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The Godmother of the Digital Image

The mathematician Ingrid Daubechies' pioneering work in signal processing helped make our electronic world possible — and beat a path for women in the field.

Ingrid Daubechies. Jeremy M. Lange for The New York Times

By Siobhan Roberts

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In the summer of 2010, while preparing for a long research trip to Madagascar, the mathematician Ingrid Daubechies bought a 50-inch flat-screen TV for her husband, so he could invite friends over to watch Premier League soccer games. After setting it up, the couple turned on a match, and while Daubechies' husband, the mathematician and electrical engineer Robert Calderbank, became transfixed by the action, she got distracted. "Oh, wow!" she said. "They use wavelets!"

Wavelets are versatile mathematical tools that can be thought of as a zoom lens, making it possible to spotlight the information that matters most in an image. The telltale signs of wavelets that Daubechies spotted were on the field, pixelating at larger scales, producing a fuzzy patchwork of green. "Look here," she exclaimed. "You can see artifacts in the grass."

"Yes, yes," Calderbank replied. "Who cares about the grass?" He just wanted to watch the game.

A professor at Duke University, in Durham, N.C., Daubechies' métier is figuring out optimal ways to represent and analyze images and information. The great mathematical discovery of her early career, made in 1987 when she was 33, was the "Daubechies wavelet." Her work, together with further wavelet developments, was instrumental to the invention of image-compression algorithms, like the JPEG2000, that pervade the digital age. "Mathematical caricature" is how Daubechies sometimes describes the way digital images strive to capture our reality with exaggerated simplifications, reducing what we see in the world to its essential features through pixel proxies and other mathematical manipulations. Wavelets can enable computers to provide greater resolution — functioning, in a sense, as human eyes naturally do, seeing more detail at the focal point and leaving the rest of the view comparatively blurry. (Daubechies, it might be worth noting, has a lazy right eye, and her left eye isn't great, either.)

One mathematician refers to the protean talents of her former adviser by describing Daubechies as 'the Meryl Streep of mathematics.'

Calderbank's amused indifference to the grassy pixelations nicely illustrates the power of wavelets: They find the action in an image, the important content. Little is lost if the grass is blurry. But when a goal is called back because of a questionable offsides decision, viewers and officials want to see fine-grained close-ups of the contentious moment.

Daubechies is most famous as a pioneer of wavelets, but more broadly, her scientific contributions over the last three decades have rippled out in all directions from the field of "signal processing." In mathematical terms, as in common parlance, a signal is something that conveys information. Jordan Ellenberg, a mathematician at the University of Wisconsin-Madison who first met Daubechies in 1998 when they were colleagues at Princeton, points out that signal processing "makes up a huge proportion of applied math now, since so much of applied math is about the geometry of information as opposed to the geometry of motion and force" — that is, it's more about the warp and weft of information than physical problems in, say, fluid dynamics or celestial mechanics.

Daubechies has sought out all sorts of ways to engage in the digital transformation of society. She has done key research studying analog-to-digital conversion technology, and through a tapestry of collaborations, she has brought her mathematical insights to areas of study including internet traffic, evolutionary morphology (analyzing data collected from lemur teeth and bones, starting with that Madagascar trip) and electrocardiogram abnormalities. Daubechies' wide-ranging and collegial mind-set has amounted to something of a social movement, the Stanford statistician David Donoho says, with projects large and small that "send a beacon out." He cites one of her more recent ventures: fine-art conservation involving the Ghent Altarpiece — "The Adoration of the Mystic Lamb," a 15th-century polyptych attributed to Hubert and Jan van Eyck, arguably among the most important paintings in history. Time after time, Donoho says, Daubechies sparks research groups that signal: "This is a happening thing."

Many accolades have followed, including Guggenheim and MacArthur fellowships. In 2012, when she became a baroness (a title granted by Belgium's King Albert II), she composed a motto for her coat of arms evoking wavelets: "Divide ut comprimas," or "Divide so you can compress" — borrowing from the Latin "Divide ut regnes," or "Divide so you can conquer." In 2019, she received an honorary degree from Harvard, alongside the German chancellor Angela Merkel (who happens to have a doctorate in quantum chemistry).

And yet at times during her career, Daubechies worried about being a complete fake. And she still considers herself an oddball as a mathematician. "I came out of left field," she says — she trained as a physicist before migrating into mathematics. "And I think there are people who feel left field is where I belong." She doesn't mind. She revels in finding meaningful and practical problems — and solutions — where other mathematicians assume there are none. Indeed, she puzzles over any problem she can find, and she is always game to take on the problems of others as well.

"I called her the deus ex machina adviser," says Cynthia Rudin, a Duke computer scientist who is one of her former Ph.D. students. "When you're in the depths of despair, your project has crashed and burned and you have almost proven that what you're trying to do is impossible, Ingrid comes along and pulls you out of the pit of doom, and you can keep going."

In the summer of 2018, when she turned 64, Daubechies threw herself a party in Brussels, about an hour away from her hometown in eastern Belgium. (Daubechies acquired American citizenship in 1996.) She chose to celebrate that birthday — rather than her 60th or 65th — because 64 is a more compelling number. It is a power of two (2, 4, 8, 16, 32, 64, and so on), and powers of two hold special sway in science, especially in digital signal processing, in which binary patterns of zeros and ones encode information. In binary notation, the powers of two are particularly pleasing, because they all begin with a one followed by increasing quantities of zeros: 2 = 10, 4 = 100, 8 = 1000, 16 = 10000, 32 = 100000. Daubechies, in the summer of 2018, was turning 1000000.

Daubechies booked a venue, a caterer, a troupe of majorette dancers known for farce — and then at the party made a surprise appearance in the baton-twirling cancan line, disguised in makeup and a tutu. Afterward, she did what a mathematician more typically does to commemorate a special birthday: She attended a conference in her honor. Three days of talks among students and collaborators past and present offered delicacies to tickle her eclectic fancy: exploring how high-dimensional geometry is revolutionizing the M.R.I. industry; "going off the deep end with deep learning," a type of artificial intelligence based on artificial neural networks; and investigating dark matter and dark energy and gravitational waves. A common denominator was wavelets, which facilitate the expansion or compression of information (often by powers of two).

In her recent fine-arts research, Daubechies has used wavelets as an intermediate tool, extracting and simplifying an image's essential features in preparation for more in-depth analysis. A week before her birthday conference, she attended the sixth international workshop on image processing for art investigation at the Museum of Fine Arts in Ghent, which featured the continuing restoration on the famed altarpiece. Her work in this area began at the first "IP4AI" workshop, in Amsterdam in 2007, with a computational analysis of Vincent van Gogh's brushstrokes to characterize the "core" of the artist's style and help identify forgeries.

One of Daubechies' desks at Duke University. Jeremy M. Lange for The New York Times

The Ghent Altarpiece's 12 panels — together standing about 12 feet wide by 17 feet tall — have presented several problems for conservators that Daubechies and her fellow mathematicians are helping to solve. One investigation involves a pair of double-sided panels depicting large portraits of Adam and Eve on one side, with smaller scenes painted on the other. When using X-rayed images to assess damage, conservators have difficulty "reading" the intermingled images. After processing the visual information using wavelets, Daubechies and her team deployed a deep neural network algorithm — typically used for facial recognition — to separate the content of the X-rays. Another investigation explored whether a book depicted in a central panel is merely symbolic, with deliberately illegible squiggles for letters, or a reproduction of an actual text obscured by the craquelure, the web of cracks in the paint. "I come up with a problem, she comes up with a solution," Maximiliaan Martens, an art historian at Ghent University, said at the workshop. "Usually, I get lost in the mathematics."

The talks quickly became technical — one mentioned "disrobing Adam and Eve with the linear-osmosis model" — and there was heated debate about the advisability of using artificial intelligence to conserve iconic artworks. On the last day, Daubechies visited the altarpiece at St. Bavo's Cathedral. "Whenever I come to Ghent, I always try to see it," Daubechies told me. She was baptized Catholic, and while she's not religious, she embraces what she calls a "feeling of spirituality." But she can't reason that out — "and I don't need to," she said. Peering up at the masterpiece through the hushed darkness, she commented that whereas beautiful art gives an emotional delight and resonates spiritually, beautiful mathematics gives "a logical shortcut, an intellectual delight."

Wavelets offer delight, for instance, because they allow “sparsity” — they succinctly capture and represent fine-grained detail only when it’s relevant or desired. “This feature is enormously helpful in a variety of A.I. and data-science settings,” says Rebecca Willett, a professor of computer science and statistics at the University of Chicago. “By leveraging a sparse representation of a signal or image, computers can ‘learn’ from fewer examples, and data can be stored with fewer bits. Ingrid’s work is enormously significant on its own, and it also inspired a generation of researchers to explore new ways beyond wavelets to represent signals and images and develop new theory and tools that can better exploit sparse representations.”

Daubechies closed out the summer of her 64th birthday at the Burning Man festival in Nevada’s Black Rock Desert. During a midnight lecture she explained how, as a mathematician working with an algorithm, she filled in the altarpiece’s craquelure. “You do it mathematically the same way as an art conservator would do it visually,” she said. After one algorithm identifies voids left by cracks, another algorithm guesses, based on the adjacent areas, what is likely to have been there. Through this process (and with expert interpretation by paleographers), the book came into focus: a work by the Italian theologian Thomas Aquinas. Daubechies concluded her talk with another motto she oft repeats: “Math can help! As always!”

Daubechies at Burning Man, in Nevada’s Black Rock Desert, in 2018. Siobhan Roberts

At a deeper level, however, it is not known what’s going on inside machine learning’s black box. Systems that humans can understand and query would make the technology more transparent, reliable and trustworthy. And to this end too, Daubechies thinks mathematics can help. Machine learning’s success — demonstrated perhaps most strikingly with GPT-3, the language-prediction model that can write essays, answer trivia questions and compose computer code, among other text-oriented tasks; and AlphaFold, an artificial-intelligence technology that, in its ability to predict protein structures, solved a 50-year-old “grand challenge” in biology — is something that Daubechies believes mathematicians and mathematically inclined scientists should attend to more. “Machine learning works very well, and we don’t know why it works so well,” she says. “I consider that a challenge for mathematicians, to understand it better. If we do, it will go much further than if we don’t.” Usually, the argument is that beautiful, pure mathematics eventually — in a year, in a century — produces compelling applications. Daubechies believes that the cycle also turns in the opposite direction, that successful applications can lead to beautiful, pure mathematics. Machine learning is a promising example. “You can’t argue with success,” she says. “I believe if something works, there is a reason. We have to find the reason.”

Coming of age in the 1970s, during feminism’s second wave, Daubechies went off to the Free University in Brussels expecting to be the best. Since childhood, she had been intrigued by mathematical truths — when she couldn’t fall asleep, she computed the powers of two in her head. Despite her interest in math, she planned to study engineering; her father was a civil engineer.

She loved making things, including patterns for her dolls' clothing, transforming flat material into three-dimensional creations. And she was interested in how machinery worked. But during a class visit to a civil-engineering department, the concrete constructions undergoing durability testing seemed like "glorified Ikea." She switched to physics. Her mother — who, Daubechies recalls, was bored out of her mind as a homemaker and so went back to college, studied criminology and found work as a youth-protection counselor — was aghast: "Physics! Engineering is a profession. Physics is like being an artist."

Physics meant a lot of math classes. One classmate was Jean Bourgain (a winner in 1994 of the Fields Medal, the so-called Nobel Prize of mathematics, who died in 2018). Daubechies quickly figured out that Bourgain was at least her equal at math. When she realized he was superior, she promptly developed a crush: "He was the first boy I met who was smarter than I was."

Daubechies did her Ph.D. at the Free University, but given her interests, the French American physicist Alex Grossmann, based in Marseilles, became one of her advisers. Not long after, in the early 1980s, Grossmann and the French geophysicist Jean Morlet began using techniques from quantum mechanics to study seismic traces, the wavy curves plotted by a seismograph. They coined the term "wavelet" — in French, "ondelette," meaning "small wave." Daubechies became swept up in her adviser's enthusiasm for tackling a new topic and forging a technique that led to the new paradigm: wavelet theory.

'When you're in the depths of despair, your project has crashed and burned and you have almost proven that what you're trying to do is impossible, Ingrid comes along and pulls you out of the pit of doom, and you can keep going.'

In mathematics, waves are fundamental and ubiquitous. The sine wave is a smooth, periodic undulation, a mathematical idealization of waves found in nature: energetic seismic waves produced by earthquakes; sonic booms propagating through air; tsunamis spreading across water. "And even things that don't have this wavy effect, things that are much more complex, can be constructed as a conspiracy of different waves," Daubechies says. "You can build almost anything by combining, in clever ways, waves of different wavelengths."

This idea dates back two centuries: In 1822, the French physicist and mathematician Joseph Fourier published a paper outlining his analytical theory of heat. (Fourier is credited with discovering the greenhouse effect.) He proposed that all periodic functions — all periodic phenomena — could be understood as sums of sine and cosine waves. Throughout the 19th century, Fourier analysis evolved to include wider classes of phenomena, including waves that change their shape over time rather than repeating identically forever. Fourier analysis helped solve problems in physics and engineering. But this approach had its limitations: It couldn't efficiently handle signals with abrupt changes, like spoken language or pictures with sharp edges and sudden transitions in luminosity. In the 20th century, scientists in disparate fields overcame these difficulties by developing tools that coalesced into the mathematical theory of wavelets.

Wavelets, in essence, allow for bespoke representations of data, a versatile tailoring to the type of information within any given data set. They are more adaptable; they can efficiently and effectively capture those abrupt changes. Sometimes Daubechies gives a fancifully impractical musical metaphor to describe the difference. For Fourier analysis, she envisions a room full of thousands of idealized tuning forks, each sustaining a uniquely assigned note indefinitely. When the tuning forks are struck, at just the right time and intensity, and within short intervals of one another, the frequencies of their reverberations — "woooOOOooo, woooOOOooo, woooOOOooo" — combine and conspire to produce a rendition of Beethoven's Ninth Symphony.

Wavelets, by contrast, are a more sophisticated symphony orchestra of tuning forks that each ring for a shorter time. They can, in a manner of speaking, read and convey all the information contained in the musical score: information about tempo and note duration, and about even more granular nuances of musicality, like variations in the same note on different instruments, or the same note on the same instrument by different musicians, or the attack at the start of a note, or the purity of tone held for bars at a time. “With wavelets you can decompose all that in an efficient way,” Daubechies says.

In 1984, still at the Free University, Daubechies became a tenured research professor in the department of theoretical physics. With Grossmann’s encouragement, she had waded into wavelets the year before. She found that when asking “why” and “how” questions in signal analysis, the answers she came up with, as she recalled in her Guggenheim statement, “were often not the same as the standard ones, and in some cases my answers were better. This was exciting, of course, and led to my first work on wavelets.”

In May of following year, she met Calderbank. He has worked in the realm of quantum computing since the beginning, in the 1990s (he is the “C” in CSS error correction); and he has made significant contributions to coding and information theory for wireless communications that support billions of cellphones. Then employed at AT&T Bell Laboratories in Murray Hill, N.J., Calderbank was on a three-month exchange to the math division of the Brussels-based Philips Research. He and Daubechies were both extricating themselves from other relationships at the time, and by the end of the three months they decided to give a go of life together. She arranged a stint as a guest researcher at New York University’s Courant Institute of Mathematical Sciences, starting in the spring of 1986. During the next year, she made her big breakthrough, the Daubechies wavelet.

The puzzle that Daubechies solved was how to take a recent wavelet advance — a thing of beauty, by the French mathematicians Yves Meyer and Stéphane Mallat, but technically impractical — and make it amenable to application. To “put it on its head,” Daubechies would say, but without making it ugly. As she said in the Guggenheim statement: “It is something that mathematicians often take for granted, that a mathematical framework can be really elegant and beautiful, but that in order to use it in a true application, you have to mutilate it: Well, they shrug, That’s life — applied mathematics is always a bit dirty. I didn’t agree with this point of view.”

By February 1987, she constructed the foundation for what grew into a “family” of Daubechies wavelets, each suited to a slightly different task. One key factor made her breakthrough possible: For the first time in her career, she had a computer terminal at her desk, so she could easily program her equations and graph the results. By that summer, Daubechies wrote up a paper and, sidestepping a hiring freeze, secured a job at AT&T Bell Labs. She started in July and moved into a house recently bought with Calderbank, whom she married after popping the question the previous fall. (Calderbank had made it known there was a standing offer, but he resisted proposing out of respect for Daubechies’ declared opposition to the institution of marriage.)

The ceremony was in May in Brussels. Daubechies cooked the entire wedding dinner (with some help from her fiancé), a Belgian-British feast of chicken with endive and Lancashire hotpot stew, chocolate cake and trifle (among other offerings) for 90 guests. She had figured that 10 days of cooking and baking would be manageable, only later to realize that she had neither enough pots and pans for the preparation nor refrigerator space for storage, not to mention other logistical challenges. Her algorithmic solution went as follows: Have friends lend her the necessary vessels; fill said vessels and pass them back for safekeeping in their fridges and for transport to the wedding. She encouraged the more gourmand guests to bring hors d’oeuvres instead of presents. Her mother, putting her foot down, bought an army of salt-and-pepper shakers.

Daubechies continued her wavelets research at AT&T Bell Labs, pausing in 1988 to have a baby. It was an unsettling and disorienting period, because she lost her ability to do research-level mathematics for several months postpartum. “Mathematical ideas wouldn’t come,” she says. That frightened her. She told no one, not even her husband, until gradually her creative motivation returned. On occasion, she has since warned younger female mathematicians about the baby-brain effect, and they have been grateful for the tip. “I could not imagine that I would ever have trouble thinking,” Lillian Pierce, a colleague at Duke, says. But when it happened, Pierce reminded herself: “OK, this is what Ingrid was talking about. It will pass.” Daubechies’ female students also mention their gratitude for her willingness to push for child care at conferences, and sometimes even to take on babysitting duties herself. “My adviser volunteered to entertain my toddler while I gave a talk,” a former Ph.D. student, the Yale mathematician Anna Gilbert, recalls. “She seamlessly included all aspects of work and life.”

In 1993, Daubechies was appointed to the faculty at Princeton, the first woman to become full professor in the mathematics department. She was lured by the prospect of mingling with historians and sociologists and their ilk, not only electrical engineers and mathematicians. She designed a course called “Math Alive” aimed at nonmath and nonscience majors and gave talks for the general public on “Surfing With Wavelets: A New Approach to Analyzing Sound and Images.” Wavelets were taking off in the real world, deployed by the F.B.I. in digitizing its fingerprint database. A wavelet-inspired algorithm was used in the animation of films like “A Bug’s Life.”

“The Daubechies wavelets are smooth, well balanced, not too spread out and easy to implement on a computer,” Terence Tao, a mathematician at the University of California, Los Angeles, says. He was a Princeton grad student in the 1990s and took courses from Daubechies. (He won the Fields Medal in 2006.) Daubechies wavelets, he says, can be used “out of the box” for a wide variety of signal-processing problems. In the classroom, Tao recalls, Daubechies had a knack for viewing pure math (for curiosity’s sake), applied math (for practical purpose) and physical experience as a unified whole. “I remember, for instance, once when she described learning about how the inner ear worked and realizing that it was more or less the same thing as a wavelet transform, which I think led to her proposing the use of wavelets in speech recognition.” The Daubechies wavelet propelled the field into the digital age. In part, wavelets proved revolutionary because they are so mathematically deep. But mostly, as Calderbank notes, it was because Daubechies, a tireless community-builder, made it her mission to construct a network of bridges to other fields.

In due course, the awards began piling up: The MacArthur in 1992 was followed by the American Mathematical Society Steele Prize for Exposition in 1994 for her book “Ten Lectures on Wavelets.” In 2000 Daubechies became the first woman to receive the National Academy of Sciences award in mathematics. By then she was mothering two young children. (Her daughter, Carolyn, 30, is a data scientist; her son, Michael, 33, is a high school math teacher on Chicago’s South Side.) And by all appearances she was handily juggling it all.

But despite her many successes, she was incapacitated by insecurities — sometimes she could barely get out of bed. At 40, after a difficult period, she found help and was finally diagnosed with chronic depression, having suffered dark episodes since puberty. Through therapy and medication, she found a manageable equilibrium. “When I’m busy and happy, I feel I don’t need the medication,” she told me at Burning Man, where the profusion of radical creativity caused her to nearly forget her pills more than once.

During the pandemic, one particularly mood-elevating project has been “Mathemalchemy,” a collaborative math-art installation that opens in January at the National Academy of Sciences in Washington. As Daubechies’ husband told her, “You found a way to do Burning Man at home” — albeit via an estimated 334 hours of virtual meetings and 7,582 emails among a team of 24.

A detail of the “Mathemalchemy” installation, which opens in January at the National Academy of Sciences in Washington. Jeremy M. Lange for The New York Times

“But it’s always a bad idea to skip,” Daubechies says of her medication, because within a day, she starts sliding. She doesn’t mind talking about depression, in part because she believes it’s good for people to know that success doesn’t inoculate against mental-health vulnerabilities and that it’s a chronic problem requiring chronic solving. “It’s never really solved,” she says. “That is the case with many, many things. There is no static equilibrium.” She likens it to bicycling: “You have to compensate, all the time.”

In 2010, Daubechies and Calderbank moved to Duke University, where he is now a professor and the director of the school’s Information Initiative. The same year, she was elected president of the International Mathematical Union — another female first — and on her watch, in 2014, the I.M.U. awarded the Fields Medal to Maryam Mirzakhani, its first female recipient, following more than 50 male winners (Daubechies served as chairwoman of the medal committee). In 2014, the University of Cambridge tried to hire both Daubechies and Calderbank. Daubechies was offered the Lucasian Chair of Mathematics, held previously by, among others, Stephen Hawking and Isaac Newton — but never by a woman. Duke successfully counteroffered: The provost guaranteed funding to recruit and hire female mathematicians until they made up 30 percent of the faculty. This is a data-driven target: Surveys by the American Mathematical Society indicate that at universities with R1 status, the highest research classification, women constitute about 30 percent of math Ph.D. students, but only about 17 percent of the tenured or tenure-track faculty.

Daubechies, for her part, has been unaware of biases affecting the trajectory of her career (though she admits to being oblivious to the subtleties of social signals). But from a societal perspective, the gender gap in math (and science) is a mere sampling of the fact that, according to a United Nations report that arrived in her inbox in March last year, 90 percent of the world's population has a "deeply ingrained bias against women." For 2020, Duke's hiring committee made offers to five women — "the Fab Five," Daubechies calls them. Only two accepted; the scarcity of female candidates makes for fierce competition. One of them, Jessica Fintzen, first met Daubechies at Duke, though she knew her work. "She's a role model as a very successful female mathematician," Fintzen says. "You need to have a certain character to ignore the biases and survive."

Countering underrepresentation is difficult and fraught, but there is also the inextricable challenge of facing down explicit sexism. For decades, the standard test image in the signal processing community was a picture, cropped to a headshot, of Lena Forsen, a Playboy centerfold model in 1972. Wearing a feathered hat and looking over a bare shoulder, Forsen made repeat appearances on conference screens and in papers. Even Daubechies used the photo for a time, unaware of its origins. But around the turn of the century, in solidarity with growing opposition to the picture, she swapped in another image that she still uses today: When she gives a talk explaining the essence of wavelets, her slides show four increasingly blurry copies of a sailboat photo (the message being that even at the coarsest scale, the image still contains useful information). The infamous "Lena" picture was still the go-to test image in the late 2000s, when the applied mathematician Rachel Ward, now a professor at the University of Texas at Austin, did her Ph.D. with Daubechies. (Ward refers to the protean talents of her former adviser by describing her as "the Meryl Streep of mathematics.") In 2013, Ward and a co-author published a paper that instead used a headshot of Fabio Lanzoni, the Italian fashion model and actor. "As young, untenured professors," Ward says, "we felt the only way we could make a statement was through parody."

Daubechies has also seen discrimination while serving on hiring and jury committees, and usually suggests that transgressors take an implicit bias test, as she has done herself more than once. Her tendency until recently was to let minor instances go with an eye-roll and perhaps a knowing glance to her colleague Lillian Pierce. But then she and Pierce had a conversation about these predicaments, and Daubechies concluded that passive exasperation was sending the wrong message. "I realized that as a more senior woman, my responsibility was to stand up," she says. She took a course at Duke called "Moving From Bystander to Upstander."

Daubechies and Pierce first met at Princeton. An undergraduate at the time, Pierce was in the habit of typing up her research in a computer lab that was always empty. One day an office administrator told her that the lab was for grad students only and that she had to get out. "I was petrified and horrified that I had done something wrong," Pierce says. "Then I heard a voice behind me saying, 'Give her a key!' I don't think I had seen Ingrid in person before that moment. But it's classic Ingrid in that she believes in enfranchising people. And if people want to do math, they should be given the key."

The advocacy sometimes generates pushback. A couple of years ago, serving on a national award committee, Daubechies backed the nomination of an excellent midcareer female mathematician instead of an older male who ended up the winner. The episode made Daubechies angry, and it brought on a period of discouragement and pessimism: "Somehow, I just felt tired. Tired of the struggle to show that women can be great mathematicians, too, and are often undervalued." Maybe, Daubechies thought, she had been living under a delusion, imagining that her efforts and those of others could have any real effect. "It is a puzzle to myself as well, to feel this way — defeatism is not something I have a lot of experience with," she says. "In fact, it was the major topic of my most recent therapy session!"

More characteristically, Daubechies redoubles her efforts — perhaps following some cathartic weeding in her garden — and perseveres. After all, she is the oddball mathematician who came out of left field and prevailed. At a big math conference not too long ago — the last she attended in person before the pandemic — Daubechies overheard a joke that she retold a few times on the way home. Somehow, it seems apropos: "I don't get even," she said. "I get odder."

Siobhan Roberts is a Canadian journalist and senior editor at MIT Technology Review. Her latest book is "Genius at Play: The Curious Mind of John Horton Conway." She is currently working on a biography of the mathematical logician Verena Huber-Dyson, forthcoming from Pantheon. **Jeremy M. Lange** is a photographer and filmmaker in Durham, N.C.

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