the skin sensory receptors



SKIN SENSORY RECEPTORS



Sensory Testing [For best viewing, please use this link]

Indications for Sensory Testing

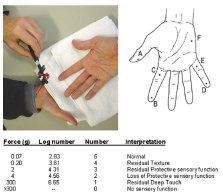
1. **Nerve Compressions (Nerve Injuries in Continuity)**
   a. Carpal Tunnel, Cubital Tunnel, Radial Tunnel Syndrome
2. **Nerve lacerations, repairs, revascularizations, amputations**
3. **Neuropathic Disease**
   a. Nerve damage due to a conditions such as diabetes, alcoholism, autoimmune diseases,

Types of Sensory Tests

1. **Threshold Tests-** minimum stimulus perceived
2. **Provocative/Stress Tests-** useful in persons whose symptoms are intermittent
3. **Innervation Density Tests-** assess useful sensibility or disability due to sensory impairment
4. **Objective Tests-**require passive participation of the person

Threshold Tests -minimum stimulus perceived

Description:	Screening tests relate only to that time Several evaluations over time are necessary to predict return, no change or worsening	
Type of Test	**Description**	**Image**
Sensory Testing	• Screening tool-defines the area of abnormal sensation • Site of reference • Initial full mapping • F/u hand screen • Following threshold tests easier	

Semmes-Weinstein Monofilament Test	• Reliable
	• Test light touch to deep pressure
	• 1.65 to 4.08 apply 3 xs for 1.5 s each to = threshold force
	• Acutely:
	• 4 to 6 wks - normal or no change for 3 exams
	
	• **1.65 to 2.83: Normal light touch**
	• **3.22 to 3.61 : Diminished light touch**
	• **3.84 to 4.31:Diminished protective**
	  ○ **Sensory Reeducation** is initiated at this level
	  ▪ Visually compensate
	  ▪ Distribute pressure when gripping
	  ▪ Avoid prolonged use of one tool
	  ▪ Check skin frequently
	• **4.56 to 6.65: Loss of protective sensibility**
	  ○ Protective sensory reeducation is essential
	• **> 6.65: Untestable. Perception of pain is questionable**
	  ○ Protective education is required
		

30HZ AND 256HZ VIBRATION	• Nerve compression, peripheral neuropathies, nerve repairs • Dellon observed that nerve compressions respond with an increase threshold • Determines when to start sensory reeducation	
PAIN PERCEPTION/ PINPRICK	• Classic test for protective sensibility • Indicated with high-level lesions and brachial plexus injuries • Pain perception is the first to be felt in nerve return	
TEMPERATURE TESTS	• Included in a sensory evaluation when pinprick is absent • Assess for protection from burns • If absent, protective education required	

Provocative/Stress Tests-useful in persons whose symptoms are intermittent

Description:	utilized as a means to detect whether certain conditions are present in a patient	
Type of Test	**Description**	**Image**

Wadsworth Elbow Flexion Test	• Assessment for Cubital Tunnel Syndrome and Ulnar Nerve Palsy at the Elbow
	  ○ The patient completely flexes the elbow.
	  ○ The elbow is held in the flexed position for up to 5 minutes.
	• **Positive Test:** If tingling or paresthesia occurs in the ulnar distribution of the forearm and hand
	  ○ A positive finding suggests the presence of cubital tunnel syndrome.
		

Phalen Test	• Patient is in standing or sitting position • Ask patient to maximally flex both wrists while pressing the dorsal side of both hands against each other • Hold this position for one minute. • **Positive test:** the patient's paresthesia in the distribution of the median nerve will be reproduced, namely tingling in the thumb, index, and middle finger and/or the medial half of the ring finger. ○ A positive finding suggests the presence of carpal tunnel syndrome	
Durkan Test	• Patient seated with elbow flexed 30 degrees • Forearm supinated • Wrist in neutral position • The examiner places both thumbs over transverse carpal ligament and applies pressure for 30 seconds maximum • **Positive test:** if the patient have symptoms of numbness, pain, or paresthesia in the median nerve distribution (the three lateral finger with the lateral half of the forth one)	 

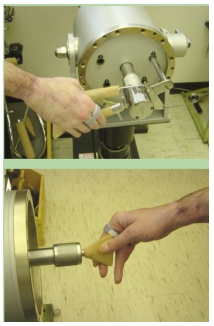
Tinel's Sign	• Tinel Sign – 2 sites
	  ○ **Proximal site** of tingling sensation is at or near the site of injury
	  ○ **Distal site** of tingling sensation shows how far the nerve has regenerated
	• **Patient is in sitting position with the forearm and hand placed comfortably on the treatment bench**
	• **The examiner then uses two fingers to tap on the median nerve at the wrist.**
	• **Tapping along the entire distribution of the median nerve from the index finger to the medial forearm.**
	• **Positive test: tingling in the thumb, index finger, middle finger, and/or medial half of the ring finger are reproduced.**
		

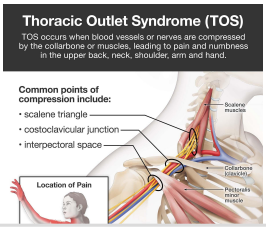
Radial Sensory Nerve Compression	• Forearm pronation with wrist flexion and ulnar deviation • **Positive test: tingling, pain, numbness when provoked**	
Stress Tests	• Test for transient stress neuropathy before and after irritating activities ○ Observe ADL tasks that elicit symptoms	

- Symptom-provoking activity for 5 -30 min
- Observe posture to rule out proximal causes

- **Positive test:** **tingling, pain, numbness after or during activity**

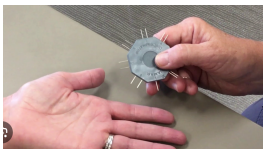
- Example: Thoracic Outlet Syndrome
  - Usually caused by overhead activities or rounded and forward shoulders

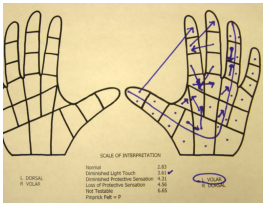




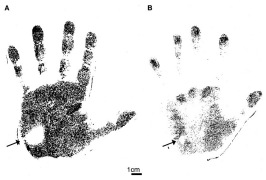
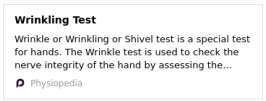
Innervation Density Tests- assess useful sensibility or disability due to sensory impairment

Description:	• Assess quality of reinnervation and the organization of the somatosensory cortex • Indicate functional usefulness of sensation in ADLs	
Type of Test	**Description**	**Image**

2 point discrimination/ Classic test of functional sensibility	• Assesses ability to interpret patterns and identify objects
	• Static 2PD recovers 2 to 6 months after Moving 2PD
	• Only finger tips are tested
	• Assess - 4 to 6 wks until normal or no change noted in 3 f/u evaluations
	
	Static 2PD: (prongs up and down)
	
	• 2PD Norms
	  ○ Normal < 6mm
	  ○ Fair 6-10mm
	  ○ Poor 11-15mm
	• Protective
	  ○ One point perceived
	• Anesthetic
	  ○ Nothing perceived
	
	Moving 2PD (prongs side by side)
	
	• Finger tip sensibility is highly dependent on motion
	• Discrimination test should be moving
	• Instrument set with 2 points 6mm apart
	• Proximal to distal
	• Prongs side by side, horizontal to long axis of digit
	• 2/3 correct responses
	
	• Gives information about ADL tasks that use moving touch
	  ○ writing, handling coins in a pocket, small buttons
	• Better test of hand function than SW and vibration
	• **Returns before static 2PD** after nerve laceration
	• Reliable
		

Localization	• Discriminative test • Most appropriate after nerve repair • Higher level of cortical perception than static 2PD • Use finest SW monofilament perceived • Learned skill – need to recall shapes of objects and textures	
Functional Task Observation	• Observe from the initial greeting • Two-handed and one-handed activities using the affected hand	
Moberg Pick-Up Test	• Median or combined median-ulnar lesions • Assesses functional touch discrimination (tactile gnosis) • Timed, involved/uninvolved hand, eyes open, eyes closed • **Dellon Modification** → asks the person to name the 12 objects • Reevaluate every 4 to 6 weeks	

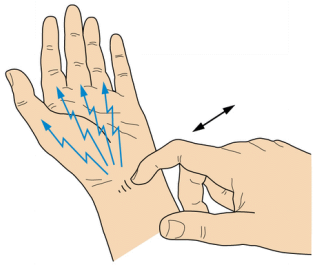
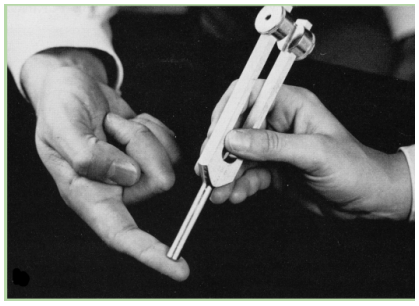
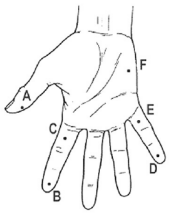
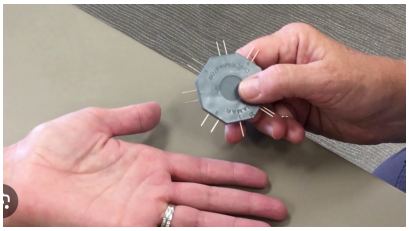
Objective Tests- require passive participation of the person

Description:	• Evaluates sudomotor function not functional sensation • Usually used for uncooperative person or child	
Type of Test	**Description**	**Image**
Ninhydrin Test	• Shows areas that do not sweat following peripheral nerve injury • Return of sweating coincides with return of pain and temperature (protective sensation)	
The O'Riain Wrinkle Test	• Tests for sympathetic nerve function • Denervated area does not wrinkle • The least reliable test • Both hands are immersed in 42C (107.6F) water for 20 to 30 minutes • Pattern of skin wrinkling is recorded • Evaluated every 4 to 6 wks until no change for 3 evaluations	  (Negative sign)

Sensory Batteries

Nerve Compression

POTENTIAL SITES OF COMPRESSION	Pattern of Recovery	Threshold changes- Symptoms	Innervation density changes- Symptoms
• Neck • Thoracic Outlet • Cubital Tunnel • Radial Tunnel • Radial Wrist • Carpal Tunnel • Guyon's Canal • Digits (laterally)	• Pain • Tinel's sign • Pressure • Light touch	• Numbness • Paresthesias • Pain	• Clumsiness • Difficulty handling small things

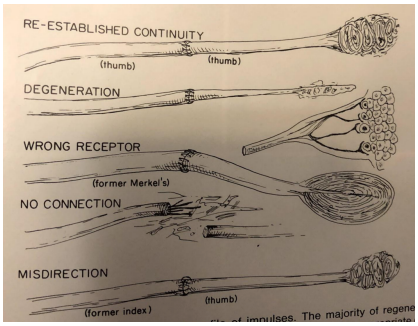
Nerve Compression Battery- Tests	Image
1. Nerve Conduction Velocity (NCV) Studies 2. Tinel test at the problem site 3. Vibration test 4. SW monofilament test **If the above are ABNORMAL then continue with →** 1. Static and moving 2PD 2. Positional and/or dynamic stress tests 3. threshold tests	1. NCV  2.Tinel  3.Vibration  4.Semmes-Weinstein   Force (g) / Log number / Number / Interpretation 0.07 / 2.83 / 5 / Normal 0.20 / 3.61 / 4 / Residual Texture 2 / 4.31 / 3 / Residual Protective sensory function 4 / 4.56 / 2 / Loss of Protective sensory function 300 / 6.65 / 1 / Residual Deep Touch >300 / -- / 0 / No sensory function **If the above are abnormal..** 1. Static/Moving 2PD 

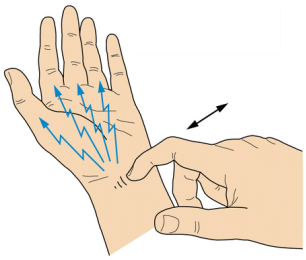
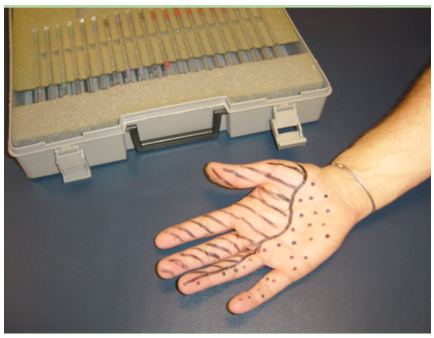
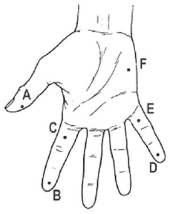
2.Positional/Dynamic Stress Tests

3.Threshold Tests

Nerve Laceration

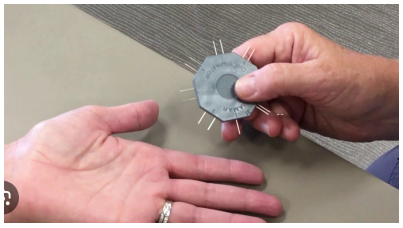
COMMON SITES OF LACERATION	Pattern of Recovery	NERVE REPAIRS- Symptoms	Re-innervation hypothesis/based on axon: corpuscle ratio

• Volar/Dorsal Wrist
• Digits
• Elbow
	• Pattern of recovery –Dellon
	  ○ Perception of pain and temperature
	  ○ Vibration (30 Hz)
	  ○ Constant touch
	  ○ Vibration (256 Hz)
	  ○ Moving 2PD
	  ○ Static 2PD
		Regenerating nerve axons frequently do not reinnervate the same fascicles and sensory fibers may be cross innervated with other sensory fibers and motor fibers.
		
		• Spontaneous sensations are usual
		• "electrical" prickly, itching, buzzing, tickling or hot and cold sensation
		• Referred touch common at first
		
		 
		
			• Meissner corpuscle (30cps vibration/moving touch)
			• Pacinian corpuscle (256 vibratory stim and moving touch)
			• Merkel Disc (static touch/discriminatory)

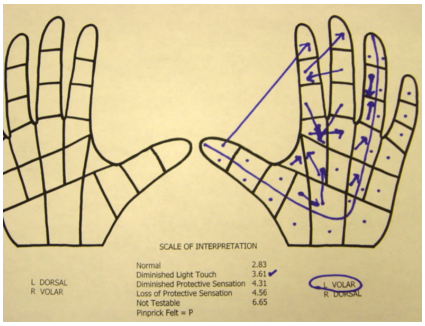
Nerve Laceration (Post-Repair) Battery- Tests	Image
1. Tinel test 2. Serial sensory mapping 3. SW monofilament test **If pt. does not respond to largest SW monofilament then** → Pinprick test **If pt. does respond to SW test then** → Functional test a. Moving 2PD b. Static 2PD c. Localization d. Moberg pickup test	1. Tinel  2.Serial sensory mapping  3.Semmes-Weinstein   **Force (g) / Log number / Number / Interpretation** 0.07 / 2.83 / 5 / Normal 0.20 / 3.61 / 4 / Residual Texture 2 / 4.31 / 3 / Residual Protective sensory function 4 / 4.56 / 2 / Loss of Protective sensory function 300 / 6.65 / 1 / Residual Deep Touch >300 / -- / 0 / No sensory function **If pt. does not respond to largest SW monofilament then** → 1. Pinprick  **If pt. does respond to SW test then** →

1. Functional test

Moving 2PD / Static 2PD



Localization



Moberg Pick-Up Test

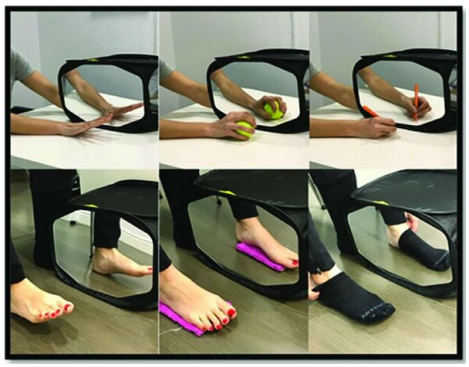
Sensory Desensitization & Reeducation

[For best viewing, please use this link]

Sensory Desensitization	Sensory Reeducation

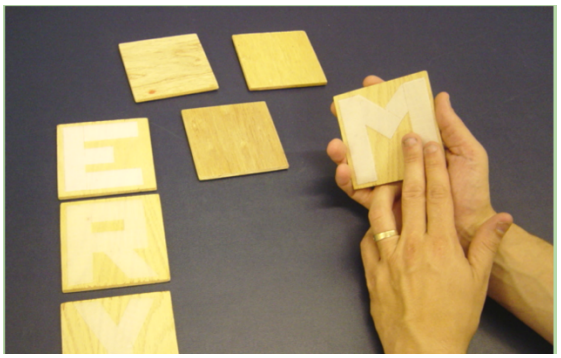
• Desensitization programs increase stimulation of the large A-Beta fibers to block input from the small pain fibers and provide the opportunity for non-painful sensory re-education with different texture discriminatory challenges
 	
• **Interventions to decrease hypersensitivity**
  ○ Decreases perception of noxious stimuli
  ○ Precedes sensory reeducation
  ○ Progress through a graded sensory program
 	
• Comes **FIRST** before Sensory Reeducation
 	
 
	• Patient learns to “know” altered patterns of perception
	• Our sensory cortex adapts and understands changed patterns is the basis for sensory - motor reeducation
	
	• **Common Reeducation Programs**
	  ○ Graded stimuli
	  ○ Localization of stimuli
	  ○ Discrimination
	  ○ object identification
	  ○ object manipulation
	
	• Comes **AFTER** Sensory Desensitization

Sensory Reeducation: Early Phase/Phase I & II

Description / Goals	What it composes of..	When should we begin?
• Patient focuses on relearning to interpret moving or constant touch that is not in the location it is perceived • Reeducation of touch localization is accomplished with practice, repetition, concentration and memorization • Stimulates the sensorimotor cortex to babysit individual neurotags	• Right/left laterality recognition  • Visualization/ Motor Imagery  • Mindfulness/observed action • Mirror Therapy	**Dellon** Begins when 30Hz and moving touch are present in the palm and thenar eminence **Imai** Begins when moving touch is perceived over the pulp of the thumb, IF or LF **Callahan** Begins when 4.31 SW monofilament is perceived at the fingertips

Sensory Reeducation: Late Phase (Discriminative or Tactile-gnosis stage)

Description / Goals	What it composes of..	When should we begin?

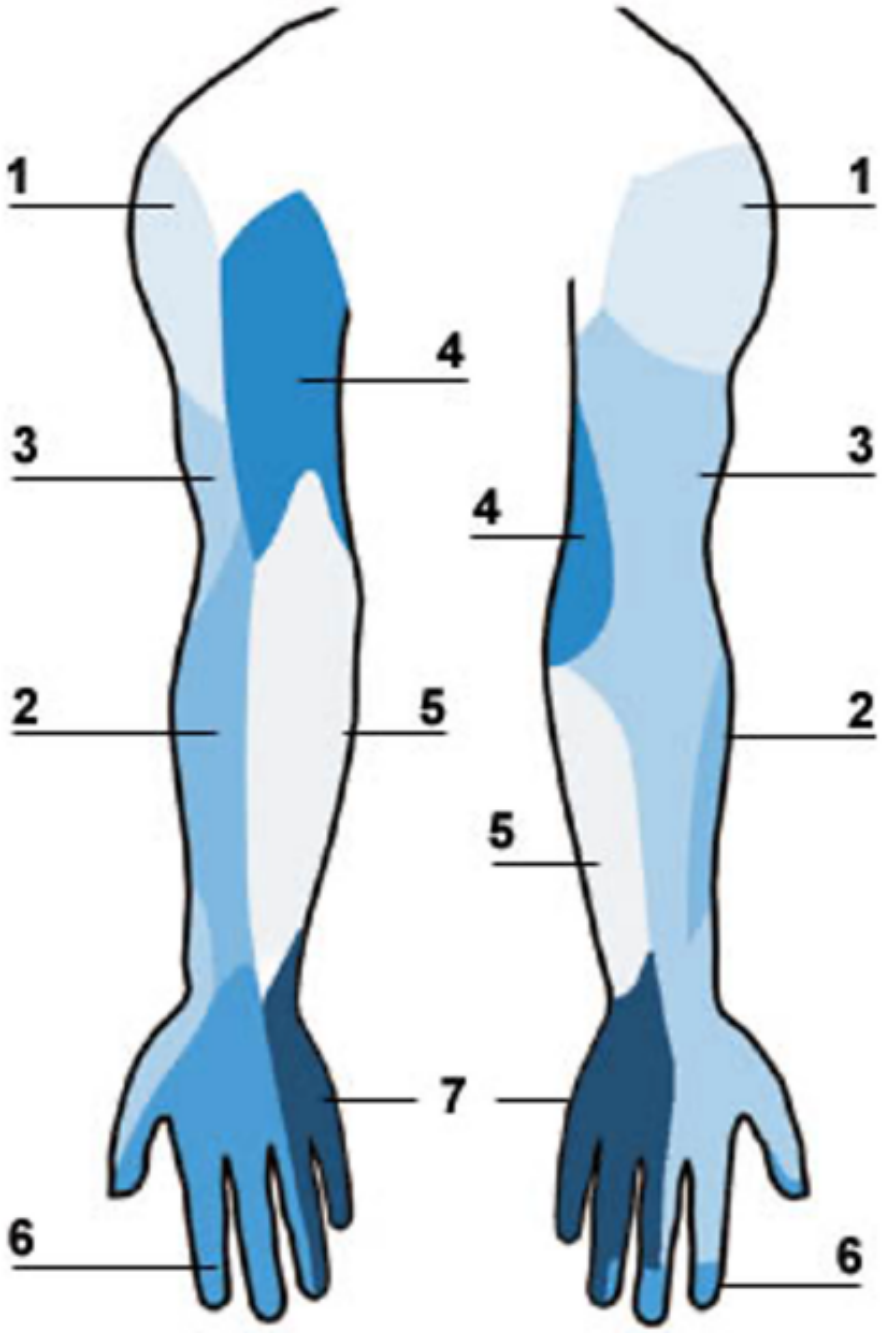
• Able to correctly identify objects
 
• Able to discriminate between objects of similar textures, sizes and shape
 
	Re-education
	• 3-5x/day, 10-15 min, short concentrated sessions over longer session
	• Focus on discriminatory tasks
	Examples:
	• Manipulate objects with..
	  ○ vision
	  ○ vision occluded
	  ○ then vision again
	  ○ → reinforces the incoming sensory and cortical information
	 
	• Retrain the person to identify new sensory experiences
	 
	• Move objects with affected digits
	• ***If motor problems*** → move objects over the digits with the unaffected hand
		Localization
		• Reevaluated every 2 to 4 wks
		• semmes weinstein 4.31 or greater
		• When moving and constant touch have advanced to the fingertips with good localization, late-phase sensory reeducation can begin

- Variety of textures, shapes, sizes, familiar household objects

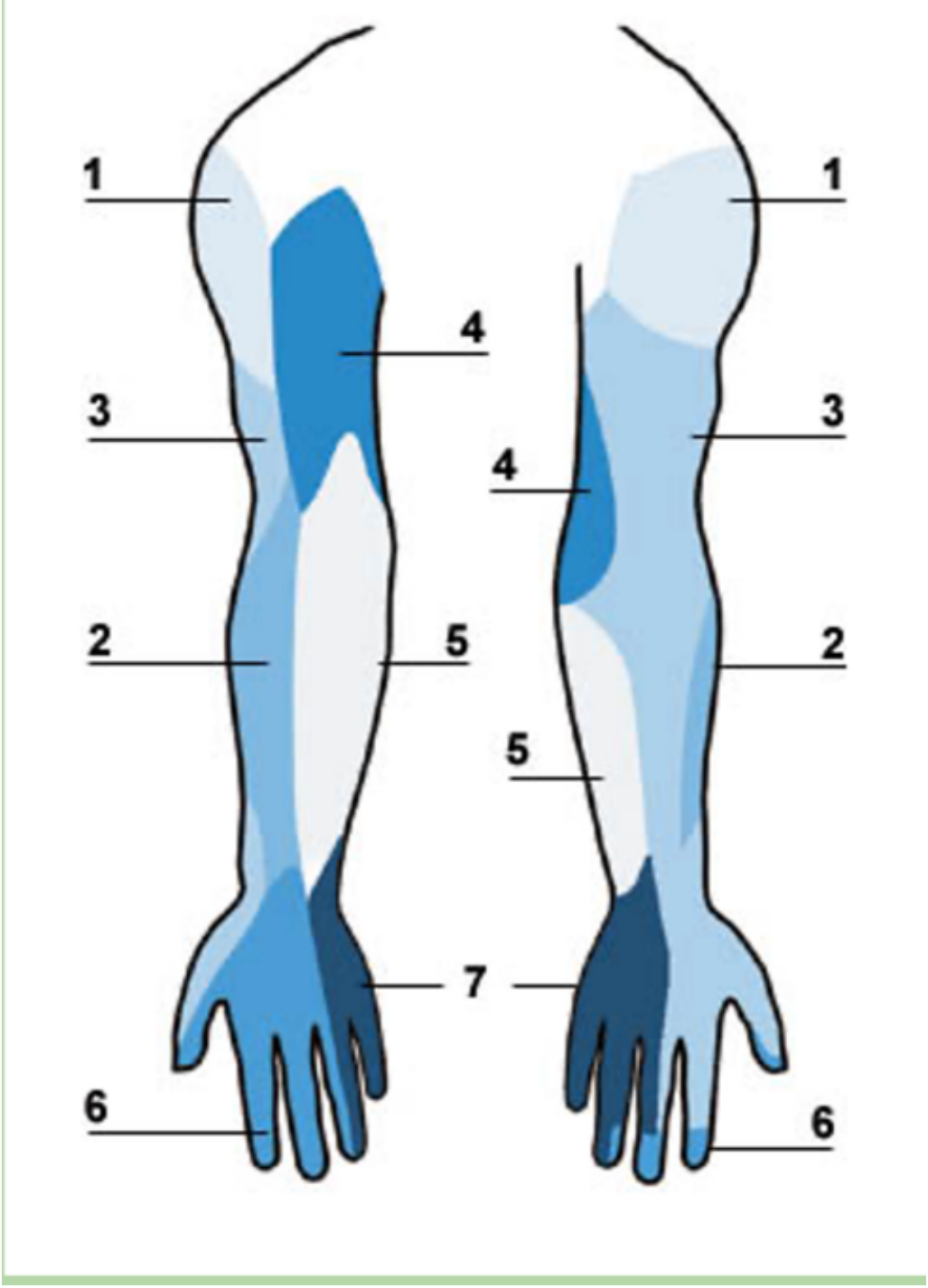
- Begin with large differences progress to finer differences

- Include functional activities stimulate the sensory cortex

- Proprioception important to precision grip - PNF
- Wynn-Parry – weighted objects
- Carter-Wilson – weight with different textures



Label the appropriate peripheral nerves on this sensory map



1. **Axillary Nerve**
2. **Musculocutaneous Nerve**
3. **Radial Nerve**
4. **Medial Cutaneous Nerve to Upper Arm**
5. **Medial Cutaneous Nerve to Forearm**
6. **Median Nerve**
7. **Ulnar Nerve**

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