Somatosensation

Module 1

The Somatosensory System

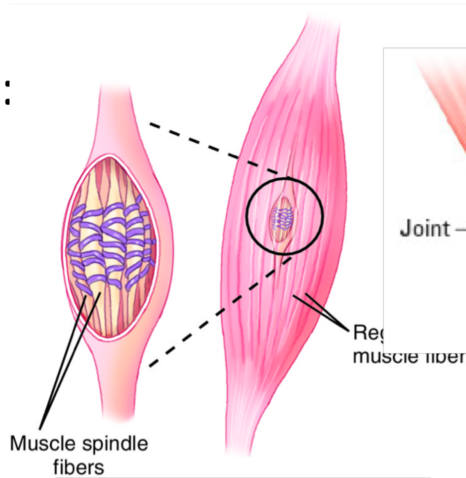
Somatosensation includes:

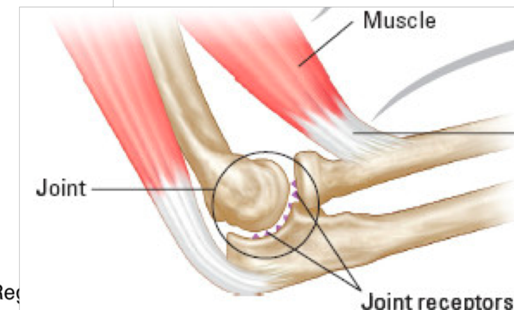
- **Proprioception**: the ability to sense the position of the body and limbs
  - **Kinesthesis**: the ability to sense *movement* of the body and limbs
- **Cutaneous senses**: Perception of stimulation of the skin
  - Touch
  - Heat
  - Some types of pain
- **From the skin to the cortex**
- **Pain**

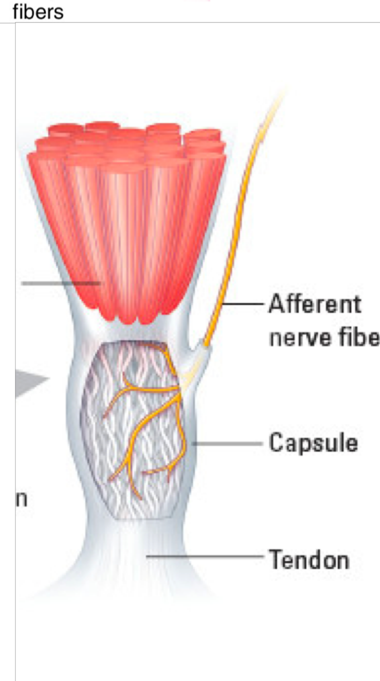
Propioception

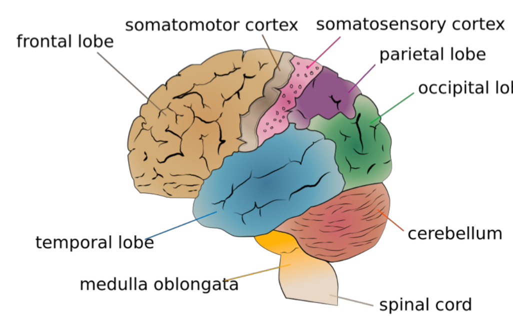
Receptors of involved in propioception:

- **Muscle spindles:** embedded in muscles that sense muscle length/contraction – info about position in space
- **Golgi tendon organs:** sensitive to force of a muscles contraction, and thus force being applied by muscle
- **Joint receptors:** sense info about angle of joint



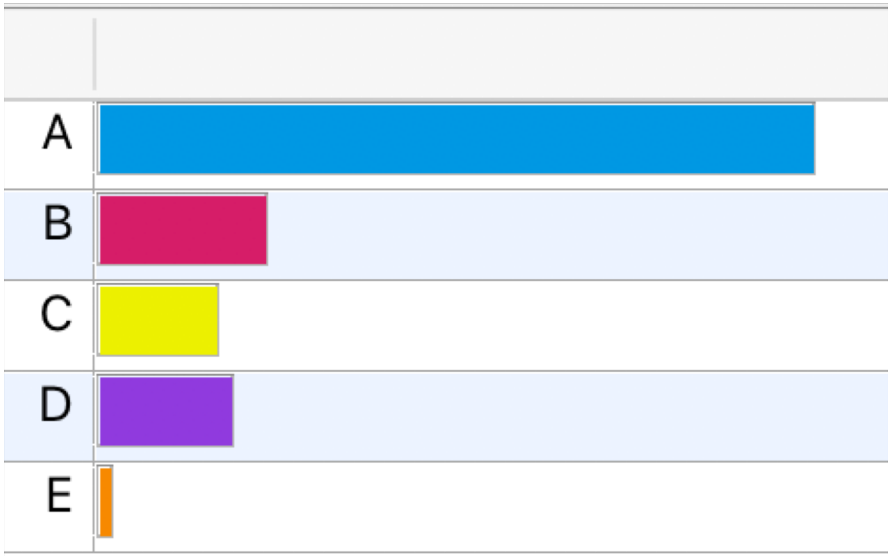






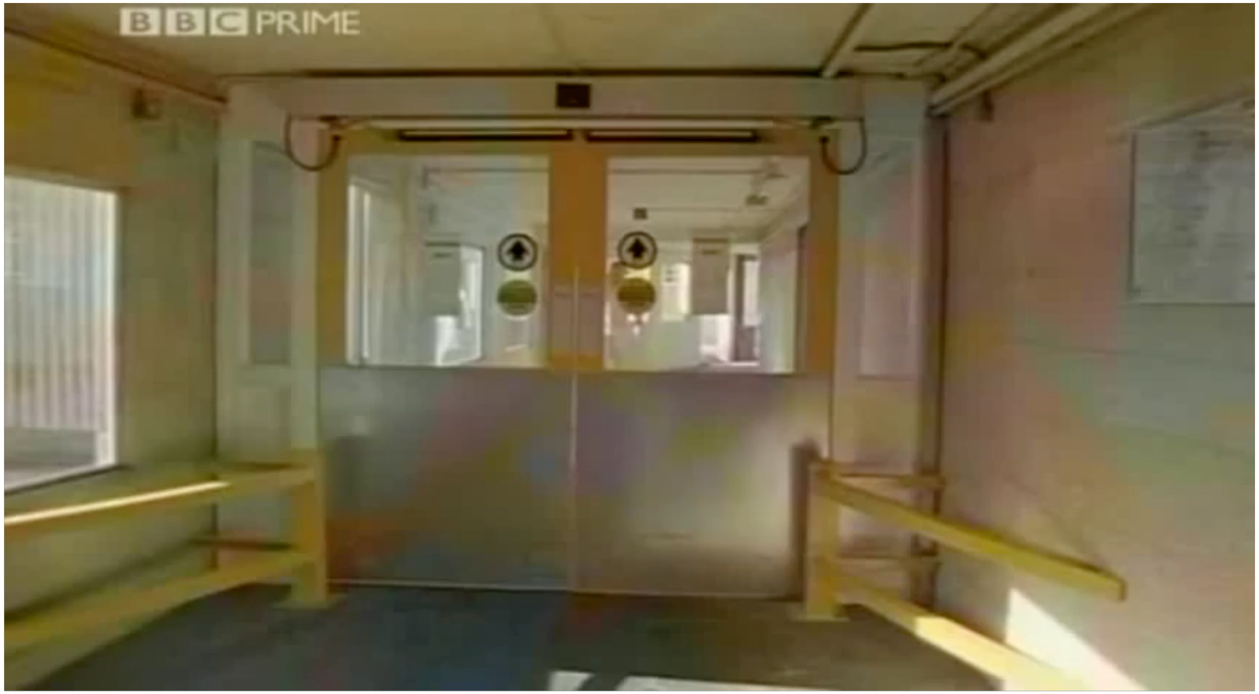
What is your favorite sense?
(which would you least like to lose?)

sight
audition
taste
touch/somatosensation
smell



Propioception

Propioception



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Haptic Exploration

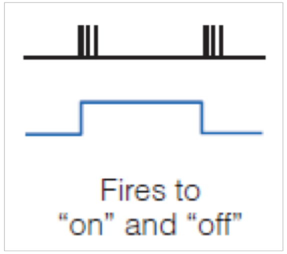
Haptic Exploration: perception in which three dimensional objects are explored with the fingers and hands. Sensory, motor, and cognitive systems all work together.

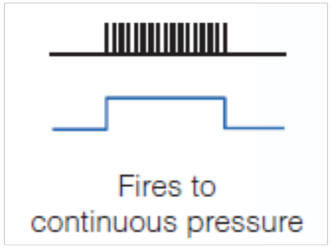
-J.J. Gibson: active and passive touch produce different qualia. We tend to relate the experience of passive touch to the skin, but relate active touch to the object being touched

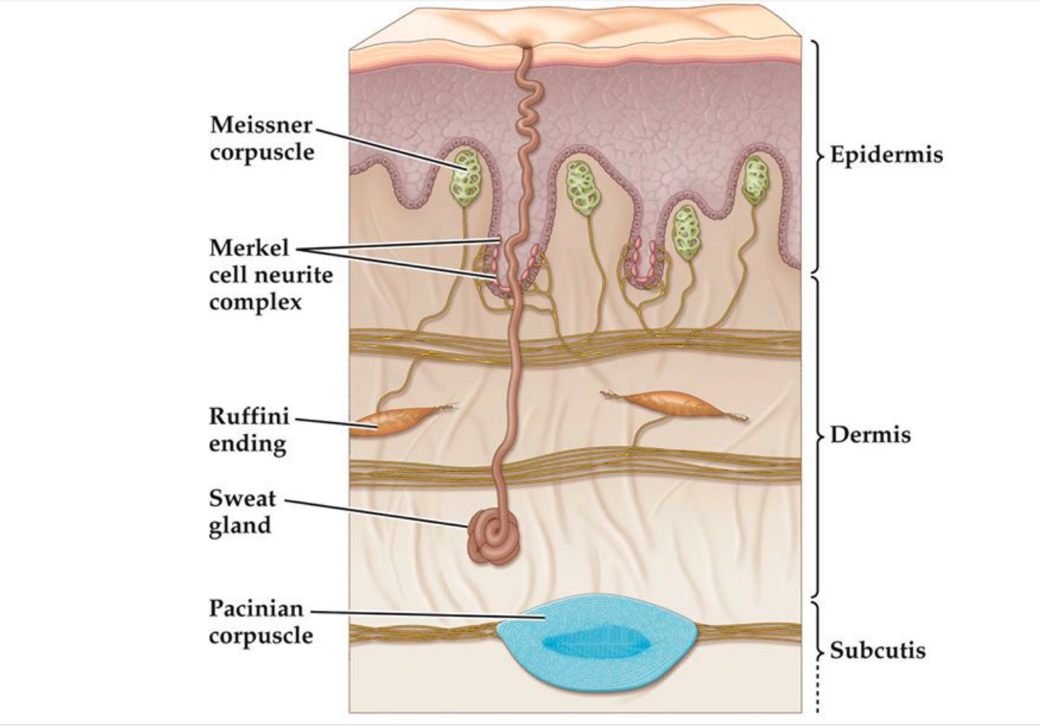
Mechanoreceptors

Mechanoreceptors: "tactile receptors" in the skin that respond to mechanical stimulation (touch and hold)

- **Adaptation rate**
  - Fast: bursts of action potentials when first applied and removed
  - Slow: remain active when in contact with stimulus







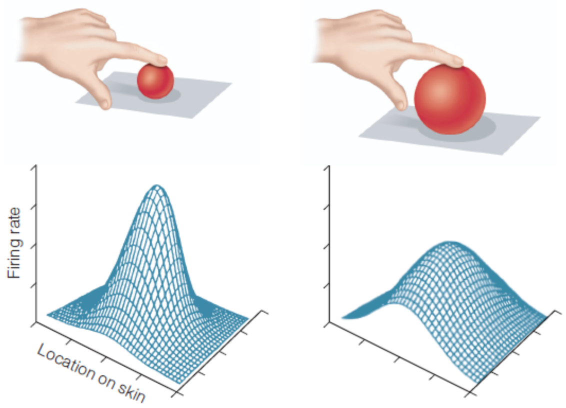
- **Receptive field**: the extent of the body area to which the receptors will respond

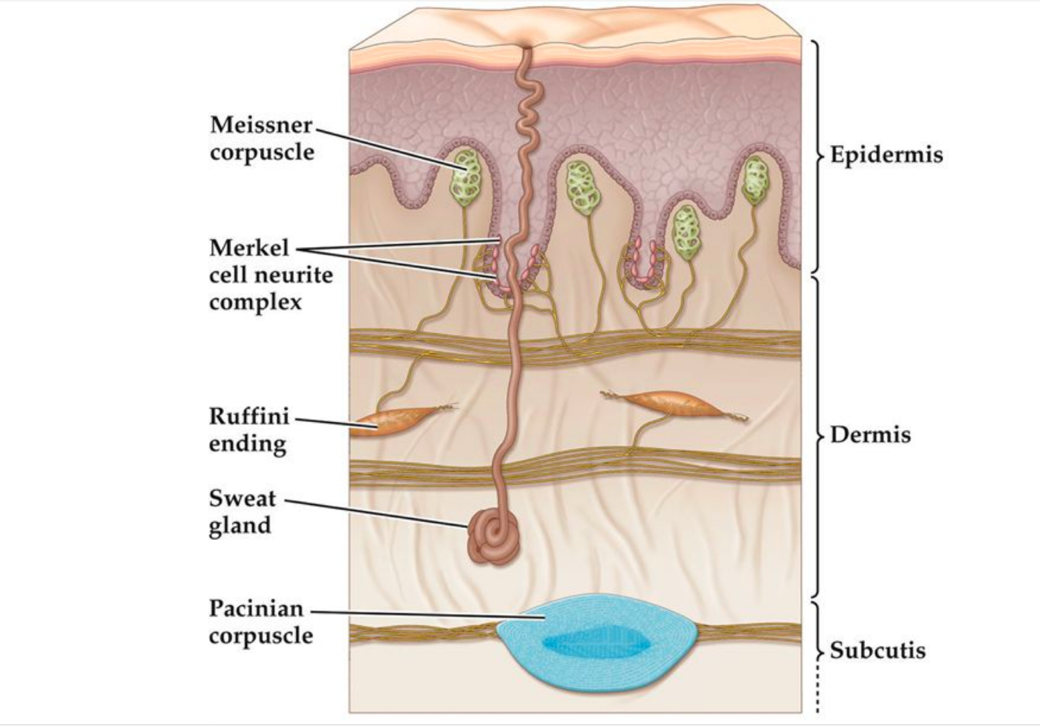
	Size of Receptive Field	
Adaptation Rate	***Small***	***Large***
Fast	Meissner	Pacinian
Slow	Merkel	Ruffini

Mechanoreceptors

Merkel Cells

- Continuous pressure (also respond to low frequency vibrations)
- Pattern and texture detection (Braille)
- Fine detail (small RFs)
- A lot in finger tips and lips





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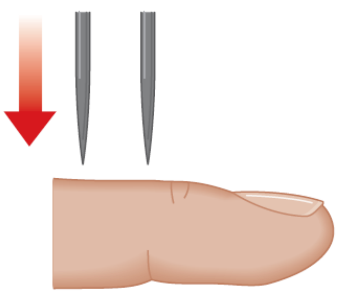
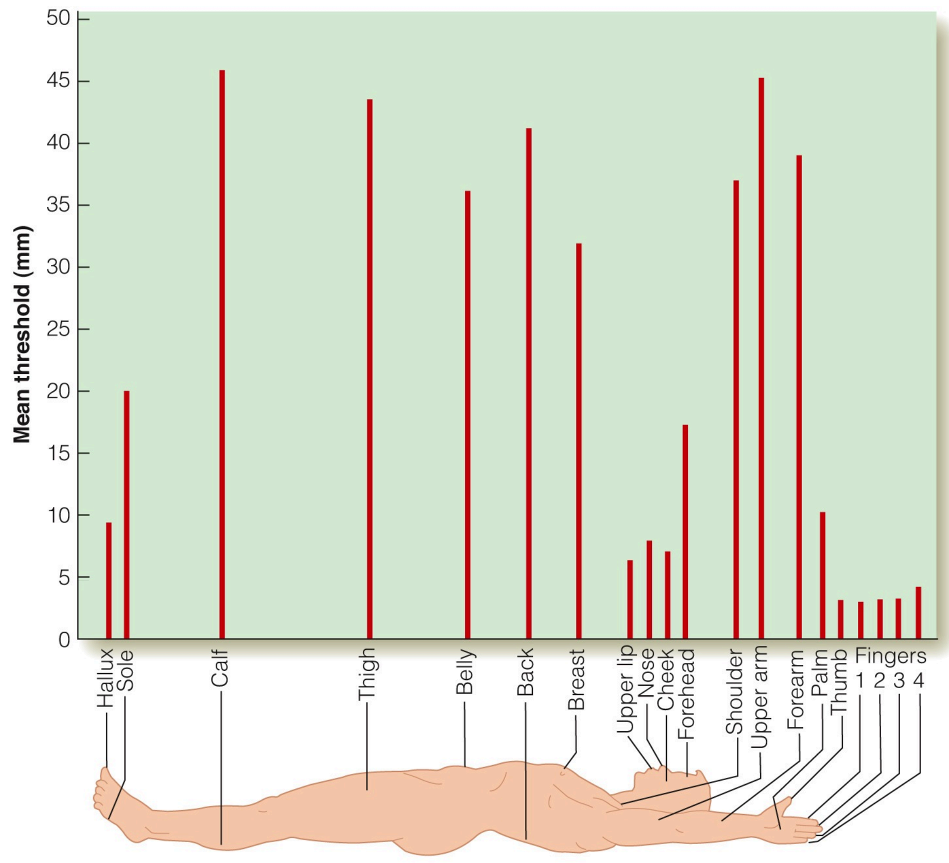
Tactile Acuity

- **Tactile acuity** is the ability to detect details on the skin
  - **Two-point threshold:** minimum separation needed between two points to perceive them as two units

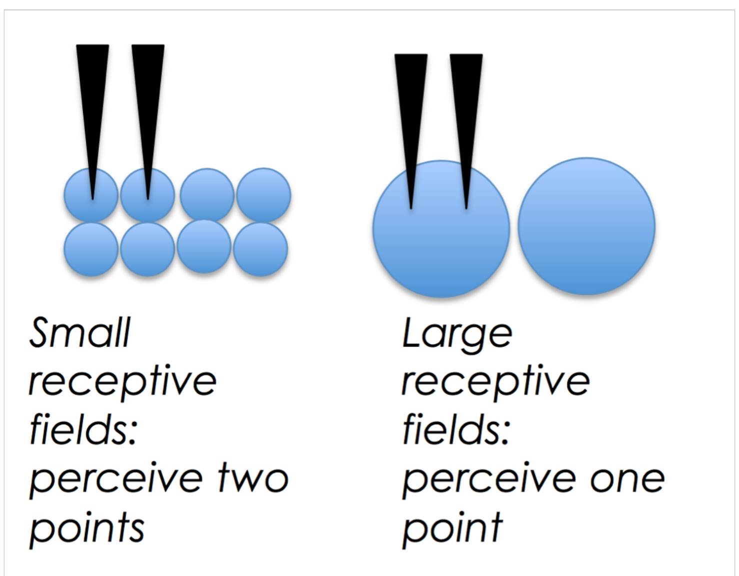


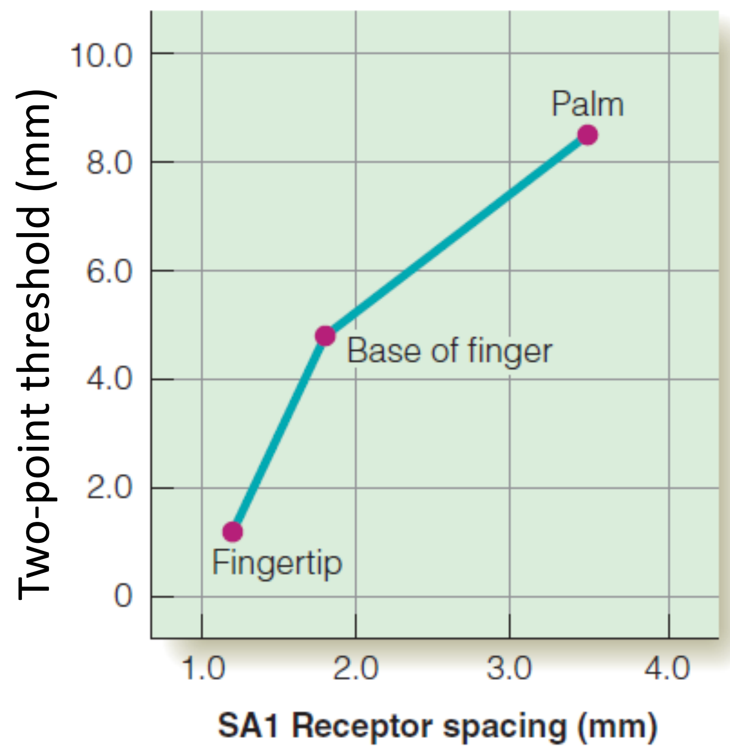


From Weinstein, S., Intensive and extensive aspects of tactile sensitivity as a function of body part, sex, and laterality. In D. R. Kenshalo (Ed.), *The skin senses*, pp. 206, 207. Copyright © 1968 by Charles C Thomas. Courtesy of Charles C Thomas, Publishers, Springfield, IL.

Tactile Acuity

- Merkel cell spacing (density) varies across different locations on the body
- The spacing of Merkel cells is strongly associated with tactile acuity: higher density Merkel cells is associated with higher levels of tactile acuity

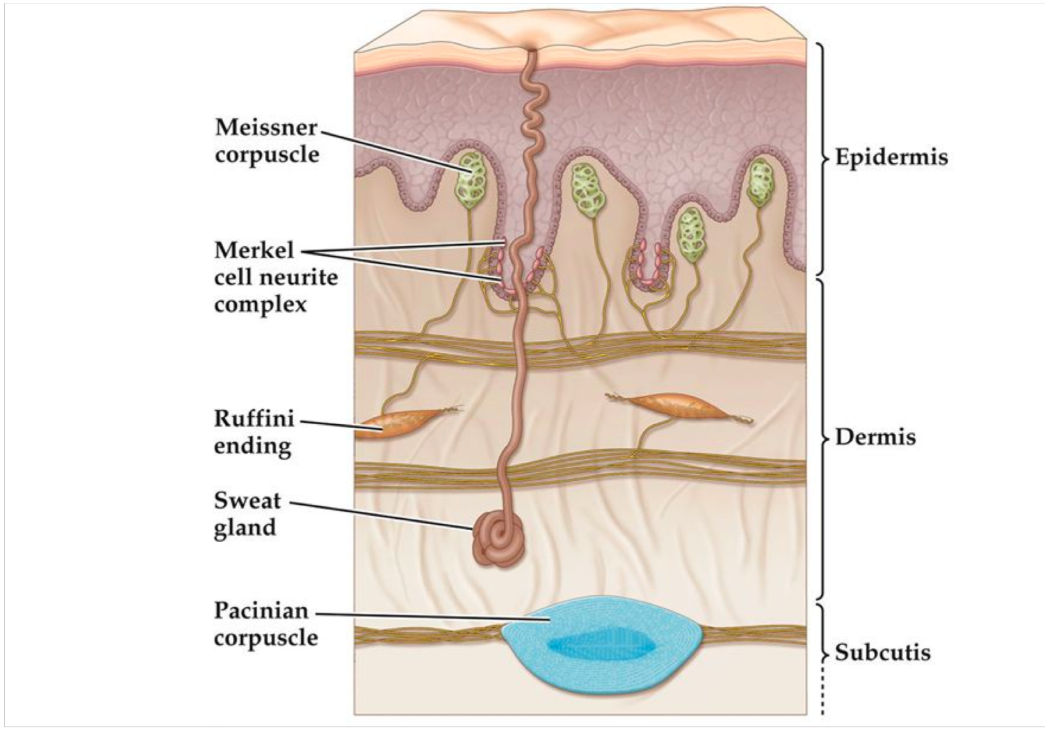




Mechanoreceptors

Ruffini cylinders

- Continuous, steady pressure
- Stretching of the skin
- Crucial sustained grasping of an objects



	Size of Receptive Field	
Adaptation Rate	***Small***	***Large***
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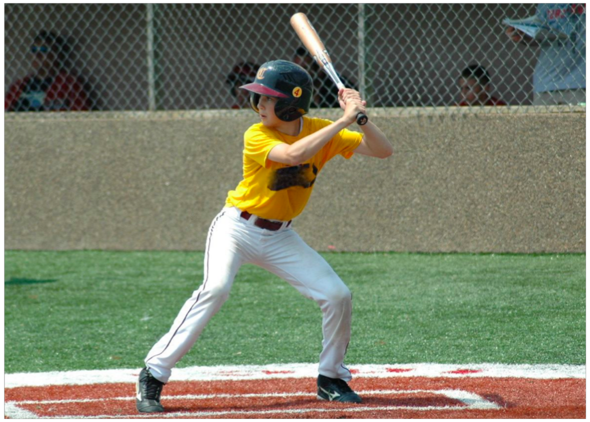
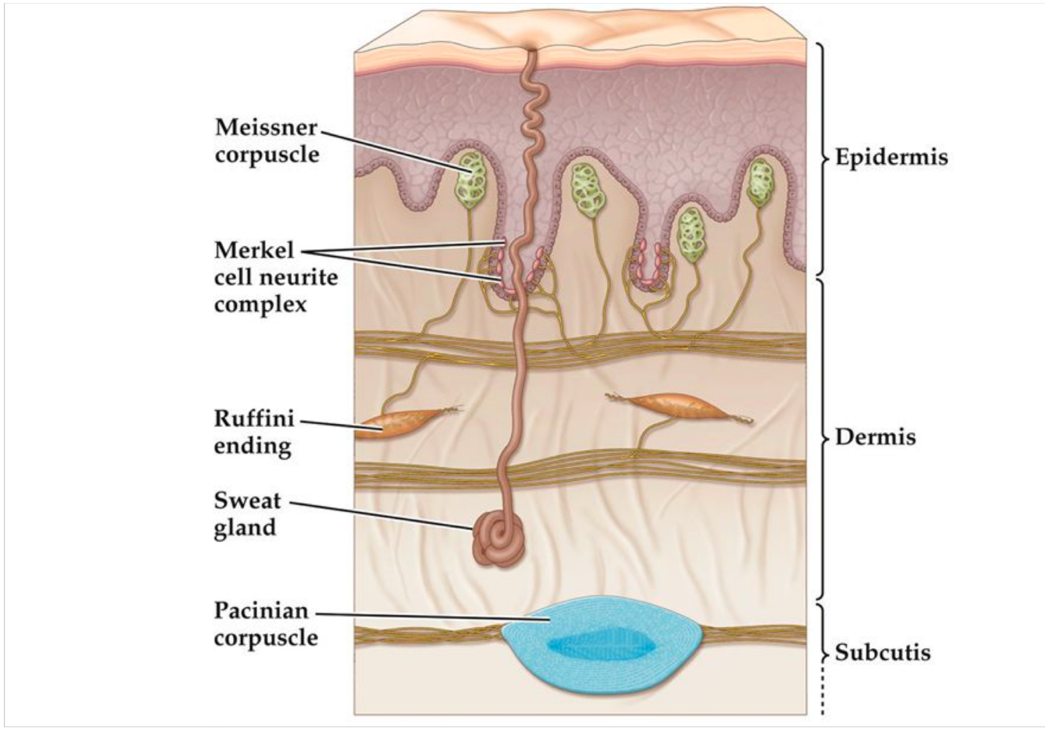
Mechanoreceptors

Meissner corpuscles

- Respond to motion across skin (caused by low frequency vibrations)
- Good at detecting "slip," and thus important for grip change





	Size of Receptive Field	
Adaptation Rate	***Small***	***Large***
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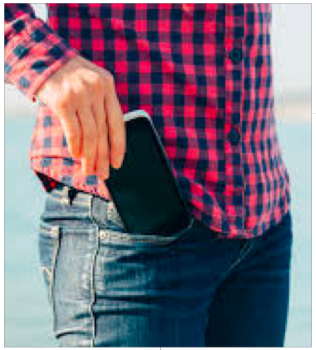
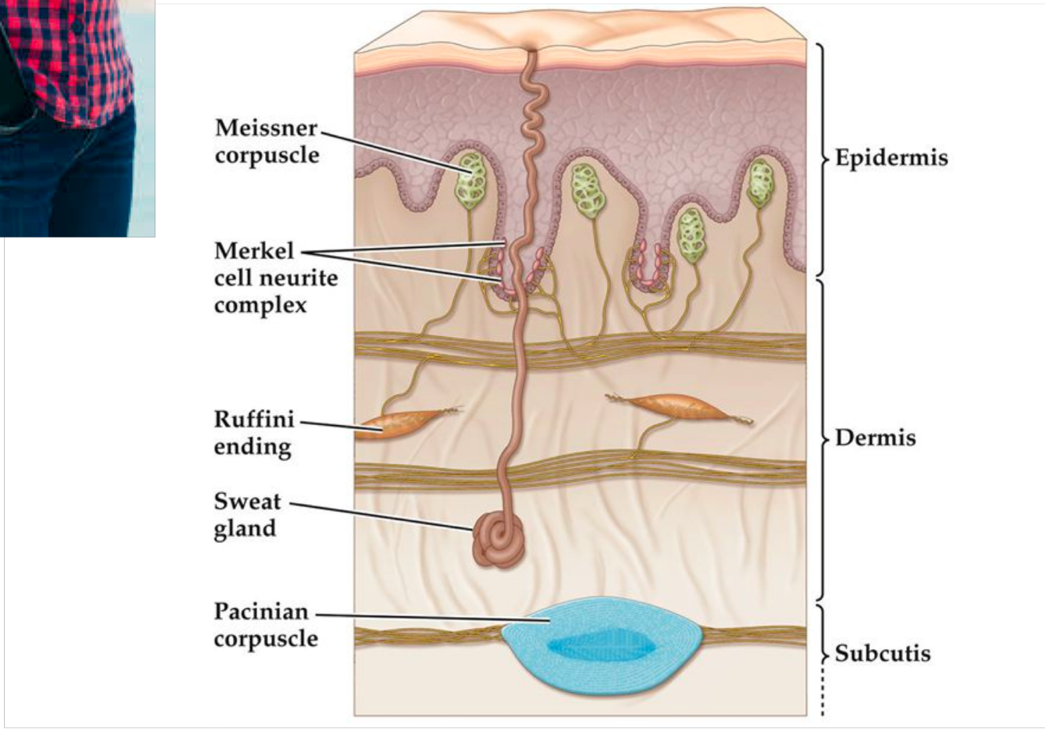
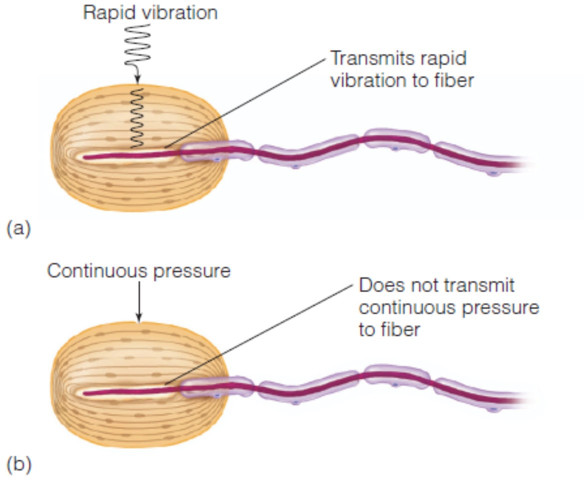
Mechanoreceptors

Pacinian corpuscles

- Respond to high frequency vibrations
- Sensation that we sense as "vibration"







	Size of Receptive Field	
Adaptation Rate	***Small***	***Large***
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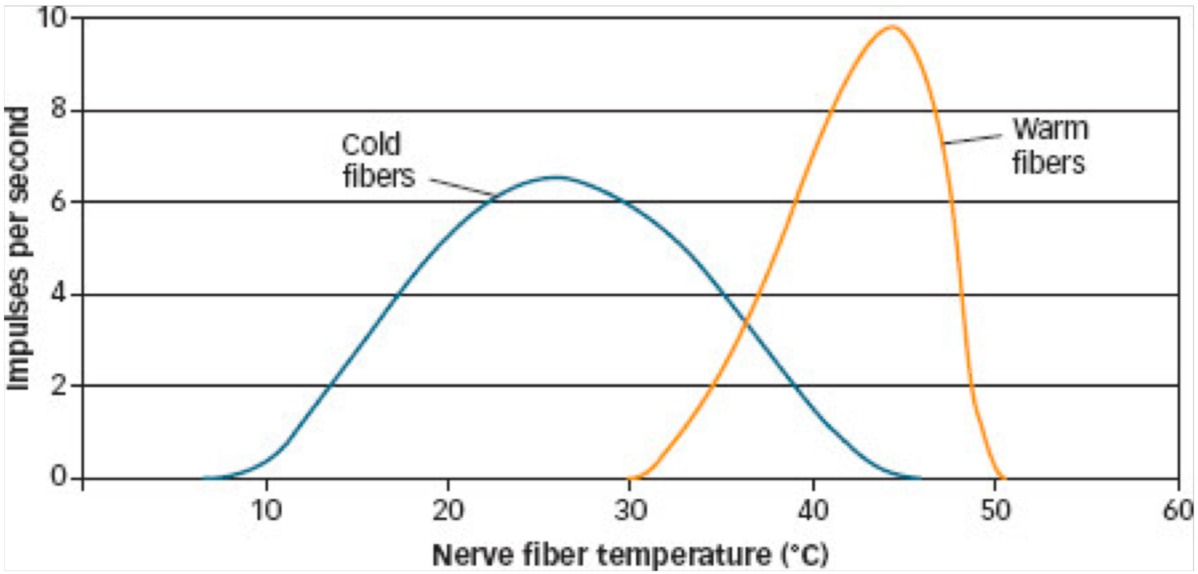
Thermoreception

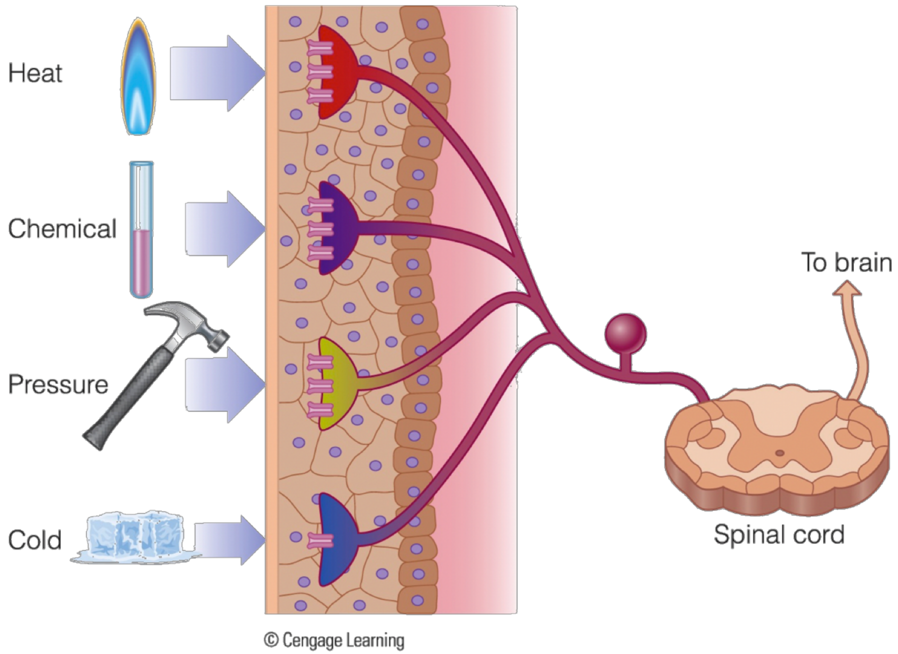
- **Thermoreception**: the ability to sense changes in temperature on the skin
- Thermoreceptors: respond to range of ***skin*** temperatures
  - Usually maintains 86-97 degrees F (physiological zero)
  - Sense skin temepratures from 63-109 degrees F (outside this range = pain)
  - Cold fibers – active below 86
  - Warm fibers – active above 97
  - Adapt (e.g. swimming pool)



Nociceptors

Nociceptive pain: receptors specialized to respond to tissue damage and potential tissue damage

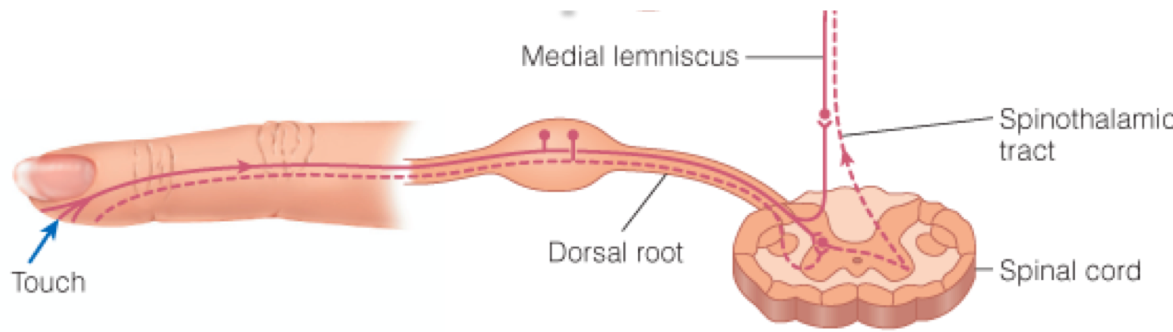
- Specific nociceptors respond to chemicals, severe pressure, heat and cold
- They typically trigger a protective (withdrawal) response



From Skin To Cortex

- Nerve fibers travel in bundles (peripheral nerves) along the dorsal root (afferant as opposed to efferent) to the spinal cord.

- Two major pathways in the spinal cord:
  - **Spinothalamic pathway**: smaller fibers that carry temperature and pain (spinothalmic pathway)
  - **Medial lemniscal pathway**: larger fibers proprioceptive and touch information



<u>Paths cross to other side of body and synapse in thalamus</u>

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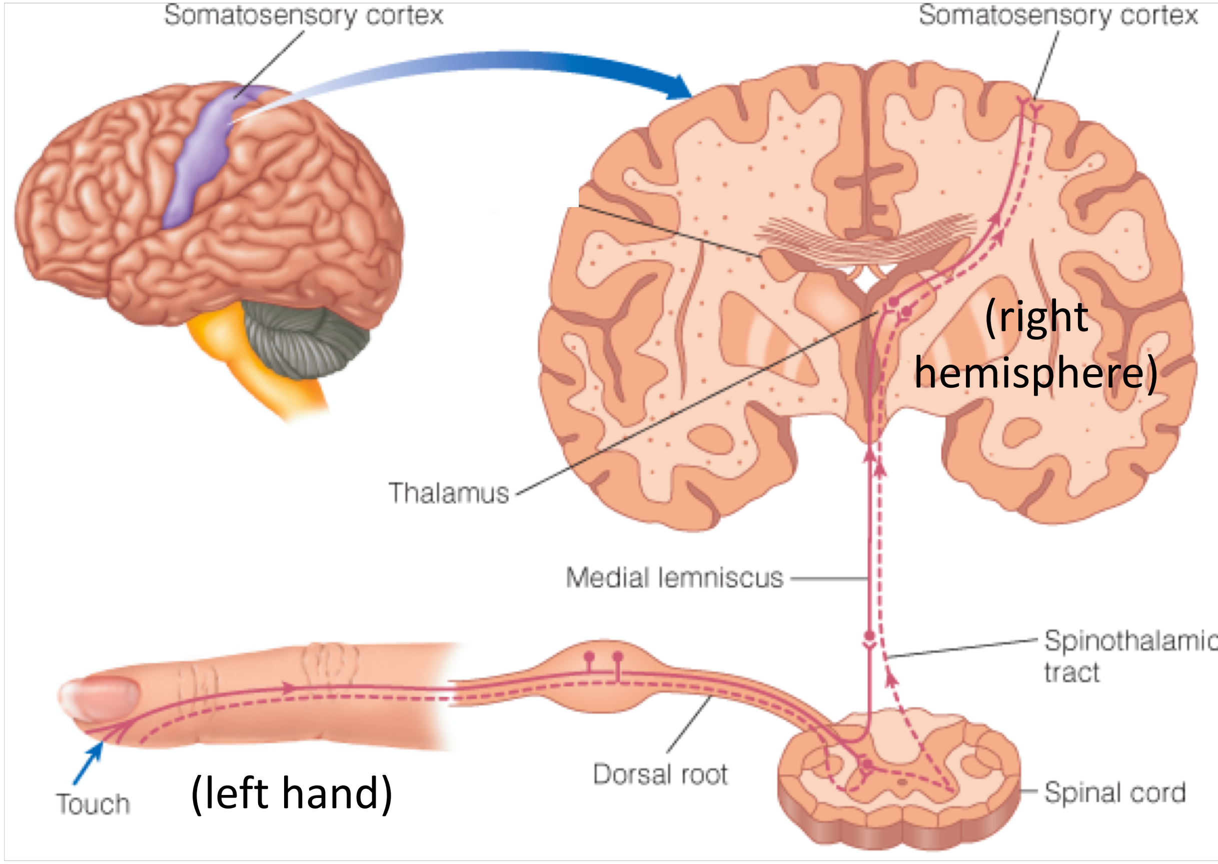


<u>Paths cross to other side of body and synapse in thalamus</u>

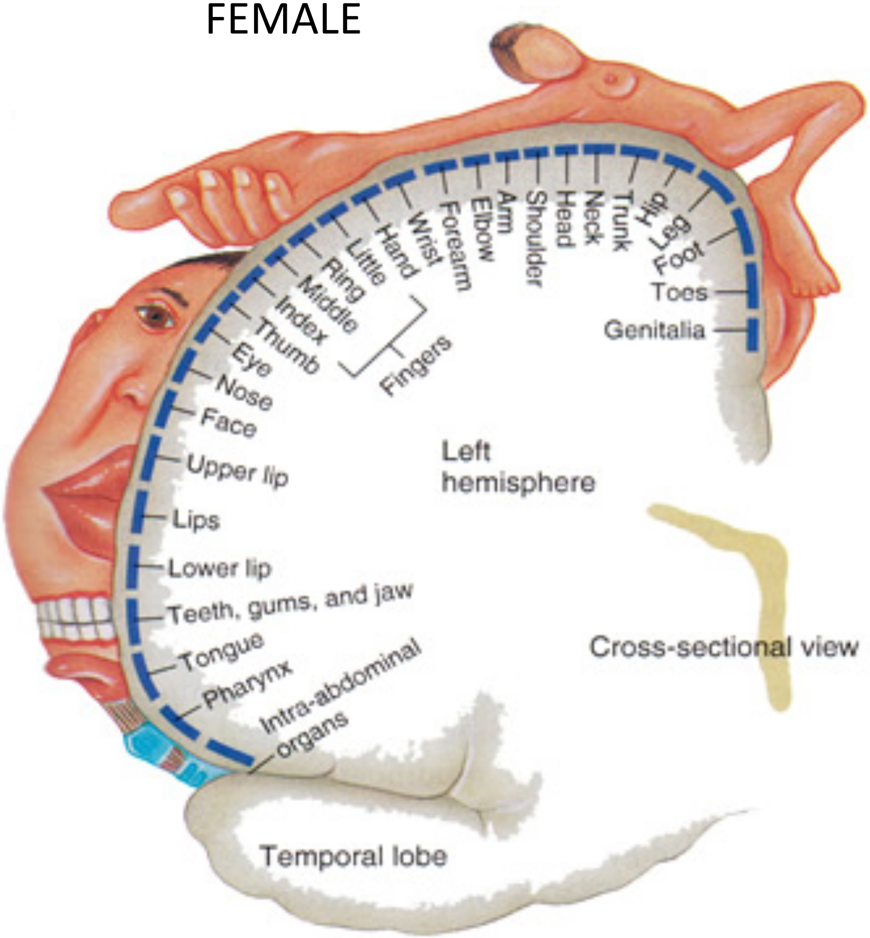
The From Skin To Cortex

Wilder Penfield and the Montreal procedure (~1950s)

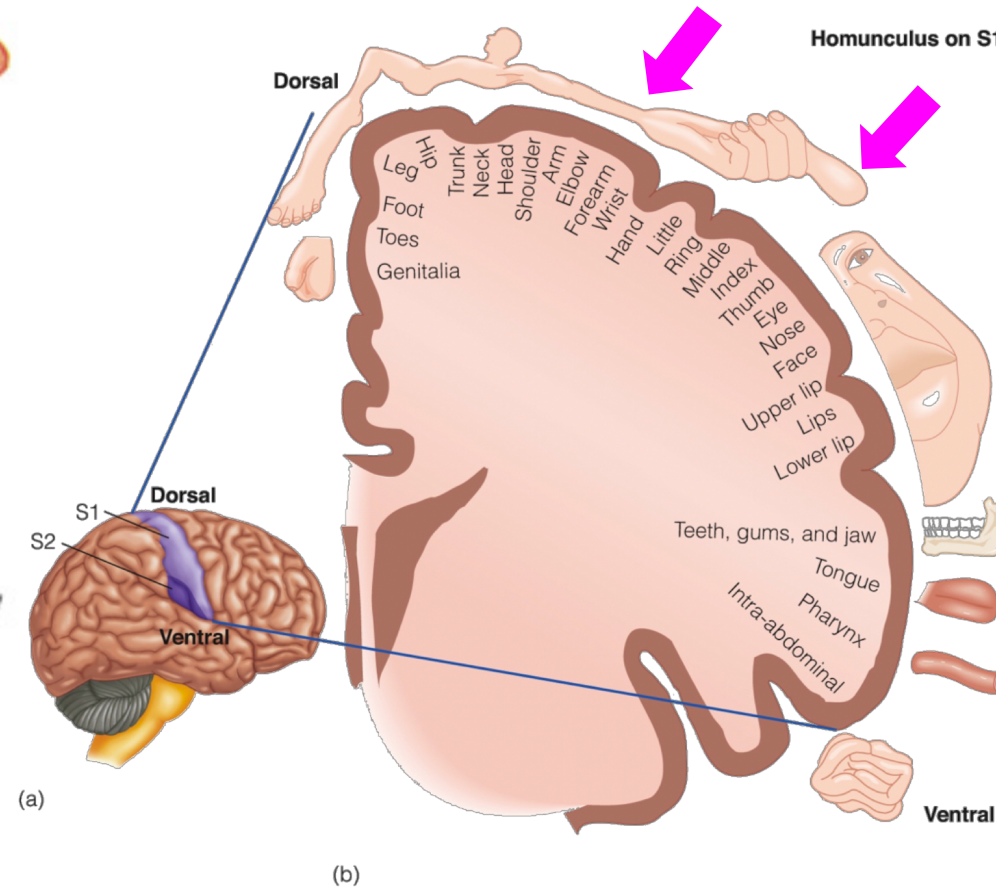
- Prior to epilepsy surgery Penfield probed the brain with electrodes and asked subjects to report their sensations
- This procedure gave us detailed **motor and sensory maps** for the human body
- Cortical representation of the body are now called **Penfield Homunculus** (i.e. sensory homunculus)

From Skin To Cortex

FEMALE



MALE

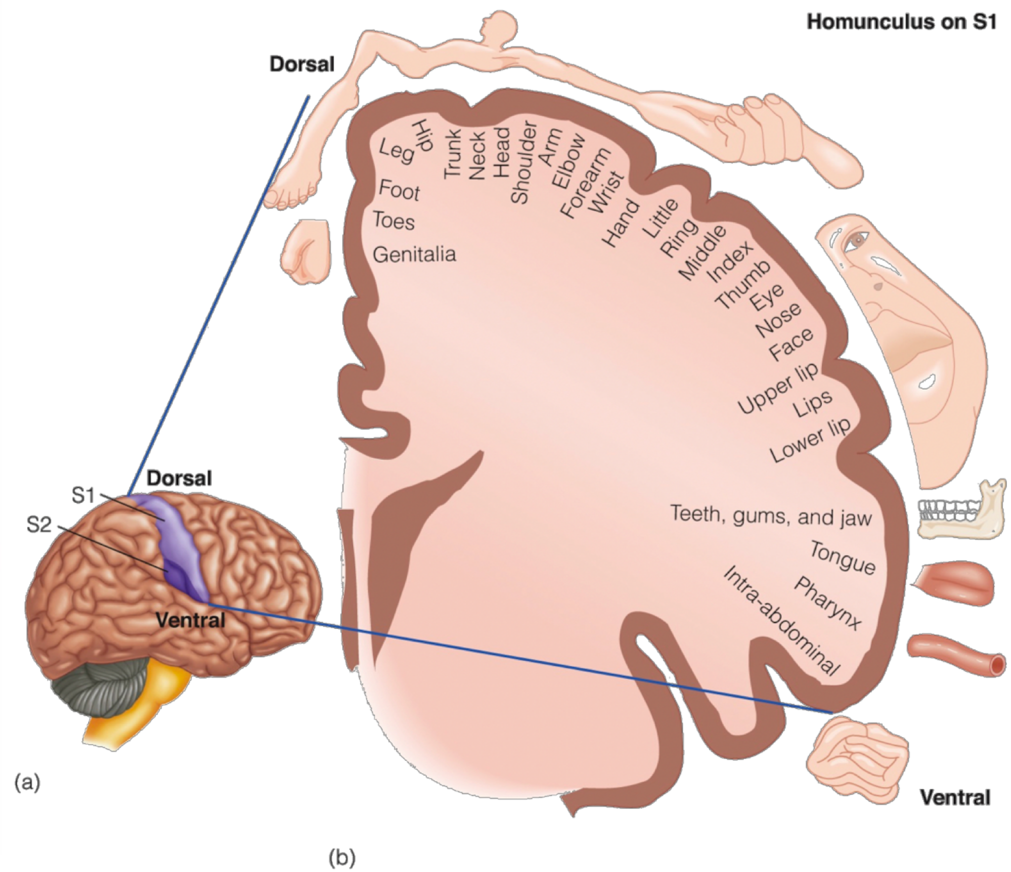


Adapted from Penfield, W., & Rasmussen, T. (1950). *The cerebral cortex of man.* New York: Macmillan.

<u>Some areas of the body are represented by a disproportionate area of the brain</u>

From Skin To Cortex

MALE



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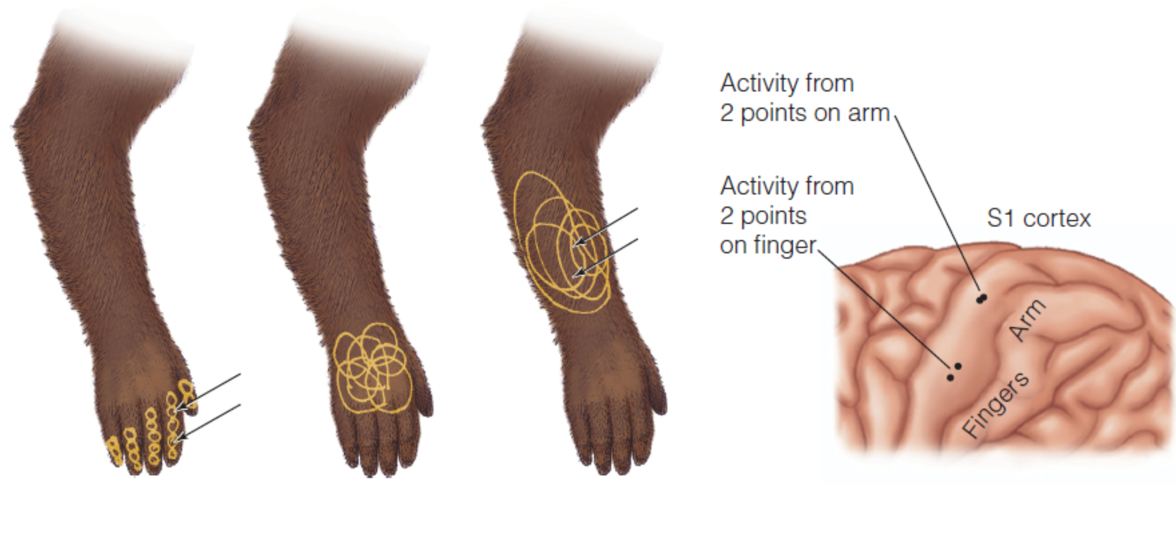
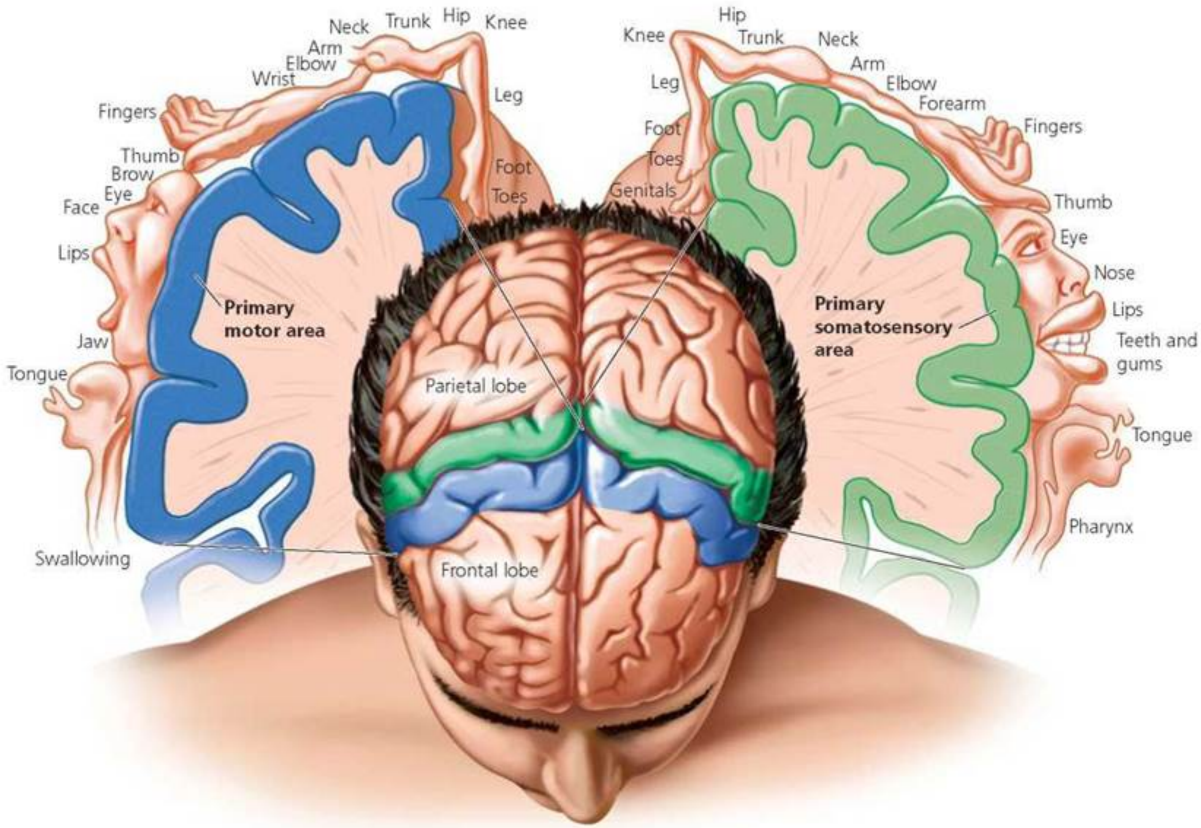
The Sensory Homunculus

- Body areas with high acuity have larger areas of cortical tissue devoted to them
  - This parallels the cortical magnification factor seen in the visual cortex for the cones in the fovea
- Areas with higher acuity also have smaller receptive fields on the skin



The Sensory and Motor Homunculi

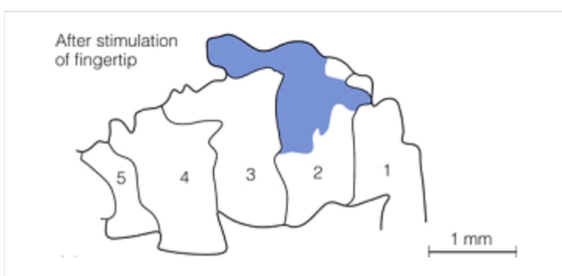
- In the frontal lobe, on the anterior side of the central sulcus, we have a similar map that is involved in motor control



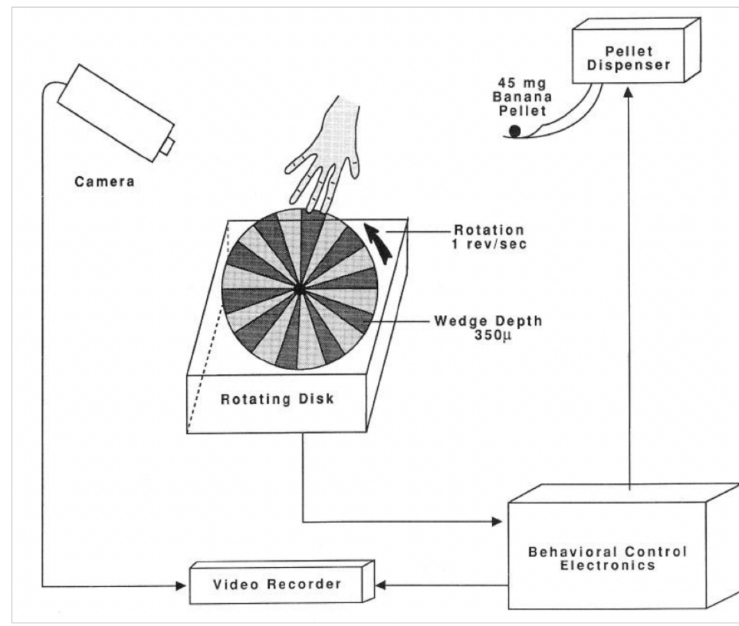
Experience Dependent Plasticity

- **Experience dependent plasticity**: neurons adapt based on person's activity and environment.
  - A basic principles of cortical organization is that cortical representation of a function can become larger if that function is used often

- Jenkins & Mezenich (1987)

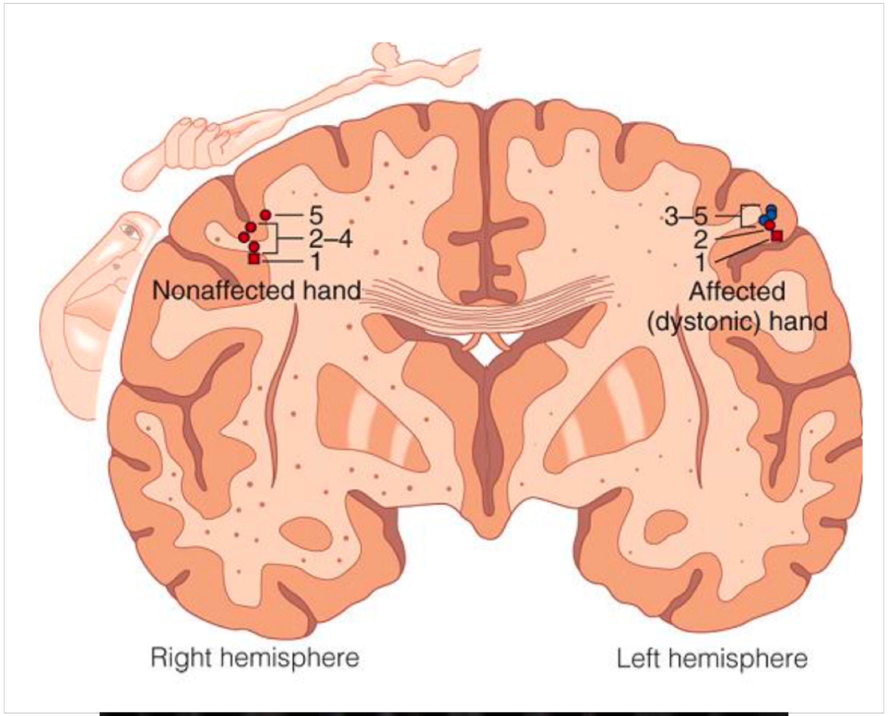


Jenkins & Merzenich (1987)



Experience Dependent Plasticity

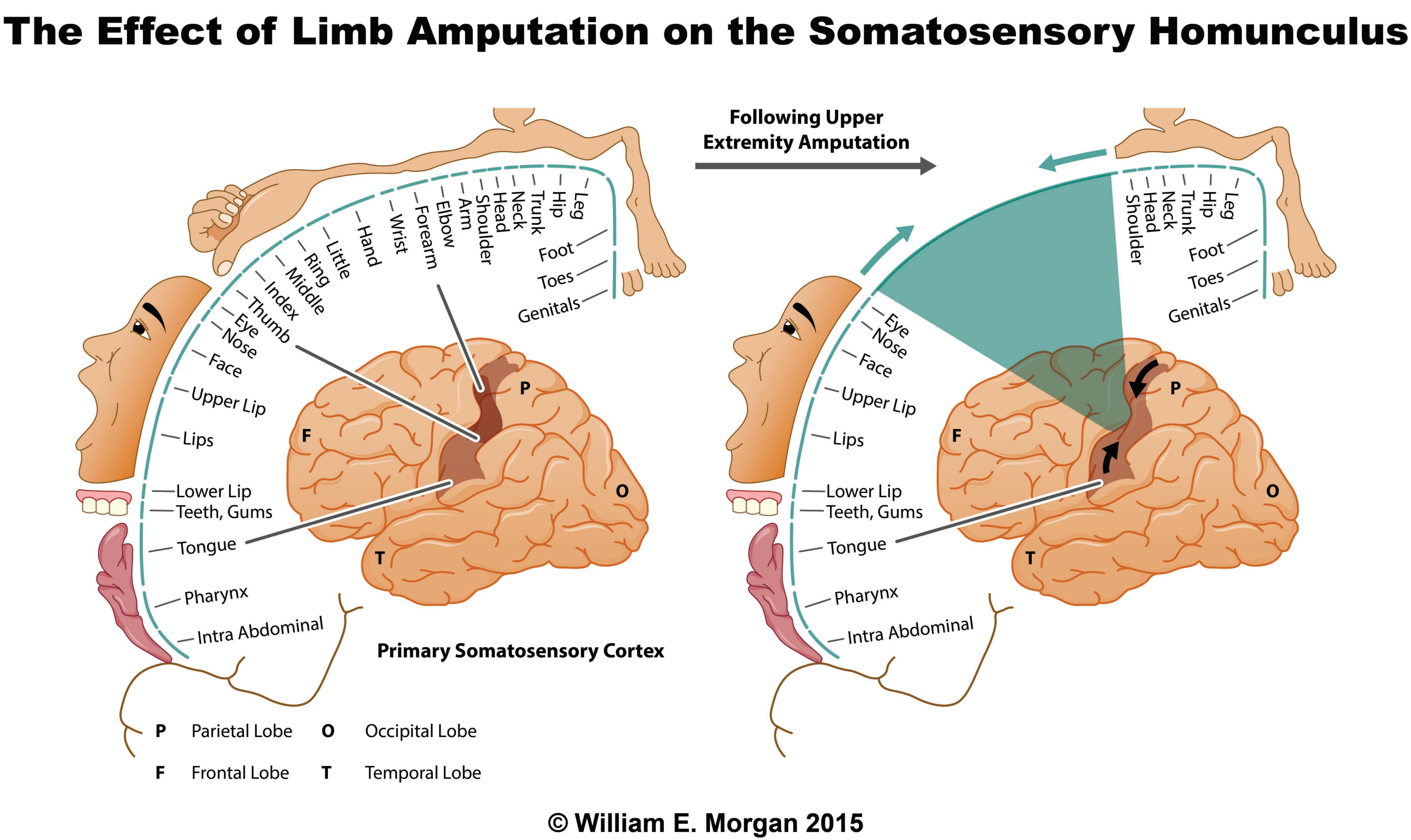
- Evidence from humans:
  - Over-representation of fingers in musicians
  - Over the course of years of practice, plasticity increases the size of the neural representation of the fingers
  - Areas responsible for controlling fingers can become fused (e.g in someone who plays a stringed instrument). This is called **focal dystonia**
  - This interferes with motor control in the fingers



Plasticity and Phantom Limbs

- Cortical plasticity can result in **Phantom limbs**
  - Sensation that an amputated or missing limb is still there
  - 60-80% of individuals with an amputation experience this
  - Can feel it move
  - Can be useful to adapt to prothetic limb

Plasticity and Phantom Limbs



One theory: Without input from the limb, other nearby cortical regions may begin to stimulate part of the phantom limb's cortical map

Plasticity and Phantom Limbs

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- In Phantom limb phenomena, people often report feeling **pain** from a the limb
  - 51% experience pain when arm amputated; 70% if amputated leg
  - Can range from mild (itching) to intense (cramping or bending in an unnatural position)
  - The pain is localized to a specific place
  - Why PAIN is unknown – thus hard to treat

Plasticity and Phantom Limbs

Training via the mirror box

- Synchronize movements of real hand and phantom
- Seeing the phantom "move" in the mirror seems to provides an update to proprioceptive maps in the parietal cortex. This creates the sensation of movement in the phantom
- Visual training can relieve pain and even help eliminate the phantom limb

Plasticity and Phantom Limbs

Multisensory Perception (multisensory integration): the idea that information from different sensory modalities such as sight, touch, smell, self-motion and taste, are integrated by the nervous system

Visual capture: vision can often override information from the other senses

Vison seems to dominate the information from propiocception

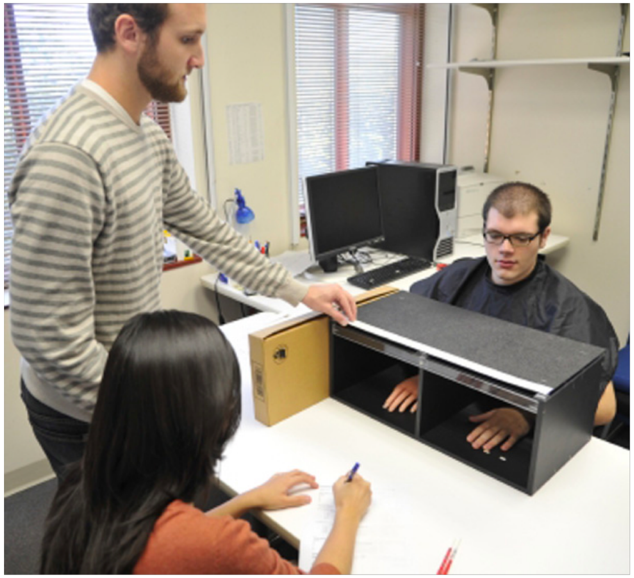
Ian Waterman used vision/visualization to recover his ability to move. He one stepped in an elevator where the lights were not working and he had to wait until he was rescued.

Rubber Hand Illusion

Rubber Hand Illusion

In the rubber hand illusion, your sense of bodily awareness is temporarily transferred to an inanimate object

- As the **visual cues** match the **tactile cues**, you dynamically re-map your proprioceptive awareness to the fake hand
- This is NOT changing the somatosensory map, buy rather changing where the body thinks the limb is located
- It works in about 66% of people (given enough time)
- Importantly, it requires visual attention to bind the visual and tactile information



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- **From the skin to the cortex**

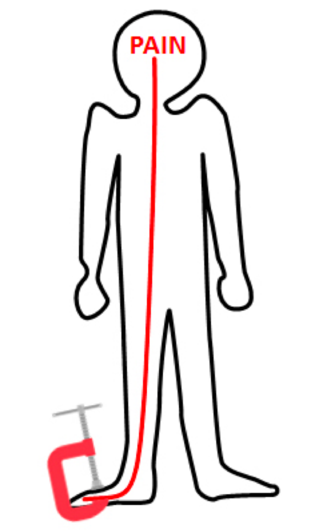
- **Pain**

Pain

- Congenital insensitivity to pain

Model of Pain

- **direct pathway model** proposed that nociceptors are stimulated by the appropriate stimuli and these signals are immediately sent to the brain



A direct connection

- Problems:
  - Can occur in absence of skin stimulation (e.g. phantom limbs)
  - Can be affected by what the person is attending to (e.g. of they don't realize they are injured)
  - Pain affected by mental state (e.g. less pain when happy)

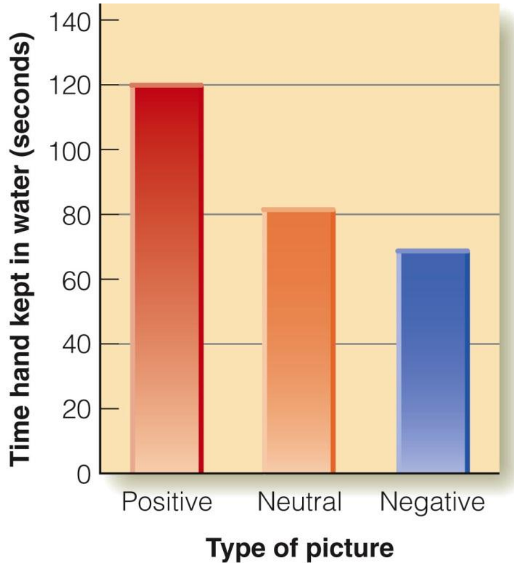
Central Control

- **Expectation** can change the experience of pain (Bingel et al, 2011)
  - **Placebo** causes a *decrease* in pain even though there is no active ingredients
  - **Nocebo** causes an *increase* in pain even though there is no active ingredients

CONDITION	DRUG?	PAIN RATING
Baseline	No	66
No expectation	Yes	55
Positive expectation	Yes	39
Negative expectation	Yes	64

Central Control

- Pain perception can be influenced by a persons **emotional state** (deWied & Verbaten, 2001)



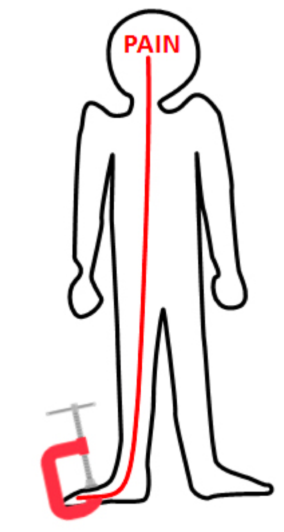
- Roy at al (2008)
  - Pleasant music can decrease pain

CONDITION	INTENSITY RATING	UNPLEASANTNESS RATING
Silence	69.7	60.0
Unpleasant music	68.6	60.1
Pleasant music	**57.7**	**47.8**

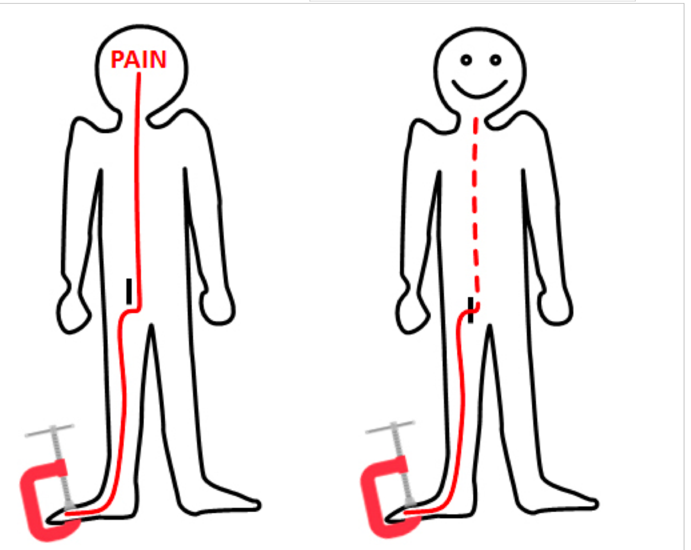
Model of Pain

- **direct pathway model** proposed that nociceptors are stimulated by the appropriate stimuli and these signals are immediately sent to the brain

- **gate control theory of pain:** non-painful input (mechanoreceptors) as well as top-down influences (affect, mood) can close the nerve "**gates**" to painful input, which prevents **pain** sensation from traveling to the central nervous system



A direct connection



Gate open   Gate closed

Social Pain??

- Some researchers have argued that **social** isolation or rejection is a form of **pain** is the experience of pain result from interactions (or lack thereof) with other people

- Cases often involve depression and social rejection

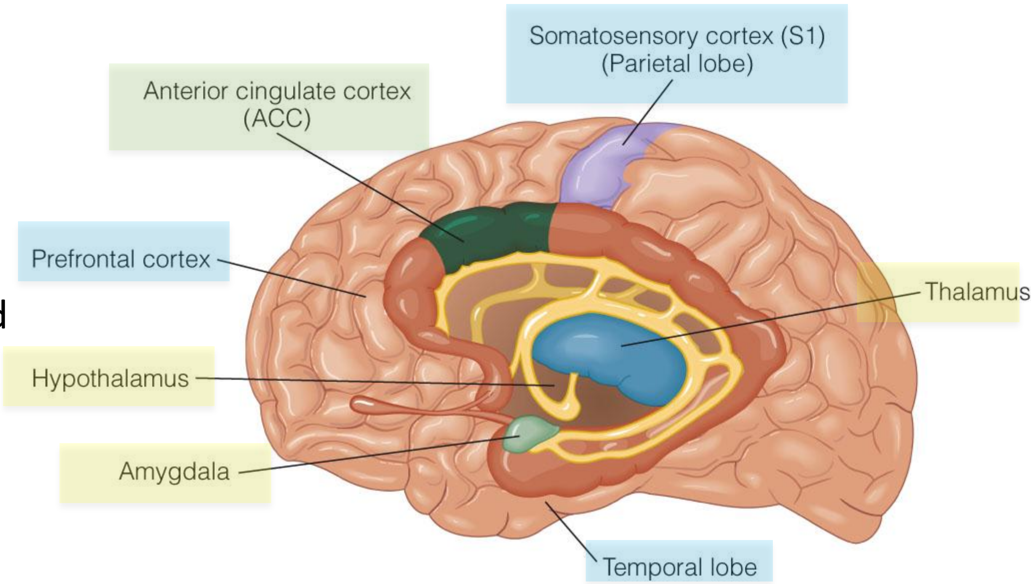
- Can be associated with interpersonal rejection or loss

- No tissue damage, but very strong affective element (aversive)

Pain in the Brain

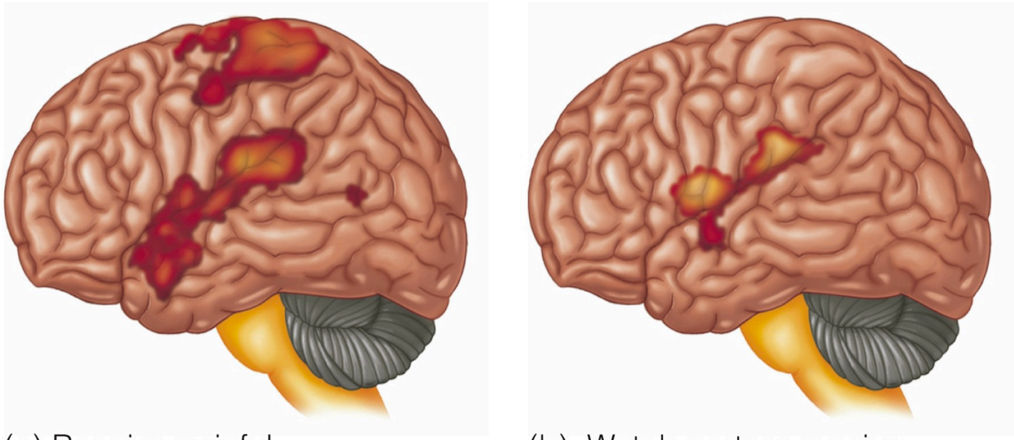
- The **pain matrix:** pain representation is widely distributed
  - Subcortical areas include: the hypothalamus, limbic system, and the thalamus
  - Cortical areas include: the somatosensory cortex, the insula, prefrontal cortices, and anterior cingulate

- **Anterior cingulate** seems to be involved in the affective (emotional component)
  - Hofbauer et al (2001) Used hypnosis to manipulate subjective pain intensity and affective component (unpleasantness). Found unpleasantness associated with activity of anterior cingulate in fMRI.



Social Pain???

- Singer et al. (2004)
- Romantically involved couples: woman's brain activity was measured using fMRI while she either *received shocks* or she *watched her partner* receive shocks.
- Similar brain areas (e.g., insula, anterior cingulate) were active in both conditions. .
- Higher levels of independently reported empathy were associated with more anterior cinculate activation



(a) Receive painful stimulation

(b) Watch partner receive painful stimulation

Adapted from Holden, C. (2004). Imaging studies show how brain thinks about pain. *Science, 303*, 1121. Reprinted by permission of Tania Singer.

Social Pain???

- If pain has a strong affective (emotional or cognitive) component, can it be experienced without the painful (injuring) stimulus?

- Experiment by Eisenberger et al. (2003)
  - “Cyberball”
  - In social psychology long known to cause *emotional* distress