Intensity Encoding in the Cochlea

- Measuring Loudness
- Perception of Loudness
- Binaural Summation
- Loudness Growth

The human auditory system is able to process signals over a large range of signal intensities greater than 100dB. Loudness is the perceptual correlate to intensity and is related to the summation of neural activity across different frequency channels. The relationship between intensity and loudness is not a 1:1 as loudness is affected by spectral and temporal aspects.

The perception of loudness is dependent on the (1) level, (2) frequency, (3) duration and (4) bandwidth of the sound. At low levels below 40dB the loudness changes more rapidly. In normal hearing individual's loudness is most sensitive in the mid-frequency region so more intensity is needed for low frequency sounds to be heard, this can be seen on the equal loudness contour curves. The duration of sound plays a role in how intensity is encoded, for a stimuli duration up to 80ms, a constant energy leads to a constant loudness and loudness increases with duration up to 200ms and then is constant past 200ms. If a sound is within the bandwidth, there is an equal loudness but if the sound is beyond the bandwidth, loudness increases as the difference in frequency increases, but this is dependent on the center frequency of the bandwidth

Binaural summation gives a boost of 3dB compared to monaural perception of loudness. We perceive intensity from a combination of different auditory nerves firing at characteristic frequency and away from it. The combination of these may be sufficient to encode audible dynamic range in mean firing rate but this could lessen frequency resolution.

For individuals with hearing loss, vowels are easier to detect in speech compared to consonants due to the vowels having a longer duration. This is due to the fact that more energy is needed for short sounds (consonants) to sound as loud as longer sounds (vowels).

Retrocochlear pathologies such as acoustic neuromas can lead to a slow growth in loudness because of the decreased activity in the affected structures. This is different from a cochlear hearing loss which tends to lead to an over-recruitment which is an abnormal rapid growth of loudness with stimulus intensity (loudness growth), leading to a small dynamic range.