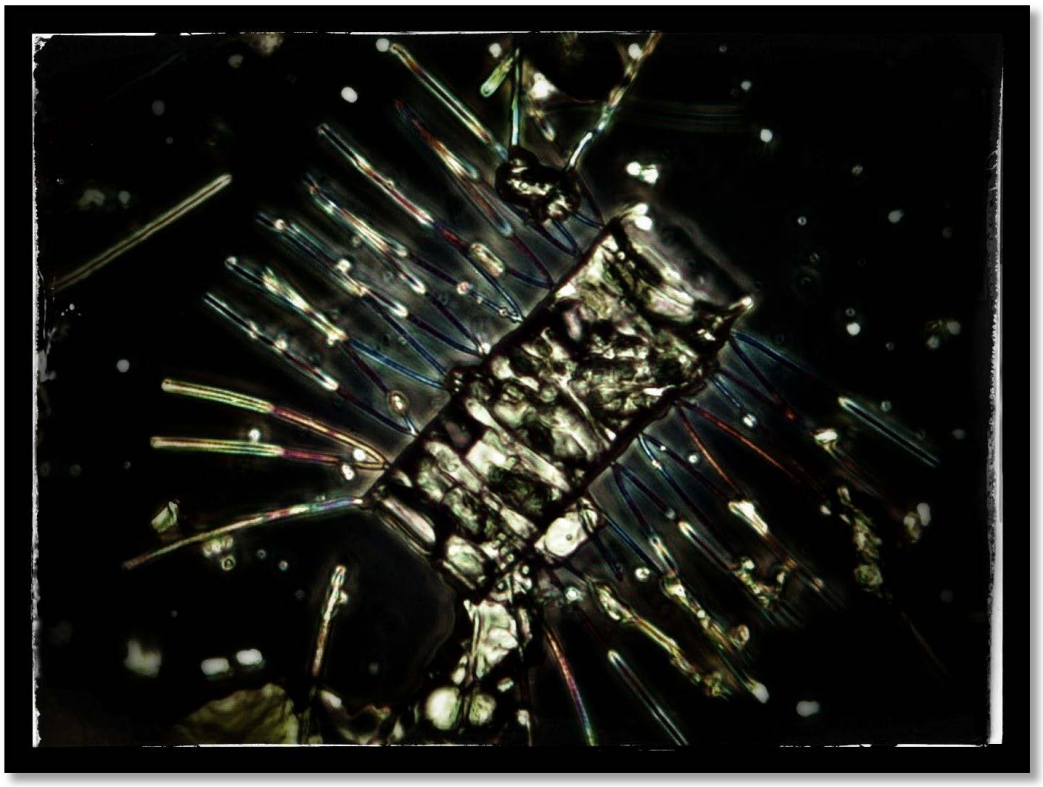
Accelerating phytoplankton phenomics through FTIR spectroscopy



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Prediction is difficult, particularly if it involves the future.

— Uncertain…depends on whom you ask.

Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.
I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Olivia Sackett

February 15, 2015

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Abstract

Marine phytoplankton play a driving role in global biogeochemical cycling, providing fuel for marine and terrestrial ecosystems, and removing substantial quantities of CO_2 from the atmosphere. Phytoplankton respond to environmental change by varying their phenotypes, including photophysiology, macromolecular composition and morphology. Southern Ocean phytoplankton are subjected to one of the most extreme habitats on earth, resulting in great phenotypic variation between and within taxonomic groups. Given they provide a significant net sink of atmospheric CO_2 and support the most biologically productive ecosystem on earth, improving our ability to predict the responses of Southern Ocean phytoplankton to environmental change is of global importance. At present, our ability to predict the responses of these critical organisms to environmental change, including climate change, is limited by a bottleneck in the efficiency with which we can characterise phytoplankton phenotypes.

This thesis demonstrates the feasibility of accelerating phytoplankton phenomics using Fourier Transform Infrared (FTIR) microspectroscopy, a powerful yet under-utilised frontier technology. The extensive phenotypic variation shown by Southern Ocean phytoplankton provided excellent scope for demonstrating the power of the microspectroscopic approach. Coupling the microspectroscopic approach with multivariate modeling tools enabled the characterisation of phenotypic plasticity from cell FTIR spectra. When combined with mass spectrometry data, cell FTIR spectra provided accurate estimates of multiple phenotypic parameters including cellular protein, carbon and energy. Of particular value, spectroscopic models were able to accurately estimate rates of carbon production from samples taken at a single time-point, circumventing the need to take measurements over time. Further, the high spatial resolution achievable with microspectroscopy enabled the analysis of individual cells, revealing taxon-specific responses to iron availability within samples taken from a mixed natural Southern Ocean phytoplankton bloom. This work demonstrates that incorporating FTIR microspectroscopy into the phenomics toolbox will improve the efficiency of phenotypic data collection and, in combination with multivariate modeling, will enable the development of powerful, taxon-specific predictive phenomic models.

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