Project title: Quaternary and methylated amine cycle in coastal oceans: new genes, novel microbes and unexpected pathways

Host institution: University of Warwick

Theme: Organisms, ‘omics’ and biogeochemistry

Key words: trace gas, climate, marine microbiology, biogeochemistry, biogeochemical cycles

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Project Highlights:
• New genes, novel microbes, unexpected pathways
• World-leading supervisory team on climate-change microbiology

Overview
Quaternary amines such as glycine betaine and choline are ubiquitous in marine biota. Once released into the marine environment, the degradation of these compounds in marine ecosystems contributes significantly to the production of climate-active trace gases, the potent greenhouse gas methane and the volatile marine aerosol precursors methylated amines (Fig. 1).

Microbial amine cycles are of great importance in the coastal oceans. For example, coastal sediments are estimated to contribute to ~75% of the global oceanic methane emissions (8-13 Tg yr⁻¹). As much as 90% of the methane produced in salt marsh sediments (Oremland 1982), is derived from the degradation products of quaternary amines. Another study showed that the addition of quaternary amines to sediment microcosms markedly stimulated methane production and these compounds accounted for up to 60% of methane production in coastal marine sediments from Lowes Cove, USA (King 1984). Quaternary amine degradation also releases methylated amines (e.g. trimethylamine) and these volatile compounds can not only be used directly by methanogens for methane production, but can also be released into the atmosphere. Recent studies have shown that methylated amines are important sources for marine aerosol formation, thereby contributing to the formation of cloud condensation nuclei and consequently may play an important role in the Earth’s climate.

Figure 1 Top: key analytic instruments for quaternary amine and methylated amine analyses, including (left to right) liquid chromatography-mass spectrometry, ion-exchange chromatography, gas chromatography. Bottom: Environmental impact of quaternary and methylated amine cycles in the oceans.

Our knowledge on the microbial transformation of these important climate-active compounds is very limited. Neither the identity nor the metabolic pathways involved in their transformations has been firmly established. Over the past five years, our groups have started to uncover many new genes, novel microbes and unexpected pathways responsible for the degradation of quaternary amines and methylated...
amines, including a novel flavin containing monoxygenase that is ubiquitous in marine microbes (Chen et al 2011 PNAS), a novel choline-to-trimethylamine pathway for trimethylamine formation (Jameson et al., 2015, 2016), a new pathway for trimethylamine oxide degradation (Lidbury et al 2014 PNAS).

Aims and Methodology:
The overall aim of this project is therefore to continue discovering many as yet uncovered genes, enzymes and novel pathways for methylamine amine cycles in coastal oceans. Specifically, we aim to 1) determine the role of sulfate reducing bacteria in trimethylamine cycle, 2) characterise novel substrates for trimethylamine formation, and 3) determine the role of novel Archaea in methylamine metabolism.

Microcosms studies will be performed using coastal sediment samples. Quaternary amines and methylamines will be quantified by gas chromatography, ion-exchange chromatography or HPLC mass spectrometry (MS). Metabolites of amine catabolism will be identified and quantified using HPLC-MS. The identity of microbes enriched in microcosms will be characterized by high throughput sequencing.

Training and skills:
The Supervisory team has an excellent record in PhD supervision. The last two PhD students completed from the Chen group has published 4 and 3 first-authored papers respectively, including 2 in PNAS, 1 in the ISME Journal, 3 in Environmental Microbiology and 1 in the FEBS Journal.

This exciting project provides cutting-edge training on cutting edge bioinformatics. It will also provide excellent training in wider aspects of marine microbiology, biogeochemistry and molecular biology using cutting edge biochemical, molecular and ‘omic approaches’, as well as in a variety of analytical techniques currently available in the Chen/Purdy group, including gas chromatography, ion-exchange chromatography, liquid chromatography-mass spectrometry.

Partners and collaboration (including CASE):
The Chen and Purdy groups at Warwick have pioneered research of microbial-mediated climate-active gas cycles in the marine environment, particularly methylated and quaternary amines. Current research in the groups is funded by NERC, BBSRC and the Gordon and Betty Moore Foundation. Dr Chen’s group: http://www2.warwick.ac.uk/fac/sci/lifesci/people/ychen

Possible timeline:
Year 1: Identify the role of sulfate reducing bacteria in methylamine amine metabolism.

Year 2: Microcosm enrichment using a range of quaternary amine and methylamines, monitoring methane formation, high throughput sequencing and bioinformatics

Year 3: Uncover novel enzymes and pathways in trimethylamine formation

Further reading:
Chen et al (2011) 'Bacterial flavin-containing monoxygenase is trimethylamine monooxygenase', Proceedings of The National Academy Of Sciences, 108 (43), 17791 - 17796

Further details:
Applicants from the UK or the EU are eligible. Applicants should hold a BSc and/or MSc degree in relevant subjects.

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