Title of Project
Development of open source camera trap powered by plant microbial fuel cell (pMFC)

Summary
We propose a competition where teams of plant biologists, designers and electrical engineers would be invited to design, build and test a prototype of plant microbial fuel cell (pMFC).
The pMFC will serve as an environmentally friendly power supply to power sensor and camera-trap in remote field locations such as tropical forests. An artistic representation of the pMFC is depicted in **Figure 1**.
The aim is that these prototypes is to contribute to the development of solutions that solve battery maintenance challenges associated with deployments of conservation technology and ultimately allowing to perform better monitor and assess the status of our natural resources worldwide.

Figure 1. Artistic representation of the pMFC

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Our Team

- **Dr Paolo Bombelli, Biochemistry, University of Cambridge:** Paolo has a multidisciplinary background with specific interests in energy conversion, photosynthesis and electrochemistry. Since 2007 he has been pioneering the development of plant and algal solar panels known as Bio Photo Voltaic (BPV) systems[1,2], featured in national and international press. He is currently a postdoctoral fellow in the Department of Biochemistry at Cambridge with the title of "algal electrician".
- **Ms. Rachael Kemp, Zoological Society of London (ZSL).**
  Rachael works as part of ZSL's Conservation Technology Unit developing and re-purposing emerging technologies to help solve conservation problems and make tech within reach of charities with limited resources, within a range of diverse projects. She organise Hackathons, bringing together disparate disciplines to work on solutions for pressing conservation challenges. This has included a community reporting mobile application that facilitates anonymous reporting of incidences of wildlife crime, and image recognition solutions to triage incoming camera trap images to identify potential poaching threats.
- **Alasdair Davies, Zoological Society of London (ZSL).**
  Alasdair Davies is an active conservationist and technologist within the ZSL Conservation Technology Unit and fellow at the Shuttlesworth Foundation[3]. His job focuses to research and understand how the latest technological advances can be utilised to better protect and conserve species and their habitats globally. He is a firm believer in the implementation of open source technologies and an advocate of knowledge sharing to drive forward open solutions. His objective is to break down the barriers that inhibit access to such technologies, delivering better, cheaper, reliable solutions to help the global conservation community better monitor and protect our planet.

Proposal - *general motivation*

Under the continuing threats of climate change, habitat loss and the illegal wildlife trade, our planet's biodiversity is being pushed to its limits. We urgently need to understand and protect our natural resources, but it is a challenge to assess change in real-time to understand how species are faring, and monitor wildlife populations across vast areas of remote landscape, with limited resources and manpower.

Conservationists at the Zoological Society of London have been examining how to overcome the time-sink presented by the maintenance of field equipment – changing batteries in camera traps and sensors, for example - that are regularly deployed as part of species monitoring and protection activities. This issue is a particularly significant challenge for conservationists, who are often pushed to their limits in terms of time and resource.

The development of a camera trap powered by pMFC could contribute to solve this pressing challenging situation.

Proposal – *methodology*

The development of the customised pMFC will be out-sourced. Teams formed by plant biologists, designers and electrical engineers will be invited to compete for designing and building a robust, transportable prototype of a BPV system that delivers a low-cost, environmentally friendly power supply to operate sensors in remote field locations. The idea is depicted in **figure 2**.

Two successful applicant teams will be selected for their ability to demonstrate both their manufacturing capability and bio-electrochemical knowledge to complete the task.

The prototypes built by the successful applicants will be expected to generate a minimum of 2500mC (@3.5V) per day – this is enough to "wake up" a device, take a single photo per day and return to a sleep mode. This energy should be able to be cumulatively stored by means of a non-toxic charge accumulator (e.g., capacitor). The designed solution must be able to work in areas beneath the canopy where conventional solar power generation is ineffective. The design will also need to use local, shade- loving vegetation to avoid the introduction of non-native species; be robust but as lightweight as possible (max 5kg per entire prototype – dry weight) and have dimensions conducive to being carried in a rucksack. All designs will be subject to open licenses. The technology on wich pMFCs operate is described in the **appendices 1**.

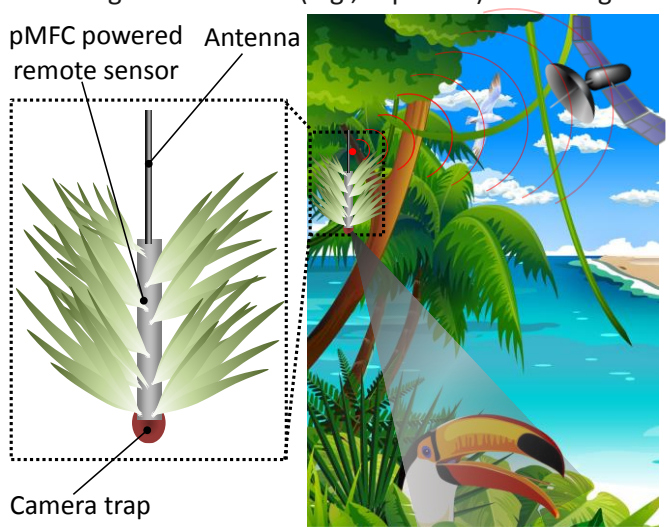

Figure 2. Cartoon of a pMFC powered remote sensor in operation.

Benefits and outcomes

Upon completion, this project will have a tangible outcomes (development of a pMFC for powering remote camera trap) which can be shared with the scientific community, as well as wider interest groups such as biohacking conservationists.

The legacy of the project will also be a pool of opensource information which will enable further development of these components for new applications.

For bio-electrochemical systems research to make progress, an interdisciplinary approach is essential, and this is reflected in our team and in the nature of the teams that will be invited to join this project. Our project promotes interactions between synthetic biologists and biochemists based in Cambridge, conservationists based at the ZSL.

While plants modified by the mean of synthetic biology can not be tested in wild remote locations, their use into experiment trials within the context of the adequate labs, could offer a valid tool for optimising the performance of pMFC systems.

The blueprints for the pMFC will be distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Sponsor for the research and cost centre

Paolo Bombelli, postdoc in Department of Biochemistry (university of Cambridge).

(I confirm that I have the full support of the sponsor listed above and that they can be added to the OpenPlant Fund mailing list to receive project updates (to which they can unsubscribe at any time)

Budget

We perceive that the funds necessary for supporting the work of the two most promising teams is in the region of £20,000.

With a generous support of £5,000 from the OpenPlants Initiative (£4,000 + £1,000) and the £5,000 already available through the Arribada Initiative we will secure 50% of our budget. We are also approaching the SAP Gatsby Foundation and other charitable organisations for the remaining £10,000, aiming to give two teams the resource they need to build three prototypes each. This gives the option for multiple deployments to enable adequate testing and iterative development. If we are unable to reach the £20,000 figure, the number of prototypes built will need to be reduced.

Relevant references

[1] McCormick 2015 *Energy Environ. Sci.*, doi: 10.1039/C4EE03875D
[2] Bombelli 2016 *Royal Society Open Science* doi: 10.1098/rsos.160249
[3] https://www.shuttleworthfoundation.org/fellows/alasdair-davies/
[4] Bombelli 2013 Appl Microbiol Biotechnol., doi: 10.1007/s00253-012-4473-6

Appendices 1 - pMFC

pMFC (Plant Microbial Fuel Cell) can be described as biological solar panels. In this configuration, the photosynthetic plants are used for feeding heterotrophic soil bacteria living in the rhizosphere of the plant. Then those bacteria produce electrons that can be collected by an anode. The schematic shown in **figure 3A** displays the main components for a generic pMFC system.

Current research in pMFC exploits several different vascular plants, for example rice (*Oryza sativa*, **figure 3B**). This investigation has also triggered a further pMFC study that has been conducted with moss species as shown in **figure 3C**.

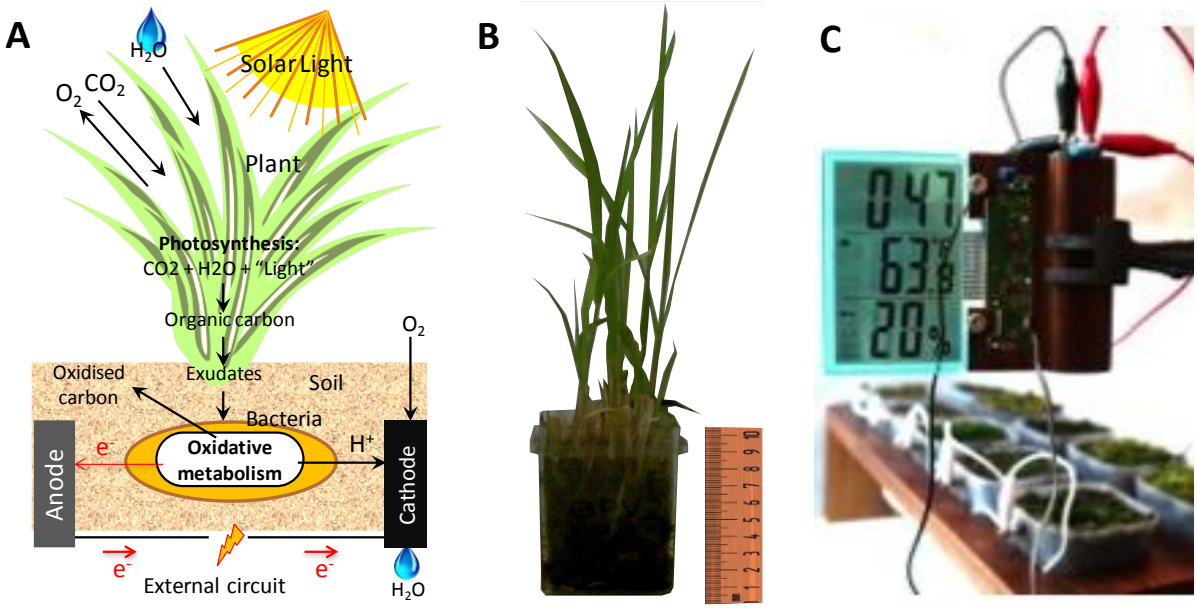

Figure 3. A) Principle of operation for a generic pMFC system. B) Actual experimental pMFC system used for experimental work[4]. B) pMFC system operated with moss and used to power an environmental sensor[3].