Keiko U. Torii

Keiko Torii likes to describe plants as "beautiful strangers" because their cells are so much like animal cells in principle and yet so very different from ours in detail. These differences have tended to make plant and animal cell biologists into strangers, but Torii is not someone who sees barriers and divisions in science. She sees prospects and bridges. The first time she attended the ASCB Annual Meeting as co-chair of a 2010 Symposium on patterns and symmetry in development, Torii was one of a handful of "plant people" in attendance. Yet the meeting was an eye opener. "The ASCB is huge. Just the section for the actin cytoskeleton is gigantic," she reports. "There were so many people there with special cell imaging techniques and then so many booths for software and microscopy." Torii even came away from the Exhibit Hall with a possible new collaborator, a company that sells pattern recognition software. Such a tool could be of use in her work with stomatal patterning on the leaves of the renowned plant model organism *Arabidopsis thaliana.*

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Perhaps Torii should have picked up more of the big-ticket microscope sales literature for her lab at the University of Washington (UW) in Seattle. Two months after the ASCB meeting, Torii got the thin envelope saying that she was a finalist in a new Howard Hughes Medical Institute (HHMI) initiative with the George and Betty Moore Foundation (GBMF) to reinvigorate basic research in plant biology. Last June, Torii made the cut, becoming one of 15 new five-year HHMI-GBMF investigators in fundamental plant science. On her desk right now is the final paperwork for an HHMI-purchased tuneable white laser confocal microscope, an instrument with powers that Torii describes as "scary/amazing."

Torii will put the new instrument to good use, says Lynn Pillitteri, a former postdoc now on the faculty at Western Washington University in Bellingham. When the HHMI-GBMF appointment was announced, Pillitteri recalls, "I wasn't at all surprised. I thought to myself that she'd be a great person to get it because Keiko will do things that are a little more risky, a little bit more out of the box. Plus she's so diligent about knowing the literature and knowing what's going on in so many different disciplines."

Ben Scheres of the University of Utrecht in the Netherlands wrote in support of Torii's HHMI nomination and so was doubly pleased with the result. He met Torii through the *Arabidopsis* world and, from her first talk, Scheres marked her as someone likely to shake things up. This was soon after she'd left Japan for a postdoc at Yale with Xing-Wang Deng in 1994. But her talk was about work from her first postdoc at the University of Tokyo with Yoshifumi Komeda. Scheres recalls a very young Japanese postdoc who gave a polished presentation and stunned the *Arabidopsis* field by describing the first cloned transmembrane receptor kinase controlling plant development through a gene called *ERECTA*.

The *erecta* Variant

The name was well known from a natural ecotype of *Arabidopsis thaliana* called the Landsberg *erecta* variant. The *erecta* variant is short with compact flowers and leaves, which makes it a favorite in crowded laboratory growth rooms. But *Arabidopsis* as a genus is famous for genetic redundancy, and tracking down the gene—if there was a single gene—behind *erecta* was a daunting prospect before 1994. "That was a remarkable piece of work for that time," Scheres recalls, "so it was immediately clear to me that we would hear more from her."

The field heard more about *ERECTA* after 2000 when Torii finally set up her own

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Arabidopsis laboratory at UW to identify other members of the *ERECTA* family. She came up with two more "*ERECTA*-like genes," which she dubbed *ERL1* and *ERL2*. And then for a time she was stalled. Obviously the *ERECTA* family affected the morphology of *Arabidopsis*, yet a single or even double knockout yielded no startling new phenotype. Meantime other developmental genes had been identified. Did they act upstream or downstream from *ERECTA*?

"It's a large gene family which has a lot of redundancy," Scheres explains, "but just by systematically continuing on the path and looking for other redundant factors which work together with *ERECTA*, she stumbled on her current love, which is stomatal development." The "stumble" came from a triple knockout of *ERECTA*, *ERL1*, and *ERL2*. It yielded a totally unexpected phenotype, a disordered riot of stomata, the tiny leaf pores through which plants exchange gases and water vapor, growing right across the epidermal surface. Stomata are small—20 or so microns in *Arabidopsis*—but mighty. Opening and closing in response to humidity and light, the stomata of the world's plants recycle the entire water content of the Earth's atmosphere every six months. But stomata are usually extremely orderly. They derive from stem cells through a complicated chain of asymmetric divisions into a precisely spaced carpet of openings, each controlled by a pair of guard cells. All begin from a single symmetric division of a guard mother cell. Torii had stumbled on a highly visible phenotype that modeled stem cell differentiation and tissue development. She did it by identifying a combination of transcription factors that sequentially activate initiation, proliferation, and differentiation of stomatal cell lineages

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Other stomatal development labs played a part, says Scheres, especially Dominque Bergmann's lab at Stanford, but in hindsight it was Torii's *ERECTA* work that revealed the details of this intricate asymmetrical development path from stem cells to daughter cells. "It's now transparent," Scheres declares. "However, if 15 years ago you'd look at how these stomata came across the leaf blade and what kind of strange division patterns were at the basis of them, it was not all clear. It was not clear first of all that it was a stem cell lineage and second of all that it was a genetically controlled series of steps. It was Keiko's work that has made much of that clear today."

Torii's stomatal model has attracted interest outside the *Arabidopsis* world. "We recently invited her here [Utrecht] for a university-wide developmental biology seminar," Scheres recalls. "She had to stand up before this audience of mainly medical biologists and explain her system, but she beautifully made the point that you can learn basic facts from looking at plants." Students crowded round afterward for discussion, Scheres reports. "My fear was that they would all go to the animal stem cell guys and we would have none left for Keiko, but the room was packed and they asked many, many questions." Torii has a talent for making her work exciting and relevant, says Scheres. "She's able to make bridges."

Science in the Blood

Her first bridge was across the Pacific. Born in Tokyo, Torii first came to the United States as a high school student when her father's business took the family to the northern suburbs of New York City for a year. It was then that she first met the scientific legend of her family, her great uncle Ichiji Tasaki, a pioneering biophysicist at the National Institutes of Health who discovered the insulating function of myelin in neurons. Years later, after she'd become a full professor, Torii visited her great uncle again in Washington, DC, shortly before his death at 98 in 2009. "He was very happy to hear that I was also in science," she recalls. "Everyone in my family says I have his blood."

Yet as an undergraduate at the University of Tsukuba in Japan, Torii was torn between her flair for biology and an equal passion for music. Playing violin in the Tsukuba University orchestra cut so deeply into her science studies that she felt she had to renounce music entirely once she was accepted into the Tsukuba graduate biophysics and biochemistry program. Music came back into her life only recently, when her two daughters, Mari, 8, and Erika, 5, began Suzuki violin lessons. Parents are urged to play along and, at first, it was agony for Torii to hear how rusty she'd become. She acknowledges a tendency toward perfectionism, but the girls enjoy playing so much that Torii says she is working on self-tolerance. "Maybe I could become a good amateur musician," she sighs.

Torii initially thought about graduate studies with the conventionally heroic dream of a career in cancer cell biology but grew intrigued by the excitement in plant biology in the late 1980s to early 1990s. Genetic engineering techniques from animal cell biology were making their way into plant science, and *Arabidopsis*, a.k.a. the mouse-ear cress, was becoming a worldwide model organism. "I thought maybe this would be a great opportunity because there were so many classic plant physiology questions that had never been answered. There would be room for students. And to be honest, almost any mutant that you screened for in those days would be new."

Arabidopsis genetics led her to a postdoc at the University of Tokyo and the *ERECTA* gene. Yet when her fellowship ran out she had no prospects in Japan, so at a world botanical congress in Yokohama she cornered Yale's Xing-Wang Deng. Eventually he promised her six months of support if she came to New Haven. Torii stayed at Yale for three and a half years working on *Arabidopsis* photomorphogenesis. It was great science, she says, but she was determined to pursue *ERECTA*. After a third postdoc at Michigan to learn cell–cell signaling and stem cell maintenance with Steve Clark, she landed an assistant professorship at UW in 1999. Ten years, two babies, and several high-impact papers later, Torii was granted full tenure.

Among other things, Torii is known today as a scientific role model—a top researcher and a deeply engaged mother of young children. With her husband, the German-born theoretical physicist Andreas Karch, Torii pursues both research and family. The day her second daughter was born in 2006, a major paper by Torii was published in *Nature*, the two achievements residing comfortably side-by-side. Torii's outspokenness about the rights of female scientists to pursue careers and family has earned her an unexpected audience—in Japan.

It's both ironic and good news, says Ben Scheres. "I'd like to point out that Keiko left for the United States because she saw there was no future for female Japanese scientists in Japan. It was an all-male world then. She came to the States and obviously she's done beautifully there. Now the Japanese have become very much aware of her because in recent years she has gotten several prestigious Japanese prizes. I think this has made her a role model for Japanese female scientists."

Torii believes that attitudes are changing rapidly in Japanese science. Increasingly, she is asked to lecture there not just on morphological development but also on promoting female scientists as a precious resource in an aging Japan. Torii points to Japanese universities that are opening day-care centers. One medical school has a place for "slightly sick children," a wonderful resource for working parents when a child is on the mend but not strong enough for school. The University of Washington, Torii notes dryly, does not have such a facility.

Return of the Natives

Besides her overarching interest in family, Torii confesses to a new hobby—invasive plant removal. She's never had any special interest in field botany or domestic gardening—although people seem to expect that from a plant biologist—but along with a new family home in the Cedar Park section of Seattle came a yard choked with invasive species such as English ivy and Himalayan blackberry. "It's become my hobby to remove them," she says. "The Pacific Northwest is so amazingly rich in soil and rain that if you remove invaders, all sorts of beautiful native plants start coming up, like salal and sword fern. You really don't have to plant much," says Torii.

You just have to look closely and see the possibilities growing under your nose. ■

—John Fleischman

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