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ATP consumption in molecular reactions of neuronal signaling

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The human brain consumes 10^6 times less energy than the currently fastest supper computer [1], while maintaining a comparable performance in many demanding task [2]. These energetic efficiency has been suggested to result from primitive computations on a molecular level [3]. However, while the importance of ion channels on energy efficiency has been the primary focus of research [4,5], most computations occur at the molecular level prior to the amplification step and prior to the information transmission. We calculate the amount of energy consumed by such computations and compare their structural and functional properties. As a starting point, we chose the molecular reactions involved in long term depression and using our stochastic model [6] estimate the molecular energy consumption. To compare our feedback loop we investigate the energy consumption of millions of feedback loops in molecular signaling. For the first time we are able to go beyond the current size limit of 15 steps [7] and, using a computer cluster, detect feedback loops with hundreds of molecular reactions. We find that the number of ATPs consumed is related with size of positive feedback loop. We conclude that the energy consumed by the long term depression is only marginally above the physical limit of storing information and higher than its silicon equivalent of random access memory. Hence, this study provides the first systematic attempt to investigate the energy consumption of information-storing primitive computations and points towards energy efficient motifs for synthetic biology.

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