

# Sensory systems. Neuroanatomy of pain.

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CNS → sensation, control of movement,  
maintaining arousal

## Sensation

1. Physical stimulus
2. Nerve impulses
3. Response

Receptor → Nerve impulse

### Aspects of a stimulus:

Modality – vision, smell, hearing, touch, taste

- submodality
- adequate stimulus

Intensity – strength of the stimulus

- sensory threshold

Duration – adaptation

Location – two point threshold

# Sensory systems

SENSORY CELL (primer, secunder, terciar) – cell body on the periphery

RECEPTOR → peripheral AXON

sensory GANGLION

central AXON → SPINAL CORD →

→ SENSORY PATHWAYS - relay stations - CORTEX

Every sensory pathway reaches the THALAMUS, except smelling

Topographical organisation (somato-, retino-, tonotopy)

# Receptors

RECEPTORS: chemo-, mechano-, termo-, and photoreceptors

EXTEROCEPTORS	external world
	giving information about the
INTEROCEPTORS	internal world

Specific group: PROPRIOCEPTORS – provide information about the position of the body and limbs in the space

Exteroceptors:   DISTANCE RECEPTOR (vision, hearing)  
                          CONTACT RECEPTOR (taste, smell, touch)

Interoceptors:   CONTACT RECEPTOR

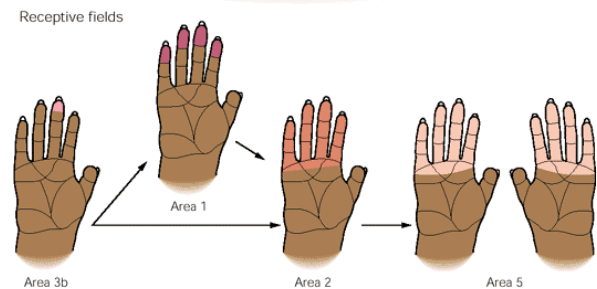
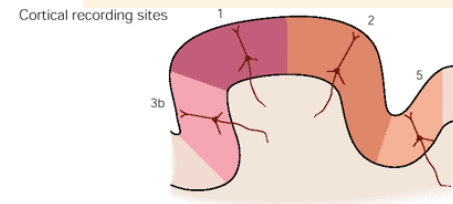
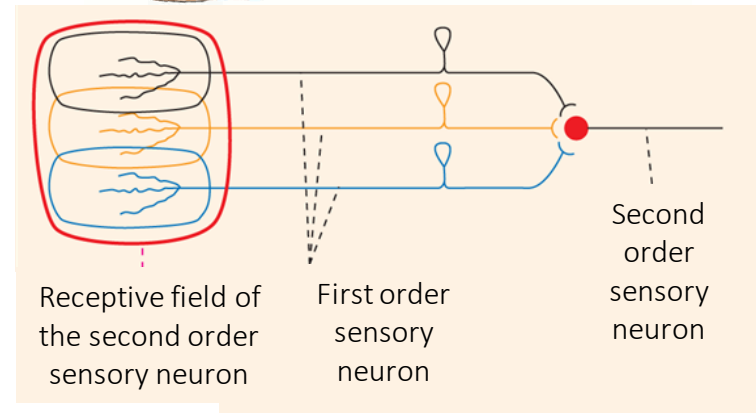
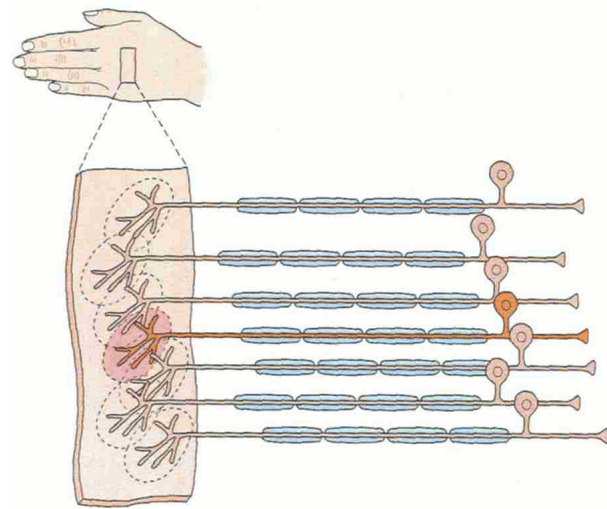
# Sensory receptors

	Modality	Exteroceptor	Interoceptor	Proprioceptor
Contact receptor	Mechanoreceptor	Skin (touch)	Sinus caroticus	Muscle spindle, Golgi tendon organ, balance
	Termo-, nociceptor		Core temperature	
	Chemoreceptor	Taste	Glomus caroticus	
Distance receptor	Mechanoreceptor	Hearing		
	Photoreceptor	Vision		
	Chemoreceptor	Smell		

# Receptive field

- 1 neuron= 1 receptive field
- overlappings
- different sizes
- lateral inhibition

two point threshold



# Nerve fiber types

New name	Old name	Diameter ( $\mu\text{m}$ )	Conduction velocity (m/s)	
Ia	A $\alpha$	12-20	70-120	Proprioception, motor
Ib	A $\alpha$	12-20	70-120	Golgi tendon organ
II	A $\beta$	5-12	30-70	Muscle spindle, flower spray endings, touch, pressure
III	A $\gamma$ , $\delta$	2-5	12-30	Temperature, pain $\gamma$ -motoneurons
	B		3-15	Preganglionic autonomic
IV	C	0,5-1	0,5-2	Free nerve endings, postganglionic autonomic

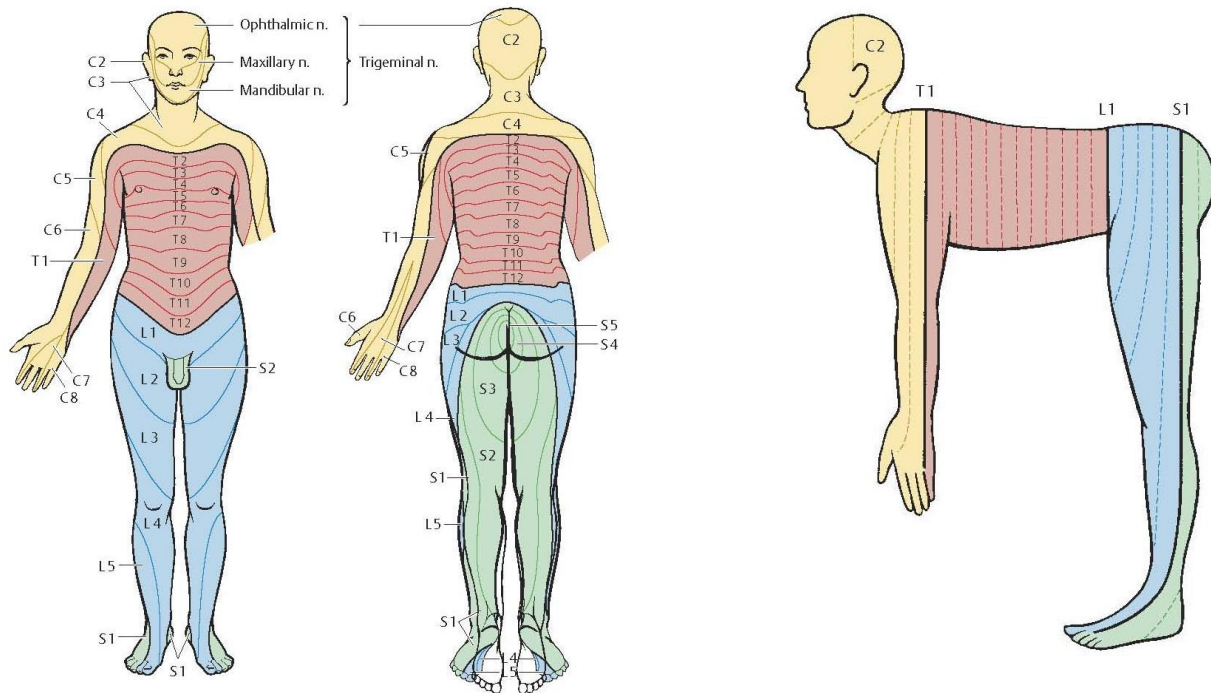
# Innervation of the skin and muscles

Myotome:

Group of muscles what a single spinal nerve innervates  
**polisegmental innervation**

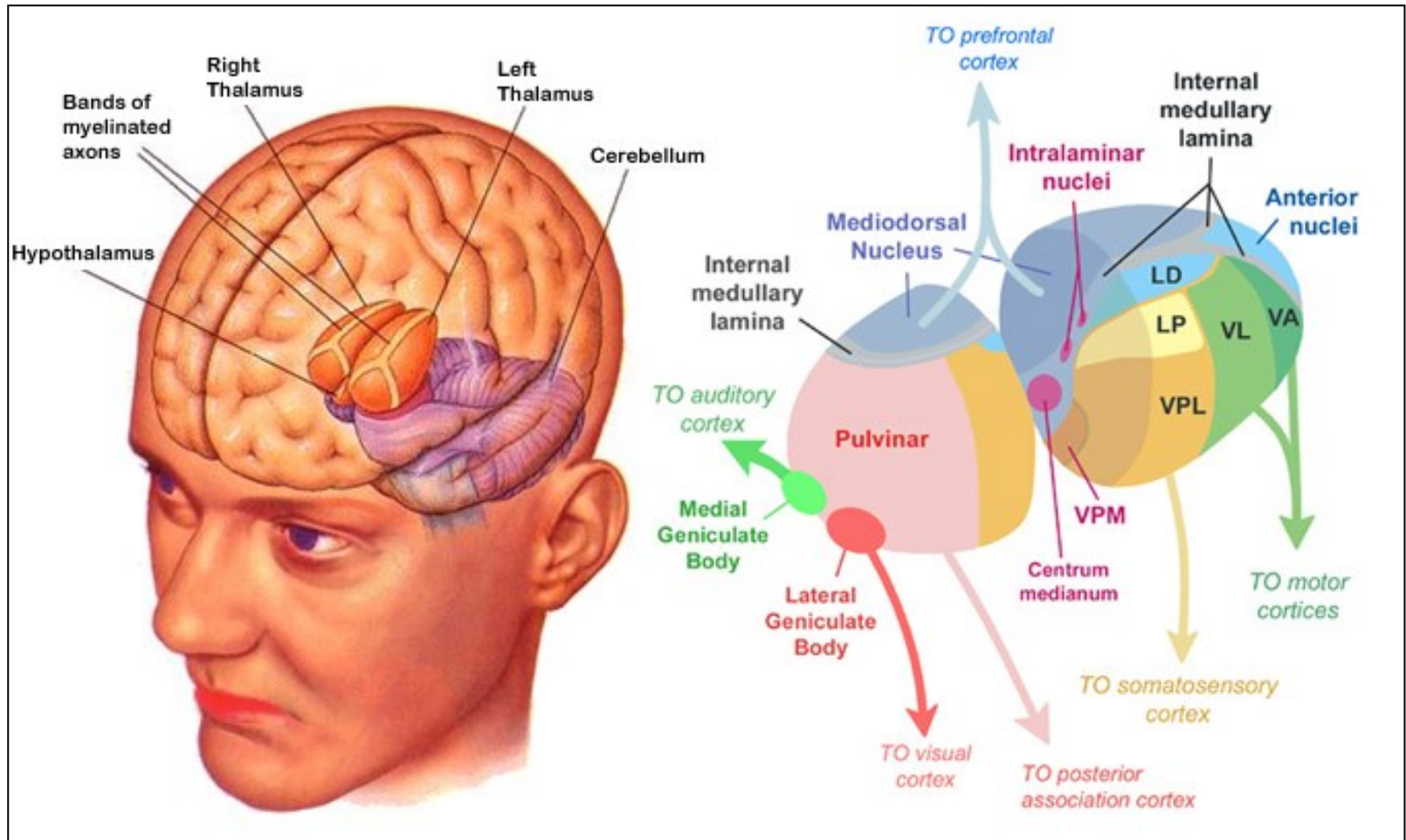
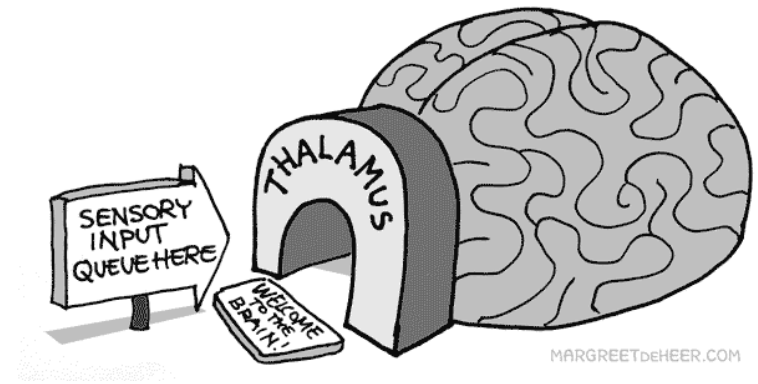
Dermatome:

Part of skin what a single spinal nerve innervates  
**segmental innervation**

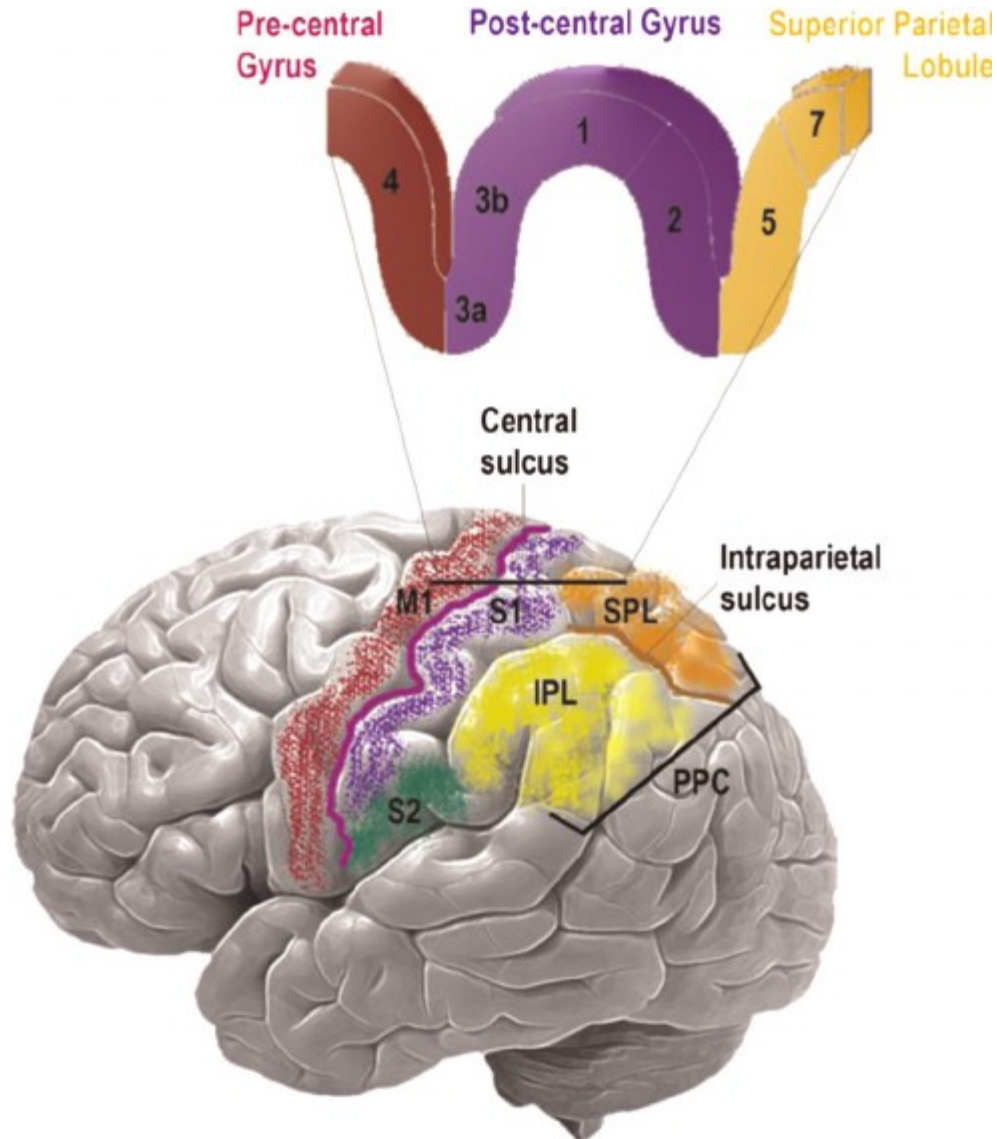




# Thalamus



# Primer somatosensory cortex



# Somatosensory systems

- Skin, mucous membranes of the internal organs, proprioception
- Conscious part: touch
- 2 anatomically and physiologically distinct parts

## EPIKRITIC

### DORSAL COLUMN- MEDIAL LEMNISCAL SYSTEM

#### Receptors

- Touch - Meissner corpuscles
- Vibration – Vater-Paccini corpuscles
- Proprioception – muscle spindle, Golgi tendon organs, nerve endings in joint capsule and ligaments

Tactile sense, proprioception

## PROTOPATHIC




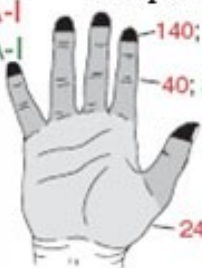



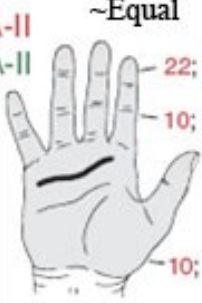
### ANTEROLATERAL SYSTEM (spinothalamic tract)

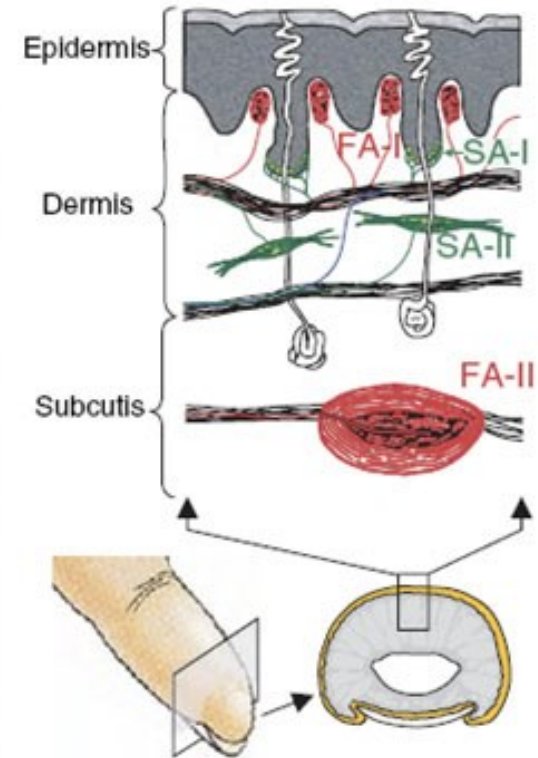
#### Receptors

- mechanoreceptors
- thermoreceptors
- nociceptors

Pain, temperature

# Somatosensory receptors

Adaptation		Receptive field	Density of innervation
Fast	Slow		
 <p>High frequency stimulation (30 Hz), sliding, moving of the object (43%)</p> <p><b>FA-I</b> Meissner</p>	 <p>Low frequency stimulation (10 Hz), pressure, shape and texture of the object (25%)</p> <p><b>SA-I</b> Merkel</p>	<p>Small, distinct borders</p>  <p><b>FA-I</b> <b>SA-I</b></p>	<p>Unequal</p>  <p>140; 70 cm<sup>-2</sup> 40; 36 cm<sup>-2</sup> 24; 9 cm<sup>-2</sup></p>
 <p>High frequency stimulation (40-400 Hz)</p> <p><b>FA-II</b> Pacini</p>	 <p>Pressure</p> <p><b>SA-II</b> Ruffini</p>	<p>Big, blurred borders</p>  <p><b>FA-II</b> <b>SA-II</b></p>	<p>~Equal</p>  <p>22; 12 cm<sup>-2</sup> 10; 16 cm<sup>-2</sup> 10; 18 cm<sup>-2</sup></p>



# Medial lemniscal system

## 1. neuron: dorsal root ganglion

Gracile and cuneate fascicle

## 2. neuron: gracile and cuneate nucleus

Internal arcuate fibers X

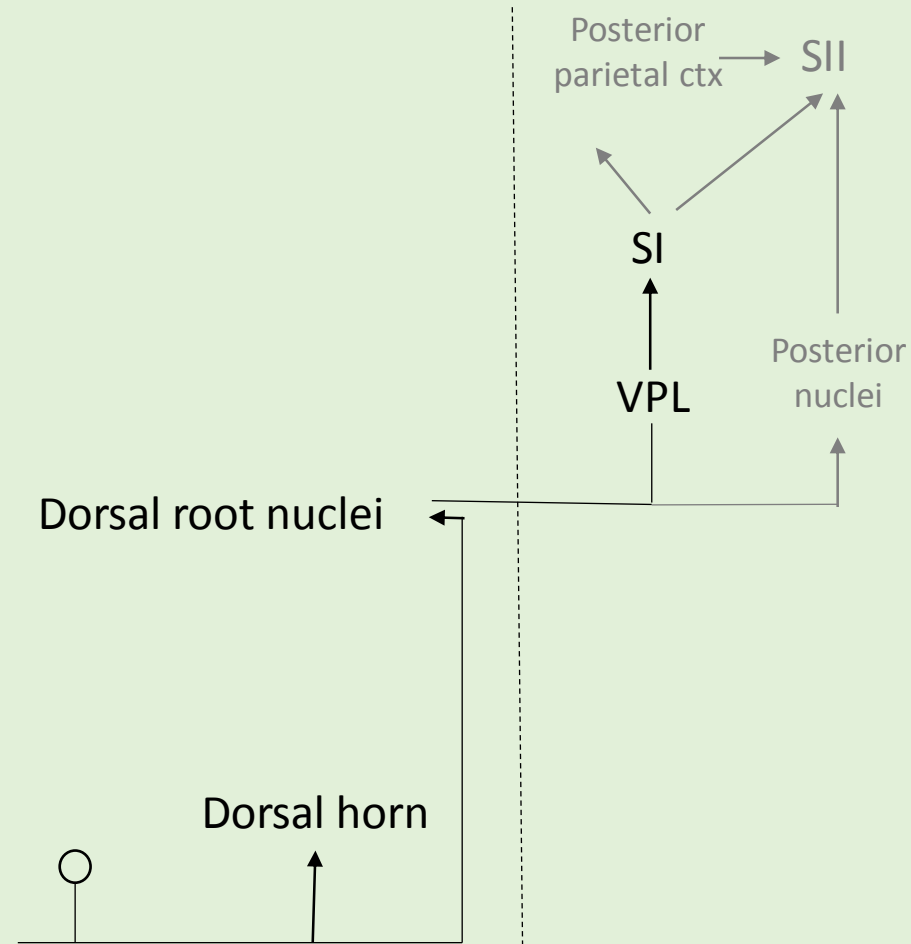
MEDIAL LEMNISCUS

## 3. neuron: thalamus VPL

sup. thalamic radiation

postcentral gyrus

primary somatosensory cortex



## MEDULLA SPINALIS

- A $\beta$  fibers
- Somatotopy
  - lower body: gracile fascicle
  - upper body: cuneate fascicle

## MEDULLA OBLONGATA

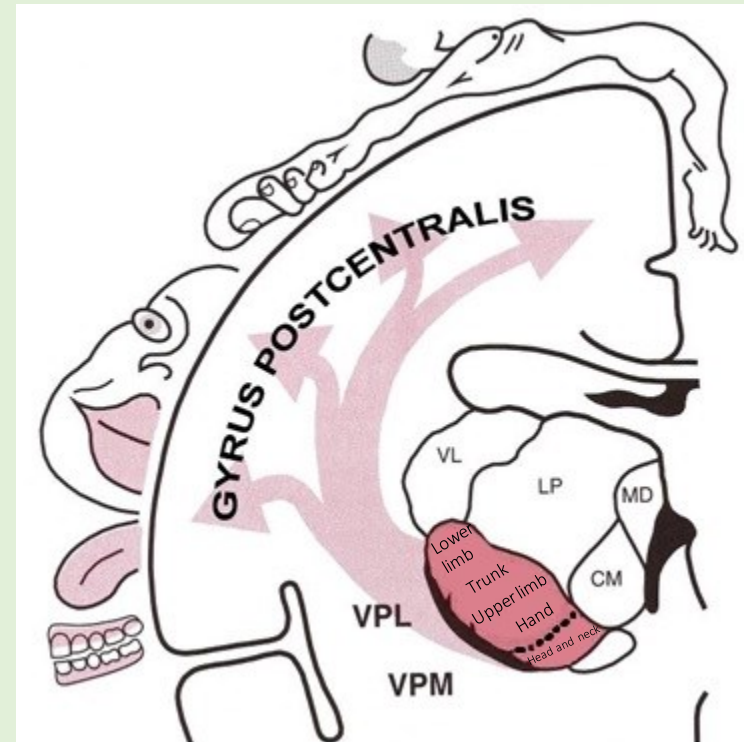
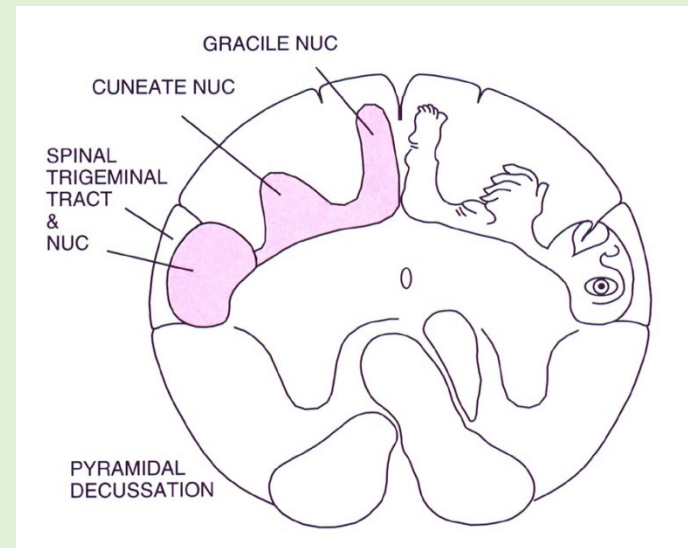
- Sensory decussation
- Internal arcuate fibers

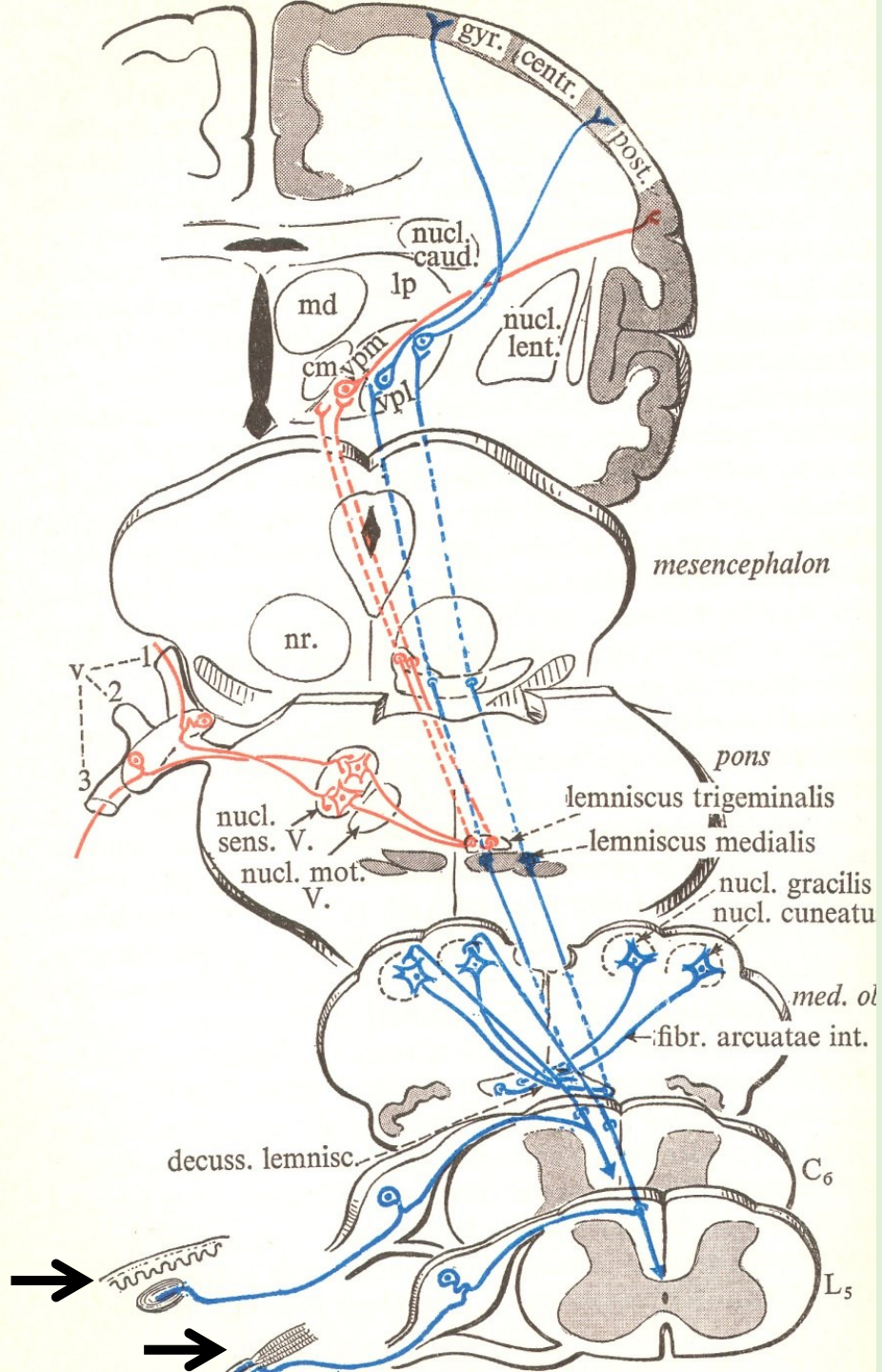
## THALAMUS

- VPL
- Radiatio thalamica

## TELENCEPHALON

- SI (Br. 1,2,3a,3b)





# Spinothalamic tract

1. neuron: dorsal root ganglion

2. neuron: dorsal horn neuron (tract cell)

anterior white commissure X

ventral spinothalamic tract (firm pressure, crude touch)

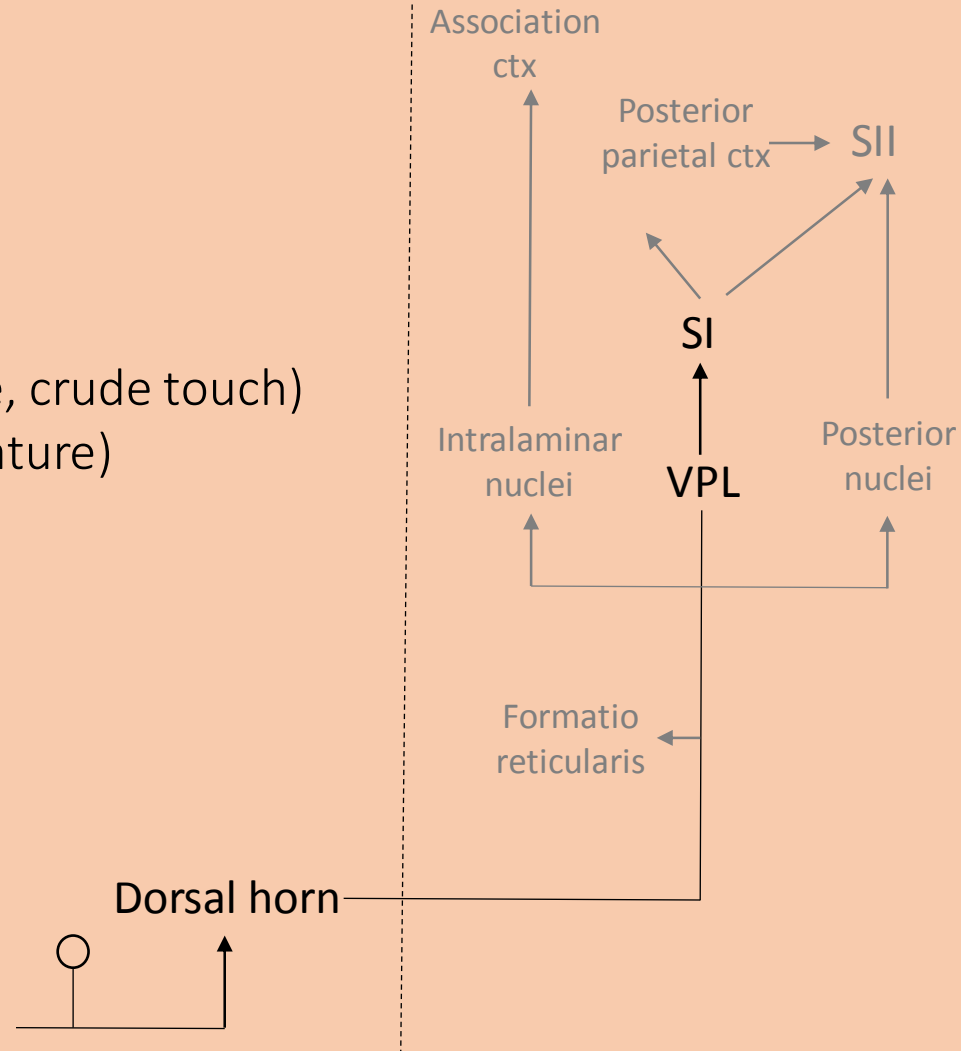
lateral spinothalamic tract (pain, temperature)

3. neuron: thalamus VPL

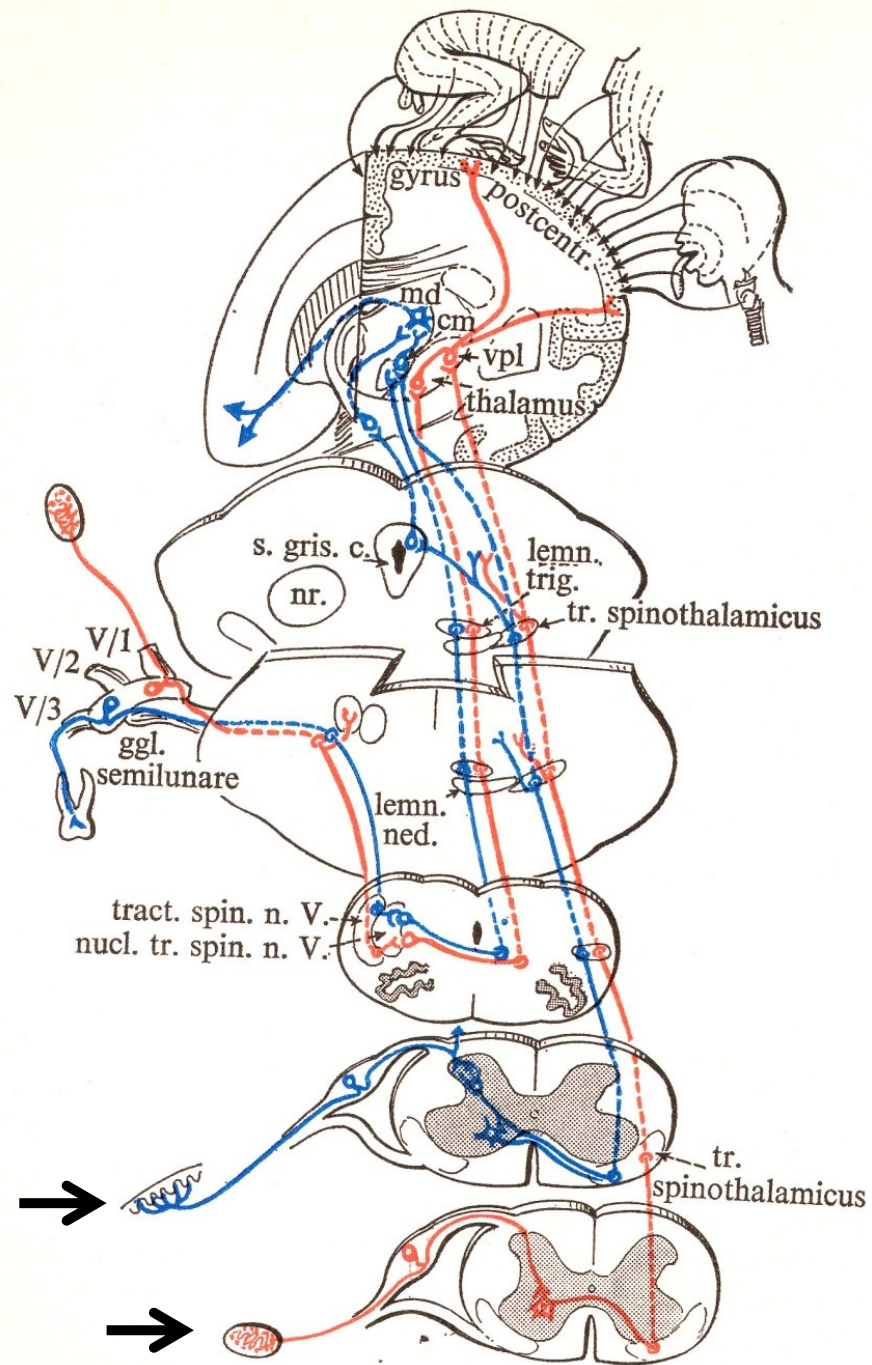
thalamic radiation

postcentral gyrus

primary somatosensory cortex

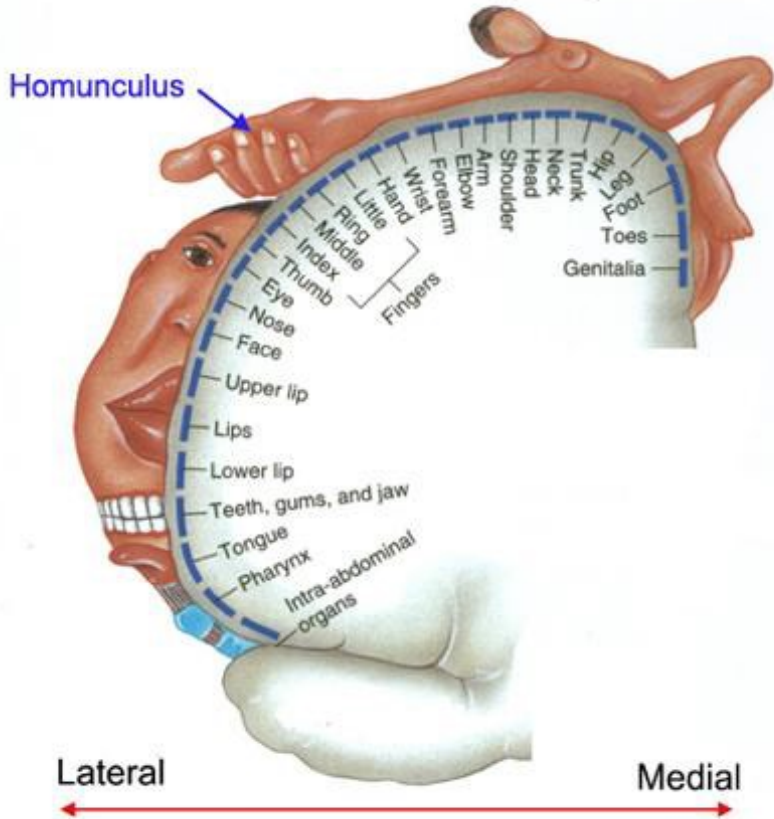






# Somatotopy - homunculus

Somatosensory Map



Rabbit



Cat



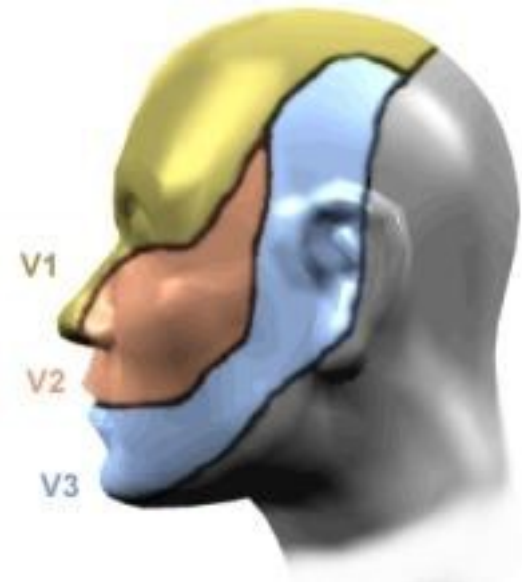
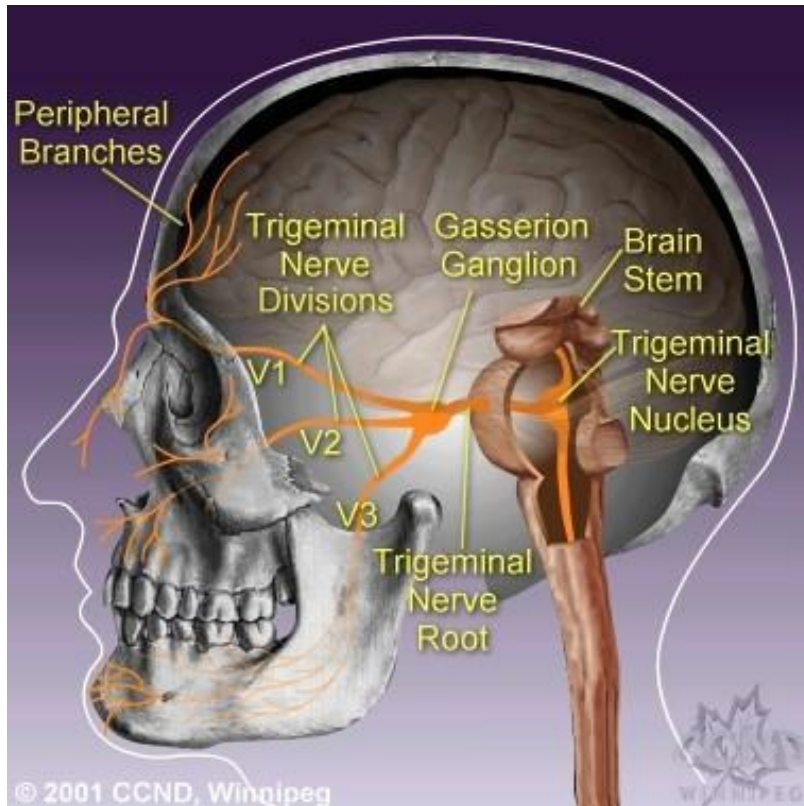
Monkey



Human



# Senses of the head



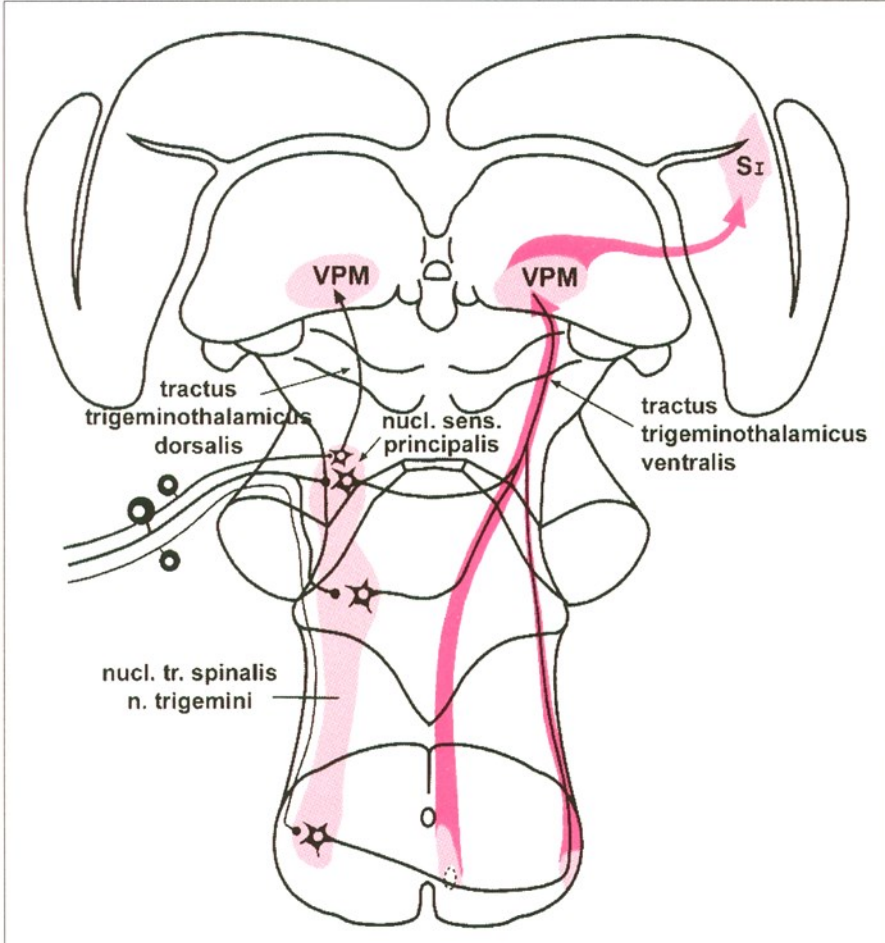
# Dorsal trigeminal tract / Posterior trigeminal lemniscus

Dorsal/posterior trigeminothalamic tract

**1. neuron: trigeminal ganglion (Gasser)**  
**mesencephalic nucleus** (masticatory muscles)  
trigeminal nerve sensory fibers

**2. neuron: principal (chief sensory) nucleus**  
X  
post. trigeminal lemniscus

**3. neuron: thalamus VPM**  
thalamic radiation  
postcentral gyrus  
primary somatosensory cortex



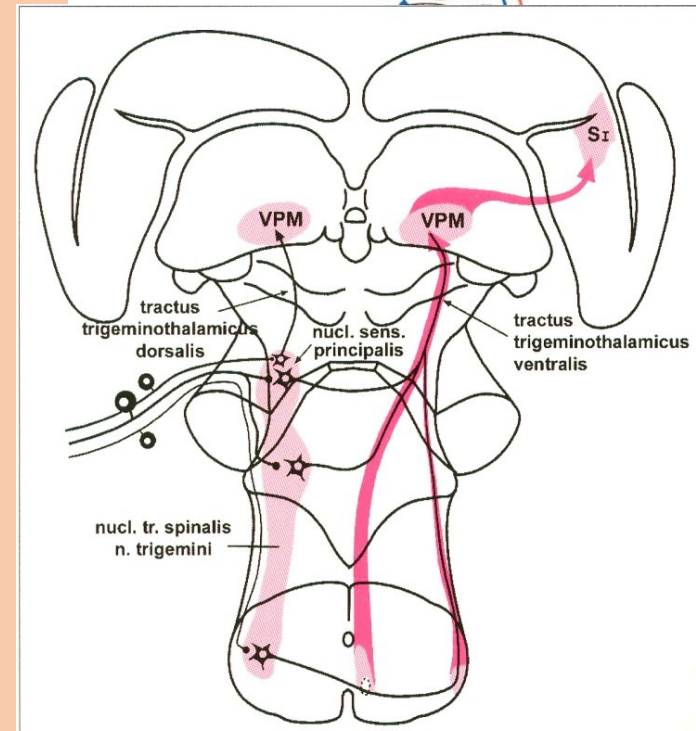
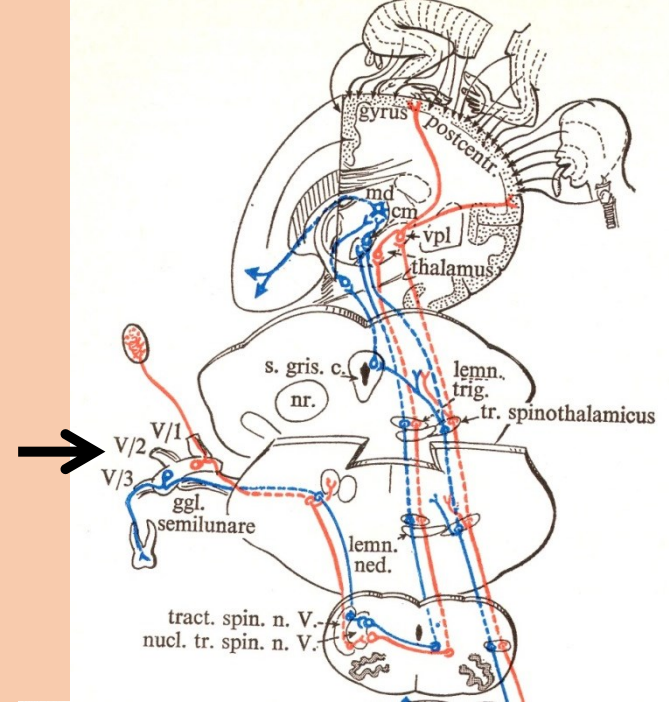
# Trigeminal lemniscus

## Ventral trigeminothalamic tract

1. neuron: trigeminal ganglion (Gasser)  
inferior, sup. ggl. IX., X.  
geniculate ggl. VII.

2. neuron: nucl. tr. spinalis n. trigemini  
X  
lemniscus trigeminalis

3. neuron: thalamus VPM  
thalamic radiation  
postcentral gyrus  
primary somatosensory cortex



# Neuroanatomy of pain

**Definition:** An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage. (IASP)

Features:

- subjective
- always a physical feeling
- unpleasant
- emotional experience can have an influence on it

Central

Peripheral – reactions

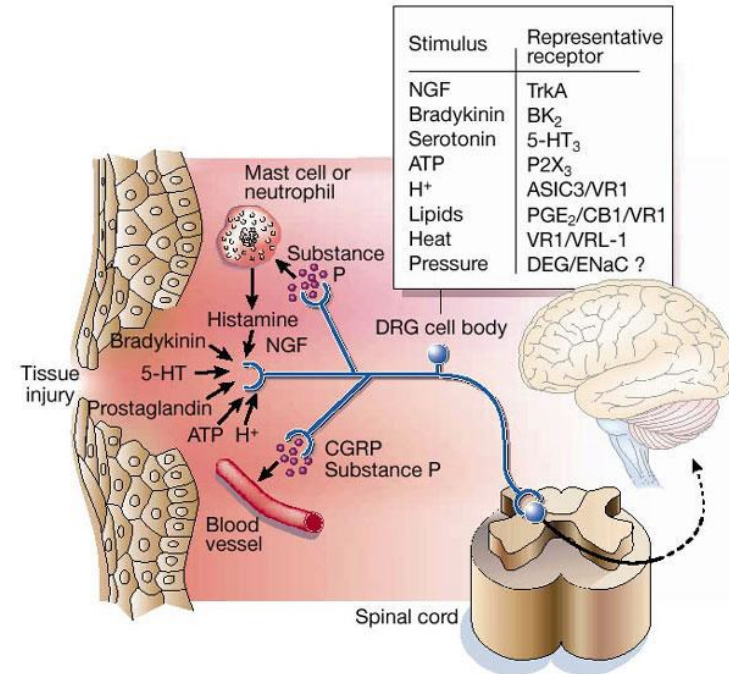
defensive reflexes (spinal cord, brain stem)

vegetative reflexes

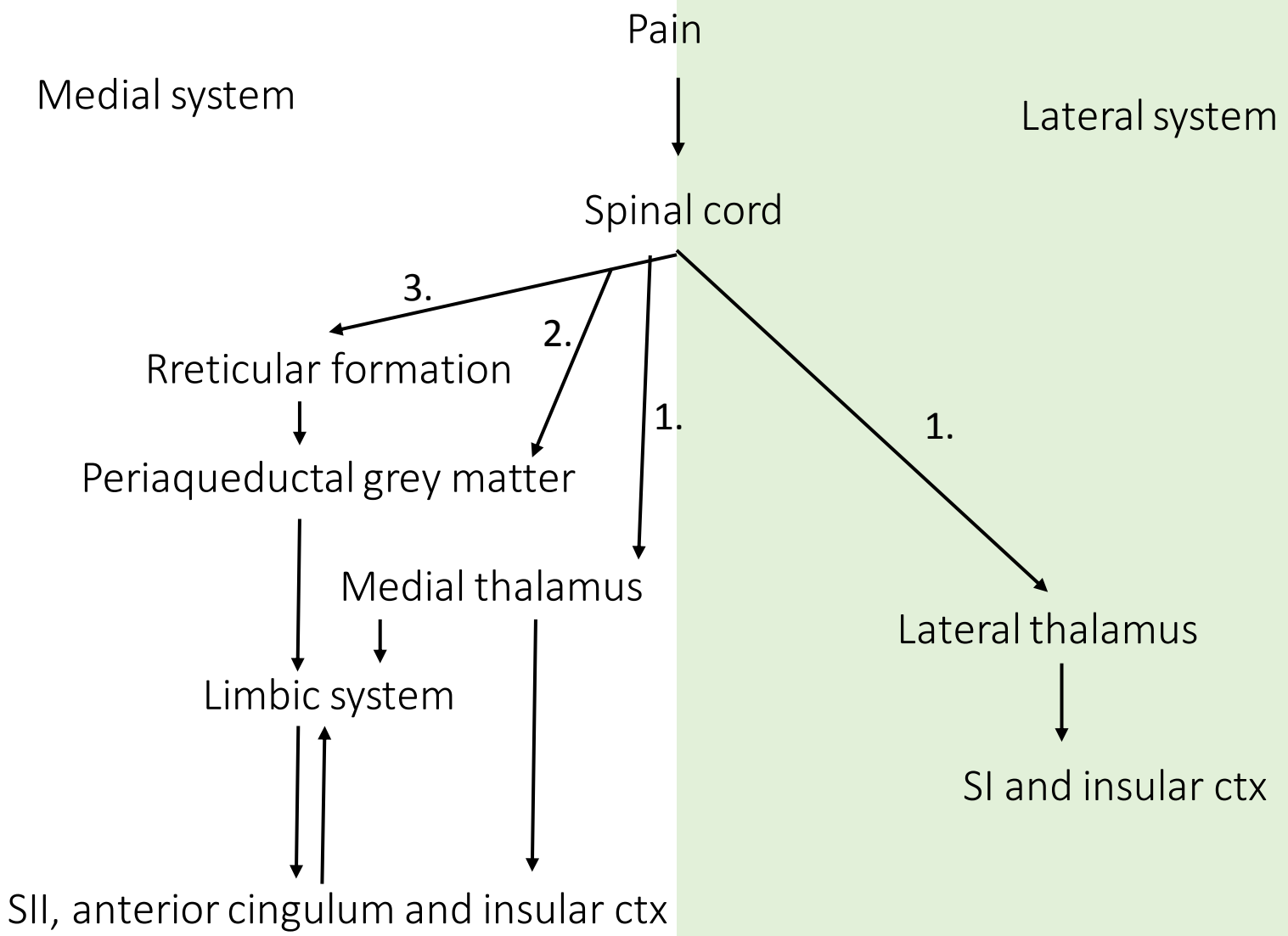
humoral (hormonal) responses (hypothalamus)

perception and localization (primary and secondary somatosensory cortex)

emotional response (limbic system)

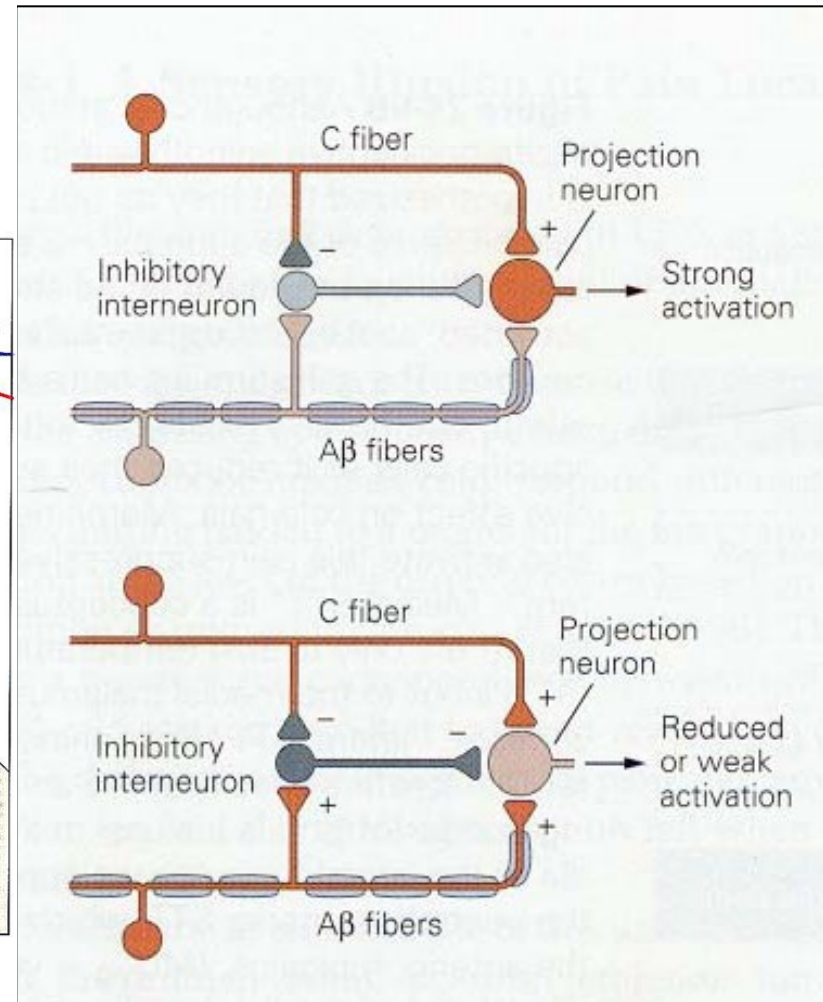
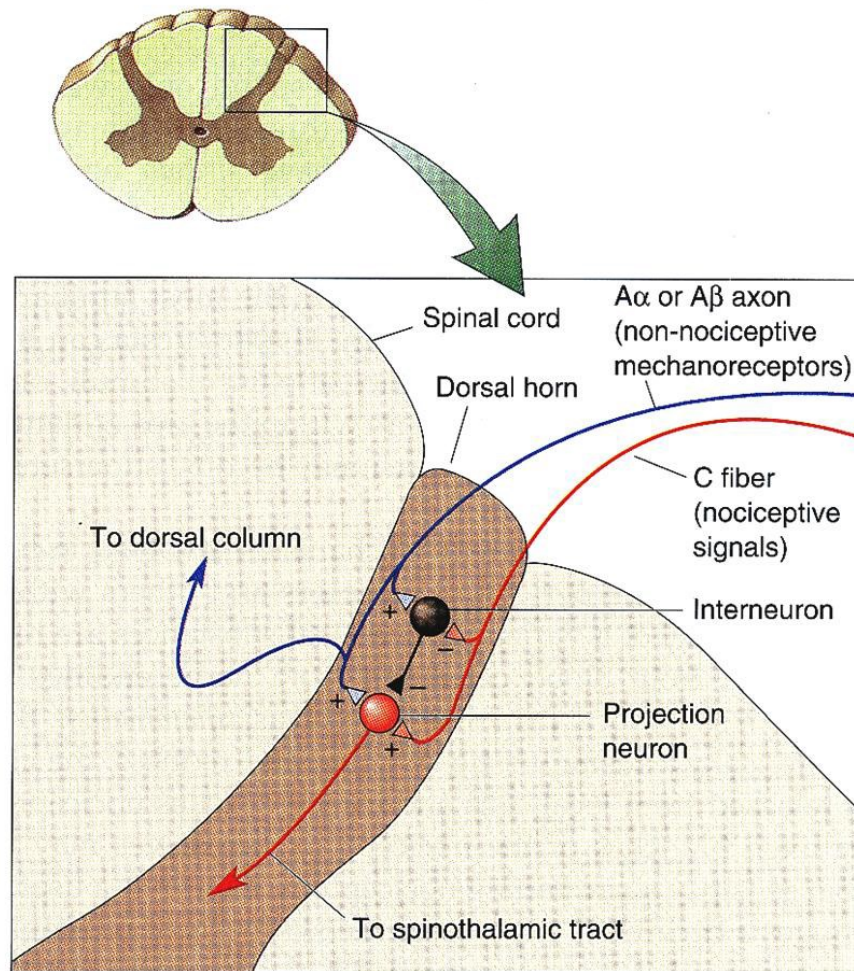


- 1. Spinothalamic tract
- 2. Spinomesencephalic tract
- 3. Spinoreticular tract



# Gate control theory

## Melzack and Wall (1965)



**Figure 12.25**  
Melzack and Wall's gate theory of pain.



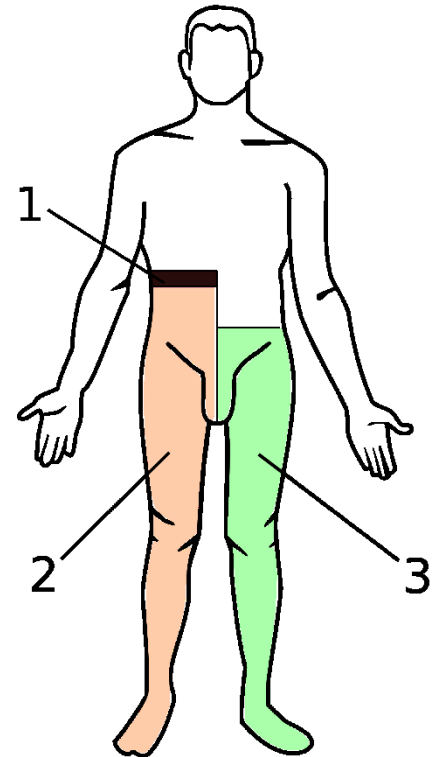
# Clinical relevance

**Analgesia:** loss of sensation of pain

**Anesthesia:** temporary loss of sensation

Brown-Sequard syndrome: damage of the half of the spinal cord

1. Anesthesia
2. Paralysis and loss of proprioception on the same side as the injury or the lesion
3. Loss of pain and temperature sensation on the other side



# Sources:

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