The Biological Solar Panel

Plants and algae are nature’s biological solar panels. By capturing light energy from the sun and converting it into dense energy molecules, through the process of photosynthesis, these organisms support most of life on our planet.

Photosynthesis is a complex system of processes consisting of hundreds of component parts that work together at the cellular level. The two major processes of photosynthesis are the so-called light-dependent and dark reactions.

In the first, photosynthetic organisms trap ‘raw’ sunlight energy that cannot be consumed by living things. The dark reactions capture carbon dioxide from the atmosphere and convert the captured light into sugars that lock up the energy for consumption.

The challenge: Integrating knowledge of photosynthetic processes that operate over a wide range of spatial and temporal scales

Decades of research have taught us a lot about the photosynthetic components, but scientists still don’t have a full picture of how photosynthesis works as a whole.

Part of the difficulty lies in the fact that most research has focused on organisms grown under static laboratory conditions instead of observing the photosynthetic components respond dynamically to natural living conditions.

Photosynthetic processes occur on time scales ranging from sub-millisecond photochemical reactions to the seasonality of leaf senescence and renewal. Spatial scales are also vast, spanning from molecules to whole leaves. It is therefore difficult to study photosynthesis within one lab or a single discipline, as the process spans a range of physical, biochemical, and structural areas of scientific expertise.

The solution: Understanding the solar panel holistically

The MSU-DOE Plant Research Lab aims to study the components and processes in a highly integrated way. We want to develop models on multiple scales that describe how photosynthesis works as a whole.

If we can understand the processes, as a whole, it will facilitate our long-term efforts to improve photosynthetic efficiency and increase crop yield, by redesigning different parts of the system to work better.

To achieve this goal, we work collaboratively across disciplines and between labs to answer fundamental questions concerning photosynthesis. Our participating researchers have expertise in various disciplines, including biophysics, biochemistry, physiology, photobiology, genetics, and cell biology.

We are currently studying photosynthesis from four angles:

1. We are focusing on chloroplasts, the subcellular compartment in which photosynthesis begins. We want to understand how the chloroplast membranes are created and maintained in living plants. We also want to examine how the chloroplast interacts with other parts of the cell that contribute to photosynthetic processes. (Benning, Brandizzi, Hu)
2. We are exploring how the structural features of the biological solar panel influence the availability of carbon dioxide in the photosynthetic compartments. We also want to look at how photorespiration and Calvin-Benson cycle regulation work together. (Hu, Brandizzi, Ducat, He, Sharkey)
3. We are studying how the Calvin-Benson cycle energy outputs coordinate with changing light intensities in the surrounding environment. We also seek to understand how these outputs match with the light-dependent reactions of the cell. (Sharkey, Froehlich, Howe, Kramer)
4. We are using engineered model plants (Arabidopsis) and cyanobacteria to understand how shifts in the allocation of carbon, the raw material for production of energy-dense compounds, are sensed by these organisms. We also seek to understand how changes in environmental conditions, including various stresses, influence carbon partitioning and the activity of photosynthesis. (Ducat, Howe, Kramer, Montgomery, Sharkey)

With this diversity of perspectives, combined with the unique technologies at our disposal, we are well positioned to understand the biological solar panel in a more holistic way.