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Stochastic feedback and beats: a generic model for circadian rhythms

Most organisms undergo circadian rhythms: at the cellular level, protein concentrations go through 24-hour cycles. These are intrinsic (they run in the absence of light) but respond to the diurnal cycle of sunlight. These cycles are thought to involve genetic regulatory processes—transcription and translation of proteins that affect the expression of other genes and produce oscillations through feedback. However, all such known 'transcriptional-translational oscillators' have periods of no more than 3 hours. So an important question is how such fast, 'ultradian' oscillations can produce slow 'circadian' ones. Another problem is that the particular genes and regulatory processes involved vary from organism to organism. This poses the theoretical question: How did circadian oscillations develop independently using different components in different organisms? We propose a biochemically realistic model that offers possible solutions to both of these questions as well as allowing entrainment by light. The mathematics is elementary but the mechanism is elegant, and some more difficult questions arise when the inherently stochastic nature of the gene regulation is taken into account.