Research Areas within Bioscience for Renewable Resources and Clean Growth / AY 2023 -2024

Supervisor: Prof Paul Dupree (pd101@cam.ac.uk)

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Department / UPI: Biochemistry

Research area:

The assembly and function of plant cell wall properties are based on polysaccharide structures and molecular interactions. They are the most abundant renewable resource on the planet and will provide the feedstock for post-fossil materials such as plastic replacements and textiles. They determine plant cell growth and shape. They are the main component of fibre in our diet. Our research aims to understand the biosynthesis, structure and function of polysaccharides, using a wide range of biochemical techniques and plant species. By discovering new structures, and manipulating the biosynthesis, we are uncovering the structure-function relationships. The project will focus on understanding synthesis of mannan, xylan or pectin, how these polysaccharides function in the plant cell wall, and how they contribute to a healthy diet.

BBSRC DTP secondary strategic theme: Bioscience for sustainable agriculture and food

Supervisor: Prof Chris Howe (ch26@cam.ac.uk)

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Department / UPI: Biochemistry

Research area:

(1) The use of photosynthetic microorganisms for direct production of electricity, and how photosynthetic microorganisms cope with stressful light intensity. We have shown that photosynthetic bacteria and microalgae can produce electrical power directly on illumination, and have successfully used this to power a small microprocessor. We aim to understand the process better in order to enhance power production and develop new applications. We also aim to understand the general mechanism of photosynthetic electron transfer in more detail, including possible pathways of protection against excessive light levels. See Bombelli et al. (2022) “Powering a Microprocessor by Photosynthesis” Energy & Environmental Science 15:2529-2536 and Slater et al. (2021) “The evolution of the cytochrome c6 family of photosynthetic electron transfer proteins” Genome Biology & Evolution, 13:8 evab146 doi:10.1093/gbe/evab146

(2) Dinoflagellate algae and coral bleaching. Symbiotic dinoflagellate algae underpin the growth of corals, but when the symbiosis breaks down the algae are expelled and the corals bleach. This is probably due to a disturbance of photosynthesis. We have developed novel methods for studying dinoflagellate chloroplast biology, which will help us understand why the symbiosis breaks down and bleaching occurs. See Nimmo et al. (2019) “Genetic transformation of the dinoflagellate chloroplast” eLife (2019) 8:e45292. doi.org/10.7554/eLife.45292

BBSRC DTP secondary strategic theme: Understanding the rules of life

Supervisor: Dr Ewa Marek (ejm94@cam.ac.uk)

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Department / UPI: Chemical Engineering and Biotechnology

Research area:

Some ureolytic bacteria are able to form CaCO3 through a process known as Microbially Induced CaCO3 Precipitation (MICP). In MICP, the ureolytic bacteria enzymatically hydrolyse urea to form dissolved inorganic carbon, and ammonium and hydroxide, by means of the urease and carbonic anhydrase (CA) enzymes, respectively. In the presence of calcium ions, the urea-sourced carbon precipitates into CaCO3, and the increase in pH increases CO2 dissolution, which may subsequently also precipitate into CaCO3. While this pH-dependent CO2 solubility is relatively well understood, the precise role of the CA enzyme as a biological catalyst for the hydration of CO2 remains little explored. A better understanding, however, could result in a greater rate and magnitude of CaCO3 precipitation and CO2 sequestration, opening doors for bio-based and bio-enhanced Carbon Capture and Storage (CCS), carbon drawdown, energy storage and heat generation with heat pumps.

Another remaining problem of MICP is NH4+, which drives the process, but when it lingers in water or soil, it can lead to NH3 emissions or groundwater eutrophication. We propose neutralising the NH4+ in-situ during the MICP reaction by precipitating the alkaline ions into struvite (MgNH4PO4·6H2O), a well-known slow-release fertiliser. Intertwining MICP with the formation of the fertiliser could help improve the quality of soils at a very low cost, e.g. in developing countries. Yet, the influence of struvite on the bacterial cycle is currently unknown and requires dedicated studies.

This would be a larger and collaborative project in a team with researchers from the Dept. of Engineering and from the University of Texas (US).

BBSRC DTP secondary strategic theme: Bioscience for sustainable agriculture and food

Supervisor: Prof Angelos Michaelides (am452@cam.ac.uk)

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Department / UPI: Chemistry

Research area:

There is plenty of water on earth but not enough of it is drinkable. To make better use of our planets greatest resource new and improved approaches for purifying and desalinating water are required. Inspired by natural water filters (aquaporin) this project will develop and apply computational approaches to understand and control water from through narrow (sub-nanometer) wide channels. The goals are to understand the fundamental principles that control water flow through such channels and to use these insights to guide the development of improved water desalination membranes.

BBSRC DTP secondary strategic theme: Transformative technologies

Supervisor: Prof Erwin Reisner (er376@cam.ac.uk)

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Department / UPI: Chemistry

Research area:

Semi-artificial photosynthesis and biohybrid systems to power sustainable chemistry by sunlight. We develop new biological and bio-inspired concepts and technologies for the conversion of solar energy and renewable electricity into sustainable fuels and chemicals for a circular economy. Thus, we explore biochemical aspects of energy and sustainability, in particular photo- and electrocatalysis and the interface of synthetic chemistry, materials and nano-science, chemical biology, synehtic biology and engineering. Central themes of our cross-disciplinary and collaborative approach are the development of processes for the upcycling of plastic and biomass waste as well as the use of carbon dioxide and water to produce green fuels and chemicals for a sustainable future.

A recent review can be found here: https://doi.org/10.1039/C9CS00496C

Two recent research articles: https://rdcu.be/cSdcA and https://doi.org/10.1073/pnas.1913463117

BBSRC DTP secondary strategic theme: Transformative technologies