COGS 101A: Sensation and Perception

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Department of Cognitive Science

UCSD

Lecture 13:

Audition

Course Information

- Class web page: http://cogsci.ucsd.edu/ desa/101a/index.html
- Professor: Virginia de Sa
  - ⋆ I'm usually in Chemistry Research Building (CRB) 214 (also office in CSB 164)
  - ⋆ Office Hours: Monday 5-6pm
  - ⋆ email: desa at ucsd
  - ⋆ Research: Perception and Learning in Humans and Machines

For your Assistance

TAS:

- Jelena Jovanovic OH: Wed 2-3pm CSB 225
- Katherine DeLong OH: Thurs noon-1pm CSB 131

IAS:

- Jennifer Becker OH: Fri 10-11am CSB 114
- Lydia Wood OH: Mon 12-1pm CSB 114

Course Goals

- To appreciate the difficulty of sensory perception
- To learn about sensory perception at several levels of analysis
- To see similarities across the sensory modalities
- To become more attuned to multi-sensory interactions

Grading Information

- 25% each for 2 midterms
- 32% comprehensive final
- 3% each for 6 lab reports - due at the end of the lab
- Bonus for participating in a psych or cogsci experiment AND writing a paragraph description of the study (just a few sentences) Deadline to sign up for experiments on Experimetrix is Wednesday of Week 9 (the day before Thanksgiving)
- New lenient midterm policy: If you do better on the final than your worst midterm, we'll downweight that midterm to 10% (and upweight the final); If you do better on the final than your best midterm, we'll downweight that midterm to 15%. There will be no downweighting of the final. We will also drop your lowest lab grade IF you complete all labs

You are responsible for knowing the lecture material and the assigned readings. Read the readings before class and ask questions in class.

Academic Dishonesty

The University policy is linked off the course web page.

You will all have to sign a form

For this class:

- Labs are done in small groups but writeups must be in your own words
- There is no collaboration on midterms and final exam

Sound

The auditory system detects sound.

What is sound?

Sound

The auditory system detects sound.

What is sound? Pressure variations within a certain frequency band (the audible range)

Speakers transduce electrical signals to sound by moving the speaker diaphragm in and out. This causes pressure variations in the air. We will see how the ear transduces these pressure changes over time into an electrical signal which it sends to the brain.

The NIDCD (National Institute on deafness and other hearing disorders) has a great website on hearing including this link

sound movie from NIDCD http://www.nidcd.nih.gov/health/education/

Parameters of a sound wave

cool animation of a sound wave http://orange.math.buffalo.edu/444

animation without the compression field http://orange.math.buffalo.edu/444

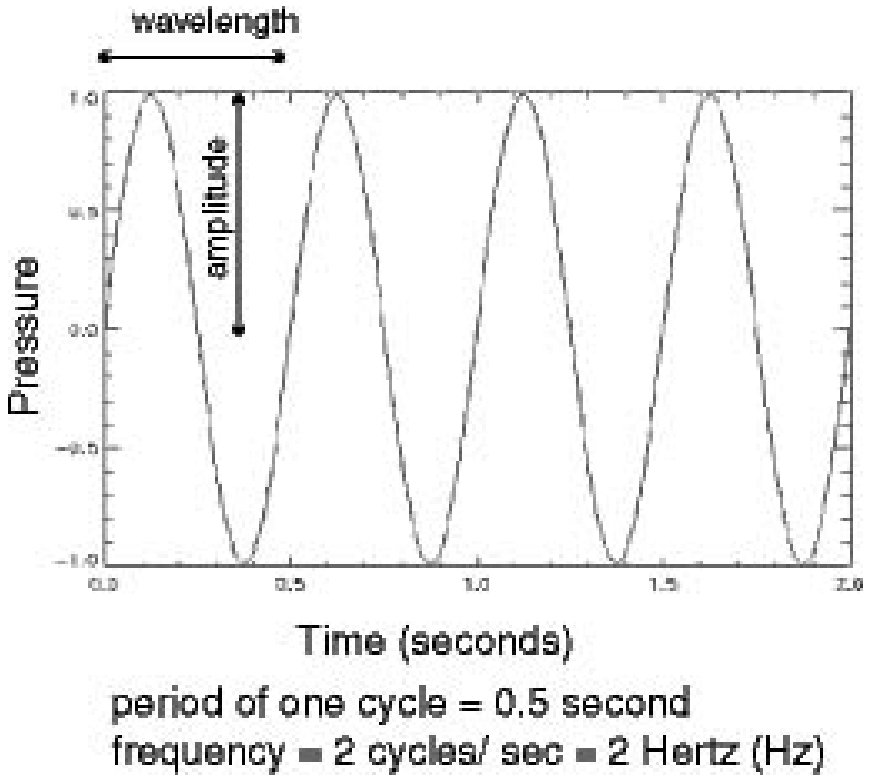
frequency measured in Hz (cycles/second)

click here to hear different frequencies

http://oceanexplorer.noaa.gov/explorations/sound01/background/acoustics/media/hz.

Parameters of a sound wave

amplitude



http://oceanexplorer.noaa.gov/explorations/sound01/background/acoustics/media/hz.html

amplitude concerns how far air molecules move and frequency concerns how fast they move

Decibels

The range of sounds that we can hear is HUGE

One way to avoid having numbers range over many orders of magnitude is to put them on a log scale. The decibel (dB) formalizes this notion for sound The decibel is named after the Canadian Alexander Graham Bell.

$$dB = 20 \log_{10} \frac{P}{P_0}$$

The notation SPL (sound pressure level) is used when $P_0 = 20$ micropascals was used

20 micropascals is about the pressure at threshold for a 1000 Hz tone in a free field (not through headphones)

$$dBSPL = 20 \log_{10} \frac{P}{20\text{microPascals}}$$

multiplying sound pressure by 10, adds 20dB

Interactive Sound ruler

The NIDCD (National Institute on deafness and other hearing disorders) has a great website on hearing including this link

interactive sound ruler link

http://www.nidcd.nih.gov/health/education/decibel/decibel.asp

Sounds can be decomposed into components with different frequency components

For example a square wave can be approximated (poorly) by a sine wave.

http://www.bores.com/courses/intro/freq/3_ft.htm

FYI when we do this, it is known as **Fourier analysis**

Auditory Response Area

Audibility curve plots threshold for hearing (in free-field) versus frequency

Humans are most sensitive between 2000 and 4000 Hz (a range important for speech) but can hear from 20 Hz to 20kHz

Area above the audibility curve is called the **auditory response area**

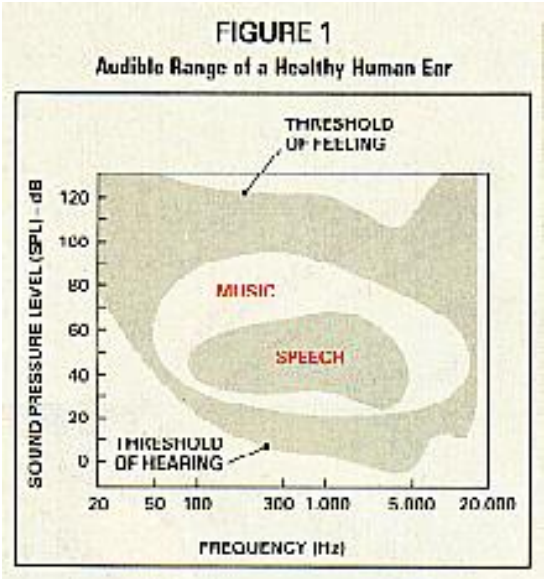
The **threshold for feeling** curve marks amplitudes that are painful (and very damaging)

Different animals have different audible ranges

Elephants can hear below 20 Hz, homing pigeons down to 0.05 Hz

Mice, dogs, dolphins can detect frequencies higher than 20kHz

Auditory Response Area



http://www.termpro.com/articles/hearing.html

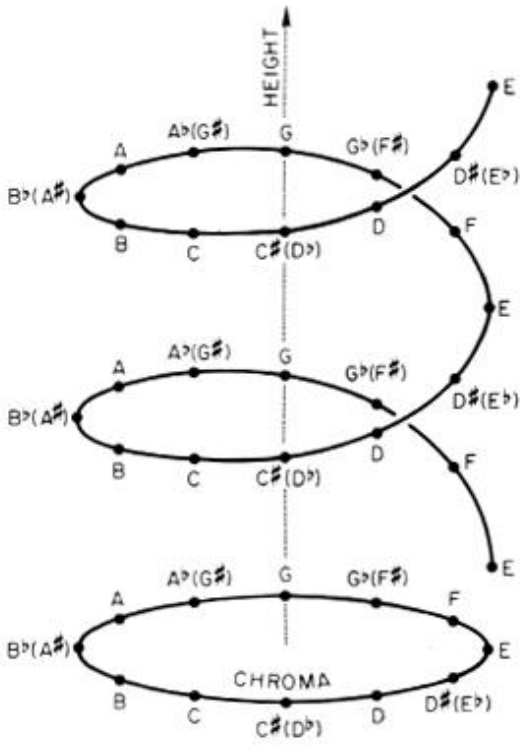
Figure 10.9 in your textbook also plots some equal loudness curves on the same Frequency(Hz) vs Sound pressure level (dB(SPL)) graph.

Amplitude is a measure of the magnitude of the physical stimulus. **Loudness** is a measure of the magnitude of sensation

Pitch is perceived frequency.

Tone chroma

tone chroma refers to the letter name we give to a tone.



[after Shepard 1982] from http://ccat.sas.upenn.edu/music/music55/sept16.html

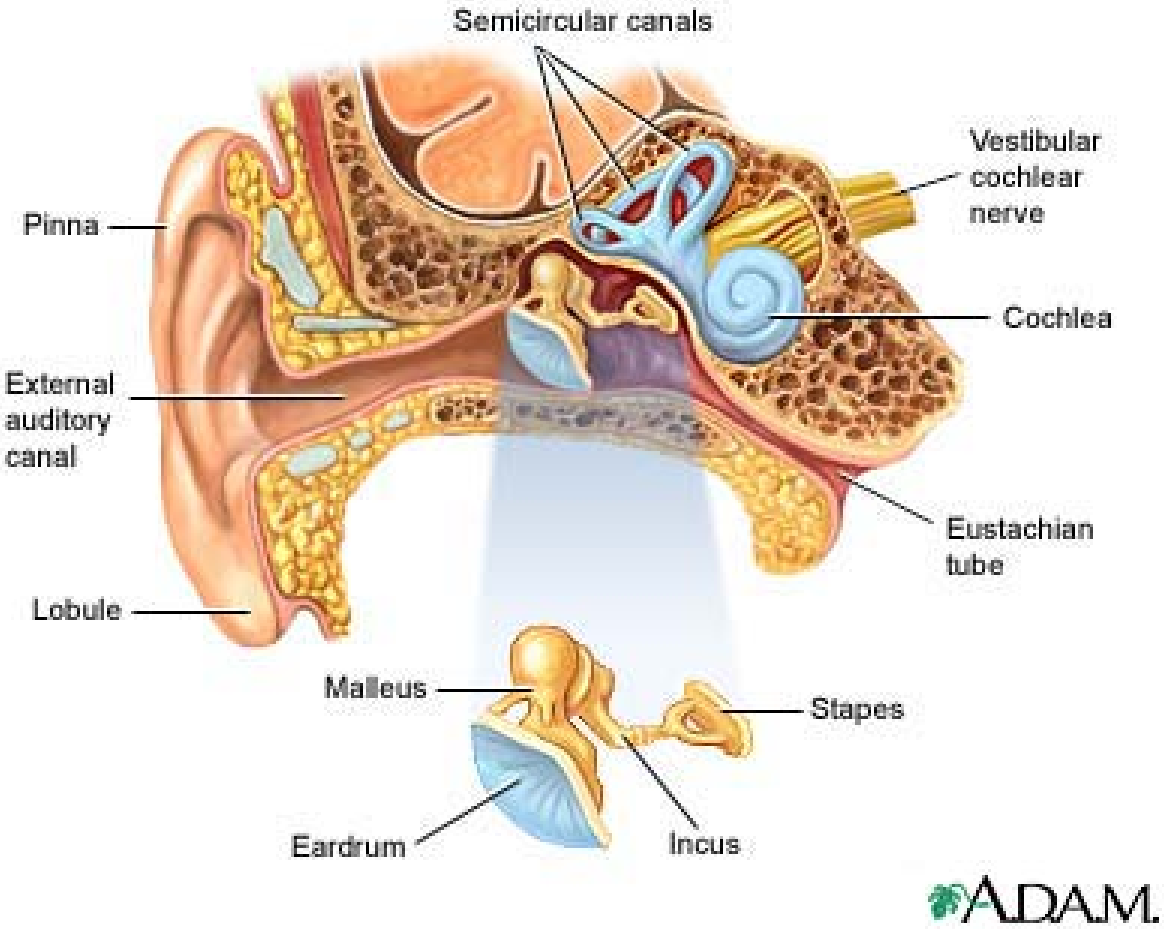
Auditory Reception

travel inside the ear video www.nidcd.nih.gov/health/education

ear on line course click on the big 3 circle great on-line course at www.ageworks.com

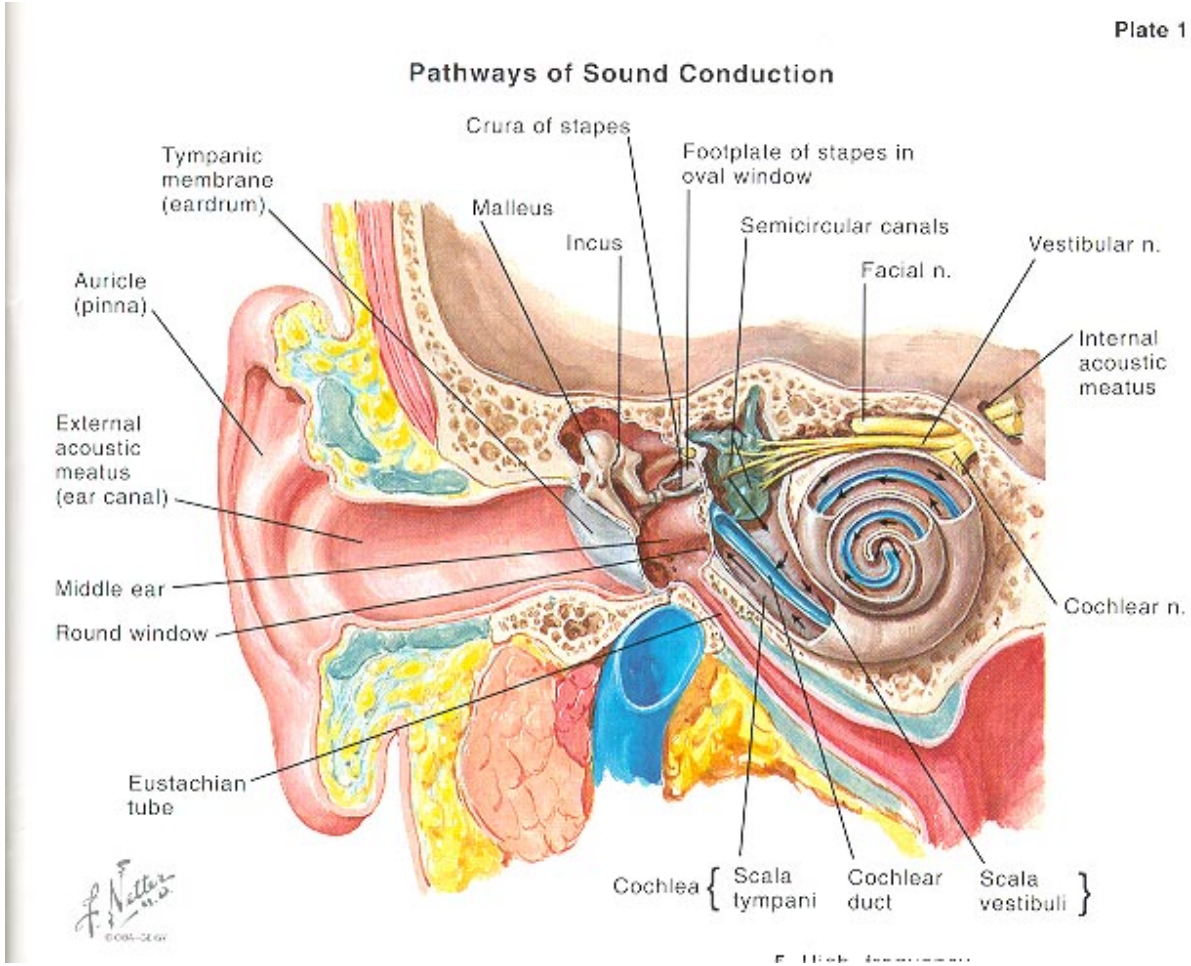
Tutis Vilis' on line course

The Ear



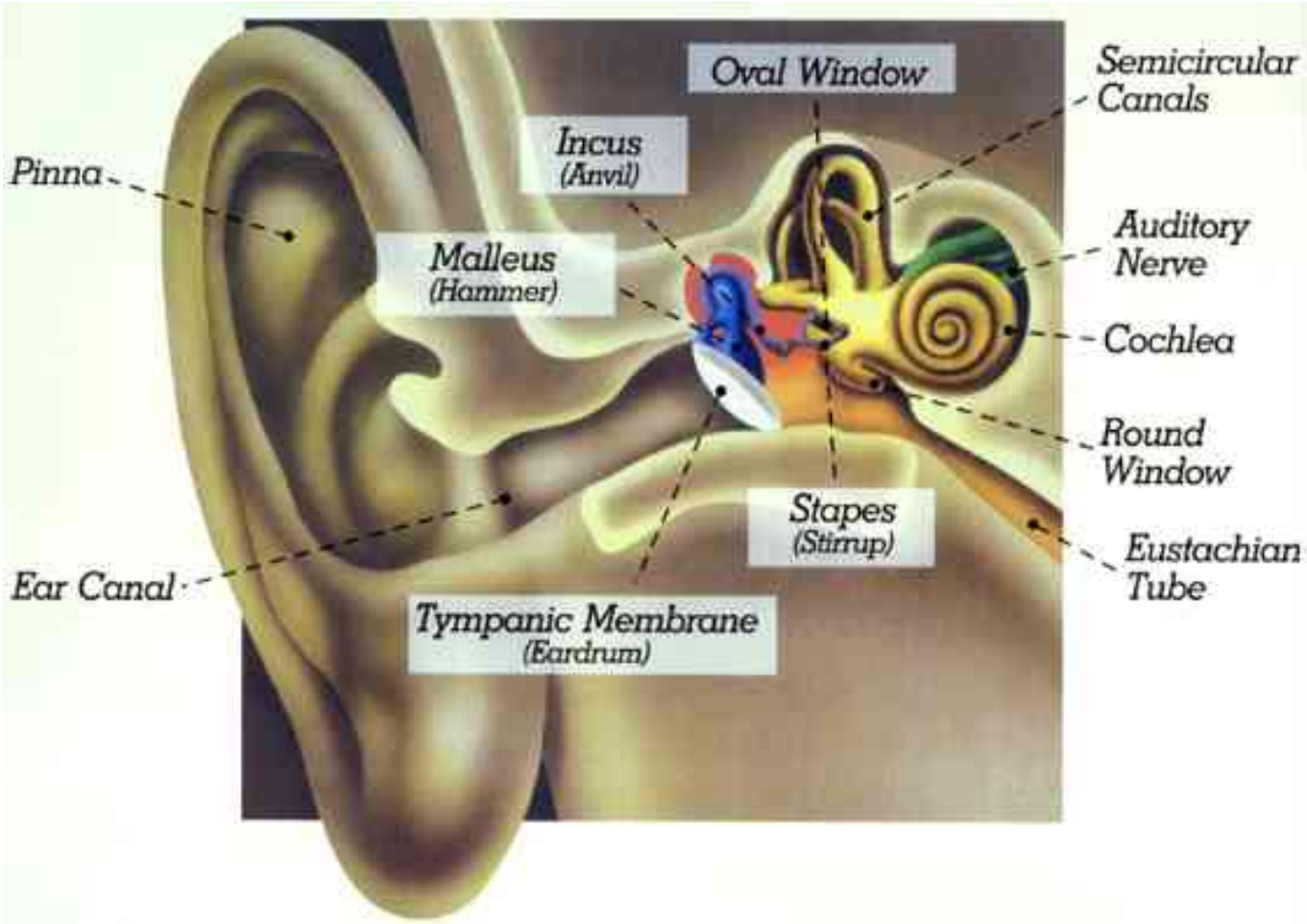
http://medicalimages.allrefer.com/large/ear-anatomy.jpg

The Ear



http://www.earsinus.com/earanatomy.JPG

The Ear



http://www.audiohearing.co.uk/Audio

Auditory Reception

Pinna - outer part of the ear. The folds help in localizing sound sources

Auditory canal conducts sound to the eardrum

Tympanic membrane (eardrum) vibrates with the sound

Malleus (hammer), Incus (anvil), Stapes (stirrup) are the 3 tiniest bones in the body and serve as a lever to amplify the pressure on the oval window. Collectively they are called the **ossicles**

Oval window membrane at base end of the cochlea

Cochlea contains the hair cells (the auditory sensory receptor cells)

Round window another membrane on the cochlea, allows vibrations at the oval window to propagate through the cochlea

middle ear muscles tiny muscles that can contract to reduce movement of the ossicles with very loud noises

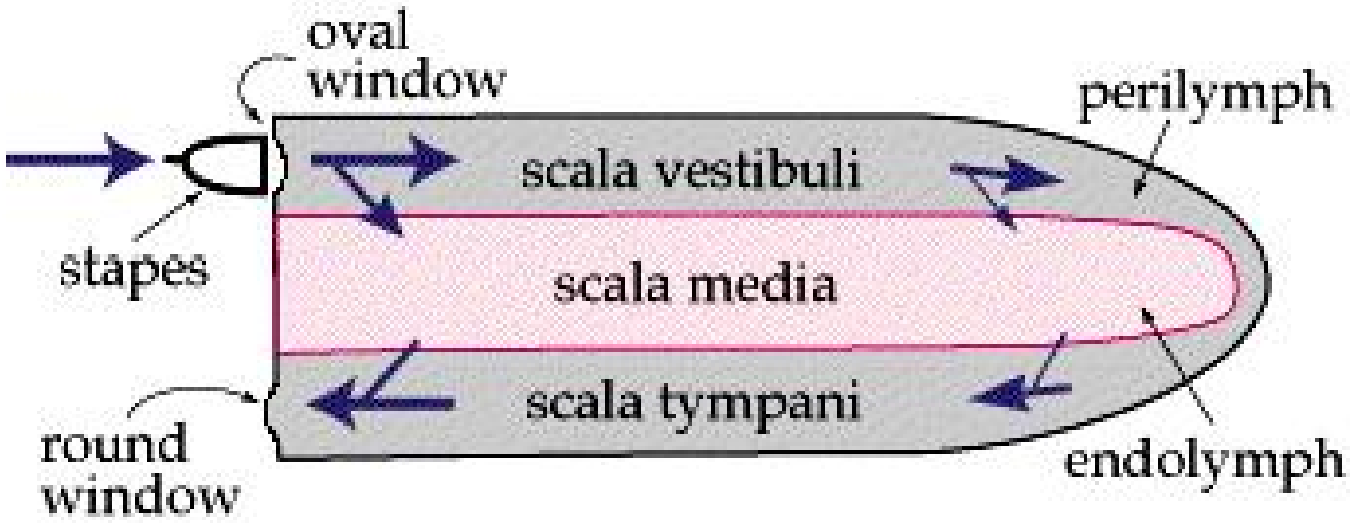
Auditory Reception

Transmitting sound from air to fluid is a very difficult process; we say there is an **impedance mismatch**. The air molecules vibrating are not strong enough to set the fluid molecules vibrating much. The malleus/incus/stapes system is important for dealing with this impedance mismatch. The tympanic membrane moves the malleus a lot, but the stapes moves less, but with more power.

The Cochlea

The cochlea is a snail shaped fluid filled structure.

Through most of its length, it is divided into 3 chambers **scala vestibuli** (top) **scala media** (middle) and **scala tympani** (bottom)



http://thalamus.wustl.edu/course/audvest.html

Pressure waves start at the oval window at base of top chamber and move to apex of cochlea then to bottom chamber and back to base of the bottom chamber (round window)

The Cochlea

The scala media (book uses the term cochlear partition) contains the **Organ of Corti** which contains the **hair cells** which transduce the vibrations.

Basilar membrane is the floor of the Organ of Corti

Tectorial membrane is the ceiling of the Organ of Corti

Hair cells lie between. **Inner hair cells** lie in the basilar membrane and don't reach the tectorial membrane. **Outer hair cells** have their hairs embedded in the tectorial membrane.

The pressure wave in the scala vestibuli and scala tympani sets up vibrations in the scala media. The basilar membrane goes up and down and the Tectorial membrane goes side to side.

great basilar membrane movie http://www.sissa.it/multidisc/cochlea/twlo.htm (Fabio Mammano)

Hair cells

The motion of the basilar membrane and tectorial membrane cause the cilia (hair like structures) on the hair cells to bend and transduce the vibrations to electrical signals.

Motion of the cilia in one direction cause depolarization of the hair cell and in the other direction cause hyperpolarization.

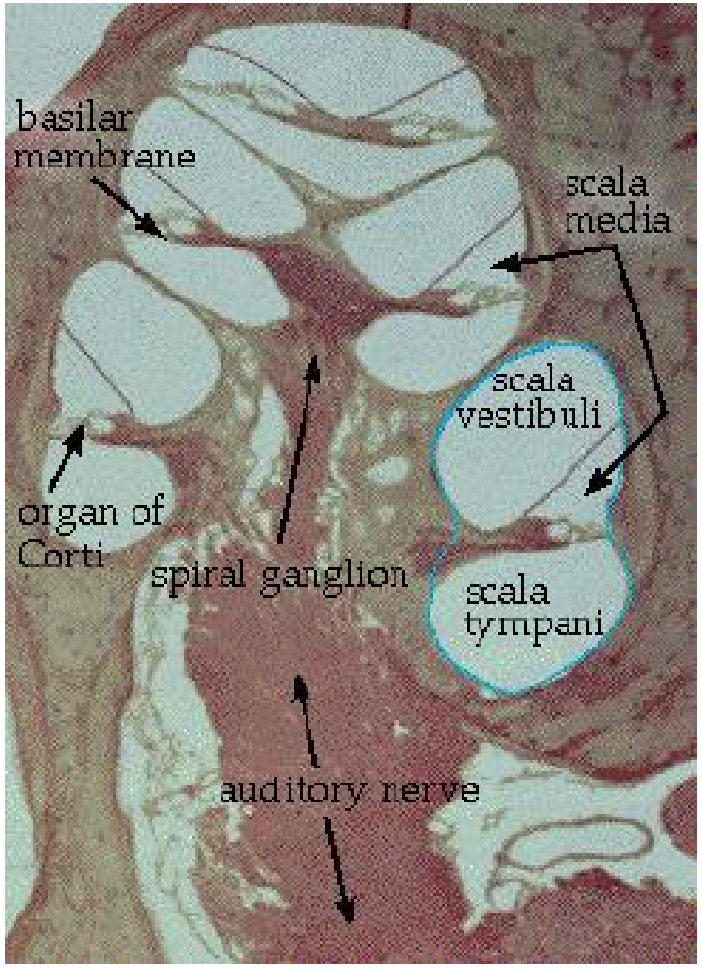
Inner hair cells are responsible for most of the sound coding

Outer hair cells serve to amplify the motion of the basilar membrane by stretching and shortening as they hyperpolarize and depolarize (respectively)

great movie of outer hair cells shortening
http://www.sissa.it/multidisc/cochlea/transduc.htm (Fabio Mammano)

real outer hair cell movie http://www.sissa.it/multidisc/cochlea/ohc.htm (Fabio Mammano)

The Cochlea



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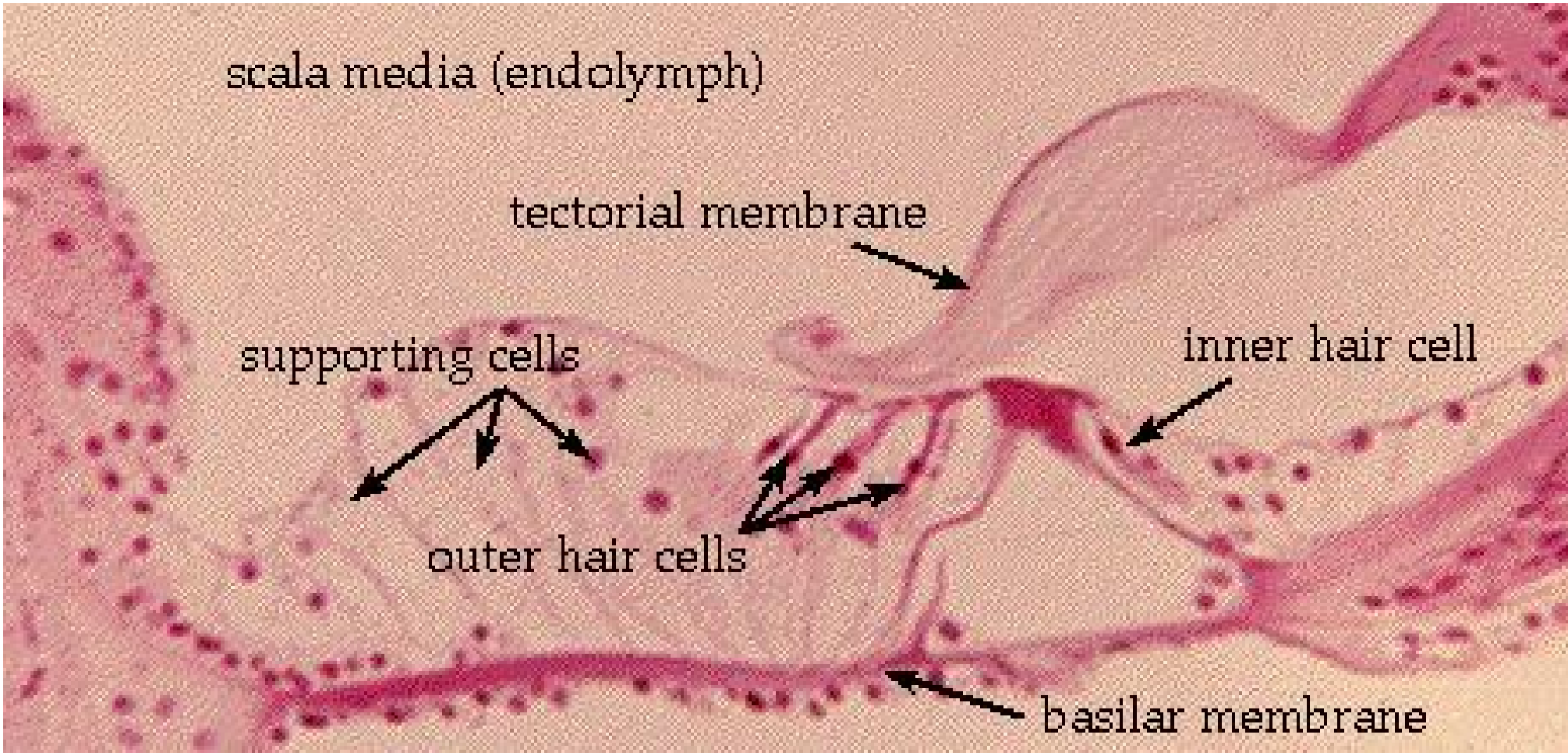
The Organ of Corti



http://thalamus.wustl.edu/course/audvest.html

Motion in the organ of Corti

great organ of Corti movie http://www.sissa.it/multidisc/cochlea/cortifm.htm (Fabio Mammano)

more good cochlea slides (including a human cochlea)

http://www.iurc.montp.inserm.fr/cric/audition/english/cochlea/fcochlea.htm

Next Class

Audition continued