Bear: Neuroscience: Exploring the Brain 3e

Chapter 12: The Somatic Sensory System

<u>FROM and to</u> THE BODY

(catchall for <u>non</u> hearing, seeing, tasting, smelling, equilibrium)

DO WE REALLY ONLY HAVE FIVE SENSES?

We also sense:

PAIN

POSITION

TEMPERATURE

DISTENSION

DIRECTION

transduced

Somatosensory System

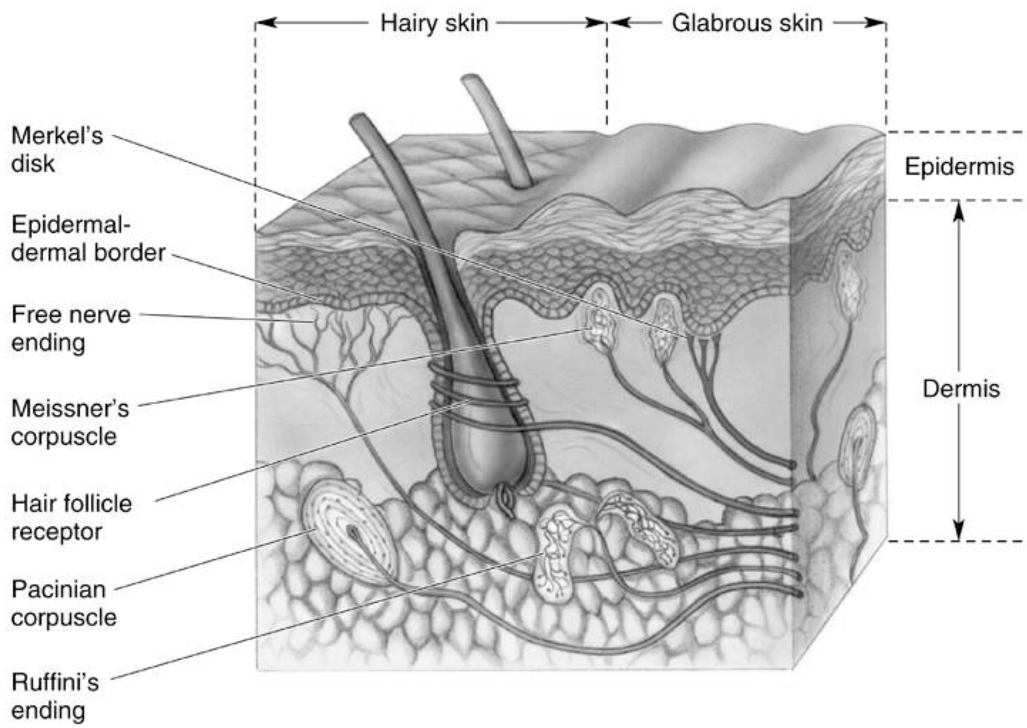
Hapsis – fine touch and pressure
Proprioception – location and movement

Nociception – pain and temperature

Some are rapidly adapting, some are slowly adapting

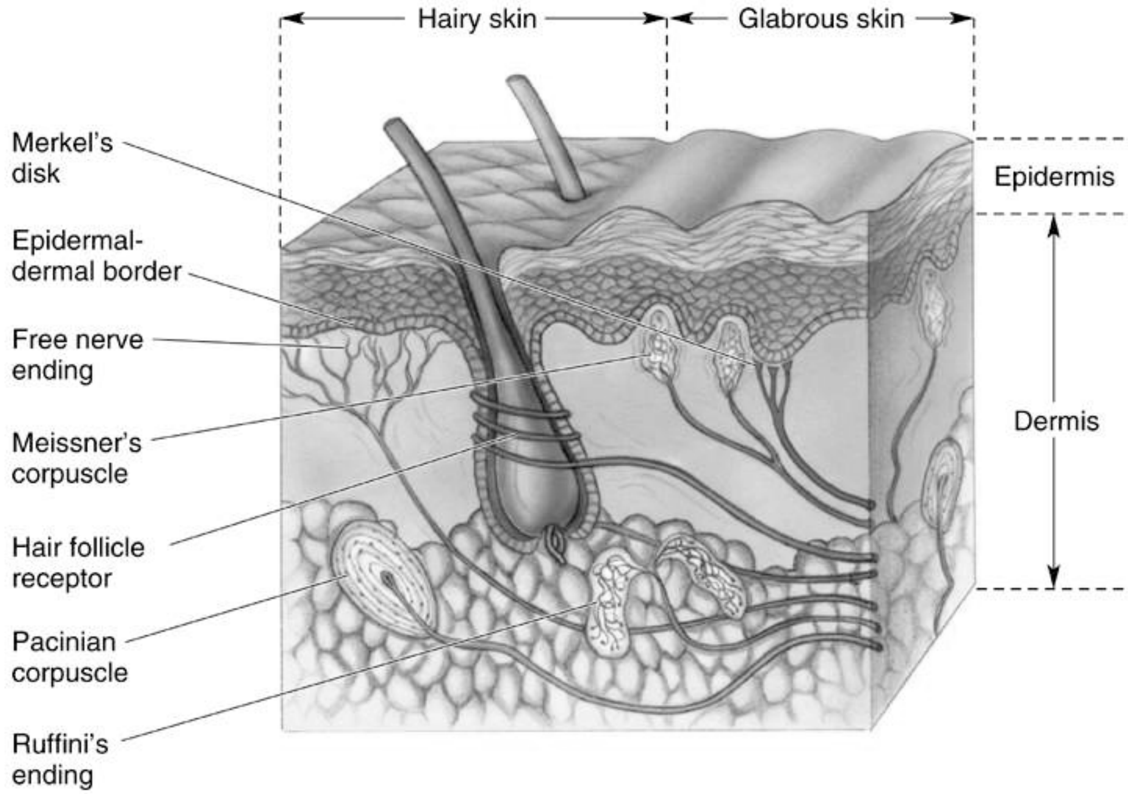
Many are <u>mechanoreceptors</u> - ion channels sensitive to physical distortion such as bending or stretching.

- Types and layers of skin
  - Hairy and glabrous (hairless)
  - Epidermis (outer) and dermis (inner)
- Functions of skin
  - Protective function
  - Prevents evaporation of body fluids
  - Provides direct contact with world



- Mechanoreceptors (Cont’d)
  - Pacinian corpuscles
  - Ruffini's endings
  - Meissner's corpuscles
  - Merkel's disks
  - Free nerve endings, hair follicles

Krause end bulbs
Balls of String
 lip edges



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MECHANORECEPTORS

Sensitivity depends on structure.

Pacinian corpuscles – pressure, stretch

largest, sensitive to flutter –

vibrations (feel the music on your speakers 200-300 Hz.)

(up to 2 mm x 1mm!) Poorly localized sensations.

large football shaped capsule, with onion skin of 20 – 70 layers and fluid in between

Pacinian corpusles-

When pressure is applied:

Capsule compresses
Energy goes to axon terminal
Terminal is deformed
Channels open
Receptor potential activates transmitter

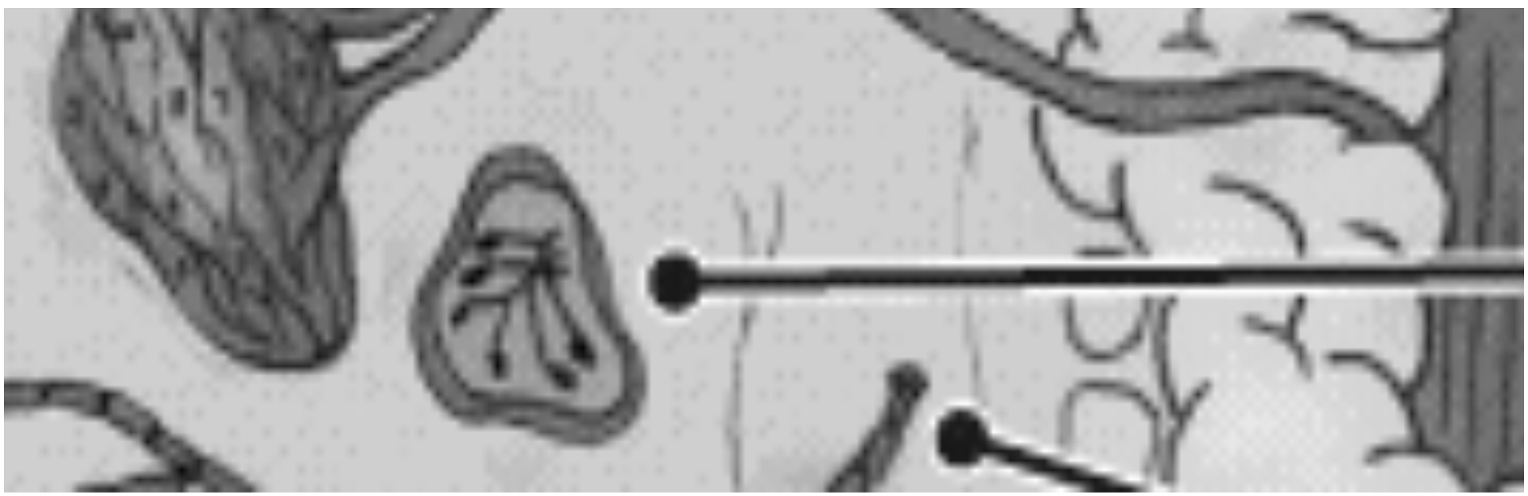
When pressure is maintained

Layers slip past each other
Energy movement stops
Axon terminal stops deforming
Receptor potential stops
Cell has adapted

Ruffini’s endings (aka lamellar)

pressure

– Vibration - a little smaller, better localized sensations



Meissner’s corpusles – very small receptor fields, in glabrous skin only (example: raised parts of your fingerprints) vibrations (50 Hz).

superficial touch , gentle fluttering, well-localized

Glabor = bald

Merkel's disk

small receptor fields consisting of nerve terminal and non- neural epithelial cells

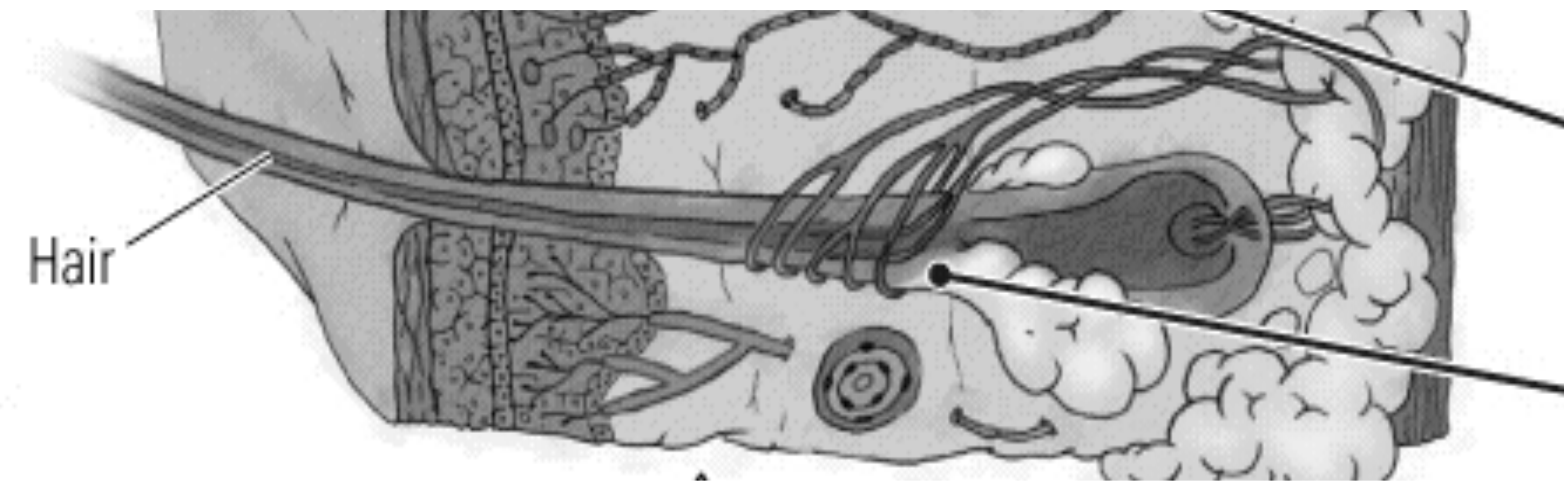
steady skin indentations

free nerve endings – most common

Temperature, pain, pressure

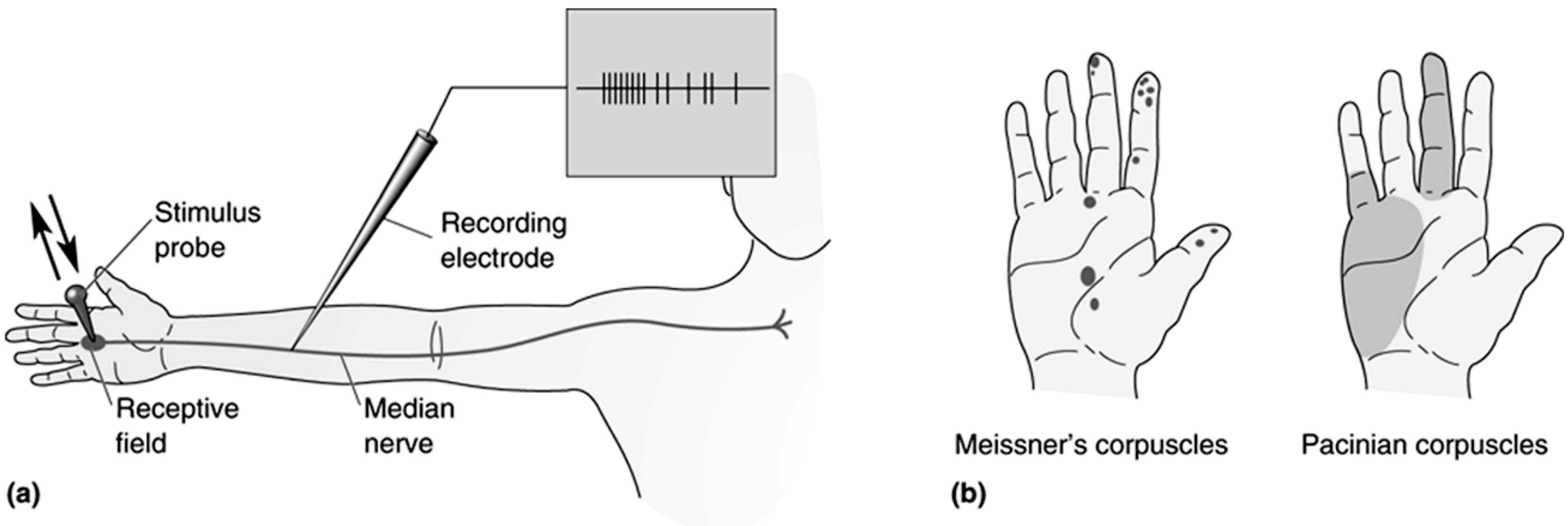
hair follicle receptor (around follicle)

Some follicles also have erectile muscles (goose pimples).



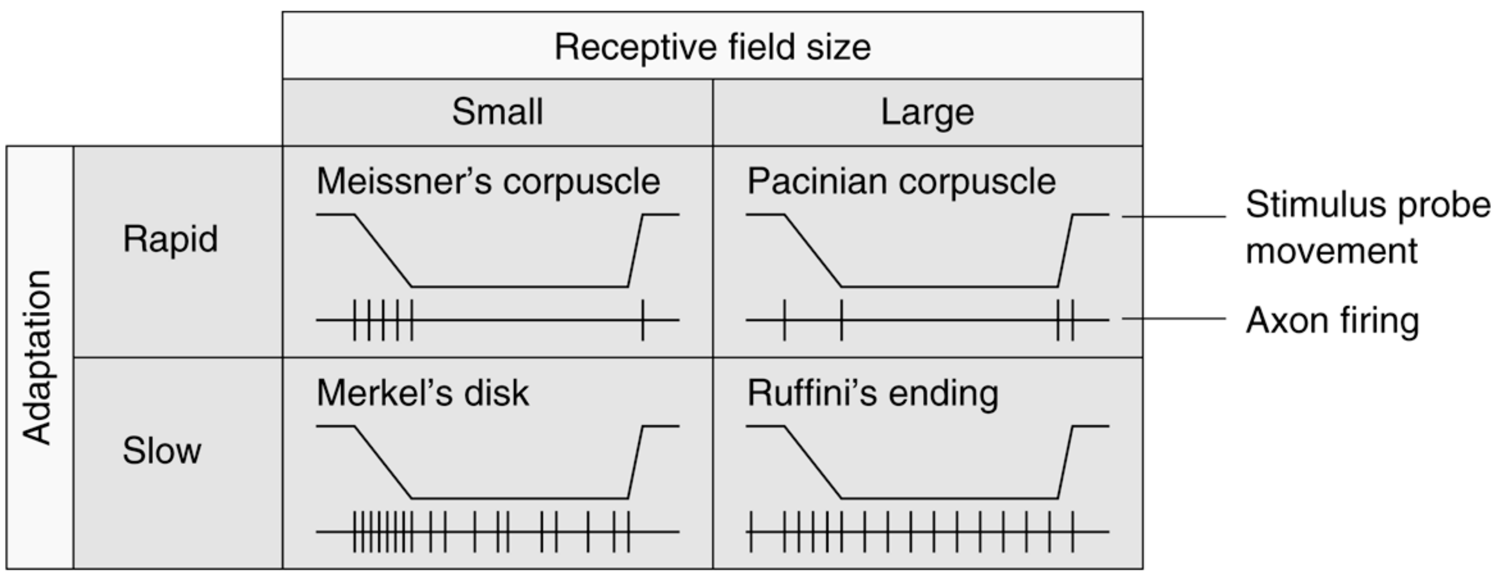
Touch

- Mechanoreceptors



Touch

- Mechanoreceptors (Cont’d)
  - Receptive field size and adaptation rate



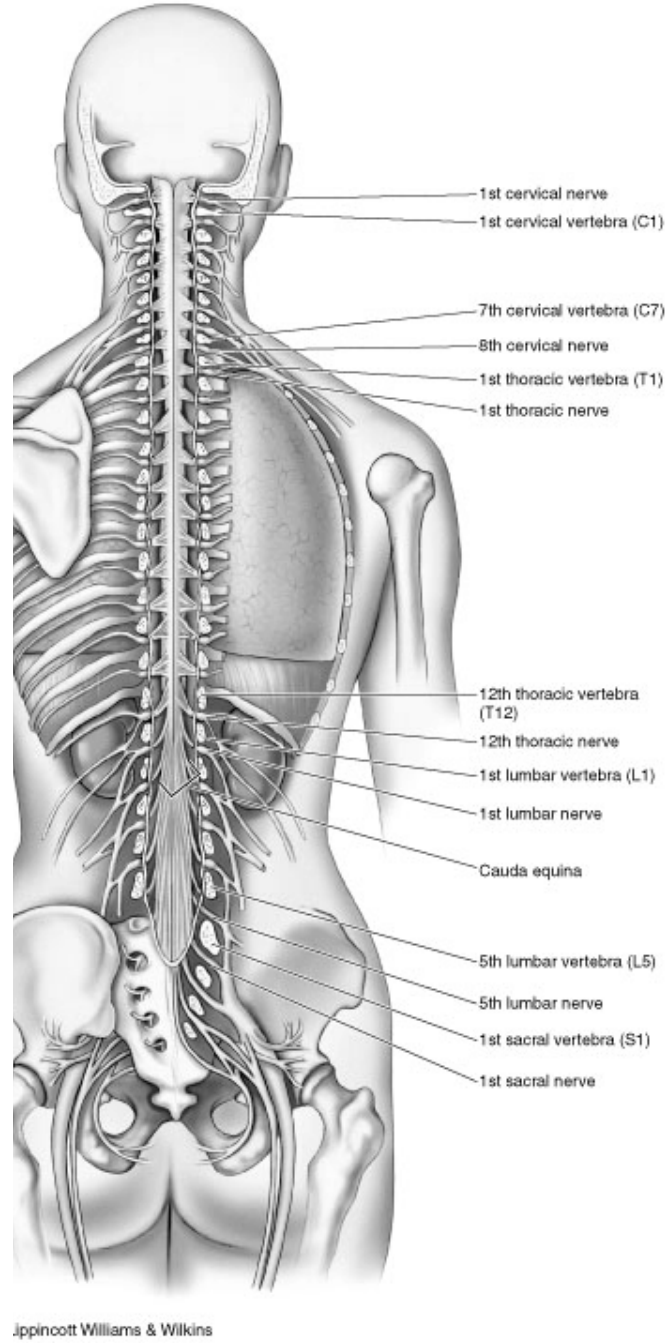
BUT WHERE IS THE CELL BODY??

Dorsal root ganglion

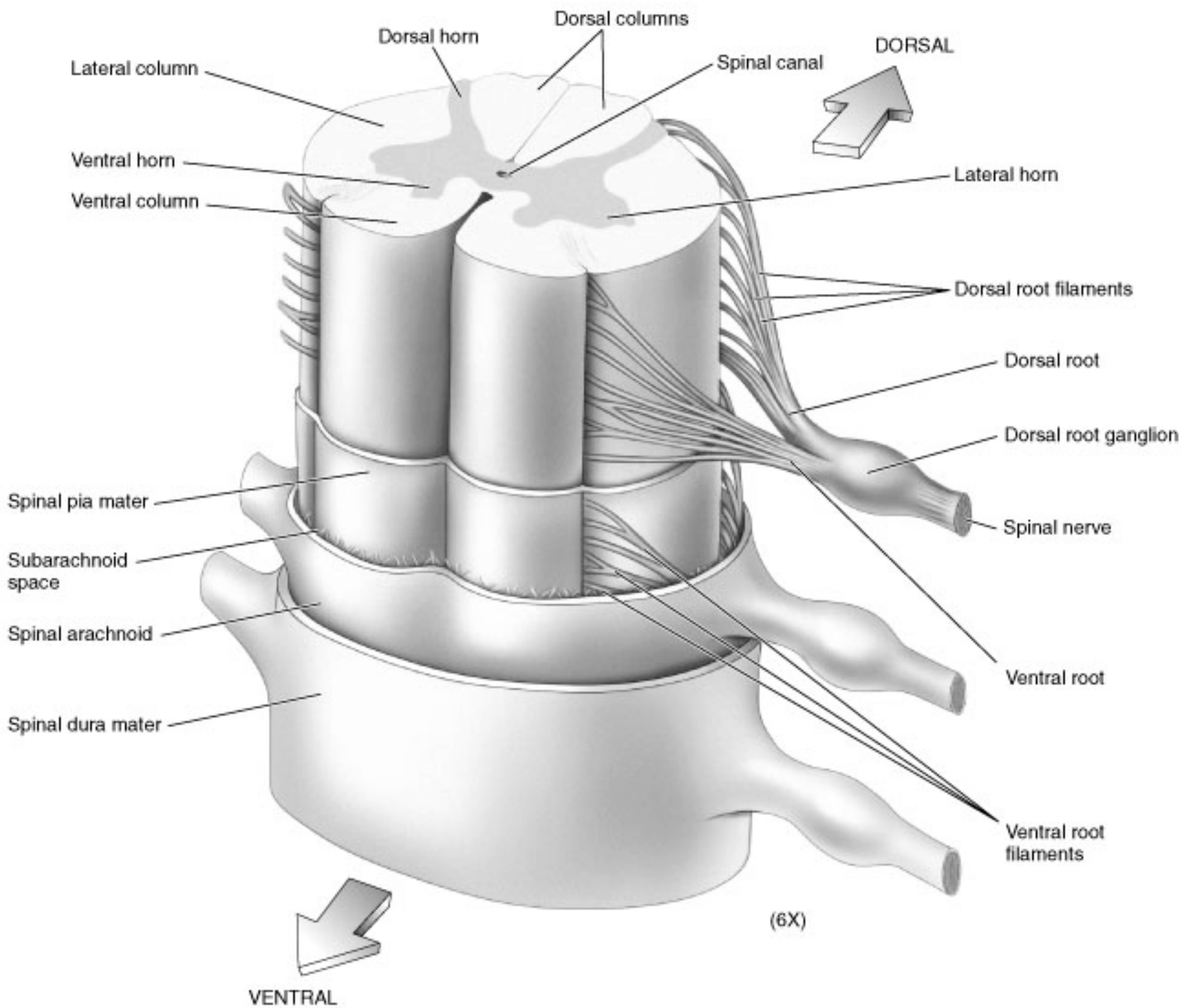
Cells have “neurites” that branch

One branch ends in the skin receptors

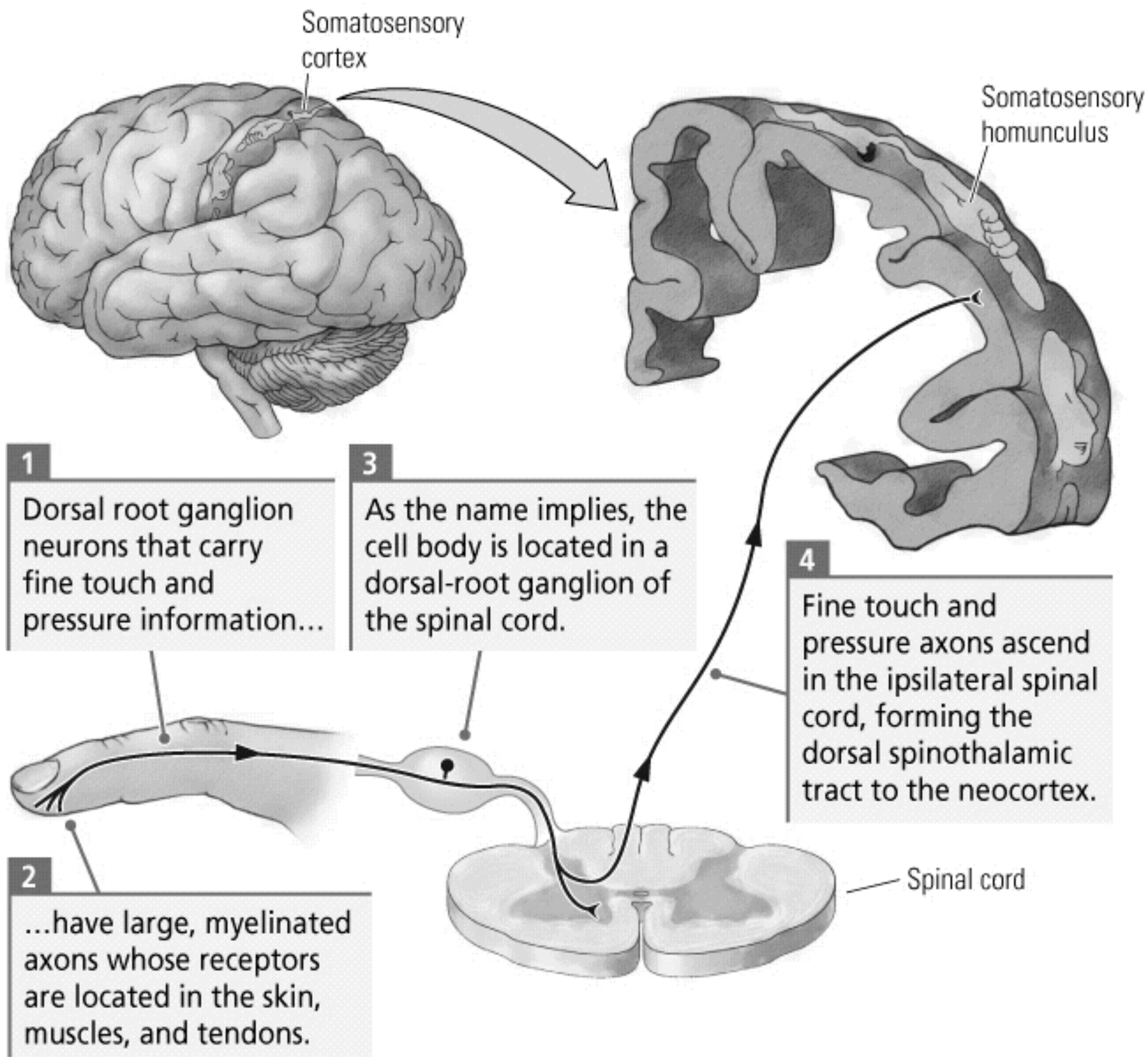
One branch heads towards the CNS



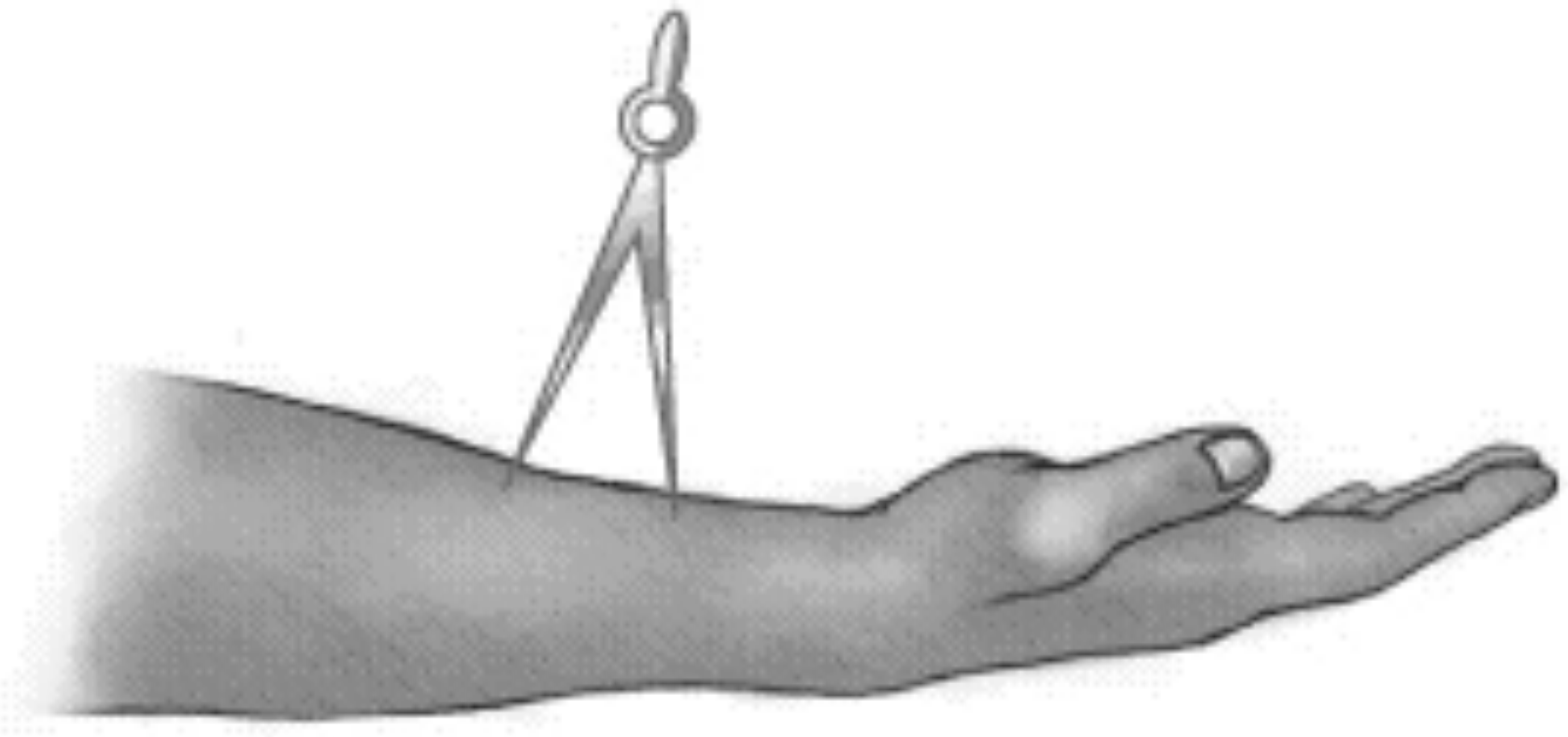
dorsal columns, the lateral columns, and the ventral columns.



cell bodies are outside spinal cord



based on size of receptor fields



Two-point sensitivity

what are receptor fields?

TWO POINT DISCRIMINATION

Simple measure of detail discrimination.

Varies across the body.

Fingertips are most sensitive.

Basis for Braille fluency (600 letters/min.)

On fingers:

High density of receptors
Small receptor fields

In brain:

More brain devoted to processing
Special neural mechanisms for high-resolution discrimination

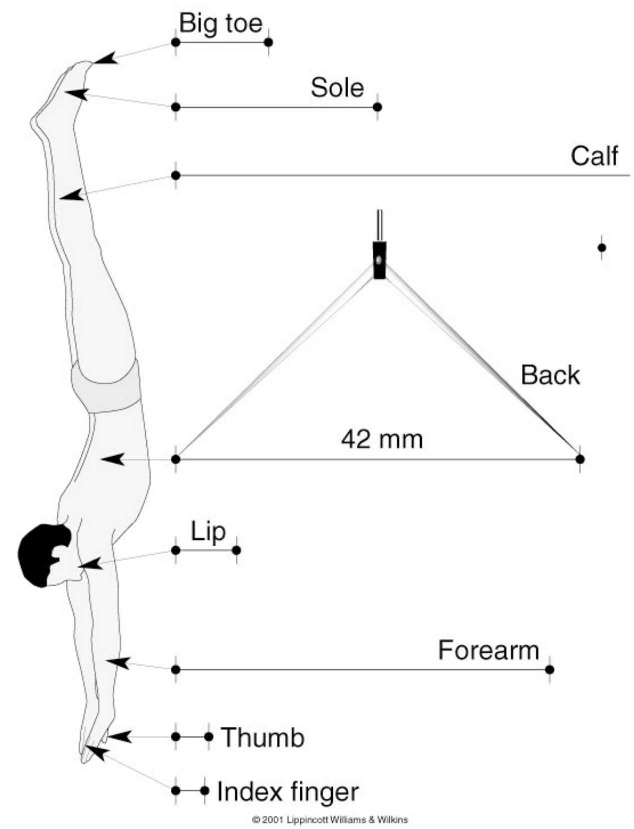


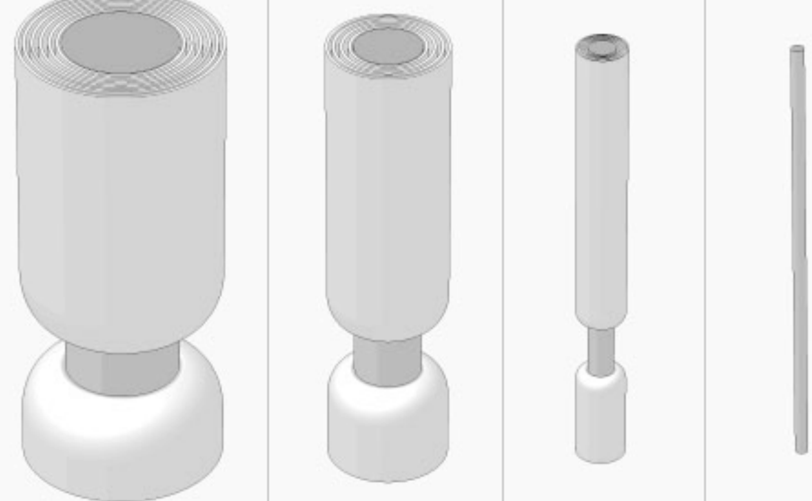
Figure 12.6
Two-point discrimination on the body surface. The pairs of dots show the minimum distance necessary to differentiate between two points touching you simultaneously. Notice the sensitivity of the fingertips compared with that of the rest of the body.

- Primary Afferent Axons
  - Aα, Aβ, Aδ, C
  - C fibers mediate pain and temperature
  - Aβ mediates touch sensations

recall SPEED

Figure 12.9
Various sizes of primary afferent axons. The axons are drawn to scale but are shown 2000 times life size. The diameter of an axon is correlated with its conduction velocity and with the type of sensory receptor to which it is connected.

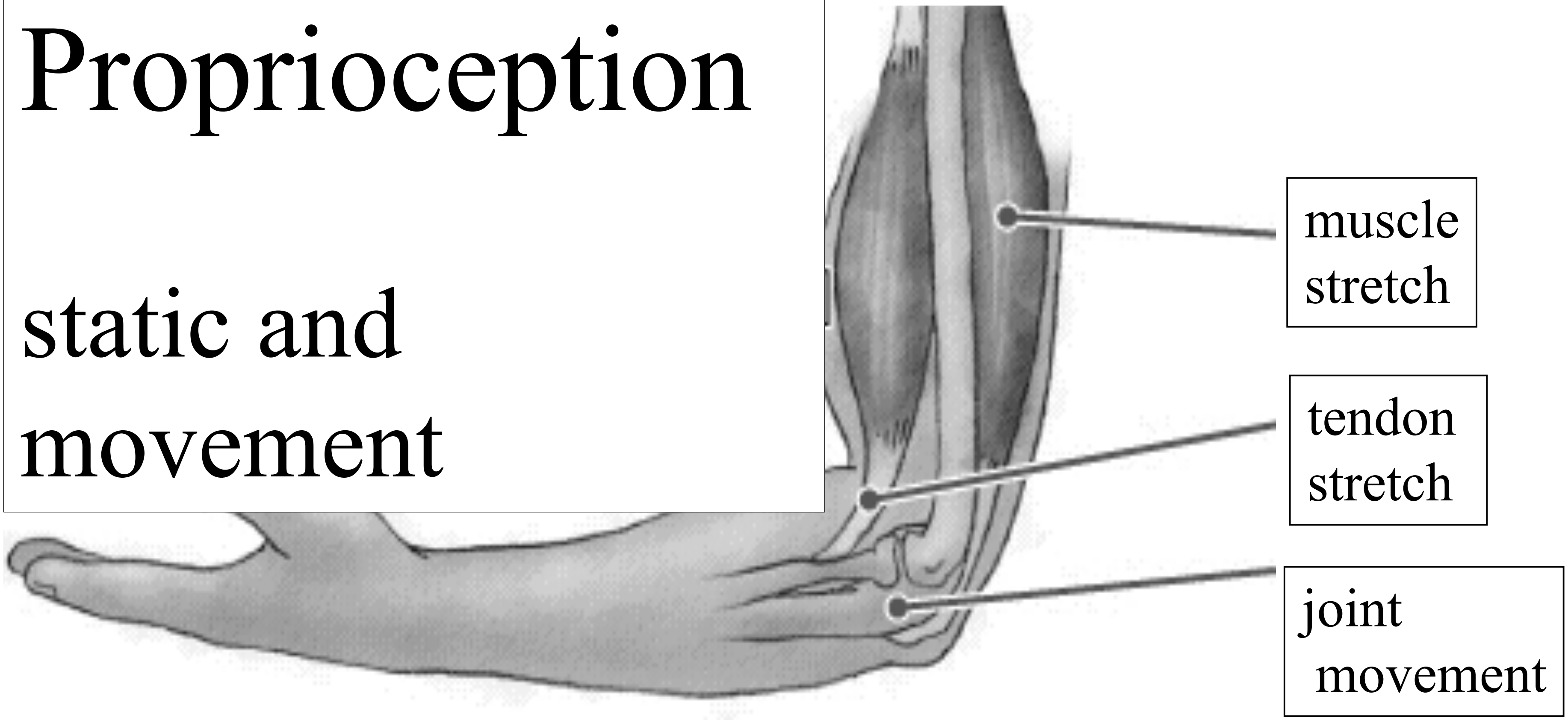
Axons from skin	Aα	Aβ	Aδ	C
Axons from muscles	Group I	II	III	IV



Axons from skin	Aα	Aβ	Aδ	C
Diameter (µm)	13Ð20	6Ð12	1Ð5	0.2Ð1.5
Speed (m/sec)	80Ð120	35Ð75	5Ð30	0.5Ð2
Sensory receptors	Proprioceptors of skeletal muscle	Mechanoreceptors of skin	Pain, temperature	Temperature, pain, itch

Proprioception

static and movement



Proprioception (body awareness)	Adaptation
Muscle spindles (muscle stretch)	Rapid
Golgi tendon organs (tendon stretch)	Rapid
Joint receptors (joint movement)	Rapid

Movements stretch the receptors to mechanically stimulate the dendrites within them to produce action potentials.

TABLE 3-1. CLASSIFICATION OF NERVE FIBERS

Sensory and Motor Fibers	Sensory Fibers	Largest Fiber Diameter (μm)	Fastest Conduction Velocity (m/s)	General Comments	
Aα		22	120	Motor	Axons of alpha motoneurons of lamina IX, innervating extrafusal muscle fibers
Aα	Ia	22	120	Sensory	Primary afferents of muscle spindles
Aα	Ib	22	120	Sensory	Afferents of Golgi tendon organs, touch and pressure receptors
Aβ		13	70	Motor	Motor axons innervating both extrafusal and intrafusal (muscle spindle) muscle fibers
Aβ	II	13	70	Sensory	Secondary afferents of muscle spindles, touch and pressure receptors, and Pacinian corpuscles (vibratory sensors)
Aγ		8	40	Motor	Axons of gamma motoneurons of lamina IX, innervating intrafusal fibers (muscle spindles)
Aδ	III	5	15	Sensory	Small, lightly myelinated fibers; touch, pressure, pain, and temperature receptors
B		3	14	Motor	Small, lightly myelinated preganglionic autonomic fibers
C		1	2	Motor	Postganglionic autonomic fibers (all are unmyelinated)
C	IV	1	2	Sensory	Unmyelinated pain and temperature fibers

Touch

- The Spinal cord Spinal segments (30)- spinal nerves within 4 divisions of spinal cord Divisions
  - Cervical (C)
  - Thoracic (T)
  - Lumbar (L)
  - Sacral (S)

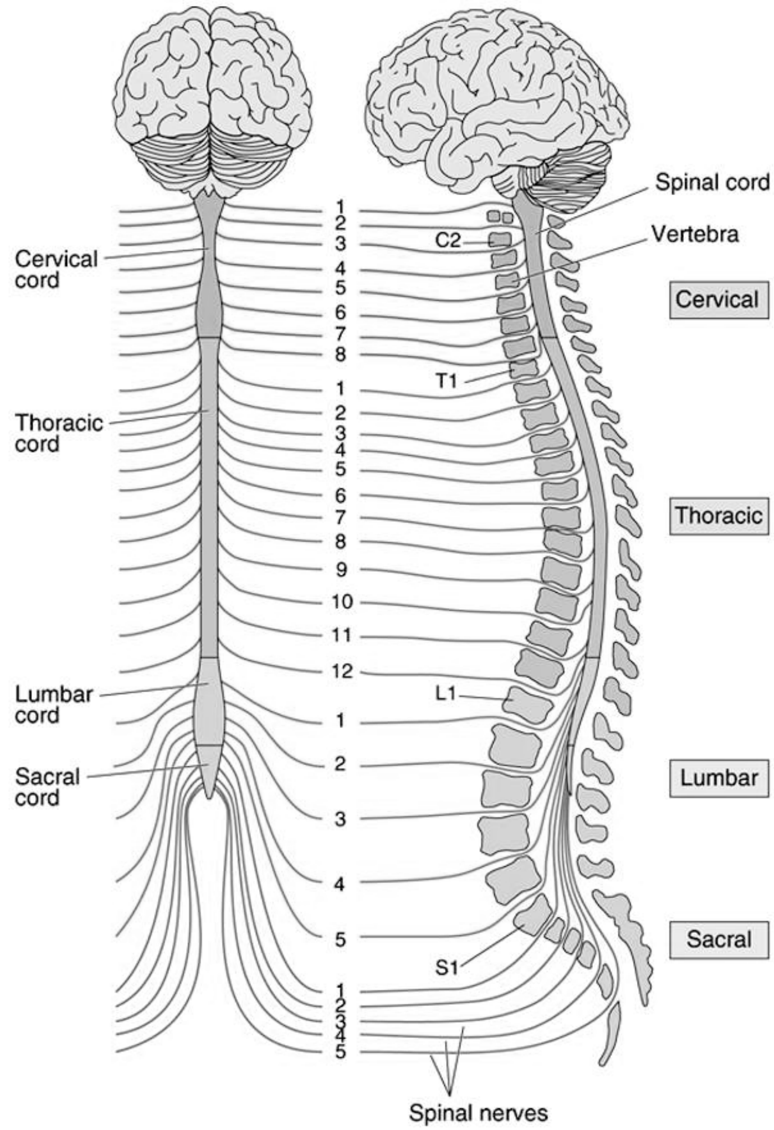


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Figure 12.11
Dermatomes. This map shows the approximate boundaries of the dermatomes.

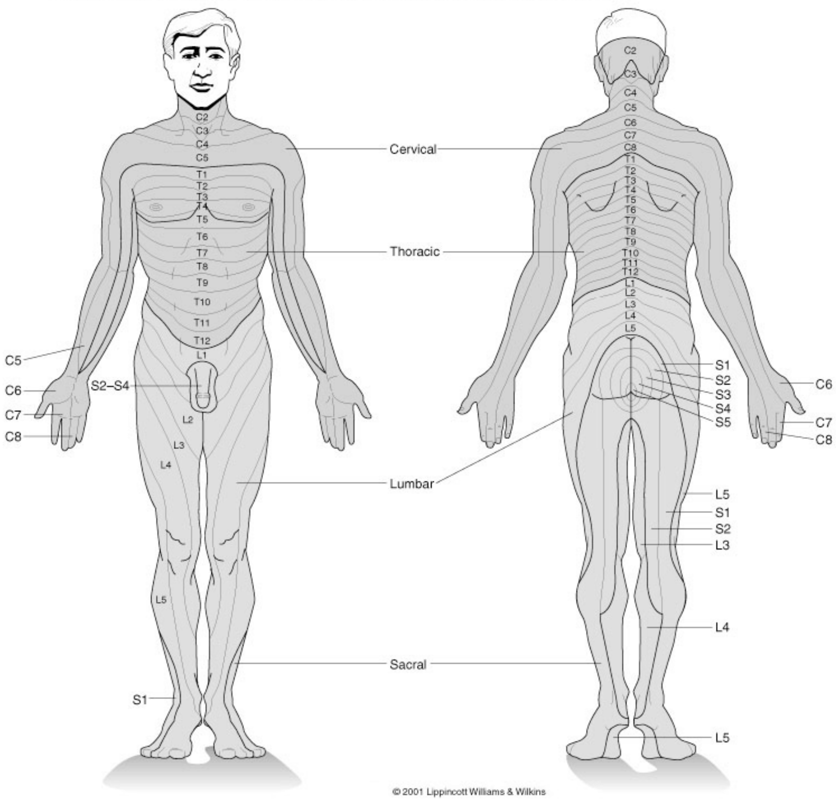
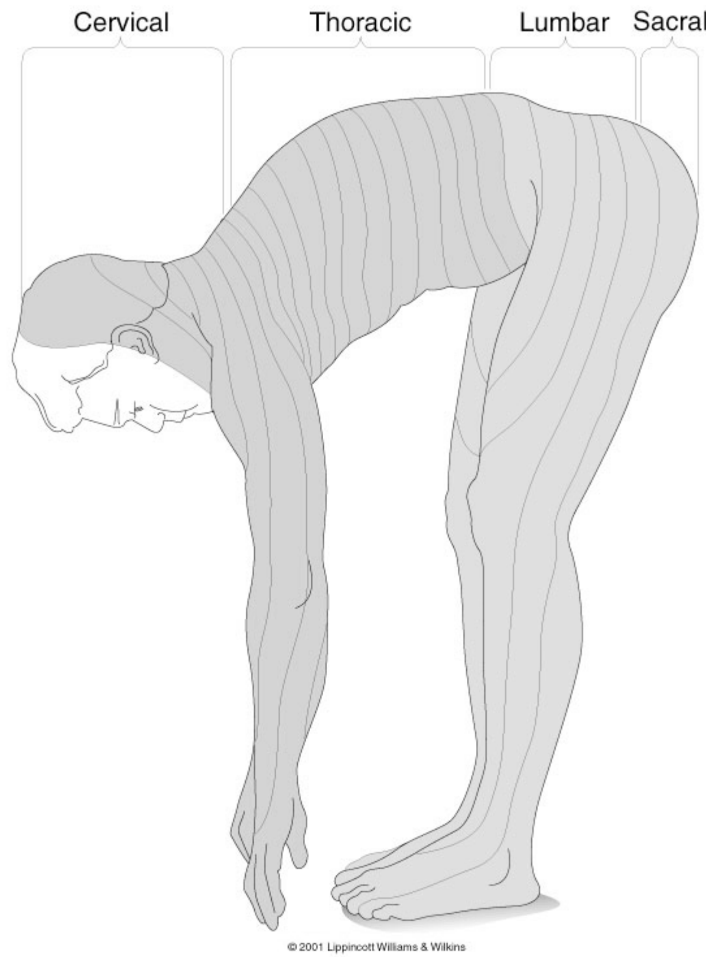


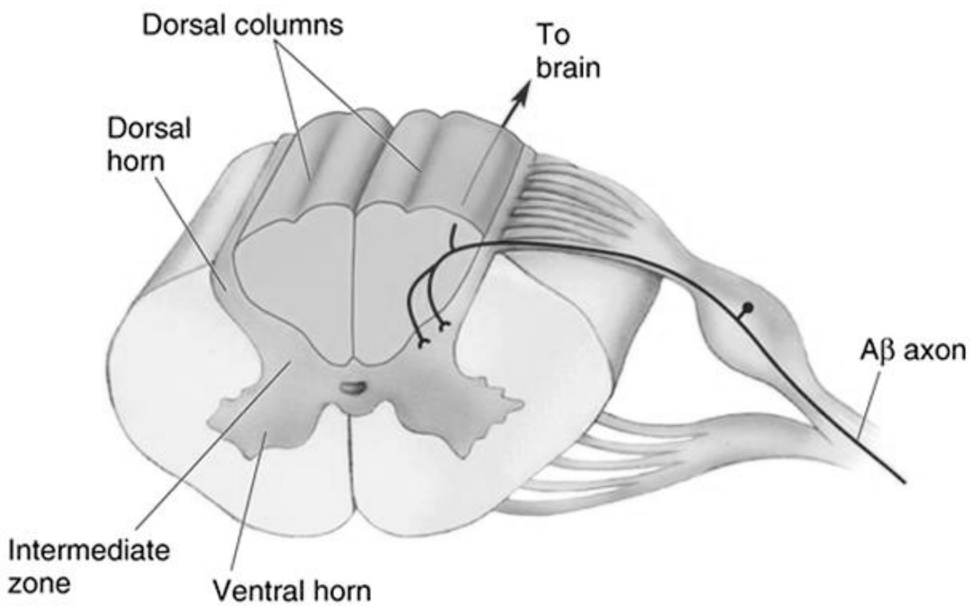
Figure 12.12
Dermatomes on all fours.



Dermatomes – skin innervation from single nerve
1-to-1 correspondence with segments
Shingles

- Spinal cord Sensory Organization of the spinal cord
  - Division of spinal gray matter:
  - Dorsal horn (sensory)
  - Intermediate zone (variable, Substance P)
  - Ventral horn (motor)

    – Sensory Myelinated Aβ axons (touch-sensitive)



- Dorsal Column–Medial Lemniscal Pathway

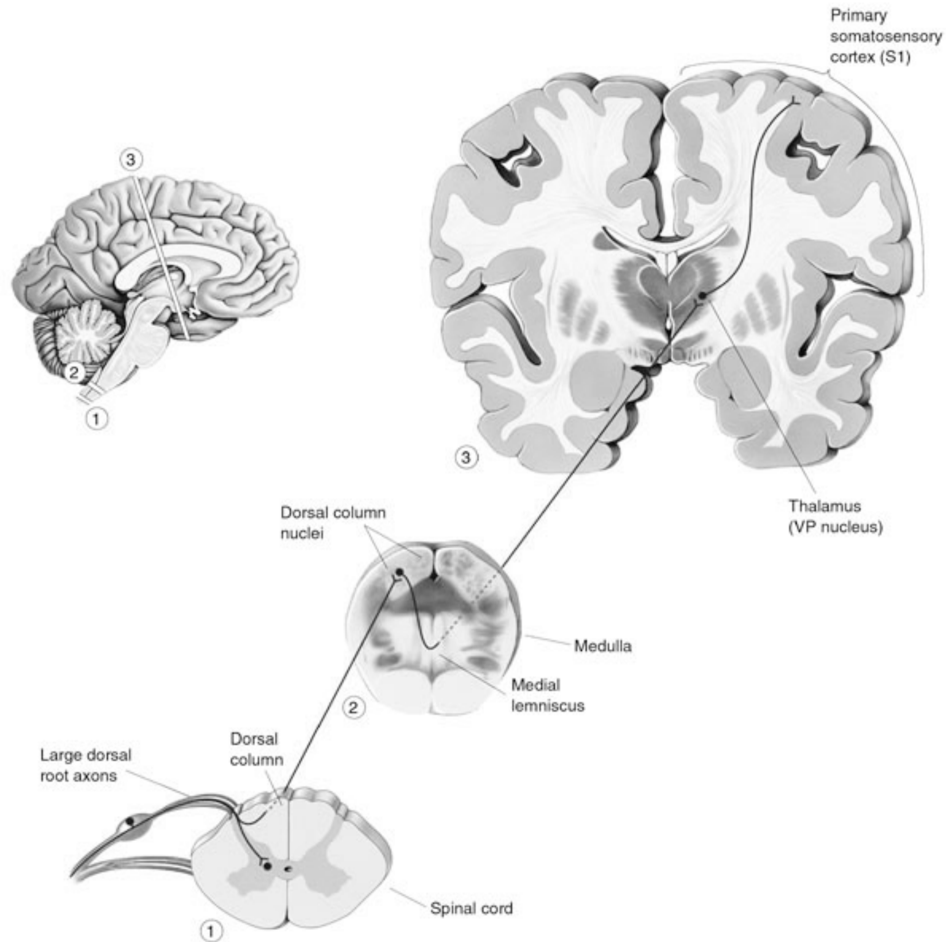
  Touch

  – ascends through dorsal column to dorsal nuclei medial lemniscus (wander – through brain stem)

  – to ventral posterior nucleus

  – to primary somatosensory cortex

Figure 12.14
The dorsal column-medial lemniscal pathway. This is the major route by which touch and proprioceptive information ascends to the cerebral cortex.



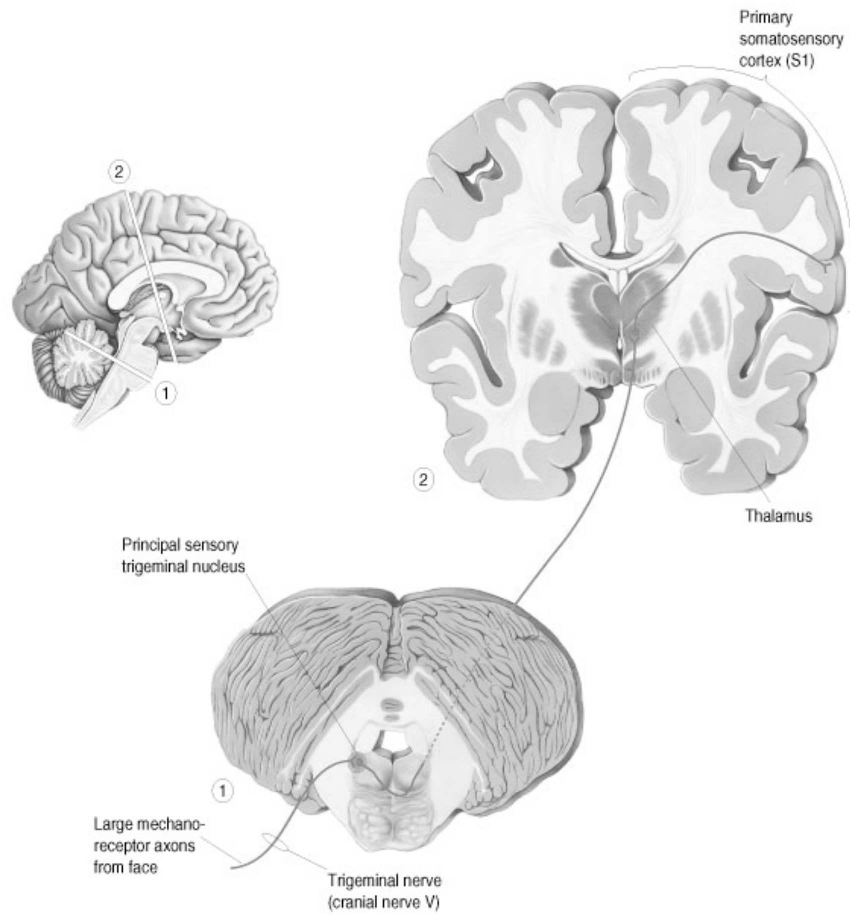
The Trigeminal Touch Pathway

Trigeminal nerves

CN V

also to VP

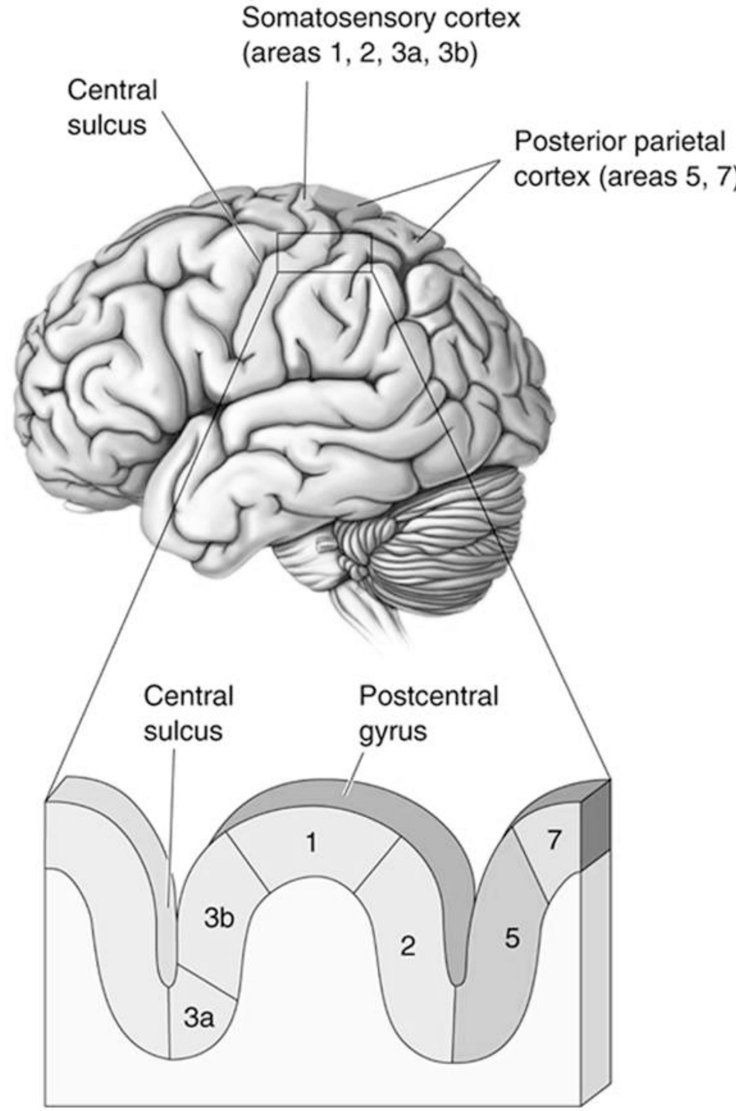
Figure 12.15
The trigeminal nerve pathway.



Touch

- Somatosensory Cortex
  - Primary SI (3b)

  - LAYER IV
  - Broadman's 1,2,3a, 3b
  - Other areas
    - Postcentral gyrus (1,2,3a)
    - Posterior Parietal (5,7)



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- Somatosensory Cortex (Cont'd)
  - Brodmann's Area 3b (or S1): Primary somatosensory cortex
    - Receives dense input from VP nucleus of the thalamus
    - Neurons: Responsive to stimuli
    - Lesions impair somatic sensations
    - Electrical stimulation evokes sensory experiences

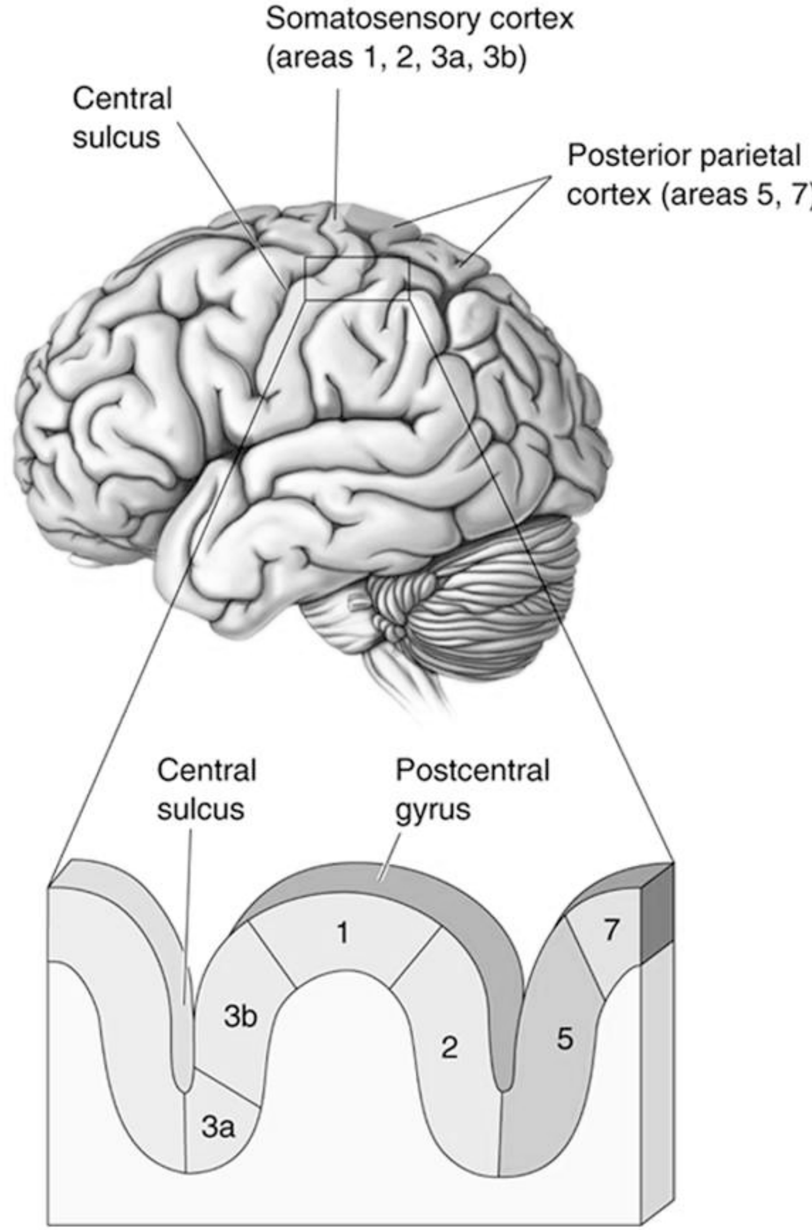
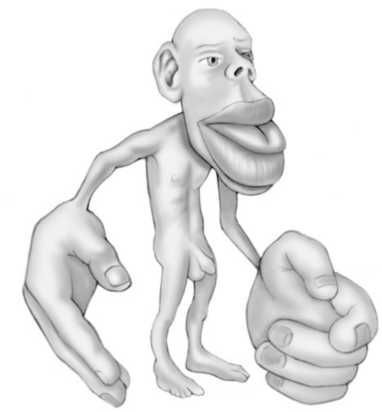
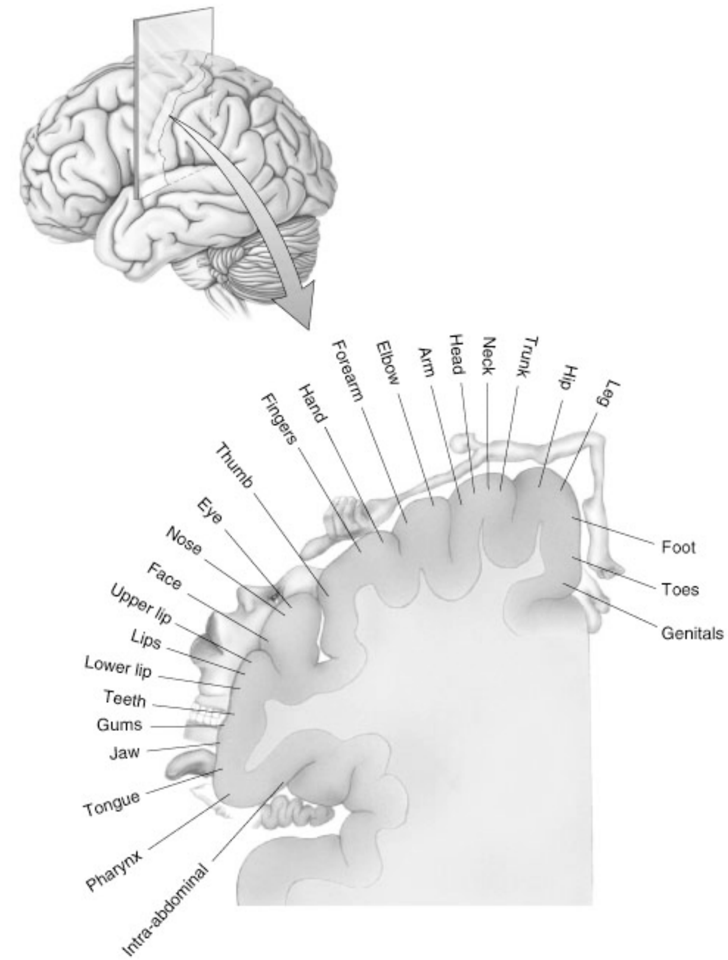


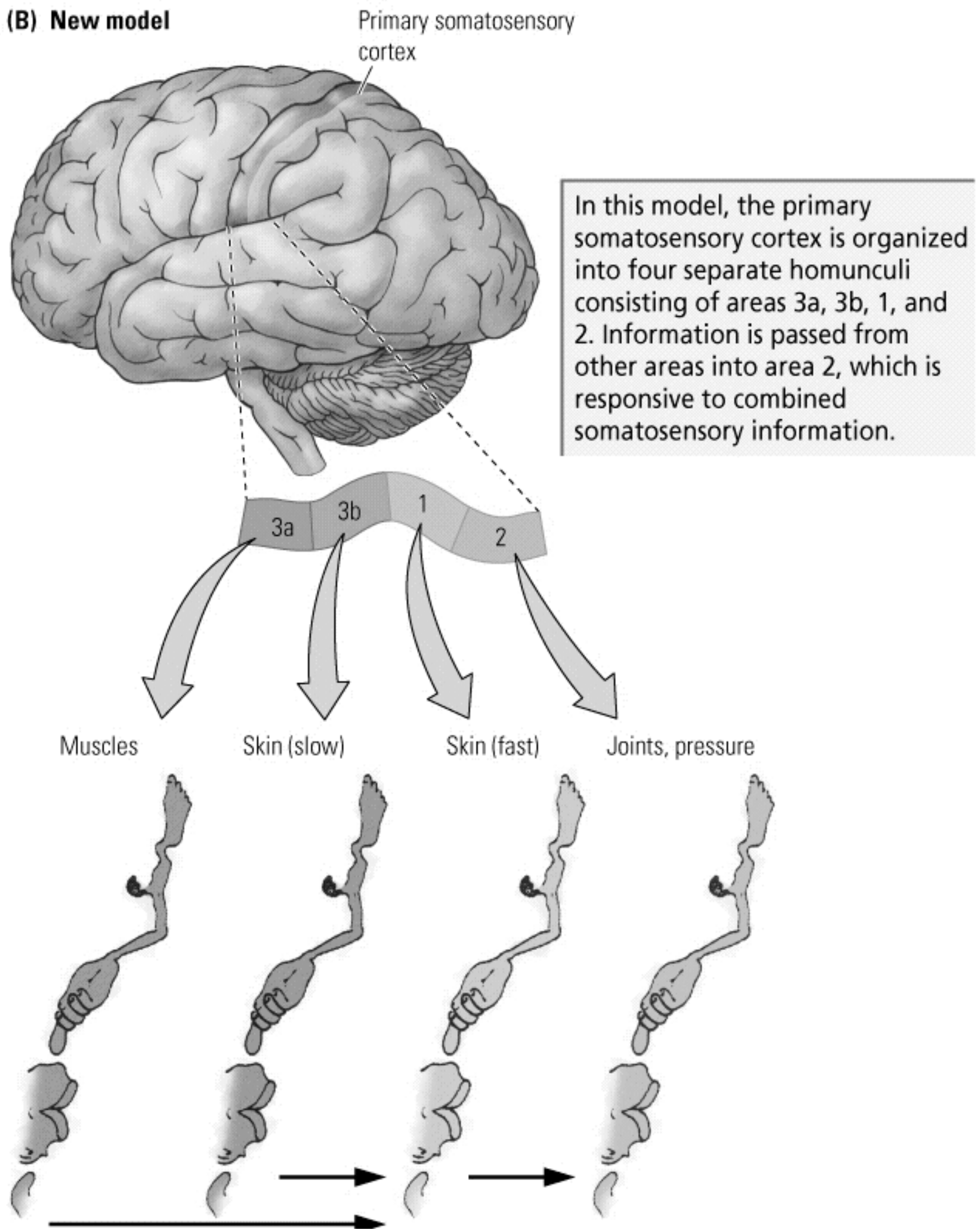
Figure 12.19
The homunculus.



- Somatosensory Cortex
  - Cortical Somatotopy
    - Homunculus
    - Importance of mouth
      - Tactile sensations: Important for speech
      - Lips and tongue: Last line of defense
    - IMPORTANT, so large
    - Or large, so important?

Figure 12.18
A somatotopic map of the body surface onto primary somatosensory cortex. This map is a cross section through the postcentral gyrus (shown at top). Neurons in each area are most responsive to the parts of the body illustrated above them. (Source: Adapted from Penfield and Rasmussen, 1952.)

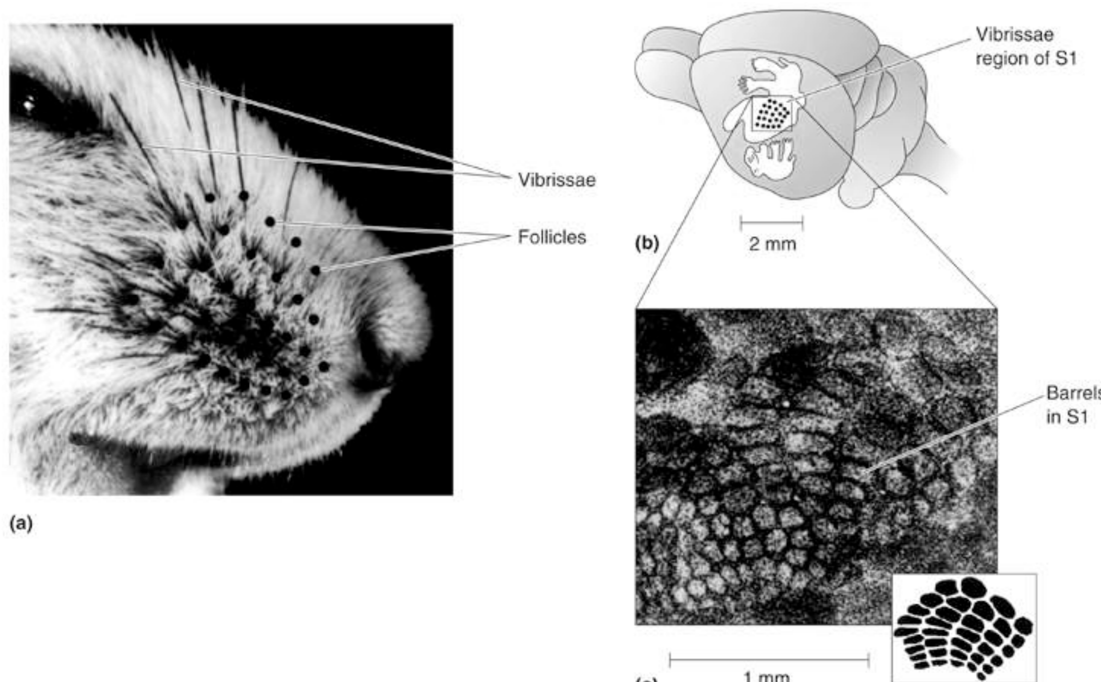




- -Why? –
  - –Sometimes we need to keep sensations separate
  - –(what is coming from within vs. environment).

Touch

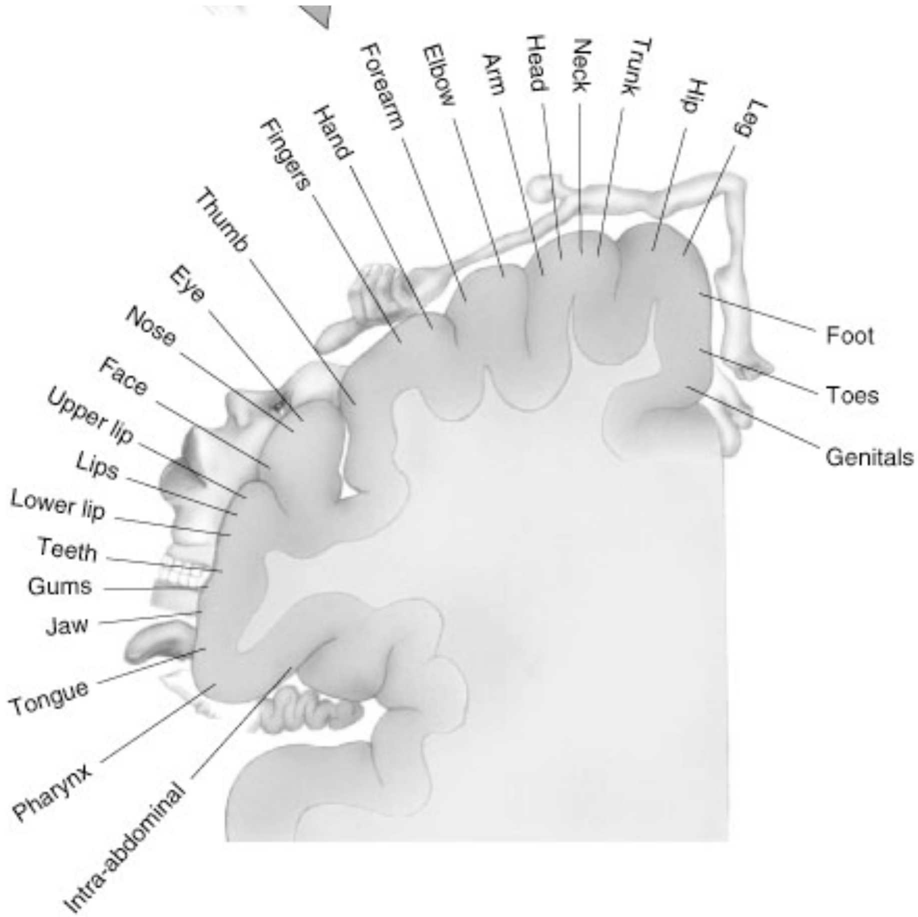
- Somatosensory Cortex (Cont'd)
  – S1: Rat
    - Vibrissae
    - "Barrel cortex"



Touch

- Somatosensory Cortex (Cont’d)
  - Cortical Map Plasticity
  - Remove digits or overstimulate – examine somatotopy before and after
    - Conclusions of experiments
      - Reorganization of cortical maps
        - » Dynamic
        - » Adjust depending on the amount of sensory experience

PHANTOM LIMB –borders? Ramachandran box 12.3



Touch

- The Posterior Parietal Cortex
    - Involved in somatic sensation, visual stimuli, and movement planning BINDING
    - Agnosia (no sensing)
    - Astereoagnosia (touching does not work)
    - Neglect syndrome (damage to right - contralateral)

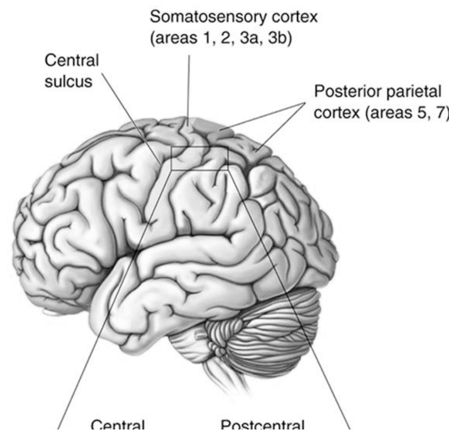
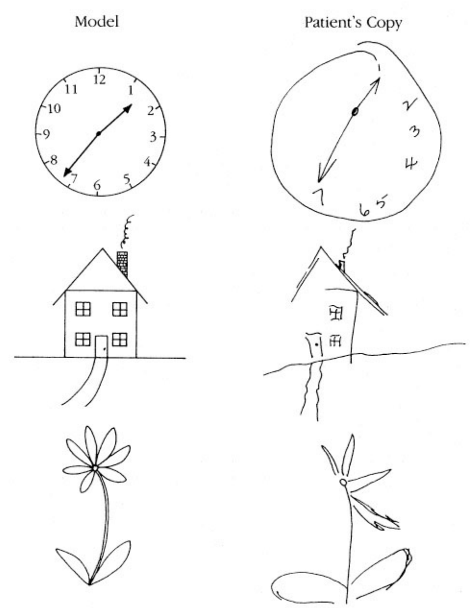


Figure 12.23
An example of a neglect syndrome. A patient who had had a stroke in the posterior parietal cortex was asked to copy the model drawing but was unable to reproduce many of the features on the left side of the model.
(Source: Springer and Deutsch, 1989, p. 193.)



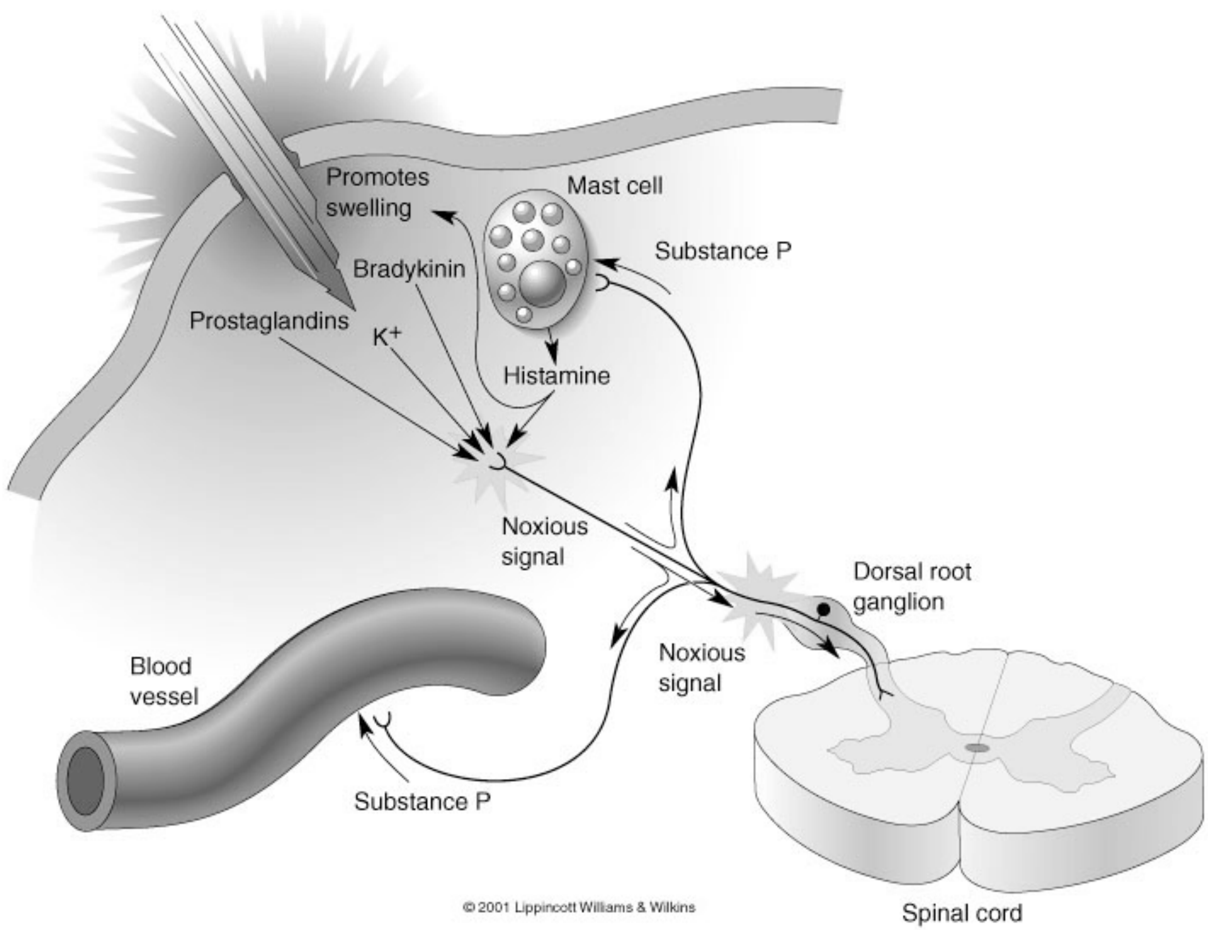
Hemispatial neglect

Pain

- Nociceptors free, branching
- Pain and nociception
  - Pain - <u>feeling</u> of sore, aching, throbbing
  - Nociception - sensory <u>process</u>, provides signals that trigger pain

Nociceptors: Transduction of Pain
Bradykinin (peptide formed following damage)
Lactic acid (H+ - activate channels)??
Mast cell activation: Release of histamine

Figure 12.24
Peripheral chemical mediators of pain and hyperalgesia.



– Types of Nociceptors:

- Polymodal nocireceptors
- Mechanical nocireceptors
- Thermal nocireceptors
- Chemical (smallest itch histamine)

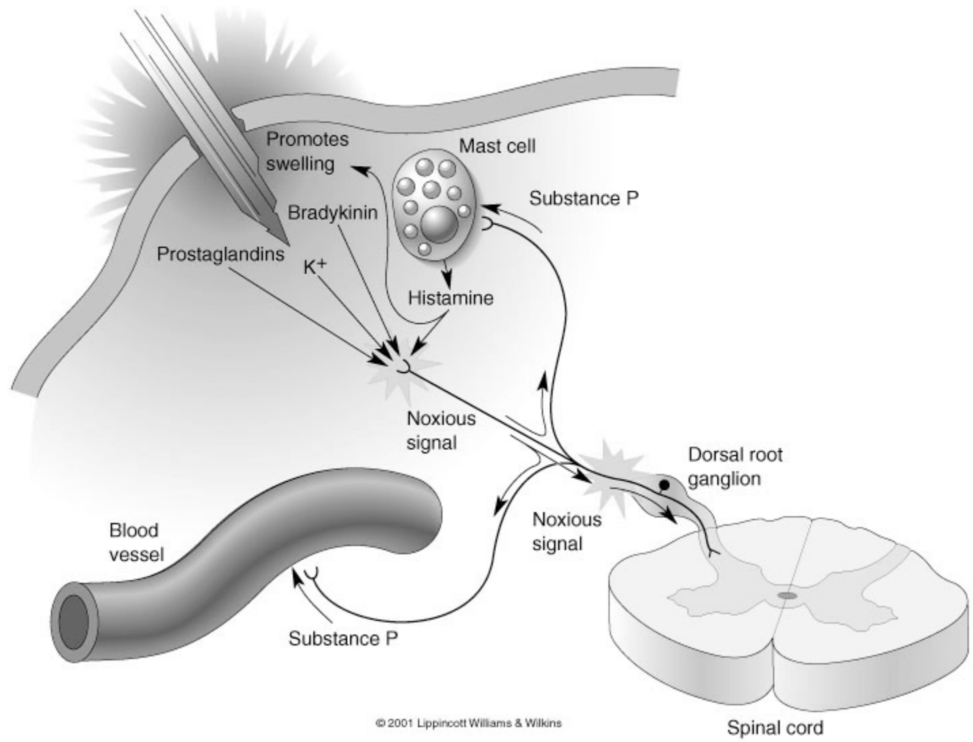
Red hot chili peppers

chemical (capsaicin) activates thermal receptors
(not in birds)
also following tissue damage (why injured skin sensitive to cold)

Hyperalgesia

- Primary and secondary hyperalgesia
- Bradykinin – also LONG lasting effects
- Prostaglandins – make receptors more sensitive
-

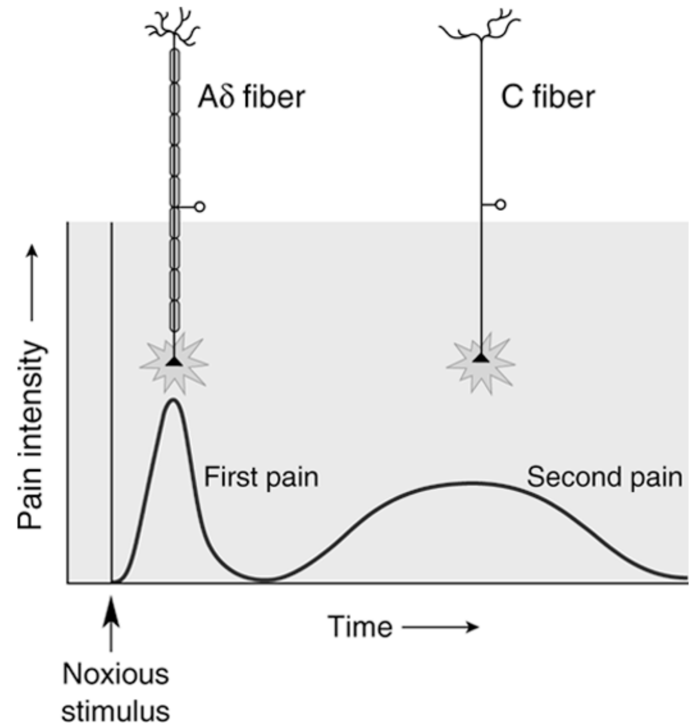
Figure 12.24
Peripheral chemical mediators of pain and hyperalgesia.



ALSO
– cells themselves up-regulate
  - substance P
– AXON BRANCHING!

Pain

- Primary Afferents and Spinal mechanisms
  - First pain and second pain
  - Referred pain: Angina
  - Mixed axons in spinal cord
  - Converge on same spinothalamic track cells



2 PAIN PATHWAYS:

FAST PAIN PATHWAY (warning)

- **few synapses (direct - free of emotion?)**
- **myelinated fibers (fast)**

does not last long

2) SLOW PAIN PATHWAY

- **more synapses (*indirect)***
- **unmyelinated fibers (slow)**
- **interacts with emotion pathways (limbic)**
- **involves prefrontal cortex**
- **lasts a long time**

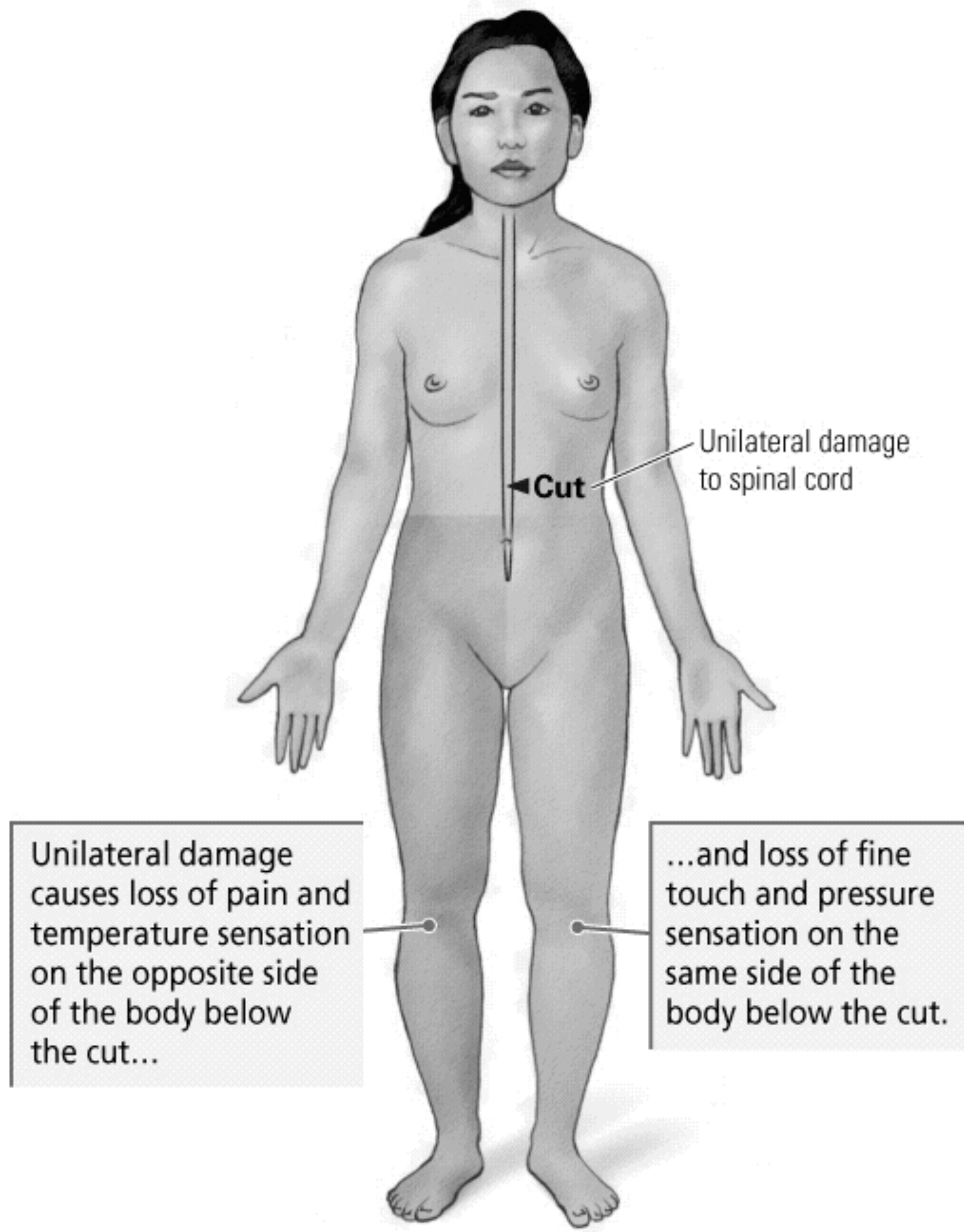
Pain

- Ascending Pain Pathways
  - Differences between touch and pain pathway
    - Nerve endings in the skin
    - Diameter of axons
    - Connections in spinal cord
      - Touch – Ascends Ipsilaterally
      - Pain – Ascends Contralaterally

TWO PATHWAYS

injury MIGHT
results in different losses

Brown-Séquard Syndrome

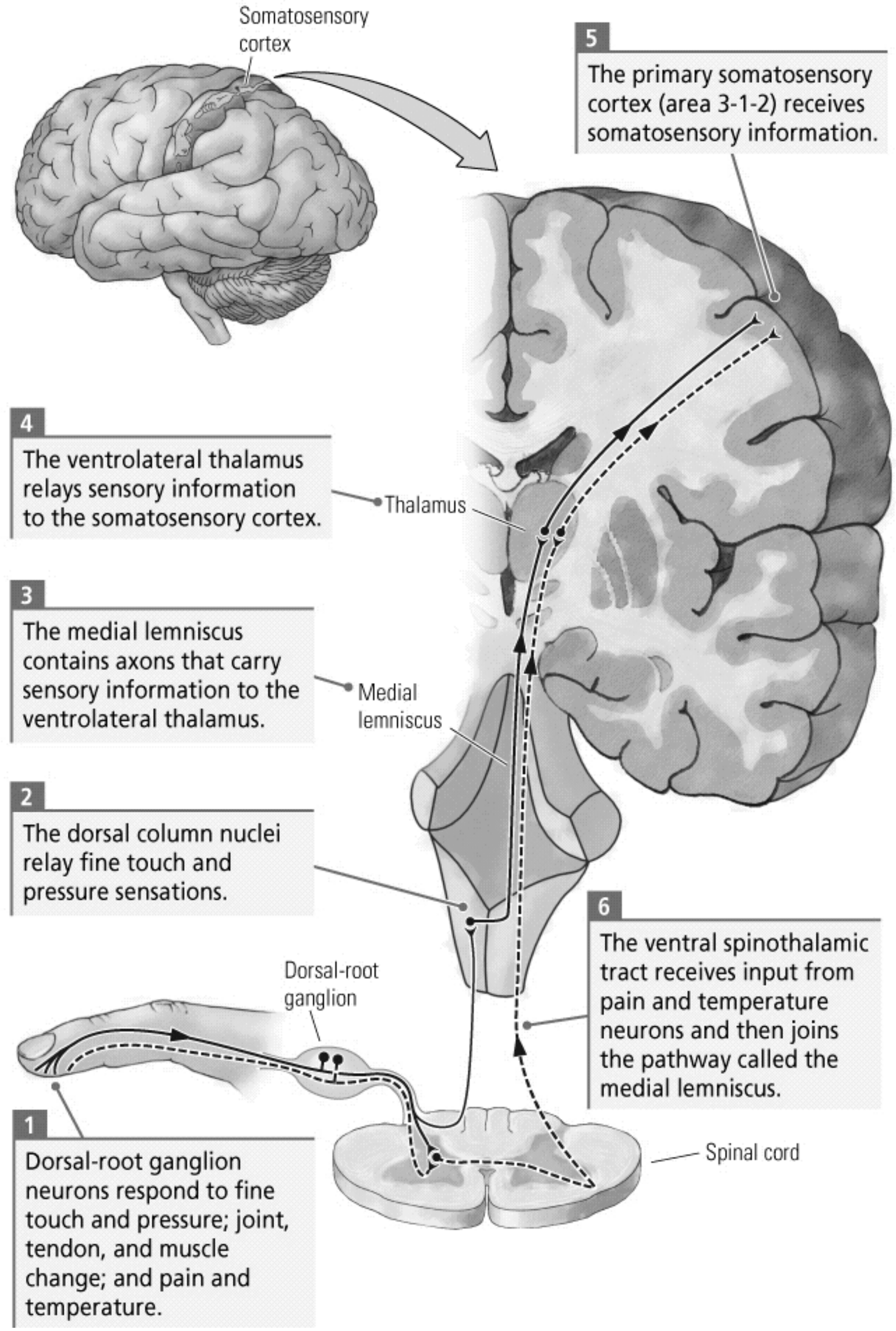


- Somatosensory Pathways

Two pathways to
 cortex
ARE A LITTLE BIT DIFFERENT

NOTE: VP sensory
VL motor

VP and VL
–deep
brain stimulation



Perception of pain
altered by attention and expectation
(placebos work)

- anxiety (Lamaze works)
- suggestibility

children and pain

infantile amnesia?

cortex not “hooked up” (myelinated)?

CANNABIS AND PAIN?

315 AD

CANNABINOID RECEPTORS – MOST PREVALENT
G PROTEIN RECEPTOR IN CNS!

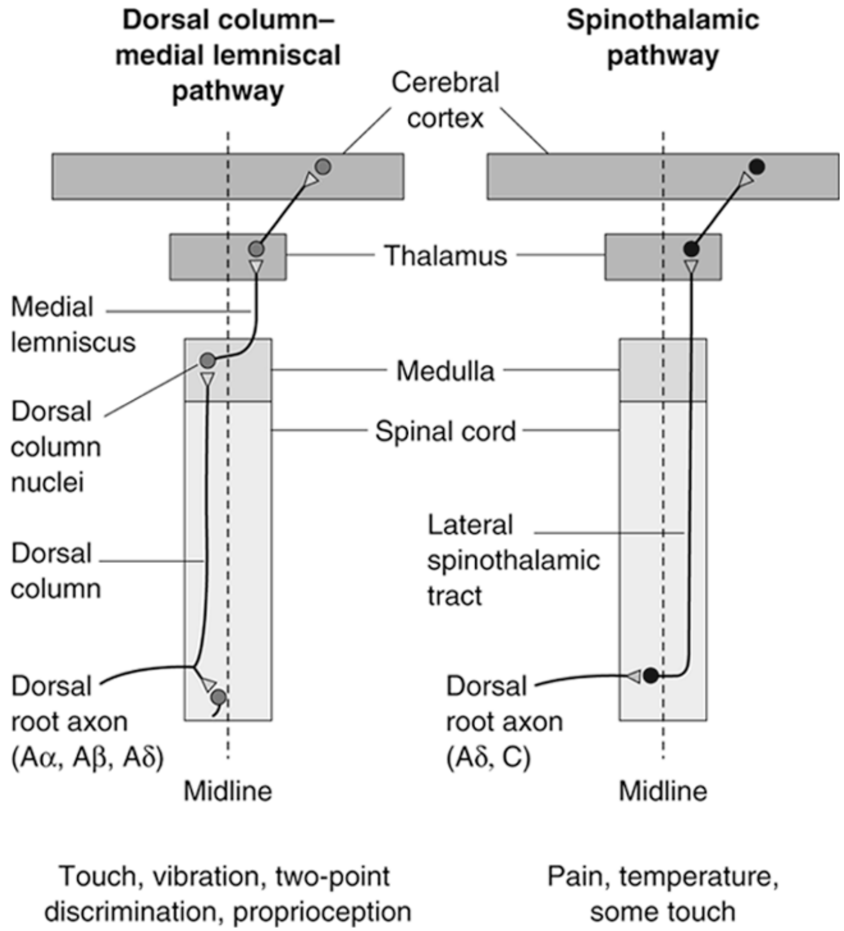
MEDULLA

SIDE EFFECTS INCLUDE MEMORY LOSS (surprise)

- Ascending Pain Pathways (Cont’d)
  - Spinothalamic Pain Pathway
    - Brown-Séquard Syndrome -
  - The Trigeminal Pain Pathway (different)
  - The Thalamus and the Cortex
    - Touch and pain systems remain segregated
    - Pain and temperature information sent to various cortical areas

Pain

- Ascending Pain Pathways (Cont'd)

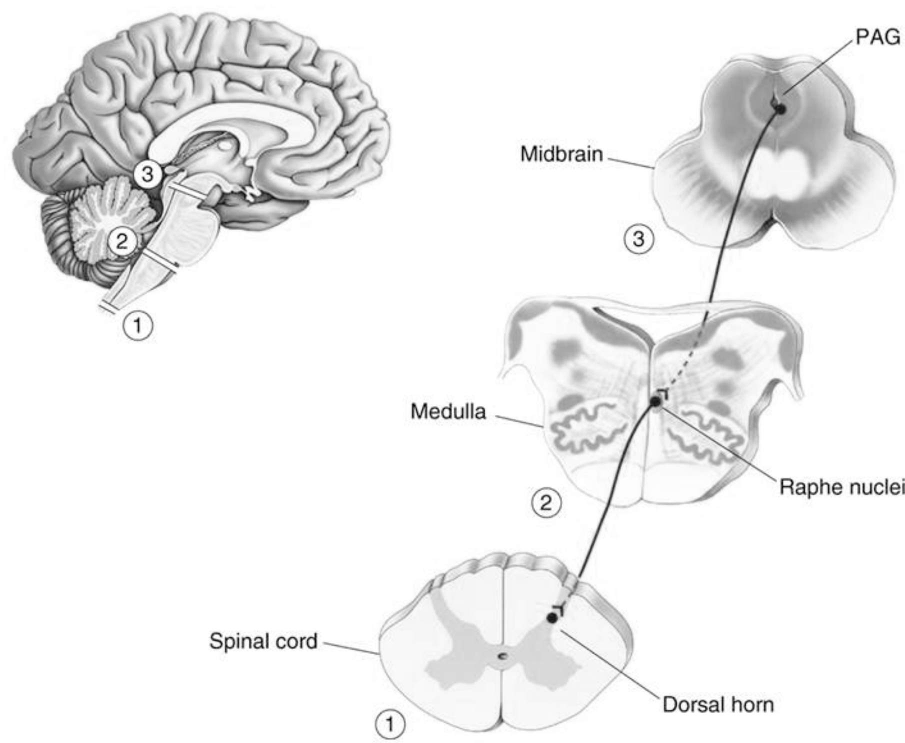


Pain

- The Regulation of Pain
  - Afferent Regulation (gate)
  - Descending Regulation (periaqueductal gray PAG)
  - The endogenous opiates
    - Opioids and endomorphins
    - PLACEBOS??? Acupuncture??
    - Naloxone (opioid antagonist) blocks placebo and acupuncture

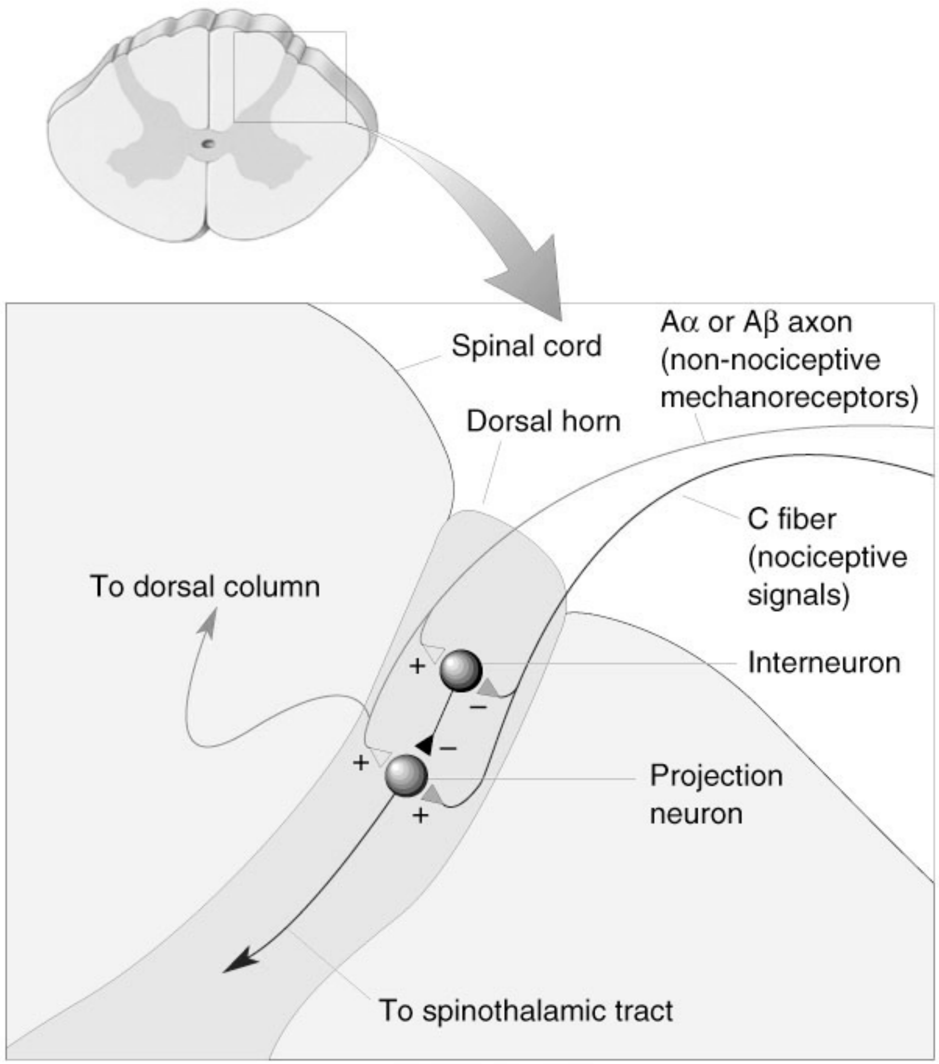
Pain

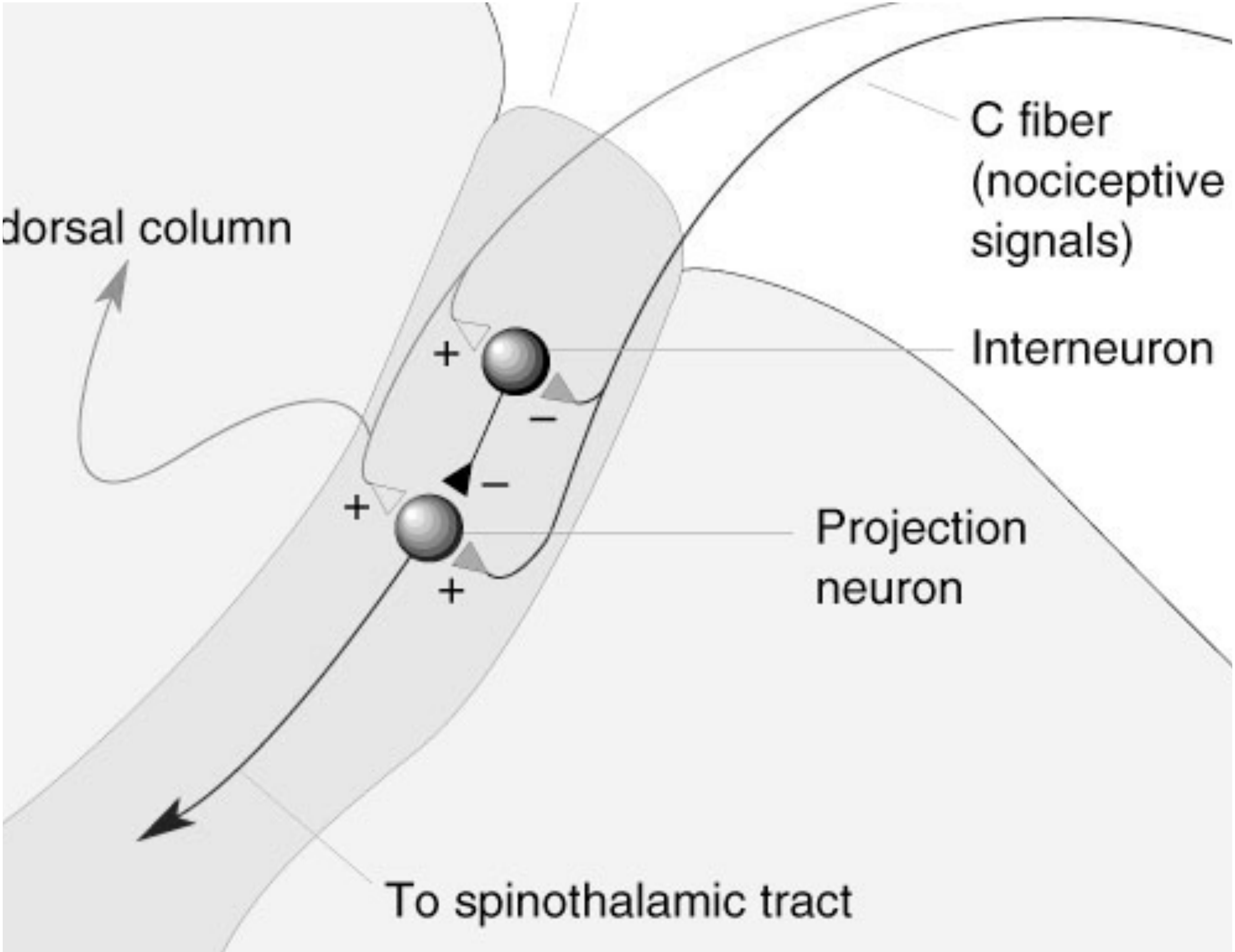
- The Regulation of Pain (Cont'd)
  - Descending regulation



Gate theory of pain

Figure 12.32
Melzack and Wall's gate theory of pain.



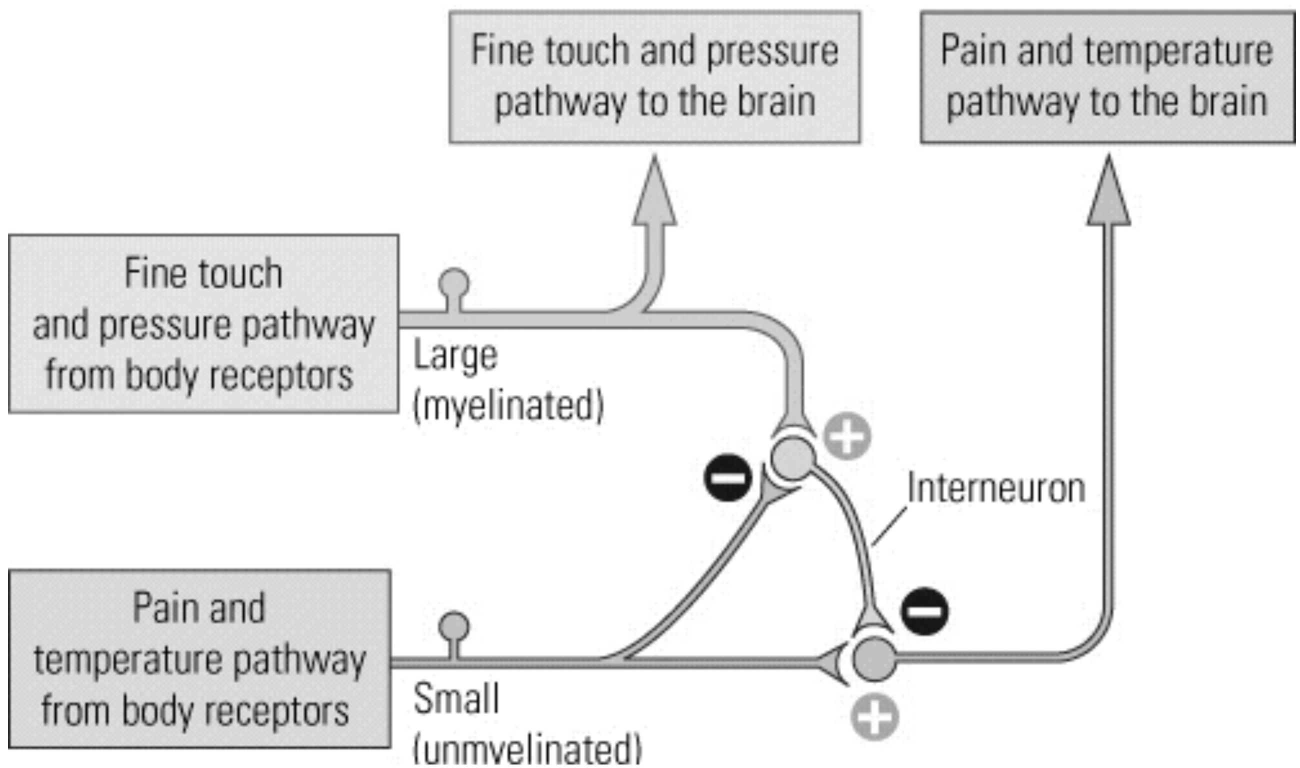

dorsal column
C fiber
(nociceptive
signals)
Interneuron
Projection
neuron
To spinothalamic tract
+
–
–
+
+

spinal cord interaction can be complex
pain is especially
puzzling

The gate theory for pain

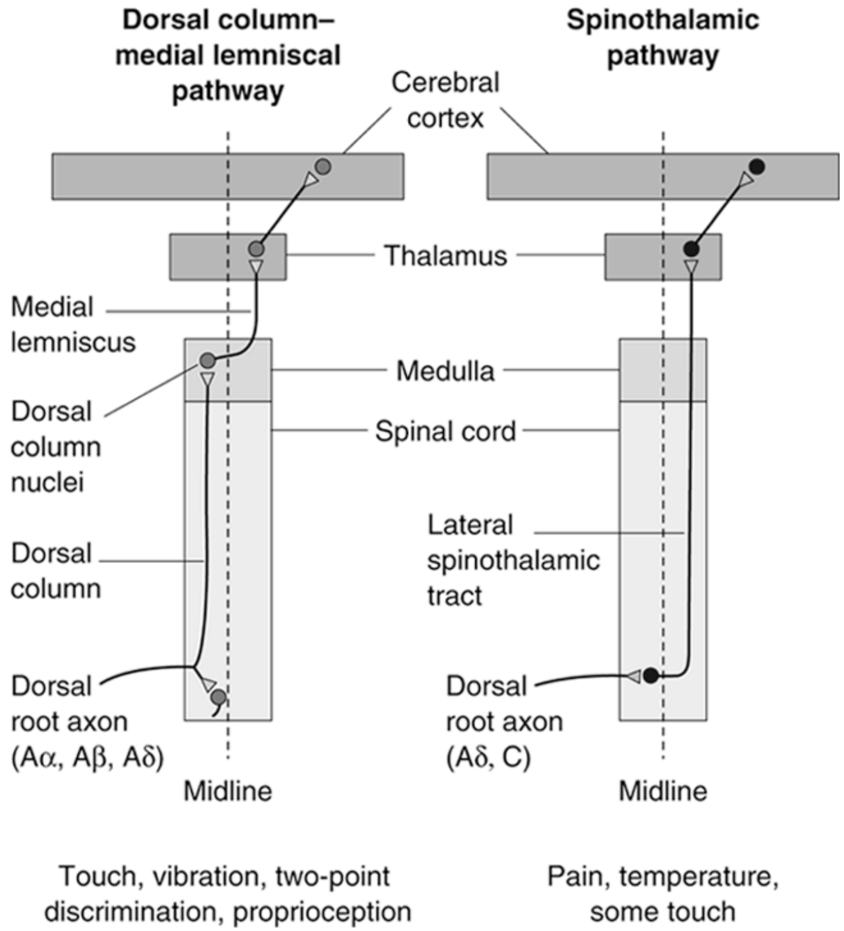
all lessen pain:

morphine
acupuncture
rubbing



Pain

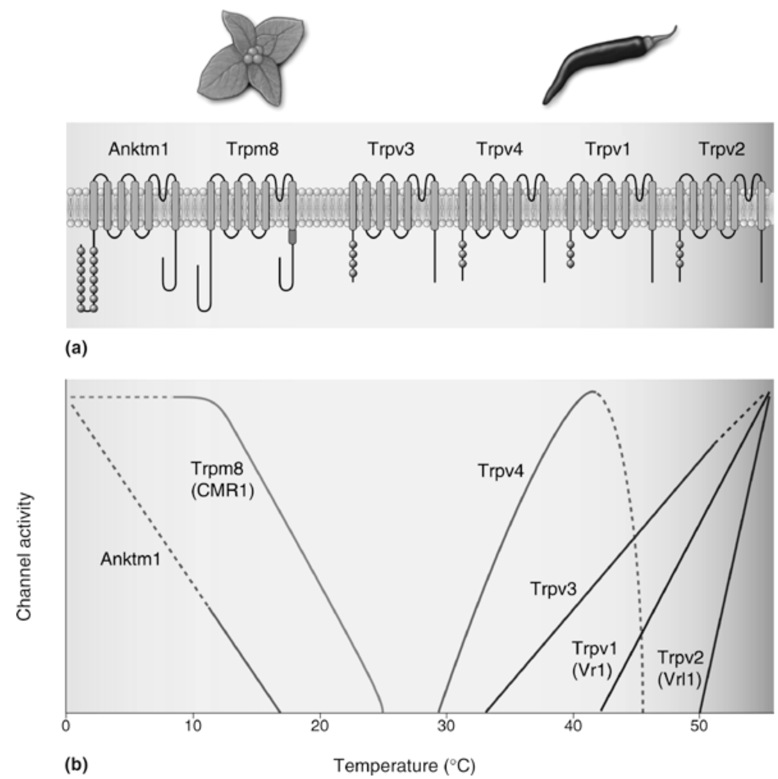
- Ascending Pain Pathways (Cont'd)



Temperature

- Thermoreceptors
  - "Hot" and "cold" receptors (mint)
  - Varying sensitivities

IMPT – remember bio labs?



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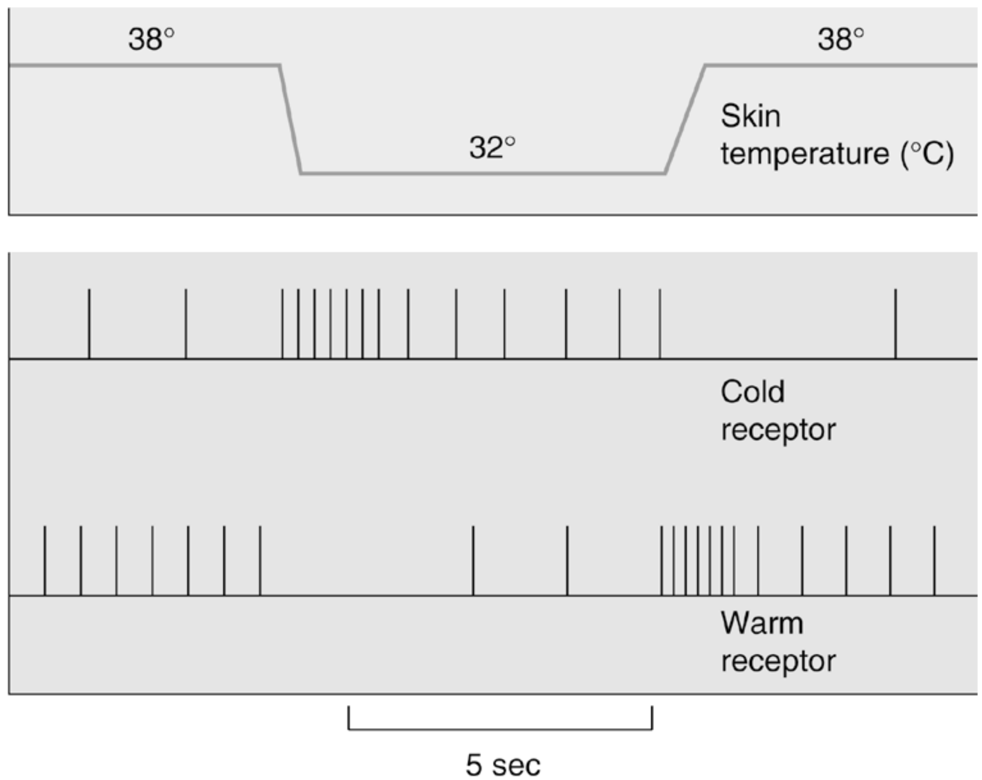
Temperature

- Thermoreceptors
  - Hot and cold receptors



Temperature

- The Temperature Pathway
  - Organization of temperature pathway
    - Identical to pain pathway
  - Cold receptors coupled to Aδ and C
  - Hot receptors coupled to C

- Somatotopy

……topy

- Retinotopy
- Tonotopy

Stimulate PAG?

Kill off substance P neurons ?

- Sensory systems exhibit similar organization and function

- Sensory types are segregated within the spinal cord and cerebral cortex

- Repeated theme
  - Parallel processing of information

- Perception of object involves the
- coordination of somatic sensory information “binding”