

Frequency Encoding in the Cochlea

Relationship Between Frequency and Pitch

Place Theory

Just Noticeable Difference

Temporal Theory/Phase Locking

Volley Theory



The relationship between frequency and pitch is somewhat S-shaped rather than linear. The frequency range of 16,000 Hz is compressed into a pitch range of only 3300 Mels.

There are three theories that explain frequency coding in the cochlea, (1) place, (2) temporal and (3) Volley. The place theory explains how the travelling wave and tonotopic organization of the basilar membrane contribute to frequency encoding. The basilar membrane is tonotopically organized such that specific frequencies are decoded at certain locations along the cochlea, with the high frequency regions being at the apex and the low frequency regions in the base of the cochlea. Some issues with the place theory are that it does not explain just noticeable difference for pure tone frequencies, and it breaks down at around 5000 Hz, leaving no explanation on the ability to perceive fundamental frequencies. The just noticeable difference (JND) refers to the smallest detectable difference between stimuli which can be measured for intensity and frequency. The place theory also does not explain the variation of with level intensity.

The temporal theory says that pitch is related to the time of the pattern of the neural spiked evoked response. Nerve cells tend to occur at a particular phase of the waveform on the basilar membrane. This process is called phase locking and it can follow stimuli up to 3000 Hz in a one to one fashion. The problem with the temporal theory is that nerve fibers only fire at a rate less than 1000 to 3000 Hz and then need a period of time to recover.

The Volley theory describes the synchronous nature of neural discharge to a certain phase of the signal. Never fibers that are all phase locked to the same stimuli, fire in response to each cycle of the sound, even though they cannot perform this individually, however they allow for a refractory period for the fibers to recover. The Volley theory is an expansion to the temporal theory because the temporal theory could not explain frequency analysis a higher than 5000Hz frequency. For example, if the maximum fiber firing rate is 1000 Hz and you have an input of a 3000 Hz sound, three fibers would give a 1000 Hz response and the recruitment of those fibers would produce the response of 3000 Hz.