**1) We uncovered a unexpected role for reactive oxygen species in balancing the energy budget of photosynthesis by activating a highly-efficient mechanism for storing light energy in ATP.**

The flow of energy from photosynthesis into ATP and NADPH must be very finely balanced to meet the demands of metabolism. Even a small imbalance will result in loss of energy and photodamage, and is thus critical for robust and efficient photosynthesis especially under fluctuating environmental conditions. We identified the reactive oxygen species, H2O2 as an unexpected signal molecule to regulate this balance. Specifically we showed that light-induced production of H2O2 in the chloroplast, which occurs when there are mismatches in the production and consumption of ATP relative to NADPH, activates cyclic electron flow through the chloroplast NDH complex, which acts to store additional energy in ATP, thus rebalancing the energy budget. This work is the first evidence for direct enzyme-level regulation of photosynthetic energy flow by a ROS.

D.D. Strand, A.K. Livingston, M. Satoh-Cruz, J.E. Froehlich, V.G. Maurino, D.M. Kramer (2015) Activation of cyclic electron flow by hydrogen peroxide in vivo. **Proceedings of the National Academy of Sciences** 112, 5539-5544

**2) Our work is opening up the field of photosynthetic ion circuitry, by identifying the importance of newly-discovered thylakoid ion transporters in regulating photosynthesis.**

The thylakoid proton motive force is the essential driving for the synthesis of ATP in photosynthesis. It also acts as a central feedback regulator of photosynthesis, and is key to preventing self-destruction of the photosynthetic apparatus under adverse environmental conditions. A critical question for understanding the regulation of photosynthesis is how these two roles are balanced. Over the past 10 years or so, my group has developed methods of probing this balancing act [1-6] and proposed that it involves the action of hypothetical ion channels and transporters and buffers. Over the past few years, we have been collaborating with two groups using two distinct approaches, we were able to confirm the existence and identities of these transports in chloroplasts, and show that they are critical for the responses of photosynthetic to fluctuating environmental conditions. I am very happy about this, not only because it confirmed our big hypothesis, but also because it has opened up a new field of the chloroplast ion circuits.

H.-H. Kunz, M. Gierth, A. Herdean, M. Satoh-Cruz, D.M. Kramer, C. Spetea, J.I. Schroeder (2014) Plastidial transporters KEA1,-2, and-3 are essential for chloroplast osmoregulation, integrity, and pH regulation in Arabidopsis. **Proceedings of the National Academy of Sciences** 111, 7480-7485.

U. Armbruster, L.R. Carrillo, K. Venema, L. Pavlovic, E. Schmidtmann, A. Kornfeld, P. Jahns, J.A. Berry, D.M. Kramer, M.C. Jonikas (2014) Ion antiport accelerates photosynthetic acclimation in fluctuating light environments. **Nat Comm** 5, 5439

**3) A new biophysical “Achilles Heal” of photosynthesis.** This work revealed a previously unrecognized biophysical mechanism for sensitizing photosystem II (PSII) to photodamage under fluctuating light that appears to limit the productivity of plants in the field. The results suggest ways to monitor plant status and select for or engineer improved photosynthesis.

(This work is still in revisions at Science Advances (reviews were quite positive, but Science kicked it down to Advances because…well….), but I think it is potentially the most important thing we’ve shown to date. )

More specifically, we showed that rapid increases in light intensity induce large “spikes” in the electric field ( component of the thylakoid proton motive force. These spikes in turn induce recombination reactions within PSII that lead to the production of the highly reactive singlet O2, causing rapid PSII photodamage. The effect is under growth, suggesting that this mechanism is an important factor in productivity loss. The work also hints at ways in which we may engineer plants to ameliorate this weakness, possibly making plants more robust and productive.

G.A. Davis, A. Kanazawa, M.A. Shoettler, K. Kohzuma, J.E. Froehlich, M. Satoh-Cruz, D. Minhas, A. Dhingra, D.M. Kramer (2016) Limitations to photosynthetic efficiency caused by proton motive force-mediated Photosystem II photodamage **Science Advances** submitted.

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