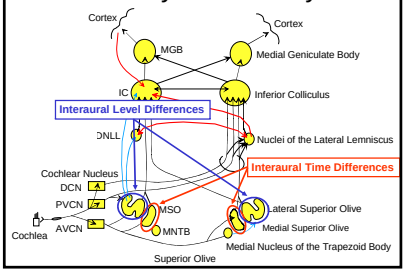
Processing in The Superior Olivary Complex

Alan R. Palmer

Medical Research Council Institute of Hearing Research
University Park
Nottingham NG7 2RD, UK

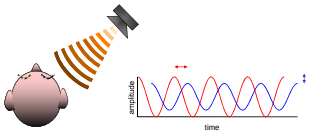
The Auditory Nervous System



Advantages of Two Ears

- *Improved detection / increased loudness*
- *Removing interference from echoes*
- *Improved detection of sounds in interfering backgrounds*
- *Spatial localization*
- *Detection of auditory motion*

Binaural cues for Localising Sounds in Space



Interaural *Time* Differences (ITDs)
Interaural *Level* Differences (ILDs)

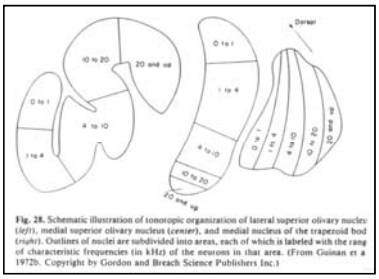
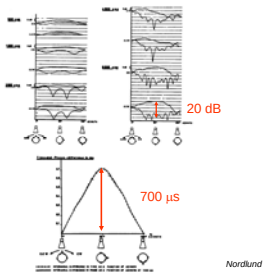


Fig. 28. Schematic illustration of tonotopic organization of lateral superior olivary nucleus (*left*), medial superior olivary nucleus (*center*), and medial nucleus of the trapezoid bod (*right*). Outlines of nuclei are subdivided into areas, each of which is labeled with the rang of characteristic frequencies (in kHz) of the neurons in that area. (From Guinan et a 1972b. Copyright by Gordon and Breach Science Publishers Inc.)



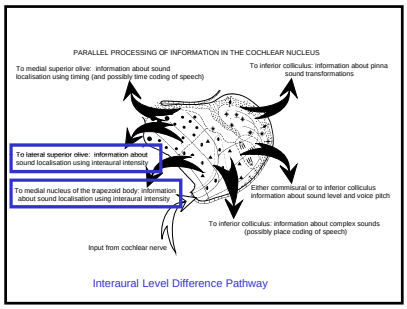
Binaural Mechanisms of Sound Localization

- Interaural time (or phase) difference at low frequency are initially analysed in the MSO by coincidence detectors connected by a delay line system.
- Interaural level differences at high frequency are initially analysed in the LSO by input that is inhibitory from one ear and excitatory from the other.

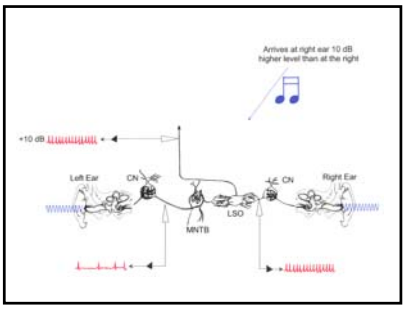
Binaural Hearing

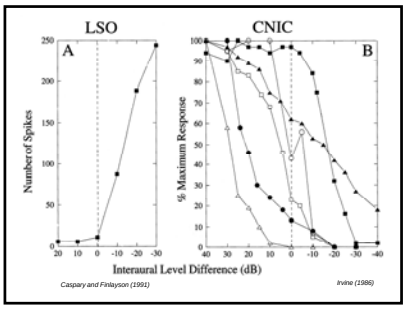
The ability to extract specific forms of auditory information using two ears, that would not be possible using one ear only.

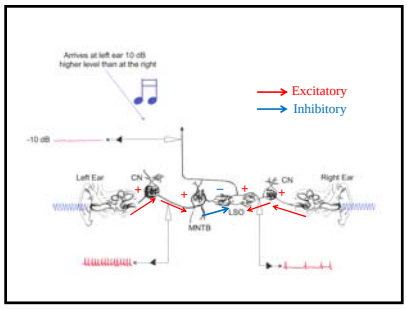
Interaural level differences (high frequency)

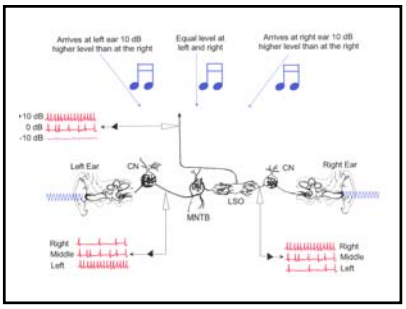


Interaural Level Difference Pathway

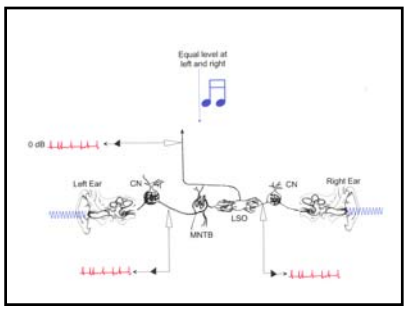


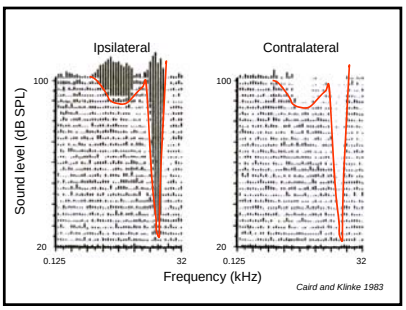




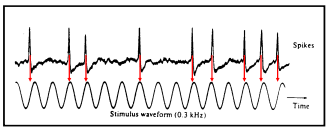


Interaural time differences (low frequency)

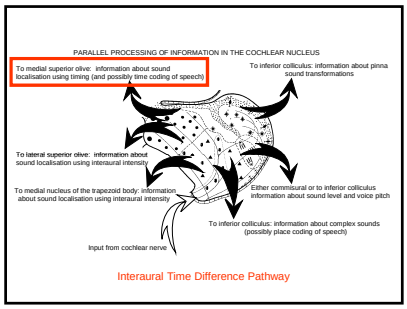


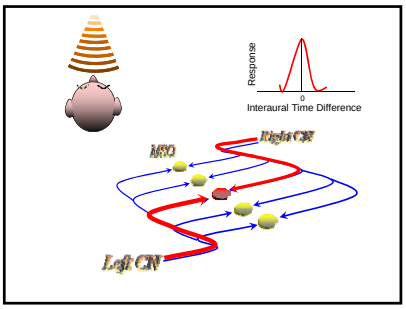


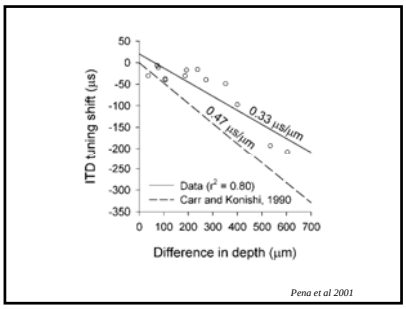
The discharges of cochlear nerve fibres to low-frequency sounds are not random; they occur at particular times (*phase locking*).

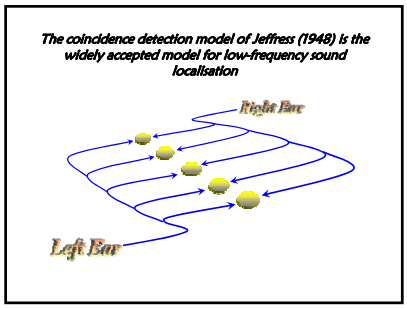


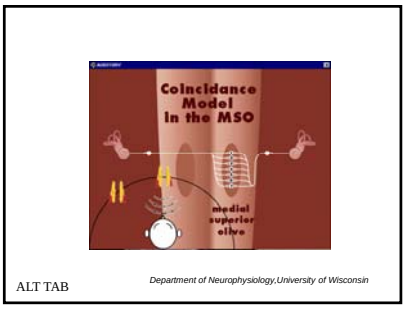
Evans (1975)

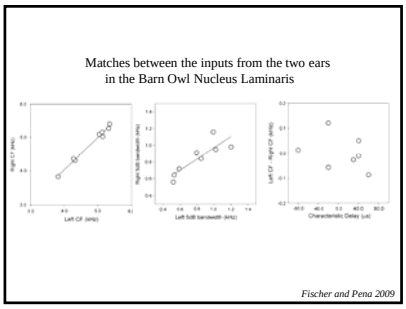

PARALLEL PROCESSING OF INFORMATION IN THE COCHLEAR NUCLEUS
To medial superior olive: information about sound localisation using timing (and possibly time coding of speech)
To inferior colliculus: information about pinna sound transformations
To lateral superior olive: information about sound localisation using interaural intensity
To medial nucleus of the trapezoid body: information about sound localisation using interaural intensity
Either commissural or to inferior colliculus information about sound level and voice pitch
To inferior colliculus: information about complex sounds (possibly place coding of speech)
Input from cochlear nerve
Interaural Time Difference Pathway

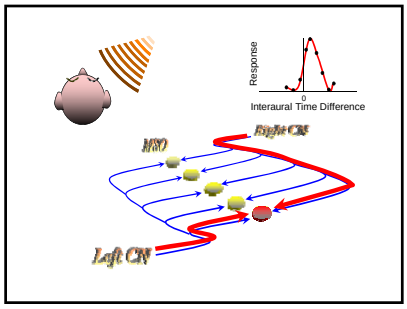

Response
0
Interaural Time Difference
MSO
Right CN
Left CN

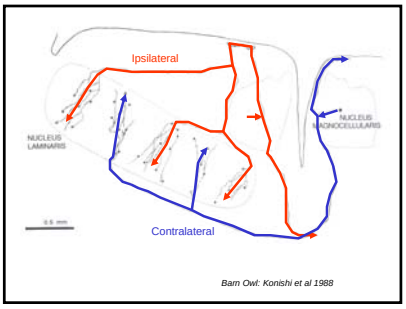

ITD tuning shift (µs)
50
0
-50
-100
-150
-200
-250
-300
-350
0.33 µs/µm
0.47 µs/µm
Data (r^2 = 0.80)
Carr and Konishi, 1990
0 100 200 300 400 500 600 700
Difference in depth (µm)
Pena et al 2001

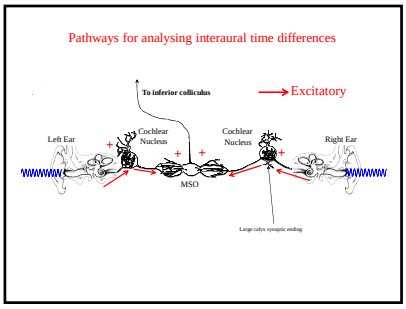

The coincidence detection model of Jeffress (1948) is the widely accepted model for low-frequency sound localisation
Right Ear
Left Ear

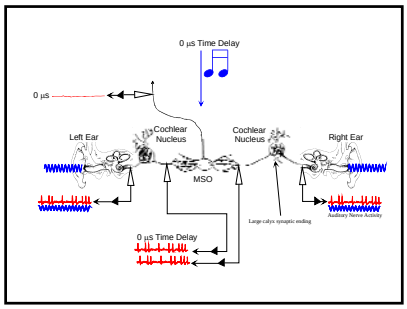

Coincidence Model in the MSO
medial superior olive
ALT TAB
Department of Neurophysiology,University of Wisconsin

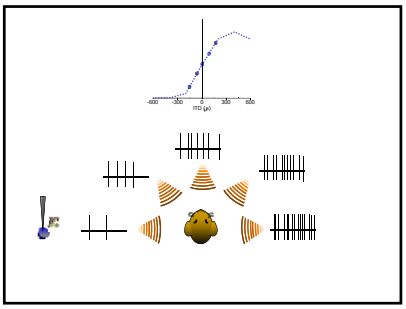

Matches between the inputs from the two ears in the Barn Owl Nucleus Laminaris
Fischer and Pena 2009

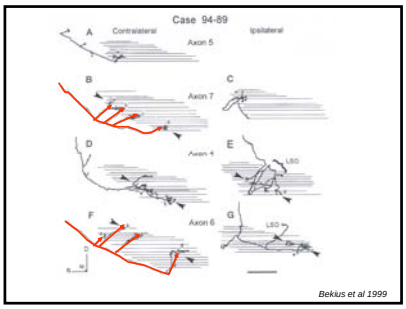

Response
0
Interaural Time Difference
MSO
Right CN
Left CN

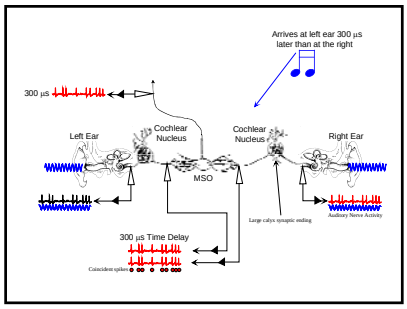

Ipsilateral
NUCLEUS LAMINARIS
NUCLEUS MAGNOCELLULARIS
Contralateral
Barn Owl: Konishi et al 1988

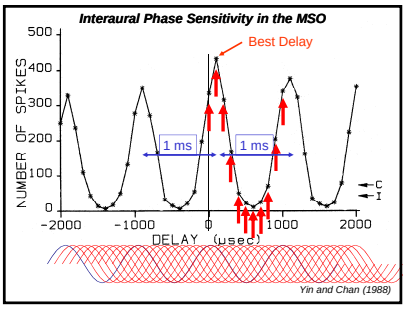

Pathways for analysing interaural time differences
To inferior colliculus
Excitatory
Left Ear
Cochlear Nucleus
Cochlear Nucleus
Right Ear
MSO
Large calyx synaptic ending

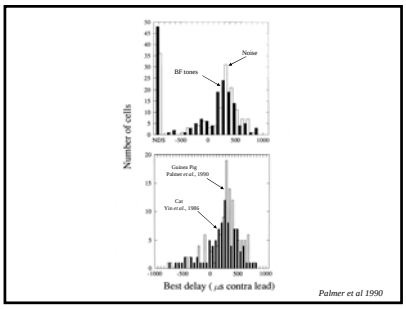

0 μs Time Delay
0 μs
Left Ear
Cochlear Nucleus
Cochlear Nucleus
Right Ear
MSO
Large calyx synaptic ending
Auditory Nerve Activity
0 μs Time Delay

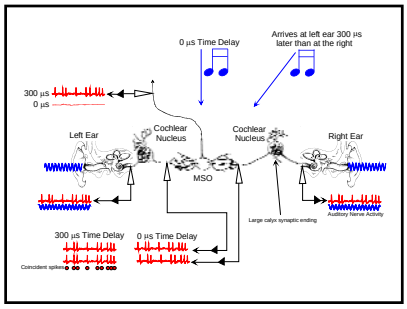

ITD (μs)

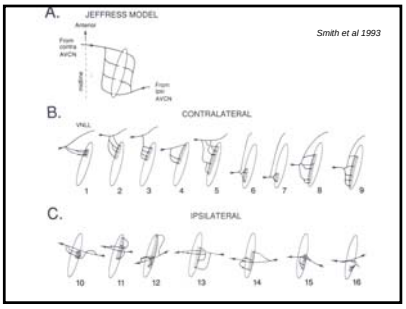

Case 94-89
Contralateral
Ipsilateral
Axon 5
Axon 7
Axon 4
Axon 6
LSO
Bekius et al 1999

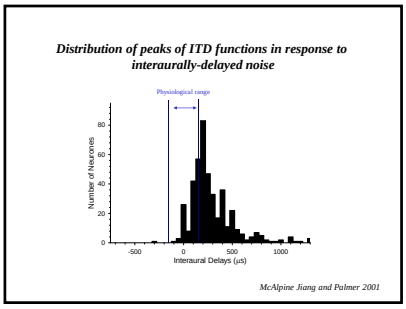

Arrives at left ear 300 μs later than at the right
300 μs
Left Ear
Cochlear Nucleus
Cochlear Nucleus
Right Ear
MSO
Large calyx synaptic ending
Auditory Nerve Activity
300 μs Time Delay
Coincident spikes


Interaural Phase Sensitivity in the MSO
Best Delay
NUMBER OF SPIKES
1 ms
1 ms
C
I
-2000
-1000
0
1000
2000
DELAY (usec)
Yin and Chan (1988)


Number of cells
Noise
BF tones
NDS
Guinea Pig
Palmer et al., 1990
Cat
Yin et al., 1986
Best delay (μs contra lead)
Palmer et al 1990


0 μs Time Delay
Arrives at left ear 300 μs later than at the right
300 μs
0 μs
Left Ear
Cochlear Nucleus
Cochlear Nucleus
Right Ear
MSO
Large calyx synaptic ending
Auditory Nerve Activity
300 μs Time Delay
0 μs Time Delay
Coincident spikes


A.
JEFFRESS MODEL
Smith et al 1993
B.
CONTRALATERAL
C.
IPSILATERAL


Distribution of peaks of ITD functions in response to interaurally-delayed noise
Physiological range
Number of Neurones
Interaural Delays (μs)
McAlpine Jiang and Palmer 2001

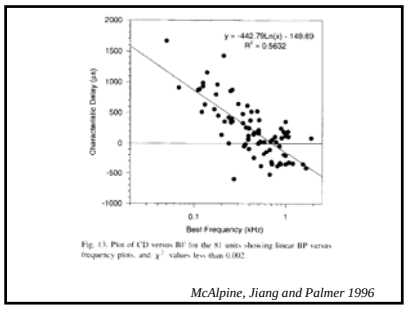
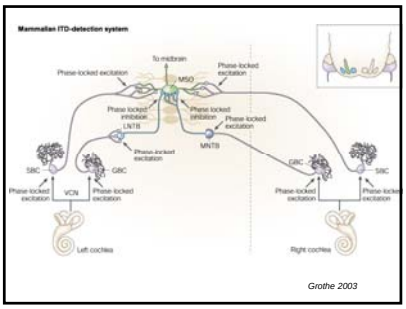


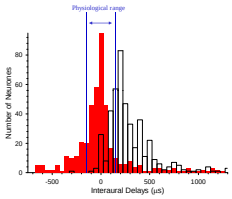
Fig. 13. Plot of CD versus BF for the 81 units showing linear BP versus frequency plots, and χ^2 values less than 0.002.

McAlpine, Jiang and Palmer 1996

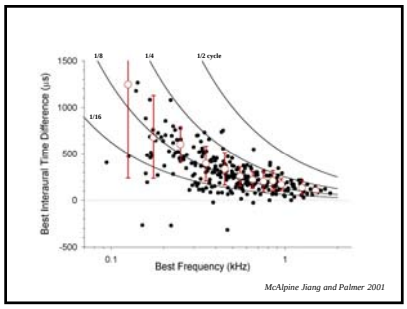


Grothe 2003

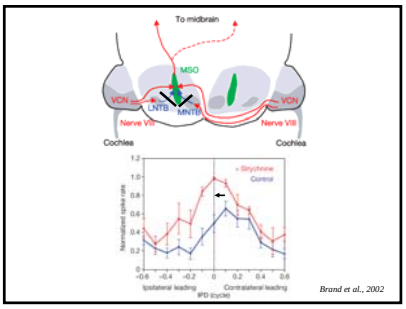
Distribution of steepest slopes of ITD functions in response to interaurally-delayed noise



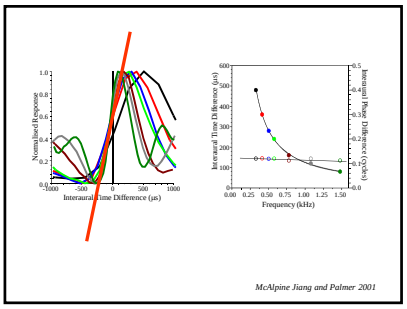
McAlpine Jiang and Palmer 2001



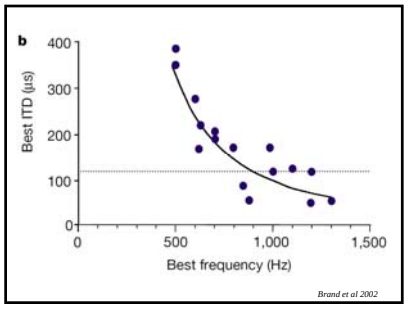
McAlpine Jiang and Palmer 2001



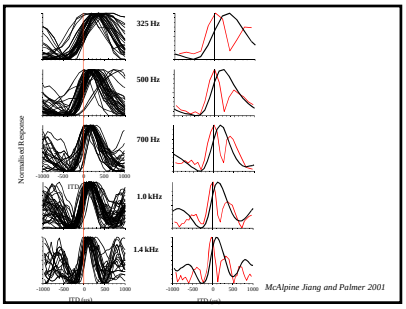
Brand et al., 2002



McAlpine Jiang and Palmer 2001



Brand et al 2002



McAlpine Jiang and Palmer 2001

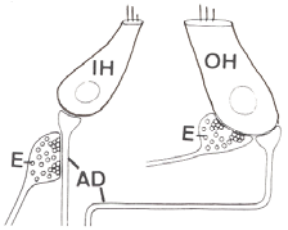
ITD processing is BF-dependent.

ITD functions are steepest around midline.

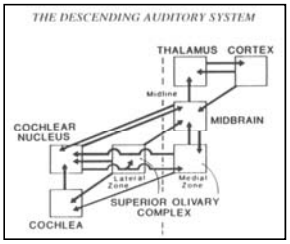
The consequence of this is that:

As ITD increases across the physiological range the activity at any frequency increases

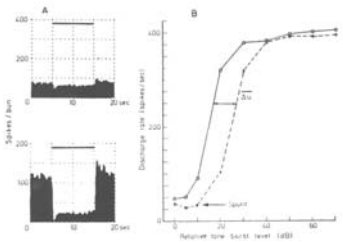
Descending pathways



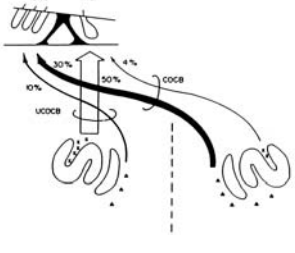
Spoendlin 1971



Spangler and Warr 1991



Wiederhold and Kiang 1971



Warr 1978, Warr and Guinan 1979

Function of the descending or centrifugal innervation

- Protection from acoustic trauma
- Control of the mechanical state of the cochlea
- Involvement in selective attention
- Detection of complex signal in noise