

Correspondence: Reply to 'Revisiting the theoretical cell membrane thermal capacitance response'

Mikhail G. Shapiro¹, Kazuaki Homma^{2,3}, Sebastian Villarreal⁴, Claus-Peter Richter^{2,3,5,6} & Francisco Bezanilla⁴

Nature Communications 8:#### doi:10.1038/s41467-017-00436-4 (2017)

We thank Plaksin, Kimmel, and Shoham for their correspondence regarding our 2012 article on the mechanism of infrared stimulation of excitable cells¹. In this study, we showed that the heating of cellular water by infrared light leads to an increase in the electrical capacitance of the cell membrane. This time-varying capacitance produces a current leading to membrane depolarization and generation of action potentials. Although our experimental findings were the primary focus of the paper and account for most of its impact to date, we also attempted to provide a theoretical explanation of how the membrane capacitance changes with temperature.

As Plaksin et al. point out in their accompanying correspondence, our theoretical explanation relied on the Genet et al.² model of the coupled double layer capacitance across the cell membrane. In adapting this model, we did not account for a difference between Genet's sign convention for transmembrane charge and what is typically used in electrophysiology studies. After correcting for this difference, it is clear that the suggested theory does not explain our experimental findings. Although the distribution of mobile charges on each side of the bilayer does change with temperature, the net effect of these changes is predicted to decrease, rather than increase, the apparent bilayer capacitance. Therefore, alternative theories are needed to provide a complete understanding of thermal stimulation. For example, Plaksin et al.³ have proposed a complete theory that considers recent experimental measurements of bilayer thickness as a function of temperature⁴.

Received: 22 March 2017 Accepted: 28 June 2017
Published online: 10 November 2017

References

1. Shapiro, M. G., Homma, K., Villarreal, S., Richter, C. P. & Bezanilla, F. Infrared light excites cells by changing their electrical capacitance. *Nat. Commun.* **3**, 736 (2012).
2. Genet, S., Costalat, R. & Burger, J. A few comments on electrostatic interactions in cell physiology. *Acta Biotheor.* **48**, 273–287 (2000).
3. Plaksin, M., Kimmel, E. & Shoham, S. Thermal transients excite neurons through universal intramembrane mechano-electrical effects. *bioRxiv* 111724 (2017). <http://www.biorxiv.org/content/early/2017/02/26/111724>
4. Szekely, P. et al. Effect of temperature on the structure of charged membranes. *J. Phys. Chem. B* **115**, 14501–14506 (2011).

Author contributions

All authors contributed to writing this Correspondence and agree with its contents.

Additional information

Competing interests: The authors declare no competing financial interests.

Reprints and permission information is available online at <http://npg.nature.com/reprintsandpermissions/>

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2017

¹Division of Chemistry and Chemical Engineering, California Institute of Technology, 1200 E. California Blvd, Pasadena, CA 91125, USA. ²Department of Otolaryngology—Head and Neck Surgery, Northwestern University, 303 E. Chicago Ave, Evanston, IL 60611, USA. ³The Hugh Knowles Center for Clinical and Basic Science in Hearing and its Disorders, Northwestern University, Evanston, IL 60208, USA. ⁴Department of Biochemistry and Molecular Biology, University of Chicago, 929 E. 57th Street, GCIS W244, Chicago, IL 60637, USA. ⁵Department of Biomedical Engineering, Northwestern University, 2145 Sheridan Rd, Evanston, IL 60208, USA. ⁶Department of Communication Sciences and Disorders, Northwestern University, 2240 Campus Dr, Evanston, IL 60208, USA. Correspondence and requests for materials should be addressed to M.G.S. (email: mikhail@caltech.edu) or to F.B. (email: fbezanilla@uchicago.edu)