

zontally, all through evolution. For example, if you look at the rice genome, how many fungal genes are there, how many viral genes are there, how many bacterial genes are there? There is nothing like a pure rice genome. So to think a couple of genes would alter the biodiversity, I really do not buy that argument because in nature every plant has been modified. The only concern in my perception is whether the gene we are introducing is safe enough.

Of course, safety is a prime concern. I have no argument on that and safety is needed. Take Bt as an example. Millions of people have been consuming Bt corn for over 15 years—Americans, Canadians, Chinese, South Africans, Argentinians, Brazilians—and I have not seen any authenticated report of any environmental risk or health risk so far as this is concerned. Bt brinjal was 8 years in trials. It was not as if overnight somebody decided that Bt brinjal should come in. Many scientists were involved in this process.

B.A.: Swaminathan was saying here that the current concerns will disappear soon, and you certainly agree with that.

G.P.: Yeah, I definitely agree with that. Current concerns, I hope, will disappear but there is I feel a deliberate attempt in India to keep raising these concerns.

B.A.: Dr. Bhargava?

P.B.: Well, as far as Swaminathan's statement is concerned, I think it is a very neutral statement that when these concerns will cease to exist, that may take 50 years, that may take 100 years, that may take 5 years.

As regards the other issues that my friend Padmanaban has raised: There is a great deal of evidence that there have been health problems amongst Americans, especially related to allergy, since the large-scale consumption of Bt corn or GM corn and GM soya started in the U.S. In fact, if you plot qualitatively the increase in incidence of gastrointestinal disorders amongst Americans over the last 12 to 13 years and the increase in the consumption of GM food, the two curves seem to overlap very substantially. And there is evidence in Latin America and Brazil where there has been increased consumption of GM crops, that there is an increase in incidence of childhood cancer and several other problems. So to say that there is no evidence of any deleterious effect on human health, on animal health, on plant health, and on biodiversity ... I think is ignoring a tremendous amount of evidence that these effects are very real.



CLIMATE CHANGE

Hansen's Retirement From NASA Spurs Look at His Legacy

For decades, American climate scientist James Hansen published important papers on global warming and shared his data at influential congressional hearings—along with his policy prescriptions. He tussled with White House officials over his right to speak his mind, lobbied leaders the world over, and testified in defense of jailed activists. The 72-year-old has also been arrested five times in protests against the continued burning of fossil fuels or to demand that the United States put a price on carbon emissions.

Few other figures in modern science have straddled—and for that matter blurred—the boundaries between science, policy, and advocacy quite like the homespun but outspoken climatologist. Now, with his 2 April retirement announcement from NASA's Goddard Institute for Space Studies (GISS) in New York City, where he served as director, Hansen is entering a new and perhaps final phase of a storied career. He wants to continue publishing as an independent scientist (although funding is proving tough) and ramp up his activism. The move has helped highlight a long-simmering debate: Is Hansen a role model to be emulated by younger researchers—or a polarizing figure whose tactics have proved counterproductive?

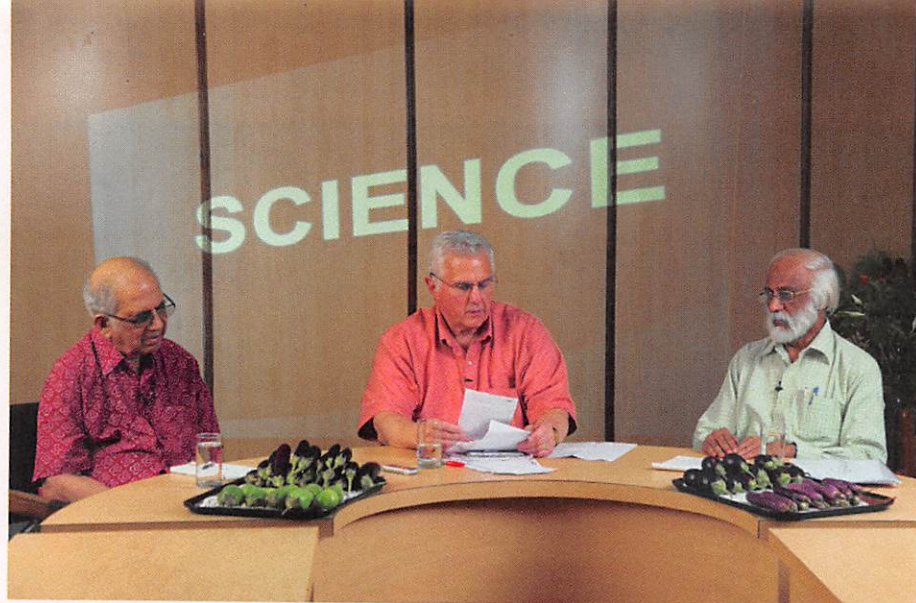
"He has done very important science really well," says Michael MacCracken of the

Climate Institute in Washington, D.C. "[And] for those whose scientific findings relate to environmental and societal welfare, Jim has been demonstrating the additional obligations that come with doing scientific research in the public service."

Hansen is "among the best climate scientists," agrees Ken Caldeira of the Carnegie Institution for Science in Palo Alto, California. But "it's important to keep value and opinions separate from scientific judgments about empirical fact and, especially in the last 5 years, [Hansen has] not made clear enough distinctions."

In an e-mail to some 7000 recipients of his regular missives, Hansen explained last month that "my aim in 'retiring' is to have more time to focus on science, to try to make the science clearer to the public, and to connect the dots all the way to policy implications." And in a 4 April editorial in the *Los Angeles Times* opposing the construction of the Keystone XL oil pipeline from Canada to the United States, Hansen did just that. "The perspective of pipeline apologists is contrary to the laws of physics and basic economics, neither of which gives a damn about politics," he wrote.

It's the kind of rhetoric that has made Hansen a media favorite. As a scientist, however, he began his career far from the hot lights



SCIENCE DEBATE

Scientists Clash Swords Over Future Of GM Food Crops in India

HYDERABAD, INDIA—One of the most contentious issues roiling India these days is whether the country should permit commercial planting of genetically modified (GM) food crops. A defining moment in the debate came in February 2010, when Jairam Ramesh, then-minister of environment and forests, called for a moratorium on the cultivation of brinjal, or eggplant, engineered with a gene from the bacterium *Bacillus thuringiensis* (Bt) that codes for an insect-killing toxin (*Science*, 12 February 2010, p. 767). The previous year, India's top biotechnology regulatory body had concluded that Bt brinjal is safe for environmental release. Public hearings held across India to discuss that recommendation tapped deep unease over GM foods. In response, Ramesh announced the ban on Bt brinjal, which he said would remain in effect until studies establish "the safety of the product from the point of view of its long-term impact on human health and [the] environment."

Three years later, the moratorium's repercussions are still being felt. Although the ban did not target research, Indian biotechnologists say that they have had a difficult time getting funding for GM experiments and permission for field trials (*Science*, 17 August 2012, p. 789). Critics and backers of the technology agree on one point: India's rules for regulating GM crops

must be strengthened. A bill introduced in Parliament last month aims to do just that by setting up an independent Biotechnology Regulatory Authority of India to assess the safety of genetic modification. All eyes are now on the Indian Supreme Court, which is mulling a petition filed by activist groups demanding a prohibition on GM food crops in India; on 17 October 2012, a panel appointed by the court to advise it on the case recommended a 10-year moratorium on the introduction of GM crops. A decision is expected in the coming weeks.

Science sought to shed light on the issues by bringing together two prominent voices in the scientific community to debate the future of GM food crops in India. Speaking for the technology's backers was G. Padmanaban, a biochemist and former director of the Indian Institute of Science in Bangalore. Speaking

Watch the debate at www.scim.ag/vidGMO



Pro and con. G. Padmanaban (left) and Pushpa M. Bhargava found little common ground on whether to commercialize GM food crops.

No holds barred. *Science* Editor-in-Chief Bruce Alberts moderated the debate.

for opponents of GM food crops was Pushpa M. Bhargava, a biochemist and former director of the Centre for Cellular and Molecular Biology (CCMB) in Hyderabad. The debate was moderated by Bruce Alberts, *Science's* editor-in-chief, and held here at CCMB on 4 April. What follows is an edited excerpt.

—PALLAVA BAGLA AND RICHARD STONE

B.A.: What is your impression of the indefinite moratorium imposed on the release of Bt brinjal for commercial cultivation?

P.B.: I believe that the indefinite moratorium that was put on open release of Bt brinjal was perfectly justified, because people did not want it. Jairam Ramesh had about seven or eight public meetings spread all over the country, and the overwhelming opinion was that it will not be in the interests of people in India to have the cheapest vegetable which is available all round the year, that is brinjal, to be genetically engineered, and that genetically engineered brinjal be available without labeling, for consumption by people. And they felt they had the right to decide what they were going to eat and what they will not eat.

G.P.: I believe this moratorium was very unfortunate. Actually, Bt brinjal was thought in terms of demonstrating a proof of principle so far as a food crop is concerned. I personally believe India would need Bt rice at some point of time. So this moratorium has sent a very wrong signal, in my opinion. That decision was more populist than based on science as such. And it has depressed most of the scientists in the area. This is something which the country should worry about. People in this field have lost enthusiasm. Even students are not willing to get into this, which I think is very, very unfortunate.

B.A.: In an article in the December 2012 issue of *Frontiers in Genetics*, M. S. Swaminathan, distinguished leader of the green revolution in India, begins with the following statement: "I believe that the current concerns of biosafety and the impact of GMOs [genetically modified organisms] on biodiversity will soon give way to an appreciation of the potential benefits that the new genetics can confer on humankind." Do you agree or disagree with that statement?

G.P.: I personally believe this biodiversity card is overplayed. After all, you will see genes have been transferred vertically, hori-

Testify. James Hansen's iconic congressional testimony in 1988 brought the global warming issue to the national stage.

of the TV studio. He joined NASA in 1967 as an astrophysicist studying Venus, later turning his focus to the greenhouse effect on Earth. National acclaim came after he appeared at blockbuster hearings held by the U.S. Congress in 1988, where he declared that the world was warming, that humans were most likely responsible, and that his climate models suggested that heat waves would increase as a result. "It is time to stop waffling," he argued, and his testimony appeared on the front page of newspapers around the world.

Many scientists, however, were put off. "What really bothers them is not that they believe Hansen is demonstrably wrong, but that he fails to hedge his conclusions with the appropriate qualifiers that reflect the imprecise science of climate modeling," *Science's* Richard A. Kerr reported a year later (*Science*, 2 June 1989, p. 1041).

Over time, however, Hansen's biggest pronouncements have proven essentially correct as the data have come in. "When I saw him give one of his plenary talks at the [American Geophysical Union], I would guess his estimate of [the planet's sensitivity to carbon] is overconfident, he did a very clever job making the case for sensitivity near 3° while staying in line with the facts as I understand them," recalls climate expert David Keith of Harvard University. Still, some of Hansen's views place him at a far end of the spectrum of the scientific consensus on climate change; he's had to qualify, for instance, some of his previous statements about the risk that Earth could spiral into a steamy, Venus-like environment. And a paper published last year in the *Proceedings of the National Academy of Sciences*, arguing that recent heat waves in Russia and the U.S. West were "a consequence of global warming," drew fire from scientists who published a competing analysis that found no direct connection.

Hansen's "exceptional trust in physical intuition," as Kerr called it, along with his determination to be heard, complicated his role as a government scientist. As GISS director in 1989, he scuffled with the administration of President George H. W. Bush over caveats about climate models that bureaucrats in the White House's Office of Management and Budget (OMB) wanted to add to his congressional testimony. Hansen argued the additions would suggest his warnings were overblown. "I should be allowed to say what is my scientific position," he added at the time.

"There is no rationale by which OMB should be censuring scientific opinion." Hansen used much the same language when, 16 years later, he fought with the administration of President George W. Bush, which attempted to bar him from giving certain interviews; Hansen won after he leaked the skirmish to the press. Such public feuds, and his outspoken views, may have led the Department of Energy to pull funding from GISS in the 1980s, Hansen told *Science* last summer. And the "sideshow" that his high profile sometimes created was growing difficult lately for NASA leaders to countenance, he added. Still, many of his GISS co-workers have said they believe that Hansen's work only helped burnish the small institute's reputation.



In protest. Hansen's willingness to be arrested as part of demonstrations against the burning of fossil fuels sets him apart.

Hansen's impact on policy also draws divided reviews. At first, his voice had big resonance, says Rafe Pomerance, who worked on climate policy as an environmental activist, Congressional staffer, and executive branch official. "After his '86 testimony, the [U.N. Intergovernmental Panel on Climate Change (IPCC)] was set up. After his testimony in '88 and '91, the U.N. Framework Convention on Climate Change got started," Pomerance notes. But Hansen's later forays into policy during the George W. Bush and Obama administrations may have had less relevance—in part because by then Hansen had become just one of many voices on the

issue, "diluting" the potency of his views, says Roger Pielke Jr., a policy expert at the University of Colorado, Boulder.

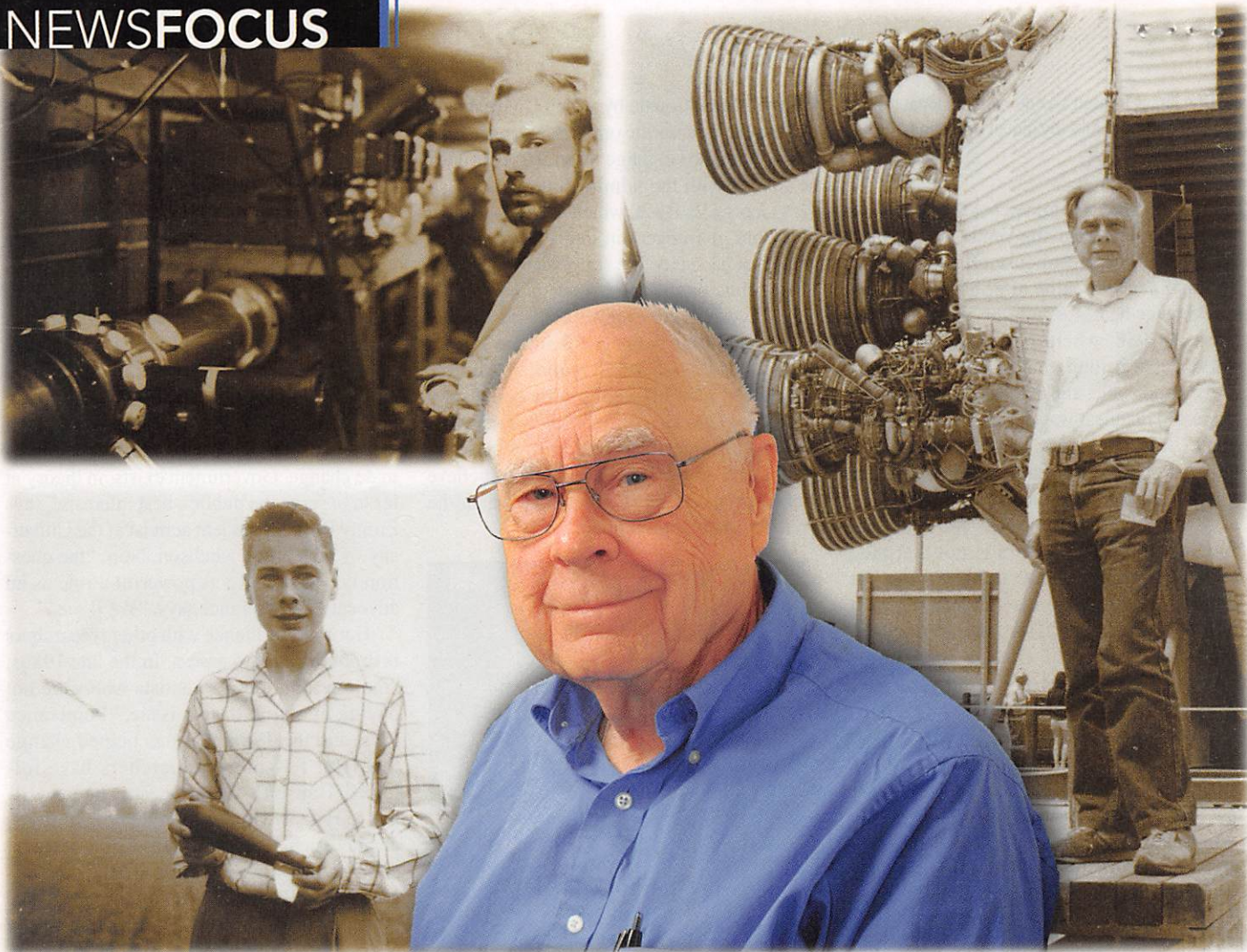
Still, Hansen's prominence allowed him, as a private citizen, to arrange lobbying visits with world leaders that few rank-and-file government scientists could dream of. Such independent advocacy "would be unheard of if he was, say, a diplomat or CIA agent freelancing on some issue outside of government policy," Pielke says. Others, though, believe that it was an appropriate role. "It's disheartening that he has to [now] remove himself from a federal position to advocate on climate change. Government exists, in theory at least, to serve the public's best interests," says Emmy Burns, a student activist at the University of Wisconsin, Madison. Now, "the question is will he have as powerful a role as an advocate?" Pomerance says. "We'll see."

Hansen's influence with other researchers is more difficult to assess. In the late 1980s, "there were a lot of scientists who were not paying attention to this issue," Pomerance says, and the 1988 hearings helped change that. But few other researchers have followed Hansen's example and been willing to risk arrest at public demonstrations, or play such a vocal role in public debates. Hansen has also never formally contributed to the IPCC process, researchers note, underscoring his loner status among his peers. But Juliette Rooney-Varga, a marine biologist at the University of Massachusetts, Lowell, says "as a scientist and a mother of three young children, I am grateful for the example that he has provided. ... Hansen took substantial professional risk in choosing to act on his moral conscience, while still maintaining an impressive scientific career."

Hansen says that he'll keep doing research despite his departure from NASA. He's trying to create a small new institute with key GISS scientists, but fundraising for that effort has proven "difficult and time consuming," he tells *Science*. In the meantime, he's keeping up his outreach efforts, including a book that he's writing called *Sophie's Planet*, consisting of letters between him and his granddaughter.

Many observers are convinced that Hansen will remain a force to be reckoned with. "He's sui generis—that's for sure," says marine biologist James McCarthy of Harvard. "He's been ahead on the science for decades and has played a very important role in communicating the science of climate change to the public. ... I've disagreed with him on some of his views on policy, ... but let's be clear: The world needs Jim Hansen."

—ELI KINTISCH



Mr. Borucki's Lonely Road to the Light

The father of NASA's Kepler orbiting exoplanet finder had to pioneer new optical techniques and overcome decades of skepticism to get his pet project off the ground

At 74, many men are happy to while away their time gardening or playing poker or watching reruns of old sitcoms. William Borucki, the architect and principal investigator of NASA's exoplanet search mission, Kepler, is cut from a different cloth. On weekends, he likes to take off with his wife, Josephine, and his boyhood buddy, Gene Westerberg, to trek through Alum Rock Park, a few miles east of San Jose, in search of kempite, a rare manganese mineral found nowhere else on Earth. So far, Borucki hasn't found any, and perhaps he never will. It doesn't matter. Borucki's journey is his destination.

If he didn't enjoy the journey so much, Borucki would have given up long before he realized his goal of launching a spacecraft to find planets outside the solar system. Kepler, which has opened the floodgates for exoplanet discoveries since its launch in 2009, would never have come about. Those who have followed Kepler from idea to reality say that the mission is a testament to Borucki's ingenuity and vision and iron will, a spirit so inured to rejection and failure that it might as well be wrapped in rhino hide.

In the late 1980s, Borucki proposed the idea of finding exoplanets by measuring the

dip in a star's brightness when an orbiting planet travels across the face of the star. For several years, he was alone in pushing the idea against a tide of scorn and hostility from many in the field who did not believe that the technique could work.

"There was no one from NASA headquarters who would support him," says David Morrison, an astronomer at NASA Ames Research Center near Mountain View, California, who was Borucki's supervisor during the early years of the struggle. "It took a lot of courage on his part because of all the negative reactions." In the end, Morrison says, Borucki proved to be "the fighter who is knocked down and gets up, is knocked down and gets up again." For this perseverance alone, some might say, Borucki should be awarded a Ph.D. That way, he'll no longer have to correct those who refer to him as Dr. Borucki.

An urge to explore

Borucki is 5'6" with kindly eyes and bushy eyebrows. One afternoon last November, he sat down for lunch with Westerberg and Josephine in the outdoor area of a restaurant, under the warm California sun. As he dug