Trapping in and escape from branched structures of neuronal dendrites

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We present a coarse-grained model for stochastic transport of noninteracting chemical signals inside neuronal dendrites and show how first-passage properties depend on the key structural factors affected by neurodegenerative diseases or aging: the extent of the tree, the topological bias induced by segmental decrease of dendrite diameter, and the trapping probabilities in biochemical cages and growth cones. We derive an exact expression for the distribution of first-passage times, which follows a universal exponential decay in the long-time limit. The asymptotic mean first-passage time exhibits a crossover from power-law to exponential scaling upon reducing the topological bias. The analytical predictions are in remarkable agreement with simulations. Our results evidence that structural irregularities can create local traps and heterogeneous patterns of signal transmission.