

Heme *b* distributions through the Atlantic Ocean: *in situ* identification of iron limited phytoplankton

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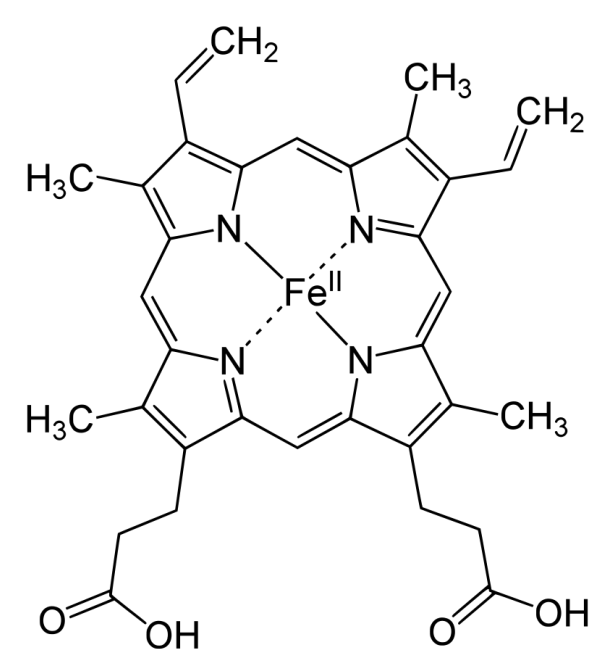
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Introduction and Motivation

What is heme *b*?

- Iron (Fe)-porphyrin complex
- The most common heme in organisms
- Prosthetic group of hemoproteins
- Found in *b* type cytochromes, catalases, peroxidases, cytochrome p450, globin and nitrate reductase



What happens to the heme *b* pool of cultured phytoplankton during Fe limitation?

- Heme *b* concentrations and quotas typically decrease
- Some prymnesiophytes and diatoms can maintain their biomass stocks despite low heme *b* [1, 2]

Motivation

- Lack of field data: heme *b* distribution poorly constrained
- Multidisciplinary research: combination of chemical oceanography, microbiology, biogeochemical modelling

Study Region and Methods

We examined the variability in heme *b* concentrations in the Atlantic Ocean by combining data from six research cruises (59.9°N to 34.6°S) (Fig. 1).

<https://www.nature.com/articles/s41598-020-61425-0/figures/1>

- Seawater (particulate matter) was sampled (filtered) from up to 6 depths per station (<200 m)
- Heme *b* was determined by HPLC-ESI-MS [3]
- Background parameters also monitored (POC, chl *a*)
- Modelled heme *b*: estimated from the biogenic iron pool as predicted from a global biogeochemical model (PISCES-v2)

Major Findings and Discussion

- Heme *b* concentrations in surface waters ranged from 0.10 to 33.7 pmol L⁻¹ (median=1.47 pmol L⁻¹, n=974).
- Highest heme *b* concentrations were determined in regions with a high biomass (as indicated by POC and chl *a*) (Fig 2).
- The ratio of heme *b*:POC exhibited a mean value of 0.44 μmol heme *b* mol⁻¹ POC.
- The value 0.10 μmol heme *b* mol⁻¹ POC was identified as the cut-off between heme *b* replete and heme *b* deficient phytoplankton.
- Heme *b*:POC was consistently below 0.10 μmol mol⁻¹ in areas characterized by low Fe supply (i.e. Subtropical South Atlantic Gyre and the seasonally iron limited Irminger Basin).

<https://www.nature.com/articles/s41598-020-61425-0/figures/2>

<https://www.nature.com/articles/s41598-020-61425-0/figures/5>

The comparison of observed and modelled heme *b* suggested that heme *b* could account for between 0.17–9.1% of biogenic iron. This range was comparable to previous culturing observations for species with low heme *b* content and species growing in low Fe (≤ 0.50 nmol L⁻¹) or nitrate culturing media, conditions often encountered in the natural oceanic environment [4].

Conclusions

- Heme *b* relative to POC can be a reliable indicator of iron limited phytoplankton communities *in situ*.
- The variability of the heme *b* to biomass ratios suggests that phytoplankton 1) employ diverse mechanisms to utilize the available iron in the hemoprotein pool, and 2) are able to regulate the hemoproteins under iron limiting conditions.
- Information on iron-utilization and regulation mechanisms of the hemoprotein pool would shed light on the molecular response and adaptation of phytoplankton to iron limitation.

References

1. Gledhill, M., Gerringa, L. J. A., Laan, P. & Timmermans, K. R. Heme *b* quotas are low in Southern Ocean phytoplankton. *Mar. Ecol. Prog. Ser.* 532, 29–40 (2015).
2. Gledhill, M., Achterberg, E. P., Honey, D. J., Nielsdottir, M. C. & Rijkenberg, M. J. A. Distributions of particulate Heme *b* in the Atlantic and Southern Oceans - Implications for electron transport in phytoplankton. *Global Biogeochem. Cycles* 27, 1072–1082 (2013).
3. Gledhill, M. The detection of iron protoporphyrin (heme *b*) in phytoplankton and marine particulate material by electrospray ionisation mass spectrometry - comparison with diode array detection. *Anal. Chim. Acta* 841, 33–43 (2014).
4. Honey, D. J. et al. Heme *b* in marine phytoplankton and particulate material from the North Atlantic Ocean. *Mar. Ecol. Prog. Ser.* 483, 1–17 (2013).

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