

SENSORY SYSTEMS

General aspects

Peter Århem
Inst f neurovetenskap
Karolinska institutet

Types of sensory information

- **Exteroception** - reception of information from outside body
- **Enteroception** - reception of information from inside body
- **Proprioception** - reception of information about "self"

Attributes of stimuli

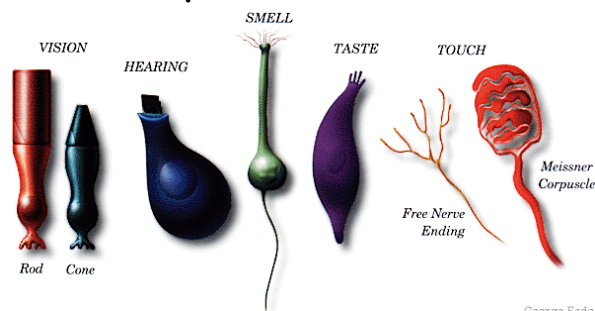
- **Modality** - Labeled line code
- **Intensity** - Frequency code
- **Duration** - Temporal code
- **Localization** - Labeled line code

BASIC CONCEPTS

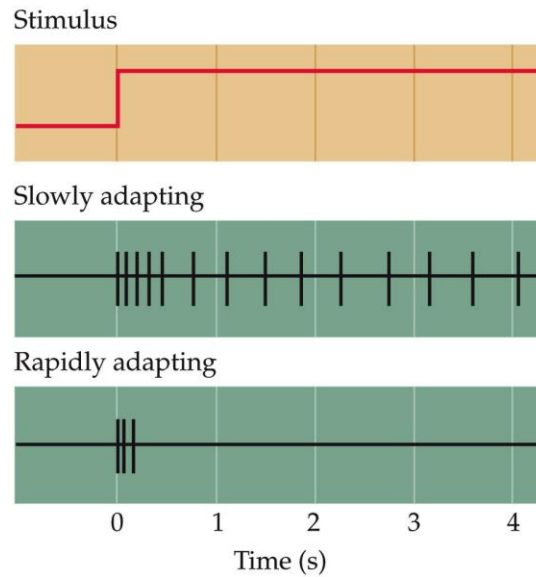
Sensory receptors

Specialized neurons or specialized parts of neurons

- Mechanoreceptors
- Chemoreceptors
- Photoreceptors
- Thermoreceptors



Adaptation

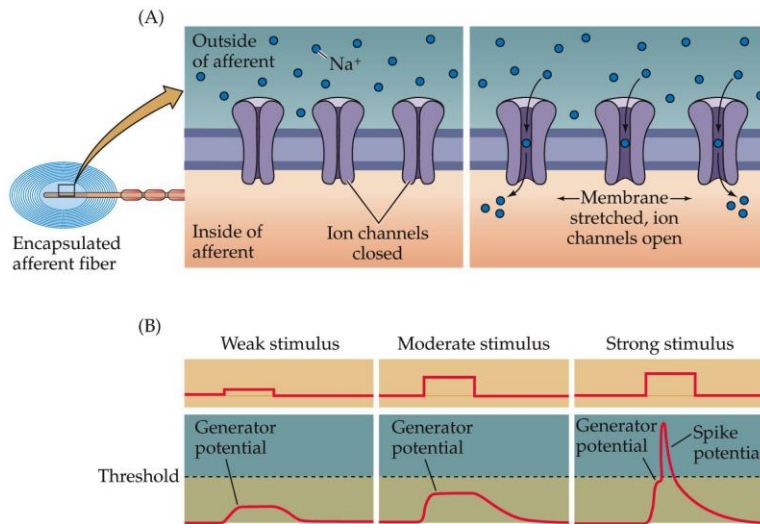


Adaptation mechanisms

Several mechanisms at different levels

- Receptor cell - Ca^{2+} affects K_{Ca} channels
- Accessory structures - Pacinian corpuscle
- Central mechanisms

Transduction



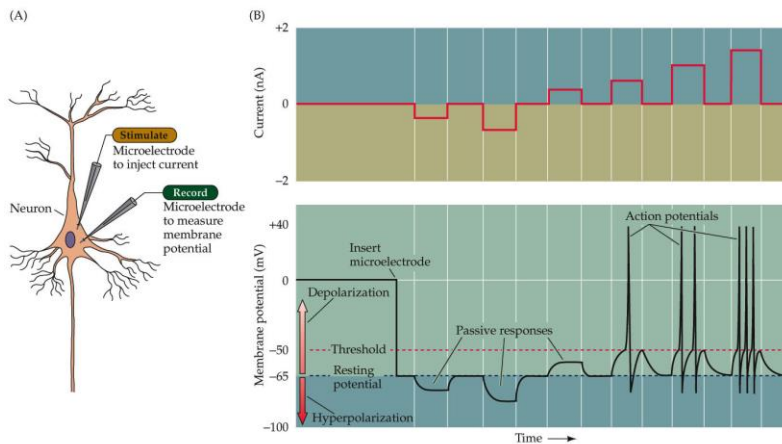
NEUROSCIENCE, Fourth Edition, Figure 9.2

© 2008 Sinauer Associates, Inc.

The transduction mechanism

Stimulus energy →
ion channels (directly or indirectly) →
receptor potential (local and graded) →
action potential (propagated and all-or-none)

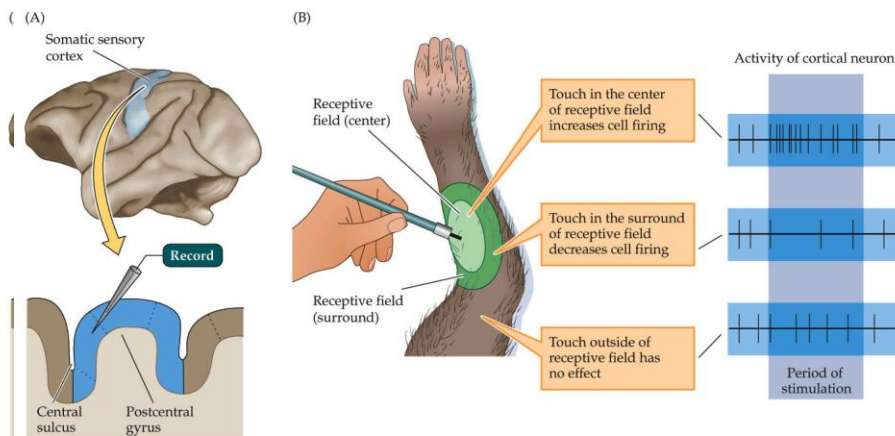
Graded vs all-or-none action potentials



NEUROSCIENCE, Fourth Edition, Figure 2.2

© 2008 Sinauer Associates, Inc.

Receptive fields



NEUROSCIENCE, Fourth Edition, Figure 1.13

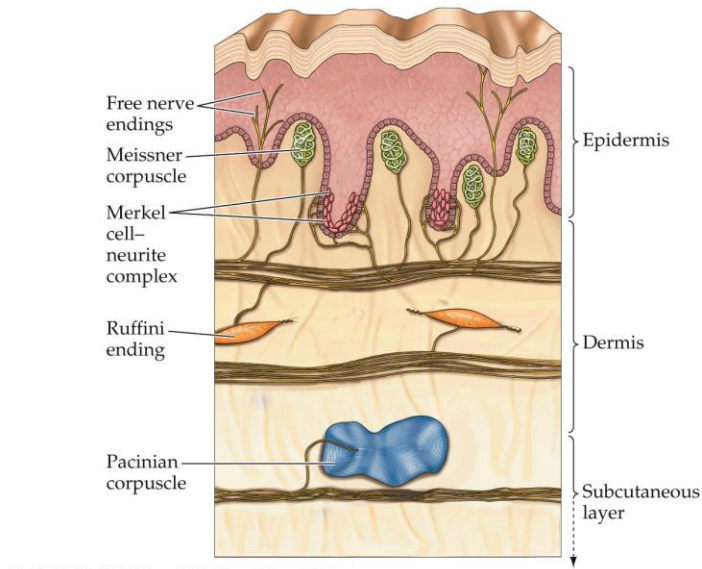
© 2008 Sinauer Associates, Inc.

BODILY SENSES

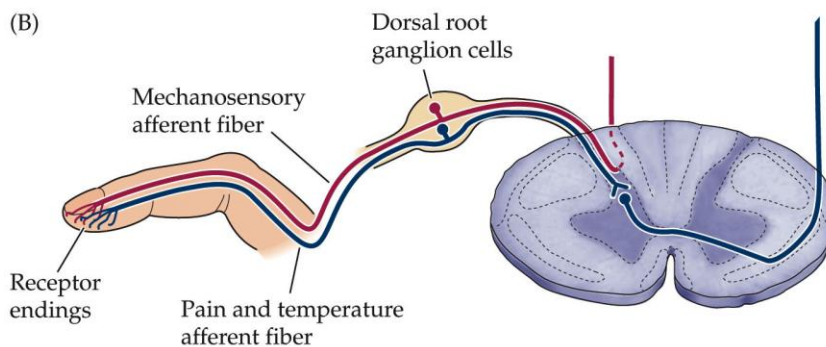
Bodily senses - four systems

- **Touch: Merkel, Meissner, Pacini, Ruffini**
- **Temperature: Free nerve endings - cold and warm receptors**
- **Pain: Free nerve endings**
- **Proprioception: Muscle spindles, Golgi tendon organs, joint receptors**

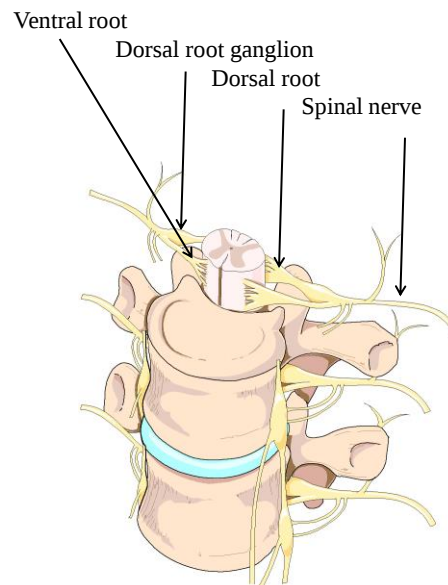
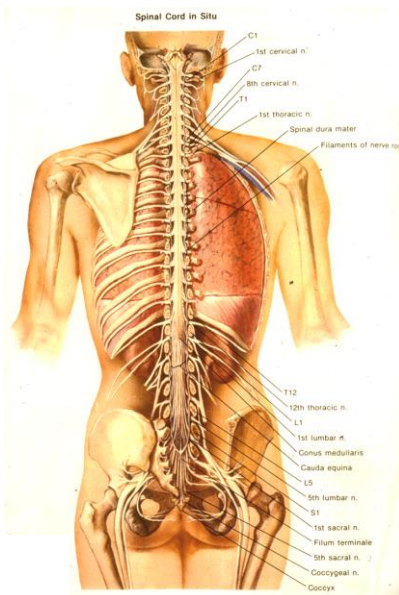
Touch, temperature and pain - skin receptors



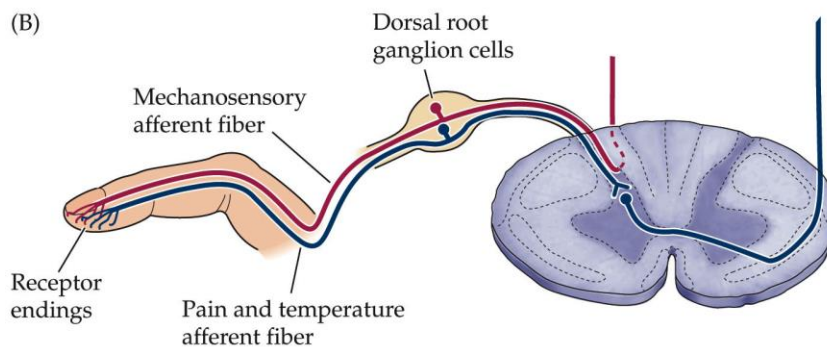
Skin receptors - specialized terminals of dorsal root ganglion cells



Anatomy of dorsal roots and spinal nerves



Two skin receptor pathways - Touch and pain/temperature

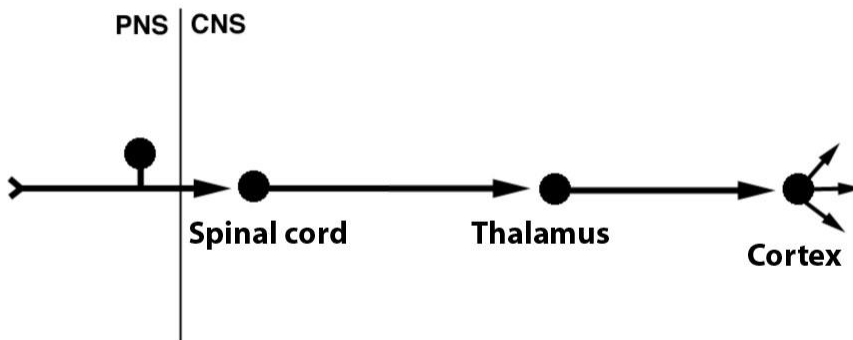


The two central pathways of touch and pain/temperature

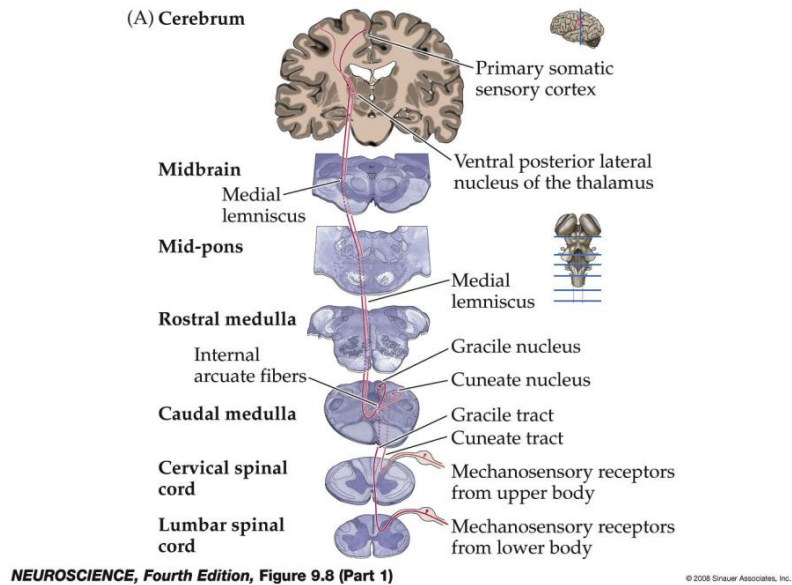
Touch and pressure - dorsal column-medial lemniscal pathway

Pain and temperature - anterolateral spinothalamic tract

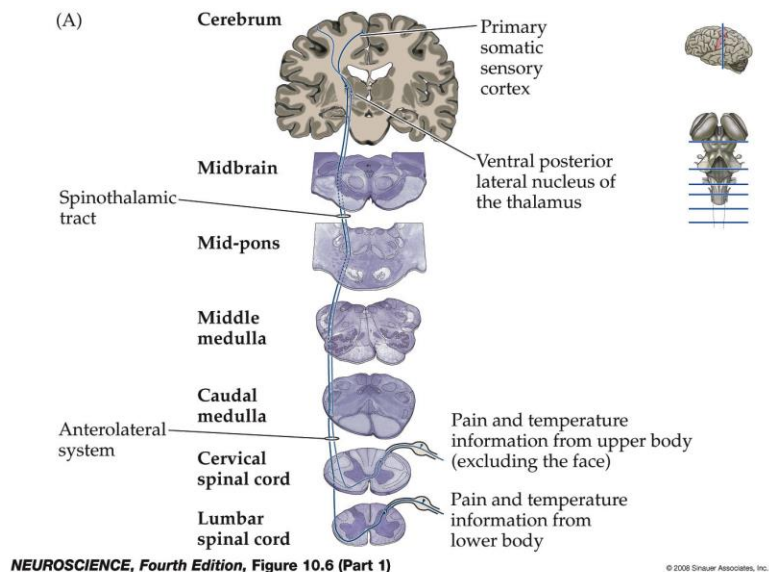
Principal organisation of sensory systems



Central touch pathway - dorsal column-medial lemniscal pathway

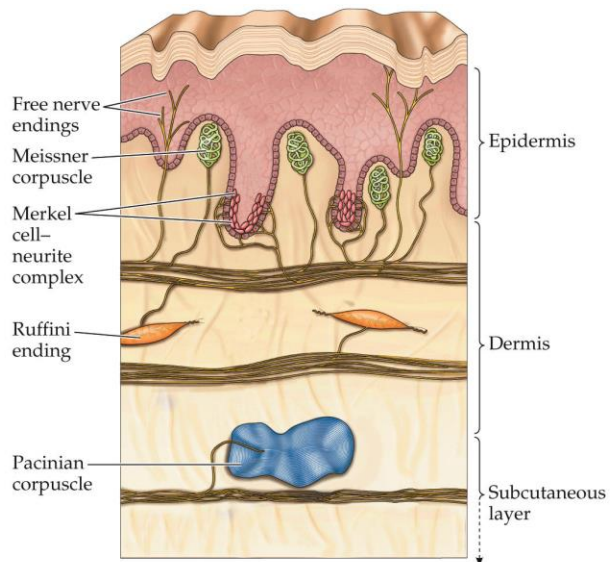


Central pain/temperature pathway - the anterolateral spinothalamic tract



TOUCH, PRESSURE, VIBRATION

Four types touch receptors - Meissner, Merkel, Ruffini, Pacini



NEUROSCIENCE, Fourth Edition, Figure 9.5

© 2008 Sinauer Associates, Inc.

Properties of touch receptors - Location and adaptation

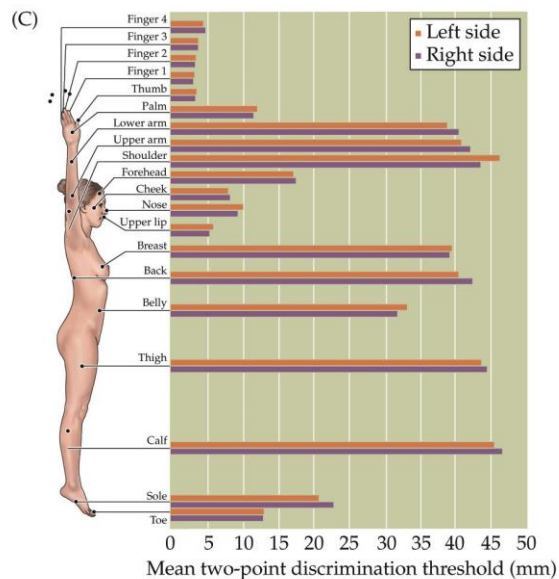
Superficial (small receptive fields - 2-4 mm)

- Meissner - rapid adaptation (sensitivity max at ≈ 30 Hz)
- Merkel - slow adaptation

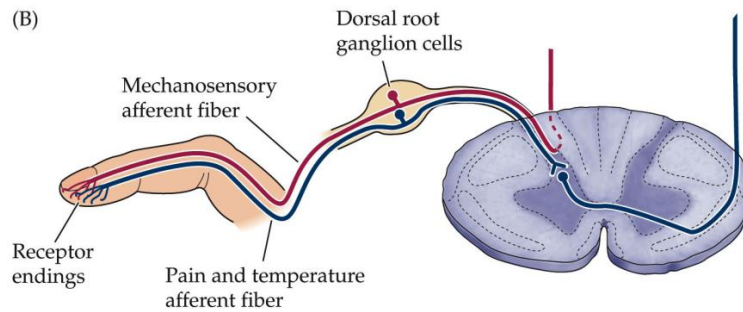
Deep (large receptive fields)

- Pacini - rapid adaptation (sensitivity max at ≈ 300 Hz)
- Ruffini - slow adaptation

The density of skin receptors tested by two-point discrimination



Touch receptor fibres are $A\beta$ fibres
Pain/temperature fibres are $A\delta$ or C fibres

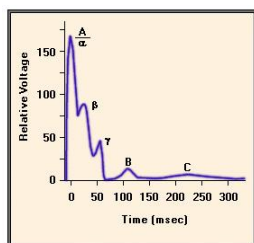


NEUROSCIENCE, Fourth Edition, Figure 9.1 (Part 2)

© 2008 Sinauer Associates, Inc.

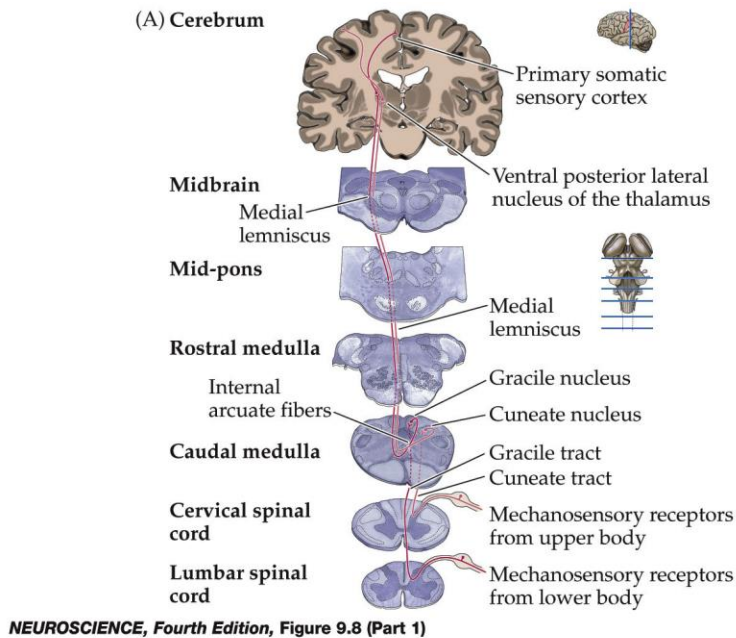
Classification of fibre types

Type	diameter (μm)	velocity (m/s)
$A\alpha$	13-20	80 -120
$A\beta$	6-12	35 - 75
$A\gamma$	5-8	25-45
$A\delta$	1-5	5 - 35
C	0.2-1.5	0.5 - 2



Erlanger och Gasser, Nobel prize 1944

The touch pathway (via spinal nerves)



The touch pathway from receptors to cortex (via spinal nerves)

Receptors →

A β fibres in spinal nerves (dorsal root ganglion) →

ipsilateral dorsal column →

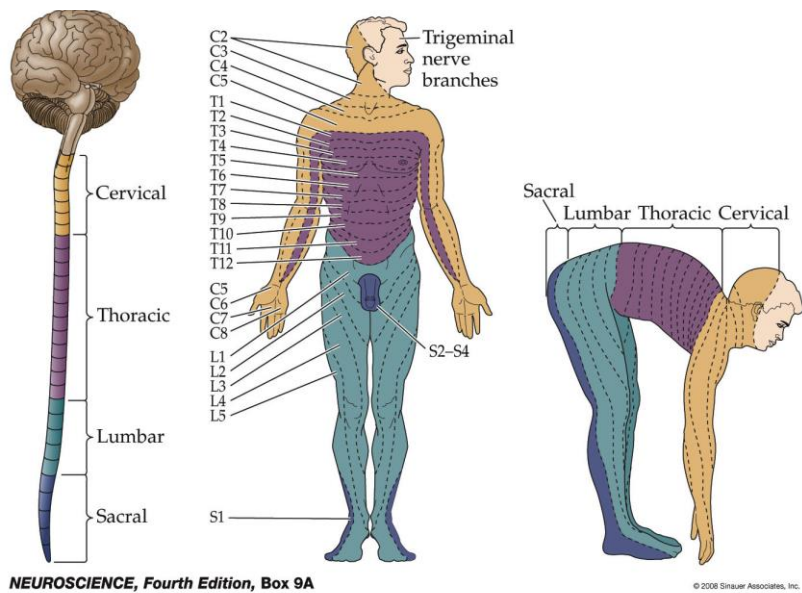
dorsal column nuclei (*nucleus cuneatus* and *gracilis*) →

contralateral medial lemniscus →

thalamus (VPL) →

somatosensory cortex (SI, SII and posterior parietal cortex)

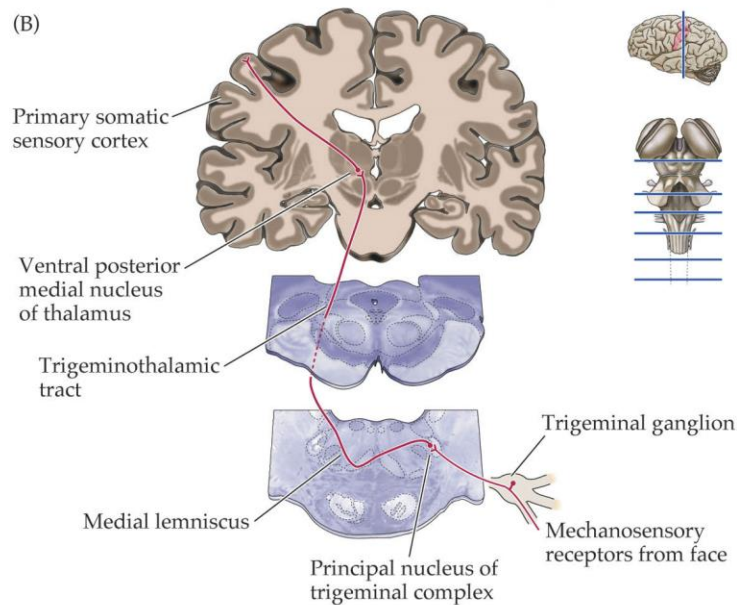
Dermatomes



Dermatome = afferent spinal nerve projection area

- C1 to C8 (cervical)
- T1 to T12 (thoracic)
- L1 to L5 (lumbar)
- S1 to S4 (sacral)

The touch pathway (via the trigeminal nerve)



The touch pathway (via the trigeminal nerve)

Receptors →

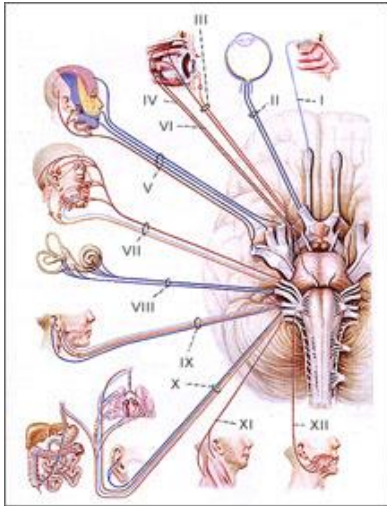
$A\beta$ fibres in n. trigeminus (trigeminal ganglion = ganglion semilunare/Gasserii) →

***ipsilateral* nucleus of trigeminal complex in brainstem →**

***contralateral* thalamus (VPM) →**

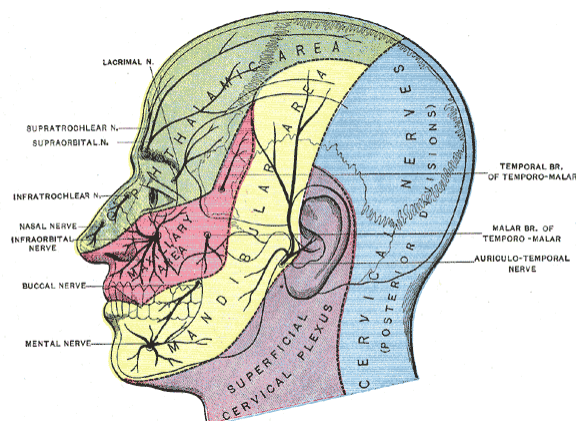
somatosensory cortex (SI, SII and posterior parietal cortex)

Cranial nerves

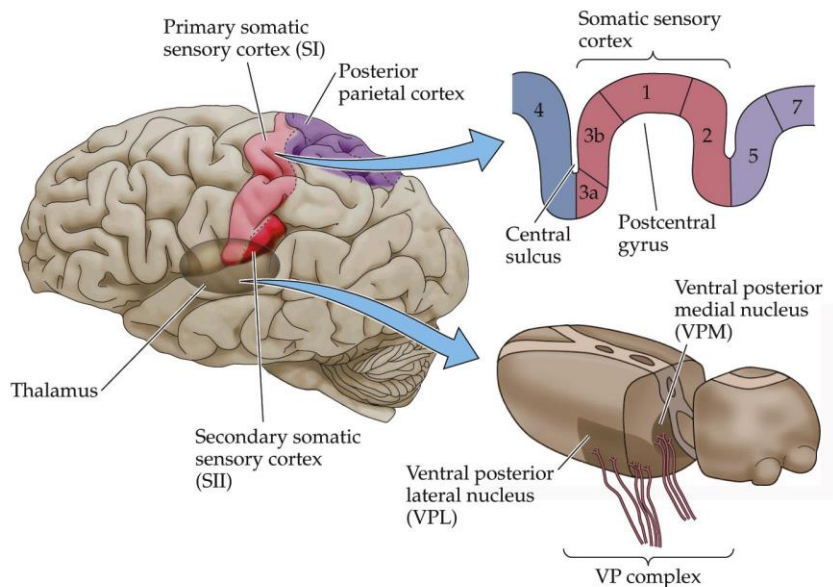


- N. olfactorius I
- N. opticus II
- N. oculomotorius III
- N. trochlearis IV
- N. trigeminus V**
- N. abducens VI
- N. facialis VII
- N. vestibulocochlearis VIII
- N. glossopharyngeus IX
- N. vagus X
- N. accessorius XI
- N. hypoglossus XII

The afferent trigeminal nerve projection areas



Touch pathways in the brain



NEUROSCIENCE. Fourth Edition. Figure 9.10

© 2008 Sinauer Associates, Inc.

Touch pathways in the brain (from spinal nerves)

Receptors →

A β fibres (dorsal root ganglion) →

ipsilateral dorsal column →

dorsal column nuclei (*nucleus cuneatus* and *gracilis*) →

contralateral medial lemniscus →

thalamus (VPL) →

somatosensory cortex (SI, SII and posterior parietal cortex)

Touch pathway in the brain (from the trigeminal nerve)

Receptors →

A β fibres in n. trigeminus (trigeminal ganglion = ganglion semilunare/Gasseri) →

ipsilateral nucleus of trigeminal complex in brainstem →

contralateral thalamus (VPM) →

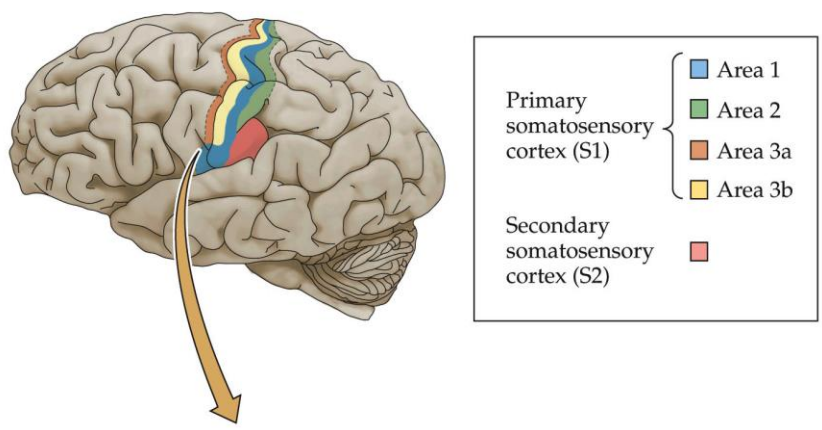
somatosensory cortex (SI, SII and posterior parietal cortex)

Organization of somatosensory cortex

- Four distinct cytoarchitectonic regions in SI (1, 2, 3a and 3b)
- Somatotopic organization - homunculus
- Each of the four regions of SI - complete body map
- Columnar organization - reflecting receptor type

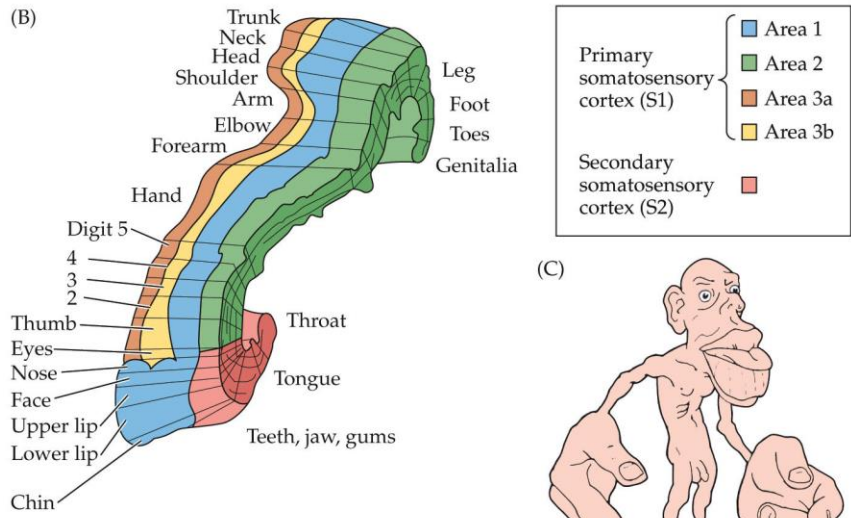
Organization of somatosensory cortex

(A)

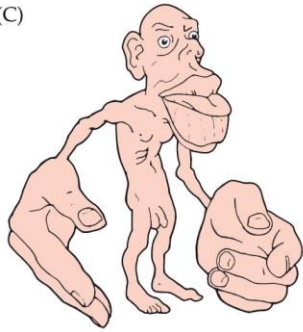


Organization of somatosensory cortex

(B)

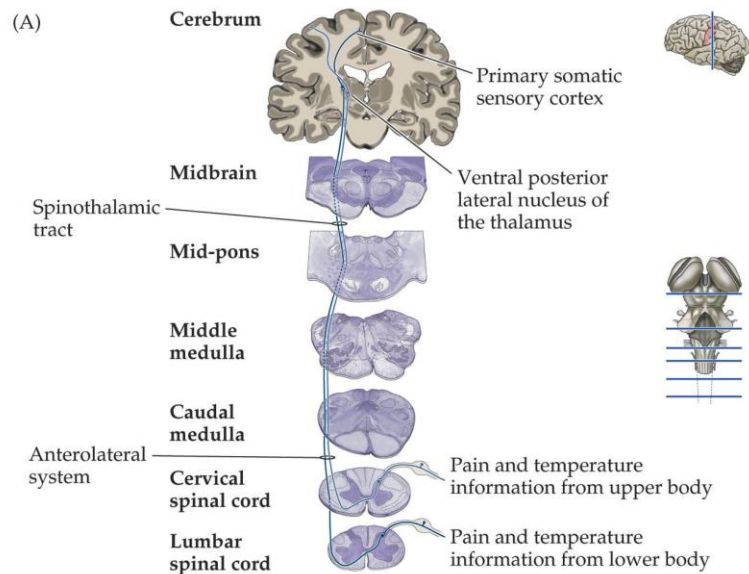


(C)



PAIN, TEMPERATURE

Central pathways for discriminative pain and temperature (from spinal nerves)



NEUROSCIENCE, Third Edition, Figure 9.3 (Part 1) © 2004 Sinauer Associates, Inc.

Central pathways for discriminative pain and temperature (from spinal nerves)

Receptors →

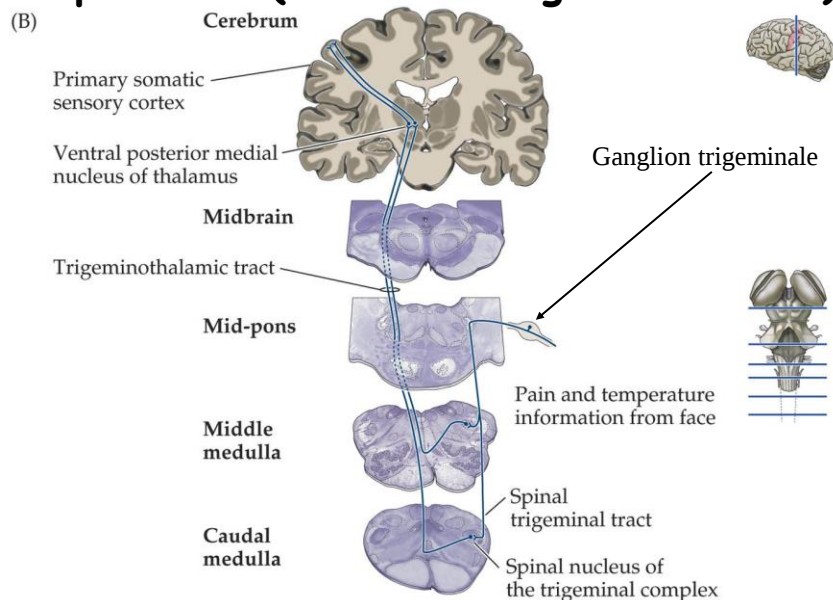
A β och C fibres (dorsal root ganglion) →

dorsal horn →

contralateral anterolateral spinothalamic tract →

thalamus (VPL) → somatosensory cortex

Central pathways for discriminative pain and temperature (from the trigeminal nerve)



Central pathways for discriminative pain and temperature (from the trigeminal nerve)

Receptors →

A δ och C fibres in n. trigeminus (ganglion trigeminale = ganglion semilunare = ganglion Gasseri) →

trigeminal complex in brainstem →

thalamus (VPM) →

somatosensory cortex

Questions (somatosensory system):

1. The four major classes of bodily sense (somatic sensory) receptors?
2. The four cutaneous mechanoreceptors (touch receptors)?
3. Which touch receptor is most sensitive to high frequency vibrations?
4. The two major somatosensory pathways to the brain?
5. What information is transported in these two pathways?
6. First neuron in the somatosensory pathways to brain?
7. Second neuron in the somatosensory pathways to brain?
8. Somatosensory nuclei in thalamus (body and face)?
9. Location of somatosensory cortex?
10. Organization of somatosensory cortex?