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Brainstem auditory time-coding nuclei in budgerigars: Physiology

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One of the general principles of vertebrate sensory systems is that amplitude coding and time coding functions become segregated and are processed in parallel. In the avian auditory brainstem, each auditory nerve afferent bifurcates and terminates on two cochlear nuclei, magnocellularis (time-coding) and angularis (amplitude-coding). The outputs from magnocellularis project bilaterally to the nucleus laminaris (NL) where neurons that are sensitive to interaural time differences (ITD) can be found. In the chicken, NL is a monolayer of neurons generating a map of ITD in the medio-lateral axis. In contrast, in the barn owl, NL is a thick multilayer structure with the ITD coding in the dorsoventral axis. Barn owls have an acute ITD-based passive auditory localization ability, and this leads us to believe that the degree of NL sophistication is related to the precision of time-coding. More precise time-coding confers an improved spatial localization ability, but also could aid processing of complex sounds. Budgerigars localize sound well, and have a well developed auditory discriminating ability. Their NLs show an intermediate level of organization between the chicken and the barn owl. This provides an opportunity to see if, in an NL of intermediate complexity, ITD is mapped in the same anatomical direction as that of the chicken or the barn owl.
We have recorded from single cells in NL to examine tuning and ITD sensitivity in response to simple tones. As in other birds, the cells of the most rostral end respond best to high frequencies and the most caudal to low frequencies. Individual cells are show fairly broad frequency response characteristics and show sharp tuning to ITDs. Along with stereotaxic mapping, we also used focal injections of biotinylated dextrans amine at the recording sites to map the tonotopic and ITD tuning organizations in these structures. NL in budgerigars approximates a twisted sheet that is oriented nearly vertically at its rostral end, more horizontal more posteriorly and at the most caudal end becomes a complex partially folded structure.

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