# Physical Mathematics Seminar

## How to build an effective $CO_2$-concentrating mechanism: a lesson learnt from the green alga Chlamydomonas


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**ABSTRACT:**

The $CO_2$-fixing enzyme Rubisco mediates the entry of roughly $10^{14}$ kilograms of carbon into the biosphere each year. However, in in many plants Rubisco fixes $CO_2$ at less than one-third of its maximum rate under atmospheric levels of $CO_2$. Many eukaryotic photosynthetic organisms enhance their carbon uptake by supplying concentrated $CO_2$ to the $CO_2$-fixing enzyme Rubisco in an organelle called the pyrenoid. Ongoing efforts seek to engineer this pyrenoid-based $CO_2$-concentrating mechanism (PCCM) into crops to increase yields. Here we develop a computational model for a PCCM based on the postulated mechanism in the green alga *Chlamydomonas reinhardtii*. Our model recapitulates all Chlamydomonas PCCM-deficient mutant phenotypes and yields general biophysical principles underlying the PCCM. We show that an effective and energetically efficient PCCM requires a physical barrier to reduce pyrenoid $CO_2$ leakage, as well as proper enzyme localization to reduce futile cycling between $CO_2$ and $HCO_3^-$. Importantly, our model demonstrates the feasibility of a purely passive $CO_2$ uptake strategy at air level $CO_2$, while active $HCO_3^-$ uptake proves advantageous at lower $CO_2$ levels. We propose a four-step engineering path to increase the rate of $CO_2$ fixation in the plant chloroplast up to three-fold at a theoretical cost of only 1.3 ATP per $CO_2$ fixed, thereby offering a framework to guide the engineering of a PCCM into land plants.


**TUESDAY, APRIL 12, 2022**
**2:30 PM – 3:30 PM**
**Building 2, Room 449**

https://math.mit.edu/sites/pms/

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