Psych 1XX3 – Music Perception Notes – Mar 18, 2010

Introduction:

- When you hear music, you perceive it as an organized whole. This organized whole can form an acoustic pattern that is so salient that you can hum the tune after hearing it only once.
- The acoustic pattern is easily recognizable, even if it's played in a different key or with different instruments.
- This suggests that what's important to the perception of this pattern is the relation between the notes, and not the individual notes themselves.

Auditory Scene Analysis:
Gestalt Principles and Auditory Analysis:

- How are we able to organize our auditory world so easily? The same Gestalt principles used to organize a visual scene also apply to organizing an auditory scene.

Figure Ground Principle:

- For example, incoming stream of sounds are separated into figure and ground.
- We can consider the "**ground**" (or background) to be whatever sounds you're not focusing on, such as the random sounds of the subway station itself and the "**figure**" as the sound of a particular arriving train, or a specific voice on the subway platform that you are paying attention to.
- Keep in mind, however, that the sounds that make up the figure and ground are not permanent, and will change as you focus your attention.

Proximity:

- The principle of **proximity** organizes sounds that occur close together in time or space.
- If you played a series of high (A) and low (B) tones both spaced apart in time you would perceive two separate tones.
- However if you played the tones closer together in time, you would hear a single tone.

Similarity:

- The principle of **similarity** allows you to group together auditory input that is similar, such as sounds that are of a similar frequency or timbre.
- This would allow you to pick out and group a series of sounds as all belonging to one particular voice among many voices.

Continuity:

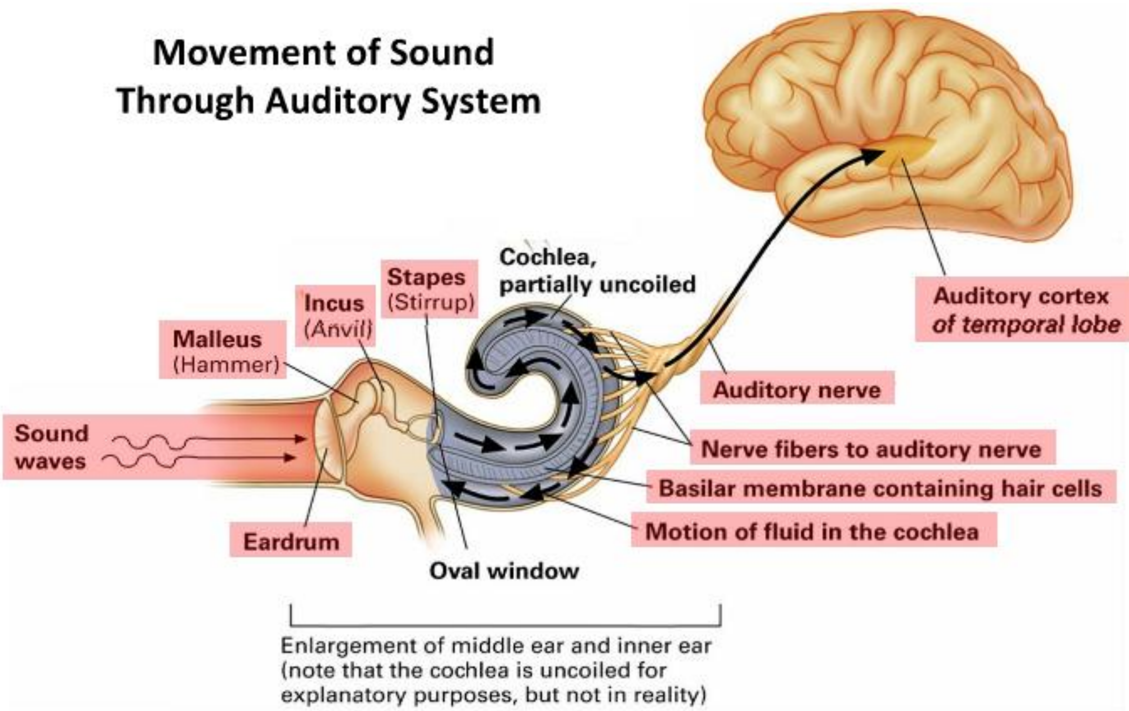
- **Continuity** is the principle that you would use to follow along with one song, even if you simultaneously heard another song playing with the same instruments.

Closure

- **Closure** is the principle that would allow you to understand a conversation, even if every other sound was muffled or missing.

Pitch Perception:

- Recall from our coverage of audition that frequency is measured in Hz, and that the lowest frequency we can hear is 20 Hz, and the highest is about 20000 Hz.
- Also, recall that sound waves enter the ear canal, vibrating the eardrum, further amplified by the ossicles, which cause a wave in the fluid in the cochlea.
- This movement of the fluid causes the hair cells along the basilar membrane to move, sending a signal that is sent down the auditory nerve to key regions in the brain. (See image below.)



- There are two theories required to explain pitch perception along the entire frequency range that we can hear.

Frequency Theory:

- **Frequency theory** is so named because it was thought that the entire basilar membrane vibrates at the frequency of the incoming sound wave.
- This causes impulses of the corresponding frequency to travel up the auditory nerve, effectively allowing the brain to decipher frequency by counting the number of neural impulses.

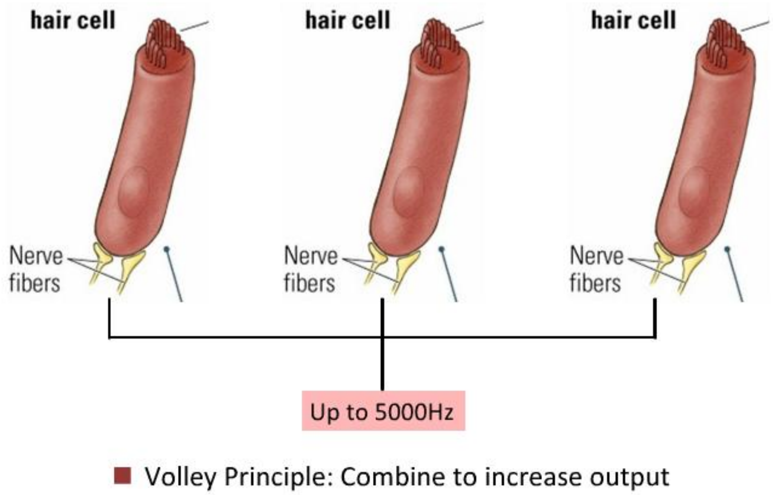
Problems

- In accordance with the predictions of the frequency theory, physiological evidence indicates that the hair cells on the basilar membrane do indeed vibrate together.
- The frequency theory made perfect sense, until it was learned that axons are incapable of firing more than 1000 impulses per second.
- This would work fine if all of the sounds that were important to our reproduction and survival were less than 1000 Hz. However we learned that humans can hear sounds with frequencies as high as 20000 Hz.

Volley Principle:

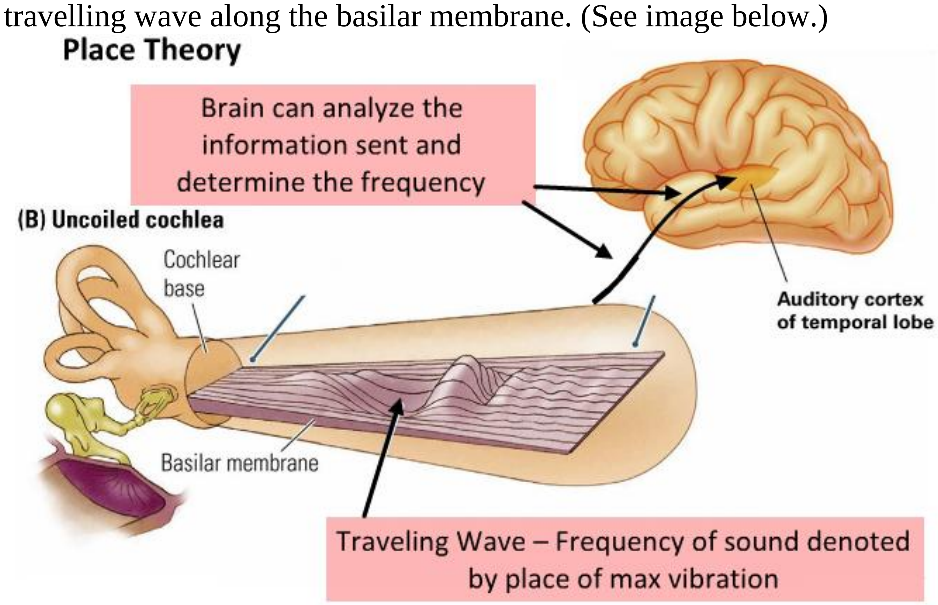
- Although a single axon cannot fire more than 1000 impulses per second, groups of auditory nerve fibres can fire a series of impulses that as a team, can signal to the brain the frequency of sound waves up to 5000 Hz.

- This is called the **volley principle**, and it extended the audible frequency range for the frequency theory up to 5000 Hz. BUT, it's still not enough to cover our entire frequency range that reaches 20,000 Hz.
- So the frequency theory of pitch perception cannot explain how we perceive pitches between 5000 and 20,000 Hz. (See image below.)



Place Theory:

- Although the hair cells along the basilar membrane move together as the frequency theory predicts, they in fact move as a traveling wave that forms a peak at a particular place along the basilar membrane.
- And so, the **place theory** of pitch perception states that the brain can decipher the frequency of the sound wave by being tuned to the specific place of the peak of its travelling wave along the basilar membrane. (See image below.)



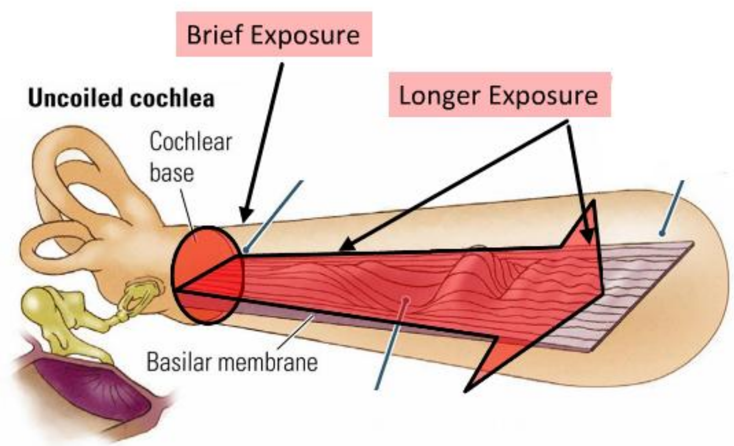
- Each inner hair cell has roughly 20 direct links with the brain, which would allow the region of each inner hair cell on the basilar membrane to be represented very specifically in the auditory cortex.
- When a sound causes a wave in the basilar membrane, high frequency sounds maximally displace the hair cells closest to the oval window, where sound initially enters the cochlea.
- On the other hand, low frequency sounds produce a wave with that peaks at the opposite end of the cochlea.

Tonotopic Representation of Pitch in A1:

- This results in a **tonotopic representation of pitch**, and this organization is maintained all the way to the **primary auditory cortex**, with neighbouring regions of the cortex responding maximally to neighbouring frequencies.

Hair Cells Respond Maximally to One Frequency:

- Although each hair cell is maximally responsive to a specific frequency, it will still respond to a range of frequencies.
- Direct evidence for tonotopic coding of pitch, and support for the place theory, comes from animal studies which have used drugs that can damage the hair cells.
- In one experiment, Stebbins and colleagues administered the drug and then tested the monkeys' ability to perceive different frequencies of sound.
- When the cochleae was later observed, they found that even brief exposure to the drug damaged hair cells near the entrance to the cochlea at the oval window; with longer exposure to the drug, damage to the hair cells extended toward the other end of the basilar membrane. (See image below.)



- The behavioural tests showed that monkeys with damage to the hair cells near the oval window were unable to perceive high frequency sounds; more damage along the basilar membrane translated into a growing inability to hear progressively lower frequency sounds.
- Taken together these results demonstrate that different frequencies are represented at specific places along the basilar membrane, with high frequencies at the entrance of the cochlea and lower frequencies at the opposite end of the cochlea.

Problems w/ Place Theory:

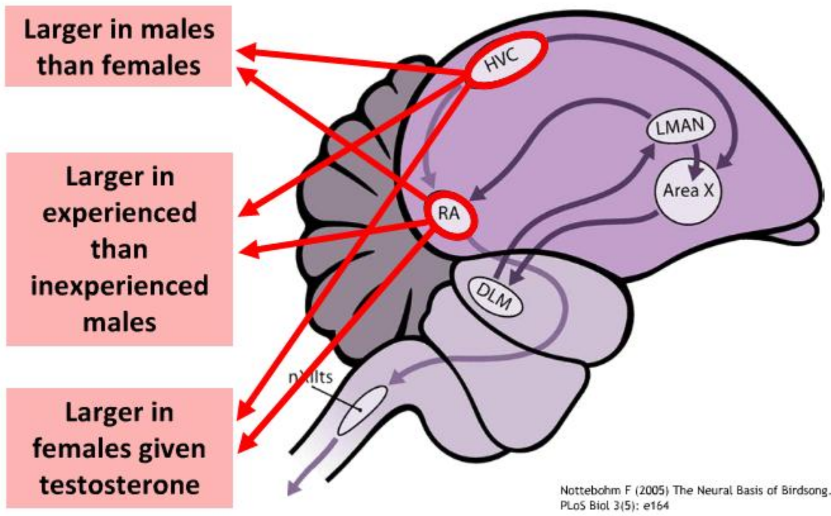
- These trends are generally true, but a problem with the place theory is that as the frequency of the sound gets lower the location of the peak of the wave along the basilar membrane gets more and more variable.
- For very low frequencies under 50 Hz, the peak actually disappears completely.
- So the Place Theory alone also cannot account for the full audible range of hearing; it turns out that both the frequency and place theories are needed to explain the full range of hearing.
- Frequency theory is useful to explain how we hear low frequencies that are below 1000 Hz and place theory explains how we perceive high frequencies above 5000 Hz.
- Both mechanisms are theoretically used for frequencies between 1000 to 5000 Hz which is coincidentally the range of frequencies that we discriminate most effectively.

Bird Song:

- Def'n of Bird Song: the music-like vocalizations that are made primarily by the male of a species during the breeding season in order to attract a female or defend his territory from other males.

High Vocal Centre and Robust Nucleus:

- Songbirds have evolved two key brain regions to deal with the complexities of producing song: the **high vocal center (HVC)** and the **robust nucleus of the archistriatum (RC).**
- As males are the primary producers of song, it's not surprising that both of these brain regions are larger in males than females.
- The sex differences are controlled in part by hormones; a female is given testosterone will show an increase in the size of these brain regions and she will begin to sing like a male.
- These key brain regions are further modified by experience; males that are particularly skilled at song have enlarged HVC and RA brain regions.



Bird Song Requires Gene-Environment Interaction:

- Bird song is an excellent example of collaboration between inherited and learned components during development to produce a **species-typical behaviour**.
- Birds may inherit a genetic predisposition to sing, but they must learn and practise to produce correct songs.

Evidence for Learning:

- The point is made in a study by Marler and Tamura, who analyzed the songs of white-crowned sparrows that lived in three different local regions.
- Their findings confirmed that songs were at least partially learned, because the same species birds living in these different regions had different dialects!
- Although their songs were similar, and these birds would certainly understand each other; but they had different accents, so to speak, and would be recognized as strangers.

Birds Learn the Songs of Their Own Species:

- Learning must be only a part of the equation, because in the wild, a young bird is exposed to many different sounds and types of bird song and yet, it comes to produce the characteristic song of its own species.
- Marler and Peters conducted a simple experiment to make the point: they took two closely related species of sparrow, the swamp Sparrow and the song sparrow, and raised them in isolation while exposed to tape recorded birdsongs from both species.
- Each species learned to produce the song of its own species, even though each group was equally exposed to the auditory input from both species.
- This suggests that there is some genetic hardwiring that guides learning toward the birds' own species-specific songs.

Baby Birds only get Exposure to Song in the Summer:

- Birds usually hatch in the spring or early summer and are only exposed to the specific bird song from the father until the end of summer.
- The young bird then gets no more exposure to the song, and has to remember it for nearly a year, when they must reproduce the song in the following spring with exquisite accuracy.
- The ability to retain something as complex as a song for such a duration suggests a rather special form of learning.

Development of Bird Song:

- Birds start out by producing subsong, which consists of vocalizations that do not sound like the final adult song at all.
- It’s “baby talk” for birds, just like human babies make a lot of babbling sounds that are not yet part of the language of words.
- Gradually, the bird enters a period of plastic song, when the song is now recognizable as belonging to its own species, however, it may still not have all of the elements of the adult song and the song itself is still changing.
- Shortly after plastic song, the bird enters the final stage of crystallized song, when the song is perfect and the bird makes no further changes to the song for the rest of its life.

Template Mode of Song Learning:

- According to the **template model**, songbirds inherit a rough template for their species-specific song.
- At some point after hatching, they have a sensitive period for learning their own song from the sounds around them, which refines their template in memory.
- Before their song crystallizes, they practice their song, trying to match the sounds they produce to their refined template.
- Here, they may use auditory feedback or social cues from others.

Infant Music Perception:

- Are we born with the ability to perceive a composition as music, rather than a bunch of random, individual notes, or is this a learned process as we experience more music.

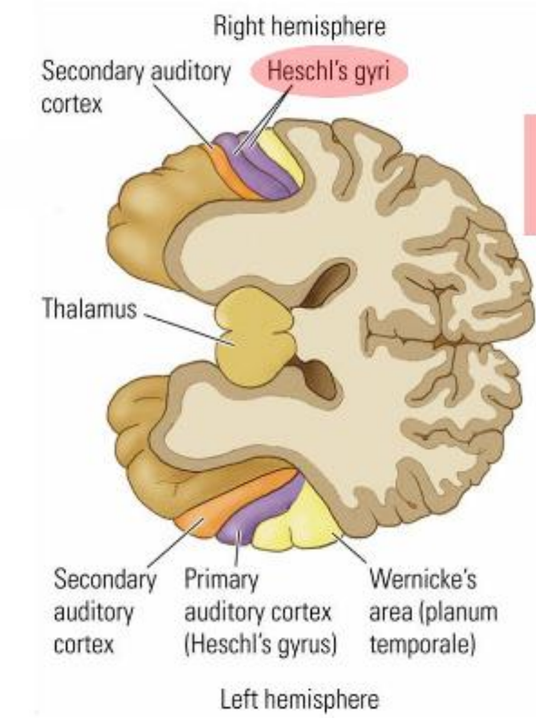
Infant Musical Abilities:

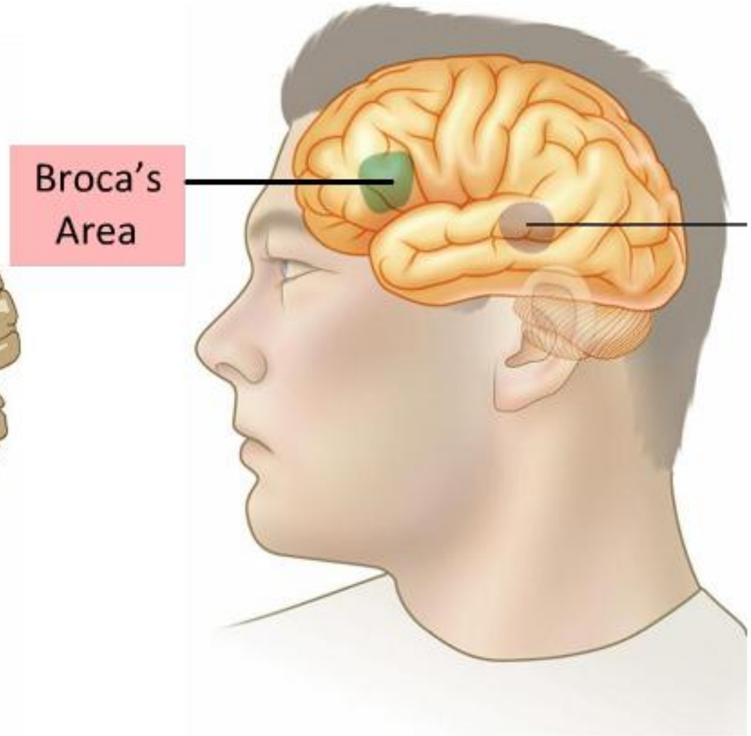
- There is a lot of evidence that infants are quite capable of perceiving many of the intricate details of music. For example, **2-3 month old infants notice changes in tempo**, (the rate at which the music is played) and they also recognize **changes in the timing between successive notes**.
- By **7 months, infants can recognize a specific Mozart sonata among other pieces of music and remember it over a two-week period**.
- They can also identify when a musical passage has been tampered with to create a less pleasing (and less musical) sound.

- Where does this interaction between movement and music come from?
- It is 6 beats long ambiguous rhythm pattern with no accented beats. People interpret this rhythm in one of two main ways.
- One way is as a “march” with accents every second beat or as a “waltz" with accents every 3rd beat
- Hypothesis: If movement affects what we perceive, then if we bounce some infants on every second beat but bounce other infants on every third beat while they listen to this ambiguous rhythm pattern, maybe this movement will influence whether they perceive it as a march or as a waltz.
- We found that they preferred to listen to the rhythm pattern that matched how they were bounced
- Through this experiment, we have shown that even in young infants, there are multi-sensory contributions to the perception of music. → *The way we move affects what we hear.*
- Infants can respond to various features of music, but at the same time, the area in the brain that processes music remains plastic for much longer

Musical Training and the Brain:

- Recently, there has been a lot of focus on the cognitive benefits of listening to music.
- Studies have found that musical training is related to measureable changes in the brain. For example, various studies have reported that in the brains of musically trained students more auditory cortex is devoted to processing musical scales and more somatosensory cortex is devoted to processing input instruments.
- Some studies have also reported a larger **planum temporale** (which is important for processing complex sounds), a larger **Broca's area** (which is involved in language processing), and a larger **Heschl’s gyrus** (which contains the primary auditory cortex).





Evidence for the Musical Brain:

- In one study, violinists, pianists and control subjects with no formal musical training were presented with different test tones from a violin, piano, or pure tones.
- Indeed, the brains of musicians responded very differently to the test tones compared to those of non-musicians reflecting plastic changes made over years of formal training.
- However, in an interesting twist, the responses of the non-musicians could be made more similar to the performance of musicians if they were given some pitch discrimination training before the experiment began.
- This suggests that **the adult brain retains plasticity** and is capable of change in a way that is related to the amount of musical training.

Pantev et. Al (2001):

- Another study by Pantev and colleagues in 2001, found that the cortical representations of musicians are especially tuned to the sound of their specific instrument.
- These findings provide strong evidence that brain differences found between musicians and non-musicians are more likely due to their different experiences with music, rather than a specific genetic predisposition to music.

Existing Connections Likely Grow Stronger

- What is happening with the brain's physiology to account for this rapid change in cortical representation?
- It's not likely to be the growth of new synapses and connections in such a short period of time, so it's more likely that existing connections become better at transmitting information.
- What all of these studies show us is that the adult brain retains some plasticity, with changes showing up after even a few hours.
- Music perception is an excellent example of the plasticity of the human brain; skills gained from musical training are reflected by neural changes.