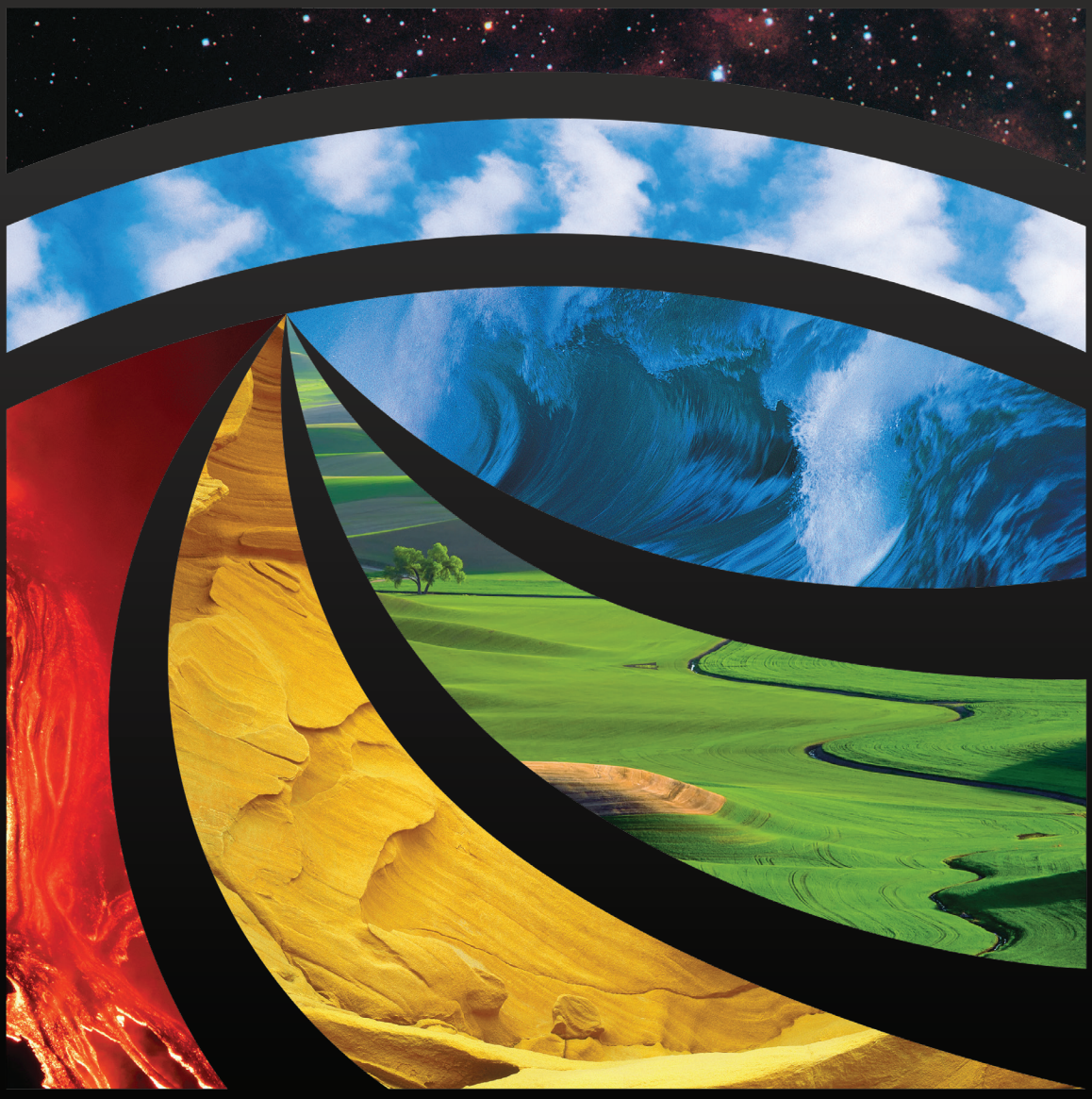
NAUTILUS

A SPECIAL EDITION POWERED BY THE AMERICAN GEOSCIENCES INSTITUTE AND IF/THEN, AN INITIATIVE OF LYDA HILL PHILANTHROPIES

Geoscience Women in STEM

LEADING THE WAY IN SCIENCE AND ENGINEERING TODAY



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COVER ANGIE WANG

NAUTILUS

Published by:

SCIENCE IS FOR GIRLS

Celebrating the next generation of geoscience pioneers.

"I grew up in my father's laboratory and played beneath the chemical benches until I was tall enough to play on them."

That's Hope Jahren, writing in her best-selling memoir, *Lab Girl*, about when she fell in love with science as a girl, a love she's nurtured into a career as one of the world's top geoscientists. Dr. Jahren is an expert in the chemical makeup of plants and trees. Her research has shown how forests have shaped the Earth's atmosphere and environment from 100 million years ago to now.

To Dr. Jahren, science is about more than creating new medicines or cars. What's the real purpose of science? "It's to feed the soul in the same way that art does," Dr. Jahren says. "The more you know about the world, the more you feel like you're part of it. That's the purpose of teaching it to children and to girls."

Dr. Jahren is one of many women doing important work in science and other fields. The Lyda Hill Philanthropies has developed the IF/THEN initiative (www.ifthenshecan.org) to create a culture shift in our society so that women innovators in science, technology, engineering, and math (STEM) are empowered to tackle our greatest global challenges and inspire the next generation of STEM pioneers. IF/THEN is highlighting over 100 of the top women in STEM careers, and giving them the opportunity to share their stories and serve as high-profile role models for women and girls.

In this special mini issue of *Nautilus*, you will meet Dr. Jahren through a lively interview about her life and career in science. Dr. Jahren shares her insights into being a woman in what has been a man's world. Her discussion of her work provides an exciting jumping-off point for educators and students to further explore the geosciences, the infinite interactions of natural systems and processes that make up the geosphere, atmosphere, hydrosphere, and biosphere.

This issue also celebrates the theme of Earth Science Week 2019, "Geoscience Is for Everyone." Lyda Hill Philanthropies, *Nautilus*, and the American Geosciences Institute (AGI) are working in collaboration through Earth Science Week 2019 (October 9–13) to advance the vision of the IF/THEN Initiative. Be sure and turn to "Classroom Connections" on pages 34 and 35, which link Dr. Jahren's work to related activities for students and teachers. Additional profiles of women highlighted by IF/THEN and educational guidance will be featured on AGI's Earth Science Week website (www.earthsciweek.org). IF/THEN will continue to offer profiles of trailblazing women STEM professionals and ways to strengthen STEM instruction, align investigations with the Next Generation Science Standards, and promote diversity, equity, and inclusion. This project is funded by IF/THEN, an initiative of Lyda Hill Philanthropies (https://lydahillphilanthropies.org/).

Everyone can take heart in Dr. Jahren's story. "As a female scientist I am still unusual," Dr. Jahren writes. "But in my heart I was never anything else."

—The Editors

Her Scientific Awakening

Hope Jahren tells us how a girl from rural Minnesota can fall in love with science and help change the world

BY MICHAEL SEGAL
ILLUSTRATIONS BY ANGIE WANG

WHAT DO YOU SEE when you look into a lab? Fluorescent lights and whirring machinery? Gee-whiz equipment and tempting red buttons? Hope Jahren, the geochemist and geobiologist, sees those things, certainly, but also something else: Home. "It just feels to me like the most wonderful, softest, warmest, safest place in the world," she says in her *Nautilus* interview.

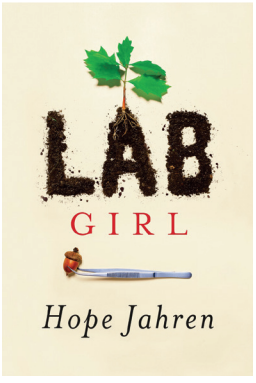
Dr. Jahren is an accomplished scientist who was a tenured professor at the University of Hawaii from 2008 to 2016. She is currently a professor of geobiology at the University of Oslo, Norway. She has received three Fulbright Awards in geobiology, and is the only woman to have been awarded both of the Young Investigator Medals given in the earth sciences. In 2005, *Popular Science* christened her one of the "Brilliant 10" young scientists.

In Dr. Jahren's 2016 memoir, *Lab Girl*, she shows us that she is also one of today's best popular science writers. Her book explores the confluence of science, identity, and belonging that has run through her career, and invites us to share in the scientist's joy of play, feeling of community, and wonder, all of which are vivid and intact on the page.

The language of her book, as Dr. Jahren explains in her interview, is the result of a kind of scientific process, each sentence considered and re-considered. She applies this same precision to her thinking about science as an institution, the role of women in science, science education, and, of course, her true love: plants.

How has your science changed your view of the world?
Personally I think that's the true purpose of science. It's to feed the soul in the same way that art does. The more you know about the world, the more you feel like you're part of it. And that's the purpose of teaching it to children and to girls. Once you spend time that way you see the world differently, and that's another thing I've really tried to bring out in my book. I use all the time I've spent sorting things and labeling things and manipulating things—it's got into me, it's soaked into me all the way into my heart and up into my brain, and it changes the way I see the world. That's something that I really love about myself and I love about my life. And I want to share that.

Something that comes to me many times a day, that I'm sure comes to me because of the scientific tasks I've performed for so many years, is the difference between staying and going. I think that's the fundamental difference between a plant and an animal, is that if an animal doesn't like where it is, it can get up and move away. Plants have to stay there and take it. There are a lot of other differences between plants and animals of course, but I believe that seeps into everything about how different they are and I believe that I can look around me and see the things that stay. Better than a person who hasn't devoted themselves to the same activities I have. I believe I know things about what it means to stay and endure and watch and grow. And I wouldn't trade that for any other life. If everything I've done only brought that to me, if that was the only reward for everything I've done, then it would be worth it a hundred times over. You can do it too, you know, look



around you and think about the things that stay. And when you walk away, they'll still be there and night will fall and rain will fall and the snow will melt and … in your mind you can inhabit another life and that's the ultimate transcendence of yourself.

Why is your relationship with science so personal?
I believe that science is practiced in the home first and foremost. That it's a way of seeing things and a way of doing things, right down to the way you sew, the way you cook, the way you measure the window to buy curtains. I saw my father do those things in the laboratory where he taught at a community college for 42 consecutive years. He taught science, all sciences, in a laboratory in a rural community college. And I saw my mother do that at home in everything she did. She optimized everything she did for efficiency and the quality of execution. And so I saw those behaviors as very deeply rooted in the way you think, the way you approach all the materials around you, and that's where I feel most comfortable. That's where I learned to interact with the world as a child, and that's the way I live now.

So when I'm doing science, when I'm manipulating things with my hands or measuring things or analyzing patterns, that's when I'm most me. That's when I'm most still in contact with the person that I knew I was as a child and the person that I am that has always stayed with me. It is very *deeply* in my identity and, you know, regardless of what my job title is or who is employing me to do these activities or what people think of how I do them—that's all secondary to living it out with my hands and with my eyes and with the people in my life who get it.

I have three older brothers and we went to my father's laboratory in the evenings after school and we played in the laboratory while he graded or set things up for the next day or repaired the demonstrations. And we played with all the stuff, and he never, ever said "don't touch that," and we always wanted to take out the lasers and clap erasers in front of them. It was play but it was special play, because it was stuff that was actually for grown-ups but we were allowed to play with it. It was a wonderful, special place. My father was very happy when he was there and we were happy to be with him. Being in a laboratory was always just

BIRTHDAY GIRL Hope Jahren with her father, Charles Jahren, a physics and earth sciences teacher. "My father taught me how to preemptively take things apart and study how they work," Dr. Jahren writes. "He taught me that there is no shame in breaking something, only in not being able to fix it."

PHOTO COURTESY OF HOPE JAHREN

A LAB OF ONE'S OWN Hope Jahren in her lab. "I still find reasons to work cross-legged on the floor," she says. "Now in my own lab instead of my father's."

Being in a laboratory was always just the most wonderful, comforting, familiar, happy, safe place.

the most wonderful, comforting, familiar, happy, safe place—and I still feel that way. Which is a little funny because it's clean and bare and it's not soft. It's angular, but it just feels to me like the most wonderful, softest, warmest, safest place in the world.

What advice would you give to parents of aspiring scientists?

This is something I always try to say, is that most scientists are drawn to their subject in a very inexplicable visceral way. And that's, I think, the most important thing I tell people with daughters or sons or whatever, is that to identify that; that will come out very early. For example, birds, I know people that study birds. I know

MATT CHING

people that will travel halfway around the world and sit out in the rain for days on end hoping that a certain bird flies by. Now, I look out at birds and I say "that is a bird" and it leaves me utterly cold. I can respect that somebody wants to know that bird's inner workings, and I can value the fact that somebody does know that bird's inner workings, and I can listen politely to an overview of that bird's inner workings, but I will never have that ... for better or worse, that's not my destiny.

Now leaves are something different. I feel drawn to leaves in a way that I cannot explain and I always have. I remember when I was in school and we were supposed to make a leaf collection. We were supposed to get 20 different leaves, and I remember my parents dropping everything and driving to Indiana to arboretums and botanical gardens, and I think my collection was 150 leaves in the end, which is great. It was great. It's something I'll remember all my life. And, you know, my parents and I don't see eye to eye on everything—but I got from them the strong message that number one, your education is something worth going overboard for. Pull out all the stops. Number two, that my inexplicable passion for these things was good, and it was a good thing about me. And it was something that the people in my life should support and jump on board for and enjoy. Those messages have stayed with me very strongly. I think that's important. Some people feel that way about stars; they can't stop looking up at them. That's the piece where people's scientific potential lies. That's what I've seen in students and that's what I've seen in myself.

Do you feel that the scientific establishment is making a sincere effort to include women?

Well, I don't know if establishments can be sincere. People can, but institutions are a different thing, and science is an institution. I think women are doing science; it's just not science that is compensated very well. My mother knew how to stitch a different tension into the thread of each button on the shirt based on how many times it was used relative to the others. You might sneer at that as an unscientific activity, but I would give anything to have an employee in the lab who got that fine scale understanding of force and tension, and understood the mechanical workings of all the small pieces. So I think ... I mean

Most scientists are drawn to their subject in a very inexplicable visceral way.

"can women do science?" That's a ridiculous question. "Do women want to do science?" That's a more interesting question.

I think wherever you look in the world, you see a field or an endeavor that's not got women in it. You can ask yourself why aren't there women there? And the answer is always the same: It's because women aren't welcome. I mean, there are women working hard everywhere you know. You can say well, science is too hard. Well, women know how to work. There are fundamental mechanisms that work to discourage women from positions of influence and access, and science has a protected elevated position in society. I always go back to my original decision in college, to be a writer or to be a scientist, as an illustration of that. It's arbitrary. And I think it's the dynamics between men and women in the market place and in the classroom and in society as a whole, that's much bigger than science. Those fundamental truths of how we've constructed society bleed into every endeavor that we've organized, and science is merely one of many, many endeavors that carries that curse.

I could rattle on and on, specific examples of times that I've been told that I'm unwelcome or, from various implicit to very explicit examples—to this day it never stops. People do get fed up and they leave. And if you don't fit the mold there's all kinds of this stuff. Any kind of minority person who doesn't fit the mold is going to have their own brand of unwelcome. But the interesting thing is you can't get away from it. Okay so you leave science, there's no magical place where these biases don't exist. I'd like to imagine that they're better

My parents and I don't see eye to eye on everything—but I got from them the strong message that number one, your education is something worth going overboard for. Pull out all the stops.

in certain spheres, but I also know that they're probably a lot worse in other spheres. The frustrating thing to me is that we're talking about it on such a superficial level. You know "do girls have the right dolls to play with when they're little? Do we have the right people on TV as role models?" And nobody wants to seem to tackle the fact that maybe we're already invested in a much larger system that counts on the fact that we need to usher some people into more lucrative labor than others.

You know, in 1950, my mother was an honorable mention in the Westinghouse talent search. That is something that is rare. Two other honorable mentions from 1950: One went on to win a Nobel Prize, and the other went on to win the Fields medal in mathematics. They were both men. She was not from a prep school out east. She was from a rural school in rural Minnesota—from a public school in rural Minnesota—and she tried to go to college and she didn't have the money. This was 1950, and so she had a family instead. And that is with me every day, I carry that.

Tell us about the language you used in your book, *Lab Girl*.

We can talk about every adverb I used, we can talk about every adjective I used, we can about every adverb I cut and the way I constructed every sentence: because it was done with scientific accuracy. There is an entire parallel language that has been constructed for use in science, in order to remove science from the realm of everyday discourse. That goes back to protecting it as a uniquely marketable skill set. It does.

I wrote this book and I said, "I don't want to write for scientists." I have written close to 70 papers in 35 different journals. I have written and written and *written* for as many audiences as I can possibly find within the scientific world. I want to talk to somebody else. After 20 years, in the field of studying plants, I've been talking to the same people for 20 years and so I wanted to write this book in order to talk to somebody new.

So, you've got a tree and a tree sits in the sun and it biochemically uses energy from the sun and carbon from the air to make a sugar. And then it turns that sugar into a leaf or it pumps the sugar down into the roots or it mixes it with nitrogen and makes protein. It has various activities. It has to choose. So, the tree has made sugar out of energy from sunlight and carbon from the air and now it has other tasks. It makes a leaf if it's spring. It doesn't make a leaf if it's fall. It transports it to the roots if it's fall; it doesn't do that if it's spring, etc. There are other things it can do based on if an insect is attacking it, it might use that sugar to make a defense compound or a medicinal compound to apply to the site of the wound, etc. I talk about that as being a choice. The tree makes a choice. I *should* talk about that as an allocation, the tree allocates to one task versus another. Now, the fact that allocation is a good word

and choice is a bad word, doesn't *mean* anything. It's just a reaction against me breaking that rule, using a word that you identify with, that you use every day in your activities, in your nonscientific activities. The other thing I'd say about making that choice, choosing that word choose instead of allocate, is I have earned that. I'm not walking around rubbing the trees and feeling their vibrations for some kind of spiritual message to me. I'm in the laboratory for hours on end for years of my life, studying this and publishing it and discoursing with my peers. I have come to these statements through a process of sincere and industrious earning.

The most fulfilling thing that I hear about the book is that people tell me "I understood this stuff: I'm not a scientist but I understood it," and they're somehow surprised at that. Somehow along the way science stopped writing stuff that people could understand and we've somehow got the reader blaming themselves that they can't understand it. I mean what a scam. So that gives me great joy, is that people will even say "I was told I'm not good at science" or "I never did any of this stuff, but gosh, I liked your book. I understood it and I feel like I know something about trees. I feel like I could do this stuff" and that is what gives me real joy. It's a sneaky textbook. You know, if you really read it and you take all that stuff in you know as much about plants as I would hope to be able to teach you in one of my courses. That is the part that is really joyful to me as a writer.

Is there a struggle to understand what human narrative we should apply to nature?

How to conceptualize nature—that's a huge, huge topic. I would love to write an essay on that, or a book on that. I've analyzed this to some extent. We have this discomfort between enlightenment and romantic views of nature. Is it something that we manipulate or is it something that's bigger and more expansive than we are? So who's on top? In the romantic version, nature is bigger than we are, it knows more, it's been here longer, it has ways of sustaining itself and healing itself that we cannot understand. In the enlightenment version, we're able to control everything about nature, we can fix it, it's our duty to make it yield, etc. And, of course, neither one of those scenarios is really right. You hear people flip back and forth between

EXPLORING OUR WORLD Hope Jahren on the Dingle Peninsula of Southwestern Ireland in the 2000s.

My inexplicable passion for these things was good, and it was a good thing about me. And it was something that the people in my life should support and jump on board for and enjoy.

PHOTO COURTESY OF HOPE JAHREN

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the two rhetorics when they discuss environmental phenomenon. You know the green technologies and the solutions is always very enlightenment rhetoric, whereas the conservation strategies, protection of nature is always very romantic rhetoric, and we kind of flip back and forth as the argument serves. But the bottom line is nature doesn't care how we conceptualize it. This is a purely human endeavor, and nature also doesn't really need us to conceptualize it. In some ways, there is a lot we don't understand. I'm not saying it doesn't matter how we think about nature. I think we always are tempted to succumb to the idea that we're more important than we are when we talk about the environment. The real challenge is living with the dissonance, living inside the dissonance of those two visions and continuing to work every day and take the measurements and walk the fields and count what's there and talk to each other about what we see. That's the challenge.

Why do you love trees?

I have a deep affection for trees. I don't think they love me back and I don't think they know me, and all that kind of stuff, but I love oak trees because there's pretty much a species of oak that can live almost anywhere. They just seem so indestructible, and they just have so many things figured out that we don't, like how to live on the planet for 100 million years without substantially wrecking everything or wrecking themselves. I wonder if we'll be able to go 5 million more. So in some ways I feel like I can transcend all the stuff that human beings worry about, each other and money and how men and women treat each other, and all that kind of stuff. I feel like I can transcend that by looking at a being that figured it out.

People are drawn to trees. They're bigger than us in almost every way imaginable. I mean there are trees that were around when you were born, and those same trees are going to be around for a lot longer when you're dead. And so I think it's natural that people have always tried to make sense of trees, and they do it using the tools that they have. They do it using their religious tools. They do it using their sensory tools. They do it using a mystical framework and I do it using a scientific framework. I count the leaves, I rip the leaves up, I go back and measure things. I think we try to make sense of the world and trees are always going to be a really magnetic draw for some of us, not because they're like us—because they're so very different.

What are some of the most interesting places on Earth for a plant lover?

I love Ireland, because it is so green. Ireland is so thoroughly green that the things that are not green stand out. You drive around and it's like "oh my gosh, there's a white lamb on that field of green." And the *shades*

of green, the million different subtle shades of green are amazing. Something about working in Ireland and being in Ireland is so immersive in the plant world. And it rains, which is miserable. It's miserable to be outside in the rain for hours on end, not moving around, kneeling, counting moss plants or something. You get cold and you get wet, and it's that kind of drizzle and it soaks you through. And then you just realize that all these plants, they never go inside, they love this stuff. It's a nice place where I go and really think this is their world, it's not mine. I get to measure a few things, but I don't know—that's the real definition of exploration, finding yourself in a different world.

Hawaii is interesting because it's the tropics, which means that everything is blooming all the time, which means that there's just an incredible amount of plant sex going on everywhere you go. And everybody's trying to make the biggest, showiest flower, and spit out the most seeds, and stuff like that. And so I'm constantly in Hawaii just bombarded with all this fertility and like frantic desperate ... it's like *Caligula* for plant life or something. So each of these ecosystems are different in a way that I appreciate not because of a mystical side; it's my scientific side that allows me to appreciate that. It's my scientific work that allows me to feel that and recognize it. And I like that crossover.

What happens to the Earth's plants if atmospheric carbon dioxide levels go off the charts?

CO_2 is an interesting thing, in that it's basically money to plants. It's a primary resource. The interesting thing about plant communities is that we've been flooding their economy with money for decades, more and more. And, just like if you went to Times Square and $1,000 dropped from the sky into the pockets of everybody who's standing there, every one of those people would make a different choice on how to spend the money. Some people would save it; some people would run out and buy clothes; some people would gamble it away within 5 minutes, etc. And in a similar vein, every plant out there makes a different choice. Some build a bunch of new leaves; some make a bunch more flowers; some shunt it into their roots; some stop making defense compounds. I call that the Costco effect. If you go buy 100 rolls of toilet paper you're going to use toilet paper at your house very differently than if you're

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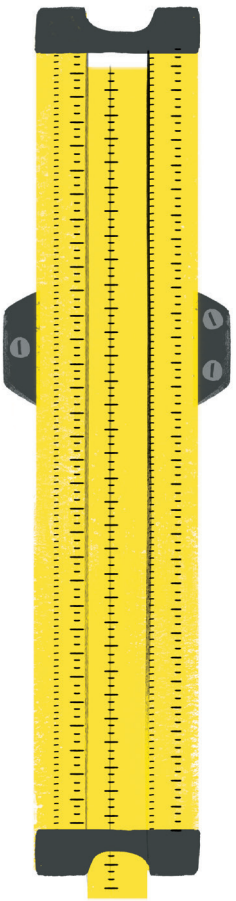


buying it roll by roll. So plants, if it's that easy to make a new leaf, you're going to treat the ones you have very differently, if that sugar is just coming in free.

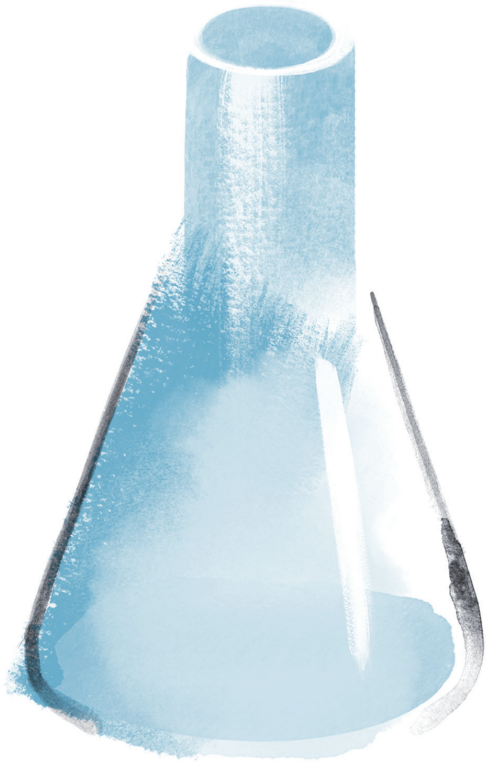
We see all that, and now we've got, you know, 20 years of good research on how this affects plants, and it does affect them differently. But when we talk about back to us, back to humans, plants, first and foremost in a lot of our minds, are three things: food, medicine, and wood. You probably stopped seeing it, but if you look around the number of articles around you that are made of wood is still incredible; it's our biggest building material on the planet. Of course food all starts with grain and a lot of our important medicines are extracted from plants. So if we flood those three economies—those three plant economies—with money, we need to start thinking about what those plants will do and hence what will happen to those resources. Will wood be just as strong? Will it weather just as long? Will crops get bigger, smaller? Will they get less able to defend themselves against pathogens? That's important. Will they be less storable? Medicinal plants—will those compounds be less potent? Will they be more potent? There's reason to believe at those very high levels, you know, really busting out of what we're looking at today, could affect plants very differently than the relatively small raises that we're looking at in the last 20 years.

It's a different world when money is free. And thinking about a world where plants operate utterly unconstrained by that particular resource is very interesting. One thing that happens of course is that other things come into play. I mean if I quadruple your salary but I don't give you any more vacation time, you can't take that around-the-world tour even if it seems cheap to you, because you can't get the time off. So now it's not money that's limiting; it's time. Plants have a similar thing in that nitrogen can become limiting, water can become limiting when temperatures go up. There may be less water available in very critical places. So the economy of plants can also tip based on these secondary limitations. That's also very interesting to us. But I think we need to start wrapping our heads scientifically around some of these scenarios that nobody wants. You know, nobody wants a hurricane on the Hawaiian Islands, but we have a system in place in case one happens. I think global change is going to be the same way.

We need to start wrapping our heads around scenarios that nobody wants. Nobody wants a hurricane on the Hawaiian Islands, but we have a system in place in case one happens. Global change is going to be the same way.

What research are you doing that you're most excited about now?

Right now, I'm interested in stress. We've done a lot of experiments around stressing plants to see how they recover and how they manage stress and things like that, which is funny because they're actually pretty sadistic experiments. I mean, you can torture a plant until it's this close to dead and then bring it back. You can do all kinds of things you could never get permission to do to animals, and it would be horrible to even think about doing such things to people—but plants are very much fair game in terms of any experiment you want to propose. Especially little small plants and stuff; which gives a kind of scientific freedom in terms of studying life. The interesting thing that we're coming to is, what is stress? How do you define stress? One thing we've noticed is there's a disconnect between what I think will stress the plant and how it actually reacts. So how do you measure stress? The same life event happens to two people—two people of the same species—they're not going to react the same. So I can say well, I won't give these little guys water for a few days, and then I'll measure how much they didn't grow, and then I'll compare the stress between them. But I've already projected my own assumption about what stress should *be* into that experiment—lack of growth. I'm having a lot of fun thinking really deeply about how subjective the experience of stress is. Subjective in terms of human subject is one thing, but subjective in terms of individual experimental plants—that's a whole other mind box that has to open in order to go there. So that's what I can say about what I'm really excited about now.



MICHAEL SEGAL is the editor at large of *Nautilus*.
This interview was originally published on *Nautilus* in March of 2016.

What a Real Superhero Looks Like

Particle physicist Jessica Esquivel on diversity, perseverance, and the search for a new understanding of our universe

BY MARY ELLEN HANNIBAL

THE PHYSICS OF SUPERHEROES is more than a fun exercise in the world of Jessica Esquivel. A particle physicist in the Muon Department of Fermi National Accelerator Laboratory, Esquivel works at what she calls "the bleeding edge" of the known universe. In the world of physics, Esquivel is frequently the "only." The only woman, the only Mexican, the only black person, and the only lesbian.

VECTOR FX / SHUTTERSTOCK

Recently she brought her experience to Wakandacon, the comic book conference based on the African-centric world of *Black Panther*. Making her own costume, Esquivel cosplayed as Shuri, the technological genius who designs weaponry for her brother, Black Panther. Esquivel also organized a panel of black scientists and was on hand to answer questions at Fermilab's booth at the conference. To many women of color interested in the hard sciences, Esquivel herself is a superhero.

You knew you wanted to be an astrophysicist from a young age. How did you get the idea?

My aunt babysat for me when I was really young and we watched a lot of sci-fi shows on television. One featured an astronaut in space fighting aliens while an astrophysicist back at NASA directed him to press this or that button, go right, go left—it was very dramatic. I thought the astrophysicist was the actual hero in the story, so I walked around saying I was going to be one. I grew up in Texas, and when I was about 12 my family took me to NASA in Houston. They sprang for the VIP tour, but I was bored! There was no astronaut floating in space on the screen, and everyone was typing on their keyboards and drinking coffee.

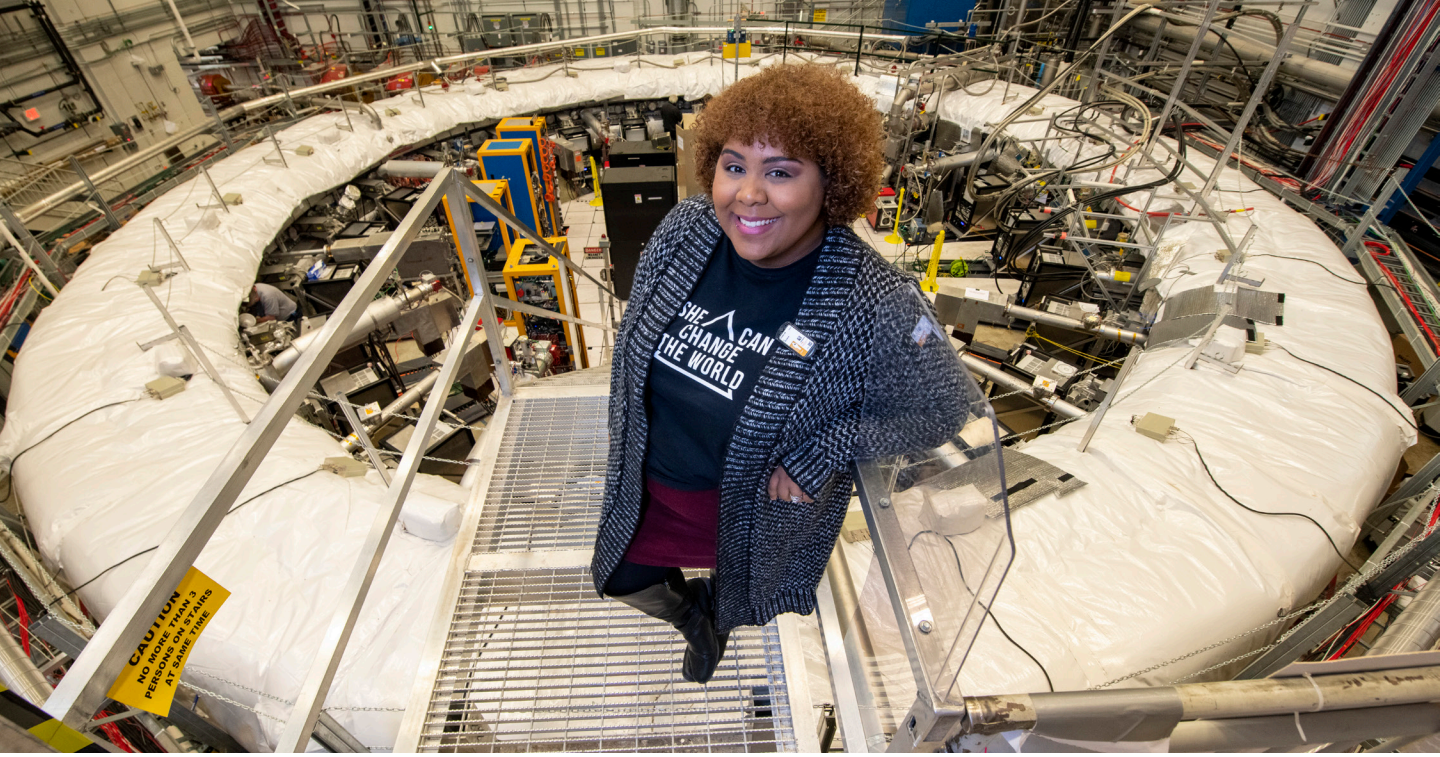
On that same trip we saw astronauts and a space shuttle in a big pool, simulating the absence of gravity in space. The scientists working on this were engineers, so I changed my ambition and said, "okay, I'll be an engineer and work on that."

How did your path unfold?

My family helped me stay the course. I did lots of science camps and went to The Science Academy of South Texas. I loved reading and English, but math and science were like puzzles, and though they didn't come easily to me I liked figuring them out. I went to St. Mary's University in San Antonio, thinking I would pursue electrical engineering. That's where I took my first physics class—physics for engineers. I fell in love with it.

The professor happened to be Dr. Richard Cardenas, an amazing person who has won national recognition for STEM [science, technology, engineering, and math] and community mentoring. He encouraged me to go into physics. My mom said, "What do physicists do? I can't pay for you to be a student for the rest of your life." In her eyes, engineers had job security. I went back to Dr. Cardenas and he said, "Okay, do both of them!" He was nonchalant, like no problem, I was going to be able to do these two massive majors. My mom agreed, as long as I finished in four years.

So I had my mom on board, and this amazing mentor, but I had to convince the engineering department. They had never seen anyone do it before, and here is a black, Mexican woman who wants to do it. I had to take 18 to 21 hours every semester until I graduated. Dr. Cardenas really rallied for me. He is an amazing mentor, and I definitely needed people in my corner.



SUPER SCIENTIST Jessica Esquivel with some of the equipment at the Muon g-2 project.

Did engineering continue to hold interest for you?
For me, physics presents the possibility of studying what no one has seen before. Engineering essentially applies knowledge and helps to create something new with it. Particle physics, for example, is about studying the smallest building blocks of nature. We think we know most of the building blocks necessary for the world around us, but there are holes in that knowledge. Physics brings us to the bleeding edge of what we know about the universe, and then engineers invent detectors to try to study and fill these holes in what we know. Physics and engineering are both amazing, but the unknown has a bigger draw for me.

Was your mother right about physics?
It has practical applications! Through internships I got to dip my toes into different types of physics. I worked part-time throughout my college career at the Air Force base, first in San Antonio and then in Houston. I worked in optical radiation physics and particle physics. Optical radiation is essentially putting lasers on eye tissue and seeing how long that can go on before it is damaging. I took a gap year and worked there full-time.

A gap year? Why?
My wife was a year behind me, and I wasn't ready to do long distance. So I waited and we both moved to New York for graduate work at the same time. That was 2012. I went to Syracuse University and she did a master's in psychology and religion at Union Theological Seminary in Manhattan. On weekends we pretty much switched off who was going where. We're both from small towns in Texas, and I always wanted city living, so I liked to "vacation" in the city.

You live in Chicago now. How do New York and Texas compare?
Everybody says the south is very red, full of racism, but both of us experienced microaggressions when we moved up north. It was interesting to be going through very rigorous schooling and dealing with microaggressions at the grocery store. I processed feelings of otherness by finding a supportive study group within the cohort at school. I also took a unique route to finding people I felt comfortable with—I worked part-time in a retail clothing store. It was an all-female group, many of us women of color, and that helped tremendously with feelings of isolation,

FERMILAB / REIDAR HAHN

This project has the potential to revise understanding of the building blocks of the universe.

otherness, and not belonging. And I really enjoy plus-size fashion!

Chicago is better. It's more diverse here. I only applied to post docs at Fermilab because they put money where their mouth is when it comes to diversity inclusion. But I did have to switch from studying neutrinos in grad school to studying muons.

Neutrinos and muons. Sounds like we're back in that sci-fi television show you used to watch!

Both are subatomic particles. A muon is the heavier brother of an electron. An electron is another subatomic particle, and we know about it because it's what goes around the nucleus of an atom. When you have moving electrons you get current—the electricity that powers everything around us. A muon is heavier, and after 2.2 microseconds it decays into an electron. To study a muon, we put millions and millions of them into a 50-foot diameter magnetic ring, where they dance like a spinning top. Studying the choreography of the muon we can probe into undiscovered physics.

You work on a project called the Muon g-2 Experiment. Can you explain it?

Muon g-2 has the potential to revise out understanding of the building blocks of the universe. We particle physicists collate our knowledge of these building blocks into the theory called the Standard Model. The Muon g-2 Experiment has the potential to lift up the veil of the universe and point us toward its secrets.

When I started working on this experiment, I didn't grasp what the scientists were doing, and I thought they were just adding a few decimal points (of precision) to an experimental measurement they had done before. But then I realized that the more precise the measurement, the more exotic the physics we can probe.

This work has implications for revising how we understand the Standard Model of particle physics. We know the building blocks that make up atoms, which then make up everything else around us. Quarks make up the neutrons and protons inside the nucleus, and the electron swirls around it. These building blocks are in the first generation of matter. When you look at the Standard Model, there are two more generations, and we don't understand why, or if there are more.

If you look at the fundamental forces in the Standard Model, the "weak force" is how the neutrinos communicate with what's around them, and the "strong force" keeps the nucleus bound. These forces are carried by particles—W and Z bosons for the weak force and the gluon for the strong force. One of the fundamental forces not accounted for in the Standard Model is gravity, which we know is all around us. But for some reason, based on what we know now, no such theory for a quantum gravitational force has worked and no gravitational force-carrying particle (coined gravitation) has been discovered yet.

What does it take to explore fundamental forces?

We test all of this with particle physics detectors and accelerators. All these weird, wonky theories—we know we're missing something and the closer we get to answering one question, many more questions pop up.

Fermilab is building the next generation of detectors. Among the questions we're trying to answer, finding out if there's a fourth neutrino messing about is high on our list these days.

Virtual particles pop in and out of existence in a vacuum. We know which ones are supposed to pop in and when, and that this will change the choreography of the muons, which spin like a spinning top in a magnetic field. When we measure this spinning, or precession, at very high precision, we can see if the muons change in an unexpected way. If that happens, it means a particle we don't know about has just appeared, just come into the vacuum. It's pretty awesome.

Physics presents the possibility of studying what no one has seen before.

You mentioned that Fermilab is committed to diversity.
Fermi is walking the walk. If we're going to change the face of STEM, we need people like me to communicate science effectively. Fermilab put me through classes on science communications, and they encourage me to meet with students and teachers to tell them about the work I do. Most recently I had this hair-brained idea that Fermi should partner with Wakandacon. That's the comic book convention based on the fictional African country in the comic book and film *Black Panther*. Wakondacon is stocked in Afrofuturism. It's for black people, created by black people, and a lot of Chicago-based writers, artists, and business owners come together there and share their art. The *Black Panther* film is also steeped in STEM.

The first Wacandacon was two years ago. I reached out to the creators and asked if I could give a talk there on what it's like to be a physicist. My talk was well received, but for me it was more than that—it was soul-filling to see all these black people with all these interests like mine, in science and physics. The community they created with this was so awesome.

How do you talk about your experience as a black woman in the world of physics?
I'm always forthright when I talk about the issues that black women have to face in our field. There are only about 150 black women with a Ph.D. in physics—and there are about 22,000 men, mostly white. When I give a keynote presentation, I have a slide dedicated to those numbers.

There's still this really bad idea out there that men's brains are better than women's, which is absurd. The harder the sciences, the more you have to "use your brain," and the more masculine the career. Then there's this compounding nature of being part of an underrepresented group, of many underrepresented groups. I focus on intersectional diversity and inclusion and make sure I'm not using statements like "women and minorities" or losing sight of lesbian women with particular issues.

What advice would you give to girls interested in physics?

I tell girls interested in STEM or physics: The physics are not the only thing that's going to be hard going on this path. But there are women that look like you who have done it before. One hundred and fifty women. There's hope. And we need you. We think differently. We've gone through different stuff and we have grit.

I'm still in shock that Lyda Hill was able to really carry off the "AAAS IF/THEN" ambassadorship—words are hard to come by. They chose 125 women in STEM to help inspire the next generation of STEM pioneers. I kept thinking, well this is totally going to work, because I'm so inspired right now! First the fact that I could see so many black women in one place was so awesome to see. Then there was this ripple effect. The conference was for women and put on by women—they were at the helm, in the driver's seat. The photographers were women. We could all really lean into the fact that women can lead.

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How Art Helps Science Advance

Jasmine Sadler on STEAM and problem solving

BY MARY ELLEN HANNIBAL

A **GROUP OF GIRLS GATHER** at a national park in San Diego to learn. They watch an elegant young woman pirouette before them, her arms arced wide. Then she does it again. This time her arms are closer to her body and her turn is faster. But the girls are not here to learn dance. "Let's look at this technically," Jasmine Sadler explains. "I turn more slowly when my arms are farther out. Pulling them in, my radius is shorter and I can turn faster. This is called angular velocity." The girls are learning science.

"Whatever you think a 'scientist' looks like in your head," Sadler tells them, "picture me. I'm a scientist and you can be, too." Sadler is a dancer, an engineer, and a rocket scientist. Her day job is founder and CEO of the STEAM Collaborative, through which she convenes workshops and provides technical expertise for a wide variety of STEM (science, technology, engineering, and math) and STEAM (science, technology, engineering, art, and math) programs. Sadler is dedicated to helping young people of color, especially girls, see themselves in roles they may not have previously imagined for themselves, and she helps give them the tools they need to achieve their dreams.

COURTESY OF JASMINE SADLER

The arts can help you approach the science.

Have art and science been twin tracks for you?
They just go together for me. I don't separate them. I'm originally from Detroit, and both of my parents were computer specialists for the government. From an early age I danced—tap and hip-hop, but ballet is still my favorite. In eighth grade I began tutoring some of my fellow students in algebra. The teacher would give us a concept, and I would reteach it. I'd say, "this is one way to understand this, and here is another way." I participated in the Detroit Area Pre-College Engineering Program and started coding and designing a website in high school. At the same time, I was always dancing. To solve problems effectively, you need to activate both sides of the brain. And dance is full of joy.

Before launching full time as a social entrepreneur, you worked for 10 years as an aerospace engineer.
I graduated from the University of Michigan with a degree in aerospace engineering in 2009. I chose the specialty in response to the 2003 Columbia space shuttle disaster. I thought, no one should experience tragedy doing the coolest job "out of this world." I wanted to make sure it never happened again. One of the main reasons to go into engineering is that it's a direct pathway to helping people.

My career as an aerospace engineer is all related to turning air into energy by improving aircraft engines, wind turbines, or oil/gas turbines. As a test engineer, I led teams of men, most of them twice my age, in manufacturing. When there was an issue with the equipment or with a test, my job was to guide them to a solution.

Our business was in selling oil and gas turbines, and we had to test them before the final sale. (A turbine is a type of engine that produces power by revolving a moving flow of air, gas, or other fluid.) Sometimes the vibrations made by the turbines were too much, and we had to shut them down. Sometimes my team would have to contact me in the middle of the night. Using software on my laptop, I could recommend where to counterbalance the weight and by how much, to keep the vibration within set limits. I would press "print" from my bed directly to the test cell. I'd bring in donuts the next day, to reward everyone for installing a new solution.

What projects have you taken on at the STEAM Collaborative?
My company began as a math-tutoring service to prepare children of color to be the smartest students in class. Educators began to request that I spend more time in the classroom, telling the students about my path and doing hands-on workshops. One example is a STEM program for high school boys. Football players came to our session in their uniforms. I asked them, "What is a problem you would like to help your community solve?" and they settled on alcohol, cigarette, and drug use in their high school. They decided to build an app to help make counseling available to students without their parents finding out, which also allowed them to stay cool and popular—the issues are around mental health and self-worth.

This is an example of a problem requiring both art and math. The boys not only created the app, they also made a pitch deck to market it. I asked them: "How many people do you expect to download your app?" I had them use San Diego census data to get actual numbers in their target age group, 18-24. They

TEACHABLE MOMENT Jasmine Sadler with some of her students.

COURTESY OF JASMINE SADLER

had to calculate the percentage of the population targeted by the app—now I'm teaching them conversions, and that's math. The product is all about numbers, what your financials are—that's a linear line. At the same time, the pitch deck has to look nice, it has to be designed well from an artistic perspective.

Did you learn about financial systems as an engineer?
I also have an MBA.

You left engineering fairly recently to concentrate on your nonprofit work. Why?
I became dissatisfied with my job because I felt it wasn't making me a better engineer. I was becoming better adapted to being an engineer, being part of the culture of engineering. I was learning how to get along in a world filled with white men. They weren't charged with learning my culture, but I had to embody theirs if I was to have any chance of success in the system. Ultimately I didn't think that was where I should focus my energy. I realized that I need to make it more normal for girls and people of color to be engineers, because when their numbers are greater in the profession, it will become inherently more inclusive.

You not only work directly with students, you also convene leaders in STEM and STEAM.
In 2017 I received a Social Innovation Challenge grant. I intended to create a STEAM camp for middle school students in San Diego, and attended many

of the camps already going on, to document lessons learned. My notes included: Pay attention to the homeless student population—these are students who need three meals a day. In some cases there was no actual art integrated into the program even though it was called STEAM. Especially when I'm working with girls, I make physics more relatable by having them dance. One example is to have them time each other dancing down a runway, then divide the distance by time to calculate speed.

Since there were a lot of STEAM camps already going on, I revised my idea and thought: Why not help support the leaders to do better STEAM? So I brought regional STEAM leaders together at Point Loma Nazarene University (where I got my MBA). The focus was on addressing inefficiencies in their own camps and programs. I brought together 20 STEAM leaders, including the head of a robotics club. It included a leader from Jack and Jill of America, which is a nationwide membership organization focused on African-American mothers with children ages 2-19, focused on developing leadership. Each program leader was reaching at least 20 students each, so I realized this was a way to truly amplify impact. I've put on three STEAM Leader Summits now. The first event became the cornerstone of the STEAM Collaborative.

To solve problems effectively, you need to activate both sides of the brain.

What words of wisdom do you have for students of color about pursuing STEM and STEAM careers?

There's no doubt it's really hard to be the only woman engineer on a job, the only African-American. It's isolating, but you have to keep yourself focused on overall goals. The hard part about engineering is not the engineering itself—it's the largely white, largely male culture. The only way for us to change that is to get more people of color and more women into engineering. Engineering is one of the few professional avenues where a bachelor's degree is sufficient—you don't need to get a master's. I tell college students who are becoming engineers, this isn't about you any more, it's about helping the community. Once you start the engineering program, finish it. If I hadn't received my degree, I wouldn't be in a position to show others that they can do it, too. The only way I can help girls become rocket scientists is to be one myself. It's all about identity, and modeling possibilities.

Any further thoughts on creative problem-solving?
Even if students decide not to pursue a career in STEM, I fully encourage them to master science, technology, engineering, and math. These all provide different ways to solve a problem. I also encourage them to add the arts to their experience, because art also enhances problem-solving—it's creative. The arts can help you approach the science.

Personally, I target students who identify as female and African-American because there are problems in their communities that may never find solutions if they don't create them. Once they learn more about STEM and STEAM opportunities, they can begin to innovate, invent, and patent solutions.

MARY ELLEN HANNIBAL is the author of *Citizen Scientist: Searching for Heroes and Hope in an Age of Extinction*, the winner of Stanford's Knight-Risser Prize in Western Environmental Literature, and a Stanford media fellow.

A Voice for the Trees

Shyla Raghav uses her ecology background to advocate for the environment

BY MARY ELLEN HANNIBAL

WHEN SHYLA RAGHAV TALKS, it's easy to listen. In fact, she's mesmerizing, and news outlets like CNN frequently call upon her to explain and comment on threats to our environment. As Vice President for Climate Change for the nonprofit Conservation International (CI), Raghav works tirelessly to push the needle on our urgent need to act. Raghav has been a key negotiator in United Nations climate talks and helped to forge the Paris agreement signed by 195 countries. She leads CI climate change work in 30 countries around the globe, emphasizing a "new environmentalism," based on maximizing nature's fundamental role in creating and sustaining a healthy Earth.

FONA / SHUTTERSTOCK

EARTH ADVOCATE Shyla Raghav leads climate change work in 30 countries around the globe, emphasizing how we can maximize nature's fundamental role in creating and sustaining a healthy Earth.

NICHOLAS KARLIN

You've helped shape the conversation about climate. Where are we now?

In the beginning the prevalent narrative was "is the science to be believed?" Other countries moved beyond the questioning of scientific fact earlier than we did. There's been an active effort in this country perpetrated by a number of think tanks funded by fossil fuels and with vested interests that stand to be disadvantaged by decarbonization. They diverted attention from scientific fact and delayed necessary conversation on action.

What are the biggest challenges you face in communicating about climate change?

The hardest thing is to motivate action while recognizing there is uncertainty. It's also hard to keep optimistic and hopeful with the dire and concerning science. If individuals can do one thing, it's to talk about climate change more. This will help ensure it is a voting issue and that our leaders take it seriously. It will also help unleash creativity and ingenuity around solutions.

Climate change is also difficult to confront in terms of human cognitive behavior. We're conditioned to act for our short-term benefit. Motivated by income and livelihood, it can seem counterintuitive to focus on the long term. Addressing climate change means making upfront investments for a benefit to be accrued in the future. It quite often means preventing a harm rather than creating value or growth. You can see the results of this mindset—today we are paying for damages from disasters rather than seeing that preventing them would mitigate those damages altogether.

But this is changing. Climate change impacts have become immediate, which is compelling us to become immediate also. We're evolving to ask how science can help us use limited resources and to decarbonize. I see people more concerned with how we are going to create solutions.

Can you describe your work?

Conservation International works to preserve and protect nature for the well-being of humanity. For too long people saw the environment and our own future as two separate things. CI is built around a deep understanding that people need nature to survive and to thrive. We use sound science to work with local communities and governments to create incentives and policies to support nature.

For example, CI established the first debt-for-nature swap in the world. In exchange for forgiving their national debt, the country of Bolivia protected nearly 4 million acres of habitat. We've utilized innovative financial mechanisms and payments for ecosystem services. To stop encroachment into forests,

The hardest thing is to motivate action while recognizing there is uncertainty.

local communities receive payments or benefits like schools, or training for farmers. We try to create long-term change while protecting the rights of people.

Beyond simply advocating for the intrinsic value of nature, we help articulate its economic value—quantifying the benefits of water filtration, storm prevention, and pollination. If policy makers could better understand nature's monetary value they would likely protect it rather than capitulating to new mines or dams.

What is your day-to-day like?

I spend a lot of time in meetings, internally, and with external partners, whiteboarding and looking at challenges. Cross-pollinating ideas is so important. A key part of my job is to facilitate free thinking in open spaces with people who think differently. I travel and communicate with diverse audiences—I constantly like to push myself to see how climate change is affecting people on a local level and to look at more effective ways of deploying solutions.

Do you have advice about how to approach climate change with varied audiences? Do you have to simplify the science?

I don't simplify per se, but I do recommend tailoring the message to address the main motivation or interests of your audience. Focusing on local impacts is also an important way to communicate climate change as a global problem, but one that also affects people in a very personal way.

One of the major drivers of climate change is deforestation of the Amazon. CI recently embarked on a massive project to restore trees, engaging indigenous people to help and to benefit. Can you tell us about it?

I'm really excited about the project, which is the largest tropical reforestation project ever undertaken in Brazil. We are utilizing a new planting technique called *muvuca*. Well, it's new to people today, but *muvuca* mimics the way nature actually works and is based on a traditional seed dispersal technique. Seeds from

more than 200 native species are spread over deforested land, and the seedlings compete for space. The hardiest thrive. It is much more effective than planting a single species sapling by sapling. Local communities are involved on every level. The project has kicked off and we're fundraising for it so we can reach the full goal of planting 30 million trees. It gives me great hope.

Where did your passion for the environment originate?
When I was quite young I saw *Ferngully*, an animated film about the impacts of deforestation. The girl at the heart of *Ferngully* is totally upended by the destruction of her forest home. I couldn't believe it—I couldn't imagine a world that condoned and even expected rampant destruction of the environment from which we get so much life-giving support. I developed a passion to help protect nature.

For too long people saw the environment and our own future as two separate things.

How would you define your career path?
I've known from the beginning that I would pursue a career deeply connected with our environment. When I started college, I pursued science to understand how ecology functions. Ultimately, I wanted to help design policy and communications tactics to help build broader community support for the environment, but first I knew I had to know how nature works. Applied ecology was a science degree—I took all the core science classes but then had an intentional focus on applying that to global challenges. I got a master's degree (from Yale) in environmental management, an interdisciplinary focus involving science and law, international relations, design, and architecture—looking at the world as a global system. I learned how to apply scientific knowledge to the classical decision-making that policy makers, corporate leaders, and investors grapple with daily.

Sometimes it seems there's a divide between people dealing with problems in their own backyard and academic science talking from an ivory tower. Have you dealt with that?
I was pretty thoughtful about the evolution of my career. I ensured I had on-the-ground field experience early on. Right after grad school I managed climate change adaptation projects in the Caribbean. That gave me more confidence and credibility in

the environmental community. Without it I would have been providing theoretical rather than practical knowledge that comes from having lived and worked in a developing country. It gave me the self-confidence to be in spaces dominated by older white men. I perfected a voice that had merit and deserved to be part of their conversations. It was really important in my own personal development.

I don't work in a lab in a traditional scientific career, but I share my understanding of science in negotiations like those at the U.N. and in management projects on the ground. I help communicate, with respect and integrity, what the science is telling us about what is happening to our planet. And I give people information about what they can do.

Eighty percent of climate change refugees are women, and women are 14 times more likely to die in a climate-induced disaster. How does being a woman impact your work?

In the past five years we've seen many more women and minorities getting into environmental work. Younger women are instrumental in getting the next generation on board as advocates for the environment. I've actually found a lot of support and encouragement in this direction.

Have you faced particular hurdles as a woman of color?

I was born in India, and lived in Australia before moving to Irvine, California when I was 6. While my accent was made fun of in India and Australia both, I felt there was no expectation of what it was to be a Californian. There was no mold for me to fit into. About half of Irvine was of Asian or Latin descent—being surrounded by diversity really helped me to feel like I belonged. It allowed me to see cultural diversity as an asset. I could shape my own identity and future, drawing on Indian culture and also on the independence accorded me in the United States. The combination helped me become a more effective practitioner of climate change and climate justice issues. Having an Indian background gave me a deeper understanding of the connection between human well-being (poverty) and the environment. It has been incredibly meaningful for me to be able to consider how development issues intersect with ecology and the environment.

One of the big impediments to saving nature is that we don't have full enough knowledge of where species are on a landscape, and when. Is CI helping with this?

CI is documenting our natural biodiversity using motion-activated camera traps in natural areas. This project utilizes local knowledge hand-in-hand with technology. We rely on local knowledge for many dimensions of the camera traps, from placing them to identifying species. We co-create solutions with local people at scale, utilizing indigenous knowledge, for example, of drought-tolerant seeds and planting seasons. We have so much to learn as we try to make our food systems more resilient. We have a project in Peru with a community of indigenous women—we are helping to digitize their knowledge of different seeds and other elements of the forest. The work is also helping to bridge a divide between younger women, mothers, and grandmothers of the community.

In the face of global political challenges, we can still work with local people and reverse negative trends through inspiration, hope, and practical solutions.

MARY ELLEN HANNIBAL is the author of *Citizen Scientist: Searching for Heroes and Hope in an Age of Extinction*, the winner of Stanford's Knight-Risser Prize in Western Environmental Literature, and a Stanford media fellow.

We Can All Be Scientists

Lessons for your classroom

For detailed lessons, materials, and resources—including the full text of the classroom activities summarized here for each of the four Geoscience Women in STEM—please visit:
WWW.EARTHSCIWEEK.ORG/IFTHEN

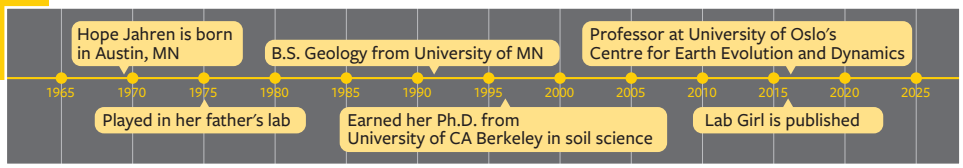
EXPLORE THE JOURNEY EACH WOMAN IN STEM TOOK ON HER WAY TO BECOMING A WORLD-CLASS SCIENTIST OR ENGINEER

WHO IS A SCIENTIST?

STUDENTS GET WARMED UP thinking about "who is a scientist" through a series of images, before analyzing interviews with the Geoscience Women in STEM in a close read. Then students produce a timeline of the scientist's journey focusing on their pathway to finding "their science." Students develop a timeline of their own life events as they consider how STEM is relevant in their lives and future path. They wrap up the lesson exploring an image array that encourages them to ask questions about the work scientists could do in those locations, and how that work might affect the people there.

NGSS CONNECTIONS:

- **Science and Engineering Practice:** Obtaining, evaluating and communicating information
- **Nature of Science:** Science is a human endeavor



HELP STUDENTS GET A GLIMPSE OF EACH SCIENTIST'S DISCOVERIES

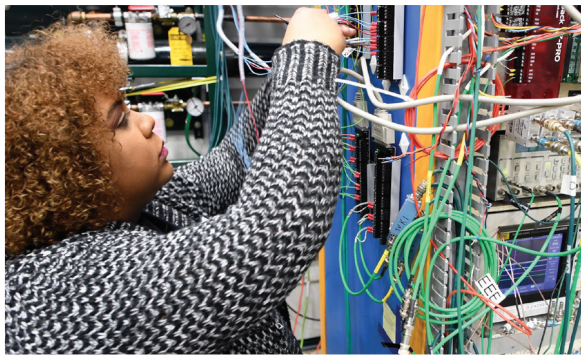
JASMINE SADLER

STUDENTS GET THE OPPORTUNITY to investigate the areas of science in which the scientists work. In the lessons devoted to Dr. Jahren's work, students explore her love of trees working with tree ring data to model paleoclimates. Students delve into climate change as the "new normal" in the lessons focused on Shyla Raghav's work. They consider changes in ocean pH, bud burst, and food production. How the world harnesses air to turn it into energy is a foundational problem in Jasmine Sadler's work. These lessons use design thinking principles to design and test wind turbines. Finally, Dr. Jessica Esquivel's work takes us to the "bleeding edge of the universe" as students try to "see" things that cannot be seen, communicate across the vastness of space, and consider space within a tiny, single atom.

NGSS CONNECTIONS:

- **Science and Engineering Practice:** Analyzing and interpreting data, Developing and using models
- **Crosscutting Concepts:** Systems and system models, Patterns, Cause and effect, Energy and matter, Stability and change

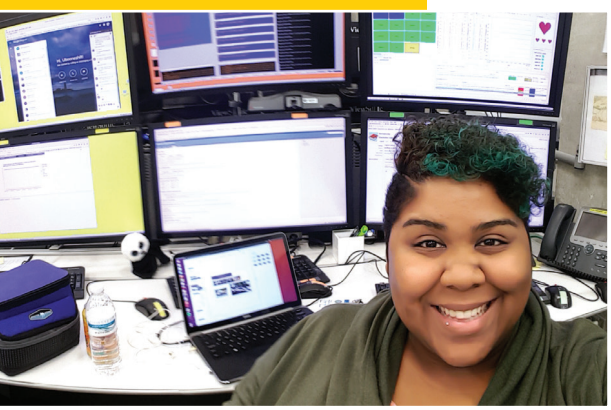
JAHREN TIMELINE GRAPHIC: AGI; PHOTO COURTESY OF JASMINE SADLER.



STEM WORK occurs in many settings. Hope Jahren studying in the environment; Shyla Raghav at an international climate meeting; Jasmine Sadler exploring technology with children; Jessica Esquivel setting up electronic lab equipment.

BUILDING STRONG CONNECTIONS BETWEEN STUDENTS AND THE SCIENCE

STUDENTS EXTEND THEIR THINKING about who is a scientist through an adventure that brings the science to their local area, helping students see how science is all around them. In these lessons students seek evidence of the carbon cycle on their school grounds, or in their state. They map their personal networks, identifying connections and growth areas, and they search for the real science in science fiction. These activities help students realize that each scientist sees the world in their own way. Their individual perspectives drive their curiosity. Depending on the questions that scientists ask, their work may have them gazing out into space or looking through a microscope. Scientists seek answers in all kinds of places. In the wrap-up activity, students use the image array activity to reflect on their perceptions about scientists, the work that scientists do, and why their thinking has changed.



JESSICA ESQUIVEL

NGSS CONNECTIONS:

- **Science and Engineering Practice:** Engaging in argument from evidence, Asking questions
- **Crosscutting Concepts:** Systems and system models, Cause and effect, Stability and change

EARTH SCIENCE WEEK

AGI american geosciences institute
connecting earth, science, and people

EDUCATION CONTENT: AIDA AWAD, CHERYL MANNING, LAURA HOLLISTER, ED ROBECK. PHOTOS CLOCKWISE FROM TOP LEFT: COURTESY OF HOPE JAHREN; © CONSERVATION INTERNATIONAL; COURTESY OF JASMINE SADLER; FERMILAB/REIDAR HAHN; COURTESY OF JESSICA ESQUIVEL.

Chiara Mingarelli

The astrophysicist on the joys of science

INTERVIEW BY MICHAEL SEGAL

How successfully is science dealing with personal biases?

It's difficult because people have preconceived notions of what a scientist should look like, and people have implicit gender biases. You can take one of the Harvard implicit bias tests and find out that you take male scientists more seriously. Even I do! And I'm a female scientist! Acknowledging this bias exists is one way of getting rid of it. You should always try to keep that in the back of your mind when you're evaluating scientific research: Am I really looking at this objectively? It's been shown that science, when we have a lot of diversity, is just so much better. People bring in different ideas, you're more productive. But the hard reality is that people like what they know—they like having clubs who are all familiar to each other. That's really difficult to change, and I think change will come slowly.

How important is crossing boundaries in your own scientific work?

One of the things that I find the most fulfilling and enjoyable about my work with gravitational waves is looking at preconceived boundaries and then getting rid of them, using all of the information that people thought were separated into different categories and then putting it all together. This is what I did for example in a paper that I wrote with some of my Australian colleagues, where I looked at measurements of completely different gravitational wave frequencies, which when you put them together you get something much better. This is another reason why I enjoy researching the ability to bring together electromagnetic counterparts with gravitational wave signals, because again it's kind of two things which should be separate, but when you put them together you get so much more.

ILLUSTRATION BY ANDY FRIEDMAN

NAUTILUS OCEANS

APRIL 29, 2020

Working with global ocean research and conservation organizations, Nautilus launches a new channel dedicated to exploring ocean science

http://oceans.nautil.us/

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Jess Cramp
IF/THEN Ambassador

Shark Researcher &
Marine Conservationist

Photo by Andy Mann

EMPOWERING THE NEXT GENERATION OF STEM INNOVATORS

IF/THEN is part of Lyda Hill Philanthropies' commitment to fund game-changing advancements in science and nature. IF/THEN seeks to further advance women in STEM by empowering current innovators and inspiring the next generation of pioneers.

Rooted in a firm belief that there is no better time to highlight positive and successful female professional role models, IF/THEN is designed to activate a culture shift among young girls to open their eyes to STEM careers by:

- funding and elevating women in STEM as role models
- convening cross-sector partners in entertainment, fashion, sports, business and academia to illuminate the importance of STEM everywhere
- inspiring girls with better portrayals of women in STEM through media and learning experiences to pique their interest in STEM careers.

IF WE SUPPORT A WOMAN IN STEM, THEN SHE CAN *change the world.*

To learn more, visit www.ifthenshecan.org

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Photo by Andy Mann