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Saturating relationship between phytoplankton growth rate and nutrient concentration explained by macromolecular allocation

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The saturating relationship between phytoplankton growth rate and environmental nutrient concentration has been widely observed yet the mechanisms behind the relationship remain elusive. Typically, the formulation to represent this trend is the Monod mathematical model and is used across biological disciplines. Here, we use a mechanistic model of phytoplankton (CFM-Phyto) to interpret this saturating relationship between growth rate and nitrate concentration, illustrating intracellular macromolecular allocation is behind this observed trend. At low nutrient levels, the diffusive nutrient transport linearly increases with the nitrate concentration, while the internal nitrogen requirement also increases with the growth rate, leading to a non-linear increase in the growth rate with nitrate. This increased nitrogen requirement is due to the increased allocation to biosynthetic and photosynthetic molecules. Allocation to these molecules reaches a maximum at high nitrate concentration and the growth rate no longer increases despite the rise in nitrate concentration. This is primarily due to the limitation in carbon, which limits the overall growth of the cell. In this study, the produced growth rate and nitrate relationships from CFM-Phyto are consistent with phytoplankton data across taxa. Our study suggests that the key control of phytoplankton growth is internal and nutrient uptake is only a single step in the overall process. Validation of the CFM-Phyto with commonly observed trends and various datasets is an essential step before incorporating this into larger ecosystem models, such as the Narragansett Bay Regional Ocean Model. This work emphasizes CFM-Phyto's ability to capture and predict trends in lower trophic organisms.