LIFE & EVOLUTION

DNA edits boost photosynthesis

Improving response to excess light may increase crop yields

BY SUSAN MILIUS

Enhancing just three genes helps plants harvest more light, raising new hopes for developing crops that can keep up with food demands from a crowded planet.

Genetically engineered tobacco plants, chosen to test the concept, managed the unusual feat of growing 14 to 20 percent more mass — meaning more crop yield — than untweaked plants, says Krishna Niyogi of the University of California, Berkeley and Lawrence Berkeley National Laboratory. The gains came from inserting different versions of three genes that control how quickly plants ramp back up to full energy-harvesting capacity after going into a protective mode to guard themselves from too-bright sunlight, Niyogi and colleagues report in the Nov. 18 *Science*.

Among results in regular air published so far, "to my knowledge, this is the first example where crop growth has been enhanced by improving photosynthesis," says plant physiologist John Evans of Australian National University in Canberra, who wasn't part of the project.

Photosynthesis, the basic green chemistry for converting the sun's energy into food, isn't a perfectly efficient process (*SN: 2/20/16, p. 12*). And the quest to improve efficiency by manipulating the interlocking steps of more than 100 reactions in plants outdoors has been complex. "We can make things worse, but this is the first time we can make something better," Evans says.

The underlying idea for the tobacco experiment came from an appreciation of how light and shade dance over leaves throughout the day in a farm field. Sudden blasts of intense sunlight are dangerous; an overload can lead to chemical scorching in a plant's light-catching chloroplasts. So when the sun's movement or a toss from a breeze suddenly exposes a chloroplast to more sunlight than it can handle, a protection system kicks in.

Enzymes in the leaf create a surge of a molecule called zeaxanthin, which helps off-load the excess energy as heat. This protection turns on within minutes but turns off more slowly when the crisis is over, Niyogi says.

Restoring full photosynthesis takes a lot more than just enhancing the back-to-normal mechanisms, the researchers found. The protein molecule ZEP is an enzyme that dismantles protective zeaxanthin when it's no longer needed. But making the plant simply build more ZEP keeps the protective system from turning on properly in the first place — which could put a plant at risk. So the researchers also enhanced the enzyme VDE, which builds the protective zeaxanthin. With those two enzymes in balance, a chloroplast can still rid itself of excess energy but get back to full operations faster.

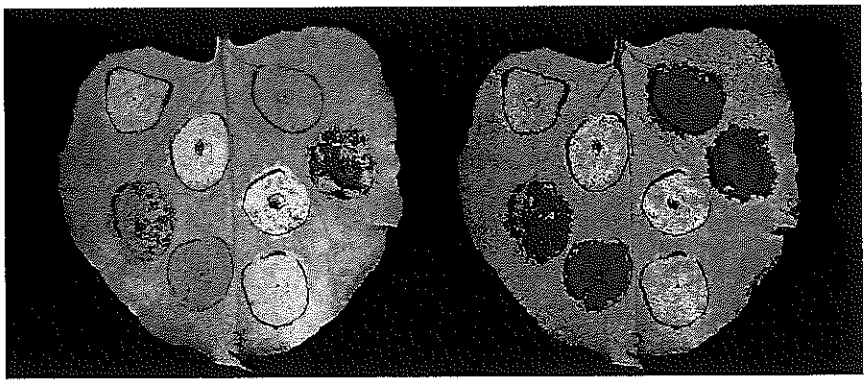
The three tobacco plants on the left, genetically modified to recover more quickly from light overloads, grew bigger than their unmodified counterpart on the right.

Enhancing a third protein, PsbS, also helped, although the researchers don't yet understand the full details of how. Tobacco plants with modified versions of all three proteins grew bigger, as measured by the weight of dried plant material, than others.

The extra growth those genes produced "is a major, economically important gain," says Maureen Hanson of Cornell University, who is working on a different approach to improving photosynthesis. Now, she says, the new paper's idea is ready for attempted transfer to plants that people harvest for grains or fruits. Hanson is hopeful that size will increase there, too.

Coaxing plants to calm down faster after a crisis is just one strategy to make photosynthesis more efficient. Evans and Hanson are among those involved in efforts to improve a notoriously slow and easily sidetracked photosynthetic enzyme called Rubisco. Other researchers are trying to transfer a naturally more efficient photosynthetic system found in some tropical and subtropical plants, called C4 photosynthesis, into rice, one of the world's main grains.

Older strategies for wringing more food from farms are not on track to keep up with soaring human population and food demands, Niyogi says. The United Nation's Food and Agriculture Organization estimates that feeding the world in 2050 could require boosting food production by 70 percent. But the success of all of this, Niyogi notes, may depend on how people around the world feel about genetically engineered food.



Colors show where tobacco leaves are wasting energy (blue, purple) by partially shutting down in response to bright light and where they are running closer to full capacity (pink, yellow). Shortening such shutdowns through genetic modifications might make plants more productive.

FROM TOP: HALEY AHLERS; LAURIEBETH LEONELLI, MATTHEW BROOKS/UC BERKELEY

MATTER & ENERGY

At low temps, bismuth superconducts

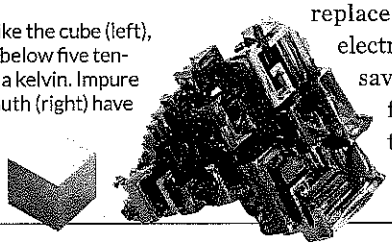
Despite few free electrons, element loses electrical resistance

BY EMILY CONOVER

An oddball superconductor is the first of its kind — and if scientists are lucky, its discovery may lead to others.

At a frigid five ten-thousandths of a degree above absolute zero, bismuth becomes a superconductor — a material that conducts electricity without resistance. Physicists at the Tata Institute of Fundamental Research in Mumbai, India, report the feat online December 1 in *Science*.

Bismuth, a semimetallic element, conducts electricity less efficiently than an ordinary metal. It is unlike most other known superconductors in that it has very few mobile electrons. Consequently, the prevailing theory of superconductivity doesn't apply.



Pure bismuth, like the cube (left), superconducts below five ten-thousandths of a kelvin. Impure bismuth (right) have bat- o

New ideas — either a different theory or a tweak to the standard one — are needed to explain bismuth's superconductivity, says theoretical physicist Marvin Cohen of the University of California, Berkeley. "It might lead us to a better theory of superconductivity with more details."

An improved theoretical understanding might then point to other new superconductors, potentially ones that work at more practical temperatures, says study coauthor Srinivasan Ramakrishnan.

Physicists' ultimate goal is to find a superconductor that operates at room temperature. Such a material could replace standard metals in wires and electronics, providing massive energy savings and technological leaps, from advanced supercomputers to magnetically levitated trains.

Ramakrishnan and collaborators chilled ultrapure crystals of bismuth while shielding the crystals from magnetic fields. Below 0.00053 kelvins (about −273° Celsius), the researchers observed a hallmark of superconductivity known as the Meissner effect, in which the superconductor expunges magnetic fields.

In the standard theory of superconductivity, electrons partner up in a fashion that removes resistance to their flow, thanks to the electrons' interactions with ions in the material. But the theory works only for materials with many free-floating electrons. A typical superconductor has about one mobile electron for each atom in the material, while in bismuth each electron is shared by 100,000 atoms.

Bismuth has previously been made to superconduct when subjected to high pressure, when formed into nanoparticles or when its atoms are disordered, rather than neatly arranged in a crystal. But under those conditions, bismuth behaves differently, so the prevailing superconductivity theory still applies. The new result is the first sign of superconducting bismuth in its normal form.

BODY & BRAIN

Report offers food allergy guidance

Little evidence supports some common prevention strategies

BY RACHEL EHRENBERG

Science's grasp of food allergies is as jumbled as a can of mixed nuts. While there are tantalizing clues on how food allergies emerge and might be prevented, misconceptions are plentiful and broad conclusions are lacking, finds a new report by the National Academies of Sciences, Engineering and Medicine.

As a result, both the general public and medical community are confused and ill-informed. Most prevention strategies and many diagnostic tests aren't supported by evidence and should be abandoned, the 562-page report concludes.

"We are much more in the dark than we thought," says Virginia Stallings, a coeditor of the report, released November 30.

While solid data are hard to come by, an estimated 12 million to 15 million Americans suffer from food allergies. Common culprits include peanuts, milk, eggs, shellfish, wheat and soy.

Food allergies should be distinguished from food intolerances, says Stallings, research director of the nutrition center at the Children's Hospital of Philadelphia. Food allergies arise from a specific immune response to even a small amount of the allergen; they can produce hives, swelling, vomiting, diarrhea and anaphylaxis, a potentially deadly reaction. These effects occur within two hours after every time a person ingests that food. The mechanisms behind reactions that fall outside this definition are probably very different, as are the outcomes, Stallings says.

Anyone suspecting a food allergy should see a specialist. Only the gold standard diagnostic test, the oral food challenge, can confirm an allergy. This test exposes a person to small amounts of the potentially offending food while under a physician's supervision. Doctors should abandon unproven tests, such as analyzing gastric juices or skin's electrical resistance, the report concludes.

Regarding prevention, the authors recommend that parents give infants foods that contain potential allergens. This advice is largely based on peanut allergy research suggesting early exposure is better than late (*SN: 3/21/15, p. 15*). Virtually all other prevention strategies, such as vitamin D supplements or women avoiding allergens while pregnant or breastfeeding, lack evidence.

Epidemiologist Anita Kozyrskyj of the University of Alberta in Canada calls the report "very impressive." Its real value, she says, is in the recommendations for parents, schools, caregivers and health care providers who deal with food allergies in the here and now.

of a mouse study published in July suggest that mismatches between the parents' nuclear DNA and the donor mitochondrial DNA could affect metabolism and aging (*SN: 8/6/16, p. 8*). Those effects could show up years or decades after birth.

The baby boy born in April is technically not the first three-parent baby. At least two children born in the late 1990s carry mitochondrial DNA from a donor. Those two and 15 other children were born to mothers who had a small amount of cytoplasm — the gelatinous fluid that fills cells and holds mitochondria — from a donor egg injected into their own eggs in an effort to improve results of in vitro fertilization. No major health problems have been reported, but the studies were abandoned because of ethical concerns, lack of funding and the difficulties in obtaining newly required permits.

La Barbera disputes the term "three-parent baby" entirely. "A person's essence as a human being comes from their nuclear genetic material, not their mitochondrial genetic material," La Barbera says. Children who are born after mitochondrial transfer procedures have only two parents, he contends.

Zhang drew fire for going to Mexico to perform the procedure. Congress currently bars the U.S. Food and Drug Administration from reviewing applications to make heritable changes in human embryos, which includes the spindle transfer technique. A panel of experts said in February that it is ethical to make three-parent baby boys (*SN Online: 2/3/16*), a provision that would prevent future generatio
donor mitochondria. Because mother
to their babies but fathers usually do n
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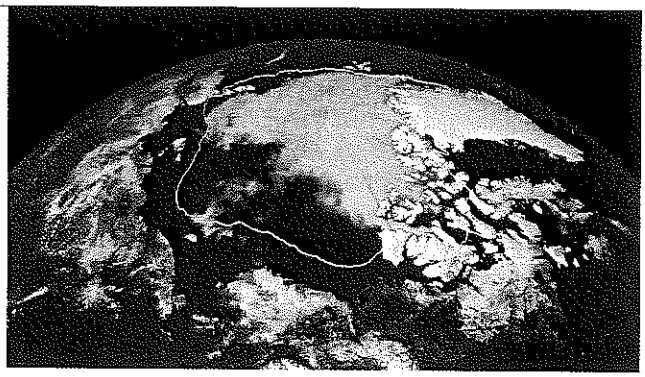
move ahead, so more babies may be b

Opening Arctic passageways will shake up ecosystems

By Susan Milius

In a better world, it would be the big news of the year just to report that Arctic sea ice shrank to 4.14 million square kilometers this summer, well below the 1981–2010 average of 6.22 million square kilometers (*SN Online: 9/19/16*). But in this world of changing climate, extreme summer ice loss has become almost expected. More novel in 2016 were glimpses of the complex biological consequences of melting at the poles and the opening of Arctic passageways, talked about for at least a decade and now well under way.



Polar melting Arctic sea ice hit its annual low on September 10, extending just 4.14 million square kilometers (shown). Though it didn't break a record, this minimum is more than 2 million square kilometers less than the average minimum from 1981 to 2010 (outlined in yellow).

With top-of-the-world trade and tourist shortcuts opening, less ice means more travel. Europe-to-Asia shipping routes will typically shorten by about 10 days by midcentury, a report in *Geophysical Research Letters* predicted. Hopes for Northwest Passage routes obsessed (and killed) explorers in previous centuries, but in 2016, the thousand-passenger cruise ship *Crystal Serenity* offered the first megascale tourist trip from Alaska to New York with fine dining, casino gambling and an escort icebreaker vessel.

Biologists are delving into consequences for organisms other than human tourists — or the much-discussed polar bear. "There's been a marked shift in the research community," says climate change ecologist Eric Post of the University of California, Davis. There's new interest in considering more than just species that dwell on sea ice, with researchers looking for the less direct effects of declining ice (see Page 15).

In the February *Global Change Biology*, eight scientists issued a call for observations of what could be early signs of faunal exchange: the mingling of Atlantic and Pacific species. One possible indicator is the sighting of gray whales off the coast of Namibia and also off Israel, even though that species went extinct in the Atlantic two centuries ago. These whales feed by snouting around in soft ocean bottoms, adding another predator to the system but also creating new habitat opportunities for some creatures (*SN: 1/23/16, p. 14*).

Since the call was published, biodiversity scientist Seabird McKeon of Colby College in Waterville, Maine, has heard new reports, such as a sighting of an ancient murrelet off the coast of Maine. It's not the first wrong-coast report for the bird, which typically resides in the northern Pacific, but repeat sightings could be important, too. "What I think we're seeing is not just new species coming across, but also perhaps an increased chance of survival and reproduction if more come over," McKeon says. He is hoping to get new data from the online Encyclopedia of Life's upcoming Fresh Data system, which connects scientists to people reporting nature observations.

For terrestrial northerners, melting ice often means loss of mobility. Peary caribou on the 36,000 or more islands of Canada's northern archipelago occasionally use ice bridges to travel to new territories and mix genes with other populations.

C. STARR/NASA GODDARD'S SCIENTIFIC VISUALIZATION STUDIO

Yet ice losses since 1979 have made it some 15 percent harder to find traveling paths, researchers reported in September in *Biology Letters* (*SN: 10/29/16, p. 8*).

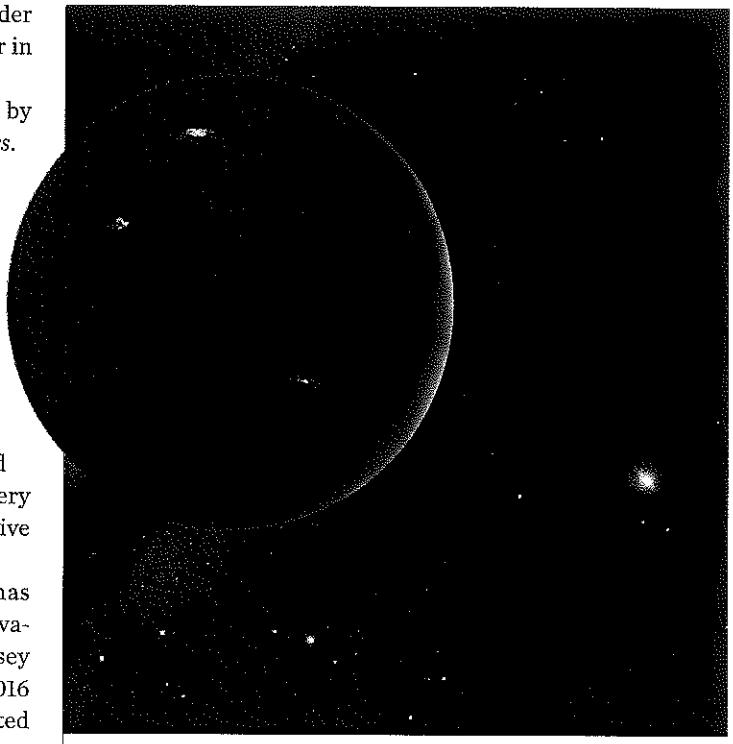
Even some plants such as dwarf birch probably travel by ice, scientists also reported in September in *Biology Letters*. Reconstructing long-ago sea ice extent and plant colonization dates suggests that seeds hitchhiked on slowly creeping frozen conveyors around northern Europe to colonize new territory at the end of the Ice Age. Losing ice roads could lead to tattered, disconnected populations as recolonization becomes less likely. Yet, there are pluses and minuses, says Post, who is helping to develop a package of scientific articles for *Biology Letters* on the biological effects of sea ice loss. Reseeding populations after a wipeout could be more difficult with tattered ice, but for the highly specialized and vulnerable plants very far north, the loss of sea ice could slow the arrival of invasive species that threaten the natives.

The minimum summer sea ice extent since 1979 has declined by about 87,000 square kilometers per year, equivalent to an area more than three times the size of New Jersey disappearing annually, as Post has put it. The September 2016 sea ice minimum didn't break a record, as some had expected it might. It tied for second worst, behind the 2012 minimum, and roughly equaled the 2007 minimum. 2016 did set a new record low for winter Arctic ice extent (*SN Online: 3/28/16*).

Sea ice changes reverberate through the ecosystem. Ice melting cues the springtime phytoplankton blooms that feed copepods and other tiny marine grazers. The grazers feed their predators and, in turn, the predators of those predators. In years when spring warming brings an early ice retreat, the phytoplankton bloom is not a huge, rich burst. It favors smaller grazing zooplankton that don't fuel as much of a boom in their predators, marine ecologist Martin Renner of Homer, Alaska, and colleagues reported in a paper for the *Biology Letters* special collection.

Tracing the effects of shrinking ice through these grazers to fish to seabirds revealed a tangled web of ups and downs and shifting foraging grounds. In the end, Renner and colleagues predict "a very different eastern Bering Sea ecosystem and fishery than we know today." And that may be far from the only sea change in the far north.

The melting of Arctic ice could affect seed dispersal among plants, such as the dwarf birch (shown here in Greenland).



Big if true

These findings would have rocked the scientific world, if only the evidence had been more convincing.

New Planet 9 clues

A giant planet lurking at the outskirts of the solar system could explain the odd orbits of far-flung hunks of icy debris (*SN: 2/20/16, p. 6*). If the planet (illustrated above) exists, its average distance from the sun would be between 500 and 600 times Earth's distance (*SN: 7/23/16, p. 7*).

Signs of ancient life

Mounds of minerals discovered in Greenland appear to have been deposited by clusters of microbes 3.7 billion years ago. If so, these stromatolites represent the oldest fossilized evidence of life on Earth (*SN: 10/1/16, p. 7*).

Lucy's big fall

A controversial study claims that Lucy, the most famous fossil in the study of human evolution, died after falling from high up in a tree (*SN: 9/17/16, p. 16*). The autopsy supports the hypothesis that *Australopithecus afarensis* split its time between the ground and the trees.

Nucleus with no charge

Researchers have spotted signs of a "tetraneutron," an atomic nucleus with four neutrons but no protons (*SN: 3/5/16, p. 10*). If confirmed, this first-of-its-kind nucleus might be explained by a new, interneutron force. — *Cassie Martin*