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**Sleep and Learning**[1]

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The neural basis of cognition represents a grand challenge problem involving multiple disciplines and approaches to the analysis of behavior. Song learning by juvenile songbirds such as zebra finches has proven to have considerable utility for exploring how behavior is represented at multiple levels of brain function. As classically described, young birds are exposed to a "tutor" (adult) song and commit that song to memory early in life, then engage in an extended period (weeks) of plastic singing as they slowly learn to match vocal output to the tutor song memory via auditory feedback. In recent years, the role of sleep in learning processes has been actively explored. Young birds isolated from adult songs, then suddenly given access to such songs at circa 40 days of age, show a sudden change in their singing behavior starting on the day following first exposure. Such birds sing songs that have less structure in the mornings than do the songs sung in the afternoons before or after that morning. This fluctuation is directly the result of sleep (not circadian rhythm), and the magnitude of fluctuation is positively correlated with the ultimate similarity to the tutor song. Examining spontaneous neuronal activity in certain brain structures during the night in sleeping adults shows "replay" of the patterns of activity the same neurons exhibit during daytime singing, and "preplay" of new patterns that will first be incorporated into daytime singing the following day. In experiments on juveniles, nighttime neuronal activity shows dramatic changes associated with song learning, even on the night after the first day of tutor song exposure (preceding changes in singing behavior). Offline processing, especially sleep, has been well documented to participate in memory consolidation in a very broad range of behaviors including in humans. Placing the bird song results in a theoretical framework thereby helps to inform a very broad range of phenomena.

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