Testing hypotheses on cellular C fluxes in *Emiliania huxleyi* by means of kinetic models

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Abstract

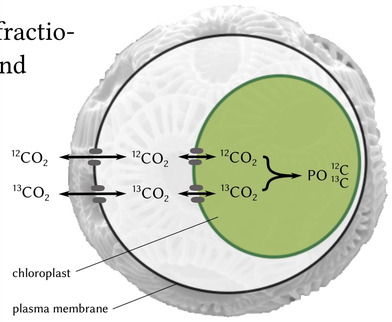
Coccolithophores play a crucial role in the marine carbon (C) cycle and thus it is interesting to know how they will respond to climate change and ocean acidification. The interplay between intracellular metabolic processes and the marine carbonate system is still not well understood. We have tested different hypotheses concerning the uptake and the flux of inorganic C species inside the cell by means of kinetic models.

Models of cellular C fluxes

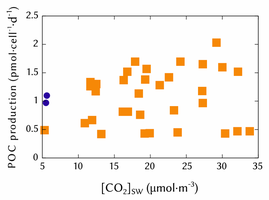
The models are constrained by experimental data of *Emiliania huxleyi*.

Isotopic C fractionation
diffusive influx of CO_2

In contrast to other C fractionation models, $^{13}CO_2$ and $^{12}CO_2$ diffuse independently of each other. The CO_2 permeability coefficient of the plasma membrane is 0.58 m·h^{-1} (aquaporin-based value measured by Uehlein et al., 2004), the one of the chloroplast envelope is one third of this value, i.e., 0.19 m·h^{-1}. Inside the chloroplast, CO_2 is fixed into POC with $^{13}R_{CO_2}$($^{13}CO_2$: $^{12}CO_2$) = $^{13}R_{POC}$ (PO^{13}C : PO^{12}C). The latter value as well as external [CO_2] were measured by Rost et al. (2002) for differently acclimated cells.

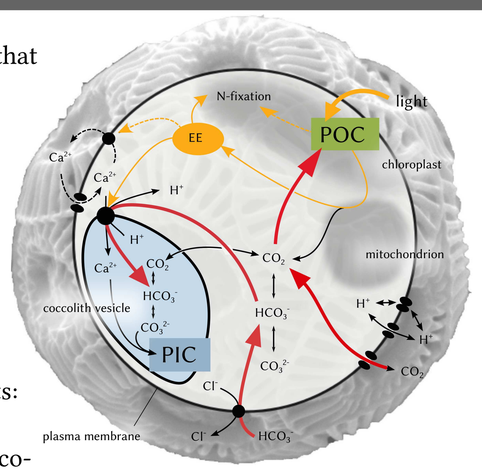


Results (fig.): 33 (orange squares) out of 35 data points of Rost et al. (2002) can be described by our model. Owing to RubisCO´s discrimination against $^{13}CO_2$, the latter CO_2 isotope accumulates inside the chloroplast and reduces the diffusive influx of $^{13}CO_2$ into the cell. An efflux of CO_2 from the cell is thus not necessary to explain the lowered ^{13}C signal of POC. A diffusive influx of CO_2 may actually provide a large part of inorganic C to organic C fixation.



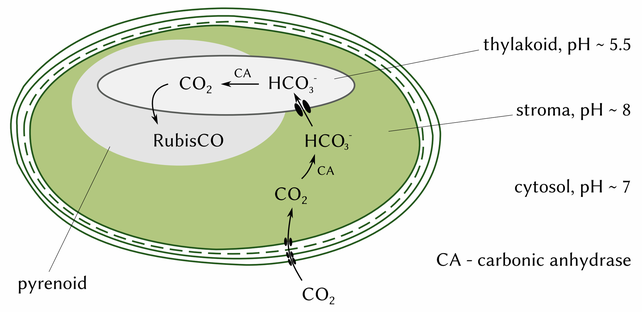
Pathway of C through cell

Based on the assumption that external CO_2 and HCO_3^- feed particulate organic carbon (POC) and particulate inorganic carbon (PIC) production, respectively (Berry et al., 2002, Kottmeier et al., in prep.), a basic cell model is established that consists of 2 compartments: the cytosol and located within the cytosol the coccolith vesicle. CO_2 enters the cytosol via diffusion with a permeability coefficient of 0.07 m·h^{-1} (aquaporin-based value of Prasad et al., 1998). HCO_3^- follows its concentration gradient into the cell with a permeability coefficient of 0.35 mm·h^{-1}. Chloroplast and mitochondria are implemented as CO_2 sink and source, respectively. The carbonate system is resolved dynamically inside both compartments. The model is constrained by POC, PIC, and external carbonate system data of Rokitta and Rost (2012) who acclimated *E. huxleyi* to four different conditions (high/low light and high/low C availability). EE in the figure stands for energy equivalents.



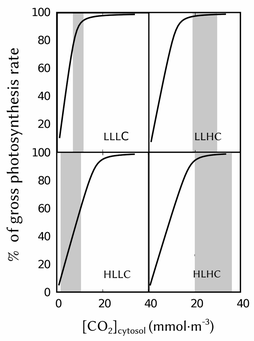
Results (red arrows in fig.): CO_2 and HCO_3^- pass the cytosol without being interconverted. According to the model, diffusive CO_2 influx can provide inorganic C for POC production.

Pathway of C through chloroplast



A potential pathway of inorganic C through the chloroplast. CO_2 follows its concentration gradient into the chloroplast (permeability coefficient: 0.19 m·h^{-1}). The gradient is established via a combination of different pH values in the chloroplast-intern compartments, carbonic anhydrase (CA) activity, and a reduced CO_2 diffusiveness into and out of the thylakoid/pyrenoid complex (permeability coefficient: 2 mm·h^{-1}). The model is constrained by the POC production data of Rokitta & Rost (2012) and the cytosolic [CO_2] calculated by the cell model.

Results (fig.): By means of the proposed mechanism, a large part of CO_2 needed for POC production can be provided. Under **H**igh **L**ight and **H**igh **C** (HLHC) as well as under **L**ow **L**ight (LLLC and LLHC) more than 80%, while under **H**igh **L**ight and **L**ow **C** (HLLC) only up to ~60% can be provided. Shaded areas indicate the range of cytosolic [CO_2] that is calculated by the cell model when assuming two different permeability coefficients for the plasma membrane: 0.07 m·h^{-1} (Prasad et al., 1998) or 0.58 m·h^{-1} (Uehlein et al., 2004).



Conclusion

An active accumulation of inorganic C inside the cell that leads to a diffusive CO_2 efflux is currently favoured in literature. Our approaches, in turn, show that a diffusive CO_2 influx may contribute strongly to photosynthetic C assimilation in *E. huxleyi*.

Literature:

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