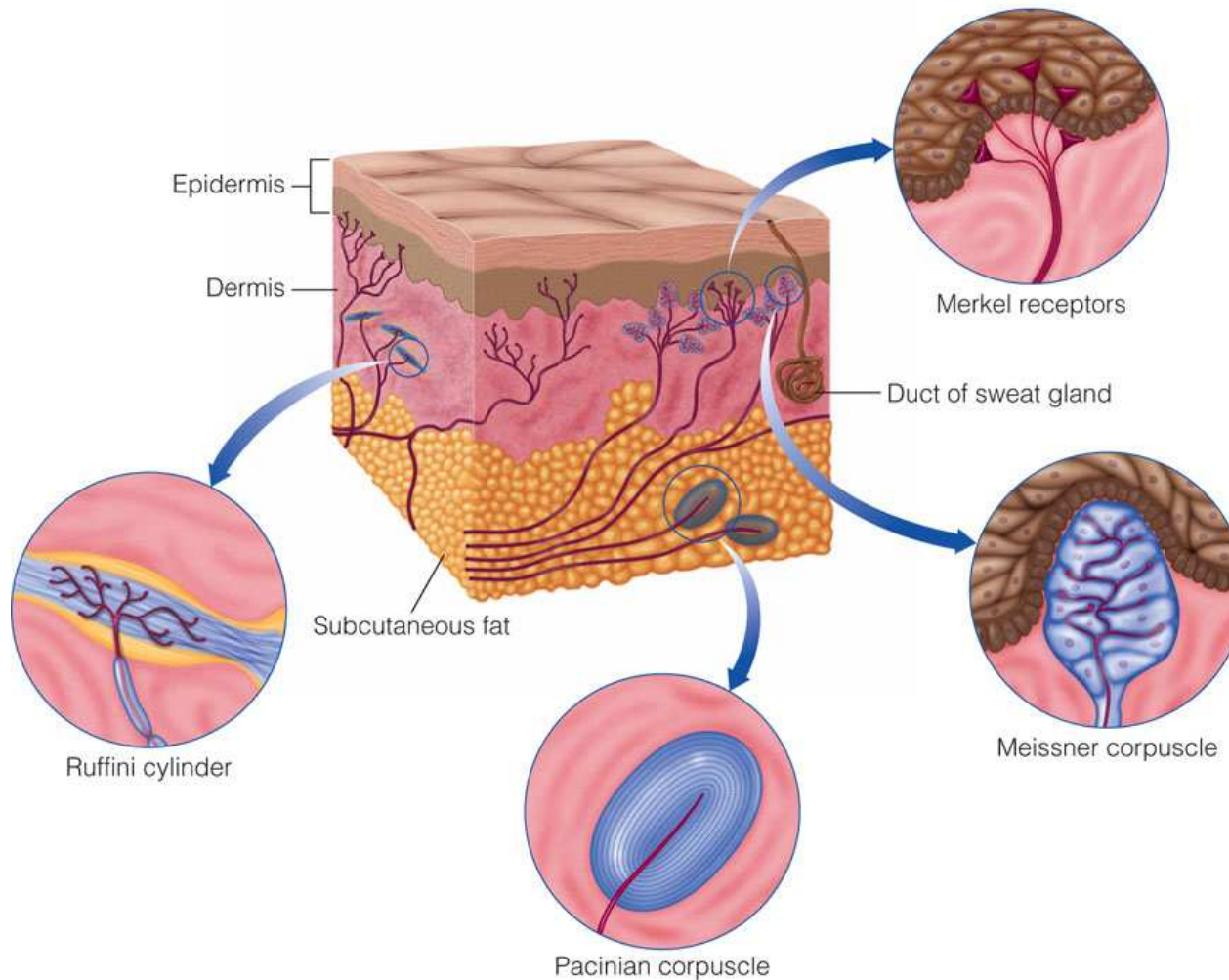


Chapter 14: The Cutaneous Senses



Cutaneous System

- **Skin** - heaviest organ in the body
 - Epidermis is the outer layer of the skin, which is made up of dead skin cells
 - Dermis is below the epidermis and contains four kinds of *mechanoreceptors* that respond to stimuli such as pressure, stretching, and vibration.



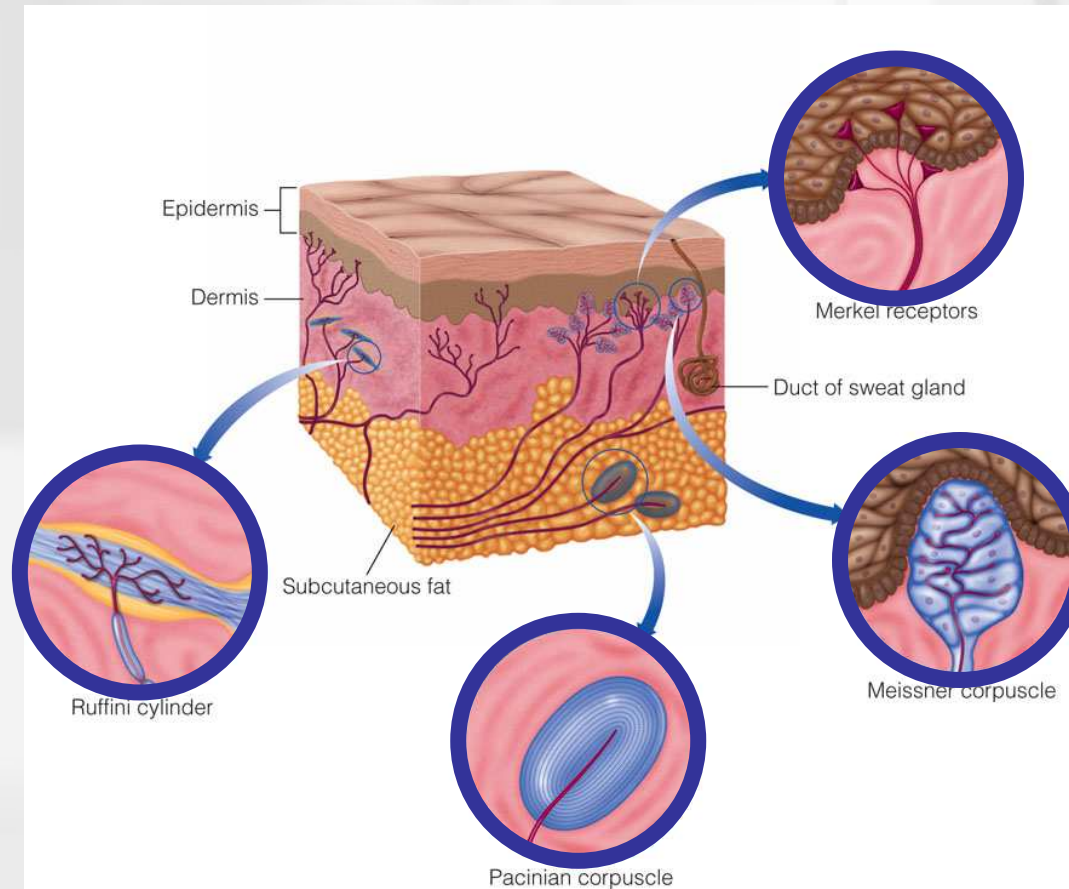
Mechanoreceptors

Merkel receptor - disk-shaped receptor located near the border between the epidermis and dermis

Meissner corpuscle - stack of flattened disks in the dermis just below epidermis

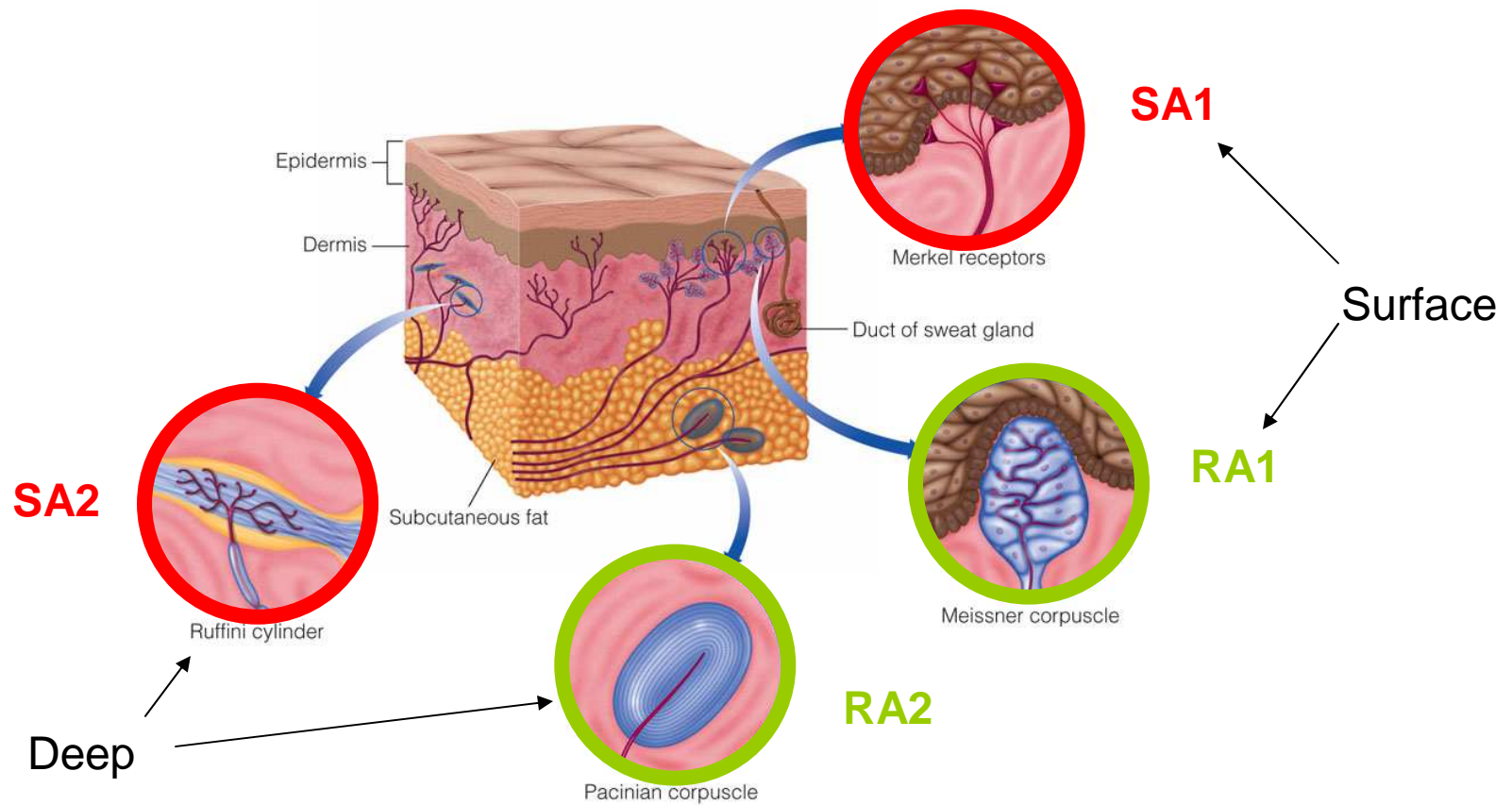
Ruffini cylinder - branched fibers inside a cylindrical capsule

Pacinian corpuscle - onion-like capsule located deep in the skin

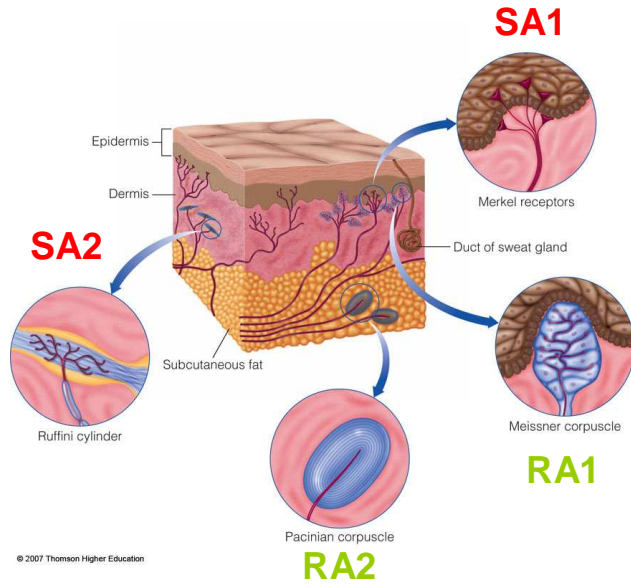


Mechanoreceptors

- Temporal Properties (adaptation)
 - Slowly adapting fibers (SA) found in Merkel and Ruffini receptors - fire continuously as long as pressure is applied
 - Rapidly adapting fibers (RA) found in Meissner receptor and Pacinian corpuscle - fire at onset and offset of stimulation

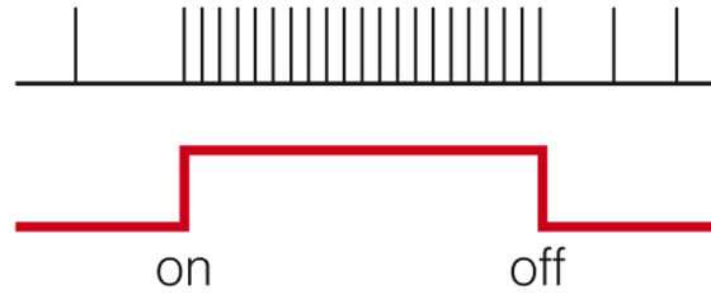


Mechanoreceptors



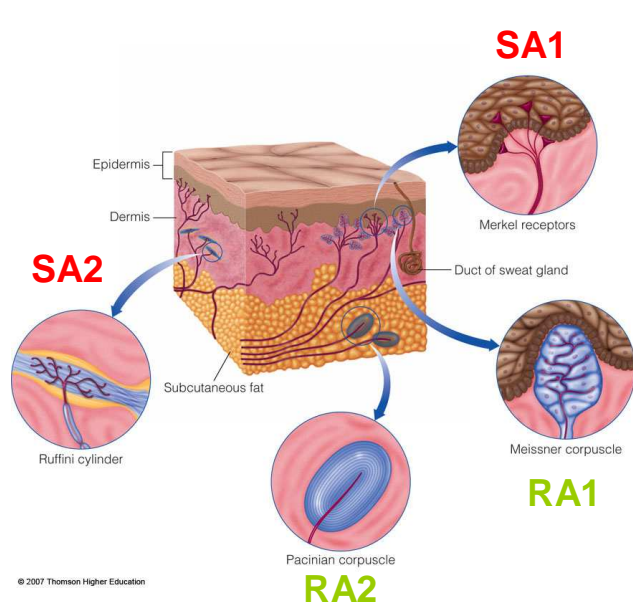
© 2007 Thomson Higher Education

Merkel (SA1)
Ruffini (SA2)



(a) Slow adapting (SA)

- Spatial Properties (detail resolution)



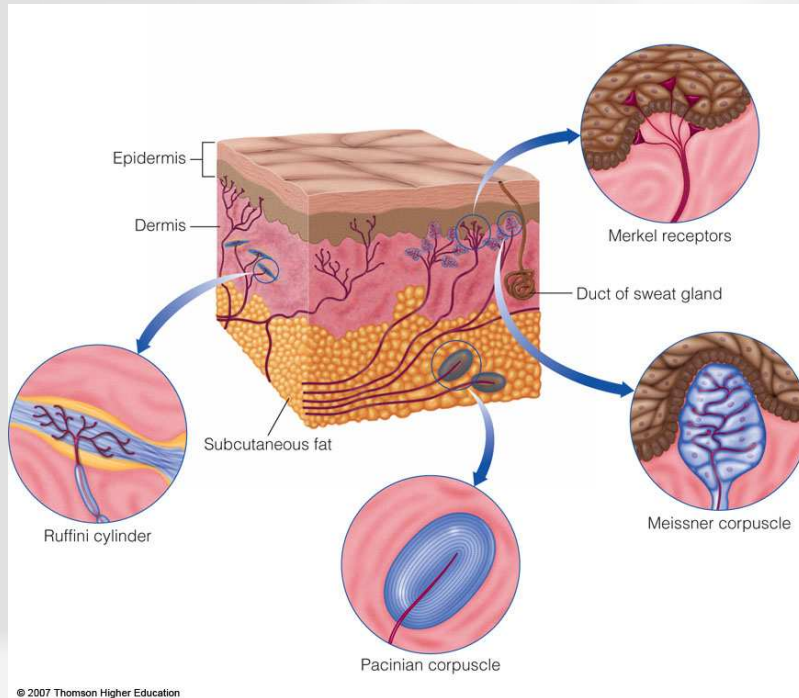
Surface receptors: Merkel receptors (SA1) and Meissner receptors (RA1) have small receptive fields and respond to slow vibration rates.

Deep receptors: RA2 fibers (Pacinian corpuscle) and Ruffini (SA2) have large receptive fields and respond to high vibration rates.

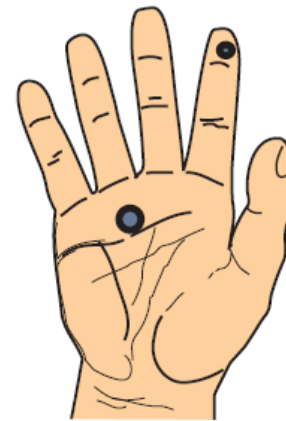
Adapting Rate

| | | Slow | Rapid |
|---------------------|------|------------------------|--------------------------|
| Vibration frequency | Low | Merkel receptors (SA1) | Meissner receptors (RA1) |
| | High | Ruffini (SA2) | Pacinian corpuscle (RA2) |

Surface receptors have smaller receptive fields than deep receptors.



small r.f.



RA1
SA1



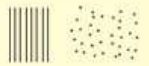
large r.f.



RA2
SA2

Properties of the four mechanoreceptor types.

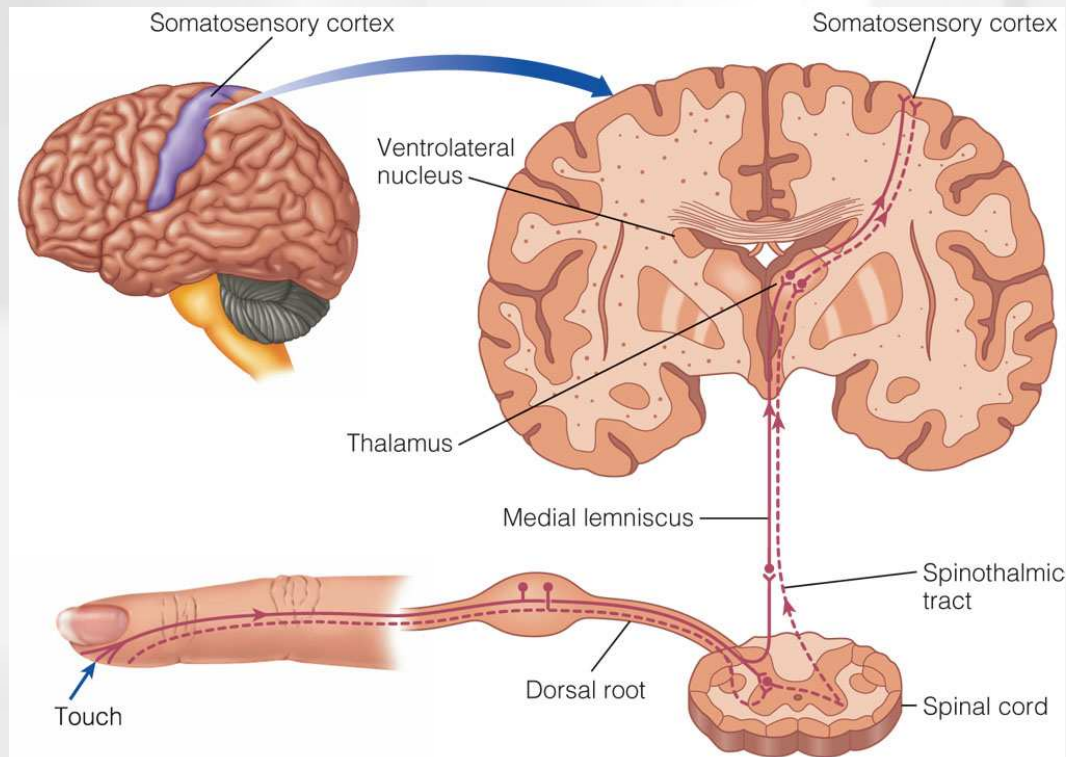
Table 14.1 ■ *Properties of Four Types of Mechanoreceptors*

| Receptor (Fiber) | How Fiber Responds | Frequency Response | Perceptions |
|---|---|--------------------------|---|
|  Merkel (SA1) |  Continuous (slow adapting) | 0.3–3 Hz Slow pushing |  Fine details |

| | | Adapting Rate | |
|---------------------|------|------------------------|--------------------------|
| | | Slow | Rapid |
| Vibration Frequency | Low | Merkel receptors (SA1) | Meissner receptors (RA1) |
| | High | Ruffini (SA2) | Pacinian corpuscle (RA2) |

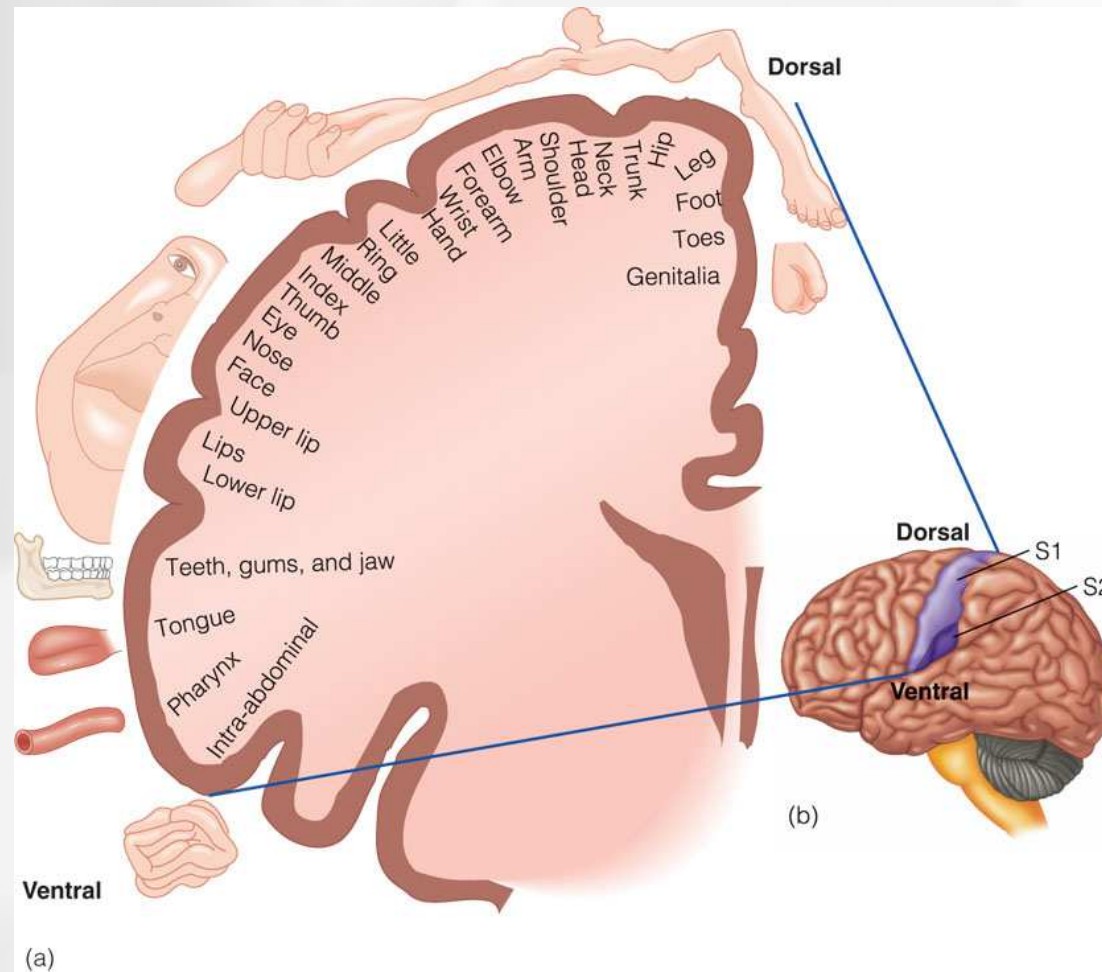
Pathways from Skin to Cortex

- Nerve fibers travel in bundles (peripheral nerves) to the spinal cord
- Two major pathways in the spinal cord:
 - Medial lemniscal pathway consists of large fibers that carry proprioceptive and **touch** information
 - Spinothalamic pathway consists of smaller fibers that carry temperature and **pain** information
 - These cross over to the opposite side of the body and synapse in the thalamus, and then on to the Somatosensory cortex, or SA1



Maps of the Body on the Cortex

- Signals travel from the thalamus to the somatosensory receiving area (S1) and the secondary receiving area (S2) in the parietal lobe
- Body map (*homunculus*) on the cortex shows more cortical space allocated to parts of the body that are responsible for detail



Discovered by
Penfield in 1950

The tongue may be used to as a substitute for sight. For more, see the ScienceNews article *The Seeing Tongue*.

http://courses.washington.edu/psy333/other/ScienceNews_Sensory_Substitution_2001.pdf

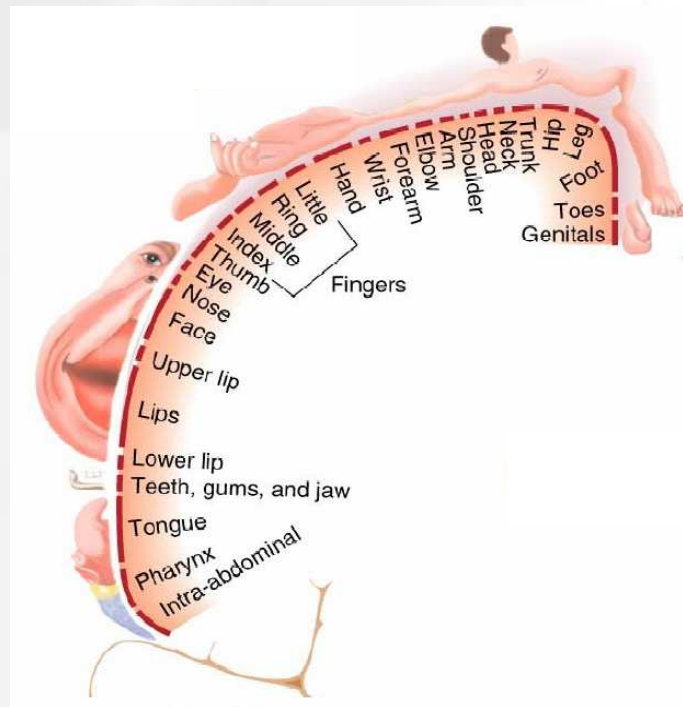


Phantom Limb Disorder

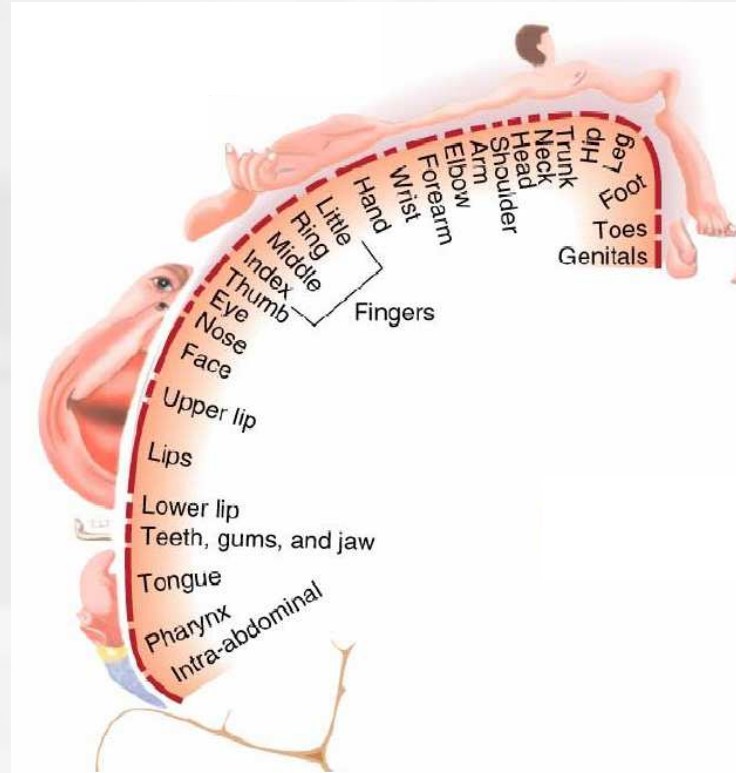
The persistent sensation of an appendage, after removal by amputation or simple denervation.

Ramachandran and colleagues has shown that touching the face of a phantom limb patient leads to sensations in the missing hand and arm.

This lead to the hypothesis that the brain is 'filling in' for the missing stimulation in the hand and arm representation in the somatosensory cortex.



Phantom Limb Disorder



Touching the chin stimulated the finger representation best, indicating that maybe Penfield got the face representation upside down.

Sure enough, an fMRI experiment in 1999 showed that Ramachandran was right and the somatosensory homunculus shown in textbooks (and Penfield) is wrong.

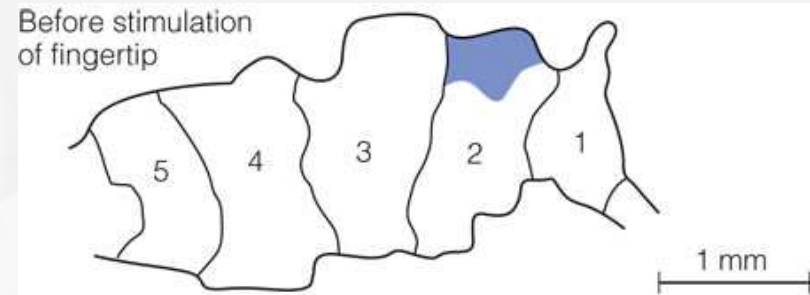
Phantom Limb Disorder

Phantom limb disorder can be painful and uncomfortable.

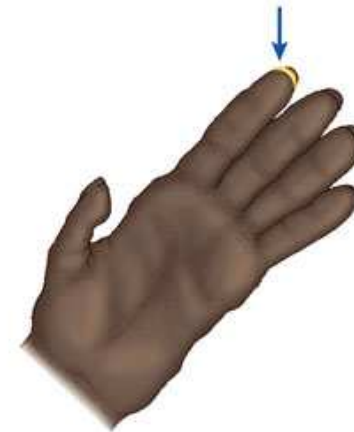
Ramachandran used a 'mirror box' to simulate the presence of the amputated hand which alleviated the symptoms in most of his patients.



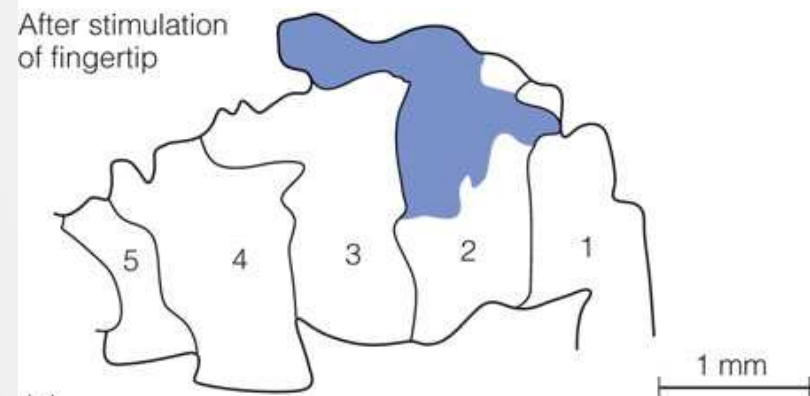
Plasticity in neural functioning leads to multiple homunculi and changes in how cortical cells are allocated to body parts



(a)



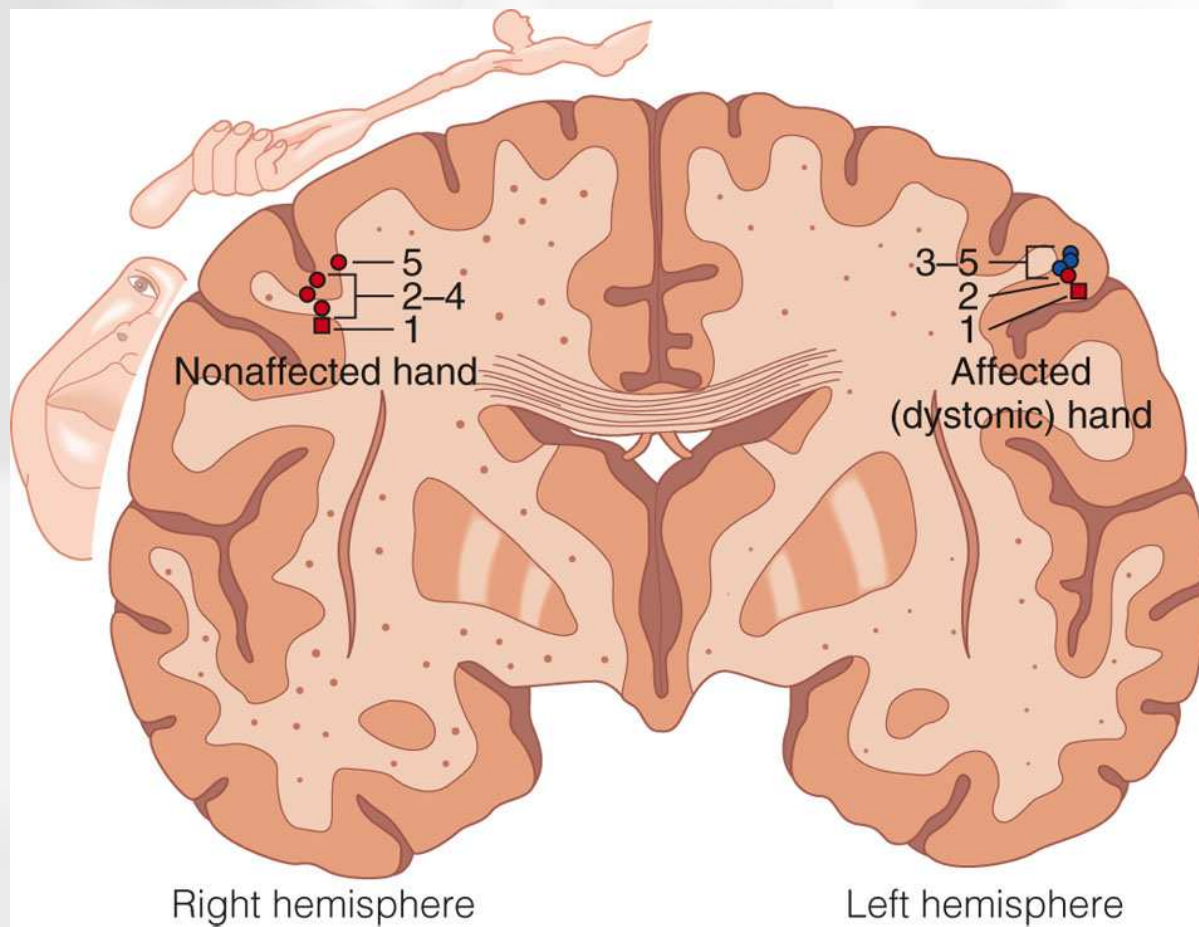
(b)



(c)

Maps of the Body on the Cortex

- Focal dystonia or “musician’s cramp” - loss of skilled hand movements
 - Research examining the cortex has found that musicians with this disorder have “fused” cortical areas belonging to the affected hand
 - Fortunately (??) this only happens in about 1% of musicians

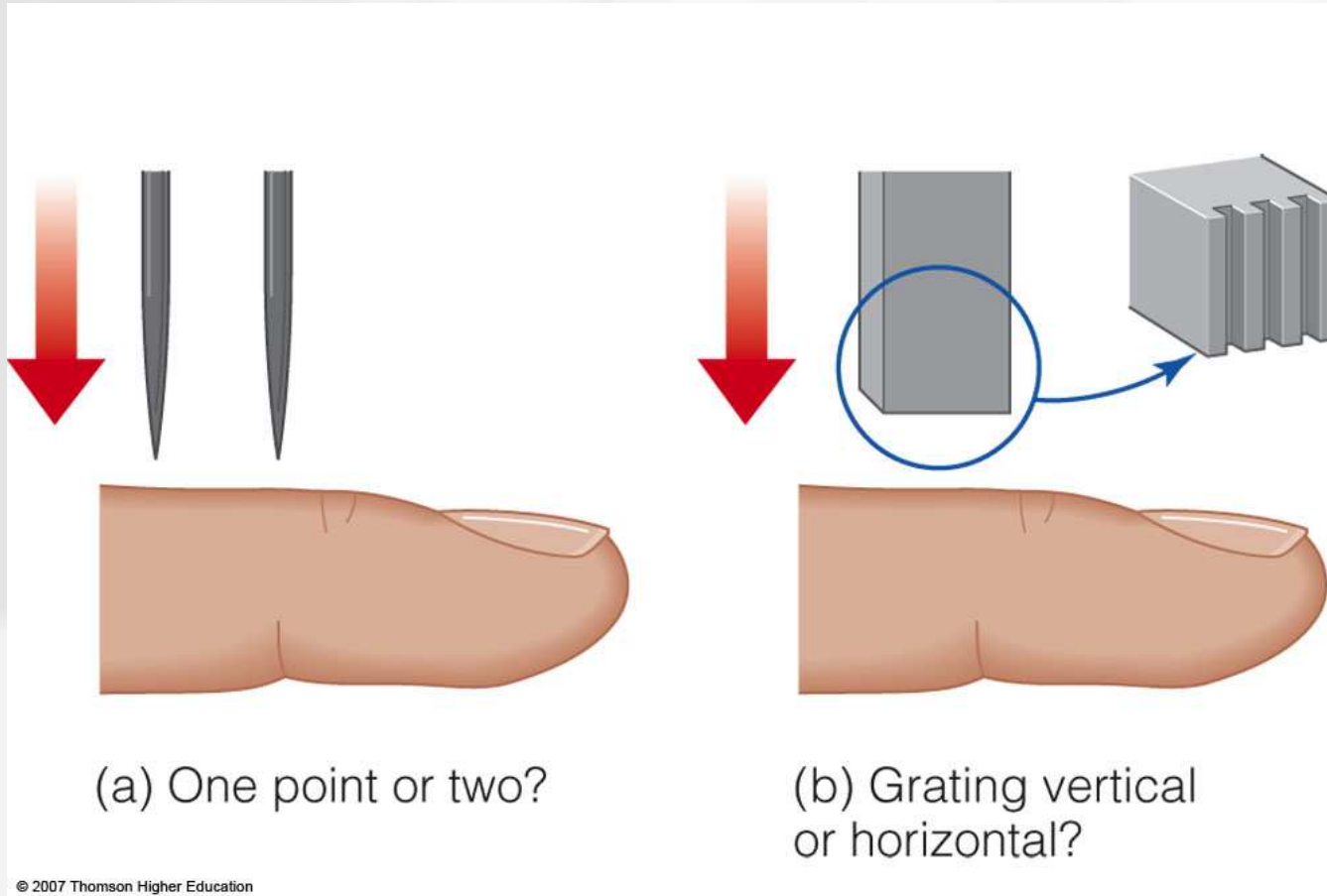


Perceiving Details

- Measuring tactile acuity
 - Two-point threshold - minimum separation needed between two points to perceive them as two units
 - Grating acuity - placing a grooved stimulus on the skin and asking the participant to indicate the orientation of the grating

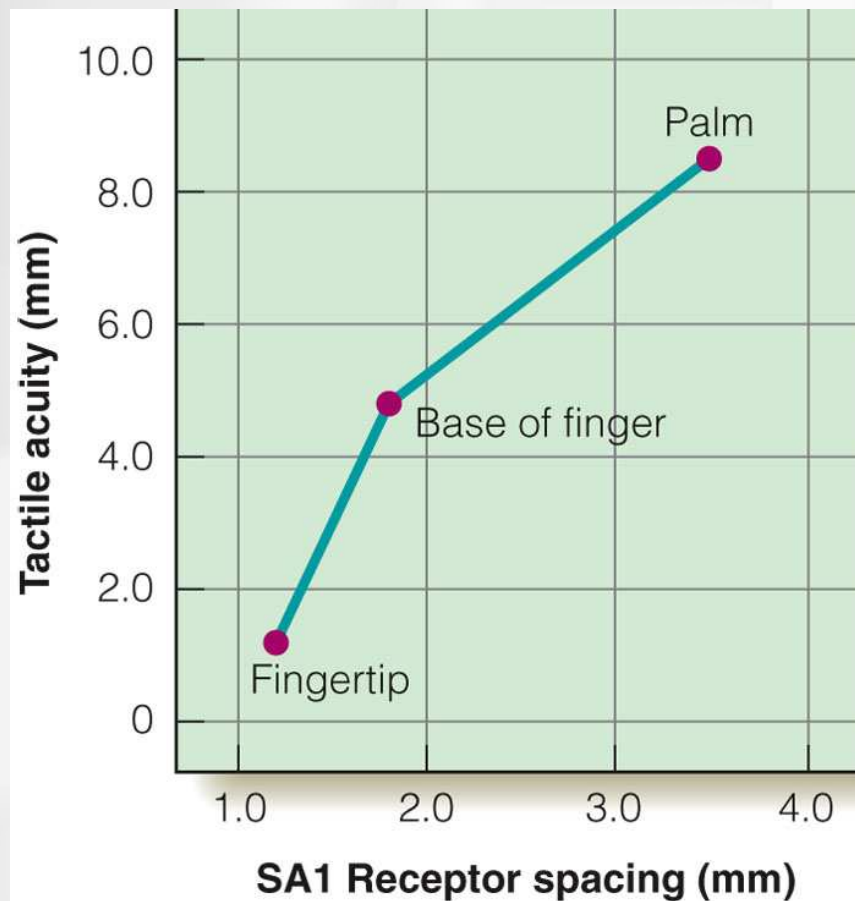


Tactile acuity thresholds are determined by Merkel receptors (SA1)



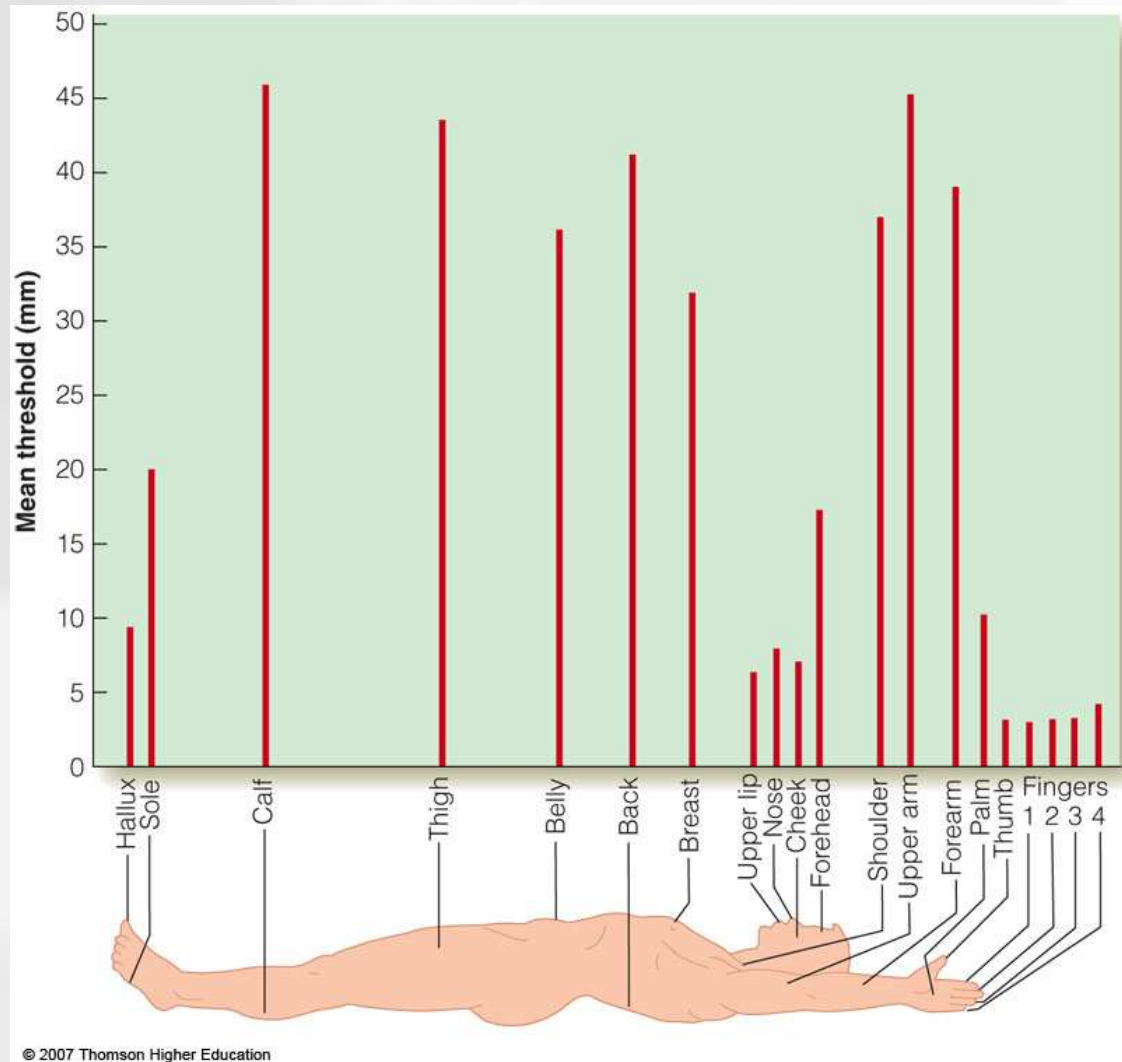
Receptor Mechanisms for Tactile Acuity

- There is a high density of Merkel receptor/SA1 fibers in the fingertips
- Merkel receptors are densely packed on the fingertips - similar to cones in the fovea
- Both two-point thresholds and grating acuity studies show these results

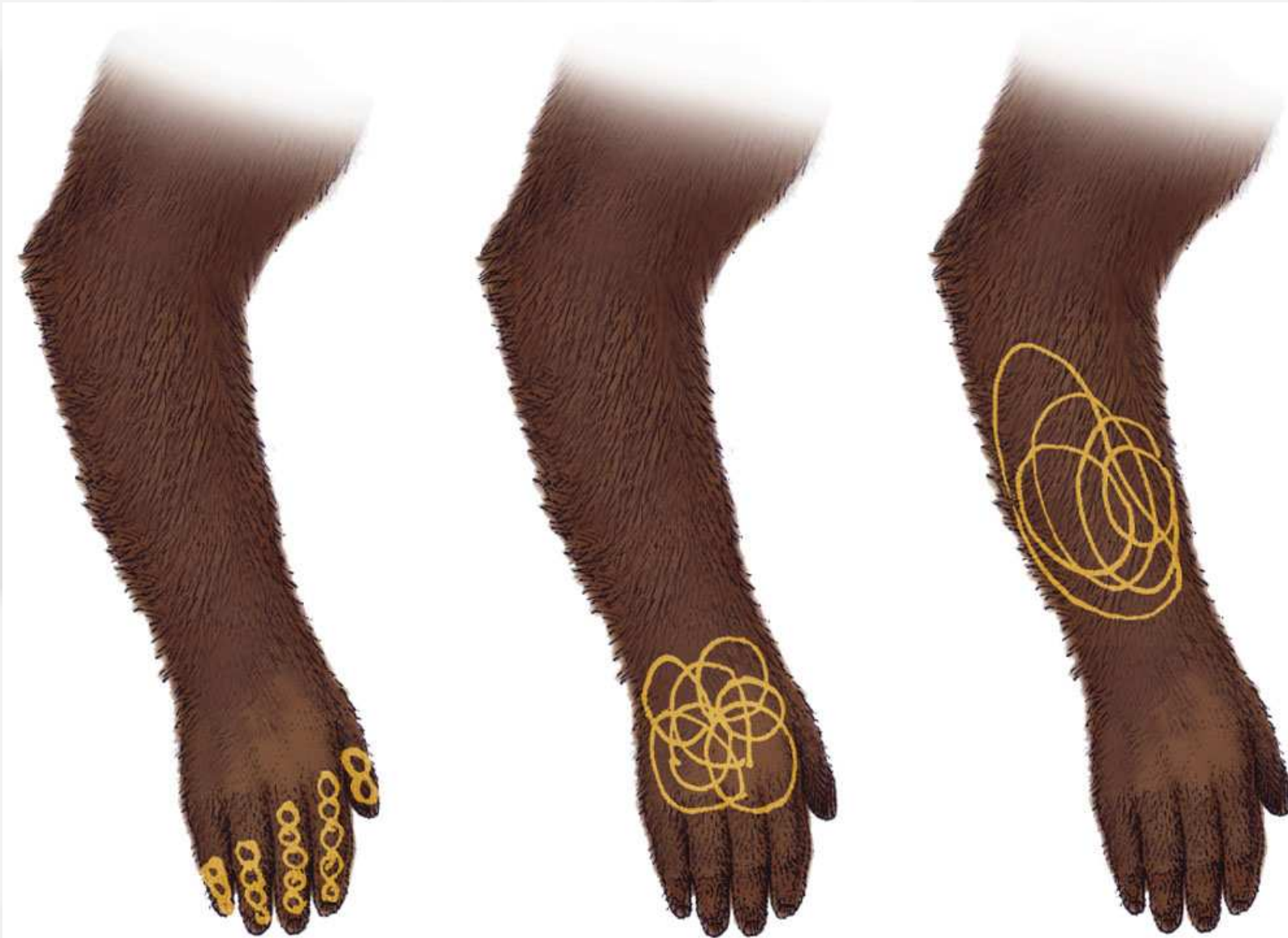


Cortical Mechanisms for Tactile Acuity

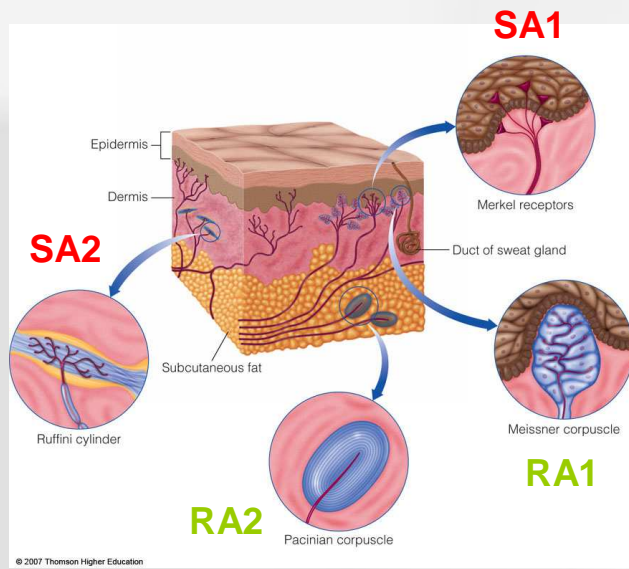
- Body areas with high acuity have larger areas of cortical tissue devoted to them
- This parallels the “magnification factor” seen in the visual cortex for the cones in the fovea



Receptive field sizes correlate with tactile spatial acuity.



Recall from yesterday:



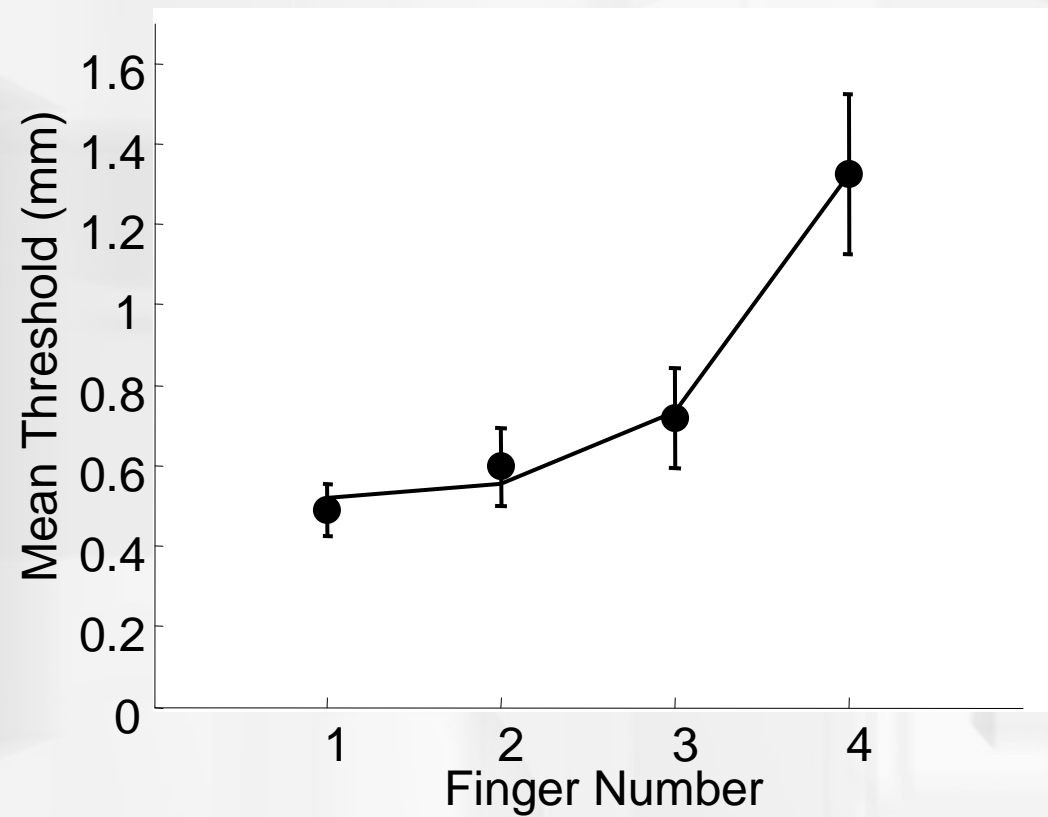
Surface receptors: Merkel receptors (SA1) and Meissner receptors (RA1) have small receptive fields and respond to slow vibration rates.

Deep receptors: RA2 fibers (Pacinian corpuscle) and Ruffini (SA2) have large receptive fields and respond to high vibration rates.

Adapting Rate

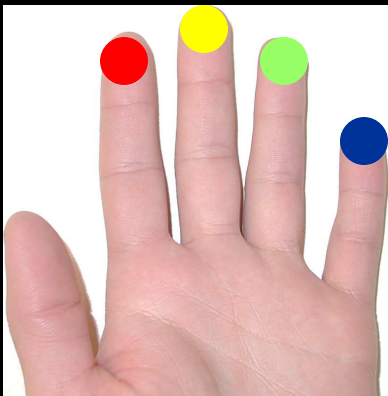
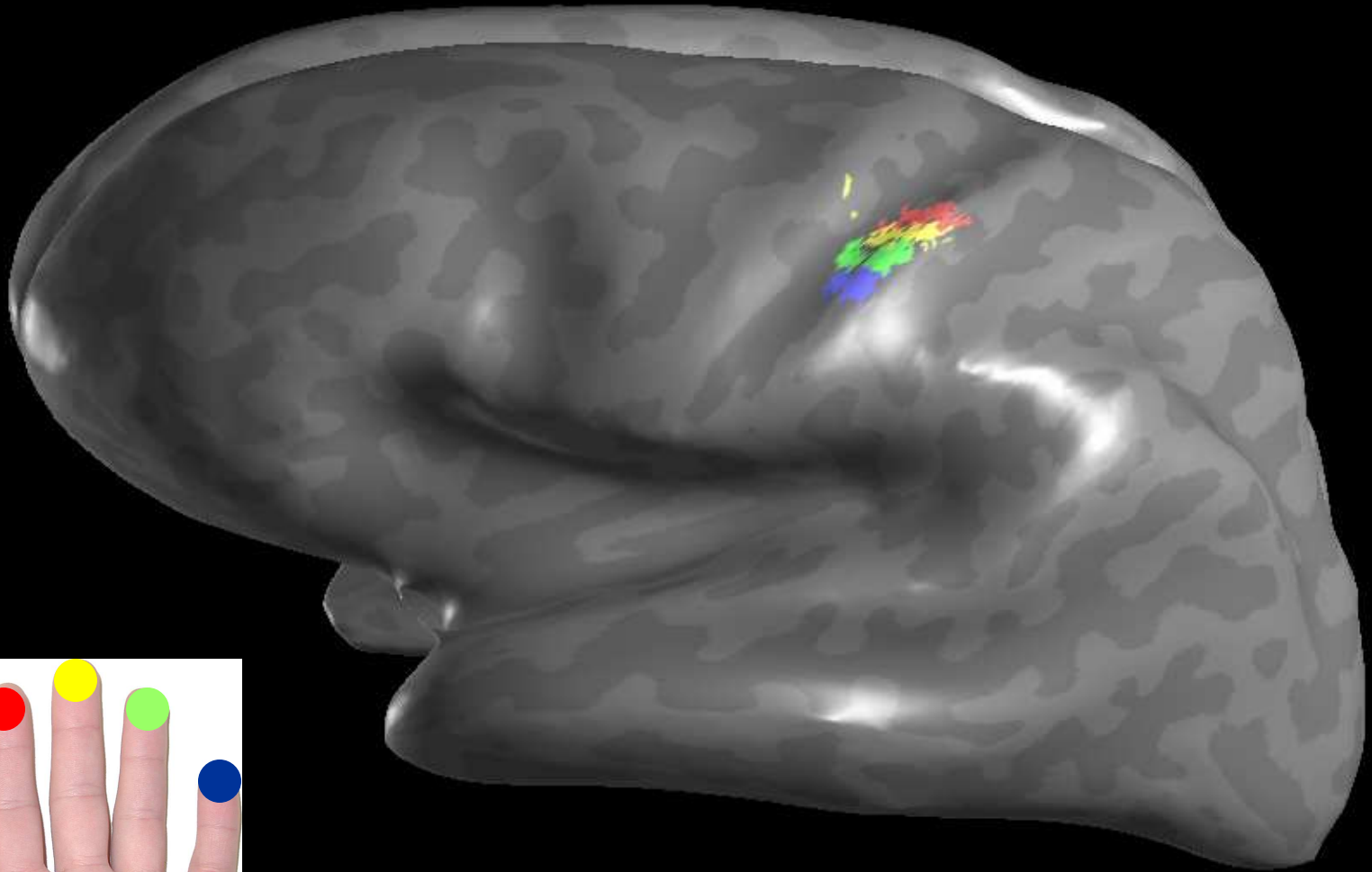
| | | Slow | Rapid |
|---------------------|------|-------------------------------|---------------------------------|
| Vibration frequency | Low | Merkel receptors (SA1) | Meissner receptors (RA1) |
| | High | Ruffini (SA2) | Pacinian corpuscle (RA2) |

Acuity decreases (thresholds increase) from the index to the pinky, but the density of Merkel receptors is the same across the fingers.



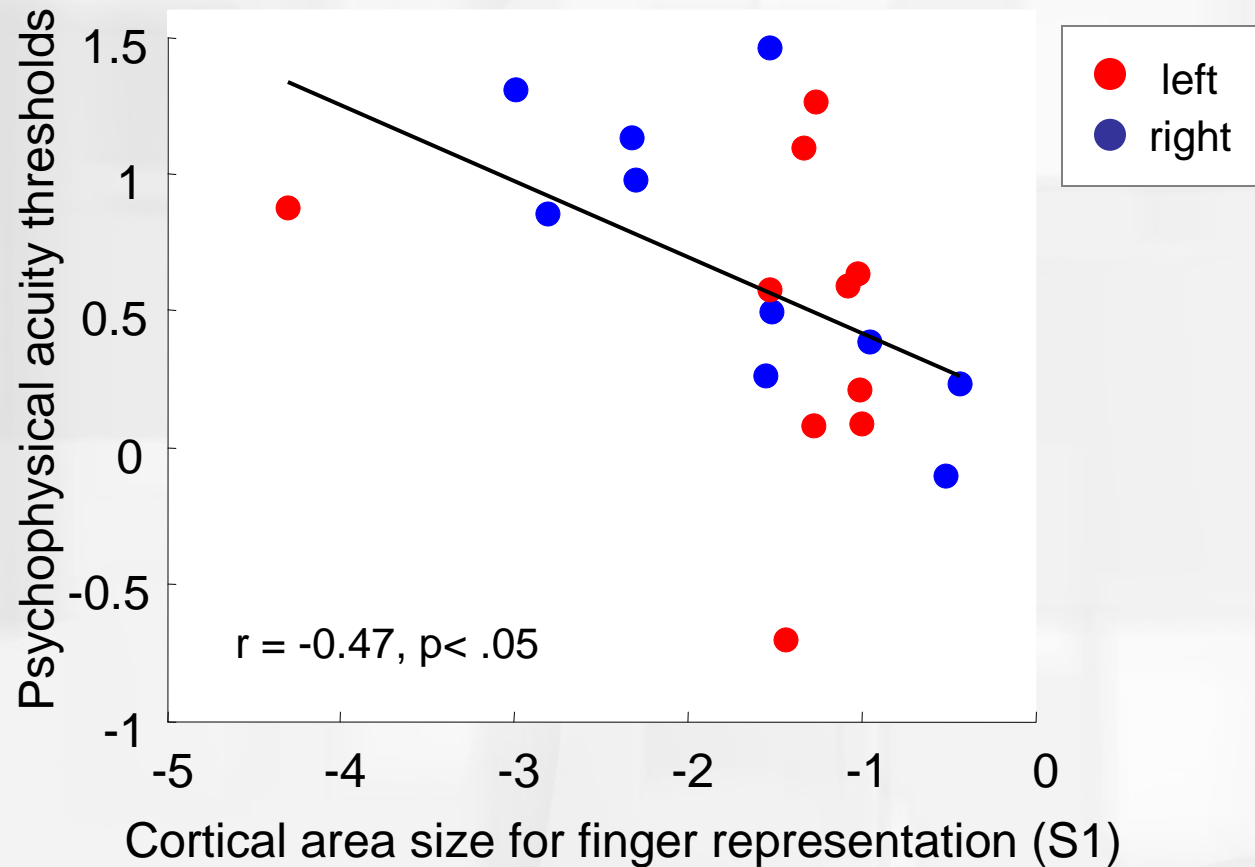
But there is a larger representation of the index finger in S1.

S1, not the Merkel receptors, seem to be the limiting factor in tactile acuity.



(Duncan and Boynton, 2007)

Subjects with better (lower) acuity thresholds have larger representations of the fingers in S1



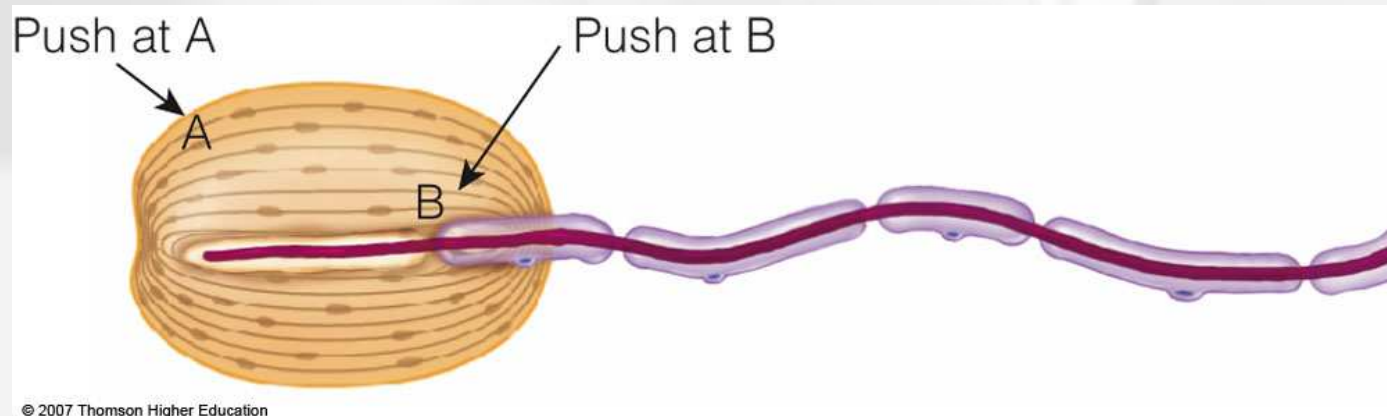
Perceiving Vibration

In the 60's, Werner Lowenstein stimulated the pacinian corpuscle itself (location A), and also after dissecting it so that he could stimulate near the nerve fiber.

Mechanical stimulation at location A caused the usual rapid adapting response.

Mechanical stimulation at location B did not produce rapid adaptation; response continued during the entire period of stimulation.

So, the onion-like structure of the pacinian corpuscle must be responsible for the rapid adaptation.



'Duplex Theory' of Texture Perception

- Katz (1925) proposed that perception of texture depends on two cues:
 - Spatial cues are determined by the size, shape, and distribution of surface elements
 - Temporal cues are determined by the rate of vibration as skin is moved across finely textured surfaces
- Two receptors may be responsible for this process - called the *duplex theory of texture perception*

