Intracellular signaling by diffusion: can waves of hydrogen peroxide transmit intracellular information in plant cells?

Amplitude- and frequency-modulated waves of Ca(2+) ions transmit information inside cells. Reactive Oxygen Species (ROS), specifically hydrogen peroxide, have been proposed to have a similar role in plant cells. We consider the feasibility of such an intracellular communication system in view of the physical and biochemical conditions in plant cells. As model system, we use a H(2)O(2) signal originating at the plasma membrane (PM) and spreading through the cytosol. We consider two maximally simple types of signals, isolated pulses and harmonic oscillations. First we consider the basic limits on such signals as regards signal origin, frequency, amplitude, and distance. Then we establish the impact of ROS-removing enzymes on the ability of H(2)O(2) to transmit signals. Finally, we consider to what extent cytoplasmic streaming distorts signals. This modeling allows us to predict the conditions under which diffusion-mediated signaling is possible. We show that purely diffusive transmission of intracellular information by H(2)O(2) over a distance of 1 μm (typical distance between organelles, which may function as relay stations) is possible at frequencies well above 1 Hz, which is the highest frequency observed experimentally. This allows both frequency and amplitude modulation of the signal. Signaling over a distance of 10 μm (typical distance between the PM and the nucleus) may be possible, but requires high signal amplitudes or, equivalently, a very low detection threshold. Furthermore, at this longer distance a high rate of enzymatic degradation is required to make signaling at frequencies above 0.1 Hz possible. In either case, cytoplasmic streaming does not seriously disturb signals. We conclude that although purely diffusion-mediated signaling without relaying stations is theoretically possible, it is unlikely to work in practice, since it requires a much faster enzymatic degradation and a much lower cellular background concentration of H(2)O(2) than observed experimentally.

General information
Publication status: Published
Organisations: Department of Micro- and Nanotechnology, Stochastic Systems and Signals
Contributors: Vestergaard, C. L., Flyvbjerg, H., Møller, I. M.
Pages: 295
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: Frontiers in Plant Science
Volume: 3
ISSN (Print): 1664-462X
Ratings:
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.951 SNIP 0.398
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
Original language: English
Keywords: diffusion, hydrogen peroxide, modeling, intracellular signaling, waves
Electronic versions:
fpls_03_00295.pdf
DOIs:
10.3389/fpls.2012.00295
Source: dtu
Source ID: n:oai:DTIC-ART:pubmed/377335035::24629
Research output: Contribution to journal › Journal article – Annual report year: 2012 › Research › peer-review