Structure and Measurement of the brain lecture notes

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2010/2011

Based on slides from Flavia Filimon, 2008

Somatosensory System

Lecture 3

Topics

- Visual attention
- Arm diagram
- Somatosensory pathway
- Somatosensory cortial areas
- Somatosensory cortical plasticity

How do we filter out irrelevant stimuli?

- our retinas are bombarded by constant stimulation
- yet we are aware of only small subset of visual stimuli
- How do we pay attention to some and not other visual stimuli?

Types of attention

- **overt** vs **covert** (w/ or w/out saccades)
- **spatial** attention vs. **object**-based attention
- **endogenous** vs. **exogenous**

- usually, these operate together

Visual pathways from V1

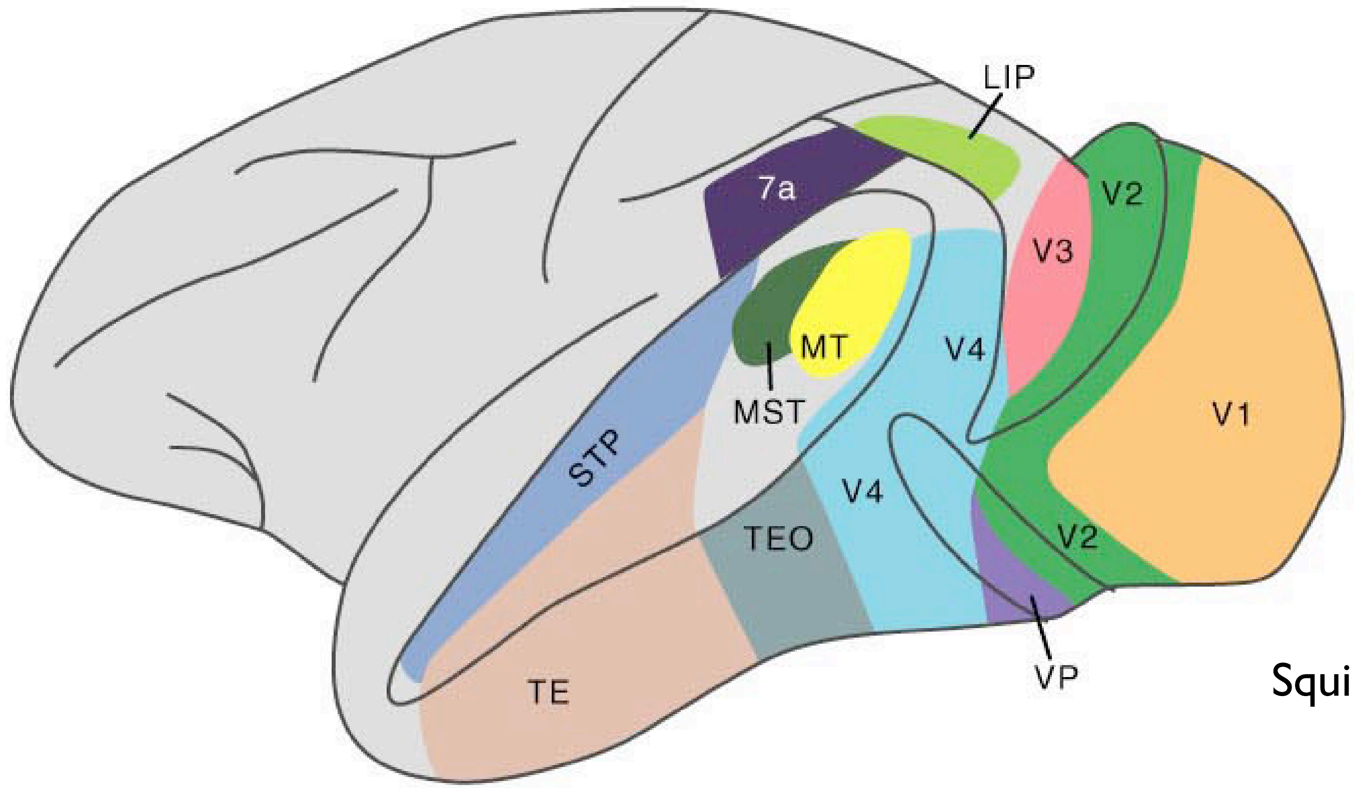
dorsal:

magno (**dLGN**) → **V1** (4Cα) → (4B, etc) → **V2** (thick stripes) → **MT** → **MSTd**, etc.

ventral:

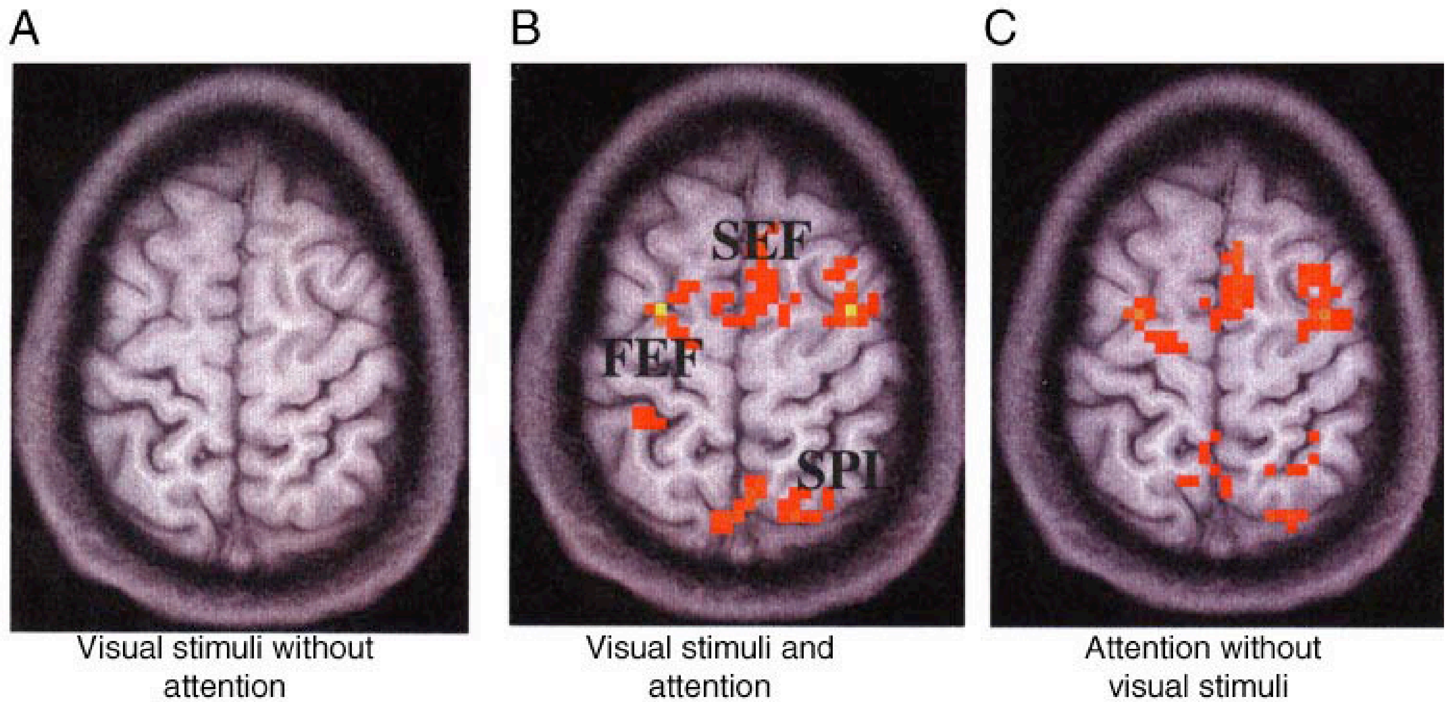
parvo (**dLGN**) → **V1** (4Cβ) → (layer 2/3) → **V2** (thin stripes) → **V4** → inferotemporal cortex

Visual pathways



Squire et al., 2003

Network of brain areas mediating spatial attention



Squire et al., 2003

- evidence from neuropsychology (neglect), neurophysiology, functional imaging: **parietal**, **frontal**, **cingulate** areas control spatial attention

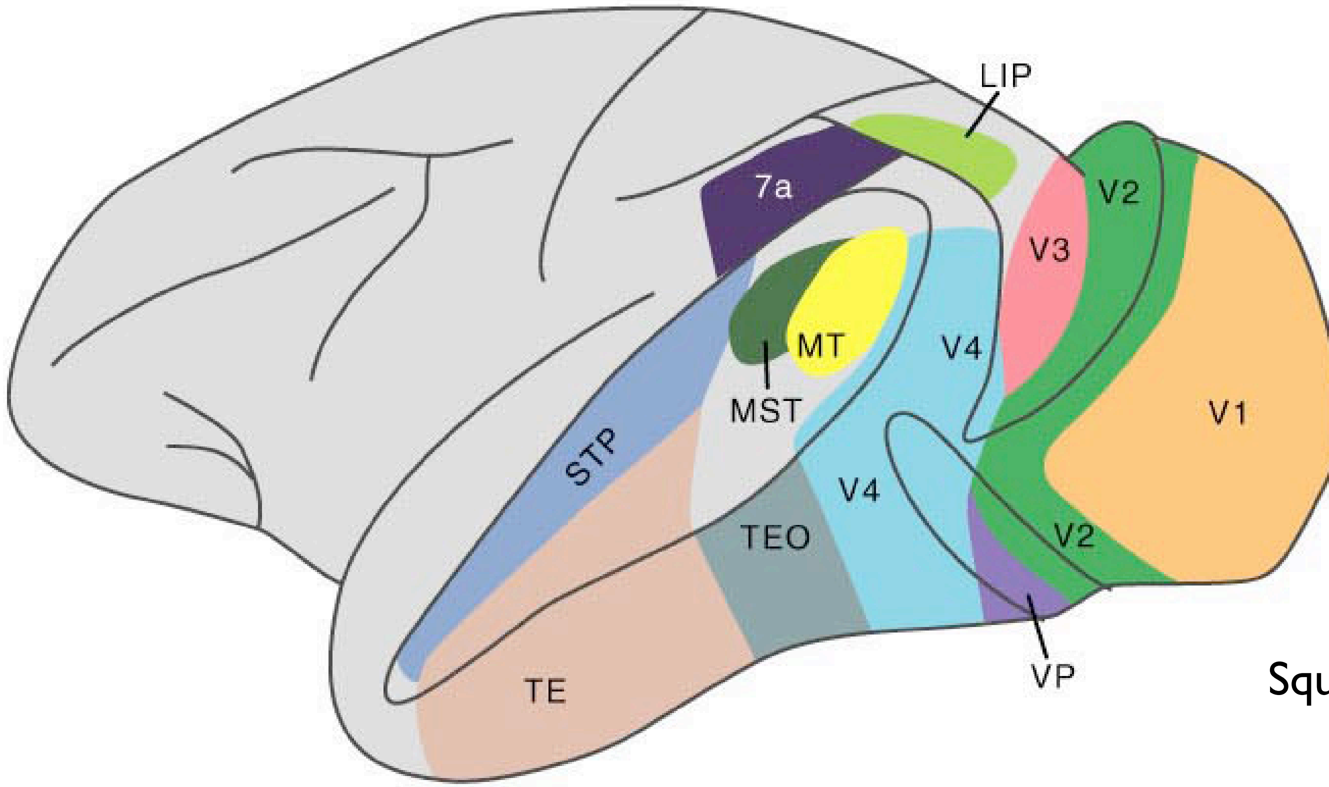
Attentional modulation of neuronal responses

- **top-down signals** from parietal and frontal cortex *increase* or *suppress* responses in visual areas that process specific stimulus attributes (e.g. color, *shape*, etc.).
- attentional modulation: at almost all levels of the visual system

Training monkeys

- why fixation cross is important: need to control visual stimulation inside a neuron's RF.
- macaque monkeys are good at covert attention (peripheral monitoring)
- reward

Single-unit recordings in V4



Squire et al., 2003

Procedure

1) isolate a V4 cell & its receptive field location

2) identify preferred (good) stimulus of cell

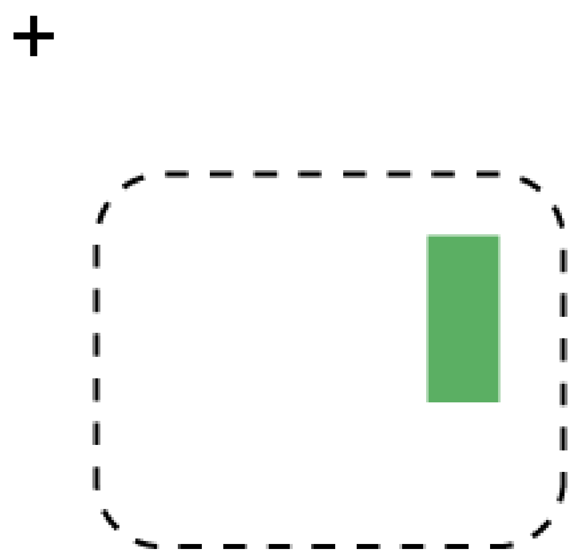
3) present both preferred (good) and non-preferred (bad) stimuli inside the RF

4) train monkey to attend to one or the other stimulus

Moran and Desimone (1985) V4 experiment

Passive response to good stimulus

fixation

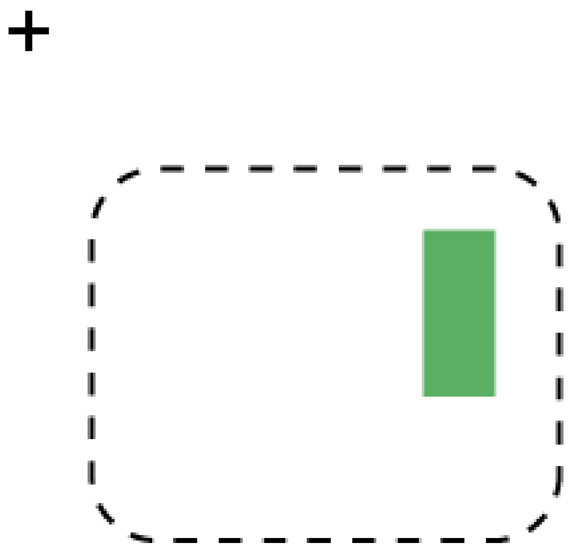


receptive field

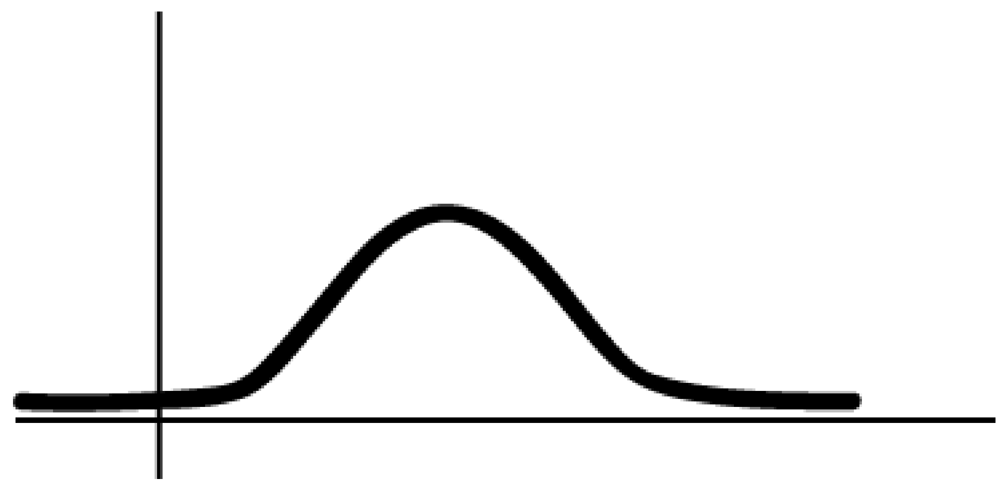
Flavia Filimon, Systems Neuroscience 2008

Passive response to good stimulus

fixation



receptive field

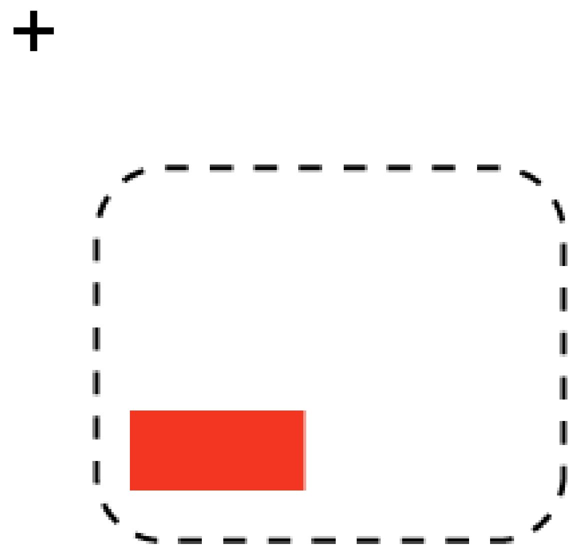


cell's response

Flavia Filimon, Systems Neuroscience 2008

Passive response to bad stimulus

fixation



receptive field

Flavia Filimon, Systems Neuroscience 2008

Passive response to bad stimulus

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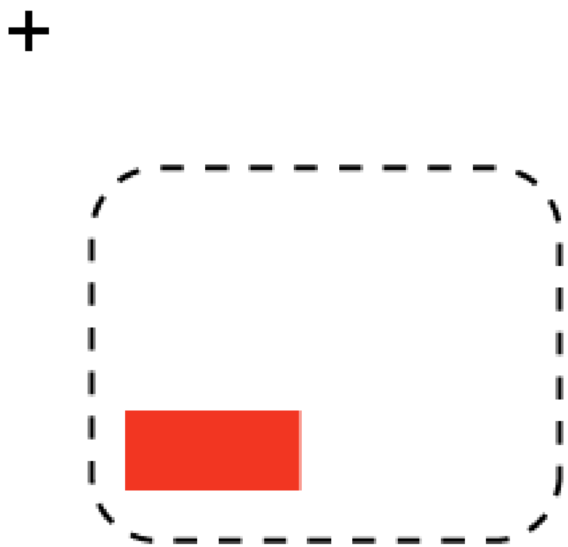
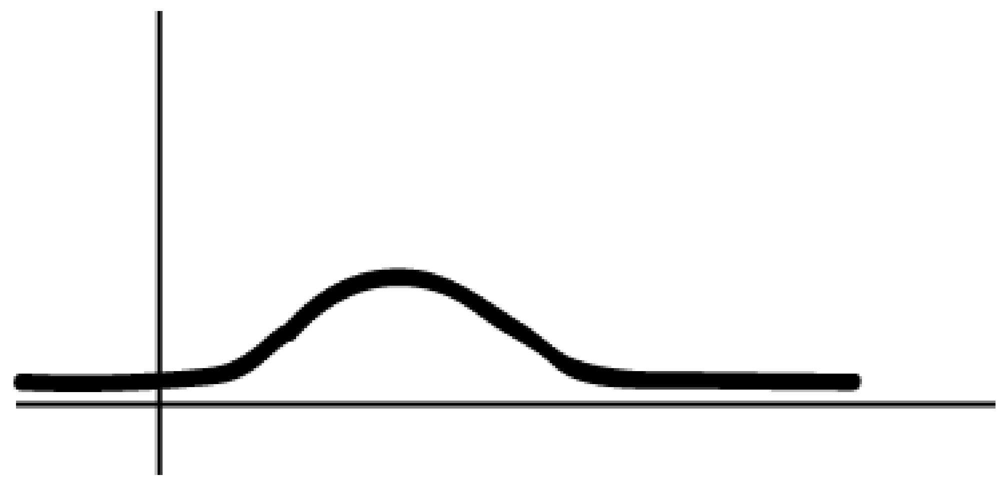


receptive field

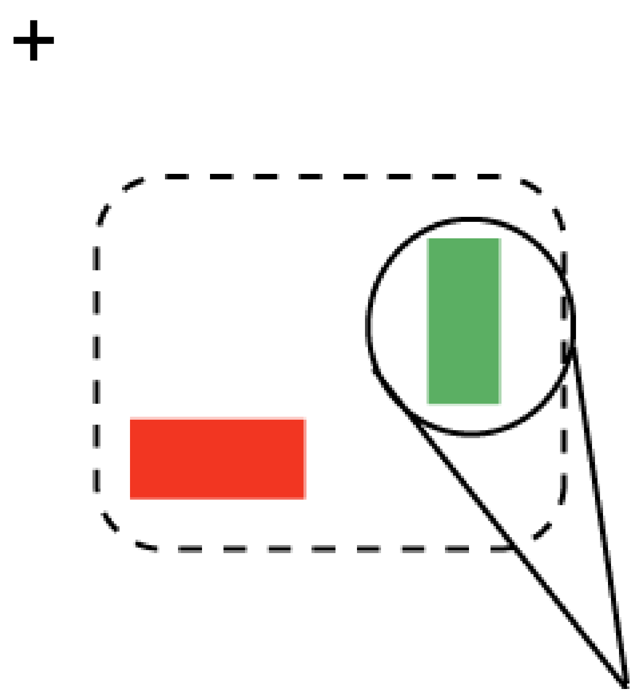


cell’s response

Flavia Filimon, Systems Neuroscience 2008

Both stimuli present, attend good

fixation



receptive field

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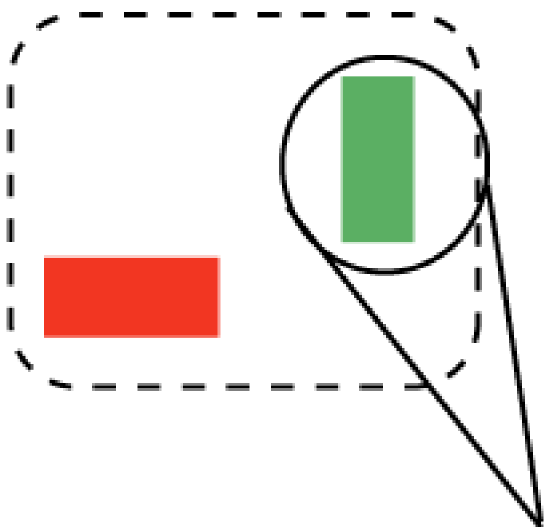
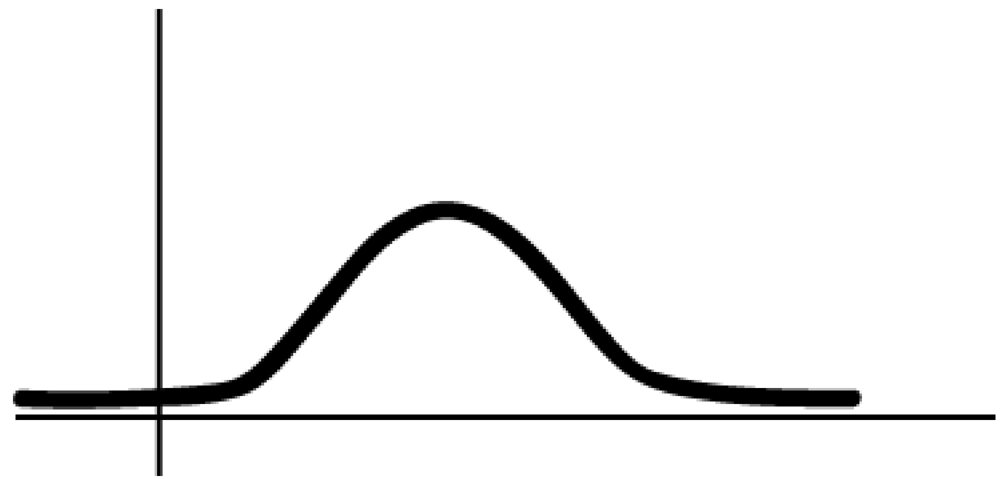
Both stimuli present, attend good

fixation

+



receptive field



cell's response

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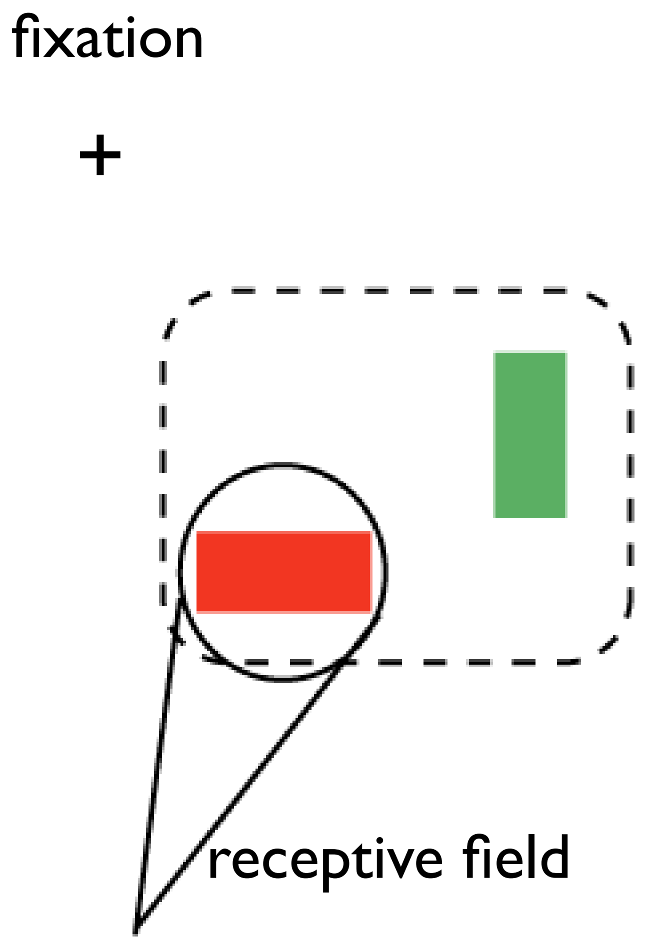
Both stimuli present, attend bad



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Both stimuli present, attend bad

fixation

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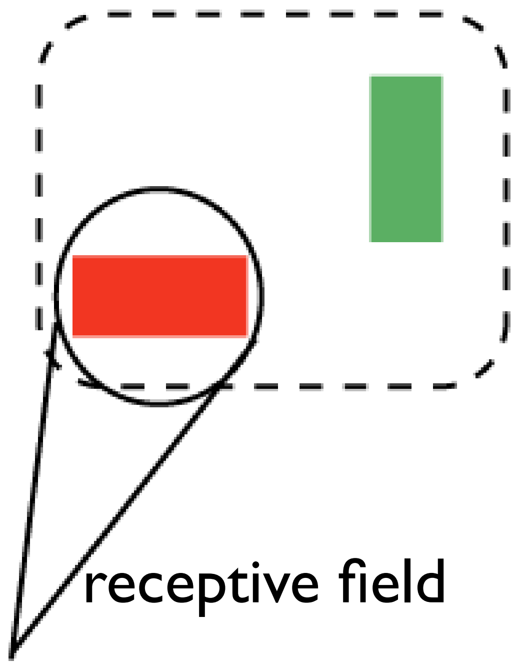
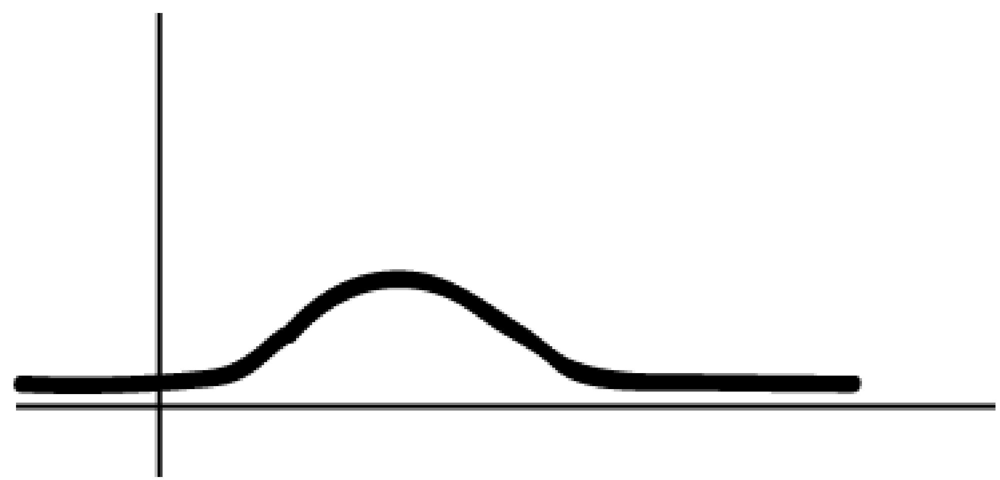


receptive field



cell's response

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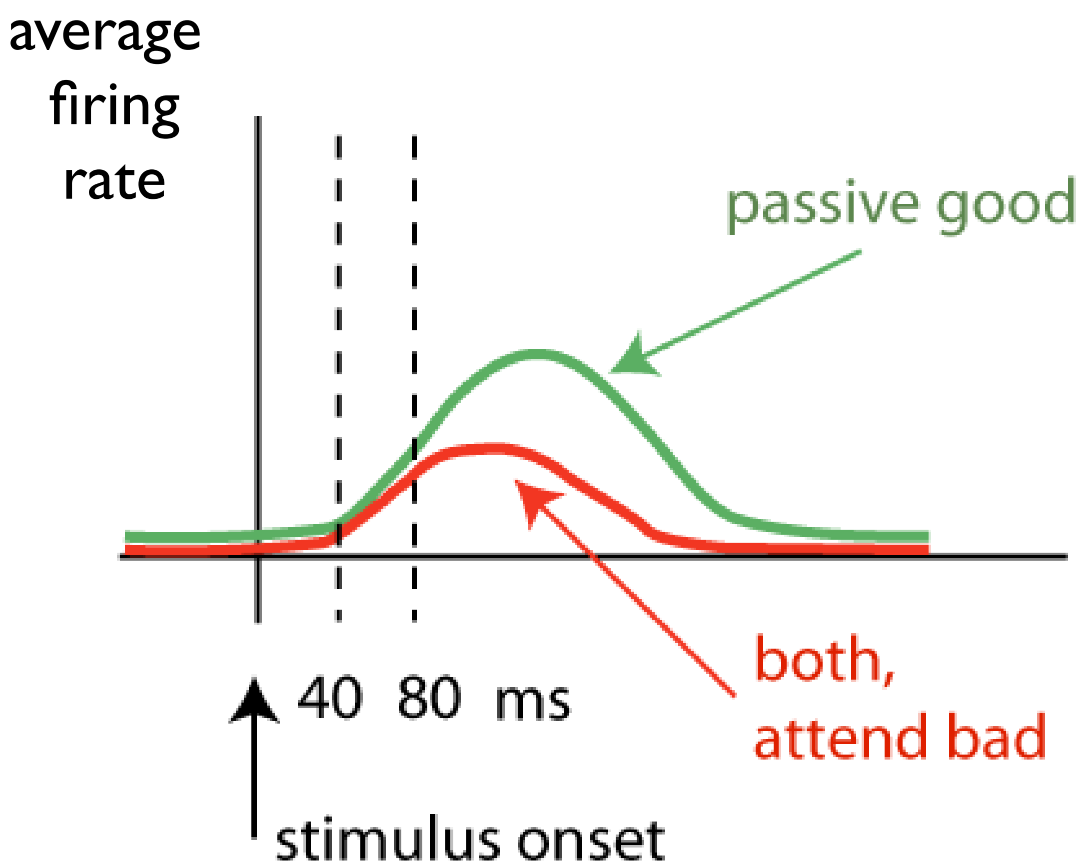
Results: Attention suppresses irrelevant stimuli in V4



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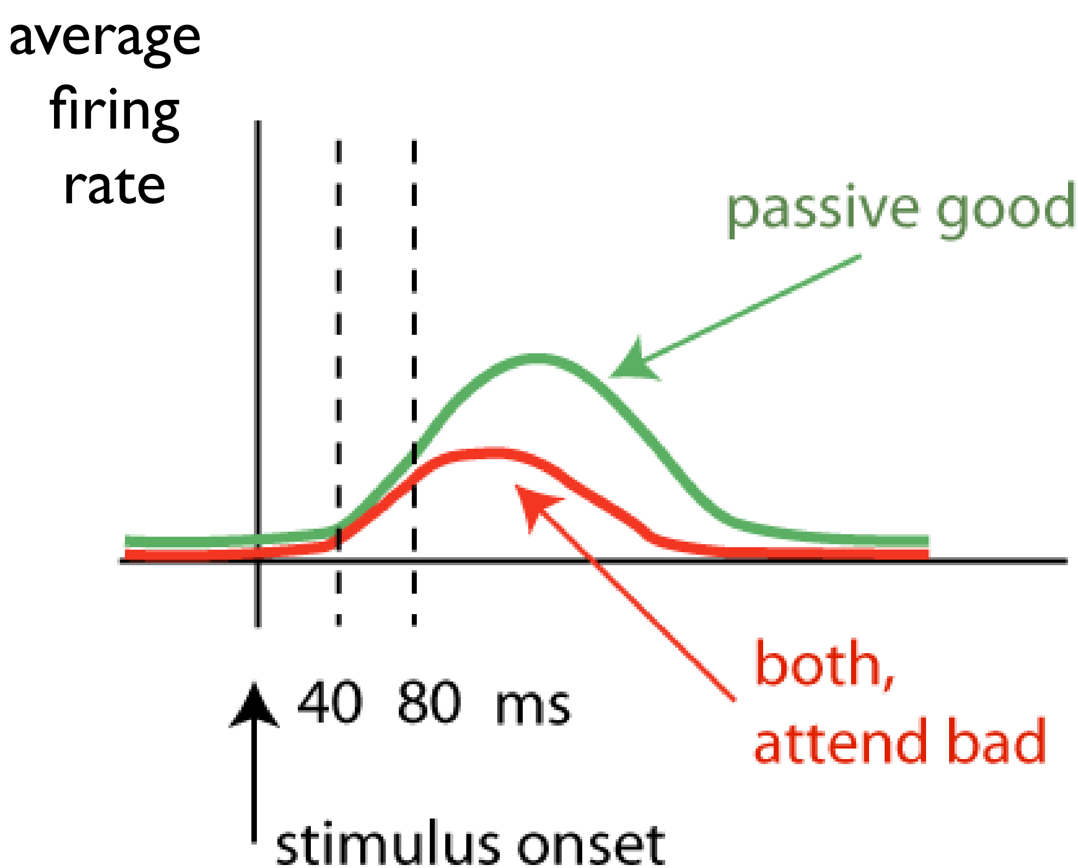
Results: Attention suppresses irrelevant stimuli in V4



- response onset ~ 40 ms after stimulus onset
- attention takes an additional 40 ms to kick in
- even though good stim. is also presented in RF, attention to bad stimulus suppresses response to good stim.

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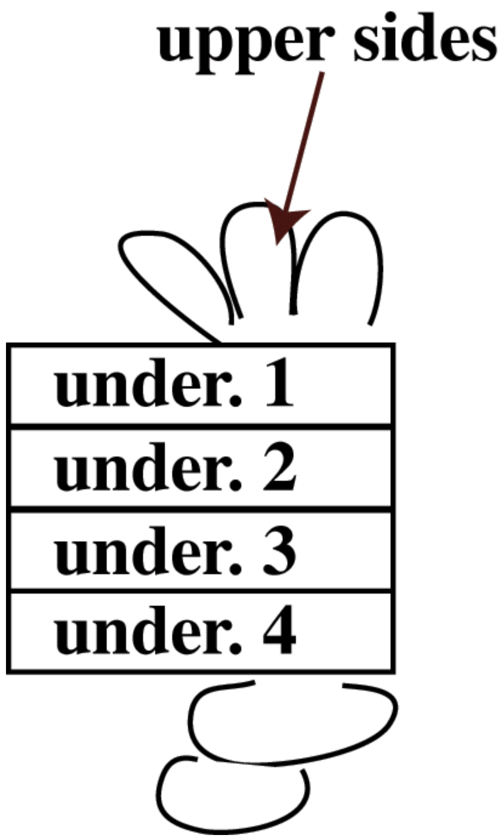
Possible mechanisms

- competition between stimuli
- top-down bias toward attended location/ feature (via feedback from fronto-parietal attentional network)

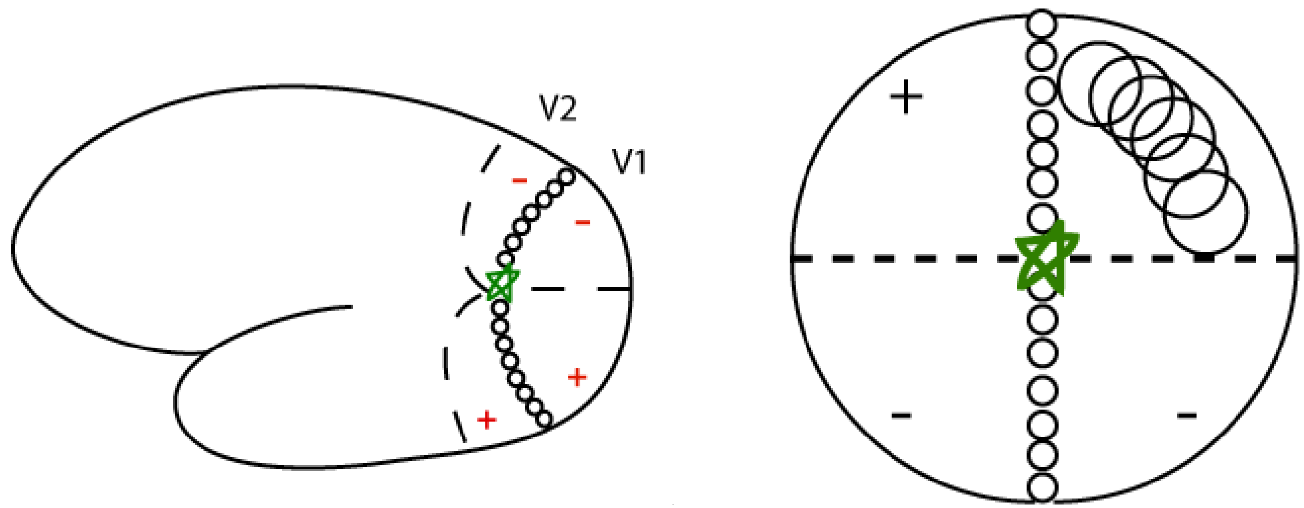
Discontinuities in the somatosensory system



finger representation

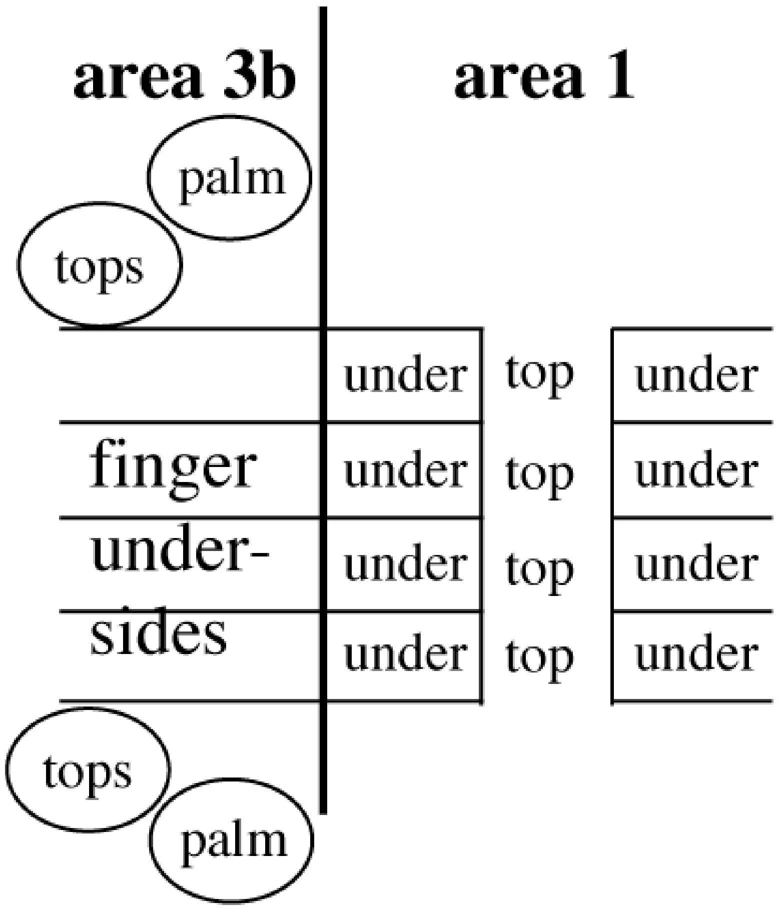
- in V1 (visual system): 2 points close together on retina are close together in cortex
- in SI (somatosensory system), you can move a small distance on cortex and end up far away on skin (e.g. from thumb to eye)

Discontinuities: somatosensory system versus visual system



- in V1 (visual system): 2 points close together in cortex are close together in the visual field
- i.e. moving a short distance in cortex = moving a short distance in visual field
- BUT: can move short distance in visual field and end up far away in cortex: e.g. <u>V2 horizontal meridian</u> (upper and lower vis. fields); <u>Left vs. Right vis. field</u> representations.

Discontinuities: somatosensory system versus visual system



- in S1 (somatosensory system): moving a short distance in cortex can mean a big jump on the skin
- e.g. from face to hand
- S1 has many discontinuous patches: e.g. tops and undersides are represented separately

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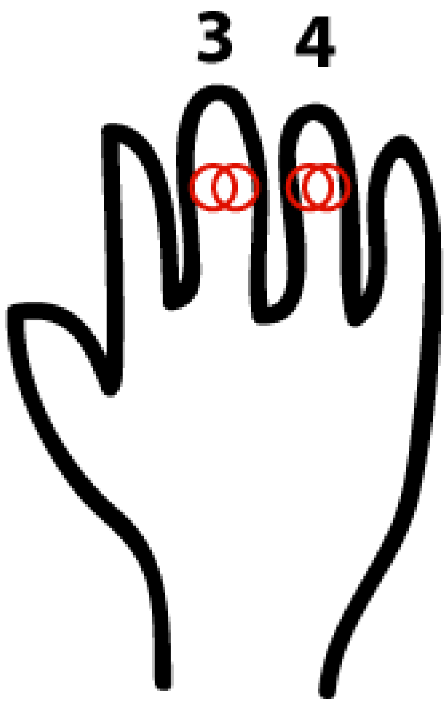
Other differences between somatosensory and visual systems



- retina is a continuous receptor surface
- skin is discontinuous: separate fingers, can stimulate each finger in isolation
- RFs from different fingers are discontinuous

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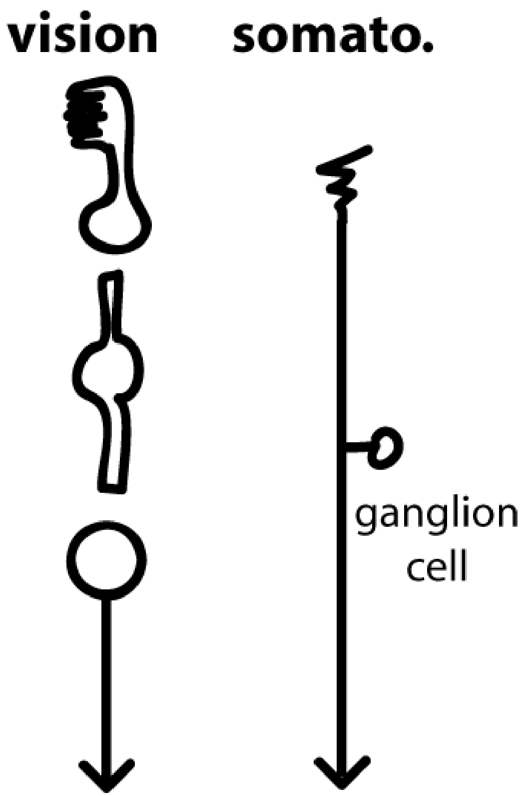
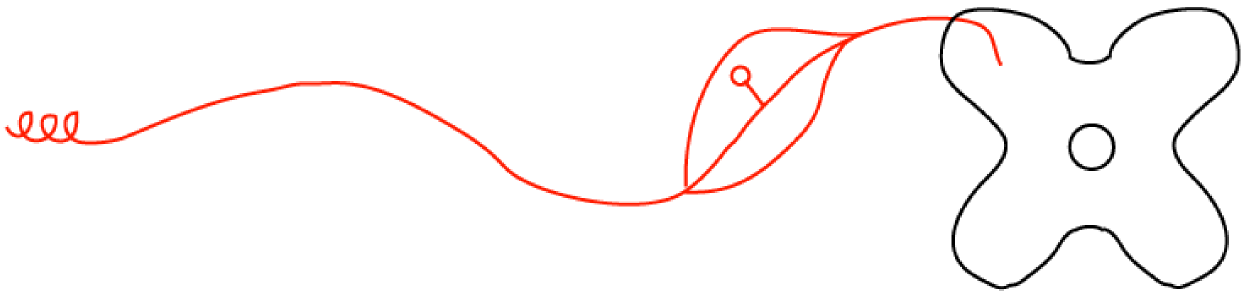
Somatosensory receptors



- in visual system, receptor does not spike
- in somatosensory system, dorsal root ganglion forms receptor → spike

(receptor and sensory neuron are the same)

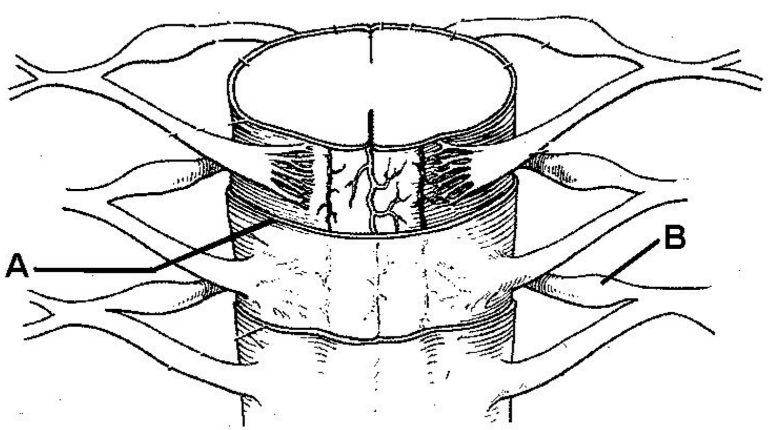
Dorsal root ganglion

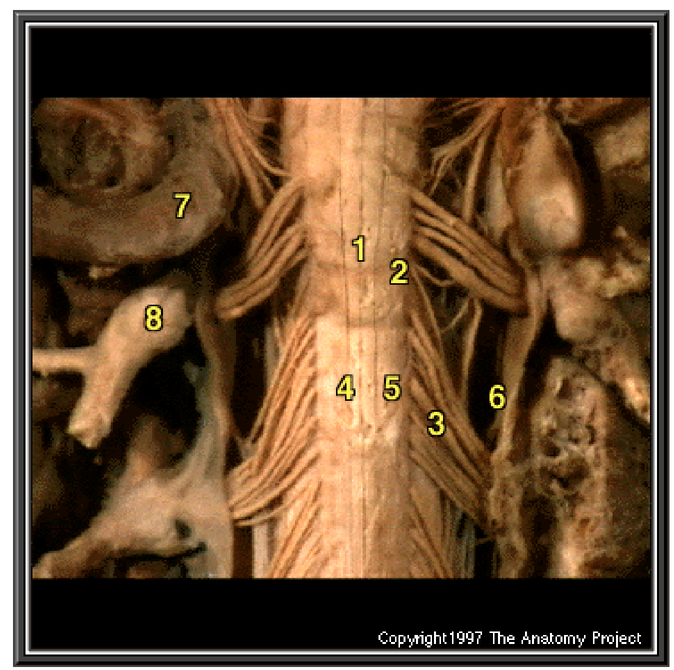


dorsal horn: sensory

spinal cord

ventral horn: motor

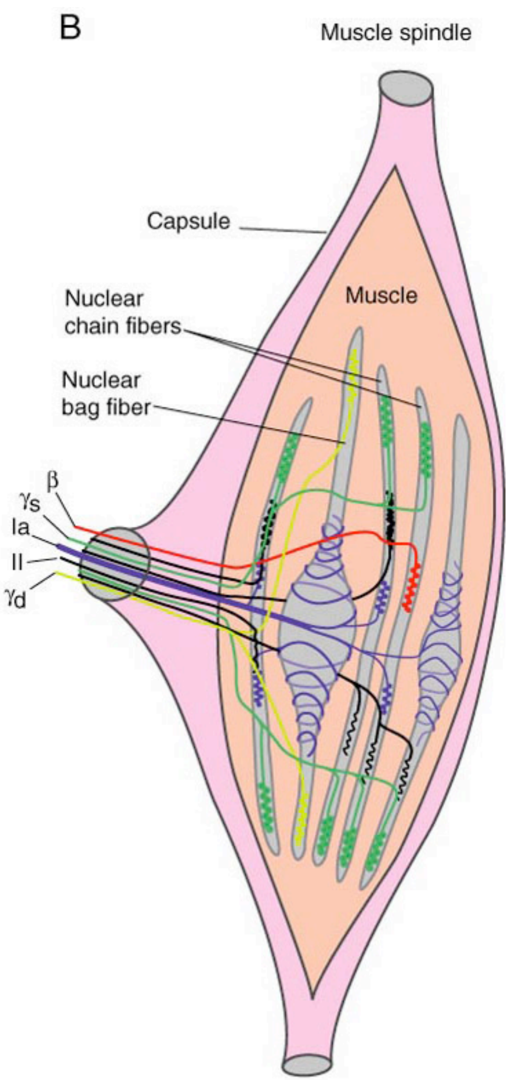




Dorsal root ganglion cells form specialized peripheral receptors

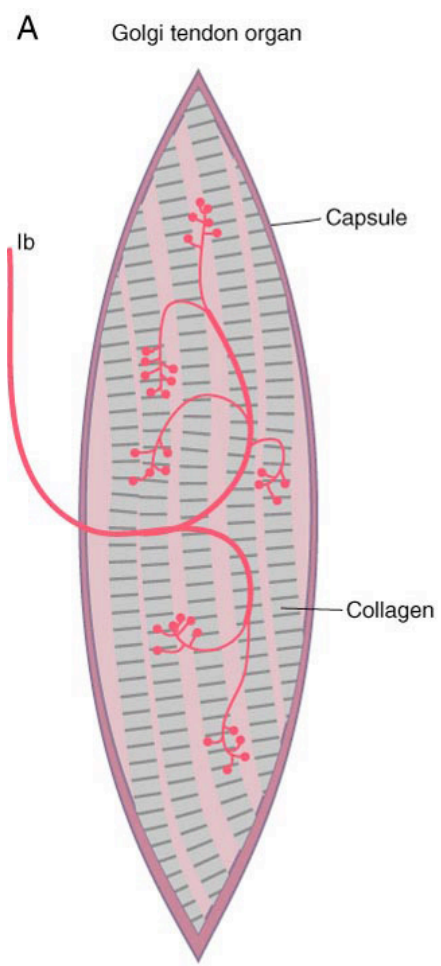
- somatosensory stimuli are broken down into multiple modalities, e.g. pain, touch, temperature → separate pathways
- exteroceptive: mechanoreception, thermoreception, nociception
- proprioceptive: kinesthesia: position + movement
- interoceptive: internal viscera

II. Proprioception - muscle spindles



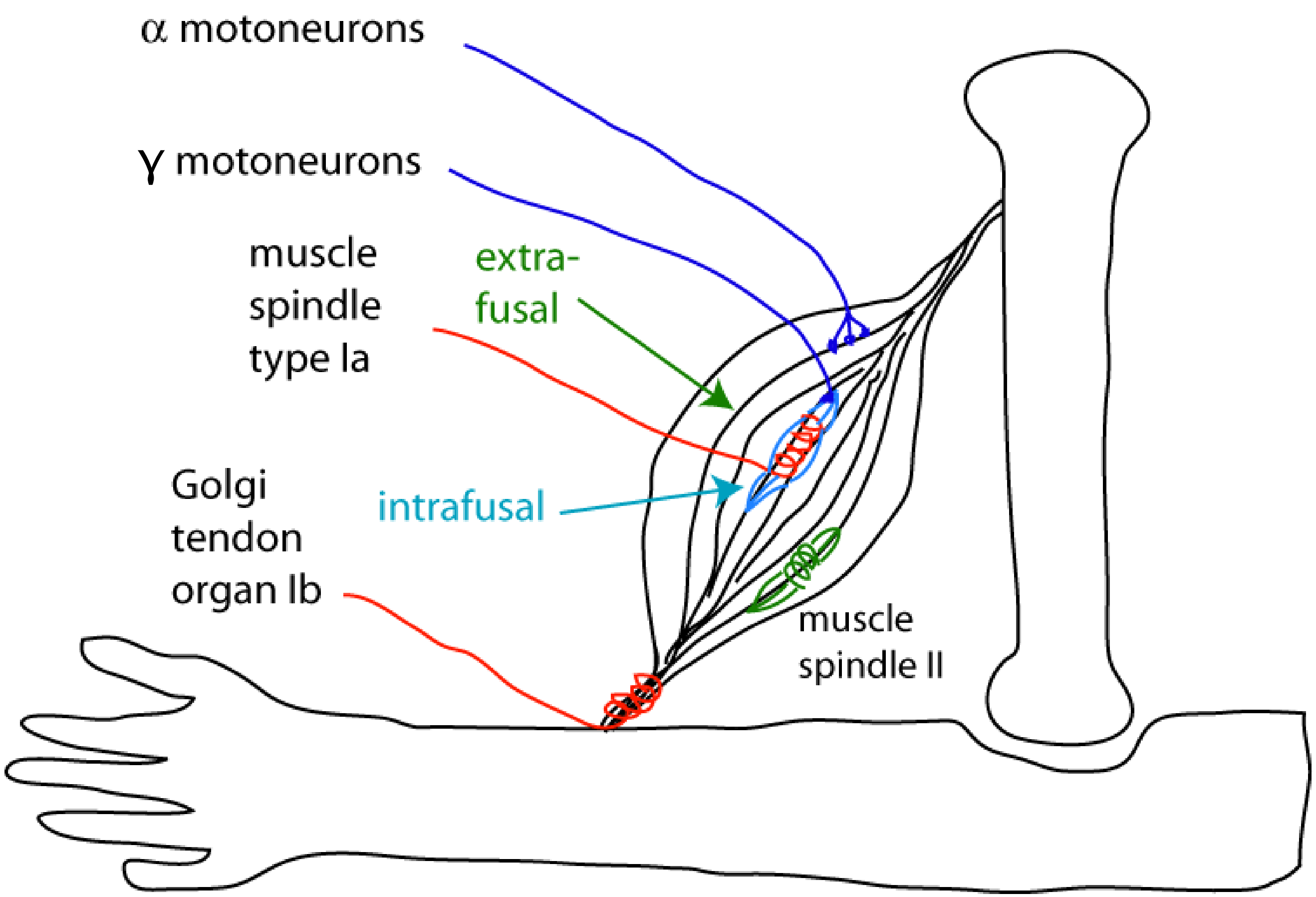
- muscle spindles: detect stretch (sustained or transient)
- encapsulated receptors
- innervated by γ motoneurons

II. Proprioception - Golgi tendon organs



- Golgi tendon organs: inside fibrous tendons of muscle
- encapsulated

Proprioceptive receptors



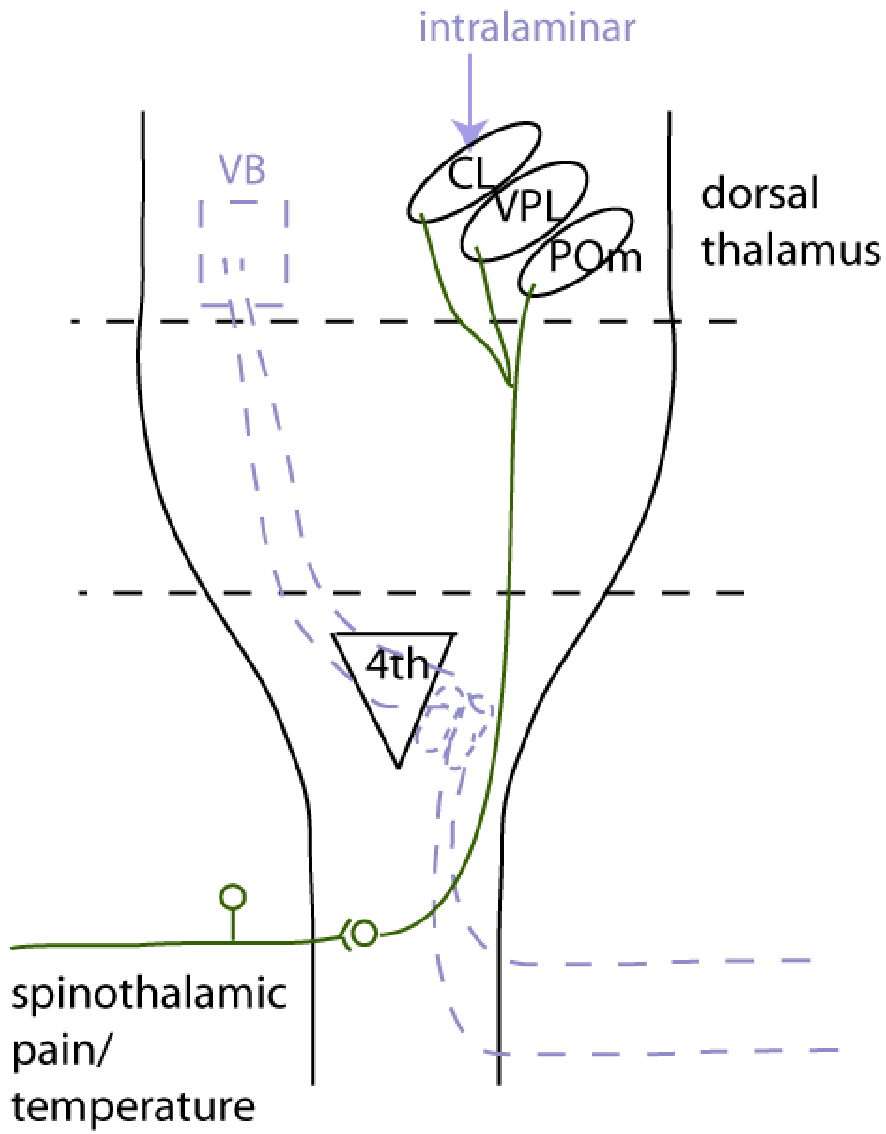
- muscle spindle **Ia**: RA, detects **stretch**
- muscle spindle **II**: SA, detects **position**
- Golgi Ib: **tendon stretch, force exerted on muscle**

Why do muscle spindles innervate muscle spindle muscles?

- contraction of extrafusal muscle fibers → if intrafusal (muscle spindle muscle) fibers were to go slack, could not detect stretch during every extension
- → intrafusal fibers do not contract; only respond to elongation
- Examples of what activates which receptors

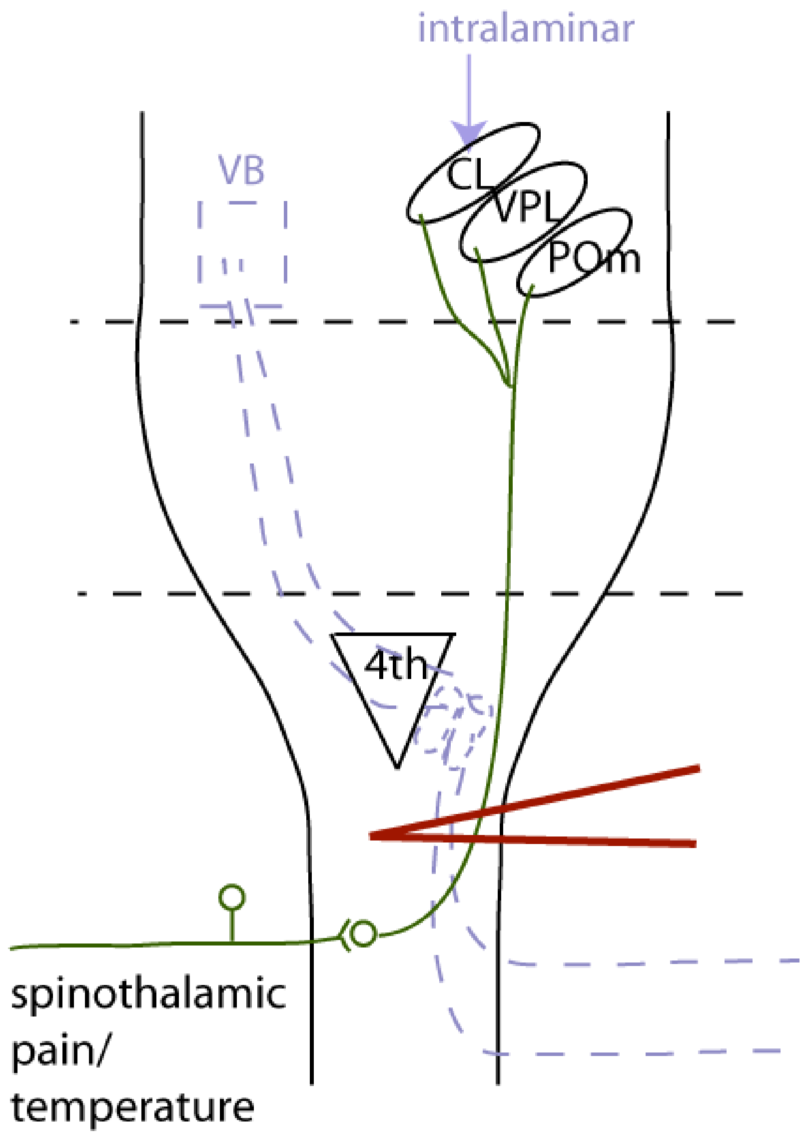
Pathways to the brain:
II: Anterolateral (spinothalamic) pathway

Pain+
Temperature
Information



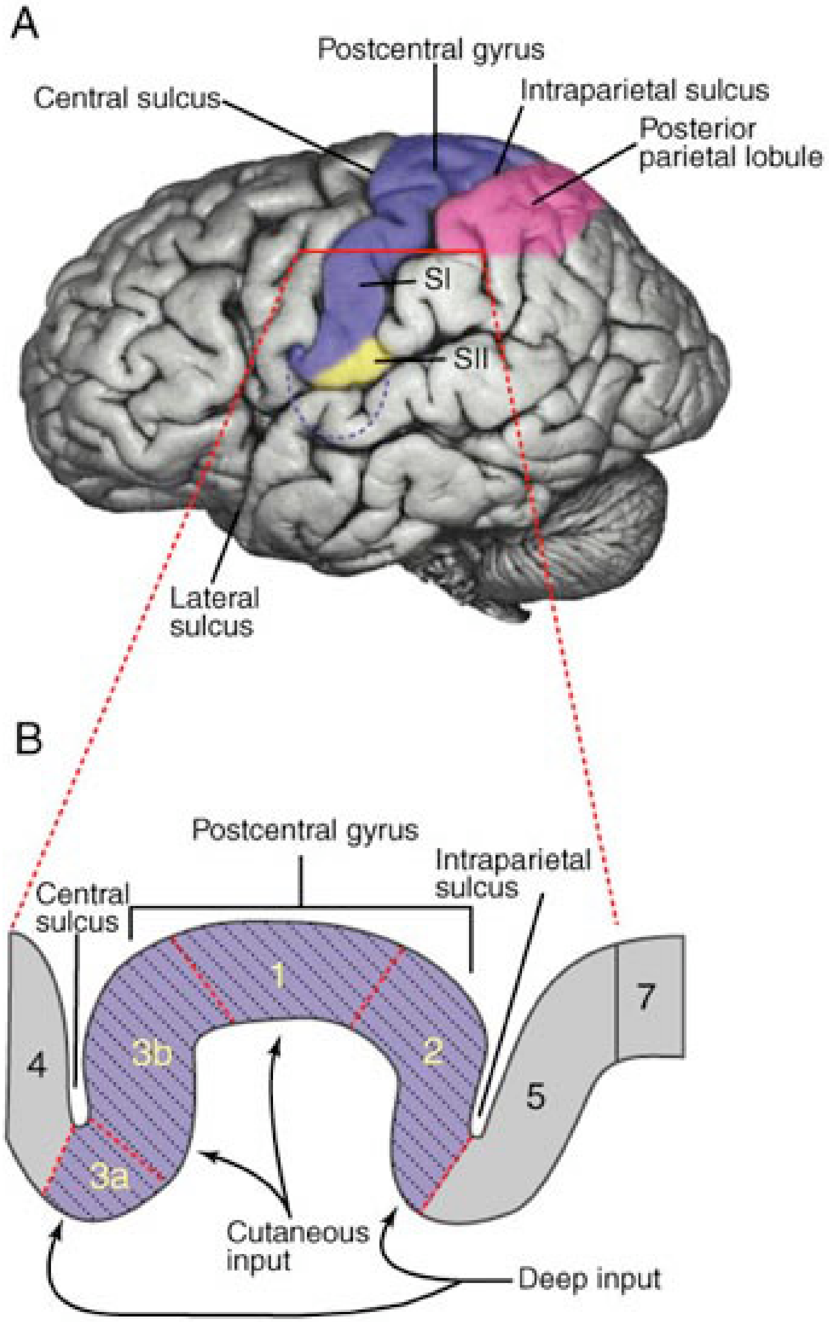
- VPL = ventro-posterolateral
- CL = central lateral nucleus (part of intralaminar nuclei)
- POm = medial nucleus of posterior complex

Pathways to the brain:
II: Anterolateral (spinothalamic) pathway



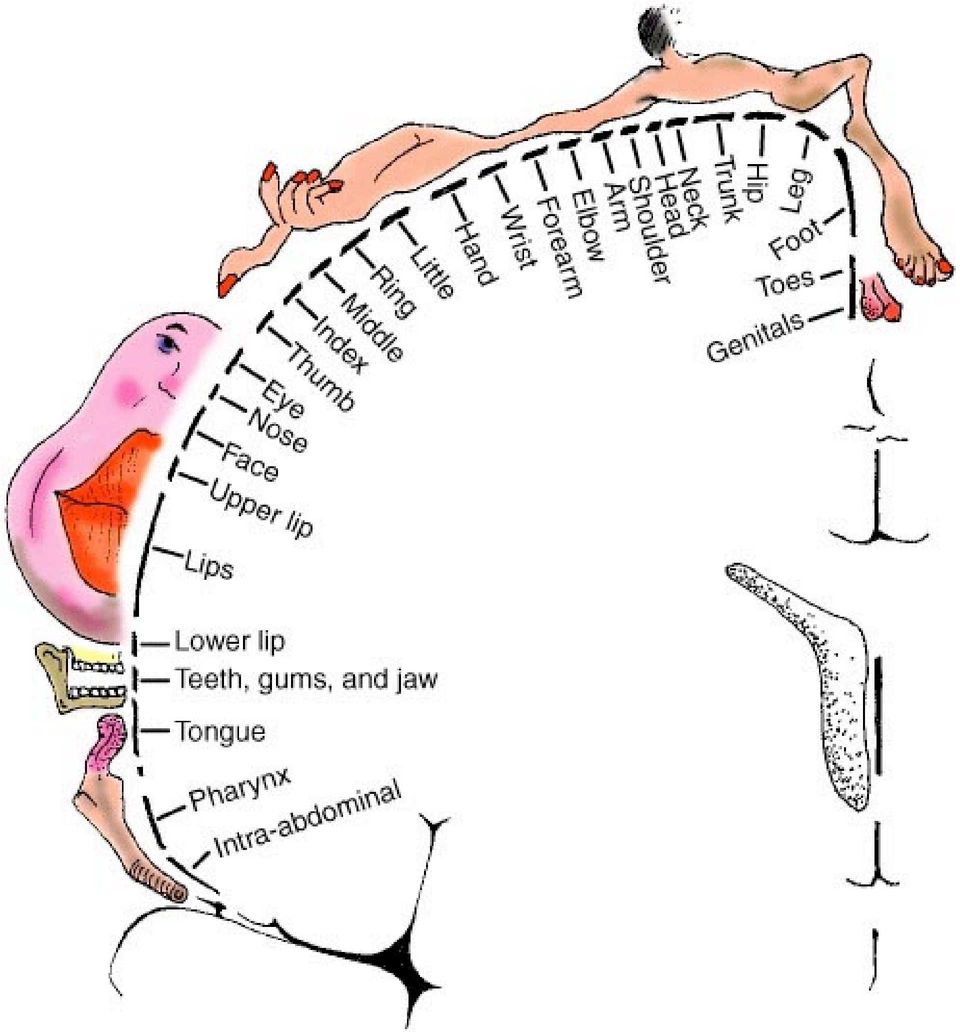
- What happens when spinal cord is cut/ injured just below 4th ventricle?

Somatosensory cortex



- primary somatosensory cortex (SI): postcentral gyrus + posterior bank of central sulcus
- contains 4 sub-regions: 3a, 3b, 1, 2

Each of the 4 areas in SI contains a homunculus



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- regions of skin with greater number of receptors are enlarged on cortical surface
- NOTE: hand and face are close together in cortex, but far apart in terms of skin distance → functional grouping

Somatosensory Plasticity Experiments (S1)

1) Deafferentation of body part: small scale (mm - finger)

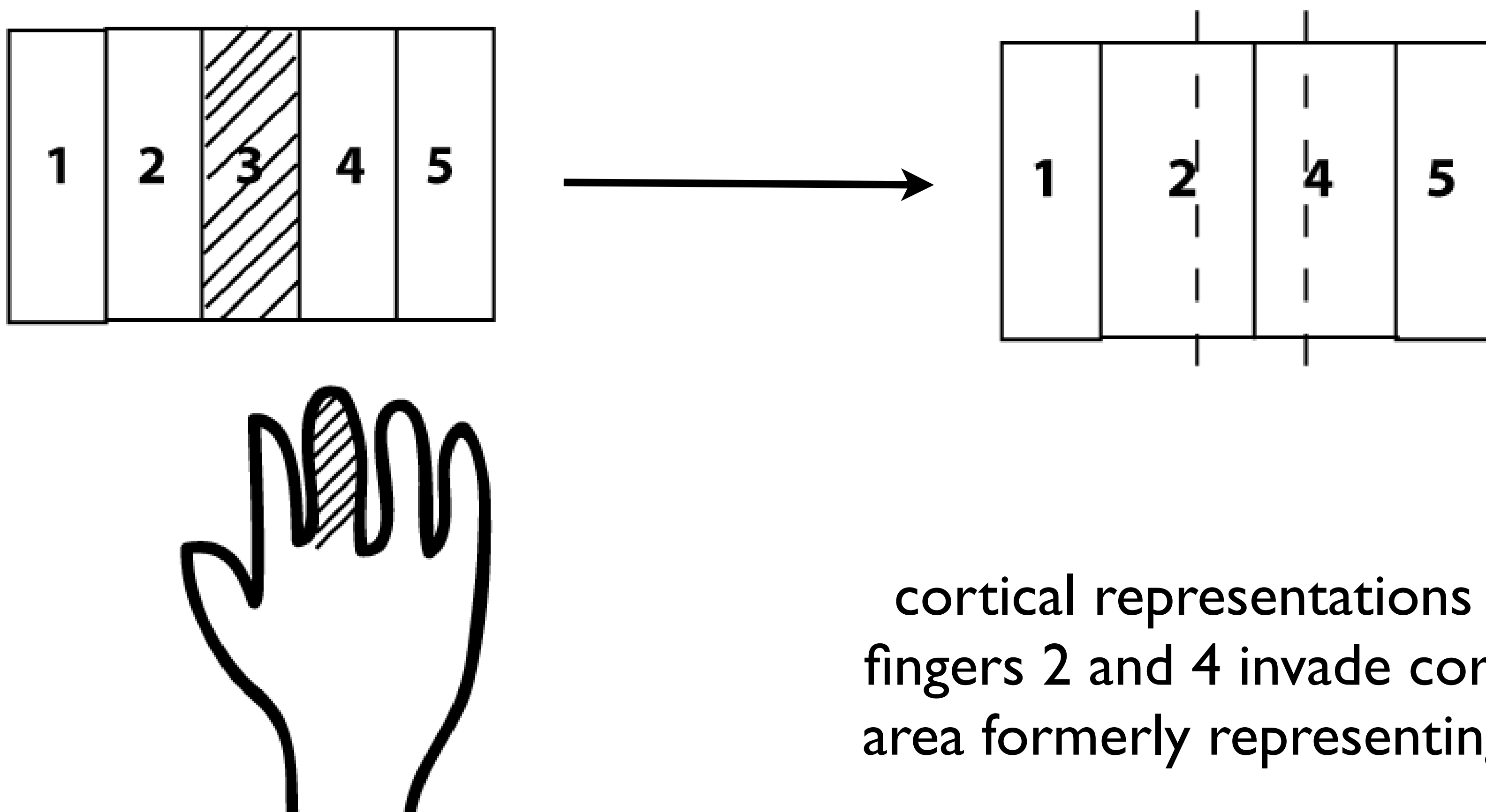
2) Deafferentation of body part: large scale (cm - arm)

3) Transferring skin patch to a different finger

4) Syndactily

5) Repetitive use of body part

1) Deafferentation of finger



cortical representations for fingers 2 and 4 invade cortical area formerly representing #3

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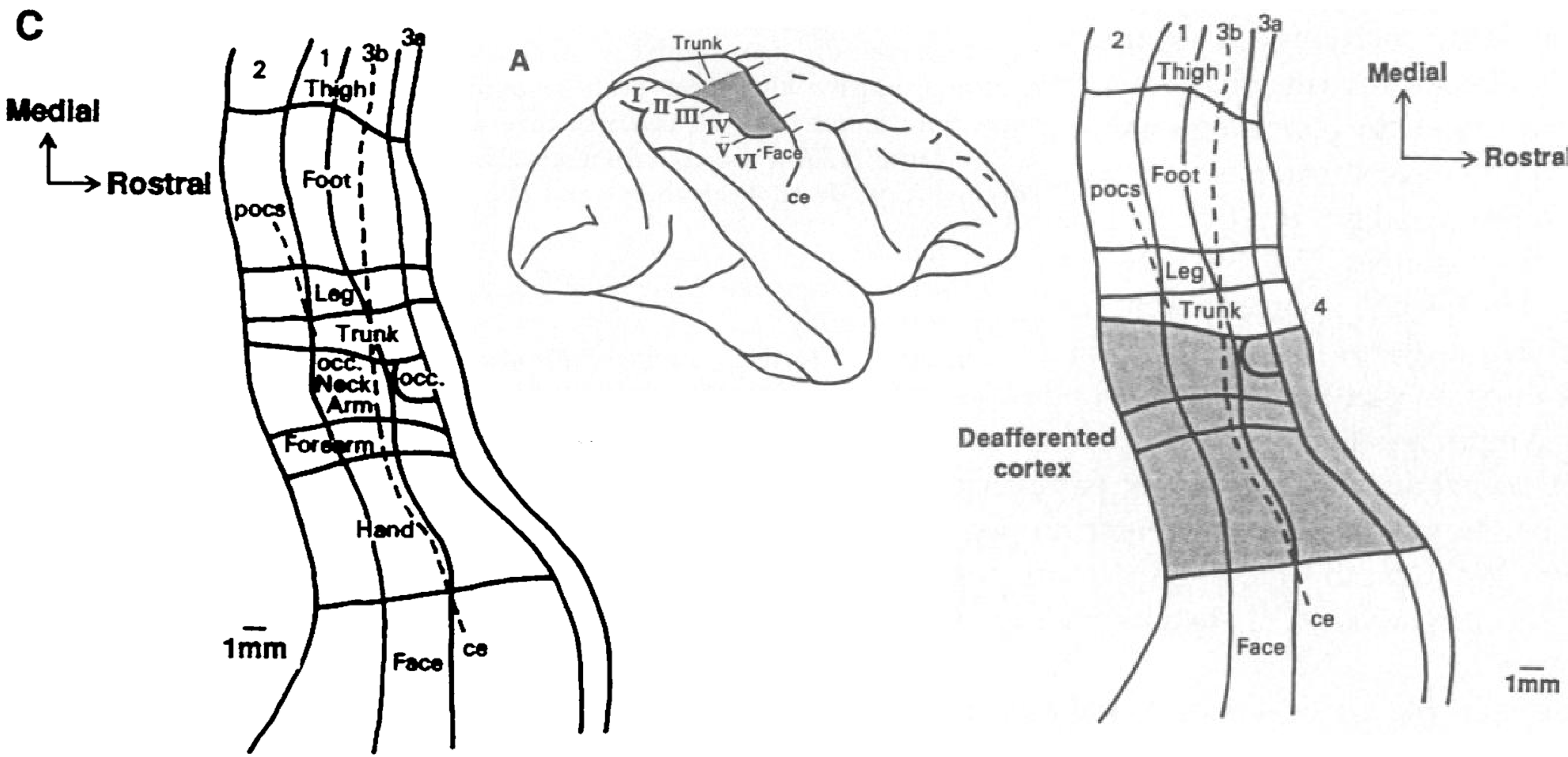
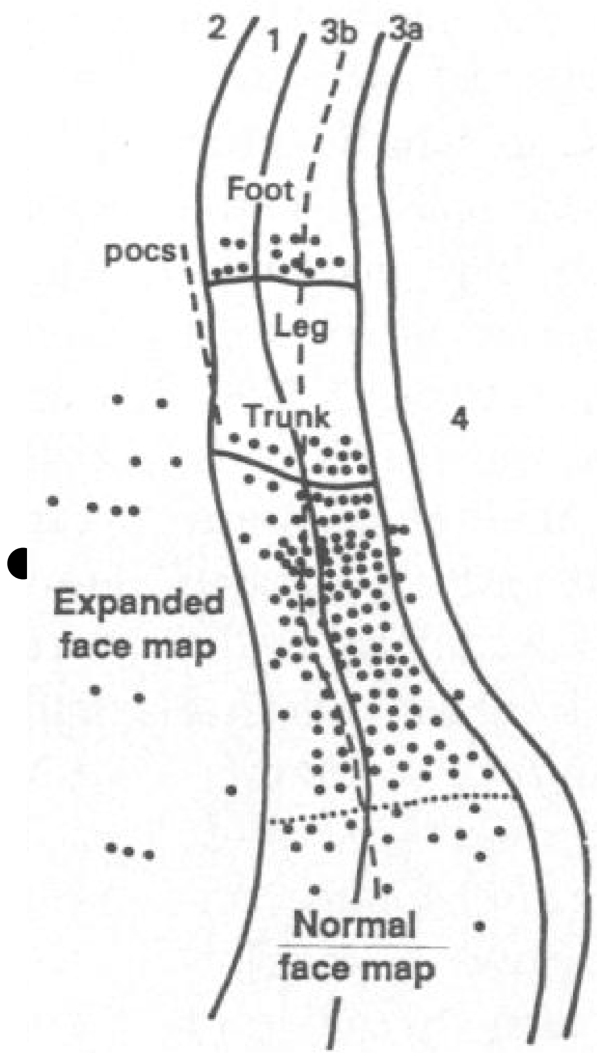
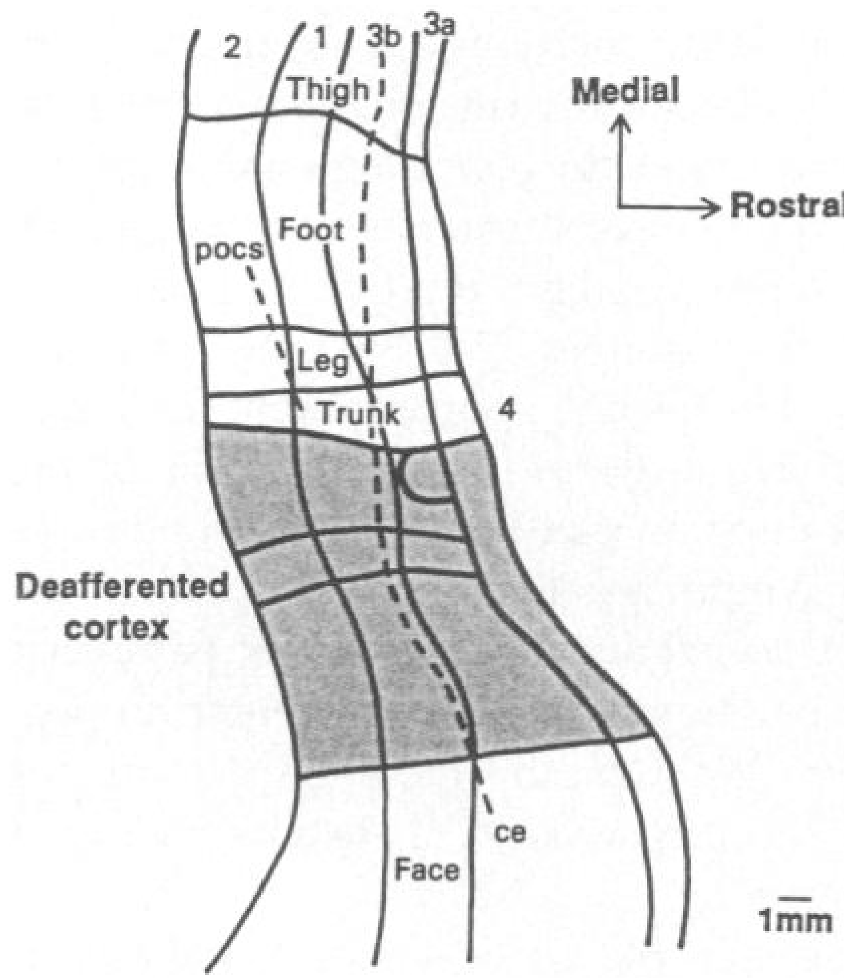
2) Deafferentation of monkey arm



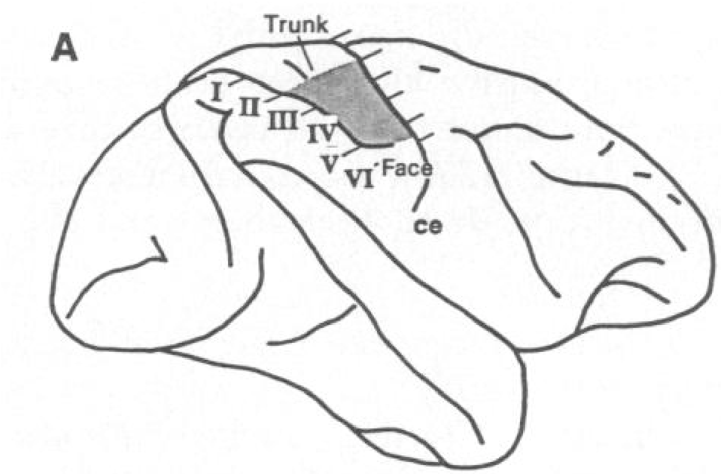
Pons et al., *Science*, 1991

Face representation invades former arm representation

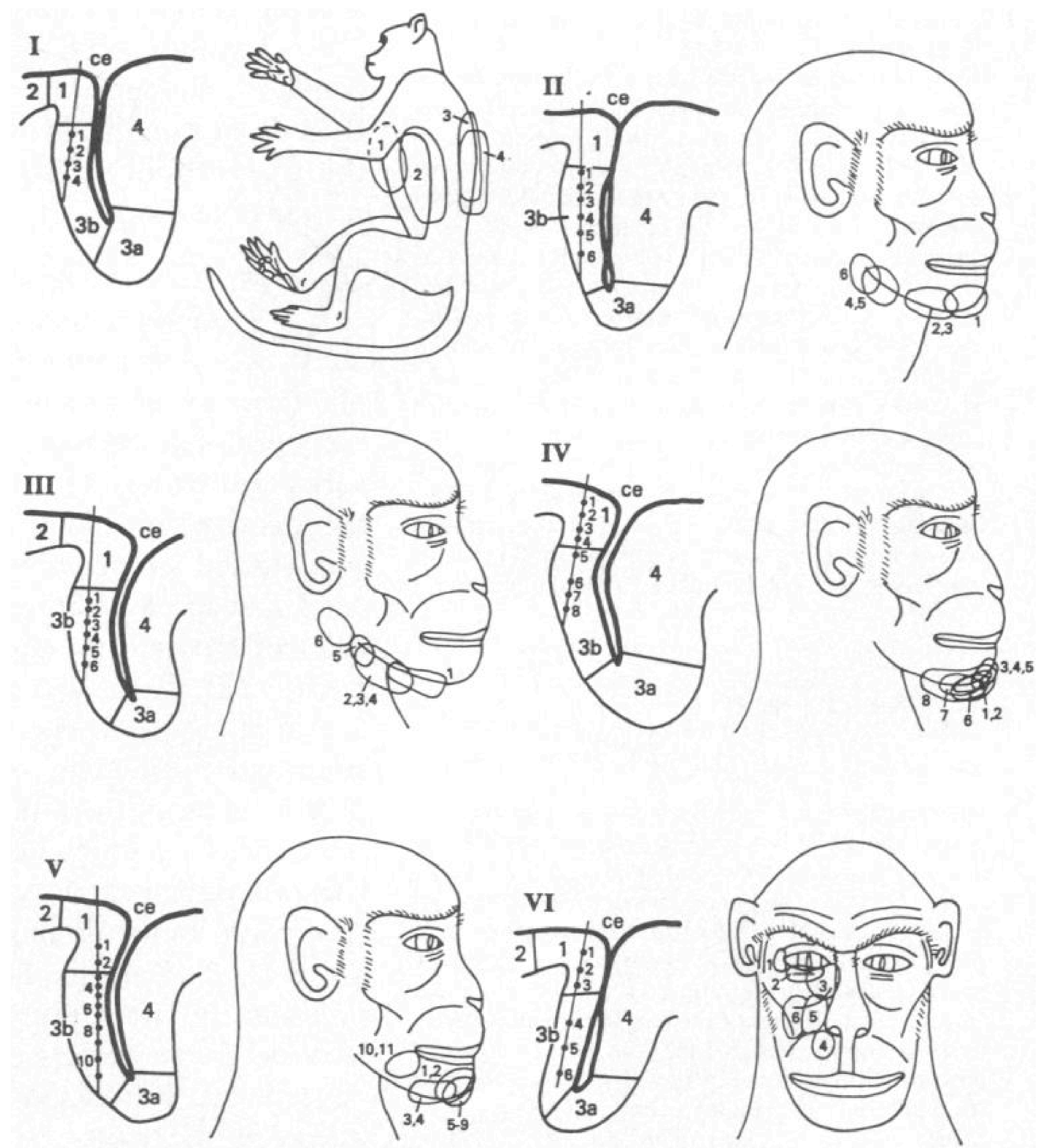




Pons et al., *Science*, 1991



> 12 years later: Stimulating parts of the face will activate neurons in arm area (see II - V)



Pons et al., *Science*, 1991

3) Skin transplant from little finger to thumb

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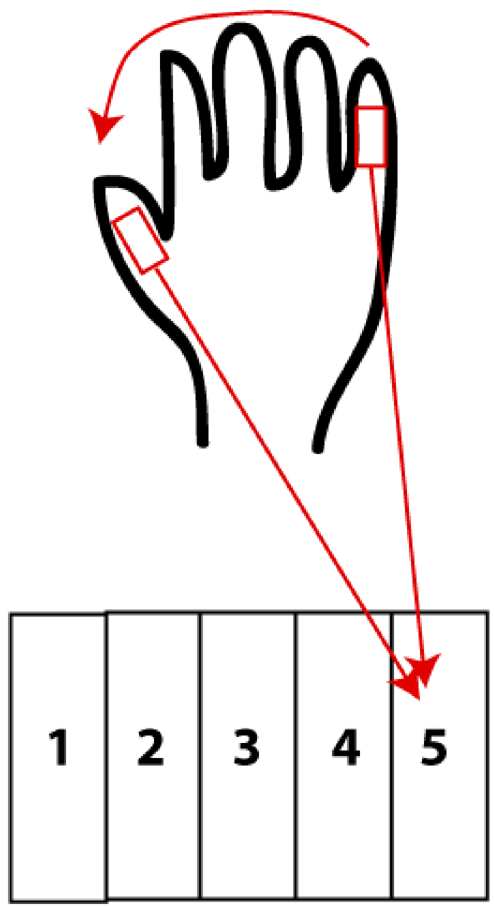
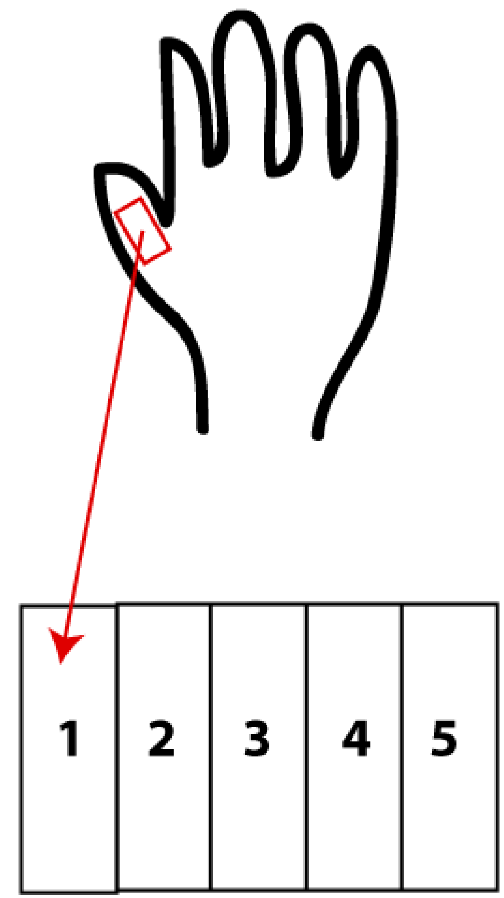
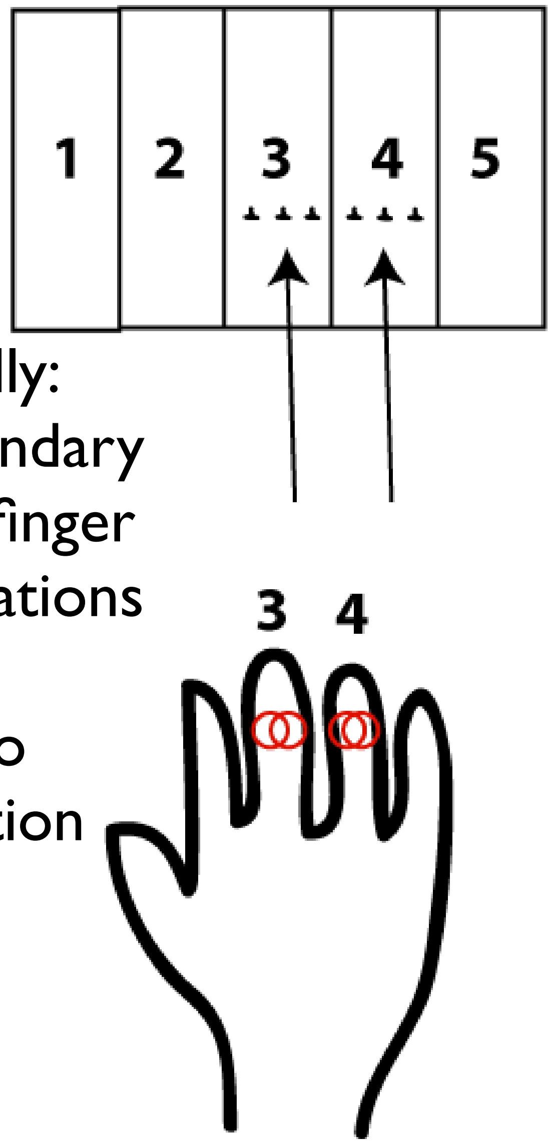


Initially, stimulating thumb will activate pinkie representation (and will feel like pinkie)



Later, thumb will activate thumb representation (and will feel like thumb)

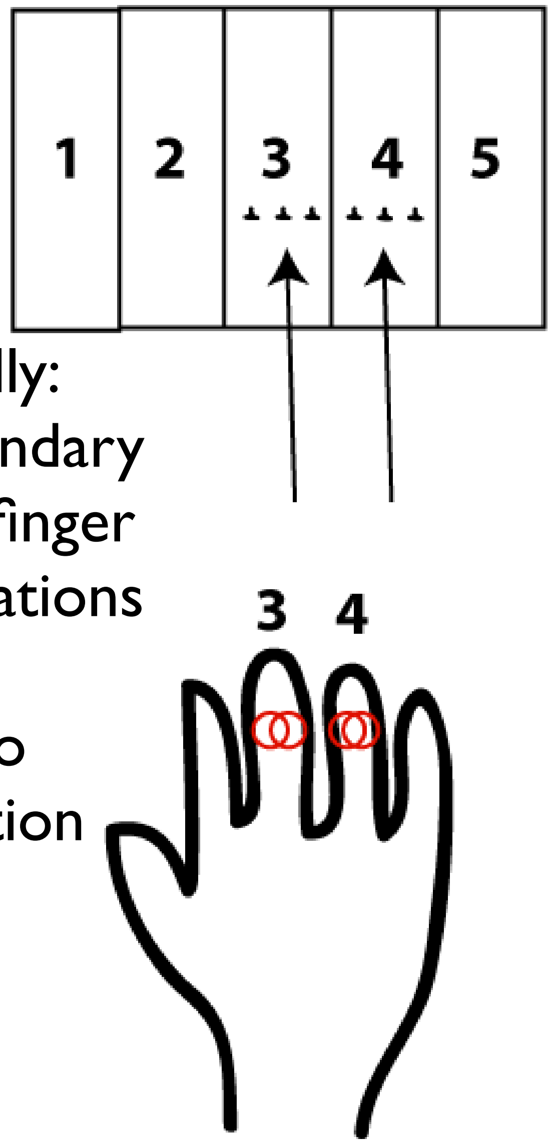
4) Syndactily



normally:
sharp boundary
between finger
representations

due to
correlation

4) Syndactily



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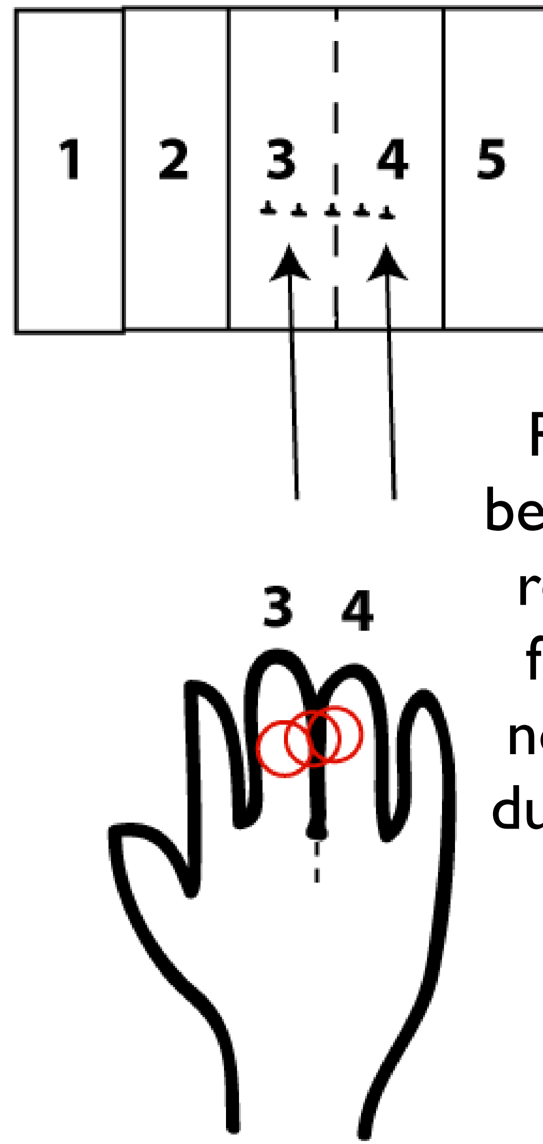
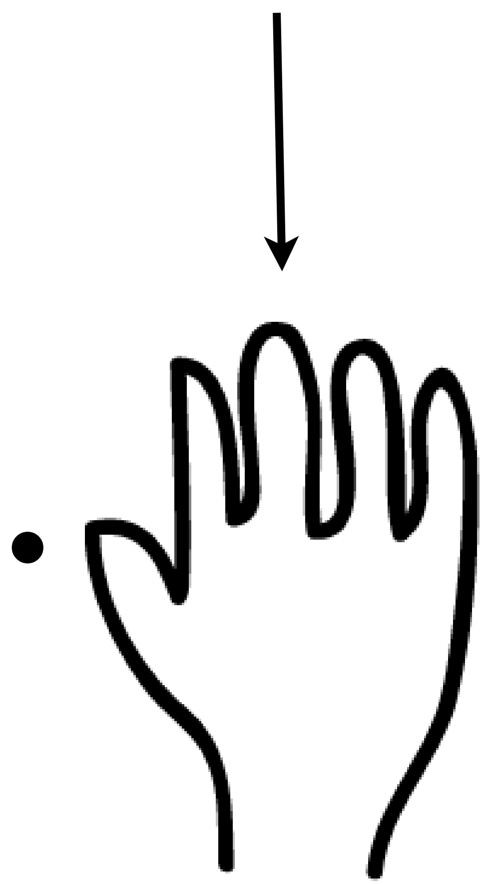
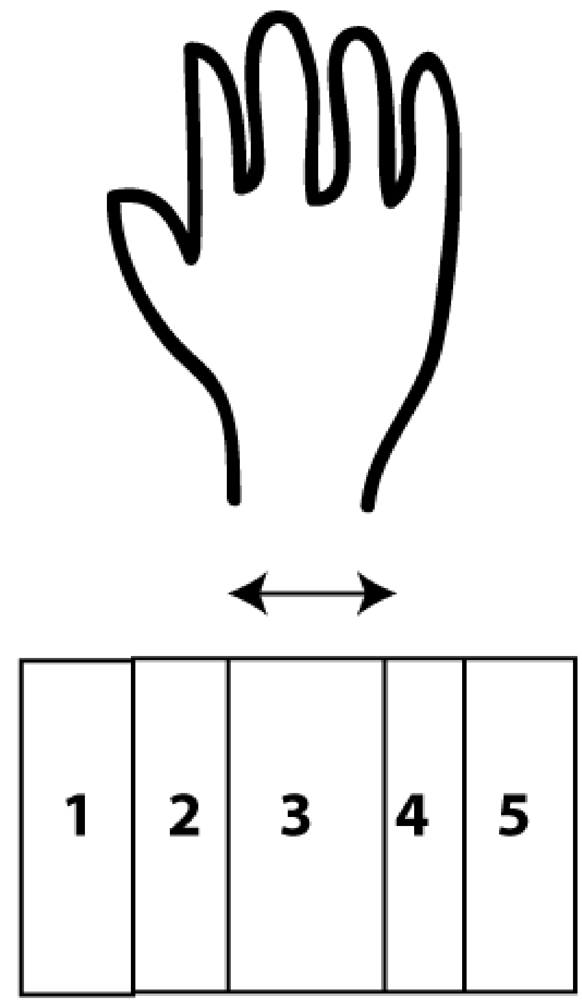


syndactily:
RFs cross over
between 3 and 4 -
representations
for 3 and 4 are
now continuous,
due to correlated
input

5) Repetitive somatosensory stimulation



Repetitive stimulation (monkey trained to touch spinning disk)



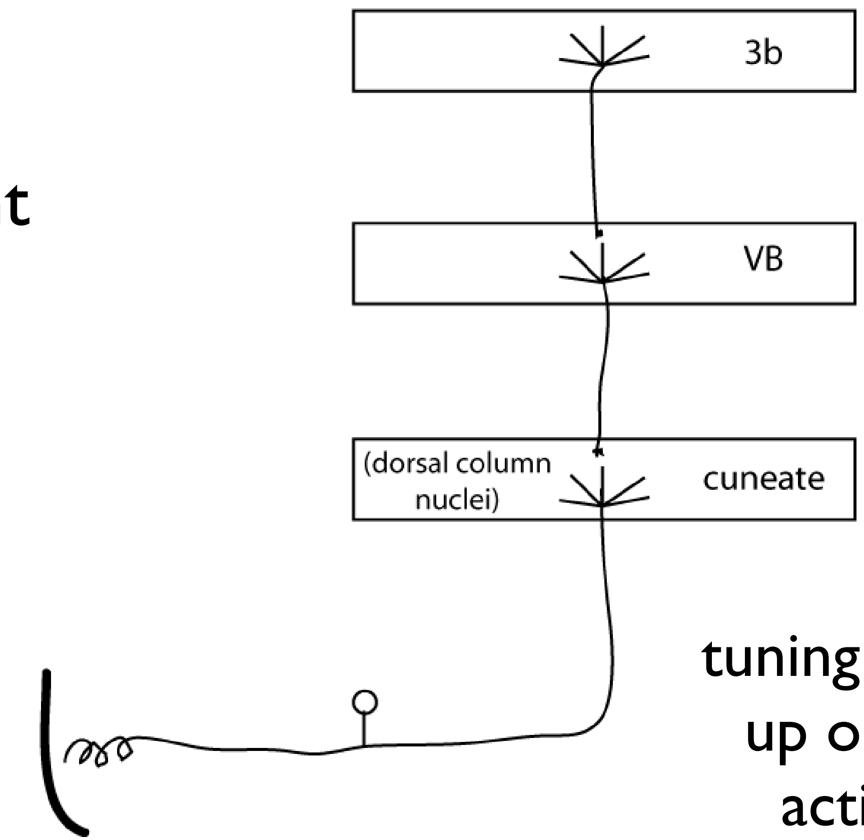
Cortical representation for that finger expands in ~2 weeks

Possible mechanisms for plasticity in adult somatosensory cortex

1) for small-scale (2-3 mm) shift: rearrangement of **existing synapses** in S1

2) for large-scale (cm) rearrangements: growth of **new axons**? (including dorsal column nuclei, VB)

synaptic spread



tuning synapses up or down; activating "silent" synapses

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Summary

- adult somatosensory cortex is PLASTIC (to some extent).
- 2 possible mechanisms for plasticity: synaptic vs. larger-scale, axonal
- somatosensory cortex (SI, SII, and other areas) is organized **somatotopically**, with body part representations also grouped by **functional correlation**/co-activation <u>(activity-dependent)</u>
- (e.g. tops of fingers are not frequently co-stimulated with undersides, so → separate; mouth is frequently co-stimulated with hand, e.g. during feeding