## All 2018 PRL stories

# Reflections from "Feed the Future" conference in Burkina Faso

1/15/18

Atsuko Kanazawa, Igor Houwat, Cynthia Donovan

*Figure 1 Banner Image by Atsuko Kanazawa*

*The US Agency for International Development (USAID) devotes resources under the Feed the Future program for research and development activities that improve the quality and management of legumes, while contributing to food security and well-being of local populations in the US, Africa, Asia, and the Americas. The Legume Innovation Lab (LIL) at Michigan State University, a key part of this initiative, recently organized a conference in Burkina Faso, bringing together scientists from around the world. Our own Atsuko Kanazawa reflects on the experience.*

Atsuko Kanazawa is a plant scientist in the **lab of David Kramer**. Her main focus is on understanding the basics of photosynthesis, the process by which plants capture solar energy to generate our planet's food supply.

This type of research has implications beyond academia, however, and the **Kramer lab is using their knowledge**, in addition to new technologies developed in their labs, **to help farmers improve land management practices**.

One component of the lab's outreach efforts is its participation in the **Legume Innovation Lab (LIL) at Michigan State University**, a program which contributes to food security and economic growth in developing countries in Sub-Saharan Africa and Latin America.

Atsuko recently joined a contingent that attended a LIL conference in Burkina Faso to discuss legume management with scientists from West Africa, Central America, Haiti, and the US. The experience was an eye opener, to say the least.

To understand some of the challenges faced by farmers in Africa, take a look at this picture, Atsuko says.

*Figure 2 Corn crops in Burkina Faso. By Atsuko Kanazawa*

“When we look at corn fields in the Midwest, the corn stalks grow uniformly and are usually about the same height," Atsuko says. "As you can see in this photo from Burkina Faso, their growth is not even.”

“Soil scientists tell us that **much farmland in Africa suffers from poor nutrient content**. In fact, farmers sometimes rely on finding a spot of good growth where animals have happened to fertilize the soil.”

**Even if local farmers understand their problems, they often find that the appropriate solutions are beyond their reach**. For example, items like fertilizer and pesticides are very expensive to buy.

That is where USAID's Feed the Future and LIL step in, bringing economists, educators, nutritionists, and scientists to work with local universities, institutions, and private organizations towards designing best practices that improve farming and nutrition.

Atsuko says, "LIL works with local populations to select the most suitable crops for local conditions, improve soil quality, and manage pests and diseases in financially and environmentally sustainable ways."

**Unearthing sources of protein**

At the Burkina Faso conference, the Kramer lab reported how a team of **US and Zambian researchers are mapping bean genes and identifying varieties that can sustainably grow in hot and drought conditions**.

The team is relying on a new technology platform, called **PhotosynQ**, which has been designed and developed in the Kramer labs in Michigan.

*Figure 3 PhotosynQ in action: the device collects data. A mobile app uploads it to an online platform for further analysis. By Harley J Seeley Photography*

**PhotosynQ includes a hand-held instrument that can measure plant, soil, water, and environmental parameters.** The device is relatively inexpensive and easy to use, which solves accessibility issues for communities with weak purchasing power.

**The heart of PhotosynQ, however, is its open-source online platform**, where users upload collected data so that it can be collaboratively analyzed among a community of 2400+ researchers, educators, and farmers from over 18 countries. The idea is to solve local problems through global collaboration.

Atsuko notes that the Zambia project's focus on beans is part of the larger context under which USAID and LIL are functioning.

“From what I was told by other scientists, **protein availability in diets tends to be a problem in developing countries**, and that particularly affects children’s development," Atsuko says. "Beans are cheaper than meat, and they are a good source of protein. Introducing high quality beans aims to improve nutrition quality.”

**Science alone is sometimes not enough**

But, as LIL has found, **good science and relationships don't necessarily translate into new crops being embraced by local communities**.

Farmers might be reluctant to try a new variety, because they don’t know how well it will perform or if it will cook well or taste good. They also worry that if a new crop is popular, they won’t have ready access to seed quantities that meet demand.

**Sometimes**, as Atsuko learned at the conference, **the issue goes beyond farming or nutrition considerations**. In one instance, local West African communities were reluctant to try out a bean variety suggested by LIL and its partners.

The issue was its color.

“One scientist reported that during a recent famine, West African countries imported cowpeas from their neighbors, and those beans had a similar color to the variety LIL was suggesting. So the reluctance was related to a memory from a bad time.”

This particular story does have a happy ending. LIL and the Burkina Faso governmental research agency, INERA, eventually suggested two varieties of cowpeas that were embraced by farmers. Their given names best translate as, “Hope,” and “Money,” perhaps as anticipation of the good life to come.

*Figure 4 Visiting the women-run farms. By Atsuko Kanazawa*

**Another fruitful**, perhaps more direct, **approach of working with local communities has been supporting women-run cowpea seed and grain farms**. These ventures are partnerships between LIL, the national research institute, private institutions, and Burkina Faso's state and local governments.

Atsuko and other conference attendees visited two of these farms in person. The Women’s Association Yiye in Lago is a particularly impressive success story. Operating since 2009, it now includes 360 associated producing and processing groups, involving 5642 women and 40 men.

“They have been very active,” Atsuko remarks. “You name it: soil management, bean quality management, pest and disease control, and overall economic management, all these have been implemented by this consortium in a methodical fashion.”

“One of the local farm managers told our visiting group that their crop is wonderful, with high yield and good nutrition quality. Children are growing well, and their families can send them to good schools."

As the numbers indicate, women are the main force behind the success. The reason is that, usually, men don’t do the fieldwork on cowpeas. "But that local farm manager said that now the farm is very successful, men were going to have to work harder and pitch in!”

Back in Michigan, Atsuko is back to the lab bench to continue her photosynthesis research. She still thinks about her Burkina Faso trip, especially how her participation in **LIL's collaborative framework facilitates the work she and her colleagues pursue in West Africa and other parts of the continent**.

“We are very lucky to have technologies and knowledge that can be adapted by working with local populations. We ask them to tell us what they need, because they know what the real problems are, and then we jointly try to come up with tailored solutions.”

“It is a successful model, and I feel we are very privileged to be a part of our collaborators' lives.”

PhotosynQ is in part funded by the **US Department of Energy, Office of Basic Energy Sciences**.

# Reviewing photosynthesis in dynamic conditions: Photosystem I as a guard

1/22/18

Igor Houwat, Eliezer Schwarz

The basics of photosynthesis, the process that converts sunlight into food and energy to power life on Earth, is now common knowledge. But the subtleties of its inner workings remain mysterious to scientists.

Take this number: **Plants store about 1% of the sunlight they absorb** as biomass suitable for human use. The **rest is shed, partially in response to environmental stresses** like excessive light exposure or drought conditions.

Researchers think that bumping up that storage rate, even by a small percentage (1 or 2 percent), could dramatically increase crop yields. But until we understand how photosynthesis adapts to changes in the environment, that goal remains elusive.

In a new study published in the journal ***Photosynthesis Research***, scientists at the MSU-DOE Plant Research Laboratory shed light on how a expand iconprotein complex, **Photosystem I (PSI), plays important roles in guarding plants from excessive sunlight exposure and in helping them navigate old age.**

This is a new view of photosynthesis that could change the way scientists study it.

**The Science: PSI responds to dynamic changes**

Eliezer Schwarz, co-author on the study, says, "**PSI**, one of the fundamental photosynthetic protein complexes, **has generally been regarded as more stable and less involved in responding to changes in the environment that affect photosynthetic productivity**."

But Eliezer, alongside co-authors **Stephanie Tietz** and **John Froehlich**, now thinks otherwise.

PSI works with another protein complex called PSII. Both host expand iconlight-harvesting antennae that capture sunlight, a bit like how a car antenna captures radio waves. **The antennae usually stick around their respective complexes, but some will hop around.**

"PSII can have different amounts of an antenna protein complex, called LHCII. (It's the one that makes plants look green.) In some cases, a small fraction of LHCII can leave PSII and associate with PSI. This has been understood as one of the ways a plant calibrates its light absorption, balancing the amount of energy absorbed by each photosystem."

But the **researchers report unusually massive amounts of LHCII migration to PSI** when:

- There is **EXCESSIVE SUNLIGHT**, which could damage PSII complexes. As a consequence, they release their light-harvesting antennae to lower light absorption rates. PSI "stores" these antennae as a safety net.

- **PLANTS AGE** and start degrading various cellular proteins, including PSII. This leads to free-floating antennae that could significantly harm the plant cell if left alone. In response, PSI picks the antennas up to prevent any damage.

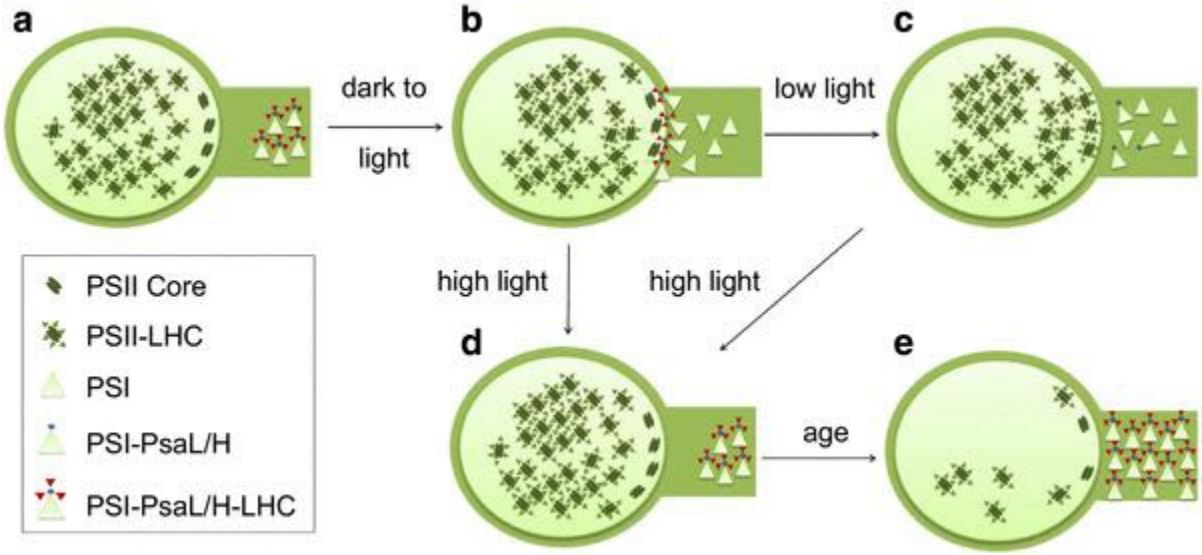



*Figure 1 The dynamics of PSI, notably parts d and e. d) Transitioning to high light, PSI picks up light-harvesting antennas from PSII. e) As plants age and PSII are degraded, PSI picks up free-floating antenna proteins to prevent damage. By Eliezer Schwarz, Stephanie Tietz, John Froehlich. **Photosynthesis Research**, **CC BY 4.0***

"This is surprising," Eliezer says. "We found that some past studies had seen something similar, but these were isolated observations with no physiological context. It doesn't seem like anyone has paid any attention to them yet."

Perhaps the **reason for this lack of attention is that PSII has traditionally been the focus of research**, specifically when it comes to light stress responses, Eliezer adds.

"Our study suggests that **some basic photosynthesis mechanisms may have been misunderstood** and that **PSI may do more things, play more central roles, than was previously recognized**."

If scientists pay attention to this research – and recent studies are independently showing similar results – it could fundamentally change how photosynthesis is taught in our textbooks.

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.
Banner image by **planetMitch aunger** on **Unsplash**.

# SP1 protein interacts with three energy-related cellular organelles

2/5/18

Igor Houwat, Jianping Hu

Recently, the Hu lab **published a paper detailing how a protein, SP1, helps construct peroxisomes**, cellular food processors that break down fatty acids (ie: fats) into smaller chunks so they can be used to produce energy in both humans and plants.

New research, **published in the journal Plant Physiology**, provides additional evidence that, as a matter of fact, SP1 interacts with three cellular organelles, expand iconchloroplasts, expand iconmitochondria, and expand iconperoxisomes. Together, the trio of organelles are important for generating and managing energy supplies in humans and plants.

"We found the SP1 expand iconprotein to target to these three organelles in the lab plant, Arabidopsis," says **Hu, who is a professor in the MSU-DOE Plant Research Laboratory** and the **MSU Department of Biology**.

"This triple location pattern is exciting and in line with the fact that the human counterpart to SP1 is known to target to both mitochondria and peroxisomes (humans don't have chloroplasts)."

Judging by its sequence and functional similarity to the human equivalent, Hu thinks it is possible that SP1 plays additional roles we haven't realized yet.

For example, the human protein (called MAPL) performs many essential functions, like helping with mitochondrial integrity maintenance, antiviral responses, and self-degradation of defective mitochondria, among other roles.

"We have still a lot to learn about SP1 in plants" Hu says. "SP1-like proteins are present in many other types of plants. Our line of research could spur further exploration, including applications for more robust crops that are better at generating energy – in other words, better crop yields."

Due to the closeness of the human and plant proteins, this also is an instance where plant science might contribute to human medicine. **Human peroxisomal disorders are very debilitating**, with symptoms including poor growth, neurological dysfunctions, hearing/visual problems, liver disease, just to name a few.

Banner image of an Arabidopsis plant by **INRA, Jean Weber**, **CC BY 2.0**

# How detecting light in the water affects how much food cyanobacteria get

2/15/18

Igor Houwat, Brandon Rohnke

The Montgomery lab has found a link between how water-dwelling bacteria, called cyanobacteria, monitor light quality in their surroundings and their capacity to do  expand iconphotosynthesis well.

The basics of photosynthesis, how sunlight is captured and turned into usable energy that powers life on Earth, are well understood.

Now, **scientists want to harness photosynthetic organisms, to syphon their energy yields into biofuels and industrial products**. Doing so requires we grow the organisms in favorable environments with the right balance of food, light, and nutrients.

Yet, **we don't know much about how an organism's territory impacts its photosynthetic performance** - in other words, what would lead to good yields.

expand iconCyanobacteria (cyanos, for short) are one of the organisms targeted for biotech applications. Although tiny – each 25 times smaller than the width of a human hair – they dominate the planet's oceans, lakes, and rivers.

*Figure 1 Cyanos growing by a hot spring. These hardy microorganisms dominate the planets waters. By brewbooks from near Seattle, USA (Grand Prismatic Spring) **CC BY-SA 2.0**, **via Wikimedia Commons**.*

Billions of years ago, they were one of the first organisms that started doing photosynthesis, the very reason there is life on Earth.

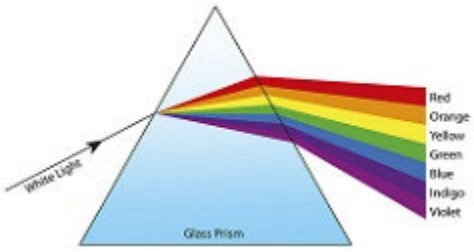
Today, cyanos are one of the planet's best photosynthetic performers, having developed countless systems to monitor light quality in their surroundings so they can fine-tune photosynthesis for optimal capacity.

**The Science: light quality changes how cyanos get food**

Brandon Rohnke, a grad student in the **lab of Beronda Montgomery** and the **Department of Biochemistry & Molecular Biology**, is part of a team that shows how a cyano, called Fremyella, tracks changes in available light wavelengths to control how much energy and food it gets out of photosynthesis. The study is **published in the journal mSphere**.

**The 2 systems explained**

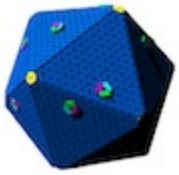
Tracking light wavelength quality




Cyanos sink or float in water to position themselves favorably in their environments, and the surrounding light wavelengths vary with depth.

For example, on the surface, cyanos are exposed to rich amounts of red light. As they sink deeper, red light grows scarcer while green light remains abundant. Cyanos constantly track light quality and adjust themselves to capture the most available wavelength at any time. It is it like dialing your car radio to the exact frequencies to capture the waves coming from your favorite stations. But you can only tune to stations available at your location.

Photosynthesis factories that produce food



In the last half of photosynthesis, carbon dioxide is taken from the air to produce energy molecules that power photosynthetic organisms. In cyanos, this step takes place inside tiny factories - call them nanofactories - officially known as carboxysomes.

In previous research, scientists genetically removed a major light detector (called RcaE) from the cyano, and it lost its ability to adapt to wavelength changes.

"To our surprise, the change impacted the nanofactories. Our lab cyano produced more nanofactories, but in smaller sizes," says Brandon. "In nature, the cyano cell will have 2 to 3 of them per cell cross-section. The mutant had up to 7."

Digging in, the team found that **the absence of light detection led to**:

**An increase in the materials that make up the external part of the nanofactory structure**, its walls;

**A decrease in the machinery that goes inside the nanofactory** and processes the cyano's food.

“What we think happened is that a larger number of structure material was competing to recruit a smaller number of available machines. The result was that the machinery was distributed among more numerous, but smaller nanofactories,” Brandon says.

“Somehow, tracking external light is a way to tightly control nanofactory amount and structure. We are not yet sure how these two systems interact.”

The team ruled out side-effects that could have caused this observation, such as the mutant’s modified cell shape or the fact it produced large amounts of toxic byproducts.

The study is part of a push at the MSU-DOE Plant Research Laboratory to **repurpose cyano nanofactories to make materials for human consumption, like renewable energy or medical products**.

“Gaining the ability to dial up or down nanofactory number and size could help manage productivity levels in future biotech contexts,” Brandon says. "But this is just one control mechanism. We have many more left to decipher.”

It’ll be a while yet before we power cars and planes with ‘cyano fuel,’ but scientists are slowly, but surely, revealing the way to get there.

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.
Banner image of **Cyanobacterial bloom near Fiji** by NASA, Public Domain; **Refraction_triangular prism** by Siyavula Education, **CC BY 2.0**.

# Stress tested: how algae change their internal solar panels to stay alive

2/21/18

Igor Houwat, Zhiyan (Rock) Du

A collaboration between the **Benning** and **Kramer** labs is revealing how nature's solar panels, found inside algae, constantly grow and shrink in size to adjust to changes in their environments, a crucial system that ensures their hosts stay healthy and alive.

The scientists want to use this knowledge to someday syphon the energy from nature's solar panels into technologies that benefit humanity. This vision requires they know how and when the solar panels work best in their natural contexts, where they face scalding sunlight, cold temperatures, drought, and countless other variables.

The solar panels, called expand iconthylakoids (thigh-la-koyds), kick start expand iconphotosynthesis, the process that powers life on Earth by capturing sunlight and turning it into food and consumable energy.

When photosynthetic organisms have enough resources to grow – nutrients, the right temperature, enough water – photosynthesis hums along and they thrive.

But during difficult times – say, nutrients are scarce, or the environment is too cold or dry – neither can the organisms grow nor can they hide from the hostile environment.

In those cases, they must dial back photosynthesis until the stress blows over. This ability to change the rates of photosynthesis is a matter of life and death. Without it, the organisms produce bad toxins that inflict self-harm that can be fatal.

The new study, **published in The Plant Cell**, shows that **a expand iconprotein in algae, called PGD1, contributes to managing the size of the solar panels in response to changes in the alga's environment**.

**The Science: The type of 'fat molecules' algae make changes how they capture sunlight**

Like actual solar panels, **thylakoids are made of layers of film (or membranes)** that contain antennae to capture sunlight. In addition, they have machines to convert that sunlight into energy and food that can be consumed by living beings.

**The film layers, the focus of the study, are made of expand iconlipids**, small molecules found in fats and oils.

*Figure 1 Working like solar panels, thylakoids capture sunlight, which kickstarts photosynthesis in organisms like algae and plants. **Pexels**, **Pixabay License***

By adjusting the amounts and types of lipids, an organism can change the size of its solar panels and control photosynthetic activity – say, the more surface, the more antennae and machines can fit on it, the higher the photosynthetic activity.

During stressful times, however, organisms change the lipids to "downsize" the film layer. With less surface area to capture sunlight, photosynthesis is dialed down.

"The lipid-processing protein, PGD1, has been known to contribute to the amount and make-up of thylakoid film lipids," says Zhi-Yan (Rock) Du, a post-doc in the Benning lab. "**What we found was that this protein manages the most abundant type of lipid, which accounts for about 50% of the thylakoid's lipid make-up**."

In fact, when the scientists genetically removed that lipid-processing protein from an alga strain, *Chlamydomonas reinhardtii*, the thylakoid structure was altered, and so was the number of antennae and machines within.

**Without adjusting the solar panels, algae can't weather stressful environments**

**The team then tested those algae lacking the lipid-processing protein under stressful conditions** they might encounter in nature to see how well they would adjust.

*Figure 2 Algae were stress tested in these bioreactors made in the Kramer lab. Each is a 'pond in a jar' that can reproduce real-world settings for testing purposes.* ***By G.L. Kohuth***

For example, if algae grow without enough nitrogen, they cannot make proteins, and they change the way they store energy. Or if algae are exposed to cold temperatures, their metabolism slows down.

In these situations, the same amount of sunlight still hits the algae, but they cannot use all the energy that comes out of it, because of their subpar metabolism. Unused photosynthesis energy can build up to levels that cause deadly damage.

That is precisely when healthy cells would downsize the solar panels and lower photosynthesis rates to prevent the damage from occurring.

"**But**," Rock says, "**our mutants that lacked the crucial lipid-processing protein had trouble doing that**. The cells accumulated toxins that hurt the algae, which got sick and lost their coloring."

"We think this ability to control solar panel size is a survival strategy for the outdoors," he adds. "Next, we plan to explore more variations on thylakoid lipid profiles to understand how photosynthesis and the algae's health are affected."

**The researchers' long-term goal is to exploit algal energy for human uses**, as algae are increasingly seen as a future source of biofuels and food in aquaculture. The aim is to develop algae with higher resistance to environmental stresses, which will improve their photosynthesis yields.

On a final note, Rock credits the collaborative structure at the MSU-DOE Plant Research Laboratory for the results. "I work on lipids in the Benning lab, while the co-author, Ben Lucker from the Kramer lab, studies photosynthesis in dynamic environments. This research would have been difficult to do if we weren't all working together."

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**. Banner image by **Marc Wieland** on **Unsplash**.

# Faculty Voice - Christoph Benning Facilitating Collaborations

2/27/18

Christoph Benning, Igor Houwat

Coming from Germany as a graduate student in the 80s, I was attracted by MSU's large number of well-renowned plant scientists. A prestigious German fellowship and contacts by my former adviser in Freiburg, Germany opened opportunities for me to study at different U.S. institutions. Comparing annual reports and faculty bodies, I chose the MSU-DOE Plant Research Laboratory for my doctoral studies. Thus, I ended up receiving my Ph.D. in 1991 from the genetics program at MSU under the mentorship of Chris Somerville.

From MSU, I went back to Germany to run an Independent Young Investigator group at the Institute for Genbiological Research GmbH in Berlin. As this place went into liquidation five years after I arrived, I was in a hurry to find a job to support my family.

I received two job offers back in the U.S., including one from MSU. What originally had attracted me to MSU, the large number of possible collaborators in the plant sciences and the outstanding research facilities, did the trick for me again, and **I joined the Department of Biochemistry at MSU in 1998**, where I made my way through the ranks to full professor.

*Figure 1 Christoph Benning. Courtesy of MSU Communications and Brand Strategy.*

**Fruitful MSU collaborations**

Most of this time, my lab was located in the Biochemistry Building, where I enjoyed interacting with my colleagues on a multitude of scientific problems. My students and I also made countless trips across Wilson Road to the Plant Biology Building to interact with other plant scientists.

Fast forward to 2012, the new, shiny Molecular Plant Sciences Building was completed, and we had the honor to be the first lab to move in. What was special about it was the open floor plan, as opposed to

isolated labs, which presented opportunities for interaction, sharing of resources and development of new collaborative projects.

As such, my direct neighbor, Eva Farre, Department of Plant Biology, and I co-mentored a recent Ph.D. graduate, Eric Poliner, on a project involving a new algal model organism. Keep in mind that Eva works on circadian rhythms and I on lipid metabolism, two areas that might seem to have little overlap, unless you collaborate on the daytime regulation of lipid metabolism in algae. We ended up sequencing the alga's genome and developing molecular tools to engineer it.

When Greg Bonito, Department of Plant Soil and Microbial Sciences, moved in next to my lab, I scratched my head because he worked on fungi and their symbiotic partners. I saw no way we could possibly collaborate. Little did I know that one of the postdocs in my lab, Zhi-Yan (Rock) Du, and Greg started talking over lunch in the common spaces of the MPS building, cooking up the idea that oil-producing algae and fungi may synergistically make more oil than either of them alone.

I admit, I did not buy it, but knowing better than insisting on my greater experience, I let them follow up on their ideas. Sure enough, one day I come into the lab seeing several people staring into a computer screen. The image that fascinated them showed algal cells living inside a fungus. In fact, Greg and Rock had discovered how to reproducibly study the beginnings of endosymbiosis in the test tube, a process as fundamental to biology as evolution itself.

In 2015, I was offered the **position of director of the MSU-DOE Plant Research Laboratory**, and I moved again, from the MPS building into the Plant Biology Building. The PRL is founded on the idea of collaborative work, and as a recent example, Rock and Ben Lucker, a postdoc in **David Kramer's lab**, collaborated on **research that combines our lipid expertise with the Kramer lab's photosynthesis knowledge**. Another collaboration features recent Ph.D. graduate, Kun (Kenny) Wang, working on chloroplast proteins and their effects on plant defense with graduate student Quiang Guo, from **Gregg Howe's lab** in the PRL.

As these snippets suggest, young inquisitive minds find plenty of fertile ground for collaborative research at MSU, if we, the "experienced people," let them do "their thing." To me, these examples show that the right facilities, such as the MPS building with its open areas, or institutes, such as the PRL with its collaborative make-up, combined with the right mindset, make MSU one of the best places in the nation — maybe the world — for young scientists to succeed in the modern plant sciences.

# Anna Hurlock, recent PhD graduate, joins biotech company BioFire Diagnostics

3/5/18

Igor Houwat

Anna Hurlock, a recent PhD graduate from **the lab of Christoph Benning**, is joining the Utah-based company, BioFire Diagnostics, as a Clinical Affairs Scientist.

Located in Salt Lake City, **BioFire** specializes in creating clinical diagnostic technologies that can accurately and rapidly identify a wide range of infections, from respiratory and gastrointestinal, to meningitis and blood diseases.

In her role, Anna will lead a science team that helps R&D assess the accuracy of the technologies by running comparative tests using the same samples from external clinical trials. Anna will then analyze that data and write up reports that are used for the FDA and other regulatory and approval processes.

Anna earned her Bachelors in Biochemistry at Purdue University, where she worked for four years in the lab of Clint Chapple, a former PRL post-doc. She came to the MSU at the recommendation of her mentor, and she eventually joined the Benning lab, where she **studied chloroplast lipid import and metabolism**. Her PhD degree is from the Department of **Biochemistry and Molecular Biology**.

*Figure 1 Anna Hurlock in the Benning lab. By Igor Houwat, MSU-DOE Plant Research Laboratory*

“I am thankful for all of the opportunities provided to me during my time at MSU which have made following a path like this possible,” Anna says. “Christoph and the people in the Benning lab have provided me with the support to pursue my chosen career path, and the PRL has been the perfect collaborative environment to carry out my doctoral research.”

Christoph Benning, Anna’s mentor, says, “A PhD in plant biochemistry can open up many career opportunities. I am confident that Anna has a great management career in the biotech industry ahead of her using the skills she learned at MSU, and I expect her to be a role model for others to follow.”

Congratulations and good luck, Anna!

# Benning lab students win at 2018 ASPB Midwest Meeting

4/4/18

Igor Houwat

Two students in the **lab of Christoph Benning** have won awards for presenting their research at the 2018 Annual Meeting – Midwestern Section of the American Society of Plant Biologists.

Nick Fekaris, an undergrad student in the **Department of Biochemistry and Molecular Biology (BMB)**, won second place for his oral presentation. Tomomi Takeuchi, a grad student in BMB, and Nick's student mentor, won first place for her poster presentation.

The **ASPB Midwest meeting**, which took place at Iowa State 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, which is why 9 members from the Benning and Hoffmann-Benning labs packed into a van and drove to Iowa.

Below are excerpts from an interview with the two winners.

**What is your research on?**

**Nick**: I work on a protein found in algae which supports them through stressful times, like when food is scarce. The protein helps them hibernate until the stress blows over. It's basically a survival mechanism.

My project is to figure out which parts of this protein are important for it to work. At the meeting, I presented on one of these portions and reported that it is not essential for the protein to function fully. The way we found that out was to remove that portion from the protein and see if the algae were still able to go into hibernation. They did!

**Tomomi**: I work on the same protein. We think that, during the hibernation period, the protein blocks normal algae functions, like growth and cell division. In fact, without this protein, the algae have trouble doing cell division and coming out of their hibernation.

*Figure 1 Nine members of the Benning and Hoffmann-Benning labs packed into a van and drove to Iowa. By Igor Houwat, MSU-DOE Plant Research Laboratory*

**Tell us about your experience presenting at the meeting.**

**Nick**: I've never given a formal scientific talk. I was nervous going in, as there were anywhere between 150 and 200 people in the lecture hall! But after watching other presenters, and seeing it was a hospitable environment, I wasn't worried as much. The opportunity to present ended up being the most unique thing for me.

**Tomomi**: I agree with Nick that the meeting was a friendly setting to present and discuss science, and in terms of my poster talk, I was essentially giving a summary of my work to whomever came up to my poster. It was enjoyable to share my work with others and see other research, and some of the professors gave me good suggestions on how to proceed with my research. I also met with some of my collaborators for the first time in person. That was pretty cool!

**What did it feel like to win?**

**Tomomi**: I was very surprised. I was just sitting there and being myself, and then I heard my name being called. I got first place among around 100 other presenters!

Winning made me feel good about myself, since this is the first competitive award I have won in graduate school in terms of presentation skills.

**Nick**: Going into it, I wasn't sure there were awards for my category. I was quite surprised to hear my name called when they announced the awards and ecstatic to go down there and get it. Plus, there was a monetary gift!

**How would you present differently next time?**

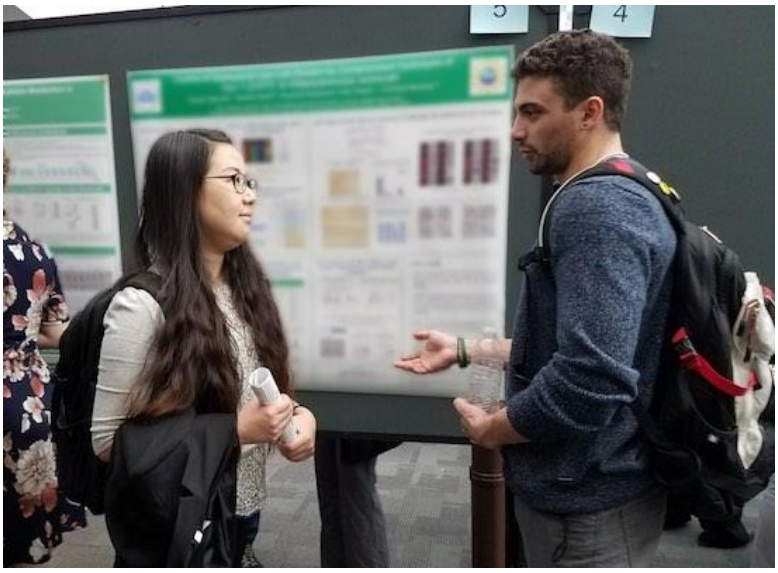


*Figure 2 Tomomi (left) and Nick (right). By Susanne Hoffmann-Benning*

**Tomomi**: I'm happy with how I presented. But, I spent too much time talking to my collaborators and didn't interact with other people as much or look up more posters as I would have wanted.

**Nick**: I think my presentation was a bit bland. I could have made it more colorful by adding figures and animating it, especially after I saw some people do things that I liked. Also, I would have practiced my presentation more.

**How does your lab environment help you develop as a scientist?**

**Tomomi**: Christoph [Benning] has always been there to offer valuable suggestions while giving me enough independence to pursue what I want, and I think it has helped me greatly in becoming a better scientist. Everyone who came on this trip from the Benning and Hoffmann-Benning lab did a great job, and it was a fantastic adventure.

**Nick**: I joined the lab looking to develop fundamental skills necessary to become a successful scientist, and that is exactly what I have gotten under Tomomi's mentorship. I greatly appreciate her guidance and knowledge and believe the success we both achieved at this event was the result of working in a great environment.

# Christoph Benning wins 2018 MSU Innovator of the Year Award with John Ohlrogge

4/23/18

Igor Houwat, Val Osowski

*Figure 1 Photo courtesy of Katie Stiefel, Moonsail North*

Dr. Christoph Benning and Dr. John Ohlrogge have won the MSU Innovation Center's 2018 Innovators of the Year award.

The scientists were recognized at the 8th annual **Michigan State University Innovation Celebration on April 19**. The event showcases innovative Spartan technologies and startups. It also honors MSU researchers and students who reported an invention, licensed a technology, or obtained patents during the academic year. Awardees receive plaques and cash prizes.

The scientists won for identifying the WRINKELD1 gene and developing its use to engineer plant oils and lipids. Benning is **MSU-DOE Plant Research Laboratory director**. Ohlrogge is University Distinguished Professor Emeritus in the **Department of Plant Biology**

WRINKLED 1 is a genetic switch that allows plants to accumulate seed oil (vegetable oil). Plant seed oil is both a basic food component and a precursor for biodiesel production.

"The foundation was laid when I isolated a mutant of Arabidopsis towards the end of my PhD at MSU. It had wrinkled seeds, reduced oil, and high sugar content," said Benning.

Following a five-year stint in Germany, Benning returned to a faculty position at MSU. Along with Alex Cernac, a post-doc in his lab, he isolated the gene responsible for the mutant's defect. It encodes a key transcriptional switch that allows researchers to engineer oil content in plant seeds and other tissues.

“As part of the **Great Lakes Bioenergy Research Center**, and even before its inception, John Ohlrogge and I have continuously collaborated on determining how WRINKLED1 activates the many genes required for oil accumulation in different plants. We have also worked on translating this knowledge into designing new biofuel crops,” Benning continued.

“Plant oils are essential for human nutrition and one of the most valuable of all agricultural commodities,” Ohlrogge said. “Having two labs study plant lipid biosynthesis has earned MSU a reputation as a world leading research center in this field. This repute has attracted many top scientists to join our labs.”

MSU owns several patents on WRINKLED1 – with Benning and/or Ohlrogge listed as inventors – thanks to the **MSU Innovation Center**.

“Translating basic discoveries into applications for the greater benefit of all is very challenging,” Benning said. “Working with MSU Technologies, especially Tom Herlache, has paved the path that eventually leads to the gene being commercialized. I am deeply grateful to all who have contributed to this project. These include Alex Cernac, John Ohlrogge, Tom Herlache, and countless students and postdocs, many who now enjoy successful careers in biotech and academia.”

Ohlrogge added, “Christoph Benning and I have had a great working relationship for more than 15 years. I think that has helped many of our students and postdocs see how valuable collaborations can be for scientific progress.”

# Yang Yang, PRL post-doc, starts science editor position at Wiley Beijing

4/30/18

Igor Houwat

Yang Yang, a former post-doc in the **lab of Christoph Benning**, has started a science editor position at the Wiley Beijing office. **Wiley** is a global company that specializes in academic publishing.

Yang Yang's main responsibilities are to oversee submitted manuscripts, to select reviewers, and to decide what research gets published. She will also scout for quality scientists in China and recruit them to publish with Wiley.

"Right now, Chinese science is developing at a quick pace," Yang Yang says. "With a lot of new research coming in, there is a need to enlarge the Chinese publishing market. Publishers also need editors to develop the publication system, which is young compared to its American counterpart."

The career step is a big change for someone who has done research in academic settings for 12 years.

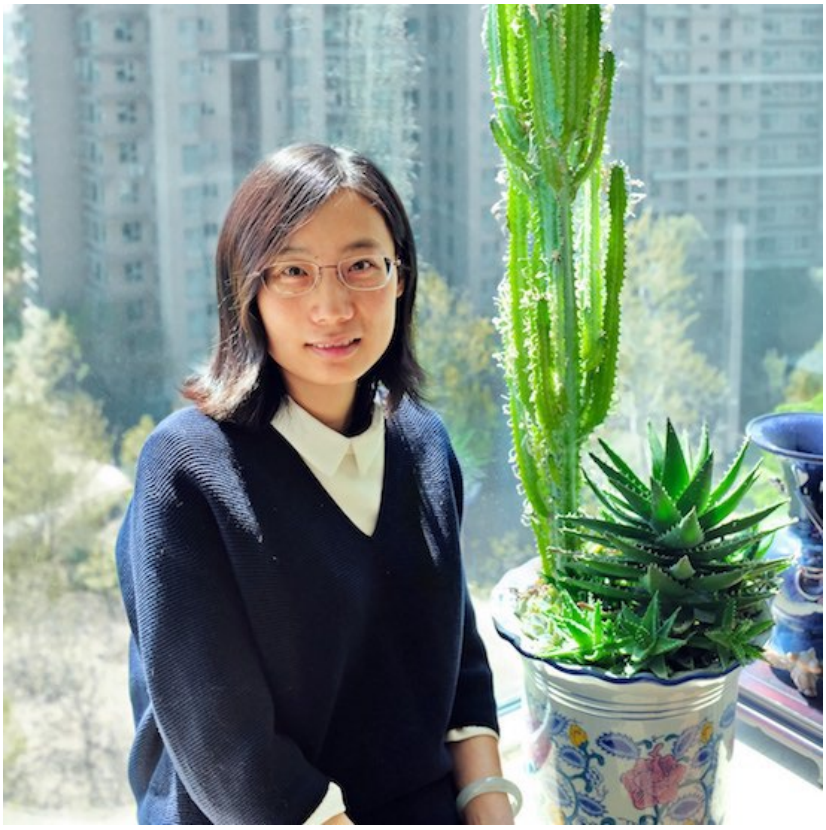


*Figure 1 Yang Yang. By Yang Yang*

"As I started job hunting, I realized I like science a lot, but I don't want to be a professor. Professors spend a lot of time teaching, attending meetings, dealing with administrative responsibilities. They don't seem to have much time for awesome science. And I like science a lot!"

An industry position was not an option, since her background does not fit Chinese companies' current needs. Then, a friend who is a science editor at Nature Plants told her about the job, and Yang Yang realized it was exactly what she wanted to do. It also was an opportunity to stay in science.

She thinks that her academic background will be a great asset in her new career.

"MSU was a great place for doing plant science and learning career skills. Christoph [Benning] encouraged me to pursue my research passions and to present at a lot of conferences. So I am more confident in my skills, compared to 5 years ago," Yang Yang says. "My lab mates are positive thinkers that have encouraged me to always keep an open mind. Linda Danhof, our lab manager, has taught me how to manage. Thanks to everyone, I am not afraid to move into a different field."

Benning, her former mentor, says, "Yang Yang is an outstanding scientist who can grasp big scientific concepts. In my laboratory she has pursued intriguing research questions and published her findings in several excellent papers. She has learned the craft of writing papers and presenting science to wider audiences first hand. These skills provide the basis for her next career step as a scientific editor for a major journal in her home country."

Yang Yang has a BS in Biotechnology from Huazhong University of Science and Technology and a PhD in Biotechnology from Peking University. She spent 6 years in the Benning laboratory **researching how to increase oil production in crops targeted for biofuels**.

# When lipids meet hormones: plants' answer to complex stresses

5/7/18

Igor Houwat, Kun Wang

Unlike animals, plants can't run away when things get bad. That can be the weather changing or a caterpillar starting to slowly munch on a leaf. Instead, they change themselves inside, using a complex system of expand iconhormones, to adapt to challenges.

**Now, MSU-DOE Plant Research Laboratory scientists are connecting two plant defense systems to how these plants do expand iconphotosynthesis**. The study, conducted in the labs of **Christoph Benning** and **Gregg Howe**, **is in the journal, The Plant Cell**.

At the heart of this connection is the expand iconchloroplast, the engine of photosynthesis. It specializes in producing compounds that plants survive with. But plants have evolved ways to use it for other, completely unrelated purposes.

Their trick is to harvest their own chloroplasts' protective membranes, made of expand iconlipids, the molecules found in fats and oils. Lipids have many uses, from making up cell boundaries, to being part of plant hormones, to storing energy.

If plants need lipids for some purpose other than serving as membranes, special expand iconproteins break down chloroplast membrane lipids. Then, the resulting products go to where they need to be for further processing.

For example, **one such protein, breaks down lipids that end up in plant seed oil**. Plant seed oil is both a basic food component and a precursor for biodiesel production.

Now, Kun (Kenny) Wang, a former Benning lab grad student, reports two more such chloroplast proteins with different purposes. **Their lipid breakdown products help plants turn on their defense system against living pests and other herbivores.** In turn, the proteins, PLIP2 and PLIP3, are themselves activated by another defense system against non-living threats.

*Figure 1 Photo of the author, Kun (Kenny) Wang. By Kenny Wang*

**Playing the telephone game inside plants**

In a nutshell, the plant plays a version of the **popular children's game, Telephone**, with itself. In the real game, players form a line. The first person whispers a message into the ear of the next person in the line, and so on, until the last player announces the message to the entire group.

In plants, defense systems and chloroplasts also pass along chemical messages down a line. Breaking it down:

**The plant senses non-living threats**, like cold or drought, and indicates it through one hormone (ABA)

**This alarm triggers the two identified proteins to breakdown lipids** from the chloroplast membrane

**The lipid products turn into another hormone** (JA) which takes part in the insect defense system. Plant growth slows to a crawl. Energy goes to producing defensive chemicals.

"The cross-talk between defense systems has a purpose. For example, there is mounting evidence that plants facing drought are more vulnerable to caterpillar attacks," Kenny says. "**One can imagine plants evolving precautionary strategies for varied conditions**. And the cross-talk helps plants form a comprehensive defense strategy."

Kenny adds, "The chloroplast is amazing. We suspect its membrane lipids spur functions other than defense or oil production. That implies **more Telephone games leading to different ends we don't know yet**. We have yet to properly examine that area."

"Those functions could help us better understand plants and engineer them to be more resistant to complex stresses."

**Moving on to Harvard Medical School**

Kenny recently got his PhD from the MSU Department of Biochemistry and Molecular Biology. He has just started a post-doc position in the **Farese-Walther lab at Harvard Medical School**.

“They look at lipid metabolism in mammals and have started a project connecting it with brain disease in humans,” Kenny says. “There is increasing evidence that problems with lipid metabolism in the brain might lead to dementia, Alzheimer’s, etc.”

“I benefited a lot from my time at MSU. The community is very successful here: the people are nice, and you have support from colleagues and facilities. Although we scientists should sometimes be independent in our work, we also need to interact with our communities. No matter how good you are, there is a limit to your impact as an individual. That is one of the lessons I applied when looking for my post-doc.”

This work was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.
Original banner image by **_Marion**, Pixabay License.

# PhD student, Aiko Turmo, awarded prestigious NSF fellowship

5/15/18

Igor Houwat

Aiko Turmo, a Ph.D. student in the lab of MSU-DOE Plant Research Laboratory (PRL) scientist **Cheryl Kerfeld**, is a recipient of the National Science Foundation Graduate Research Fellowship.

The program, one of the country's most prestigious and competitive awards for graduate students, directly supports graduate students in various science, technology, engineering and mathematics fields.

**NSF Graduate Research Fellows** benefit from a three-year annual stipend of $34,000 along with a $12,000 cost of education allowance for tuition and fees, opportunities for international research and professional development and the freedom to conduct their own research at any accredited U.S. institution of graduate education they choose.

**What research and activities will the award fund?**

Aiko will study the relationship between carboxysome shell permeability in cyanobacteria and how microcystins, a cyanobacterial toxin, binds to RuBisCO to enhance carbon fixation and the growth of the cyanobacterium.

NSF fellows also participate in professional development programs that expose them to a variety of science careers. Aiko, who has career interests in the biotech and science policy fields, plans to explore the internship opportunities associated with the program.

*Figure 1 Aiko Turmo. By Igor Houwat, MSU-DOE Plant Research Laboratory*

**What are your feelings having won this award?**

"I think it was 6am, I woke up and read the email I got the award," Aiko, who is in the **Department of Biochemistry and Molecular Biology**, says. "I was so excited, I couldn't believe it! I had to read the email a couple of times. I hit 'Accept,' immediately."

"I am lucky to have very caring and supportive mentors in the Kerfeld lab and at the PRL. Cheryl [Kerfeld] is always motivating me to do my best and provides me with feedback to improve myself," Aiko says.

"The post-docs have also sacrificed a lot of their time to teach me for which I am incredibly grateful. The mentorship provided to me continues to inspire me to work hard to achieve my aspirations."

**Thoughts from Aiko's mentor and the PRL's director**

Cheryl Kerfeld, Aiko's mentor, says, "Aiko has all of the requisite talent to succeed in graduate school and beyond: aptitude for critical thinking and research, persistence, work ethic and tremendous soft skills. She's a pleasure to coach, she really wants to learn and works hard to improve herself. I really don't think I have ever had a student so simply willing to work hard and learn in order to achieve her goals. She is always looking for opportunities to grow, to learn more, do more—and to do something with impact. She has the potential to become a leading female scientist."

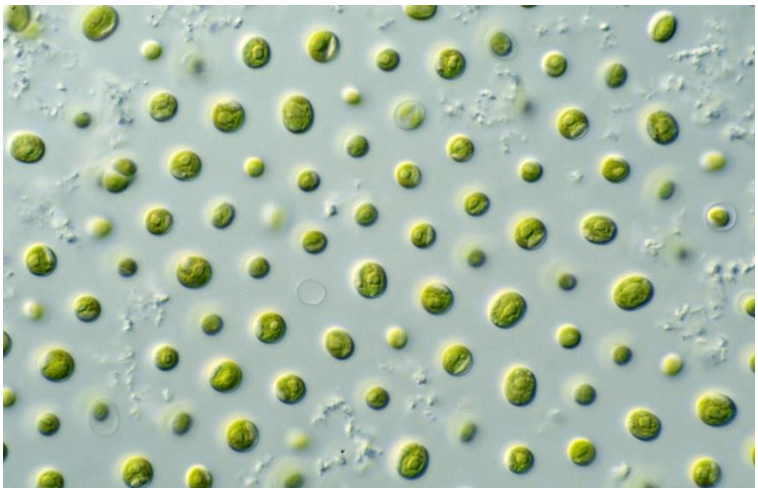
**Christoph Benning**, director of the MSU-DOE Plant Research Laboratory, adds, "I am very happy that Aiko received this NSF graduate fellowship and I congratulate her on behalf of everyone in the PRL. This award is a great honor and speaks for Aiko's ability to present a great project. It is also the result of excellent mentoring by Cheryl Kerfeld."

***Go here** for a complete list of College of Natural Sciences recipients.*

# A new DNA editing toolkit for the alga Nannochloropsis

5/17/18

Igor Houwat, Eric Poliner



**Eric Poliner** and a team of MSU scientists in the **Farre** and **Benning** labs have released a new genetic engineering toolkit for the alga Nannochloropsis. The alga is of interest for the production of biofuels and other oil-based chemicals.

Over the past decade, the science of engineering genes has become much more precise. That goes especially for CRISPR, a set of tools to delete or edit genes in an organism's DNA.

Scientists are using CRISPR to understand how plants and animals work. They are also exploiting it to create new applications in order to benefit humanity.

"Our new CRISPR toolkit targets Nannochloropsis, which is a great candidate for useful applications. This alga is quick to grow. It is easy to study. And it produces a lot of oil, which is interesting for industrial production," Eric says.

This genetic toolkit is a bit of a first, adds Eric. Although we have robust toolkits to manipulate microorganisms, like yeast or E. coli, those do not yet exist for algae.

**'Hit and run' that changes algae's DNA**

The heart of CRISPR is that it targets specific stretches of DNA for mutations. Scientists insert a gene construct – a package – in an organism. The construct includes a guiding mechanism to reach desired DNA areas and instructions to delete, expand, or change them.

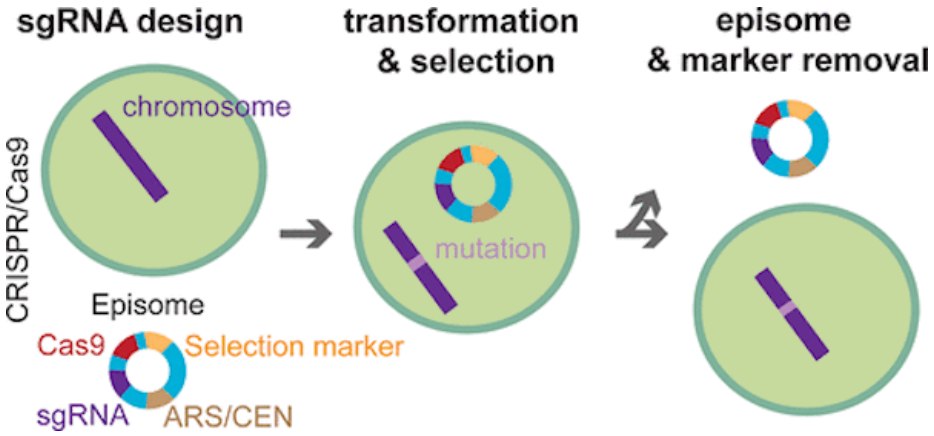



*Figure 1 From left to right, the three steps to inserting a mutation in Nannochloropsis. Reprinted with permission from Eric Poliner (DOI: 10.1021/acssynbio.7b00362). Copyright 2018 American Chemical Society.*

"We insert mutations with the help of episomes, circular pieces of DNA foreign to Nannochloropsis. Our alga can maintain that foreign DNA for a while, which is unusual, as most other algae can't."

But as the algal cells multiply over the generations, a high percentage of the population loses the foreign DNA. They leave behind the precise mutation they brought to the genome.

"Using the episome approach is ideal for CRISPR. The mutation brought in with the construct survives in subsequent generations. It becomes an integral part of the genome," Eric says.

This feature would address public safety concerns in case engineered algae are ever mass-produced in open ponds. They might not be considered genetically modified organisms, due to the lack of foreign DNA.

In addition to the method to insert mutations, the toolkit includes tools to screen and introduce foreign genes. (See more below.)

"There are several university labs and biotech companies now working on this. The hope is that the toolkit will help the research community to expand," Eric adds. "My goal is to help researchers to do their advanced studies. I don't want them to reinvent the wheel, so the information is easily available to the community."

**Technical Specifications**

The latest study on the toolkit is published in **ACS Synthetic Biology**. The toolkit can be found on **Addgene**. Tools included:

- **Cas9-reporter fusions**: NanoLuciferase, GFP, and an HA tag;
- **sgRNA** produced with flanking self-cleaving ribozymes. A bidirectional promoter that drives coproduction of both components;
- **Vectors containing the resistance markers** for Blasticidin and Hygromycin;
- **Vectors for overproducing multiple proteins** simultaneously.

**Banner image by CSIRO, CC BY 3.0**. This work was funded by the National Science Foundation, MSU Agbio Research, and the **US Department of Energy, Office of Basic Energy Sciences**.

# SPL1 protein plays a positive role in building plant cell peroxisomes

5/29/18

Igor Houwat, Jianping Hu

The Jianping Hu lab is furthering our knowledge about how the protein, SPL1, helps build peroxisomes in the plant cell. **The study is in The Plant Journal**.

Peroxisomes are the plant cell's food processors. They break down fatty acids (aka, fats) into smaller pieces that end up in energy compounds that power the plants. They also help protect plants from environmental stresses and support the process of photosynthesis.

Scientists are trying to understand how plants build these cellular parts. The knowledge could help us create better plants in the future. It also might benefit the medical field, as humans have peroxisomes and seem to share similar building mechanisms with plants.

The Science

Peroxisomes need two types of proteins to get built:

1. **The builder proteins**: called PEX, they come from other parts of the plant cell.
2. **The manager proteins, the focus of the study:** they control the import and export of the builders.

Recently, **the Hu lab found one protein**, SP1, slows the inflow of PEX proteins when there are no 'building needs.'

Now, they report a new protein, called SPL1, with a different function.

"SPL1 has a more positive role in building the peroxisome. It helps maintain the numbers of some of the builder proteins," says **Jianping Hu**, Professor at the MSU-DOE Plant Research Laboratory. "SPL1 does that by restraining the other protein, SP1, that dampens the inflow of the builders."

In other words, SPL1 is the gas pedal while SP1 puts on the brakes, and plants need both.

"The goal is to maintain the right balance for optimal building activity. That balance ensures plants stay healthy," Hu says.

"We are also finding that plants use these two proteins to build other plant cell components, in addition to peroxisomes."

Hu adds that there is evidence that humans, and other species, share similar proteins with plants.

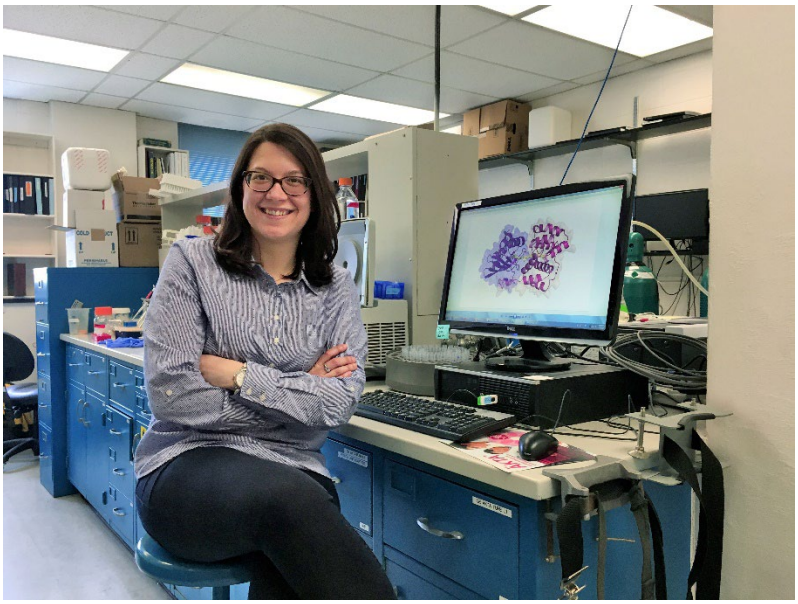
In humans, peroxisomes that go bad can cause severe health problems. Perhaps understanding how they work in plants will lead to new insights in human medicine.

**Banner image** by Inra, DIST, Jean Weber, CC BY 2.0

# Tina Dominguez-Martin awarded prestigious Marie Curie Fellowship

5/31/18

Igor Houwat, Maria Agustina Dominguez-Martin



Maria Agustina (Tina) Dominguez-Martin, a post-doc in the **Kerfeld lab**, has earned the prestigious Marie Curie Global Fellowship. The award provides up to $300,000 over 3 years to support her research on marine cyanobacterial photoprotection.

**Marie Curie Fellowships**, awarded by the European Union, support the best and most promising researchers at all stages of their careers, regardless of age or nationality. Tina was among over 1,300 winners out of a pool of over 9,000 applicants.

“I feel extremely happy about this award. It is very competitive and well-known worldwide,” Tina says. “It also helps awardees establish new career paths, and I will use this opportunity to pursue an academic career.”

Her project, PHOTO-CY-APPs, will focus on how two species of marine expand iconcyanobacteria protect themselves from damaging, excessive exposure to light. The cyanobacteria in question, marine *Synechococcus* and *Crocosphaera watsonii*, are some of most abundant photosynthetic organisms on the planet. They photoprotect primarily through the expand iconOrange Carotenoid Protein (OCP).

“We think expand iconphotoprotection could be a key reason why marine cyanobacteria are so abundant and successful. After all, they constantly manage high levels of light exposure in the open ocean,” Tina says.

“I aim to characterize the OCP and its evolutionary precursors in the two important species of marine cyanobacteria,” Tina adds. “We think their proteins have particular features that will help us understand

how photoprotection works in the ocean. We suspect their pigment content may differ from that in their freshwater counterparts."

Tina's research will span the Kerfeld lab in the US and Jose Manuel Garcia-Fernandez's lab in Spain. The project also falls under the Kerfeld lab's wider goal to engineer synthetic OCP for agriculture, biotechnology, and health applications.

"I would like to thank Cheryl Kerfeld for her continuous mentoring and as I pursue my scientific career. I wouldn't have gotten this fellowship without her help and that of the lab in Spain. I feel so thankful for this opportunity."

Cheryl Kerfeld, Tina's mentor at the PRL says, "Tina has chosen an important research question, that will lead to new fundamental understanding of how organisms respond to light and that has novel biotechnological applications. The Marie Curie Fellowship is a great investment in the career of talented young scientist."

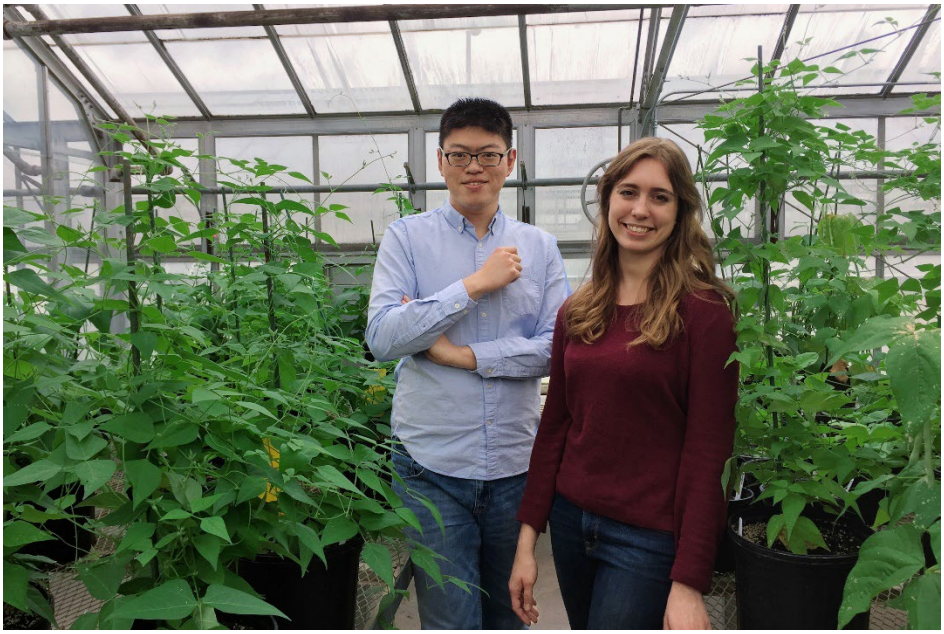
Before joining the Kerfeld lab, Tina obtained her B.S., M.S., and Ph.D. from the University of Cordoba, Spain. Her thesis was on nitrogen metabolism in the most abundant and smallest marine cyanobacteria.

The fellowship is named after Marie Skłodowska Curie, a Polish and naturalized-French physicist and chemist who conducted pioneering research on radioactivity. She was the first woman to win a Nobel Prize; the first woman to become a professor at the University of Paris; and the first woman to be entombed on her own merits in the Panthéon in Paris.

# Announcing the inaugural winners of the Keegstra and Thomashow 2018 Travel Award

6/7/18

Igor Houwat



Pengfei Cao and Alyssa Preiser have been awarded the inaugural Keegstra and Thomashow Travel Award. Both graduate students were each awarded $1200 to present their research at upcoming science conferences.

The award was established to enrich the education and future careers of promising PRL students. It helps them attend high quality science conferences, where they get to network, learn about new discoveries, and pursue new lines of collaboration and research.

Alyssa is a graduate student in the **Department of Biochemistry and Molecular Biology** and the **lab of Thomas Sharkey**. Her research focuses on the Calvin cycle, the photosynthetic mechanism that provides carbon for plant development and defense.

She says, “I was happy to hear that I received the travel award. I will attend two conferences over the summer, and I'm really excited to share the work that I've been doing. I have benefitted from a lab environment and Dr. Sharkey’s direction that encourages us to tell the stories of our research, and it's an honor to be recognized as having a story worth telling.”

Pengfei is a student in the **Department of Plant Biology** and the **lab of Federica Brandizzi**. He focuses on mechanisms that regulate the morphology of the endoplasmic reticulum, the plant cell’s main protein manufacturer.

He says, “I feel excited and honored to be a recipient of the travel award. I cherish this award as a recognition of research that I could only accomplish under Dr. Brandizzi’s supervision and as a member

of the PRL family. With the provided opportunity, I will spare no effort to enrich my education and broaden the research impact of the PRL."

The award was established by two former PRL directors, Ken Keegstra (1993 – 2006), and Michael Thomashow (2006 – 2015) and their spouses, Sue Keegstra and Suzanne Thomashow.

The former directors and their spouses believe that graduate students need to learn how to effectively communicate their research at high quality scientific conferences. However, financial support for such activities is becoming ever more limited, which is why they created this award.

# 2018 Anton Lang Memorial Award Winners Announced

6/11/18

Igor Houwat

Han Bao and **Eric Poliner** were awarded the 2018 Anton Lang Memorial Award during a ceremony which took place on Monday, May 14, 2018 at the Molecular Plant Sciences 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 – given this year by Dr. Kazuo Shinozaki from the RIKEN Center, Japan – and recognizing a graduate student and a postdoctoral research associate who exemplify the research excellence, ideas, dedication, and vision of Anton Lang.

Han, from the **lab of Cheryl Kerfeld**, won the post-doc award. She studies the molecular basis of photosynthesis, particularly photoprotection. **Her current project** is to study the Orange Carotenoid Protein (OCP) mediated non-photochemical quenching mechanism of cyanobacteria. She and her colleagues have discovered new families of the OCP with different photoprotective properties.

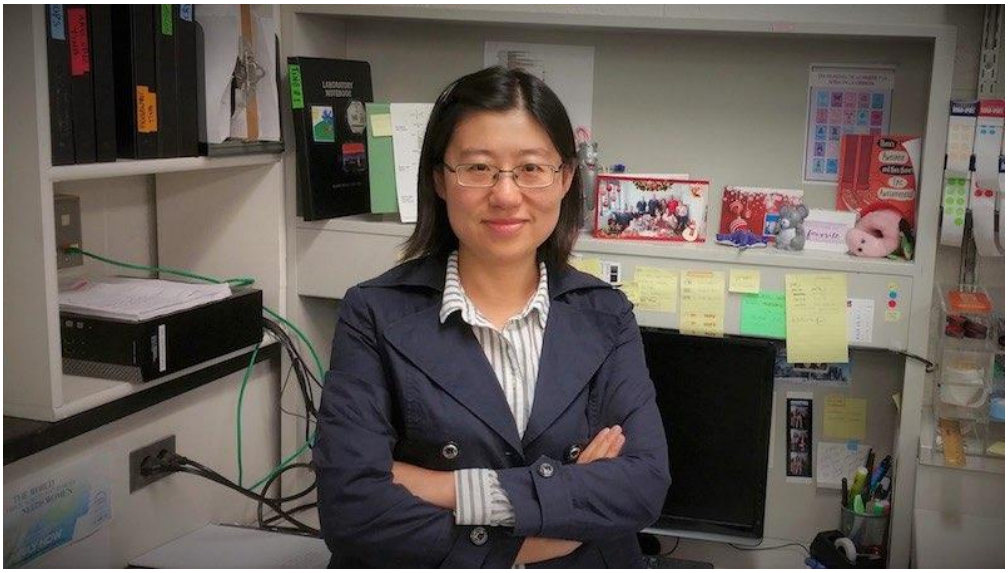


*Figure 1 Han Bao. Courtesy of Kerfeld lab*

“I want to say thank the PRL for selecting me for this award,” Han says. “The PRL is such a great place for doing research. I am so grateful to work in this creative and collaborative environment. I would not have won this award without the support of Cheryl [Kerfeld] and the Kerfeld lab.”

Eric, previously in the labs of **Christoph Benning** and **Eva Farré**, won the graduate student award for **his work on synthetic biology tools for microalgae**.

Eric says, “Thank you to all the mentors, lab mates, and collaborators that have helped and encouraged me along the way."

“I am pleased about the selection of the two outstanding awardees by the PRL Personnel Affairs Committee based on their recent accomplishments and scientific excellence. I would like to congratulate Han and Eric on behalf of all members of the PRL and wish them good luck for their future endeavors”, says Christoph Benning, Director of the PRL.

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.

# Study shows how a gene helps plants manage their protein production in stressful times

6/12/18

Igor Houwat, Ya-Shiuan Lai

*Figure 1 Banner by Thomas Regnault, CC BY 4.0, https://doi.org/10.6084/m9.figshare.5371444.v1*

The **lab of Federica Brandizzi** is showing how a gene helps plants adjust protein production during stressful times. The study is in the **Proceedings of the National Academy of Sciences**.

**The background**

expand iconProteins are the lifeblood of plants. These molecules come in many shapes and sizes and do a lot of things to keep plants healthy. For example, some carry water up from the roots to nourish the leaves. Others make insecticides to kill pests. There are even proteins that work like alarm systems during dangerous situations.

The expand iconendoplasmic reticulum (ER) is the hub that produces one third of the proteins that keep a plant growing.

It also has to be on standby for emergencies. Say, a caterpillar starts eating a leaf. The plant then asks the ER to ramp up the number of defense proteins.

These special production demands can overwhelm the ER, which still has to continue its routine production. The added stress can lead to defective proteins which can harm and even kill plant cells.

To cope with the stress, plants rely on an alarm signaling system, called the expand iconunfolded protein response (UPR). The UPR protects cells from defective proteins and instructs the ER to produce healthy ones.

**We still don't know much about how the UPR works in plants**. But understanding it could be a key to breeding plants with enhanced resistance to stresses. The result: improved yields.

**The Science: a gene as a crossroads between two defense systems**

**A gene that "blocks" the UPR in order to keep plants safe**. "We identified one gene, called NPR1, that reduces the activity of the UPR," says **Ya-Shiuan Lai**. Ya-Shiuan is the main co-author and a grad student in the **Cell & Molecular Biology Program**.

When the scientists took the blocking gene out of lab plants, the UPR was more active. The plants were more resistant to stress.

"We think it is harmful for plants to keep an active UPR at all times during stressful situations. It consumes a lot of energy," Ya-Shiuan adds. "That is why plants use these 'negative' regulators, as we call them, to maintain a proper energy balance."

**Teasing out how the gene works in plant cells**. "The gene product changes its structure, depending on the mix of chemicals inside plant cells," Ya-Shiuan adds .

"During stress periods, the gene morphs into a simpler structure that enters the cell nucleus. There, it interacts with the DNA-interacting factors that are responsible for turning on the UPR."

The scientists are still debating how the gene actually blocks the UPR. "Does the gene simply block the system from working? Or does it fuse with it, creating an inactive larger complex?"

**The same gene, playing a different role, also helps plants defend against harmful bacteria.** "In this case, it doesn't play a blocking role. On the contrary, it supports the making of compounds that fight bacteria," Ya-Shiuan says.

Somehow, the gene's work doesn't seem to bleed over between the 'stress' and the bacterial defense systems. It can confine its activity within the system it is working in.

One reason might be that **plants face different stresses that need to be dealt with by separate defense systems**. It is helpful for the systems to interact so they keep plants well-protected on the whole.

"I'm thankful for Dr. Brandizzi's support. She helped me keep the faith during the long publishing process," Ya-Shiuan says. "The MSU-DOE Plant Research Laboratory's culture of teamwork was very helpful. **Dr. He's lab** works on plant bacterial defenses. They helped me interpret the data and progress with my research."

# PRL alumnus, Richard Vierstra, elected to National Academy of Sciences

6/18/18

Igor Houwat

A **MSU-DOE Plant Research Laboratory** (PRL) alumnus and leading plant scientist, Richard Vierstra, has been elected to the National Academy of Sciences.

Vierstra was a former PRL graduate student in the lab of Kenneth Poff. He is currently the George and Charmaine Mallinckrodt Professor of Biology at Washington University in St. Louis.

Vierstra's current work focuses on intracellular protein degradation in plants and the roles of the ubiquitin-26S proteasome and autophagy in this breakdown. He also studies how the phytochrome family of photoreceptors help plants sense light and entrain their growth and development to the daily and annual cycles in their light environment.

"It was a great honor to be elected into the National Academy," Vierstra says. "Much of my lab's success over the years began with the excellent graduate training provided to me by the PRL; it was certainly a rich experience."

*Figure 1 Richard Vierstra. Courtesy of Vierstra*

The 2018 academy cadre includes **84 new members and 21 foreign associates** in recognition of their distinguished and continuing achievements in original research.

The **National Academy of Sciences** is a private, nonprofit institution established under a congressional charter signed by President Abraham Lincoln in 1863. It recognizes achievement in science by election to membership, and – with the National Academy of Engineering, Institute of Medicine and National Research Council – provides science, technology and health policy advice to the federal government and other organizations.

# Two plant cell 'hotspots' tell the cell where to import its resources

6/19/18

Igor Houwat, Giovanni Stefano

Scientists in the **Brandizzi lab** are increasing our understanding of expand iconendocytosis, how plant cells import molecules from their surroundings.

During endocytosis, the cell identifies an external molecule. The cell's outer cover, the plasma membrane, folds inwards, luring in that molecule. The folded part then pinches off and takes the surrounding cargo to its destination inside the cell.

Endocytosis is essential for plant health. It is how cells fine-tune the amounts of molecules they import. Otherwise, plants can get damaged. For example, experiments where the process is faulty leads to smaller roots and shoots.

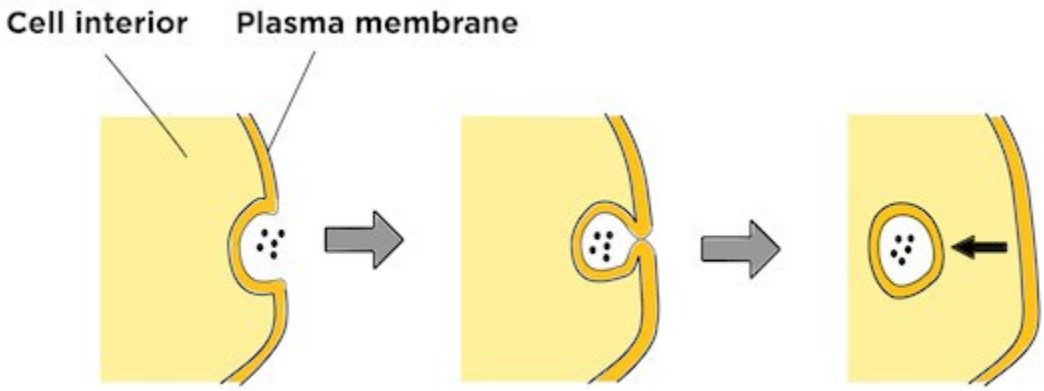



*Figure 1 Endocytosis: 1) the cell identifies a molecule; 2) The plasma membrane engulfs the molecule; 3) the pocket pinches off and enters the cell. By すじにくシチュー, CC0 1.0 Universal*

“We do not still fully know how this process works. We want to understand how it talks with other parts of the cell and hands them the imported molecules,” says **Giovanni Stefano**. Stefano is a Research Assistant Professor in the lab of Federica Brandizzi.

Now, Stefano and a team of scientists reveal one way how the expand iconendoplasmic reticulum (ER), the plant’s protein factory, is connected to the process. **The study is in the journal Cell Reports**.

**The Science: 'hotspots' trigger endocytosis**

The scientists focused on two proteins, called VAP27-1 and VAP27-3. Both are found at the contact sites between the ER and the plasma membrane.

“It seems that these two proteins bridge the ER with the endocytic membranes through an interaction that involves lipids,” Stefano says. “We are the first to show, through various analyses and microscopic imaging, how these proteins impact endocytosis.”

The VAP proteins work like hotspots that tell the cell where endocytosis should take place. They do it by recruiting a component, known as clathrin, which triggers endocytosis.

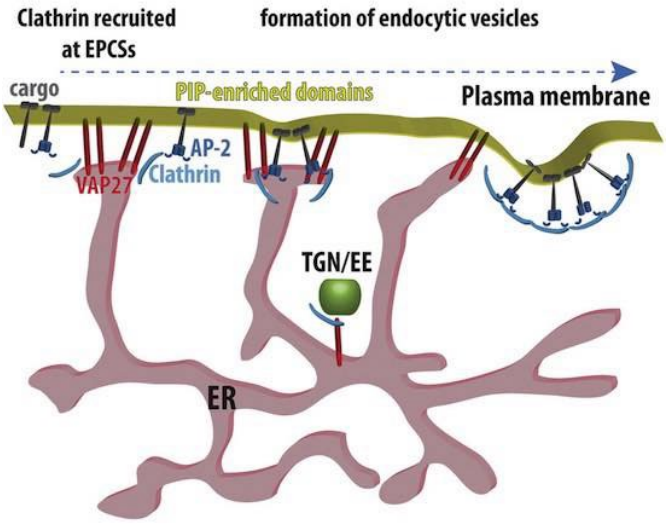



*Figure 2 Top left: VAP proteins (red) bridge the ER and plasma membrane; Top middle: VAPs recruit clathrin (blue); Top right: clathrin triggers endocytosis. By Giovanni Stefano et al, as found in **Cell Reports**, CC BY-NC-ND 4.0*

And the VAP proteins seem to be a crucial part of the process.

“When we remove them from a plant, endocytosis and growth rates become unbalanced,” Stefano says. “But endocytosis is only partially compromised. We are not sure yet if there are other components that explain why it still works to a certain degree.”

The two VAP proteins in the study belong to a larger collection of four proteins, all called VAP.

“All four proteins are found at the contact site between the ER and the plasma membrane,” Stefano says. “We think they play overlapping roles in endocytosis. Each one might target a different plant tissue.”

Banner image by rawpixel.com, CC0 License, www.pexels.com/photo/two-person-holding-white-and-black-android-smartphones-926984/

# Gutter Ball XXIV: Lee Alexander wins bowling tournament

6/21/18

John Froehlich

On Friday, May 11, while the weather outside may have been cloudy and rainy, inside the City Limits Bowling Center, it was raining down bowling pins.

Once again, determined bowlers from various departments gathered at Gutter Ball XXIV to showcase their throwing skills in the hopes that by the end of the evening they would be crowned the overall Gutter Ball Champion.

Certainly, we applaud everyone's efforts, but in the end, the prestigious "Gutter Ball Champion" title went to: Lee Alexander, who works in the GLBRC Cell Wall Analysis Facility. Congrats Lee!!

*Figure 1 From left to right: Igor Houwat, John Froehlich, Tony Schilmiller, Ryan Mosley, Starla Zemelis. By Starla Zemelis*

A very special mention goes out to all of the "young" bowlers who participated this year. By their enthusiastic involvement, the future of Gutter Ball looks very bright!!

Also, thanks to ALL the bowlers (over 100 from many different departments and labs!!!) who came out this year! Special mention goes out to the Howe lab, which was represented by four lanes of "JA induced", enthusiastic and determined bowlers!!! Not to be outdone, the Hamberger Lab showed their team spirit by purchasing "THE TOWER". While this beer device may not have enhanced their scores, it certainly made their lab one of the more animated groups of the evening.

*Figure 2 The Hamberger Lab showed their team spirit by purchasing "THE TOWER." By the Hamberger Lab*

Finally, maybe it was the pressure or the thrill of possibly becoming the Gutter Ball Champion, that resulted in an array of bowling strategies being showcased this year: from Patrick Horn's baby-assisted bowling technique, to Igor Houwat's foot-foul strategy (four in all!) and to Ryan Mosely's "just throwing heat" strategy (23-25mph bowling ball speeds)! All very interesting strategies that just came up a little short. Who knows what novel approaches we'll see next year. Some people will do anything to get an advantage!

Hopefully, this overwhelming enthusiasm will be carried over to next year when the Gutter Ball will be observing its 25th Anniversary!! Certainly, this milestone will be celebrated by the ultimate bowling "Extravaganza" that you do not want to miss!

Mark our words, it's going to be Huge!!!

# Grad student, Alyssa Preiser, receives Barnett Rosenberg Assistantship

6/28/18

Igor Houwat

Alyssa Preiser, a Ph.D. student in the lab of MSU-DOE Plant Research Laboratory (PRL) scientist Thomas Sharkey, is a recipient of the Barnett Rosenberg Assistantship in Biological Sciences.

The pre-doctoral assistantship is sponsored by the College of Natural Sciences. It is geared towards advanced students who have shown a distinguished record of accomplishment. Awardees receive a stipend of $30,000 plus health insurance and tuition waver for one year.

Alyssa, who is in the **Department of Biochemistry and Molecular Biology**, studies the Calvin-Benson cycle, a photosynthetic mechanism that provides the majority of carbon for plant growth, development, and defense.

“Many global issues, such as climate change, food supply, energy sources, and agriculture, rely on an understanding of this basic plant cycle,” Alyssa says. "The Calvin cycle has been common knowledge for decades, but the Sharkey lab has recently proposed an alternative pathway that works in parallel with the cycle."

The extra pathway seems to stabilize the cycle during certain conditions. **Alyssa’s research is to tease out this pathway’s regulation and impact**.

Alyssa says, “I am extremely grateful to be recognized with this award. I’ve received so much encouragement from peers and my mentors, especially Dr. Sharkey, that have helped me get to where I am today. They are always motivating me to do my best in my work- whether at the bench or in the community. It’s exciting to have the work that I’m doing be recognized.”

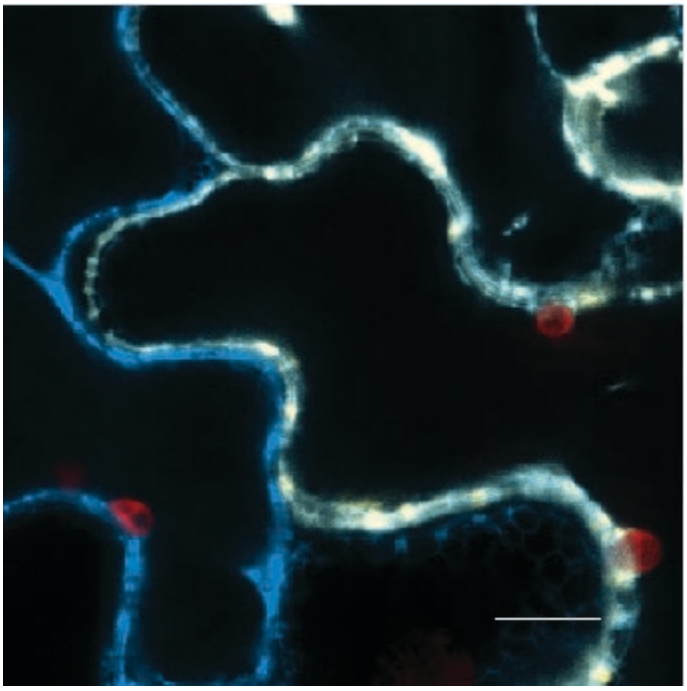
**Tom Sharkey**, Alyssa's mentor, says, "I am very happy to see Alyssa's great work recognized by this award. She has made a significant contribution to our understanding of one of the most important biochemical pathways that is the source for all plant-based products."

The award celebrates Barnett Rosenberg, a former MSU faculty member who **discovered the cancer drug, Cisplatin**. The royalties from that work helps finance the research assistantship fund.

# Keeping up with lipids on the move: a new molecular tracking method

6/29/18

Igor Houwat, Anna Hurlock



In one of the older Star Wars movies, Jedi master Yoda instructs his apprentice, Luke, on the ways of the Force in a series of now-iconic scenes. The Force, Yoda says, is an energy field that penetrates us, that surrounds us, that binds us.

One could say the same about expand iconlipids, small molecules in fats, oils, and waxes found in living things.

Lipids are found in a lot of places and do many things. They make up the boundaries of our cells, from which our tissues and organs are formed. They make up membranes that let plants do photosynthesis. Lipids are also great at storing energy, one reason researchers are targeting them to produce biofuels.

Scientists want to work with lipids to improve crop yields or make those biofuels. First, they are exploring how different types of lipids are made. But this research is tricky. Different parts of plant cells contribute to the process, so lipids are always moving in those cells. That makes it hard to keep track of them.

A new study from the **Benning lab** at the MSU-DOE Plant Research Laboratory presents a minimally-invasive lipid tracking method. The lab also tests the method on lipids related to photosynthesis in plants to explore where they are made in the plant cell. The study is **published in The Plant Journal.**

**Lipid tagging and tracking system**

“Most lipid precursors come from two sources in plant cells, the expand iconendoplasmic reticulum and the expand iconchloroplast,” explains **Anna Hurlock**. Anna is a former grad student in the Benning lab.

“But we don’t know how much each source contributes to the final product. We don’t know how lipid precursors move around,” says Anna.

Current methods to track lipids can be problematic. They involve attaching a fluorescent molecule, about the same size as a lipid, to that lipid.

But this method causes lipids to act strangely, which can cast doubts on any findings.

The new approach is subtler.

Scientists take a lipid-editing protein (delta-6 desaturase) from a moss and insert it into a plant that doesn’t have it.

“The foreign protein creates lipids we don’t tend to see in the plant,” Anna says. “Lipids are cobbled together with different building blocks, called expand iconfatty acids. That foreign protein creates new types of fatty acids, slightly different from the ones the plants make. These new building blocks mix in with the usual ones we expect to find.”

“We can detect and track these unusual lipids as they move in the cell. Their unique make-up is the tell-tale,” Anna adds.

Testing out the method, the team observed new subtleties with regards to lipid production. “For example, we thought that one lipid, PG, is nearly all made in the chloroplast. With the new method, we saw that about 18% of the precursors are from the endoplasmic reticulum.”

There is a rub, however. The approach relies on genetic changes to the plant so it can take in the foreign protein. The plant doesn't seem to mind low levels of the new lipids. But it might not like it if there are a lot more of them, which could alter its natural lipid metabolism.

"Still, we've shown that this approach is highly informative," Anna adds. “It could help fill our knowledge gaps of lipid movement, especially if we can replicate it in wild plants."

Despite this advance, the movement of lipids in plants is still a mystery, much like the mythical Force. It’s definitely worth exploring.

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

# Scientists find new methods to control bacterial factories for biotech aims

7/24/18

Igor Houwat, Andrew Hagen

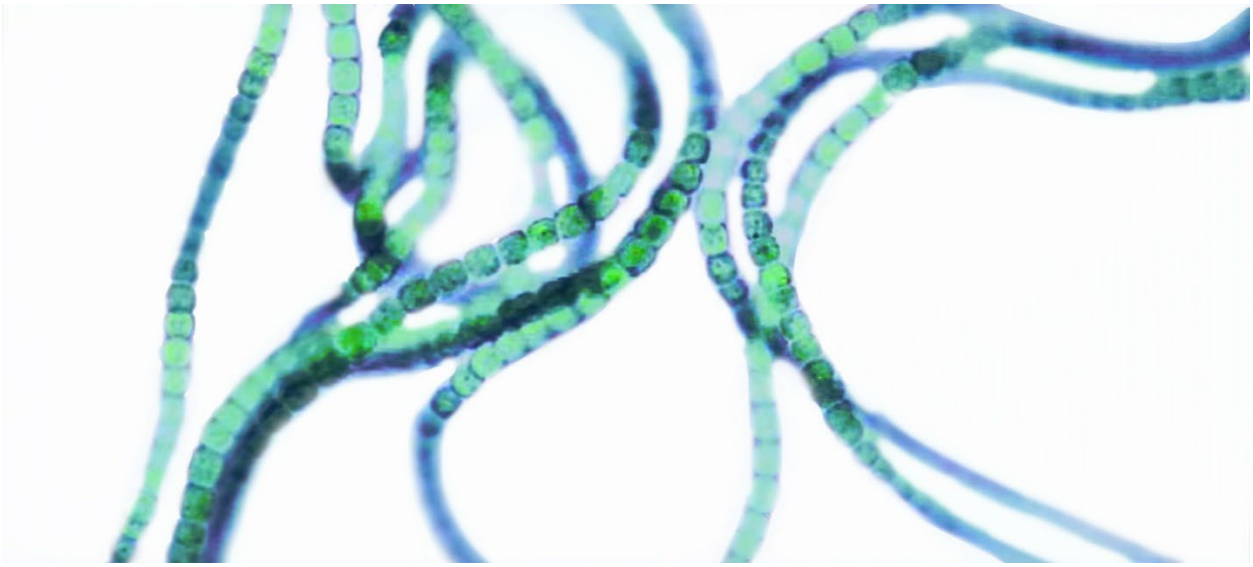


*Figure 1 Banner of cyanobacteria by MSU CABS*

The lab of Cheryl Kerfeld has announced a breakthrough in manipulating miniature factories, found in bacteria, that hold much promise in the biotech field.

The factories, called expand iconbacterial microcompartments, are widespread in nature and do different things depending on the host. For example, in expand iconcyanobacteria which harvest energy from the sun, they help to  construct high energy compounds. In our own guts, pathogenic bacteria use the factories – because the processes they perform are inefficient outside of them and sometimes use toxic materials – to outcompete our “good” bacteria.

Scientists want to retrofit the factories with new machines to perform designed functions. The synthetic versions could sustainably make biofuels, industrial materials, and nanoscale medical devices.

But the factories are very tough to work with.

“Current technologies require many days to prepare and extract a synthetic factory shell," says **Andrew Hagen**, a post-doc in the **Kerfeld lab**. "We also have had limited options to insert custom machinery in it. I wanted to develop better ways to do those two things.”

In a new **Nature Communications publication**, the MSU-DOE Plant Research Lab team announces new methods to manipulate factories:

- **Complementation-based Affinity Purification (CAP)**: which quickly screens for the assembly and extraction of the factories

- **Encapsulation via Covalent-linkage (EnCo)**: which helps to predictably insert custom machinery in the factories

**CAP: Piecing together factories like soccer balls**

The factories look like soccer balls. Their walls are made of expand iconprotein tiles, shaped like hexagons and pentagons, that snap together to form an enclosure.

In the lab, scientists rely on chemical mixtures to make synthetic factories. The challenge has been to efficiently fish those out from the mixtures once they're completed.

The new method shows an easier way to extract the factories:

1. **The team creates a factory that lacks one type of the wall protein tiles**. Imagine a soccer ball without the black pentagon parts;
2. **They add a tag to the missing tile**. The tag works like a microchip that identifies a house pet;
3. **They add the tile back to the mixture, where it snaps into place when it finds the factories**;
4. **The team extracts the factory with the help of the tagged tile.** The team attracts that tag with a system that works like Velcro.

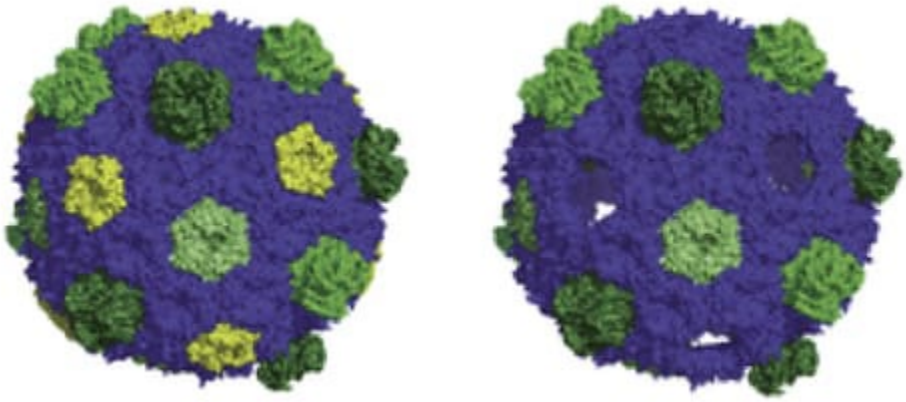


*Figure 2 Left: factories are like soccer balls, made of different types of tiles. Right: a factory missing its yellow tiles. By Andrew Hagen, **Nature Communications**, CC BY 4.0*

**EnCo: molecular super glue**

The scientists also report a method to insert custom expand iconenzymes, the machines, inside the factories. It relies on a new technology, called SPY, that works like protein super glue.

“The system has two entities, SpyTag and SpyCatcher, that are attracted to each other,” Andrew says. “We insert a SpyCatcher “docking site” on the inside of a factory wall. We then add a SpyTag on the machinery. Once in the same environment, the SPY system comes together like glue.”

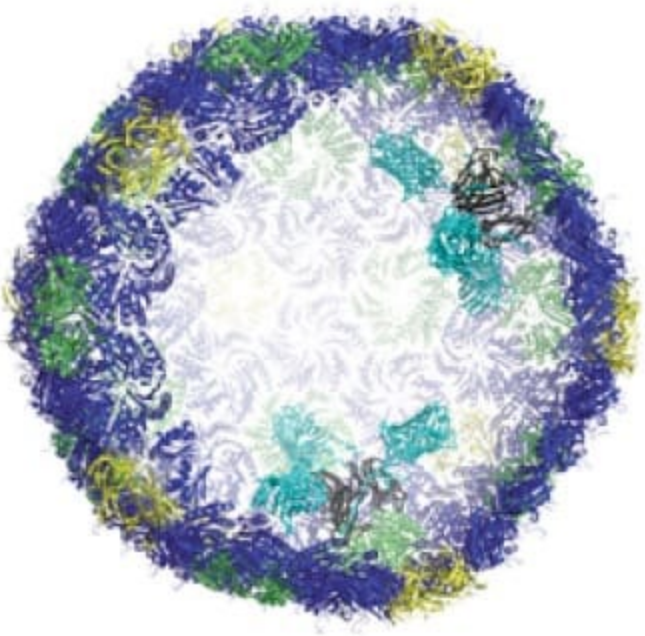


*Figure 3 Factory cutout: in black, SpyCatcher docking sites inside the wall; in turquoise, attached machinery with (not visible) SpyTag. By Andrew Hagen, **Nature Communications**, CC BY 4.0*

Once 'glued' to a factory, the machinery can't get out.

So far, the team has managed to insert 60 copies of a single enzyme into a factory. The team aims to increase that number, as one factory could ideally fit around 200 copies.

Andrew adds, "We even put in two different colored proteins. We showed we can program different ratios of each protein, based on the final "hue" of the shell. This is important for factories that will require multiple production steps."

Future Directions

The two new methods work well together. The team has produced a factory shell, inserted machinery, sealed it off, and extracted it in experiments.

Next is to **realize some of the technology's promise**.

One application is to produce chemicals that are used in industry. Another Kerfeld lab scientist is working on producing the molecule that gets turned into rubber, a process that usually needs fossil fuels. The team is also considering medical applications, like vaccines, and energy materials that are friendly to the environment.

"We think other scientists can use these methods with different bacteria and their factories," Andrew says. "There is a good chance they will adopt them widely."

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

# [VIDEO] New biofuel production system powered by a community of algae and fungi

9/4/18

Igor Houwat, Zhi-Yan (Rock Du)

https://youtu.be/AoFZZtYIRYc

MSU scientists have a new proof of concept for a biofuel production platform that uses two species of marine algae and soil fungi. It lowers cultivation and harvesting costs and increases productivity, factors that currently hold back biofuels from being widely adopted.

The species of alga, *Nannochloropsis oceanica*, and fungus, *Mortierella elongata*, both produce oils that we can harvest for human use. With these oils, we could make products like biofuels to power our cars or omega-3 fatty acids that are good for heart health.

When scientists place the two organisms in the same environment, the tiny algae attach to the fungi to form big masses that are visible to the naked eye. This aggregation method is called bio-flocculation.

When harvested together, the organisms yield more oil than if they were cultivated and harvested each on their own.

“We used natural organisms with high affinity for each other,” says Zhi-Yan (Rock) Du, the study’s first author. “The algae are very productive, and the fungus we use is neither toxic to us nor edible. It’s a very common soil fungus that can be found in your back yard.”

Other **advantages reported by the researchers**:

- The system is **sustainable**, since it doesn’t rely on fossil fuels. The fungi grow on sewage or food waste, while the algae grow in sea water.
- It is **cheaper to harvest**, as the big masses of algae and fungi are easily captured with simple tools, like a piece of mesh.
- The method is **potentially easier to scale**, as the organisms are wild strains that have not been genetically modified. They pose no risks of infecting any environment they come in contact with.

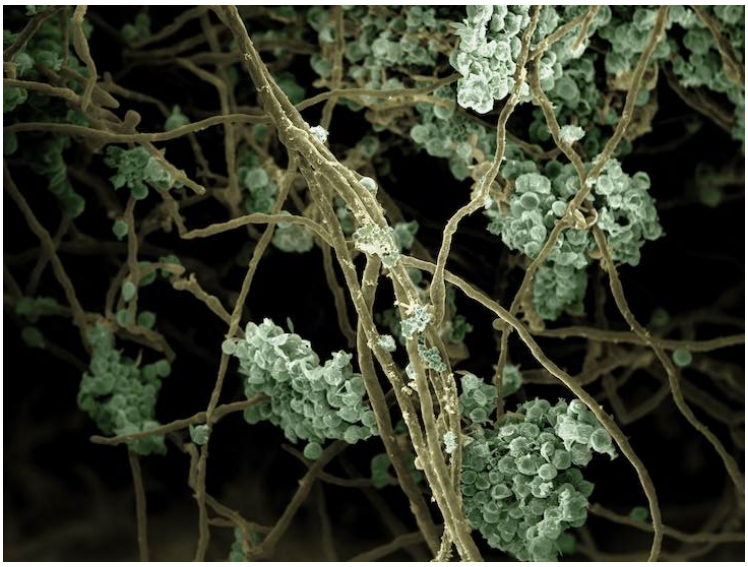


*Figure 1 When scientists place the organisms in the same environment, the algae (green) attach to the fungi (brown). By Zhi-Yan Du and Igor Houwat; MSU-DOE Plant Research Laboratory, 2018*

**Solving problems that hamper biofuel production**

Bio-flocculation is a relatively new approach. Biofuels systems tend to rely on one species, such as algae, but they are held back by productivity and cost problems.

**First, systems that only rely on algae suffer from low oil productivity**.

"Algae can produce high amounts of oil when their growth is hindered by environmental stresses, such as nitrogen starvation. The popular method in the lab for algae oil is to grow the cells to high density levels and then starve them by separating them from the nutrients with centrifugation and several washing methods," Du says. "This approach involves a lot of steps, time, and labor, and is not practical for industrial scale production."

The new approach feeds the algae with ammonium, one source of nitrogen that algae can quickly use for growth. However, the ammonium supply is controlled so the algae produce the maximum cell density and automatically enter nitrogen starvation. The closely monitored nitrogen diet can increase oil production and lower costs.

**The second problem is the high cost of harvesting oil, because algae are tiny and hard to collect**. Harvesting can take up to 50% of oil production costs.

"With bio-flocculation, the aggregates of fungi and algae are easy to harvest with simple and cheap tools," Du says.

Looking forward, the scientists want to mass produce biofuels with this system. They also know the entire genomes of both organisms and could use genetic engineering tools to further improve the method.

The study was conducted in the labs of **Christoph Benning** and **Gregory Bonito**. It is **published in the journal Biotechnology for Biofuels**. It was primarily funded by the **US Department of Energy, Office of Basic Energy Sciences**.

# Kyaw (Joe) Aung joins Iowa State University as an Assistant Professor

9/5/18

Joe Aung, Igor Houwat


Freshly minted PRL alumnus, Kyaw (Joe) Aung, has joined the Department of Genetics, Development, and Cell Biology at **Iowa State University (ISU)** as an Assistant Professor.

His lab will explore how pathogenic microbes, including bacteria and fungi, manipulate plant communication systems to their advantage. Joe aims to research these dynamic interactions between pathogenic microbes and plant cells at their primary contact sites. His group will work to provide solutions to develop innovative approaches to control plant diseases.

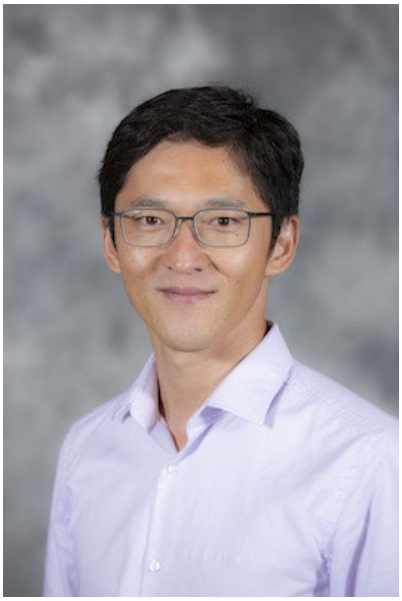


*Figure 1 Joe Aung. By Christopher Gannon*

Joe came to MSU and joined **Jianping Hu's lab** as a graduate student in 2007. There, he studied the biogenesis of peroxisomes and mitochondria - essential energy organelles within plant cells. After graduating, Joe moved to **Sheng Yang He's lab** as a post-doc, where he investigated cellular and molecular biology of plant-microbe interactions. In particular, he focused on understanding how pathogenic bacteria manipulate plant cell-to-cell communication to spread disease. Joe was **awarded a 2016 National Institutes of Health Pathway to Independence Award** to establish this research program, which he will continue at ISU.

"I feel extremely grateful to have had the privilege to learn from great scientists at PRL. The nourishing environment and the scientific culture at PRL laid a solid foundation for me to becoming a dedicated scientist," says Joe. "Moving forward, I will apply everything I learned from here to develop exciting research programs and to mentor next generation scientists."

Jianping Hu, Joe's graduate advisor says, "It was a pleasure having Joe as a graduate student in those five years. He was a mature, productive and collegial student who made significant contributions to my research program. I am so happy to see him move on to establish his lab at Iowa State."

Sheng Yang He, Joe's post-doc mentor says, "Joe is great – an excellent scientist and a super nice guy. We are already missing him. In my lab, Joe did everything an excellent postdoc would do, from doing creative research, writing grants, mentoring students, networking with colleagues on and off campus, to paying close attention to job applications and interviews. It was very easy to be Joe's mentor!"

Joe was born and raised in Burma (Myanmar). He earned his B.S. and M.S. in the Department of Horticulture from **National Chung-Hsing University**, Taiwan. Before joining MSU, he worked as a research assistant with Dr. Tzyy-Jen Chiou in **Academia Sinica**, Taiwan. During his time at PRL, Joe has published a dozen peer-reviewed articles in the field of plant cell biology and plant-microbe interactions.

Good luck, Joe!

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# As climate changes, plants might not suck carbon from the air fast enough

9/13/18

Igor Houwat, Tom Sharkey

Current climate change models might be overestimating how much carbon dioxide plants can suck from the atmosphere.

Thanks to molecular research on photosynthesis done at the MSU-DOE Plant Research Laboratory (PRL), **non-MSU atmospheric scientists have factored in a lesser understood photosynthetic limitation into their models**.

The result: models suggest that **atmospheric carbon dioxide concentrations might increase more rapidly than previously expected**.

Photosynthesis supports life on Earth. Photosynthetic organisms capture carbon dioxide from the atmosphere and process it through a series of reactions known as the Calvin-Benson cycle.

Specifically, the carbon is used to make triose phosphate, a molecule which eventually turns into sucrose, the energy currency that powers plants and the food chain above them. The process is referred to as TPU (triose phosphate utilization).

**But there is a limit to how much carbon plants can use**.

“When photosynthesis gets too much carbon dioxide, it can’t process it into sugars fast enough,” says **Tom Sharkey, University Distinguished Professor at the PRL**. “Photosynthesis cannot indefinitely

increase its productivity levels. It reaches a ceiling, and more carbon dioxide won't help. In fact, plants sometimes absorb less carbon dioxide as levels increase in the atmosphere."

"Some of our PRL labs have been studying the molecular bases of this TPU limitation," Tom adds. "The atmospheric scientists approached my lab to properly factor that limitation into their model. As a result, we saw a rapid rate of increase of carbon dioxide in the model."

***"Plants' ability to help us control atmospheric carbon dioxide levels is weaker than we thought."***

For example, when the researchers assumed TPU limitation was doubled, further restricting photosynthesis, the models showed that 9 gigatons of carbon would remain in the atmosphere by 2100, instead of going into plants.

"The prognosis is more alarming than we previously thought. We need to better understand TPU limitation, because it is affected by many factors. So far, we know the limitation is worse at high light levels, when temperatures are colder, and at high carbon dioxide levels," Tom says.

"The takeaway is that plants' ability to help us control atmospheric carbon dioxide levels is weaker than we thought."

The study is published in the journal **Environmental Research Letters**.

Participating institutions include the National Center for Atmospheric Research, Texas Tech University, Purdue University, Cornell University, and the Brookhaven National Laboratory. The photosynthesis research contributing to these findings was funded by the **US Department of Energy, Office of Basic Energy Sciences**. Banner image of **Industry Sunrise Air**, Pixabay License.

# Berkley Walker joins PRL faculty

9/17/18

Igor Houwat

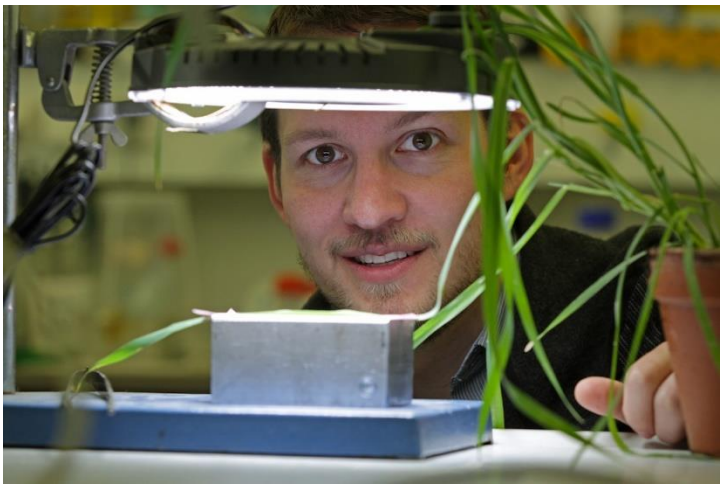

*Figure 1 Banner by Joerg Mueller*

We are pleased to announce that **Berkley Walker** has joined the MSU-DOE Plant Research Laboratory as a new faculty member.

Berkley is a broadly-trained biochemist and biologist who focuses on resolving photosynthetic fluxes from cellular to canopy scales.

“With increasing population, and accompanying changes in consumption and climate, it is vital to understand how photosynthesis will respond to these greater challenges and explore opportunities to hack it to produce more food, fuel and fiber more sustainably,” Berkley adds.

*Figure 2 Dr. Berkley Walker*

Research in his lab will focus on resolving the biochemical, cellular and canopy-level mechanisms that determine photosynthetic fluxes of carbon and oxygen with the end goal to better model plant response to climate change and engineer more efficient crops.

“The PRL and MSU have a rich tradition in laying bare the secret lives of plants. I hope to continue that tradition while enjoying the wonderful state of Michigan with my family,” Berkley says.

Berkley received his PhD from Washington State University. He was a post-doc at University of Illinois/USDA-ARS and was most recently a von Humboldt Postdoctoral Fellow at Heinrich-Heine University in Düsseldorf, Germany.

“I am delighted that Berkley Walker joins the PRL and Plant Biology faculty. He is bringing new expertise towards the study of photosynthesis in plants, complementary to that already existing at MSU,” says **Christoph Benning, PRL director**. “On behalf of the PRL and the plant science community at MSU, I like to extend our warmest welcome to him and his family.”

# Koichi Sugimoto joins Yamaguchi University, Japan, as Assistant Professor

9/20/18

Igor Houwat

Koichi Sugimoto will join the Science Research Center at **Yamaguchi University in Japan** as Assistant Professor.

Koichi will train and maintain facilities, including teaching a class on analytical chemistry and a lab course to training students how to use available equipment. He will manage a variety of scientific equipment, including confocal microscopes, fluorescent/luminescent image scanners, large bacterial fermenters, and more.

Koichi joined the **lab of Gregg Howe** at the PRL in 2013 as a **Japan Society for the Promotion of Science** fellow and remained as a post-doc. He started a research project on the **divergence of herbivore defense responses among domesticated and wild tomato species**, in collaboration with Ming-Jung Liu from the **Shiu lab**. He also researched metabolic regulation in tomato trichomes, the little hairs on the surface that are probably the first layer of defense from caterpillars and other pests.

“I am very happy to start a new position and hope to continue collaborating with my current colleagues,” Koichi says. “I will apply for research grants in Japan, and my MSU experiences and connections should help me start new projects. I want to continue working on why plants deploy specialized metabolites to defend against herbivores and how to synthesize and diversify the chemicals and the biosynthetic pathways that produce them.”

“In addition to the Howe and Shiu labs, I want to thank Dan Jones' lab, Rob Last's lab, Corny Barry's lab, and Erich Grotewold's lab for their support.”

“It has been a privilege to work together with Koichi on research projects aimed at understanding the chemical basis of plant interactions with other organisms. His deep level of expertise in analytical biochemistry, combined with his scientific leadership and enthusiasm for collaboration, has been a tremendous asset to our lab,” Gregg Howe says. “I wish Koichi all the best in his new position and look forward to the possibility of continuing our collaboration in the future.”

Koichi earned his Ph.D in Life Sciences from **Tokyo University of Pharmacy and Life Sciences**.

Good luck Koichi!

# Blazes of light reveal how plants signal danger over long distances

9/24/18

Eric Hamilton, Igor Houwat, Gregg Howe, Layne Cameron

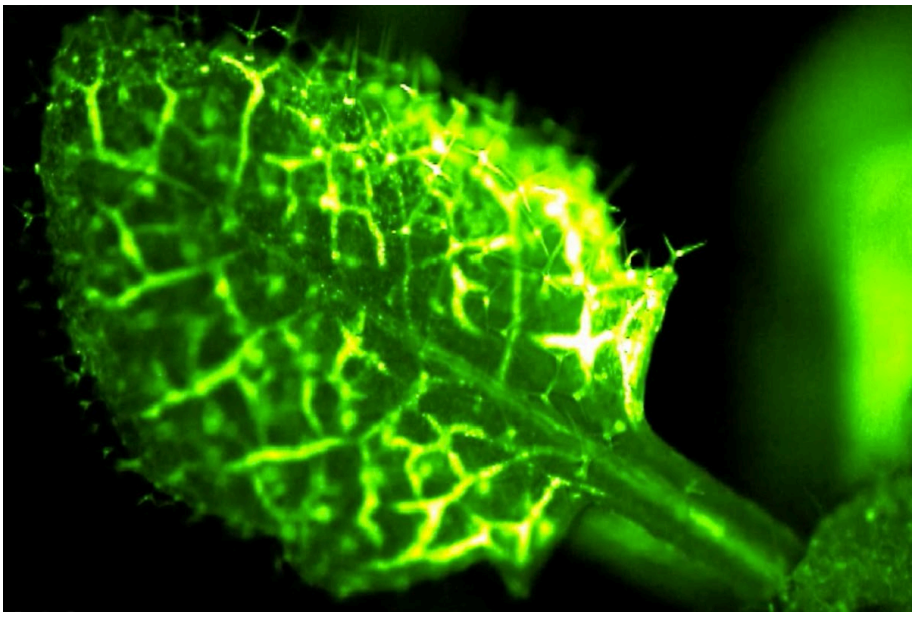

*Figure 1 Banner image by Toyota and Gilroy*

Michigan State University was part of a multi-university study that revealed how plant communication systems respond to threats from herbivores. The results, **featured in Science**, show that once wounded, plants use calcium signals to warn distant tissues of future attacks.

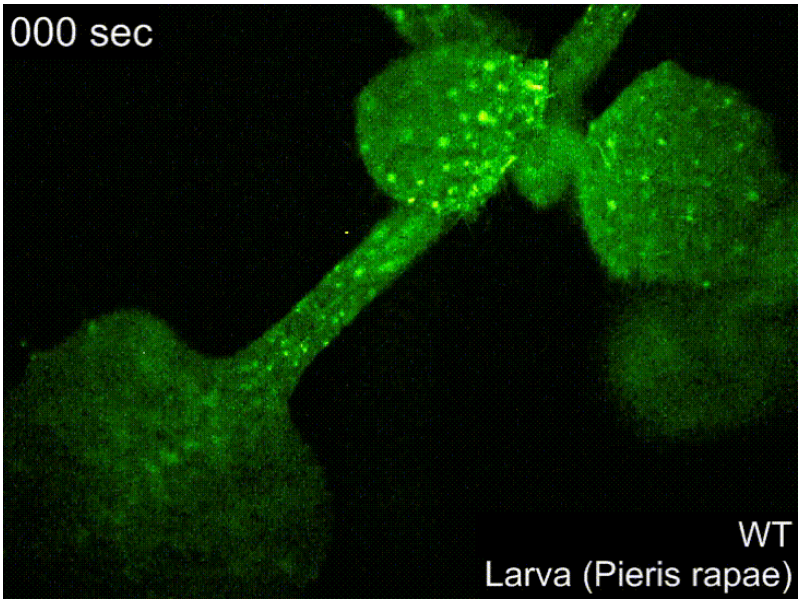


*Figure 2 As a caterpillar easts one leaf, calcium signals wash over other leaves. By Masatsugu Toyota and Simon Gilroy, Science, 2018*

In one video, you can see a hungry caterpillar, first working around a leaf's edges, approaching the base of the leaf and, with one last bite, severing it from the rest of the plant. Within seconds, a blaze of fluorescent light washes over the other leaves, a signal that they should prepare for impending attacks by the caterpillar or its kin.

That fluorescent light tracks calcium as it zips across the plant's tissues, providing an electrical and chemical signal of a threat. The video is part of a study that shows how glutamate – an abundant neurotransmitter in animals – activates this wave of calcium when the plant is wounded.

Masatsugu Toyota led the work as a postdoctoral researcher in the lab of Simon Gilroy at University of Wisconsin–Madison. Gilroy and Toyota collaborated with **Gregg Howe, MSU Foundation Professor and AgBioResearch scientist,** and researchers from the Japan Science and Technology Agency and the University of Missouri.

"For decades, it's been known that leaf damage, inflicted by mechanical wounding or caterpillar munching, rapidly activates defense responses in distant, undamaged leaves of the plant," Howe said. "But what triggers this rapid response has largely remained a mystery."

When a leaf is wounded, an electrical charge races across the plant to warn other tissues of possible danger. What triggered that electric charge, and how it moved throughout the plant, were unknown.

Calcium was one candidate. It is ubiquitous in cells and often acts as a signal of a changing environment. And because calcium carries a charge, it can produce an electrical signal. But it is hard to track because its concentration levels spike and dip quickly.

The researchers created a method to see the calcium in real time. They developed plants that produce a protein that fluoresces around calcium, letting the researchers track its presence and concentration. Then came caterpillar bites, scissor cuts and crushing wounds.

In response to each kind of damage, videos show the plants lighting up as calcium flows from the site of damage to other leaves. The signal moved quickly, about one millimeter per second, reaching out to distant leaves in just a couple minutes. A few minutes later, levels of the defense hormone, jasmonate, spiked in those distant leaves. They were preparing the plant for future threats by producing noxious chemicals that ward off predators.

Previous research by Swiss scientist Ted Farmer has demonstrated that defense-related electrical signals depended on receptors for glutamate, an amino acid and a major neurotransmitter that facilitates long-range information exchange within animals and plants. Farmer showed that mutant plants missing glutamate receptors lost their electrical responses to threats.

Following up on that research, the scientists tested mutants that knock out the glutamate receptors. The calcium barely showed up on the videos as marginal flashes of light. The results suggest that glutamate exiting a plant wound leads to rapid propagation of a calcium wave, which in turn leads to production of jasmonate and defense responses.

The study connects decades of research that have revealed how plants have evolved clever defense strategies, in the absence of a central nervous system. The videos provide the best look yet at these plant communication systems that are usually hidden from view.

“We often think of plants as being passive and at the mercy of their environment. My jaw literally dropped when I first saw these videos from the Gilroy lab – they beautifully illustrate how active and complex plants really are,” Howe says.

This work was supported by grants from the National Science Foundation (MCB-1329273, IOS- 1557899, IOS-1456864), Department of Energy (DE–FG02–91ER20021), NASA (NNX14AT25G) and Japan Science Technology Agency PRESTO, KAKENHI (17H05007, 18H04775, 18H05491).

# Stressed plant roots warn the rest of the plant of looming dangers

9/25/18

Igor Houwat, Federica Brandizzi, Ya-Shiuan Lai

Natural disasters. Humans can't avoid those. But we have systems in place to predict their activity so we minimize loss of life through preventative measures. Take a hurricane. Meteorologists track it with satellites, airplanes, and forecasting models, so people in risk-prone areas can be warned to prepare for the big hit.

It seems plants work the same when under stress, according to a new Michigan State University study. Scientists have shown that when a stress response common to many plant species – the expand iconunfolded protein response (UPR) – is triggered in the roots, the rest of that plant feels it too. The **study is in the journal, Nature Communications**.

Here's how the UPR works: inside each plant cell is a massive factory, called the expand iconendoplasmic reticulum (ER). It produces one third of a cell's proteins and other building blocks that keep plants healthy and working.

But the factory can get overloaded with production demands during times of disease, extreme heat, even cell growth spurts that demand more new proteins than usual. These stresses cause the ER to make defective expand iconproteins that could harm the plant. So, cellular alarm bells go off, and the UPR kicks in to tame the cells. It destroys or fixes bad proteins and 'resets' the factory to produce healthy ones.

"We have assumed this response happens on the cellular level," says **Ya-Shiuan Lai**, co-author and recent graduate from the **lab of Federica Brandizzi**. "Then my mentor asked me, if a cell experiences ER stress in one part of the plant, does the rest of the plant feel it too?"

To answer the question, Lai first developed a way to track the UPR throughout a plant. The control experiment was to attach a fluorescent molecule to a gene found at the center of plant roots. As expected, the fluorescent molecule lit up the root's center, indicating the gene stayed there. Then, Lai added a UPR genetic trigger – called bzip60 – to the combination of fluorescent molecule/central root gene. After treating the roots with a toxic chemical that causes stress, the fluorescent molecule moved to the outside layers of the root.

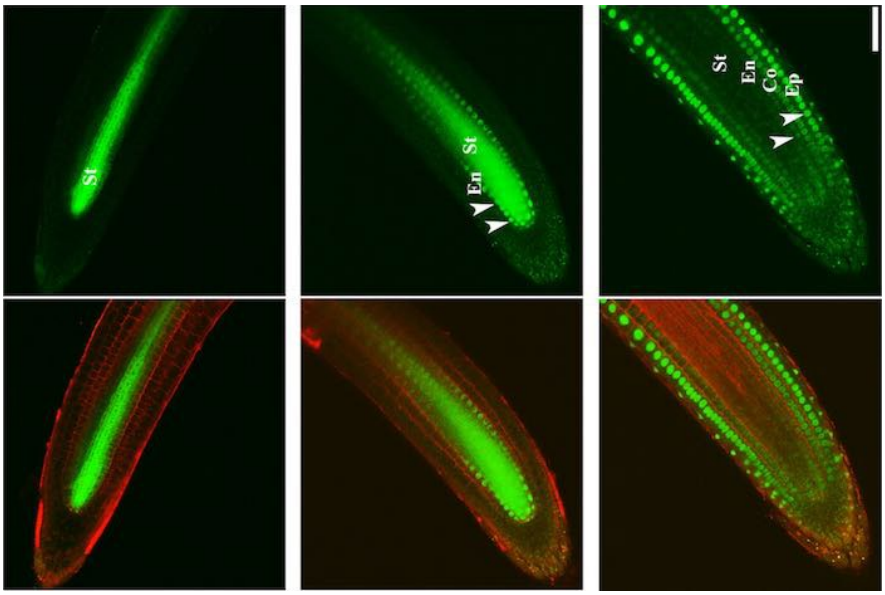


*Figure 1 Left panels: control experiment where the green fluorescent molecule stays at the root center; Right panels: the UPR genetic trigger causes the green signal to move to root edges, which indicates the stress response was communicated over a certain distance. By Ya-Shiuan Lai and Brandizzi Lab. Ya-Shiuan Lai, Federica Brandizzi, **Nature Communications**, 2018, **CC BY 4.0***

That meant that the genetic trigger had caused the movement. “We also found that the UPR was activated in those areas where the fluorescent molecule lit up,” Lai adds. “That indicates that the gene triggered the stress response wherever it went.”

**Splitting a plant cuts off contact**

With the help of Starla Zemelis, a lab technician in the Brandizzi lab, Lai confirmed the idea through an elegant, but challenging, micro-grafting experiment that took years to perfect. They modified the roots of an Arabidopsis plant - the lab rat for plant scientists - so that the ER could not trigger the UPR in those root cells.

Then they grafted healthy, unmutated plant shoots on top of those mutated roots. When the researchers stressed root cells, the warning signal did not make it to the shoots. But in healthy plants, they saw a long-distance movement of the signal from root to shoots.

“We think the signal moves between cells through the plasmodesmata, which is one of the contact points between neighboring cells. It is as if the cells in those healthy plants ‘pass the baton’ to help the gene travel and trigger the UPR across the entire plant,” Lai says.

According to Federica Brandizzi, Lai’s mentor, the fact the gene moves from roots to shoots, and not the other way around, is likely important.

“Roots are sensitive organs. They have to explore the ground and warn the plant about potential stresses,” Brandizzi says. “In the case of the UPR, we think that long-distance communication is a warning from the roots to the plants to prepare for the big ‘hit’ and to allocate resources appropriately.”

# Plants, put in the dark, reveal over 100 active peroxisome proteins

10/1/18

Igor Houwat, Jianping Hu

A study by **the Hu lab** has identified 111 peroxisomal proteins in plants, including six newly identified ones. **The study is in the Journal of Integrative Plant Biology**.

expand iconPeroxisomes work like food processors in plant cells. They break down fatty acids (aka, fats) into smaller pieces that end up in energy compounds to fuel plants. They also play more roles, like breaking down toxins, protecting plants from environmental stresses, and participating in expand iconphotosynthesis.

“We still haven’t fully mapped the functions of plant peroxisomes. To do so, we have to catalogue their body of expand iconproteins,” says Jianping Hu, Professor at the MSU-DOE Plant Research Laboratory.

The new study focused on senescent plants – plants that had aged or that were deteriorating due to some extreme stress. During such times, plants slow down their activity and break down their structures and cellular parts, including proteins and lipids.

“The stage of senescence is one of the lesser investigated areas," says Hu. "Peroxisome shape and function does change, depending on the age of the plant and on where it is located, whether it be the leaf or seed.”

**Plants in the dark**

Hu and her team grew Arabidopsis plants for four weeks. Then they put them in the dark for two days.

They found 105 proteins that are known to relate to peroxisome activity. They also identified 6 new proteins in both seeds and leaves. Similar studies in non-plant systems, such as humans or fungi, have

yielded smaller numbers of proteins. These findings suggest that plant peroxisomes can play more roles compared to their human or fungal counterparts.

"We think the newly identified proteins might help break down compounds and clean up toxic materials," Hu says. “They also might help produce plant defenses against bacteria and assist plants in combatting oxidants (humans drink orange juice and eat leafy greens to fight oxidants).”

“We even found one protein that is localized on the surface of three expand iconorganelles – peroxisomes, chloroplasts and mitochondria. It is possible that this enzyme helps detoxify these three organelles that are metabolically linked,” Hu says.

Hu adds that there is more work to be done. But scientists face major obstacles to establishing an entire catalog of peroxisomal proteins. One, they are difficult to detect. And, two, it is hard to catch transient proteins that are active under specific conditions, like during senescence or under different environmental stresses.

“We still need to compare proteins in different tissues and investigate other plant organs,” Hu says. “Although we looked at plants exposed to the dark, we need to expose them to other conditions, like chemicals and other stresses. These experiments might lead to different observations.”

This research has multiple applications down the road, including breeding crops that are better at generating energy and producing higher yields. There is even a potential benefit to medical science, as some human and plant peroxisomal proteins are closely related. In humans, **peroxisomal disorders are very debilitating**, with symptoms including poor growth, neurological dysfunctions, hearing/visual problems, liver disease, just to name a few.

This is one instance where plant science might indirectly contribute to human health.

# Overspending on defense arsenal bankrupts a plant's economy

10/22/18

Igor Houwat, Qiang Guo, Ian Major

Defend or grow? Can plants do both at the same time? Michigan State University scientists might be inching closer to answering these questions. The answers matter. They could someday help us understand natural ecosystems or help farmers increase yields, without increasing dependence on chemicals to resist pests.

The **lab of Gregg Howe** at the **MSU-DOE Plant Research Laboratory** has genetically tuned a plant to become highly resistant to insect attacks. But becoming such a fortress compromises its growth and procreative capabilities. The research is **published in Proceedings of the National Academy of Sciences**.

The findings seem to support a long-held paradigm called the growth-defense trade-off. It goes something like this: plants work with a fixed energy budget. So, they prioritize resource usage depending on need. If they spend more energy on growth, their defenses are compromised. On the other hand, having more defense capabilities penalizes growth.

Plants, in nature, seem to follow this general rule. When stressed by drought, disease, or insect pests, plants will mount defensive responses, which typically slows growth to a crawl. But if plants have to grow fast, for example to compete with neighbors for light, their defenses are weakened.

*Figure 1 If plants spend more energy on growth, their defenses are compromised. But having more defenses slows growth, as seen in the jazD plant (right). By Howe Lab, MSU-DOE Plant Research Laboratory, 2018*

“Our study provides evidence that large investments in defense necessarily reduce the amount of resources that otherwise would be available for growth and reproductive fitness,” says Qiang Guo, a graduate student in the Howe lab.

The study focuses on the defense system against herbivores, which depend on plants for shelter and food. If a caterpillar starts munching on a leaf, the system produces toxins that ward it off. But in the absence of danger, the plant shuts down its defense system with a battery of 13 repressor  expand icon**proteins**, called JAZ, that put the brakes on defense in order to save energy.

A former post-doc in the Howe lab, Yuki Yoshida, genetically bred a plant missing 10 of these 13 repressor proteins. The result was a plant in continuous, overdrive defense mode.

“It kept producing defense compounds, even in the absence of threats. As expected, it showed high resistance to insects,” says Guo. “Unleashing this defense arsenal also provided protection against fungi that target plant tissues.”

**Plants must balance their budgets too**

Alas, there are dire consequences to a strong plant without…. “All that JAZ.”

“They have a much slower growth rate compared to their wild type counterparts. We can literally see and measure the deficit in growth rate *per day*.”

The plants also have strongly compromised reproductive success. They produce 1/3$^{rd}$ fewer seeds, and those seeds germinate later than usual. The seeds tend to be smaller and of lower quality, packed with less nutritional fats and with a different  expand icon**lipid** make-up.

The team ruled out that  expand icon**photosynthesis** – which is how plants obtain energy resources – was compromised. Enter Ian Major, a post-doc in the Howe lab.

“The mutated plant gets the same amount of energy compounds from photosynthesis as its wild, natural counterpart,” Major says. “However, it consumes more energy than usual. We think the plant is fueling the massive and constant production of defense compounds, which draws resources away from growth.

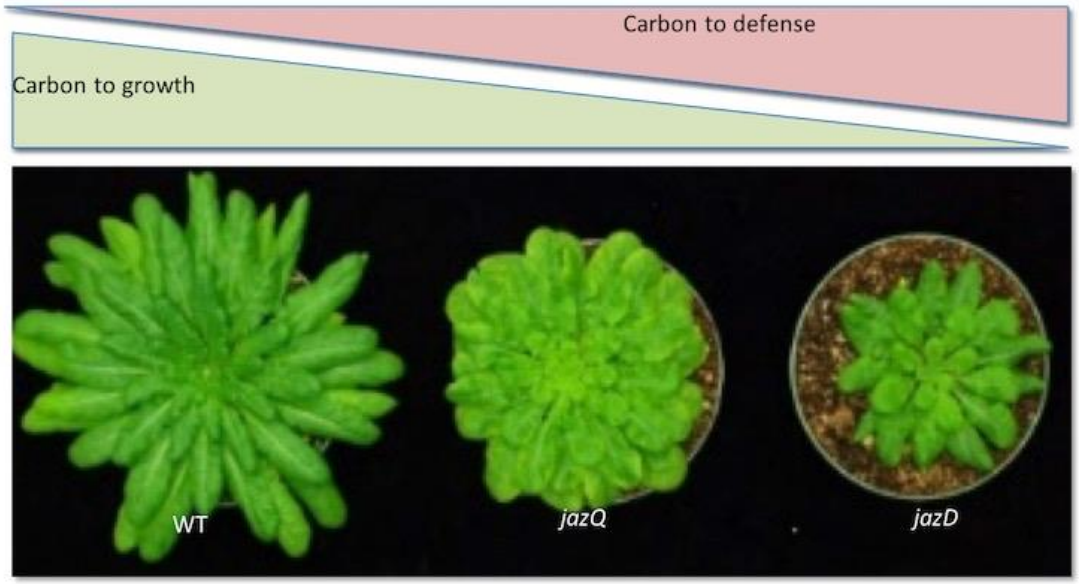


*Figure 2 Left: wild type plant. Center: jazQ plant with 5 JAZ proteins knocked out. Right: jazD, the smallest but most defended plant, with 10 JAZ proteins knocked out. By Howe Lab, MSU-DOE Plant Research Laboratory, 2018*

Guo adds that the high-energy usage starves the plants of nutrients. “It doesn’t have enough energy to perform other functions optimally, like growth” he adds. “To illustrate that point, we fed the plant with sugar, a fuel source, and it partially recovered its growth.”

“Our conclusion is that JAZ proteins help plants grow and reproduce by taming their defenses when the threat of attack is low, which conserves energy. Depending on the severity of the threat, the JAZ proteins will dial up the defenses as needed, perhaps like a dimmable light switch,” Major says.

The research team highlights the importance of Dr. Yoshida’s ten-year effort to knock out the JAZ proteins, one by one. “He ignored a lot of us when we told him it was a high-risk, difficult project. But now, we have new ways of thinking about plants and how we can combine plant traits in new and useful ways,” Major says.

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

# Jonathan Walton 1953-2018

10/23/18

Christoph Benning

We are saddened that **Jonathan Walton** passed away on October 18, 2018 after a brief illness. Jonathan began his career at MSU in 1987, when he joined the MSU-DOE Plant Research Laboratory and the Plant Biology Department (at the time Botany and Plant Pathology) as an Assistant Professor. He was promoted from Assistant Professor to Associate Professor in 1992 and then to Full Professor in 1997. In 2003, Jonathan was awarded the MSU Distinguished Faculty Award. He served as President of the International Society for Molecular Plant-Microbe Interactions from 2003 – 2005 and, from 2007-2010, was the Editor-in-Chief for the society's journal *Molecular Plant-Microbe Interactions.* In 2007, Jonathan was named the MSU Assistant Director for the Great Lakes Bioenergy Center and, in 2011, its MSU Director. In 2008, Jonathan became a Fellow of the American Phytopathological Society and, in 2012, he was elected Fellow of the American Association for the Advancement of Science.

Jonathan was a pioneer and an internationally recognized leader in the study of plant-pathogen interactions. He worked on the corn pathogenic fungus *Cochliobolus carbonum*. Applying organic chemistry, biochemistry, molecular biology and genetics, his work has led to a comprehensive understanding of the disease syndrome caused by this fungus: production of a host-selective toxin by the fungus, the mode of action of the toxin, and the mechanism of plant resistance against the toxin. Notably, he identified the biochemical basis of the first disease resistance gene in plants. Later, he worked as member of the Great Lakes Bioenergy Research Center on fungal cell wall degrading enzymes used for the conversion of plant lignocellulosic materials into biofuels. Most recently, Jonathan used genome sequencing to identify genes encoding the biosynthesis of cyclic peptide toxins, such as α-amanitin and phalloidin, in deadly mushroom species of *Amanita, Lepiota* and *Galerina*. He was developing novel strategies for using cyclic fungal toxins as therapeutic drugs, and just completed a book on the molecular biology of these mushrooms ***"The Cyclic Peptide Toxins of Amanita and Other Poisonous Mushrooms"***.

Jonathan was an outstanding mentor and friend to many students and postdocs. He also hosted Visiting Scholars from countries around the world and was a sought after collaborator. He taught challenging graduate courses as well as large introductory biology classes. During the past three years, he was instrumental in developing the Molecular Plant Science Graduate Program at MSU and he became its inaugural director.

Just before his death, Jonathan expressed how much he enjoyed his work environment and how fortunate he felt in his job interacting with his colleagues, staff, and friends at the Plant Research Laboratory and the Department of Plant Biology.

He will be dearly missed.

Christoph Benning, PRL Director

# Christian Danve Castroverde wins NSERC Postdoctoral Fellowship

11/5/18

Igor Houwat

**Christian Danve Castroverde**, a post-doc in the **lab of Sheng Yang He**, has won a Natural Sciences and Engineering Research Council of Canada (NSERC) Postdoctoral Fellowship. The fellowship provides $45,000 of financial support per year for two years.

The **NSERC** Postdoctoral Fellowship aims to aid, “the most promising Canadian researchers in natural sciences and engineering at a pivotal time in their careers. This support allows fellows to seek out the best research programs in their chosen fields, both within Canada and abroad.”

"I am very delighted and feel honoured to be awarded the NSERC postdoctoral fellowship!” Danve said. “I will be able to continue pursuing innovative research here at Michigan State University and further develop myself professionally. It is definitely a privilege to have these opportunities from both MSU and NSERC. Hopefully, I could contribute to the advancement of our understanding of fundamental mechanisms in plant biology, and deliver long-lasting solutions for the benefit of society."

*Figure 1 Christian Danve Castroverde. MSU-DOE Plant Research Laboratory, 2018.*

Plant diseases, which are a major threat to global food security, are profoundly influenced by environmental conditions. Because the molecular mechanisms behind these diseases are poorly understood, Danve aims to address this important knowledge gap. Recently, **research from the He lab showed that higher temperatures enhance disease in Arabidopsis plants** by suppressing the plant’s salicylic acid (SA) production and signaling.

“My current research is to elucidate the mechanisms on how elevated temperature sensing leads to loss of SA accumulation and SA-mediated immunity,” Danve added. “Once I identify key temperature-sensitive points, I plan to use this knowledge to rationally engineer plants that can recover SA levels and immunity at elevated temperatures.”

Sheng Yang He, Danve’s mentors, said, “Danve wrote a compelling proposal and I am so happy that he received the fellowship. This award will allow him to explore how climate conditions influence plant defense responses. This is an exciting and timely research topic and, for a new postdoc, a great area to carve a niche towards research independence. I look forward to assisting Danve in his research and training over the coming years.”

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**. Danve is currently a member of both the MSU-DOE Plant Research Laboratory and the **Plant Resilience Institute**.

# New ways to control bacterial factories for future biotech uses

11/7/18

Igor Houwat, Andrew Hagen, Jeff Plegaria, Bryan Ferlez

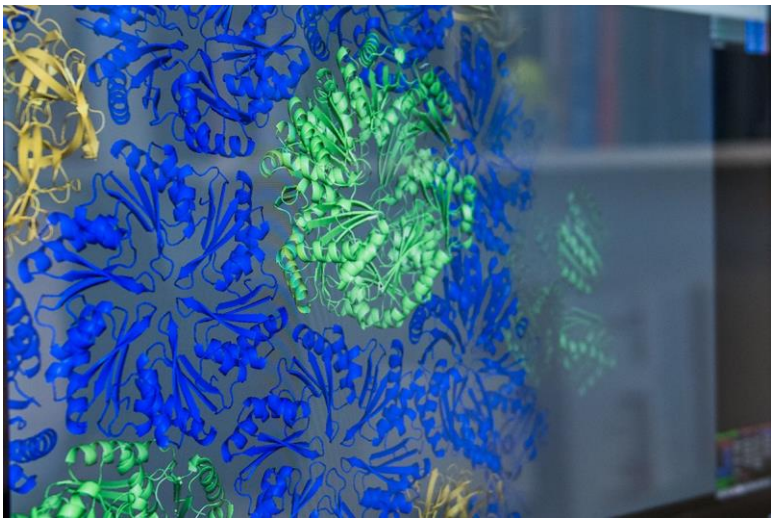

*Figure 1 Banner image by Michigan State University Communications*

The **lab of Cheryl Kerfeld** has developed a new method to manipulate miniature factories found in bacteria that could someday lead to new medical, industrial, or energy applications.

The factories, called expand iconbacterial microcompartments – or BMCs – are found in bacteria all over the world. They are very flexible in variety and function, which is why scientists want to create **synthetic versions, modeled on the real thing, to perform new functions** that benefit human beings.

But the **factories can be tough to work with in the lab**.

With the new method, scientists can build factories in test tubes, allowing for high levels of control. Then, they change the electric charge on the inside of the factory walls, or shells, and attract desired cargo inside them, resulting in custom factories with new uses. The **study is published in ACS Nano Letters**.

**Putting factories together on demand**

BMC functions vary, depending on the host, which could be a photosynthetic bacterium in the Arctic or a pathogenic bacterium in your gut. But their outer walls are made of the same building blocks. Basically, these are three types of expand iconprotein tiles that snap together to form a shape like a soccer ball.

“We want to control how and when these building blocks assemble into a wall. However, on their own, some of them assemble in unproductive ways. That dynamic makes it impossible to isolate and work with them,” says Andrew Hagen, a post-doc in the Kerfeld lab.


*Figure 2 The new technique controls factory assembly, on demand. By Andrew Hagen, Igor Houwat, MSU-DOE Plant Research Laboratory, 2018*

So, the team created a way to thwart factory assembly and then trigger it on command. They genetically fused an additional protein domain that functions as a “protecting group,” to one of the protein building blocks (BMC-H) of the factory. This fusion prevents the pieces from coming together and forming these microcompartments.

After all necessary factory components are added, the scientists add an expand iconenzyme that cuts off the protecting group. Then, the proteins can snap together to make the factory walls. The effect leaves no scars or remnants of the protecting group.

“This level of control will help us to isolate the proteins, manipulate them, study them, make them shelf stable,” Andrew says.

**Proof of concept**

The team then tried to incorporate inorganic molecules inside the factory walls, using the new method. But they had to come up with a couple more tricks.

Jeff Plegaria and Bryan Ferlez, both Kerfeld lab post-docs, switched two negatively-charged expand iconamino acids inside the BMC-H protein tile into positively-charged ones.

Then, they introduced negatively-charged cargo to the mix. In principle, the opposing charges would attract cargo to the building blocks, causing them to attach to each other.

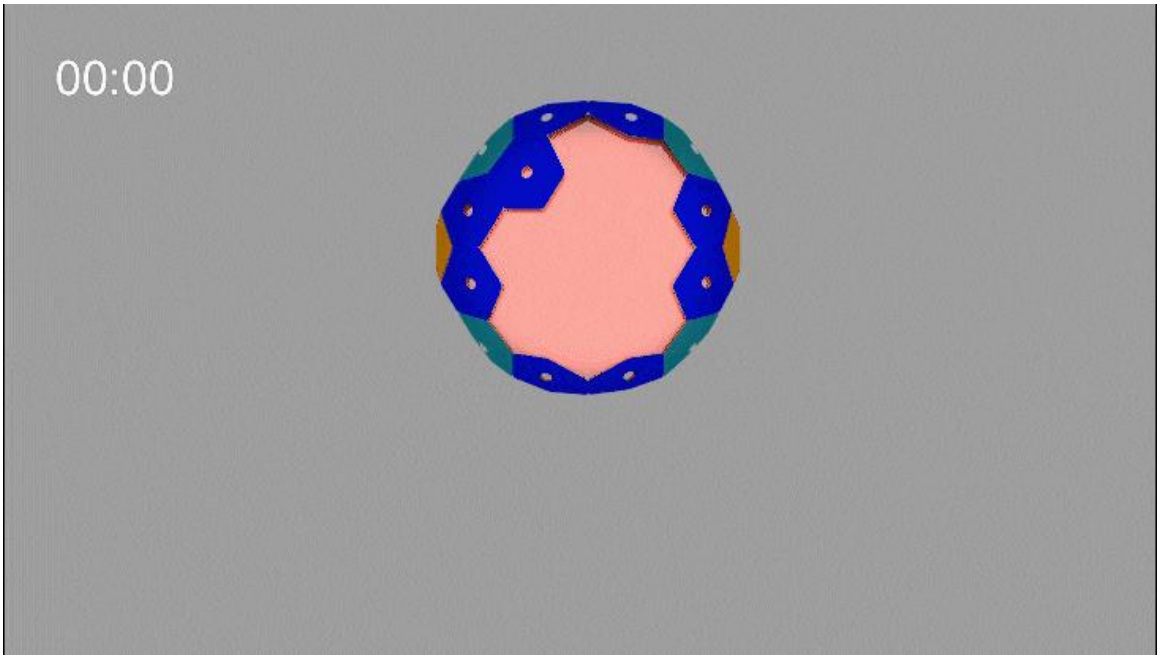


*Figure 3 A new method to introduce cargo into synthetic factories. By Andrew Hagen, Igor Houwat, MSU-DOE Plant Research Laboratory, 2018*

"We tried incorporating both inorganic, negatively-charged gold nanoparticles, and a fluorescent protein fused with an extra negatively charged piece," says Jeff. "The result was successful. Our microscopes showed both types of cargo adhering to the inside of factory walls once those snapped into formation."

In the case of the fluorescent protein, the negative charge was the Velcro that glued the cargo to the wall. In theory, one could add this Velcro to their favorite protein that they want to target into the factory.

"This proof of concept of building factories in test tubes holds exciting promise for the field," says Bryan. "We are showcasing the ability to put a whole new type of molecular machinery inside the factories. And these developments help us **look toward the future of applying this technology**."

For example, some medical imaging technologies rely on inorganic materials like the gold nanoparticles. The new method could eventually use repurposed BMCs to safely ferry such cargo around the body for imaging purposes.

Beyond carrying exotic new materials, the factories will also be easier to study by researchers trying to understand the basic science behind their assembly. Previous methods try to 'graft,' grow, and study the factories inside other living bacteria. However, so much goes on in those bacterial systems that gets in the way of studying the factories.

"Now, we can study factory wall assembly in a test tube, where we can use analytical methods that are impossible to do in a living cell," says Andrew. "We also have evidence the method works with factories from diverse bacterial species. That means researchers could apply it to their particular bacterial microcompartment of interest. They will also be able to more rapidly build prototypes of custom factories."

# [VIDEO] How bacteria organize their factories, and what it means for a bioeconomy

12/6/18

Igor Houwat, Danny Ducat

https://youtu.be/bwTApnZK1As

Deep in the bowels of the Arctic Ocean, or floating at the edges of scalding hot springs at Yellowstone National Park, cyanobacteria thrive in conditions that kill most other life forms. One out of three breaths we take is thanks to the oxygen they create through the process of expand iconphotosynthesis.

Cyanos – as they are called for short - are tiny, each 25 times smaller than the width of a human hair. But they are great at photosynthesis because each cyano cell contains special factories, called expand iconcarboxysomes. The carboxysome increases the efficiency of capture of carbon dioxide from the air. That carbon dioxide is then used to make energy molecules that the cyanos live on.

The factories are so productive that scientists want to use them to make stuff they don't naturally create. New products could include biofuels, industrial materials, or medical tools. And these green production methods wouldn't require fossil fuels to work.

But first, we are learning how the factories are built and how they work.

New research from the labs of **Danny Ducat** and **Katherine Osteryoung**, from Michigan State University, and **Anthony Vecchiarelli**, from the University of Michigan, shows how the factories 'get in an orderly line' inside their hosts, to maximize their impact. The knowledge gives us the potential to someday control their movement inside cyanos (**see video**). The study is **published in eLife**.

**The Science: Skating across DNA**

"Each cyanobacterium has 4 to 8 factories that are aligned in the cell through a mechanism that separates them from one another, and spaces them evenly apart. But that mechanism has eluded us so far," says **Daniel Ducat**, Assistant Professor at the MSU-DOE Plant Research Laboratory.

**Joshua MacCready**, a graduate student in the Ducat and Osteryoung labs, found that factories get in line in their spots in a system that works like Velcro.

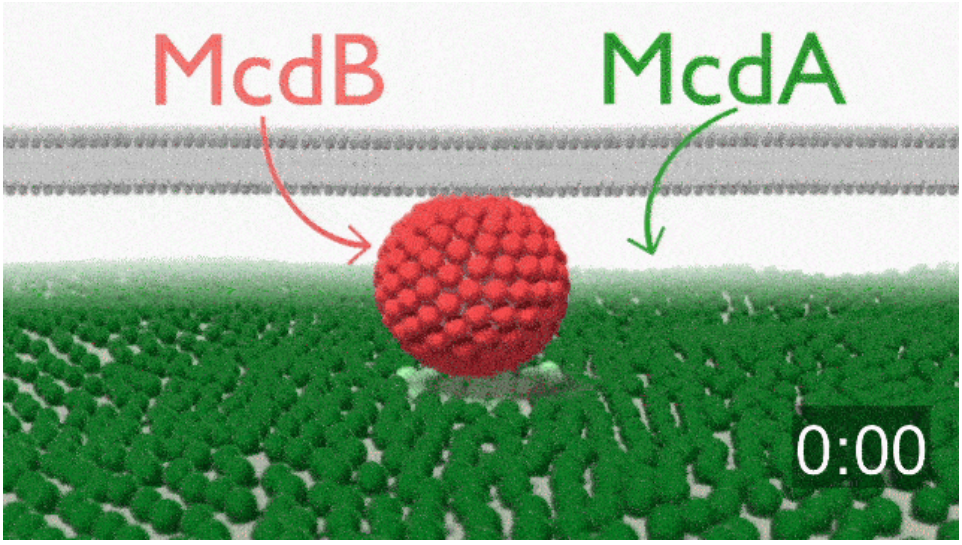


*Figure 1 McdB (red) interacts with McdA (green), causing the carboxysome to skate across the DNA. Courtesy of Ducat and Vecchiarelli labs*

A expand iconprotein, called McdB, coats the outside of the factories and acts like Velcro hooks. Another protein, called McdA, analogous to tiny loops, binds to the DNA that floats inside the entire cyano.

As a factory moves in the cell, the “hooks” on its surface find a “loop” on the DNA. The two connect, and the factory is pulled in the direction of that connection.

Unlike Velcro however, the hooks (McdB) can pull the loop (McdA) off of the DNA. That leaves the factories free to look for another partner, using DNA as a surface to ‘skate' across. This continual search for new binding partners pulls the carboxysome factory in a certain direction (*see gif above*).

The system also keeps factories spaced away from each other inside a cyano cell (*see figure below*).

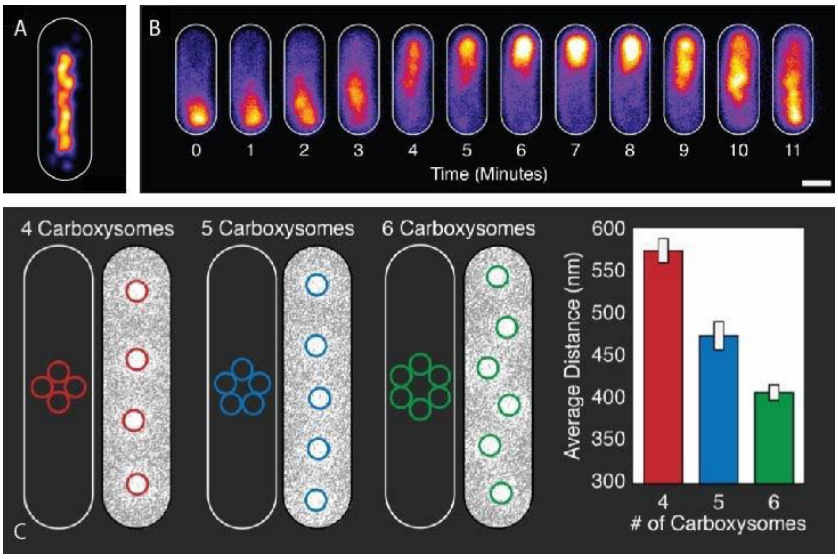


*Figure 2 A) Heat map of the McdB/McdA interaction localizing on a cyanobacterium cell's central axis; B) The system stays on that axis as it moves inside the cell; C) Differing numbers of carboxysome per cell impacts their linear arrangement, but they remain centrally aligned and equally spaced from each other. By Joshua MacCready, 2018*

The team thinks this mechanism serves two purposes:

- **Cell division**. By controlling where it places factories, a parent cyano makes sure its daughter cells each get the same number of factories and starts its life on an equal footing.
- **Resource usage**. By staying apart, carboxysome factories don't compete for their surrounding resources.

"The beauty of this system is that it is self-organized. There is no master regulator directing it. It is all based on local chemical attractions," Danny says.

So what applications does this knowledge tease?

**To repurpose these factories to make biofuels and other products**, scientists will need to control their placement inside cells, so they can do their most efficient work

"If we can make this work, making products like biofuels from sunlight and some carbon dioxide might be even more efficient. The result is a much friendlier environmental output," Danny says.

"There is evidence this system is universal across different types of factories found in various bacterial species. That means we have a lot of options to test out different end products."

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