Time in the cell: a plausible role for the plasma membrane

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All cells must keep time to consistently perform vital biological functions. At that end, the coupling and interrelatedness of diverse subsecond events in the complex cellular environment, such as protein folding or translation rates, cannot simply result from the chance convergence of the inherent chemical properties of these phenomena, but may instead be synchronized through a cell-wide pacemaking mechanism. Picosecond vibrations of lipid membranes may play a role in such a mechanism.

Mechanistically, through the generation of rate-capable byproducts, and cellular energy costs can be precipitated, leading to a competitive and cyclical cellular activity. As an example, the nucleotide ribosomes, which are more rapid and stable, may be derived from a mitochondrial cell cycle, in which the protein phosphorylation of Cdk1 occurs as a main switch, operates on much longer timescales. On a genome level, transcriptional burstiness is species-specific, and although stochasticity in their search is understood, they cannot provide a species-conserved and steady pulse.

The remaining alternative is the plasma membrane. Intracellular water-dependent picosecond vibrations in the phospholipid membrane (Mashaghi et al., 2012) are well shorter than the reported periodic gene expression-time, and the membrane's properties as an elastic network allows it to couple the 'outside' to the 'inside environment.' This could be an ideal characteristic for a cellular timemarker. The membrane as a pacemaker, through which can also shift the essential task of synchronizing cellular events in both, cellular or multicellular organisms. This could explain observations that cell division can affect cell-fate reversibility (Skaggs et al., 2009).

This hypothesis can be refined if two pieces of evidence become available: First, how consistent is the frequency of oscillations of the membrane? Second, how can the oscillations of an as-yet-unformed lipid membrane be generated this oscillation? If these and similar questions confirm the timekeeping potential of the membrane, it would be crucial to explore whether studies controlled conditions of a cell-culture medium, for example, followed by length density comparisons, or developments in synthetic-phospholipid membranes. Similar models have been proposed for 'the' environment' of the cell (Mall et al., 2007), which emerges out of a chaotic phase when it is severed (Skaggs et al., 2009) or cuts out of the cellular level, for example, constitutes a natural source of activity in cancer or neurodegenerative disease research.

References

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