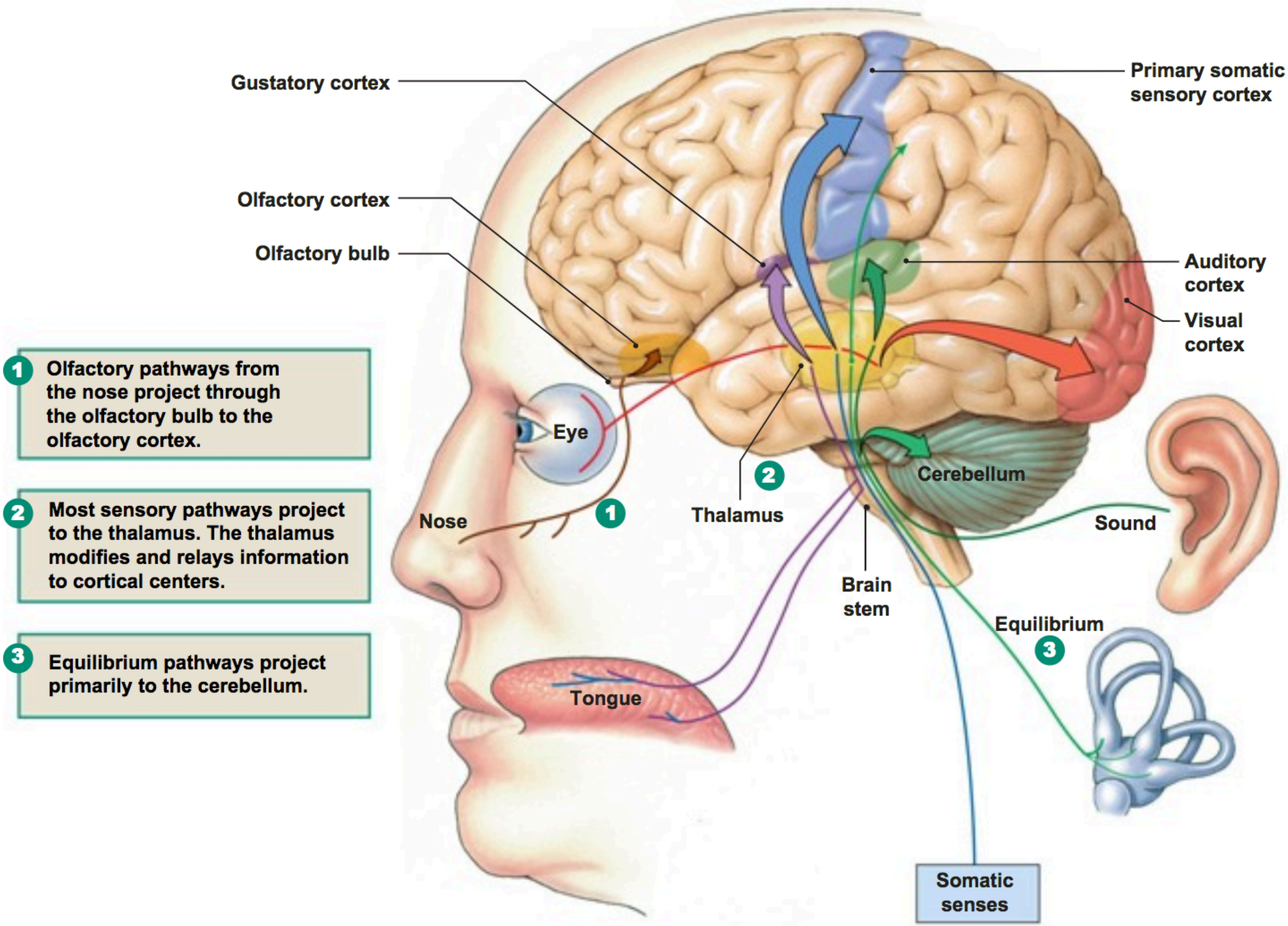
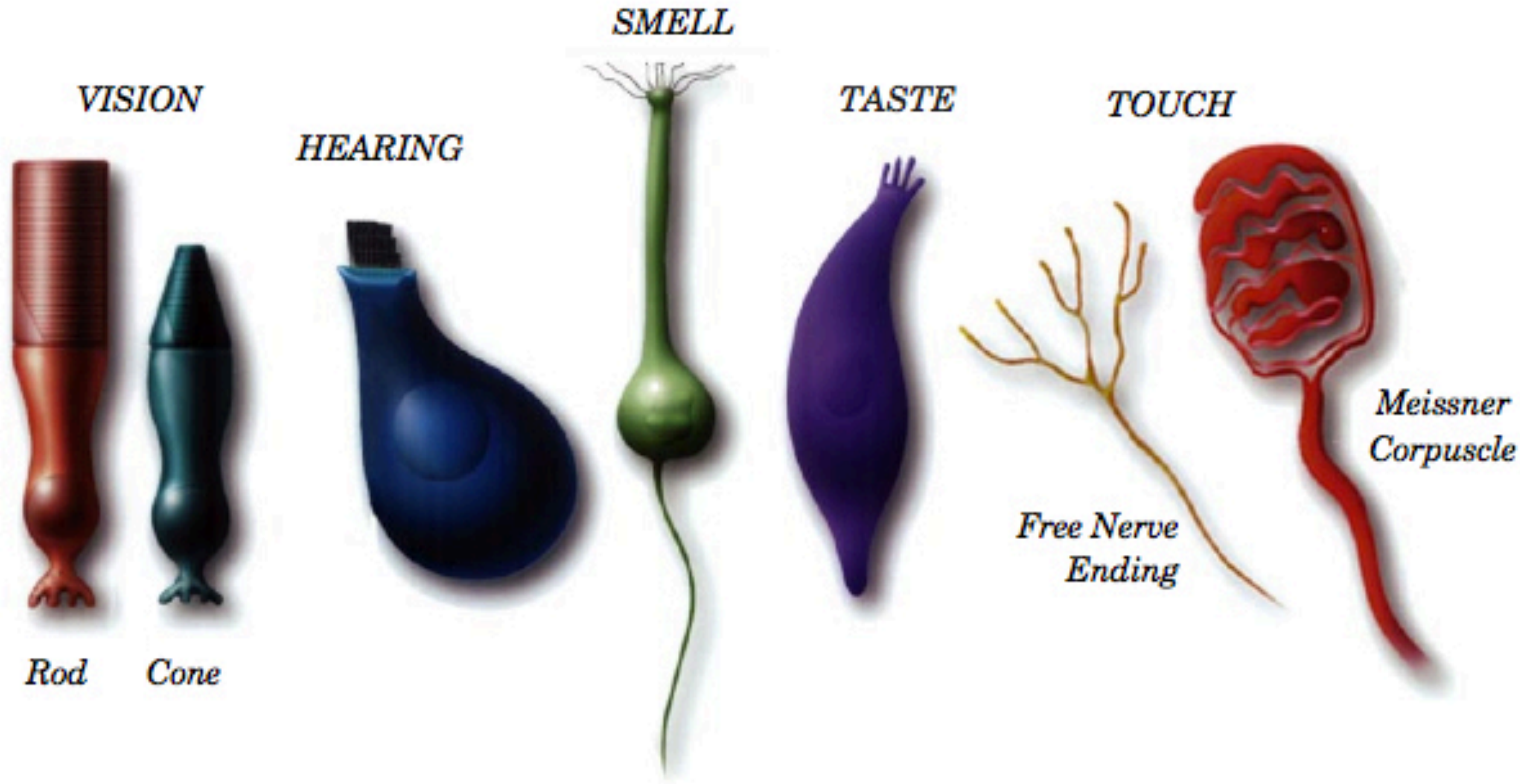
# CSE485: Sensation & Sensory Systems

Vinoo Alluri


Gustatory cortex
Olfactory cortex
Olfactory bulb
Primary somatic sensory cortex
Auditory cortex
Visual cortex
1 Olfactory pathways from the nose project through the olfactory bulb to the olfactory cortex.
2 Most sensory pathways project to the thalamus. The thalamus modifies and relays information to cortical centers.
3 Equilibrium pathways project primarily to the cerebellum.
Eye
Nose
1
2
Thalamus
Cerebellum
Sound
Brain stem
Equilibrium
3
Tongue
Somatic senses

## SPECIAL RECEPTOR CELLS FOR EACH OF THE SENSES




*Rod and cone cells in the eye respond to electromagnetic radiation—light.*

*The ear's receptor neurons are topped by hair bundles that move in response to vibrations—sound.*

*Olfactory neurons at the back of the nose respond—and bind—to odorant chemicals .*

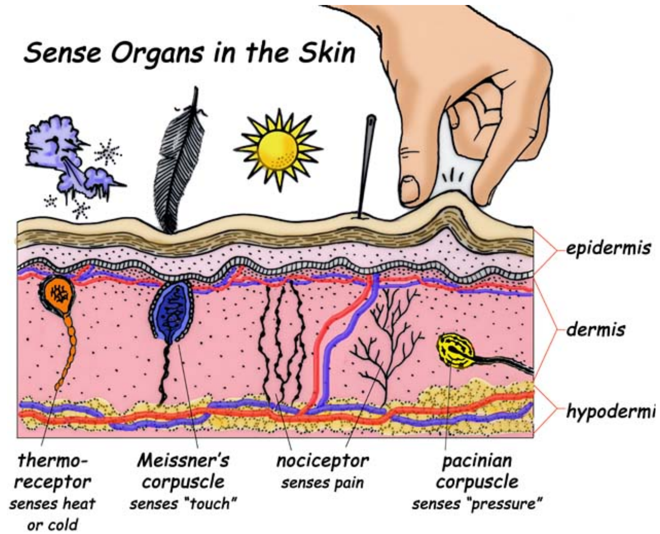
*Taste receptor cells on the tongue and back of the mouth respond—and bind—to chemical substances.*

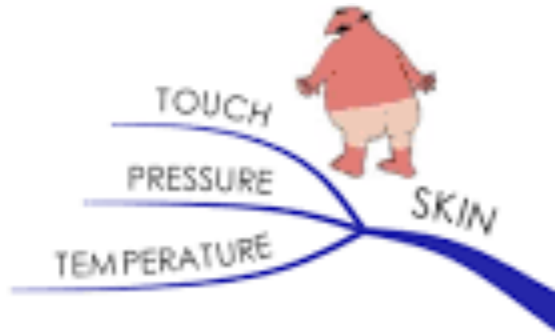
*Meissner corpuscles are specialized for rapid response to touch, while free nerve endings bring sensations of pain.*

tactile

# Sensory Systems:  Tactile

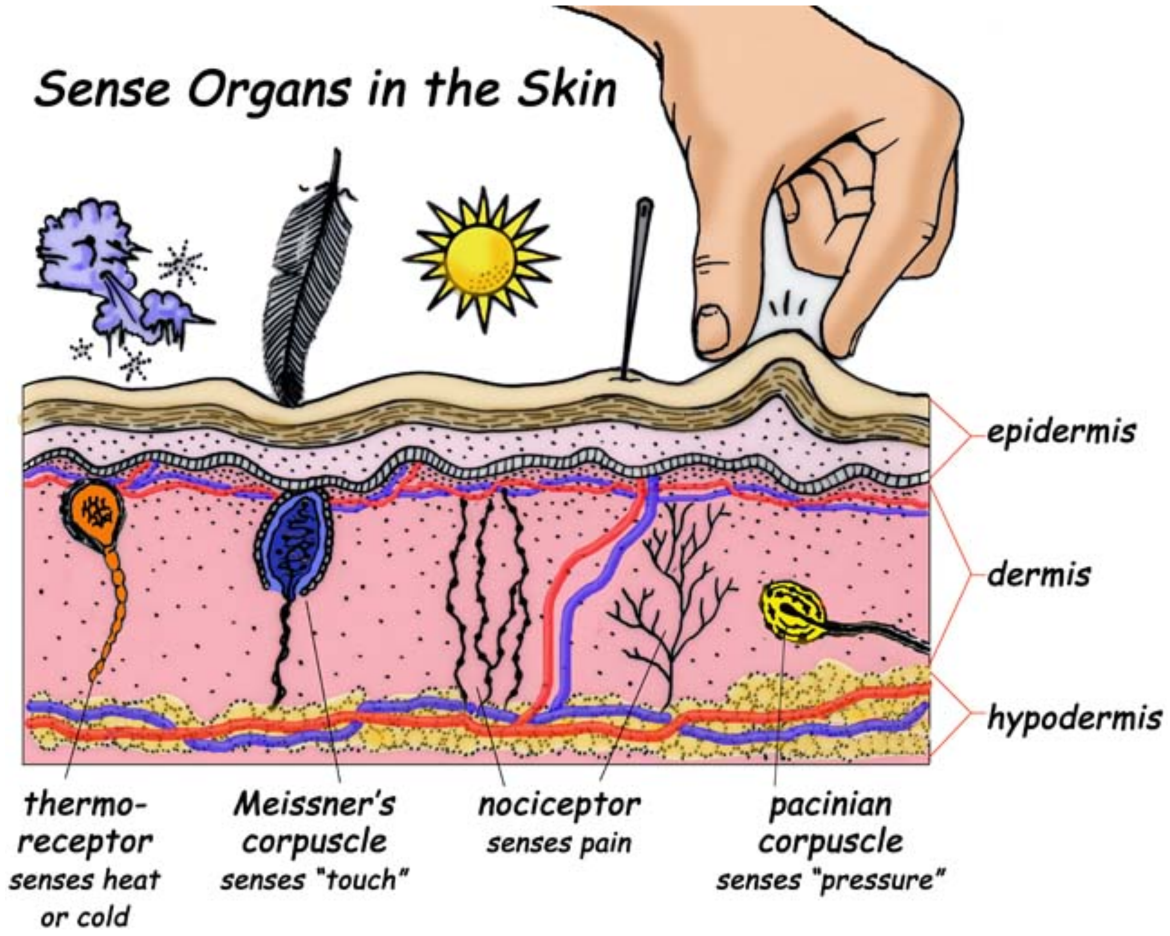
- Importance
  - survival (pain, temperature, pressure)
  - pleasure
- Receptors located in our skin



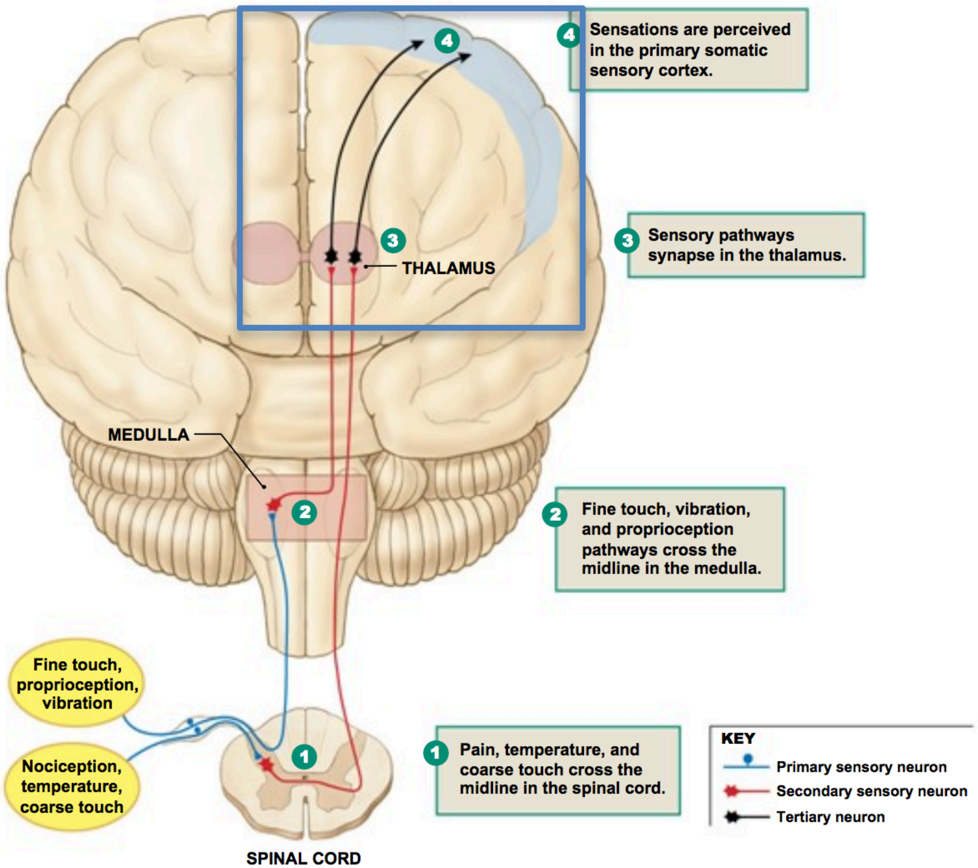
# Sensory Systems: Tactile

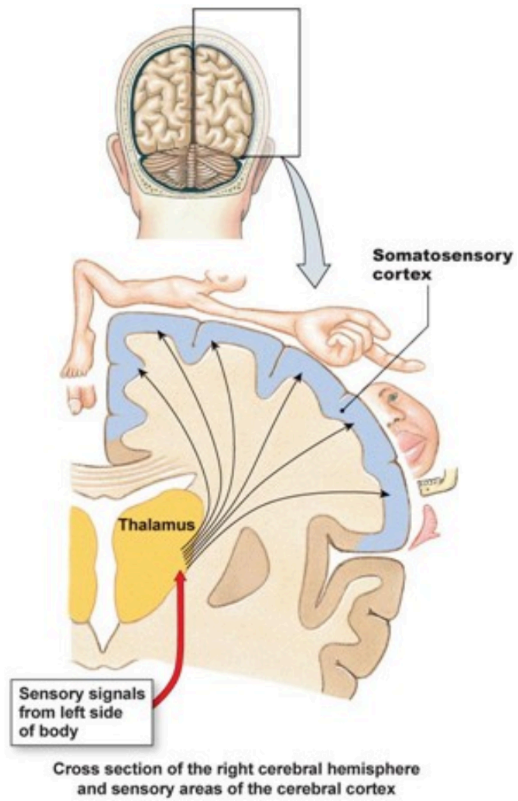
- Free nerve endings
  - Primary receptors for pain (Gracely & Farrell, 2002)
- Basket cell fibers
  - Receptors for heat, touch, and light pressure (Heller & Schiff, 1991)



# Tactile Perception

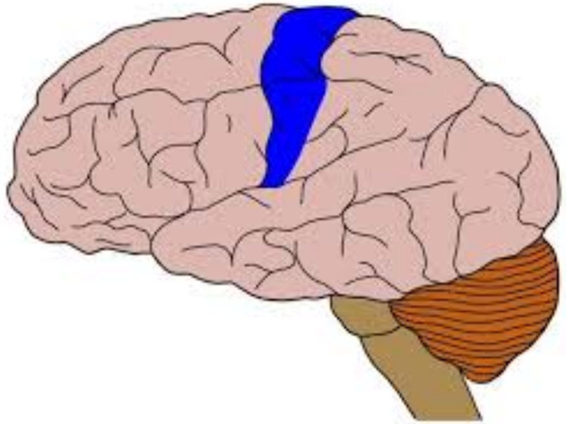
- The ability to detect and interpret sensory information cutaneously (of or on the skin)

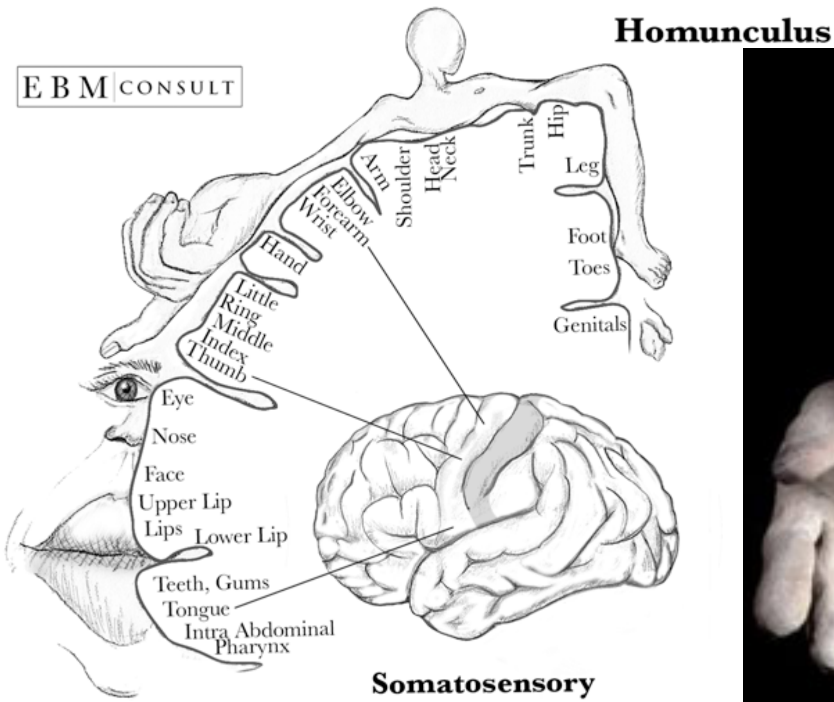


# Somatosensory cortex

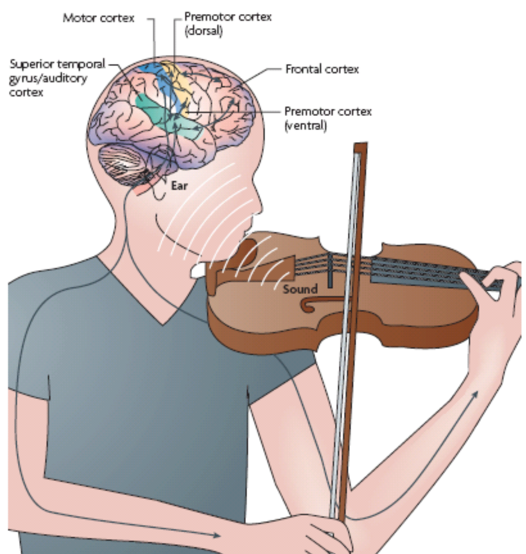
- **homunculus** - topological map/ representation of the surface of your body





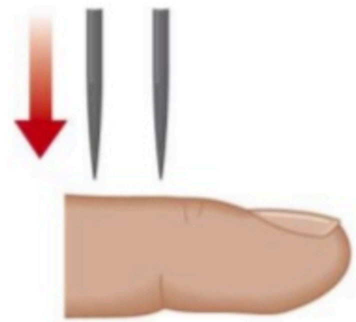

# Somatosensory cortex

- String instrument players have larger representation areas for __**LEFT**__ hand fingers in the motor and somatosensory areas (Elbert et al., 1995; Schwenkreis, P. et al. 2007)

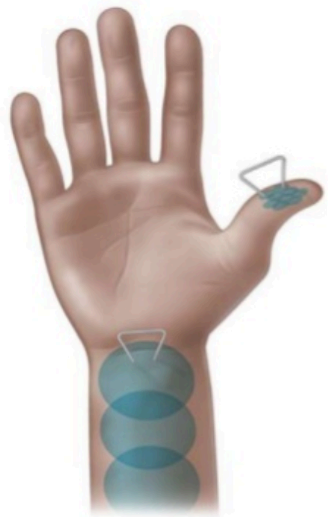


# Tactile Perception

- Tactile acuity (touch sharpness)
  - two point discrimination - minimum distance needed between two pressure points to perceive them as two units
  - based on receptive field of the sensory neuron at that point

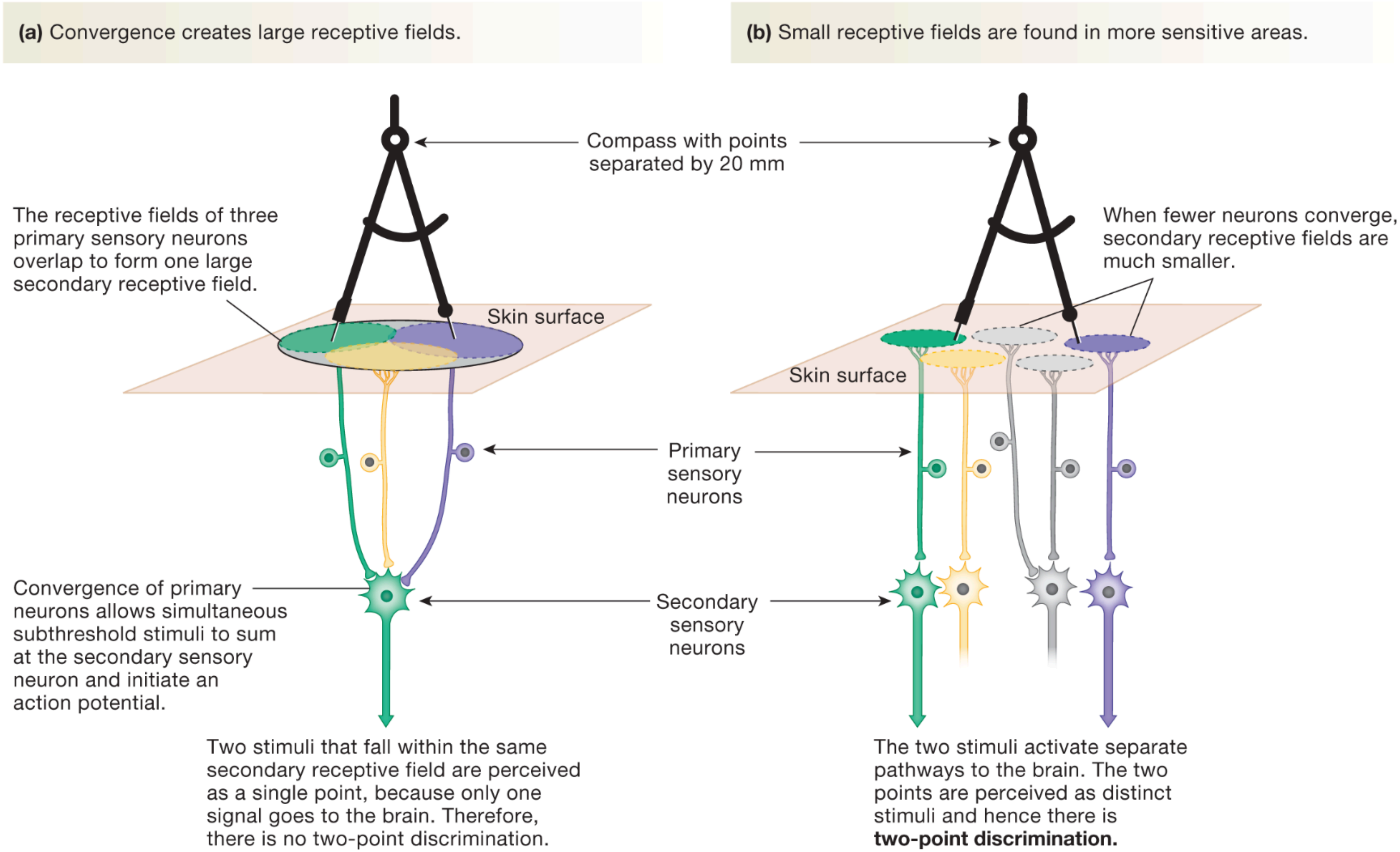


(a) One point or two?

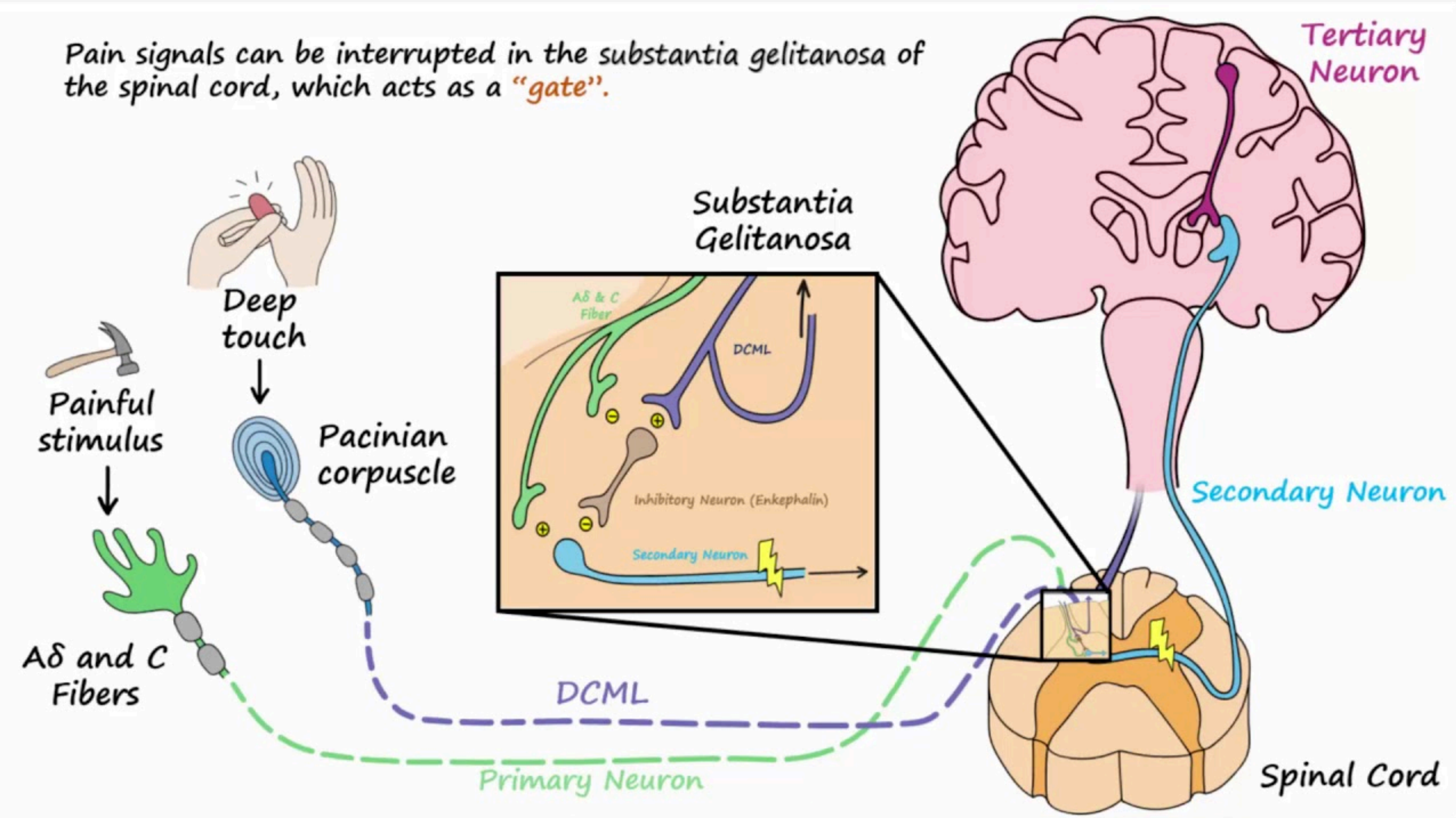


Try this out !!

# Tactile Acuity




PAIN



Pain signals can be interrupted in the substantia gelitanosa of the spinal cord, which acts as a "gate".
Tertiary Neuron
Substantia Gelitanosa
Deep touch
Painful stimulus
Pacinian corpuscle
Aδ & C Fiber
DCML
Inhibitory Neuron (Enkephalin)
Secondary Neuron
Secondary Neuron
Aδ and C Fibers
DCML
Primary Neuron
Spinal Cord

# Gate control theory of pain

19 November 1965, Volume 150, Number 3699

SCIENCE

## Pain Mechanisms: A New Theory

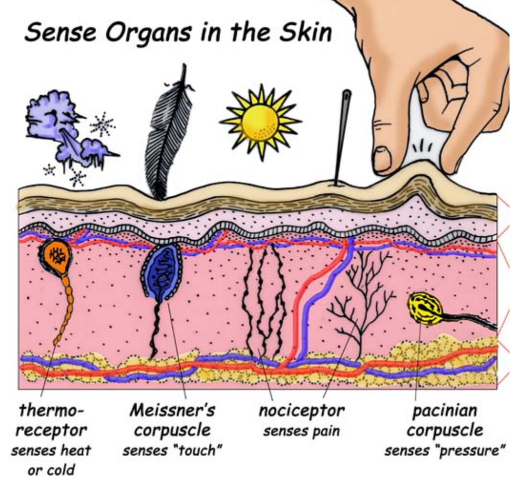
A gate control system modulates sensory input from the skin before it evokes pain perception and response.

Ronald Melzack and Patrick D. Wall

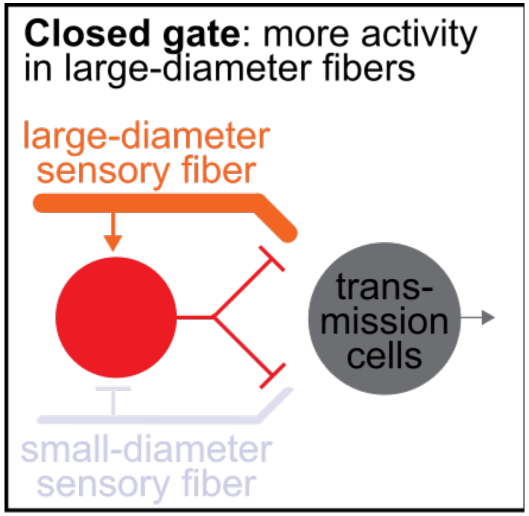
after amputation of a limb), and the peripheral neuralgias (which may occur after peripheral nerve infections or degenerative diseases) provide a dramatic refutation of the concept of a fixed, direct-line nervous system. Four features of these syndromes plague patient, physician, and theorist (*8*, *10*).

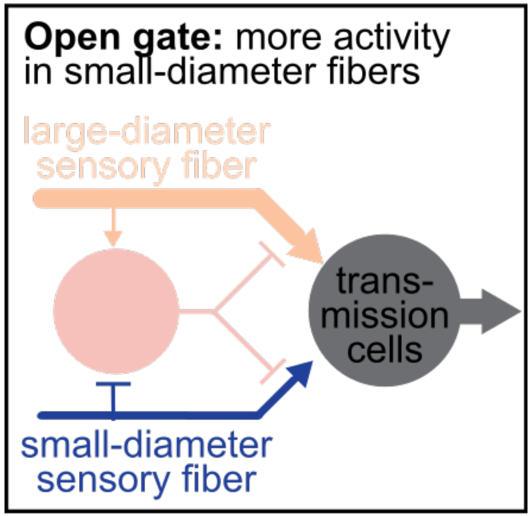
1) Surgical lesions of the peripheral and central nervous system have been singularly unsuccessful in abolishing these pains permanently, although the lesions have been made at almost every level (Fig. 2). Even after such operations, pain can often still be elicited

# Gate control theory of pain




- non-painful input closes the "gates" to painful input, which prevents pain sensation from traveling to the central nervous system
    - ex: massaging painful area, thermal pack
- small nerve fibers ***open*** the gate
- large nerve fibers ***close*** the gate



# Phantom Limb

- amputees experience sensations from missing limb
- reorganisation of neural connections - ***neural plasticity***
- commonly cause sensations of pain post amputation

https://www.youtube.com/watch?v=KdihphPp1Q0

**NEUROLOGICAL REVIEW**

SECTION EDITOR: DAVID E. PLEASURE, MD

## Phantom Limbs and Neural Plasticity

*Vilayanur S. Ramachandran, MD, PhD; Diane Rogers-Ramachandran, PhD*

# Phantom Limb

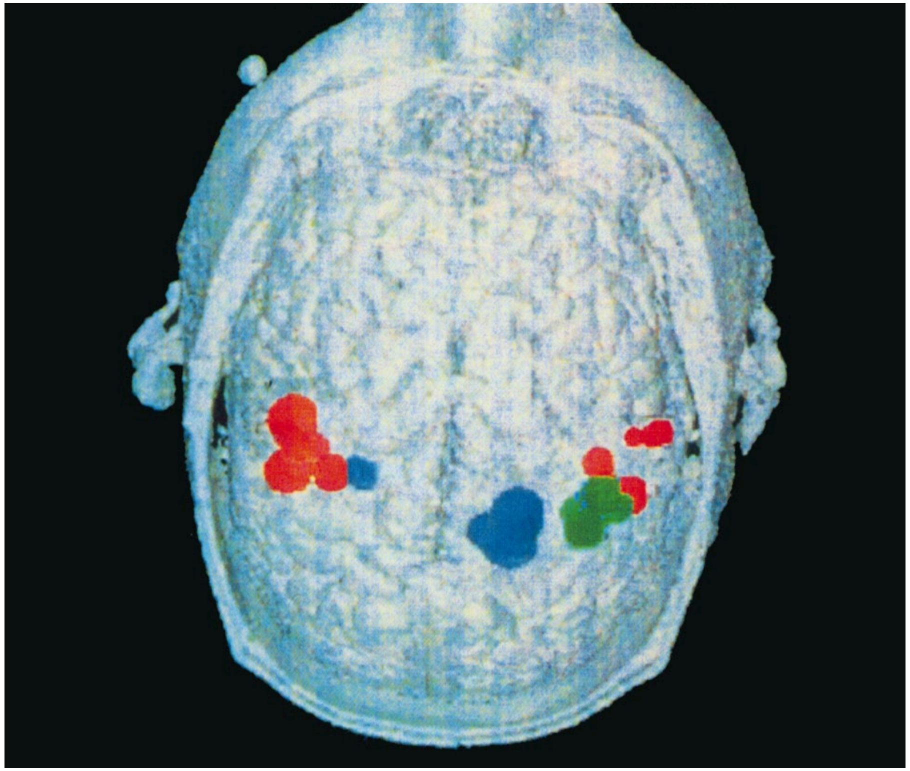


**Fig. 2** (**A**) Top view of a combined MEG and 3D surface-rendered MRI of an adult whose right arm was amputated below the elbow at the age of 11 years. The right hemisphere is normal and shows the primary somatosensory face area (red) lateral, anterior and inferior to the hand localizations (green), which are in turn lateral, anterior, and inferior to the upper arm region. The left hemisphere shows the face (red) and upper arm (blue) regions extending into the expected hand territory, reflecting reorganization of the sensory map following amputation.

*Brain* (1998), **121**, 1603–1630

*INVITED REVIEW*

The perception of phantom limbs

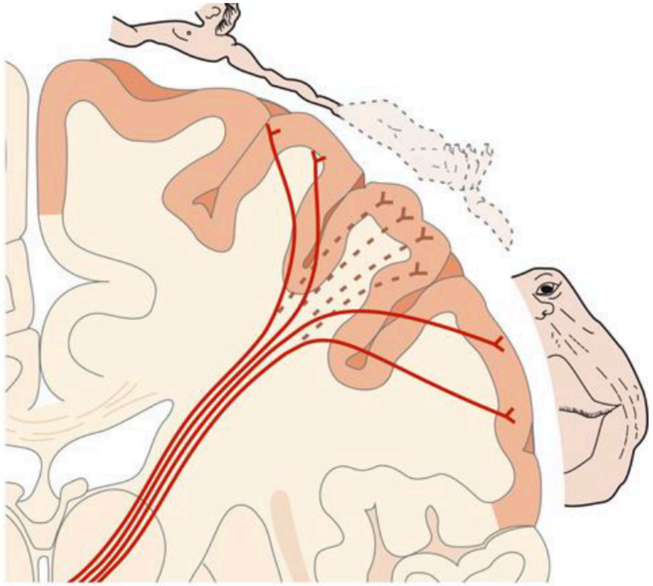
The D. O. Hebb lecture

V. S. Ramachandran and William Hirstein

# Phantom Limb

remapping hypothesis

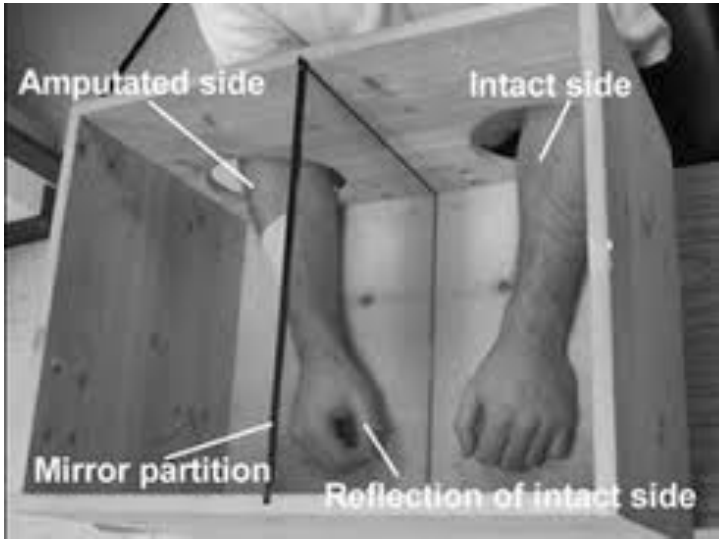

**Figure 2.** *Points on the face of a patient that elicit precisely localized, modality-specific referral in the phantom limb 4 weeks after amputation of the left arm below the elbow. Sensations were felt simultaneously on the face and phantom limb.*



- sensory homunculus: cortical area receiving inputs from the hand is adjacent to that of the face
- rearrangement of cortical inputs is thought to be responsible for some types of phantom limb sensation

# Phantom Limb Pain

- mirror therapy treatment (Ramachandran 1996)
  - helps unclench it from potentially painful positions



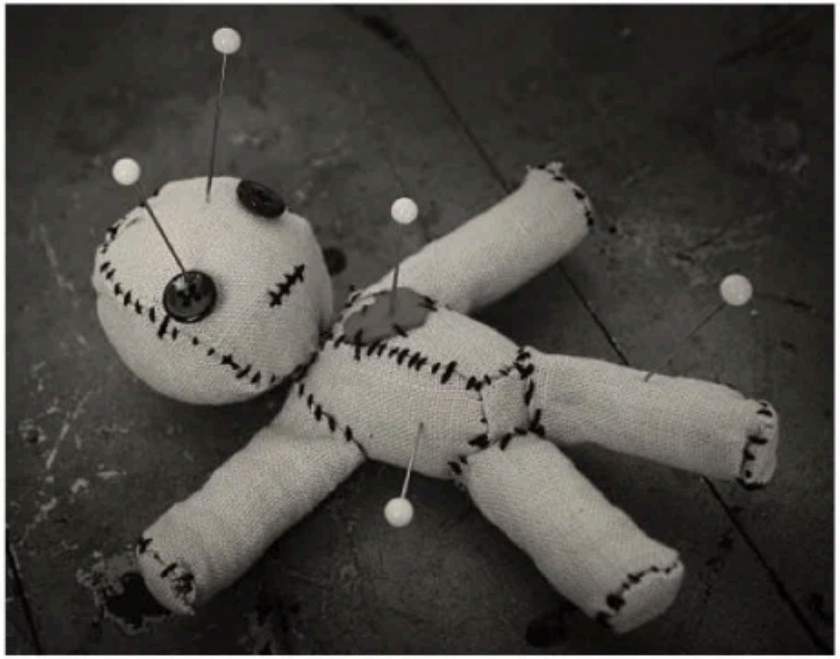
# Phantom Limb Pain

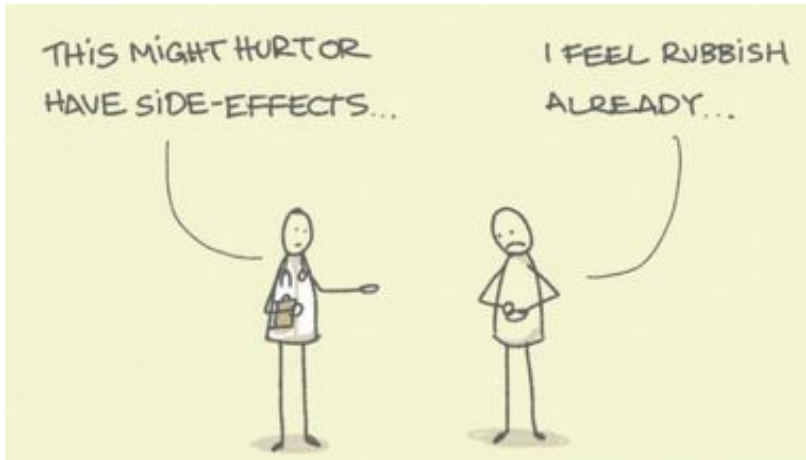
- mirror therapy treatment (Ramachandran 1996)
  - helps unclench it from potentially painful positions
- virtual reality
  - immersive game experiences

# NOCEBO EFFECT

a harmless thing that causes harm

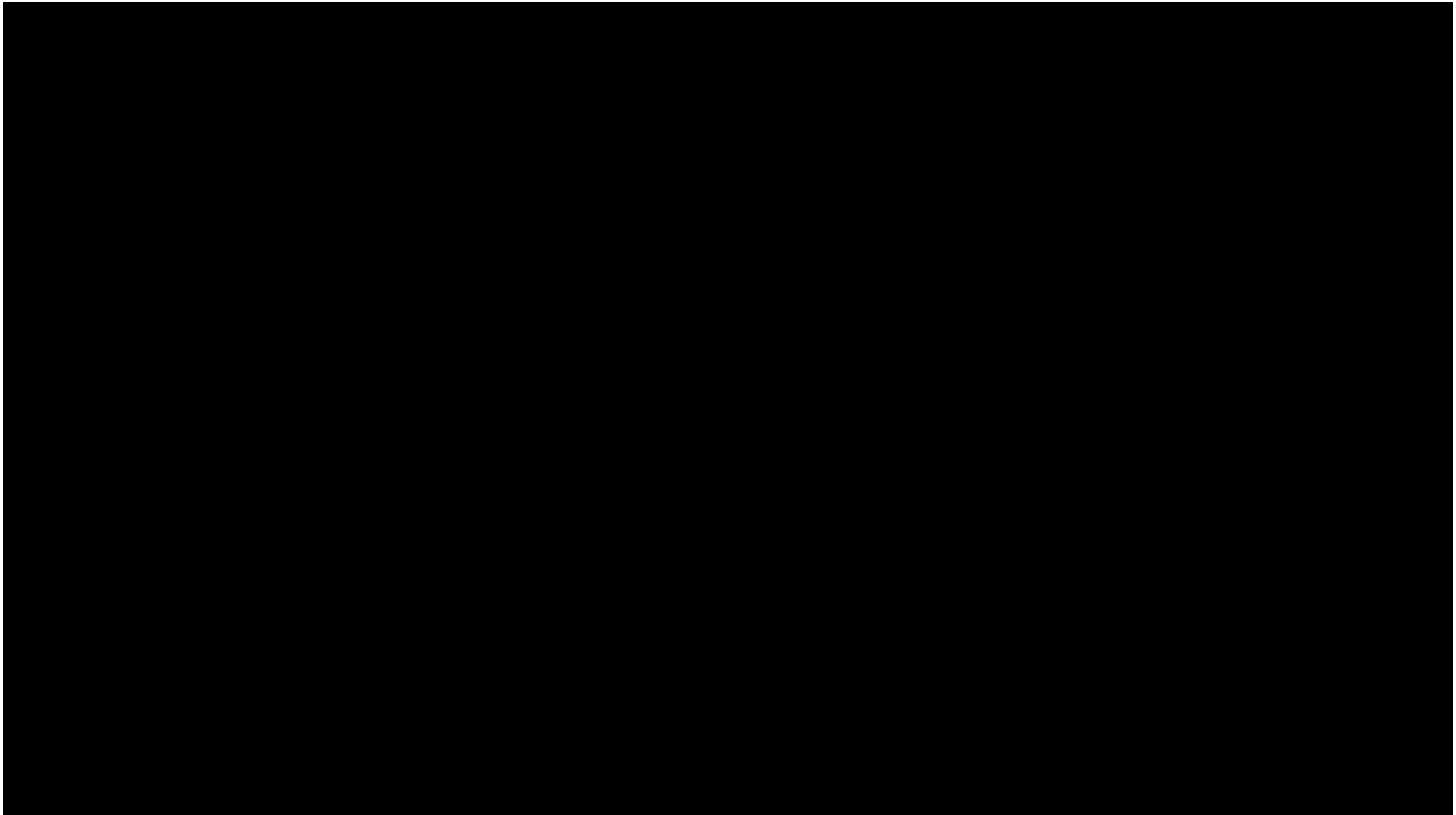
**because you believe it's harmful**

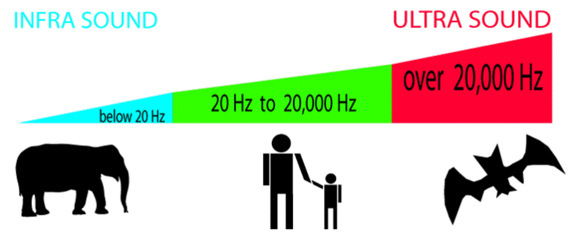




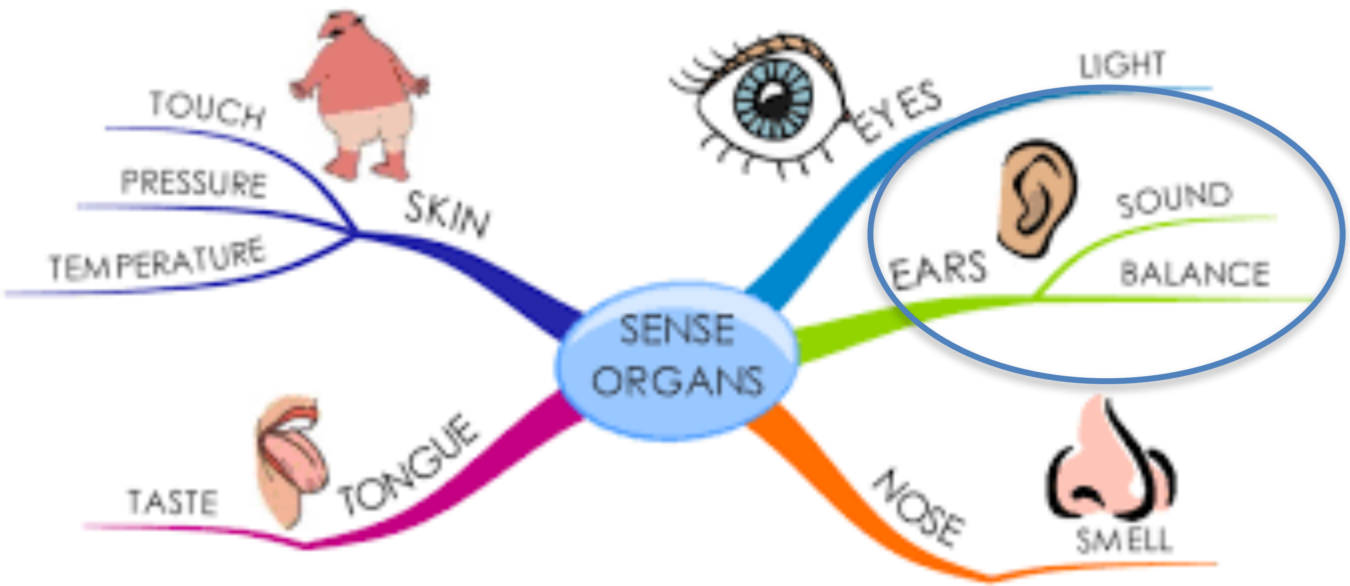
# Somatosensory Illusions

https://www.youtube.com/watch?v=OUdXMoY6fLY

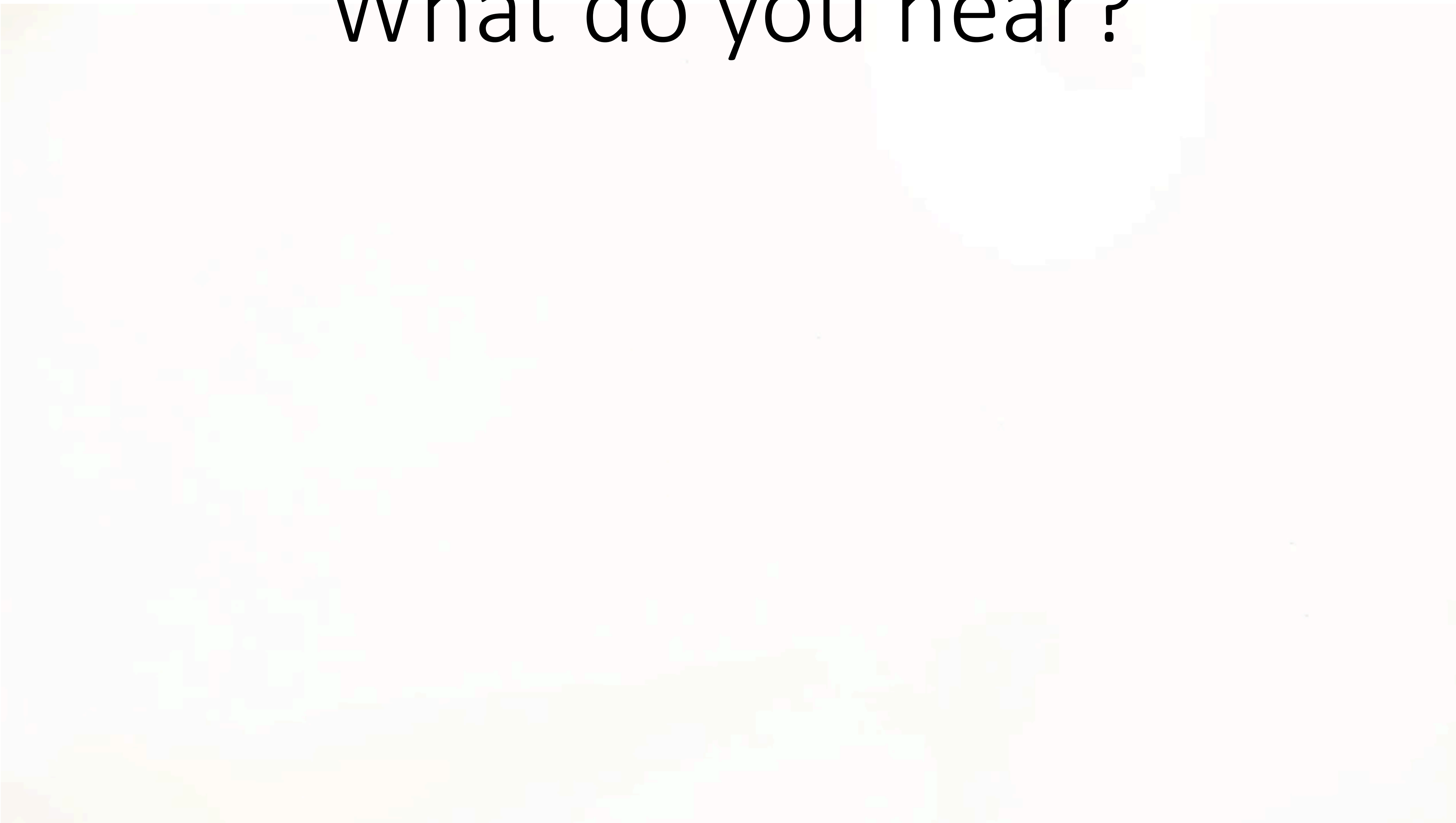





# Sensory Systems



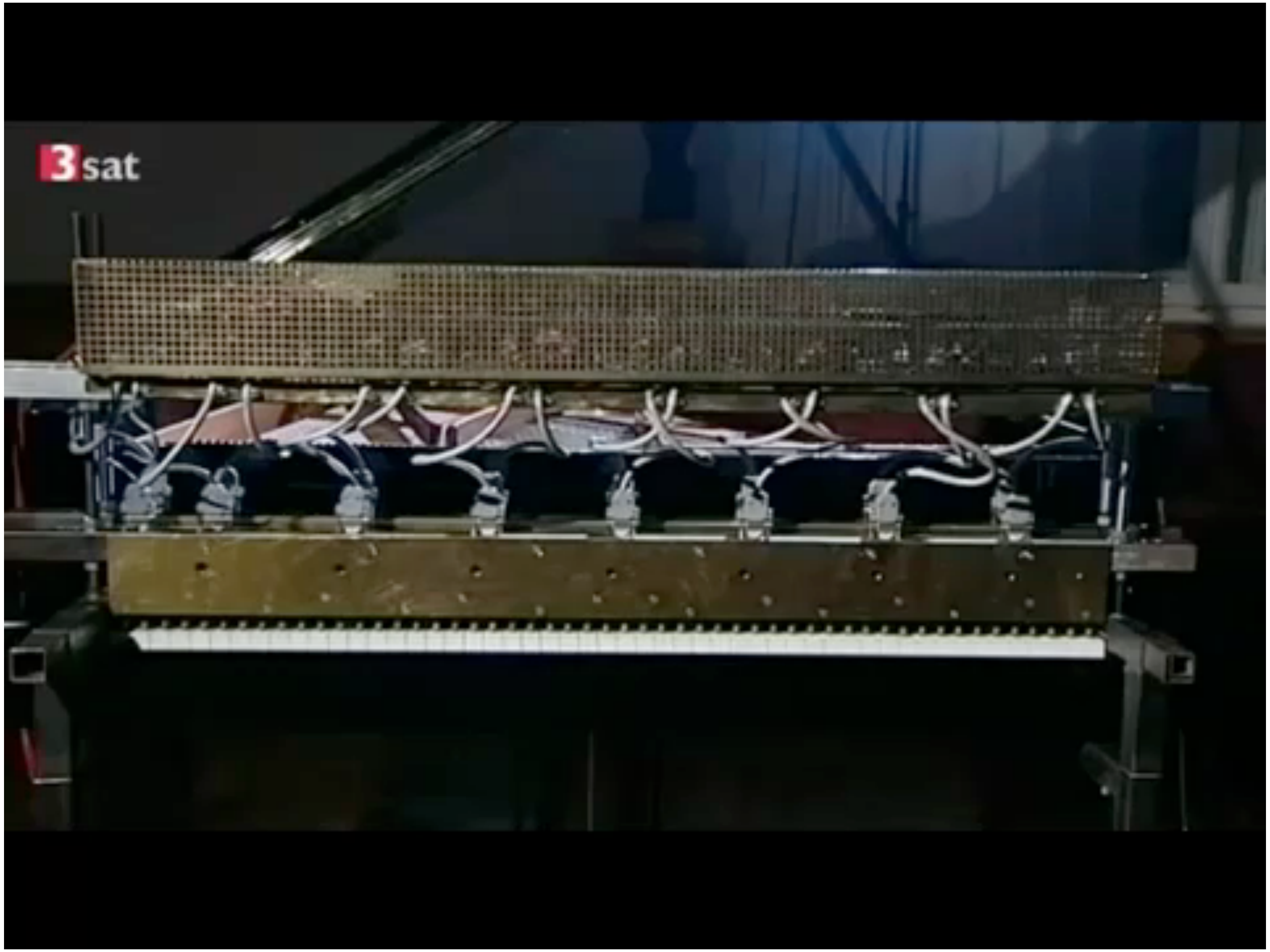
# What do you hear?



https://www.youtube.com/watch?v=kzo45hWXRWU

# What do you hear?

https://www.youtube.com/watch?v=sjtZxjEH6cM&pbjreload=101



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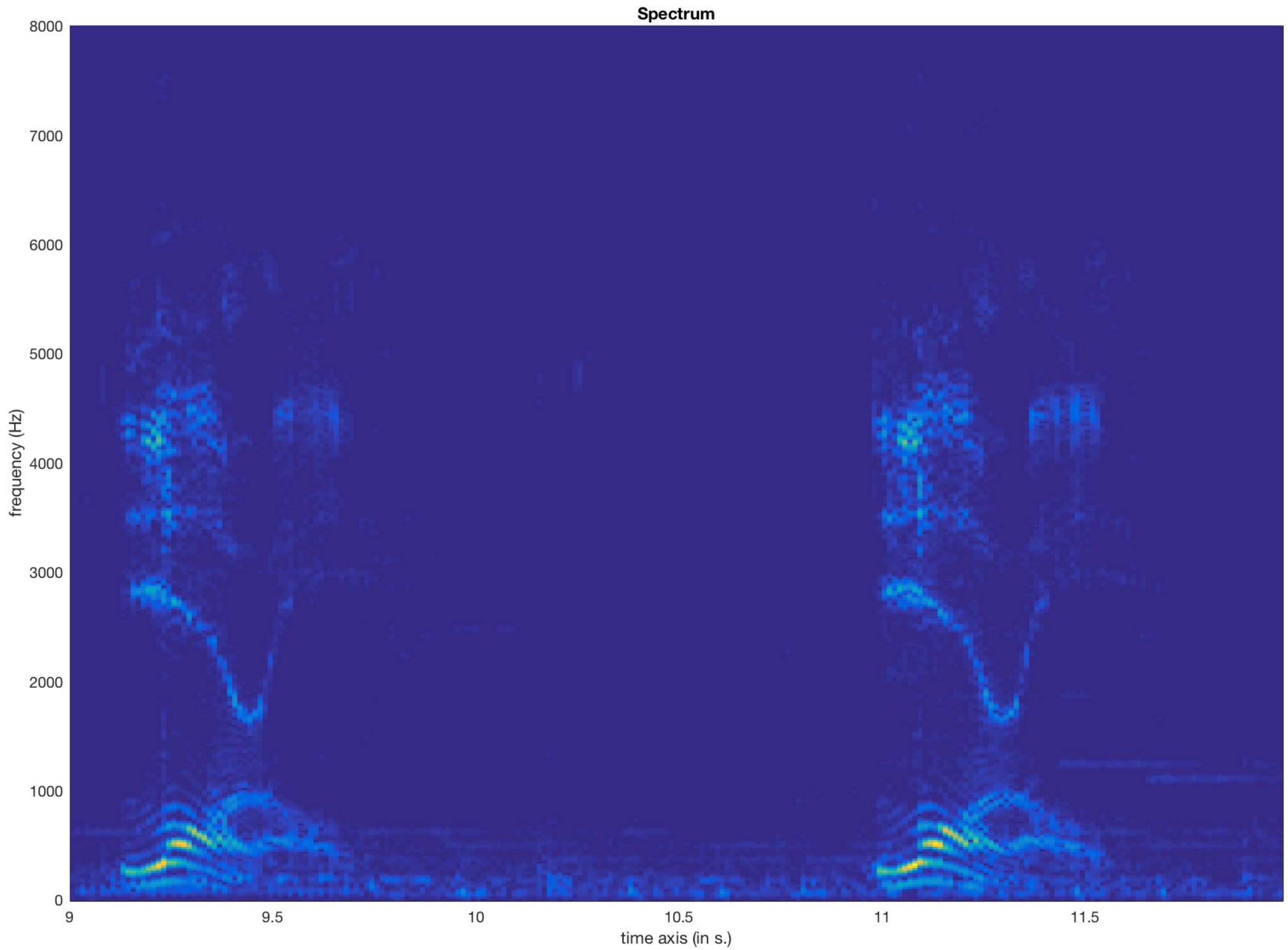
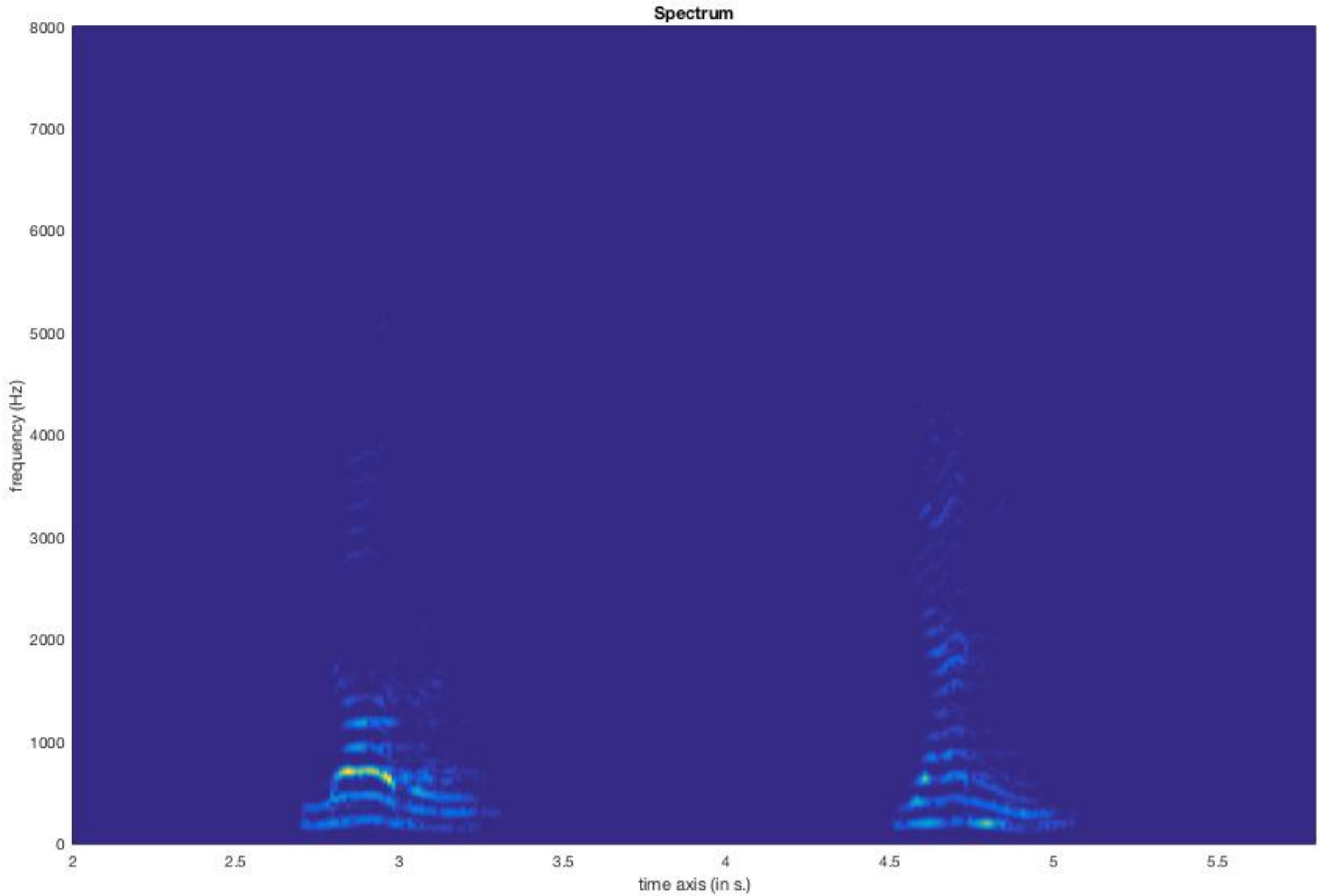
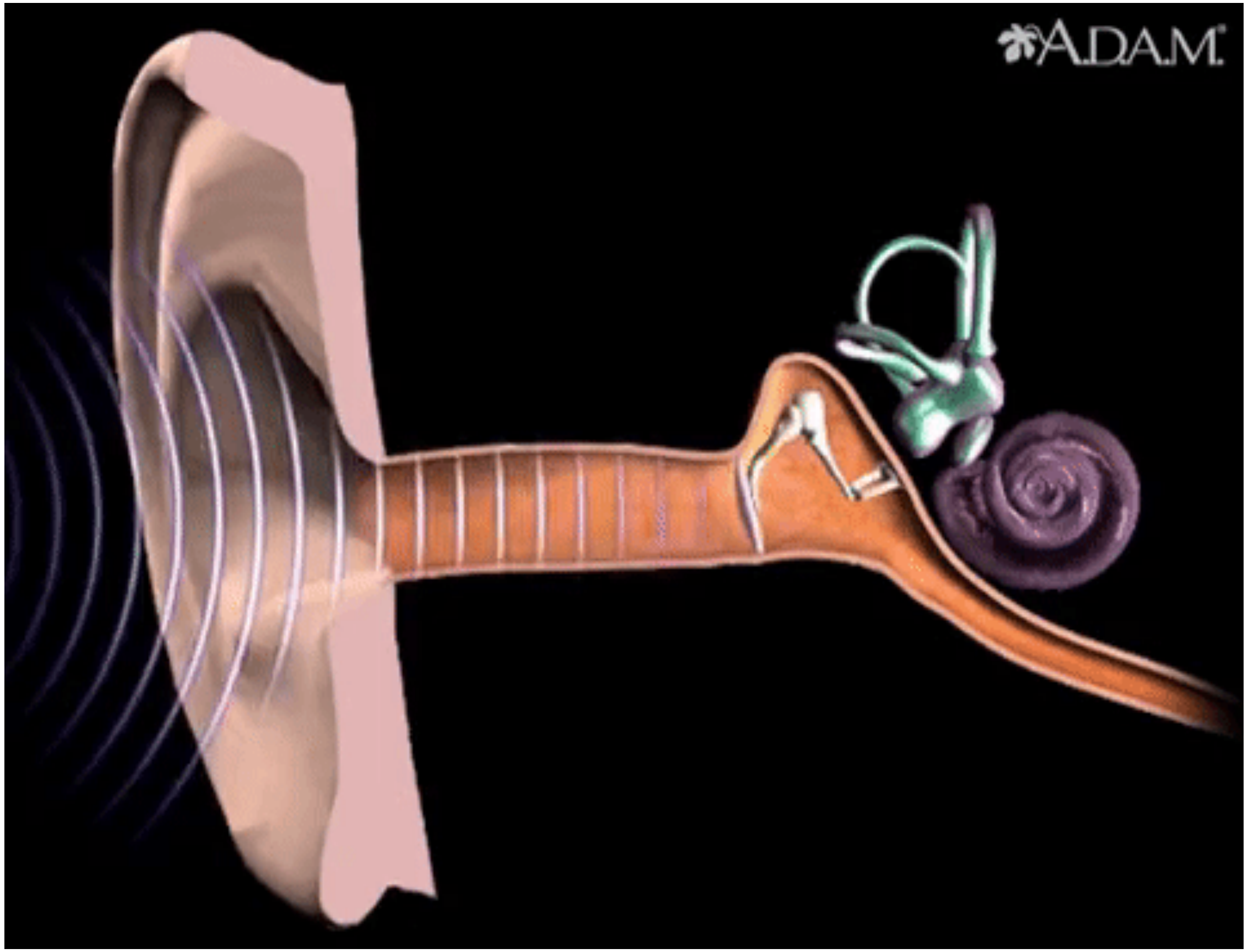
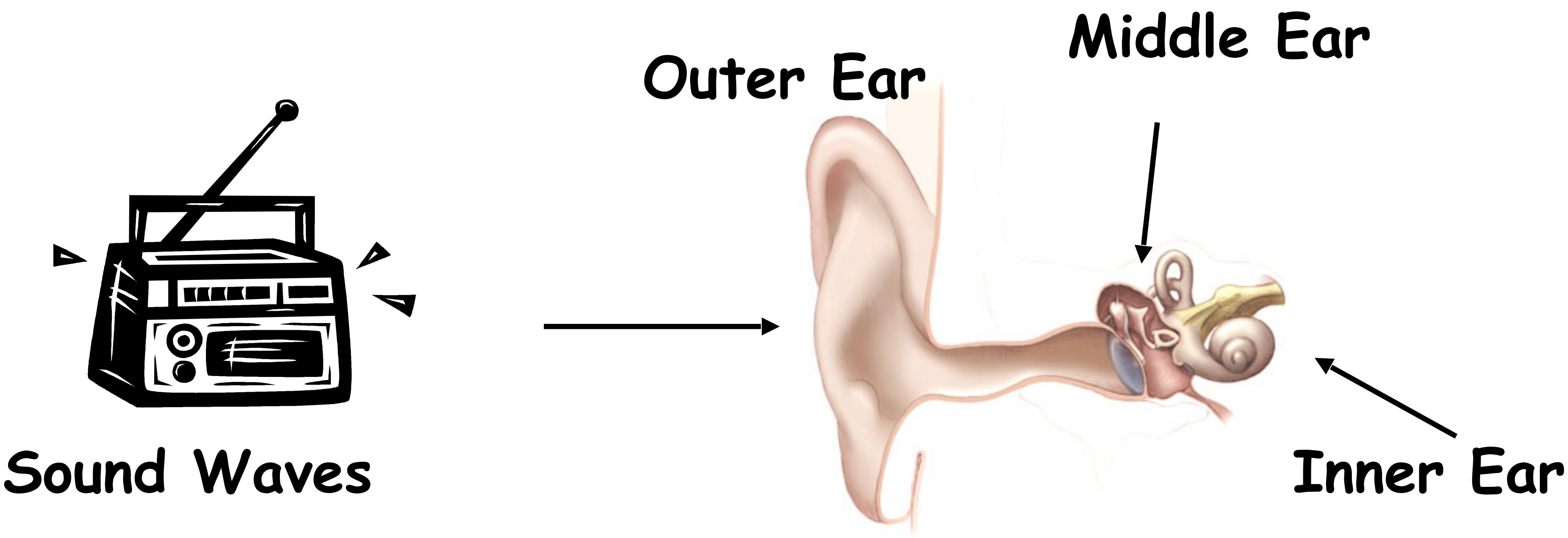



Spectrum
frequency (Hz)
8000
7000
6000
5000
4000
3000
2000
1000
0
2
2.5
3
3.5
4
4.5
5
5.5
time axis (in s.)



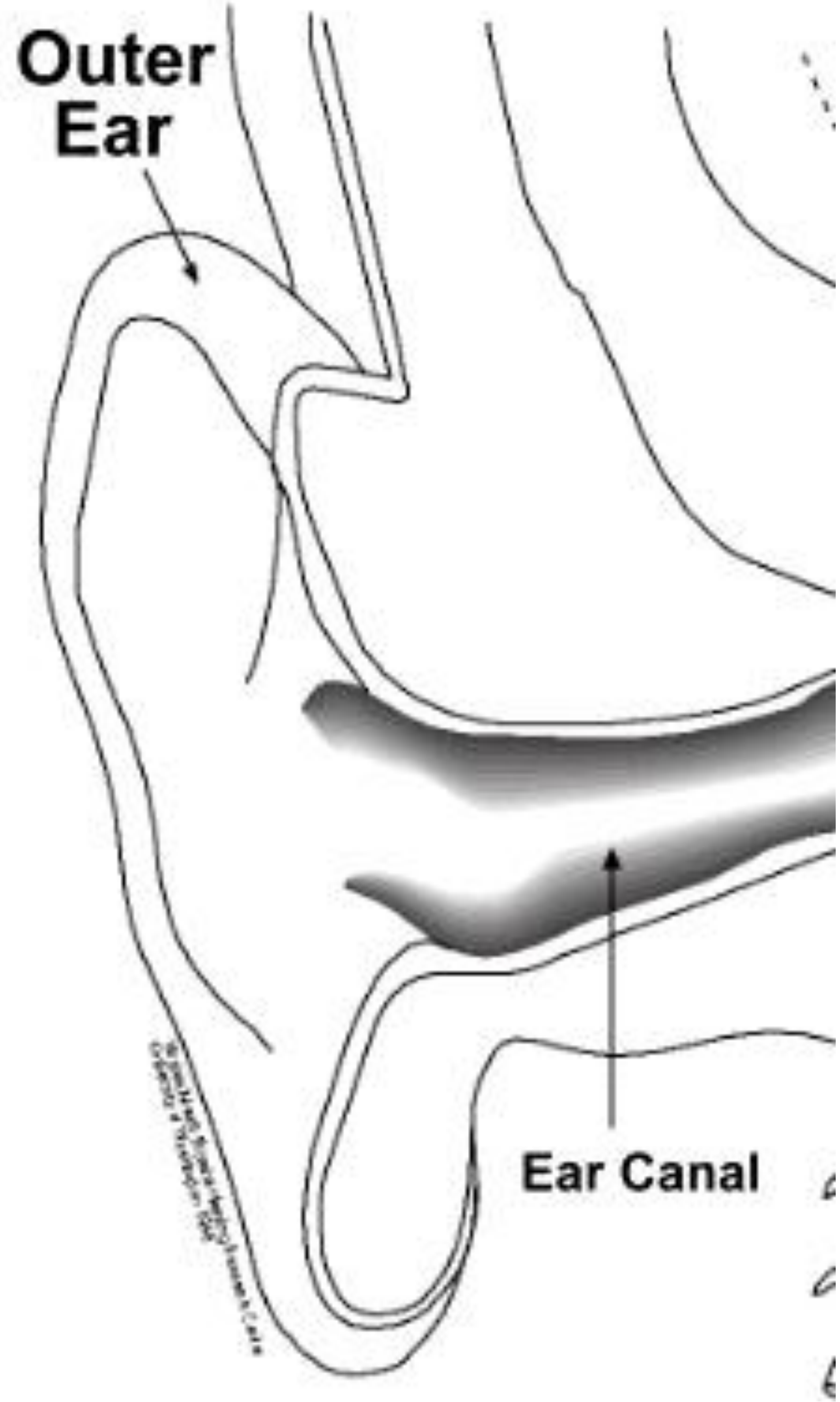
# How does the ear work?

- The <u>outer ear</u> “catches the sound waves”.
- The <u>middle ear</u> takes the sound waves and <u>“vibrates”</u> <u>the eardrum</u>.
- The <u>inner ear</u> sends the messages to the brain.



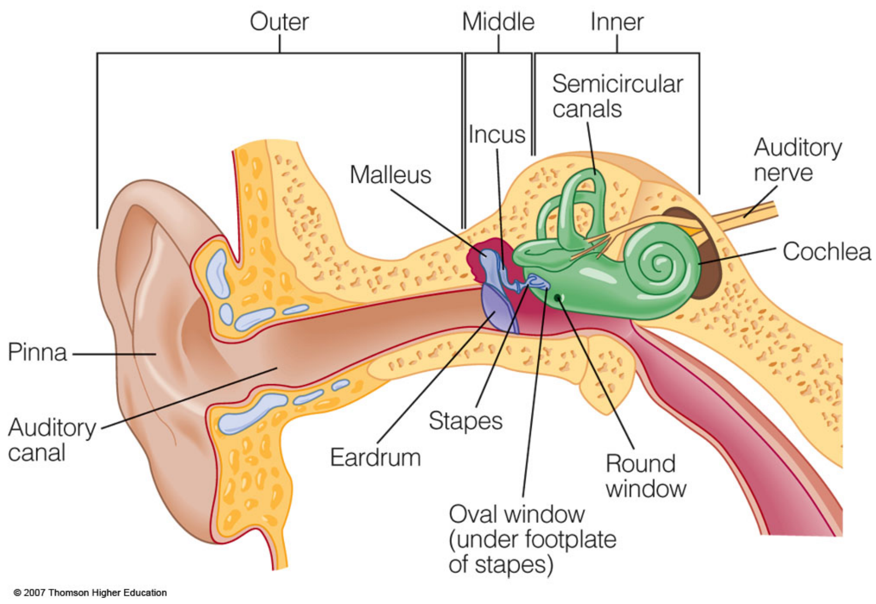
# The Outer Ear

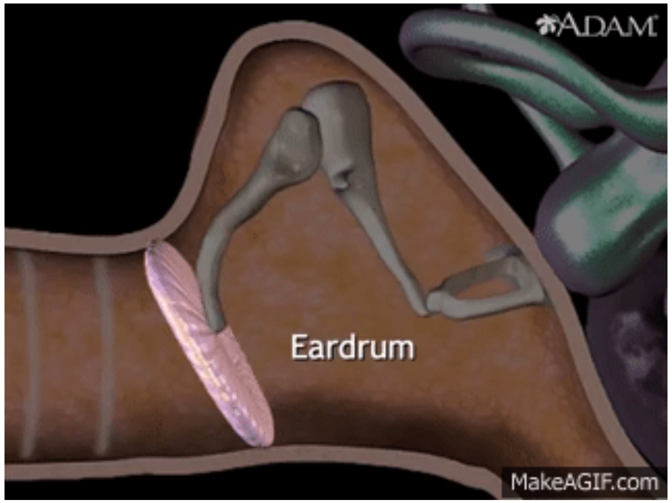
- The  curved formation on the outside (the pinna) helps funnel sound down the ear canal to the eardrum.



# The Middle Ear

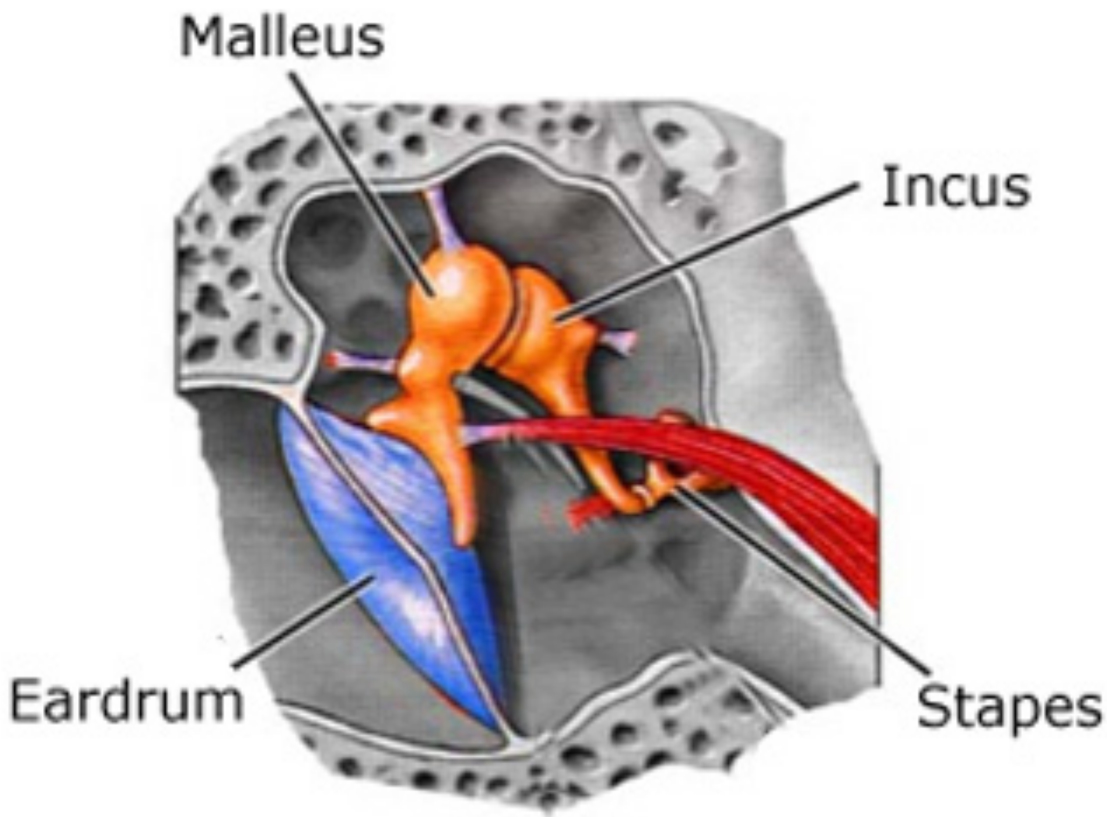
- transfers the energy of a sound wave by vibrating the three bones found there.
- ossicles are arranged and interact with each other as a lever system
- **amplifier** - without them, only about 0.1 percent of sound energy would make it into the inner ear.



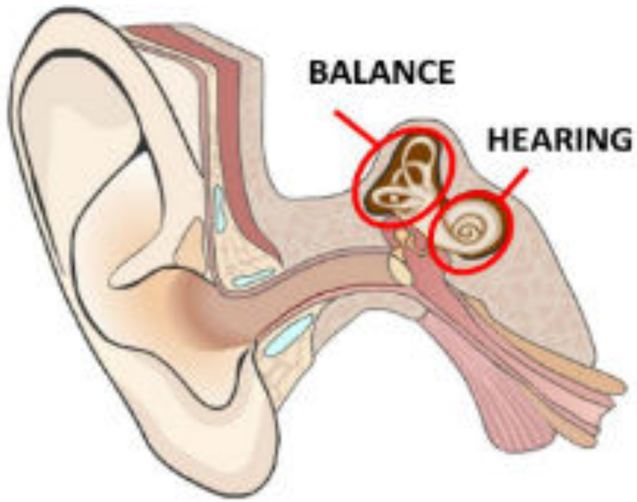
# Bones of the Middle Ear

- These are the smallest bones in your body!



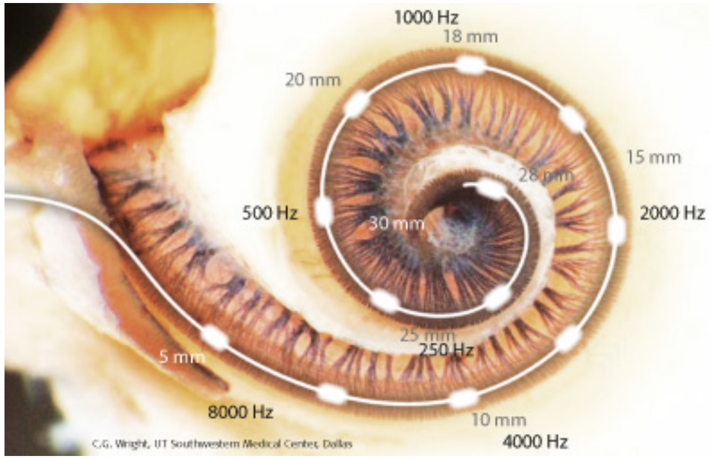

# The Inner Ear

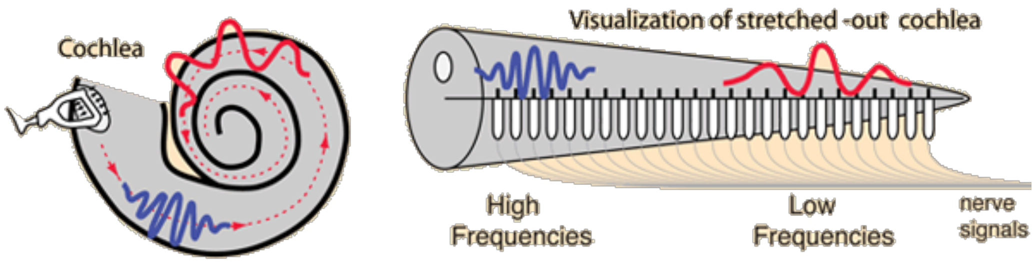
- Two main parts:
  - **Vestibular system** (**balance**) - Semicircular Canals- Fluid filled tubes attached to the cochlea that help us maintain our sense of balance
  - **Cochlea** (**hearing**) converting sound pressure patterns from the outer ear into electrochemical impulses which are passed on to the brain via the auditory nerve.

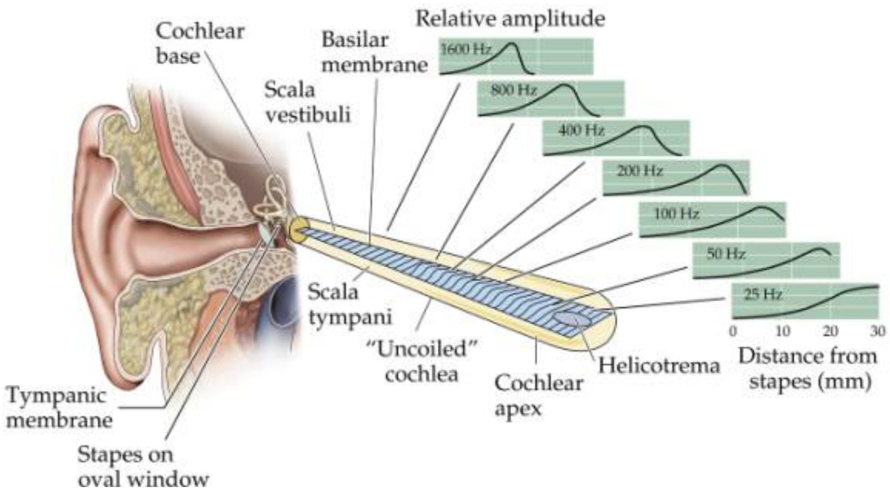


# The Inner Ear

- **Cochlea**
  - Coiled like a snail shell, fluid-filled; it is lined with cilia (tiny hairs) that move when vibrated and cause a nerve impulse to form.
  - Contains approximately 300,000 hair-like cells
  - tonotopic map - a location code formed on the cochlea (place coding)

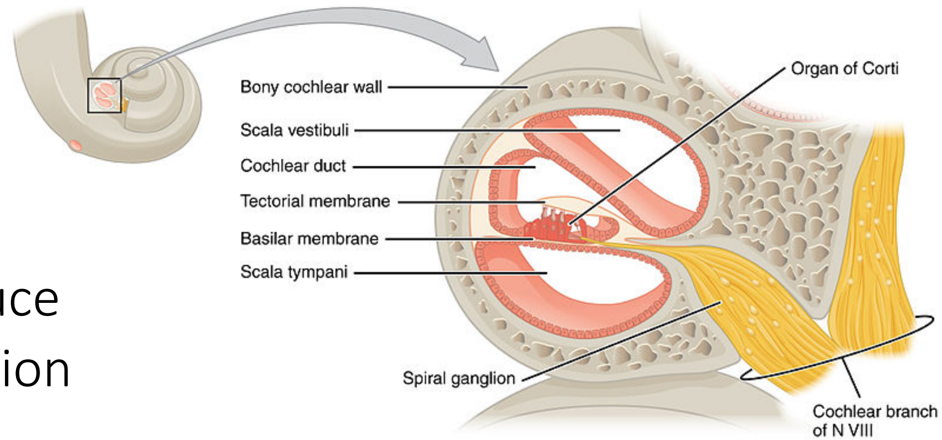


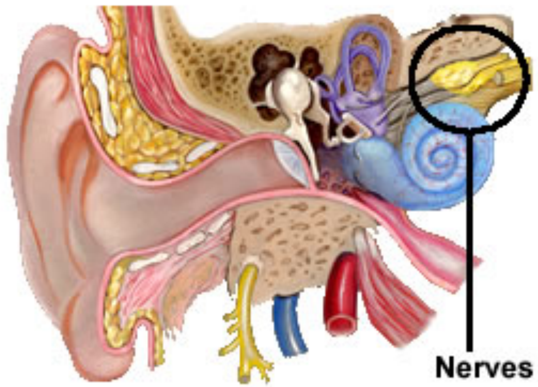



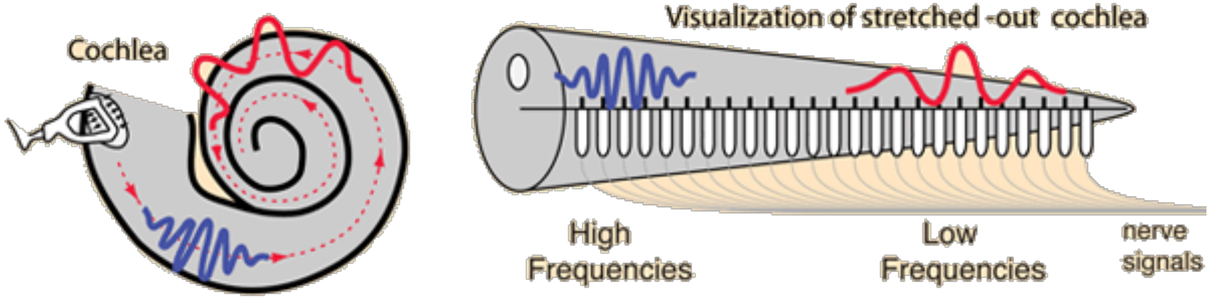
# The Inner Ear

- **Basilar membrane**
  - stiff long structural element varying in width and stiffness
  - base for the sensory cells of hearing
- **Organ of Corti**
  - contains auditory receptors that transduce auditory signals into nerve impulses' action potential
- **Auditory/Cochlear nerve**
  - these carry electro-chemical signals from the inner ear (the cochlea) to the brain.



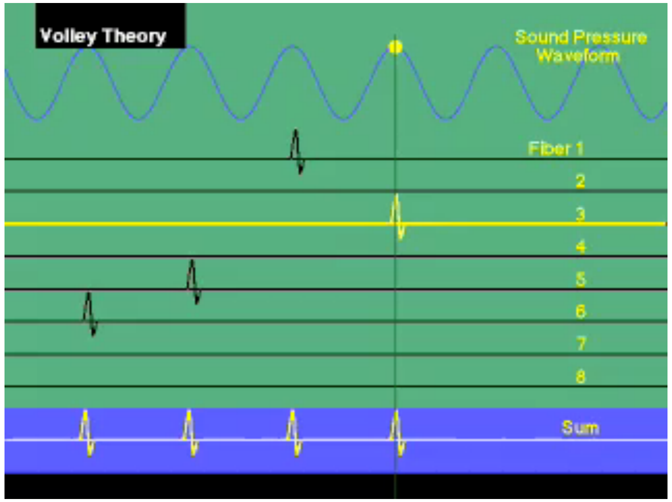
# Frequency Coding



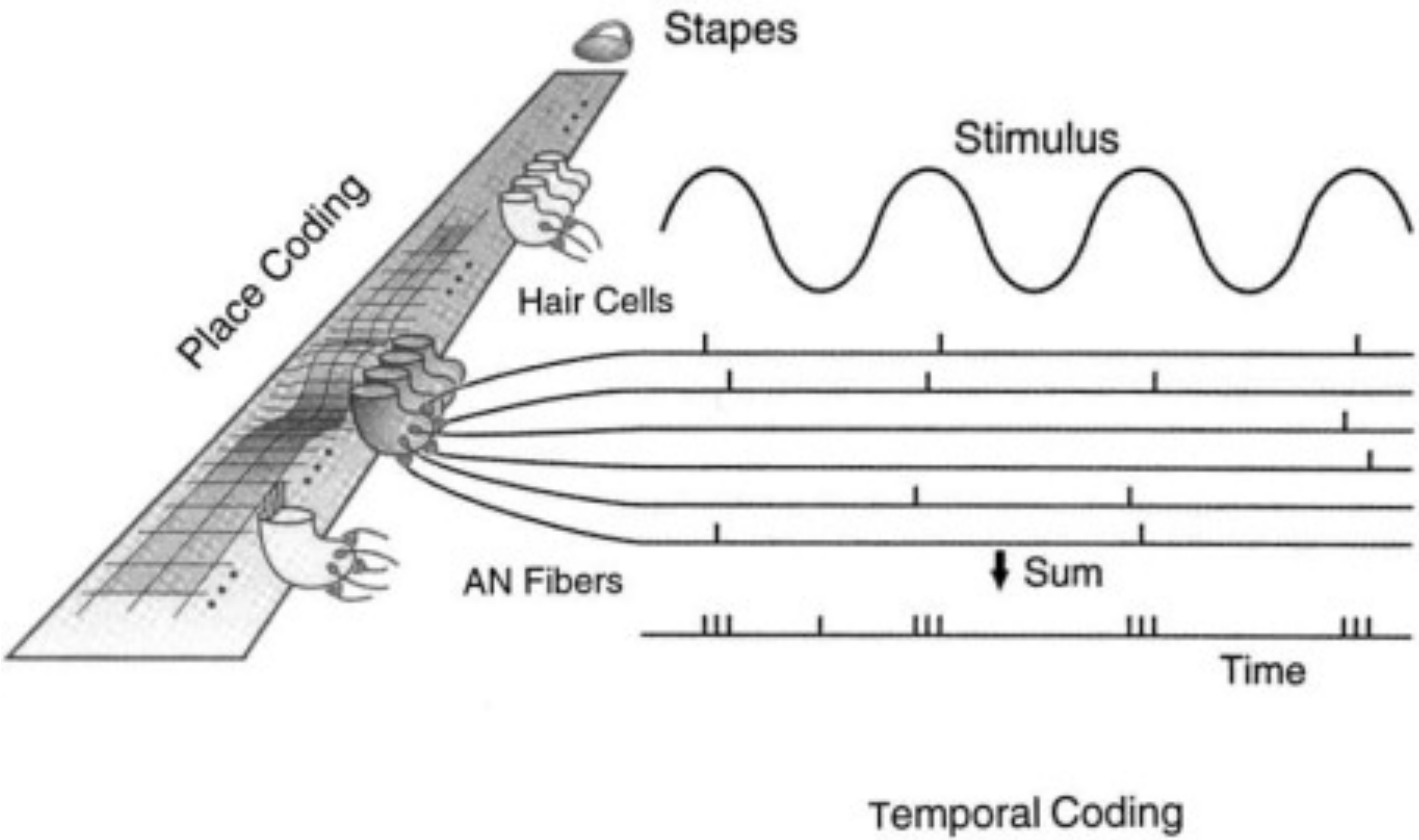

place coding

**Volley Theory:** (temporal coding)

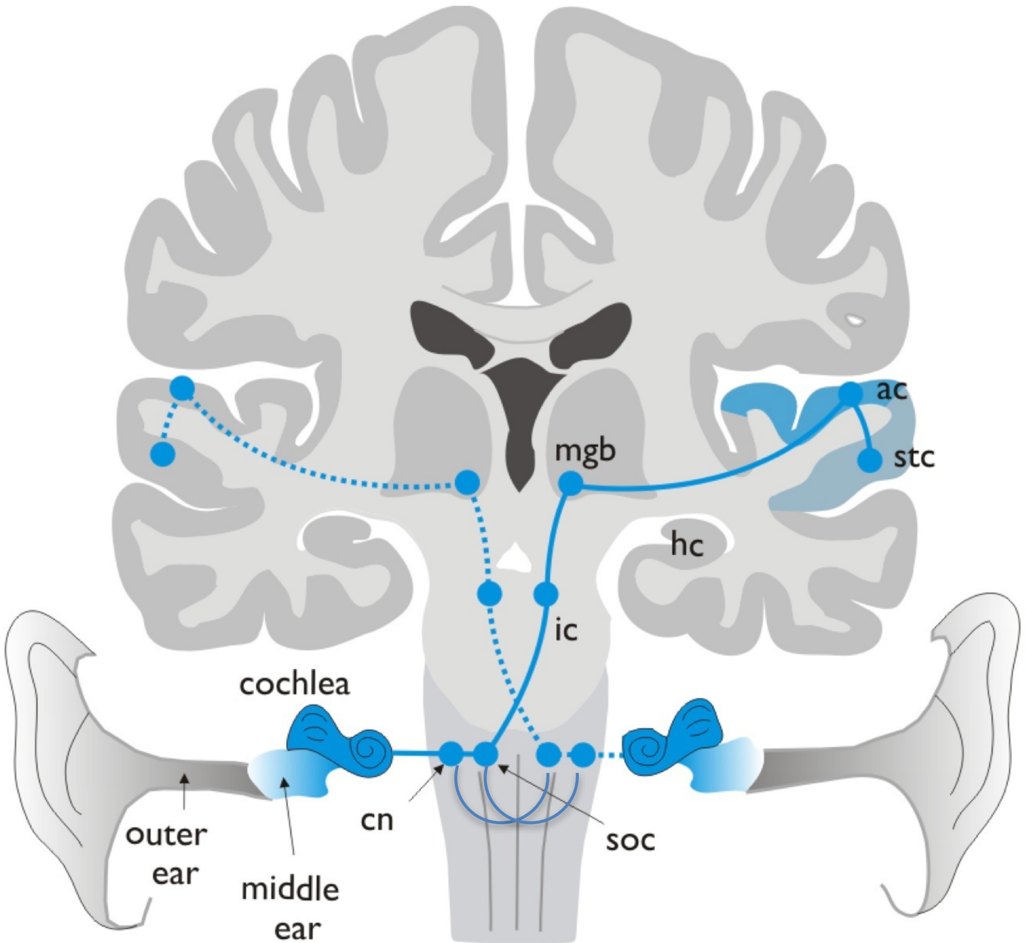
- synchronization of several adjacent neurons encodes periodicity information
- groups of auditory neurons use phase-locking to represent subharmonic frequencies of one harmonic sound



# Frequency Coding



# Auditory pathway




tonotopic organization (Ress & Chandrasekaran, 2013)

Frühholz, S., Trost, W., Grandjean, D. (2014) The role of the medial temporal limbic system in processing emotions in voice and music. Prog Neurobiol.