

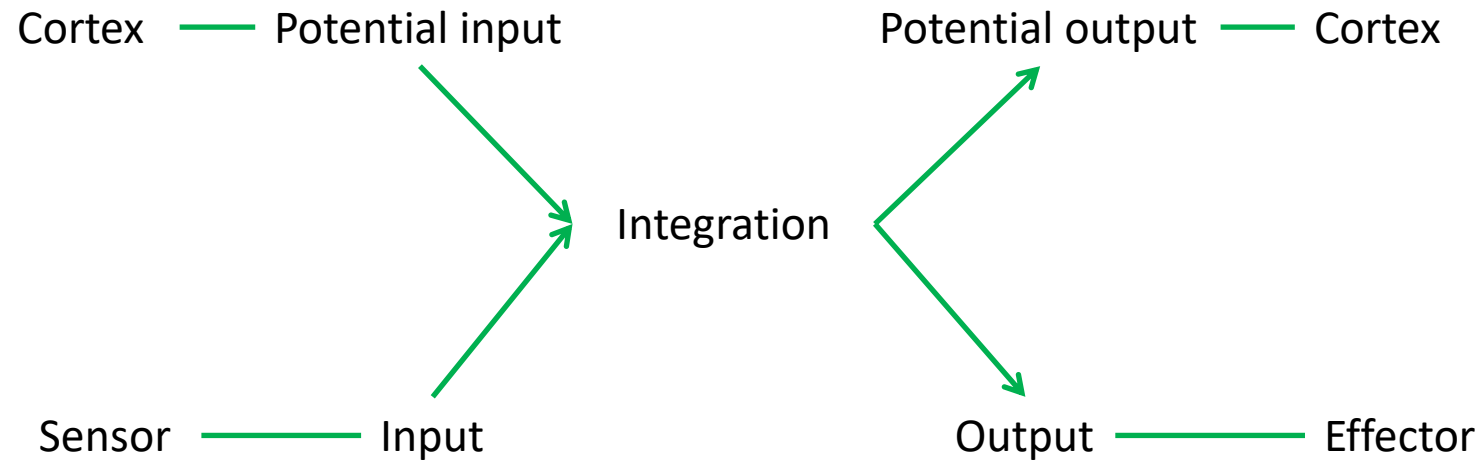
M U N I

M E D

# **Somatosensitivity, pain**

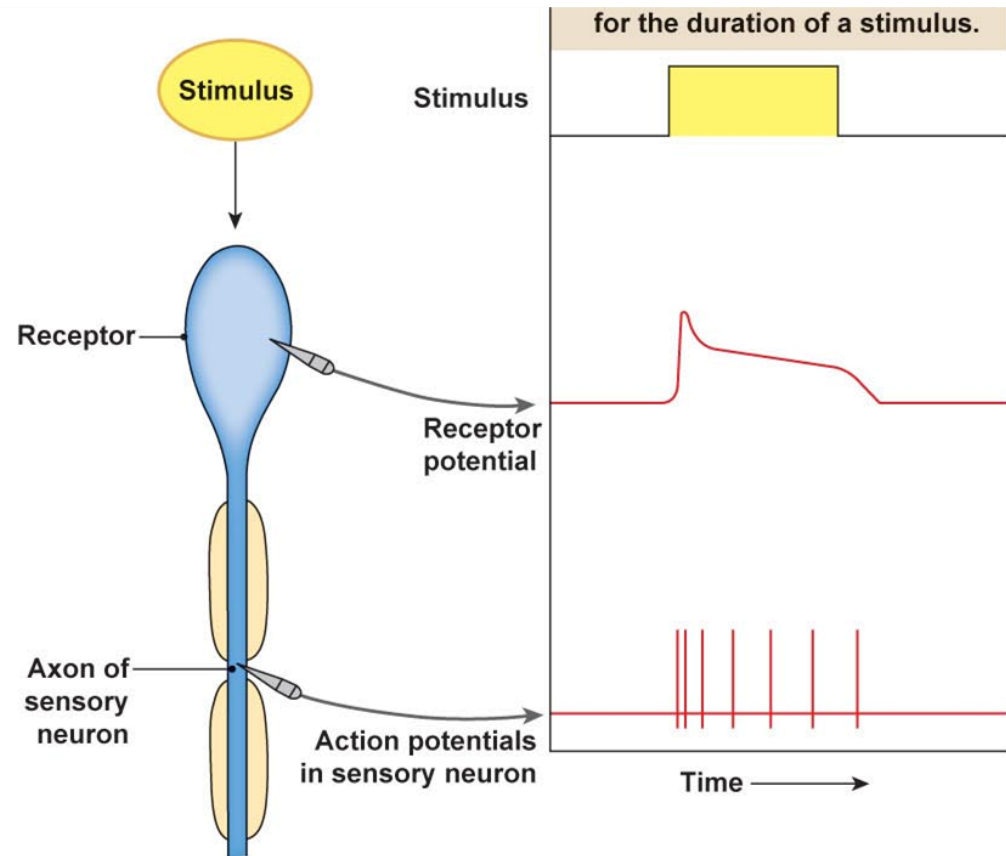
# The role of nervous system

**ANTICIPATION**



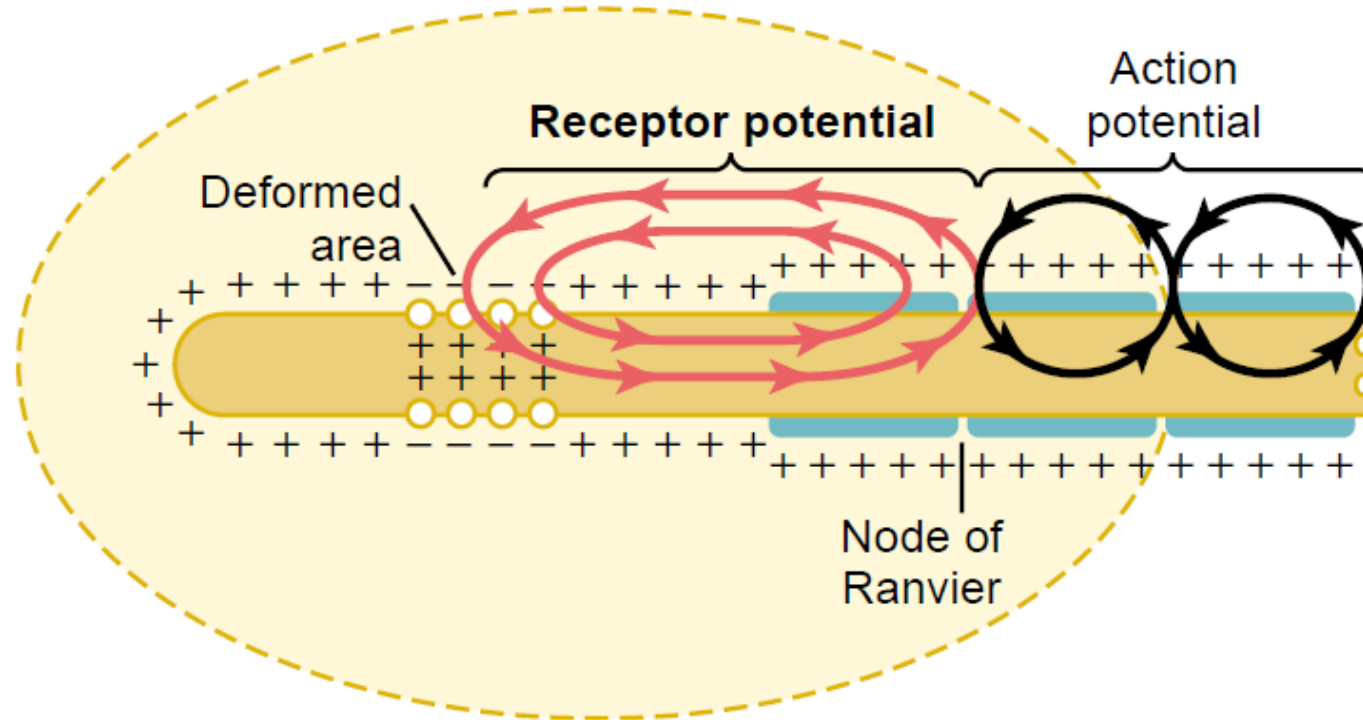
# Receptors/sensors

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



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

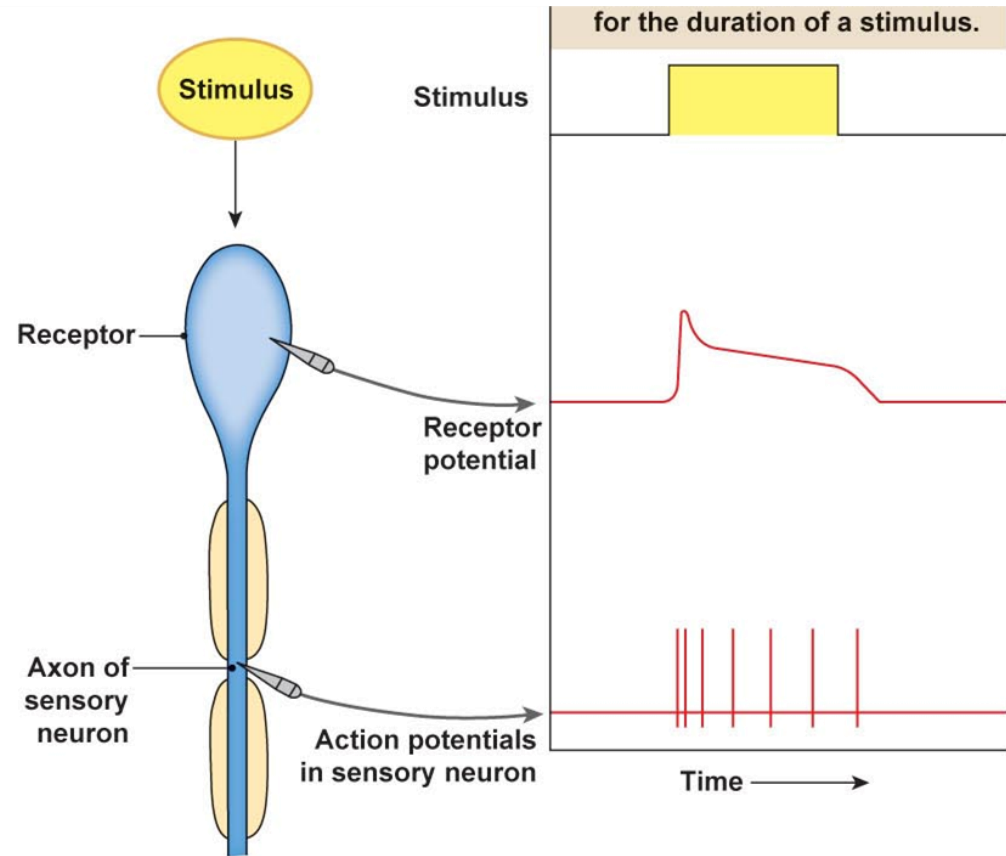
# Receptor/generator and action potential



<http://www.slideshare.net/drpsdeb/presentations>

# Receptors/sensors

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

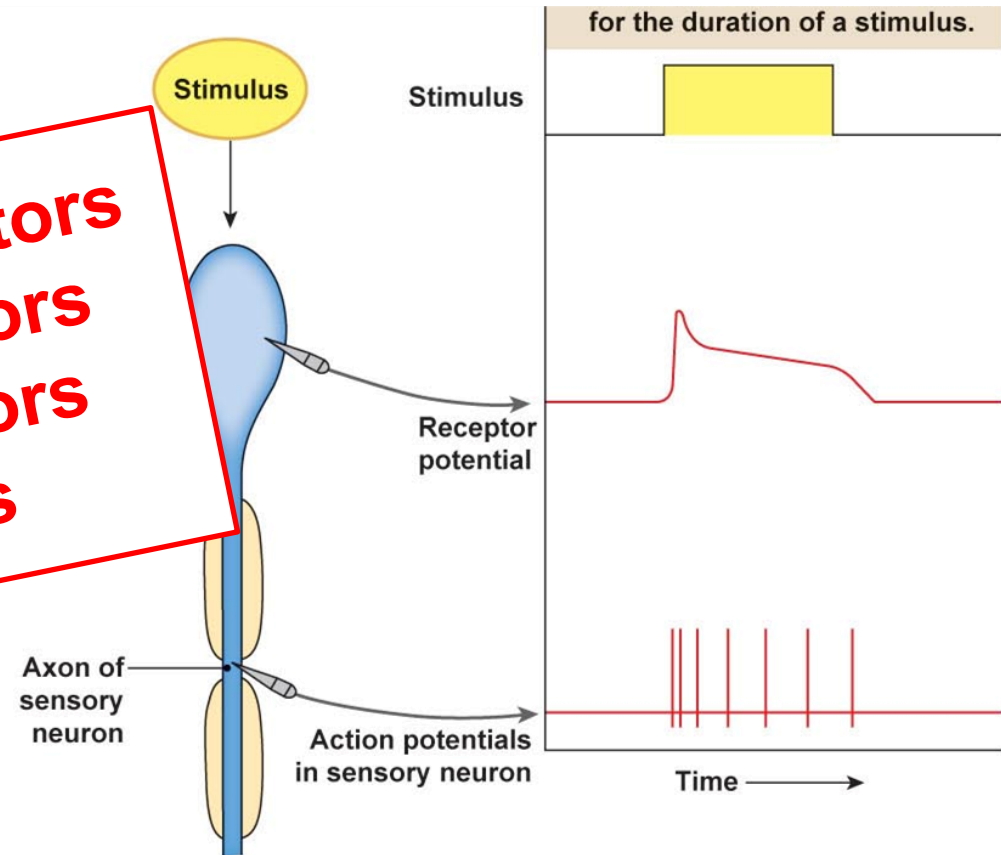


<http://www.slideshare.net/CsillaEgri/presentations>

# Receptors/sensors

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

✓ **Mechanoreceptors**  
✓ **Thermoreceptors**  
✓ **Chemoreceptors**  
✓ **Fotoreceptors**

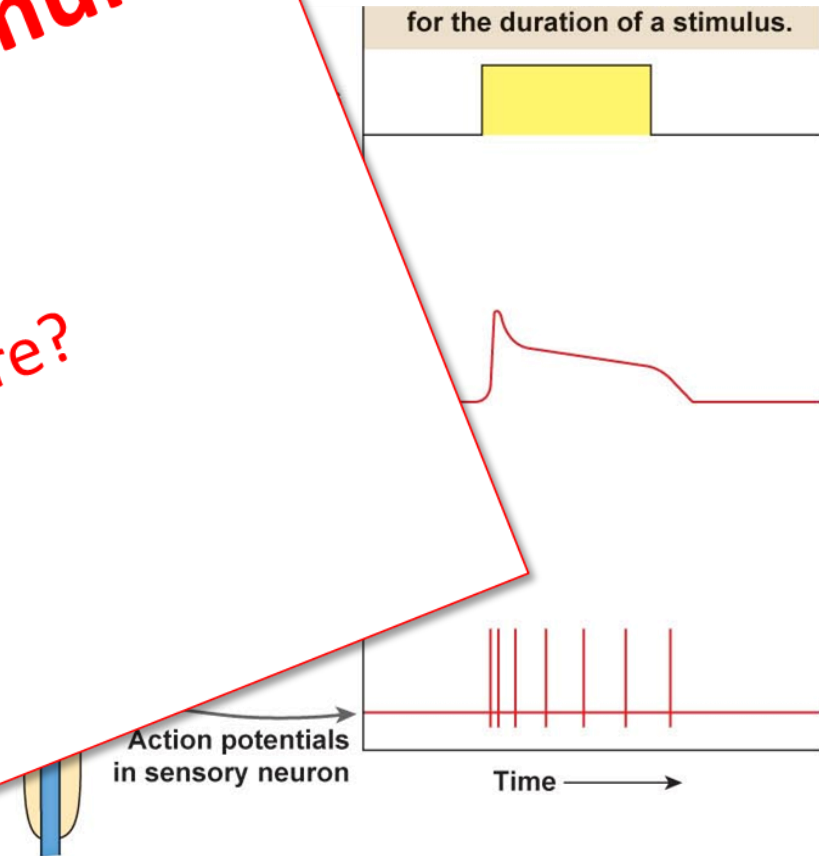


<http://www.slideshare.net/CsillaEgri/presentations>

# Receptors/sensors

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

**Basic attributes of stimulus**  
**Qualitative**  
**Modality - What?**  
**Localization - Where?**



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



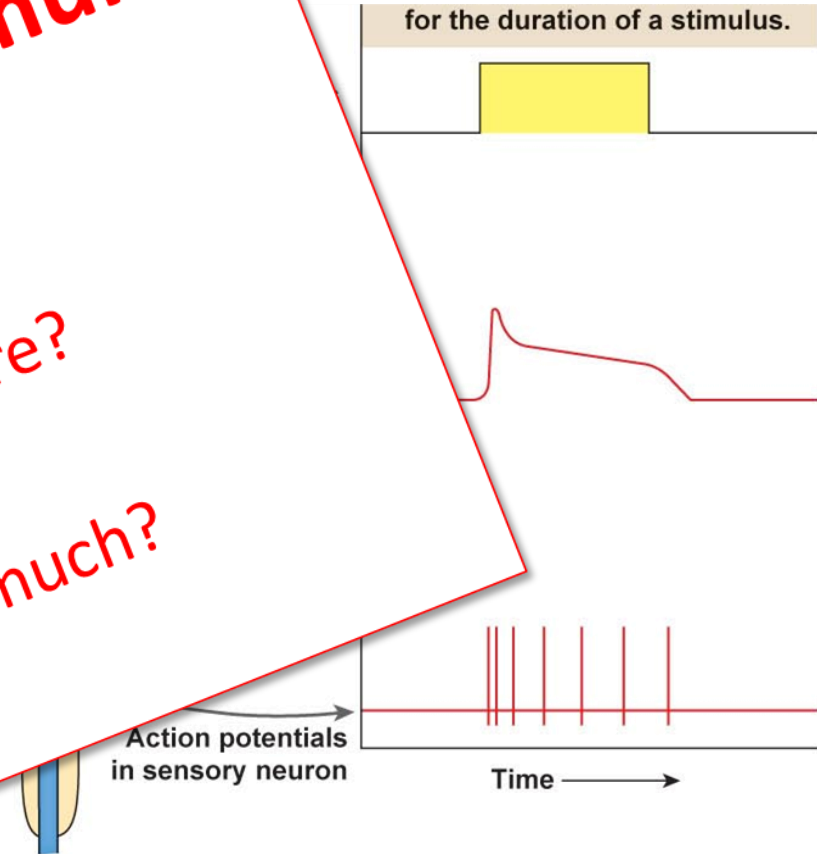
# Receptors/sensors

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

**Basic attributes of stimulus**

**Qualitative**  
Modality - What?  
Localization - Where?

**Quantitative**  
Intensity - How much?



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

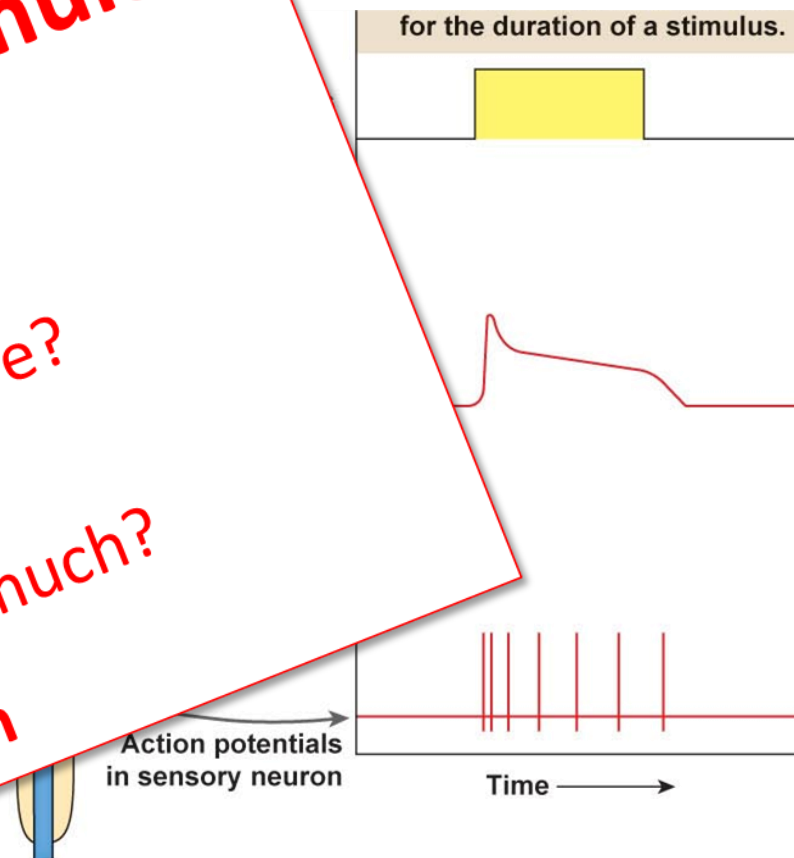
# Receptors/sensors

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

**Basic attributes of stimulus**

**Qualitative**  
Modality - What?  
Localization - Where?

**Quantitative**  
Intensity - How much?  
**Duration**

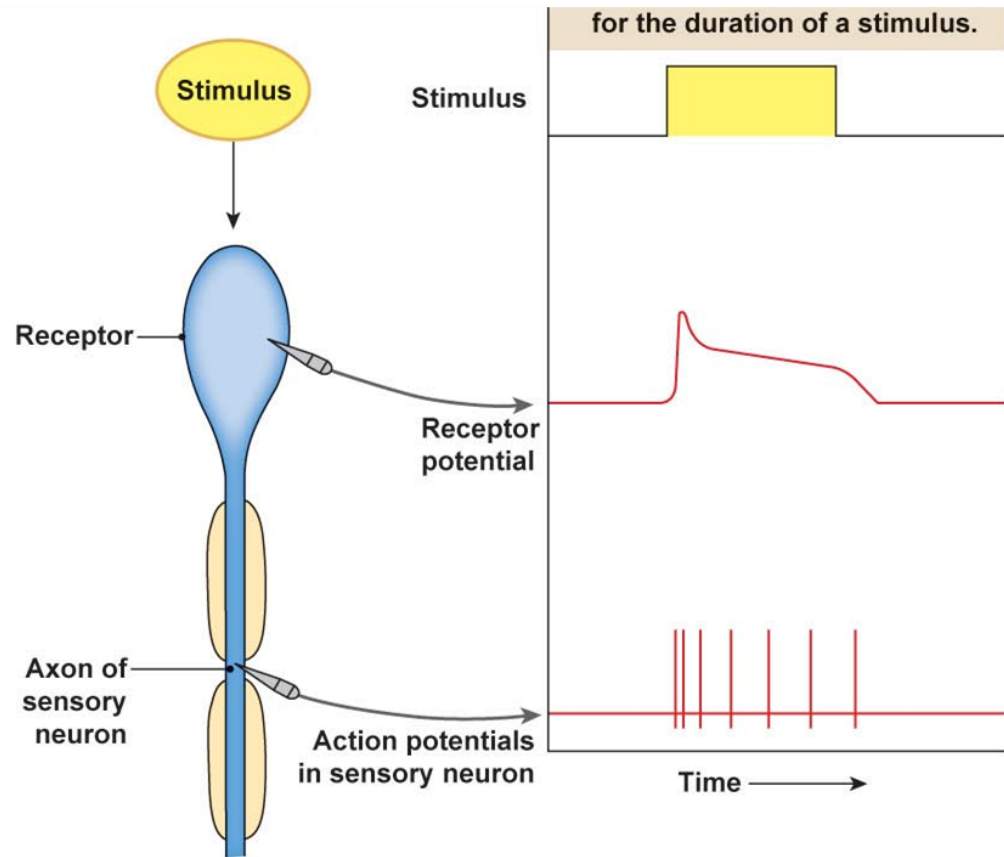


<http://www.slideshare.net/CsillaEgri/presentations>

# Intensity coding

How much?

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

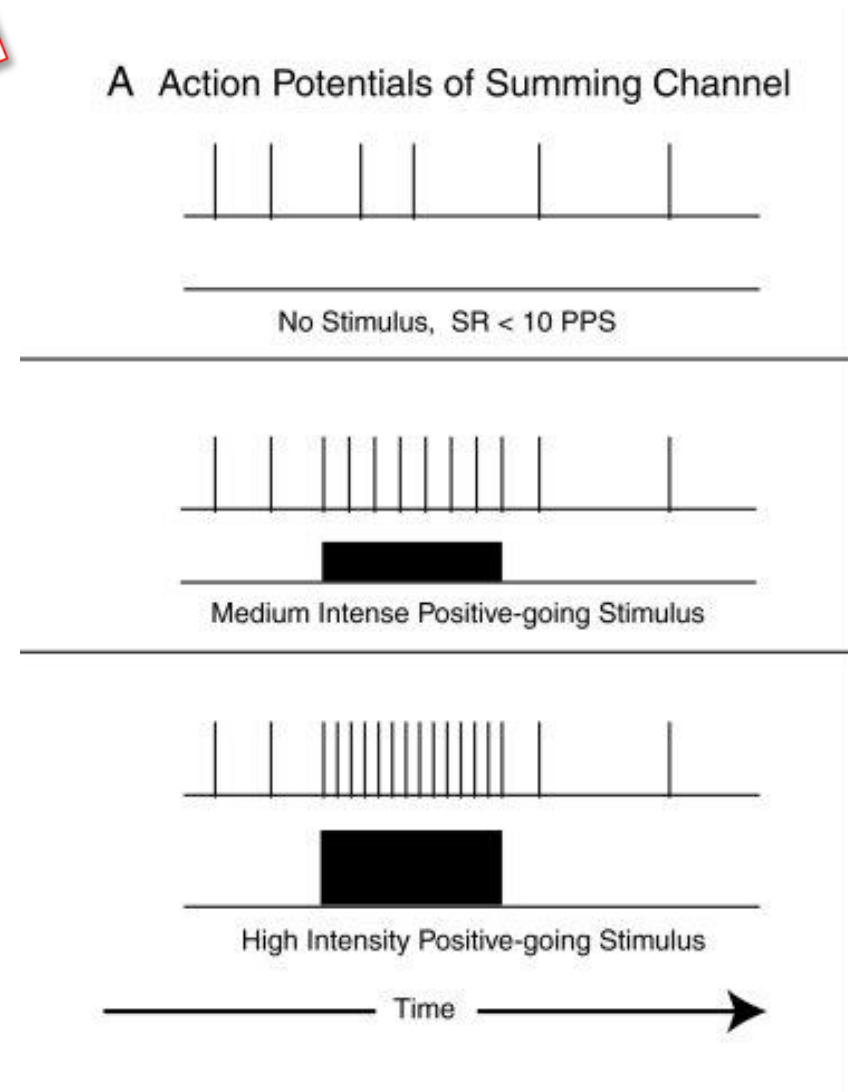


<http://www.slideshare.net/CsillaEgri/presentations>

# 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

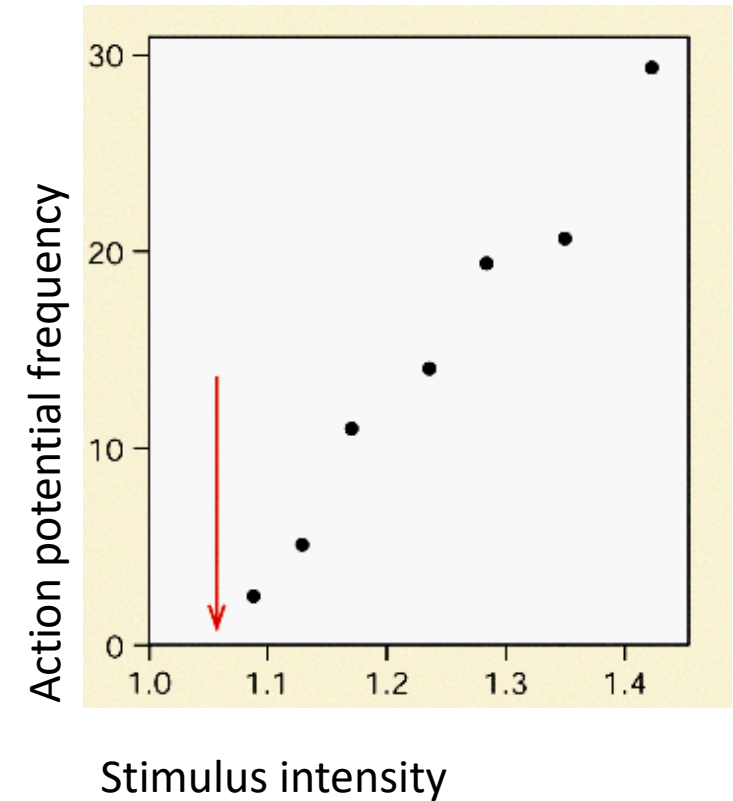
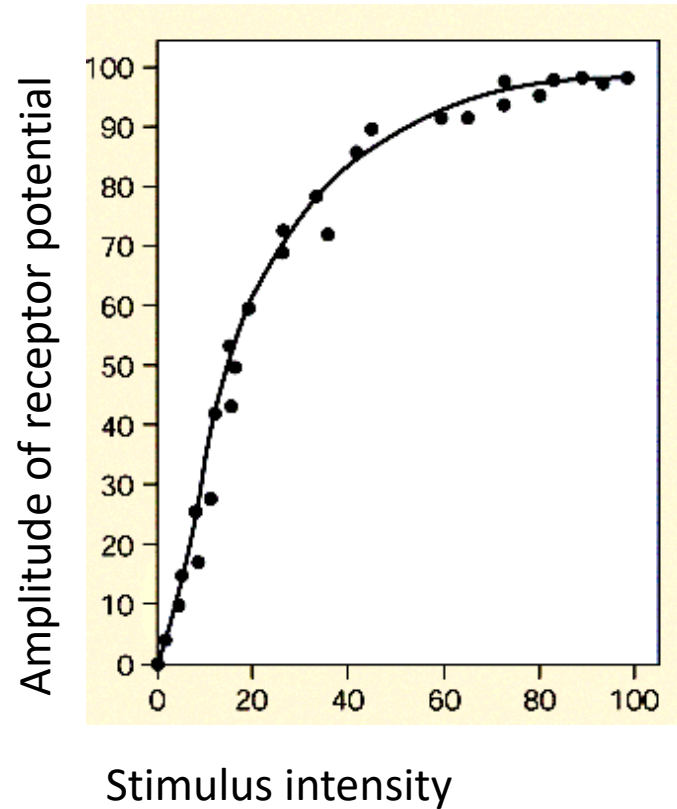


<http://neuronresearch.net/neuron/files/neuralcode.htm>

# Intensity coding

How much?

- Relation between receptor and action potential is logarithmic



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

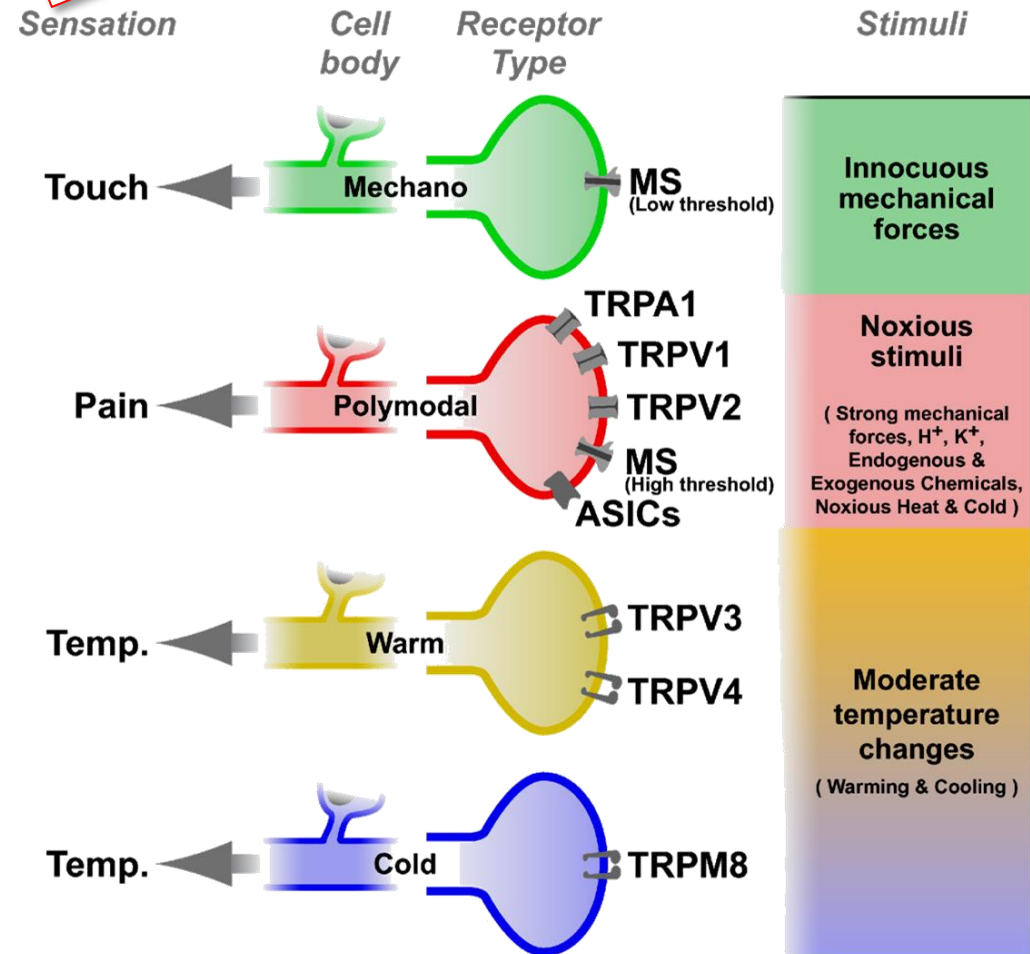
# Qualitative information

What?  
Where?

- The law of specific nerve energies:

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

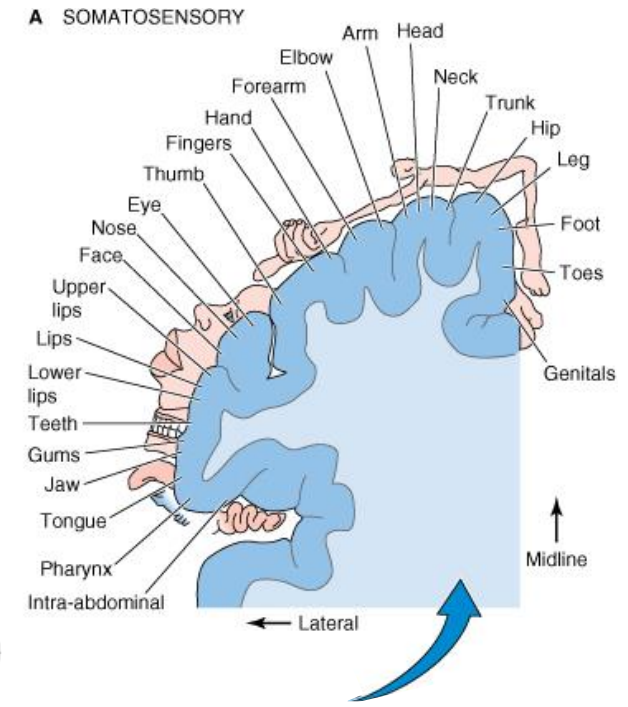
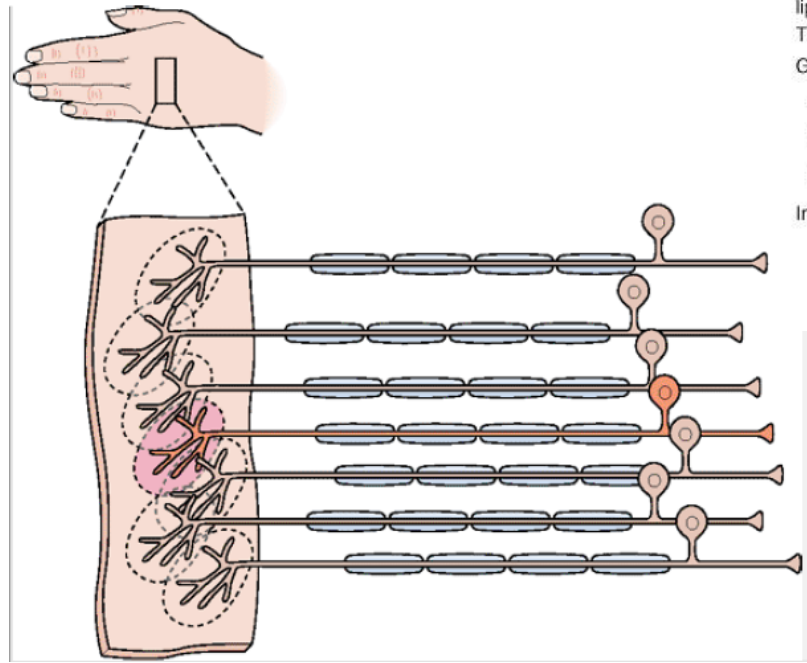
- Labeled line coding define the information about quality



# Qualitative information

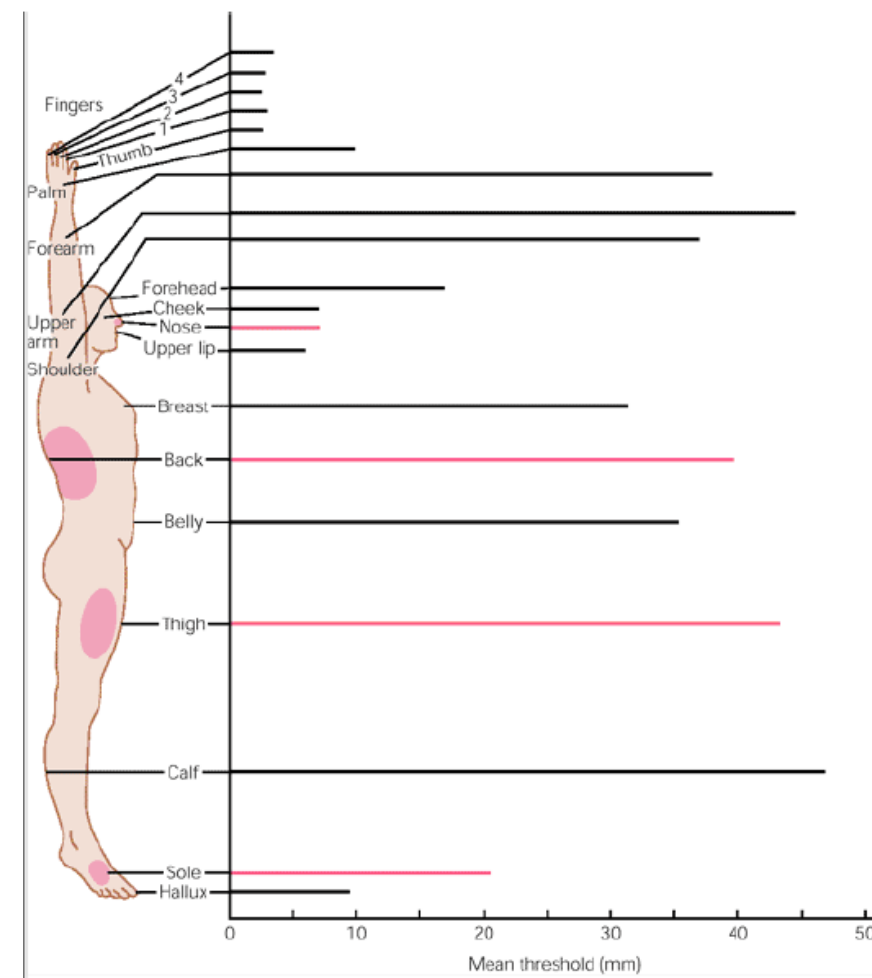
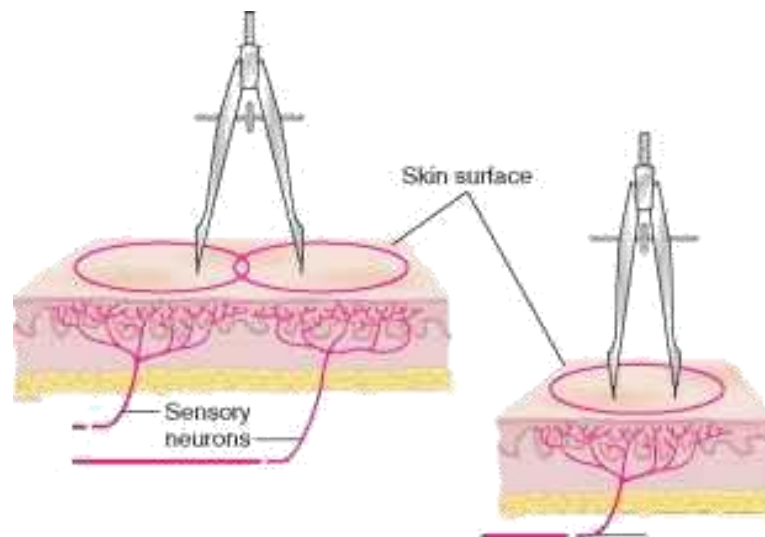
What?  
Where?

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



# Receptive fields

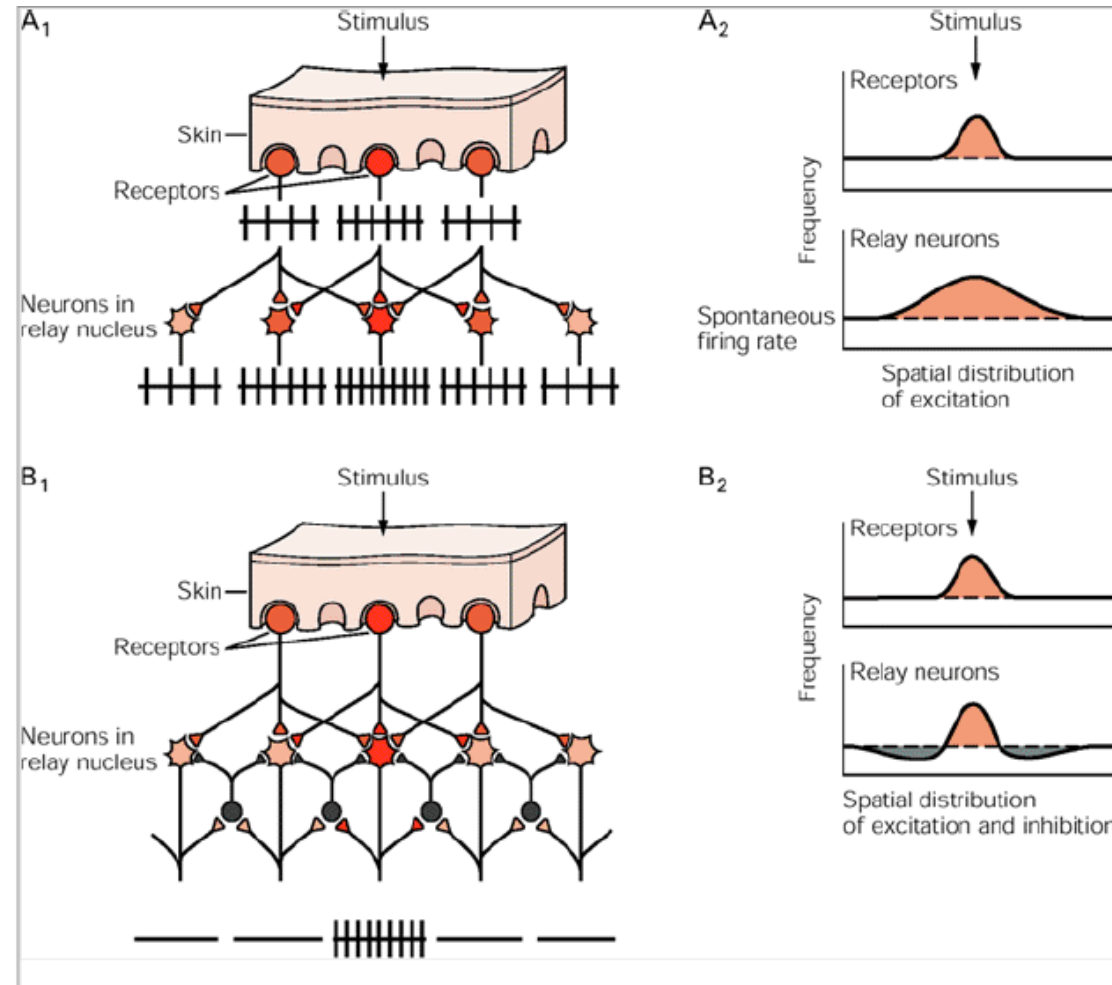
- Various size and overlap
- Small receptive field – high resolution
- Spatial resolving power increased by lateral inhibition



<http://www.slideshare.net/drpsdeb/presentations>



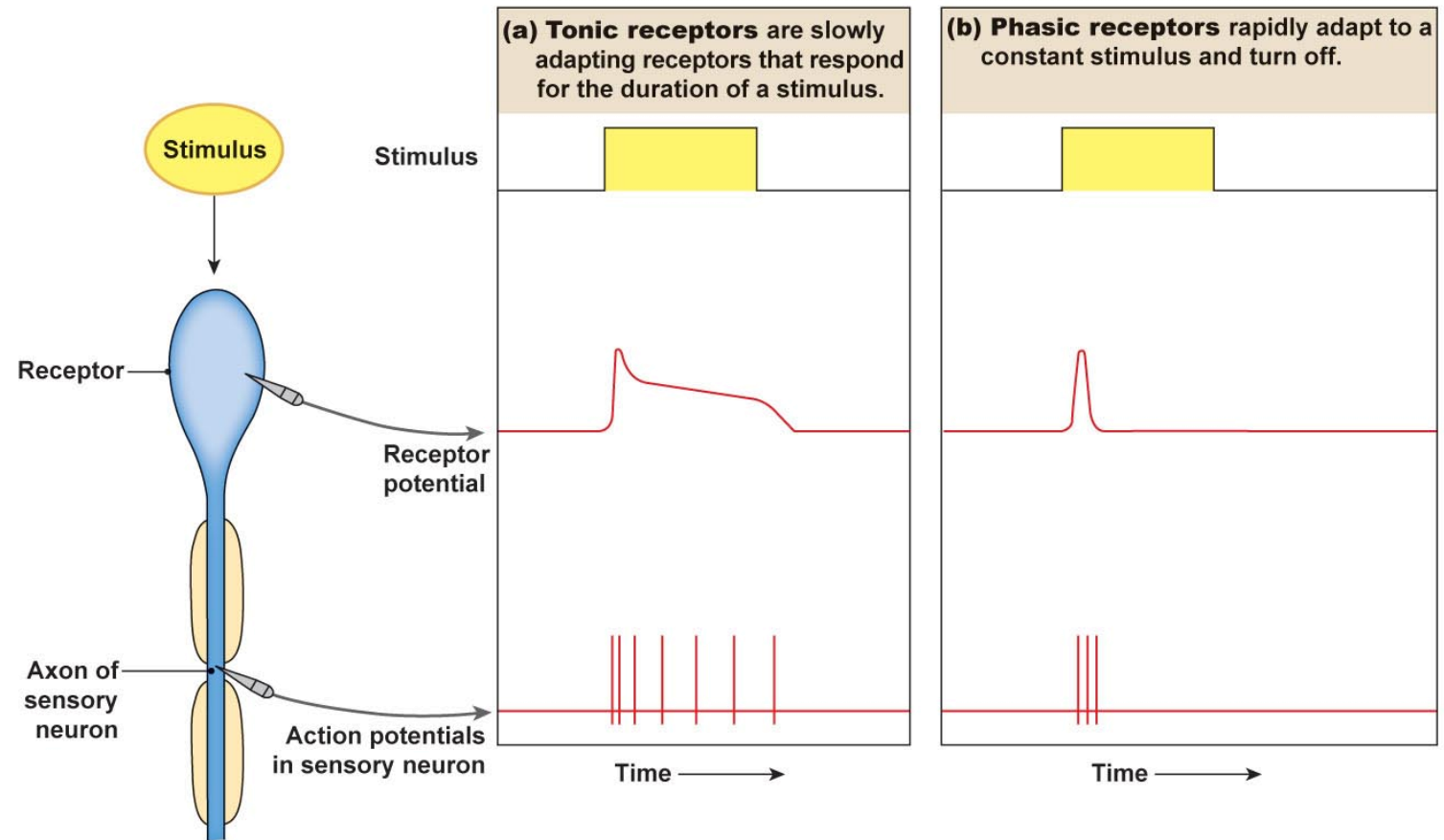
# Lateral inhibition



<http://www.slideshare.net/drpsdeb/presentations>

# 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



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

# Receptors

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

# Receptors

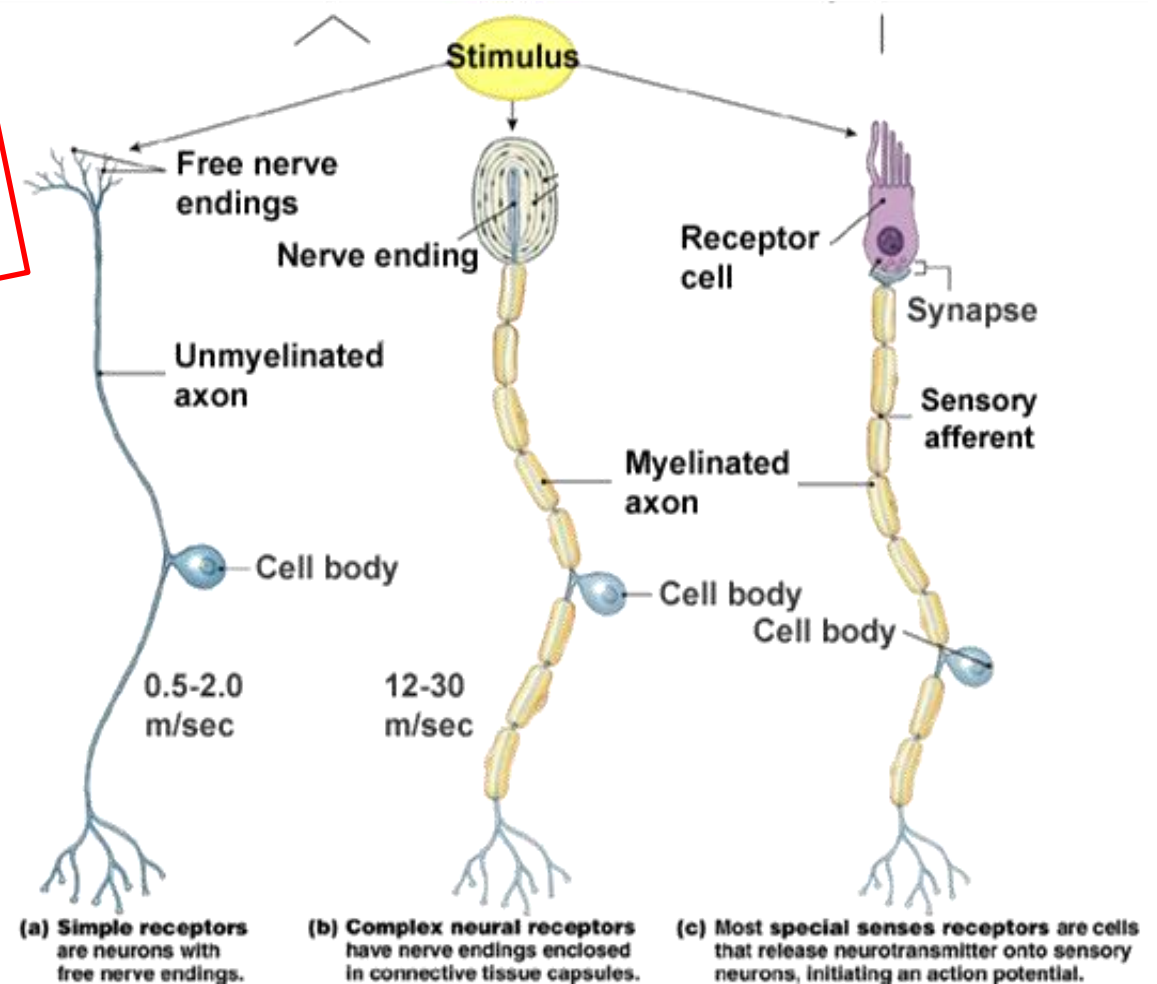
- ✓ **Mechanoreceptors**
- ✓ **Thermoreceptors**
- ✓ **Chemoreceptors**
- ✓ **Fotoreceptors**

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

# Receptors

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

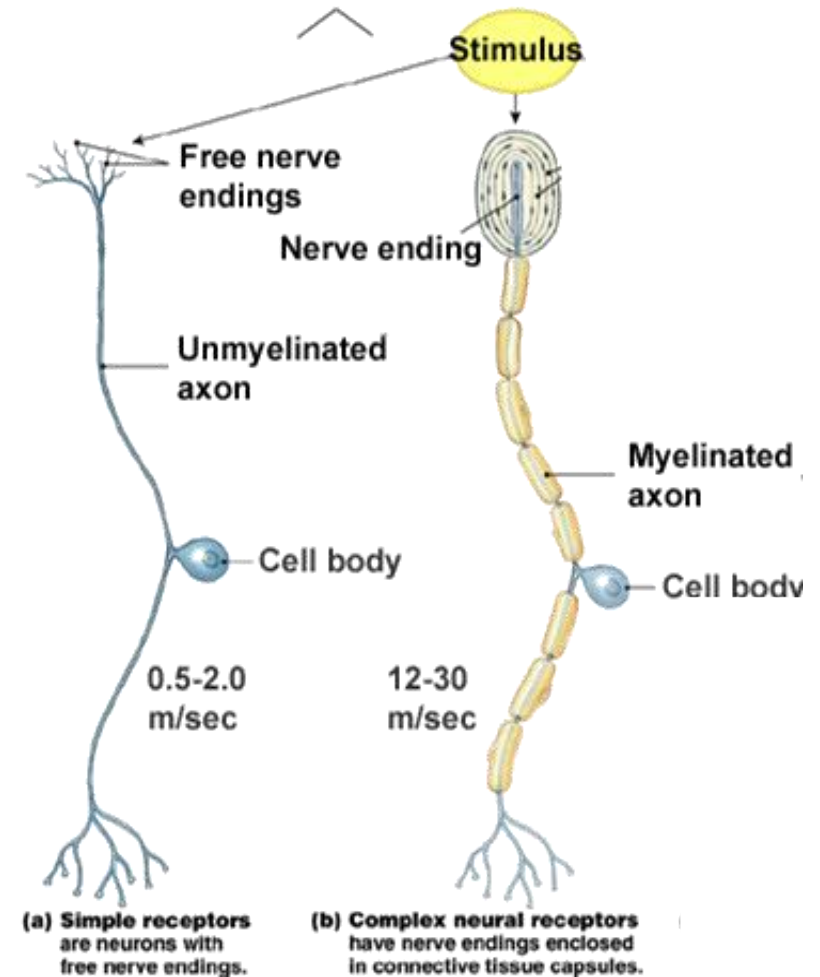
- Simple
  - Superficial – somatosensors
  - Deep – viscerosensors
  - Muscles, tendons, joints – proprioceptors
- General
  - Part of sensory organs
- Special
  - Part of sensory organs



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

# Somato/viscero/ proprio

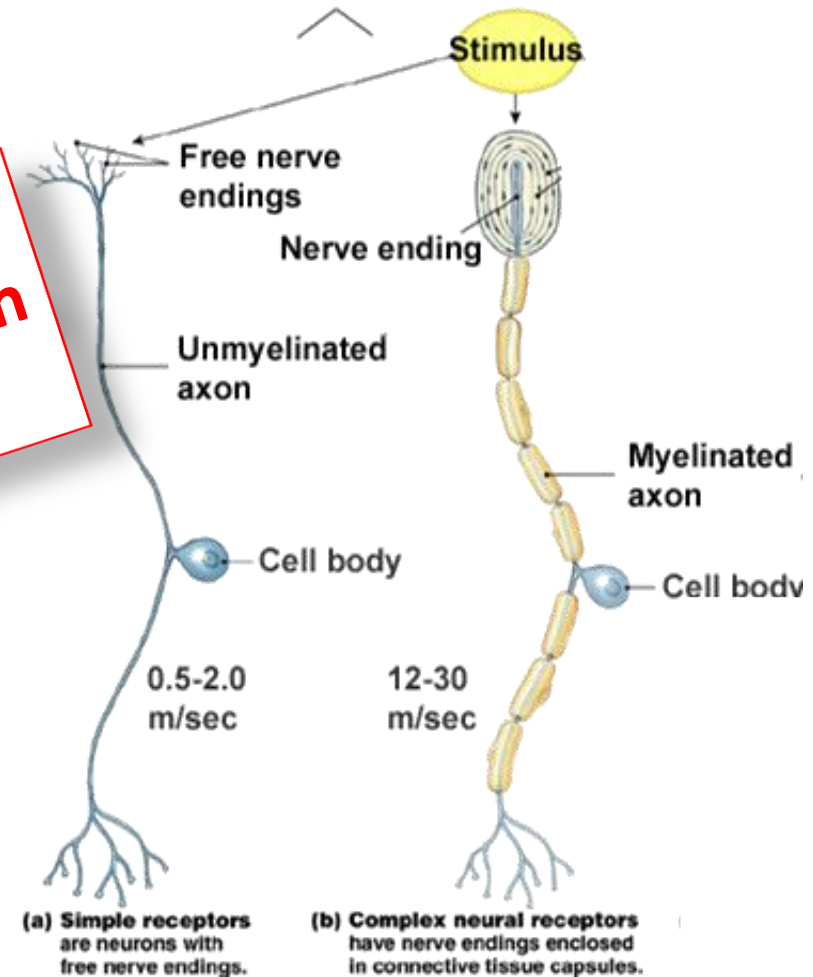
- Somatosensitivity
  - Pain
  - Temperature
  - Touch
- Viscerosensitivity
  - Pain
- Proprioception
  - Position
  - Movement



# Somato/viscero/ proprio

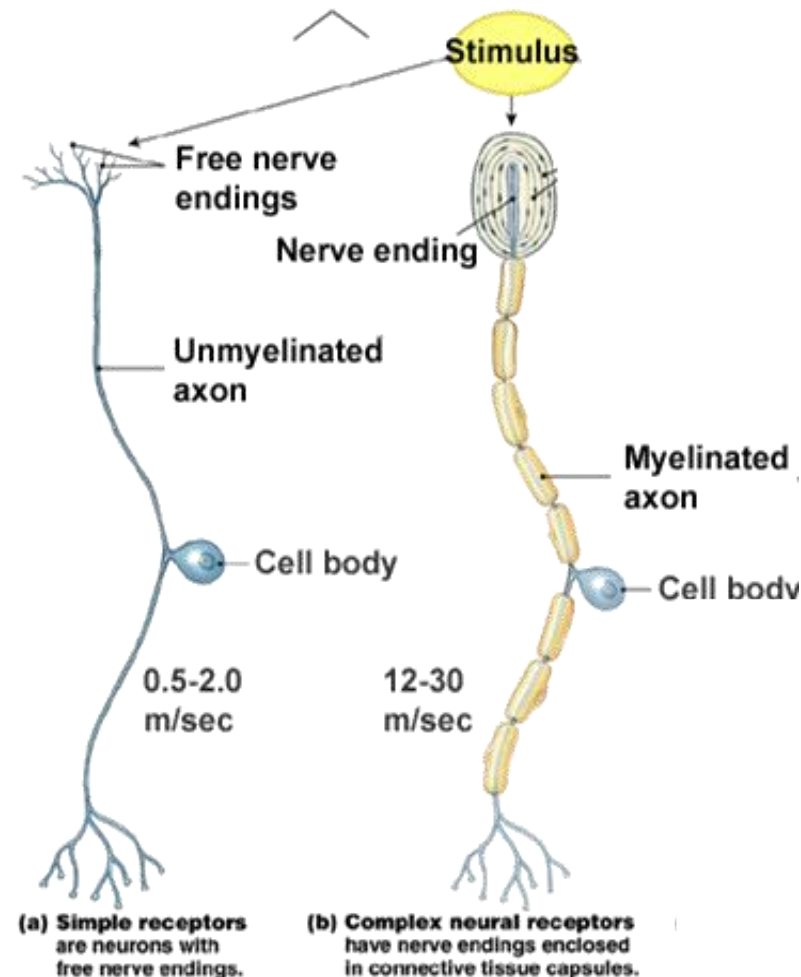
- Somatosensitivity
  - Pain
  - Temperature
  - Touch
- Viscerosensitivity
  - Pain
- Proprioception
  - Position
  - Movement

**The majority of information does not reach consciousness**



# 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





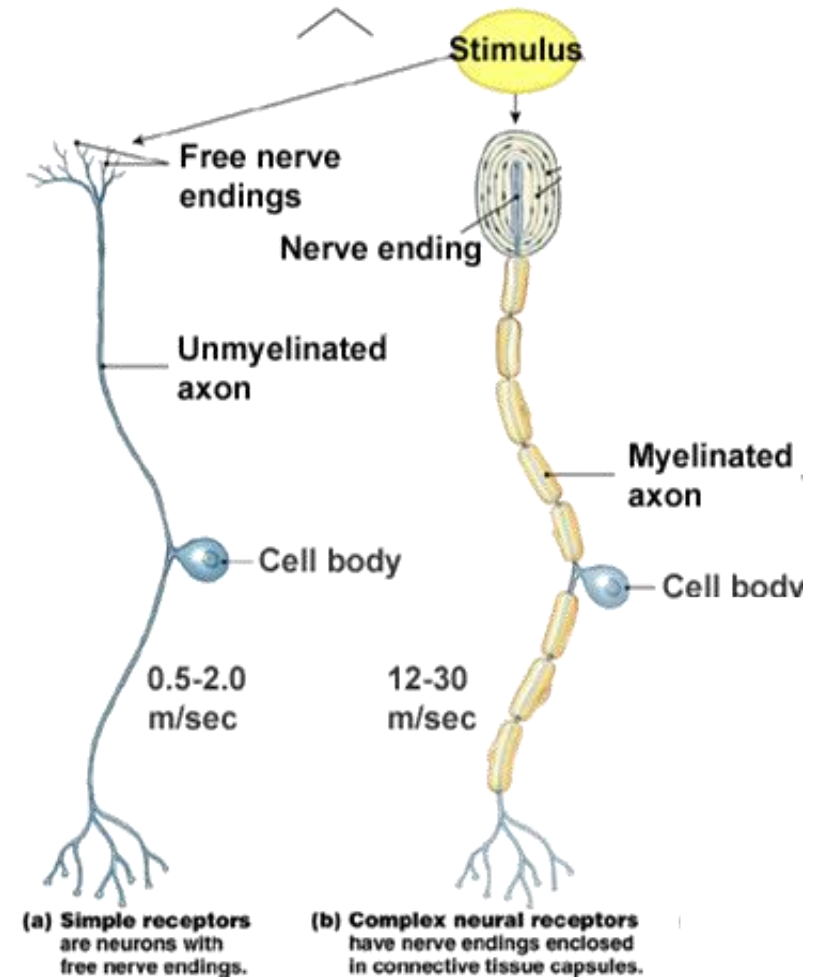
# Evolutionary point of view

- The signals indicating potential damage are the most important for the corresponding early survival involved

**Immediate survival**

**Long-term survival**

- The touch receptor has an adaptive value and a higher survival value

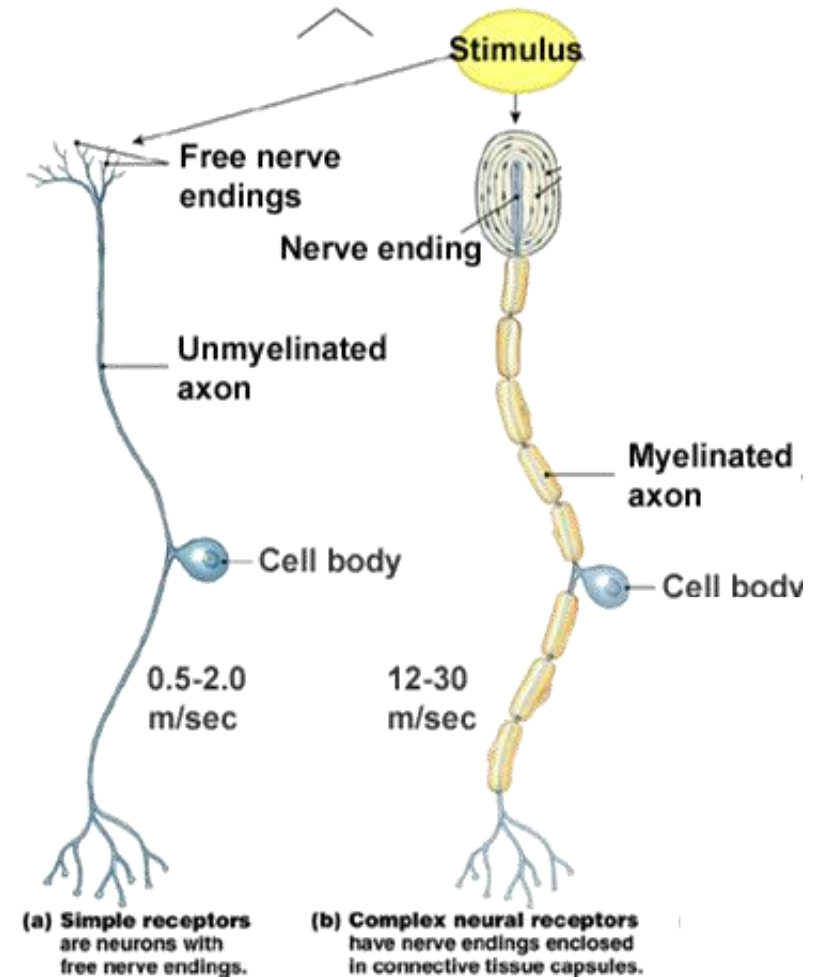


# Evolutionary point of view

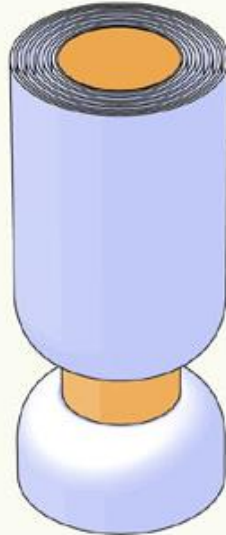

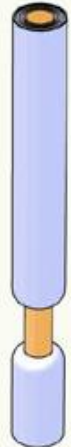

- The signals indicating potential damage are the most important for the corresponding early evolution involved
  - temperature
- The touch receptors have adaptive value and are more complex
- The structure of the receptor, nerve fibers and pathways reflects the evolution

**Immediate survival**

**Long-term survival**



# Nerve fibres

	A $\alpha$	A $\beta$	A $\delta$	C
Axons from skin				
Axons from muscles	Group I	II	III	IV
				
Diameter ( $\mu\text{m}$ )	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

# Nociceptors

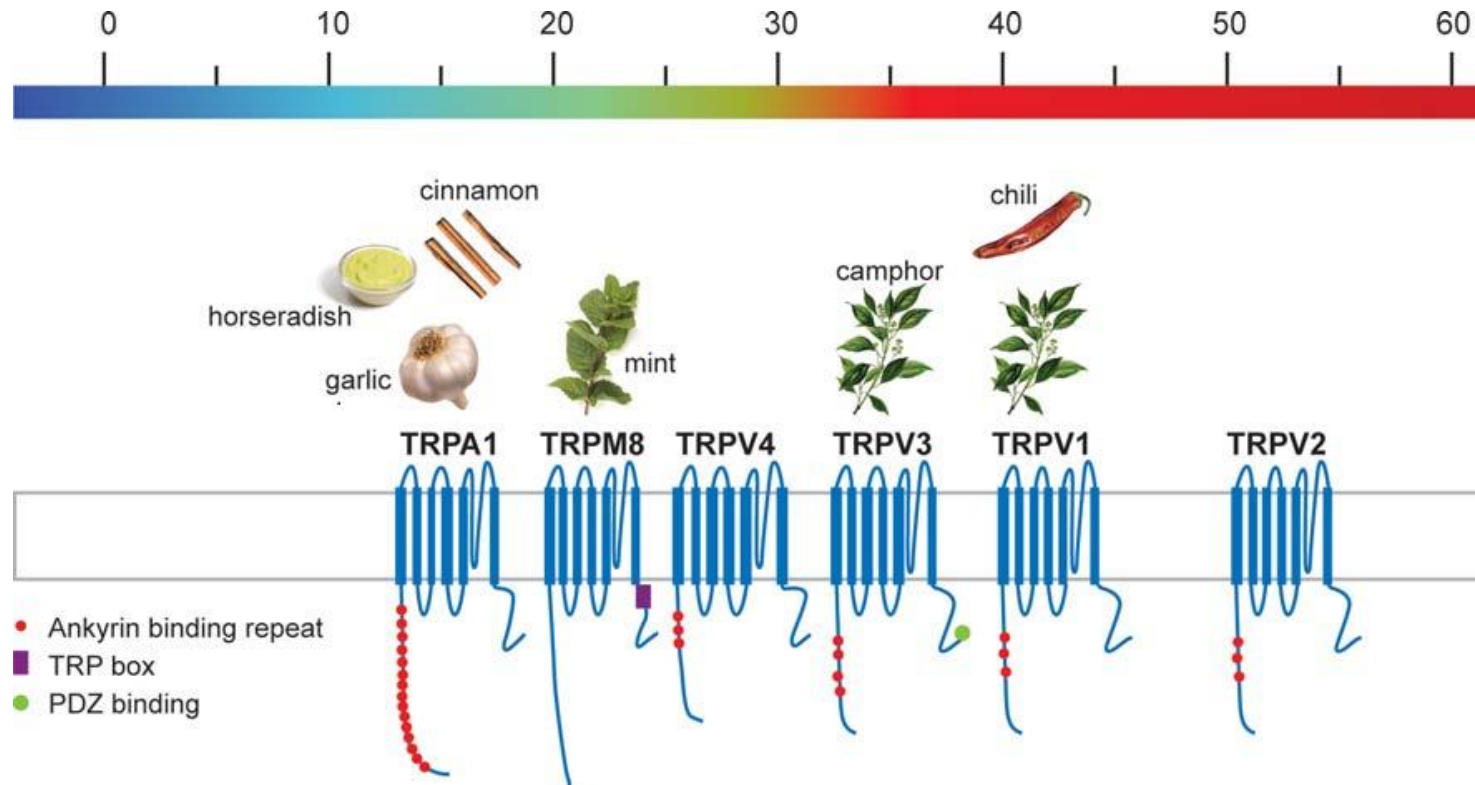
- Free nerve endings responding to high-intensity stimuli
- Stimulus
  - Mechanical
    - ✓ High pressure
    - ✓ Sharp object
  - Thermal
    - ✓ Above approx. 45°C
    - ✓ Low threshold – variable
  - Chemical
    - ✓ pH
    - ✓ Mediators of inflammation and so on

**A delta fibers**  
– sharp, localised pain

**C fibers**  
– dull, diffuse pain

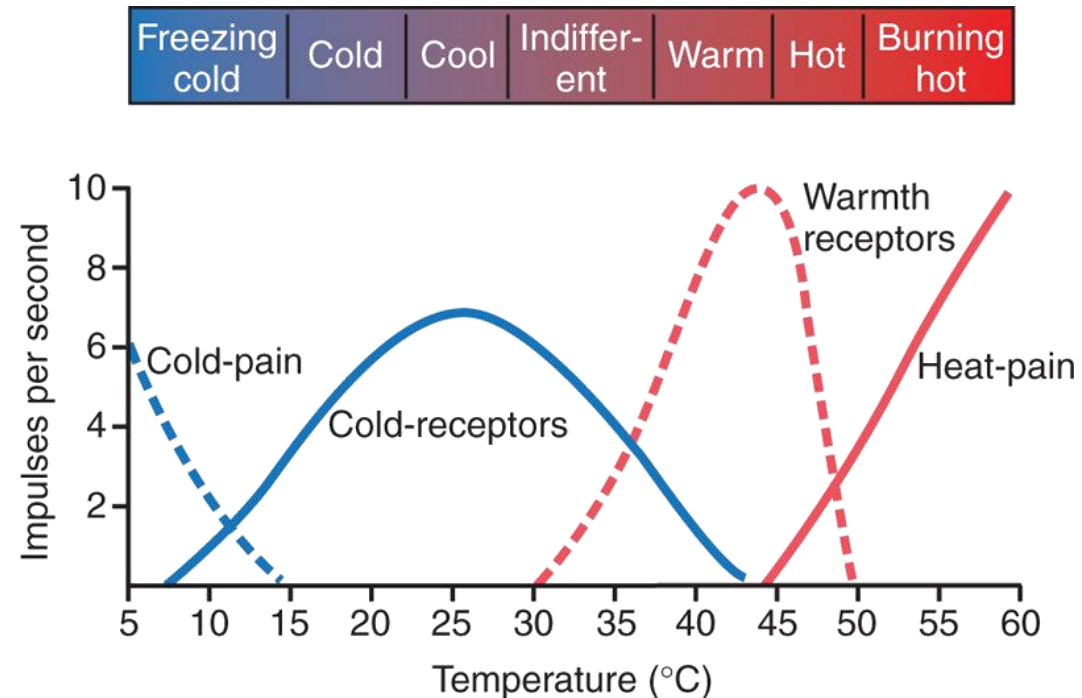
# Thermoreceptors

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



# Thermoreceptors

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

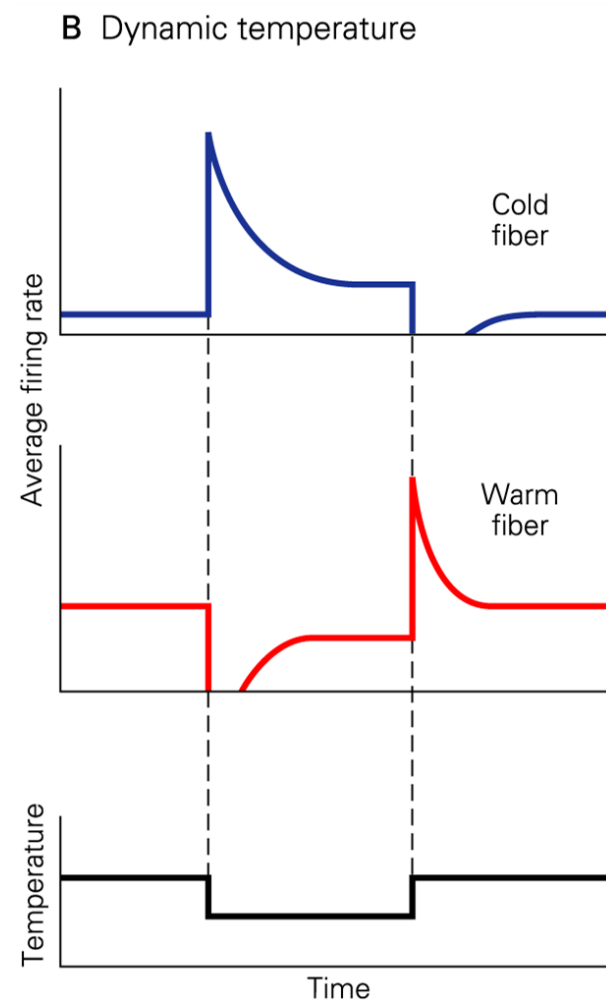


Hall: Guyton and Hall Textbook of Medical Physiology, 12th Edition  
Copyright © 2011 by Saunders, an imprint of Elsevier, Inc. All rights reserved.

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

# Thermoreceptors

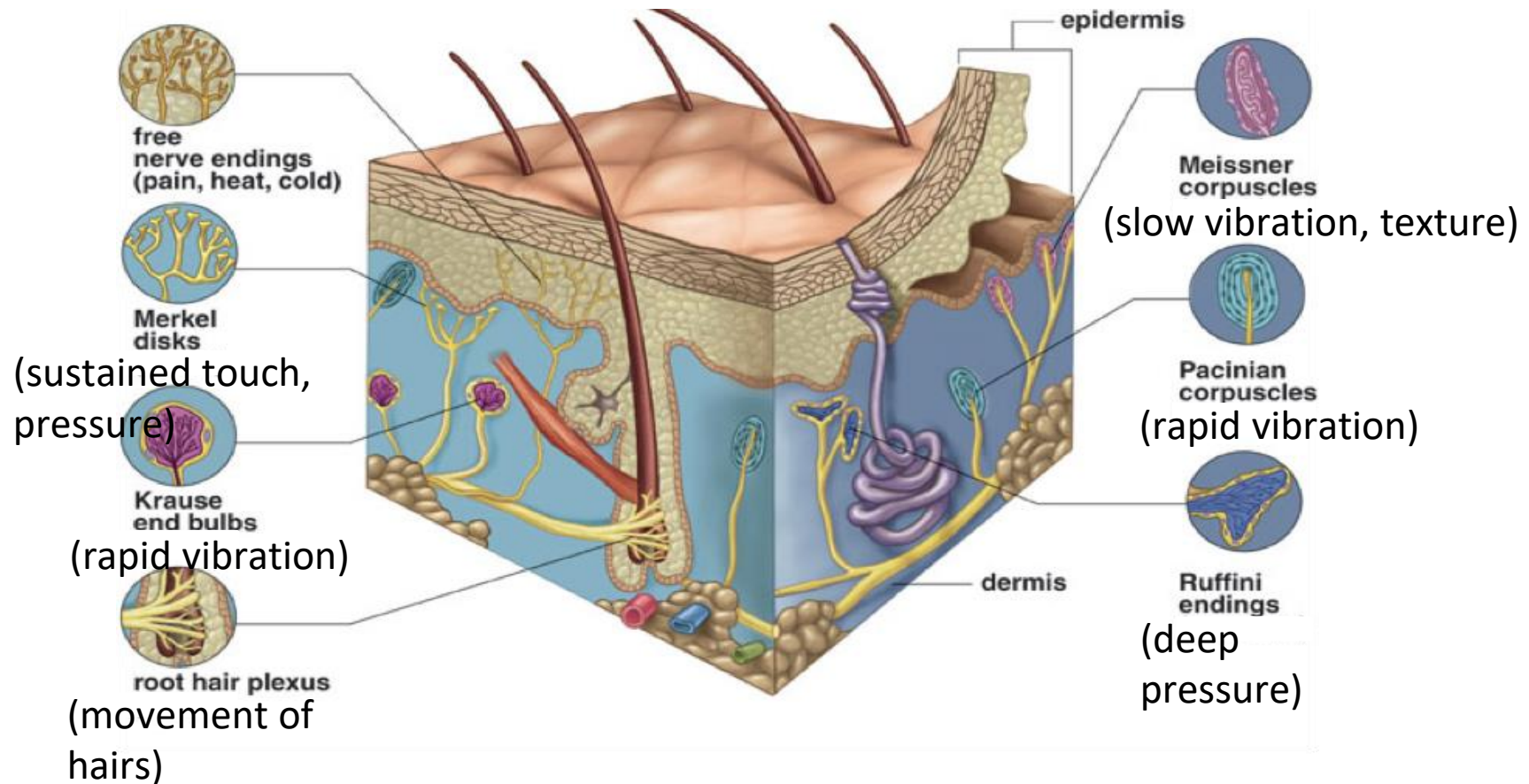
- Mostly phasic response



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

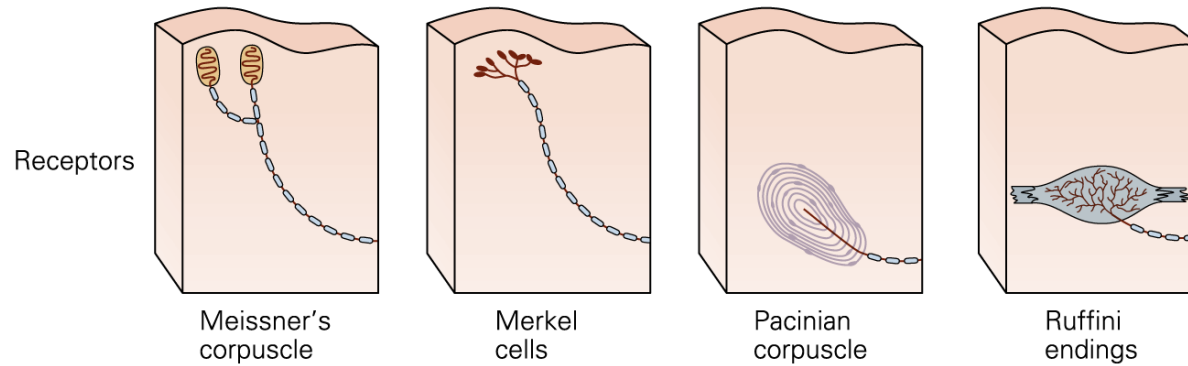
# The receptors of the skin

- Simple versus complex

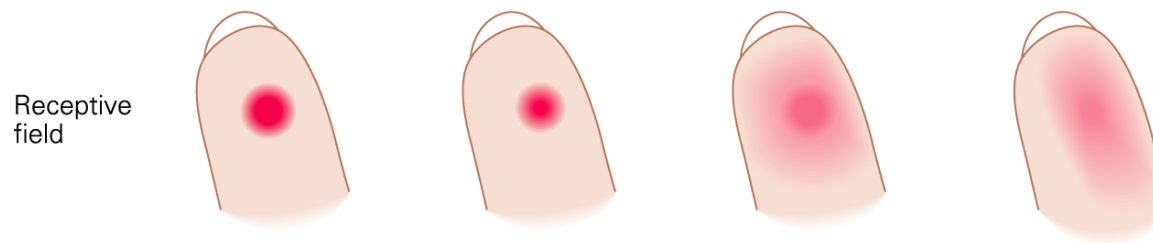




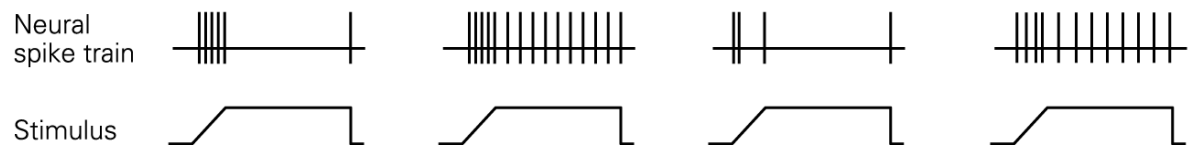
# The receptors of the skin



## B Location



## C Intensity and time course



# The receptors of the skin

Receptor	Type	Sensation	Signals	Adaptation
<b>Meissner corpuscle</b>	Encapsulated & layered	Touch: Flutter & Movement	Frequency/Velocity & Direction	Rapid
<b>Pacinian corpuscle</b>	Encapsulated & layered	Touch: Vibration	Frequency: 100-300 Hz	Rapid
<b>Ruffini corpuscle</b>	Encapsulated collagen	Touch: Skin Stretch	Direction & Force	Slow
<b>Hair follicle</b>	Unencapsulated	Touch: Movement	Direction & Velocity	Rapid
<b>Merkel complex</b>	Specialized epithelial cell	Touch, Pressure, Form	Location & Magnitude	Slow
<b>Free Nerve Ending</b>	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 information

✓ Parasympathetic nervous system (VII., IX., X., sacral PNS)  
– „Operational information“ (blood pressure, pO<sub>2</sub>, pCO<sub>2</sub>)

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

# Proprioception

- Information from
  - Muscles
  - Tendons
  - Joints
- Important for
  - Precise coordination of movements
  - Overload protection

# Somatosensory pathways

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

# Somatosensory pathways

- Three systems
- (Archispinothalamic)
  - Interconnection of adjacent
- Paleospinothalamic
- Neospinothalamic
  -
- Dorsal column-medial lemniscus
  - tr.

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

# 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

# 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

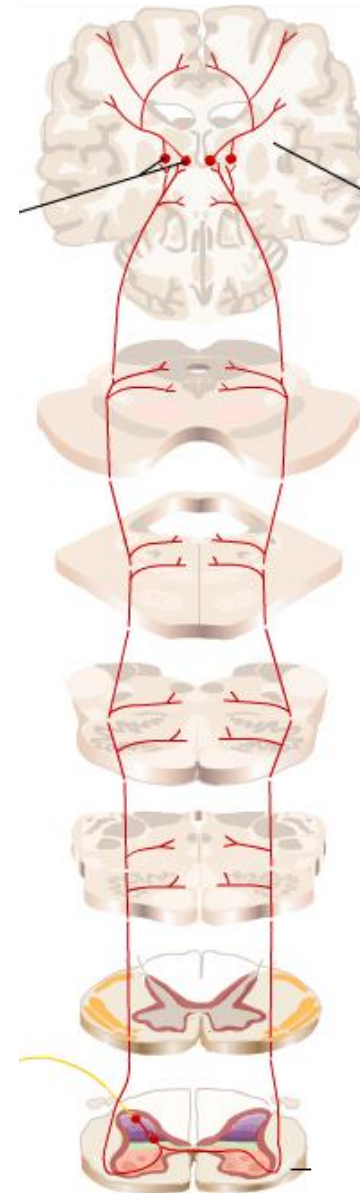
**Immediate survival**

**Long-term survival**



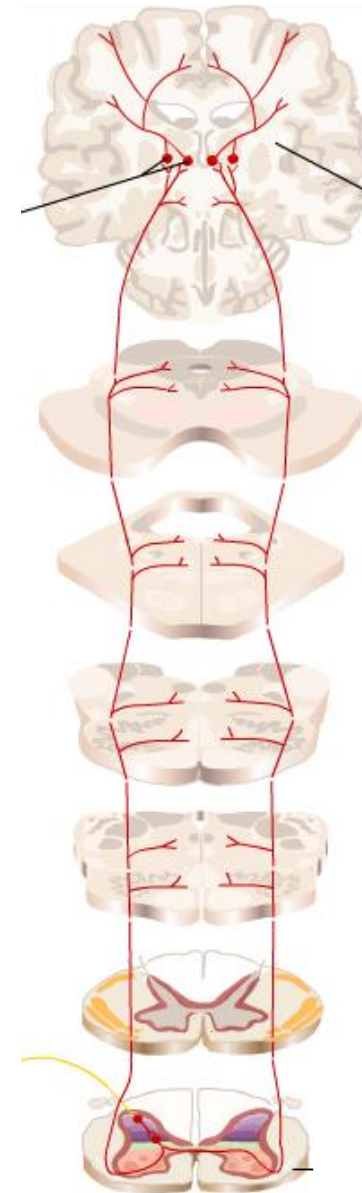
# Paleospinothalamic system

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



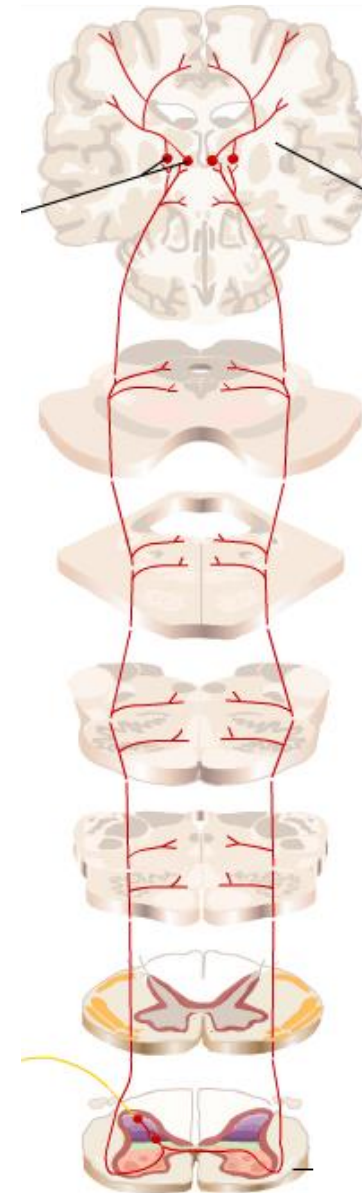
# Paleospinothalamic system

- 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.



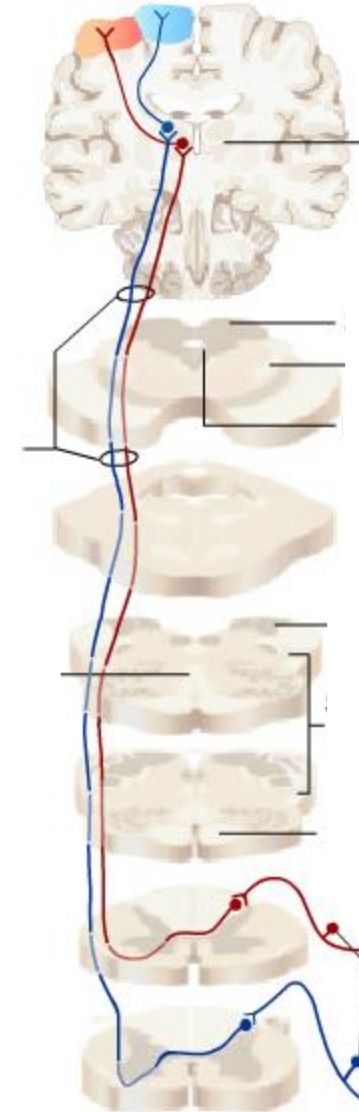
# Paleospinothalamic system

- 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



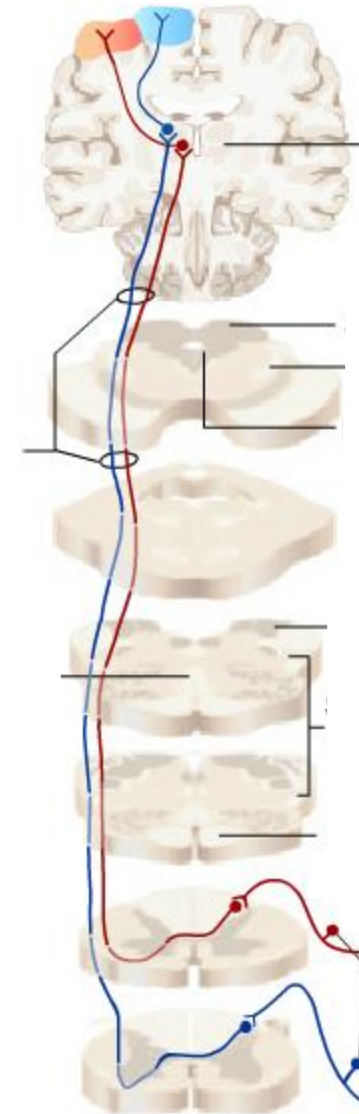
# Neospinothalamic system

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



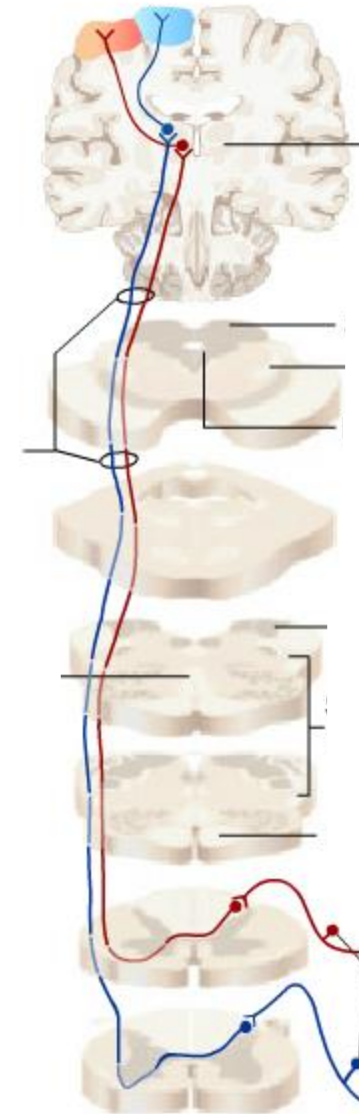
# Neospinothalamic system

- 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



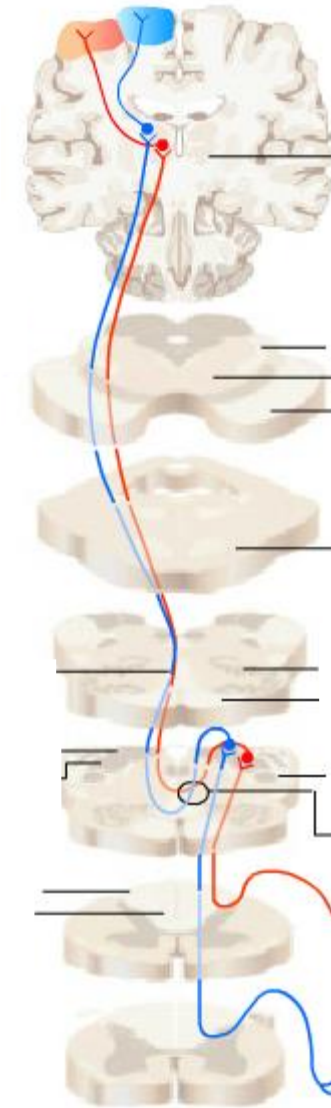
# Neospinothalamic system

- 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



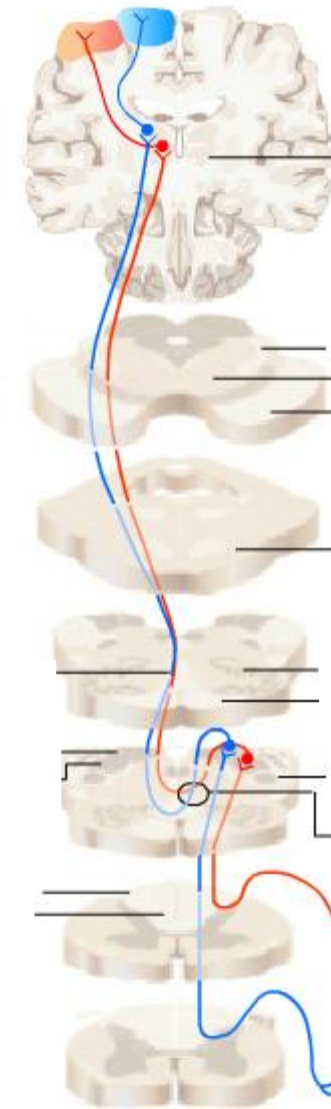
# Dorsal column system

- Tr. Spinobulbaris
- The youngest system
- High capacity



# Dorsal column system

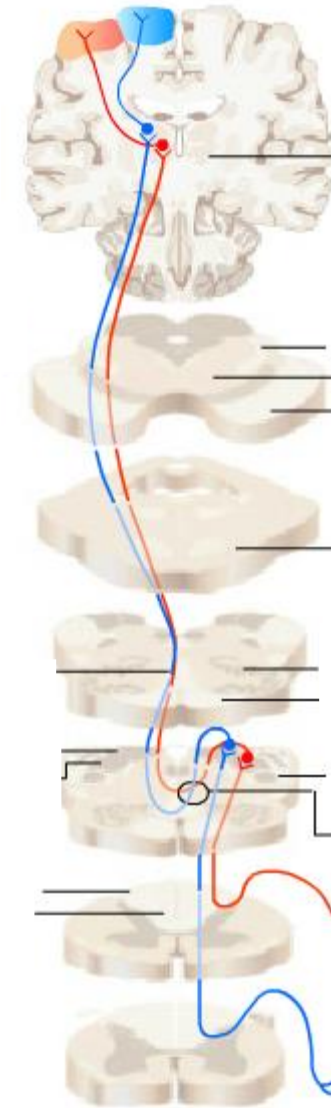
- Tr. Spinobulbaris
- The youngest system
- High capacity
- Tactile sensation
- Vibration





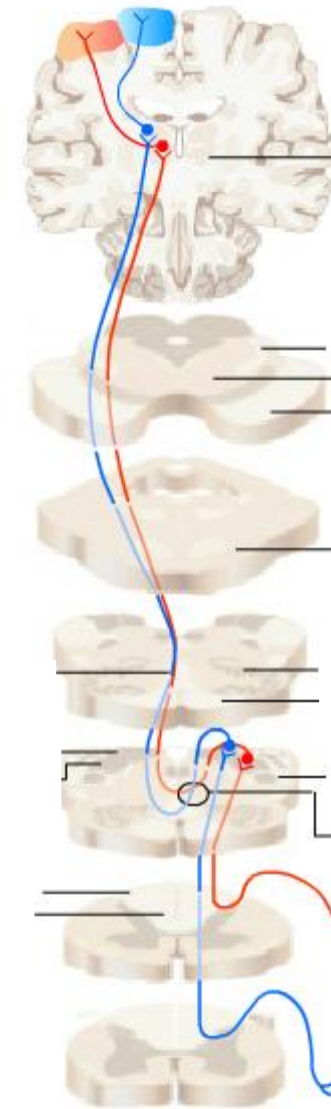
# Dorsal column system

- 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



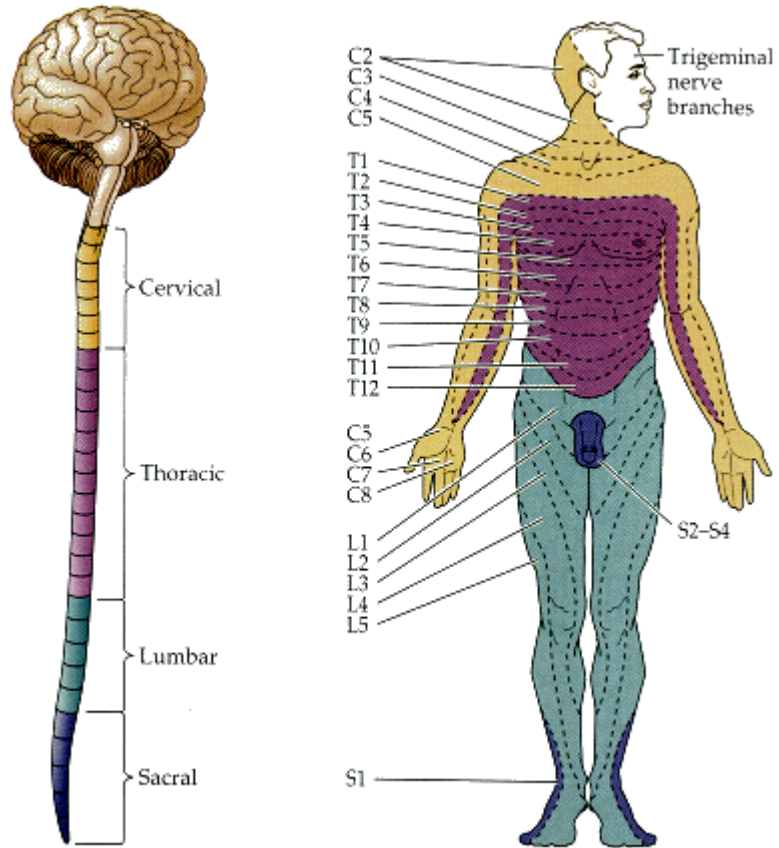
# Dorsal column system

- 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

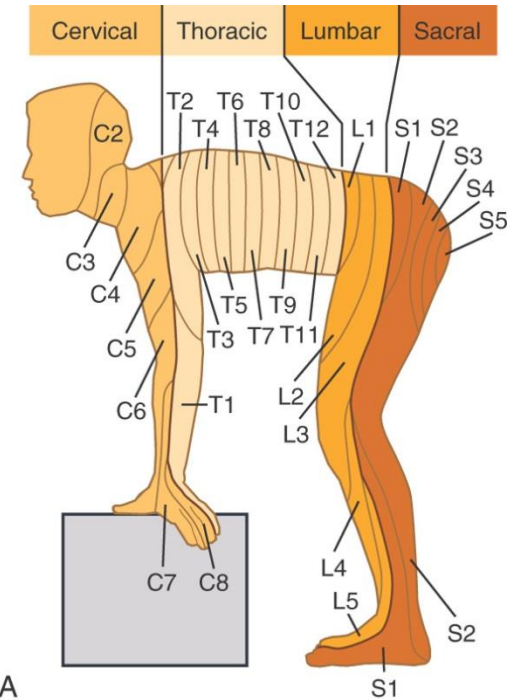


# Dermatoms

- Somatotopic organization somatosensitive nerves



<http://www.slideshare.net/drpsdeb/presentations>

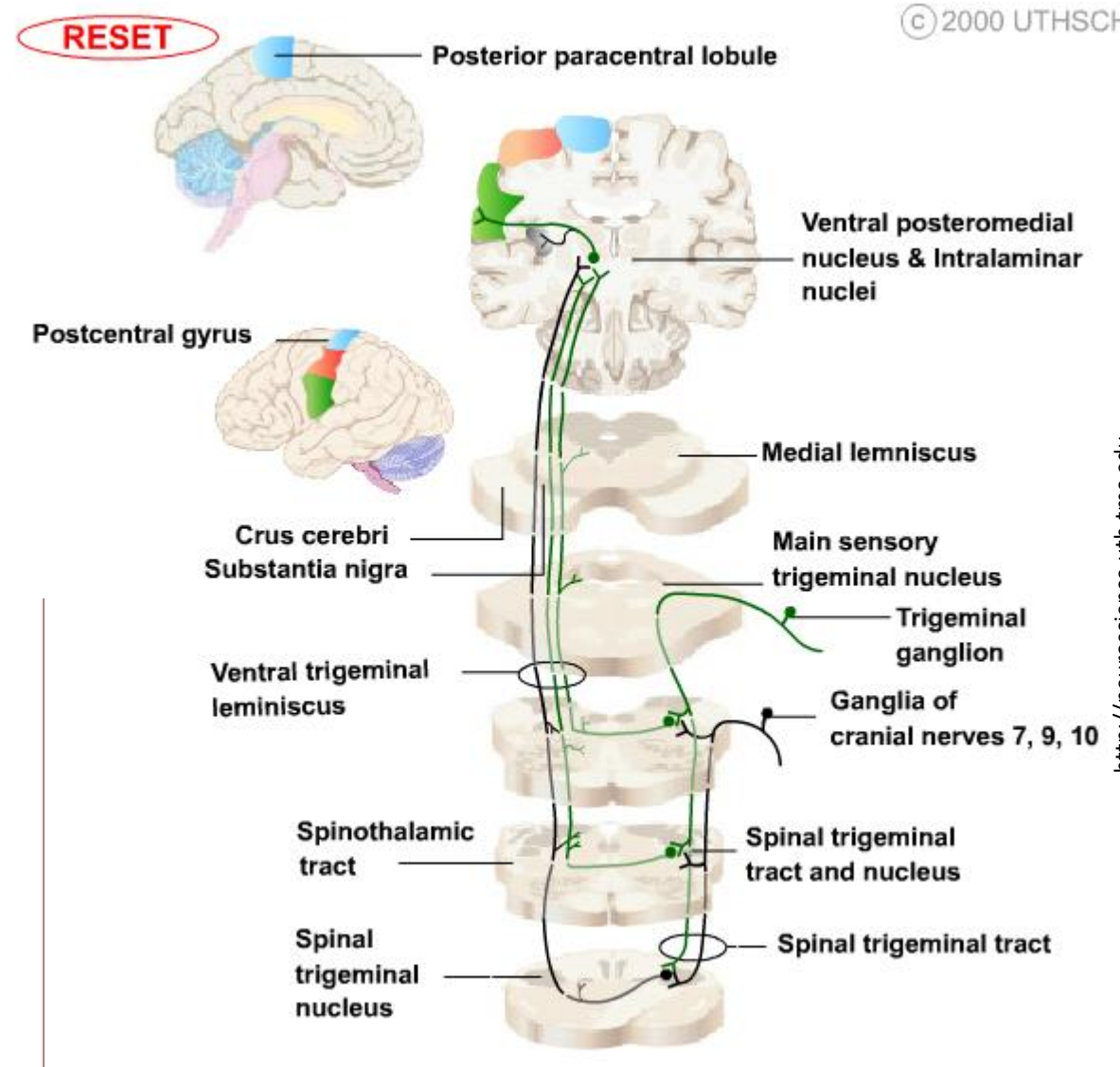
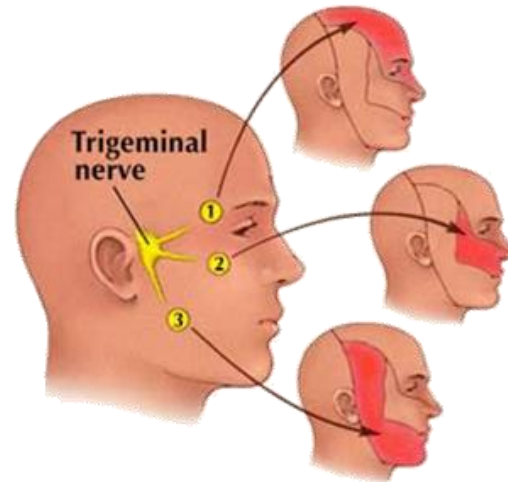
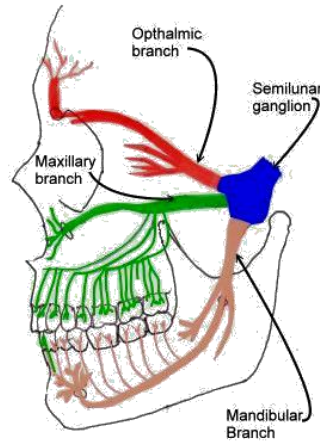


Copyright © 2008, 2004, 1999, 1993, 1988, 1983 by Mosby, Inc., an affiliate of Elsevier Inc.

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

# Trigeminal system

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



<http://www.slideshare.net/drpsdeb/presentations>

<http://neuroscience.uth.tmc.edu>

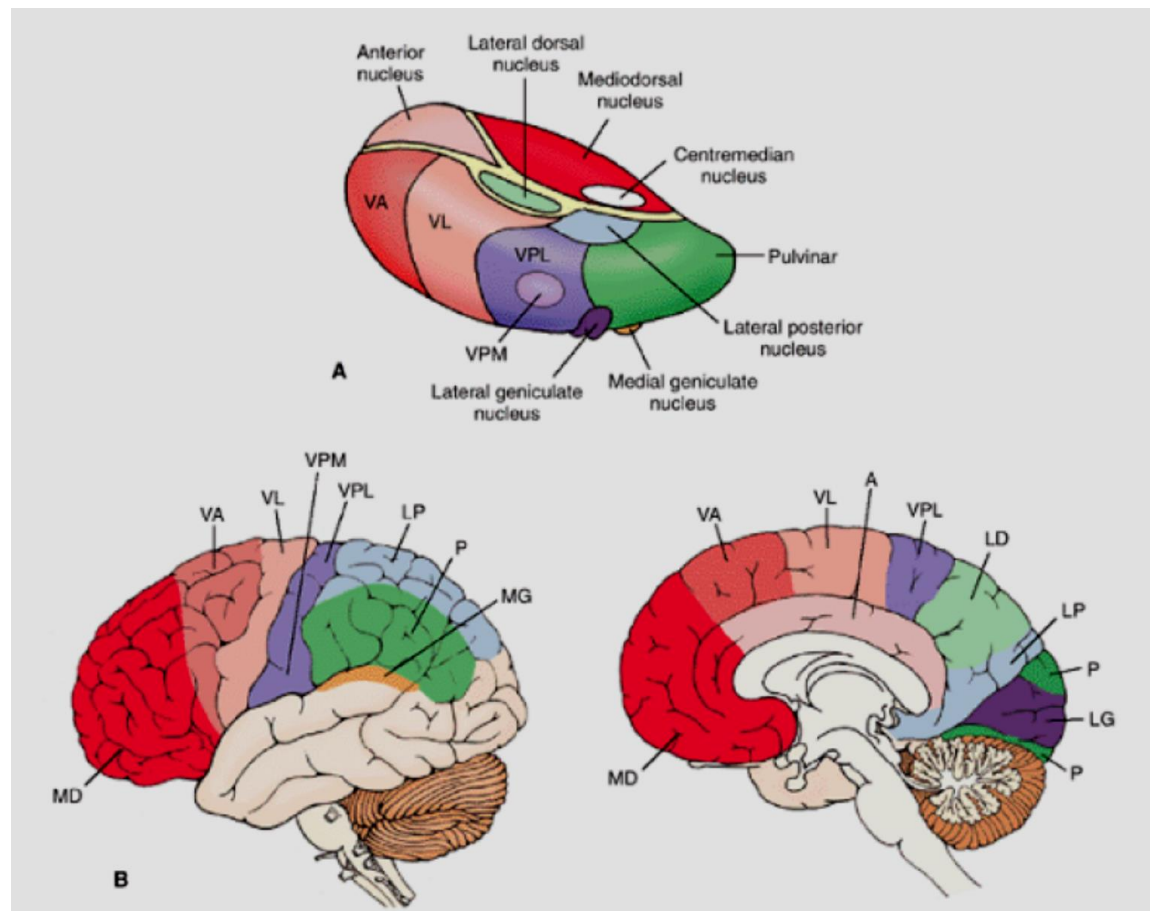
# Somatosensory pathways

<p style="text-align: center;"><i>Table I</i> <i>The Sensory Modalities Represented by the Somatosensory Systems</i></p>				
Modality	Sub Modality	Sub-Sub Modality	Somatosensory Pathway (Body)	Somatosensory Pathway (Face)
<b>Pain</b>	sharp cutting pain		Neospinothalamic	Spinal Trigeminal
	dull burning pain		Paleospinothalamic	
	deep aching pain		Archispinothalamic	
<b>Temperature</b>	warm/hot		Paleospinothalamic	
	cool/cold		Neospinothalamic	
<b>Touch</b>	itch/tickle & crude touch		Paleospinothalamic	
	discriminative touch	touch	Tr. spinobulbaris	
		pressure		
		flutter		
		vibration		
<b>Proprioception</b>	Position: Static Forces	muscle length		
		muscle tension		
		joint pressure		
	Movement: Dynamic Forces	muscle length		
		muscle tension		
		joint pressure		
		joint angle	Main Sensory Trigeminal	

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

# Thalamus and neocortex

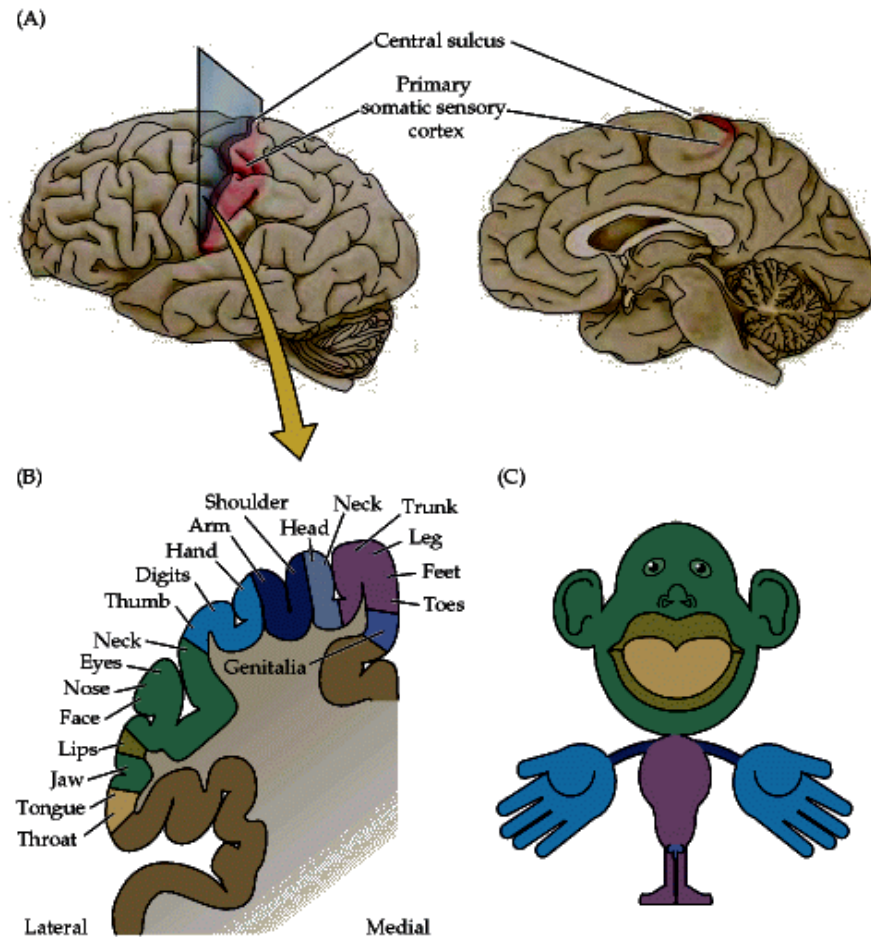
- Almost all the afferent information gated in the thalamus
- Olfaction is an exception
- Bilateral connections between neocortex and thalamus



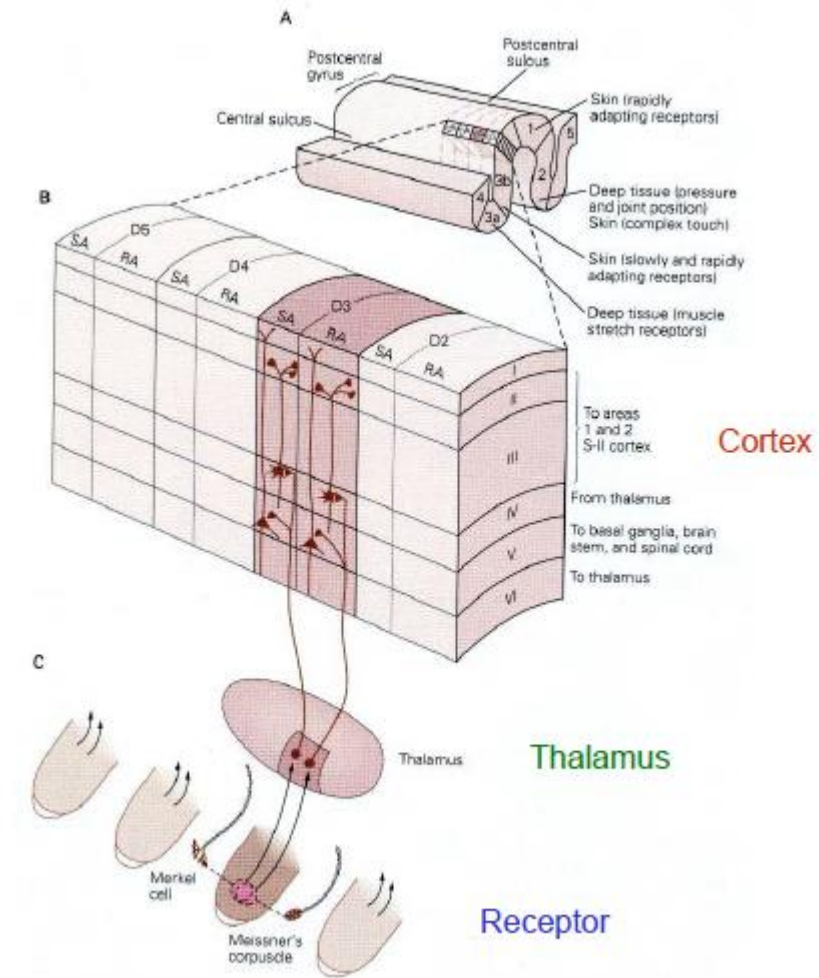
<http://www.slideshare.net/drpsdeb/presentations>

# Neocortex

- Somatotopic organization
- Cortical magnification



<http://www.slideshare.net/drpsdeb/presentations>

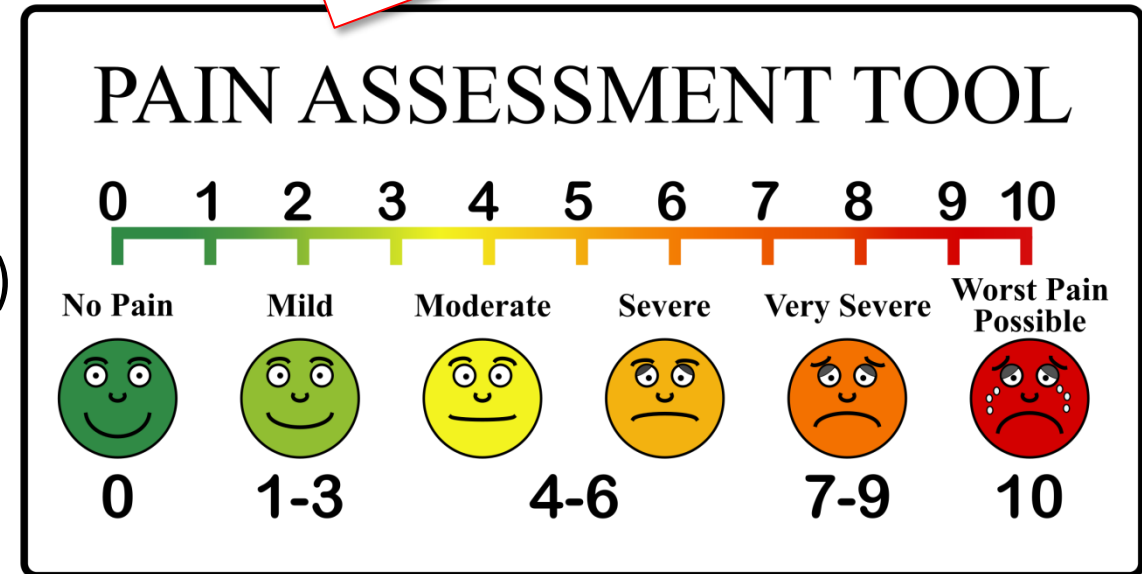


[http://www.shadmehrlab.org/Courses/physfound\\_files/wang\\_5.pdf](http://www.shadmehrlab.org/Courses/physfound_files/wang_5.pdf)

# 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) – „activating“
- Chronic (more than 6 months) – „devating“

Subjective character

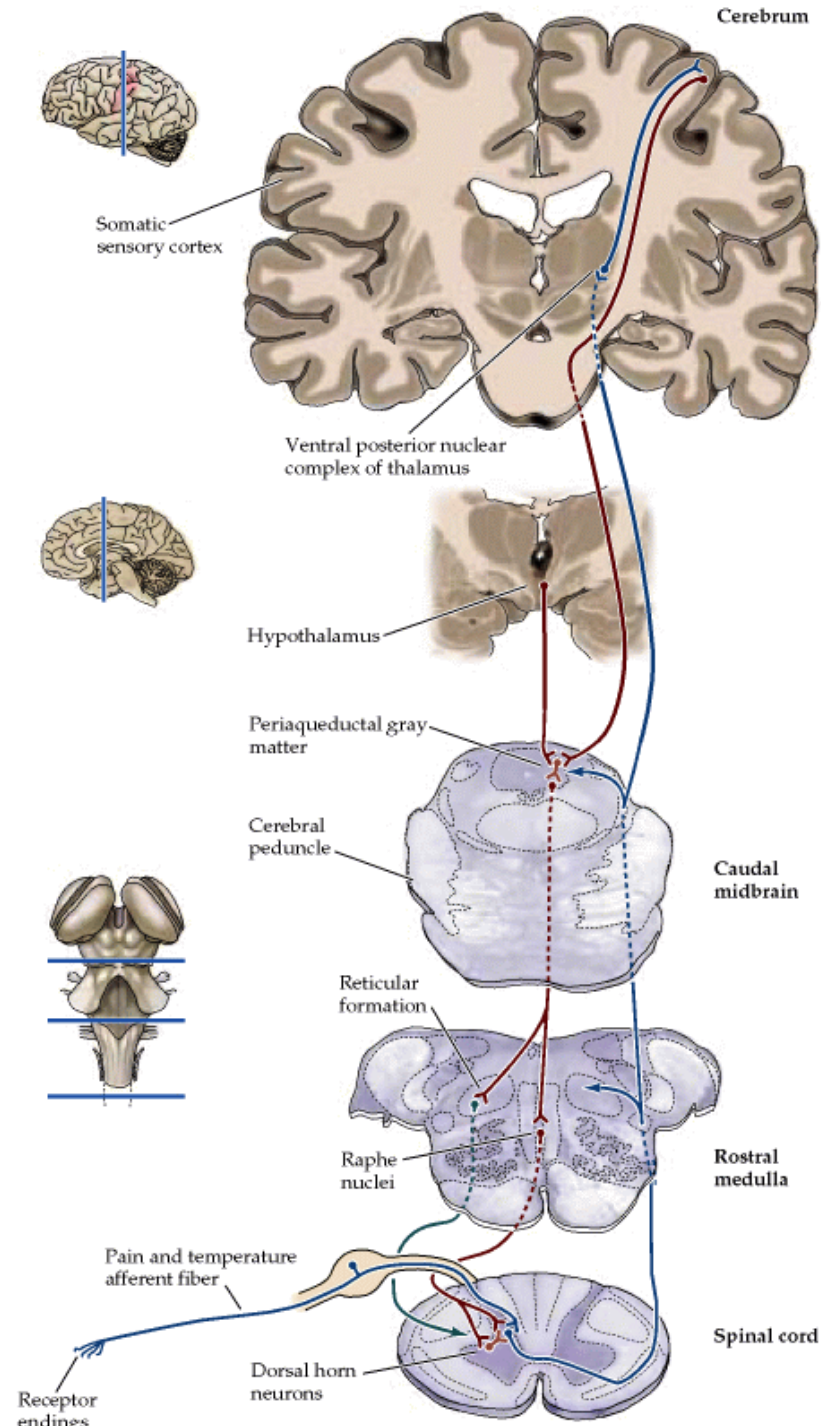


[https://www.cheatography.com/uploads/davidpol\\_1460561912\\_Pain\\_Scale\\_\\_Arvin61r58.png](https://www.cheatography.com/uploads/davidpol_1460561912_Pain_Scale__Arvin61r58.png)



# Descendent pathways modulating pain

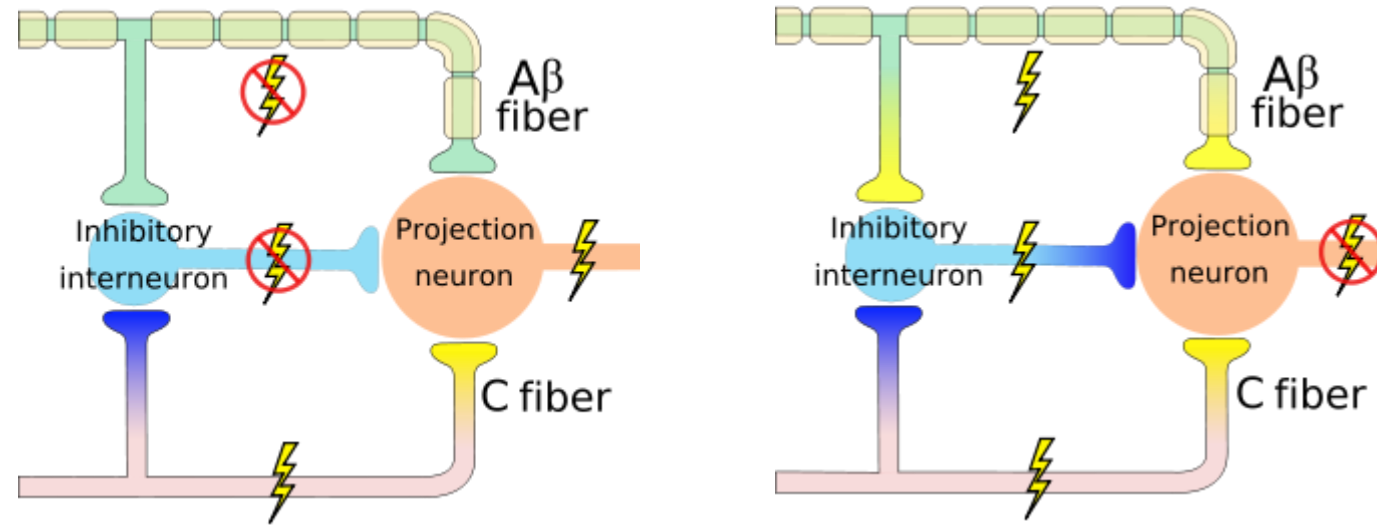
- Somatosensory cortex
- Hypothalamus
- Periaqueductal gray
- Nuclei raphe



<http://www.slideshare.net/drpsdeb/presentations>

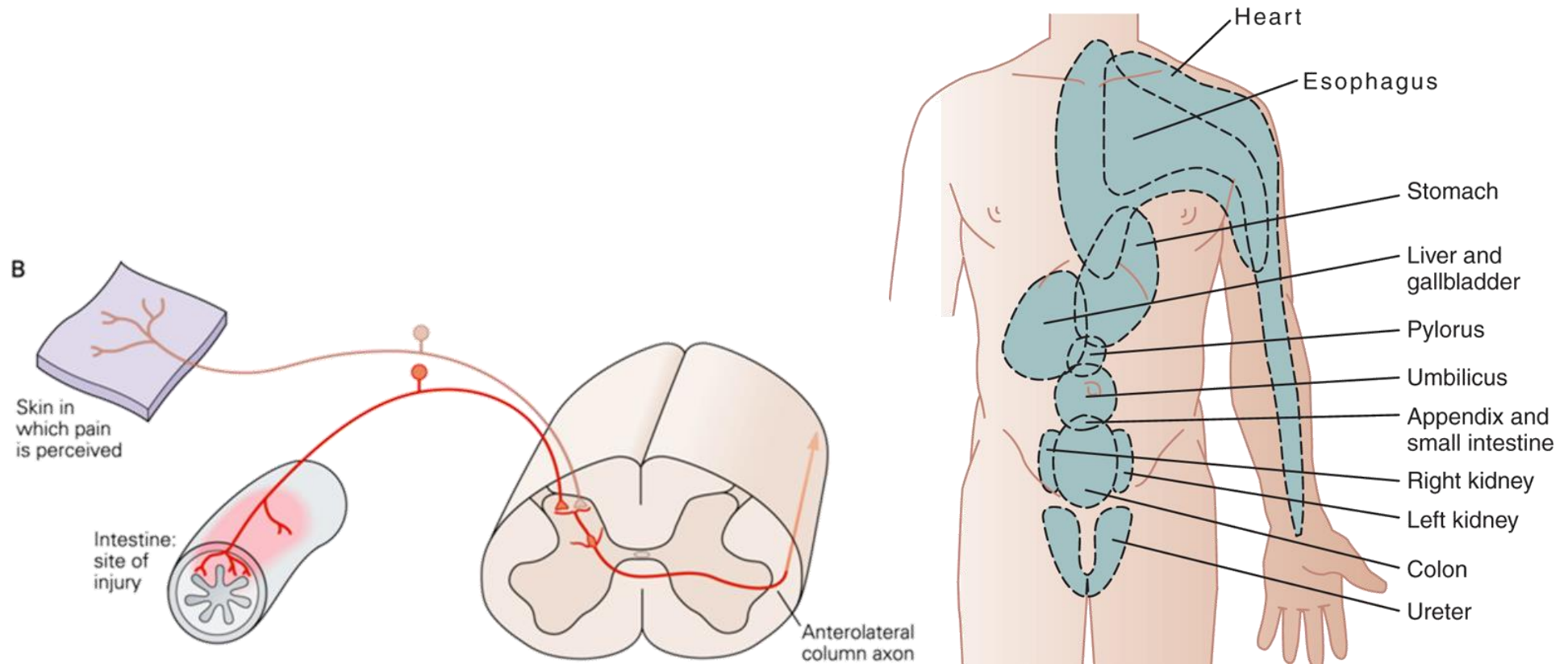
# Pain modulation on the spinal level

## Gate control theory of pain



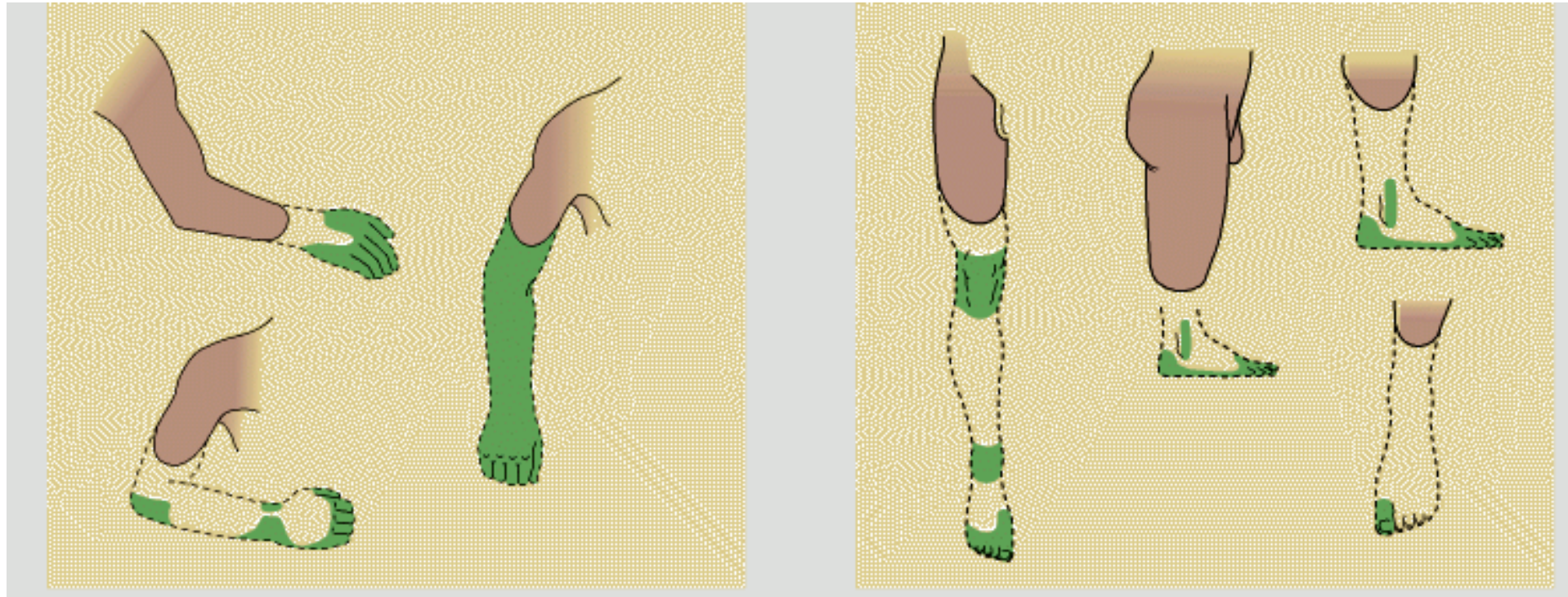
[https://en.wikipedia.org/wiki/Gate\\_control\\_theory](https://en.wikipedia.org/wiki/Gate_control_theory)

# Referred pain



<http://www.slideshare.net/drpsdeb/presentations>

# Phantom limb pain



<http://www.slideshare.net/drpsdeb/presentations>

M U N I

M E D