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Department of Chemical Engineering

Does my Research Need more Math???

The Wonders of Bioelectrochemistry

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Today's talk

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1. An introduction to Biological Fuel Cells

   Discovering 'electrical' bacteria!

2. Energy from wastewaters

   The pee power!

3. Sensors for water

   If bugs don't like it, you better don't drink it!

4. Where is the MATH?

I have a vision…

To develop:

1. Effective bioelectrochemical devices for the *renewable* and *carbon-neutral* generation of electricity from wastewaters.
2. *Compact*, *handy* and *cost-effective* biosensors for quick *on-site* and *real-time* assessment of water quality.

BFCs: Principles of operation

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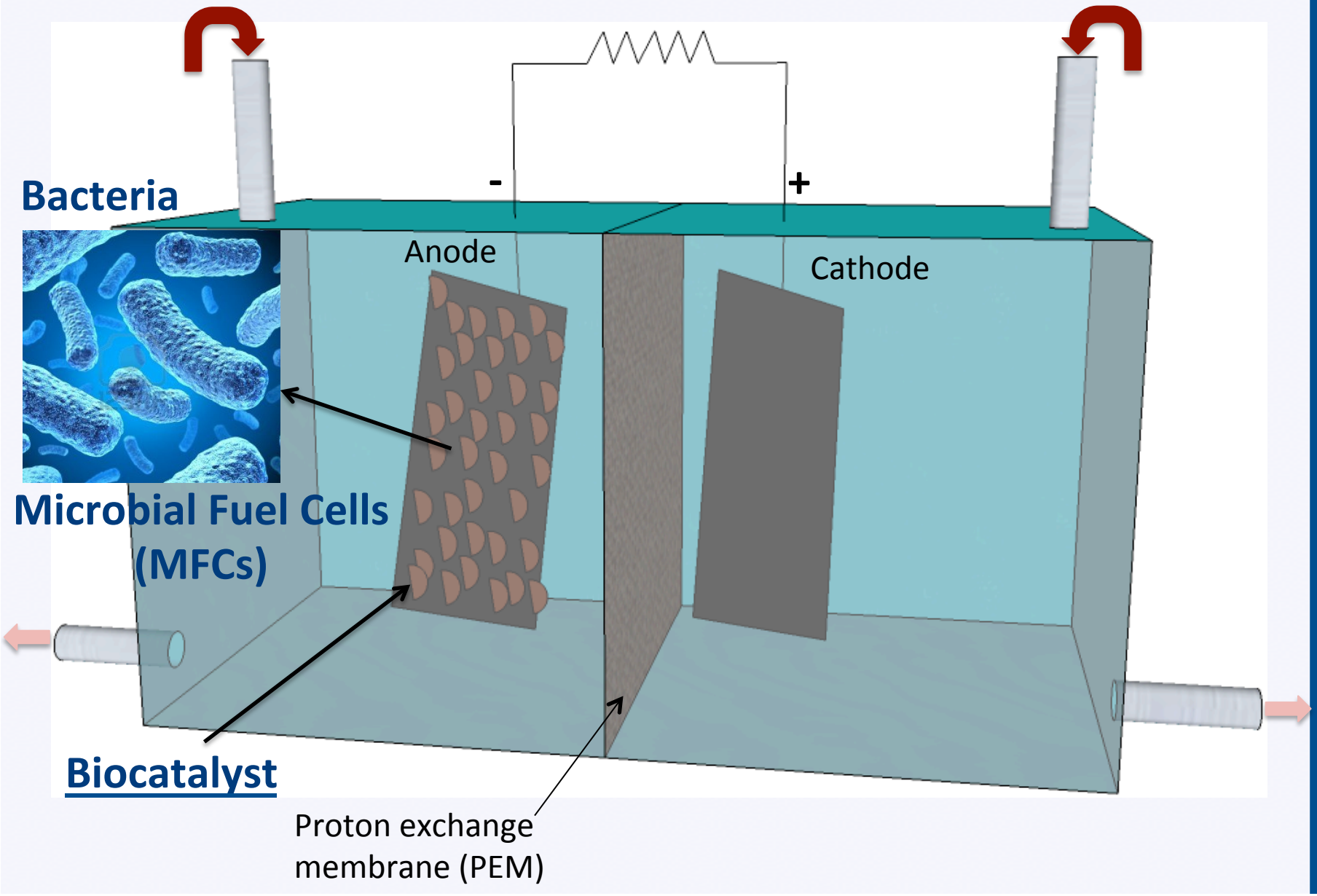

BFCs: Principles of operation

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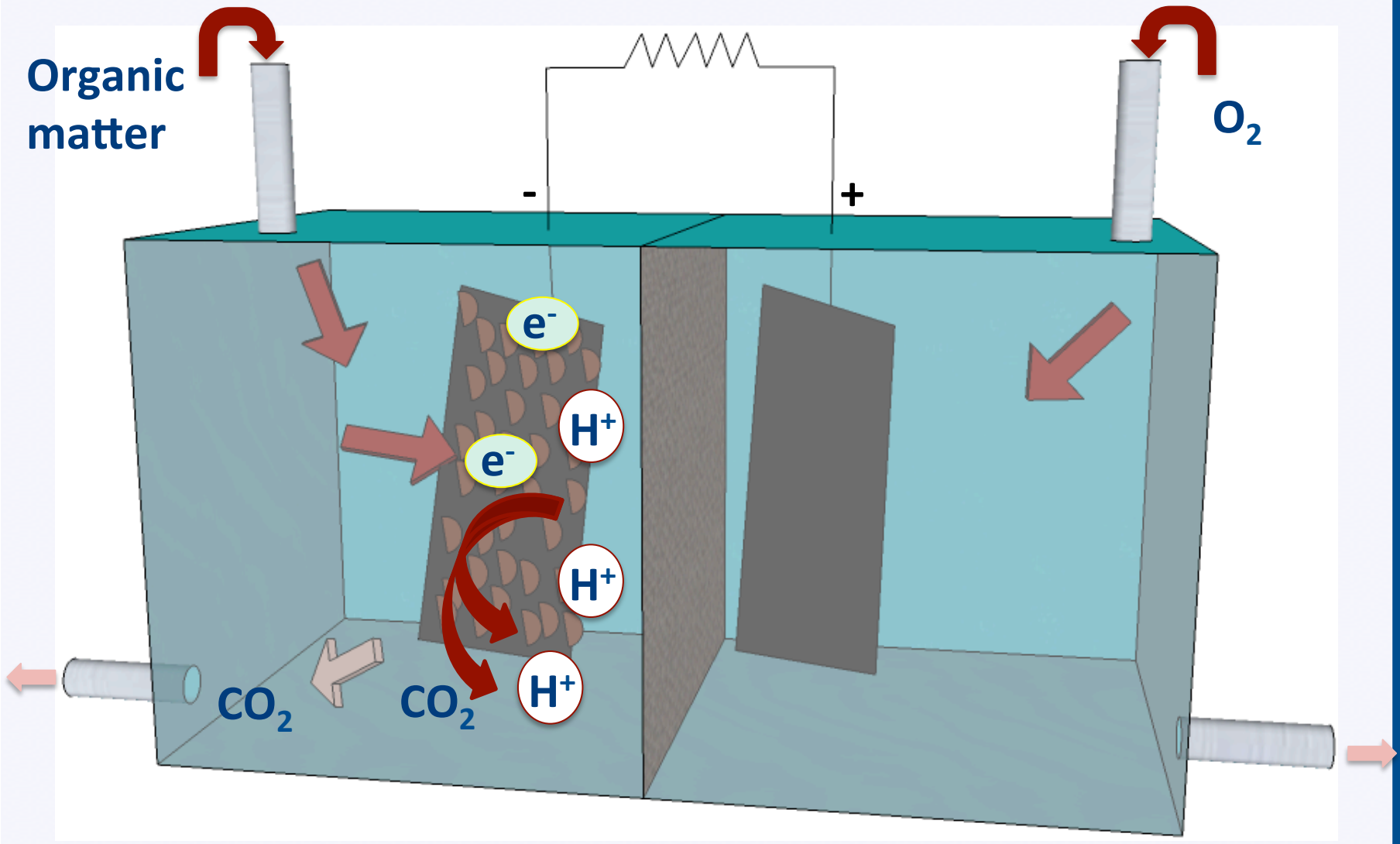

Organic matter $\longrightarrow$ e^- + H^+ + CO_2

BFCs: Principles of operation

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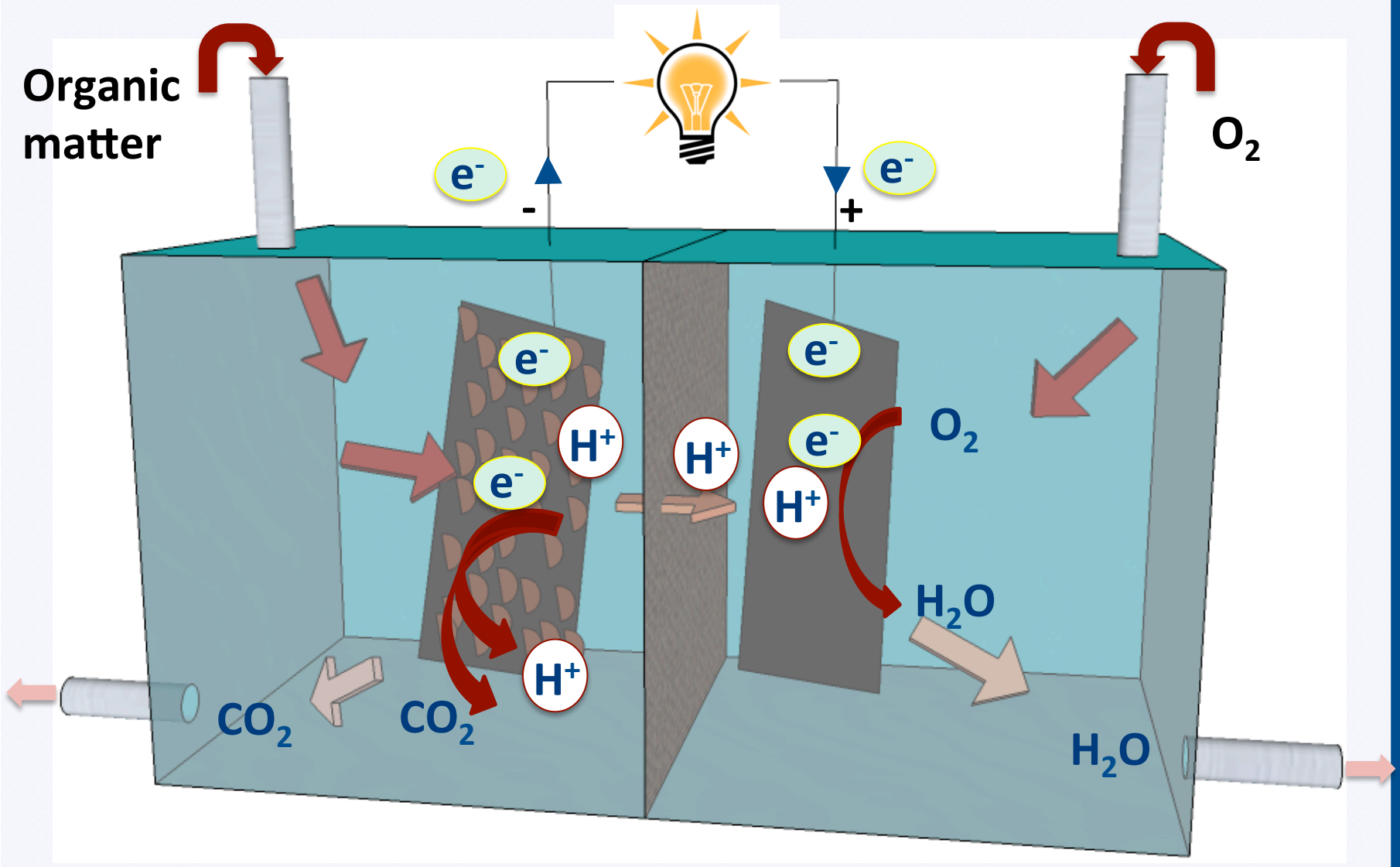
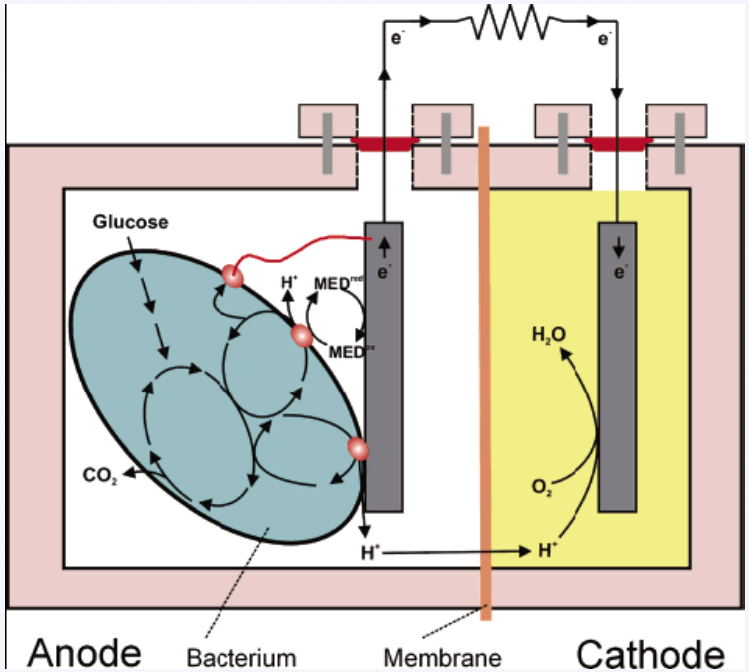


Organic matter $\longrightarrow e^- + H^+ + CO_2$

$O_2 + e^- + H^+ \longrightarrow H_2O$

How can bacteria generate electricity?

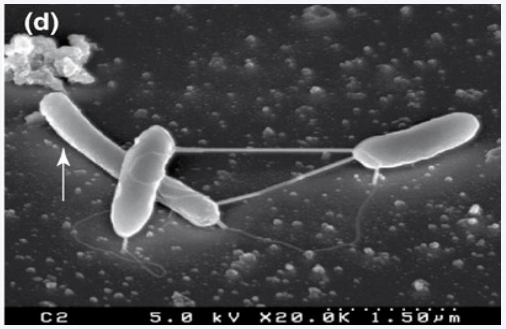


Mediated electron transfer (MET):

- By means of low molecular weight electron shuttles
- Electron shuttling proteins

Direct electron transfer (DET):

- From cell surface of redox active proteins
- Via electron conductive "nano-wires" produced by the bacteria (wired community)
- By other yet undiscovered pathways



Trends in Microbiology, Vol 14, No.12

BFCs harvest energy from waste

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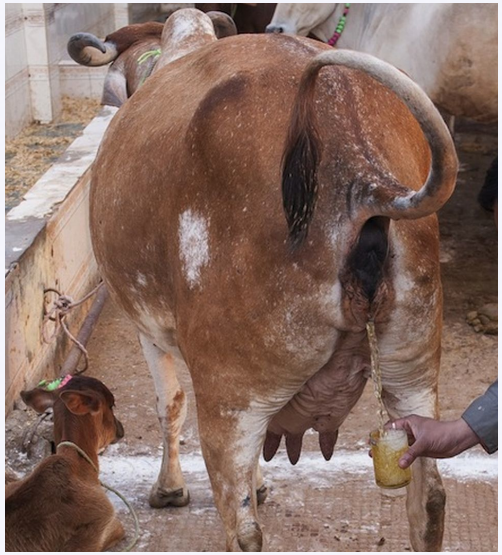
Industries

Agriculture



Farms

Domestic

2. Energy from wastewaters

Waste as a resource

- 2.4 billion people worldwide have no sanitation
- In UK over 10 bn litres of sewage produced every day
- Almost 2% of the average daily electricity consumption in UK is used to treat sewage
- Wastewaters contain more chemical energy than this!
- Giving value to these wastes would alter economics in favour of deploying treatment, and would improve social conditions, environmental emissions and energy conservation and security

Areas of research

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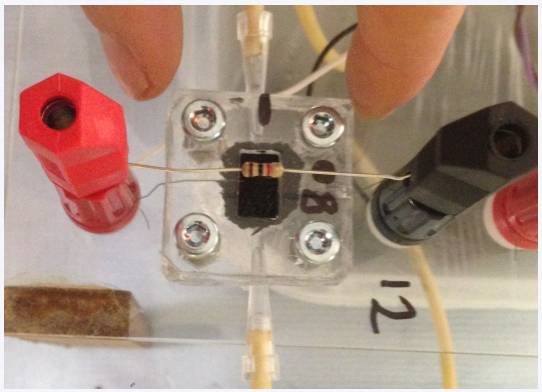
1
Innovative designs

3
Optimising the operational conditions



2
Cost-effective materials

Enhancing power generation

Pee power!

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2. Energy from wastewaters

Powered by a pee

Battery that has a wee bit more power

MONDAY 18.04.2016 DAILY MIRROR

McBoatface is top name

Urine mobile power for £1

MORE AT DAILYRECORD.CO.UK

Generating electrici-pee

Tiny fuell cell uses urine to generate electricity

- Miniature device costs as little as £1
- New design is small and powerful

Mini fuel cell spark of hope from urine

New fuel cells produce electricity using urine

Fuel cell is re-volt-ing

Tiny fuel cell uses urine to make electricity

Wee idea that set to have a big impact

...and finally

Photo-BFCs

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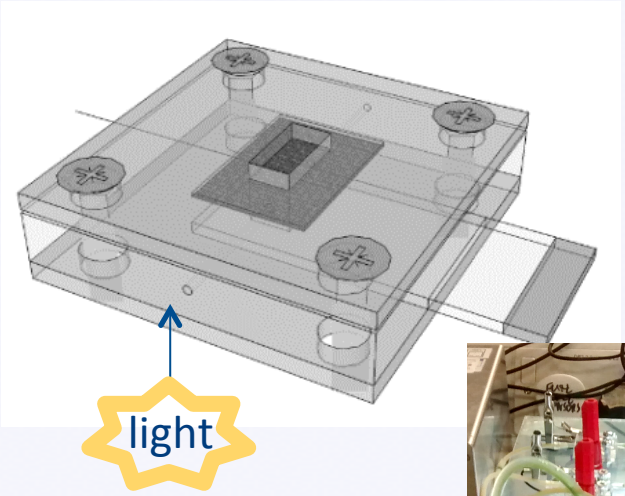
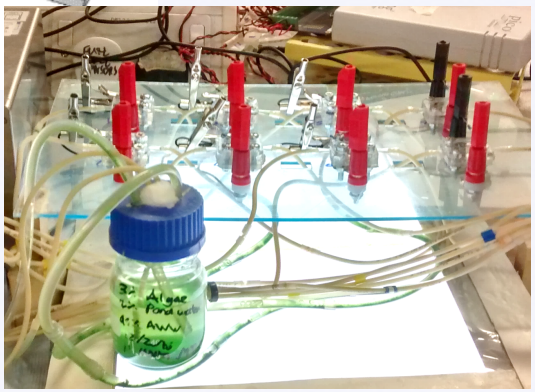
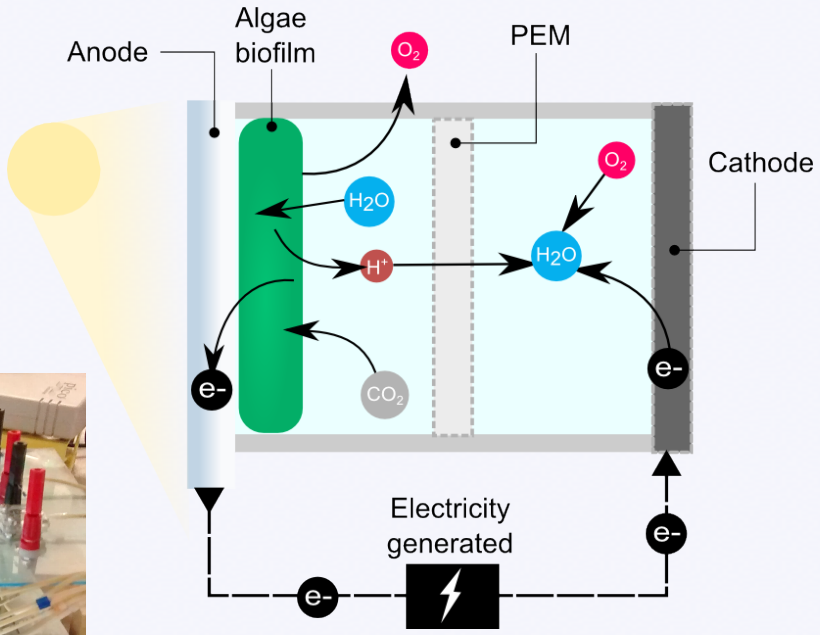
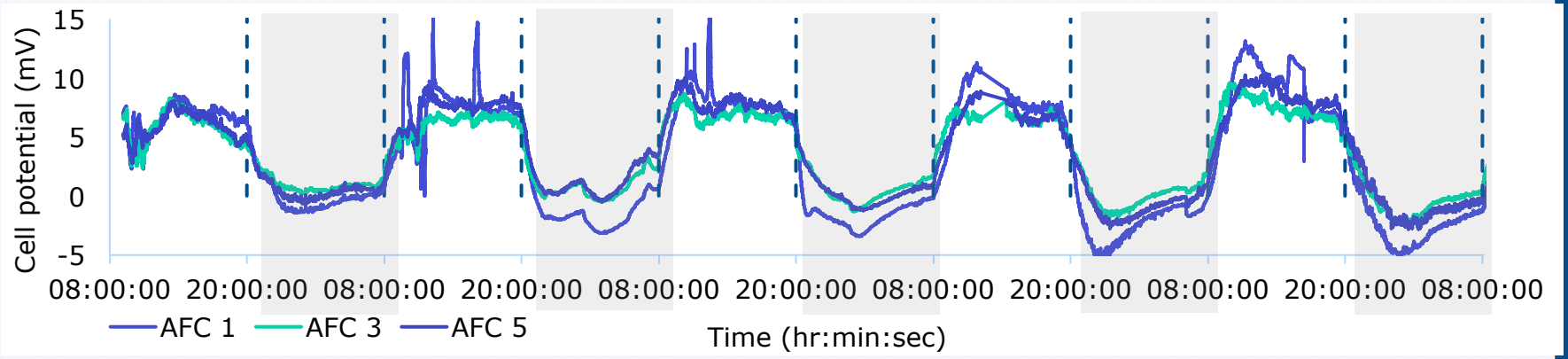


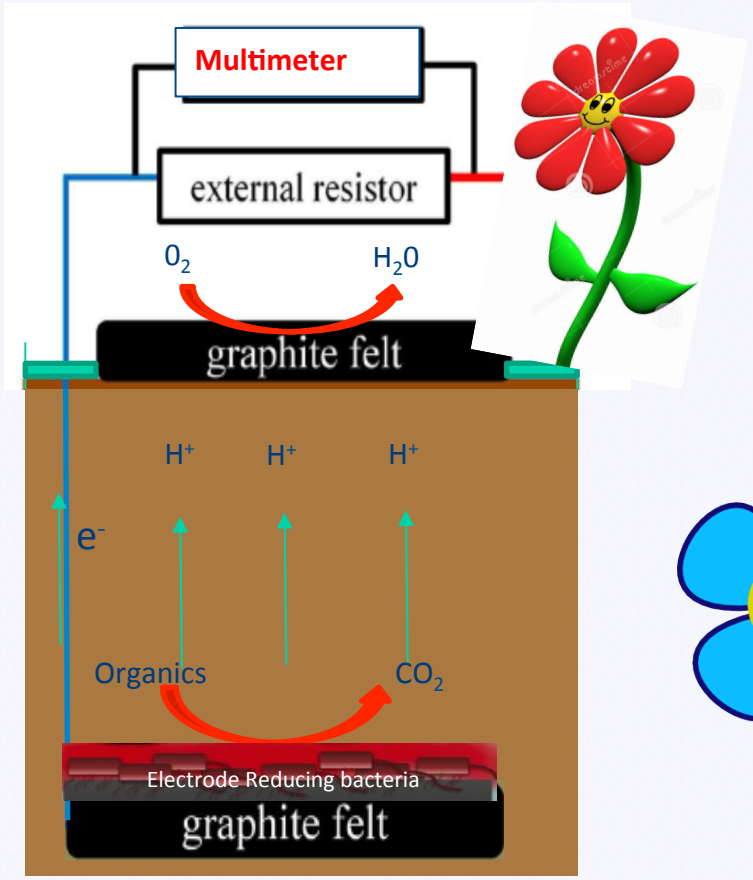


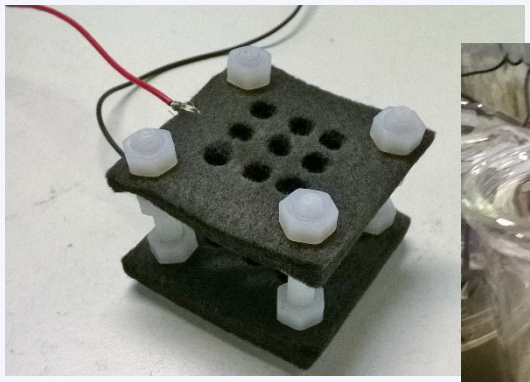




2. Energy from wastewaters

Power from the pot!





Why water quality monitoring

The heavy use of chemicals (agricultural, industrial and domestic) has increased the risk of freshwater contamination.

The detection at very low concentration (*micropollutants*: picograms per litre to nanograms per litre) via traditional analytic tools can be difficult.

Real time on site monitoring is important to:

- Undertake *immediate action;*
- *Map the distribution* of micropollutants in surface water;
- Assess and *monitor the efficacy* of the wastewater treatment.

MFC sensors

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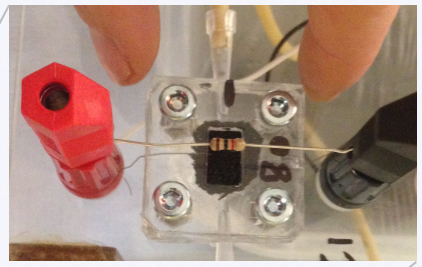
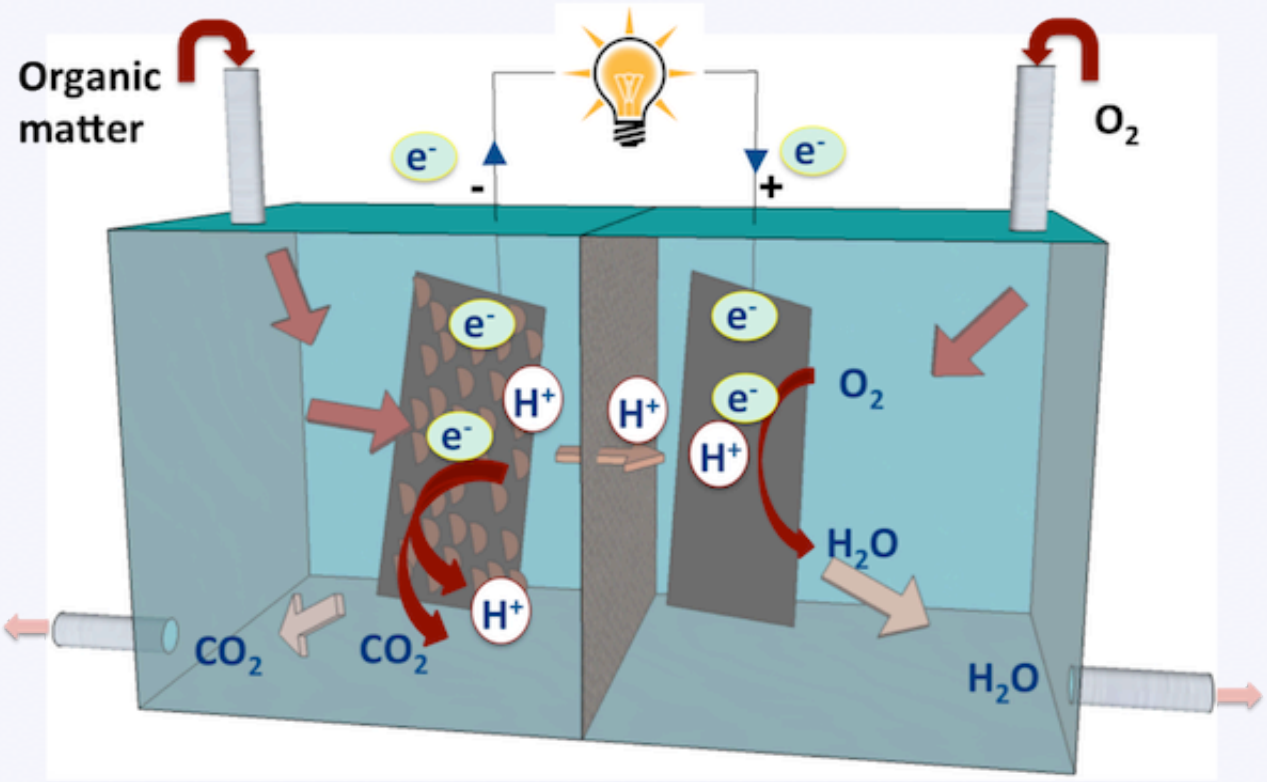
Microbial fuel cells as sensors for water quality:

Bioactivity investigations
Online monitoring
On site operation
Cost-effective and simple
Self-powered operation



How BFC can be used as biosensors?



The current generated by the BFC is an *indicator* of the *metabolic activity* of the electroactive bacteria at the anode

Detection of toxicants

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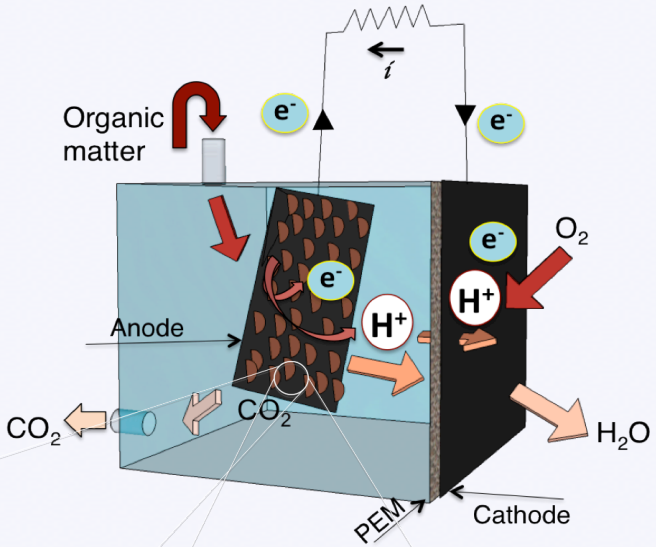
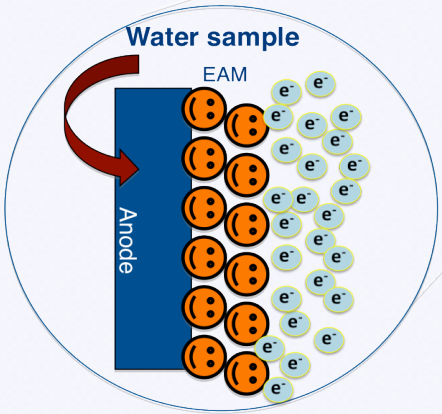
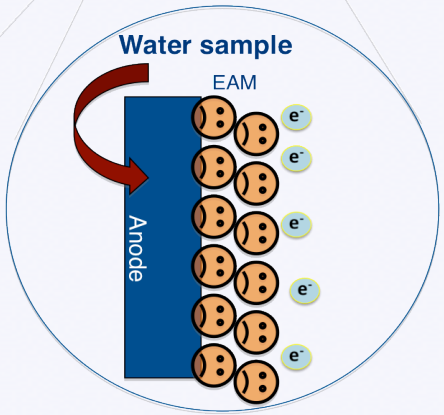
If the BFC works at ***saturated*** fuel concentration, and other parameters such as pH, salinity, temperature and anode potential are fixed, then unexpected variations in the current output can be associated with the presence of toxicants in the feeding stream





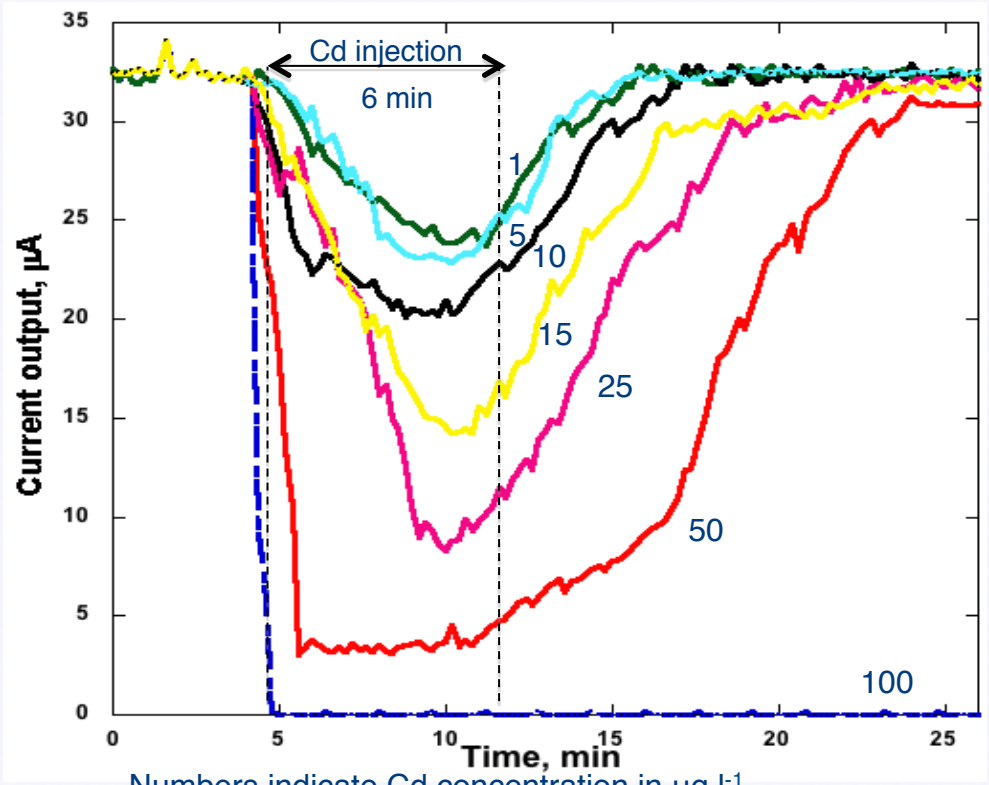
SAFE WATER



WARNING!

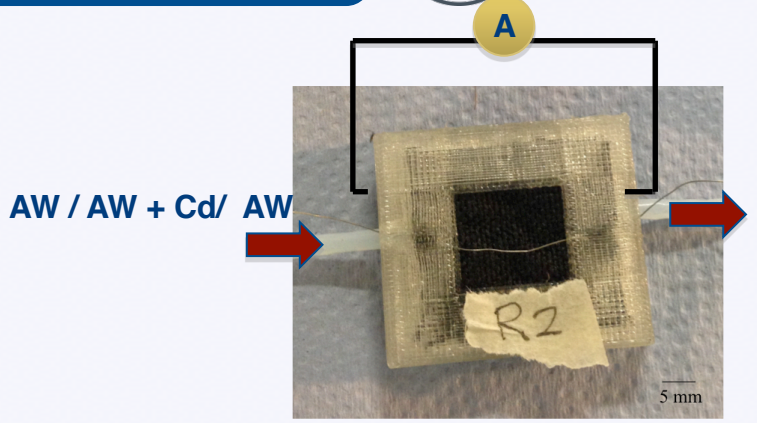
EAM: electroactive microbes

Response to cadmium (as $Cd^{2+}SO_4^{2-}$)

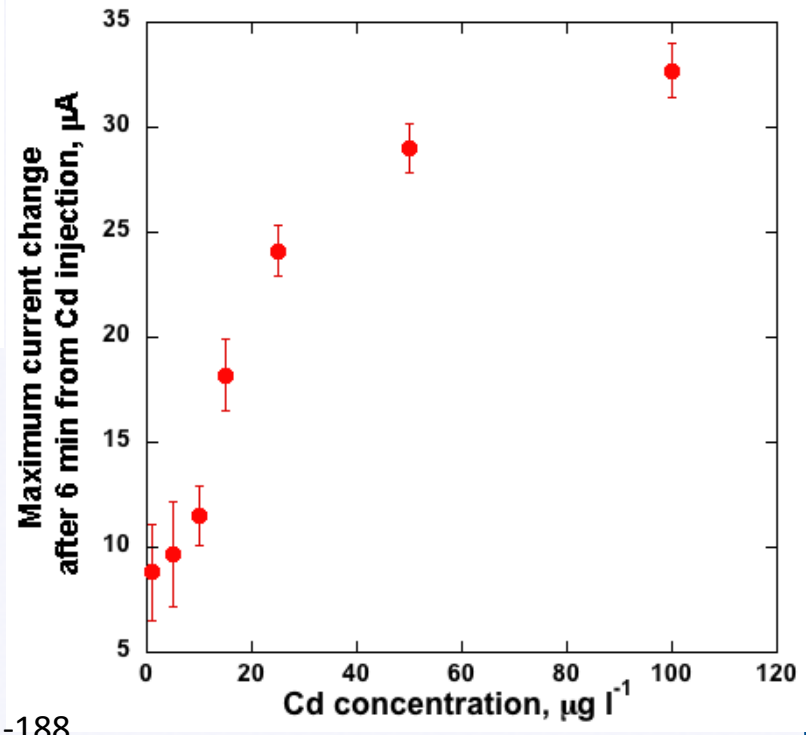


Numbers indicate Cd concentration in µg l^{-1}

- Dynamic range: **1 - 25 µg l^{-1}**
- Lower detection limit: **1 µg l^{-1}**
- Sensitivity (with respect to anode surface area): **0.2 µA $µM^{-1}$ cm^{-2}**



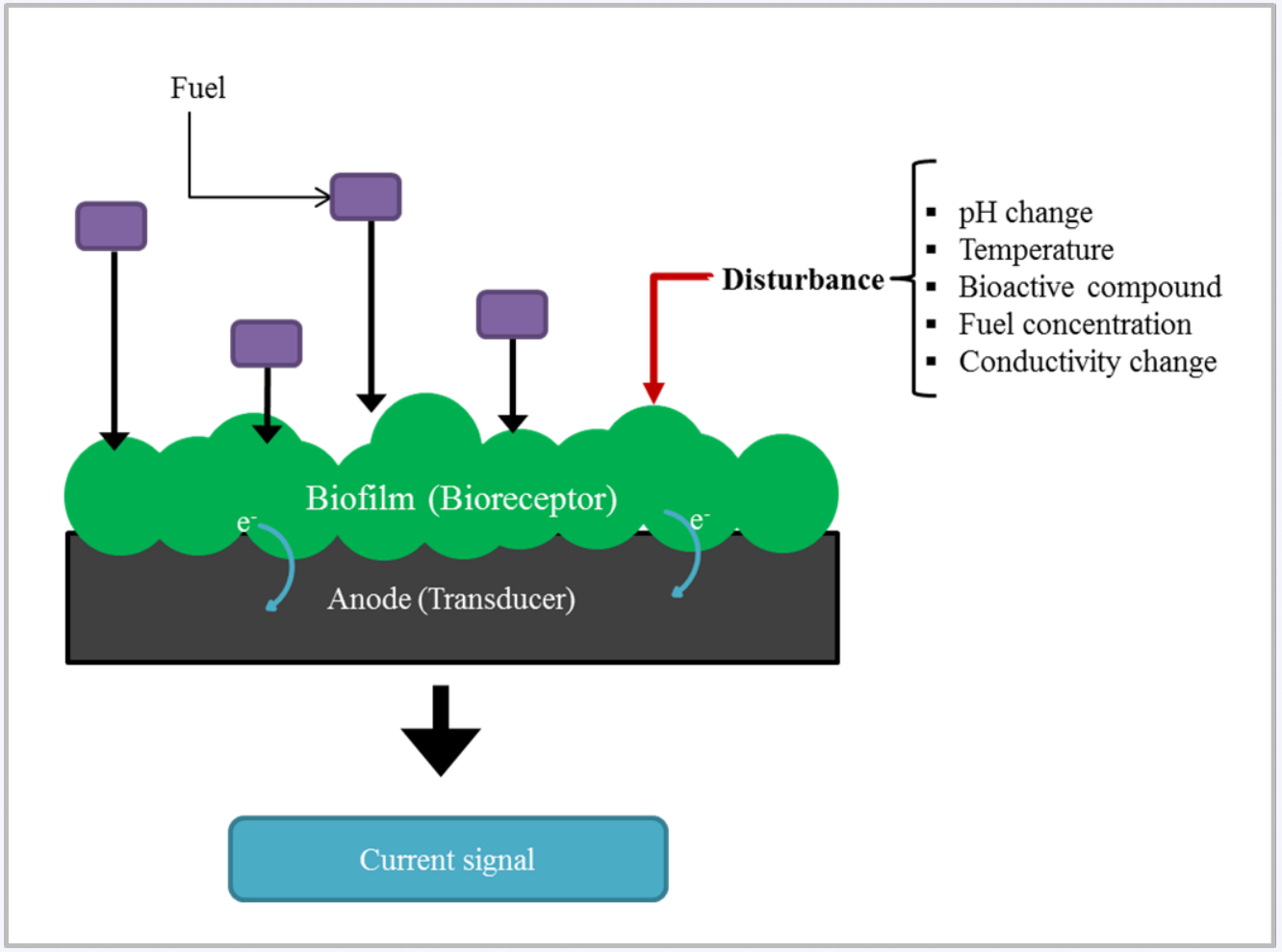
AW: Artificial wastewater containing 3 mM of acetate as fuel



Di Lorenzo M, et al. 2014 Biosensors and Bioelectronics, 62:182-188

3. Sensors for Water

Does my research need more math?



Chouler and Di Lorenzo, Biosensors, 5(3), 450-470, (2015)

Does my research need more math?

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- Need for:
- A consistent method to interpret the output signals of the BFC sensor and filter out all the noise and disturbances to prevent false positives or false negatives;
- A way to ‘display’ complex data in a user-friendly way that also non-experts can easily understand;
- A way to support effective device designs with mathematical models