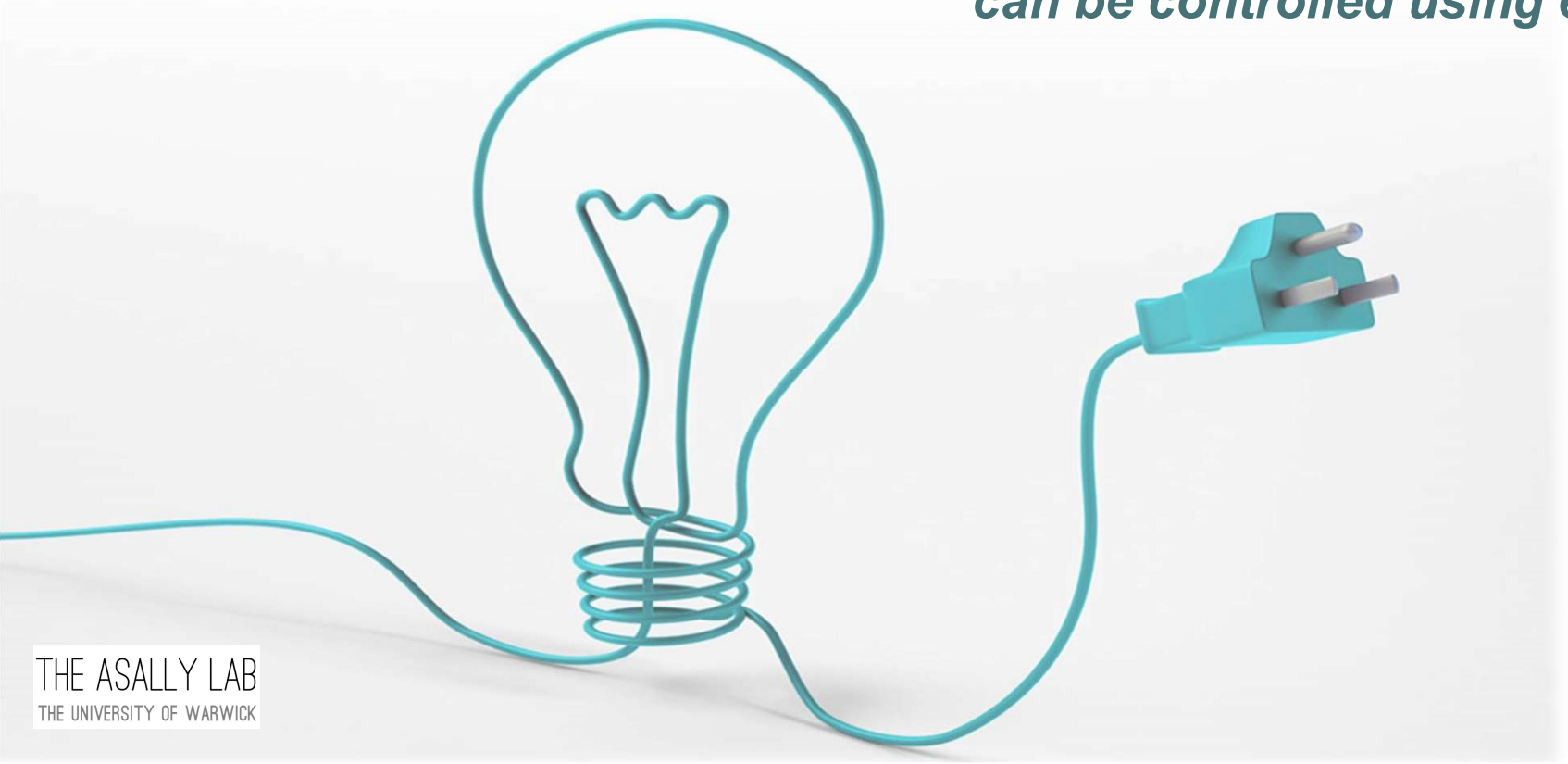
Munehiro Asally
University of Warwick

@munelectro

Can we use electricity to control bacteria?

— just like the way neural functions can be controlled using electricity…



ELECTRICALLY INDUCED BACTERICAL MEMBRANE POTENTIAL DYNAMICS

James Stratford, Conor Edwards,
Manjari Ghanshyam, Dmitry Malyshev,
Marco Delise, Yoshikatsu Hayashi, Munehiro Asally

Bee

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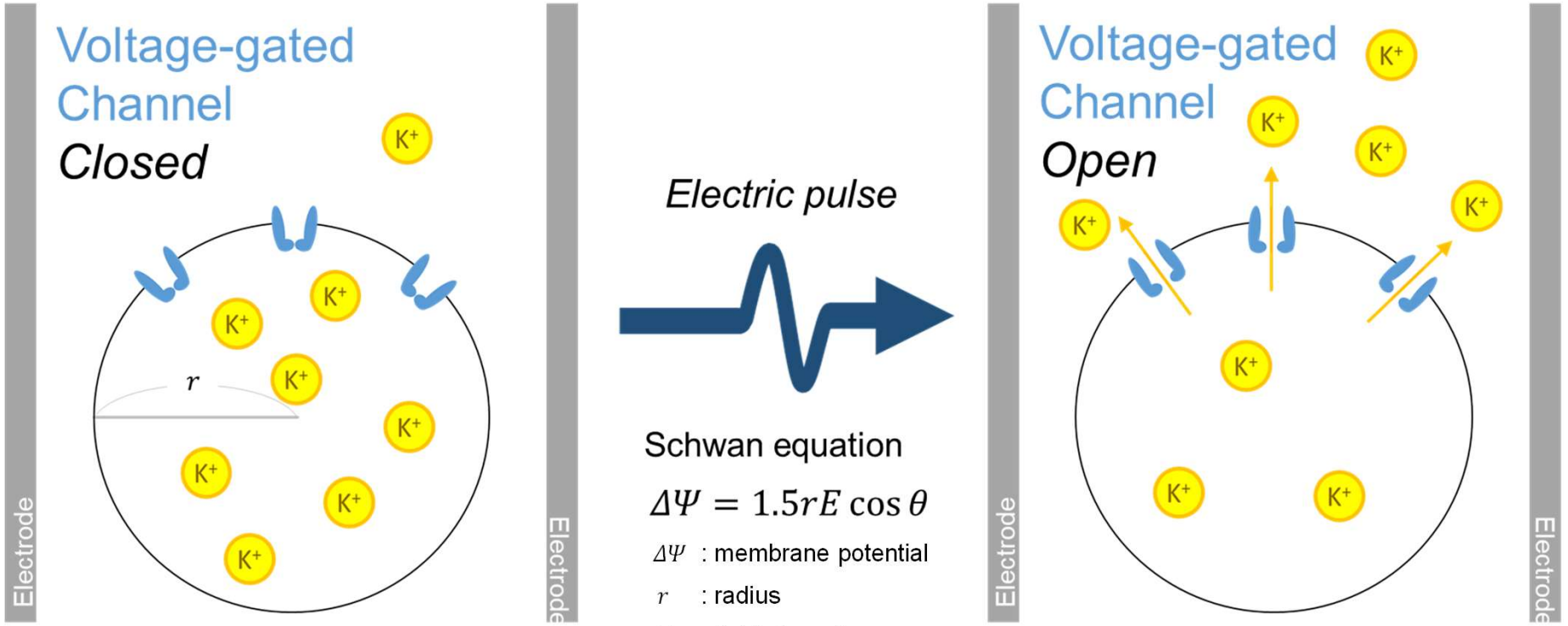
How can we induce membrane potential?

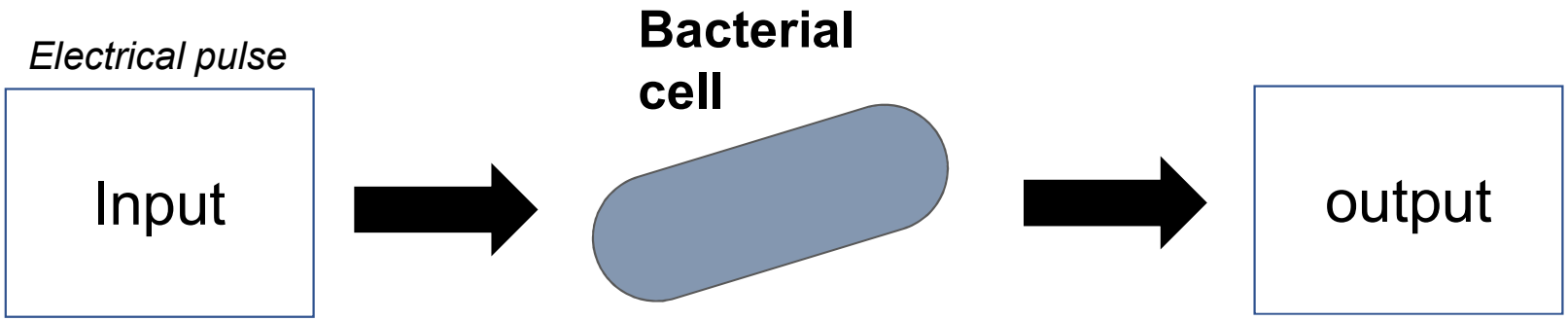
Exogenous electrical pulse should be able to open voltage-gated ion channels.



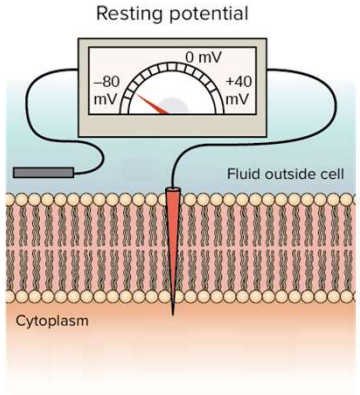
Stratford, Edwards et al., unpublished

AIM:

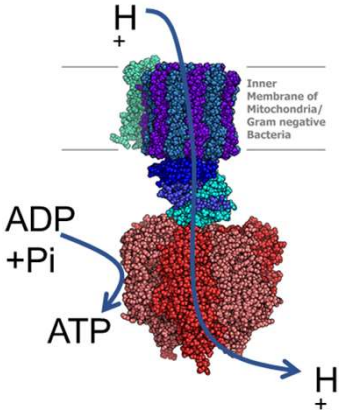
Elucidate the input-output relation of bacterial electrical signalling.



Membrane potential ($\Delta\psi$)

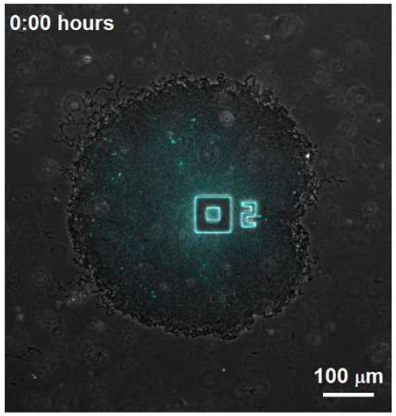


Metabolic activities

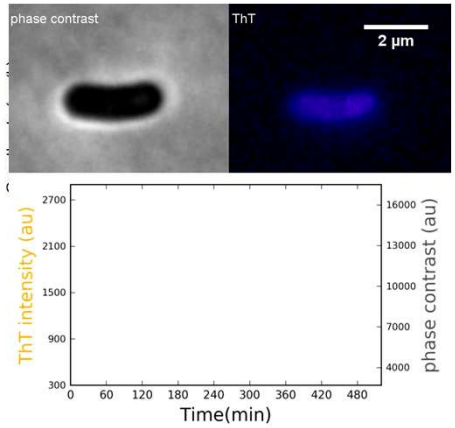


?

Electrical signalling



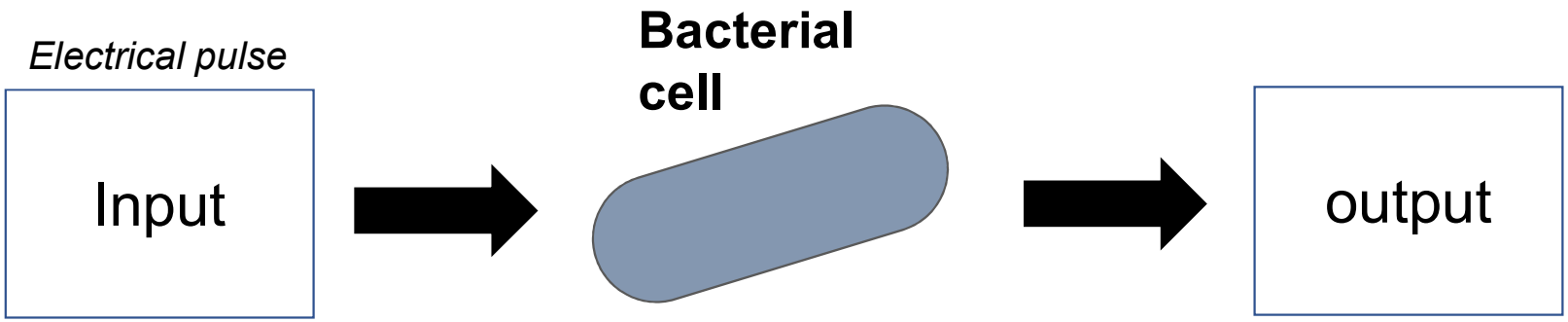
Prindle et al (2015)



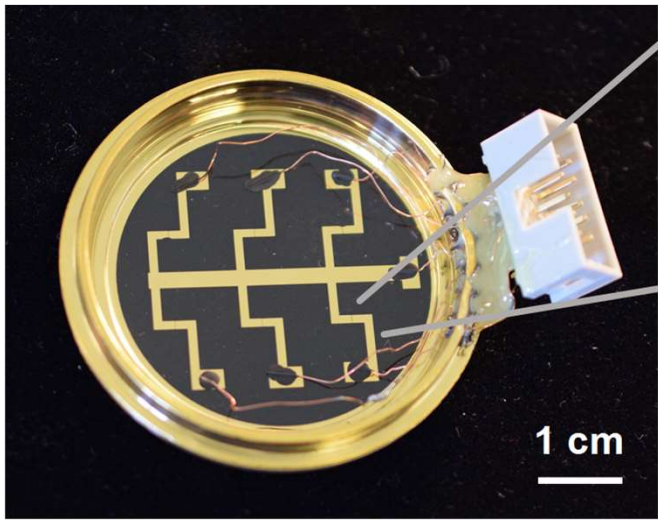
Sirec et al (2019)

QUESTION:

Do proliferation capacities affect the input-output relation of electrical signaling?

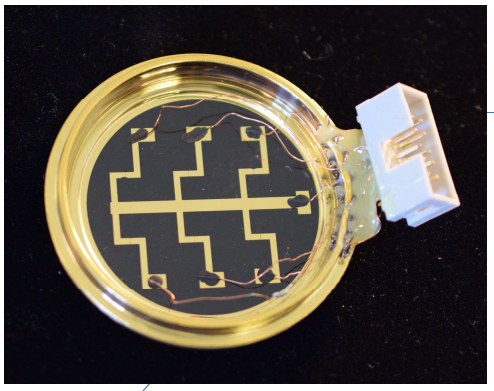


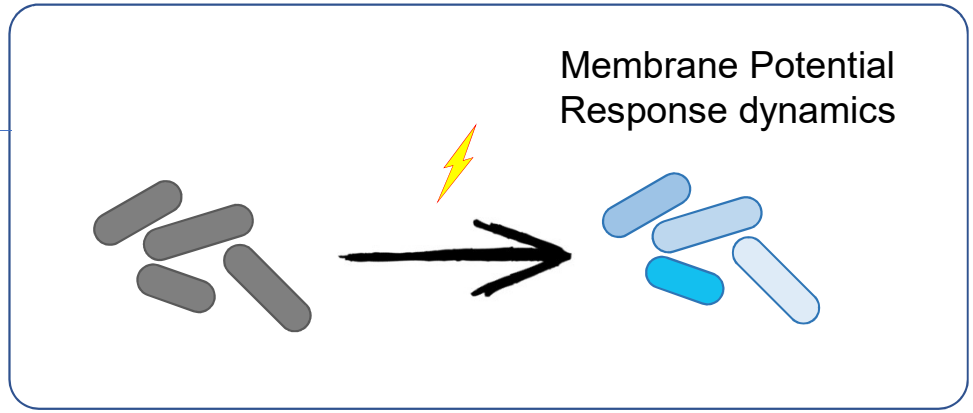
An experimental setup that enables monitoring the cellular response to exogenous electrical stimuli.



Stratford, Edwards et al., unpublished

Experimental design

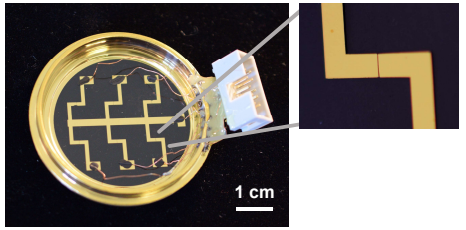


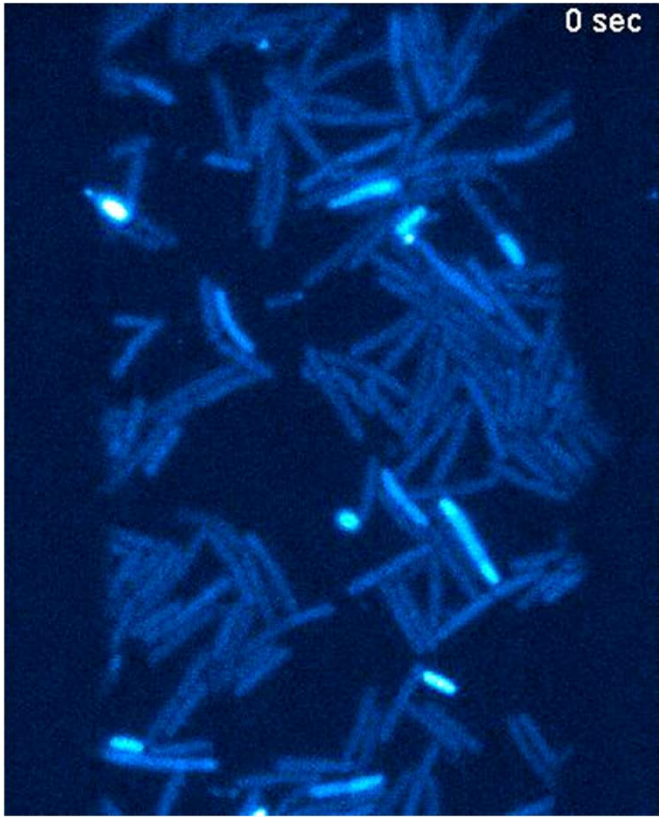


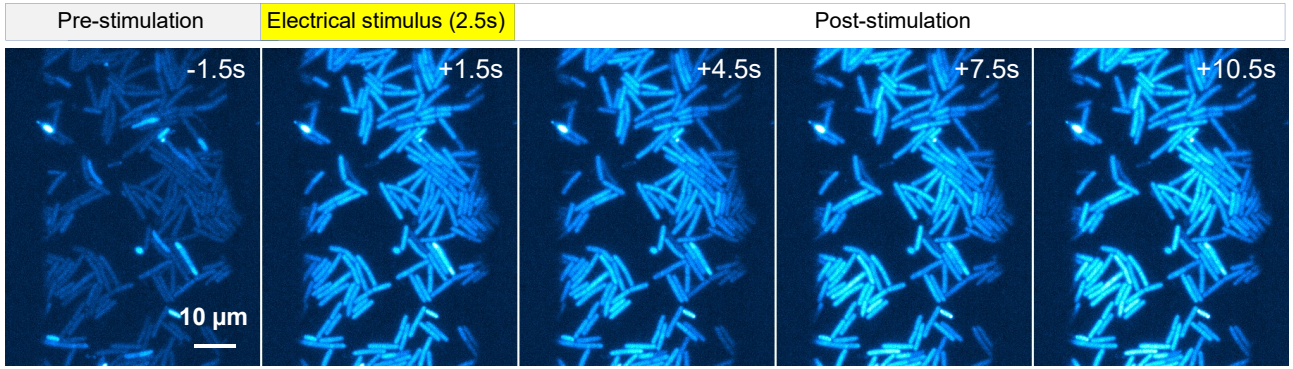
Single-cell Fluorescence
Time-lapse Microscopy

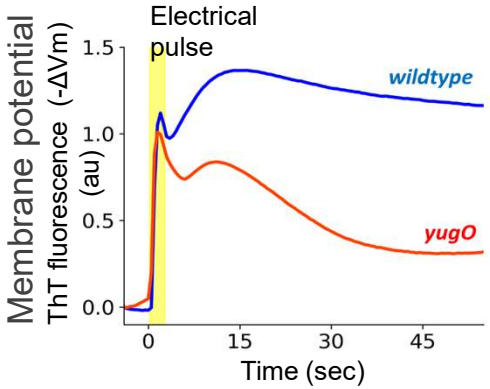
Stratford, Edwards et al., unpublished

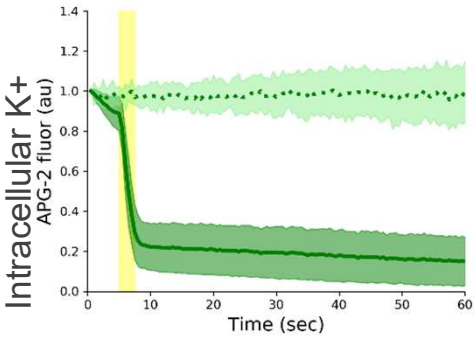
An exogenous electrical stimulus causes hyperpolarization in bacterial cells.

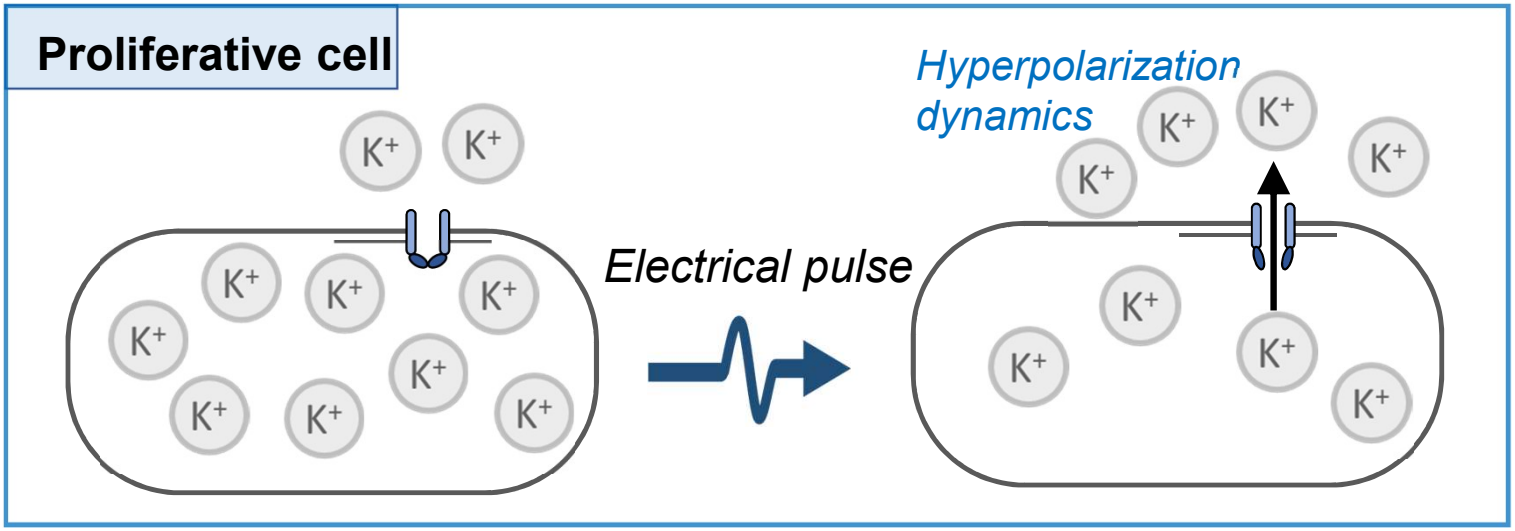






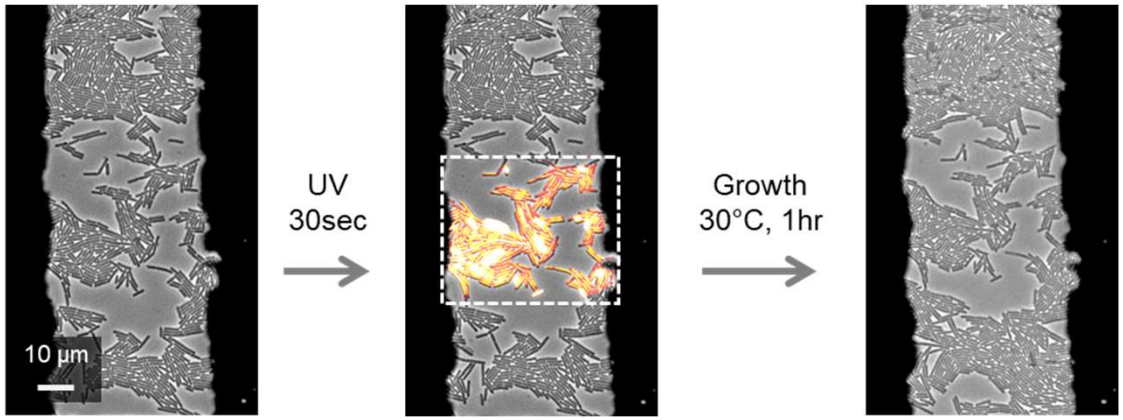


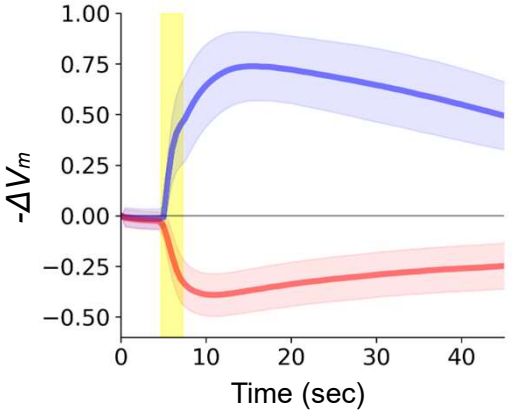


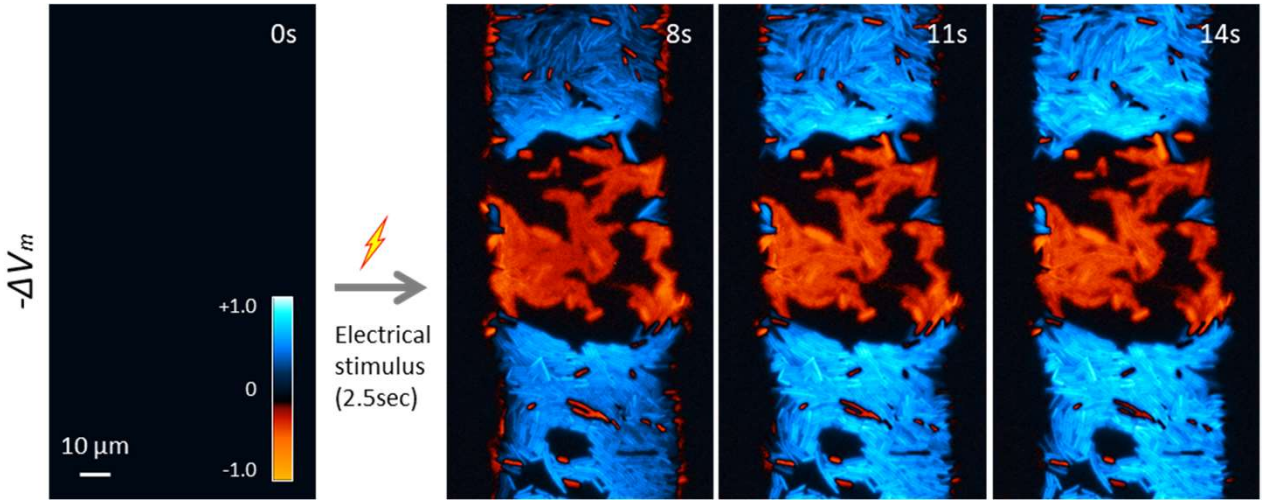


Stratford, Edwards et al., unpublished

UV irradiated cells depolarize to the same electrical stimulus.

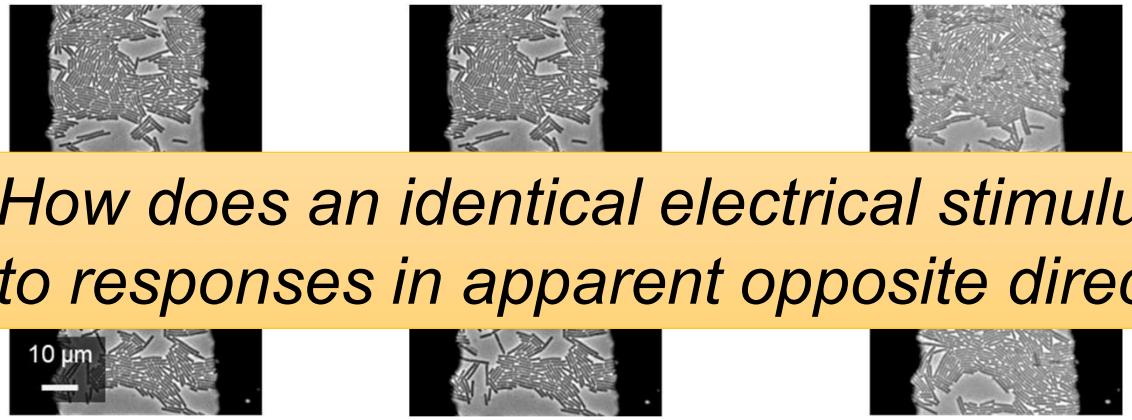




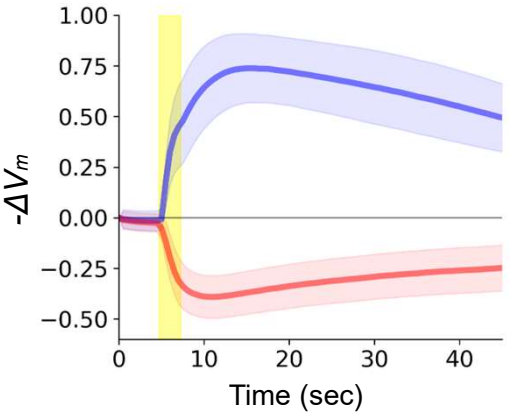


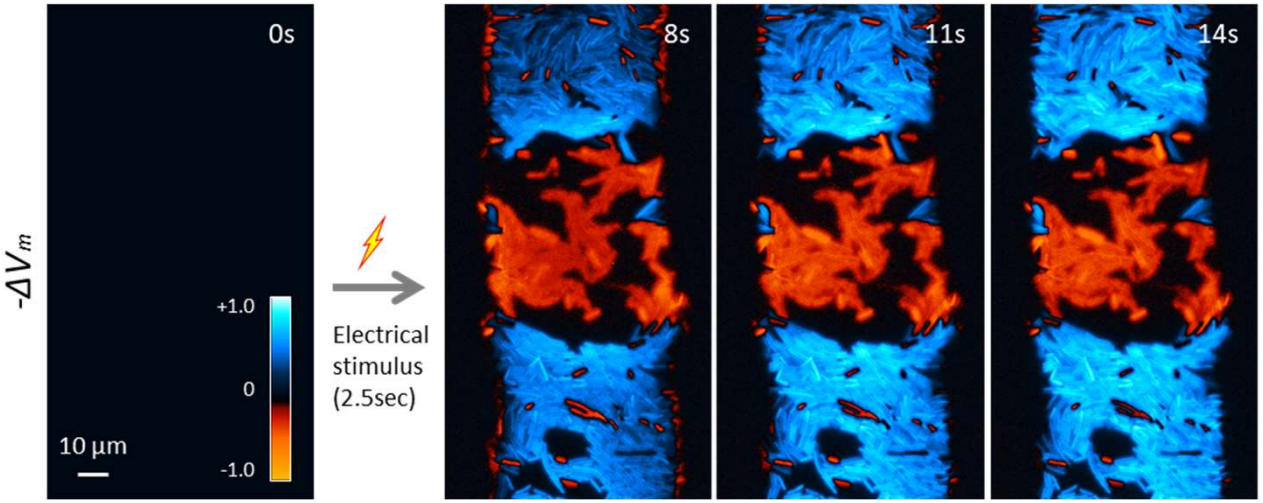
Stratford, Edwards et al., unpublished

UV irradiated cells depolarize to the same electrical stimulus.



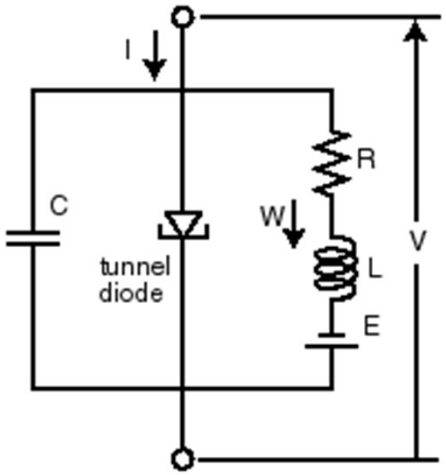
How does an identical electrical stimulus lead to responses in apparent opposite directions?



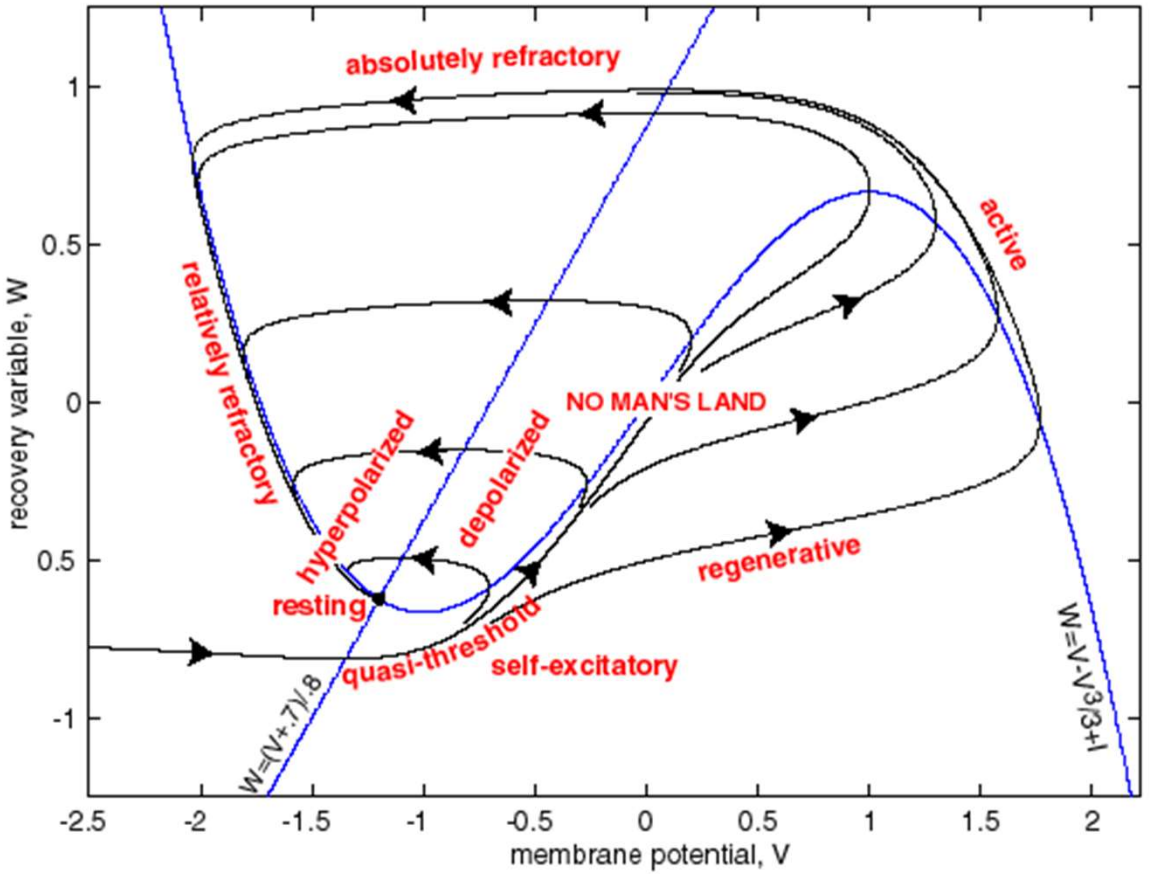


Stratford, Edwards et al., unpublished

FitzHugh-Nagumo (FHN) neuron model



Circuit diagram of the tunnel-diode nerve model of Nagumo et al. (1962).

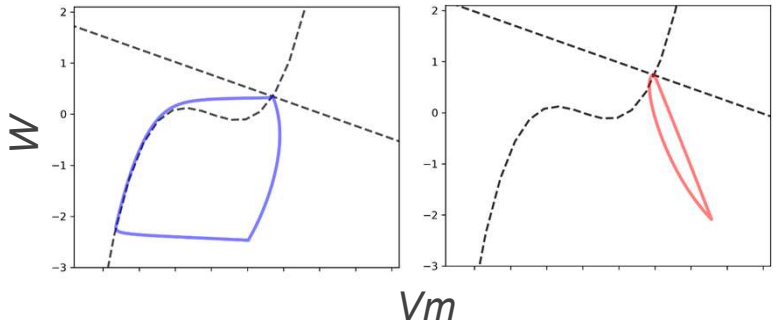


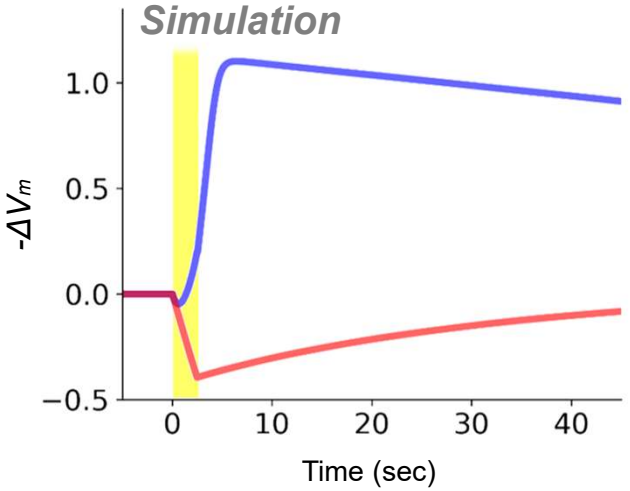
http://www.scholarpedia.org/article/FitzHugh-Nagumo_model

FitzHugh-Nagumo (FHN) *bacteria* model

$$\frac{dV_m}{dt} = k_K((V_m + V_{m,0}) - \alpha(V_m + V_{m,0})^3 + W) + \frac{dI_v}{dt}$$

$$\frac{dW}{dt} = -((V_m + V_{m,0}) + \beta - W) + \frac{dI_w}{dt}$$





V_m : membrane potential

W : recovery variable

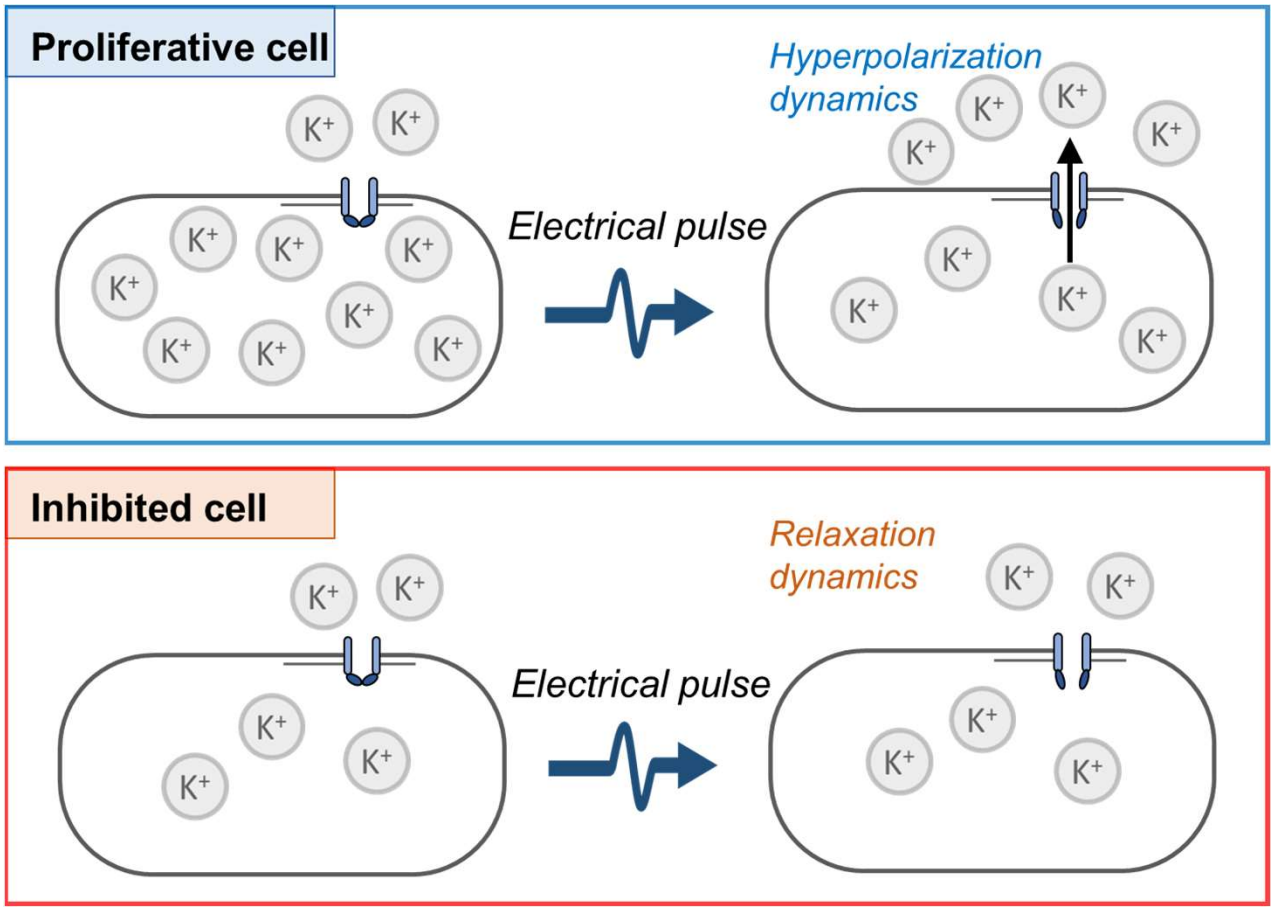
I : electrical stimulus

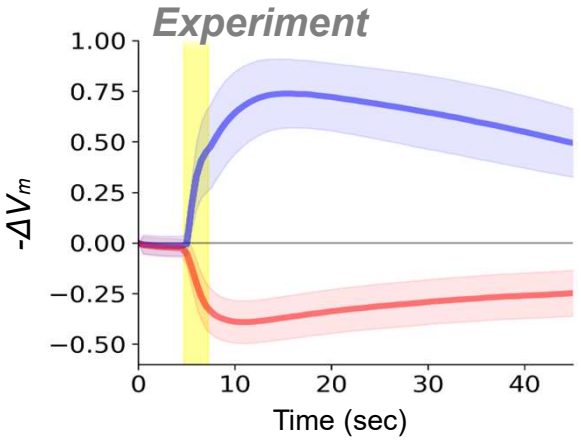
$V_{m,0}$: basal level membrane potential

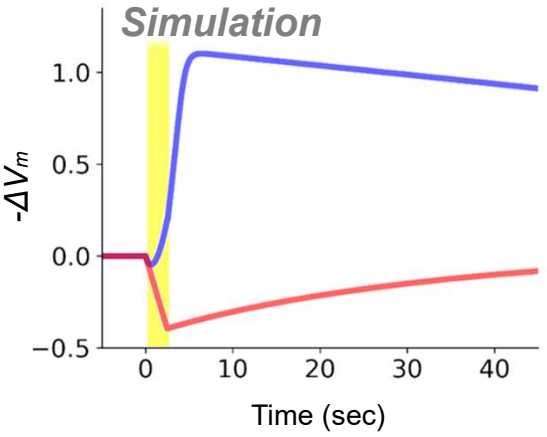
k_K : degree of transmembrane potassium gradient

Stratford, Edwards et al., unpublished

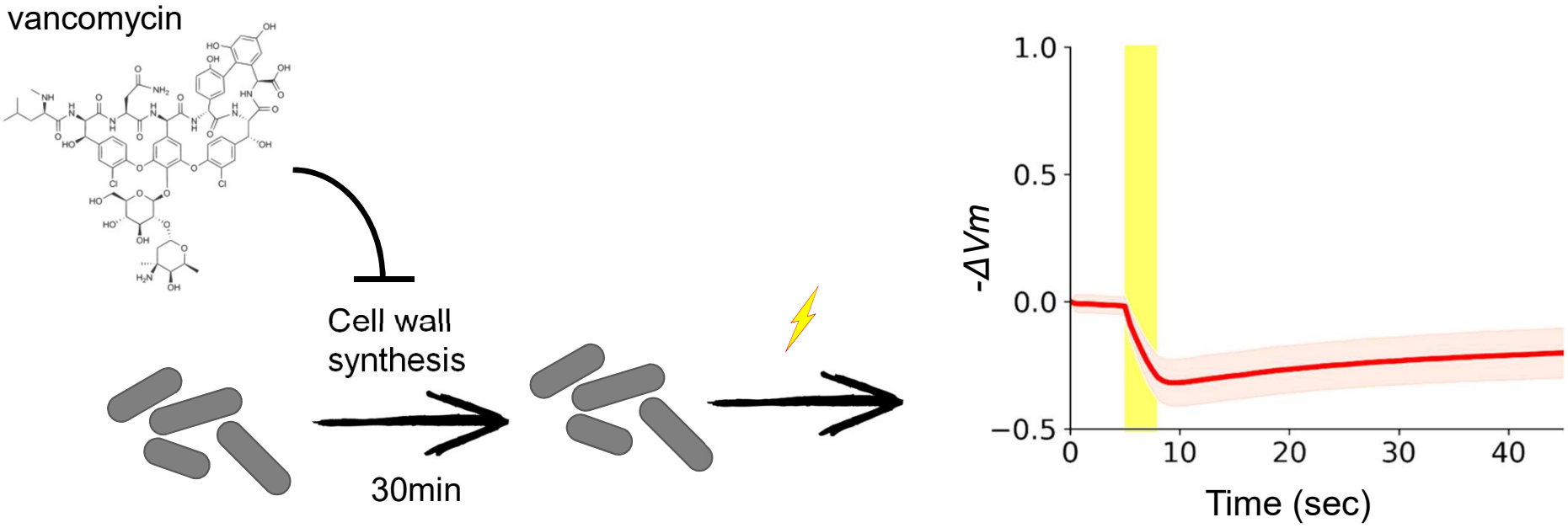
Response dynamics depends on the resting membrane potential.





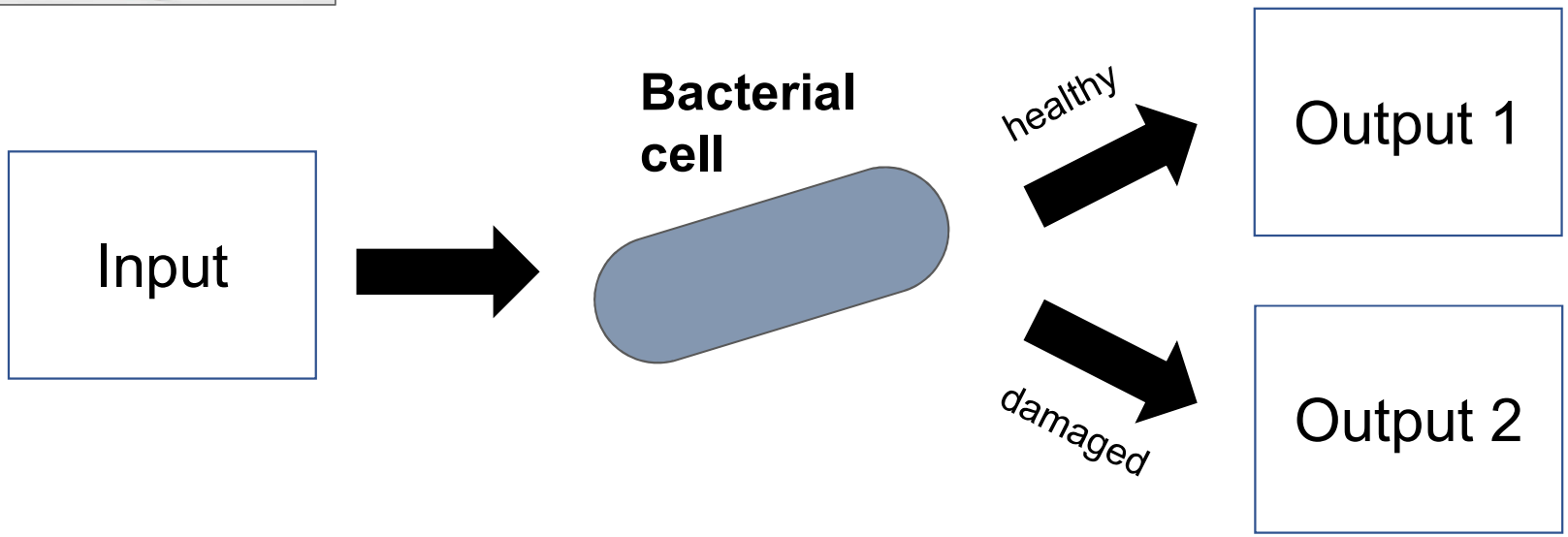


Antibiotics, ethanol and CCCP all make cells to respond with depolarization.

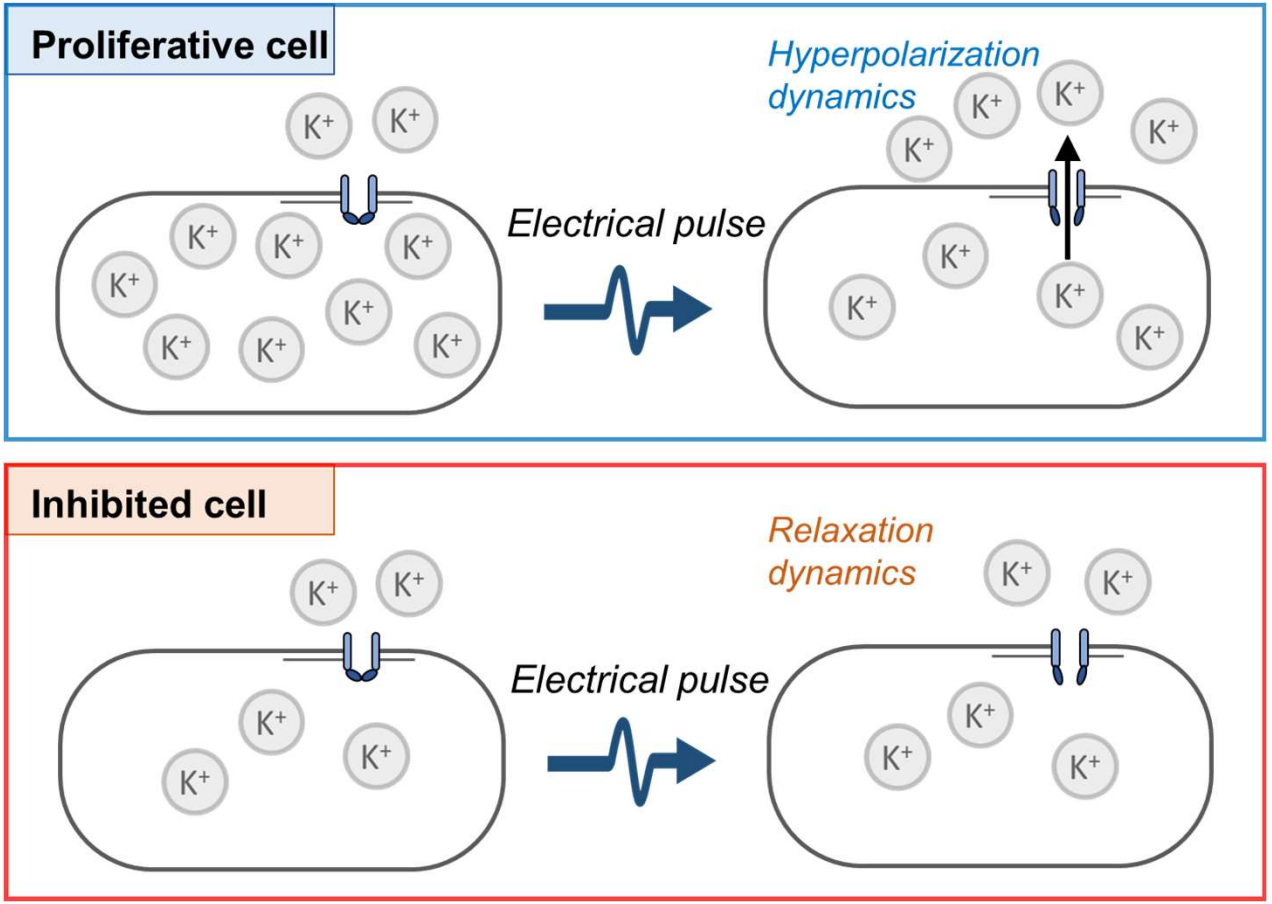


Stratford, Edwards et al., unpublished

How do bacteria respond to electrical signal input?



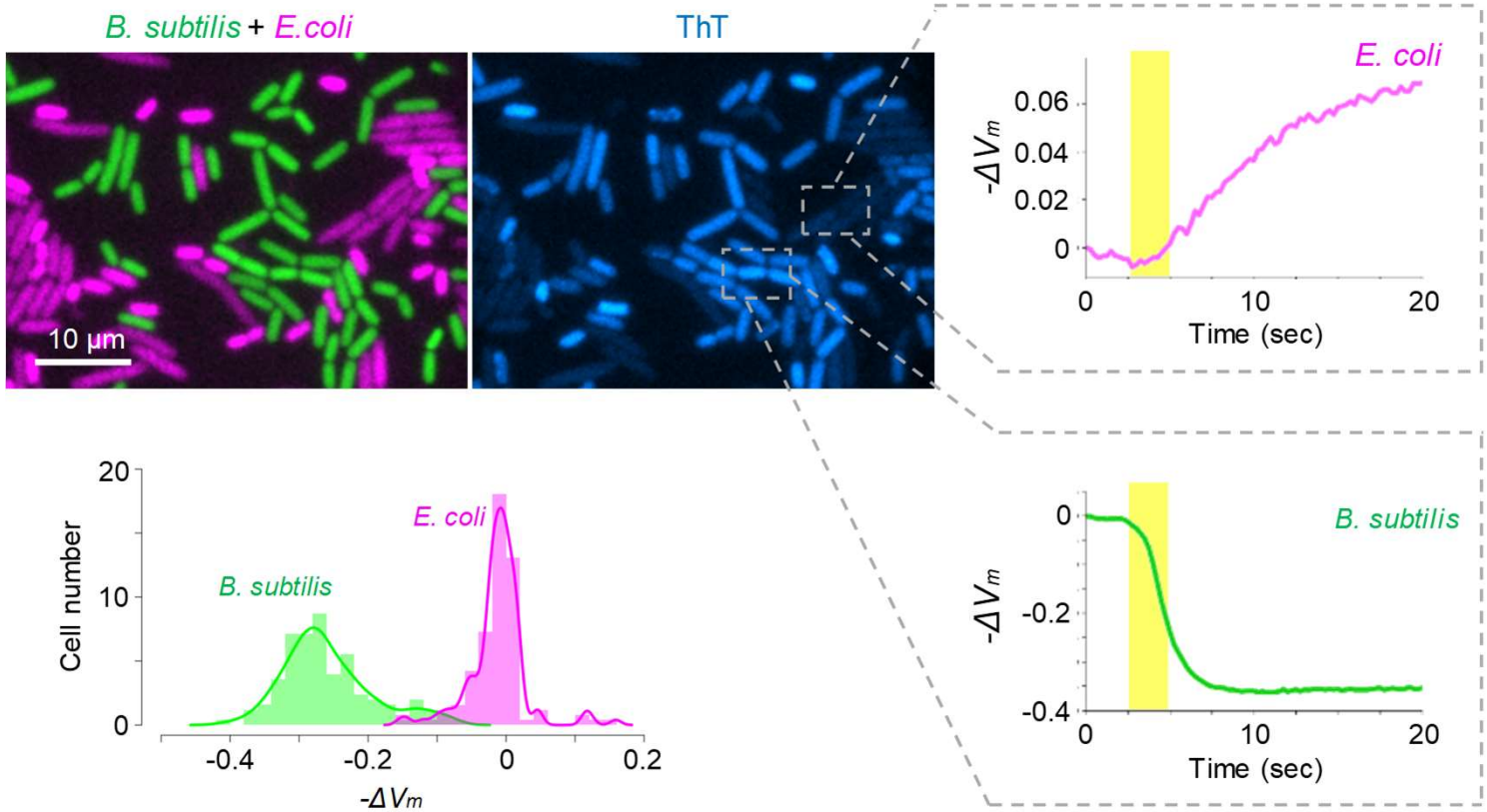
Response dynamics to exogeneous electrical stimulus as an indicator of intracellular proliferative state.



Detecting proliferative bacteria is an important task in industries as well as medical sector.

Is it possible to differentiate different species using our approach?

→ Yes! We can combine it with microbiology techniques.



Cytecom

Quick, easy and sensible detection system for bacteria

ICURe

warwick ventures

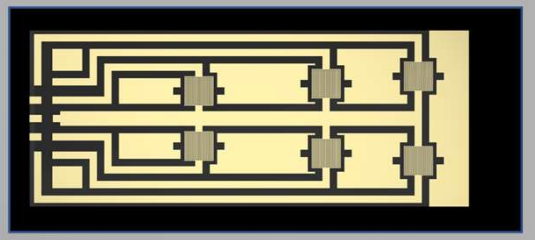
Innovate UK

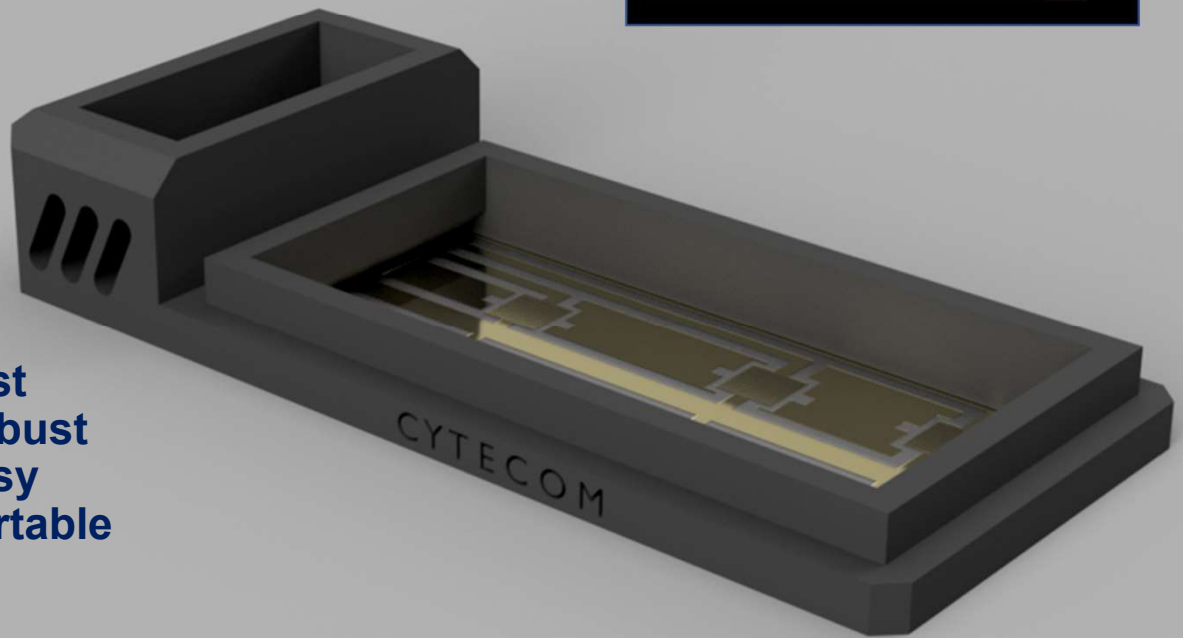
oxford technology

Electrode chip for BEE

- Rapid vitality assay.
- Biophysical investigation
- Antibiotics susceptibility test
- Test of new anti-bacterial treatments

… and more?





- Fast
- Robust
- Easy
- Portable

Acknowledgements

THE ASALLY LAB
THE UNIVERSITY OF WARWICK

Marco Delise
Iago Lopez-Grobas
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Dmitry Malyshev
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Mar Moreno
Elena Ontanon

Alumni:
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Conor Edwards
Teja Sirec
Pauline Buffard

Cytecom

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Akio Ishiguro/ Takeshi Kano (Tohoku, Japan)
Vasily Kantsler (Warwick, UK)
Marco Polin (Warwick, UK)
Patrick Schafer (Warwick, UK)
Orkun Soyer (Warwick, UK)
Pat Unwin (Warwick, UK)

Funding:

Research

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