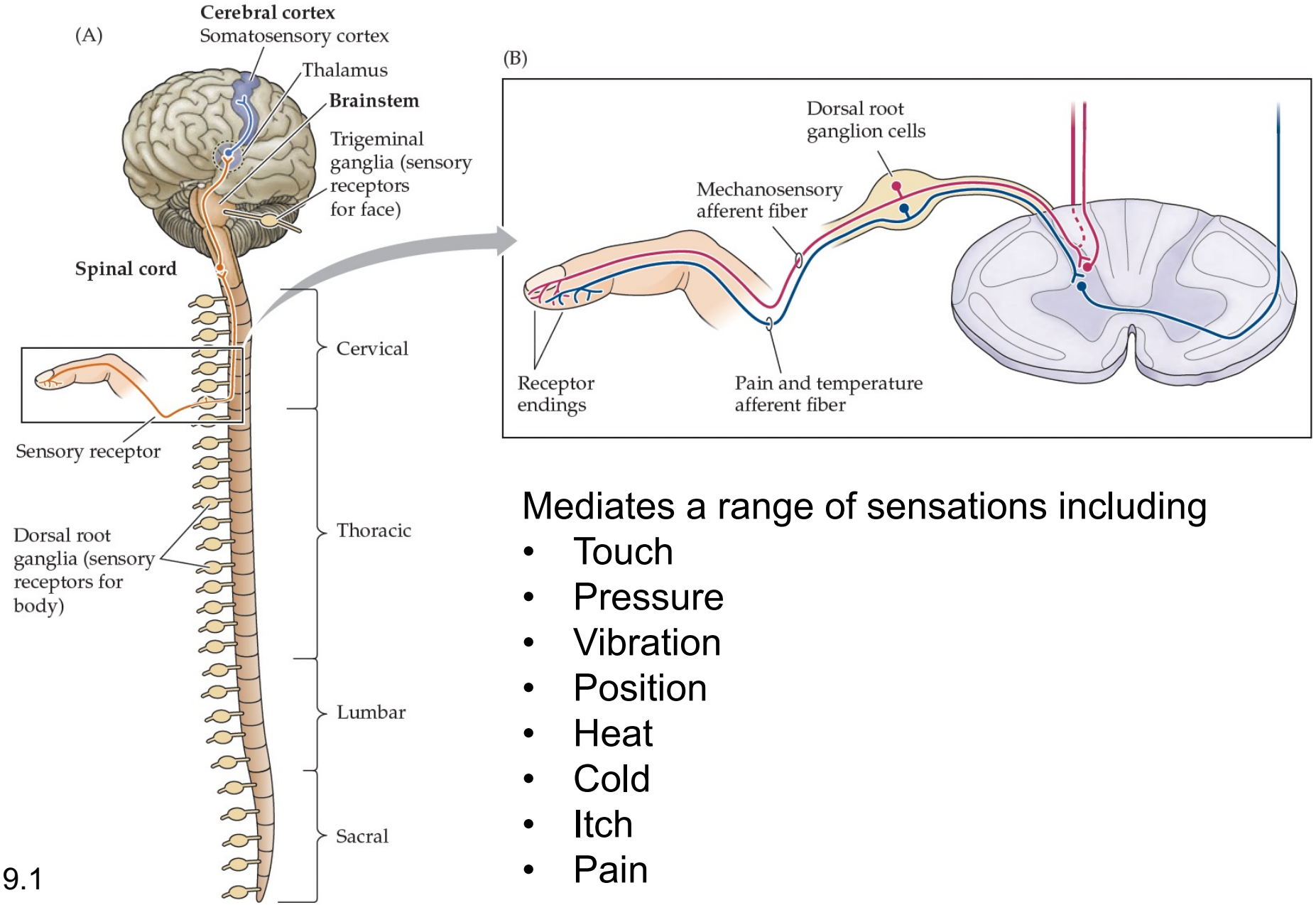
Sensory systems: somatosensation (touch)

Prof. Pavan Ramdya

Reading: ***Purves* Chapter 9** (pp 193 – 211)

Image credit

What is the somatosensory system?

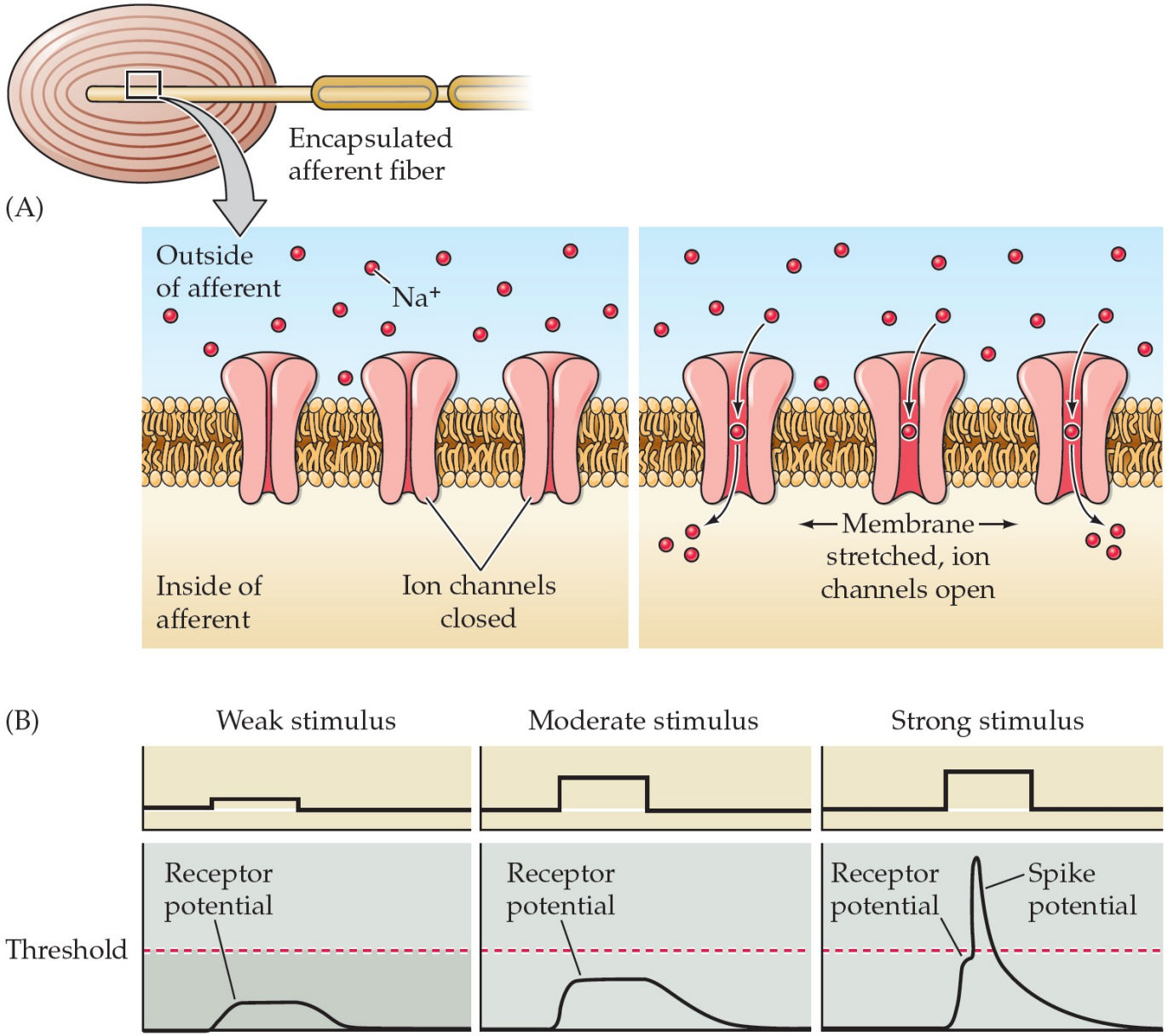


Mediates a range of sensations including

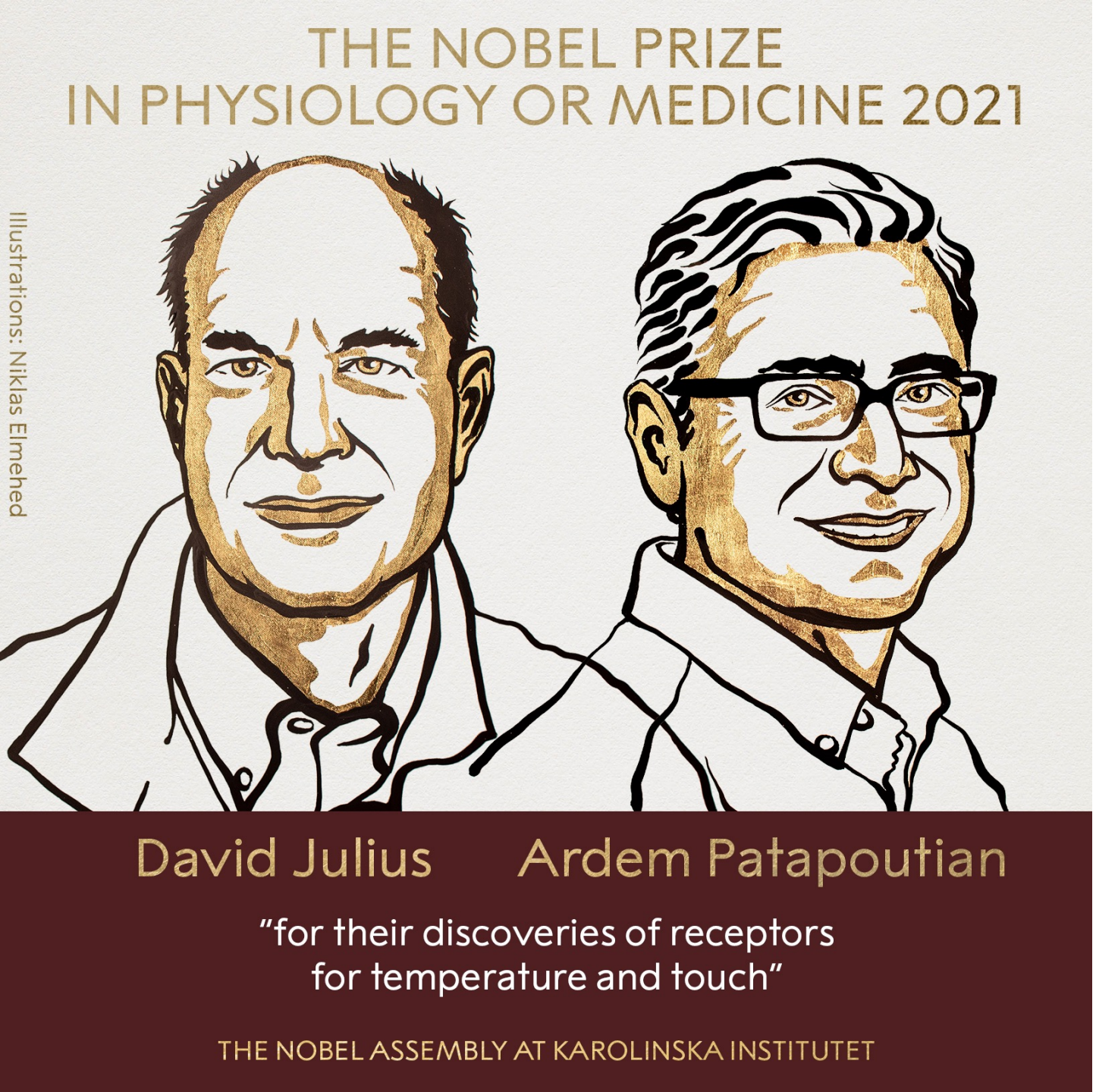
- Touch
- Pressure
- Vibration
- Position
- Heat
- Cold
- Itch
- Pain

Purves, Figure 9.1

Sensory transduction is mediated by mechanoreceptors



Purves, Figure 9.2



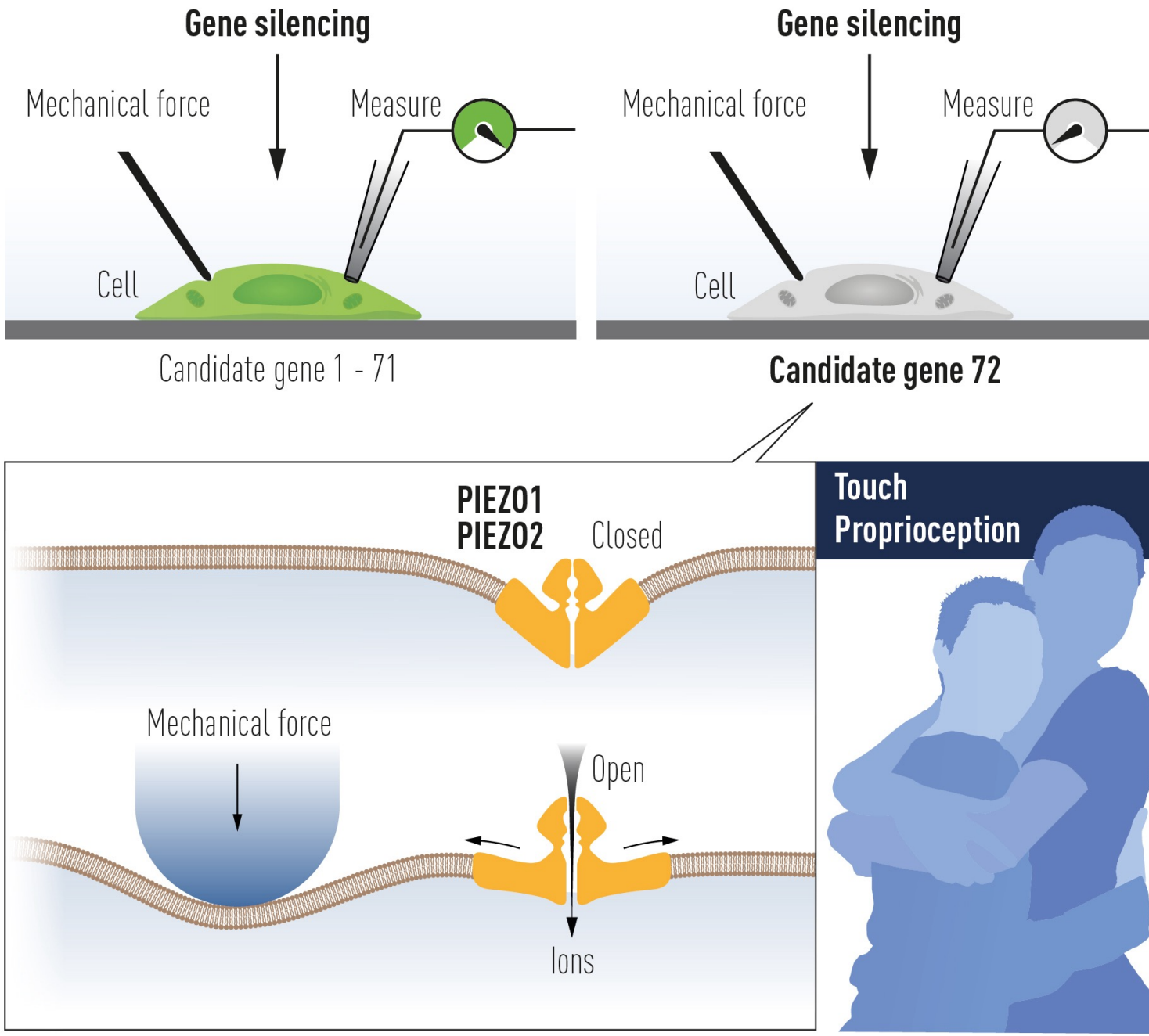
David Julius used capsaicin, the compound in chili pepper that elicits the sensation of heat, to identify the ion channel, **TRV1**, the first temperature sensor.

Ardem Patapoutian discovered a family of pressure-sensitive **PIEZO** ion channels**.**

Science. 2010 Oct 1;330(6000):55-60. doi: 10.1126/science.1193270. Epub 2010 Sep 2.

Piezo1 and Piezo2 are essential components of distinct mechanically activated cation channels

Bertrand Coste [1], Jayanti Mathur, Manuela Schmidt, Taryn J Earley, Sanjeev Ranade, Matt J Petrus, Adrienne E Dubin, Ardem Patapoutian



Different receptors have different sensory functions

TABLE 9.1 ■ Somatosensory Afferents That Link Receptors to the Central Nervous System

Sensory function	Receptor type	Afferent axon type[a]	Axon diameter	Conduction velocity
Proprioception	Muscle spindle	Ia, II	13–20 μm	80–120 m/s
Touch	Merkel, Meissner, Pacinian, and Ruffini cells	Aβ	6–12 μm	35–75 m/s
Pain, temperature	Free nerve endings	Aδ	1–5 μm	5–30 m/s
Pain, temperature, itch, non-discriminative touch	Free nerve endings (unmyelinated)	C	0.2–1.5 μm	0.5–2 m/s

[a] During the 1920s and 1930s, there was a virtual cottage industry classifying axons according to their conduction velocity. Three main categories were discerned, called A, B, and C. A comprises the largest and fastest axons, C the smallest and slowest. Mechanoreceptor axons generally fall into category A. The A group is further broken down into subgroups designated α (the fastest), β, and δ (the slowest). To make matters even more confusing, muscle afferent axons are usually classified into four additional groups—I (the fastest), II, III, and IV (the slowest)—with subgroups designated by lowercase roman letters! (After Rosenzweig et al., 2005.)

Purves, Table 9.1

What are somatosensory neurons sensitive to?

Receptive fields

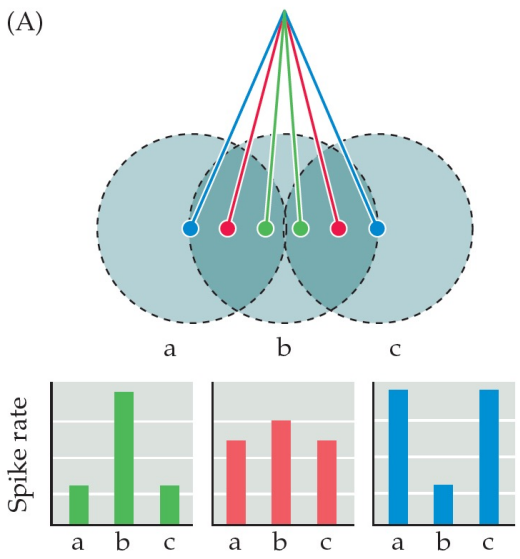
Receptive field: The "part" of the outer world to which a given sensory neuron is most responsive. This can be determined in functional mapping experiments

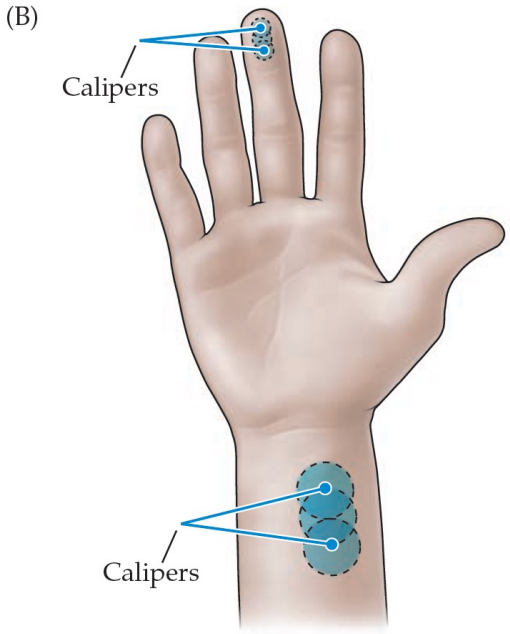
Audition: The sound frequency to which a neurons responds most strongly.
"tonotopic map“

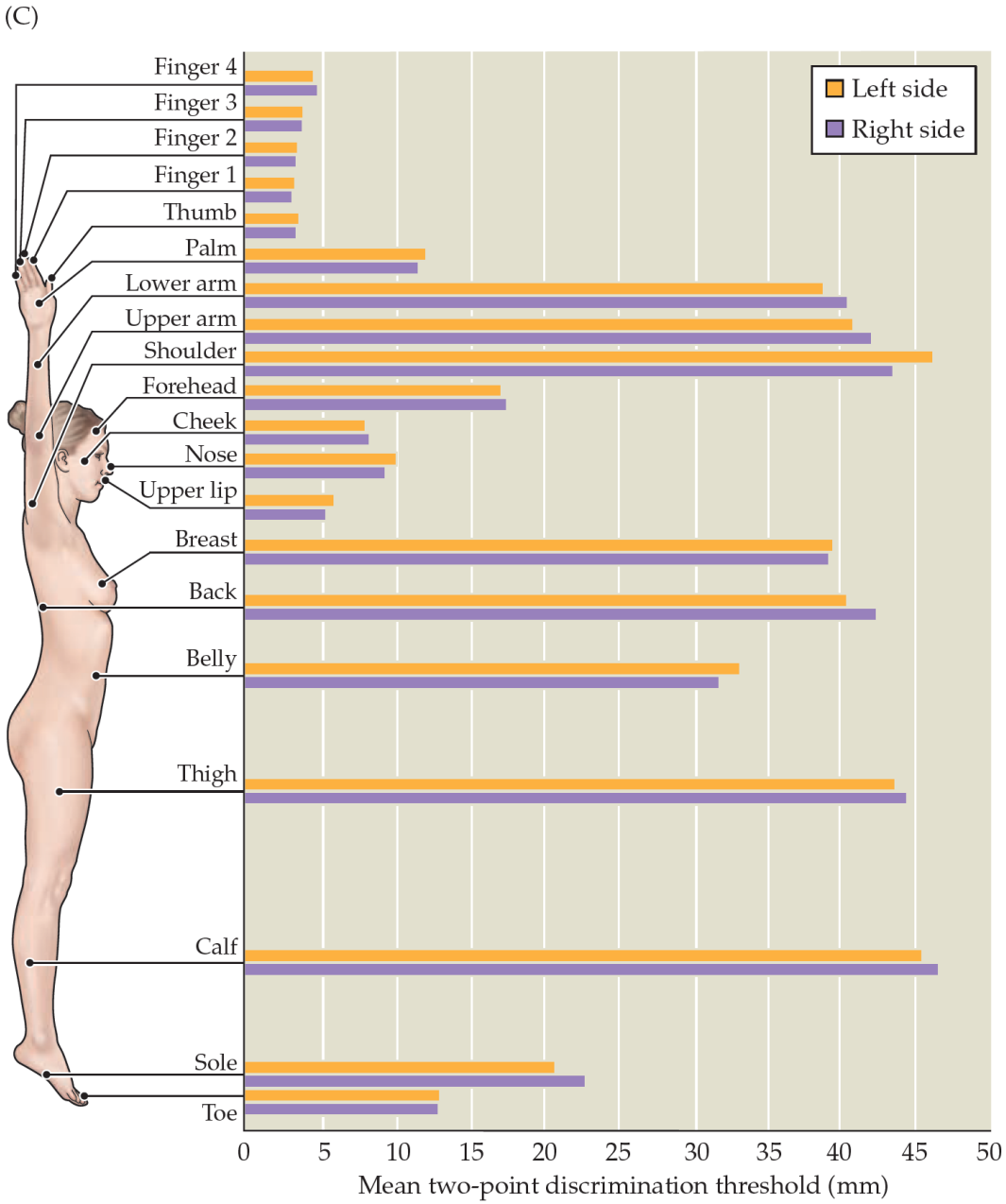
Somatosensation: The part of the body which, when touched, drives a sensory neuron most strongly.
"somatotopic map"

Vision: The area of the visual field which drives a visual system neuron most strongly.
"retinotopic map"

Receptive fields and the two-point discrimination threshold

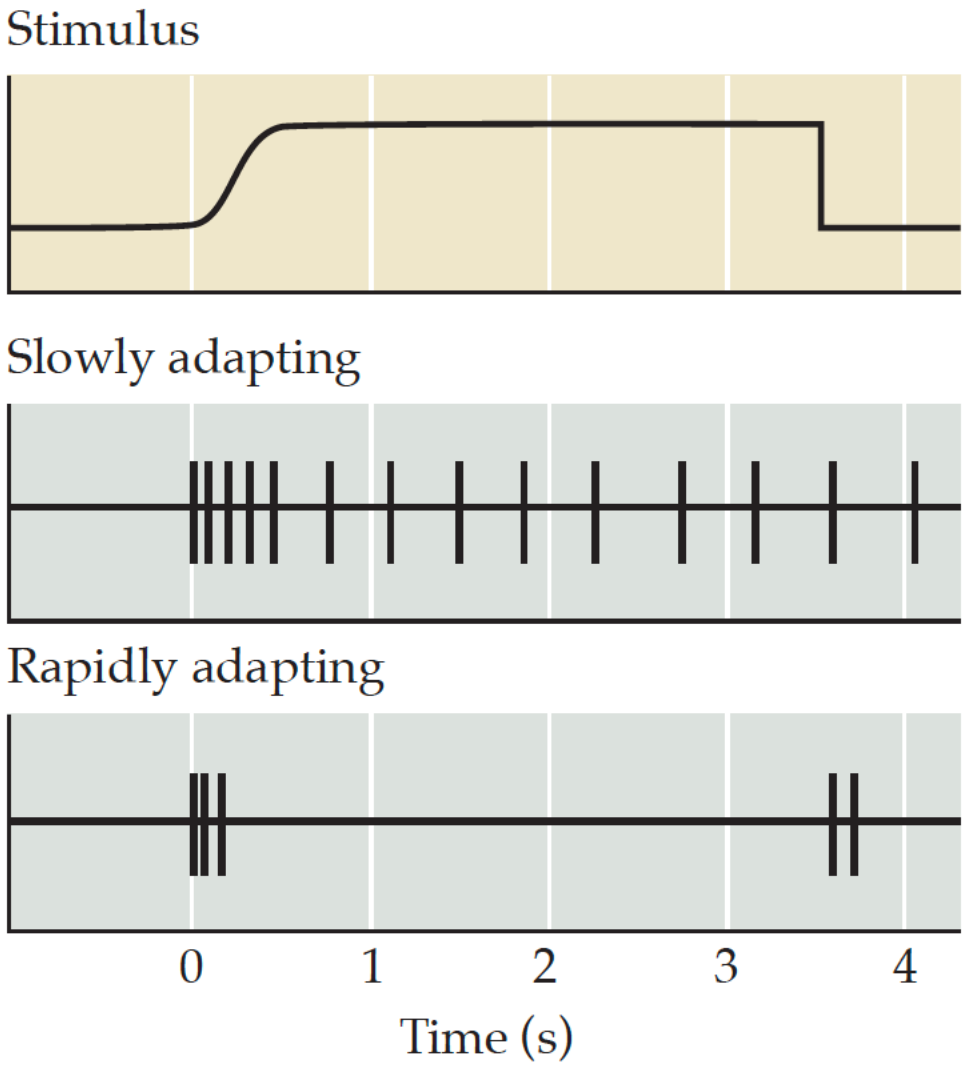






Purves, Figure 9.3

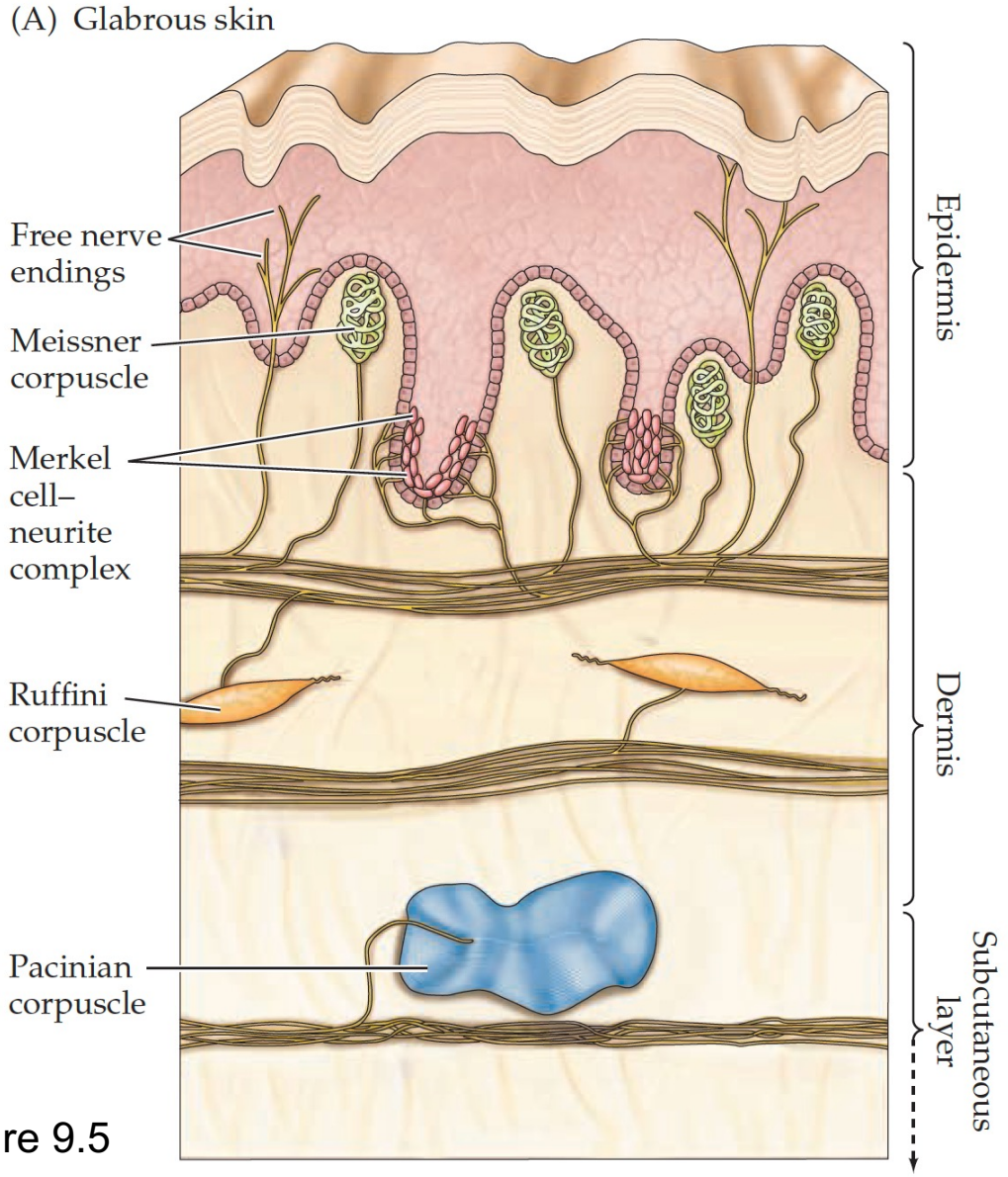
Slowly and rapidly adapting mechanoreceptors provide different information



This helps explain why you don‘t feel your clothes on your body

Purves, Figure 9.4

The skin harbors a variety of morphologically distinct touch mechanoreceptors



Free nerve endings
(esp. important for *pain* sensation)

Meissner‘s corpuscles
3-40 Hz (low frequency)

Merkel cell afferents
slowly adapting; highest spatial resolution

Rufini‘s endings

Pacinian corpuscles
(250 -350 Hz)
High sensitivity (10 nm)

Purves, Figure 9.5

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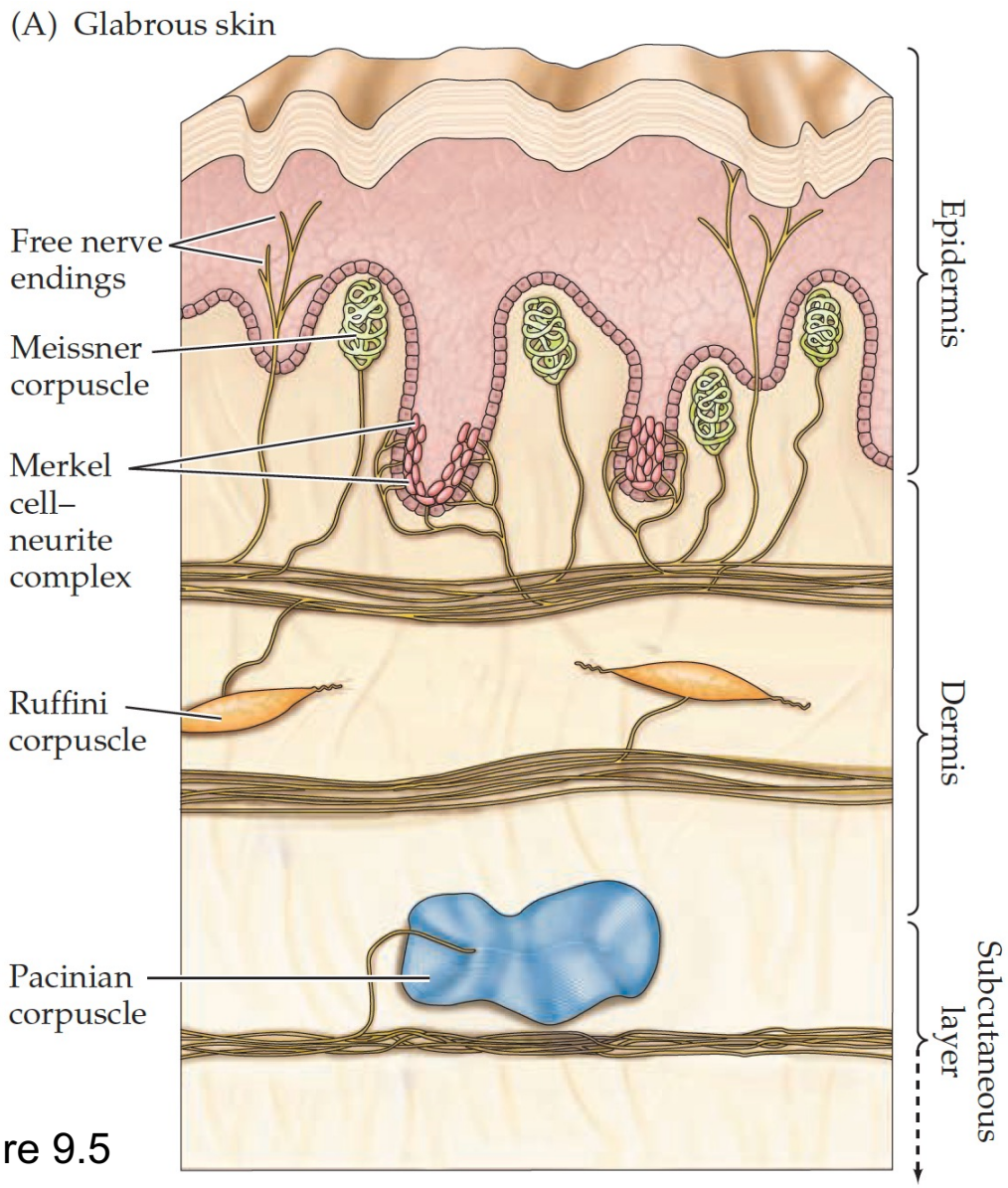
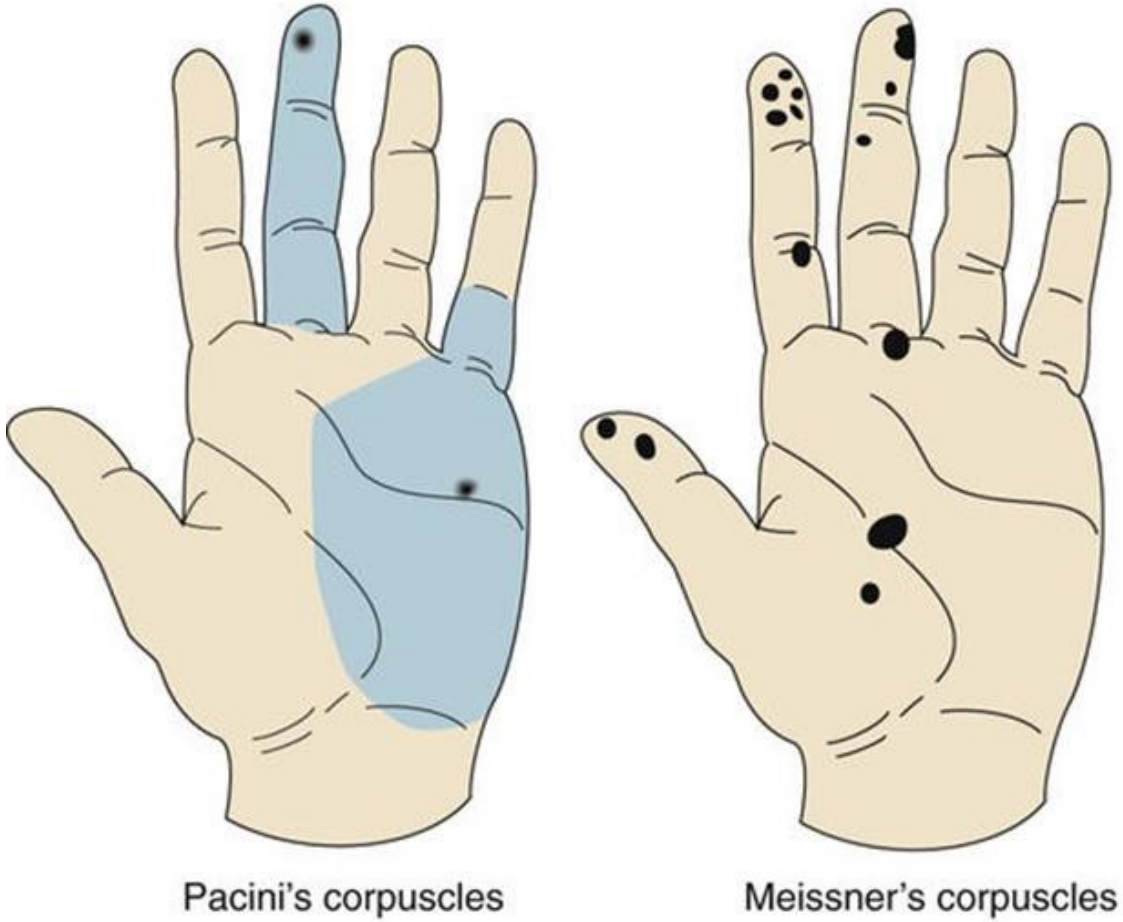


Purves, Figure 9.5



In Kenshalo DR [ed]:
The Skin Senses.
Springfield, IL,
Charles C Thomas, 1968.

Different types of mechanoreceptors in the skin ("cutaneous mechanoreceptors")

TABLE 9.2 ■ Afferent Systems and Their Properties

	Small receptive field		Large receptive field	
	Merkel	**Meissner**	**Pacinian**	**Ruffini**
Location	Tip of epidermal sweat ridges	Dermal papillae (close to skin surface)	Dermis and deeper tissues	Dermis
Axon diameter	7–11 μm	6–12 μm	6–12 μm	6–12 μm
Conduction velocity	40–65 m/s	35–70 m/s	35–70 m/s	35–70 m/s
Sensory function	Shape and texture perception	Motion detection; grip control	Perception of distant events through transmitted vibrations; tool use	Tangential force; hand shape; motion direction
Effective stimuli	Edges, points, corners, curvature	Skin motion	Vibration	Skin stretch
Receptive field area[a]	9 mm^2	22 mm^2	Entire finger or hand	60 mm^2
Innervation density (finger pad)	100/cm^2	150/cm^2	20/cm^2	10/cm^2
Spatial acuity	0.5 mm	3 mm	10+ mm	7+ mm
Response to sustained indentation	Sustained (slow adaptation)	None (rapid adaptation)	None (rapid adaptation)	Sustained (slow adaptation)
Frequency range	0–100 Hz	1–300 Hz	5–1000 Hz	0–? Hz
Peak sensitivity	5 Hz	50 Hz	200 Hz	0.5 Hz
Threshold for rapid indentation or vibration:				
Best	8 μm	2 μm	0.01μm	40 μm
Mean	30 μm	6 μm	0.08 μm	300 μm

[a]Receptive field areas as measured with rapid 0.5-mm indentation.

(After K. O. Johnson, 2002.)

Purves, Table 9.2

Simulation of activity patterns in different mechanosensory afferents in the fingertip

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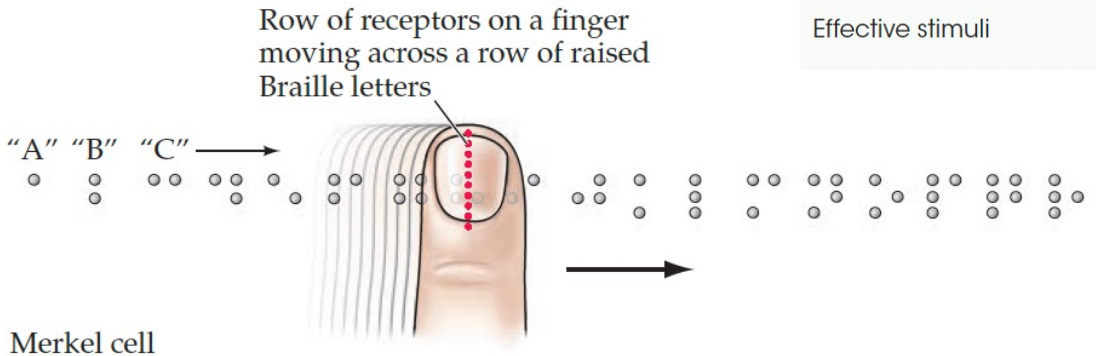
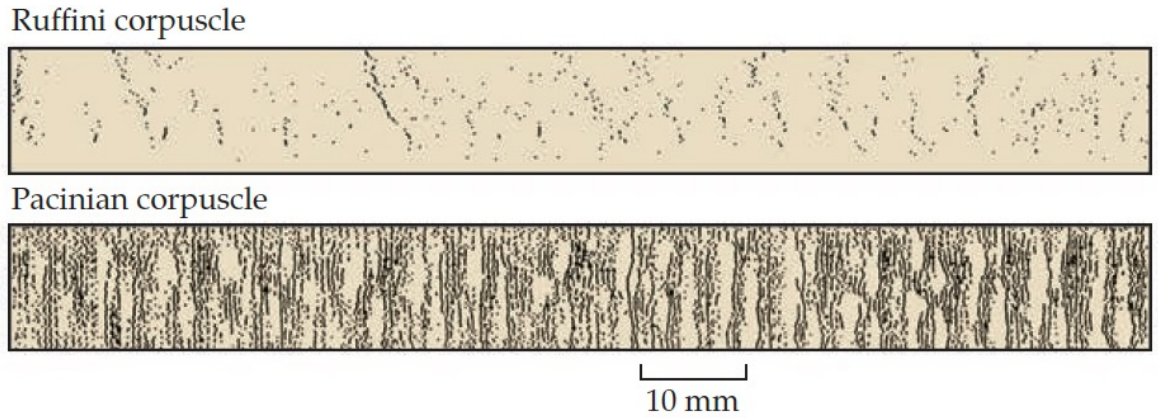




Purves, Figure 9.6

Studying somatosensation and medical pathology

Measuring the sense of touch in the laboratory

www.youtube.com/watch?v=2ENakkiIZc0

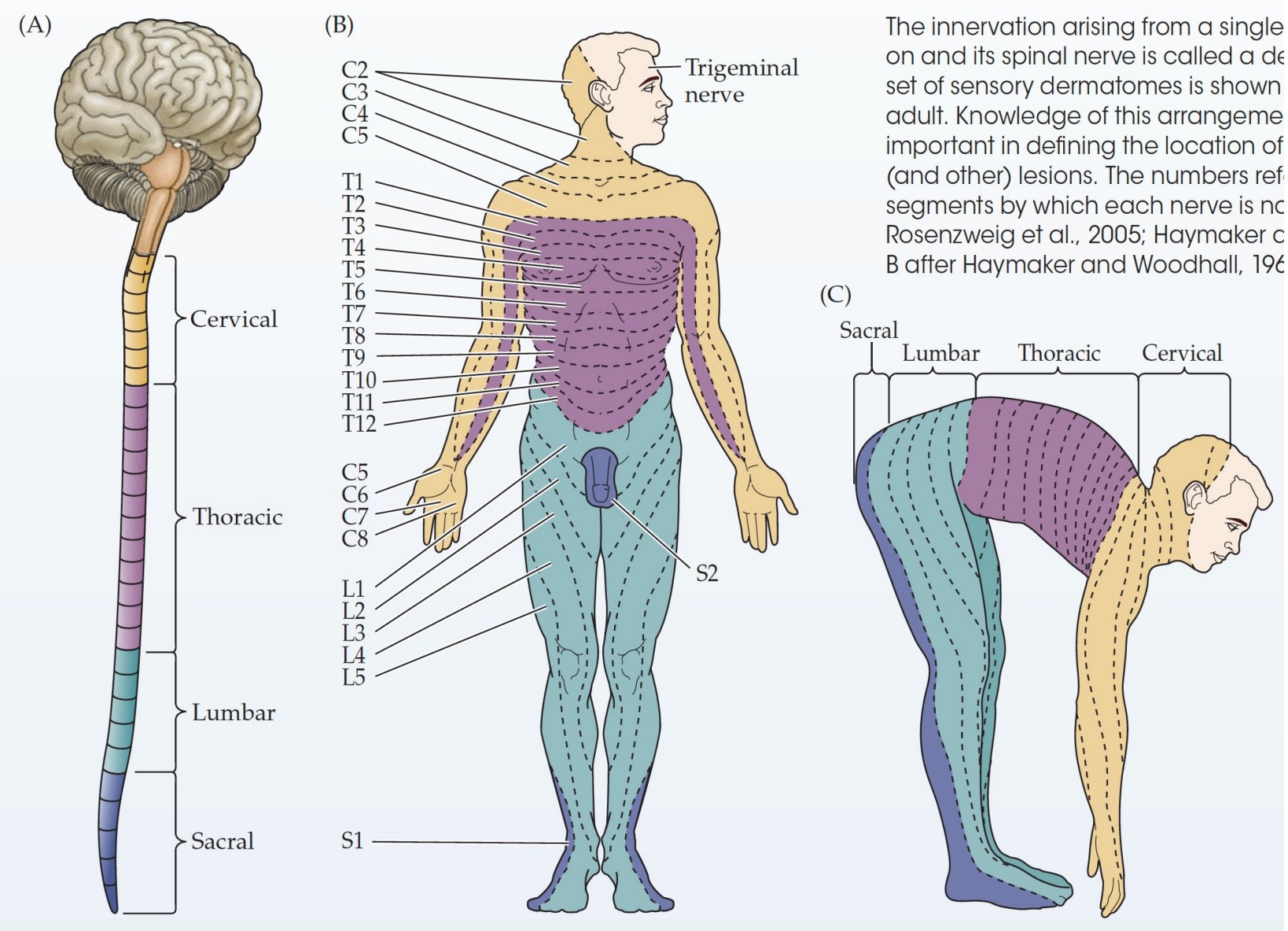
How do you measure the sense of touch?

Loss of touch and proprioception

www.youtube.com/watch?v=kUsSU_MVYd8

Losing Touch and Proprioception - The 4 min story of IW

Dermatomes: using deficits to map the location of spinal cord injury

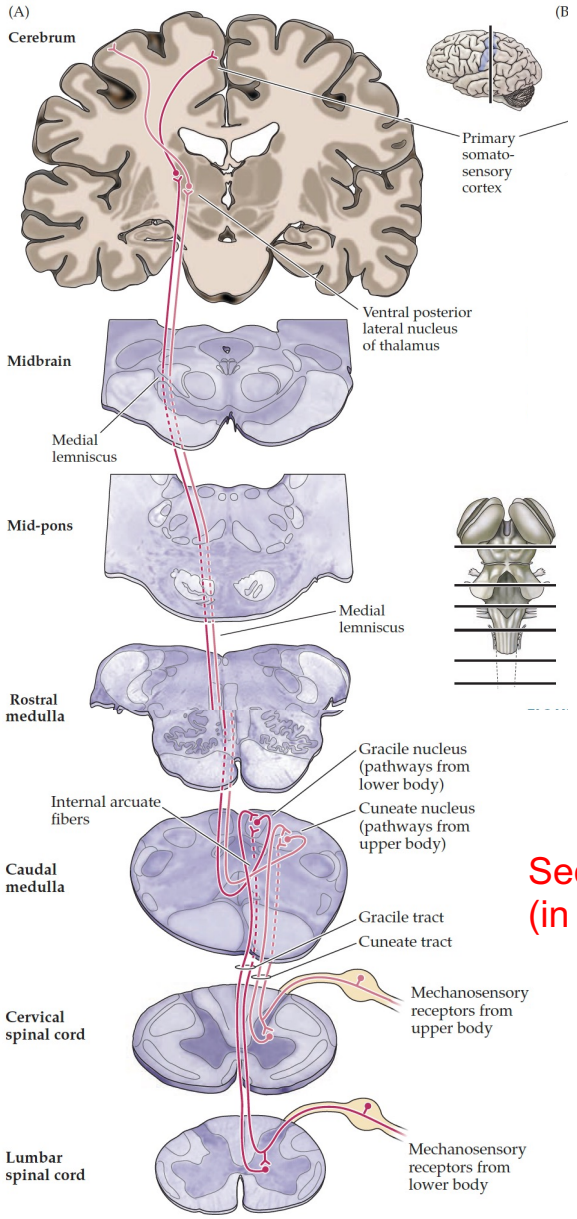


Purves, Clinical app.

Where does somatosensory information go in the brain?

Pathway for low threshold mechanosensing

Tertiary neurons
(in the thalamus)



Touch information goes to the Cortex

Secondary sensory neurons
(in the brainstem)

Primary sensory neurons

Purves, Figure 9.8

Dorsal column – medial lemniscus pathway

- Nerve endings of mechanosensitive neurons in periphery

- Cell bodies in the DRG

- Central axon:
    - ascends in dorsal column to a nucleus in the medulla (brainstem)
    - where it makes an **first excitatory synapse** (glutamate)

- Axons of medulla neurons (secondary somatosensory neurons)
    - **cross** the midline
    - then ascend in the brain to the thalamus
        (s-s thalamus: ventro-posterior -VP- complex)
    - there they make **excitatory synapses** (glutamate)

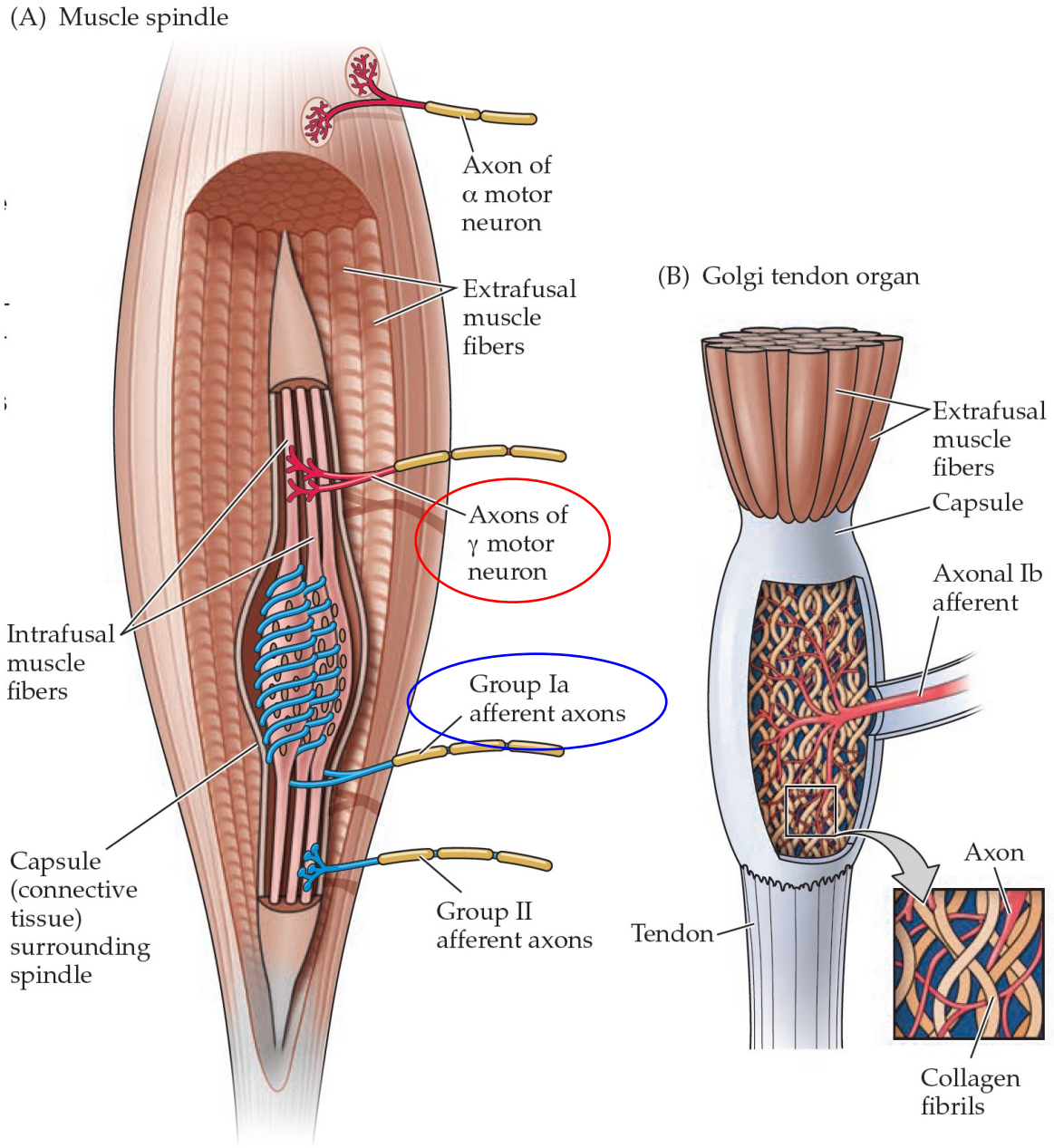
- Axons of the thalamus
    - ascend to the cortex, L4
    - there they make **excitatory synapses** (glutamate)

Proprioceptors in the musculoskeletal system

Efferent fiber carries information *from* the CNS *towards* the periphery

… an *efferent* fiber

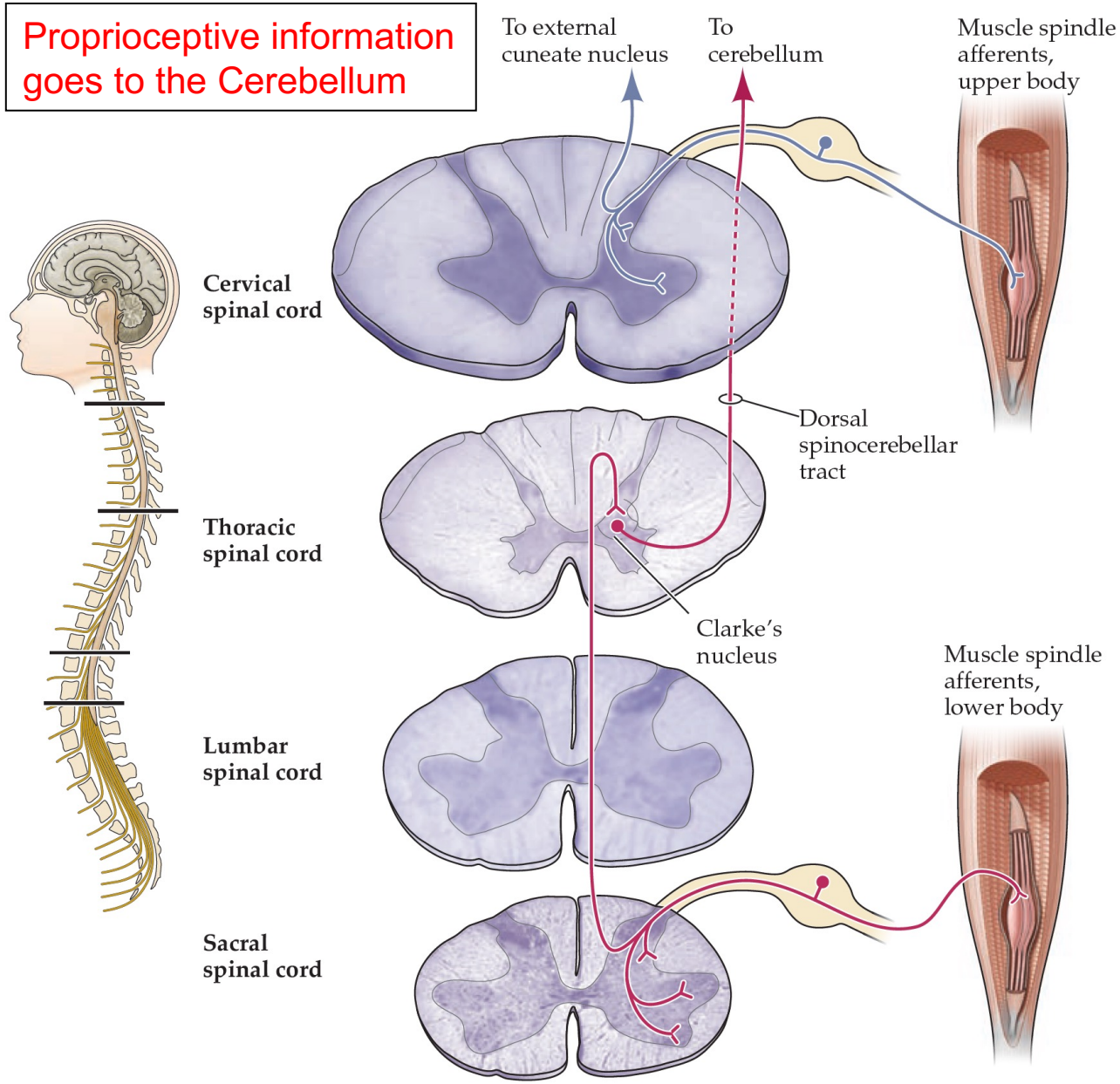
… an afferent fiber



Purves, Figure 9.7

Proprioceptive pathways for the upper and lower body

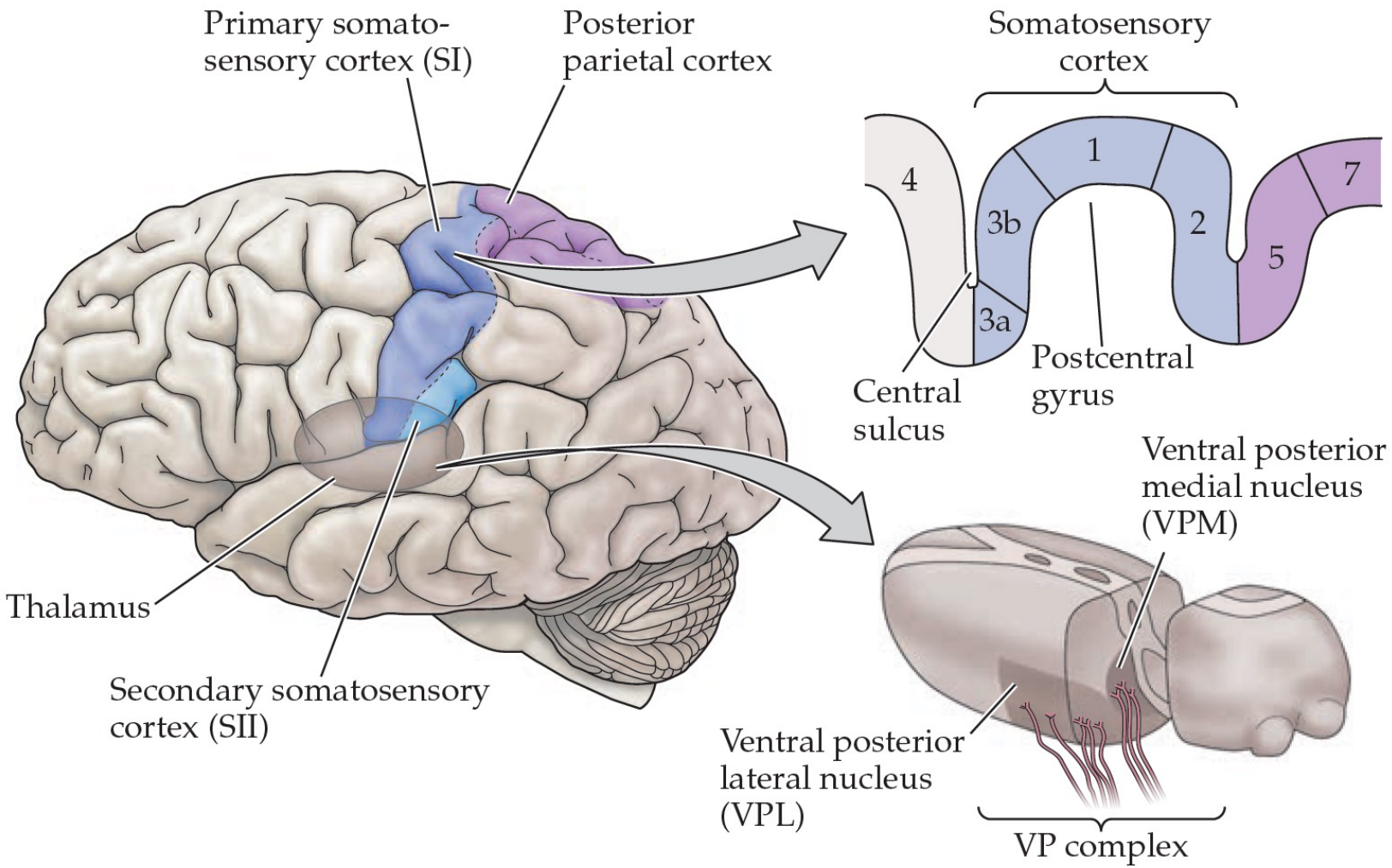
Proprioceptive information goes to the Cerebellum



Purves, Figure 9.9

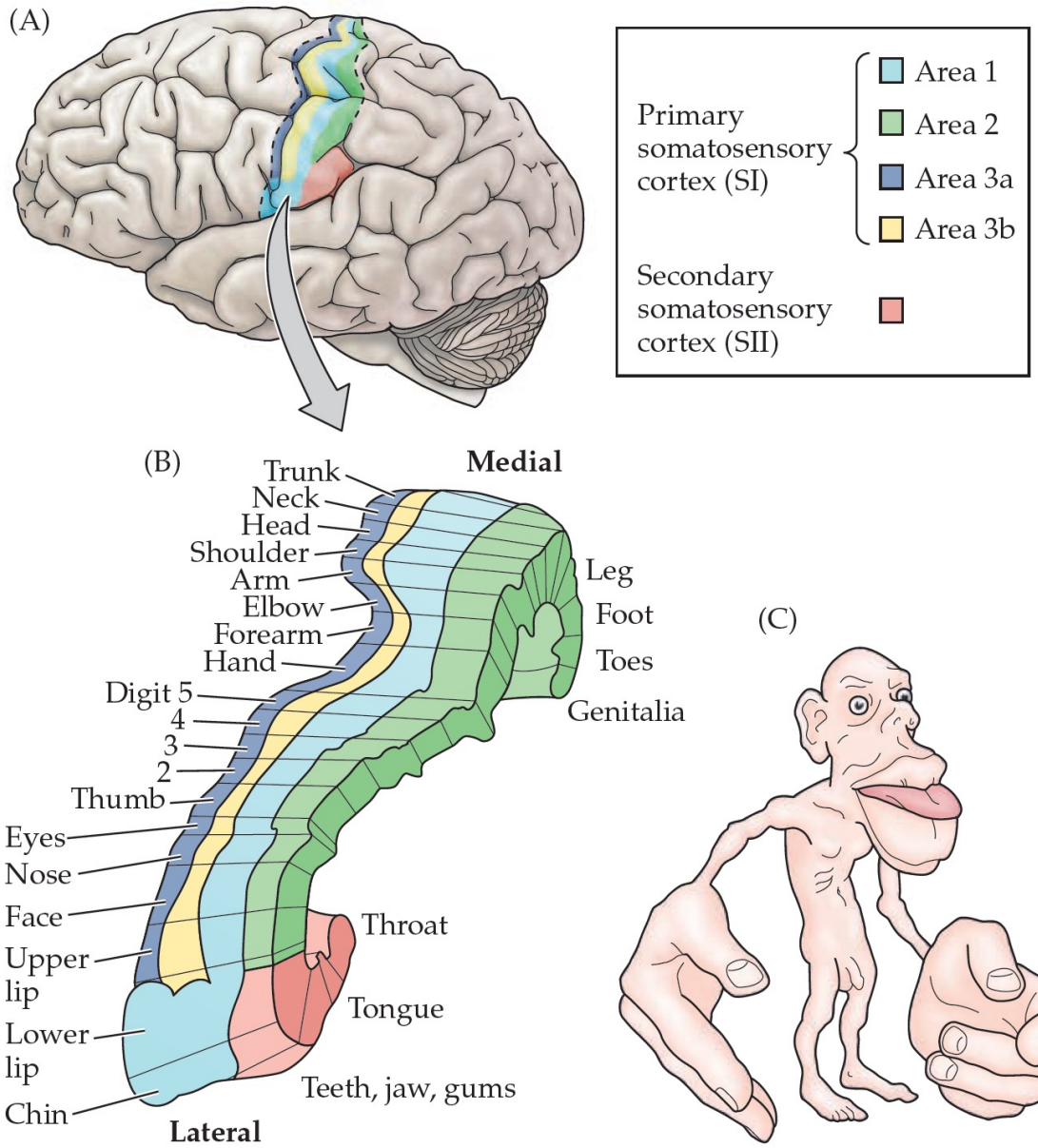
How is somatosensory information organized in the brain?

Somatosensory portions of the thalamus and their cortical targets in the postcentral gyrus



Purves, Figure 9.10

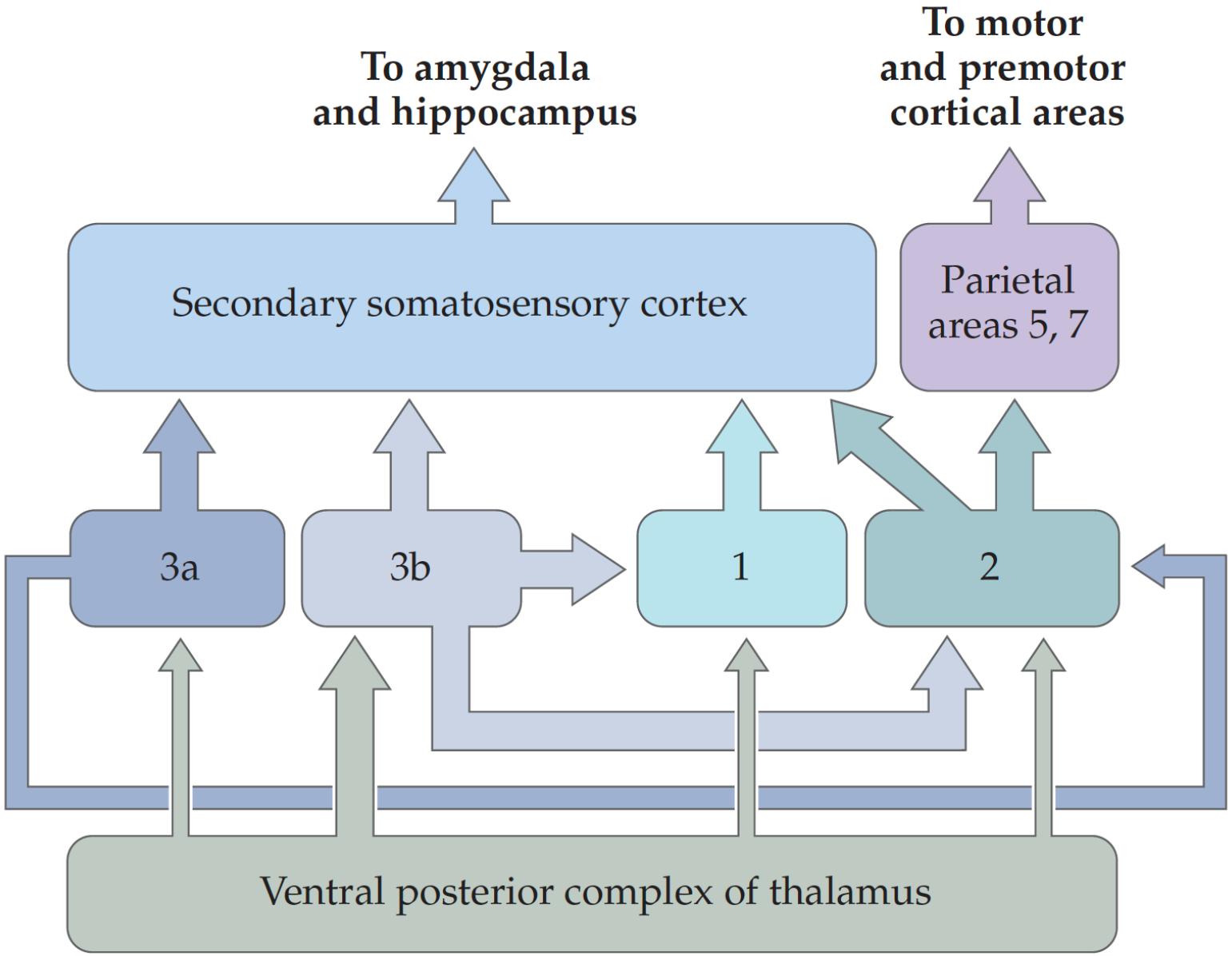
Somatotopic order in the human primary somatosensory cortex



Locations with "high spatial resolution“ (hands, face, lips, toes) are strongly represented areas in the "homunculus"

Purves, Figure 9.11

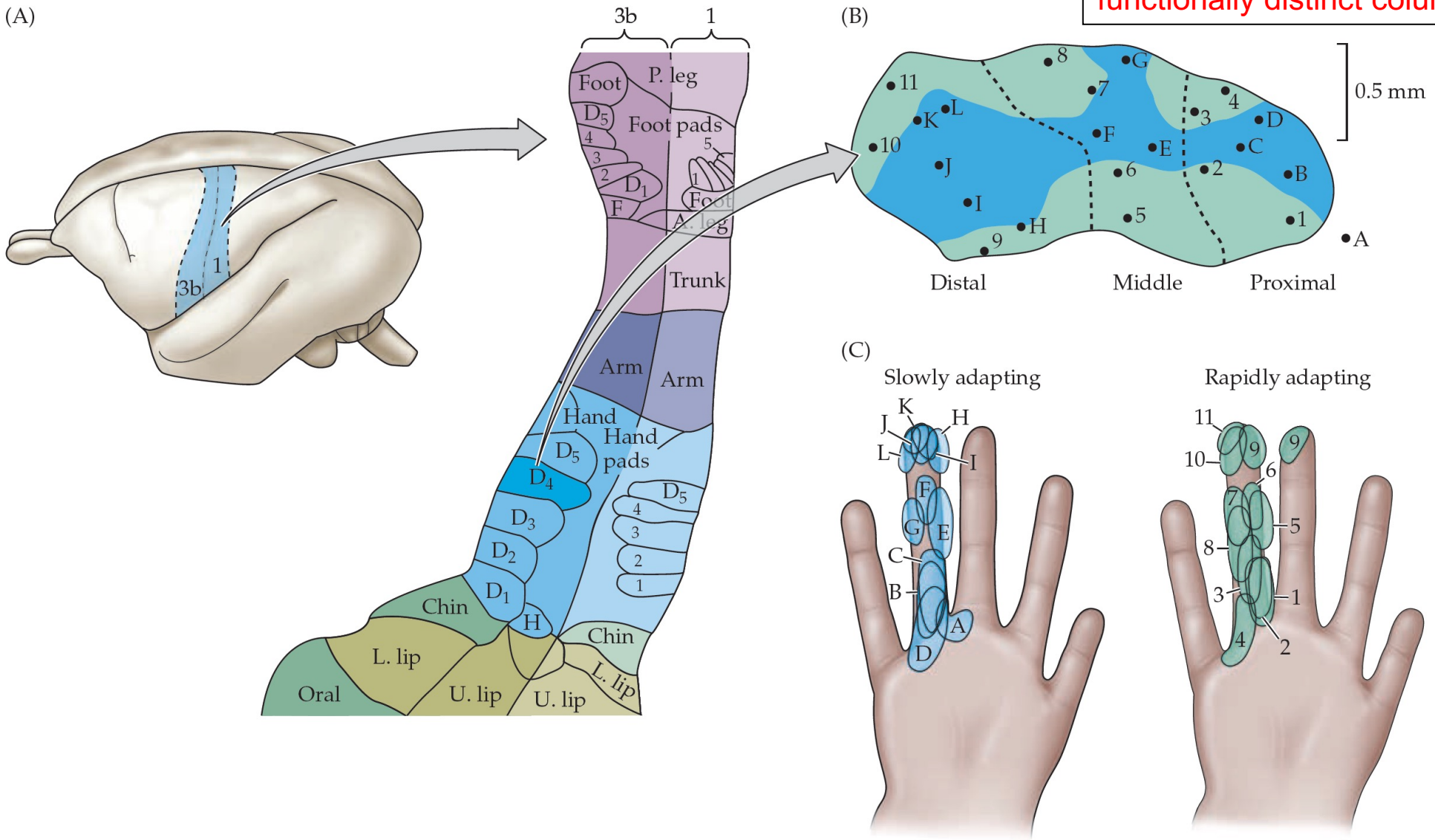
Connections within the somatosensory cortex establish functional hierarchies



Purves, Figure 9.12

Neurons in the primary somatosensory cortex form functionally distinct columns

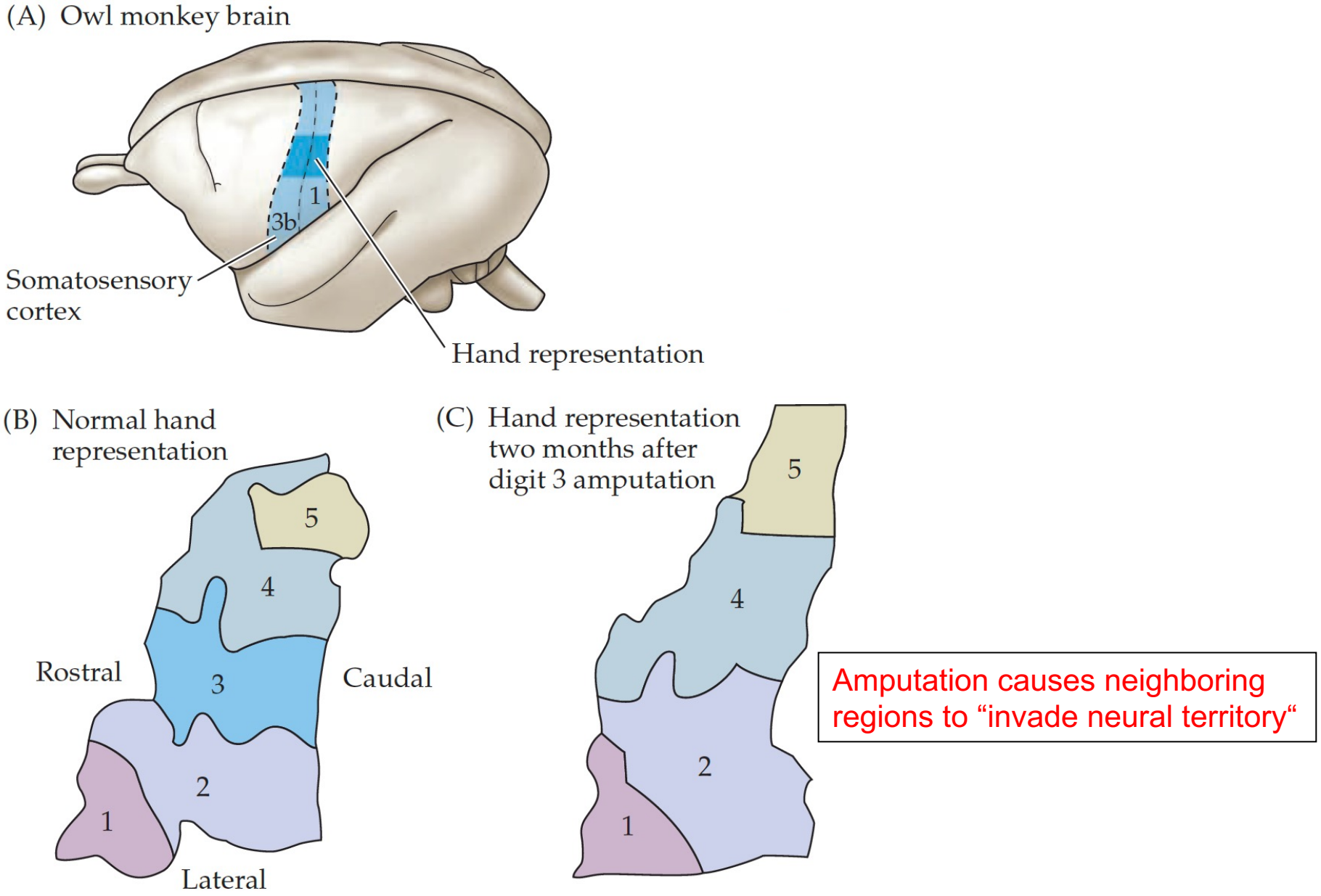
Spatially overlapping but functionally distinct columns



Purves, Figure 9.13

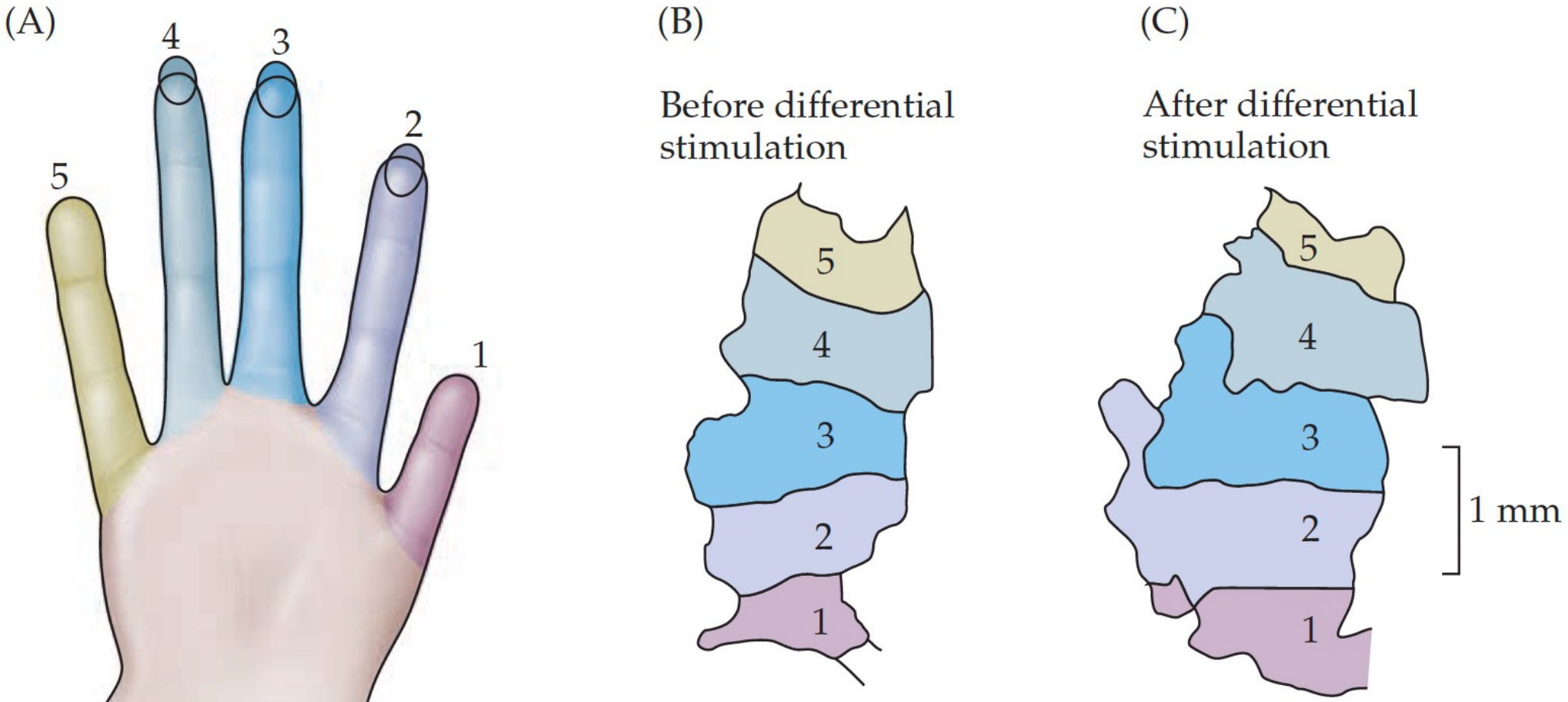
How “plastic“ is somatosensory organization in the brain?

Functional changes in the somatosensory cortex following amputation of a digit



Purves, Figure 9.14

Functional expansion of a cortical representation by a repetitive behavioral task



Repeated use causes regions to expand and "invade" as well

Purves, Figure 9.15

Summary: Somatosensation - Important concepts and keywords

- What are the diverse kinds of information sensed by the Somatosensory system?
- How do mechanosensory channels work?
- How was the PIEZO channel discovered (leading to a Nobel Prize in 2021)?
- What are the 4 kinds of Touch receptor types and what distinguishes them?
- How are somatosensory receptive fields determined and where are they most precise?
- Where is tactile (touch) versus proprioceptive sensing relayed to in the higher brain?
- What is a somatotopic map? How is it organized in somatosensory cortex?
- What happens to a somatotopic organization after finger amputation or behavioral training?