Amplitude of circadian oscillations entrained by 24-h light-dark cycles

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We consider the processes of the gene-protein network which can promote the generation of circadian oscillations and then analyze the entrainment of circadian oscillations by 24h light-dark cycles.

[1] We study the simple models for circadian rhythms and examine the condition for the generation of oscillations. By comparing models with different complexity, we can show that oscillations are more likely to occur if the protein transport to nucleus has cooperativity with nonlinear dependence on the substrate concentration and if the products of two clock genes form a heterodimer that suppress the both of their own genes.

[2] Free-running period of circadian clocks is not exactly 24 hours. Pittendrigh and Daan (1976) showed that the stable entrainment to natural 24h light-dark cycle becomes more difficult the closer an animal's natural period is from 24h. However it is not fully clear why the free-running period of circadian clock is of the order of 21.5h in Neurospora, and 24.4h in Drosophila, instead of precisely 24h. Using models for circadian rhythms in Neurospora and Drosophila, we determine how the entrainment of these rhythms is affected by the free-running period and by the amplitude of the external light-dark cycle. We first consider the model for Neurospora, in which lights acts by inducing the expression of a clock gene. We show that the amplitude of the oscillations of the clock protein entrained by light-dark cycles is maximized when the free-running period is smaller than 24h. Moreover, if the amplitude of the light-dark cycle is very strong, complex oscillations occur when the free-running period is close to 24h. In the model for circadian rhythms in Drosophila, light acts by enhancing the degradation of a clock protein. We show that if the free-running period is smaller than 24h, the range of entrainment is centered around 24h in this model. We discuss the physiological relevance of these results in regard to the setting of the free-running period of the circadian clock.