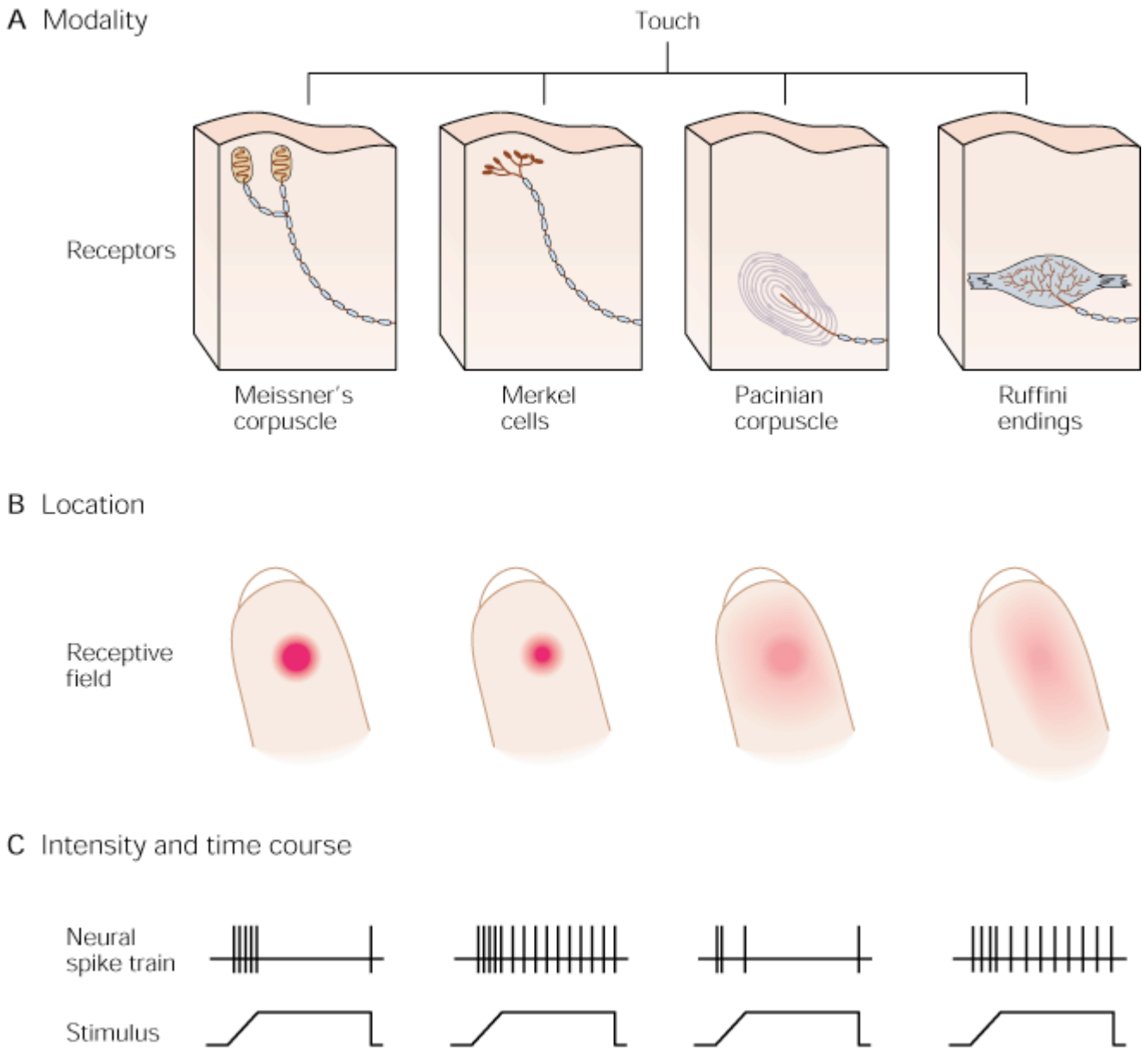
The Sense of Touch

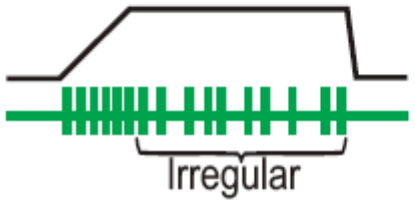
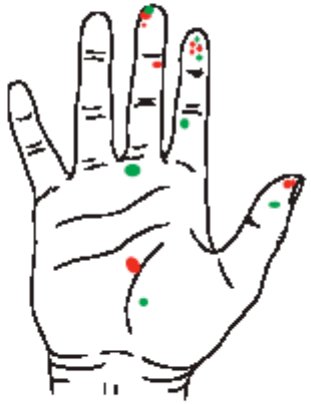
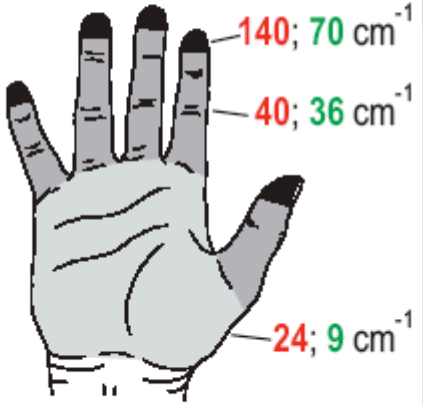
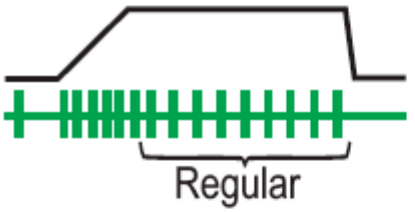
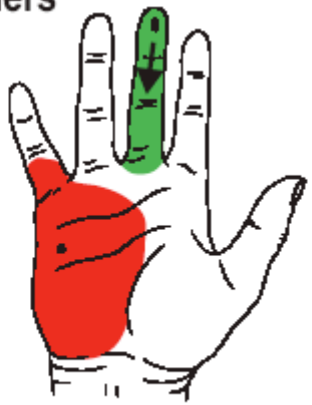
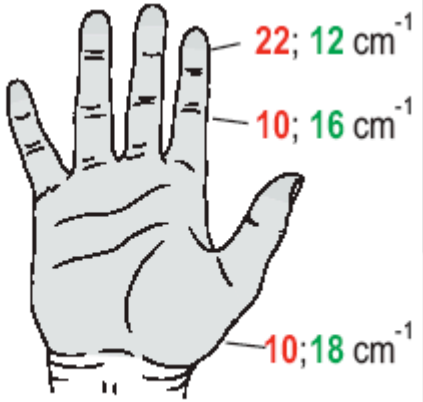
Jusepe de Ribera
c. 1615-16

Norton Simon Museum
Pasadena CA

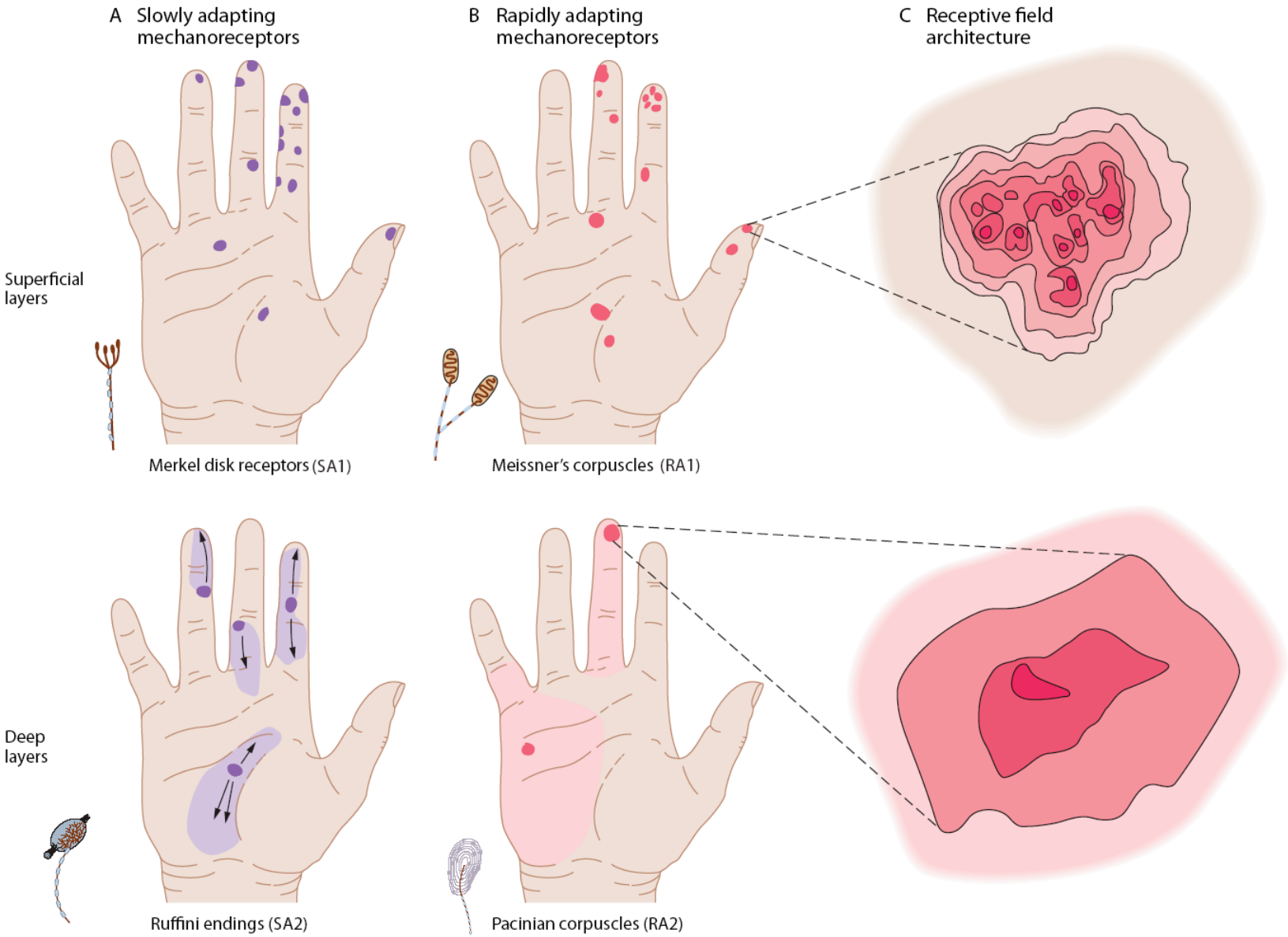
Four classes of touch receptors



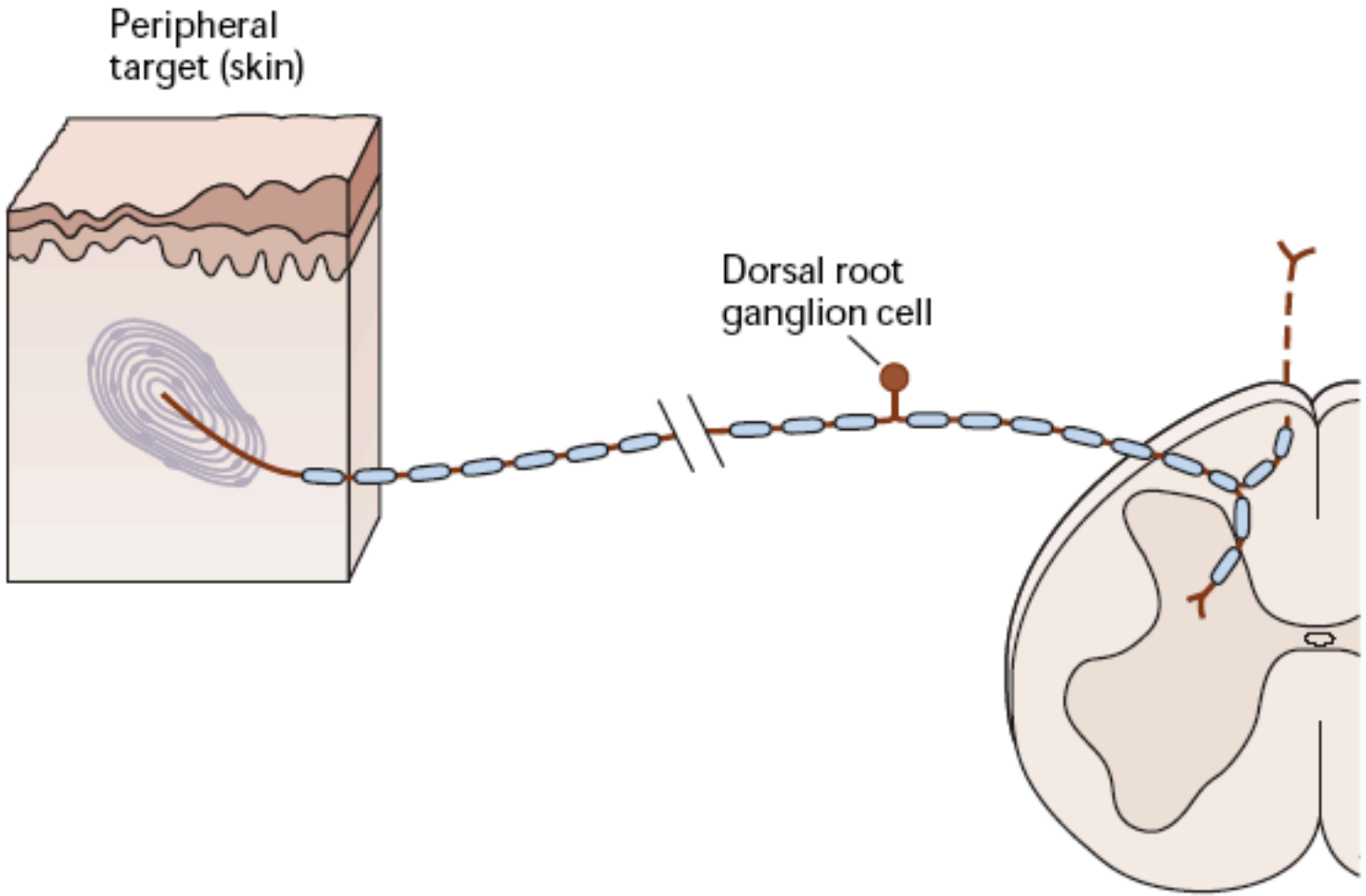
Mechanoreceptor response properties

ADAPTATION		RECEPTIVE FIELDS	INNERVATION DENSITY
Fast. no static response	**Slow, static response present**		
Changes in fingertip forces, fine form discrimination, moving stimuli, slips, friction etc. **FA-I** (43 %) **Meissner**	 Finger tip forces, fine form discrimination etc. **SA-I** (25 %) **Merkel**	**Small, sharp borders** 	**Increase distally** 
Mechanical transients & vibration (~40 - 400 Hz) **FA-II** (13 %) **Pacini & Pacini-like**	 Directional strain in deep dermal and subdermal tissues **SA-II** (19 %) **Ruffini**	**Large, obscure borders** 	**~Uniform** 

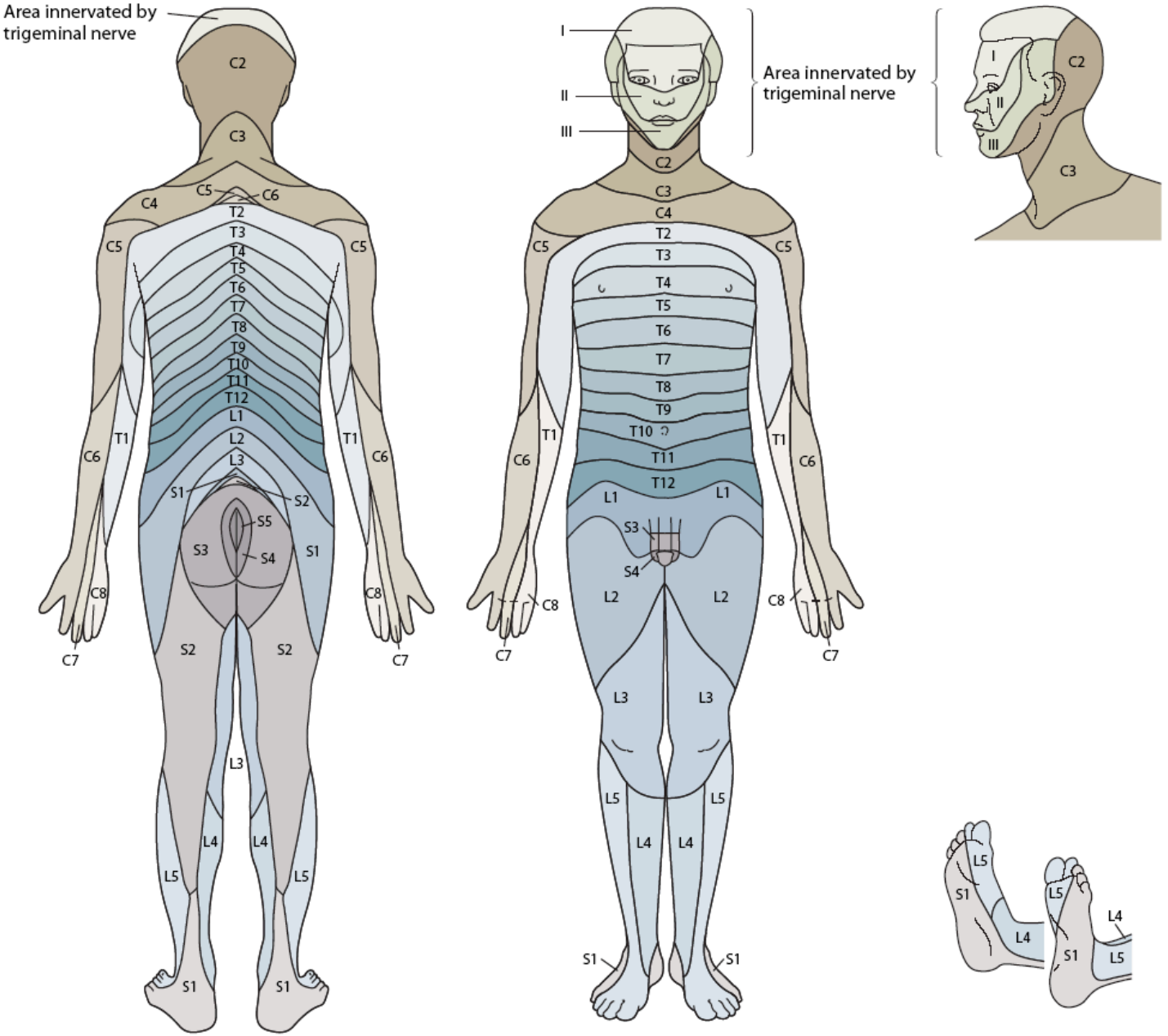
Touch fibers innervate small regions of skin



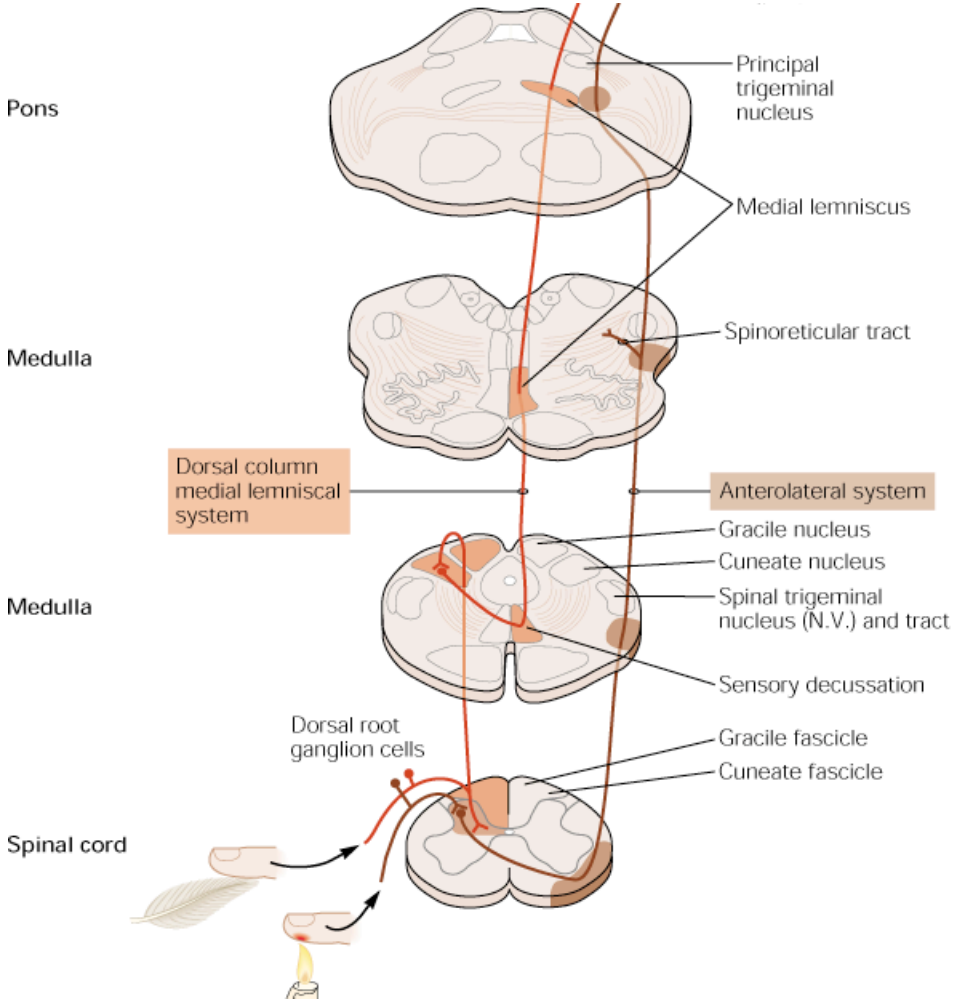
Central projections of touch fibers in the spinal cord

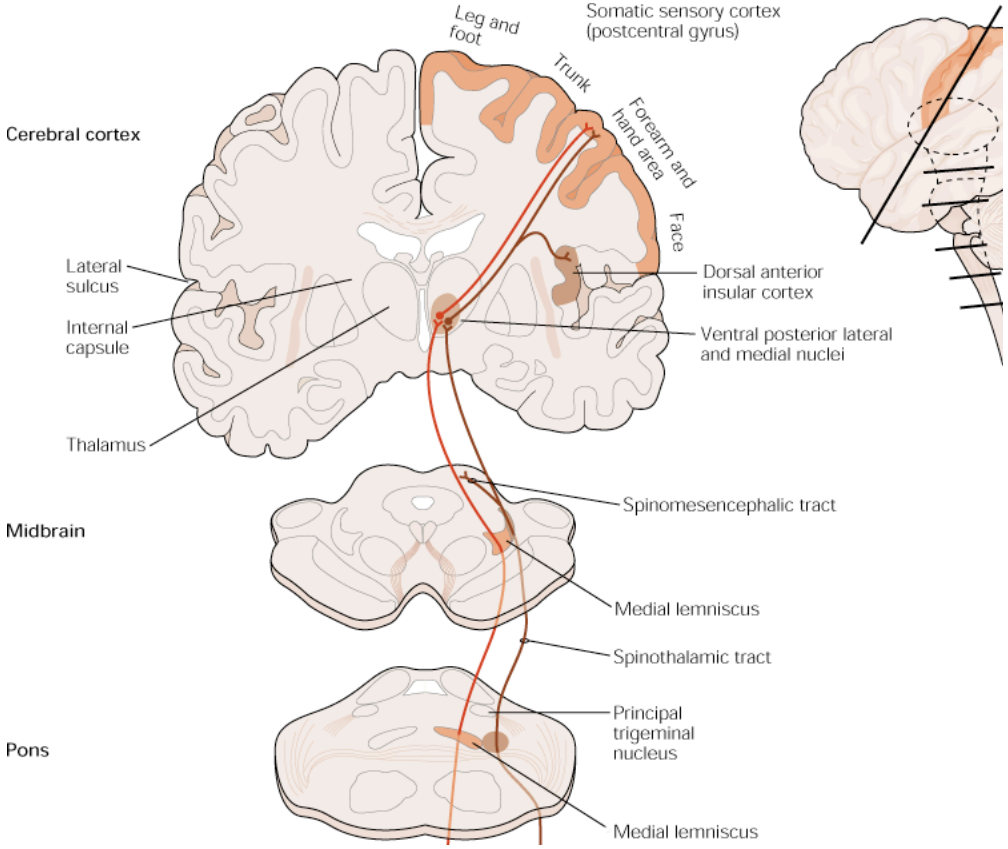


Dermatomes represent the body in the spinal cord

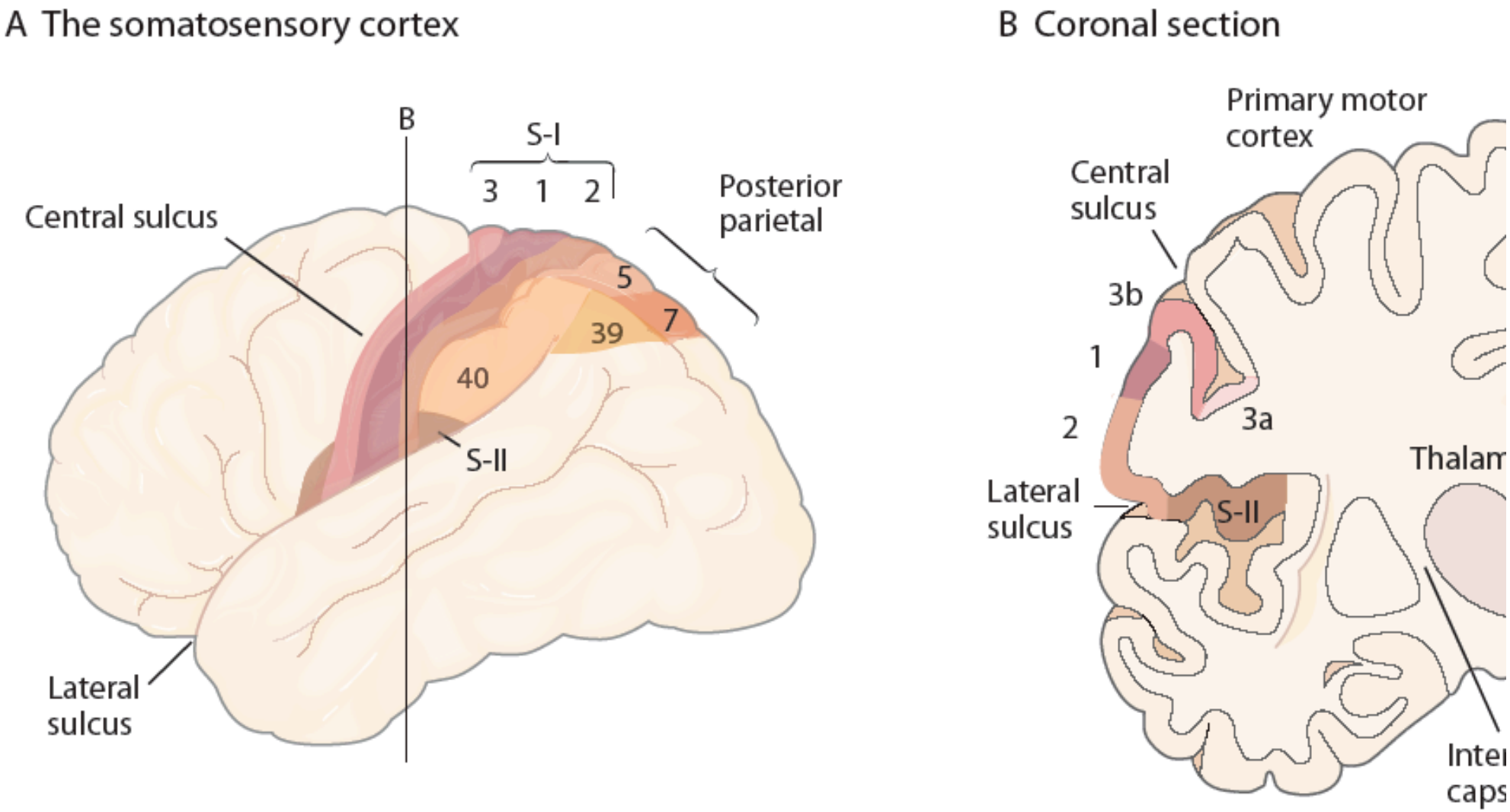


Touch is Relayed in a Distinct Pathway

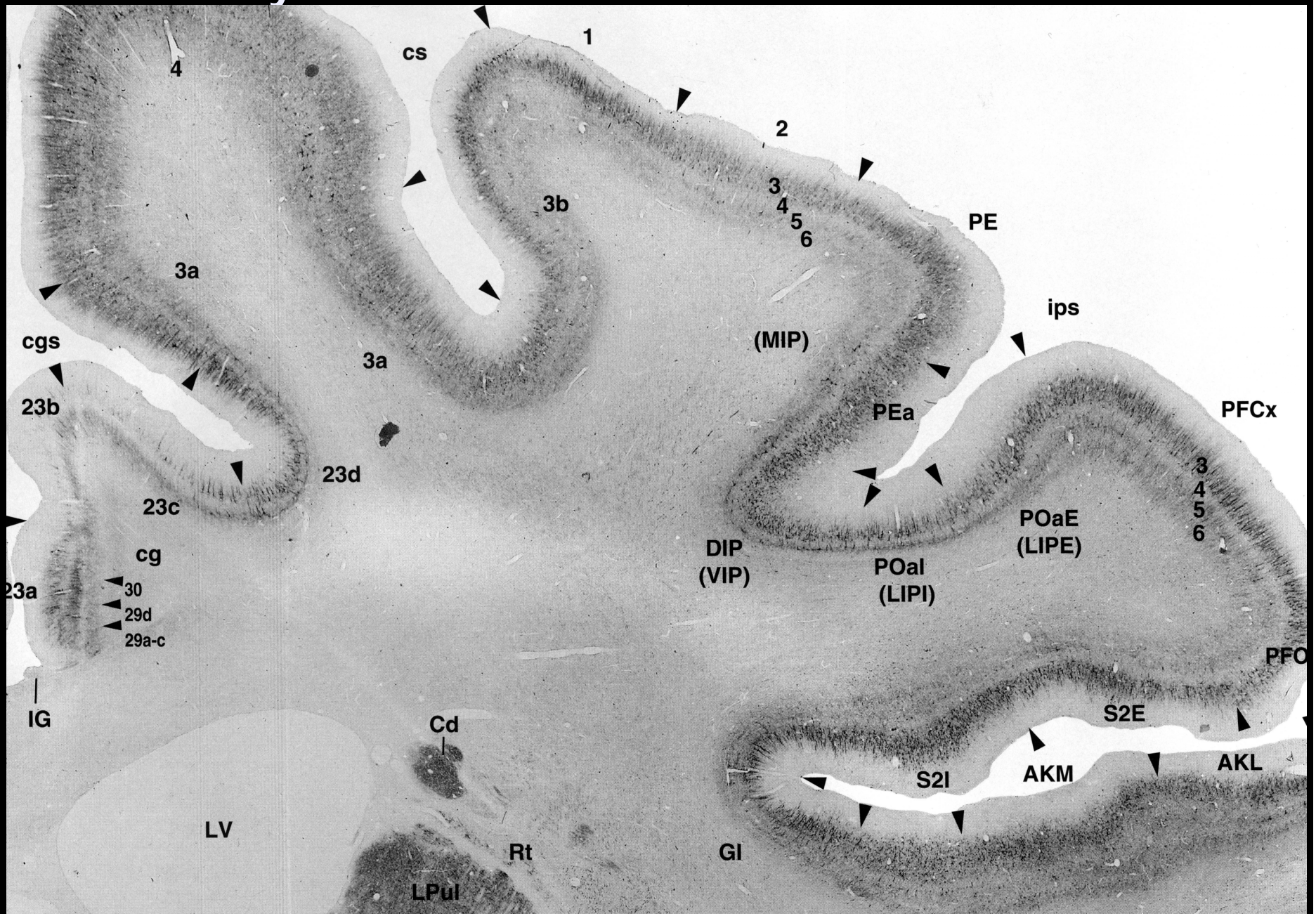




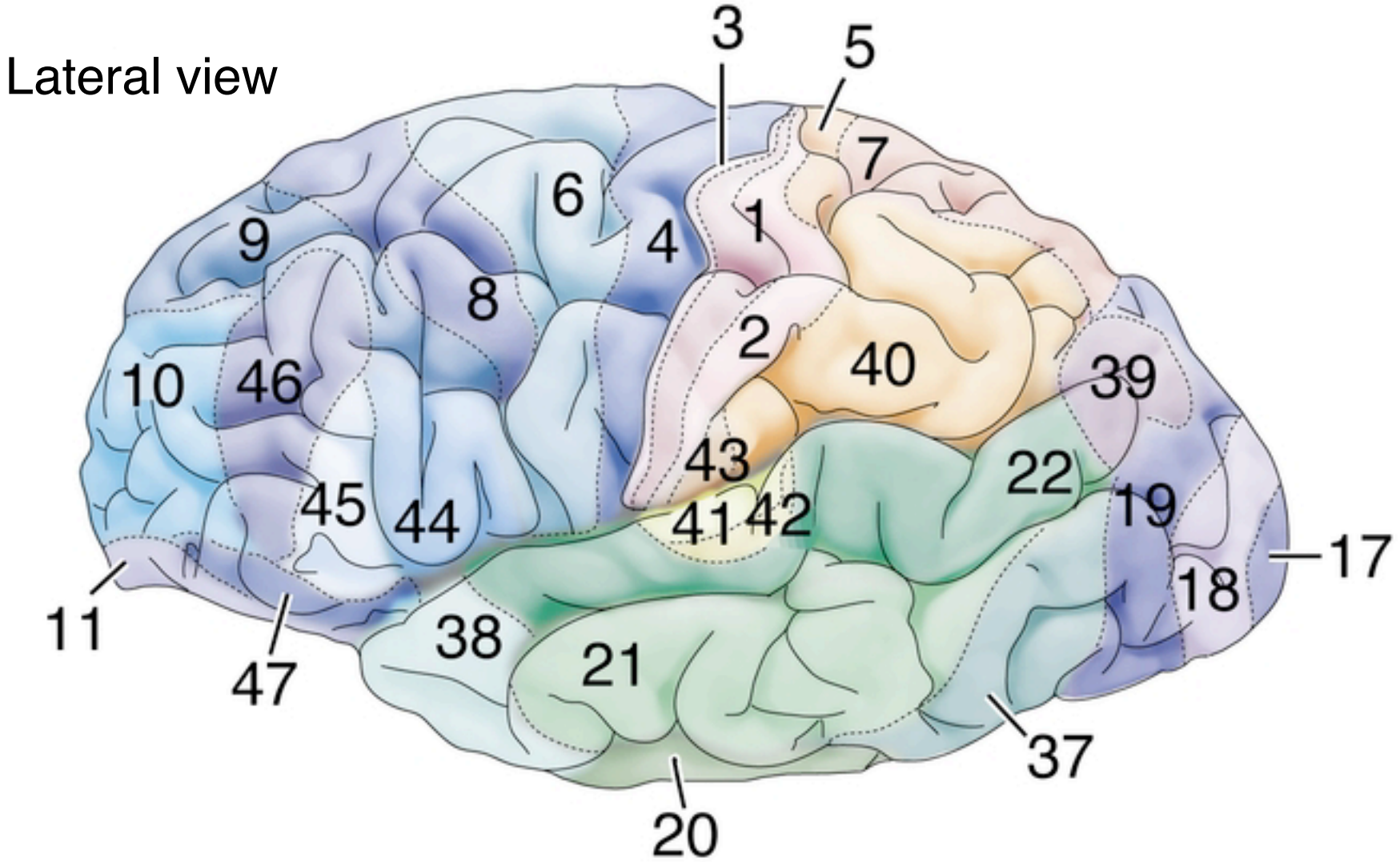
Somatosensory Areas of the Cortex



Cortical Cytoarchitecture

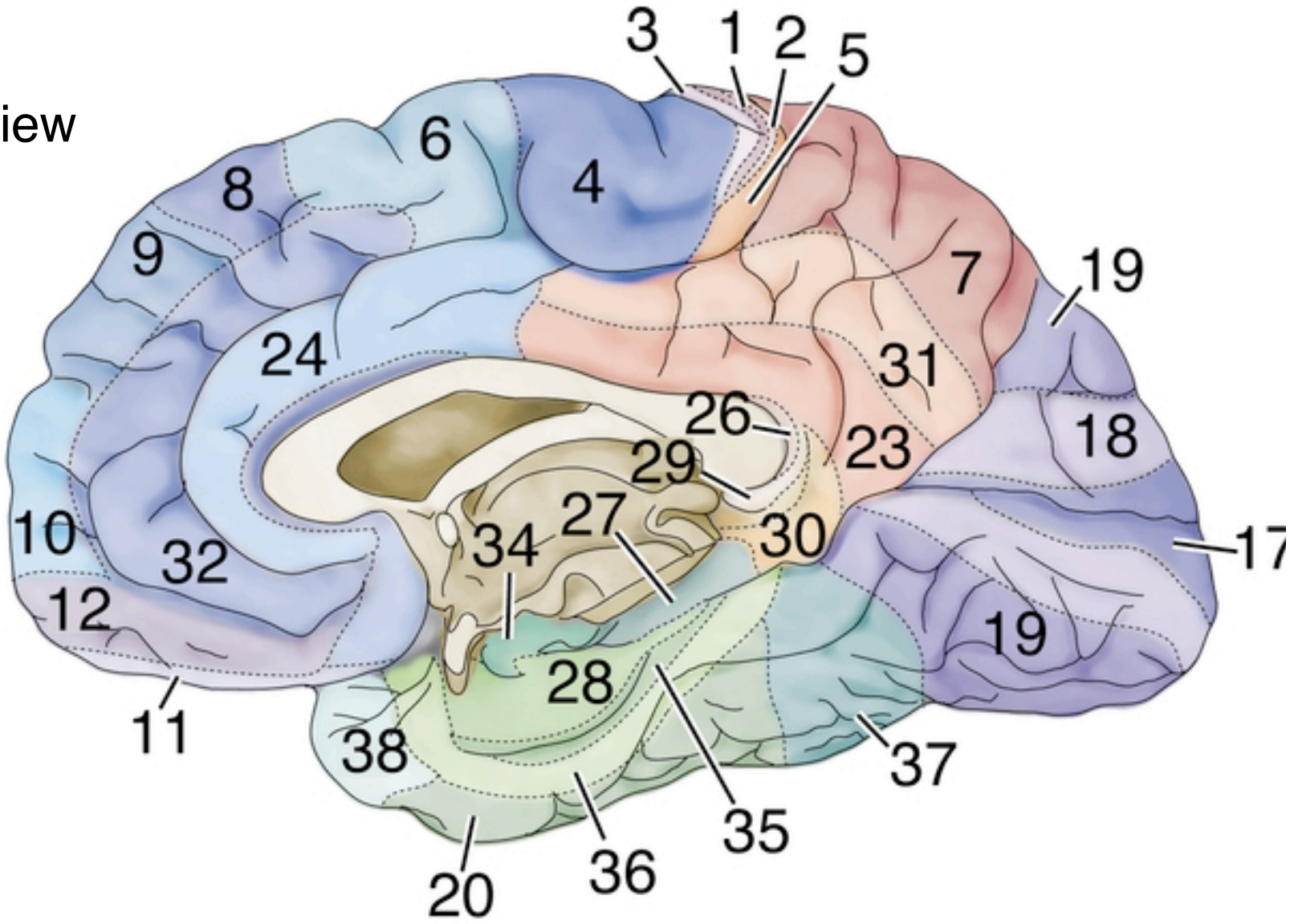


Parietal Cortex Includes S-I, S-II and PPC



Parietal Cortex Includes S-I, S-II and PPC

Medial view



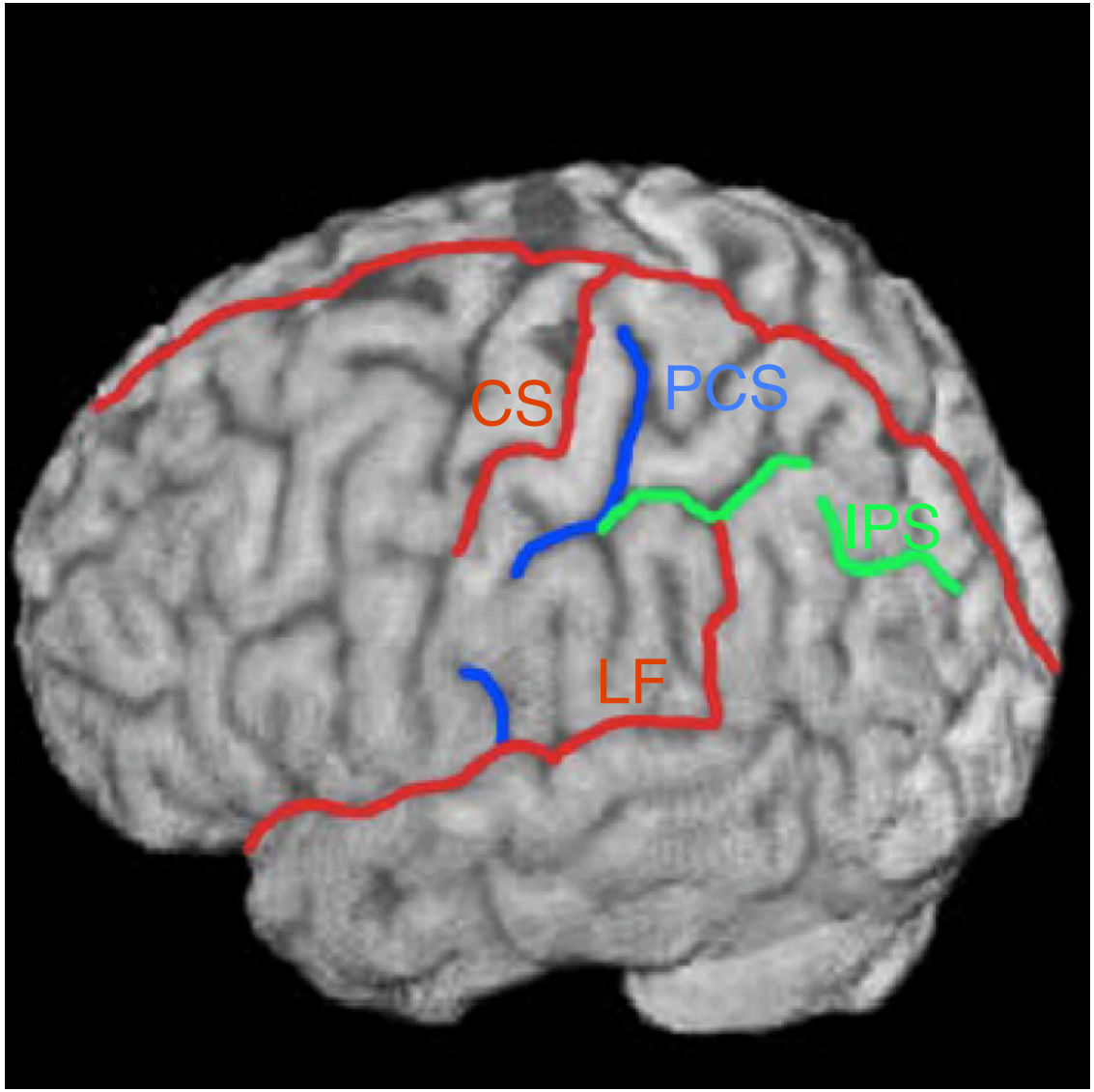
Major sulci of the parietal lobe

CS: Central sulcus

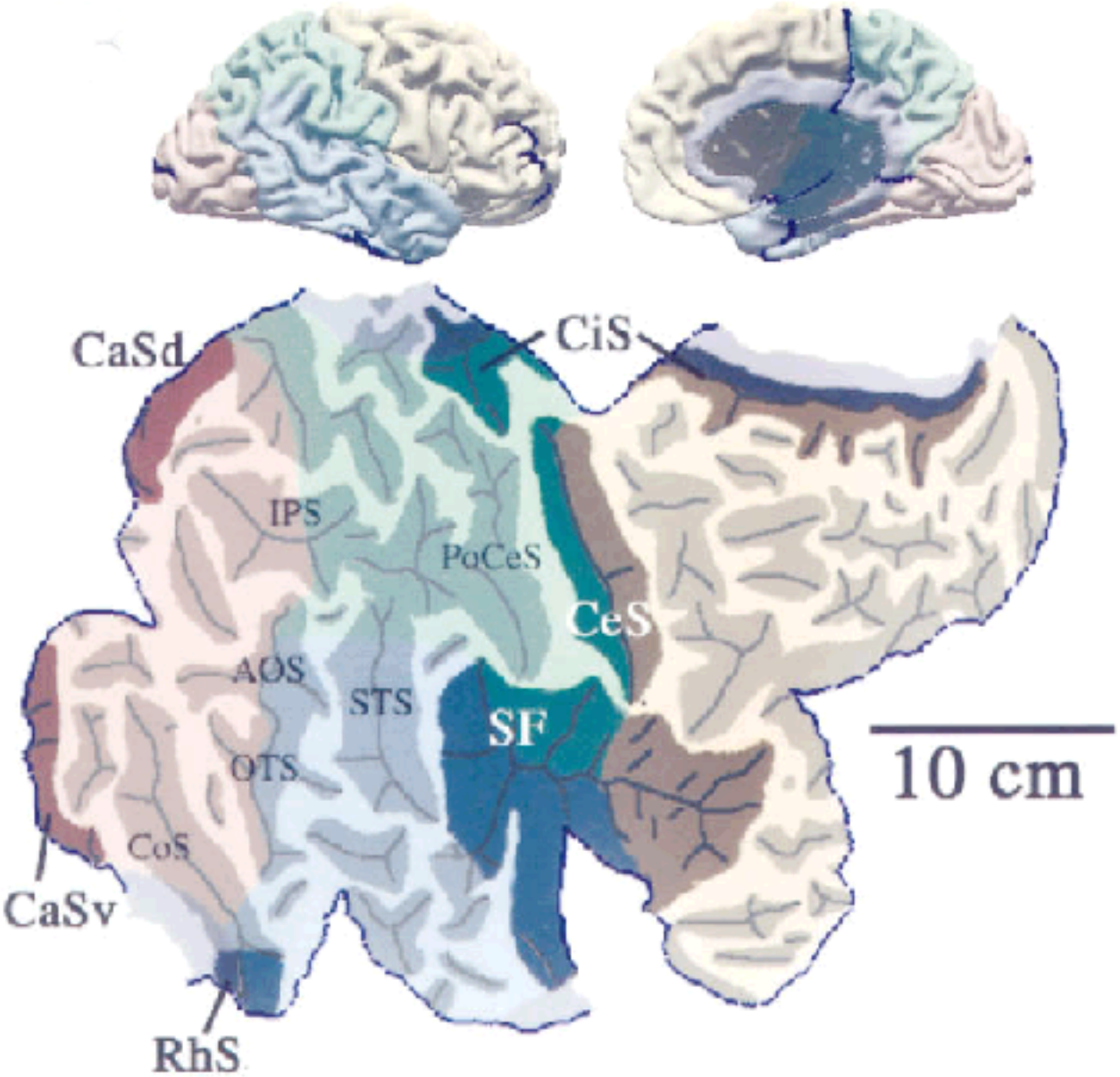
PCS: Postcentral sulcus

IPS: Intraparietal sulcus

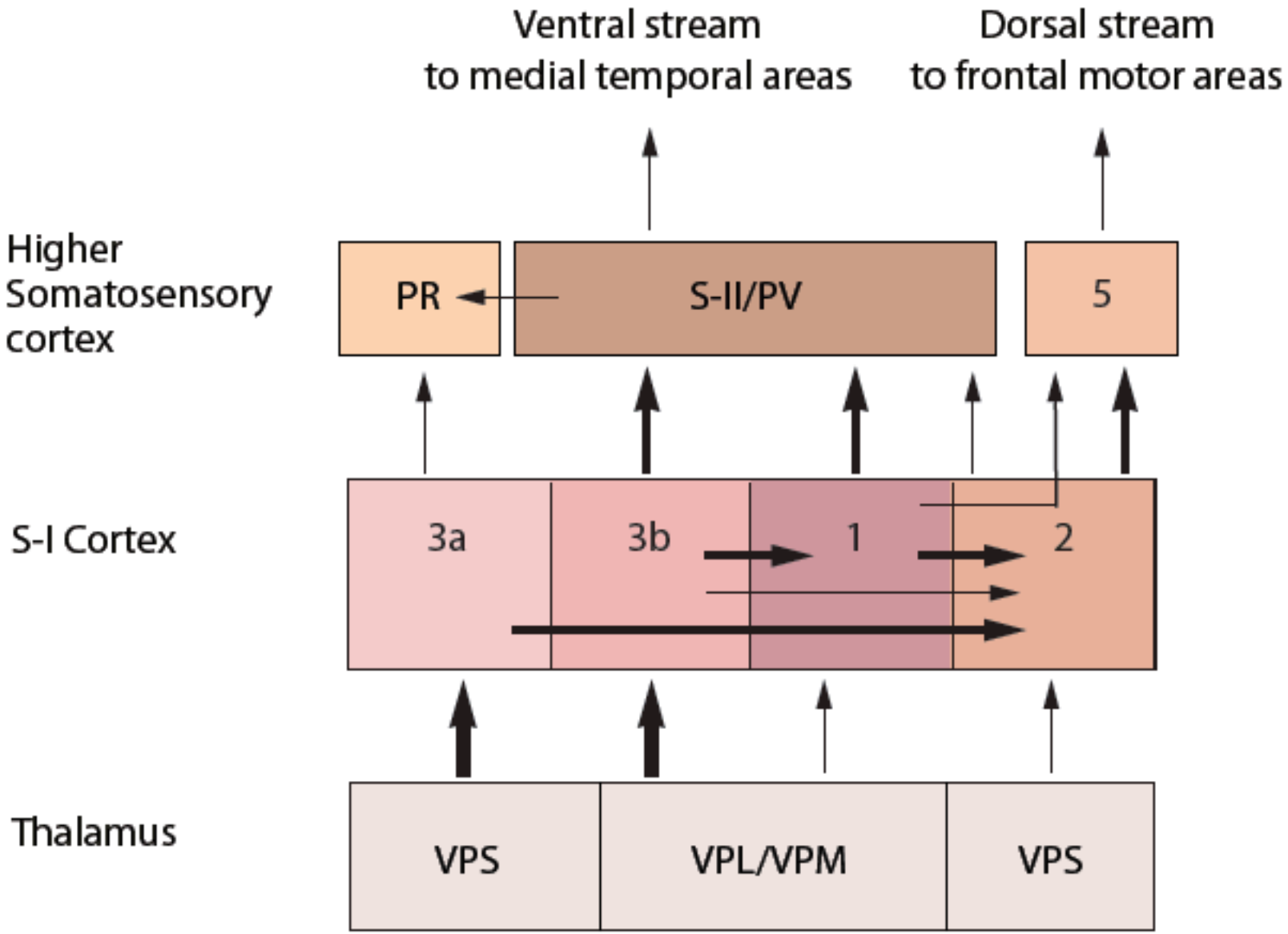
LF: Lateral fissure



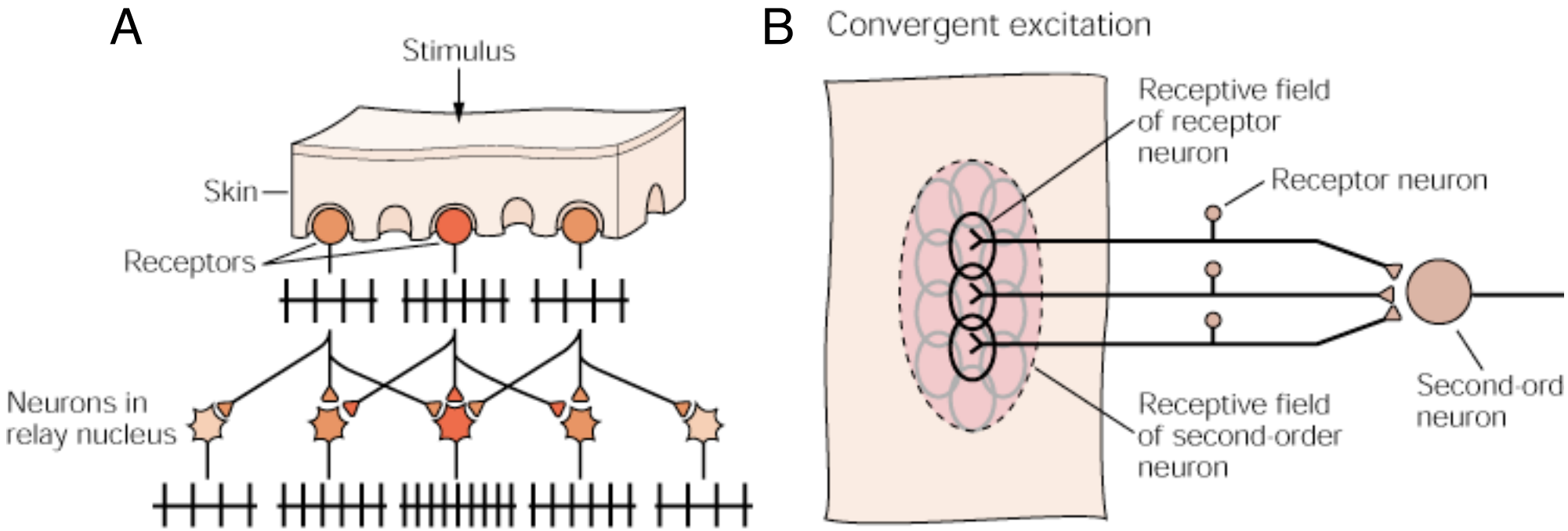
Nearly Half of the Cortex Buried in Sulci



Anatomical Projections to and from S-I Cortex

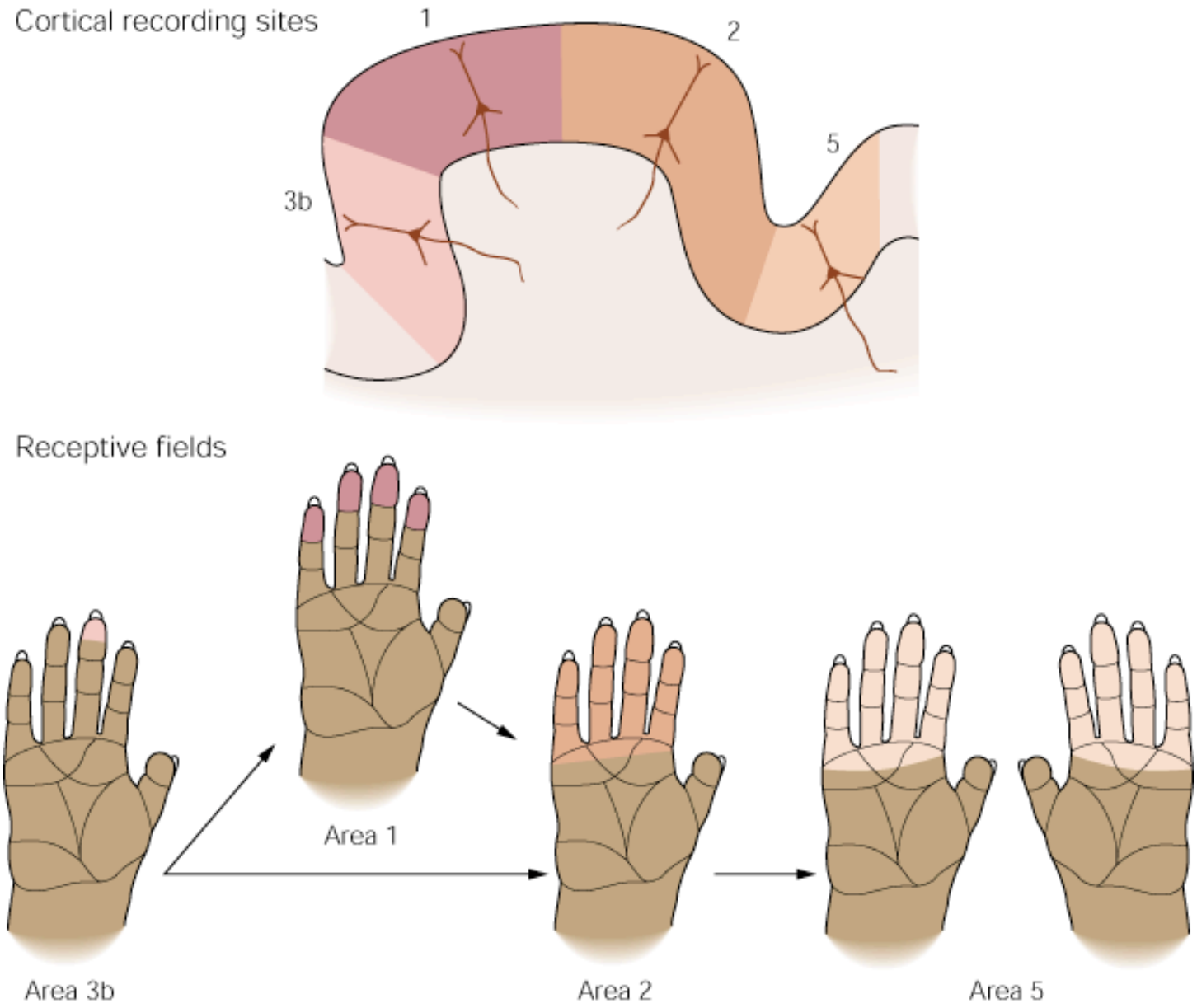


Convergence Increases Receptive Fields

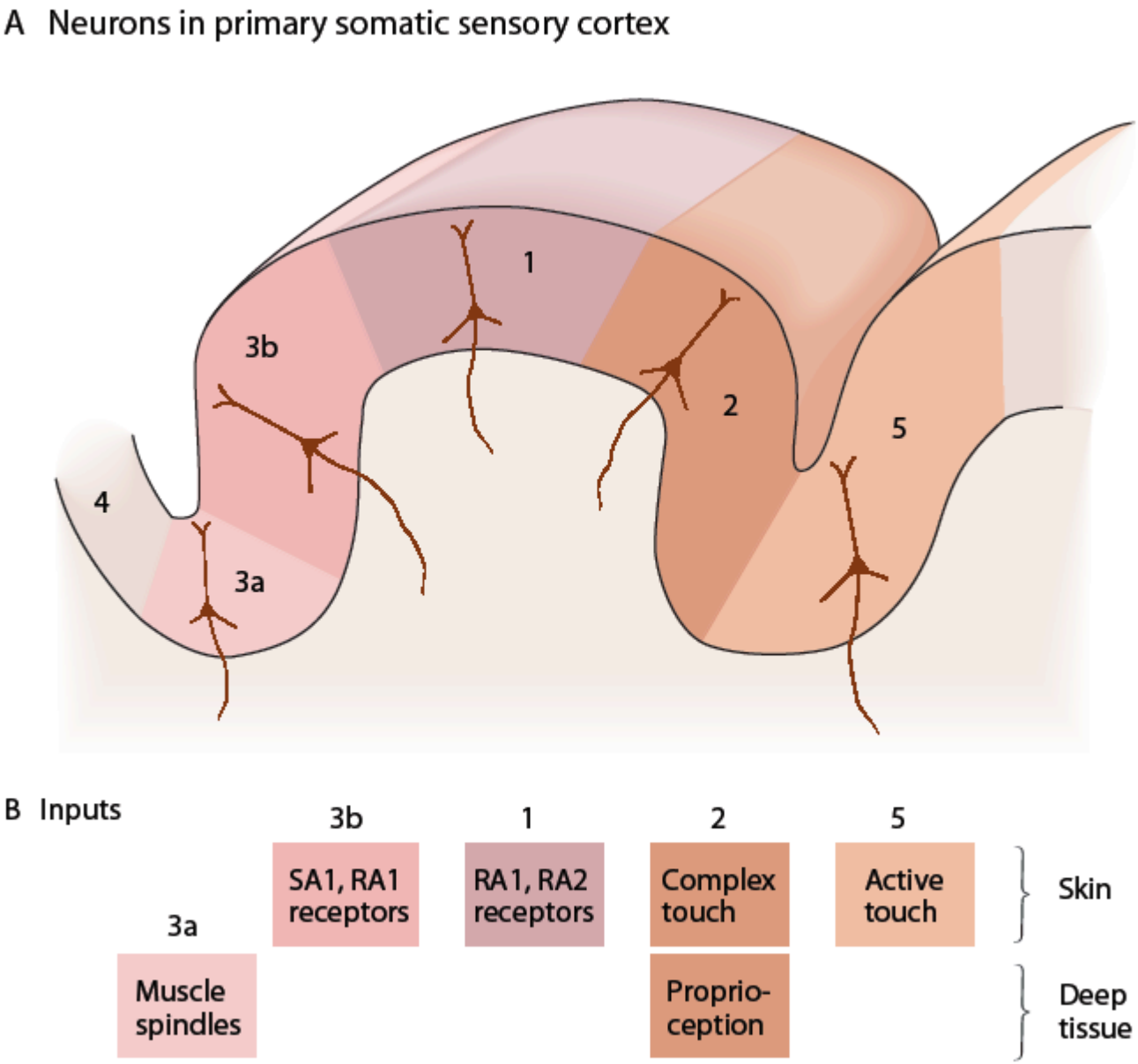


- Convergence from same receptor class (modality)
- Convergence from neighboring skin areas (stimulated together wire together)
- Arrangement selects features (e.g., edge orientation)

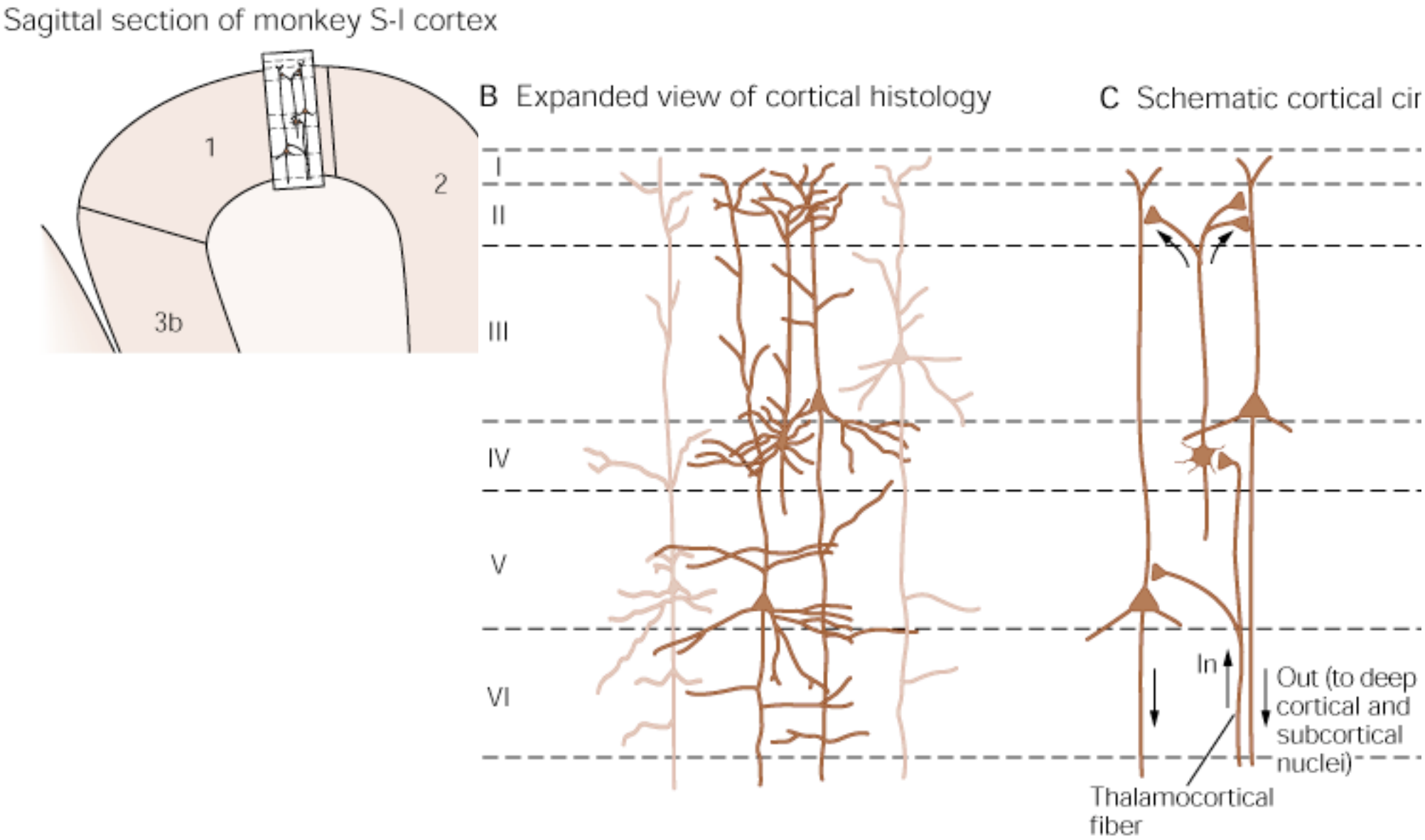
Cortical receptive fields enlarge at each synapse



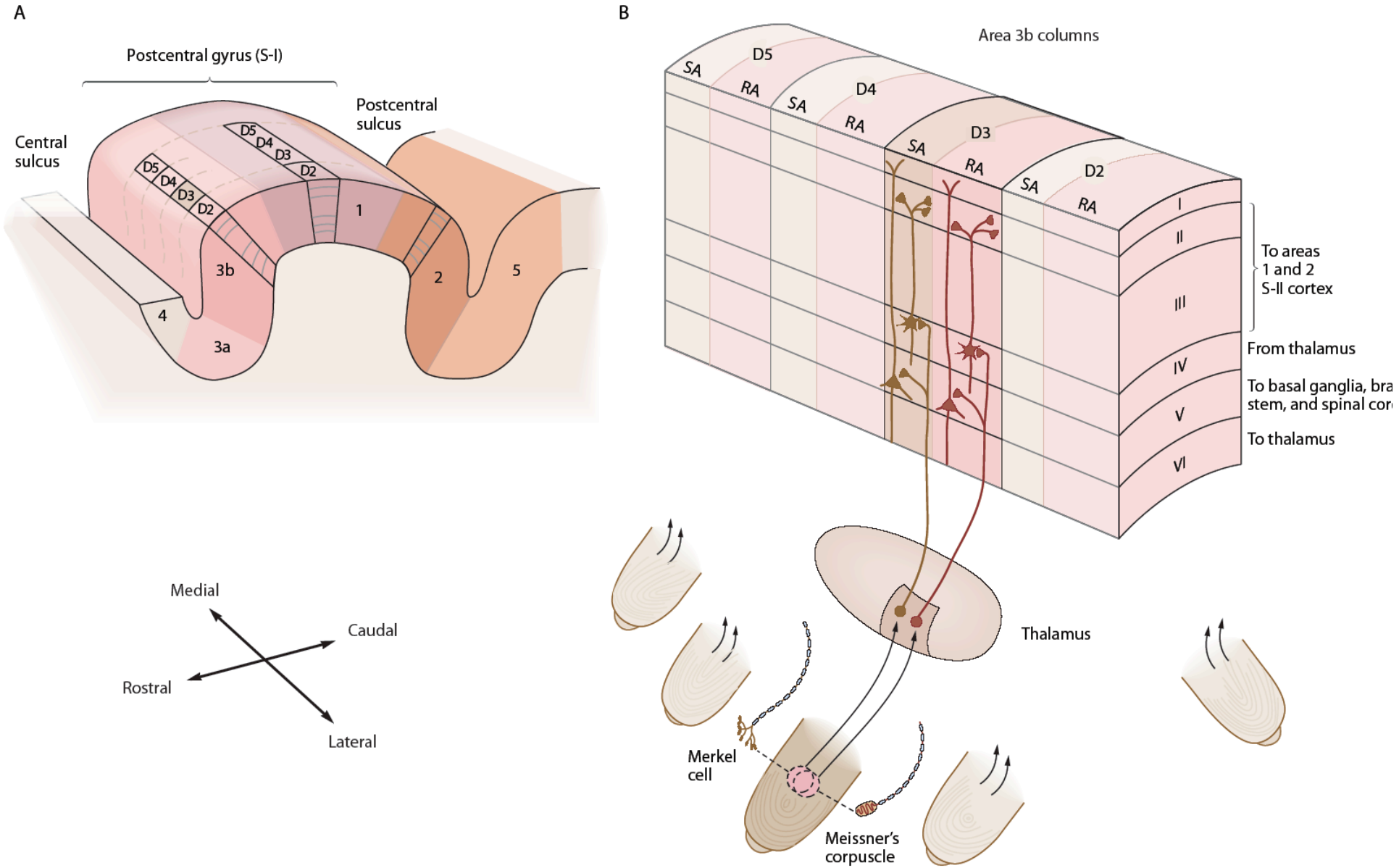
S-I neurons receive inputs from specific modalities



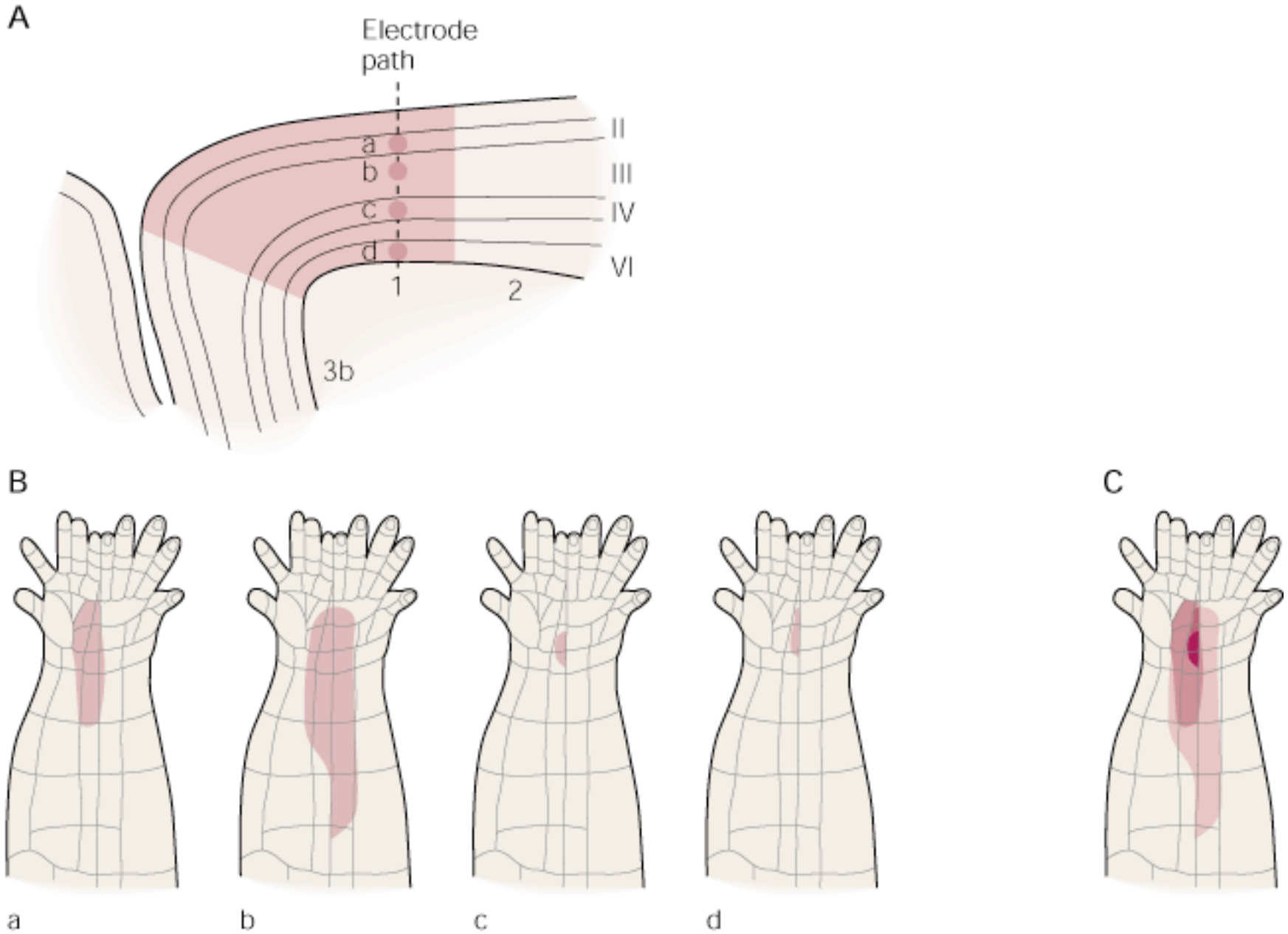
Information is processed in columns of cortical neuro



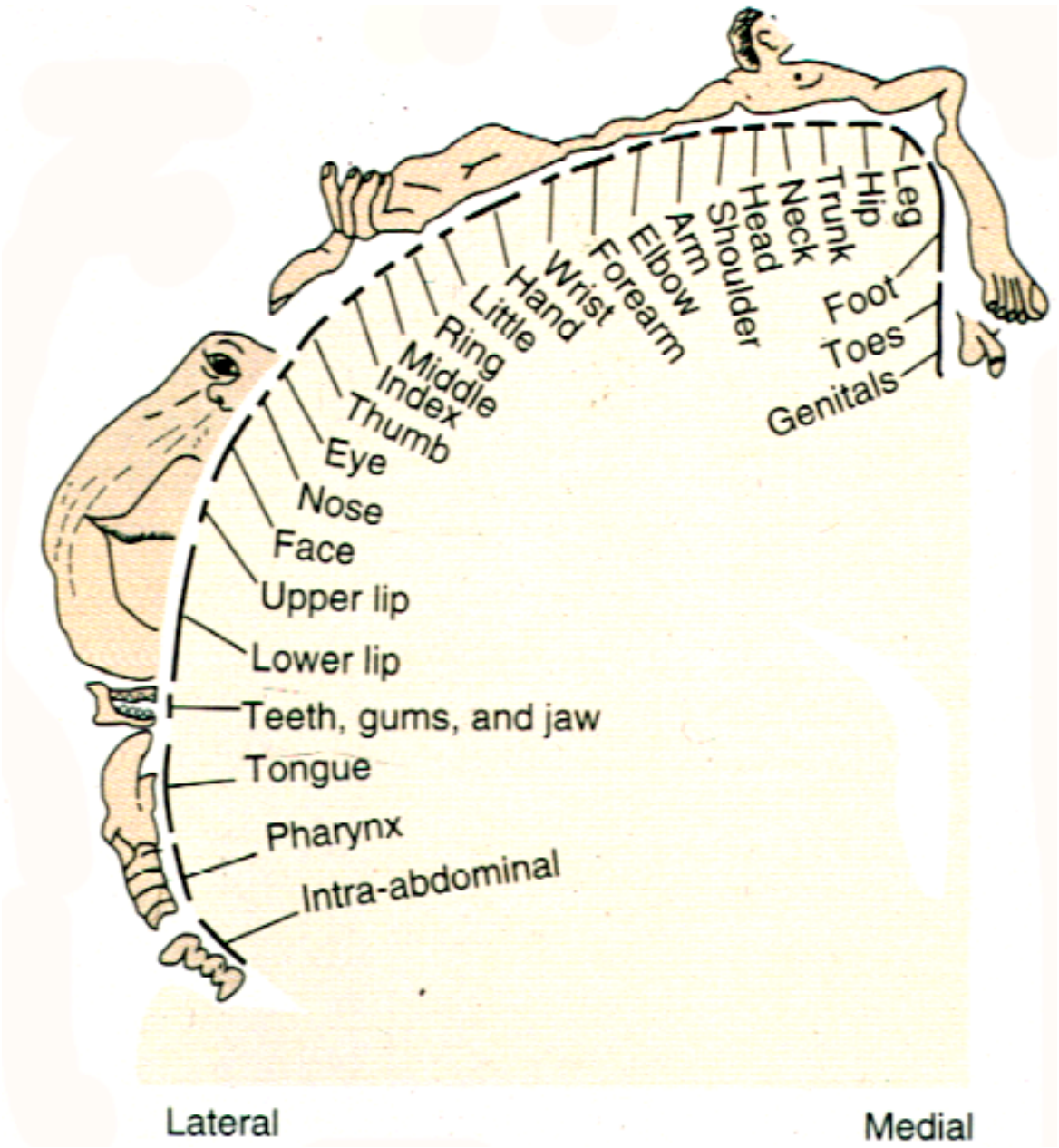
Columnar organization of the cortex



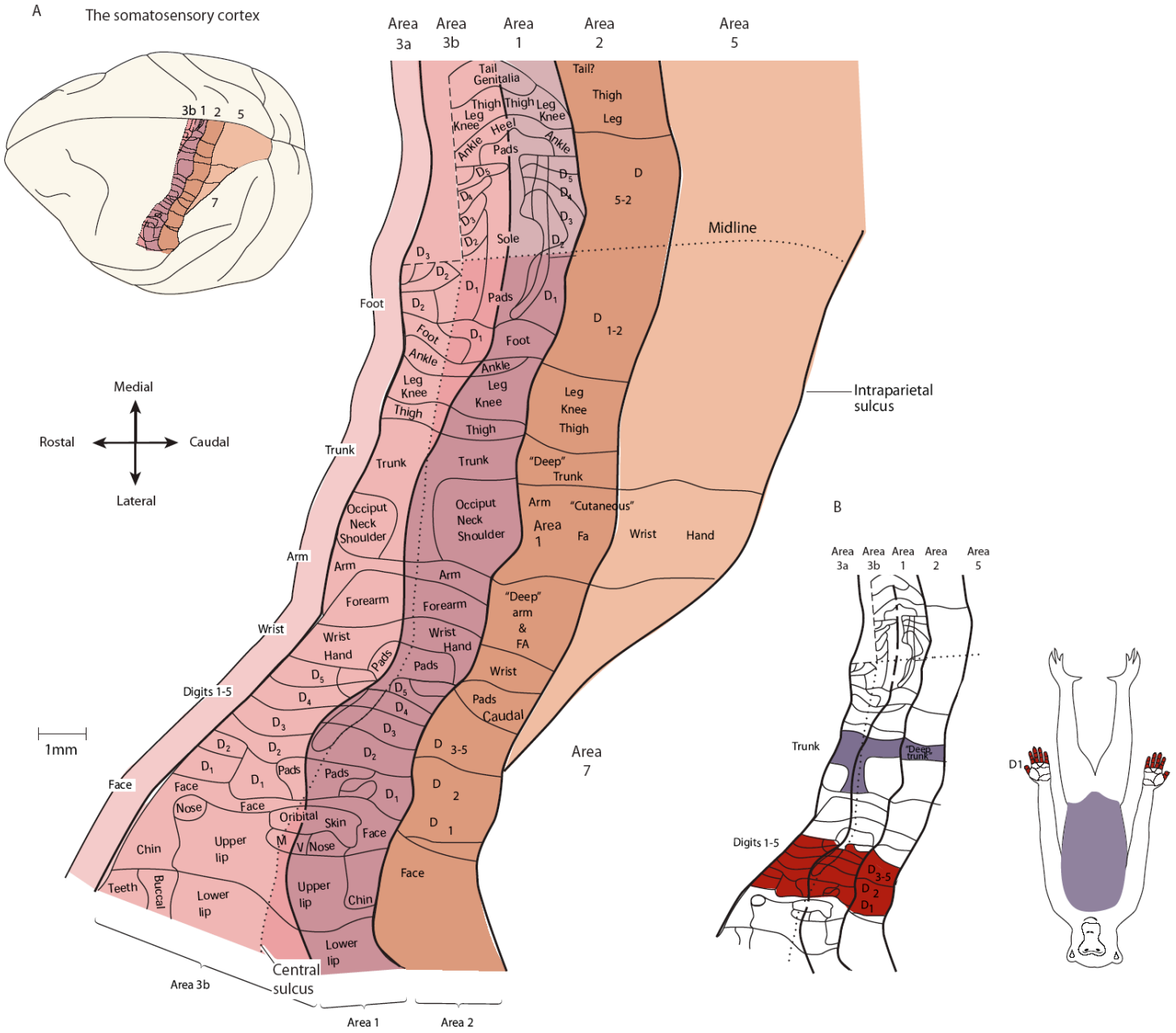
Receptive fields in a cortical column overlap



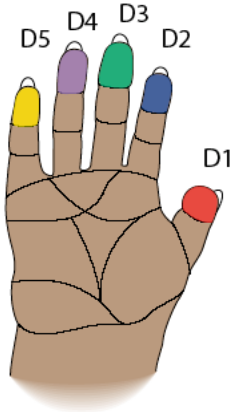
Orderly maps of the body in the brain (homunculus)

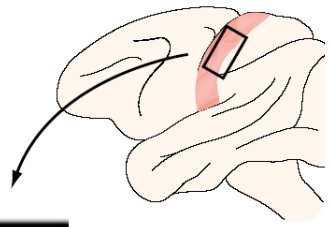


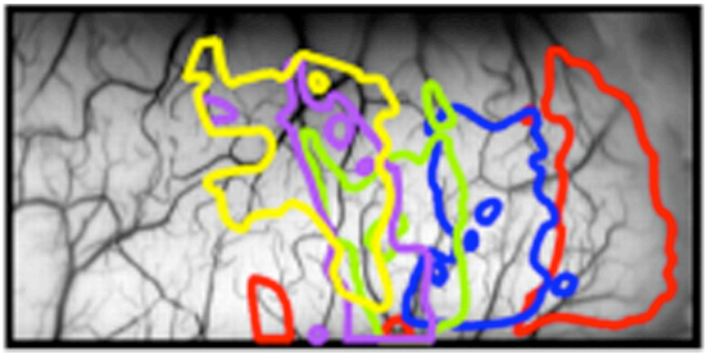
Brain maps reflect innervation density

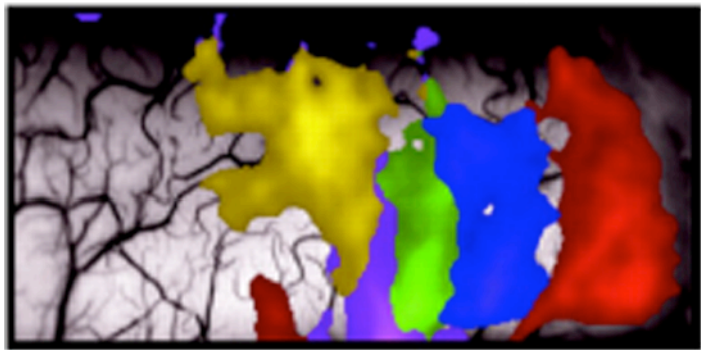


Optical imaging of brain maps in monkeys

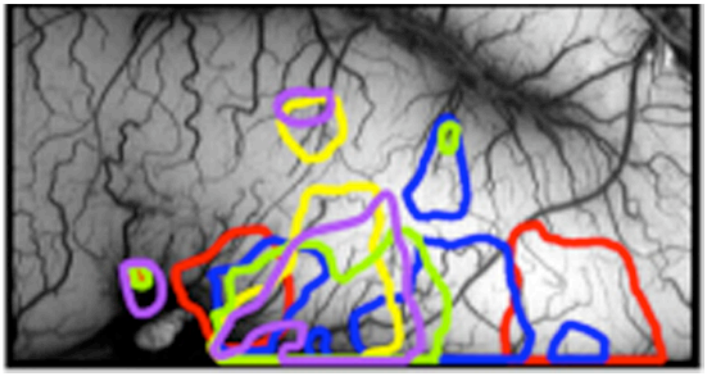


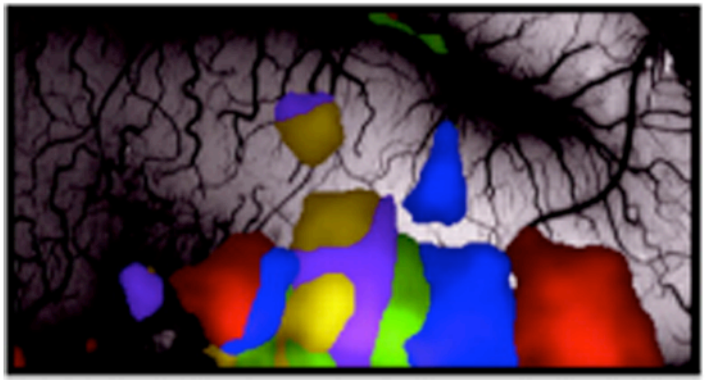




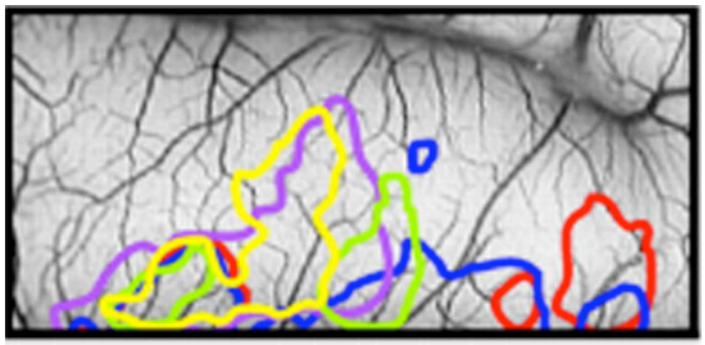


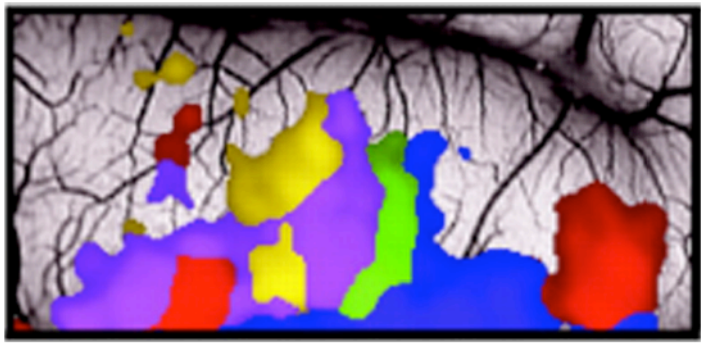
Subject 1





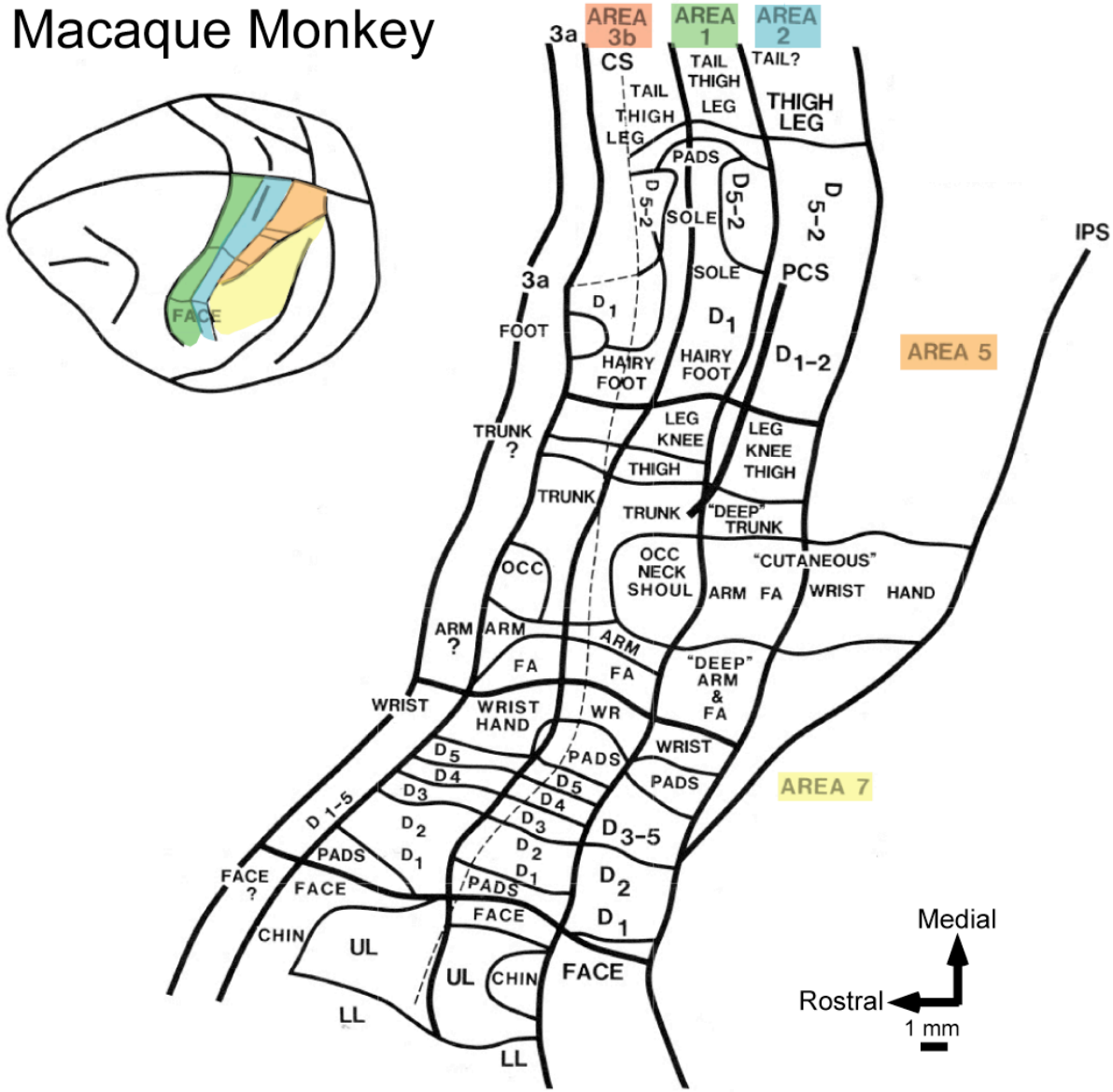
Subject 2



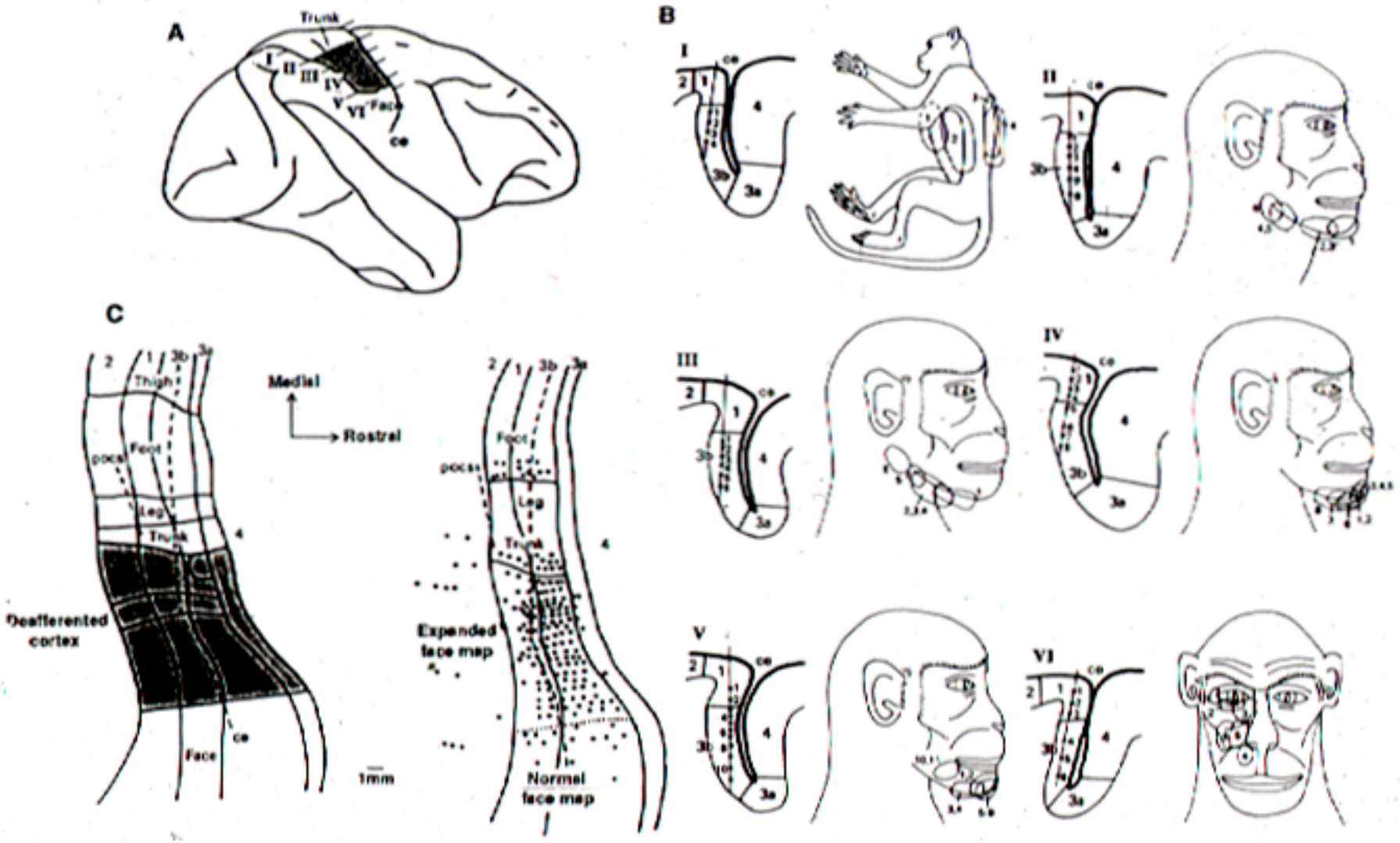


Subject 3

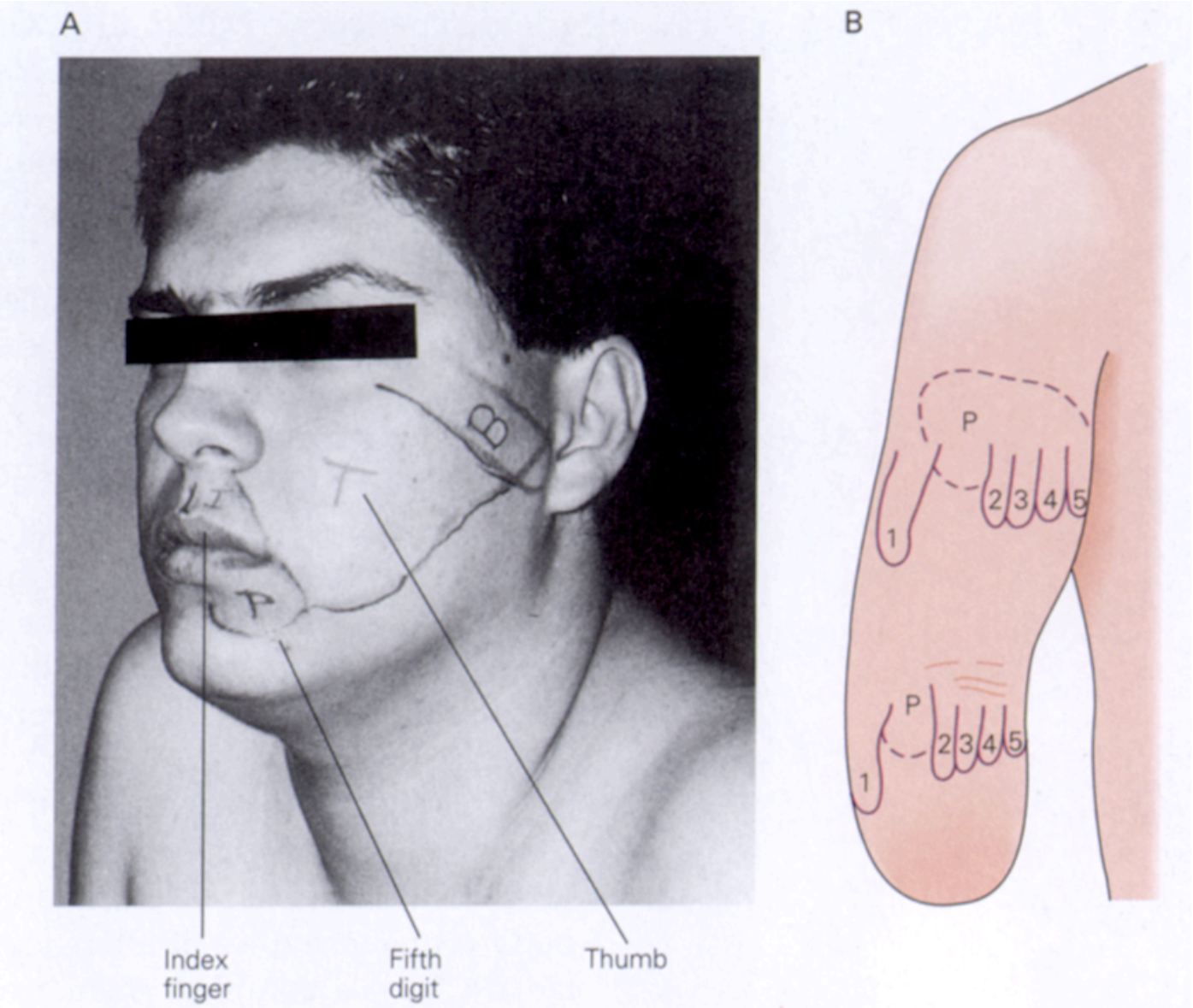
The hand is represented between the arm and face



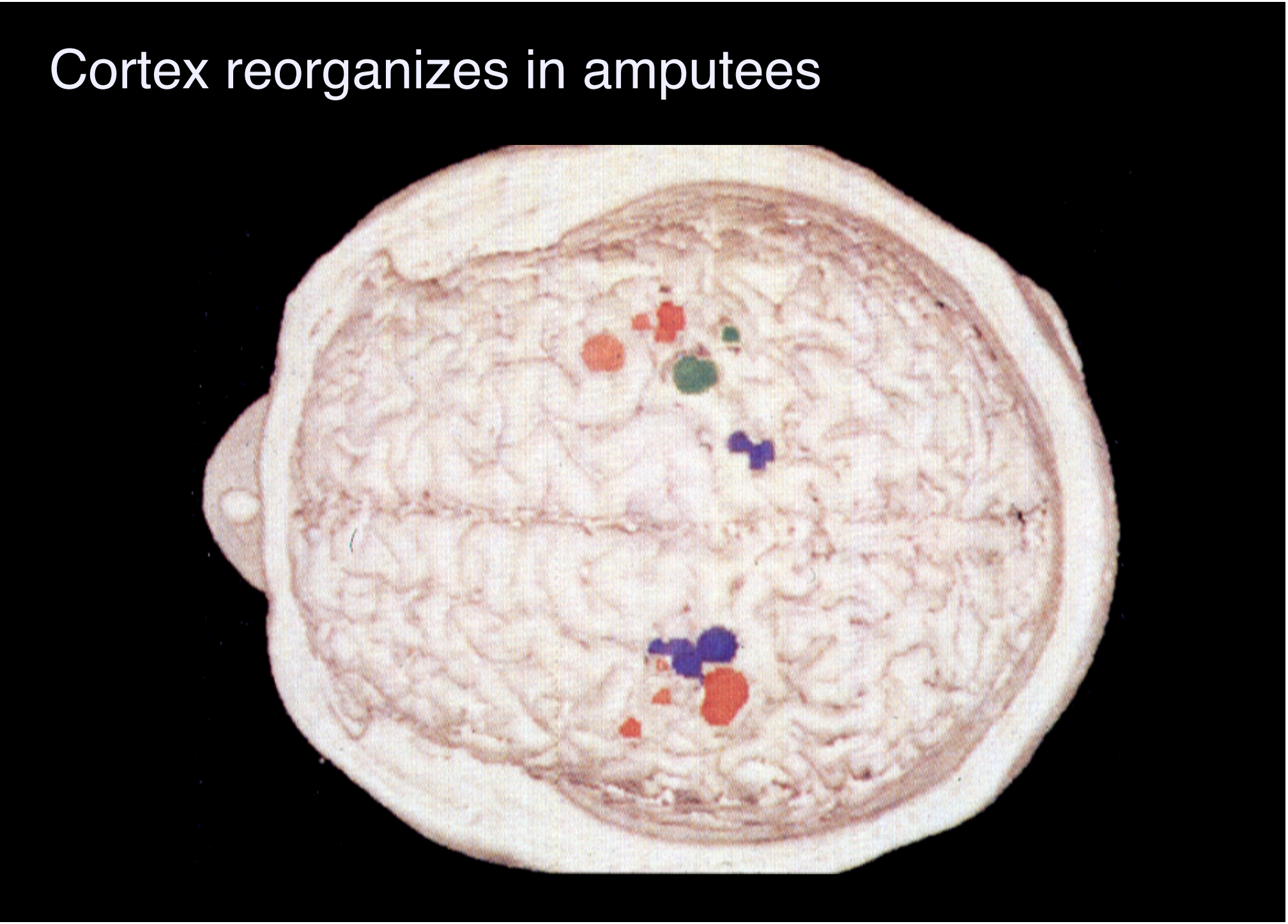
Cortical maps are altered by experience



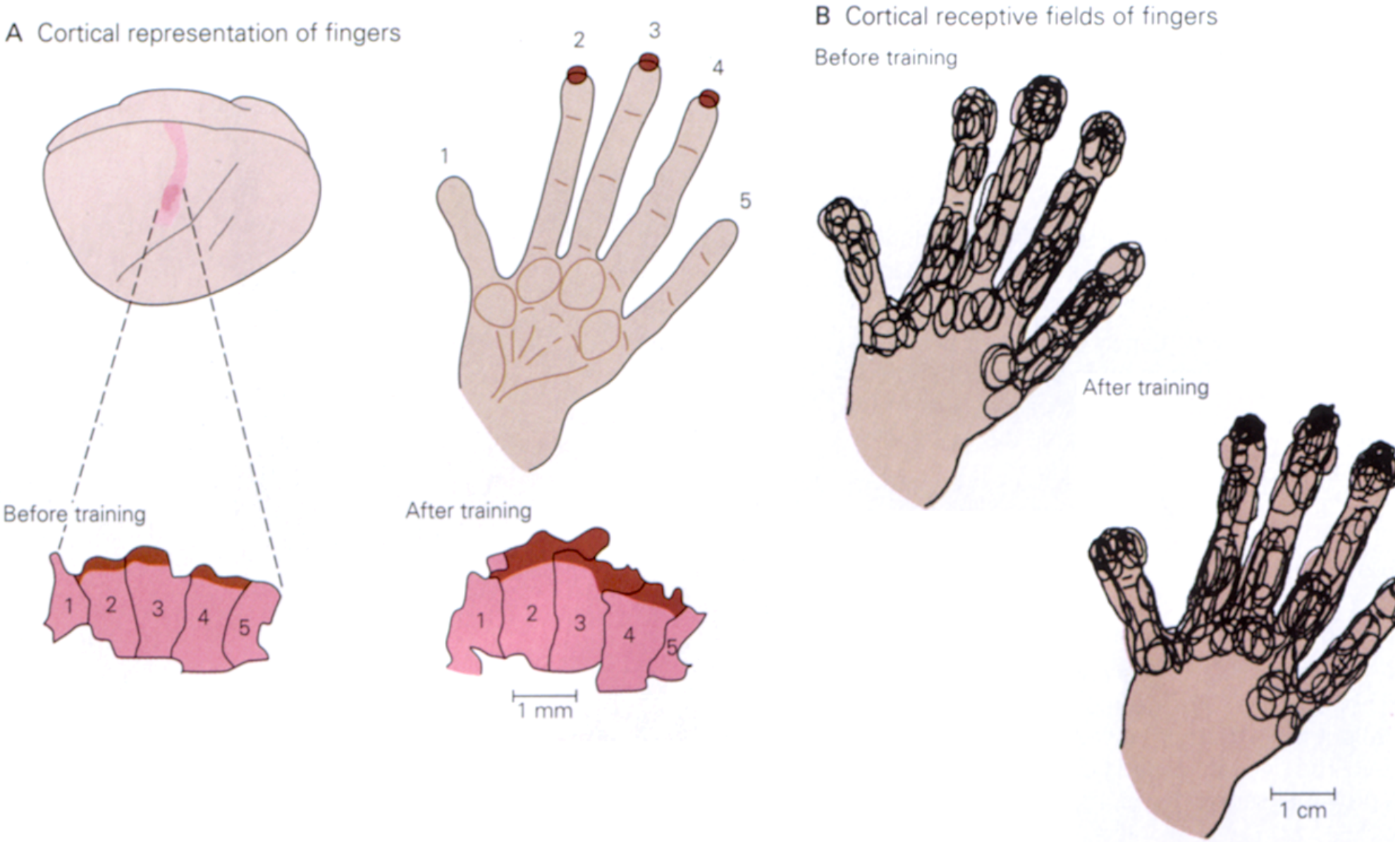
Amputees experience phantom sensations



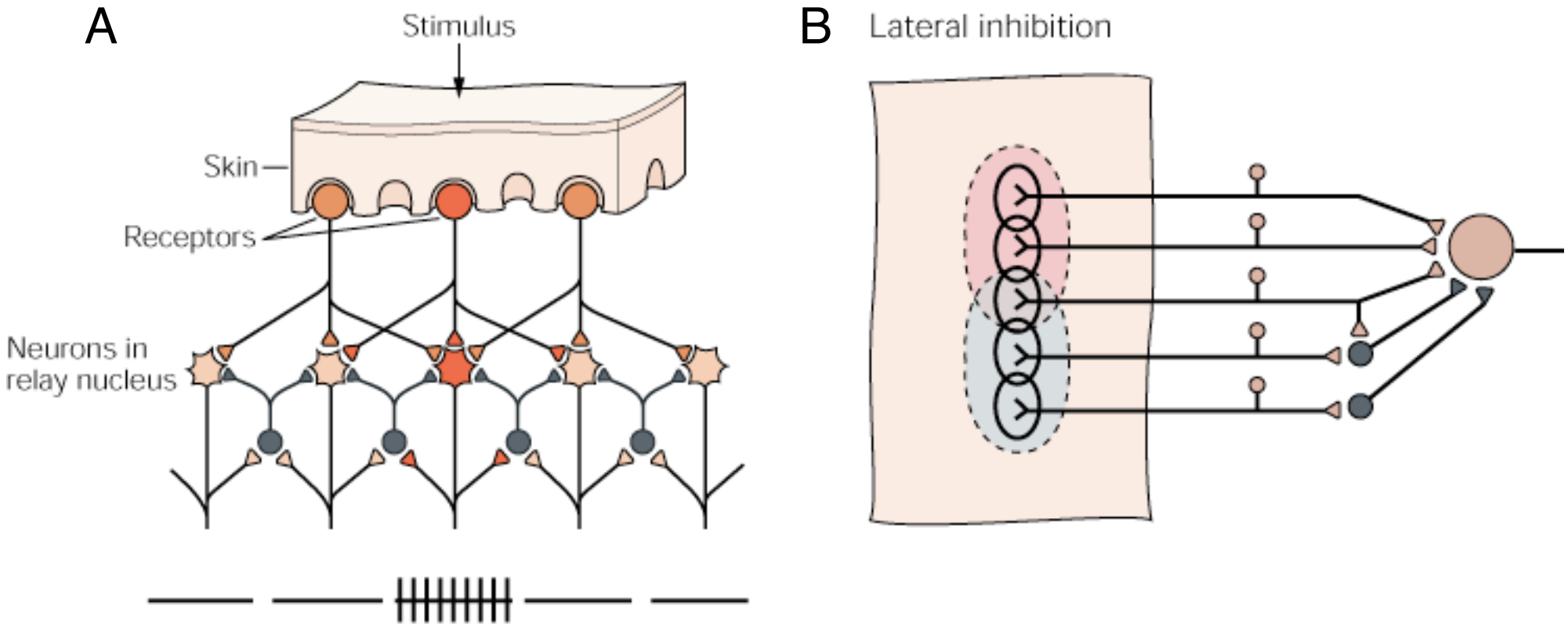
Cortex reorganizes in amputees



Learning alters brain maps

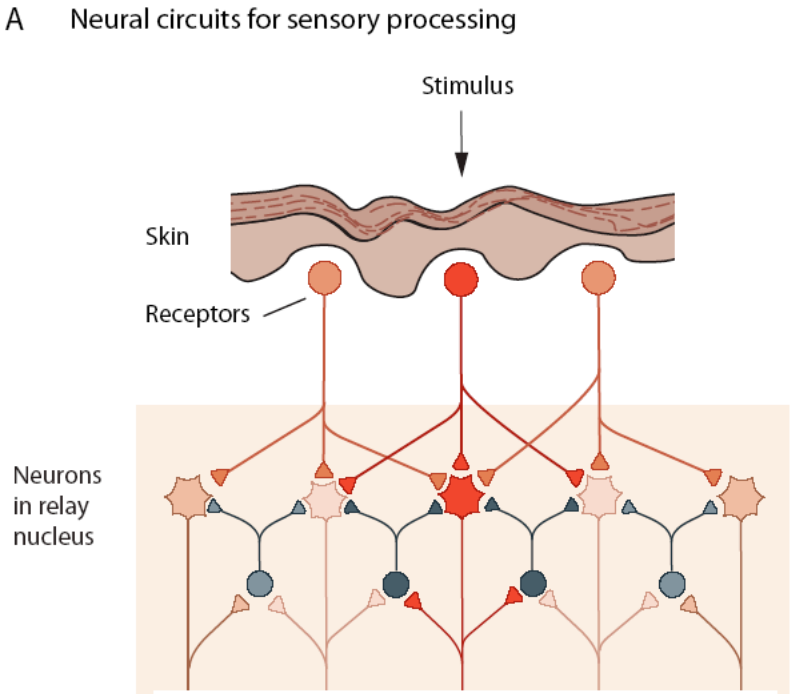


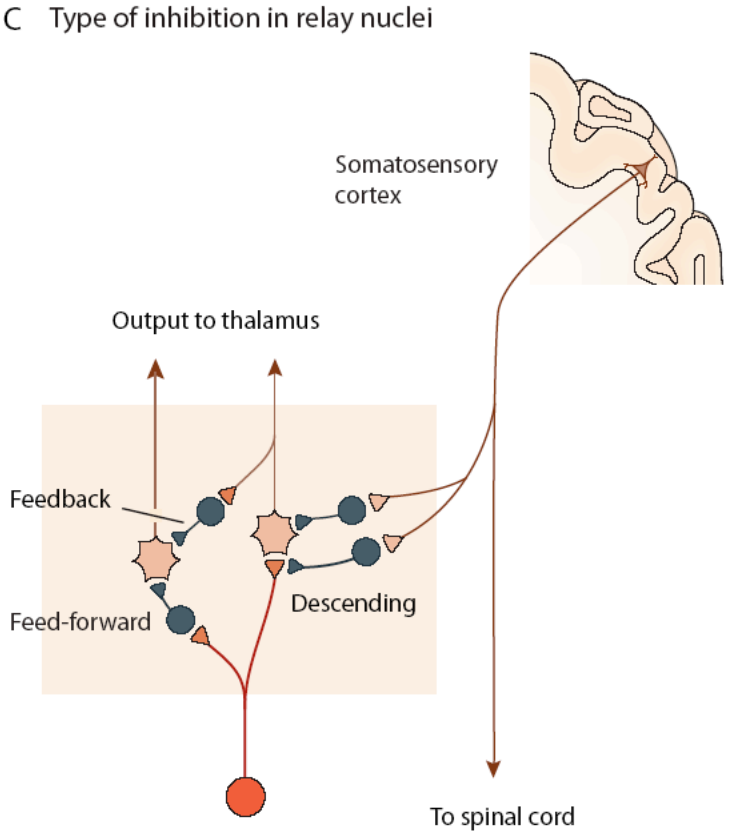
Inhibition extracts important features

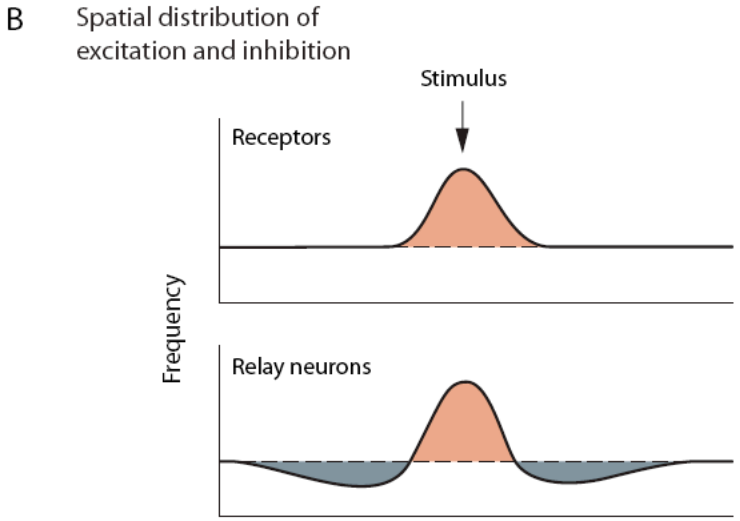


- Winner-take-all sharpening of strongest inputs (feedback inhibition)
- Order of receptor stimulation determines output (lateral inhibition)
- Higher areas can control ascending output (descending inhibition)

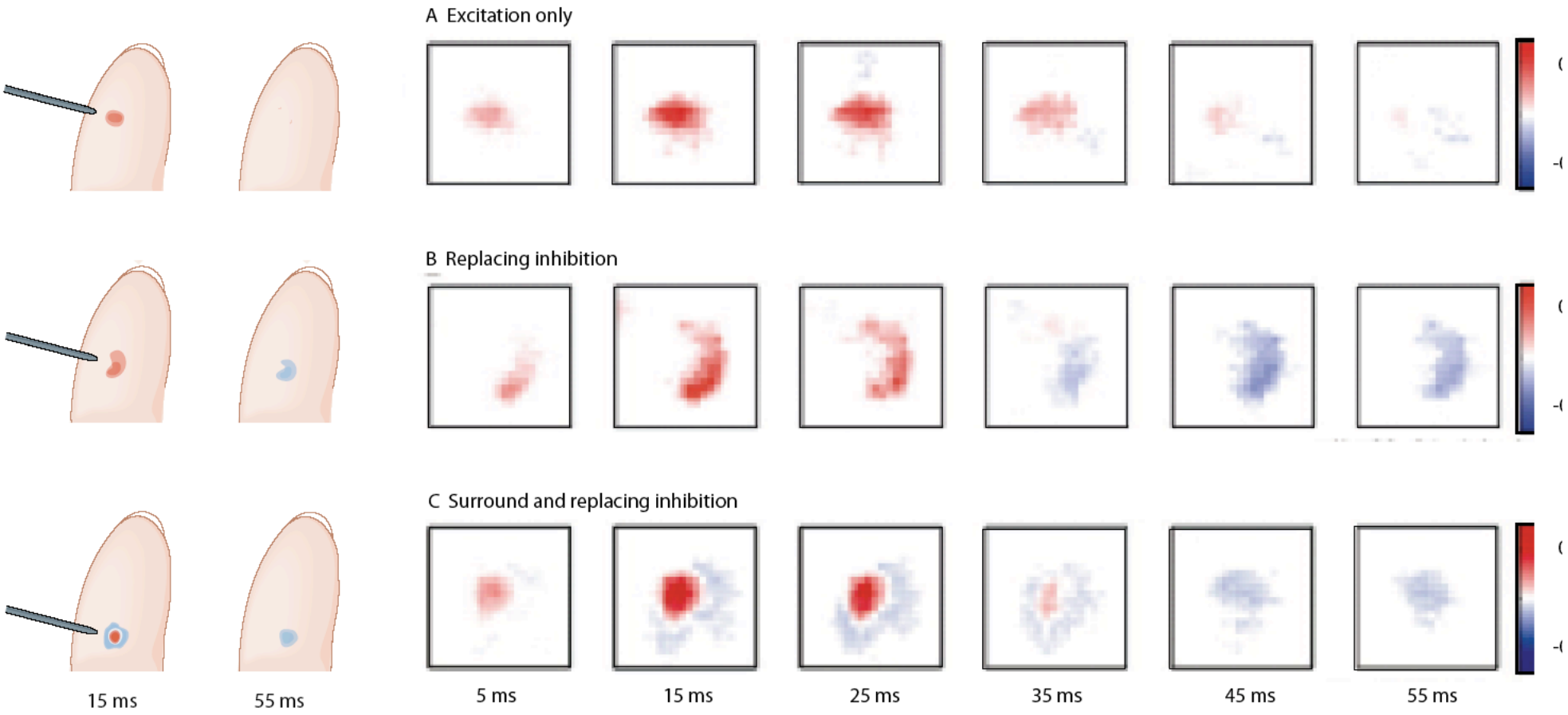
Inhibition modifies receptive fields





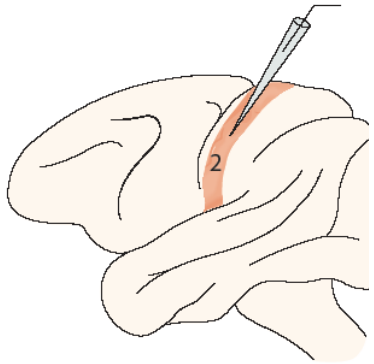


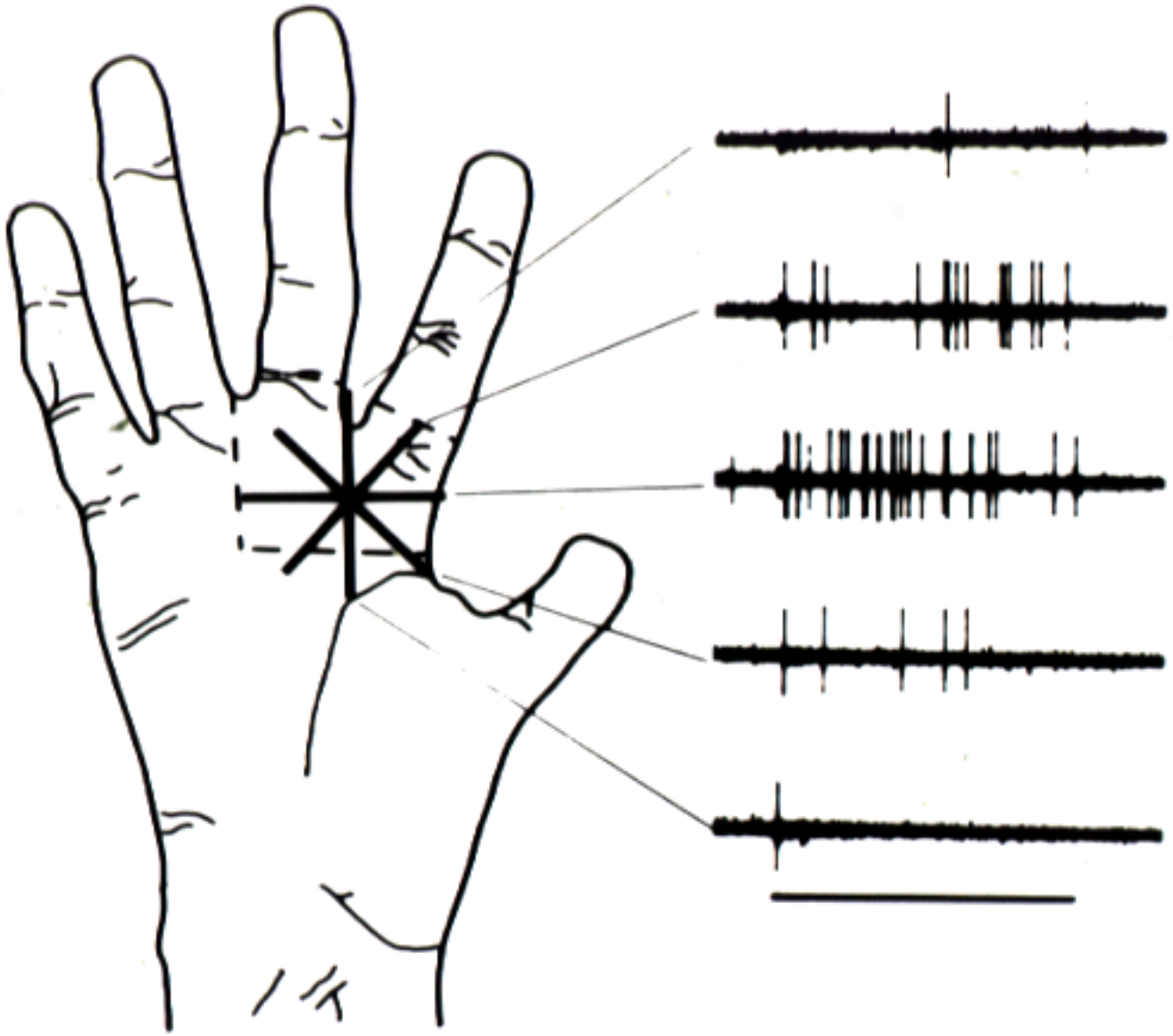
Cortical spatiotemporal receptive fields



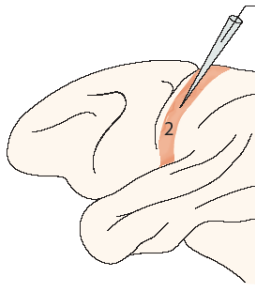
Reverse correlation used to study touch

Orientation selective neuron (Area 2)

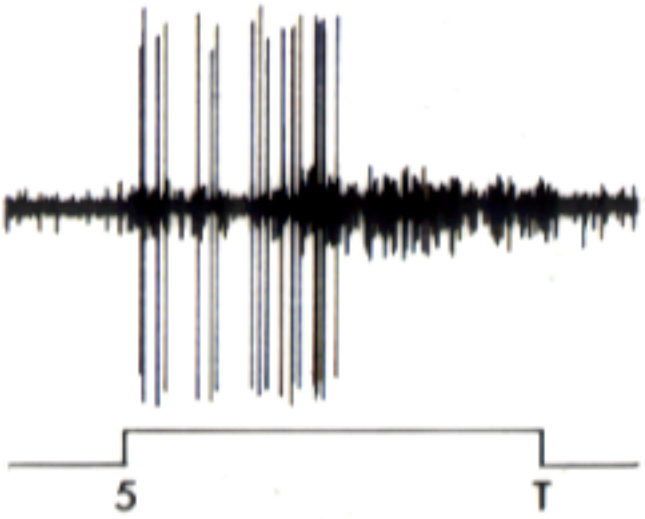




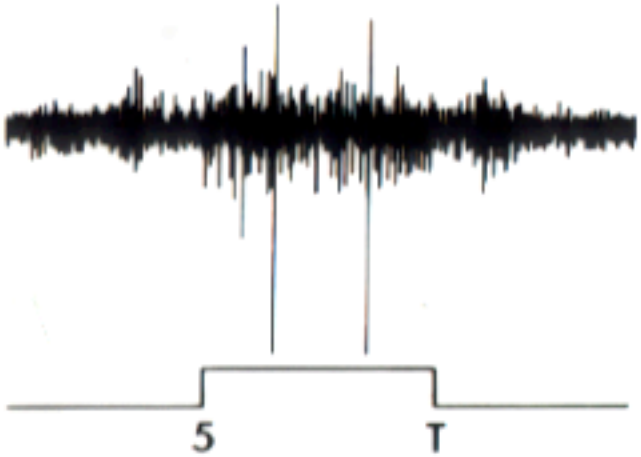
Direction sensitive neurons (Area 2)

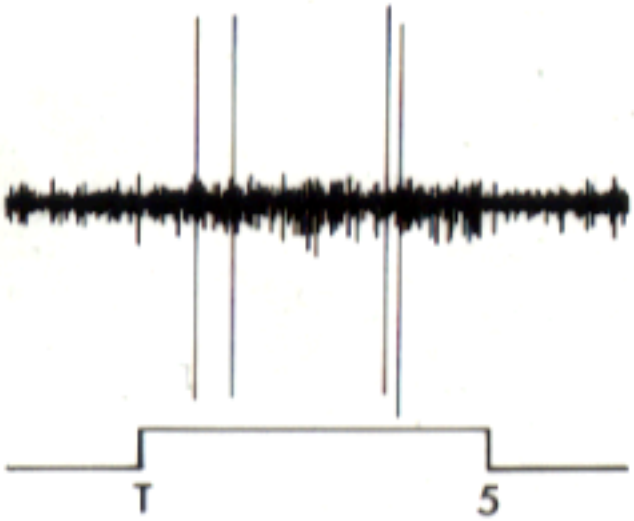


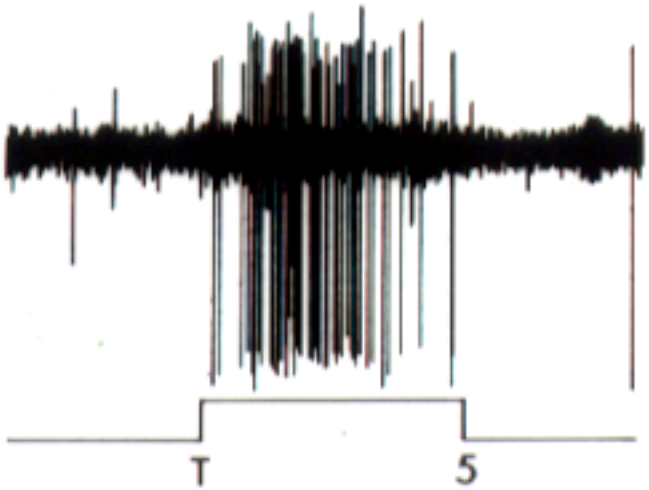
UNIT 9–6



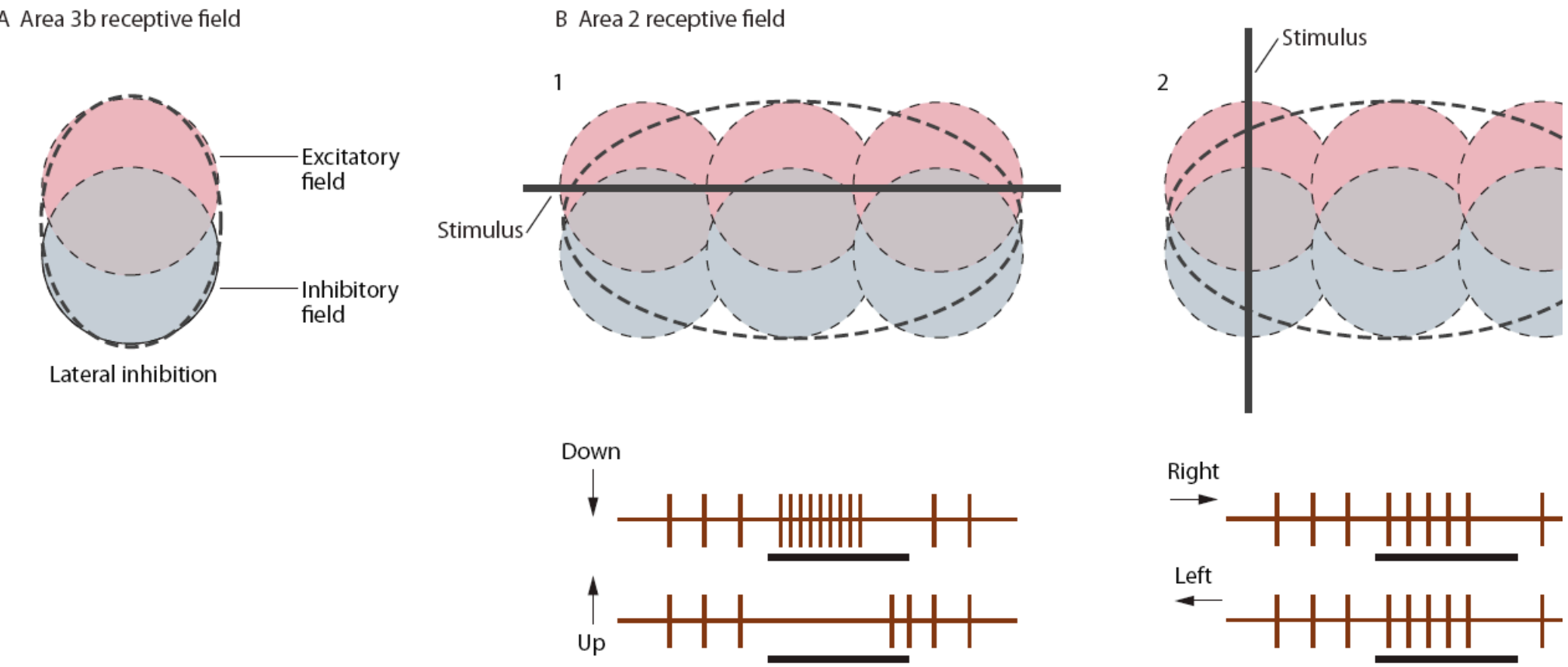
UNIT 9–7







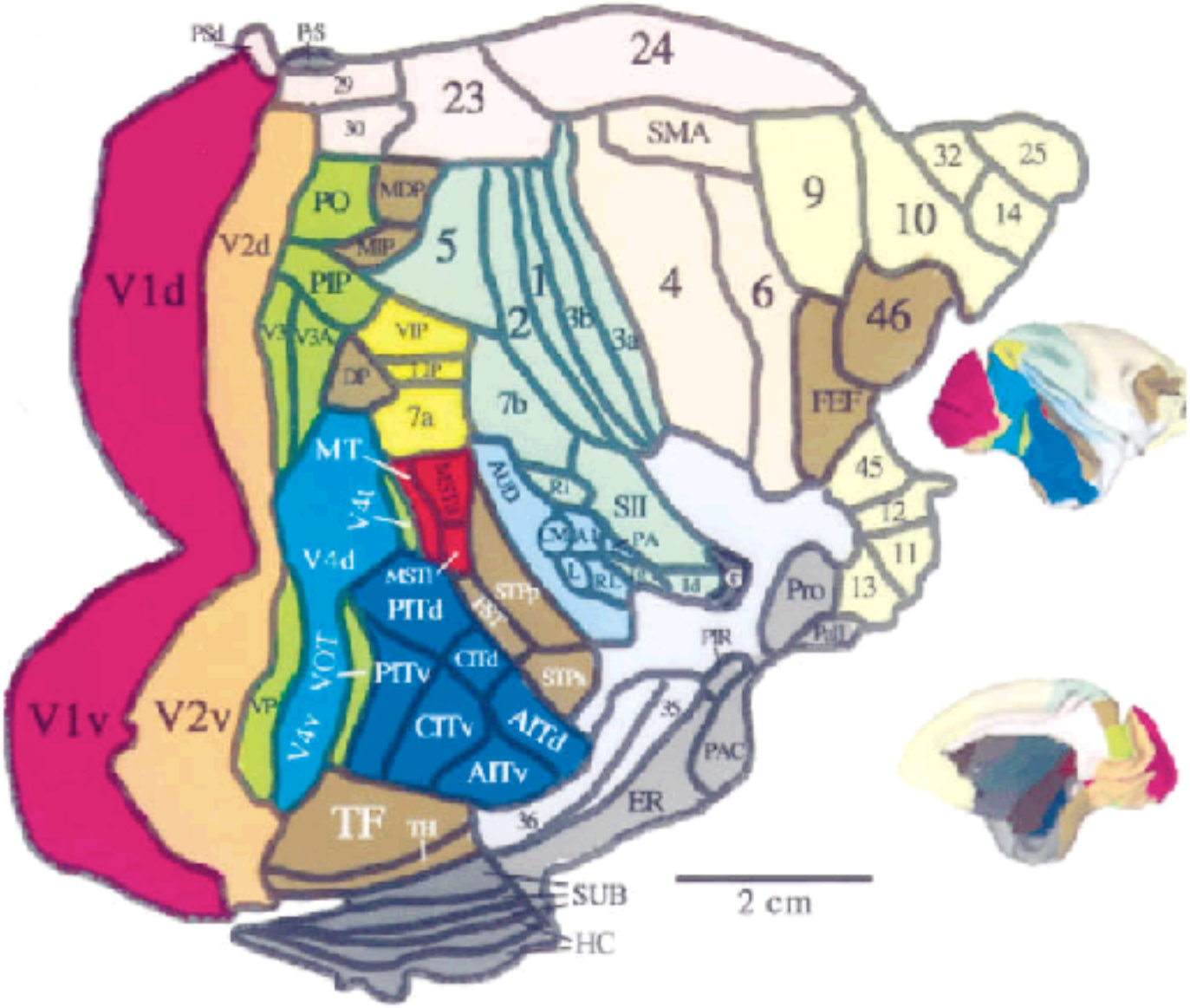
Convergence patterns enable feature detection

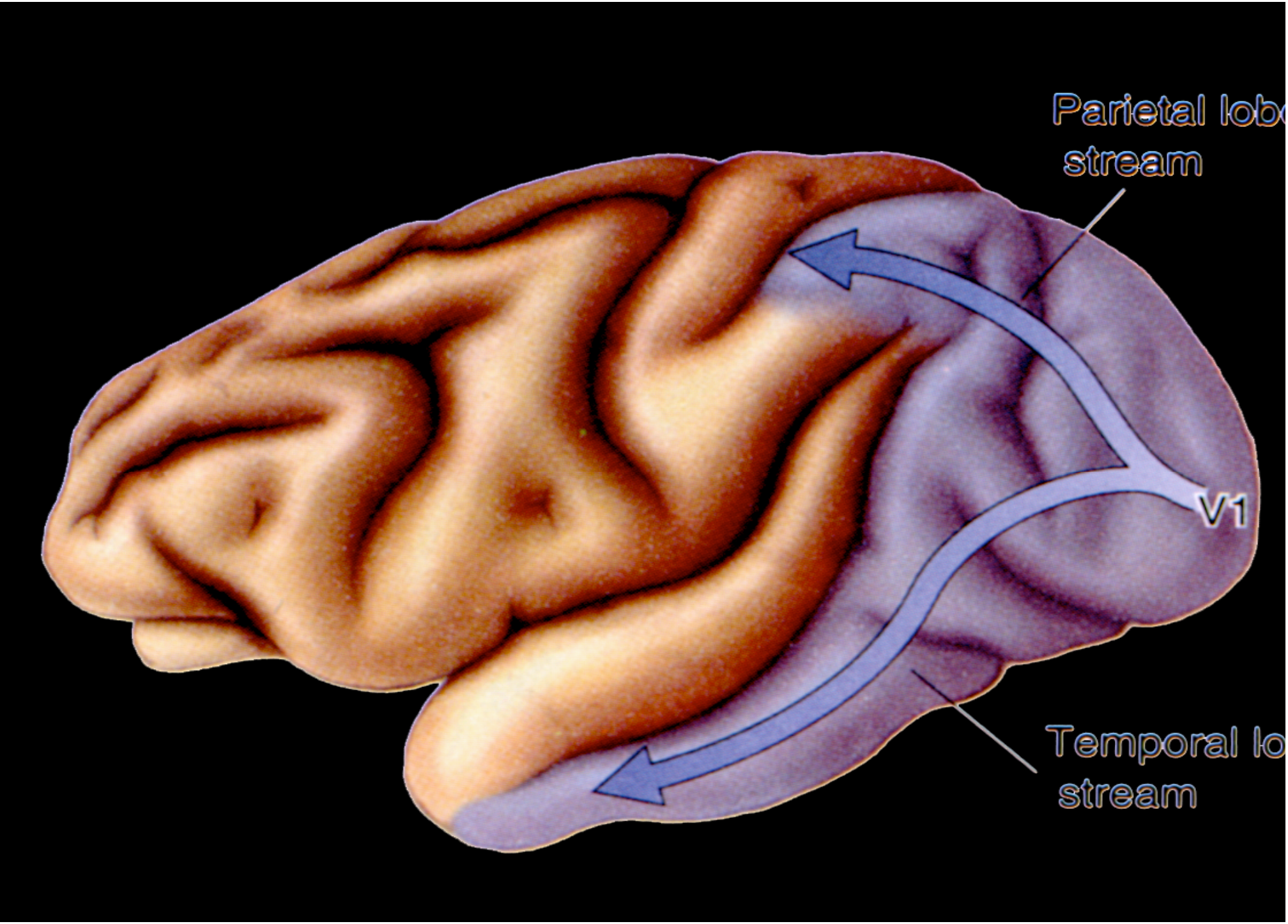


Information Processing in Cerebral Cortex

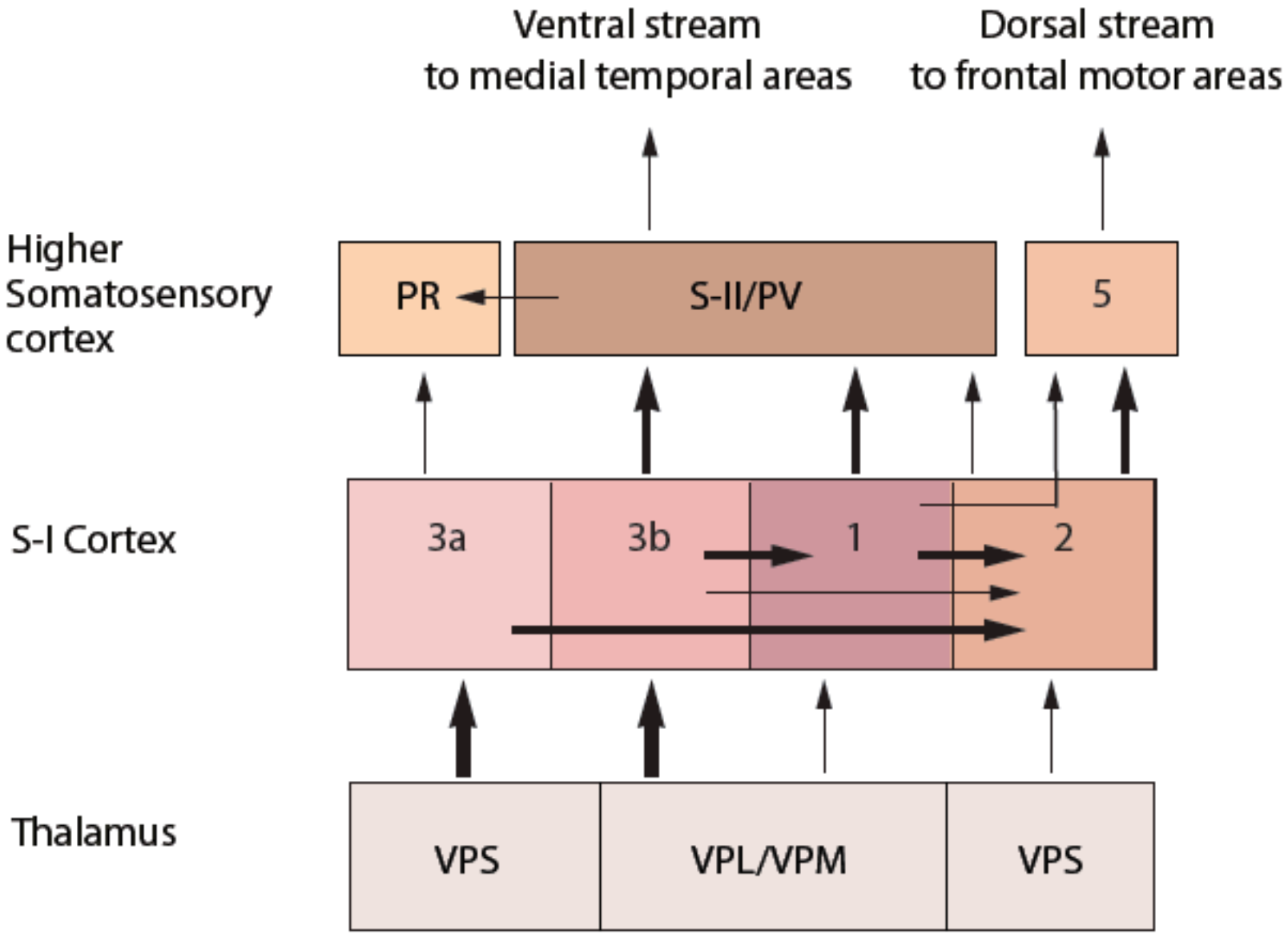
- Bottom up: Receptors encode stimuli
  1. *What:* the sensory modality
  2. *Where:* position in space or body
  3. *Intensity:* stimulus amplitude
  4. *Duration:* persistence or adaptation
- Top down: Information interpreted in context
  1. *Memory:* previous encounters and learning
  2. *Attention:* selection of features relevant to task
  3. *Circuitry:* structure of pathways and synapses
  4. *Motivation:* emotional connotation

Multiple Cortical Areas for Touch




Parietal lobe
stream
V1
Temporal lo
stream

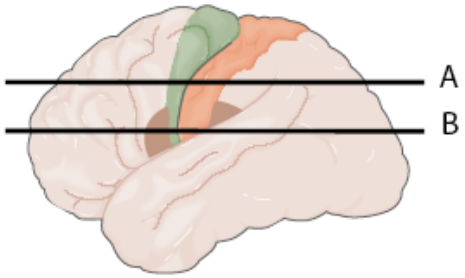
Anatomical Projections to and from S-I Cortex



Cognitive Touch: Object Identification

- Stereognosis: identification by touch
- Integration of features detected by receptors
- Template matching: compare features to previous examples
- Naming
  - Declarative memory
  - Template storage and modification (learning)
  - Ventral stream (hippocampus)

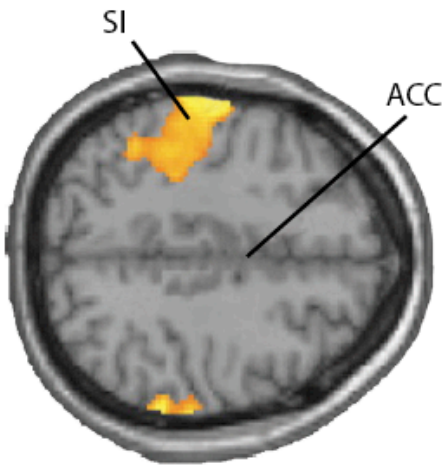
fMRI responses to passive and active touch

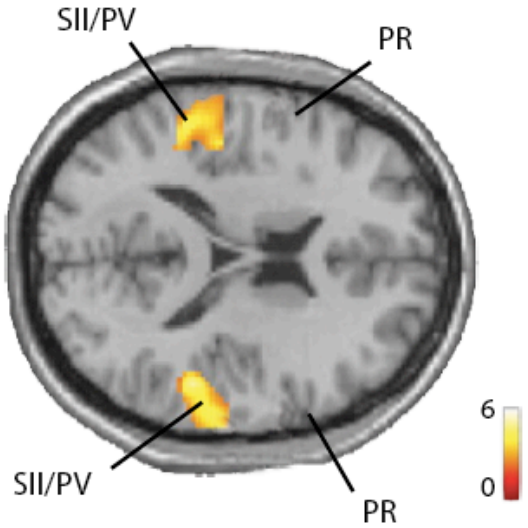


A Activity along the central sulcus (S-I)

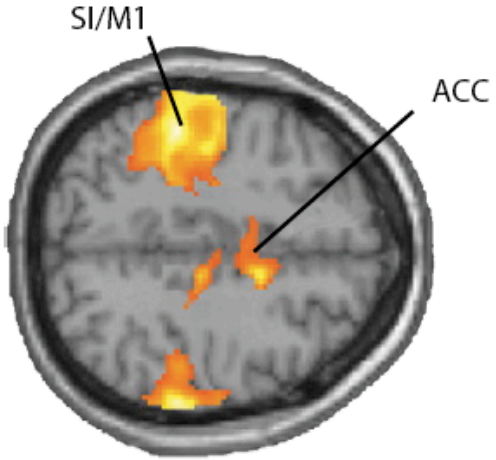
B Activity along the lateral sulcus (S-II)

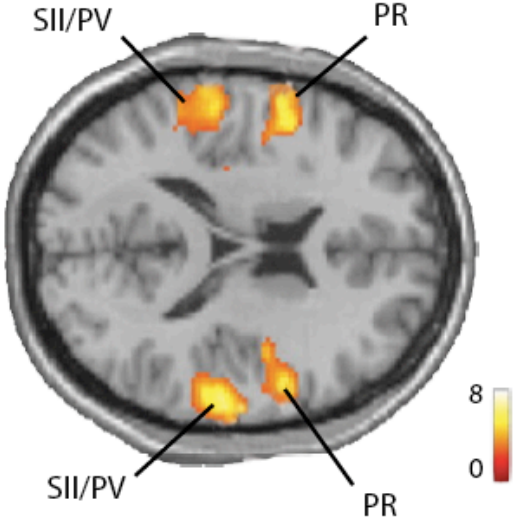
Passive touch





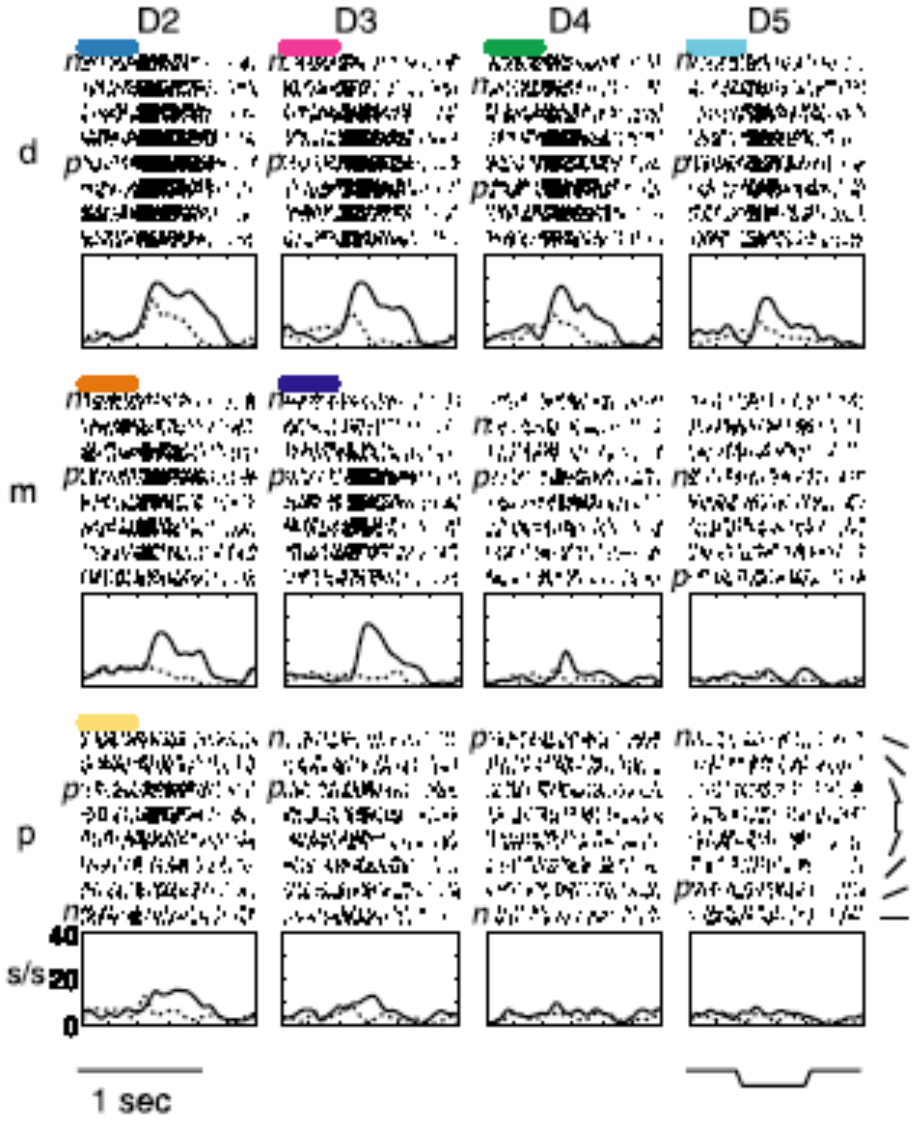
Active touch



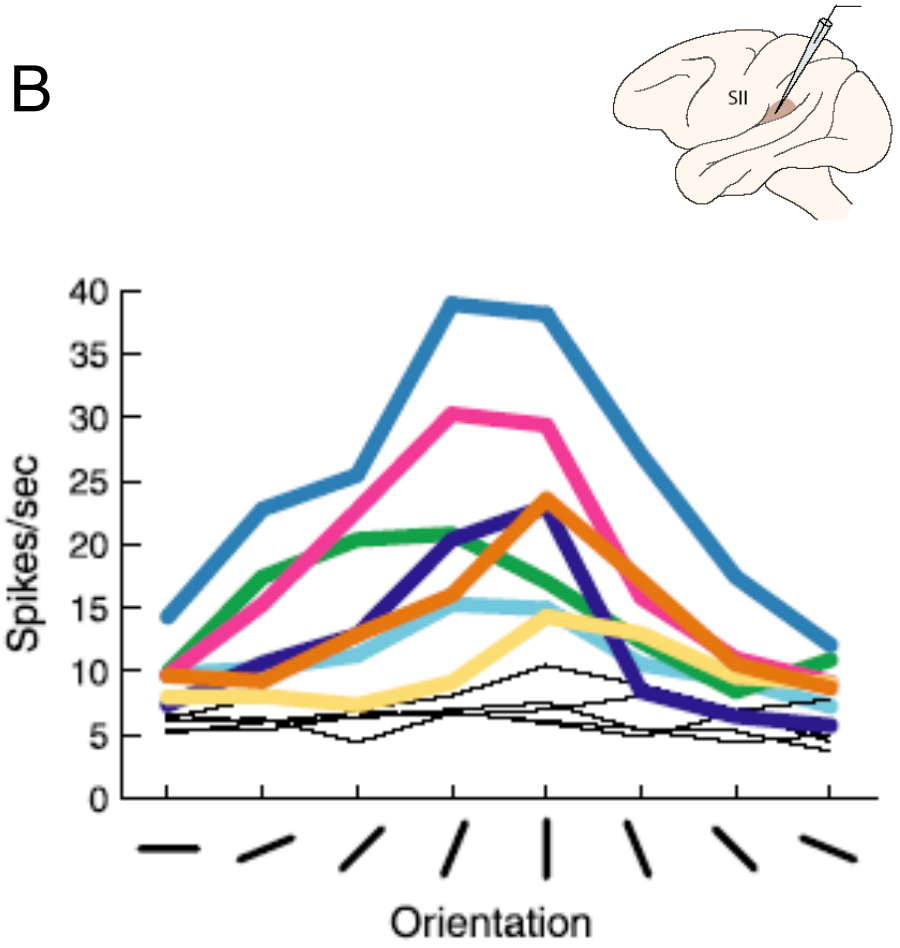


Orientation sensitive neuron detects object features

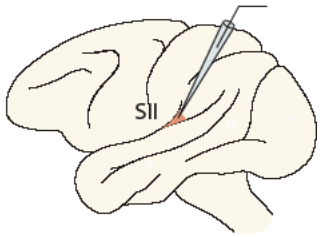
A



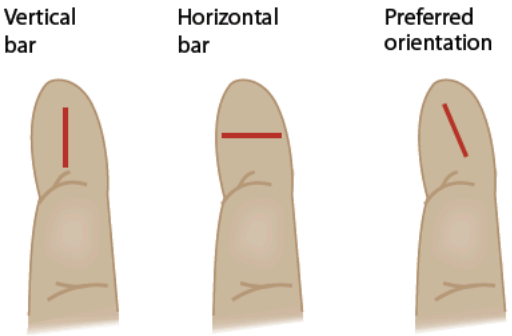
B



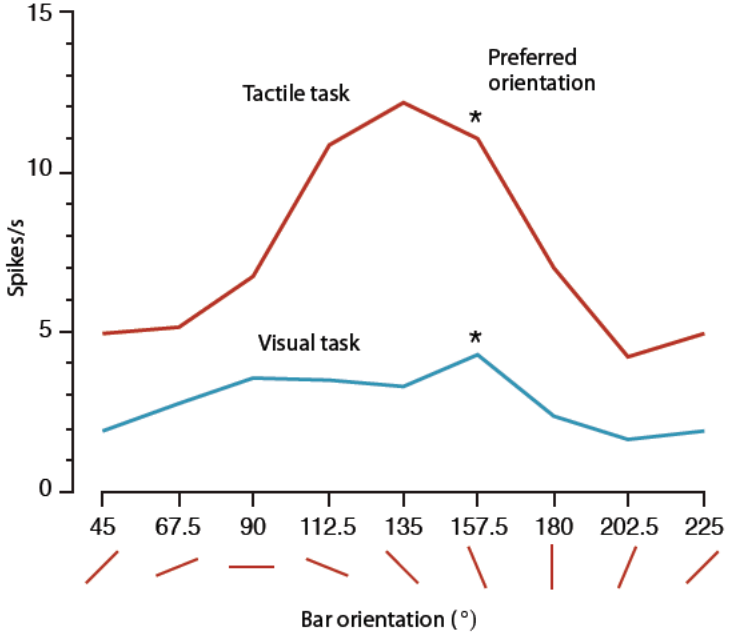
Attention modulates S-II responses



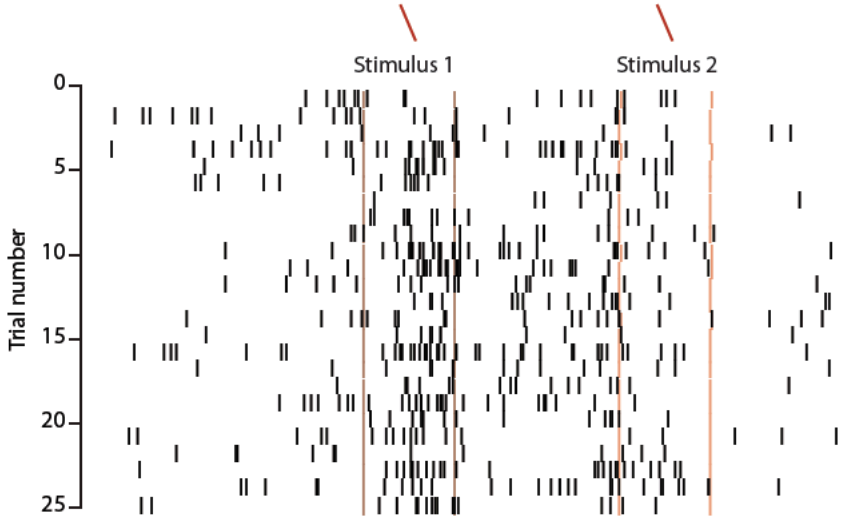
A Tactile stimuli (for both visual and tactile tasks)



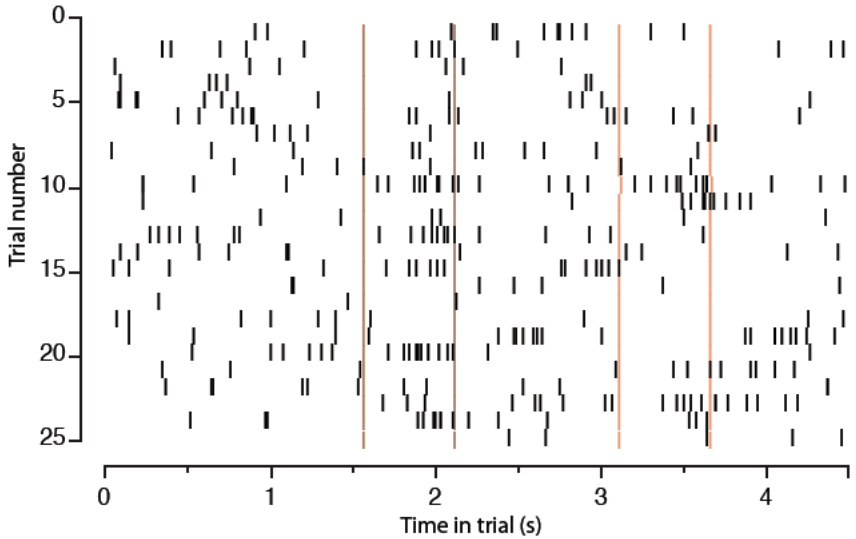
B Mean firing rate (Stimulus 1)



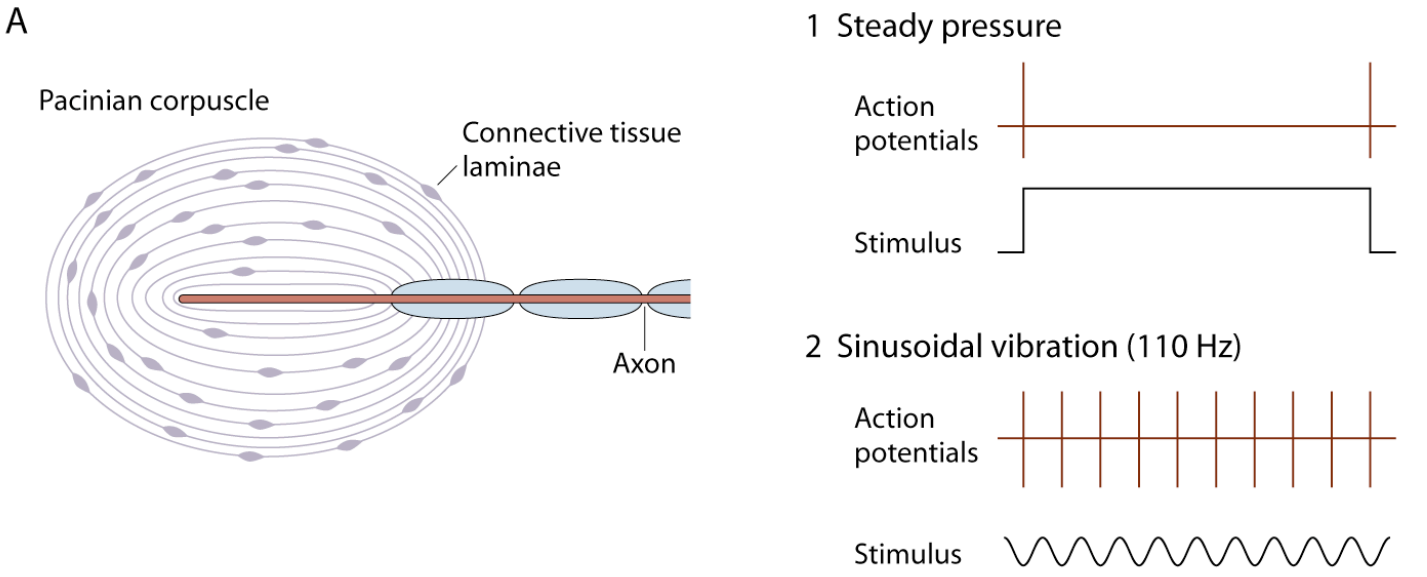
C Subject attending (tactile task)



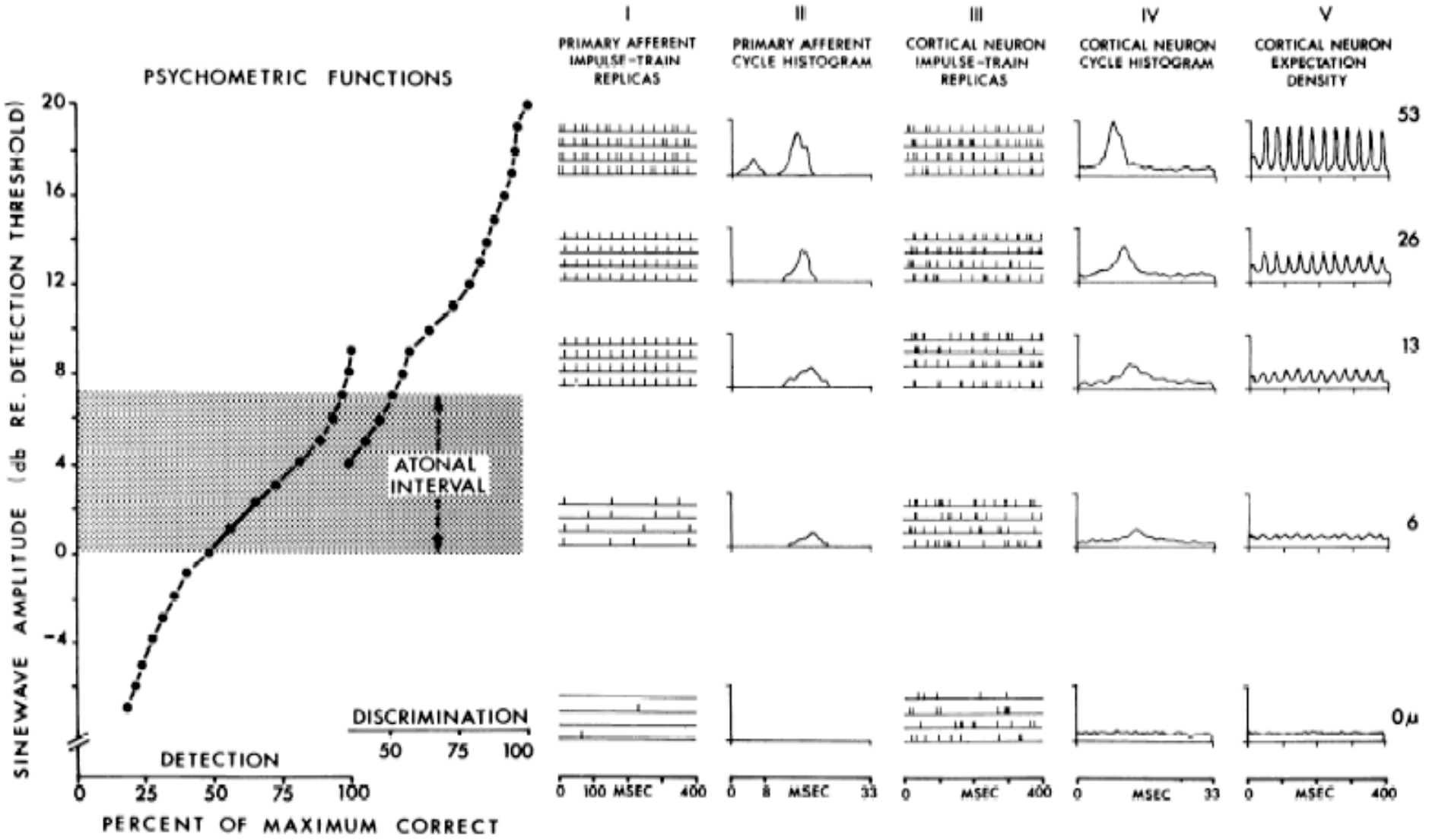
D Subject distracted (visual task)



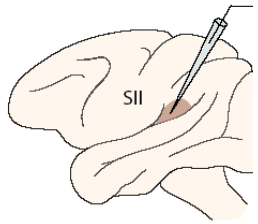
Vibration frequency is coded by firing rates

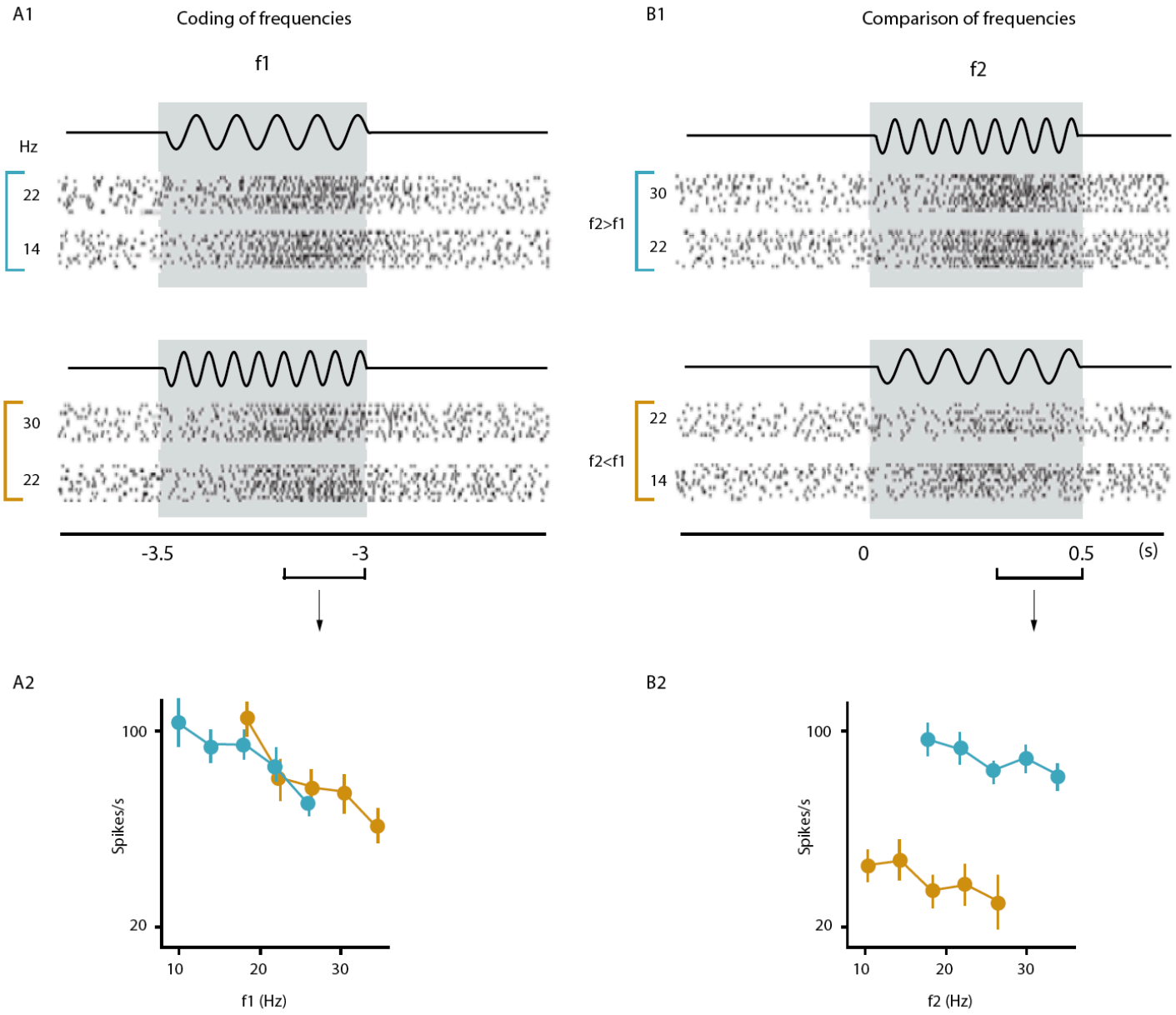


Vibration detection and discrimination



S-II integrates sensory and learned responses

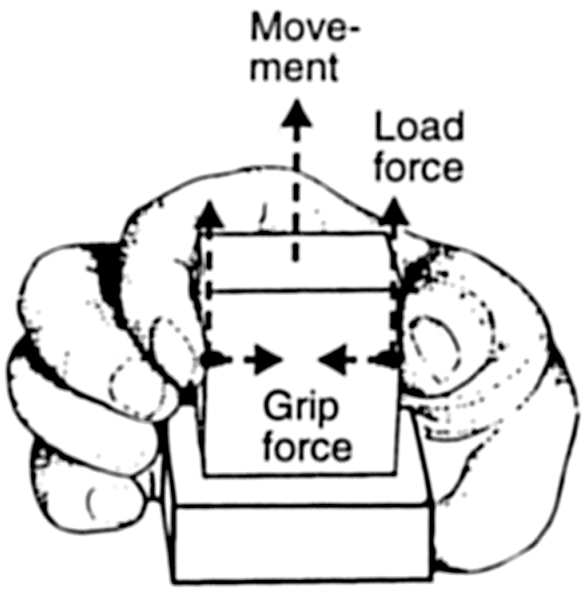


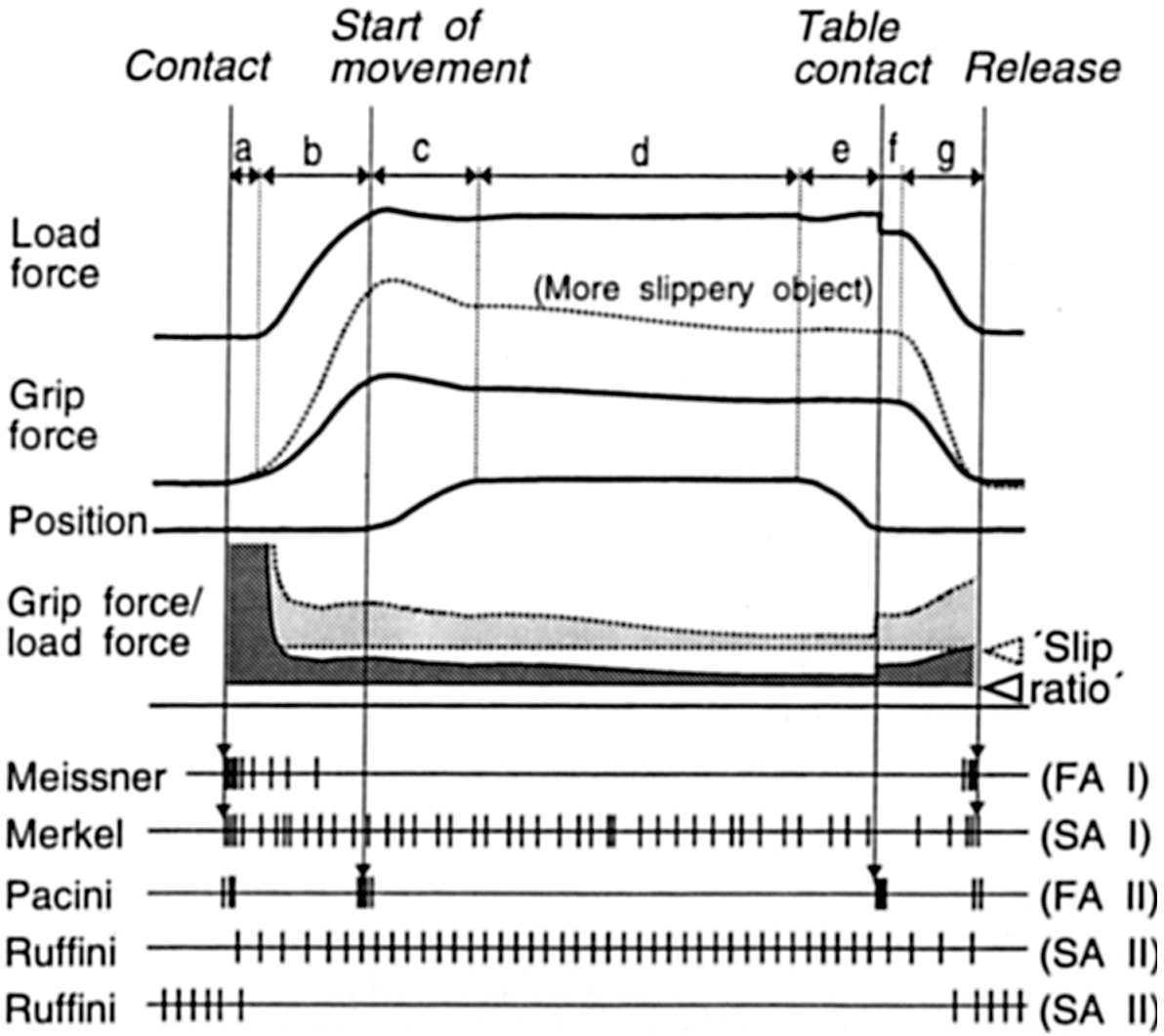


PPC important for motor control of the hand

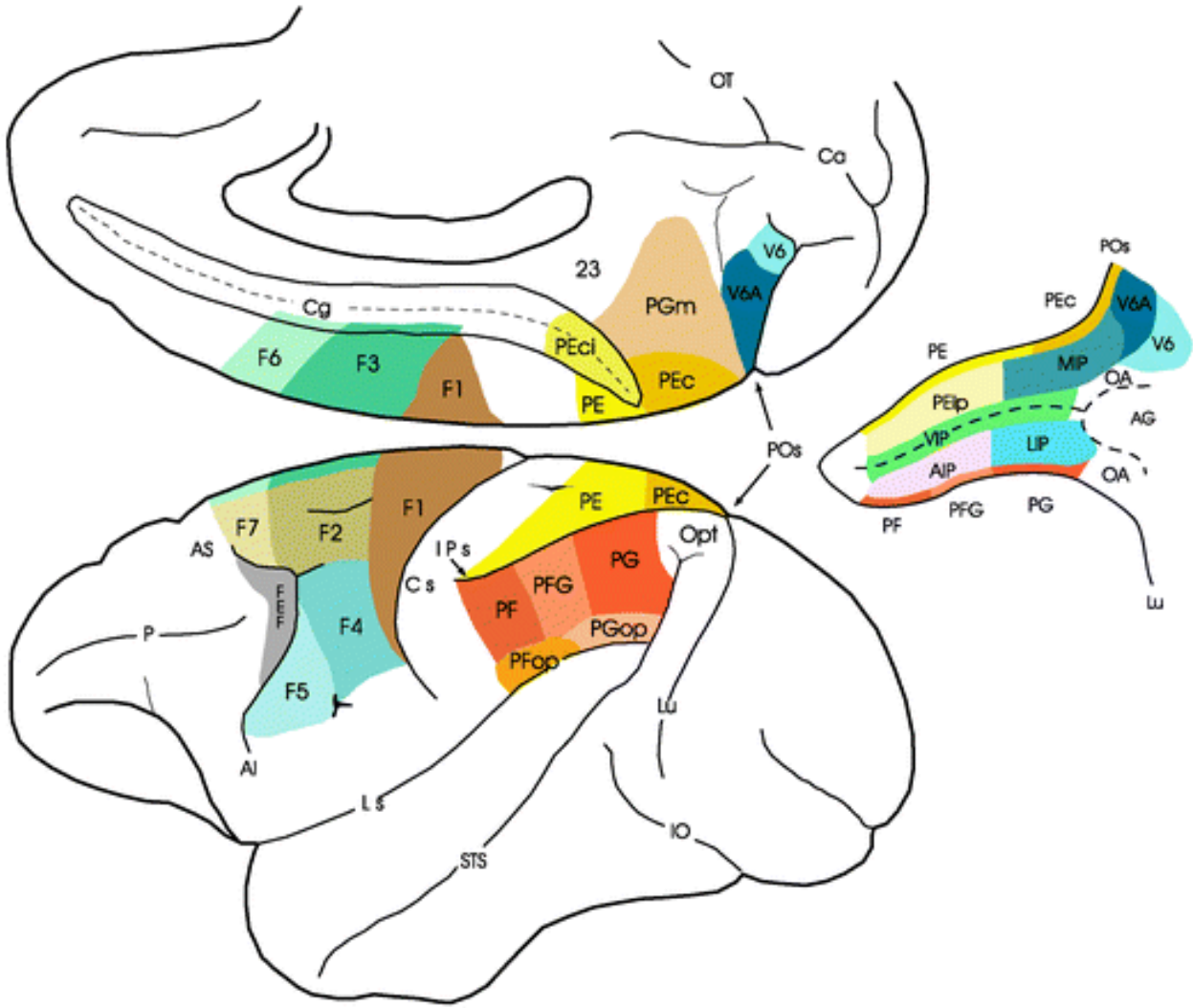
- Anticipatory feed-forward behavior
- Representation of body position in space
- Sensory input is used for error correction
- Integrates somatosensory and visual inputs
- Projects to premotor cortex
- Lesions cause dysmetrias in contralateral field and clumsy movements
  - Reach undershoot
  - Poor hand preshaping and wrist orientation

Mechanoreceptors Sense Hand Actions





Posterior Parietal Cortex and frontal motor areas

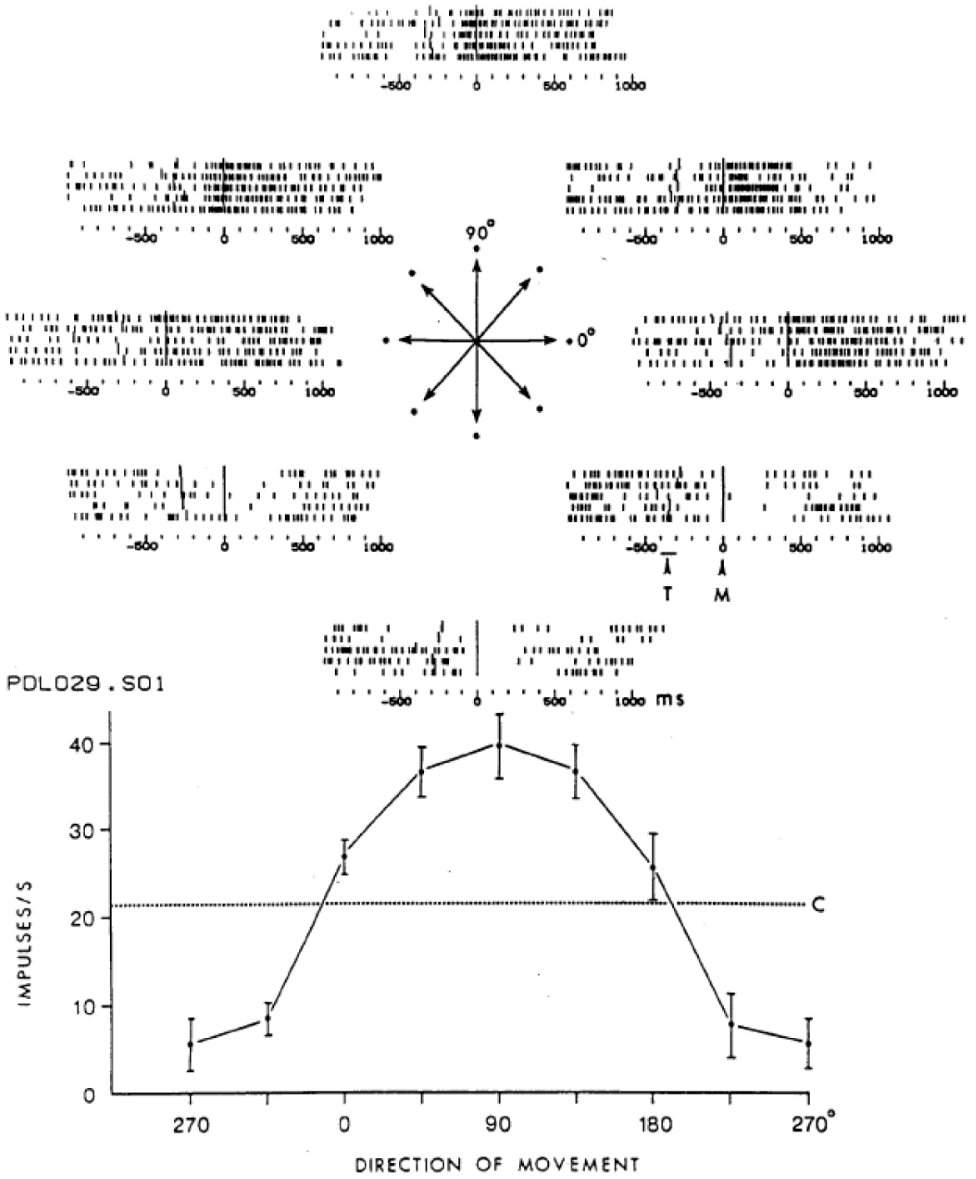


IP (unfolded)

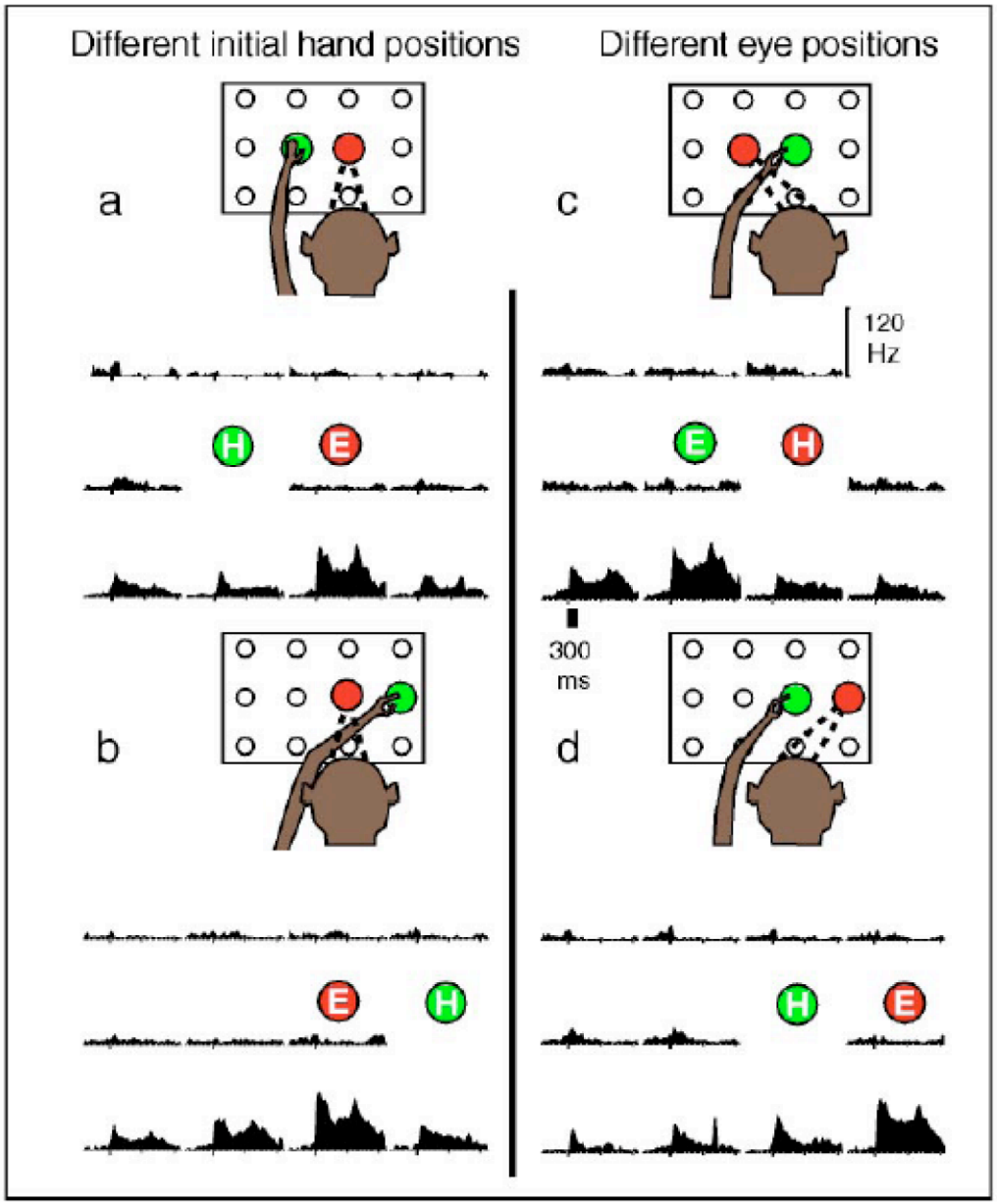
A

P

PPC neurons signal direction of reaching

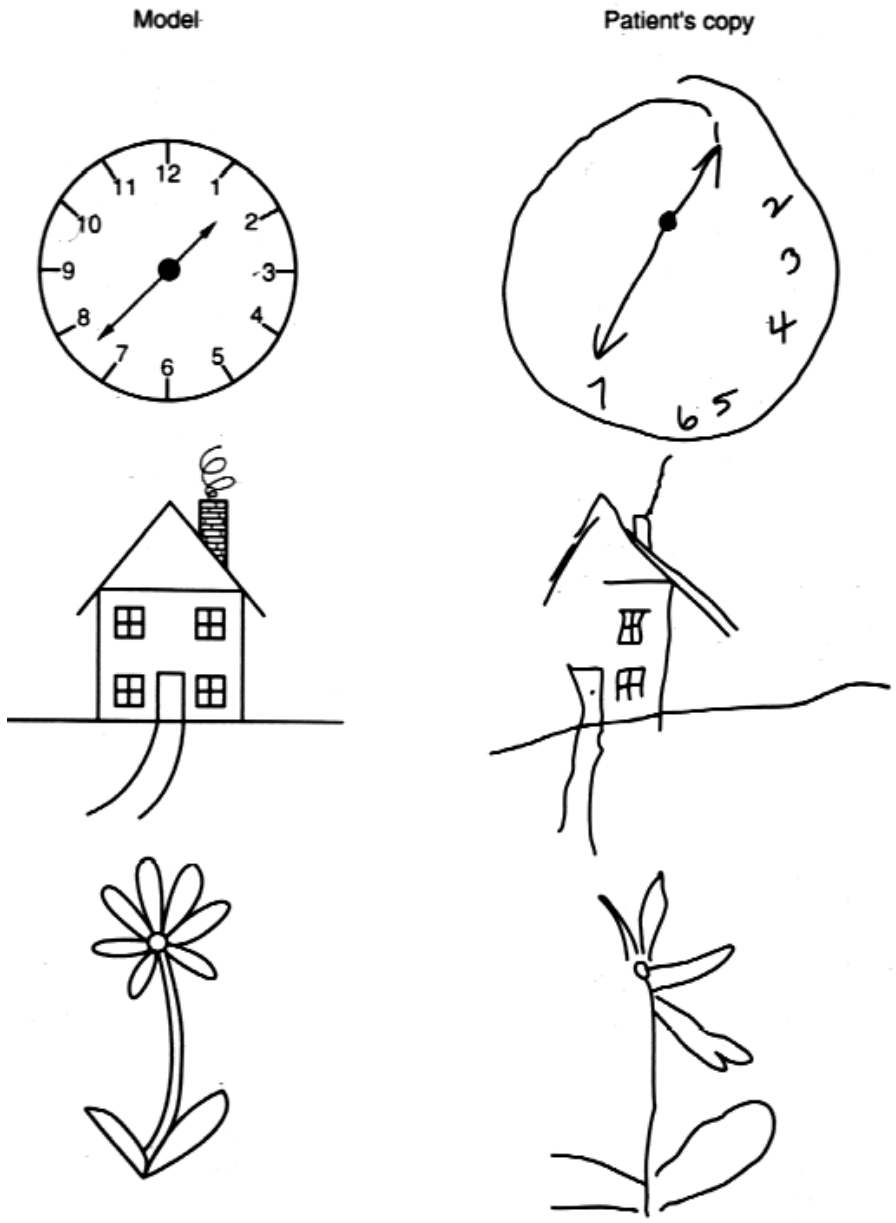


PPC neurons represent spatial locations

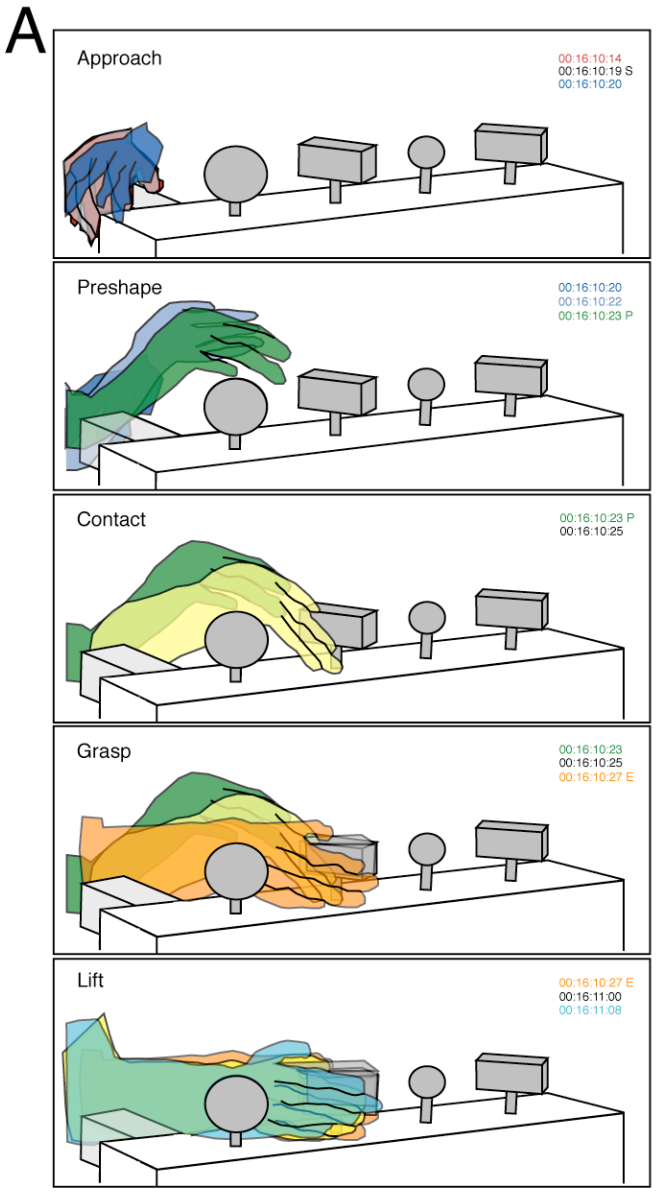


Neglect of contralateral space (optic ataxia)

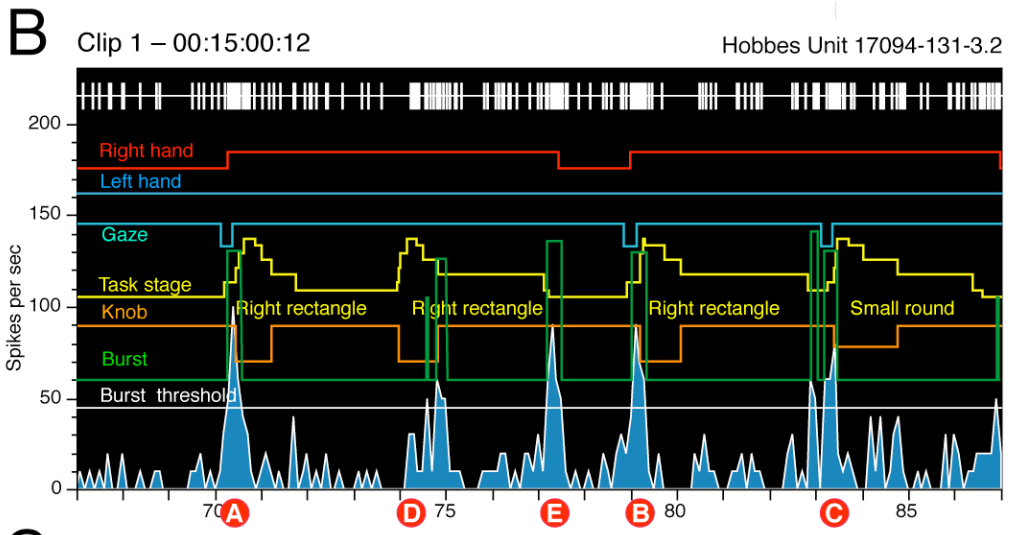
Lesion of Right Posterior Parietal Cortex

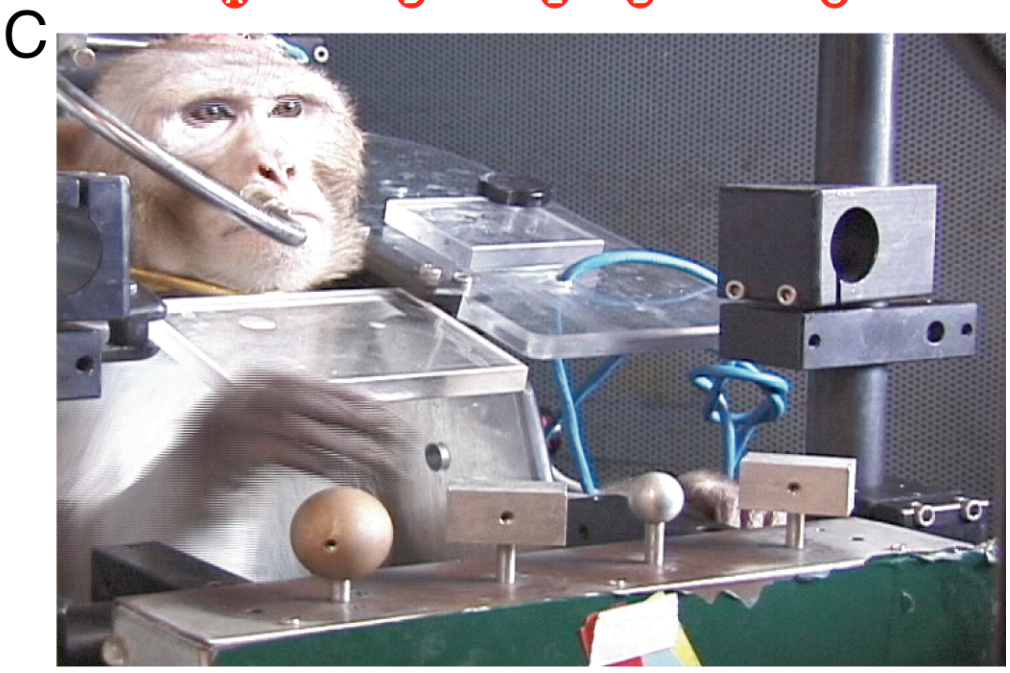


PPC neurons respond to reach and grasp

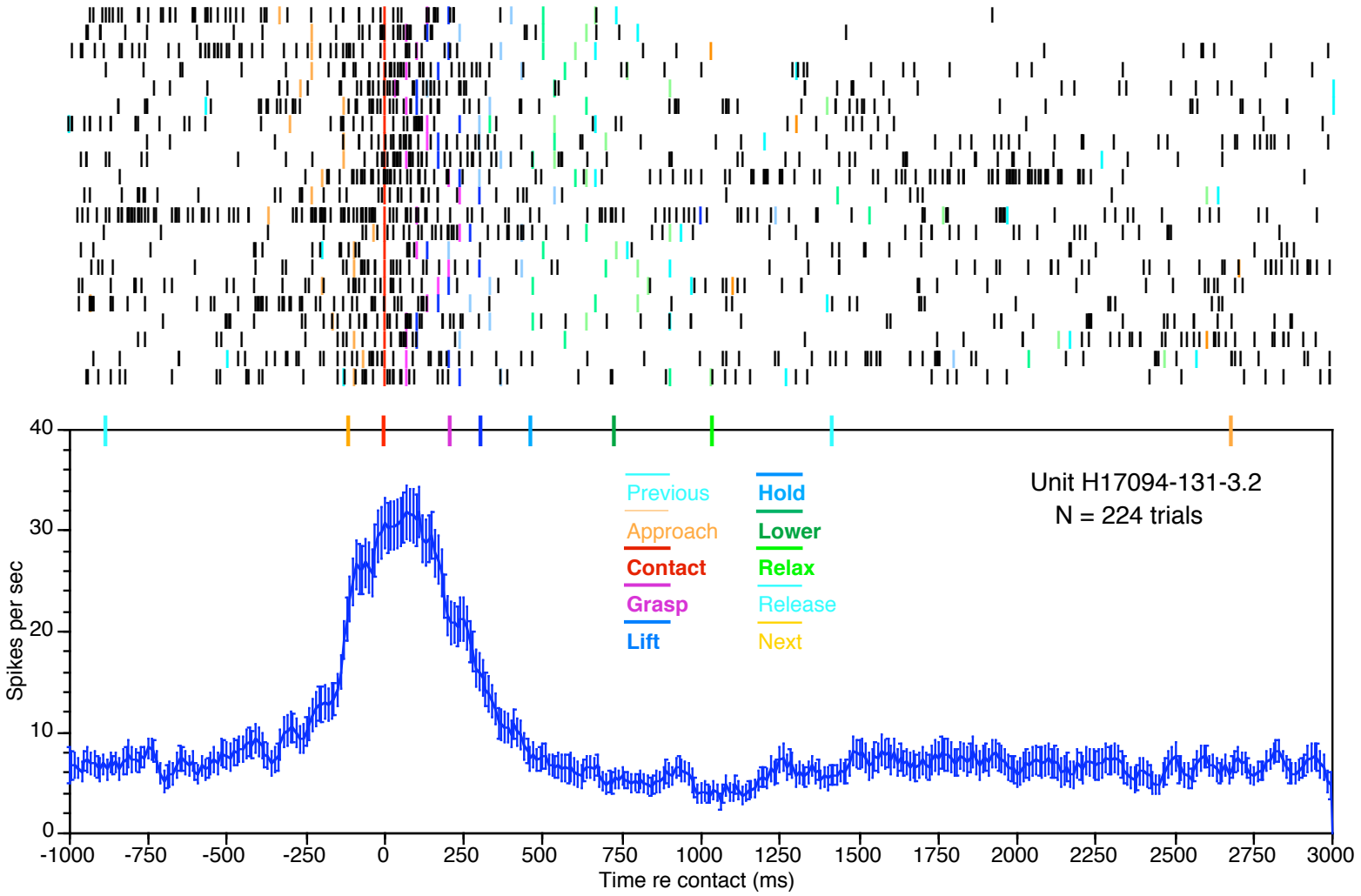


Hobbes Unit 17094-131-3, clip 1



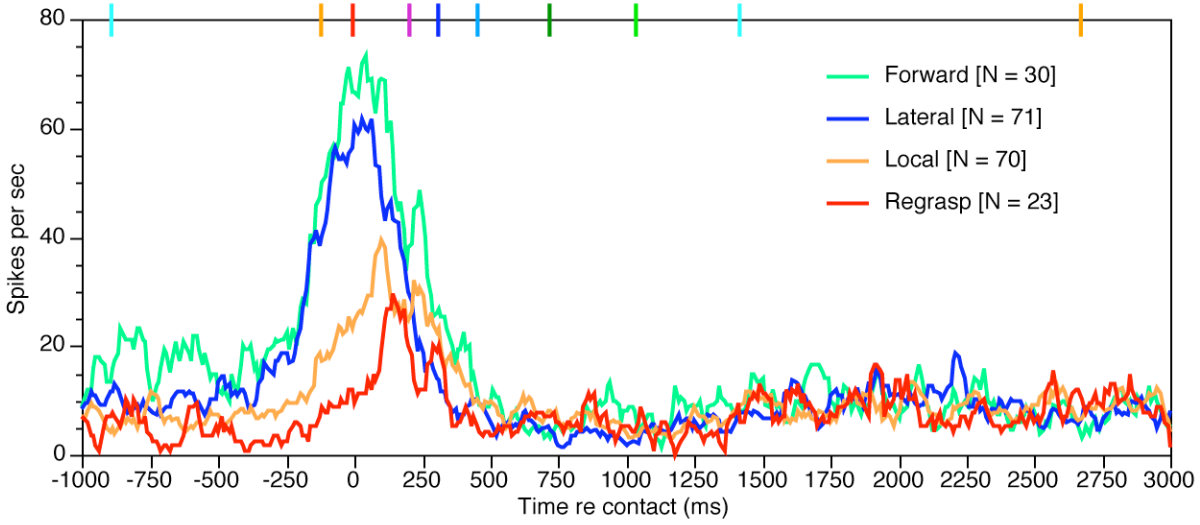


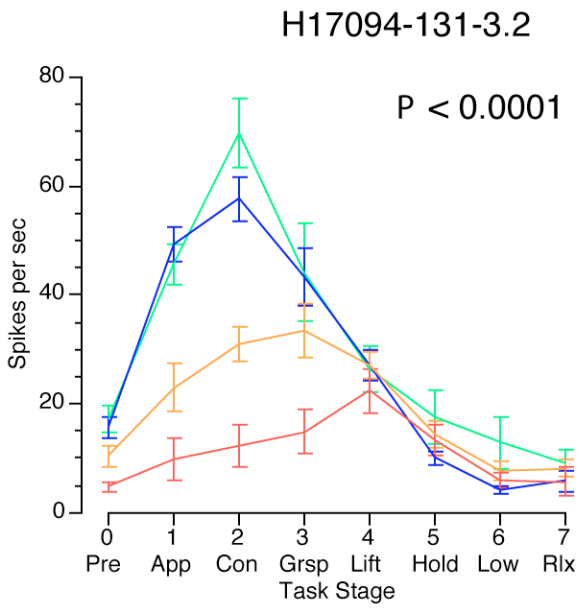
PPC neurons respond before touch



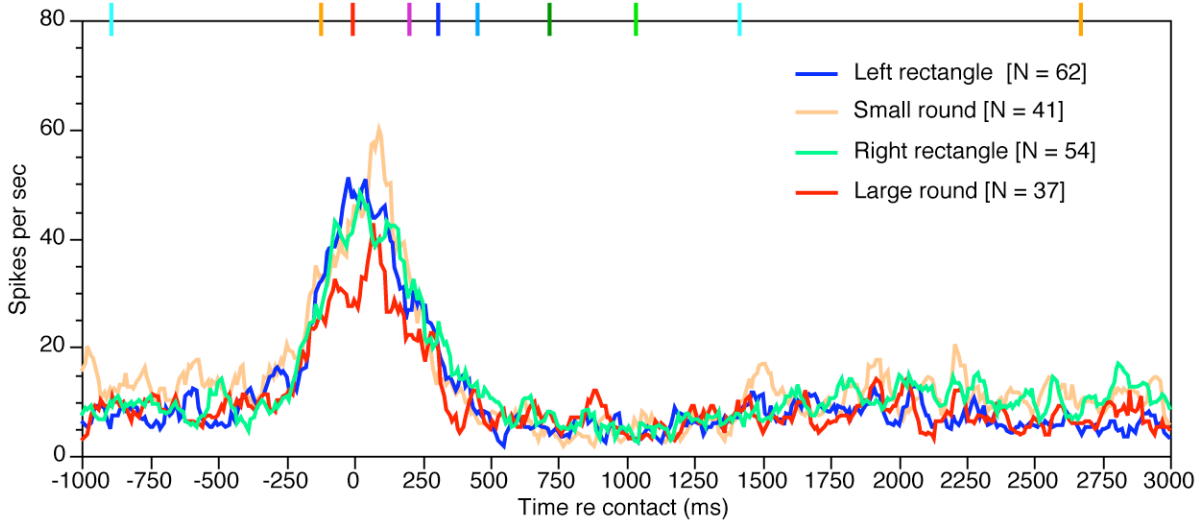
PPC neurons signal hand actions

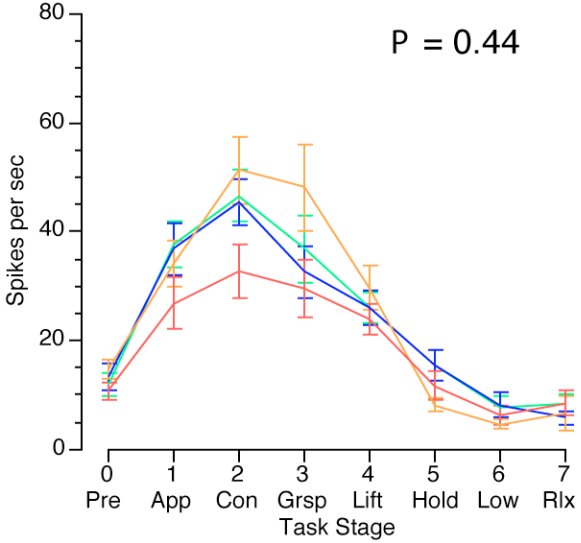
A. Approach style



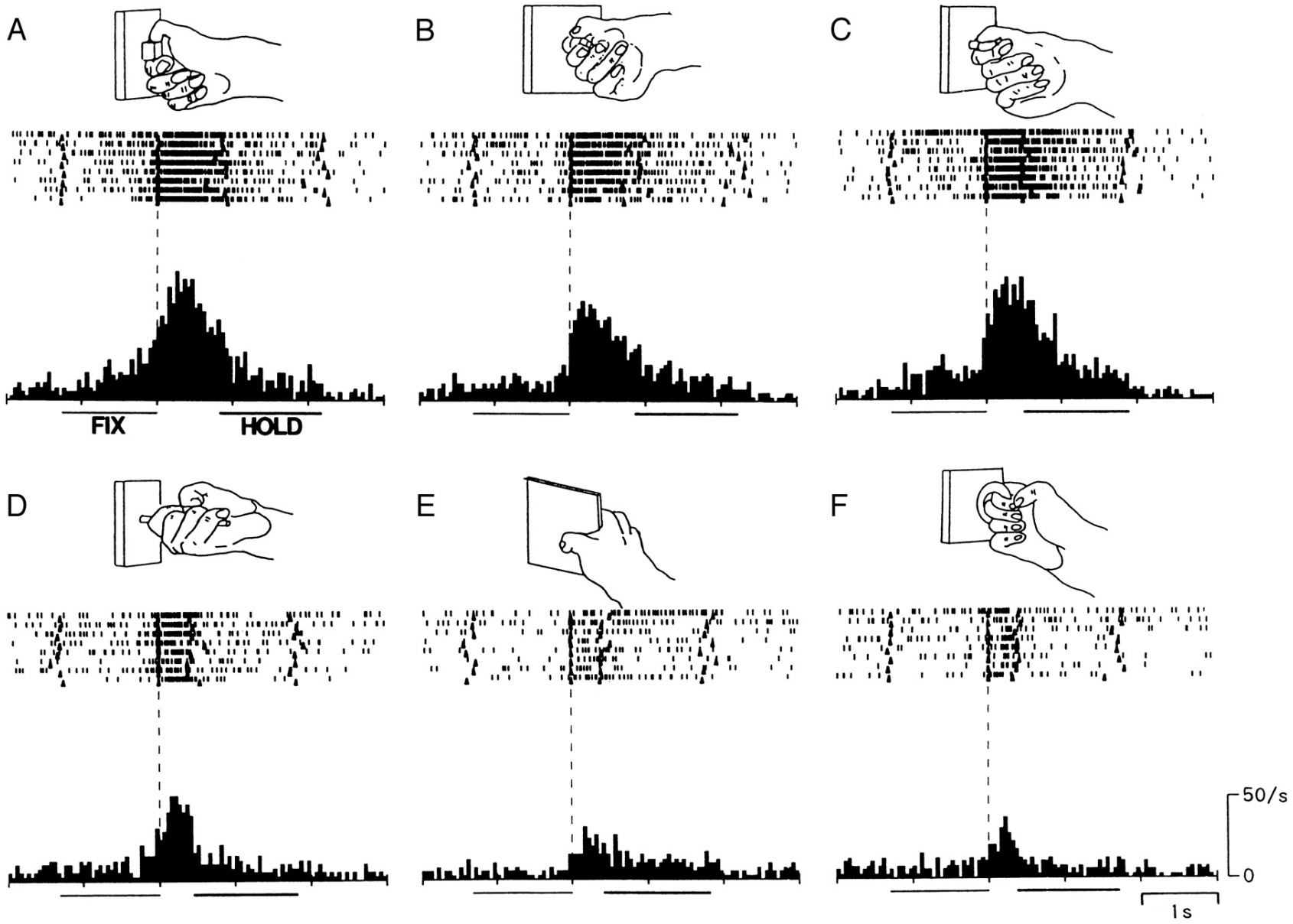


B. Object shape





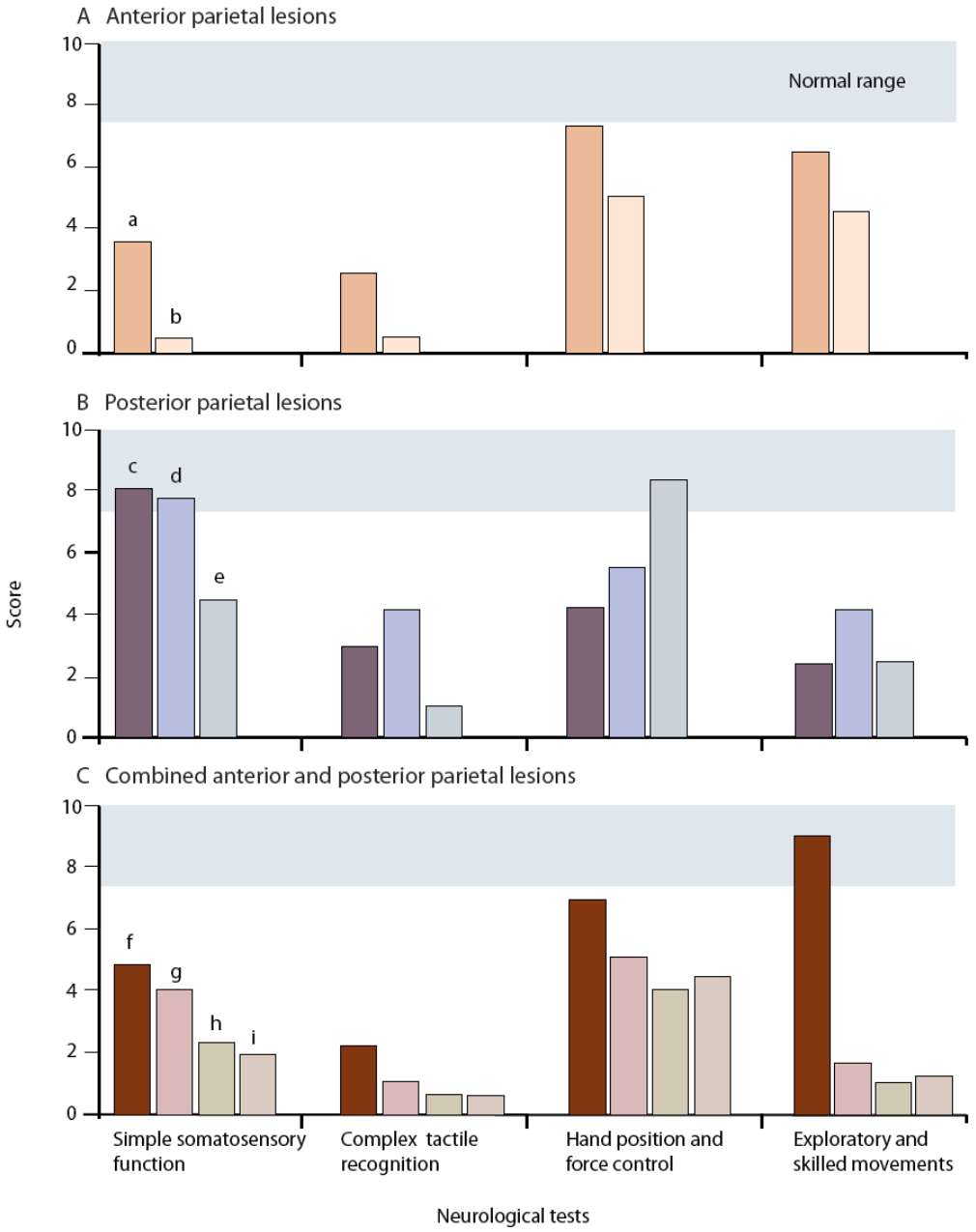
PPC neurons code hand posture

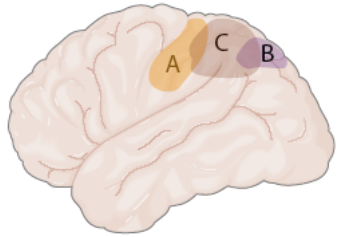


S-I Cortical Lesions Impair Touch

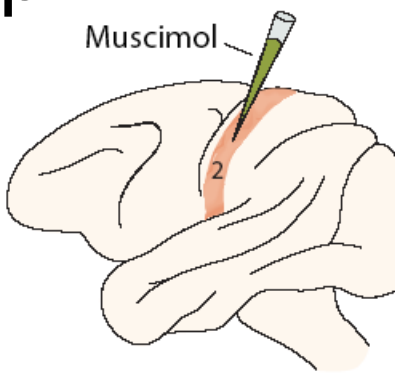
- Loss of touch sensation in lesioned area
  - Impaired two-point discrimination
  - Poor texture discrimination
  - Loss of stereognosis
  - Localized to specific body region in the map
- Impaired motor function especially hand
  - Clumsy grasping
  - Poor motor coordination

Parietal lobe sensorimotor deficits in 9 patients





Area 2 inactivation produces clumsy grasp



Ipsilateral hand normal

Contralateral hand affected