PSYCH 260/BBH 203

Sensation

Rick Gilmore

2022-03-29 08:30:23

Prelude (4:56)

Announcements

- Exam 3 this Thursday

Today's Topics

- Sensory systems
- Somatosensation
- Pain

Sensory systems

My smartphone and me…

Let’s design the Galaxy 20/iPhone XX

- What information do your users need to acquire?
- Why do they need to know it? In what context, for what purpose?
- What types of information does your device need to gather, through which channels?

Multisensory processing in a smartphone

- Accelerometer
- Gyroscope
- Magnetometer
- Proximity sensor
- Ambient light sensor
- Barometer

http://www.phonearena.com/news/Did-you-know-how-many-different-kinds-of-sensors-go-inside-a-smartphone_id57885

Multisensory processing in a smartphone

- Thermometer
- Mic
- Camera
- Radios (Bluetooth, wifi, cellular, GPS)

http://www.phonearena.com/news/Did-you-know-how-many-different-kinds-of-sensors-go-inside-a-smartphone_id57885

My turn…

- What information do I need to acquire?
- Why do I need to know it? In what context & for what purpose?
- What types of information do I need to gather, through which channels?

Dimensions of sensory processing

- *Interoceptive*
  - How am I?
- *Exteroceptive*
  - What’s in the world, where is it?

Questions for interoception: How are you?

- Tired or rested?
- Well or ill?
- Hungry or thirsty or sated?
- Stressed vs. coping?
- Emotional state?
- Where are you?

Questions for exteroception

- Who/What is out there?
- Where is it?

Mrs. Potraz was wrong…there aren't 5 senses

TABLE 8.1 ***Classification of Sensory Systems***

Type of sensory system	Modality	Adequate stimuli
Mechanical	Touch	Contact with or deformation of body surface
	Hearing	Sound vibrations in air or water
	Vestibular	Head movement and orientation
	Joint	Position and movement
	Muscle	Tension
Photic	Seeing	Visible radiant energy
Thermal	Cold	Decrement of skin temperature
	Warmth	Increment of skin temperature
Chemical	Smell	Odorous substances dissolved in air or water in the nasal cavity
	Taste	Substances in contact with the tongue or other taste receptor
	Common chemical	Changes in CO_2, pH, osmotic pressure
	Vomeronasal	Pheromones in air or water
Electrical	Electroreception	Differences in density of electrical currents

How sensory channels differ

- What is the energy/chemical source?
- How does the channel inform…
    - What’s there?
    - Where’s it located or moving?

Somatosensation

What is somatosensation

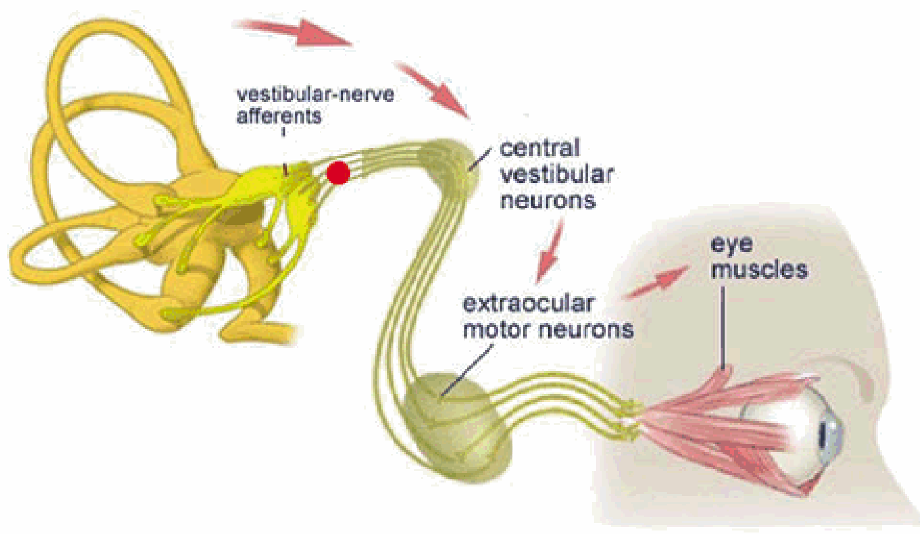
- Sensations about the body

Types of somatosensation

- Internal (interoceptive)
  - Where am I? How do I feel?
  - Proprioception (perception of the self)
- External (exteroceptive)
  - What’s in the world?
  - Where is it?

Internal senses

- Vestibular sense
  - Head position (relative to gravity)
  - Head movement (rotation, translation)


vestibular-nerve
afferents
central
vestibular
neurons
eye
muscles
extraocular
motor neurons

Vesibulo-ocular response (VOR)

- Keeps eyes steady when head moves
- Can’t walk & text without it

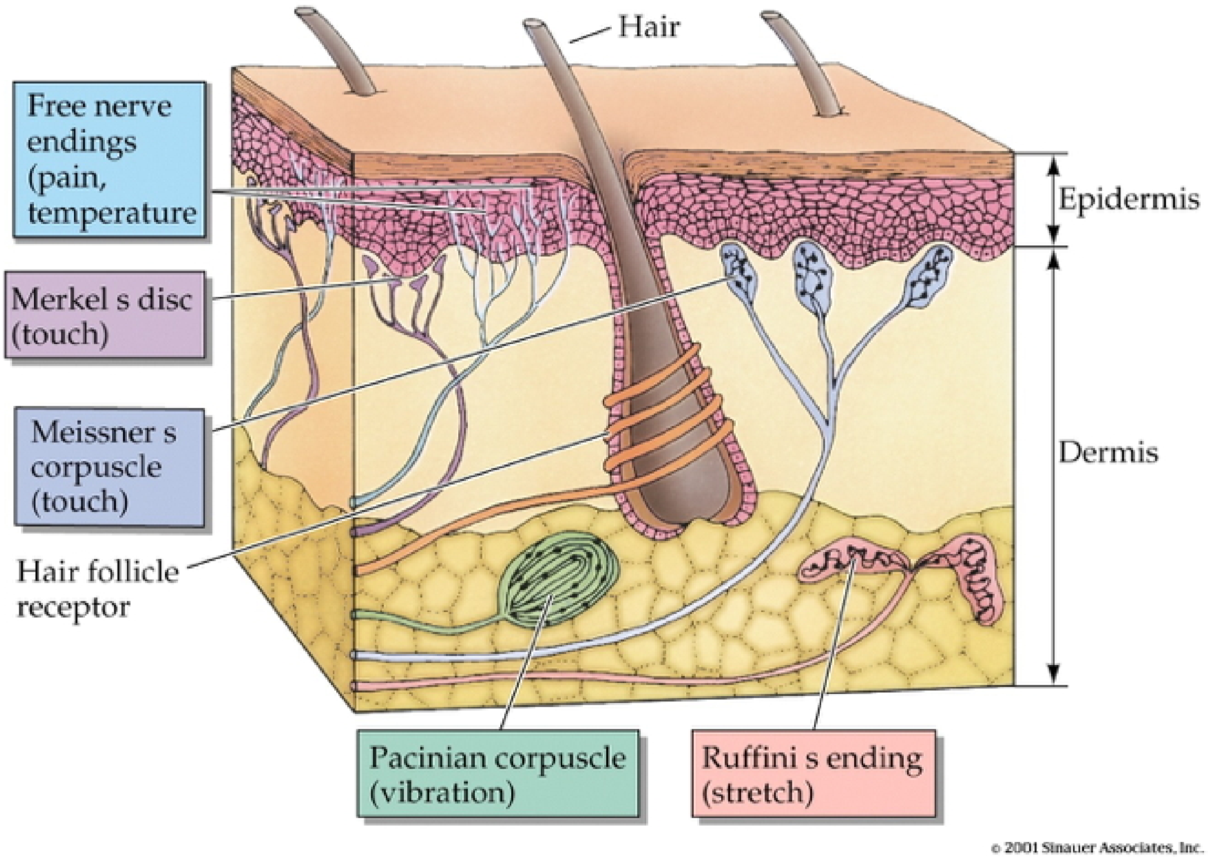
Internal senses

- Kinesthesia
  - Body position
  - Movement
- Pain

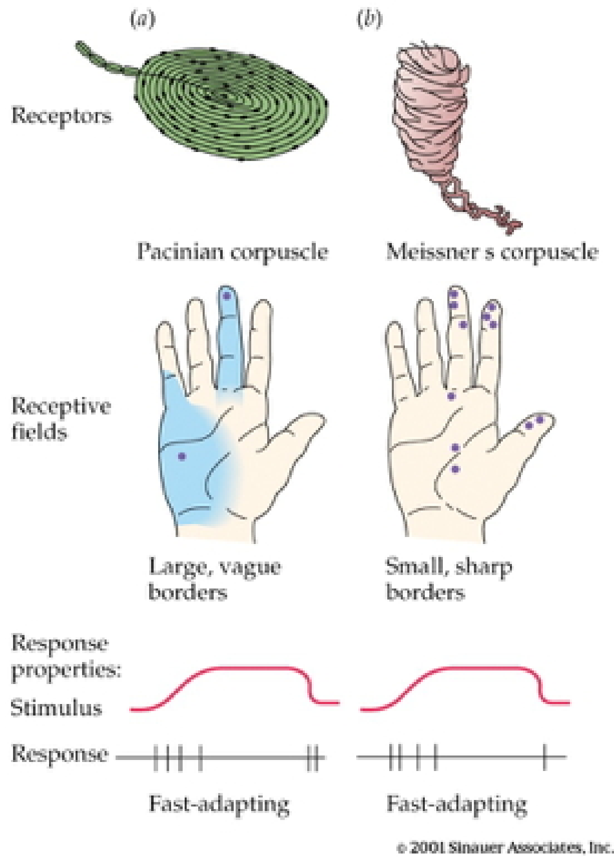
External senses

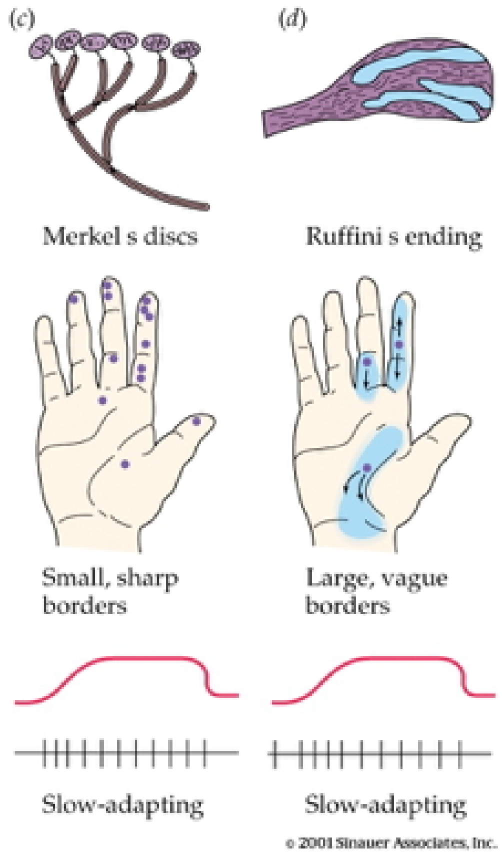
- Cutaneous senses (touch)
  - Hot, cold
  - Pressure
  - Vibration
  - Damage (pain)
- Plus kinesthesia (why?)

Cutaneous (in the skin) receptors



Receptors specialize



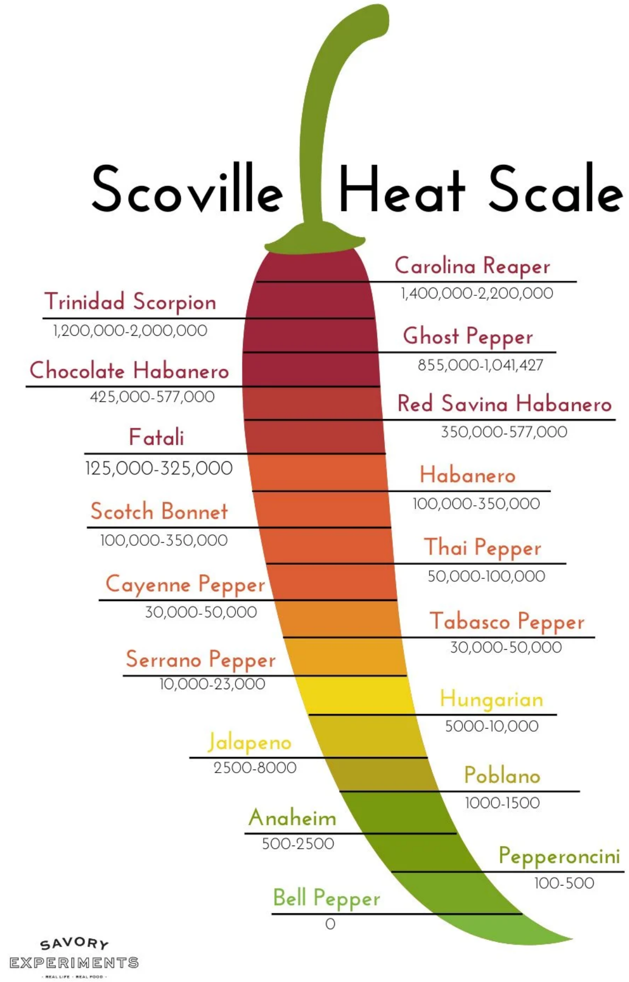

(c)
(d)
Merkel s discs
Ruffini s ending
Small, sharp borders
Large, vague borders
Slow-adapting
Slow-adapting
© 2001 Sinauer Associates, Inc.

Combined thermo and chemo receptors

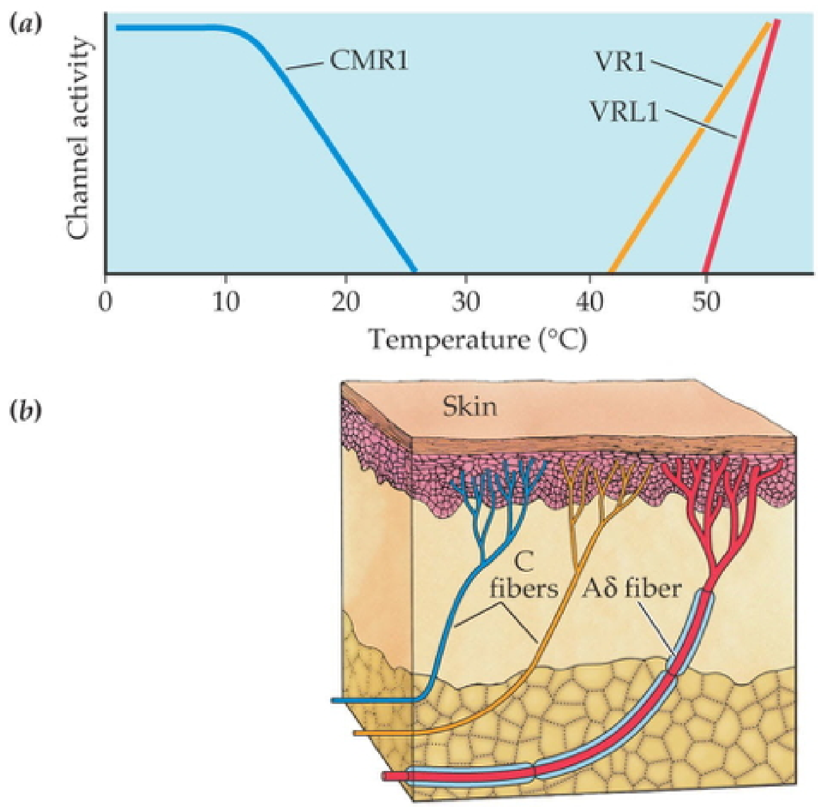
- Why are minty foods cool?
- Why are spicy foods hot?

Combined thermo (heat/cold) and chemo receptors

- Menthol/mint receptor (CMR1)
  - Also signals “cool” temperatures
- Vanilloid Receptors (TrpV1/VR1, VRL1)
  - Respond to capsaicin (in peppers), allyl isothiocyanate (in mustard, wasabi)
  - Also signal “hot” temperatures

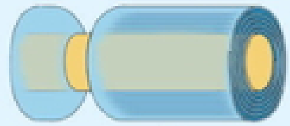
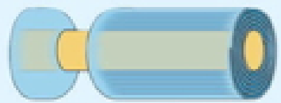
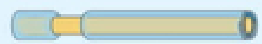
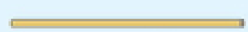

Scoville Heat Scale
Carolina Reaper
1,400,000-2,200,000
Trinidad Scorpion
1,200,000-2,000,000
Ghost Pepper
855,000-1,041,427
Chocolate Habanero
425,000-577,000
Red Savina Habanero
350,000-577,000
Fatali
125,000-325,000
Habanero
100,000-350,000
Scotch Bonnet
100,000-350,000
Thai Pepper
50,000-100,000
Cayenne Pepper
30,000-50,000
Tabasco Pepper
30,000-50,000
Serrano Pepper
10,000-23,000
Hungarian
5000-10,000
Jalapeno
2500-8000
Poblano
1000-1500
Anaheim
500-2500
Pepperoncini
100-500
Bell Pepper
0
SAVORY
EXPERIMENTS

Menthol & vanilloid receptors



Size/speed trade-off

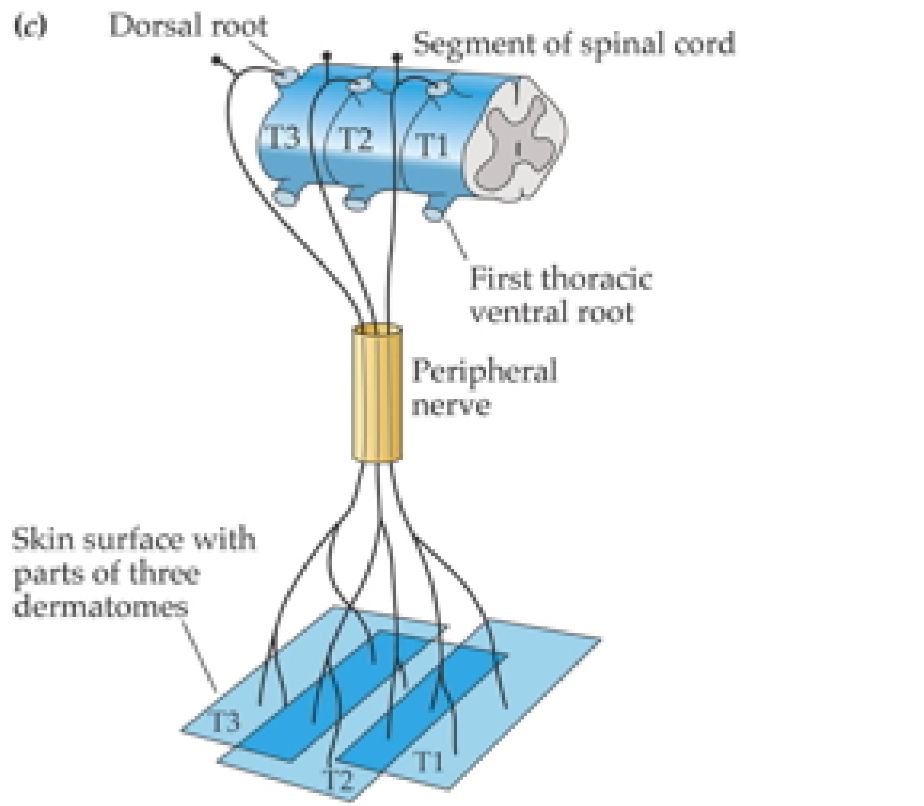
TABLE 8.2 ***Fibers That Link Receptors to the CNS***

Sensory function(s)	Receptor type(s)	Axon type	Diameter (μm)	Conduction speed (m/s)
Proprioception (see Chapter 11)	Muscle spindle	 $A\alpha$	13–20	80–120
Touch (see Figures 8.12 and 8.13)	Pacinian corpuscle, Ruffini's ending, Merkel's disc, Meissner's corpuscle	 $A\beta$	6–12	35–75
Pain, temperature	Free nerve endings; VRL1	 $A\delta$	1–5	5–30
Temperature, pain, itch	Free nerve endings; VR1, CMR1	 C	0.02–1.5	0.5–2

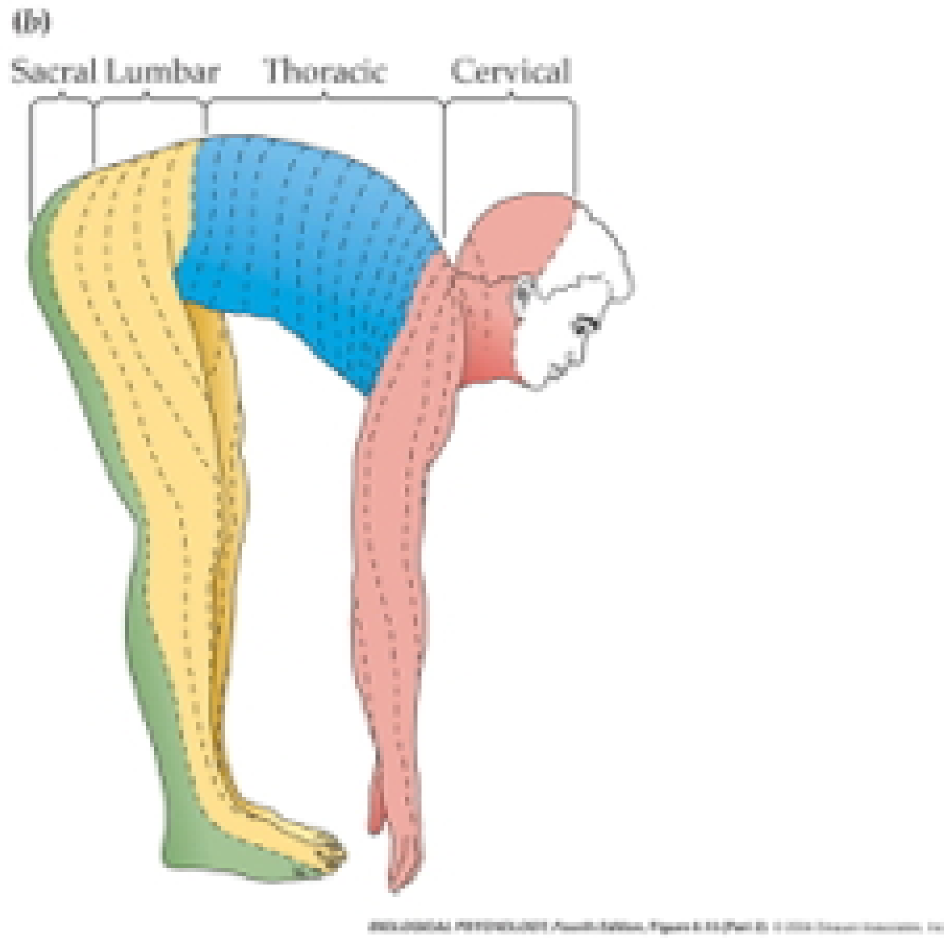
From skin to brain

- Cutaneous receptors
- Dorsal root ganglion
- Ventral posterior lateral thalamus
- Primary somatosensory cortex (S-I)
  - Post-central gyrus of parietal lobe

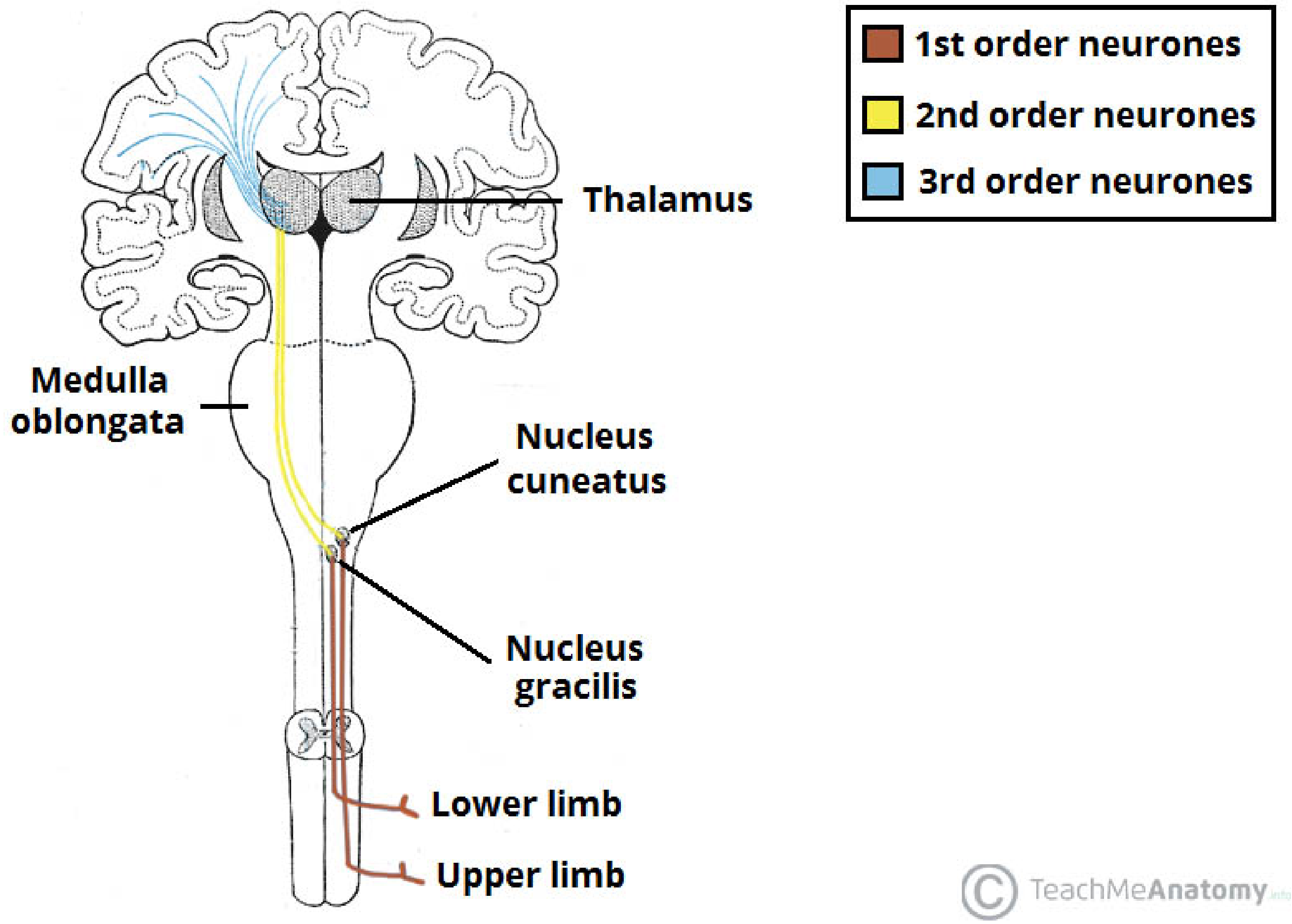
Dermatomes

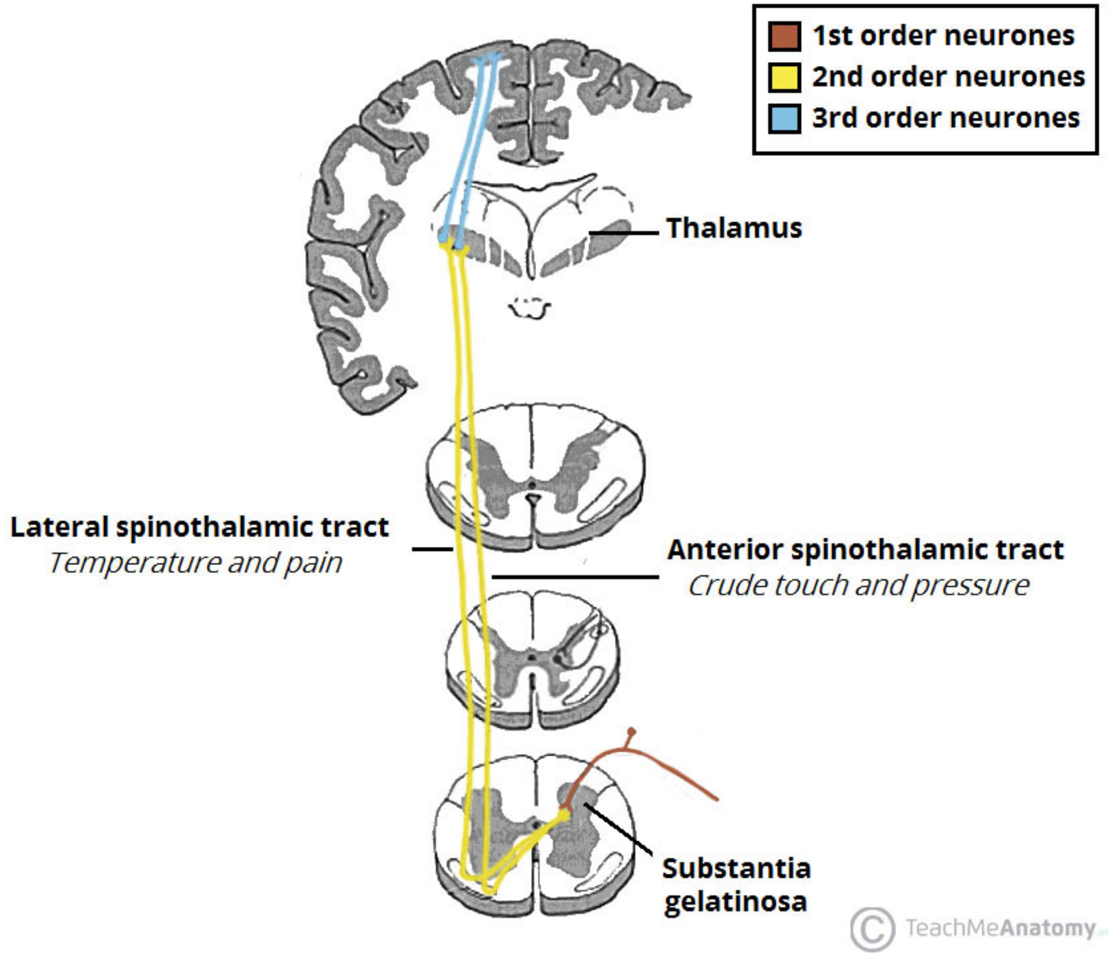

(c)
Dorsal root
Segment of spinal cord
T3
T2
T1
First thoracic
ventral root
Peripheral
nerve
Skin surface with
parts of three
dermatomes
T3
T2
T1

Dermatomes



Functional segregation



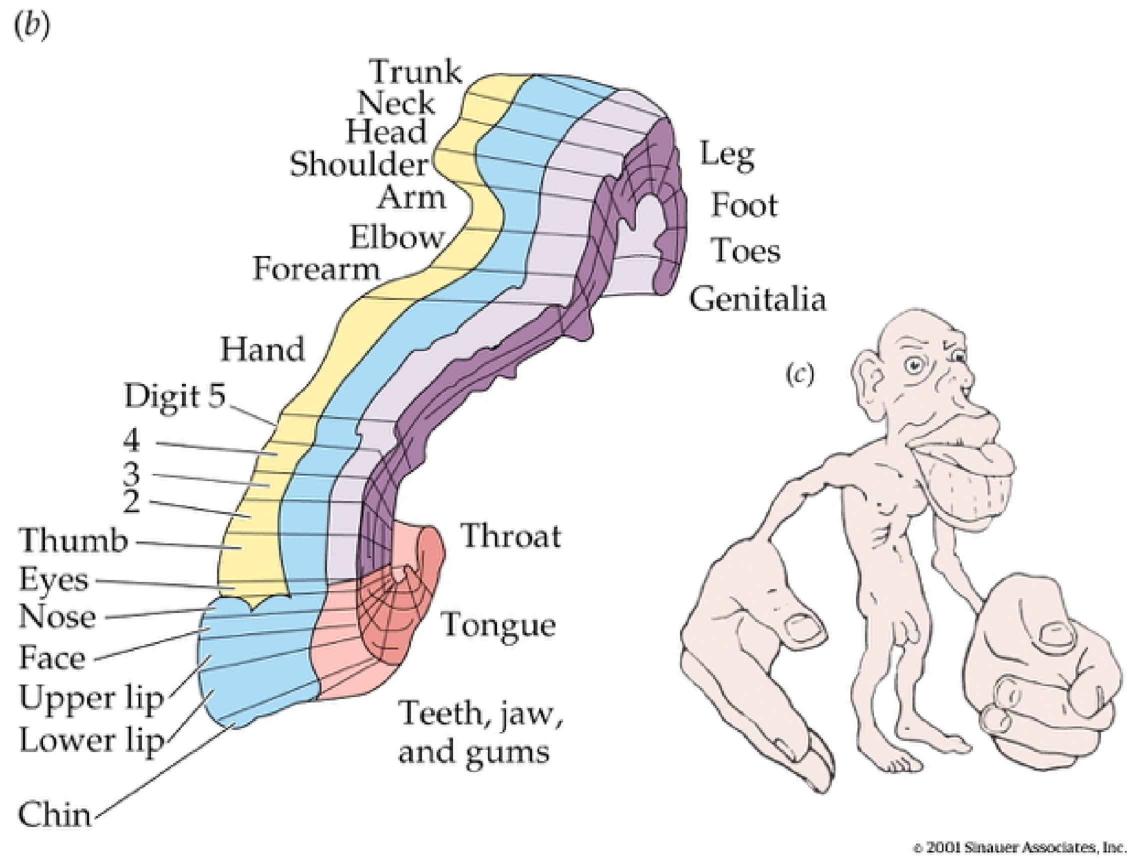


1st order neurones
2nd order neurones
3rd order neurones
Thalamus
Lateral spinothalamic tract
Temperature and pain
Anterior spinothalamic tract
Crude touch and pressure
Substantia gelatinosa
© TeachMeAnatomy

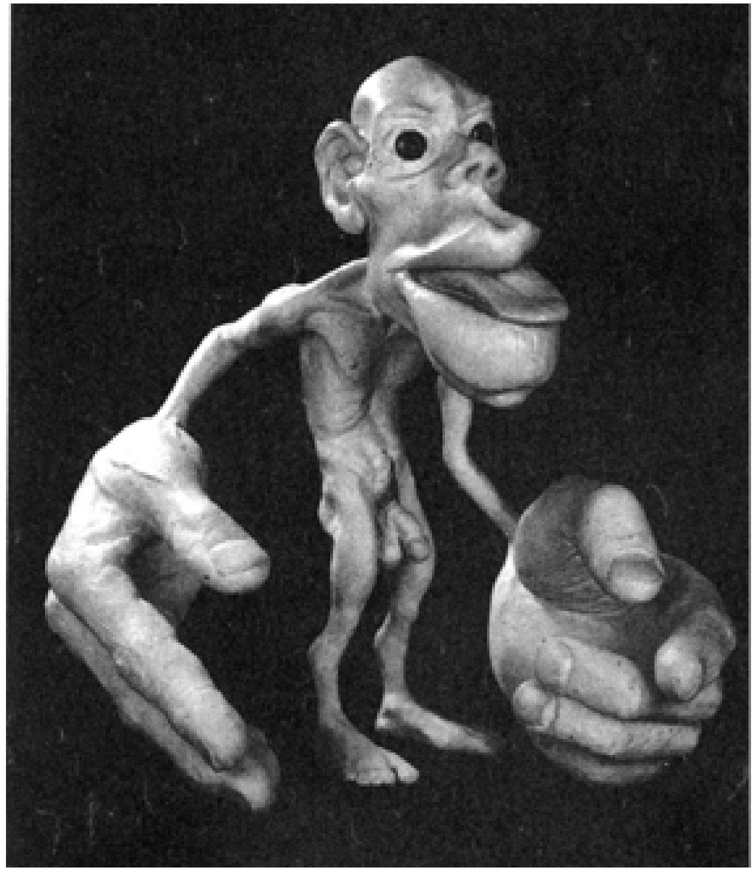
Functional segregation

- Separate pathways for different information types
- Dorsal column/medial leminiscal pathway
  - Touch, proprioception
- Spinothalamic tract
  - Pain, temperature

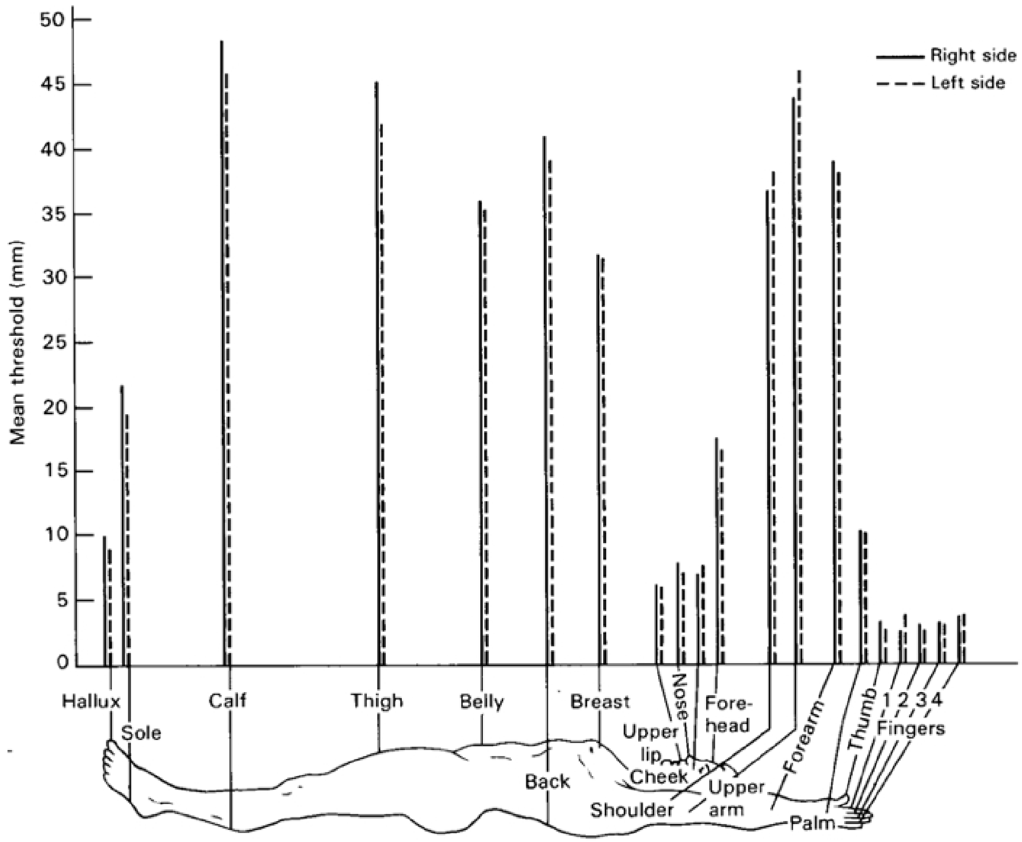
Somatatopic maps



Non-uniform mapping of skin surface

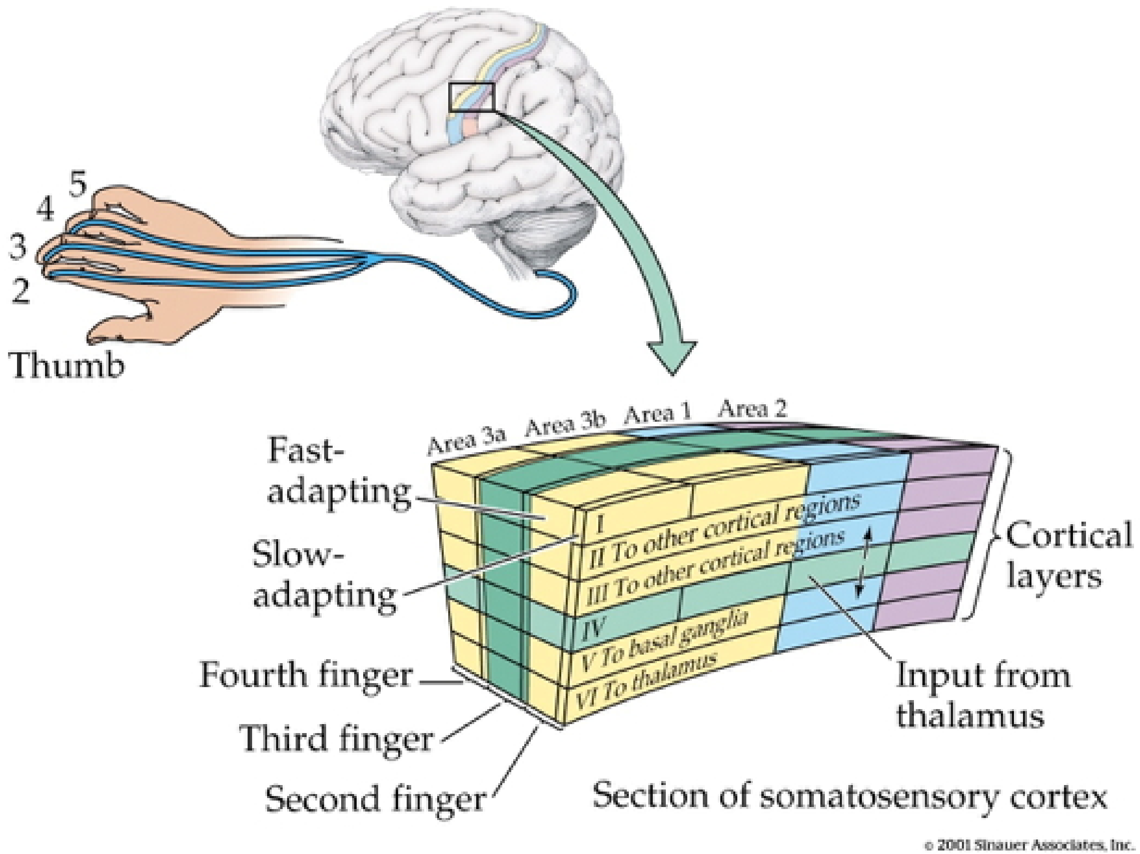


Non-uniform mapping of skin surface



http://jov.arvojournals.org/data/Journals/JOV/933499/jov-3-10-1-fig001.jpeg

Columnar organization/functional segregation

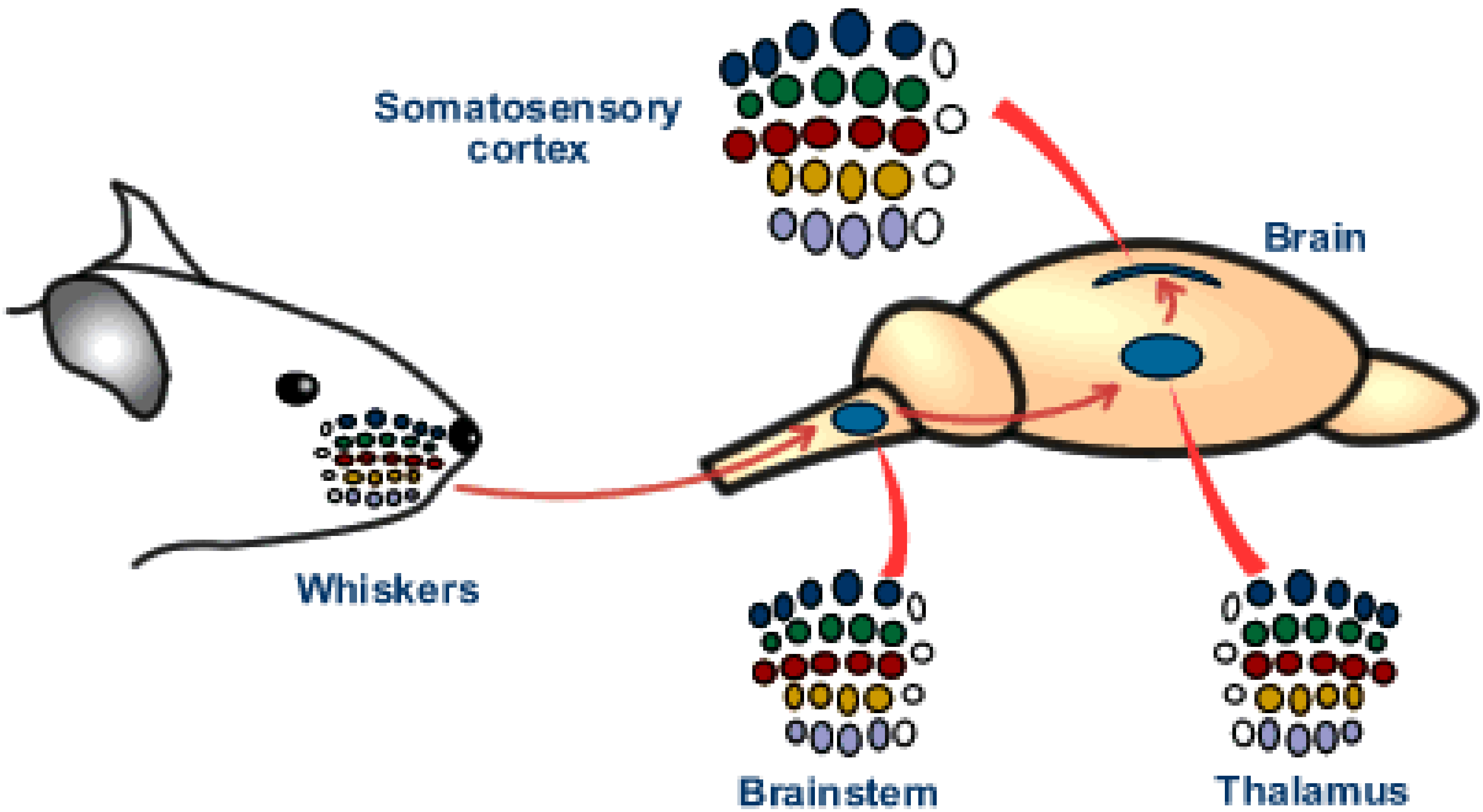


Phantom Limbs

What/where

- Perceiving Where
  - Somatotopic maps – where on skin
  - Kinesthesia – configuration of limbs
- Perceiving What
  - Patterns of smoothness, roughness, shape, temperature

Somatosensation in other animals



Pain

The neuroscience of pain

- *Nociceptors* (Latin *nocere* to harm or hurt) detect harmful or potentially harmful stimuli of varied types:
    - chemical
    - mechanical
    - thermal

Nociception

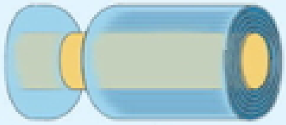
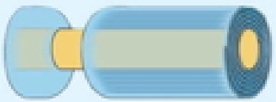
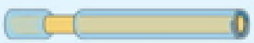
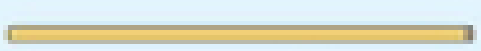
- External
  - Skin, cornea (eye), mucosa
- Internal
  - Muscles, joints, bladder, gut

Different types of nociceptors…

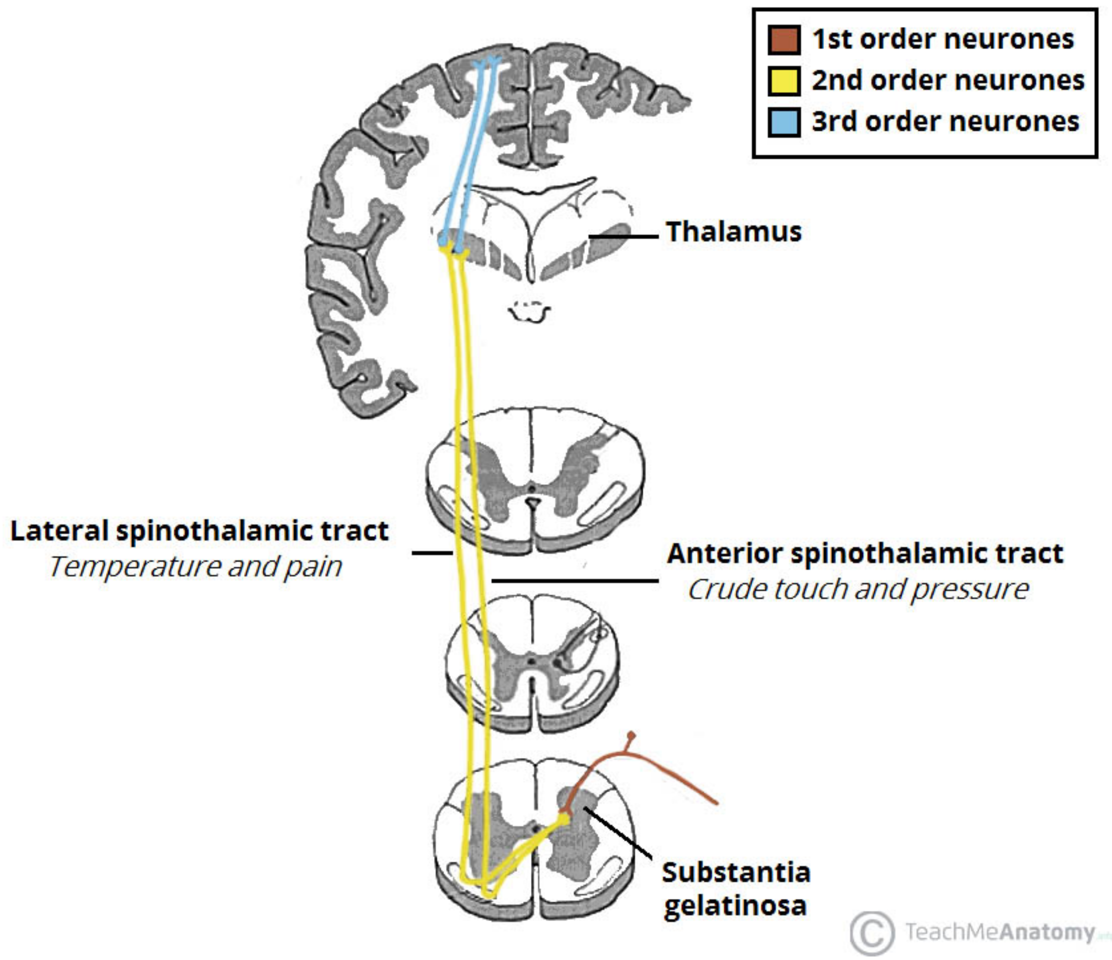
- metabolism (acidic pH, hypoxia, …)
- cell rupture (ATP and glutamate)
- cutaneous parasite penetration (histamine)
- mast cell (white blood cell) activation (serotonin, bradykinin, …)
- immune and hormonal activity (cytokines and somatostatin)

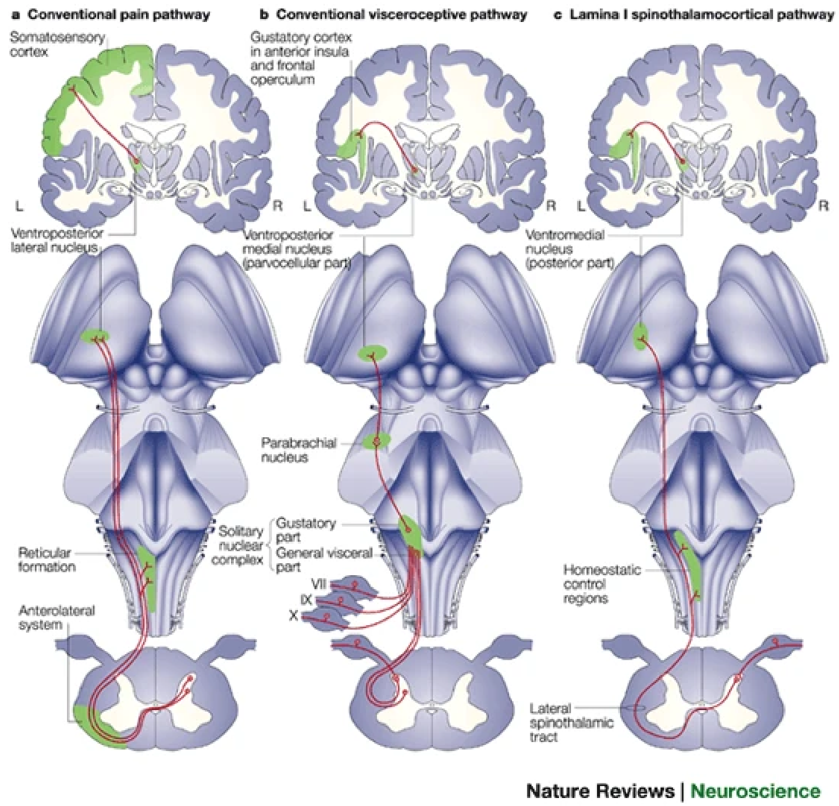
Fast ($A\delta$) and slow (C) transmission to CNS

TABLE 8.2 ***Fibers That Link Receptors to the CNS***

Sensory function(s)	Receptor type(s)	Axon type	Diameter (μm)	Conduction speed (m/s)
Proprioception (see Chapter 11)	Muscle spindle	 Aα	13–20	80–120
Touch (see Figures 8.12 and 8.13)	Pacinian corpuscle, Ruffini's ending, Merkel's disc, Meissner's corpuscle	 Aβ	6–12	35–75
Pain, temperature	Free nerve endings; VRL1	 Aδ	1–5	5–30
Temperature, pain, itch	Free nerve endings; VR1, CMR1	 C	0.02–1.5	0.5–2

Projection to brain via anterolateral system




a Conventional pain pathway
b Conventional visceroceptive pathway
c Lamina I spinothalamocortical pathway
Somatosensory cortex
Gustatory cortex in anterior insula and frontal operculum
L
R
Ventroposterior lateral nucleus
Ventroposterior medial nucleus (parvocellular part)
Ventromedial nucleus (posterior part)
Parabrachial nucleus
Solitary nuclear complex
Gustatory part
General visceral part
Reticular formation
Homeostatic control regions
VII
IX
X
Anterolateral system
Lateral spinothalamic tract
Nature Reviews | Neuroscience

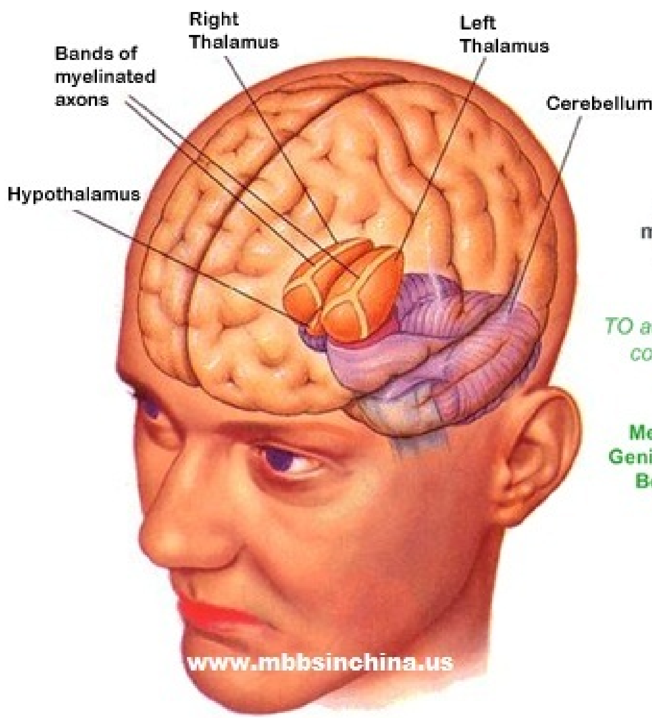
(Craig, 2002)

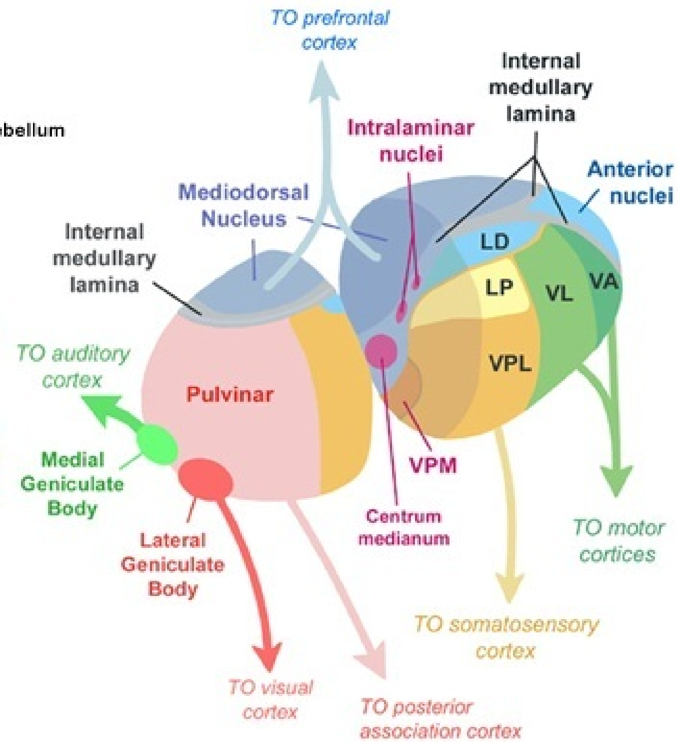
Key CNS nodes in network

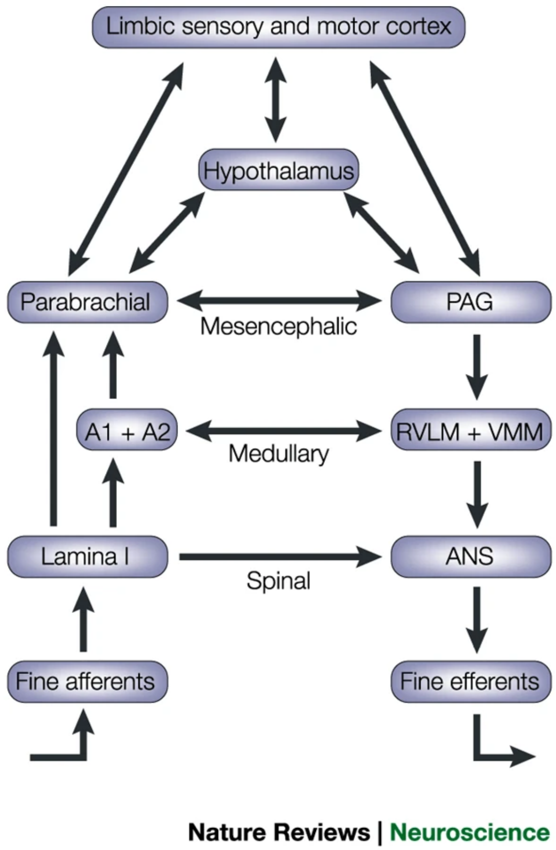
- Periaqueductal grey (PAG) in midbrain
- Insular cortex (insula)
- Hypothalamus
- Amygdala

Key CNS nodes in network

- Thalamus
    - Ventroposterior lateral nucleus
    - Ventroposterior medial nucleus
    - Ventromedial nucleus

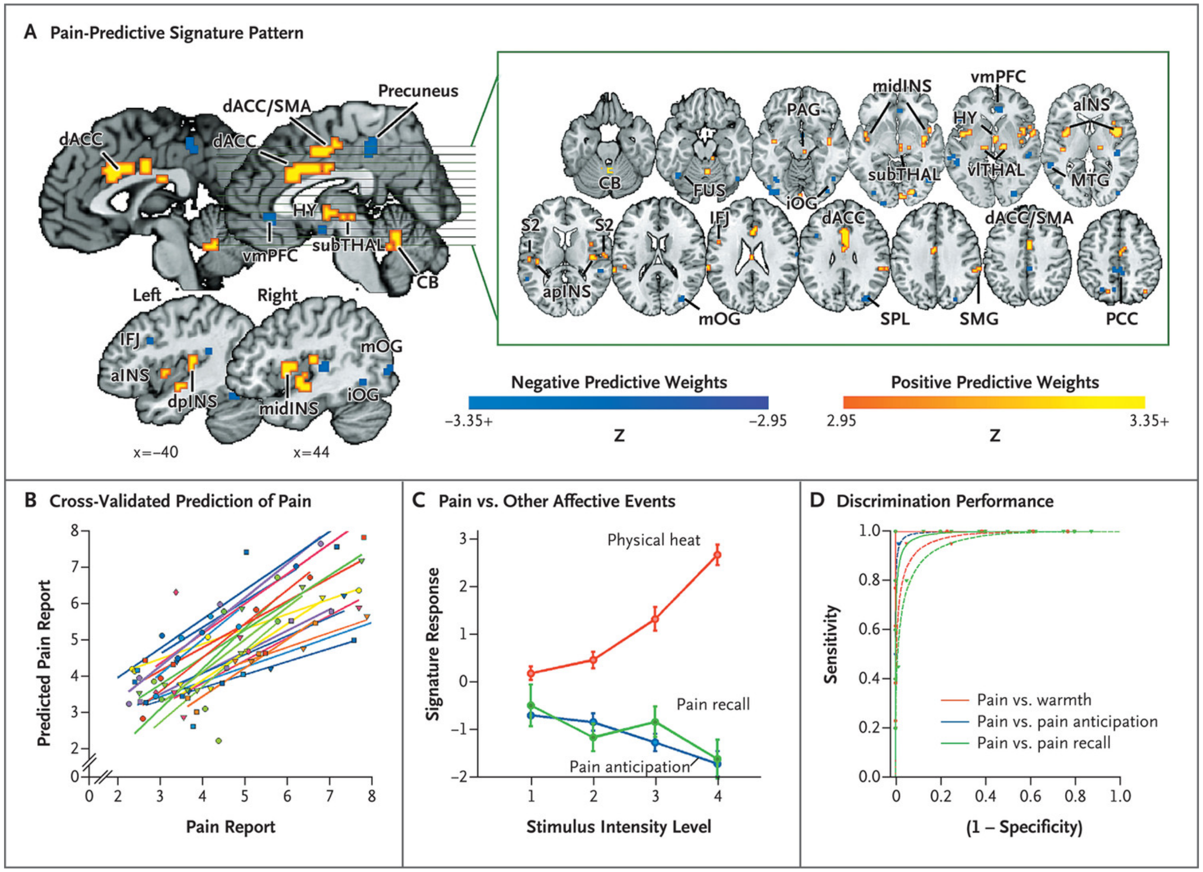

Right Thalamus
Left Thalamus
Bands of myelinated axons
Cerebellum
Hypothalamus
www.mbbsinchina.us


TO prefrontal cortex
Internal medullary lamina
Intralaminar nuclei
Anterior nuclei
Mediodorsal Nucleus
Internal medullary lamina
LD
LP
VL
VA
VPL
TO auditory cortex
Pulvinar
Medial Geniculate Body
VPM
Centrum medianum
TO motor cortices
Lateral Geniculate Body
TO somatosensory cortex
TO visual cortex
TO posterior association cortex


Limbic sensory and motor cortex
Hypothalamus
Parabrachial
PAG
Mesencephalic
A1 + A2
RVLM + VMM
Medullary
Lamina I
ANS
Spinal
Fine afferents
Fine efferents
Nature Reviews | Neuroscience

(Craig, 2002)

Pain in the brain



(Wager et al., 2013)

Pain in the brain

"…we used machine-learning analyses to identify a pattern of fMRI activity across brain regions — a neurologic signature — that was associated with heat-induced pain. The pattern included the thalamus, the posterior and anterior insulae, the secondary somatosensory cortex, the anterior cingulate cortex, the periaqueductal gray matter, and other areas…"

(Wager et al., 2013)

Pain relief

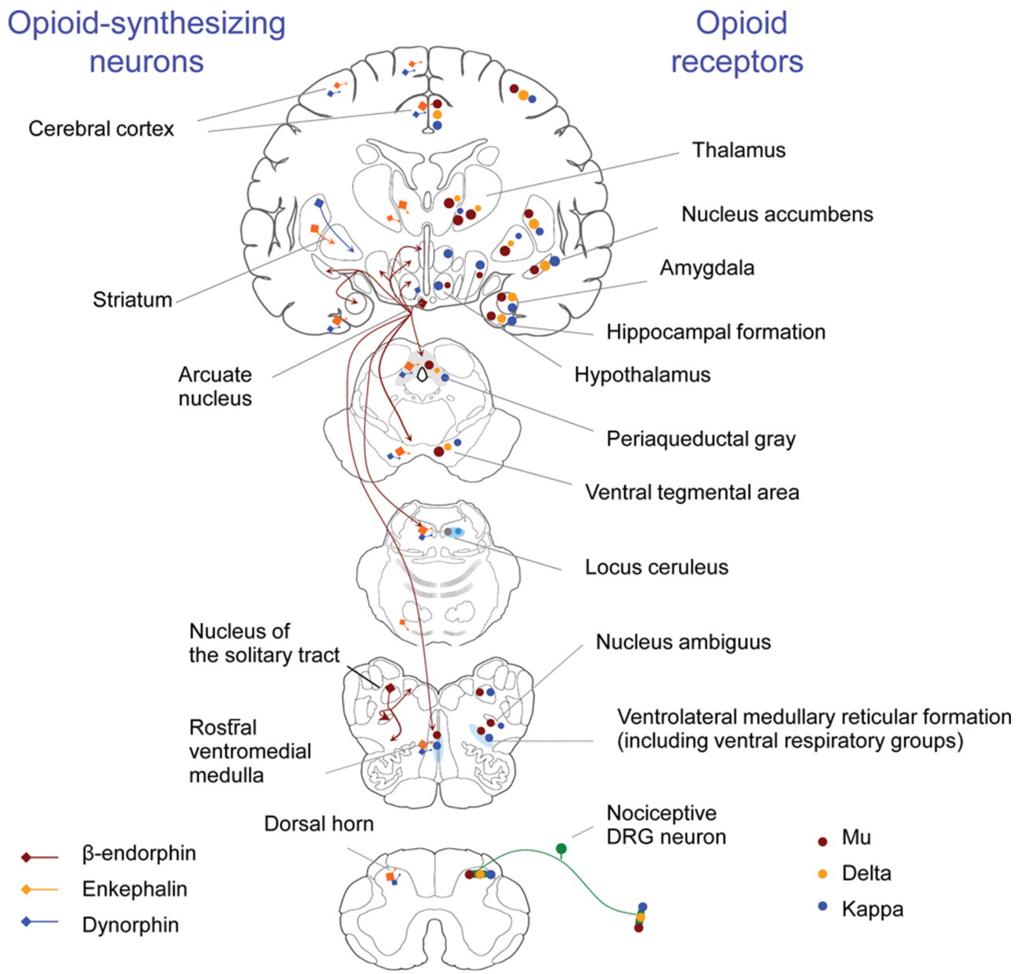
- *Prostaglandins*
    - hormone-like effects, but released in many places
    - trigger vasodilation and inflammation

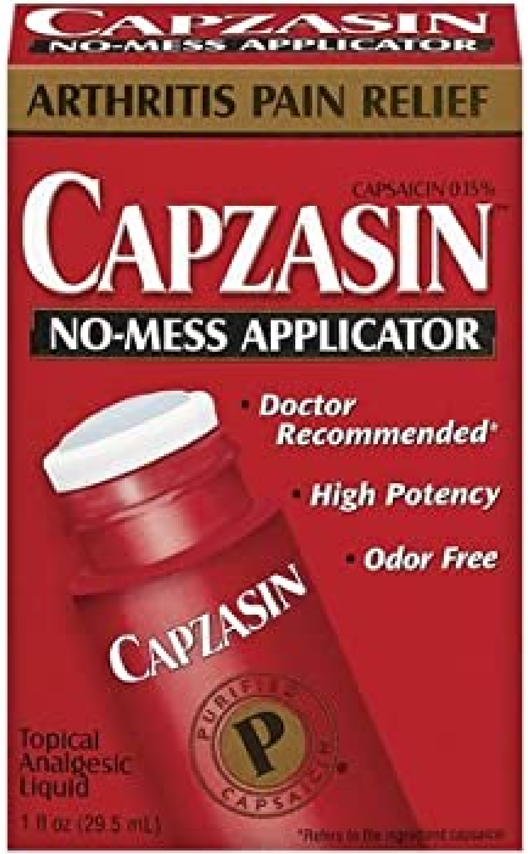
Pain relief

- *Paracetymol (acetaminophen)*
    - Mechanism not fully understood
    - inhibits synthesis of prostaglandins via cyclooxygenase (COX) enzyme
    - may modulate endocannabinoid system
- *Nonsteroidal anti-inflamatory drugs (NSAIDs)*: aspirin, ibuprofen
    - Also inhibit prostaglandins via COX

Pain relief

- *Opioids*
  - Activate endogenous opioid systems
  - multiple receptor types (δ, κ, μ,…)
  - peripheral sensory neurons, amygdala, hypothalamus, PAG, spinal cord, cortex, medulla, pons,…
  - brainstem opioid neurons provide *descending* inhibition of nociceptors


Opioid-synthesizing neurons
Opioid receptors
Cerebral cortex
Thalamus
Nucleus accumbens
Amygdala
Striatum
Hippocampal formation
Hypothalamus
Arcuate nucleus
Periaqueductal gray
Ventral tegmental area
Locus ceruleus
Nucleus of the solitary tract
Nucleus ambiguus
Rostral ventromedial medulla
Ventrolateral medullary reticular formation (including ventral respiratory groups)
Dorsal horn
Nociceptive DRG neuron
β-endorphin
Enkephalin
Dynorphin
Mu
Delta
Kappa


CAPZASIN
NO-MESS APPLICATOR
ARTHRITIS PAIN RELIEF
CAPZASIN
NO-MESS APPLICATOR
• Doctor Recommended*
• High Potency
• Odor Free
CAPZASIN
PURIFIED CAPSAICIN
P
Topical Analgesic Liquid
1 fl oz (29.5 mL)

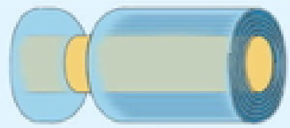
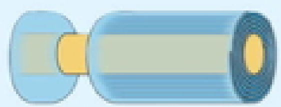
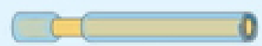
Pain relief

- *Capsaicin*
  - Binds to TrpV1/VR1 thermo/nociceptors
  - Eventually causes decrease in TrpV1 response
  - Alters how peripheral neuron responds to mechanical stimulation
  - (Borbiro, Badheka, & Rohacs, 2015)

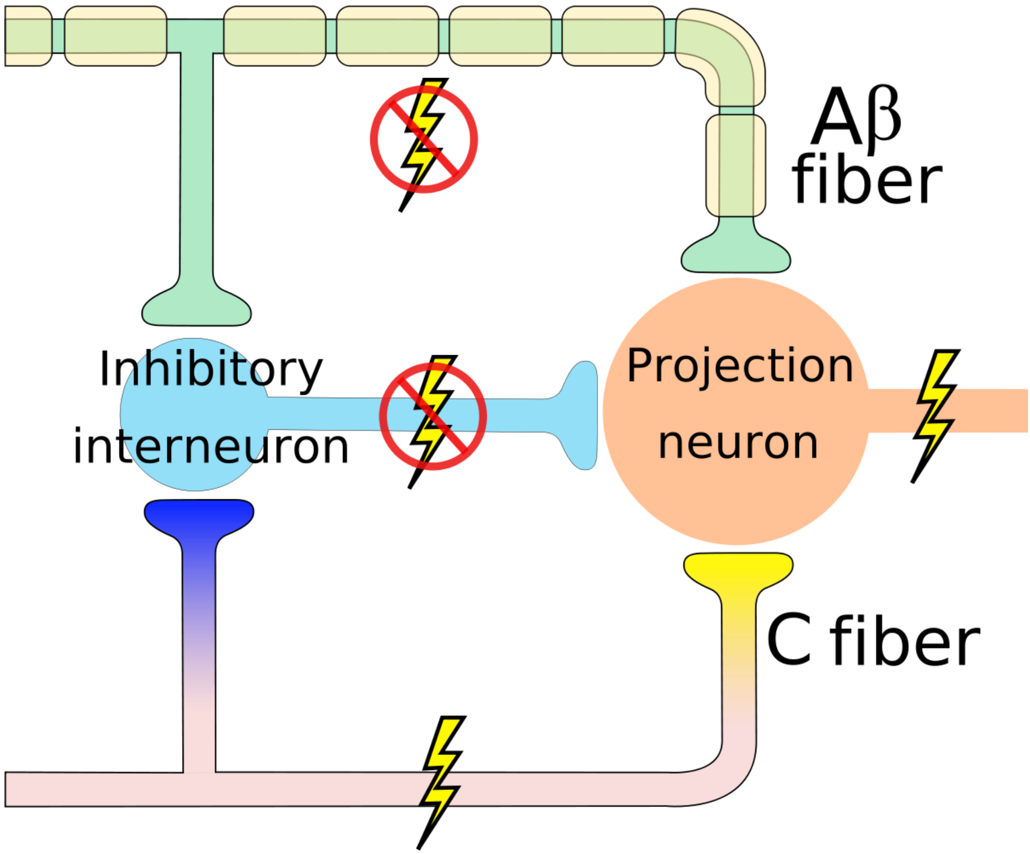
Pain relief

- Why rubbing can help

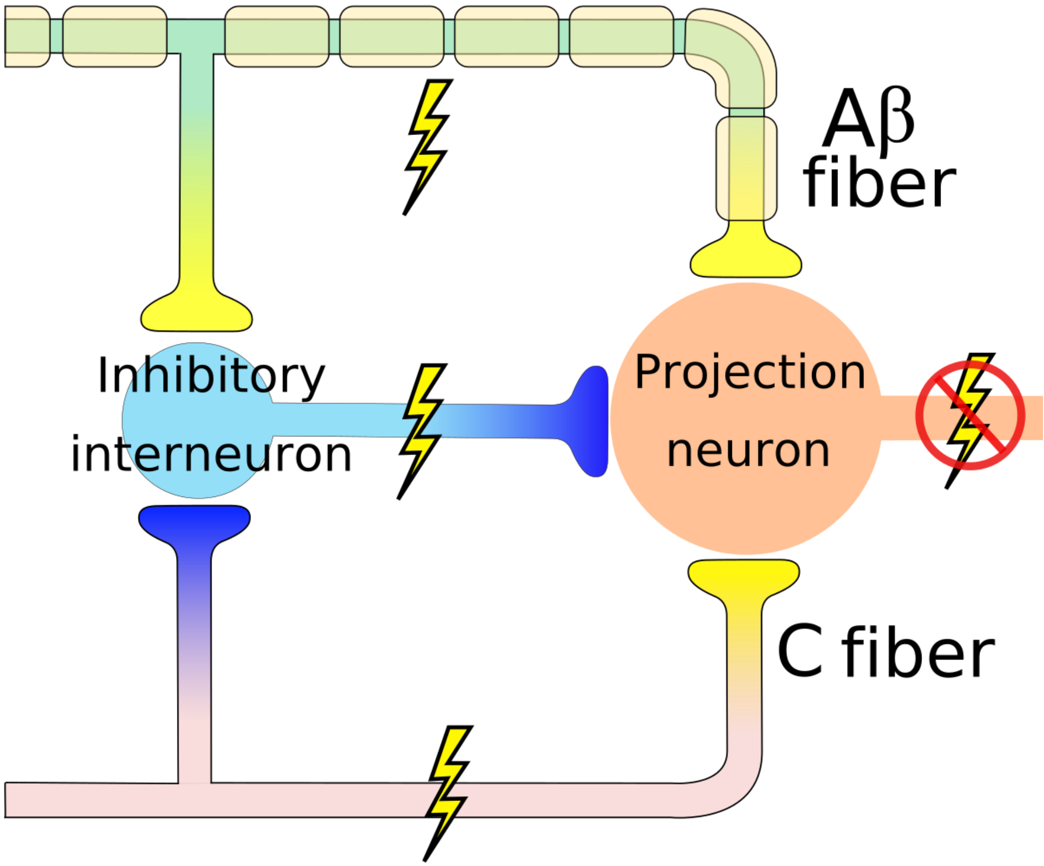
TABLE 8.2 ***Fibers That Link Receptors to the CNS***

Sensory function(s)	Receptor type(s)	Axon type	Diameter (µm)	Conduction speed (m/s)
Proprioception (see Chapter 11)	Muscle spindle	 $A\alpha$	13–20	80–120
Touch (see Figures 8.12 and 8.13)	Pacinian corpuscle, Ruffini's ending, Merkel's disc, Meissner's corpuscle	 $A\beta$	6–12	35–75
Pain, temperature	Free nerve endings; VRL1	 $A\delta$	1–5	5–30
Temperature, pain, itch	Free nerve endings; VR1, CMR1	 C	0.02–1.5	0.5–2

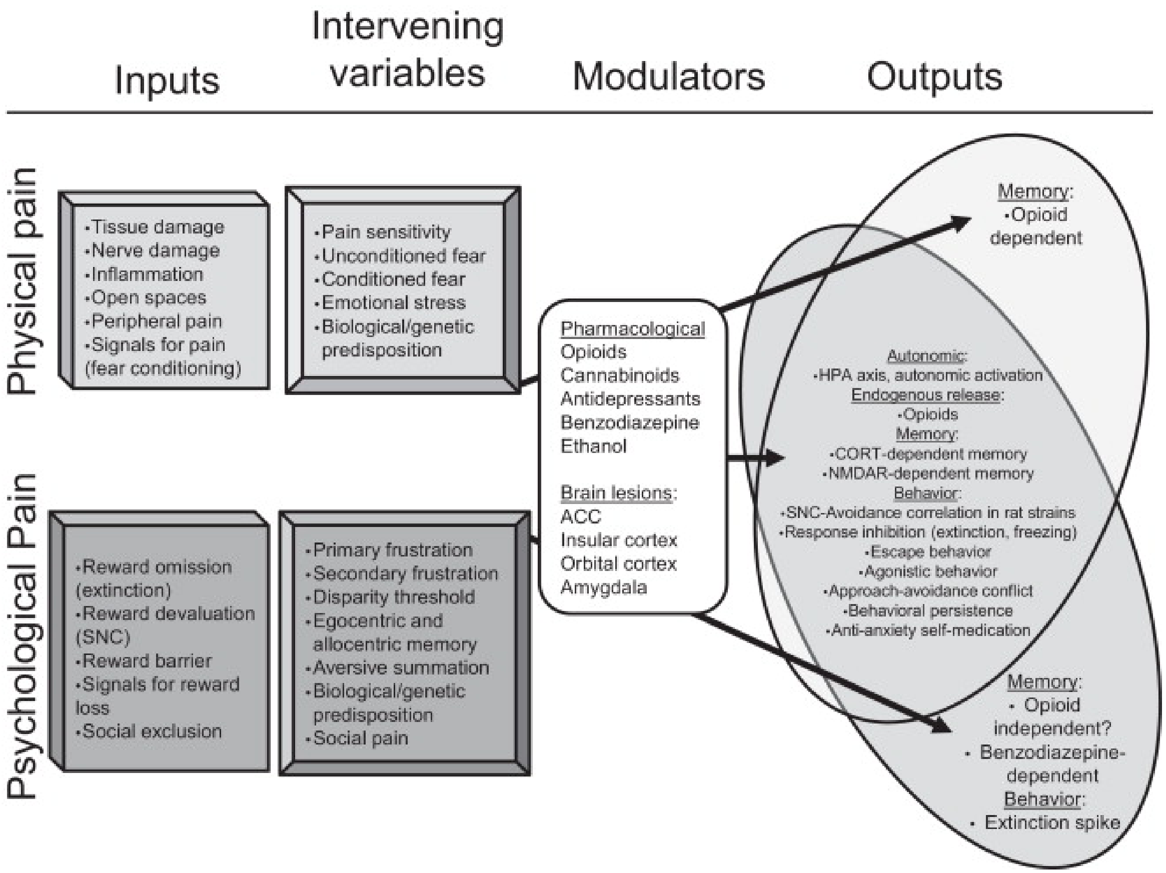
Gate control theory (Melzack & Wall, 1965)



Gate control theory (Melzack & Wall, 1965)



Psychological & physical components of pain



(Papini, Fuchs, & Torres, 2015)

Main points

- Somatosensation
  - Exteroception via
    - Cutaneous receptors + proprioception
  - Interoception via
    - Widely distributed receptors
    - Specific and non-specific

Main points

- Pain
  - Multiple receptor channels
  - Highly interconnected CNS network
  - Multiple targets for modulation

Next time…

- Exam 3

References

Borbiro, I., Badheka, D., & Rohacs, T. (2015). Activation of TRPV1 channels inhibits mechanosensitive piezo channel activity by depleting membrane phosphoinositides. *Sci. Signal.*, *8*(363), ra15. https://doi.org/10.1126/scisignal.2005667

Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nat. Rev. Neurosci.*, *3*(8), 655–666. https://doi.org/10.1038/nrn894

Melzack, R., & Wall, P. D. (1965). Pain mechanisms: A new theory. *Science*, *150*(3699), 971–979. https://doi.org/10.1126/science.150.3699.971

Papini, M. R., Fuchs, P. N., & Torres, C. (2015). Behavioral neuroscience of psychological pain. *Neurosci. Biobehav. Rev.*, *48*, 53–69. https://doi.org/10.1016/j.neubiorev.2014.11.012

Wager, T. D., Atlas, L. Y., Lindquist, M. A., Roy, M., Woo, C.-W., & Kross, E. (2013). An fMRI-based neurologic signature of physical pain. *N. Engl. J. Med.*, *368*(15), 1388–1397. https://doi.org/10.1056/NEJMoa1204471