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A neurobiological model of the human sleep/wake cycle

Michael J Rempe*[1], Janet Best[1,2] and David Terman[1,2]

Address: [1]Mathematical Biosciences Institute, Ohio State University, Columbus, OH 43210, USA and [2]Mathematics Department, Ohio State University, Columbus, OH, 43210, USA

Email: Michael J Rempe* - mrempe@mbi.ohio-state.edu

* Corresponding author

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We present a biologically-based mathematical model that accounts for several features of the human sleep/wake cycle. These features include the timing of sleep and wakefulness under normal, sleep-deprived and nap conditions, as well as ultradian rhythms. Additionally, if the input from the neurotransmitter orexin is removed, the system exhibits more frequent switching between sleep and wakefulness, consistent with the sleep disorder narcolepsy. The model demonstrates how each of these features depend on interactions between a circadian pacemaker and a sleep homeostat and provides a biological basis for the two-process model for sleep regulation [1]. The model is based on Saper's two flip-flop models for sleep/wake [2] and REM/NREM [3] and we explore whether the neuronal components in Saper's flip-flop models, with the addition of a sleep-homeostatic process, are sufficient to account for the features of the sleep/wake cycle listed above. The model is minimal in the sense that, besides the sleep homeostat and constant cortical drives, the model includes only those nuclei described in Saper's flip/flop models. Each of the cell groups is modeled by at most two differential equations for the evolution of the total population activity and the synaptic connections are consistent with those described in Saper's models. However, in order to account for certain features of the ultradian rhythms, we found it necessary to add an additional hypothesis about the connections.

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