Robust Photosynthesis in Dynamic Environments

**Main text:**

Plants rely on absorption of light energy to meet their biochemical needs for cell maintenance, growth, and defense, through photosynthesis, the process that provides food and energy for most of life on Earth.

Decades of research have given us a detailed view of the core cellular components of photosynthesis. These components have been studied the most thoroughly under highly controlled laboratory conditions.

But plants' natural environments are highly unpredictable: light conditions can change in fractions of a second, while rapid changes in other factors, such as temperature or moisture, can affect how well the photosynthetic machinery can operate.

Understanding how plants survive in natural environments is crucial, not only for increasing our knowledge of how they work, but also to produce crops with higher photosynthetic efficiencies and increased yields, as we tackle the problems of climate change, feeding billions more people, and producing biofuels with cleaner environmental footprints.

# The challenge: studying photosynthesis in dynamic environments

At the PRL, we are researching how photosynthetic reactions are managed and tuned in natural environmental conditions. After all, plants have evolved in ever-changing environments, and the photosynthetic machinery has adapted to anticipate unexpected changes, through a number of support functions.

These support functions must adjust the system for short term changes, such as fluctuating light due to a passing cloud, and for long term events, such as heat waves or droughts.

Despite the importance of these functions to plants thriving in the real world, the nature of their components and how they interact with the core photosynthetic machinery is relatively unexplored.

Part of the difficulty in studying these components is the lack of good tools to approach the problem systematically. An ideal platform would possess the following features: 1) capacity to grow plants in dynamic, reproducible conditions; 2) real-time monitoring of photosynthetic parameters over long time periods; 3) capacity to process a large number of plant strains and mutants; 4) ability to rapidly analyze and interpret the large datasets that result from such experiments.

# Our solution: "Bringing the field to the lab"

We are tackling this challenge through a combination of strategies:

1. Developing **new scientific instruments** (ex: Dynamic Environmental Phenotyping Imagers, aka DEPI) that allow us to study photosynthesis under a wide range of realistic conditions;
2. **Collaborating** with researchers across Michigan State University with expertise in established methods of studying photosynthesis;
3. Taking advantage of **large on-campus collections of plants** with distinct ecotypes and mutants;
4. Continuously developing**automated data processing streams and bioinformatic pipelines**.

Ultimately, this enables our team to bridge the gaps between the lab and field environments.

For example, our growth chambers allow a researcher to program in fluctuating, yet reproducible conditions. It is possible to gather environmental data from a natural site – say light and temperature readings from an Autumn day in a Michigan park – and then replay these conditions faithfully within the chamber.

On-board detectors monitor the growth and health of the plant lines and can determine how efficiently their photosynthesis proceeds, without destroying the plants, by using spectroscopic and fluorescence sensors.

Furthermore, crowdsourced analysis of plant performance allows for data gathering from all across the globe, including a wide range of real-world conditions.

In this way, we are uncovering the functions of previously unknown genes that are essential to protect photosynthesis against environmental fluctuations and stresses.