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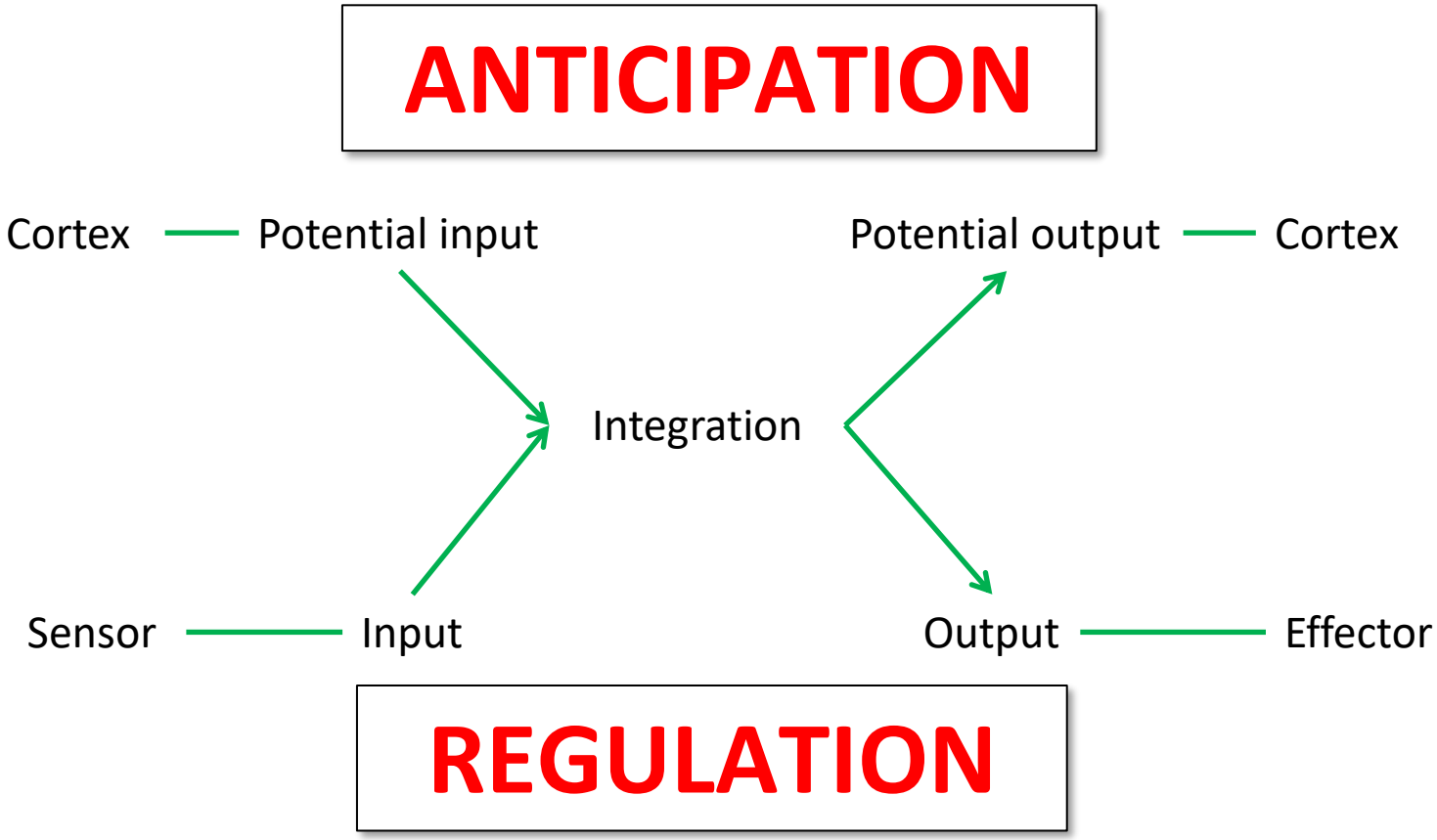
Somatosensitivity, pain

The role of nervous system



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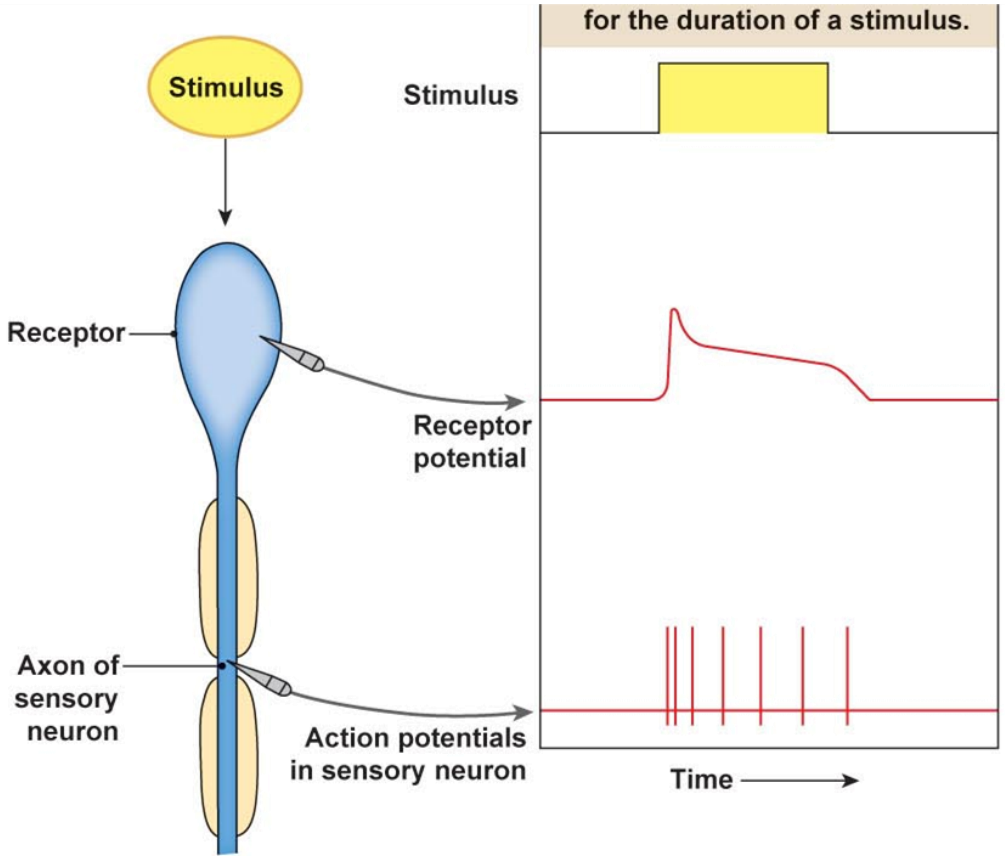
Receptors/sensors

- Energy convertor
  - Signal reception
  - Signal transformation
- Receptor potential
  - Generator potential
- Action potential



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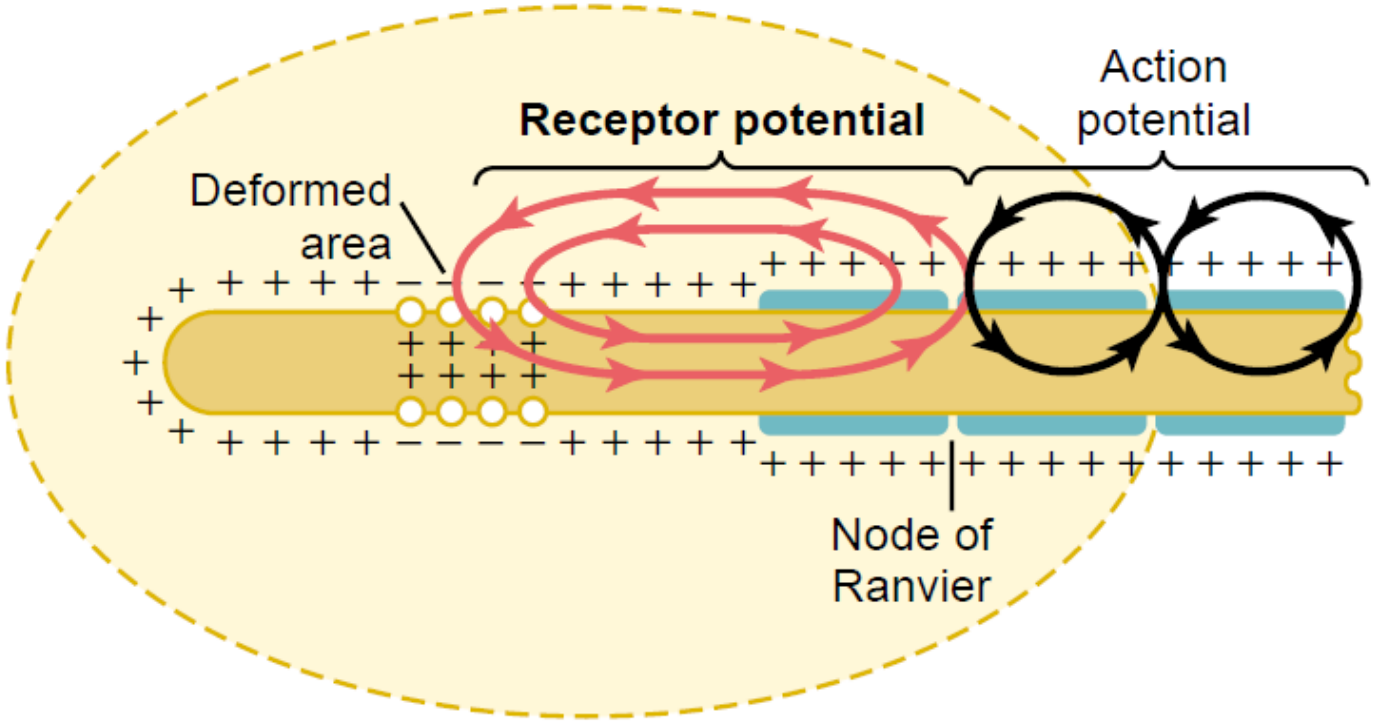
Receptor/generator and action potential



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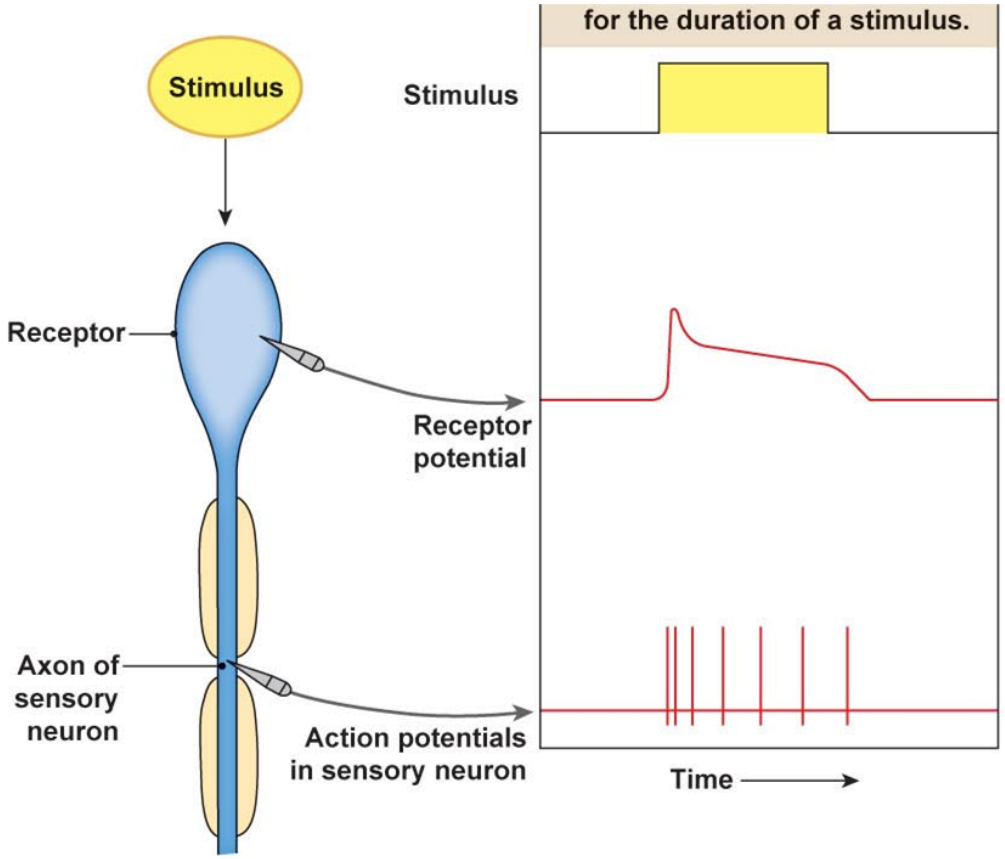
Receptors/sensors

- Energy convertor
  - Signal reception
  - Signal transformation
- Receptor potential
  - Generator potential
- Action potential
- Adequate stimulus
- Non adequate stimulus



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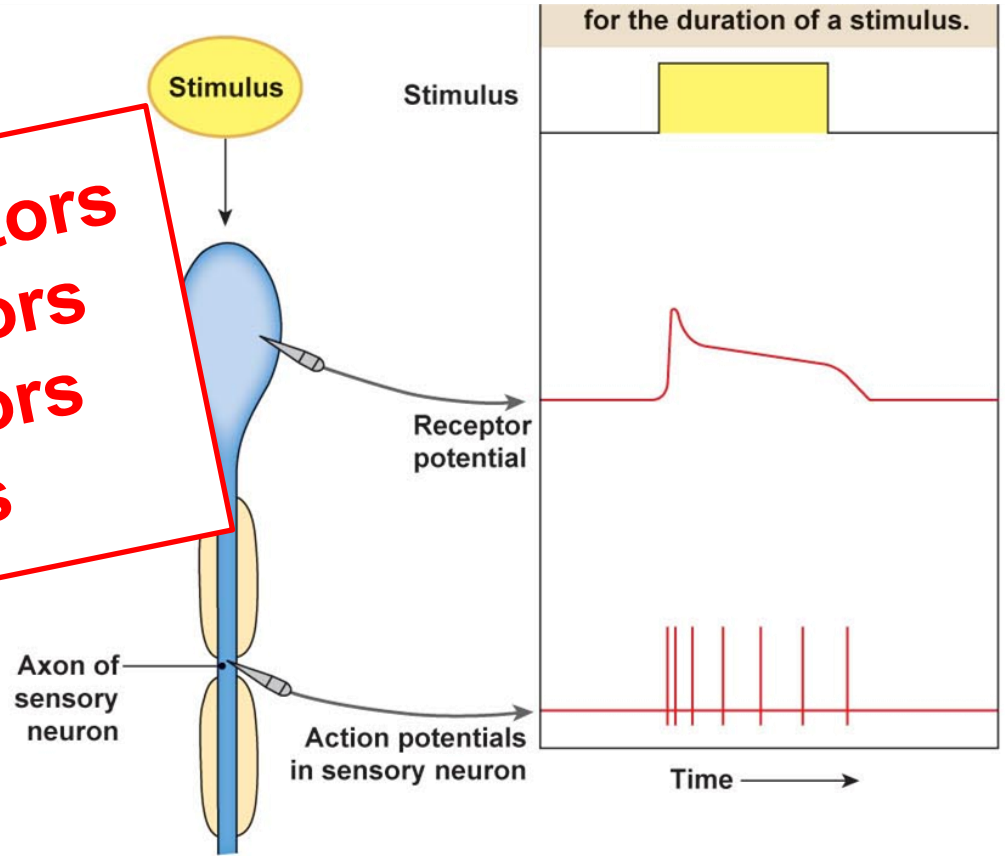
✓ Mechanoreceptors
✓ Thermoreceptors
✓ Chemoreceptors
✓ Fotoreceptors



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Receptors/sensors

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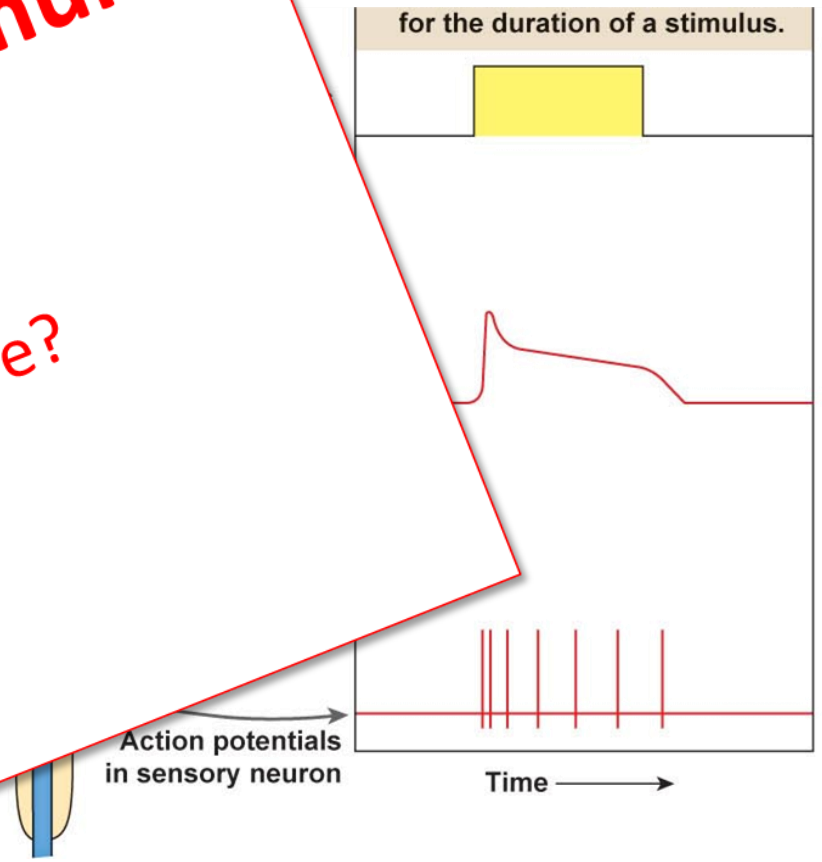
- Adequate stimulu
- Non adequate stim

Basic attributes of stimulus

Qualitative

Modality - What?

Localization - Where?



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Basic attributes of stimulus

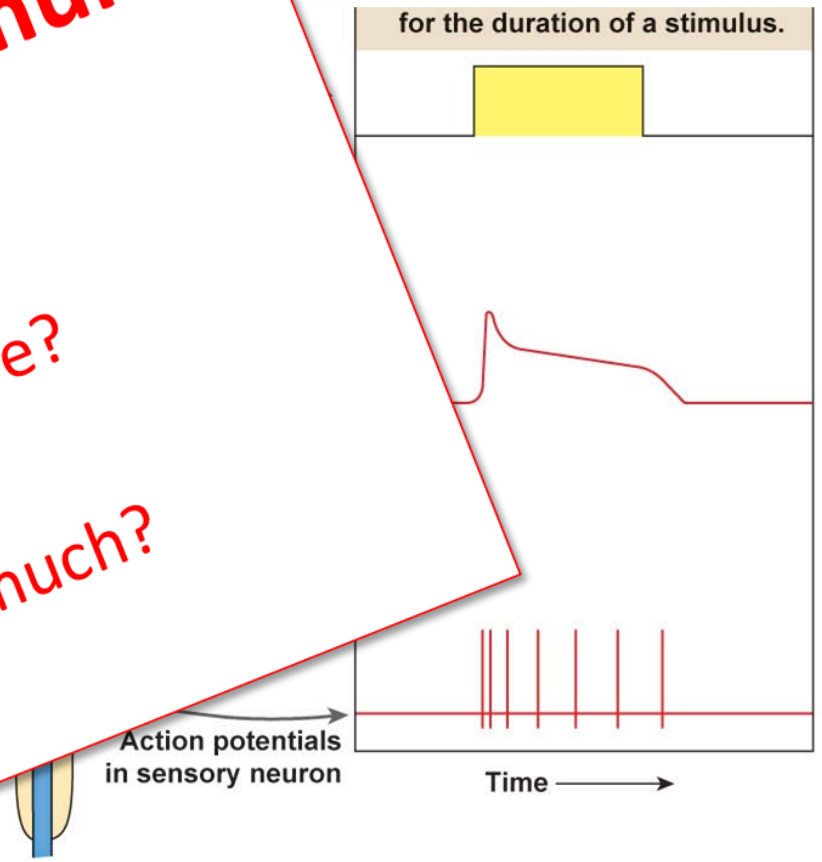
Qualitative

Modality - What?

Localization - Where?

Quantitative

Intensity - How much?



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Basic attributes of stimulus

Qualitative

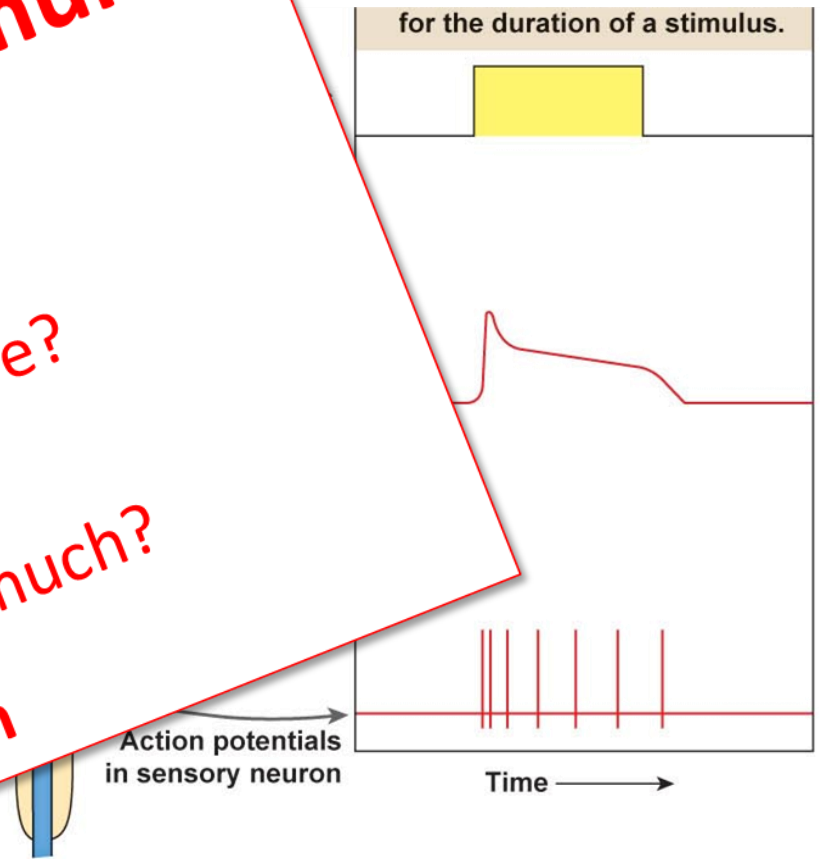
Modality - What?

Localization - Where?

Quantitative

Intensity - How much?

Duration



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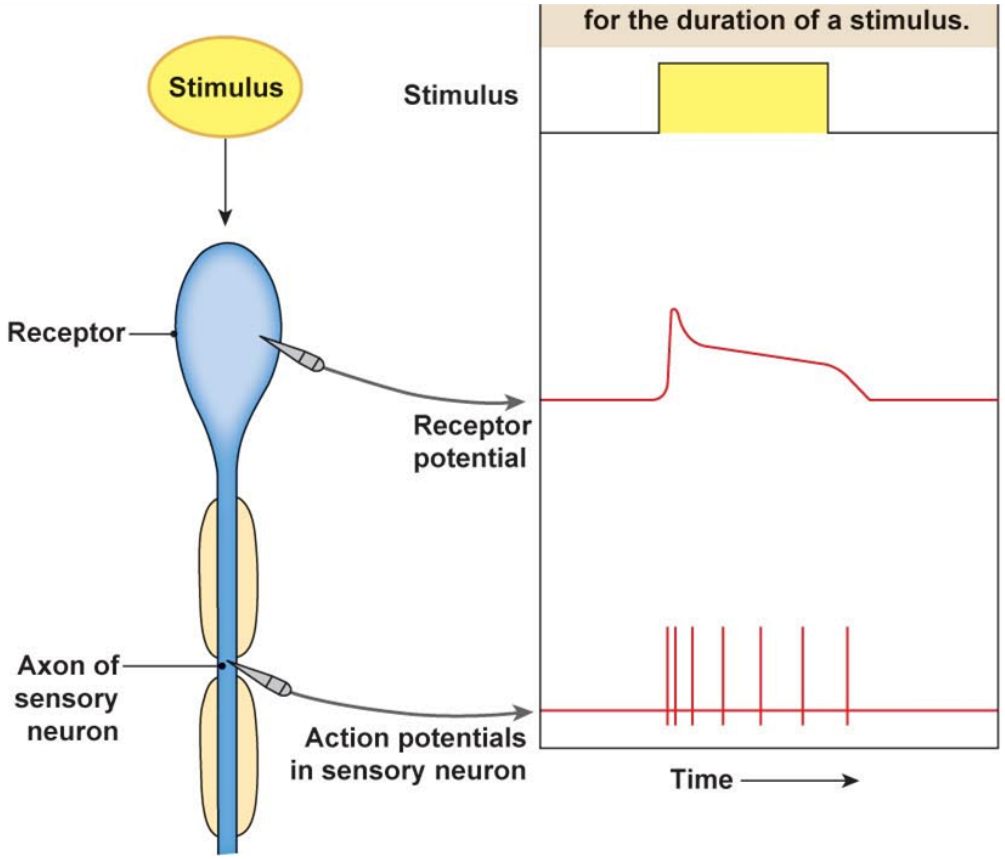
Intensity coding

How much?

- Amplitude of receptor potential is transtucted into the frequency of AP



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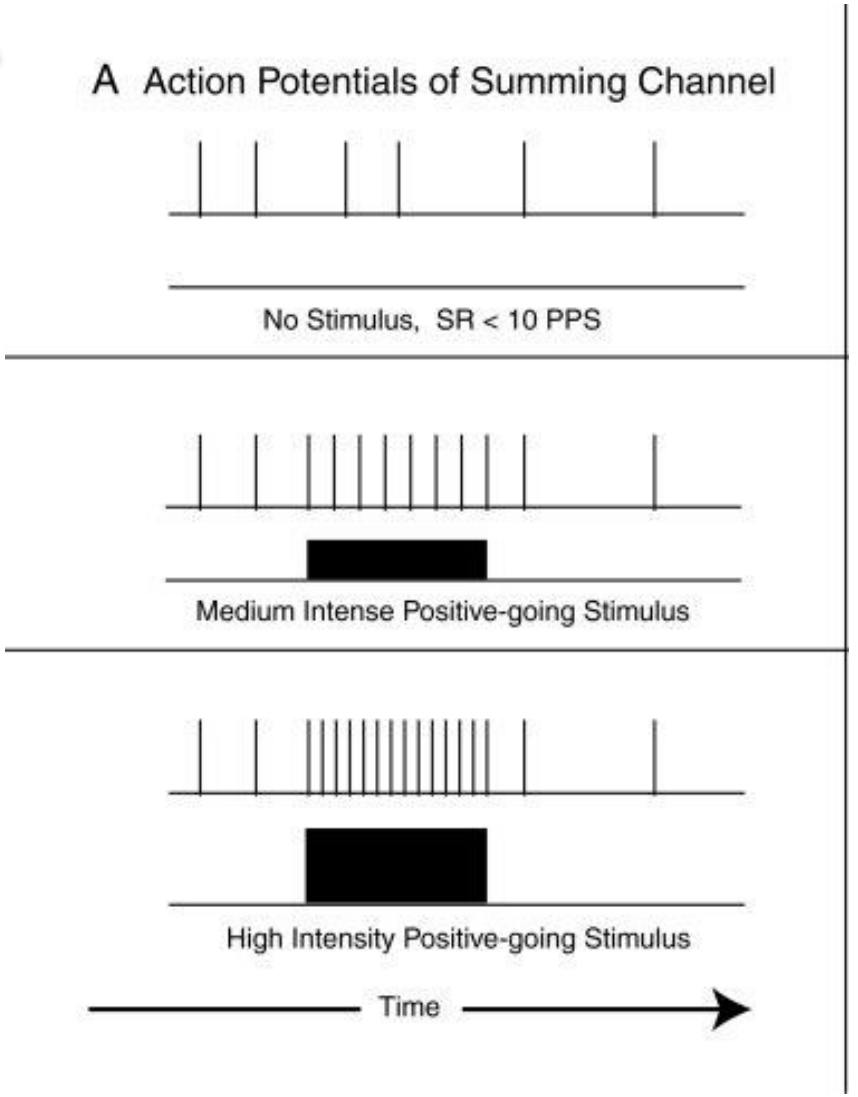
Intensity coding

How much?

- In the other words: an increased intensity is associated with increase in frequency of AP
- A high-intensity stimulus may also activate more receptors



http://neuronresearch.net/neuron/files/neuralcode.htm

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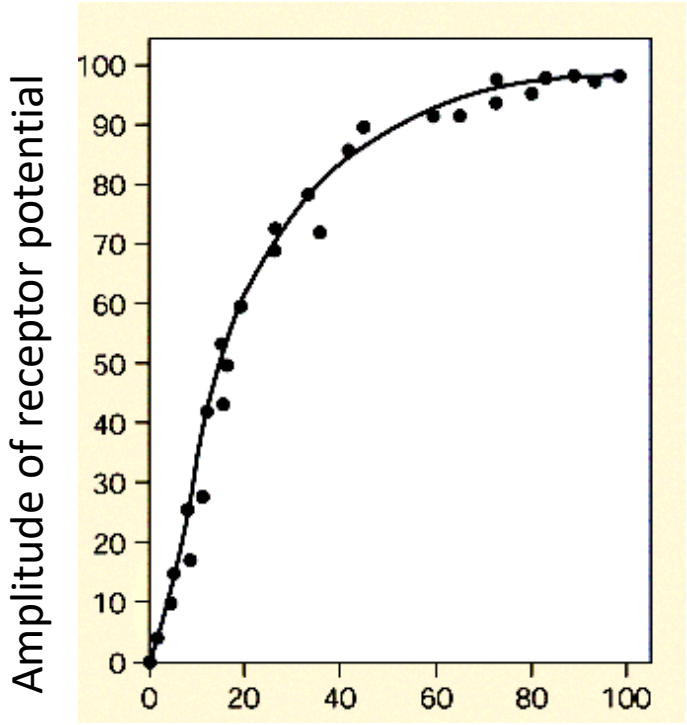
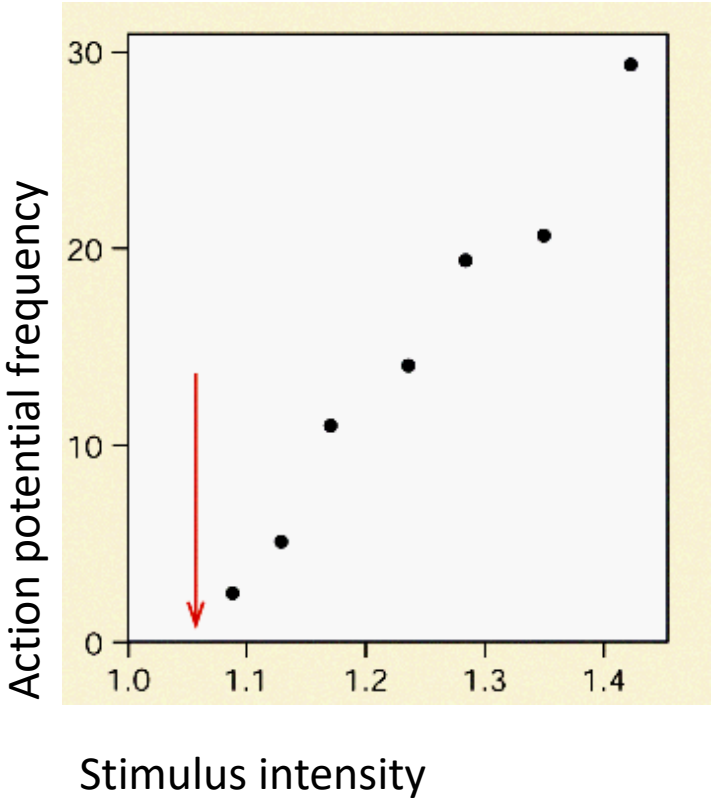
Intensity coding

How much?

- Relation between receptor and action potential is logarithmic





http://slideplayer.cz/slide/3217923/

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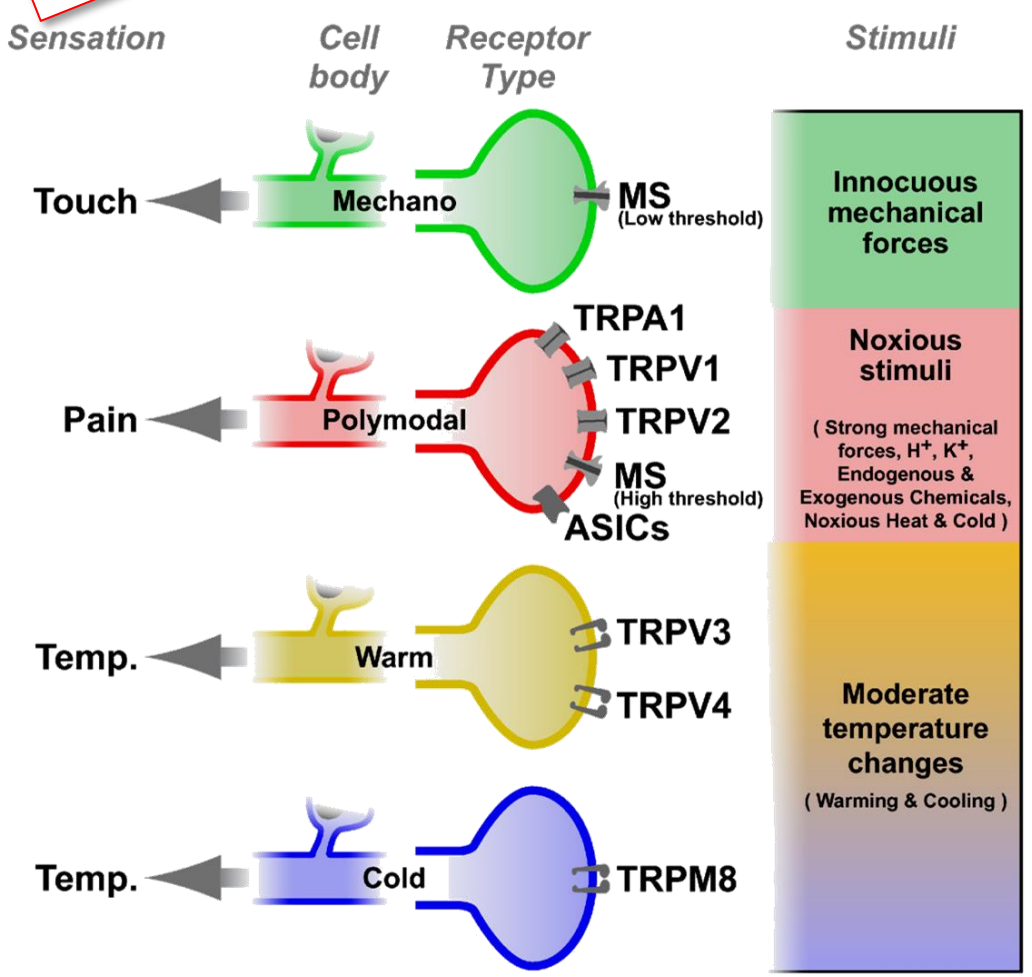
Qualitative information

What?
Where?

- **The law of specific nerve energies:**

  The nature of perception is defined by the pathway over which the sensory information is carried

- Labeled line coding define the information about quality



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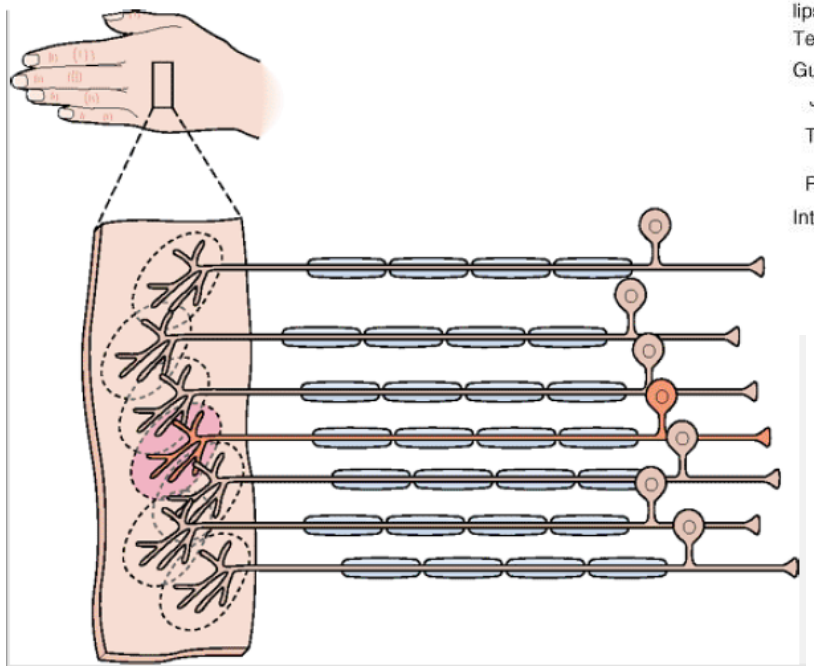
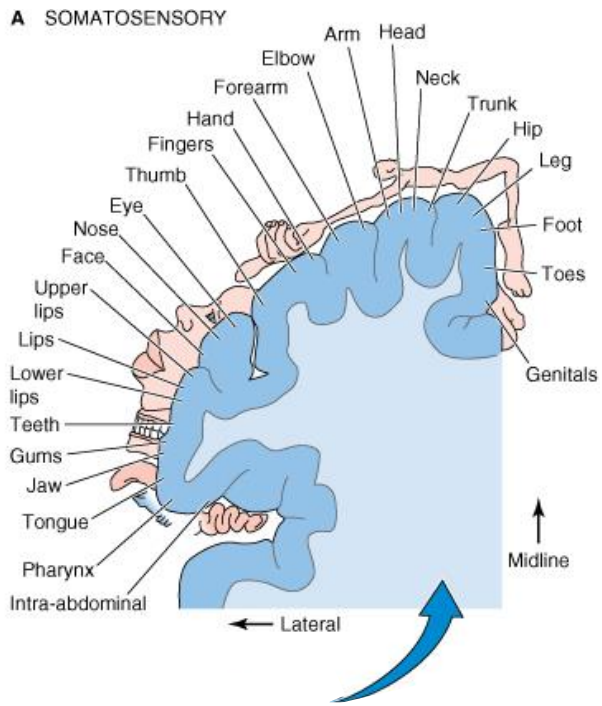
Qualitative information

What?
Where?

- Labeled line coding
- Receptive field
- Nerve stimulation mimics receptor stimulation





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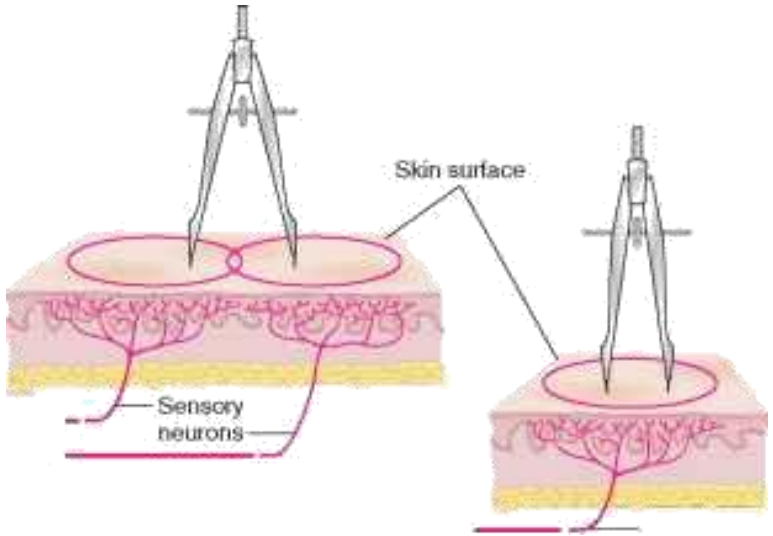
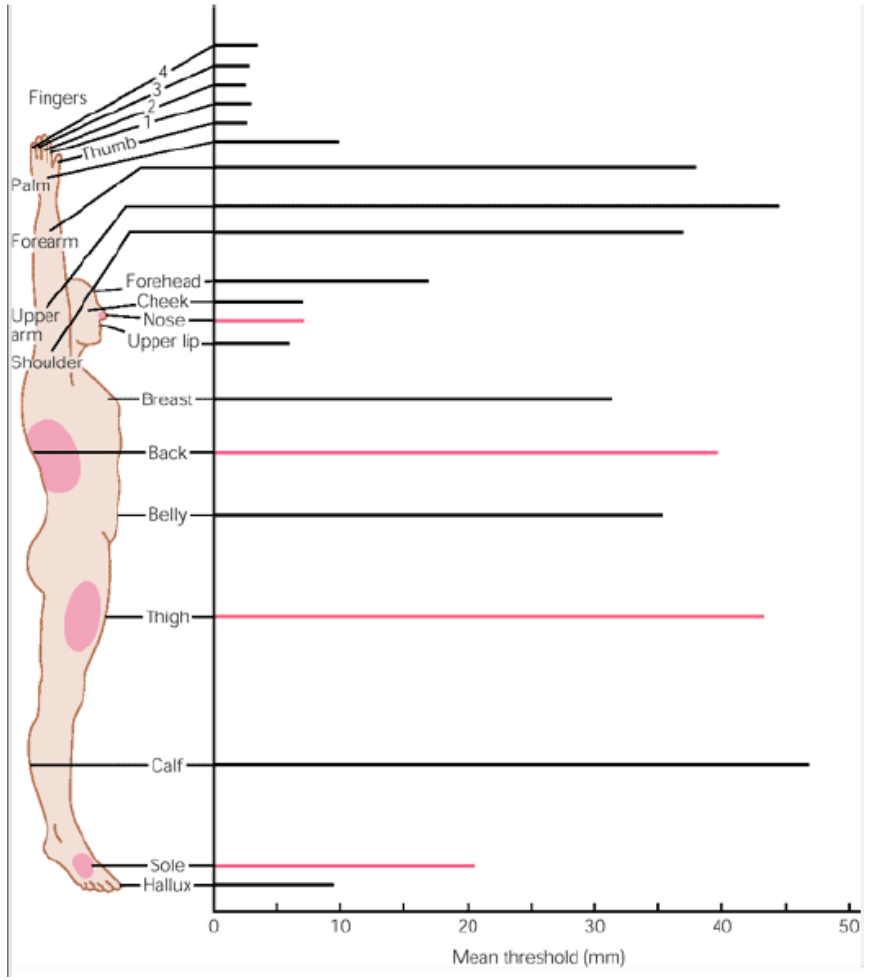
Receptive fields

- Various size and overaly
- Small receptive field – high resolution
- Spatial resolving power increased by lateral inhibition





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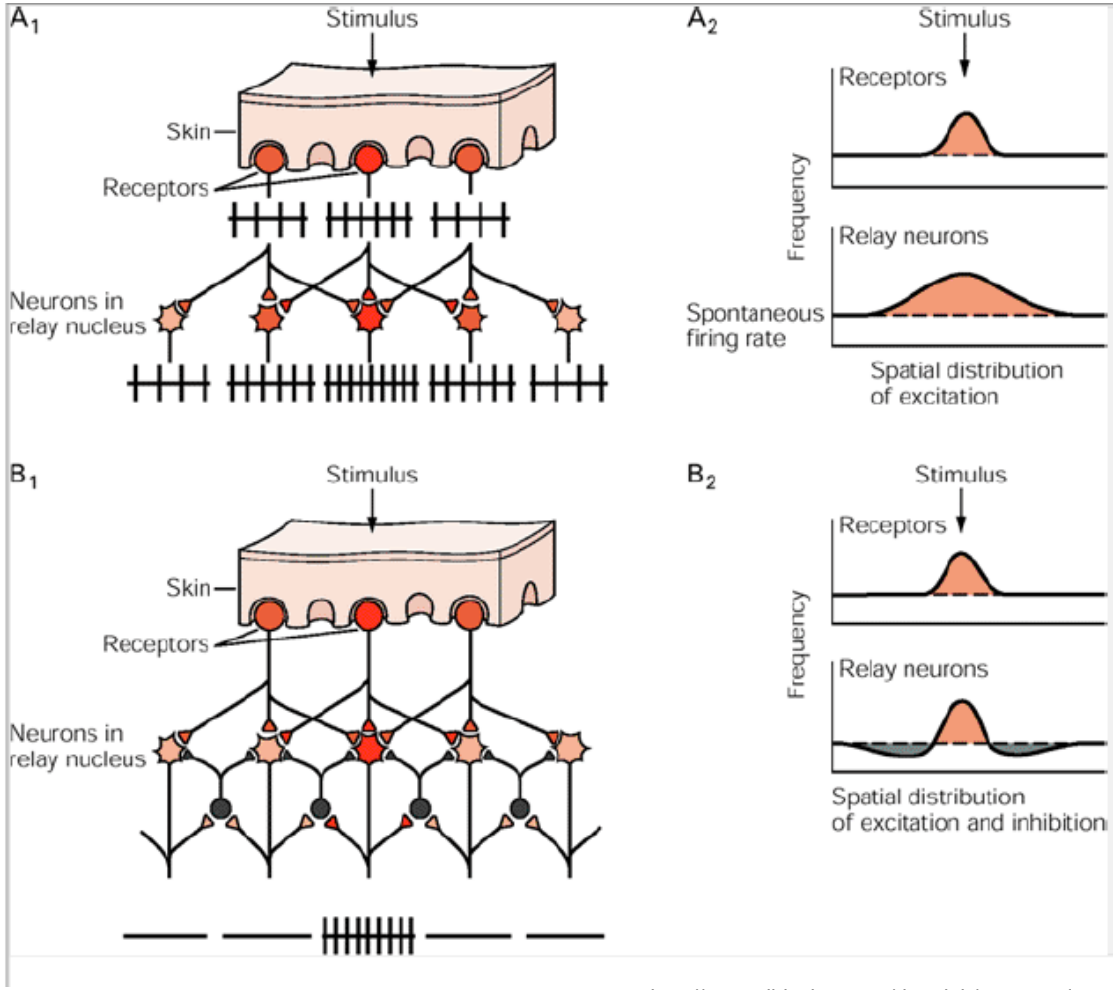
Lateral inhibition



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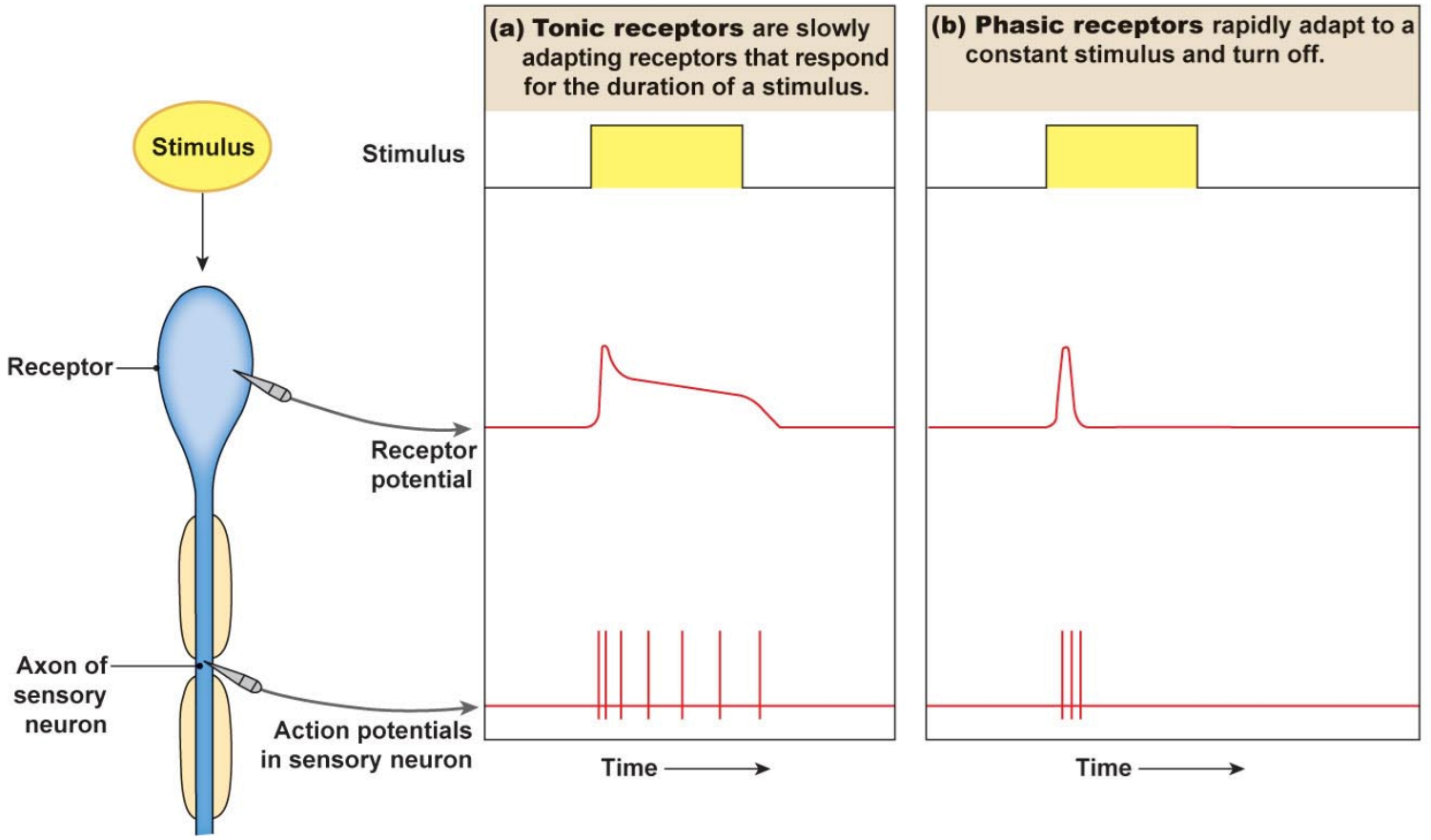
Receptor adaptation

- The decline of receptor responses in spite of stimulus presence

- Tonic receptors – slow adaptation – presence of stimulus, position

- Phasic receptors – rapid adaptation – change of stimulus



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Receptors

- General
  - Superficial – somatosensors
  - Deep – viscerosensors
  - Muscles, tendons, joints – proprioceptors
- Special
  - Part of sensory organs

Receptors

- ✓ Mechanoreceptors
- ✓ Thermoreceptors
- ✓ Chemoreceptors
- ✓ Fotoreceptors

- General
  - Superficial – somatosensors
  - Deep – viscerosensors
  - Muscles, tendons, joints – proprioceptors
- Special
  - Part of sensory organs

Receptors

- Simple
- Complex
- General
  - Superficial – somatosensors
  - Deep – viscerosensors
  - Muscles, tendons, joints – proprioceptors
- Special
  - Part of sensory organs

✓ Mechanoreceptors
✓ Thermoreceptors
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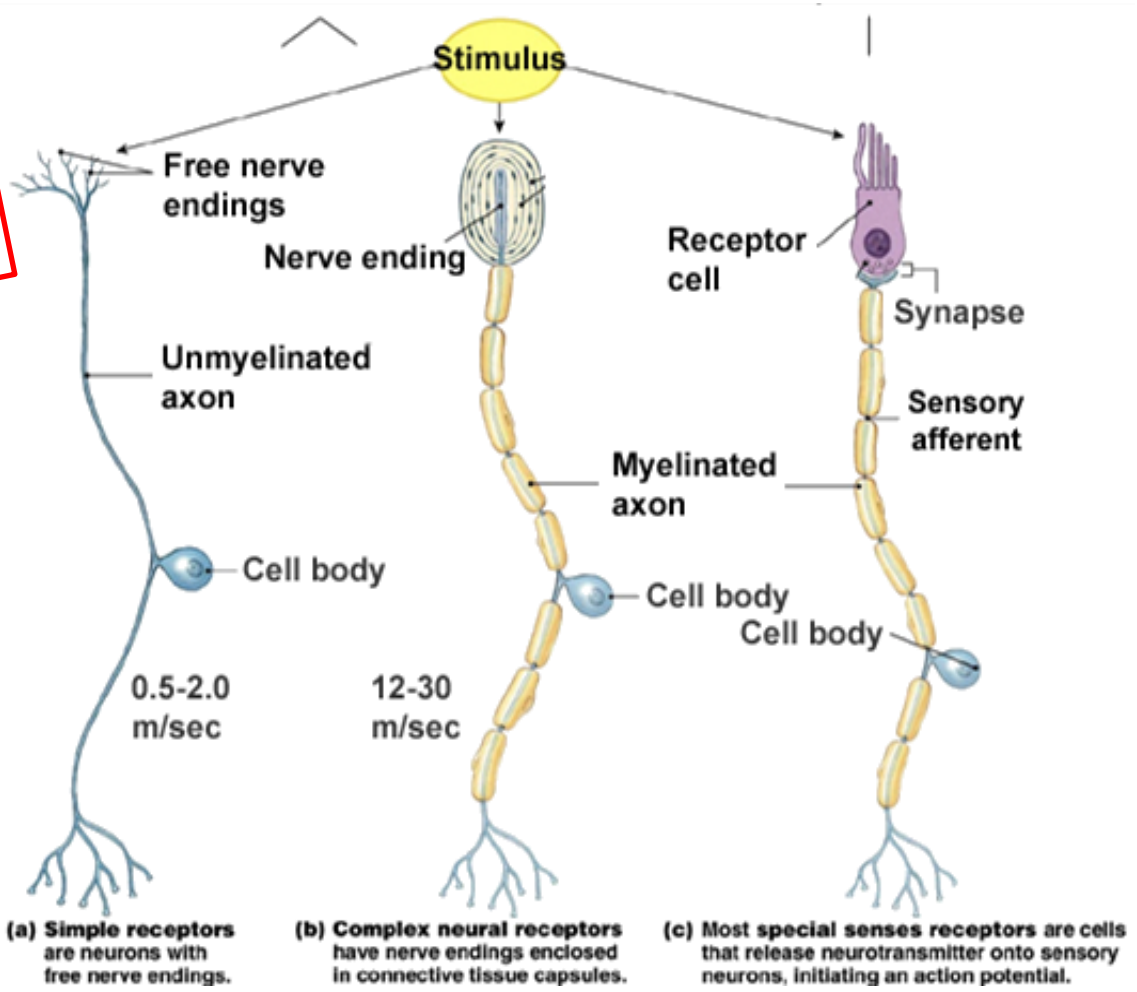

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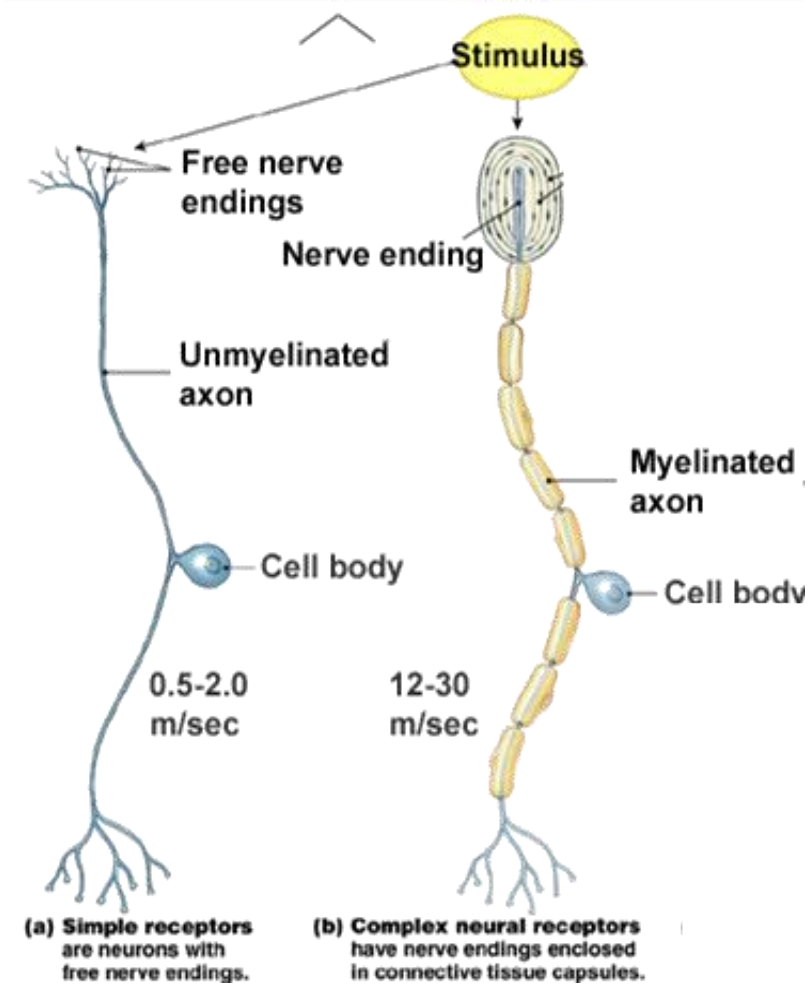
Somato/viscero/ proprio

- Somatosensitivity
  - Pain
  - Temperature
  - Touch
- Viscerosensitivity
  - Pain
- Proprioception
  - Position
  - Movement



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MUNI MED

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- Somatosensitivity
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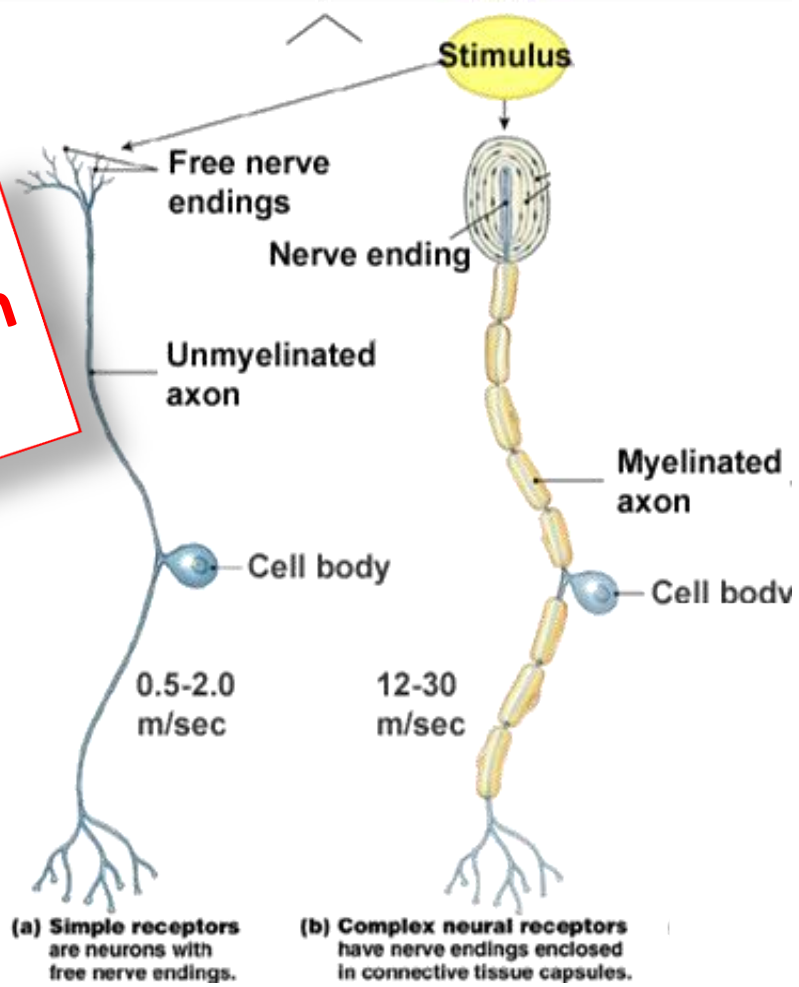
  - Position
  - Movement

The majority of information does not reach cousciousnes



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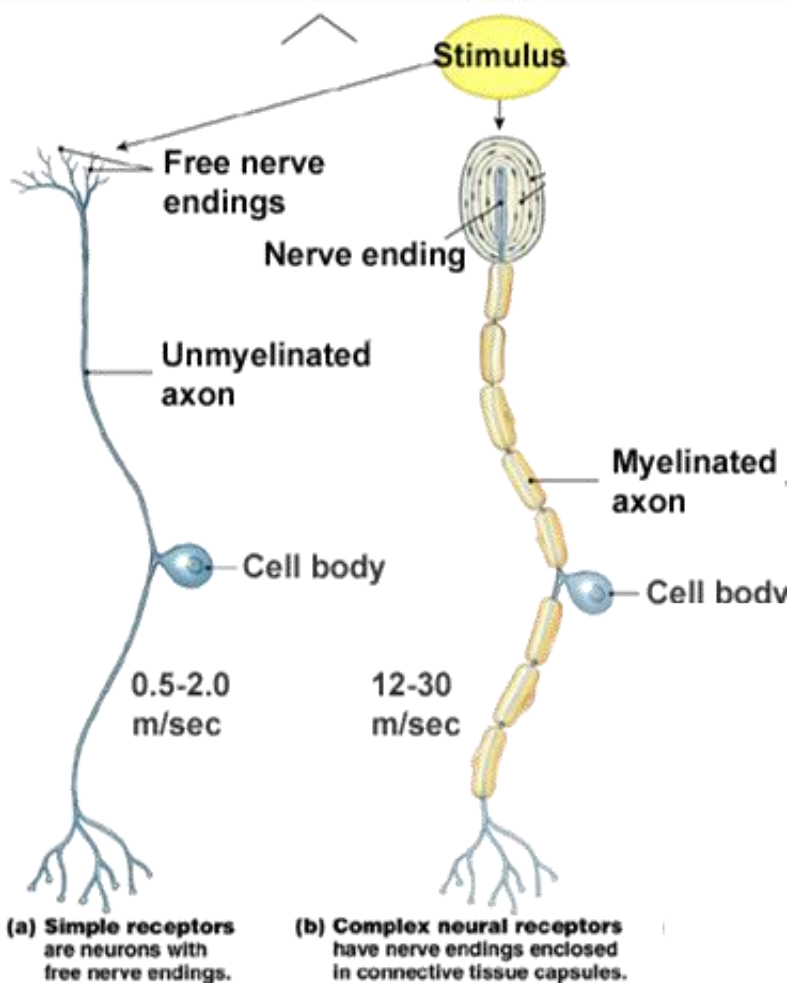
Evolutionary point of view

- The signals indicating potential damage are the most important and the corresponding systems evolved early
  - Pain
  - Temperature

- The touch signals have adaptive value and evolved later



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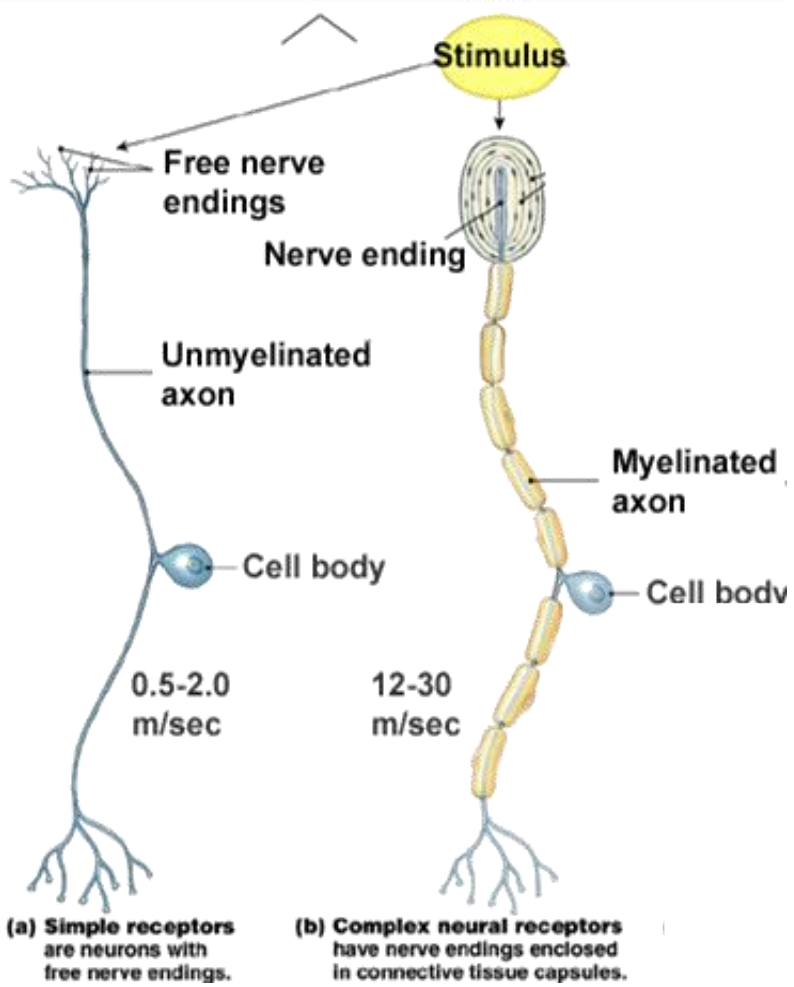
Evolutionary point of view

- The signals indicating potential damage are the most i… the correspo… volved earl…
  - …
  - Temperature
- The to… daptive value and …ter

Immediate survival

Long-term survival



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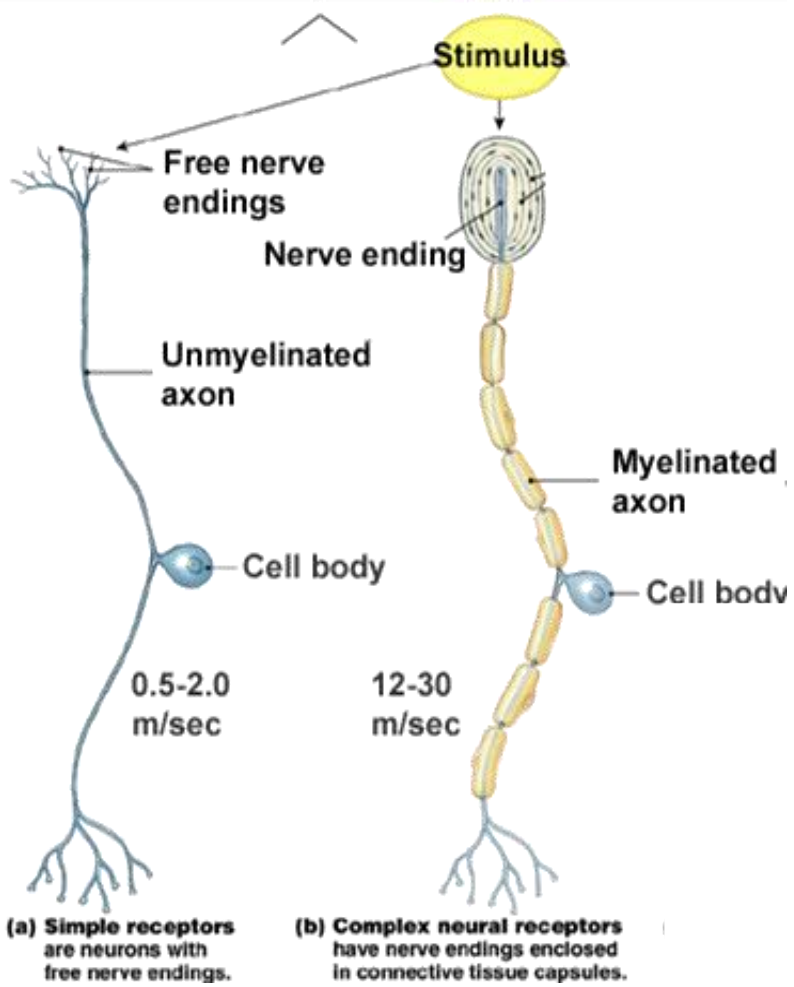
Evolutionary point of view

- The signals indicating potential damage are the most i… the correspo… volved earl…
  - …
  - Temperature
- The to… adaptive value and …ter
- The structure of the receptor, nerve fibers and pathways reflects the evolution

Immediate survival

Long-term survival



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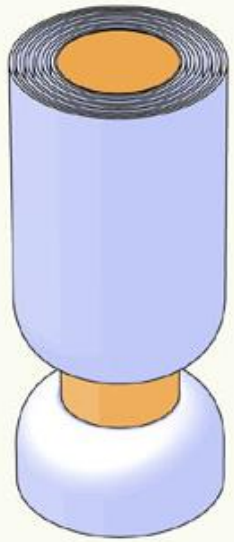
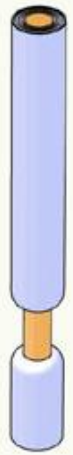
Nerve fibres

Axons from skin	Aα	Aβ	Aδ	C
Axons from muscles	Group I	II	III	IV
				
Diameter (μm)	13–20	6–12	1–5	0.2–1.5
Speed (m/sec)	80–120	35–75	5–30	0.5–2
Sensory receptors	Proprioceptors of skeletal muscle	Mechanoreceptors of skin	Pain, temperature	Temperature, pain, itch

http://www.slideshare.net/CsillaEgri/presentations

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Nociceptors

- Free nerve endings responding to high-intensiti stimuli
- Stimulus
  - Mechanical
    - ✓High pressure
    - ✓Sharp object
  - Thermal
    - ✓Above aprox. 45°C
    - ✓Low treshold – variable
  - Chemical
    - ✓pH
    - ✓Mediators of inflammation and so on

A delta fibers
– sharp, localised pain

C fibers
– dull, difuse pain

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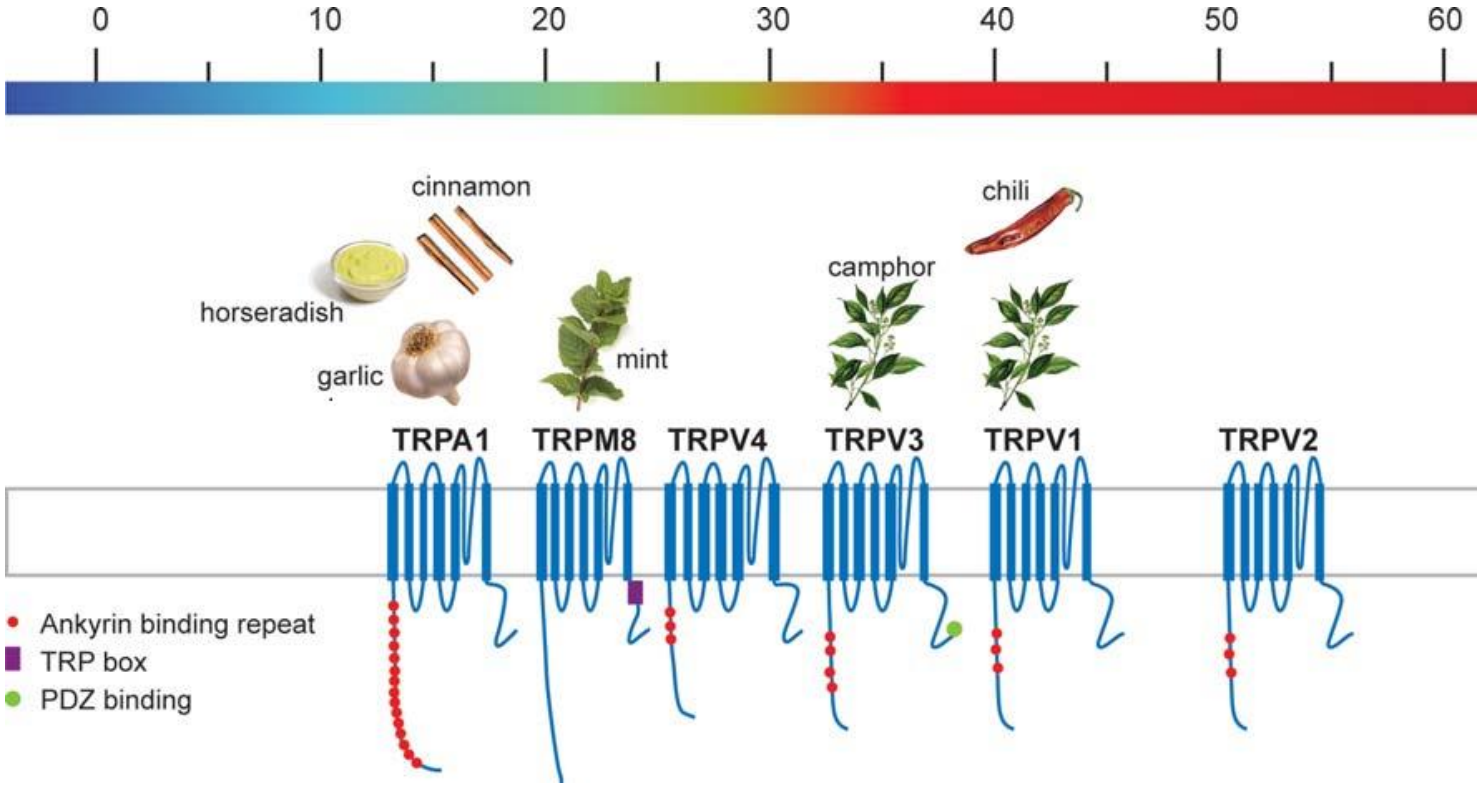
Thermoreceptors

- Free nerve endings receptive to thermal stimuli
- TRP (transient receptor potential) channels
  - Polymodal receptor (chemoreception, thermoreception)
  - Present also in many cells (including neurons, keratinocytes, mechanoreceptros)



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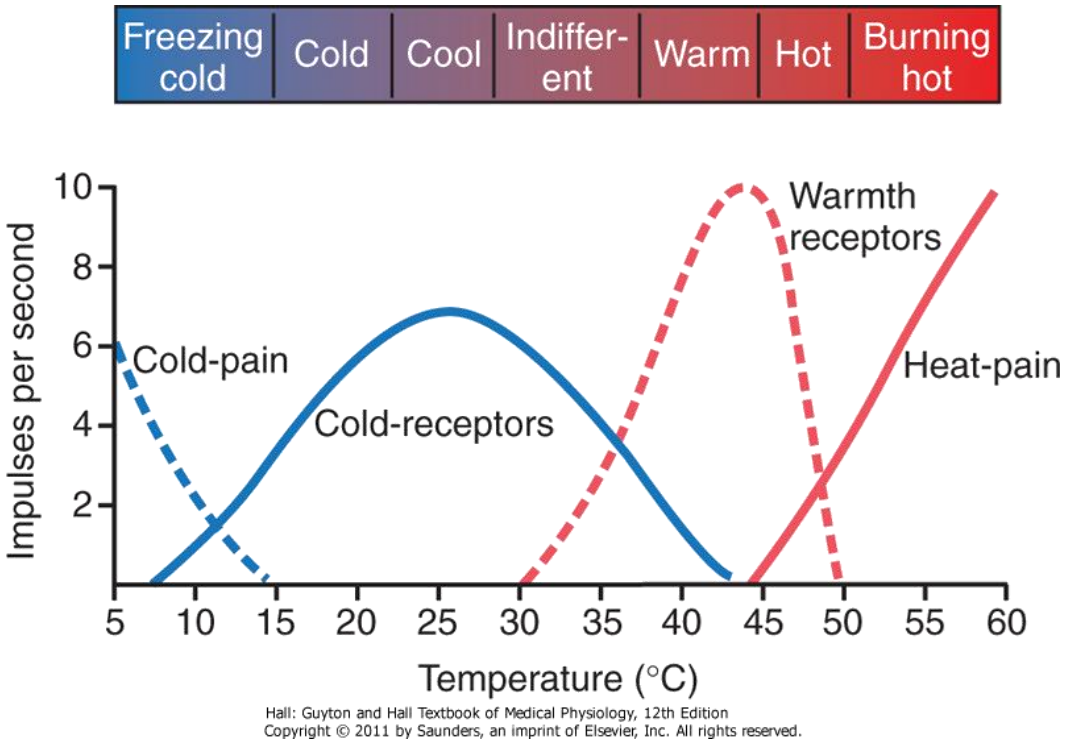
Thermoreceptors

- Perceived temperature is determined by relative activity of cold and warm receptors



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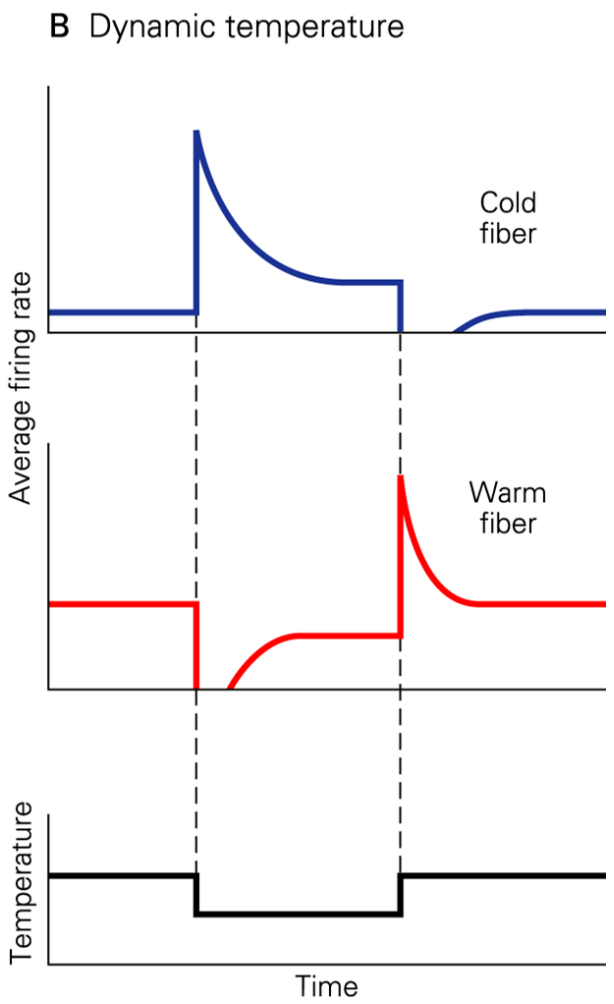
Thermoreceptors

- Mostly phasic response



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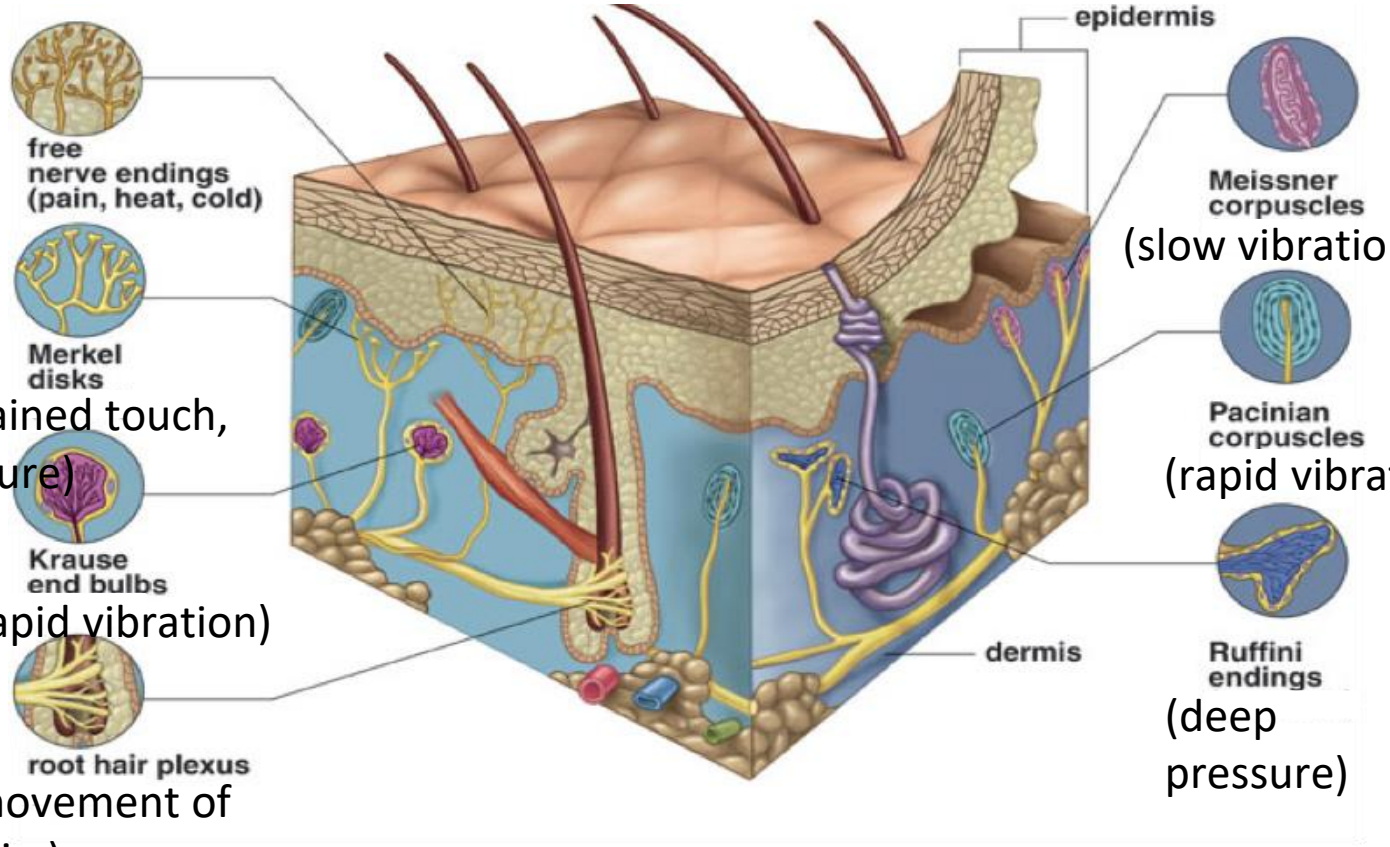
The receptors of the skin

- Simple versus complex



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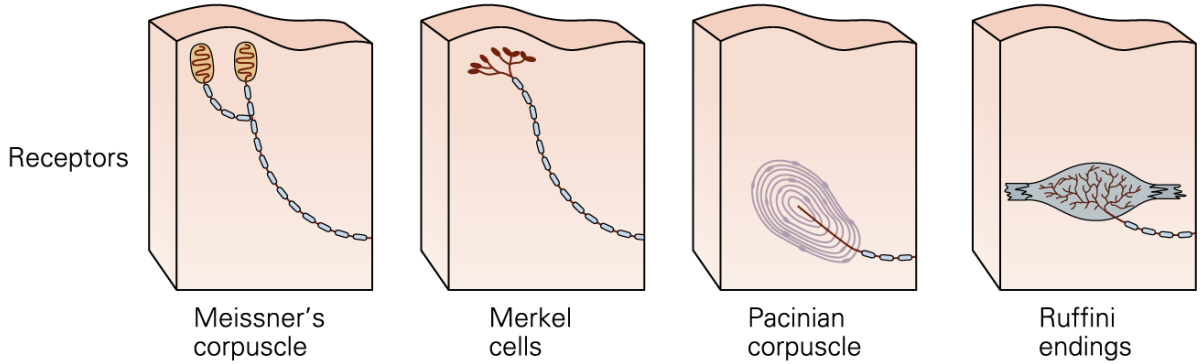

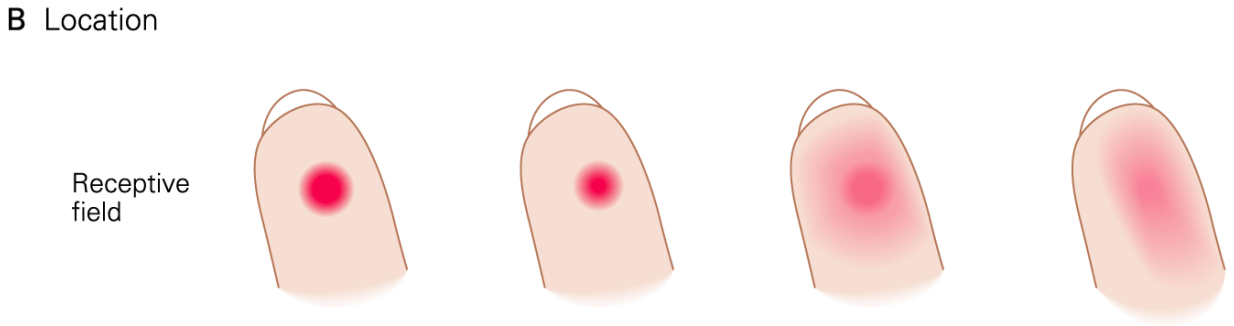

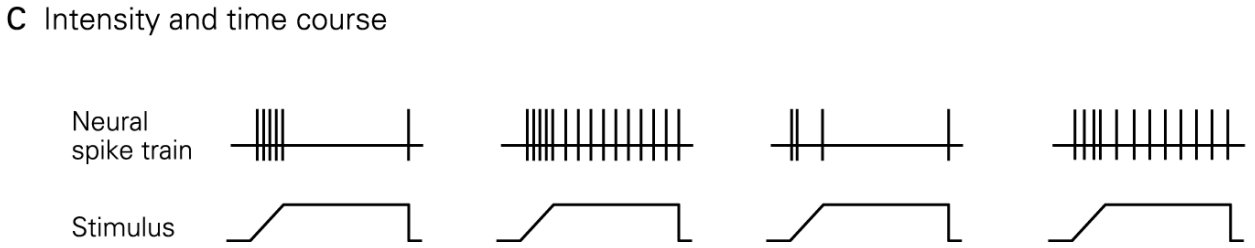

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The receptors of the skin

Receptor	Type	Sensation	Signals	Adaptation
Meissner corpuscle	Encapsulated & layered	Touch: Flutter & Movement	Frequency/Velocity & Direction	Rapid
Pacinian corpuscle	Encapsulated & layered	Touch: Vibration	Frequency: 100-300 Hz	Rapid
Ruffini corpuscle	Encapsulated collagen	Touch: Skin Stretch	Direction & Force	Slow
Hair follicle	Unencapsulated	Touch: Movement	Direction & Velocity	Rapid
Merkel complex	Specialized epithelial cell	Touch, Pressure, Form	Location & Magnitude	Slow
Free Nerve Ending	Unencapsulated	Pain, Touch, or Temperature	Tissue damage, Contact, or Temperature change	Depends on information carried

http://neuroscience.uth.tmc.edu/s2/chapter02.html

Viscerosensitivity

- An information from visceral and cardiovascular system
- Linked to the autonomic nervous system

- The most of information does not reach higher structures than hypothalamus

- The most of informatio

✓ Parasympathetic nervous system (VII., IX., **X., sacral PNS**)
– „Operational information“ (blood pressure, pO2, pCO2)

✓ Sympathetic nervous system
– „Potential danger“ (pressure, pain, cold)

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Proprioception

- Information from
  - Muscles
  - Tendons
  - Joints

- Important for
  - Precise coordination of movements
  - Overload protection

Somatosensory pathways

- Three systems

- (Archispinothalamic)
  - Interconnection of adjacent segments (tr. Spinospinalis)
- Paleospinothalamic
  - tr. Spinoreticularis, tr. Spinotectalis…
- Neospinothalamic
  - tr. Spinothalamicus
- Dorsal column system
  - tr. Spinobulbaris

Somatosensory pathways

- Three systems
- (Archispinothalamic)
  - Interconnection of adjacent
- Paleospinot
- Ne
  -
- Dors
  - tr.

EVOLUTION….

Evolutionary old structures have not been replaced by new ones during evolution, but the old has been kept and the new added

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Somatosensory pathways

- Paleospinothalamic
  - Low resolution – dull, diffuse pain („slow pain“)
- Neospinothalamic
  - High resolution – sharp, localized pain („fast pain“), temperature
  - Low resolution – touch
- Dorsal column system
  - High resolution – fine touch

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Immediate survival

Long-term survival

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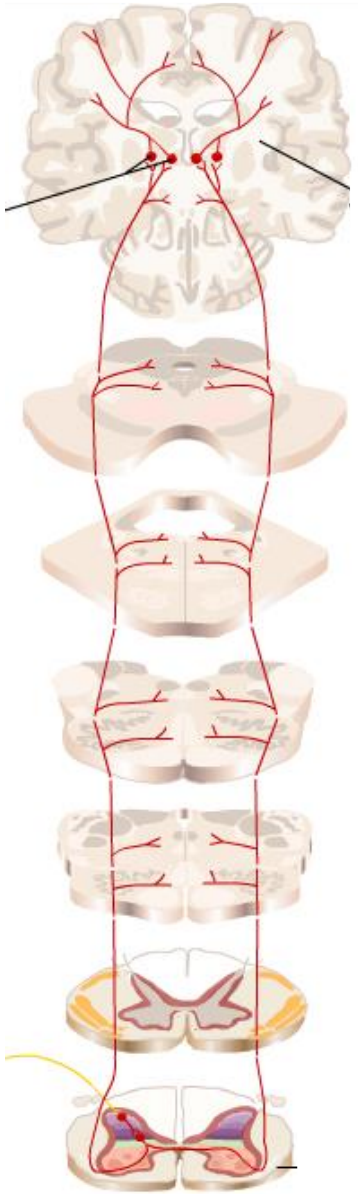
Paleospinothalamic system

- Tr. Spinoreticularis, spinotectalis…
- Evolved before neocortex
- The primary connection to the subcortical structures



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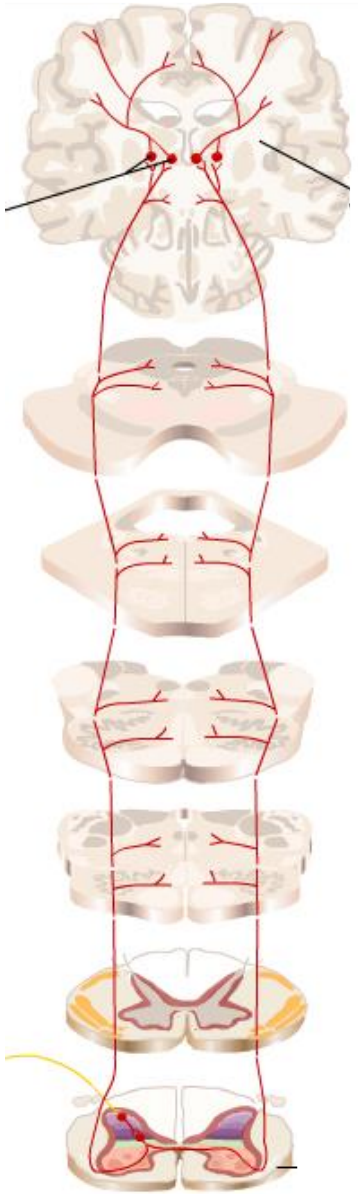

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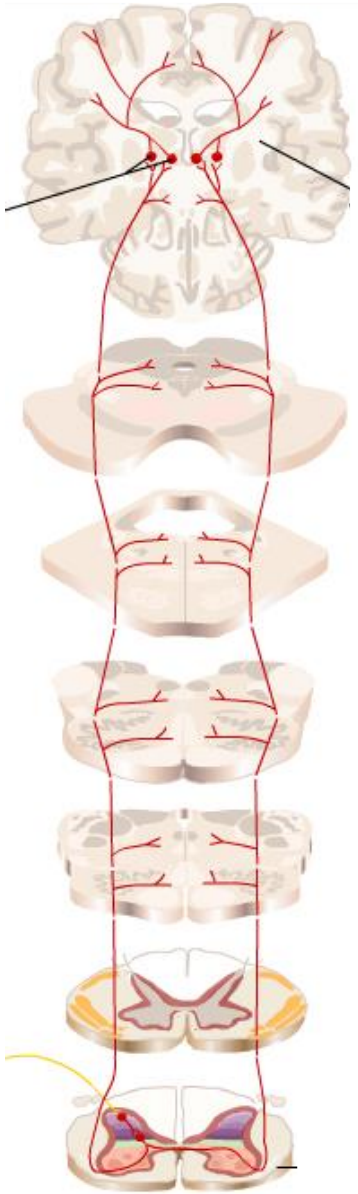
Paleospinothalamic system

- Tr. Spinoreticularis, spinotectalis…
- Evolved before neocortex
- The primary connection to the subcortical structures
- Basic defensive reactions and reflexes - vegetative response, reflex locomotion - opto-acoustic reflexes etc.
- Secondarily connected to cortex (after its evolution; tr. Spino-reticulo-thalamicus), but this system has a small resolutions – dull diffuse pain
- This tract is not designed for „such a powerful processor as neocortex“
- Approximately half of the fibers cross the midline



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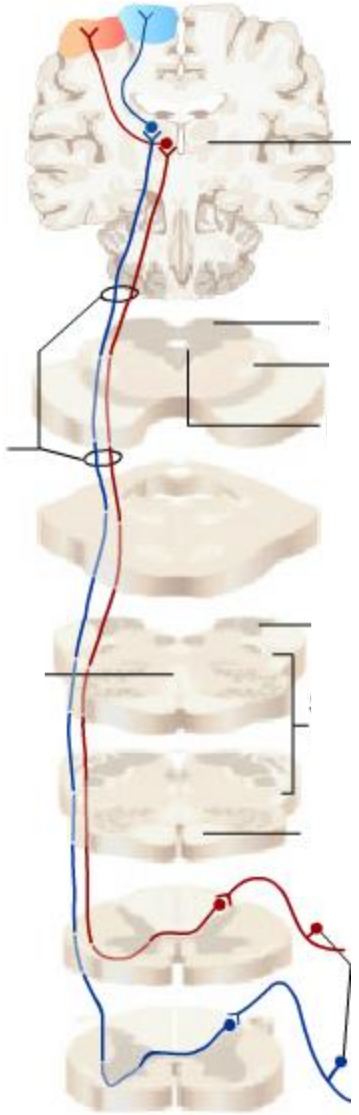
Neospinothalamic system

- Tr. Spinothalamicus
- Younger structure primarily connected to neocortex
- „High capacity/resolution“



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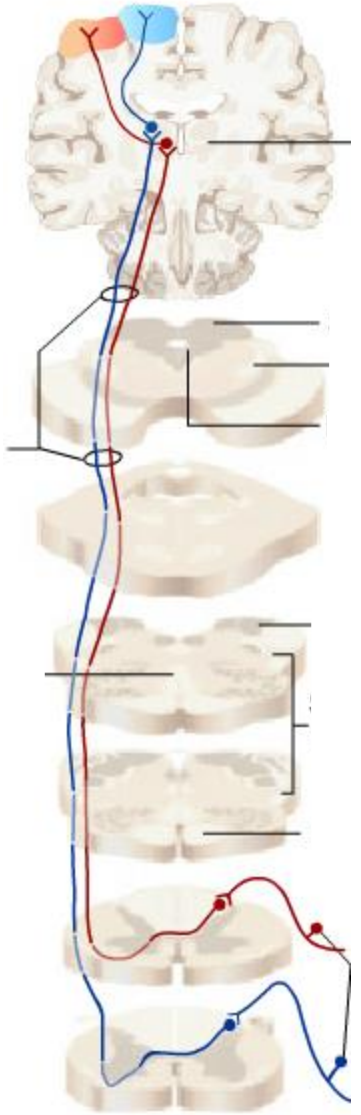
Neospinothalamic system

- Tr. Spinothalamicus
- Younger structure primarily connected to neocortex
- „High capacity/resolution“
- Detail information about pain stimuli (sharp, localized pain)
- Information about temperature
- Crude touch sensation



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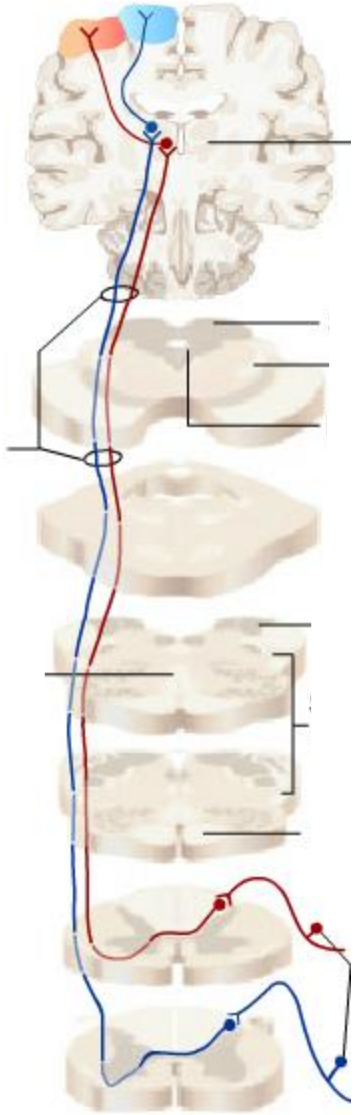
Neospinothalamic system

- Tr. Spinothalamicus
- Younger structure primarily connected to neocortex
- „High capacity/resolution“
- Detail information about pain stimuli (sharp, localized pain)
- Information about temperature
- Crude touch sensation
- The fibers cross midline at the level of entry segment



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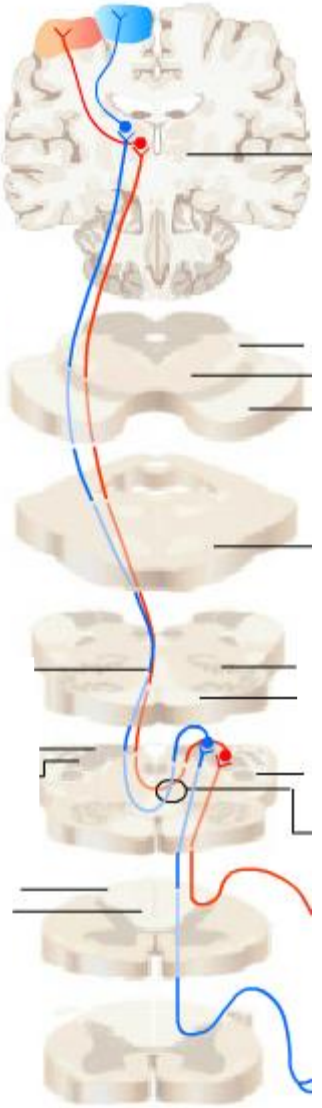
Dorsal column system

- Tr. Spinobulbaris
- The youngest system
- High capacity



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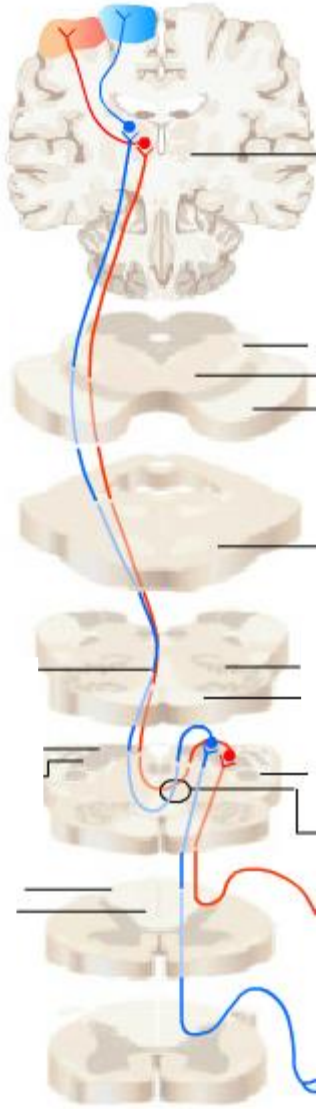
Dorsal column system

- Tr. Spinobulbaris
- The youngest system
- High capacity
- Tactile sensation
- Vibration



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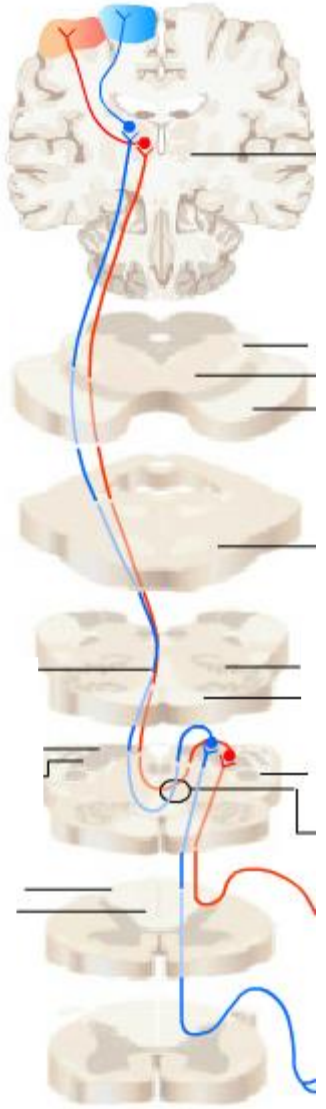
Dorsal column system

- Tr. Spinobulbaris
- The youngest system
- High capacity
- Tactile sensation
- Vibration
- Fine motor control
- Better object recognition
- Adaptive value
- The fibers cross midline at the level of medulla oblongata



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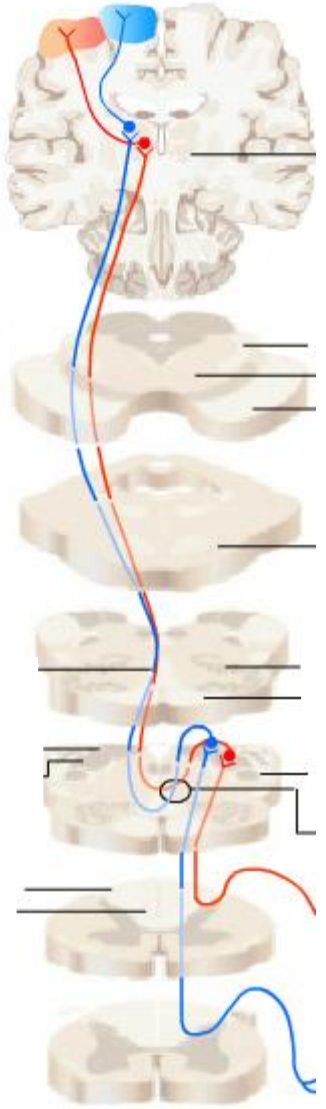

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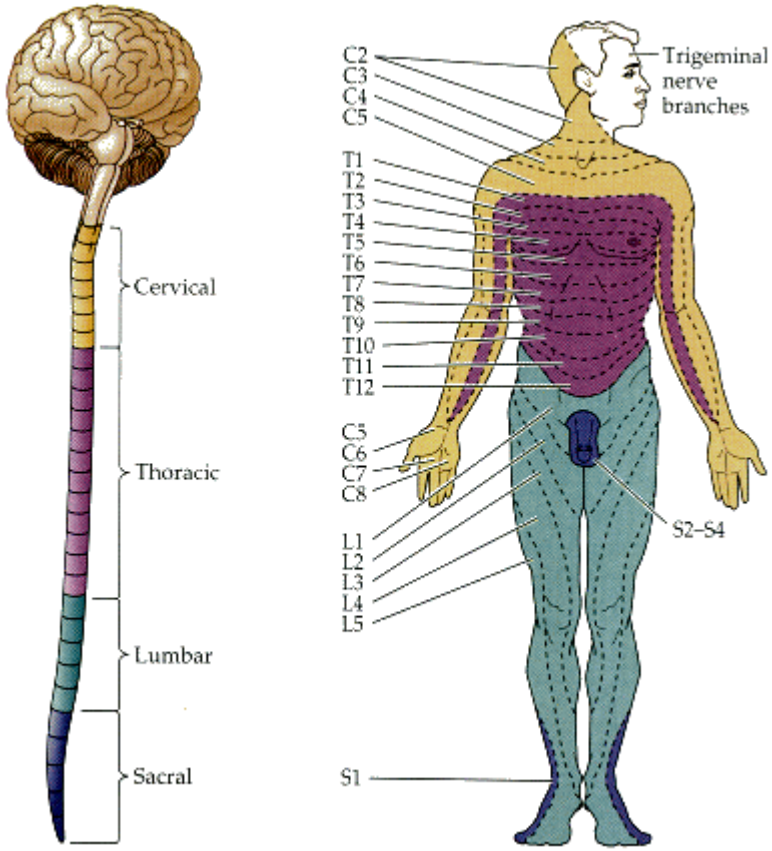
Dermatoms

- Somatotopic organization somatosensitve nerves



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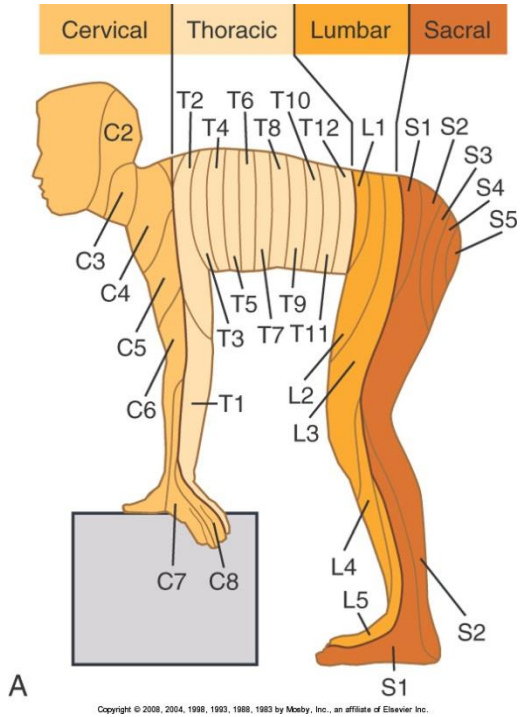

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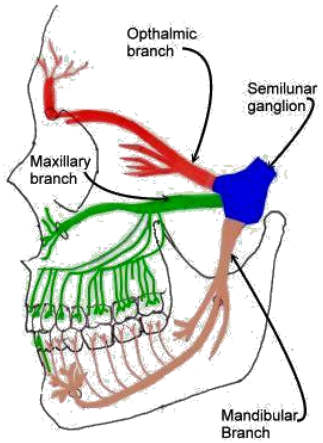
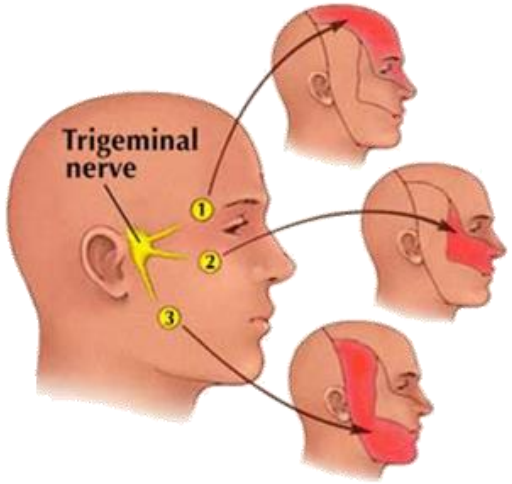
Trigeminal system

- Spinal TS
  - Pain, temperature
- Main sensory TS
  - Touch, proprioception





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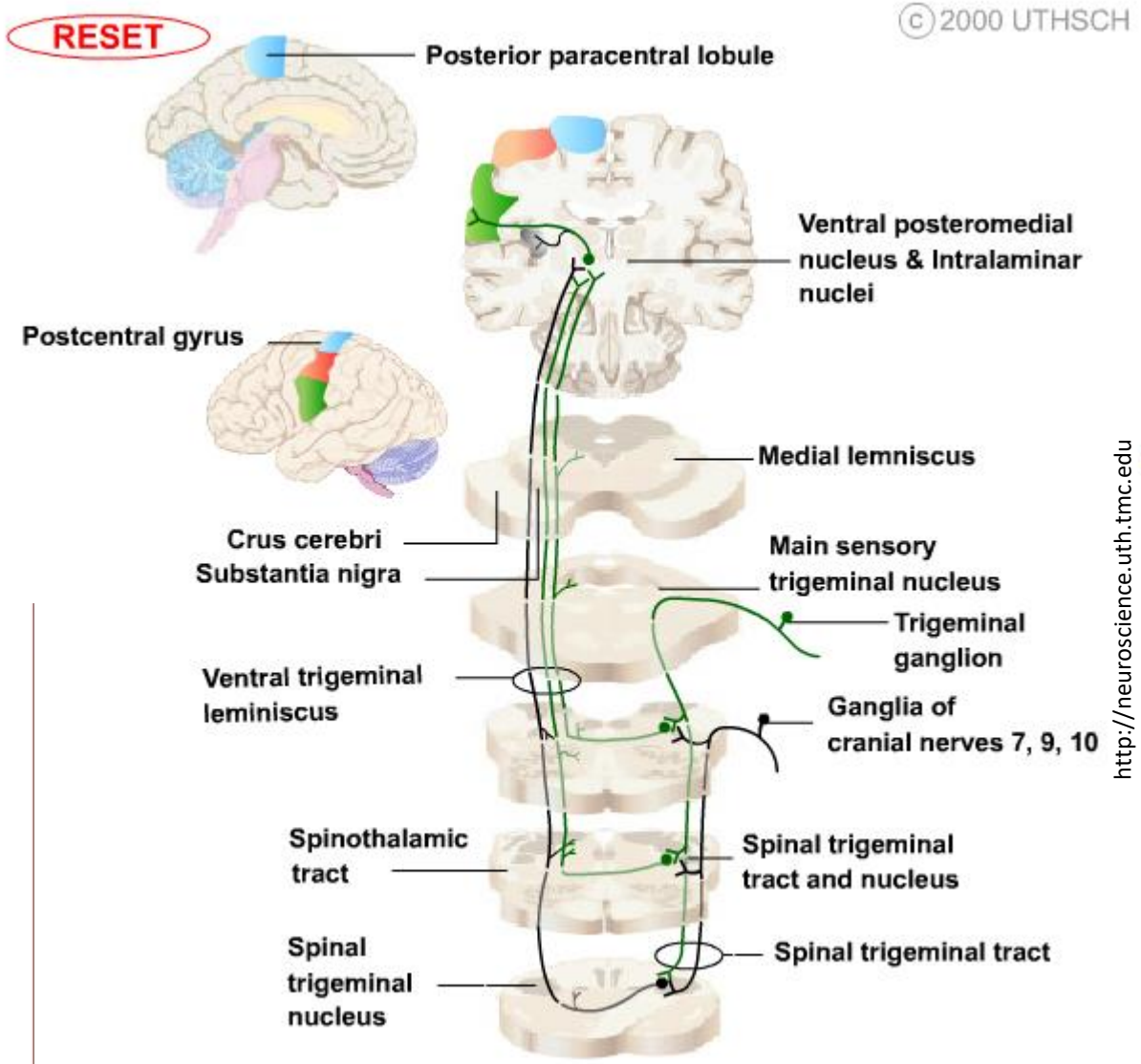

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Somatosensory pathways

Table I
The Sensory Modalities Represented by the Somatosensory Systems

Modality	Sub Modality	Sub-Sub Modality	Somatosensory Pathway (Body)	Somatosensory Pathway (Face)
Pain	sharp cutting pain		Neospinothalamic	Spinal Trigeminal
	dull burning pain		Paleospinothalamic	
	deep aching pain		Archispinothalamic	
Temperature	warm/hot		Paleospinothalamic	
	cool/cold		Neospinothalamic	
Touch	itch/tickle & crude touch		Paleospinothalamic	
	discriminative touch	touch	Tr. spinobulbaris	Main Sensory Trigeminal
		pressure		
		flutter		
		vibration		
Proprioception	Position: Static Forces	muscle length		
		muscle tension		
		joint pressure		
	Movement: Dynamic Forces	muscle length		
		muscle tension		
		joint pressure		
		joint angle		

http://neuroscience.uth.tmc.edu/s2/chapter02.html

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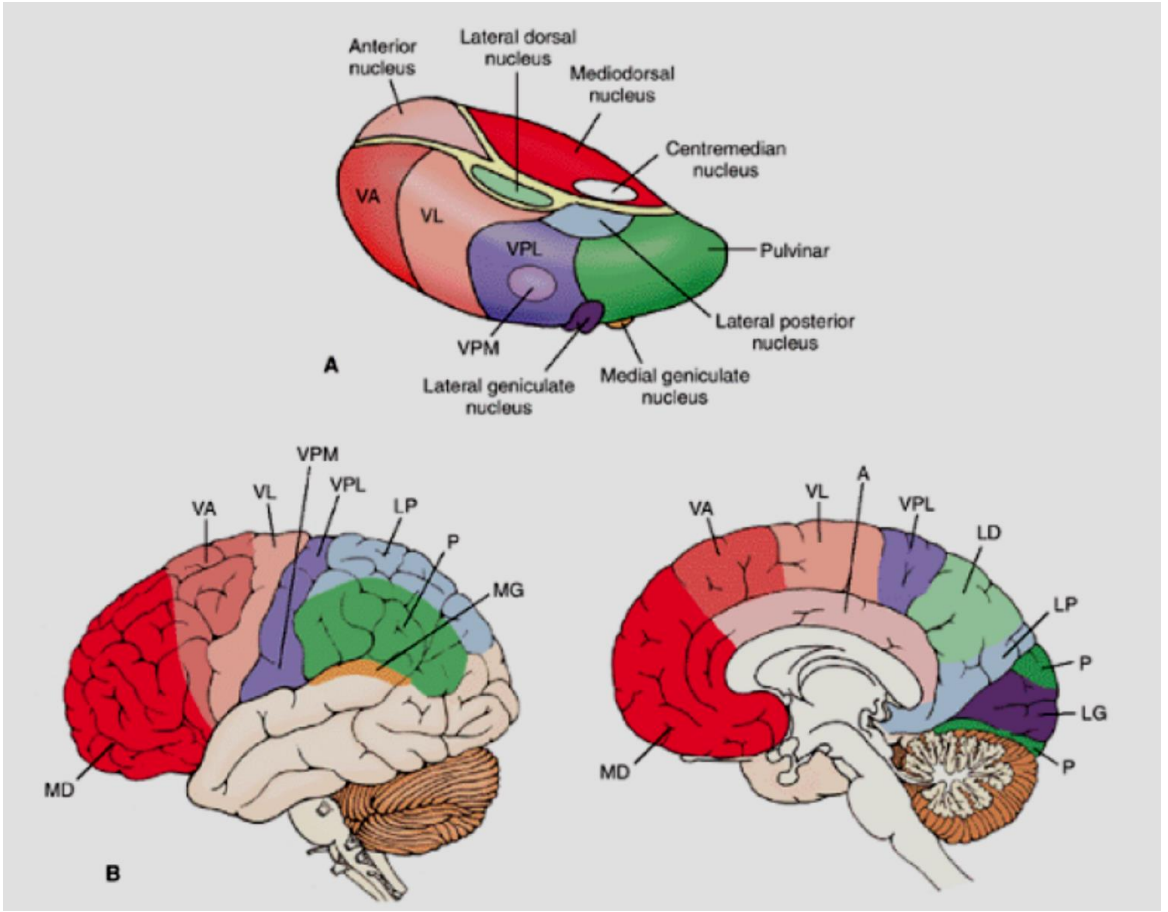
Thalamus and neocortex

- Almost all the afferent information gated in the thalamus
- Olfaction is an exception
- Bilateral connections between neocortex and thalamus



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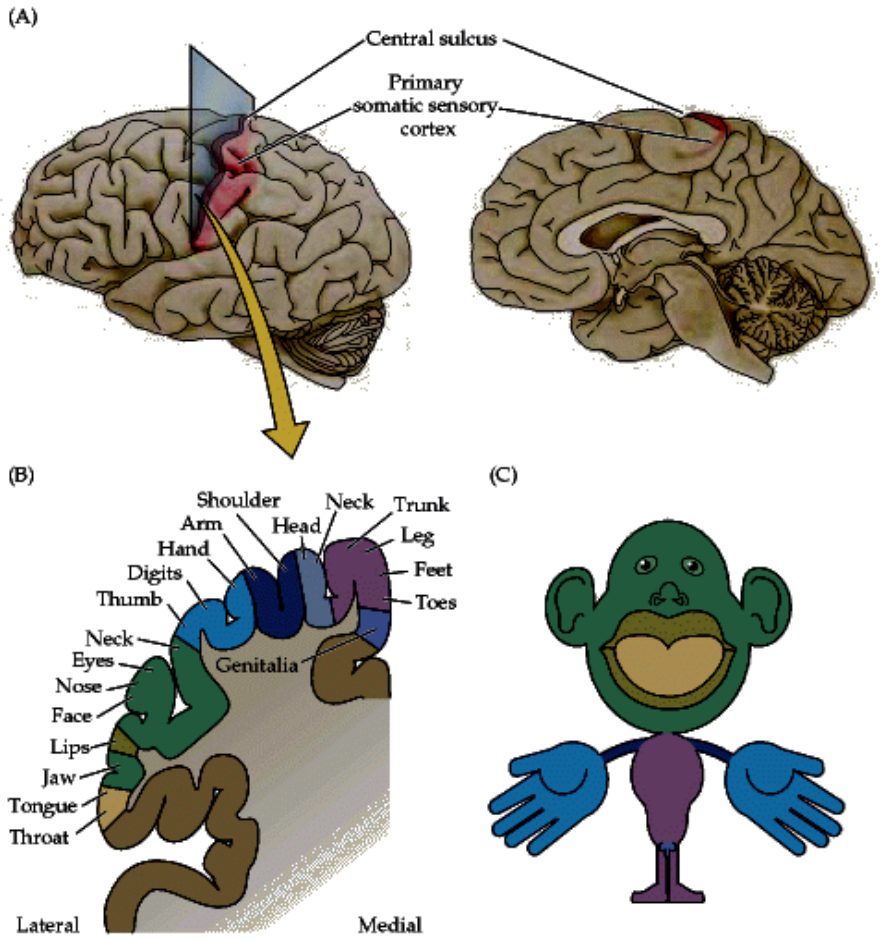
Neocortex

- Somatotopic organization
- Cortical magnification



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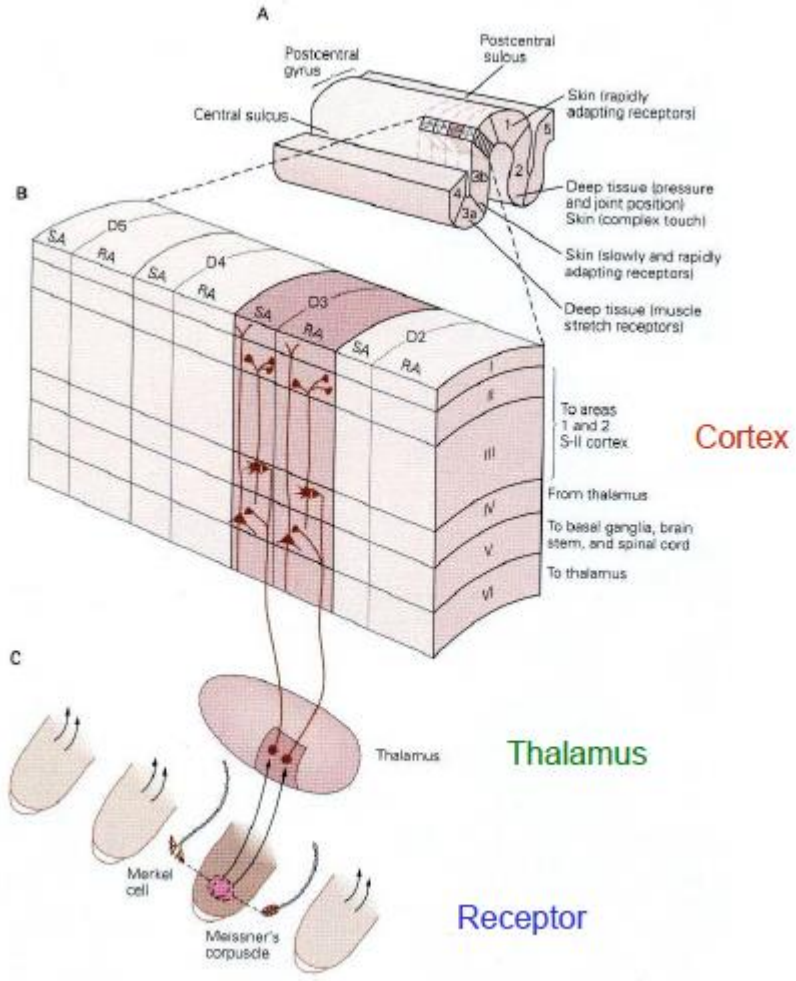

http://www.shadmehrlab.org/Courses/physfound_files/wang_5.pdf

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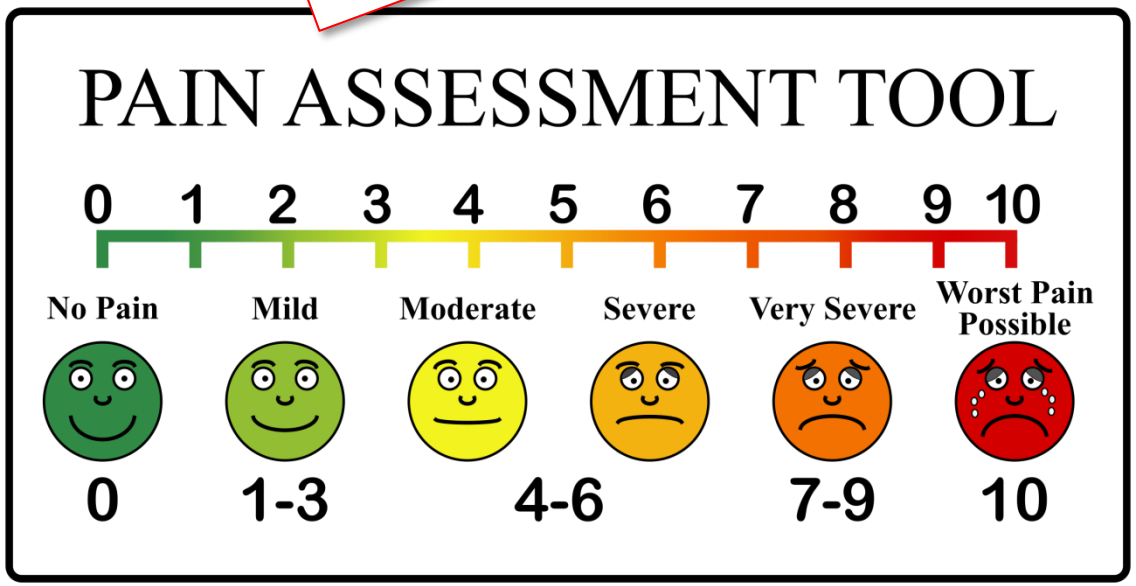
Pain

- Distressing feeling associated with real or potential tissue damage
- Sensor x psychological component
- Physiological pain (nociceptor activation)
- Pathological pain (not mediated by nociceptors)
- Acute (up to 6months) – „activiting“
- Chronic (more than 6 months) – „devating“

Subjective character



https://www.cheatography.com/uploads/davidpol_1460561912_Pain_Scale__Arvin61r58.png

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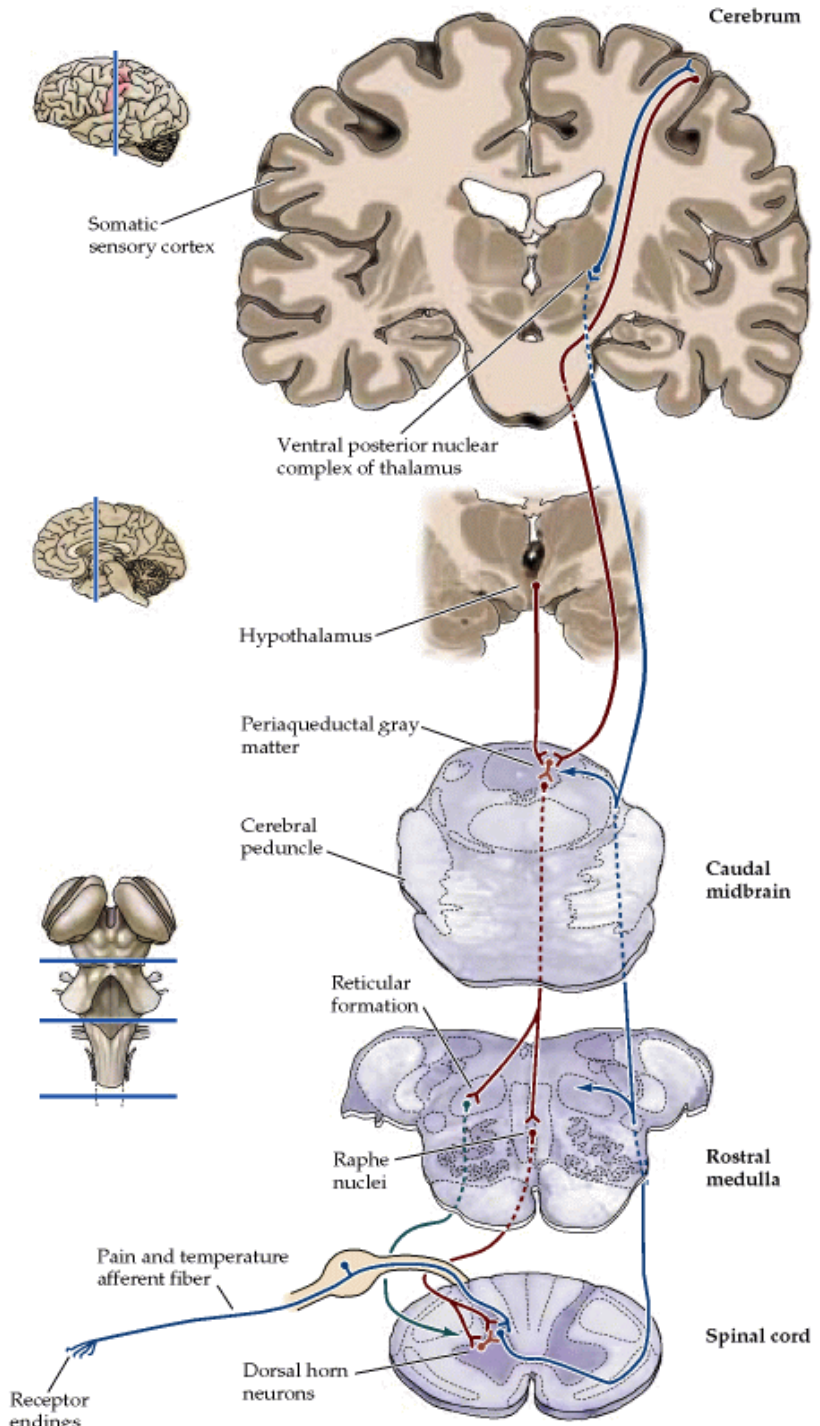
Descendent pathways modulating pain

- Somatosemcoric cortex
- Hypotalamus
- Periaquaeductal gray
- Nuclei raphe



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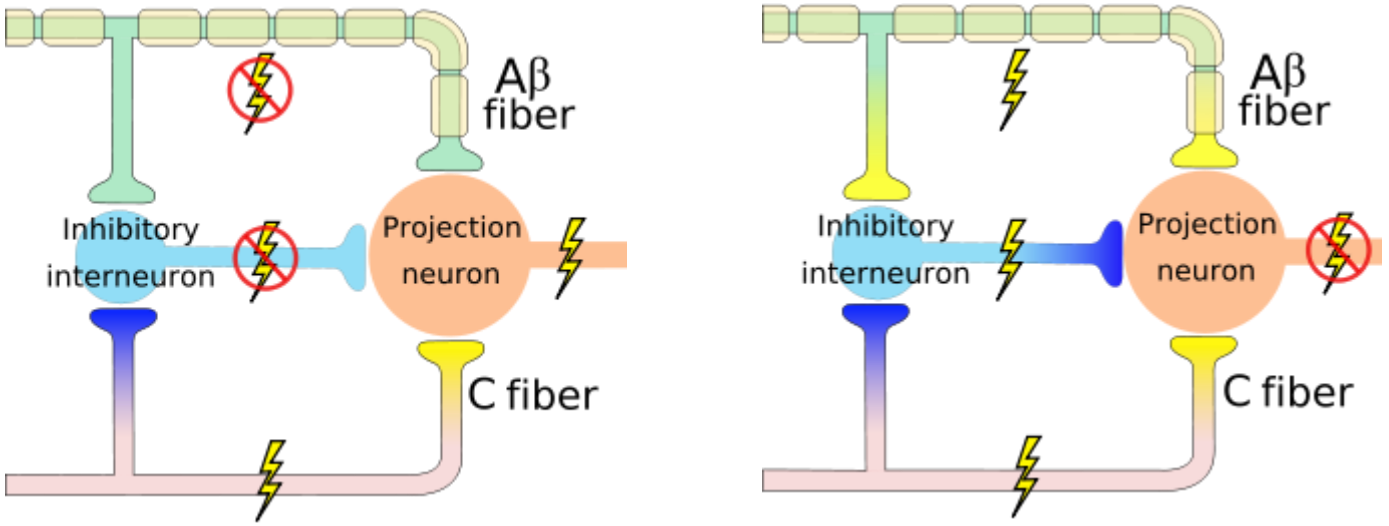
Pain modulation on the spinal level

Gate control theory of pain



https://en.wikipedia.org/wiki/Gate_control_theory

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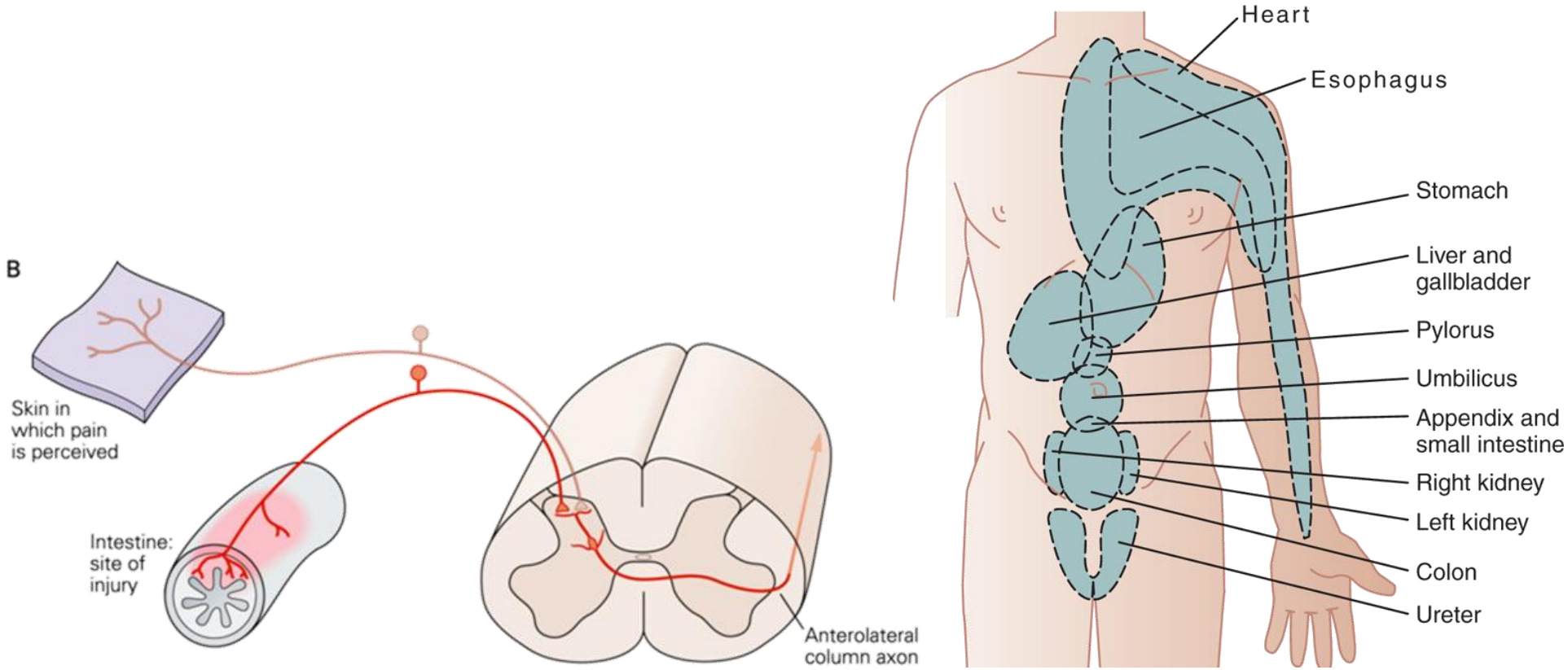
Referred pain



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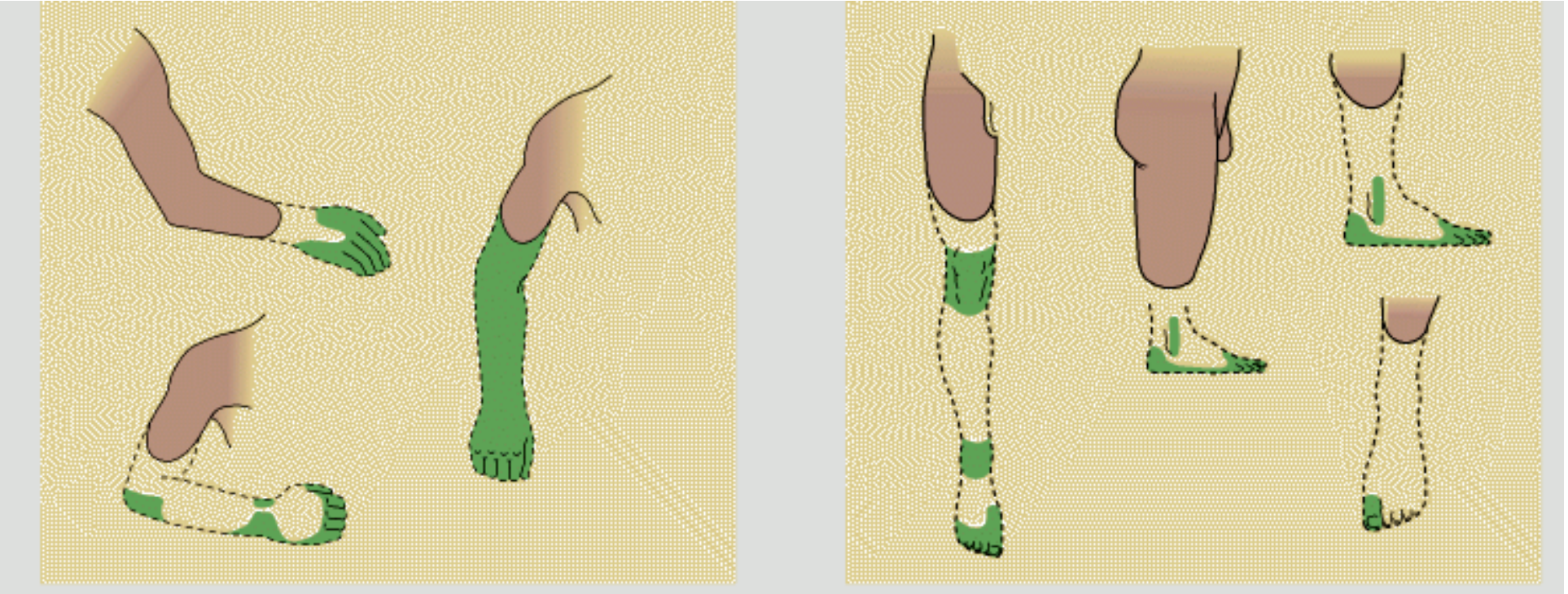
Phantom limb pain



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