DEPARTMENT OF BOTANY

Harnessing plant chemistry to build a sustainable society

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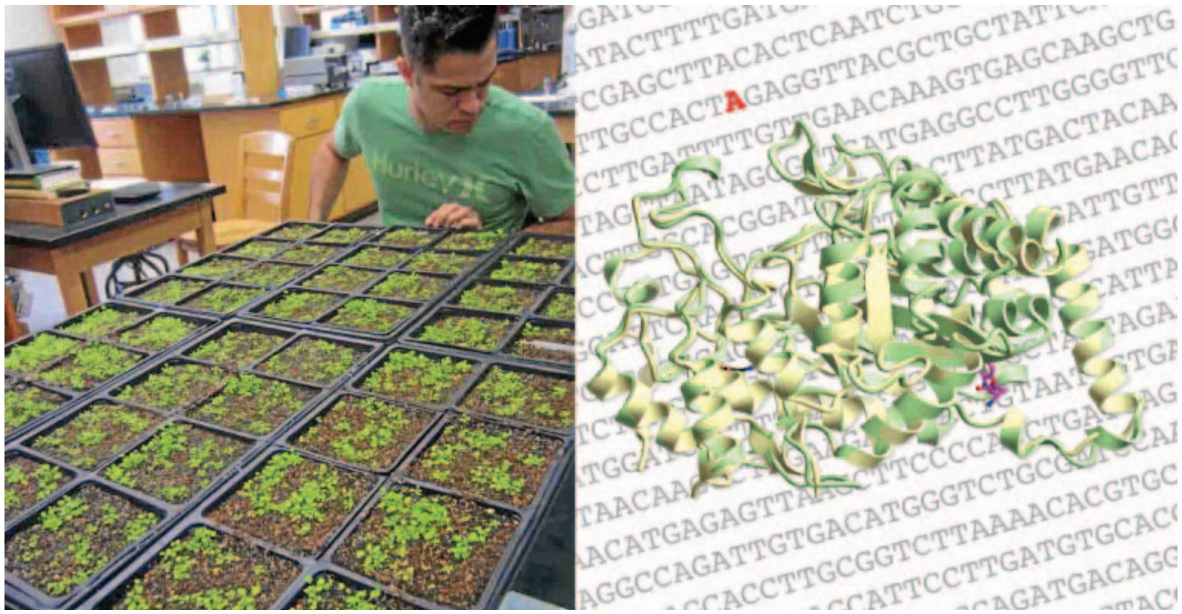
Plants cannot easily move, but some plants, like bristlecone pines, live nearly 5,000 years where they initially germinated. Instead of moving around like we do, plants deal with life matters by producing thousands of chemicals. For example, plants make nasty chemicals to protect themselves from being eaten by insects and infected by viruses and bacteria. Other plant chemicals create the sweet smells of the petunia and the beautiful colors of the strawberry, and these attract butterflies and birds that pollinate and carry seeds to distant locations. Strikingly, plants make all these chemicals using mainly carbon dioxide (CO_2) from the air and energy from the sun.

As an undergraduate, I became fascinated by this tremendous power of plants to convert CO_2 into a variety of chemicals. "This must be critical for solving many issues in the future," I thought—somewhat vaguely at the time. I then came to the U.S. Midwest for my graduate study, where plant biochemistry research is very active. Now, my laboratory at UW-Madison studies how various plants control and decide which chemicals to make through a process called "metabolism."

We know that studying human metabolism helps prevent human diseases. But did you know that studying plant metabolism can improve human wellbeing, by helping us understand how to create healthier foods and essential medicines? In one study, we analyzed beets and related plants like cactus and four-o'clock, which produce vivid red pigments called betalains. These red colors of beets and cacti are different from the more typical red pigments found, for example, in cranberry fruits and rose petals. By studying the metabolism of these betalain-producing plants, we learned they have a very efficient way to make a specific amino acid, called tyrosine, the starting material for betalains.



Dr. Marcos de Oliveira, a scientist in the Maeda Lab, screened nearly 80,000 Arabidopsis plants and isolated several mutant plants that show elevated CO_2 uptake and aromatic compound production in leaves (left). Reading the whole genome DNA sequences of these mutant plants discovered point mutations that alter the functionality of a specific protein, called DHS enzyme, and caused these dramatic metabolic changes (right).

Betalains have antioxidant activity, beneficial to human health, and are used as the major natural red dye in our food. If you carefully read a label of organic strawberry ice cream, you often find beet juice, or betalain, is added. The problem is that betalains are much more expensive than artificial food dyes made from petroleum. We are applying our basic finding to make more tyrosine in various plants and to efficiently produce betalain pigments. Plants also use tyrosine to make many pharmaceutical compounds, such as morphine and related alkaloids, and we can use the same technology to improve the production of medicine made from tyrosine.

Understanding and improving plant metabolism can also battle against global warming. Plants have been converting CO_2 into diverse chemicals for over 500 million years, which shaped the environment we live in and generated many fossil fuels we use today. In our recent work, we discovered genetic mutations in plants that can accelerate the process of converting CO_2 into one group of chemicals, called aromatic compounds. Further digging into the molecular mechanism, we found that these mutations release a natural "brake" that controls a key connection between photosynthesis and the metabolic pathway to synthesize various aromatic compounds in plants. Relaxing the brake allowed more CO_2 to be captured and converted to aromatic compounds.

Aromatics are highly stable chemicals and used everywhere in our society from plastics, fuels, food dyes, cosmetics, medicine, and many more. Unfortunately, most of them are currently extracted from fossil fuels. Our findings can be utilized to enhance sustainable production of aromatic chemicals and also to reduce atmospheric CO_2 at the same time. While the technology is still at an early phase of development, we are working to translate these basic discoveries in fast-growing plants such as bioenergy crops, sorghum and poplar, to capture more CO_2 and produce essential aromatic chemicals without relying on fossil fuels.

I am now certain that studying plant metabolism is key to building a truly sustainable society. My job is to foster a supportive lab, classroom and community, where people from diverse backgrounds and career stages can bring together various ideas and tackle this enormous challenge. One thing that has changed since my college time is that the situation is much more urgent.

About the author

Hiroshi A. Maeda is a professor in the Department of Botany at University of Wisconsin-Madison. Maeda's research and teaching focus on exploring and harnessing plant chemical and biochemical diversity with the ultimate goal of building a sustainable society.