All 2019 PRL Stories

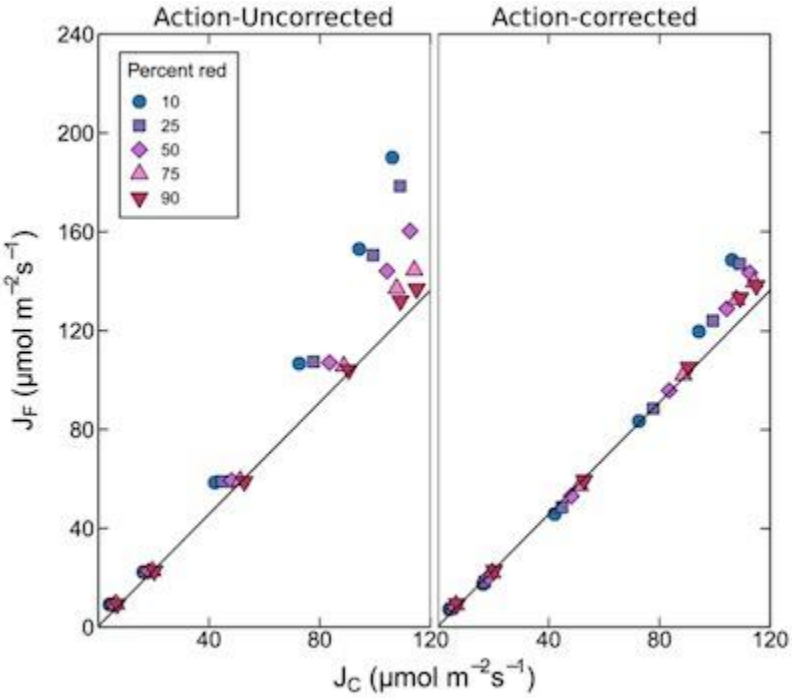
Research Highlights

Stories

Building a better fluorescence estimation of electron transport in plants

10/15/19

In a letter published in the journal New Phytologist, researchers suggest a correction for fluorescent measurements of electron transport.



Correcting fluorescent measurements of electron transport (JF) for this discrepancy (above) improves linearity between JF and the calculated electron usage for carbon metabolism (JC).

Scientific Achievement

A correction for non-photosynthetic absorption of light in calculations of electron transport.

Significance and Impact

Fluorescence measurements of electron transport help determine crop productivity. This correction addresses overestimations of photosynthetic quantum yield that distort the calculation. This correction is important for models of carbon assimilation, CO_2 diffusivity through the leaf, and nitrogen assimilation, indicators of photosynthetic productivity and crop yield.

Research Details

- There is variation in quantum yield of carbon by wavelength, described by an action spectrum. The action spectrum by McCree (1970) was used as justification for eliminating far-red and ultraviolet light as photosynthetically active – the plant absorbs somewhat at these wavelengths, but it does not drive photosynthesis.

- Plants absorb more blue light than red light, but blue light is less effective at driving photosynthesis due in part to absorption by non-photosynthetic pigments.
- Correcting fluorescent measurements of electron transport (J_F) for this discrepancy (see figure) improves linearity between J_F and the calculated electron usage for carbon metabolism (J_C).
- Action-corrected data will be important for methods requiring accurate electron transport measurements, including estimations of mesophyll conductance and nitrogen assimilation.

Related people: Alain McClain, **Thomas D. Sharkey (CA)**

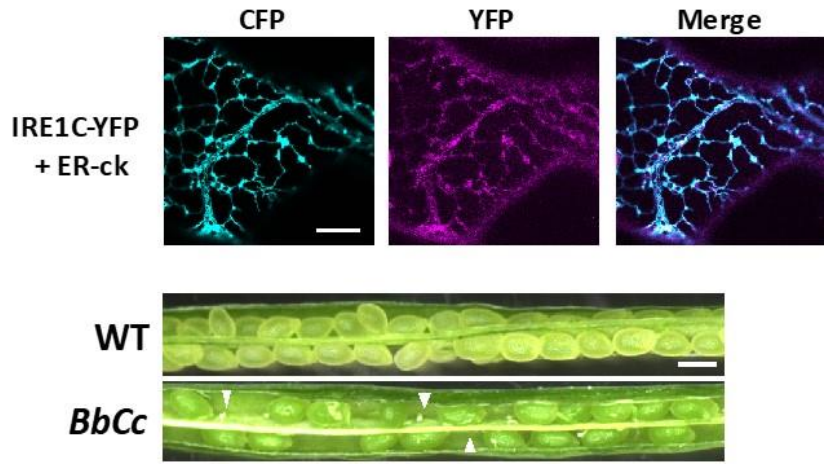
DOI: **10.1111/nph.16255**

Download the highlight

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

A new protein variant that controls reproduction and growth in plants

The protein IRE1C, a variant of the conserved IRE1 family, has been newly identified.



Top: Representative images of transient expression of ER-ck, IRE1C-YFP or both constructs in tobacco leaves showing IRE1C localizes on ER. Scale bar = 10 μm; Bottom: The siliques of the ire1b+/- c+/- showed gaps with abnormal seed development, indicated by white arrowhead. Scale bar = 100 μm;

Scientific Achievement

The protein IRE1C, which is a variant of the conserved IRE1 family, is indispensable for producing plant reproductive cells when another variant, IRE1B, is depleted.

Significance and Impact

IRE1 proteins are ubiquitous in eukaryotes. They control physiological growth and stress response in the endoplasmic reticulum (ER) of eukaryotic organisms. This work has identified a unique IRE1 variant.

Research Details

- IRE1C lacks the ER lumenal domain compared with IRE1A and IRE1B, but it remains to have the kinase and ribonuclease domain. *IRE1C* is expressed throughout the plants at a low expression level.
- Confocal microscopy shows that IRE1C localizes to the ER just like the other two homologs.
- No *ire1b ire1c* homozygous alleles could be obtained, while *ire1a ire1c* mutant is viable as WT. Reciprocal crosses showed non-Mendelian segregation ratio between *ire1b+/- ire1c+/-* and WT, suggesting IRE1C is involved in gametogenesis when IRE1B is depleted.
- Phenotypic assay of *ire1c* mutants under ER stress conditions indicated that IRE1C is not essential in the ER stress activated UPR.

Related people: Yunting Pu, Cristina Ruberti, Evan Angelos, **Federica Brandizzi (CA)**

DOI: **10.1002/pld3.187**

Download the highlight

Kenny Wang wins 2018 Kende Award

1/17/19

Igor Houwat, Kenny Wang

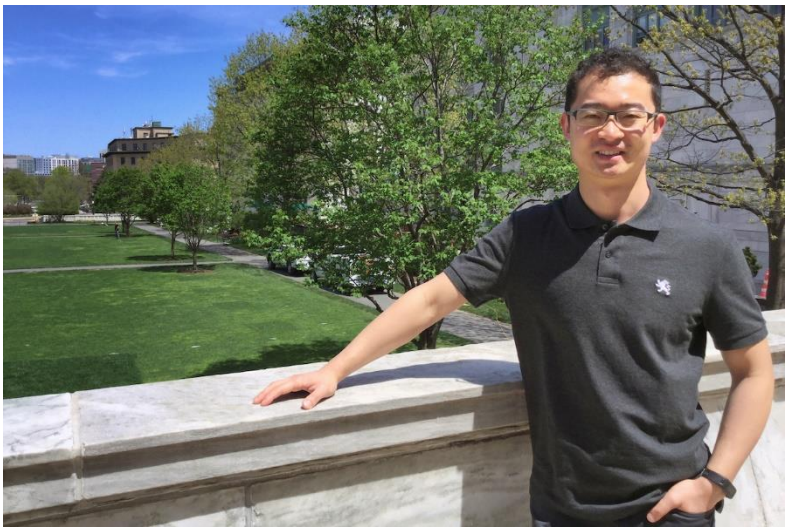


Figure 1 Banner image by Kenny Wang

Kun (Kenny) Wang is the recipient of the 2018 Kende Award, which recognizes the best doctoral dissertation in the plant sciences at Michigan State University (MSU) over the last two years.

In addition to winning a monetary award, Kenny presented a research seminar on January 14, 2019. The award recognized his PhD thesis work on the functions and mechanisms of chloroplast membrane remodeling. During his time at MSU, Kenny found that a chloroplast enzyme, **called SENSITIVE TO FREEZING 2 (SFR2)**, mediated a membrane remodeling mechanism that protects tomato from dehydration and salt stress.

He also characterized a group of chloroplast membrane degrading enzymes, designated PLASTID LIPASE (PLIP1, 2, and 3), showing that they participate in various biological processes. Those **processes include oil production**, which is of interest for biofuels research, **and jasmonic acid production**, which protects plants from herbivore and pest attacks.

Kenny says, “During my PhD, I benefited a lot from PRL’s collaborative environment with leading experts in various areas,” Kenny says. “My vision and scientific taste were nurtured in this environment, preparing me for the next stage of my career.”

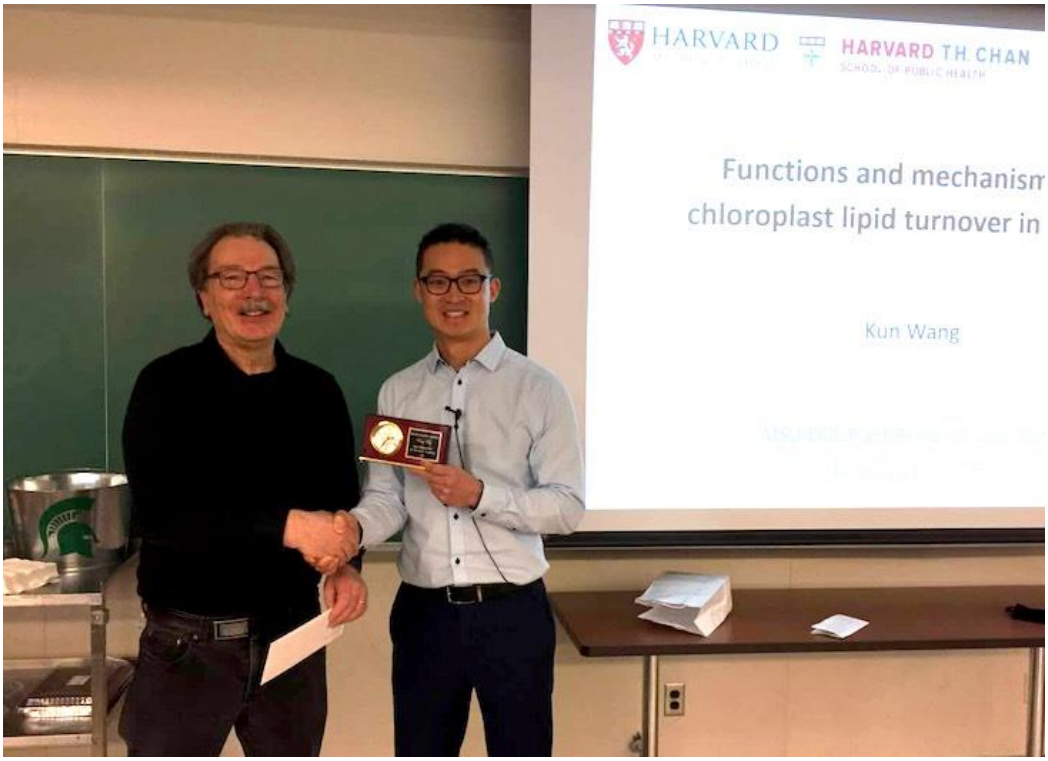


Figure 2 Christoph Benning (left) handing the award to Kenny Wang (right). By Sheng Yang He, MSU-DOE Plant Research Laboratory, 2019

"Kenny excelled during his work towards his PhD, because of his willingness and tenacity to learn new technologies and to become one of the top experts in a field new to him. He is well prepared for the next step in his career and I think he has a great future in science ahead of him," says **Christoph Benning**, Kenny's PhD mentor and director of the MSU-DOE Plant Research Laboratory.

Kenny obtained a B.S. in Biological Sciences at Shandong University, China and a PhD in Biochemistry and Molecular Biology from MSU. He is currently a postdoctoral fellow at Harvard Medical School.

"I am working on human lysosomal proteins in brain cells relevant to neurodegeneration diseases," Kenny adds. "I have been applying protein biochemistry and lipid omics skills acquired during my PhD training. This is an instance where plant research crosses over to the health sciences."

New insights into plant cell organelle and molecule movement

1/29/19

Igor Houwat, Luciana Renna

Michigan State University scientists have identified a new protein, called TGNap1 (TGN associated protein 1), that they found at a poorly understood plant cell organelle, the Trans-Golgi Network (TGN).

The TGN is at the intersection of pathways that control molecule traffic into (endocytosis) and out of (exocytosis) the plant cell. The TGN and its network of supporting expand iconproteins are essential to proper metabolism many organisms. But their function remains a mystery to scientists.

We do know that the TGN contributes to building up expand iconplant biomass, which is important for plant-based products, like fuels, food, and animal feed. In humans, TGN defects cause neurodegenerative diseases and hereditary neuromuscular disorders.

The new study provides insights into how the TGNap1 protein supports the TGN in structure and function. It then describes how the protein assists with TGN movement, through an interaction with microtubules, which impacts the TGN's biogenesis. The research is published in **Nature Communications**.

Plant mutants defective in trafficking

Luciana Renna, a research associate in the lab of **Dr. Federica Brandizzi**, identified TGNap1 in a plant mutant defective for expand iconsecretion.

"In the absence of the protein, a subclass of TGN seems to mature poorly during its formative stages," Luciana says. "The TGN grows larger and has an aberrant morphology. As a result, we see defects in one of its functions, secretion. In other words, cargo that should be delivered outside of the cell is partially retained in the endoplasmic reticulum, which is part of the exocytic secretion pathway. This defect in secretion leads to malforming of this organelle as well."

The mutant plant is also defective in endocytosis, the opposite process that allows cells to import molecules.

"It is important to note that TGNap1 only targets that specific subclass of TGN," Luciana adds. "This supports evidence that plant cells contain different types of TGN, where each subpopulation might specialize in different functions. But scientists have found it difficult to classify and characterize these subpopulations."

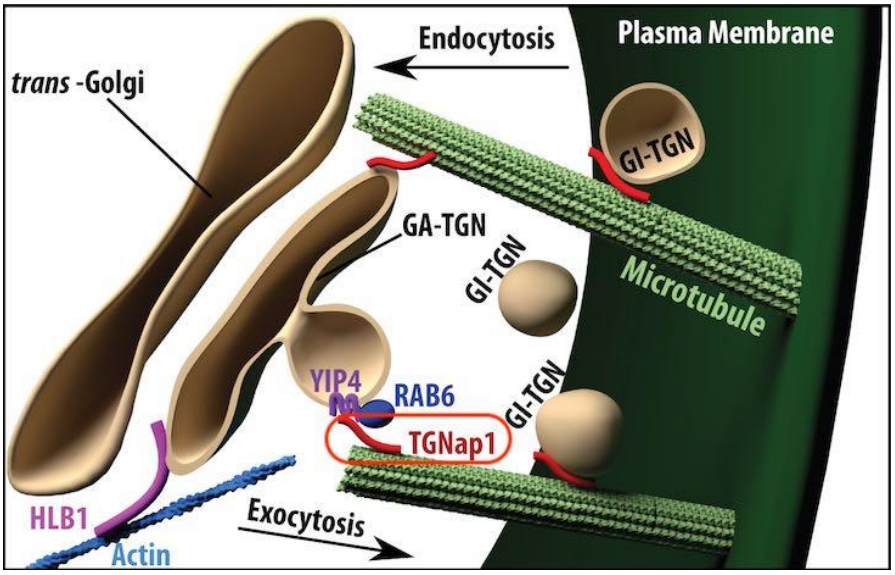


*Figure 1 TGNap1 (circled in red) associates to a subpopulation of TGNs in plant cells, where it influences biogenesis and function of the TGN as well as its movement. TGNap1's role in exocytosis involves Rab6 and YIP4, but its role in endocytosis is likely independent from YIP4, given the lack of a requirement of YIP4 in endocytosis. By Luciana Renna & Jonathan Davis, **Nature Communications** CC BY 4.0*

Microtubules: a new model of organelle movement

The N-terminal of TGNap1 has a domain that links it to the TGN and binds it to microtubules, which are like railroad tracks that organelles use to move inside a cell.

“We think the microtubules position the TGN in the right places,” Luciana says. “The protein connects both components (***see model above***). Without it, the link is gone, and movement is hampered. We think this disruption causes the defects we observed in our mutant.”

Microtubule-driven movement is a new line of thought in plant science. Scientists have tended to think that movement relies on another component called actin.

Moving forward, the researchers will further study the protein. Luciana says that the trafficking defects in the absence of TGNap1 were partial. That hints at a larger picture including more factors that impact the TGN. Or, perhaps the protein works under specific developmental conditions.

“We are excited to have found this new component that ties together TGN movement, biogenesis, and function,” Luciana says. “We are showing that various processes, like membrane transport, cytoskeleton interactions, membrane architecture, and dynamics are interdependent. Our field has tended to study each process in isolation.”

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

Harnessing synthetic biology to co-produce high-value terpenoid biomaterials and biofuel in plants

2/20/19

Igor Houwat, Radin Sadre, Bjoern Hamberger

Michigan State University scientists have developed synthetic biology tools to co-produce high-value compounds in plants. The study is published today **in the journal Nature Communications**.

Terpenoids form the largest class of natural products in plants and have been used by humans for thousands of years. Modern applications for terpenoids range wide, from pharmaceuticals, fragrances, nutraceuticals, biopesticides to chemical feedstocks. However, in the context of industrial scale production, plant accumulation of terpenoids is rather low. And, in the pursuit to extract natural terpenoids, some wild plant species have even become endangered.

“We investigated novel strategies to sustainably produce high-value terpenoid biomaterials in plants”, says Radin Sadre, Synthetic Biologist/Biochemist in the Department of Horticulture. Sadre is the lead author of the study conceived by **Christoph Benning**, **MSU-DOE Plant Research Laboratory** director and **Bjoern Hamberger**, Assistant Professor in the **Department of Biochemistry and Molecular Biology**.

The new synthetic biology tools allow to produce both terpenoids and oil, a biofuel resource, in plant leaves. Plants do not normally accumulate large amounts of oil in leaves. **Benning’s work on plant oils and lipids** served as a basis to enhance the oil content in leaves. The oil is stored in plant cells in small lipid droplets that are surrounded by a lipid layer coated with proteins.

The study shows that expand iconlipid droplets can themselves serve as an engineering platform for terpenoid production. The Hamberger lab focuses on metabolic engineering of terpenoid biosynthetic pathways.

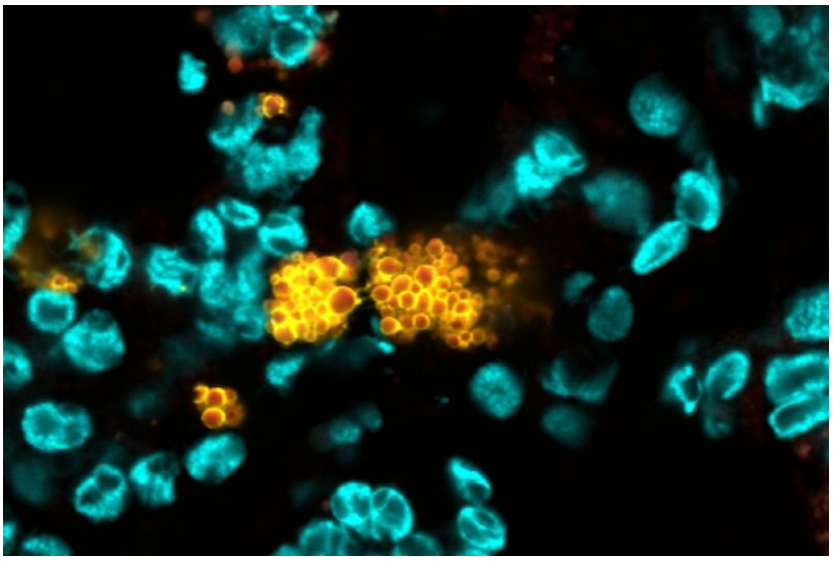


*Figure 1 Microscopy: The lipid droplets (red) cluster together. Terpenoid synthesis enzymes (yellow) are anchored onto the surface of lipid droplets with the help of a lipid droplet surface protein. Chloroplasts are in light blue. By Sadre Radin, **Nature Communications** CC BY 4.0*

Normally, terpenoid biosynthesis occurs at specific sites within the plant cells. The synthetic biology approaches retarget and boost the production of the terpenoid building blocks and terpenoids in engineered plants.

“We used a lipid droplet surface expand iconprotein from a microalga to anchor different terpenoid synthesis expand iconenzymes onto the surface of the plant lipid droplets”, Sadre says. “Targeting of distinct terpenoid synthesis steps to the lipid droplets leads to efficient production of terpenoids.”

These experiments were done at laboratory scale in the tobacco relative, *Nicotiana benthamiana*. But, the ultimate goal is the production of industrially relevant terpenoids in high-yield biomass crops, such as switchgrass.

Another feature of this system is that the terpenoids are trapped in the lipid droplets. This finding may prove useful in the future for industrial processing of engineered biomass crops.

Sadre says, “Once we break open the plant cells in the lab, we can easily collect the lipid droplets – basically, oil – with the terpenoids simultaneously. I can see many applications where both can be used together, for example, certain ‘essential oils’ in perfumes or speciality biofuels.”

“Alternatively, further processing can separate terpenoids from the oil for applications where purer compounds are required.”

MSU researchers contributing to this study include Peiyen Kuo, Jiaxing Chen, Yang Yang and Aparjita Banerjee. This work was primarily supported by the U.S. Department of Energy-Great Lakes Bioenergy Research Center (DE-FC02-07ER64494) and partially by the **Division of Chemical Sciences, Geosciences and Biosciences, Office of Basic Energy Sciences of the United States Department of Energy Grant** (DE-FG02-91ER20021) and by AgBioResearch, Michigan State University.

Two PRL grad students advocate for science on Capitol Hill

2/21/19

David Arnosti, Val Osowski, Igor Houwat

PRL graduate students, Brandon Rohnke and Aiko Turmo, were part of a MSU **Department of Biochemistry and Molecular Biology** (BMB) team that met with staff at the offices of Senator Peters, Senator Stabenow, Representative Slotkin and four other representatives to advocate for science funding. The February 5-7 event was sponsored by the American Society of Biochemistry and Molecular Biology (**ASBMB**).

“Advocacy for science funding is a fundamental part of professional training in Biochemistry,” noted BMB professor and graduate director **David Arnosti**. “Some students will be interested in future careers in the intersection between policy and research, while others will remember the role federal programs play in science, as they develop their careers in research, teaching, and the private sector as publically engaged scientists.”

ASBMB’s experienced Director of Public Affairs Ben Corb personally accompanied the MSU group on their meetings. The studentshad the opportunity to personally describe the fundamental research supported by federal funding, while Corb introduced them to the intricacies of the budgetary process that underwrites their work.

The students expressed a shared and keen interest in science policy and advocacy and how lobbying and the legislative process work.

“I’ve been considering a career in science policy for a while now, and a trip to DC to advocate for science really highlighted how important it is to have scientists interested in science policy,” said **Brandon Rohnke**, who is also a member of the **Montgomery** lab. “I was excited the whole trip, which is encouraging as I consider a career track in the field!”

Aiko Turmo, a member of the **Kerfeld lab**, thought, “I learned about how science advocacy worked at the federal level. It was a great opportunity to experience an environment other than academia and meet new people with different backgrounds who were passionate about science. I appreciate Dr. Arnosti for giving us this unique opportunity. Also, I am grateful to Mr. Ben Corb from ASBMB for showing us around the Capital Hills and coaching us on how to communicate our exciting science to our legislators.

Banner image by David Arnosti. Caption: Between visits to the offices of US Senators and Representatives, Director of Public Affairs Ben Corb from the ASBMB joins MSU Biochemists on the steps of the Capitol. Aiko Turmo is second from right and Brandon Rohnke is in the back, second from right.

Keeping plants nourished: the workings of a photosynthesis backup system

3/25/19

Igor Houwat, Thomas D. Sharkey

Summary

- **Plants introduce carbon into their diet through the Calvin-Benson cycle**. Carbon nourishes plants and the rest of the food chain.
- **The cycle only works when there is light**, otherwise it collapses.
- **The shunt is a backup that quickly restarts the cycle** when it slows down.
- The Sharkey lab has studied **how a mutant plant uses a workaround to restart the Calvin-Benson cycle with the help of the shunt**.
- **The shunt requires photosynthetic energy** to work.

Photosynthesis is how plants ‘make their food' and feed the rest of the planet. The key ingredient in that recipe is carbon. So, the process captures energy from the sun, which is then used to tear away carbon from atmospheric CO2.

But the journey from sunlight to feeding the planet is not a straight line. It’s more of a series of routes and detours that lead to the finish line. The reason is that things can go wrong. Light quality changes, or it gets too dry, or too cold. These changes can slow down or damage photosynthesis. So, plants have backups to work around these situations.

Scientists want to know these ins and outs of in order to improve expand iconphotosynthesis. The big picture goal is to create plants with better yields in order to feed our rapidly growing population.

Now, researchers at the MSU-DOE Plant Research Laboratory (PRL) shed more light on one of the backups that support photosynthesis through difficult conditions. The study is **published in Plant Physiology**.

Carbon: the plant's money-maker

Plants introduce carbon into their diet through a photosynthetic process known as the expand iconjavascript:void(0)Calvin-Benson cycle. This series of reactions mixes carbon with other chemicals to make new compounds, like starch or sugars, that sustain the plants and the rest of the food chain.

Carbon is truly key to having life on Earth.

However, two out of five times, the cycle picks up oxygen instead of carbon dioxide. That hiccup, called expand iconoxygenation, creates compounds that plants can't use to grow. Even worse, it grinds the cycle to a halt.

Plants have to clean those compounds and re-introduce them into the cycle so it can restart. The effort costs time and energy and requires moving the compounds to special cleaning sites elsewhere in the cell.

"The Calvin-Benson cycle has built-in backups to quickly restart the process whenever it slows down," says **Tom Sharkey**, University Distinguished Professor at the PRL. "**The best way is a shunt, a series of side reactions that keeps a low flow of carbon products in the cycle**. That makes sure the cycle restarts as fast as possible."

Now, the Sharkey lab, using plants that can't clean up compounds made by oxygenation, sheds more light on how the shunt works and how it needs extra photosynthetic energy to function.

The shunt: keeping the money-maker safe

An analogy for the shunt is the pilot light found in older gas appliances. This small flow of gas keeps the flame lit at a minimal level, so that when gas is supplied, the furnace, hot water heater, or stove very quickly turns on.

“The pilot light could seem to be a waste of gas,” Tom says. “But it serves an important function by keeping the system ready to come on fully very rapidly, without the user having to find a match to light the flame.”

Tom and two other labs at the PRL, Kramer and Hu, screened for mutant plants with defects in cleaning compounds mixed with oxygen. One mutant had a flaw at one of the special cleaning sites, the peroxisome.

The mutation slowed down the cleaning process, which led the plant to accumulate bad compounds at much higher levels compared to healthy plants.

That accumulation stopped the Calvin-Benson cycle. Since the mutant plant couldn’t properly restart the cycle, it found a workaround:

1. **The plant moved carbon outside the cycle** and into the plant cell;
2. **It partially processed the carbon** in a way similar to what goes on in the cycle;
3. **It reinserted the carbon into the cycle through a backdoor** that opened up for this situation.
4. **The shunt grabbed and then pumped some of that carbon back into the cycle** to help reboot it.

“The shunt’s increased activity requires extra energy,” Tom says. “Photosynthesis compensates by cranking up production (of ATP) in order to feed the shunt and drive the Calvin-Benson cycle.”

How the shunt works in real-world conditions

Even though the mutant is an exception, it forced the plant to reveal workarounds that are hard to see in healthy plants.

“In healthy plants, the Calvin-Benson cycle only works when there is light,” Tom says. “But in nature, there can be wide changes, like moving clouds, that make light flicker on and off. In those situations, it is easy to collapse the Calvin-Benson cycle. We think the shunt plays a role in restarting it.”

“Nowadays, electronics have made the pilot light obsolete,” Tom adds.
“Similarly, once we fully understand the shunt, maybe we will be able to replace it with a more efficient system.”

Tom concludes, “We’re lucky at the PRL. This project wouldn’t have happened if the other PRL labs hadn’t asked me questions about the Calvin-Benson cycle. It is unusual to have so many people, specializing in different parts of photosynthesis, working together under one roof. We can get out of our comfort zones, talk, and collaborate on research projects that otherwise don’t come up.”

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

MSU students win at 2019 ASPB Midwest Meeting

3/27/19

Igor Houwat

Figure 1 Banner image by Suejin Park

Michigan State University student researchers won multiple awards presenting their research at the 2019 Annual Meeting – Midwestern Section of the American Society of Plant Biologists.

- **Chase Lindeboom**, an undergraduate in the **lab of Christoph Benning** and **Biochemistry and Molecular Biology department**: 2nd place in the undergraduate oral presentation category. He discussed the genetic and molecular analysis of a protein invoved in cell cycle regulation in the microalga Chlamydomonas.
- Briaunna Murray, an undergraduate in the **lab of Susanne Hoffmann-Benning** and the **Neuroscience program**: 2nd place in the undergraduate poster presentations category. Briaunna presented her work on the generation, genotyping and phenotyping of plants overexpressing a phloem lipid-binding protein in the plant Arabidopsis.
- **Amanda Koenig**, a grad student in the Hoffmann-Benning lab and a double major in **Genetics** and **Molecular Plant Sciences**: 3rd place in the graduate student oral presentation category. Amanda discussed her findings on the function of the lipid phosphatidic acid in long-distance stress and developmental signaling in plants.

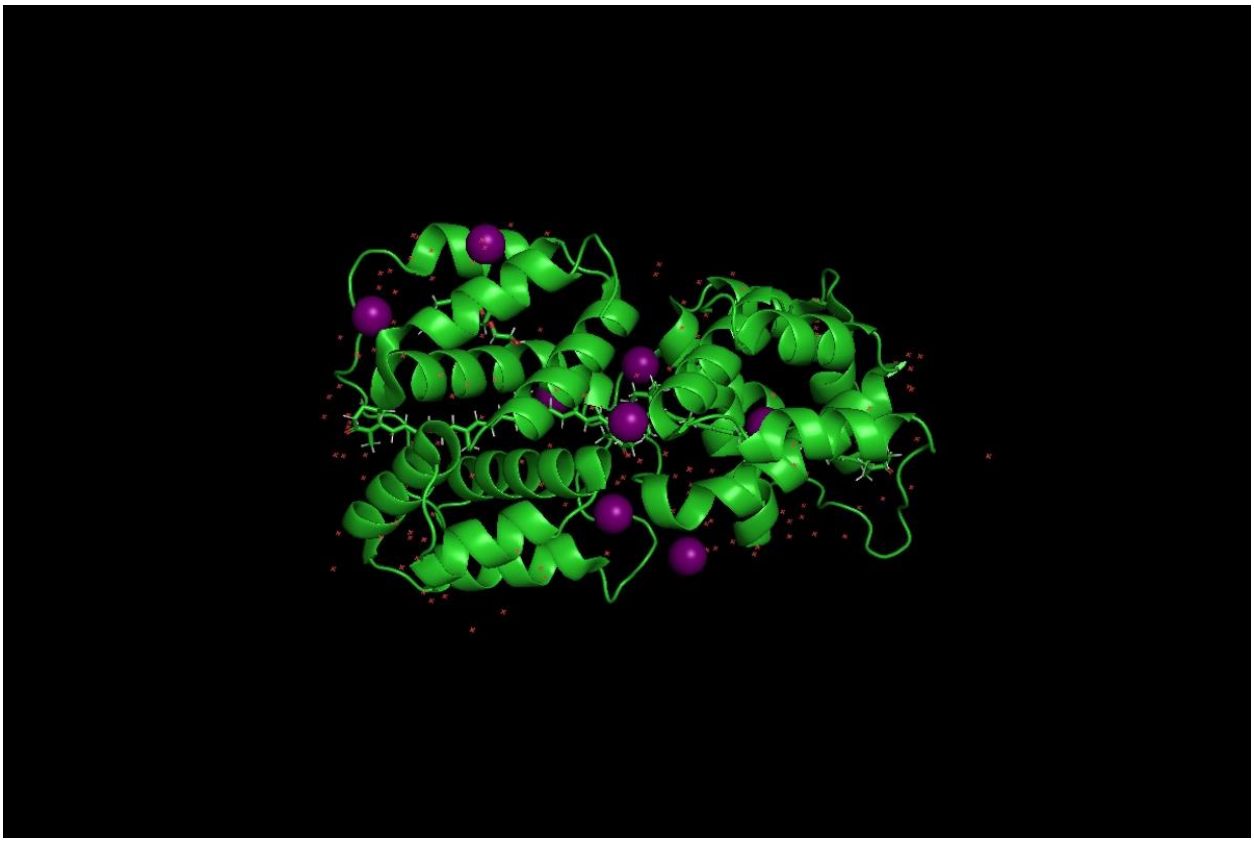
ASPB Midwest meeting, which took place at West Virginia University, “provides scientists at all career stages opportunities to discuss research efforts, teaching programs, funding scenarios, and career designs,” in the field of plant biology. It is also an opportunity for students to practice presentation skills.

Congratulations to all that were recognized at this meeting!

Our first look at a new light absorbing protein in cyanobacteria

4/2/19

Igor Houwat, Maria Agustina Dominguez-Martin



Cyanobacteria are tiny, hardy organisms. Each cell is 25 times smaller than a human hair, but don't let the size fool you. Their collective ability to do expand iconphotosynthesis is why we have air to breathe and a diverse and complex biosphere.

Scientists are interested in what makes expand iconcyanobacteria great at photosynthesis. Some want to isolate and copy successful processes. Those would then be repurposed for human usage, like in medicine or for renewable energy.

One of these systems is expand iconphotoprotection. It includes a network of proteins that detect surrounding light levels and protect cyanobacteria from terrible damages caused by overexposure to bright light.

The **lab of Cheryl Kerfeld** recently **discovered a family of proteins, the Helical Carotenoid Protein (HCP)**, who are the evolutionary ancestors of today's photoprotective proteins. Although ancient, HCP still live on alongside their modern descendants.

This discovery has opened new avenues to explore photoprotection. And for the first time, the Kerfeld lab structurally and biophysically characterizes one of these expand iconproteins. They call it HCP2. The study is in the **journal BBA-Bioenergetics**.

The Science

Structurally, the HCP2 is a monomer when isolated in a solution. But, in its expand iconcrystallized form, it curiously shows up as a dimer.

“We don’t think that the dimer is the protein’s form when it is in the cyanobacteria,” says **Maria Agustina (Tina) Dominguez-Martin**, a post-doc in the Kerfeld lab. “Most likely, HCP2 binds to a yet unknown partner. The dimer situation during crystallization is artificial, because the only available molecules in the environment are others like itself.”

The scientists try to determine HCP2s functions. It is a good quencher of expand iconreactive oxygen species, damaging byproducts of photosynthesis. But since many other proteins can do that as well, Tina doesn't think that is HCP2's main function.

“We have yet to identify a primary function,” Tina says. “The difficulty is that the HCP family is a recent discovery, so we don’t have much basis for comparison.”

Other experiments include:

- Measuring HCP lightwave absorption bandwidths
- Identifying what expand iconcarotenoid it interacts with
- Examining whether they quench **antennae proteins that capture light** for photosynthesis (they don’t).

Future applications

The ability to detect light is key for applications, especially in **biotech**. One promising area is optogenetics, **a technology that uses light to control living cells**. Optogenetics systems are like light switches that activate predetermined functions when struck by a light source.

HCP2 could play a part in such applications. But this is all far down the road.

“There are 9 evolutionary families of HCP to explore. That adds up to hundreds of variants with possibly distinctive functions that we have yet to discover,” she adds. “With that in mind, we're characterizing other proteins from the HCP family to expand our available data set.”

Because these **proteins likely play a role in photoprotection**, they may represent a system that scientists could engineer for “smart photoprotection,” reducing wasteful photoprotection which would then help photosynthetic organisms become more efficient.

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**The HCP2 in this study is from the cyanobacterium, Fremyella, studied by the **lab of Beronda Montgomery** at the **MSU-DOE Plant Research Laboratory**. The Kerfeld and Montgomery labs have teamed up to understand the structure and function of the HCPs.

Explore the Science and Art of Plants at Third Annual Fascination of Plants Day @ MSU: Arts Go Green

4/9/19

Igor Houwat

Figure 1 Banner image by Harley J Seeley

Michigan State University hosts the third annual Fascination of Plants Day @ MSU. This year, plant sciences meet the arts in a collaboration between MSU plant scientists, the Eli and Edythe Broad Art Museum at Michigan State University (MSU Broad), and the East Lansing Art Festival.

Date: Saturday, May 18th
Time: from 11a - 6p
Locations (*there are two*): MSU Broad Art Lab (565 E Grand River Ave, E. Lansing, MI 48823) and Children's Art Activity Area at the East Lansing Art Festival.

The public is invited to explore the amazing world of plants, enjoy family-friendly activities, and meet researchers and artists at one of the world's best plant science institutions. Attendees will:

- **Experience hands-on science and art activities**: extract DNA from strawberries, manipulate plant 3D images in Virtual Reality, create cyanotypes of beautiful microscopic structures
- **Learn about the many benefits of plants**: bioenergy crops station and plant-based industrial products
- **Discover the plant scientist's lab toolkit**: microscopes, measuring instruments, GMOs and plant DNA
- **Meet MSU researchers**: and learn about the exciting science that goes on at MSU.

Fascination of Plants Day is a worldwide event promoted by the European Plant Science Organization. It aims to get the public enthused about the importance of plant science on their day-to-day lives (agriculture, pharmaceuticals, etc.). Fascination of Plants Day @ MSU: Arts Go Green will take place alongside hundreds of others worldwide.

The MSU Broad Art Lab is an expression of the MSU Broad's commitment to creating engaging arts and cultural experiences for a diverse audience, connecting art to other disciplines, and positioning the museum as innovative and inclusive.

The 56th annual East Lansing Art Festival aims to enhance the sense of community and appreciation of art, culture and creativity in East Lansing and the greater Lansing region. The festival presents hundreds of artists and craftspeople and attracts tens of thousands of visitors annually.

For more information, visit the event website at **https://mps.natsci.msu.edu/fopd/**or the **Facebook page**.

Contacts:

Anne-Sophie Bohrer, Event Coordinator, **bohreras@msu.edu**
Igor Houwat, Communications Coordinator, **houwatig@msu.edu**

Two PRL students win first prize at UURAF 2019

4/19/19

Igor Houwat

Figure 1 Banner image of UURAF 2019 by Trumpie Photography

Madeline Bresson from the **Sharkey lab** and Jacob Wright from the **Ducat lab** have won first prize at the 2019 University Undergraduate Research and Arts Forum (UURAF). Both students were recognized for their poster presentations on their research.

The **UURAF gives MSU undergrads the chance to present their work in a public setting**, which allows them to gain presentation experience, interact and answer questions from audience members, and receive feedback from judges. The best presenter in each category was awarded $100.

Jacob's research focuses on a **bacterial microcompartment shell protein**. It is a potential source of biomaterial to engineer nano-sized scaffolds. The current research is examining how to efficiently recruit cargo onto the surface of these scaffolds. The long term goal is to use these scaffolds as a way to reengineer biochemical processes that occur inside of living cells.

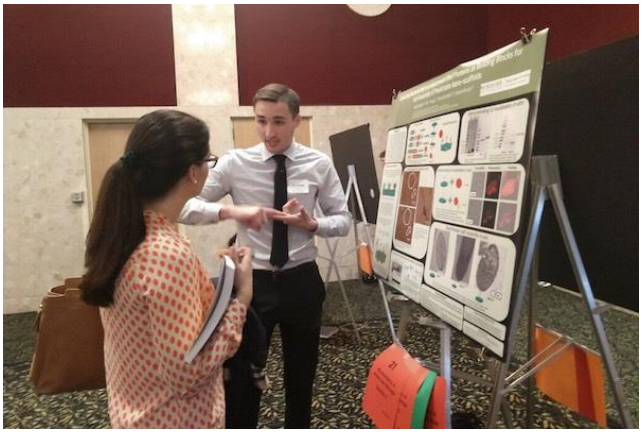


Figure 2 Jacob Wright presenting at the UURAF. Courtesy of Jacob Wright.

“The opportunity to present such exciting work is something I’m always happy to take advantage of,” Jacob says. “But the best part of the UURAF experience is to explore research outside of your own field, and there was such diverse research that I had the pleasure of learning about. I find there is always a need for us, as researchers, to step outside our areas of expertise, as ideas from other fields allow us to see our own work from alternate perspectives and generate enthusiasm and inspiration in our own work.”

Madeline is examining a hypothesis stating that leaf sucrose export is critical for pollen development under conditions of high temperature stress. Her lab has identified a new gene that potentially plays a role in the process. The long term goal is to generate heat tolerant plants, either through traditional breeding or transgenic approaches.

Figure 3 Madeline Bresson with her poster. By Trumpie Photography, 2019.

“I am earnestly grateful for the recognition for the work I have done and am extremely proud to achieve this honor,” Madeline says. “I could not have achieved this success without the guidance, help, and support from everyone in the lab. Preparing for UURAF allowed me to fully immerse myself in my research and learn how to design a research poster. By presenting at UURAF, I have learned how to effectively present my research in a more concise manner. I enjoyed the opportunity to display the fascinating research that I am doing and to learn about additional exciting research being performed at MSU.”

Congratulations to both!

Anastasiya Lavell wins BMB Outstanding Graduate Student Teaching Award

4/22/19

Igor Houwat

Figure 1 Banner image of Anastasiya Lavell and Christoph Benning courtesy of Christoph Benning

Anastasiya Lavell, a graduate student in the Benning lab, has won the Department of Biochemistry and Molecular Biology (BMB) Outstanding Graduate Student Teaching Award.

Anastasiya was among the honorees recognized at the annual **BMB** Awards Banquet on April 11. The award is "given to a student for exceptional performance as a graduate teaching assistant during his or her graduate program." It also provides the winner with $500 to support that person's student career.

"I am incredibly thankful for receiving this award in particular," Anastasiya says. "Teaching and mentoring are activities that I care about a great deal, and it's an honor to be recognized for my efforts. Receiving this award further encourages me to work on becoming a better teacher and a better mentor."

Anastasiya has been a Teaching Assistant for an Advanced Biochemistry Lab course (BMB471) and Cells and Molecules (BS161), an introductory biology course. In addition to TAing, she is currently working on obtaining a certification through the College of Natural Science which aims to train doctoral students in teaching math and science at the college level.

"**Anastasiya Lavell is not only an outstanding scientist** working on a challenging research project, she is also an amazing mentor of undergraduate students in the laboratory and instructor in the class room", says **Christoph Benning, her PhD thesis advisor**. "This award is well deserved, and I am very happy for Anastasiya."

Anastasiya started out her college career at a community college in MN, Anoka Ramsey Community College, where she obtained an Associates in Arts and Sciences degree. After transferring, she received her BS in Biochemistry from the University of Minnesota. She currently is on track to defend her PhD this Fall 2019 at Michigan State University, where she is a recipient of a **Plant Biotechnology for Health and Sustainability Fellowship**.

MSU scientists teach kids about plant defense at MSU Science Festival 2019

4/25/19

Igor Houwat

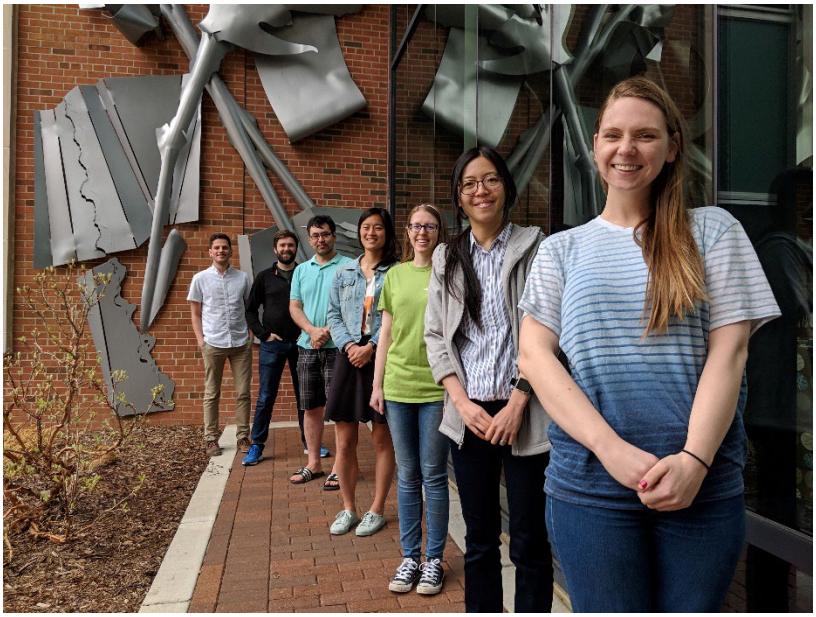


Figure 1 Banner image of MSU scientists by Igor Houwat

MSU plant scientists packed their stuff and took the lab out to two schools, Radmoor Montessori and Hope Middle School, as part of this year's MSU Science Festival. The 115 school students, ranging from 4th to 6th graders, got to learn about plant defense mechanisms and got a taste of how to observe and think critically as a scientist.

The brains behind the events was Leah Johnson, a graduate student in the lab of Gregg Howe. She shared her reflections in the following interview.

What did you have the kids do?

We had three different stations that the students got to experience.

The first was a display of various plant chemical and physical properties. They got to touch wild eggplant relatives with thorns, a wild tomato species, *Solanum pennellii*, that is sticky to the touch, and normal tomato plants with smelly leaf compounds.

The second station showcased plant defenses in the face of hungry caterpillars! We brought in two plants, one normal, and one which we modified in the lab so it couldn't defend itself. Then, we showed them some caterpillars that had been feeding on these plants for two weeks before the event. The kids had to decide which caterpillars were eating which plants, based on how big they grew. Obviously, the ones feeding on the defense-less plants were fatter! The kids loved that station because they could touch and poke the caterpillars. It was hard to get them away from it!

Figure 2 A student with a caterpillar. By Sheena Lashua

The last station was about Chlorophyll extraction, which is safe and easy to do in a school. This activity was more about the science process. We showed how scientists use chemicals to extract substances from plants so we can measure them in labs. The kids liked that one too, because if you shake a leaf long enough in the mixture, it turns white. It's because the chlorophyll is leeching out into the mixture.

What was the theme tying these activities together?

We wanted the students to process the scientific method by performing their own experiments. The idea was to avoid tedious memorization of details, but to figure out answers through observation and deduction. Plus, we didn't want 10 to 12 year-olds sitting through a lecture!

Figure 3 Leah with students. By Sheena Lashua

What is your personal motivation behind your participation at the MSU Science Festival?

I became passionate about science outreach during high school. I didn't have a lot of exposure to science back then. One of my teachers started a program called "Time for Real Science," where we got to create our independent research projects, guided by a few teachers. It was life changing! I know many of my colleagues said that this program helped determine their career path. So I saw the importance of exposing students to science and research, showing them what career opportunities there are. That's the goal for me right now, especially with students who don't get a lot of science exposure, which is common in schools.

How did the kids like it?

Overall, the students were excited to participate and wanted to take the experiments home! The best part for us was to see these kids – who aren't challenged enough by science in their schools – walk through activities, make connections, and suddenly, things would click for them.

Figure 4 Kids observing tomato plants. By Sheena Lashua

Some of the kids even asked some interesting, in-depth questions. One type of question that came to the fore was, why do we like science? They don't really know why anyone would want to do this.

Here's what we said: Plant science is very important. In the face of variable climate conditions and a growing population, plant science research can provide sustainable options to help feed the world. Additionally, science provides us with the tools to learn about our world, and it's exciting to understand how and why things work!

The MSU volunteers were: Leah Johnson - *Graduate student, Gregg Howe lab*; Ian Major - *Postdoc, Howe lab;* Jake Bibik - *Graduate student, Bjoern Hamberger lab;* Kailey Miller - *Undergraduate student, Kramer lab*; Danielle Young - *Graduate student, Yair Shachar-Hill lab;* Paul Fiesel - *Graduate student, Rob Last lab;* Yann-Ru Lou - *Postdoc, Rob Last lab*

Simpler & smaller: a new synthetic nanofactory inspired by nature

4/29/19

Igor Houwat, Bryan Ferlez, Sean McGuire

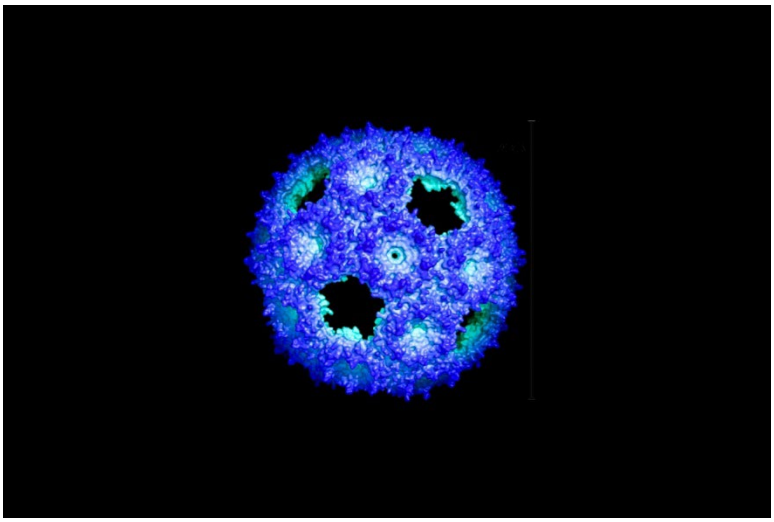


Figure 1 Banner image of synthetic shell by Markus Sutter

Bacteria across our planet contain nanometer-sized factories that do many different things. Some make nutrients, others isolate toxic materials that could harm the bacteria. We have barely scratched the surface of their functional diversity.

But all share a common exterior, a shell made of expand iconprotein tiles, that we are learning how to manipulate in the lab. This will allow us to build factories of our own design, using these natural building blocks. Indeed, **scientists see these structures as a source of new technologies**. They are trying to repurpose them to do things they don't in nature.

In a new study, **the lab of Cheryl Kerfeld** reports a new genetically engineered shell, based on natural structures and the principles of protein evolution. The new shell is simpler, made of only a single designed protein. It will be easier to work with and, perhaps, even evolve in the lab. The study is published in **ACS Synthetic Biology**.

Natural shells are made of up to three types of proteins. The most abundant is called BMC-H. Six BMC-H proteins come together to form a hexagon shape to tile the wall.

At some time in evolutionary history, some pairs of BMC-H proteins became joined together, in tandem. Three of these mergers, called BMC-T, join to also form a hexagon shape.

Figure 2 Animation of how BMC-H evolves to BMC-T, and how these proteins contribute to form a nanofactory shell. MSU-DOE Plant Research Laboratory, 2019

"The two halves of a BMC-T protein can evolve separately while staying next to each other, because they are fused together. This evolution allows for diversity in the structures and functions of BMC-T shell proteins, something that we want to recreate by design in the lab," says Bryan Ferlez, a postdoc in the Kerfeld lab.

Taking their cue from this natural evolution of shell proteins, the team created an artificial BMC-T protein, called BMC-H^2, by fusing two BMC-H protein sequences together. The new design was successful.

"To our surprise, BMC-H2 proteins form shells on their own. They look like wiffle balls, with gaps in the shell," says **Sean McGuire** a former undergraduate research student and technician in the Kerfeld lab. This is because natural shells are icoshedral, meaning that they are made of expand iconhexamer and expand iconpentamers — think of a soccer ball.

Next, the team capped the gaps in the wiffle ball shell with BMC-P, the third type of shell protein that forms pentamers.

"The result is a shell, about 25 nanometers wide, made up of only two protein types: the new BMC-H^2 and BMC-P," Bryan says. "It is around half the size of the structure built with all three protein types."

The next goal is to fit it with custom expand iconenzymes and fine tune it to enhance the chemical reactions within. The new 'designer' shell could have **uses in biofuel production, medicine, and industrial applications**.

This work was primarily funded by the **National Institutes of Health**, **National Institute of Allergy and Infectious Diseases**, and the **US Department of Energy, Office of Basic Energy Sciences**.

Barb Sears receives Faculty Emeriti Association award

4/30/19

Igor Houwat

Dr. Barbara B. Sears, an MSU Faculty Emerita retired from the Department of Plant Biology, has been awarded the 2019 MSU Faculty Emeriti Association Award for "Outstanding Contributions by an Individual."

Dr. Sears was recognized by the **MSU Faculty Emeriti Association** at their annual **FEA Recognition Awards** on April 19. The rationale for her award is, “to recognize the activities of individuals who, during their retirement, have made formidable contributions to the MSU Community or their unit or to fostering the engagement of MSU Faculty Emeriti.”

Sears, who currently works in the **lab of Christoph Benning**, has recently made essential contributions to research aimed at understanding how the alga Chlamydomonas controls cell division in response to nutrient supply. The work has implications for biofuel and cancer research.

She is also co-mentoring graduate and undergraduate students and postdocs working on this NSF-funded project. As a result, Sears has co-authored several important research papers.

Figure 1 Barb Sears (left) receiving her award. By Derrick L. Turner, © 2018 MSU Board of Trustees

“Being able to work in Christoph Benning’s lab has provided a welcoming and stimulating academic environment,” Dr. Sears says. “I’ve been able to contribute to the algal projects as a geneticist, complementing the lab’s emphasis on biochemistry and molecular biology. Our collaboration has

allowed me to continue to pursue research while relinquishing the administrative and teaching responsibilities of academia.

Benning, who also is **MSU-DOE Plant Research Laboratory** director, says, “I have been collaborating with Dr. Sears for many years on algal biology, and she has made many critical contritbutions to our research as a Professor Emerita of Plant Biology. She has also helped me mentor a number of graduate and under graduate students, and I am lucky to have her continue collaborating with me.”

Danny Schnell, chair of the **Department of Plant Biology**, adds, “Barb is a model for how emeritus faculty can continue to make valuable contributions to many areas of research and teaching. In particular, Barb has shown a remarkable commitment to training a new generation of scientists in Christoph’s lab, and Plant Biology is delighted that her efforts are recognized by this award.”

Dr. Sears obtained her PhD from Duke University. She came to MSU as an Assistant Professor immediately after a 3-year postdoctoral research stint at the University of Duesseldorf, Germany. Her research prior to retirement was on the extranuclear genetics of the chloroplasts and mitochondria of plants and algae, with an emphasis on replication, repair and recombination of organelle DNA.

She became a full professor in 1998 and Director of the Genetics Graduate Program in 2003. In the latter position, she helped create and subsequently coordinated an exchange program with the Heinrich Heine University of Duesseldorf. She continued this leadership role for five years after her retirement in 2013.

2019 Anton Lang Memorial Award Winners Announced

5/9/19

Igor Houwat

Luciana Renna and Ben Mansfeld were awarded the 2019 Anton Lang Memorial Award during a ceremony which took place on Monday, April 23, 2019 at the Biochemistry building.

The Anton Lang Memorial Fund was established in honor of the founding director of the MSU-DOE Plant Research Laboratory (PRL), who passed away in 1996. Proceeds from the fund go towards annually supporting the Anton Lang Memorial Lecture and recognizing a graduate student and a postdoctoral research associate who exemplify the research excellence, ideas, dedication, and vision of Anton Lang.

This year's lecture was given by Dr. Jorge Dubcovsky from the University of California-Davis. Dr. Dubcovsky's talk focused on genetic tools to dissect wheat spike development.

Figure 1 Luciana Renna, left, with PRL director, Christoph Benning. By MSU-DOE Plant Research Laboratory, 2019

Luciana, from the **lab of Federica Brandizzi**, won the post-doc award. For a long time, she has been fascinated with the endomembrane system. She recently identified a new molecular player localized on the Trans Golgi Network (TGN) that ties together TGN movement, biogenesis, and function. This discovery was recently published on Nature communications.

Luciana says, "I feel honored to be receiving this award. I am extremely grateful to be a part of this resourceful community that the PRL is!"

Ben, who works in the **lab of Rebecca Grumet**, won the graduate student award. His PhD work focuses on a developmentally acquired disease resistance in cucumber to the pathogen *Phytophthora capsici*, which causes cucumber fruit rot. Ben utilized a diverse array of tools to study this trait, including

transcriptomic, metabolomic and genomic analyses. Ben has also developed an R package for performing bulk segregant analyses using sequencing data.

Ben says, “I am truly honored to receive this award! I have to thank my advisor Dr. Rebecca Grumet, who has been an amazing mentor over the last few years. My advisory committee has also been extremely influential and helped shape me in to the scientist I am today. Finally, I want to thank my friends and family for the support.”

Figure 2 Ben Mansfeld, left, with PRL director, Christoph Benning. By MSU-DOE Plant Research Laboratory, 2019

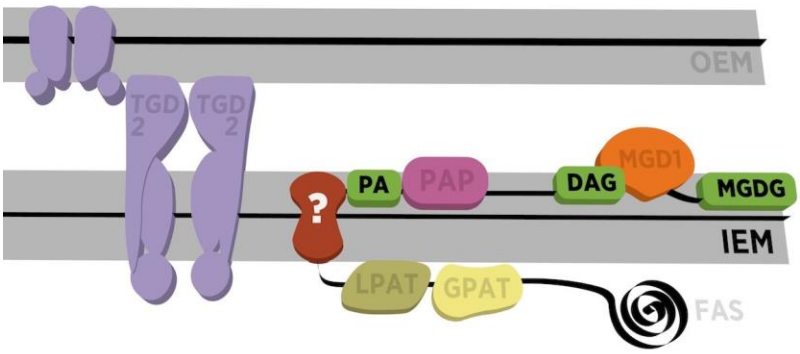
Christoph Benning, PRL Director, says, “The Anton Lecture presented by Dr. Jorge Dubcovsky, who has made tremendous contributions in the field of wheat breeding and genetics, set the perfect background for the awards ceremony. Luciana Renna and Ben Mansfeld are promising young scientists in the plant sciences at MSU and fully represent the spirit of the Anton Lang Award. I would like to congratulate both on behalf of the entire PRL and Molecular Plant Science community.”

The awardees received an engraved rosewood piano finish clock, a cash reward, and their names have been added to a permanent award plaque located in the Plant Biology Laboratories building.

A new rhomboid-like protein that helps plants produce lipids

5/14/19

Igor Houwat, Anastasiya Lavell



The Benning lab has identified a rhomboid-like protein that may help plant expand iconchloroplasts tune their lipid production. The study is **published in The Plant Journal.**

expand iconLipids are molecules that make up fats and oils in living beings, and they perform a variety of functions. They make up our cell boundaries, from which we get tissues and organs. Lipids store more energy than other molecules, which is desirable for developing biofuels. They also provide plants with the membrane building blocks needed to harvest light for expand iconphotosynthesis.

In plant cells, an assembly line of expand iconenzymes makes, modifies, and deploys lipids to the proper locations in a cell.

One of the big mysteries in plant lipid studies is how plants control this production system. Figuring this out could give us clues on how plants optimize photosynthesis, even when surrounding conditions are difficult, like drought or heat. We might also learn how to boost plant productivity, through genetic or breeding tools.

“When I joined the Benning lab, I wanted to start a new project addressing these outstanding questions,” says **Anastasiya Lavell**, a graduate student in the **lab of Christoph Benning**. “I searched a database for mutants that had changes in their lipid make-up and found one with a disrupted gene that encoded a rhomboid-like protein 10, which we call RBL10.”

Figure 1 GIF Part 1: Regular lipid production in a chloroplast, a conveyor belt of enzymes and intermediary lipids leading to MGDG. By MSU-DOE Plant Research Laboratory, 2019

The team of scientists thinks the protein is found in the inner envelope membrane of chloroplasts, a busy conveyor belt of processes.

“When we remove RBL10 from plants, we see a blockage in chloroplast lipid production," Lavell says. "Specifically, phosphatidic acid (PA), an intermediary form of lipid, does not turn into monogalactolipid (MGDG), the most abundant lipid in plants that's very important for photosynthesis."

Lavell suspects RBL10 helps move the intermediary lipid towards the next processing station in the assembly line. Or, perhaps, RBL10 affects another protein that moves this lipid.

Figure 2 GIF Part 2: Without RBL-10, lipid production is disrupted, and plant development is negatively affected. By MSU-DOE Plant Research Laboratory, 2019

The absence of RBL10 in the mutant plants causes a cascade of changes. The block in conversion of PA to MGDG causes the plants to produce new MGDG in alternative molecular pathways. But there are downstream costs to this change in the production system.

“We see that the plants have negatively affected flower and pollen development,” Lavell says. “There are also potential deficiencies in the production of hormones that defend the plant against wounding from herbivores.”

This is the first time a rhomboid-like protein – and how it influences the synthesis and transport of lipids – has been studied in detail in plants.

“Rhomboid-like proteins are found across a large number of organisms, like bacteria, flies, even us humans,” Lavell says. “These proteins are better studied in those other organisms, but not in plants. For context, the plant we study, Arabidopsis, has thirteen of them. Two are in the chloroplast. So, it’s probably important.”

“One reason we lag behind in plant science is that plant lipids are hard to study,” Lavell says. “For example, the chloroplast has a complex membrane structure, tough to observe. It also is deeply interwoven into many plant functions, like growth, photosynthesis, and defense. So, it is hard to tease out where its influence begins or ends. But the challenge makes it all the more exciting to see where this goes.”

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

Gutter Ball 25: Tony Schilmiller claims third championship

5/20/19

John Froehlich; Images by Igor Houwat

Last Friday, the City Limits Bowling Center, was invaded by enthusiastic, and sometimes rowdy, Gutter Ball 25 bowlers attempting to win the ultimate prize of being crowned the 'Gutter Ball 25 Champion"!

Over 100 bowlers - from many different departments and labs - attended the event. (**Check out the event pictures here**)

The evening saw many twist and turns but after the last gutter ball was thrown and all potential challengers were vanquished, only one bowler survived the 'Game of Thrones'-level struggle to win this prestigious event: Dr. Tony Schilmiller (Assistant Core Manager of the Mass Spec Facility). He's seen here, second from right.

It should be noted that Tony has been a previous winner of the Gutter Ball (2015 and 2016) but winning 'Gutter Ball 25' is indeed a special honor and will only add to Tony's already considerable list of accomplishments!

Everyone looked sharp in their in official Gutter Ball bowling shirts (thanks to Linda Danhof's efforts and compliments of a ThermoFisher shirt donation).

Thanks for the shirts Linda (she just got a strike)!

There were people of all ages...

....there was much joy...

... and the general feeling was that our loyal bowling combatants have never looked better!

Special mention goes out to Igor Houwat, the official event photographer, who valiantly played a game with one arm in a cast. Now that is truly Spartan Will! Also, special mentions go out to the faculty members who came out and played this year!

Thank you to ALL the bowlers who came out this year and made GUTTER BALL 25 a very, very, special event!

Notable Scores:

- Tony Schilmiller 180, 185
- Brian St Aubin 183
- Connor Bertocci 168
- John Froehlich 167
- Judd 165
- Reid 160
- Wajid 158
- Erik Durfee 156,150
- Jonathan Sakkos 156
- Lee Alexander 155

Women's Division:

- Zoe Hansen 149
- Anne Rea 142
- Starla Durfee 140
- Colleen Curry 140
- Emily Walker 140

Previous Gutter Ball Champs:

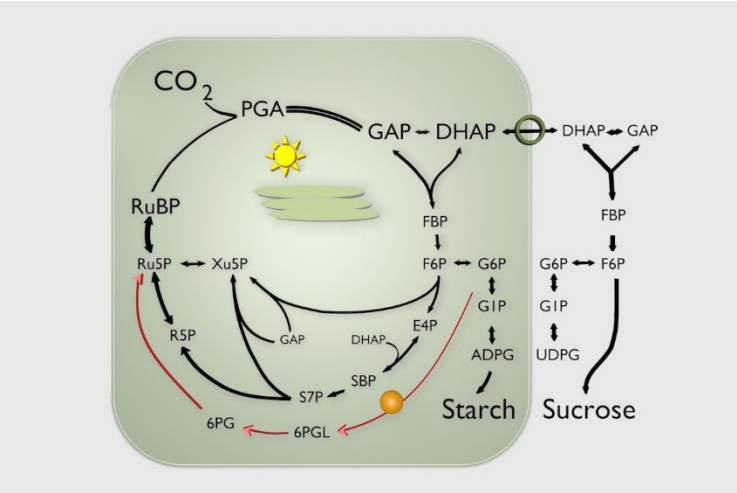
- John Froehlich (2003, 2006)
- Ken Keegstra (2004, 2007)

- Jon Glynn (2005)
- Jackson Gehan (2008)
- Robin Harris (2009)
- Katie Cabot (2010)
- Andy Scollon (2011)
- Erik Durfee (2012)
- Matt Oney (2013)
- Henrik Tjellstrom (2014
- Tony Schilmiller (2015,2016
- Eric Young (2017
- Lee Alexander (2018)
- **Tony Schilmiller (2019)**

Protecting photosynthesis from stalling: a 24-hr molecular hotline

5/20/19

Igor Houwat, Alyssa Preiser



Photosynthesis is the process that powers life on earth. Photosynthetic organisms capture energy from sunlight, which they use to tear carbon from atmospheric carbon dioxide. The carbon ends up in sugars and starches that sustain these organisms and the food chain above them.

The reactions that add carbon to the diet are the expand iconCalvin-Benson cycle. Nowadays, scientists know its main workings, but they continue to explore its details. Those include sub-cycles that support it and evidence that surrounding conditions – like light quality or temperature – affect its performance.

A new study from the **Sharkey lab** looks at a pivotal sugar molecule, called glucose 6-phosphate (G6P), that is the first step towards making starch. Starch in leaves breaks down at night to feed the plant when the sun is not shining. The G6P sugar molecule comes at a crossroads where it is either processed or transported by one of four different enzymes.

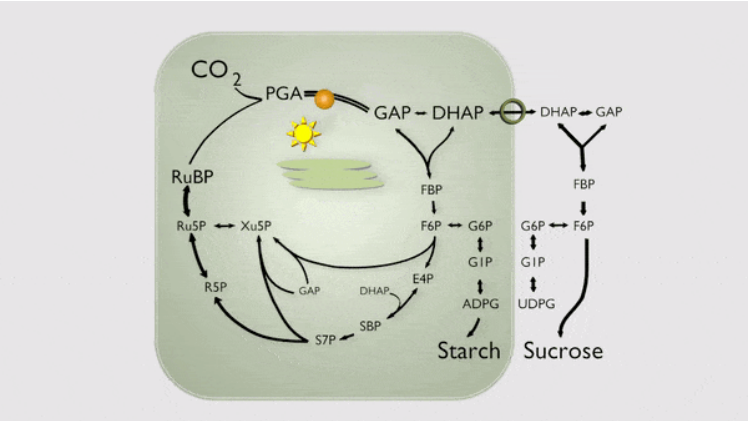


Figure 1 The pathway taken in the Calvin-Benson cycle to produce starch that feeds plants at night. This journey is full of chemical reactions and intermediary molecules. By MSU-DOE Plant Research Laboratory, 2019

Here, the researchers analyze the enzyme, G6PDH, that diverts G6P away from starch synthesis. They also show it can work during the day. Previous studies, dating back to the 60s and 70s, claimed it is only active at night when its products help the plant. The study is published in **Biochemical Journal**.

Protecting the cycle through side reactions

"The G6P sugar molecule is very flexible," says **Alyssa Preiser, a student in the Department Biochemistry & Molecular Biology**. "It can turn into precursors for sucrose and starch that go on to feed the plant. Or it can re-enter the Calvin-Benson cycle through a couple different ways."

One of these ways is a **series of side reactions that protect the cycle**. The Calvin-Benson cycle is fragile and will stall if no carbon molecules are pumped into it. The side reactions pump a low flow of carbon into the main cycle to keep it running.

Enter the enzyme G6PDH. It diverts G6P from turning into starch and into the protective side reactions. Importantly, the G6P sugar fuels the first step of these reactions.

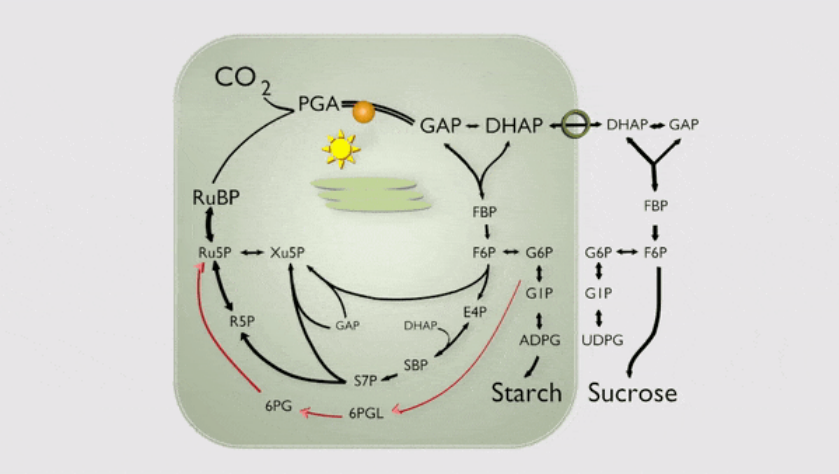


Figure 2 G6PDH diverts G6P from turning into starch and into the protective side reactions (red arrows). That is how resources are pumped back into the cycle to keep it active. By MSU-DOE Plant Research Laboratory, 2019

"We also looked into an earlier assumption that the enzyme just works at night," Alyssa adds. "We found it active throughout the day. It's usually at 10 to 20% of its maximum capacity. But under certain conditions, performance can increase."

"During the day, there are times that expand iconphotosynthesis is so active, the Calvin-Benson cycle can't keep up with the inflow of carbon. And again, it is also prone to breaking down," Alyssa says. "The side reactions probably take excess carbon away from the cycle to reduce the pressure. Then, they feed the carbon back into the cycle when the time is right."

From a practical point of view, Alyssa, adds, it is **important to understand how the Calvin-Benson cycle works**. The cycle is the key to organic life on Earth. We could someday improve it so plants increase their sugar and starch production. These enhancements would help farmers get higher crop yields.

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

Altering how cyanobacteria capture light from the sun can impact their health

5/29/19

Igor Houwat, Beronda Montgomery

Figure 1 Banner by Christoph Benning

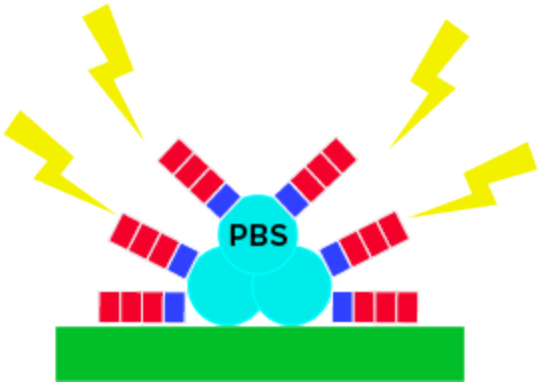
Scientists have delved further into how cyanobacteria, one of the planet's most abundant organisms, manage how they capture light to do expand iconphotosynthesis.

At the center of it all are proteins called expand iconphycobilisomes (PBS). PBS are antennae that safely capture light waves from the sun and fuel the process of photosynthesis.

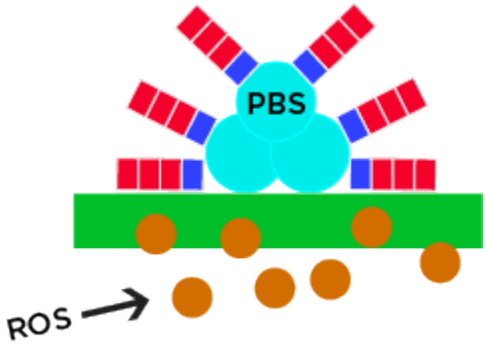
A new study from the **MSU-DOE Plant Research Laboratory** examines how various ways of affecting PBS can lead to different responses – whether the expand iconcyanobacteria remain content or become stressed. The responses depend on the species of cyanobacteria and the nature of the modification. The study is published in **Frontiers in Microbiology**.

To be or not to be… content

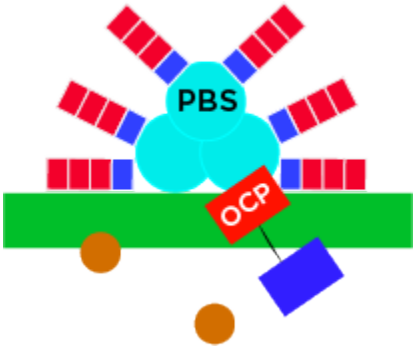
Light capture works like this:



1. **PBS capture light**: PBS make pigments that match the light waves in a specific environment



2. **Light damage**: if PBS pigments can't match the surroundings, expand iconreactive oxygen species (ROS) build up, which is damaging for cells. (It is what causes ageing in human cells).



3. **Damage control**: a protective protein, called expand iconOCP, attaches to PBS to slow light capture. OCP also scavenges ROS.

Beronda Montgomery, MSU Foundation Professor and study co-author, says, "In a previous study, we mutated a cyanobacterium to have smaller PBS. As a result, the number of protective OCP proteins went down. It makes sense. With little to no PBS, the cell doesn't need to spend energy on protection."

The goal here was to see if this reaction applies across cyanobacteria species. The previous study focused on *Fremyella*, a multicellular organism. This one used *Synechocystis*, a simpler uni-cellular organism.

“As in the previous study, we knocked out the gene, *cpcF*, resulting in a reduction in PBS function. In this case, we also knocked out another gene, called *cpcG1,* for comparison purposes.” Montgomery says.

Both mutations reduce PBS function, but differently. Removing CpcF dismantles the PBS such that some function remains. Removing CpcG1 is like cleaving off PBS cleanly from a cell, which is easier for the cell to endure.

The big conclusion is, how PBS are removed affects whether a cell is content or becomes stressed:

	CpcF	CpcG1
PBS levels	Lower	Lower
ROS levels	Higher	Unchanged
OCP levels	Higher	Higher
Stressed cell?	Yes	No

Also, disrupting PBS leads to an increase in the levels of OCP in *Synechocystis*. This is the opposite of the reaction from the previous study.

“This result could be explained by the fact that different cyanobacteria evolved to live in distinct environments. They also have different complements of OCP-related genes which lead to different responses and ability to resist stress,” Montgomery says.

cpcG1 is promising for biotech

Additional testing shows the *cpcF* mutants are stressed, by default. They resort to various protective mechanisms, in addition to the OCP protein.

“However, the *cpcG1* mutant is resistant to oxidative stress, which opens up potential uses in biotech,” Montgomery says. “ROS slows down cell growth, which isn’t good for mass producing biotech products. Being able to resist oxidative stress and limit ROS accumulation could solve some of these productivity problems.”

“What I do like about this study is that we start out with a basic question – comparing cyanobacteria species – and end up thinking about biotech applications we didn’t set out looking for!”

Banner image: Mats of colored cyanobacteria at Yellowstone National Park. The research was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

Christian Danve Castroverde joins Wilfrid Laurier University as Assistant Professor

5/30/19

Igor Houwat

Christian Danve Castroverde, a postdoctoral fellow in the lab of Sheng Yang He, has joined as an Assistant Professor in the Department of Biology at **Wilfrid Laurier University** in Waterloo, Ontario, Canada.

Danve's lab will investigate the transcriptional and hormonal regulation of plant immune responses under various environmental and abiotic stresses, using a combination of model organisms and important crop plants. His research program aims to further refine and integrate our understanding of the mechanisms underlying plant diseases in a changing environment, in order to better understand and improve plant resilience.

Danve joined the He lab in 2016 and was a member of both the MSU-DOE Plant Research Lab (PRL) and Plant Resilience Institute (**PRI**). He has researched how **environmental conditions, specifically high temperatures, influence plant disease**, a major threat to global food security. In 2018, he **won a Natural Sciences and Engineering Research Council of Canada Postdoctoral Fellowship** to support his efforts.

Figure 1 Castroverde, left, with his mentor, Sheng Yang He. MSU-DOE Plant Research Laboratory, 2019

“I am very excited to begin this new chapter in my academic career!” Danve says. “I am very grateful to have been given an opportunity to work with the distinguished and collegial group of Sheng Yang He, and also to interact with exceptional researchers in the hallowed halls of PRL and PRI. It will be bittersweet to leave MSU, but I plan to continue collaborating with colleagues here. This institution has been an integral part of my life for the past three years.”

Sheng Yang He, Danve’s mentor, adds, “Danve came to MSU with well defined goals and did every thing right in terms of preparing for a faculty position. He is a wonderful researcher, teacher, and mentor. His love of science and his interactive personality stand out. Danve will be missed.”

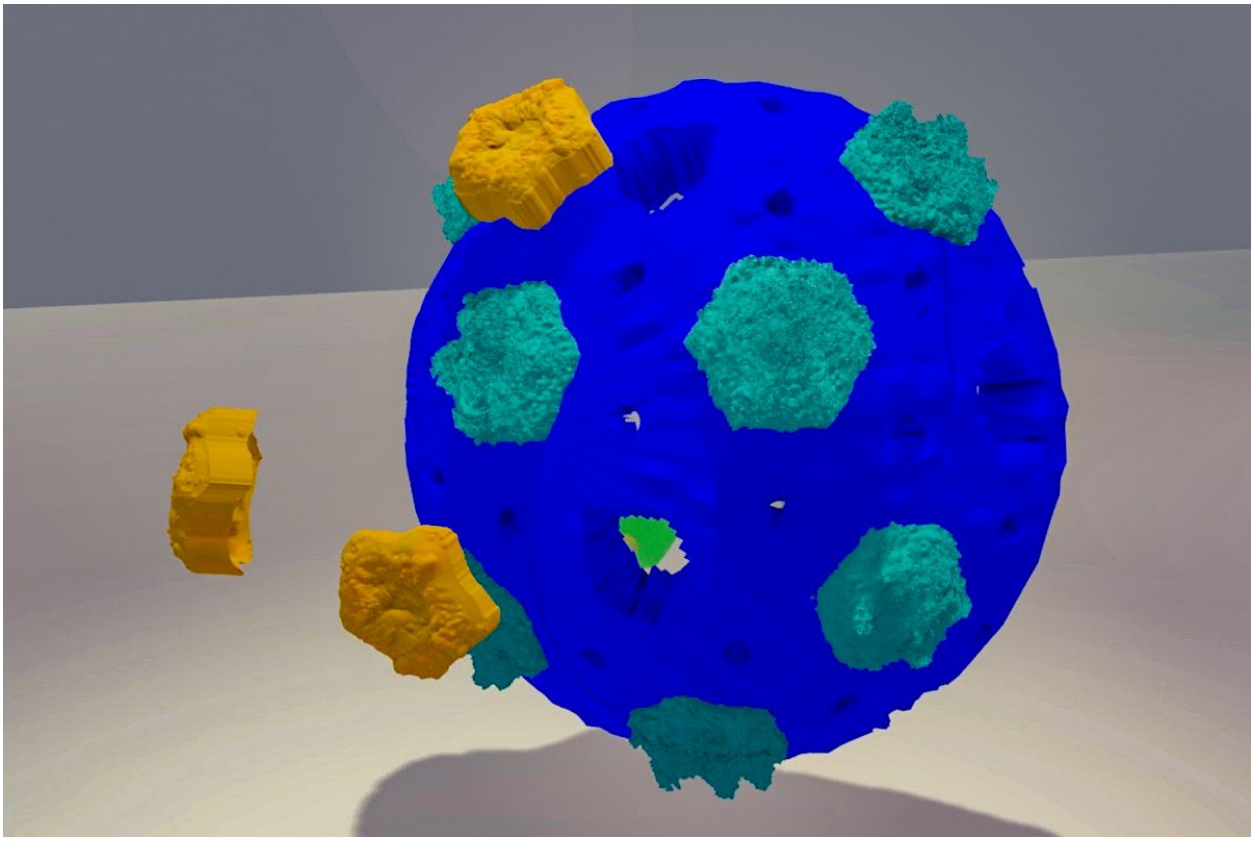
Danve obtained his BS in Molecular Biology and Biotechnology at the **University of the Phlippines** and his MSc and PhD in Molecular and Cellular Biology at the **University of Guelph, Canada**.

Good luck, Danve!

[VIDEO] A new way to 'hoard' resources in nano-sized factories targeted for biotech

6/4/19

Igor Houwat, Bryan Ferlez



THE STORY IN 60 SECS

https://youtu.be/HnQJFcfIVfU

The **lab of Cheryl Kerfeld** has created a synthetic nano-sized factory, based on natural ones found in bacteria. This research could someday lead to new medical, industrial, or bioenergy applications. The new study is **published in Metabolic Engineering**.

Natural nanofactories are found in bacteria all over the planet. Some make nutrients. Others sequester toxic materials that would otherwise make the bacteria sick — or even die.

But all factories share a common exterior, a shell made of protein tiles. Scientists want to design new factories, based on those found in bacteria naturally, for use in biotechnology.

One way to direct useful expand iconenzymes to these factories is by physically attaching them to the tail ends of the proteins that make up the factory shells. But there is a catch.

The ends, or expand icontermini, of most shell expand iconprotein tiles face the outside of a factory. So any molecules fused to the protein ends will end up on the outside surface and not the inside. This is a problem if the goal is to keep one or more enzymes inside a factory separated from the rest of the cell.

Turning a wall tile 'inside-out'

“In order to send proteins to the inside of the factory, we needed a new kind of building block that still assembled into shells,” says Bryan Ferlez, a post-doc in the Kerfeld lab. “We aimed to redesign a shell protein so its termini face the inside. The end result is that cargo connected to this shell protein would also end up inside the shell.”

(**See our quick video explainer above for more.**)

In the new study, the scientists take the most abundant shell protein, called BMC-H, and turn it ‘inside-out’ through a technique called circular permutation.

They shuffle segments of the the expand iconamino acid sequence and glue the original ends together. They then introduce new termini on the inner face of the protein. The result is a new, synthetic shell protein that looks almost identical to its natural counterpart. Except now, both new ends face the inside of the shell.

The new structure is a usable building block to construct factory shells. The scientists have successfully produced factory shells, with the new protein. They are similar in size and appearance to the original shells.

The new structure can incorporate molecules inside the shell. The team tested the concept by fusing a fluorescent cargo protein to the new BMC-H protein. Microscopy and biochemical testing show the cargo on the inside of the shell.

Scientists can control the amount of cargo imported into the new structure. Bryan says, “By making more or less of the new BMC-H protein with a fluorescent protein fused to its terminus, we were also able to control the amount of cargo that incorporates into the shell.”

Next, Bryan wants to **target ‘useful’ molecules into a synthetic factory** made with the new shell protein.

“We can start to build metabolic pathways, or assembly lines, and define the amounts and locations of enzymes within these nanofactories. Someday, we could use this system to **enhance the production of rubber, biofuels, and other commodities**,” he adds.

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

Plants can crash when photosynthesis rates are high. This is one way they slow down.

7/9/19

Igor Houwat, Sean Weise

(Cheesy poem warning)

With the need for speed;
a car goes far.
We avoid deadly mistakes,
With the one thing slowing us down: the brakes

Just as brakes are essential to whiz down a highway, plants rely on special expand iconproteins to maintain high rates of photosynthesis without crashing.

The big picture is this. expand iconPhotosynthesis is how plants 'make food' for us all. Improving it is one of the last scientific barriers to increase crop yields and feed the world's growing population. But researchers can't simply force plants to put the pedal to the metal. That would be disastrous, because their 'brakes' are more complex than a car's.

In a new study, the **lab of Michigan State University's Thomas D. Sharkey** delves into a 'brake' protein, called GPT2. It helps manage photosynthesis in the presence of high levels of light or carbon dioxide, which can push photosynthesis into overdrive mode. The study is in the journal, ***Frontiers in Plant Science***.

A molecule to manage starch production

GPT2 is part of the photosynthetic processes that introduce carbon into our diets. **It is carbon that becomes the sugars and starches that fuel life**.

"Starch is a plant's backup battery," says **Sean Weise, Research Assistant Professor in the Sharkey lab**. "A plant builds it up during the day when it can do photosynthesis. It uses the starch at night when it can't, because the sun is gone."

GPT2 sits in the chloroplast membrane and helps manage that starch production by allowing sugars to move into the expand iconchloroplast.

When photosynthesis increases rapidly, like when the sun peaks out from a cloudy day, **GPT2 is quickly turned on**.

"We think this recycles sugars back into the chloroplast for starch production," says Sean. "Other genes responsible for starch synthesis also get turned on rapidly. However, genes involved in almost every other aspect of carbon dioxide metabolism, including sucrose synthesis, are turned down. That last part was a surprise to us, and we're looking into it."

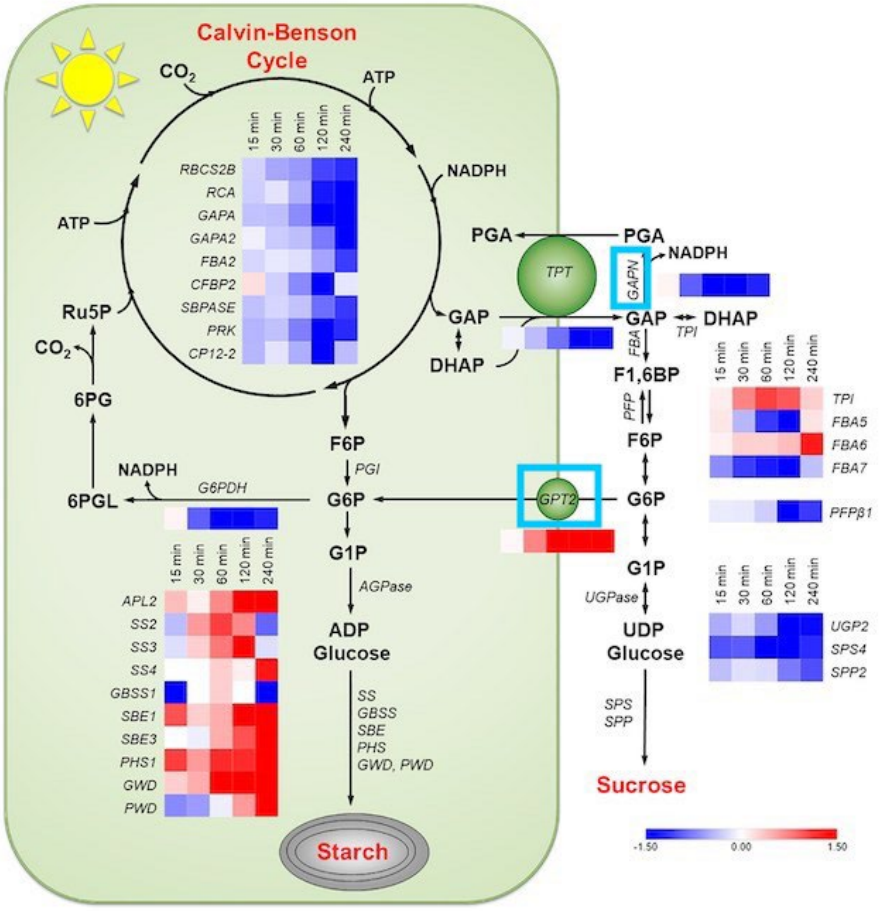


Figure 1 When photosynthetic activity is high, genes responsible for starch synthesis get turned on rapidly (red boxes) while genes in almost every other aspect of carbon dioxide metabolism are turned down (dark blue boxes). GPT2 and GAPN are highlighted (light blue boxes). By Sean Weise, as found in Frontiers in Plant Science, CC By 4.0, 2019

The team thinks plants activate **GPT2 as a sort of brake to allow the plant's cells to keep up with increased photosynthetic activity** and to increase starch stores for use at night.

What triggers this photosynthesis slowdown?

When photosynthesis activity is high, a lot of energy compounds are pumped from the chloroplast into the rest of the plant cell. Most of the time, this is desired, but too many of these compounds can cause chemical reactions that harm the plant cell.

That's one situation where plants 'step on the brakes.'

"When GPT2 is active, another gene, called GAPN, that processes the high energy compounds that end up in the expand iconcytosol, is muzzled," Sean says. "That is how plants recycle compounds back into the chloroplast to keep them away from the rest of the plant cell."

Another trigger that activates GPT2 is a expand icontranscription factor known as RRTF1.

“Transcription factors influence large numbers of genes at once,” Sean says. “If you control one transcription factor, you can affect dozens or even hundreds of other genes. That is why RRTF1 could potentially be an exciting target for improving photosynthesis through genetic engineering.”

Stepping back, Sean considers the big picture: improving photosynthesis.

“At first blush, GPT2 seems counterproductive. High rates of photosynthesis are good.” Sean says. “Why would a plant reduce its export of high energy compounds? Why put the brakes on productivity gains and instead recycle resources? However, when we look at plant metabolism more closely, we realize that **there really can be too much of a good thing, and this could damage the plant cell**.”

“Understanding the ‘brakes’ only gives us a more complete view of photosynthetic plant metabolism. It also identifies new targets for improvement. Perhaps, in the future, we can engineer plants that don’t need to put on the brakes as often.”

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

These algae can live inside fungi. It could be how land plants first evolved.

7/17/19

Igor Houwat, Zhi-Yan Du

Picture a typical documentary scene on the evolution of life. It probably starts with little bugs in a murky, primordial soup. Eons of time zip by as bugs turn into fish, fish swim to land as their fins morph into limbs for crawling animals, which then stand up on two legs, to finally end up with walking humans.

The picture is very animal-centric. But what about plants? They also made the jump from water to land. Scientists think that green algae are their water-living ancestors, but we are not sure how the transition to land plants happened.

New research from Michigan State University, and **published in the journal eLife**, presents evidence that algae could have piggybacked on fungi to leave the water and to colonize the land, over 500 million years ago.

“Fungi are found all over the planet. They create symbiotic relationships with most land plants. That is one reason we think they were essential for evolution of life on land. But until now, we have not seen evidence of fungi internalizing living algae,” says Zhi-Yan Du, study co-author and member of the **labs of Christoph Benning**, and now, **Gregory Bonito**.

Researchers selected a strain of soil fungus and marine alga from old lineages, respectively *Mortierella elongata* and *Nannochloropsis oceanica*.

When grown together, both organisms form a strong relationship.

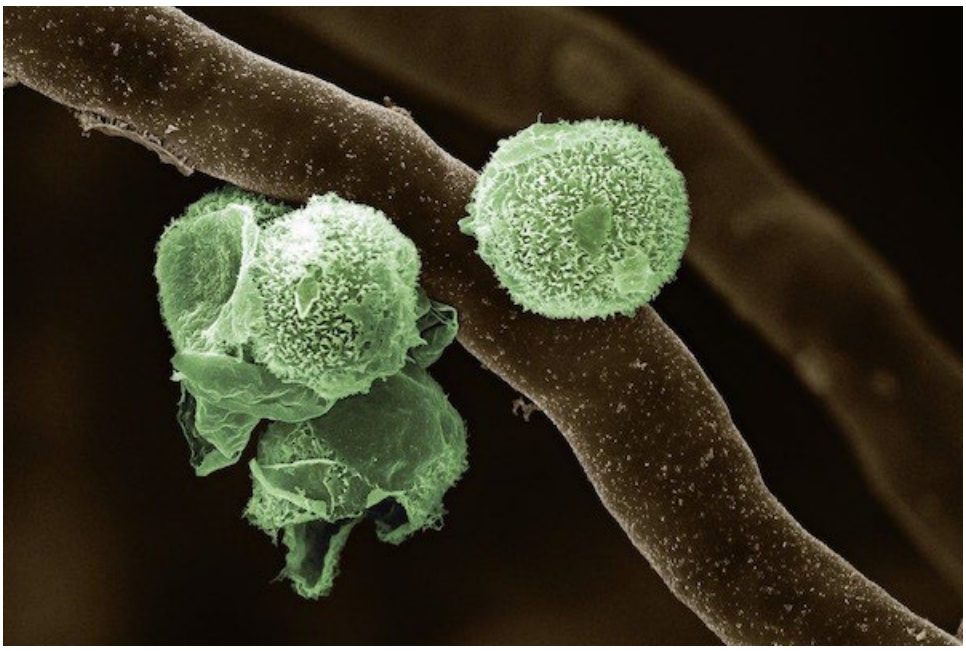


*Figure 1 A strong relationship as algal cells (green) attach to fungal cells (brown). By Zhi-Yan Du, colored by Igor Houwat; from **eLife**, Du et al, CC BY 4.0, 2019*

“Microscopy images show the algal cells aggregating around and attaching to fungal cells,” Du says. “The algal wall is slightly broken down, and its fibrous extensions appear to grab the surface of the fungus.”

Surprisingly, when they are grown together for a long time – around a month – some algal cells enter the fungal cells. Both organisms remain active and healthy in this relationship.

This is the first time scientists have seen fungi internalize a expand iconeukaryotic, photosynthetic organism. They call it a ‘photosynthetic mycelium.’

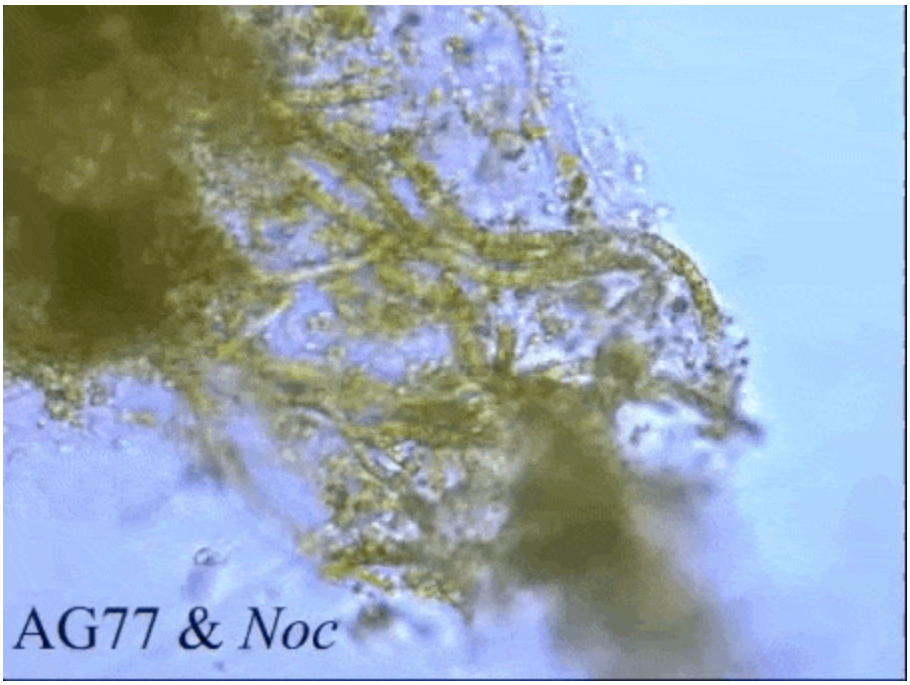


*Figure 2 After growing together for a while, some algal cells enter the fungal cells - the wispy filaments - which is why the filaments look green. By Zhi-Yan Du, from **eLife**, Du et al, CC BY 4.0, 2019*

“Both organisms get additional benefits from being together,” Du says. “They exchange nutrients, with a likely net flow of carbon from alga to fungus, and a net flow of nitrogen in the other direction. Interestingly, the fungus needs physical contact with living algal cells to get nutrients. Algal cells don’t need physical contact or living fungus to benefit from the interaction. Fungal cells, dead or alive, release nutrients in their surroundings.”

“Even better, when nutrients are scarce, algal and fungal cells grown together fend off starvation by feeding each other. They do better than when they are grown separately.”

Perhaps this increased hardiness explains how algae survived the trek onto land.

“In nature, similar symbiotic events might be going on, more than we realize,” Du adds. “We now have a system to study how a expand iconphotosynthetic organism can live inside a non-photosynthetic one and how this symbiosis evolves and functions.”

Both organisms are biotech related strains because they produce high amounts of oil. **Du is testing them as a platform to produce high-value compounds**, such as biofuels or Omega 3 fatty acids.

“Because the two organisms are more resilient together, they might better survive the stresses of bioproduction,” Du says. “We could also lower the cost of harvesting algae, which is a large reason biofuel costs are still prohibitive.”

This work was partially funded by the **US Department of Energy, Office of Basic Energy Sciences**. It was primarily a collaboration between the Michigan State University labs of Gregory Bonito (focus on fungi) and Christoph Benning (focus on algae)

Christoph Benning is named University Distinguished Professor

7/22/19

Igor Houwat

Dr. Christoph Benning has been promoted to University Distinguished Professor. He is among ten Michigan State University faculty members who have earned the distinction this year.

The title of University Distinguished Professor is among the highest honors that can be bestowed on a faculty member by the university. Those selected for the title have been recognized nationally and internationally for the importance of their teaching, research and outreach achievements.

Benning is a recognized leader in research on lipid metabolism in photosynthetic organisms. One area of particular interest is the assembly and maintenance of the photosynthetic membrane in plants and algae. The photosynthetic membrane contains a unique set of polar lipids. The Benning lab studies the biosynthesis and movement of lipids of the photosynthetic membrane. Specific functions of these lipids in photosynthesis, especially during dynamic conditions, is investigated by applying state-of-the-art phenotyping to Arabidopsis and Chlamydomonas lipid mutants.

Figure 1 Christoph Benning. By Igor Houwat, MSU-DOE Plant Research Laboratory, 2019

Benning is also engaged in mentoring the next generation of scientists and interested in advancing science communication.

“I am truly honored by this promotion and would like to thank everyone who worked tirelessly with me, the students, post docs, staff members and collaborators, in advancing our understanding of lipids in photosynthetic organisms,” says Benning.

The MSU Board of Trustees voted on and approved their ten recommendations on June 21. Those holding the professorship will receive, in addition to their salary, a stipend of $5,000 per year for five years to support professional activities.

A reception to honor the newly designated University Distinguished Professors will be held on November 21, 2019.

Bethany Huot starts new position at MSU Department of Biological Sciences

8/1/19

Bethany Huot, Igor Houwat

This fall, Bethany Huot, post-doc in the lab of Sheng Yang He, will start a new position as Instructor with the Department of Biological Sciences (BioSci) team at Michigan State University (MSU).

Bethany's primary responsibility will be teaching four sections of an undergraduate Cell & Molecular biology laboratory course (**BS 171**). In addition, she will contribute to **BioSci's** efforts to continue improving their curriculum. One of the reasons Bethany was chosen for the position was her ideas on what she calls "Strategic Career Management" and how they might be incorporated into the program.

This **new position is a culmination of years of research training and work in the realm of science education**.

Her mentor, **Sheng Yang He**, says, "It was a real pleasure to mentor Bethany during an important phase of her career. She is an accomplished scientist and a critical thinker, fearless in pursuing her dreams. With a sunny personality and exceptional communication skills, Bethany is taking a career path that few are capable of trying. We wish her all the best."

Following are excerpts of an interview with Bethany.

How does a person whose career has been focused in scientific research end up getting a position in education?

The short answer: community impact. **My life has always been influenced by the communities around me**. As an undergrad, I really began to feel the impact that community can have on one's career. I had a great mentor who gave me broad opportunities to explore that most do not get. As a result, I discovered my passion for scientific research and teaching, but I knew I did not want a tenure track faculty position.

Not knowing what position was the best fit, I spent time building experience and skills outside of academia, including three years at the Dow Chemical Company. There, my love for science was deepened but the opportunity to pursue it at the level I wanted was limited. So, with the support of my community there I came to MSU to get my PhD. While every community has its positives and negatives, these experiences forced me to start viewing education as a part of my career and to approach it more strategically.

Figure 1 Bethany Huot. By Igor Houwat, MSU-DOE Plant Research Laboratory, 2019

What is "Strategic Career Management?" How does that fit in with your career goals?

It initially grew out of my experiences: my undergrad mentor encouraged me to evaluate and adjust my path, my mentors at Dow encouraged me to pursue my passion and adjust accordingly, **Sheng Yang** supported me to pursue things "beyond the bench." Then, during graduate school when I ran The PubClub, I developed it into what we in science call an S.O.P. (standard operating procedure).

The first step is defining your career objective through reflection and exploration. Who am I? What am I most passionate about? What careers best align with my interests?

The next step is strategically working towards becoming the most attractive candidate for your dream position by defining "The Void," which is the gap between the skills you need and the skills you have. It can be scary to look at everything in The Void, but also necessary to begin tackling it strategically.

For example, I went to a scientific conference to present my research, but because of my work with The Pub Club was invited to co-host a communication workshop. I didn't yet know how this would specifically fit with my career path, but it matched my passion and helped fill The Void, so I did both.

During my time running The Pub Club, and now The Community of Minds (**TheCOM**), I have encouraged others to do the same. I have had many students tell me they are where they are because "it was just the next thing to do." It is frustrating and a bit scary trying to make big decisions about your life with such limited information. There are so many factors outside of our control.

*In a nutshell, **Strategic Career Management** helps to minimize the anxiety we all face due to the factors we can't control by giving us things we can control. It is a flexible road map towards an uncertain destination in a purposeful direction.*

The key is looking forward to where you want to go. That place may be vague at times, as it was when I returned to school to get a PhD. That place may change, as it did for me several times moving from

strictly research to helping others take ownership of and direct the education phase of their career. But I ultimately landed my dream job by treating every decision as strategically important towards reaching that goal.

“The first step is defining your career objective. Who am I? What am I most passionate about? [Next is] strategically becoming the most attractive candidate for your dream position..."

How did all of that bring you back to MSU as an instructor?

I wanted to see if I could build a career applying this Strategic Career Management approach in a learning environment. I also wanted to focus on the undergraduate level where I could impact more people earlier in the scientific training process.

So, I reached out to faculty at Calvin College to build my community and, after sharing some of my ideas, we decided to pilot TheCOM’s **Educative Research Initiative** there. I designed my research project for two freshman biology laboratory courses and spent all last year teaching their students with this integrated approach - career, community and research.

I discovered that an integrated learning position was where my unique path had led me. I had found a way to apply my passion.

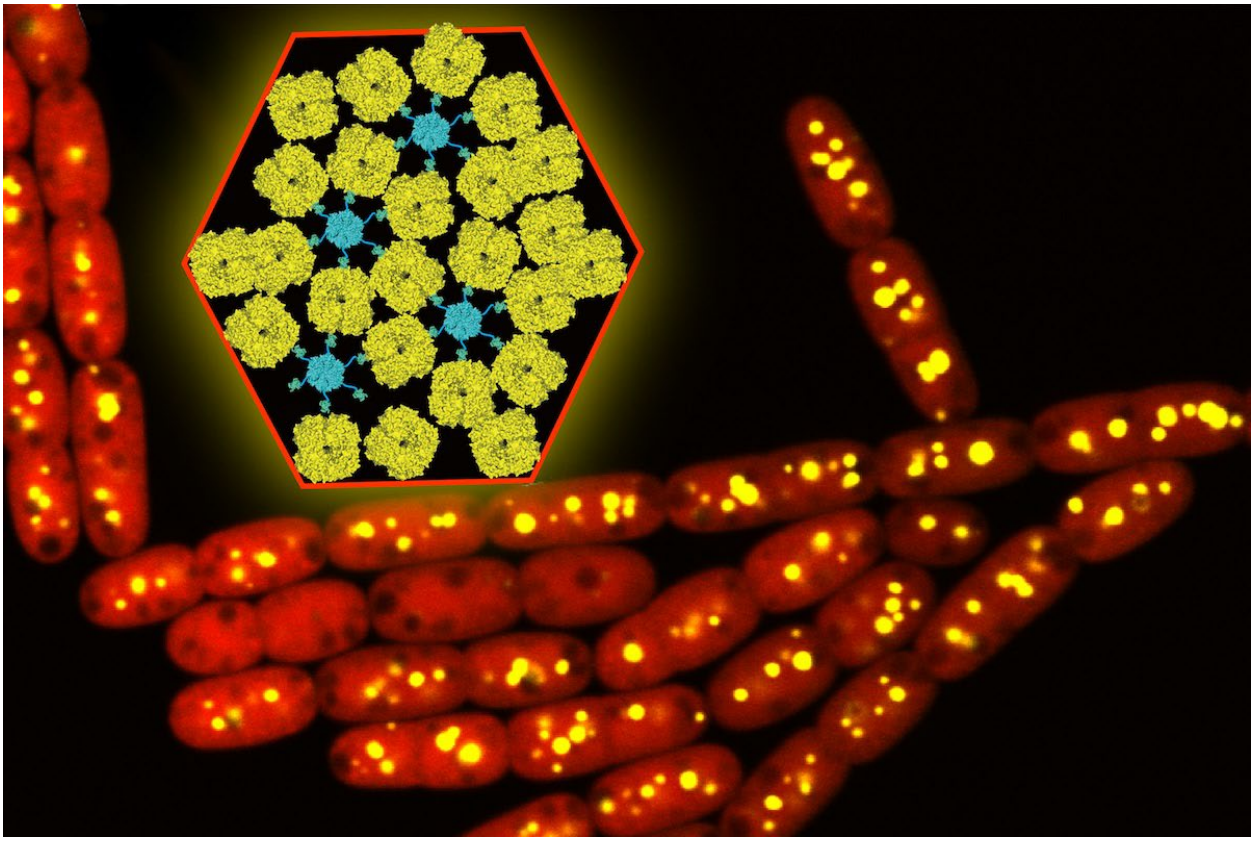
Just as the program was wrapping up, this position opened at MSU and it was exactly what I had been doing at Calvin College. I couldn’t have found a better fit. The bonus is I will be working with people who want to do this type of educating at MSU. Besides using authentic research as a tool to teach, I will also apply the same scientific method to teaching. We can hypothesize on teaching methods and measure what works and what doesn’t. This first year I will be learning the ropes and becoming a part of my new BioSci community. I am excited for both what I can contribute to and what I can learn from my new team.

In the end, I am proof that tapping into your community can help you achieve your goals. A Strategic Career Management approach may produce a “unique plan,” but that plan will lead you to fulfilling your passion. **As I have said before**, I decided who I wanted to be, and then I was that person on purpose!

Identifying a cyanobacterial gene family that helps control photosynthesis

9/30/19

Igor Houwat, Sigal Lechno-Yossef



A new Michigan State University study has identified a family of genes in cyanobacteria that help control carbon dioxide fixation. The discovery furthers our basic knowledge of photosynthesis. It also opens new doors to design systems for sustainable biotech production. The research is **published in the journal, New Phytologist**.

expand iconCyanobacteria and plants share an enzyme in common, rubisco, which captures carbon dioxide from the atmosphere. Carbon capture is the first in a series of reactions that turn carbon into high-energy molecules that feed the planet's organisms.

In plants, rubisco is often blocked from working by small molecules that attach to it. In response, the protein, Rubisco activase (Rca), comes to the rescue, removing the unwanted molecules so rubisco can work again.

Recent advances in bioinformatics have allowed the **lab of Cheryl Kerfeld** to identify a cyanobacterial gene that looks like the one that encodes plant rubisco activase.

The new gene encodes what the lab is calling, activase-like cyanobacterial protein (ALC).

“This gene is widespread in many taxonomic groups of cyanobacteria. Those include various unicellular and multi-cellular, filamentous species,” says **Sigal Lechno-Yossef**, Research Assistant Professor in the Kerfeld lab.

The cyanbacterial ALC’s function remains unknown. The scientists tried mixing the ALC from a model cyanobacterium, *Fremyella diplosiphon*, with inhibited rubisco from the same organism, in a test tube. The ALC did not relieve rubisco from inhibition by small molecules.

However, in the cell, the protein is physically close to rubisco, just like its plant counterpart is. That is one reason Lechno-Yossef thinks they might work together.

“We also have bioinformatic evidence that shows ALC evolving along with rubisco in cyanobacteria. This finding is further support for interaction between these two proteins,” Lechno-Yossef says.

So if ALC does not unblock rubisco, what does it do?

“We saw ALC causing rubisco proteins to aggregate,” Lechno-Yossef says. “This function is similar to that of another cyanobacterial protein, which is known to contribute to rubisco regulation and localization in the cell.”

There is also evidence ALC helps its host detect CO2 levels in order to adjust photosynthesis rates. When the team deleted the *alc* gene in a lab cyanobacterium, the organism did not experience dramatic changes in their growth. (In plants, deleting the analogous rubisco activase causes them to starve for carbon, a crucial nutrient.)

However, those same strains experienced morphological changes when grown in CO2-rich environments.

The new research holds promise for the biotech field. In plants, rubisco activase is the focus of much study, as part of **efforts to increase rubisco performance**. Improving rubisco would lead to plants with higher nutrition contents, and higher crop yields. But such efforts have gone unrewarded so far.

“Cyanobacterial researchers also want to to increase energy yield from photosynthensis,” Lechno-Yossef says. “The goal would be to rewire cyanobacteria’s photosynthetic machine to produce renewable energy compounds or materials for use in medicine or industry.”

“Now we know that cyanobacteria have an enzyme that supports rubisco, we could try making more robust cyanobacteria for industrial applications.”

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**. Banner image by Sigal Lechno-Yossef. The research project was a collaboration with **Brandon Rohnke** and the **lab of Beronda Montgomery**.

Ya-Shiuan Lai wins 2019 Kende Award

10/24/19

Igor Houwat

Ya-Shiuan Lai is the recipient of the 2019 Kende Award, which recognizes the best doctoral dissertation in the plant sciences at Michigan State University (MSU) over the last two years.

In addition to winning a monetary award, Ya-Shiuan, a former member in the lab of Federica Brandizzi at the MSU-DOE Plant Research Laboratory (PRL), presented a research seminar on October 14, 2019. The award recognized her Ph.D. thesis work on the **mechanism of unfolded protein response signaling** in plants.

"It is a great honor for me to win this award which recognizes my signature work during my Ph.D. career," Ya-Shiuan says. "I would like to share this honor with the members of the Brandizzi lab. Throughout my graduate studies, I had great support from my advisor, Dr. Brandizzi, and engaged in fruitful collaborations from my colleagues. In addition, given the PRL's open and interactive atmosphere with plenty of resources, my scientific thinking and logicism were constantly trained and helped advance my career to the next level."

Figure 1 Ya-Shiuan receiving her award from MSU-DOE Plant Research Laboratory director, Christoph Benning. By Igor Houwat, MSU-DOE Plant Research Laboratory, 2019

"I am so proud of Ya-Shiuan's academic achievements during her PhD in my lab," **Federica Brandizzi** adds. "She is the human incarnation of strength, stamina and high intellect."

Ya-Shiuan obtained a M.S. in Biochemistry and Molecular Biology from National Central University, Taiwan and a Ph.D. in Cellular and Molecular Biology from Michigan State University. Currently, she is a postdoctoral fellow in the biology department at the University of California, San Diego.

"For my postdoctoral training under Dr. Maho Niwa, I will build on my previous training in signal transduction by moving into yeast and mammalian systems. This shift will allow me to address additional questions regarding the effects of endoplasmic reticulum stress in eukaryotic cell cycle progression and human neurodegenerative disease."

Unlikely gathering of scientists generates extraordinary research team, idea - the fat free cell

11/7/19

Sarah Zwickle, writer, NatSci Communications

In late February 2019, the National Science Foundation (NSF) gathered a group of scientists from widely different disciplines who rarely communicate—let alone collaborate—into one room, provided skilled facilitators to push their ideas to the edge of innovation and stepped back to see what would happen.

“Ideas Labs” like these undergird the NSF’s $36 million dollar investment in its Understanding the Rules of Life portfolio aimed at accelerating development in two key areas of science and engineering research: building a synthetic cell and epigenetics.

According to **Cheryl Kerfeld**, MSU Hannah Distinguished Professor in the **MSU-DOE Plant Research Laboratory** and **Department of Biochemistry and Molecular Biology** who attended this particular Ideas Lab outside of Washington, D.C., what happened was akin to the “wheel” people getting together with the “suitcase” people—a breakthrough.

Kerfeld will lead this unlikely team of scientists that includes five research groups from universities across the nation in a $3.4 million Rules of Life grant to engineer a synthetic cell.

“We are going to take building blocks from different scientific disciplines that would never naturally get together—physics, biology and materials chemistry—to build a functional, multi-compartmental and fat-free cell, or ‘ProteoCell,’” Kerfeld said. “Outside of the Ideas Lab context, we never would have self-assembled into a team, and it never would have occurred to me to build a cell without lipids.”

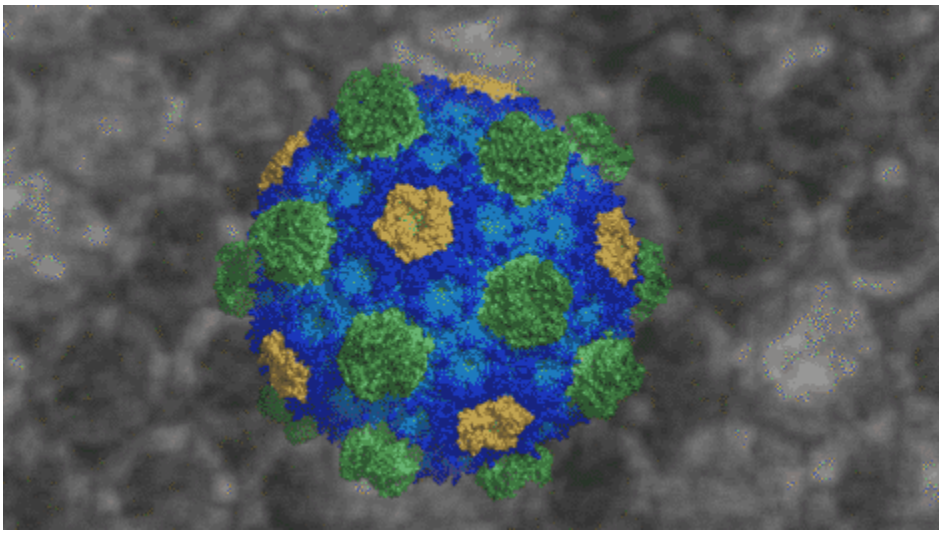


Figure 1 Bacterial cell organelle, made entirely of proteins. By Markus Sutter, Kerfeld lab

Classically, all cells are composed of the four basic macromolecule groups: proteins, carbohydrates, DNA and the fats, or lipids.

“The lipids make up the boundaries of individual cells and their internal compartments—known as organelles,” Kerfeld explained. “But those lipids are not directly encoded by your genome, so we have little control over them, and this presents a fundamental challenge in building synthetic cells.”

The Ideas Lab took this challenge out of the equation with a simple question. Are lipids necessary?

With years of research on bacterial organelles under her belt, it was a question that **Kerfeld’s lab** was poised to answer. Until recently, the prevailing distinction between eukaryotes, like humans and plants, and prokaryotes, like bacteria, was that bacteria lacked the organelles to perform discreet activities.

Kerfeld’s lab has prominently contributed to the knowledge that bacteria do indeed have organelles, only they are made entirely of proteins.

“Instead of using lipids, we are going to take the ‘membrane’ of bacterial organelles, programmable proteins, and test the limits of their potential for composing organelles and even the cell membrane itself,” Kerfeld said.

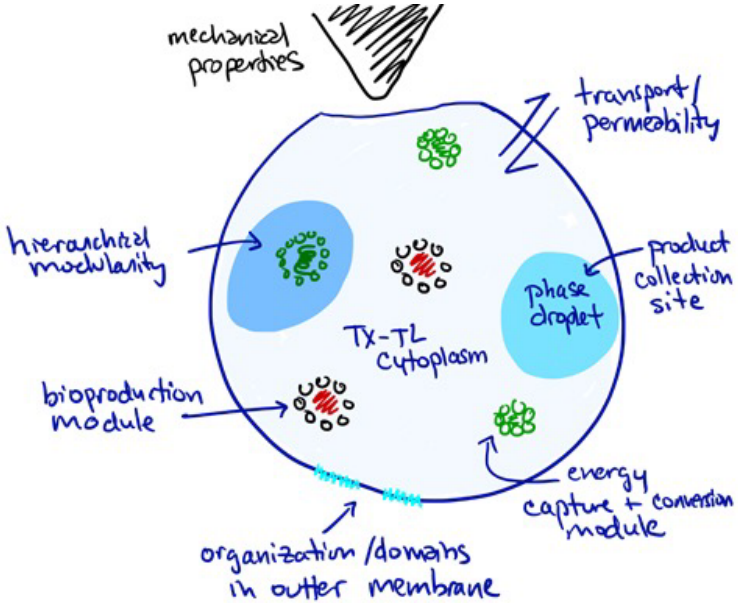


Figure 2 “Back of the envelope” ProteoCell drawing designed by the research team during the NSF Ideas Lab. Courtesy of Kerfeld lab.

Although the first and fundamental goal of the project is to make a synthetic cell without lipids, the project also has significant implications in the production of biomaterials and biofuels in the United States.

“When industries try to use cells as factories for renewables in the bioeconomy, one of the big problems is bioseparation, or getting the product away from the cell material,” Kerfeld said. “If we can engineer cells made of only three macromolecules, it will be simpler to recover product. This is one way that free cells could have a tremendous impact on human health, sustainability and the environment.”

Kerfeld’s Rules of Life team members are: Christine Keating, professor of chemistry from Penn State University; Millie Sullivan, professor of chemical and biomolecular engineering from the University of Delaware; Vincent Noireaux, professor of physics from the University of Minnesota; Giovanna Ghirlanda,

professor of chemistry from Arizona State University; and Barbara Harthorn, professor of anthropology from the University of California Santa Barbara.

“There are important and introspective questions that need to be asked as we develop new technologies,” Kerfeld said. “A cell without lipids is highly artificial, and if we are successful, it may lead to a self-propagating system that could be harnessed for industrial applications. There are ethics around this as well as the fundamental questions that we are asking, like what is life?”

Figure 3 Cheryl Kerfeld portrait. By Michigan State University Advancement

With NSF’s encouragement and support, the team will also study the societal perceptions of a synthetic cell as well as how engineering a new kind of cell might also change the scientists.

“The NSF’s Rules of Life is one of the grand challenges of biology,” Kerfeld noted, “and MSU should be proud that we are leading an elite group of high caliber researchers and faculty able to address these questions.”

For more information about NSF’s Rules of Life Initiative, please visit: **https://www.nsf.gov/news/special_reports/big_ideas/life.jsp**.

Three faculty named 2019 Highly Cited Researchers

11/21/19

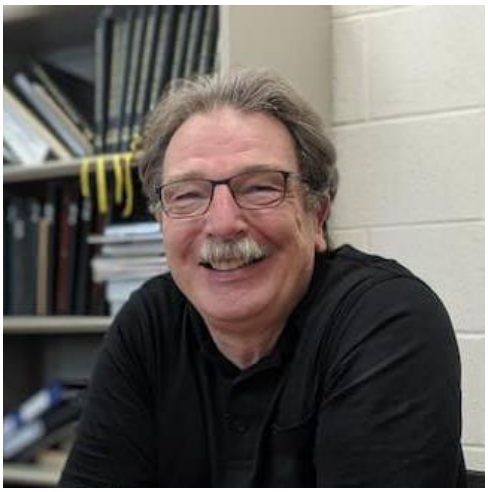
Igor Houwat

Figure 1 Banner image by Kurt Stepnitz, Michigan State University Communications

Three MSU-DOE Plant Research Laboratory (PRL) researchers have been recognized in the 2019 **Highly Cited Researchers List** compiled by Clarivate Analytics.

Each year, the Web of Science Group identifies the world's most influential researchers. The list includes those who have been most cited by peers over the past decade. According to the **report**, "in 2019, fewer than 6,300, or 0.1%, of the world's researchers, across 21 research fields, have earned this exclusive distinction."

The three faculty members are:



Christoph Benning, whose research addresses lipid metabolism in plants and algae. This is his maiden appearance on the list.

Sheng Yang He, who researches plant–pathogen interactions, with an increasing focus on how climate conditions and plant microbiome impact such interactions. He has earned the distinction for six years in a row.

Sheng Yang He, who researches plant–pathogen interactions, with an increasing focus on how climate conditions and plant microbiome impact such interactions. He has earned the distinction for six years in a row.

Cheryl Kerfeld named AAAS Fellow

11/26/19

Aliyah Kovner (Lawrence Berkeley National Laboratory) and Igor Houwat

Cheryl A. Kerfeld has been named a Fellow of the American Association for the Advancement of Science (AAAS). This honor recognizes AAAS members for extraordinary achievements in advancing science.

Kerfeld has been recognized for her, “distinguished contributions to the field of structure of microbial photosynthetic proteins and compartments, particularly the elucidation of design criteria of bacterial microcompartments.”

Kerfeld is the Hannah Distinguished Professor of Structural Bioengineering at the **Michigan State University-DOE Plant Research Laboratory (PRL)** and the Department of Biochemistry and Molecular Biology. She is also guest faculty in Berkeley Lab’s Environmental Genomics and Systems Biology and Molecular Biophysics and Integrated Bioimaging Divisions.

Kerfeld’s research combines methods in bioinformatics, cellular imaging, and synthetic and structural biology to understand the fundamental principles of bacterial metabolism.

In addition to her ongoing work on bacterial microcompartments and cyanobacterial photoprotection, Kerfeld’s career has also focused on developing and implementing innovative undergraduate biology curriculum.

She first worked to improve the curriculum at UCLA, where she had completed her training as a National Science Foundation Postdoctoral Fellow. Then, in 2007, she established the Genomics and Bioinformatics Education Program at the US Department of Energy Joint Genome Institute. This program trains STEM faculty on how bioinformatics tools and resources can be used to help teach students through research projects.

Christoph Benning, PRL director, says, "This is a well deserved honor for Cheryl Kerfeld, recognizing her for her work in synthetic biology on bacterial microcompartments and the orange carotenoid protein. On behalf of everyone at the PRL, I would like to congratulate her."

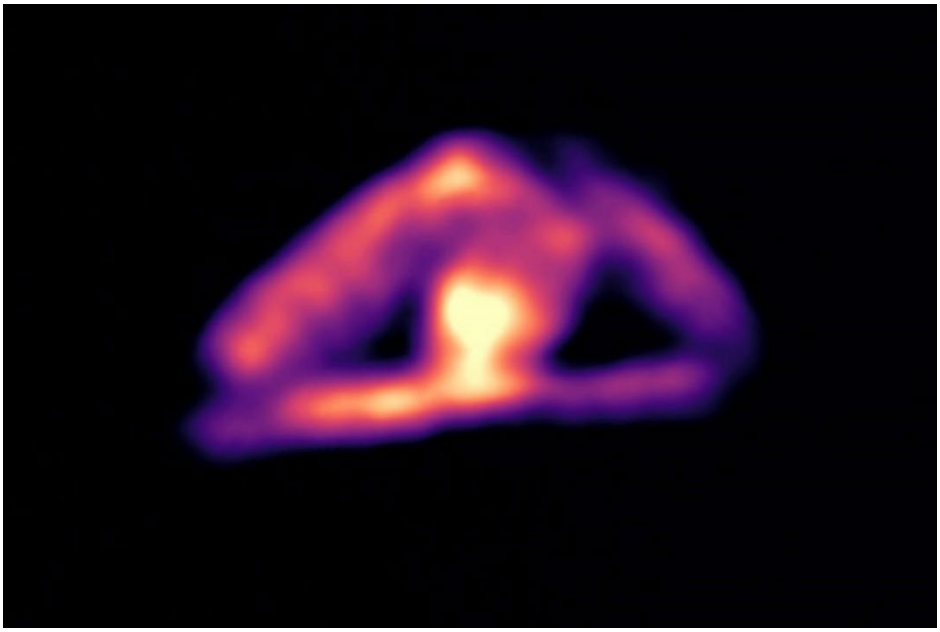
AAAS' annual tradition of recognizing leading scientists as Fellows **dates to 1874**. The list of distinguished scientists includes astronomer Maria Mitchell, elected a Fellow in 1875; inventor Thomas Edison (1878); chemist Linus Pauling (1939); and computer scientist Grace Hopper (1963).

As a side note, the PRL's own **Tom Sharkey** nominated Kerfeld for her 2019 fellowship.

Chasing order beyond the realm of the visible: a new tool tidies up molecules at the nano level [VIDEO]

12/9/19

Igor Houwat, Eric Young



THE STORY IN 90 SECS

https://youtu.be/AvFH3hnhrBE

Tidying up. Not an idea associated with living cells on the nanoscale. But just as a mismash of IKEA bits scattered throughout your bedroom is less useful than a neatly-assembled dresser, synthetic biologists wish to have tools to organize “scattered” components inside living cells.

This simple idea is important for scientists studying how to engineer life at the cellular, and even smaller, levels.

A new study from Michigan State University reports the design of new, artificial cellular parts that can organize, ‘tidy up’, molecules inside living cells.

Synthetic biologists like to view living cells as a collection of biological parts that can be taken apart. One can begin to learn the rules of molecular life by studying each part. Then, once they are understood, one can tinker with them, mix and match parts to create new, never before seen functions. Think: renewable energy resources, or new ways to deliver medicines, just to name a couple applications.

Eric Young, a former graduate student in the **Ducat lab** in the MSU-DOE Plant Research Laboratory team, works with a promising family of building blocks — known as BMC-H expand iconproteins. In nature, they help create cellular factories in expand iconbacteria to make food or isolate toxic materials.

In the new study, the researchers engineered BMC-H proteins to act as homing beacons that attract molecular cargo inside a cell.

“We know that some BMC-H proteins can come together to create different shapes, like tubes, sheets, and other unique assemblies,” Eric says. “These shapes can act as scaffolds to host other molecules, but they can’t do it on their own. So we gave them new protein extensions, from another ‘parts’ library, and added them to the BMC-H building block.”

The new designs form never-before seen nanostructures within the cells.

Next, the team tested if the extensions work as homing beacons inside living cells. The ‘bait’ was a glowing test molecule, linked to another extention, and set free to travel throughout a cell. Indeed, the glowing molecules clustered in the same space as the engineered BMC-H proteins. (The glowing molecule emits light under a microscope, which provides visual proof the concept works.)

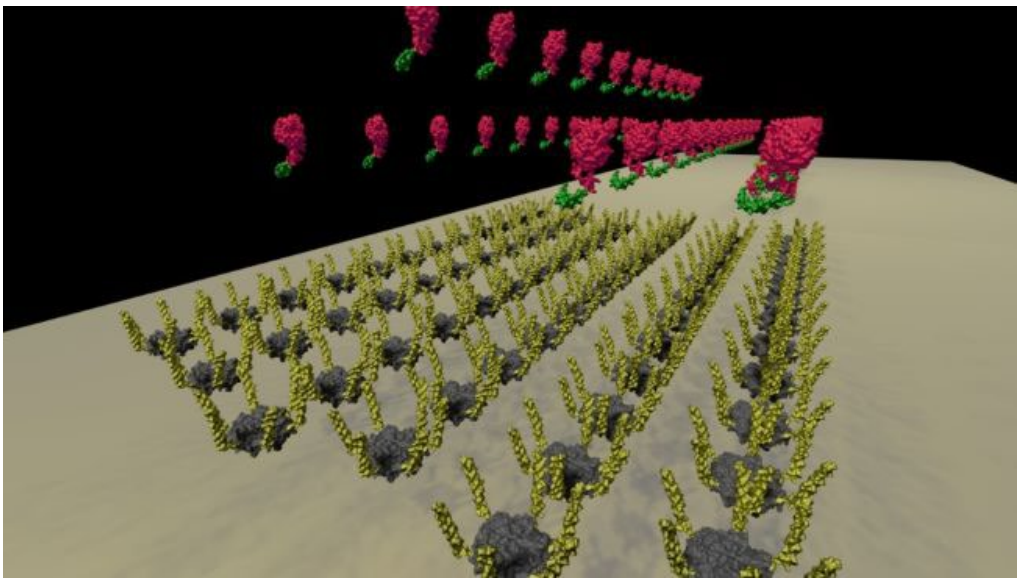


Figure 1 BMC-H proteins (grey) with added extensions (yellow) form scaffolds and act as homing beacons to attract the glowing molecules (pink). By MSU-DOE Plant Research Laboratory, 2019

“We eventually found we could delay production of the scaffold, then turn the ‘on’ switch, and simply watch the ‘bait’ move in response,” Eric says. “We really got creative in imaging the process. It still amazes me to watch how the organization of molecules begins to change, due to our influence.”

Now they have figured out the ‘tidying up’ part, the team wants to learn more about the system and develop new parts.

“The molecular dream is to be able to build whatever we want on the nano-scale,” Eric says. “Just like we can organize resources at the macro-scale, we could use different scientific approaches to **engineer nano-sized structures for specific applications**.”

“For example, we could use these parts to create little landing pads to cluster resources and speed up the production of medical or industrial compounds.”

Eric also wants to share the tool with like-minded scientists. He thinks it could be a useful educational and production toolkit. “It can be relatively easy to learn and fun to use. I hope it can inspire the next generation of scientists and engineers to see, with their own eyes, how one can shape matter at the nanoscale.”

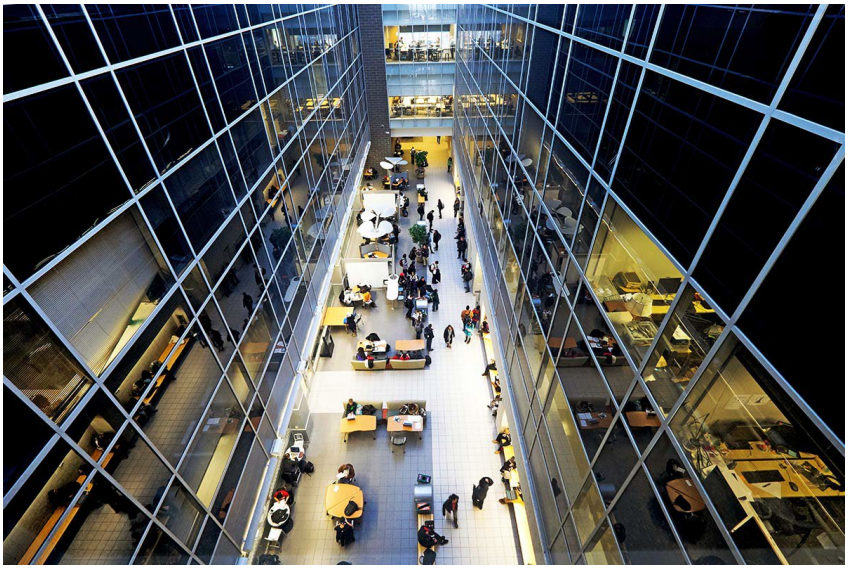
The study is published in Nano Letters.

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

Two PRL undergraduates win Biochemistry & Molecular Biology Departmental awards

12/11/19

Igor Houwat



Chase Lindeboom and Hainite Tuitupou are among the Department of Biochemistry & Molecular Biology (BMB) 2019-20 undergraduate awardees. Both will earn stipends in support of their education and will officially receive their awards at the BMB Awards Banquet in April 2020.

Hainite, a senior in the **lab of David Kramer**, was awarded a BMB Undergraduate Research Fellowship. This award is ,"given to an [undergrad] who has attained at least junior standing, carries a 3.0 GPA or higher, and [is] committed to pursuing a career in research. These are students who want to do research, but cannot because of the need to work."

Figure 1 Hainite Tuitupou from the Kramer lab. By MSU-DOE Plant Research Laboratory, 2019

The Kramer lab is working on understanding controls on photosynthetic controls using spectroscopy. Hainite is contributing to the development of tools and protocols for phenotyping photosynthetic parameters of plants in the field and the lab.

“The most important skill that I want to develop from pursuing research is the ability to solve problems by asking and answering questions,” Hainite says. “I want to be able to ask my own questions and answer them. The support I am receiving from my team and from this award are directly helping me to understand the skills that I need to achieve this goal.”

All of her time outside of school is spent on developing herself in combat sports. You might not know it, but she is a 4-0 amateur MMA cage fighter, president of MSUs judo club, and am in the process of qualifying for the Olympics for boxing through her home country of Tonga.

Chase is a senior in the **lab of Christoph Benning**. He was awarded the Outstanding Undergraudate Student Award, dedicated to senior students who have demonstrated the highest excellence in scholarship and research activities.

Figure 2 Chase Lindebloom from the Benning lab. By MSU-DOE Plant Research Laboratory, 2019

Chase researches a protein, called CHT7, which is thought to be involved in cell-life cycle decision making in the unicellular algae, *Chlamydomonas reinhardtii*. Understanding the regulatory mechanism of cell life-cycle decision making in algae has applications for engineering micro-algae for more efficient production of feedstock for biofuels.

“I am deeply honored to receive this award,” Chase says. “I am very grateful to Dr. Benning and the rest of my lab for what they have taught me and the opportunities that I have been given. I hope I can continue to learn and grow as a scientist in the near future.

Outside of the lab, Chase is working hard on a computer science minor. When he has time, he enjoys escape rooms, hanging out with friends, and playing video games.

Congrats, Chase and Hainitie! **Go here for the complete list of awardees**.

Identifying a plant cell barrier to breeding more nutritious crops

12/18/19

Igor Houwat, Pengfei Cao

What if we could grow plants that are larger and also have higher nutritional content? Michigan State University scientists have identified a expand iconprotein that could be a major roadblock to growing such plants.

Proteins perform most, if not all, of life's functions, like promoting growth, repairing body tissue, or building muscle. And if proteins are like 'words,' amino acids are the 'letters.' Our bodies use about 20 amino acids, in various combinations, or 'spellings,' to produce different proteins.

Our bodies produce some expand iconamino acids . But there are 9 'essential amino acids' that we and other animals can't make. We get these through foods, such as meats, dairy, and ultimately plants.

For decades, scientists have been trying to dial up amino acid content in crops by ramping up their production systems. But they always run into the same problem. The crops get sick, and the scientists are confused as to why plants suffer from the abundance of these amino acids.

The new study suggests the target of rapamycin (TOR) protein is a major roadblock. The work is **published in eLife**.

Plants unsure if they're 'hungry'

"TOR protein is a master regulator of metabolism in plant cells," says **Pengfei Cao**, post-doc in the lab of **Federica Brandizzi**. "It detects variables, like nutrient availability, energy levels, growth cues, and so on. TOR protein uses this information to control cell growth and metabolism functions."

When TOR senses an adequate amount of nutrients, it promotes growth. The twist: TOR is so powerful in controlling many biosynthetic processes and cell structures, that it can cause problems if it is not regulated well.

It turns out TOR judges nutrient availability through a sample size of three amino acids. If you give the plant a lot of these, TOR assumes nutrients are plentiful and goes into overdrive mode.

In reality, nutrient availability might not be adequate.

Overactive TOR distorts plant cells

Such an overactive TOR, might change the structure of the cell, to the detriment of a plant's health.

Here is an example. One of TOR's functions is to tinker with little cellular filaments, called actin.

"Actin filaments make up the 'skeleton' of the plant cell that upholds the cell's expand iconendomembrane system. The latter builds several of the cell's building blocks. These filaments also help determine the cell's shape," Pengfei adds. "We find that an overly active TOR will lead to higher protein production and larger cell size."

"But the cell shapes are abnormal. For example, the root cells fail to fully form root hairs so that they can absorb water."

In other words, the result is an unhappy plant that develops at a slower pace.

"Here is my takeaway: when scientists have tried to boost amino acid production in crops, the problem is not that there are too many amino acids. Maybe these crops get sick due to side effects on tiny structures inside their cells." Pengfei says. "Once we figure out some major dynamics that cause plants to get sick, we could retry ways to overproduce amino acids in a balanced and healthy way."

On a last note, Pengfei thinks the interdisciplinary nature of the work allowed for the breakthrough. "We work with plant cell structures. Our collaborators from the lab or **Robert Last** study biochemical pathways. If we had worked on this project separately, we wouldn't have the expertise to examine where the defects crop up."