

NAUTILUS

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



Science Is Her Home

MEET "LAB GIRL" HOPE JAHREN p.2



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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 an Ambassador for IF/THEN, an initiative of Lyda Hill Philanthropies. The goal of IF/THEN (www.ifthenshecan.org) is 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 will inspire the next generation of STEM pioneers. IF/THEN is highlighting 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 middle school 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 14 and 15, which link Dr. Jahren’s work to related activities for students and teachers. Additional IF/THEN Ambassador profiles and educational guidance will be featured on AGI’s Earth Science Week website (www.earthsciweek.org) during and after the 2019 celebration. IF/THEN will continue to offer profiles of trailblazing women geoscientists 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.”

—Kevin Berger
Nautilus Editor

The views and opinions expressed here are those of the authors and do not necessarily reflect those of the American Geosciences Institute, Lyda Hill Philanthropies, or *Nautilus*.

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.

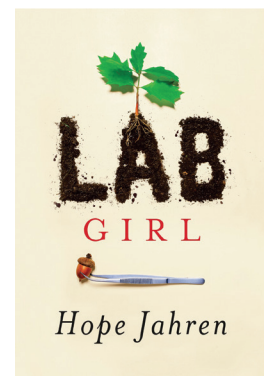
How has your science changed your view of the world?

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."



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 arbore-tums 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 over-board 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

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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.

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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*

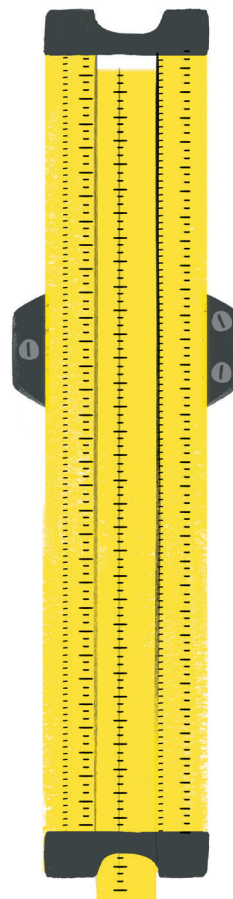
of green, the million different subtle shades of green are amazing. Something about working in Ireland and being in Ireland is so immersive in the plant world. And it rains, which is miserable. It's miserable to be outside in the rain for hours on end, not moving around, kneeling, counting moss plants 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?

CO₂ 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

People are drawn to trees. They're bigger than us in almost every way imaginable.



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.



We Can All Be Scientists

Lessons for your classroom

For detailed lessons, materials, and resources—including the full text of the three classroom activities summarized here—please visit:

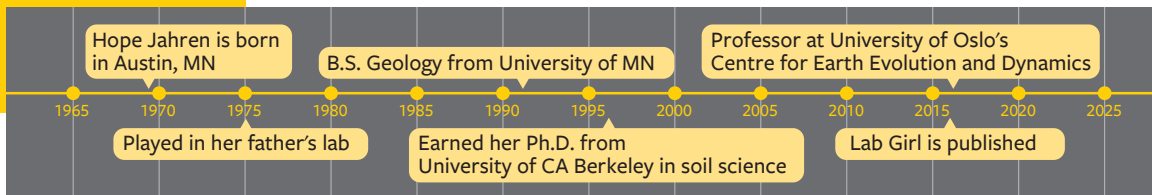
WWW.EARTHSCIWEEK.ORG/IFTHENAMBASSADORS

EXPLORE THE JOURNEY “LAB GIRL” DR. HOPE JAHREN TOOK ON HER WAY TO BECOMING A WORLD-CLASS SCIENTIST

IN THIS LESSON STUDENTS get warmed up thinking about “who is a scientist” through a series of images, before analyzing an interview with Dr. Hope Jahren using a close reading strategy. The students will produce a timeline of Dr. Jahren’s journey from a young girl to a world-class scientist. Students are invited to 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 with a video featuring Dr. Jahren talking about how scientists have been portrayed to the public.

NGSS CONNECTIONS:

- **Science and Engineering Practice:** Obtaining, Evaluating, and Communicating Information
- **Nature of Science:** Science is a human endeavor.

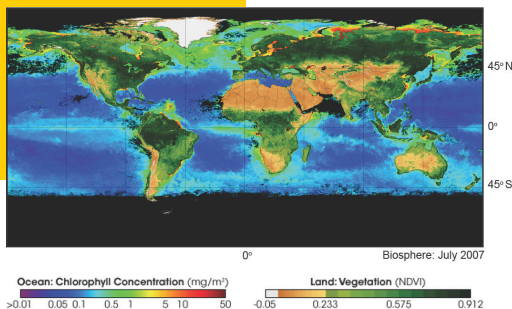


TREES: THE COMPLEX STORY THEY TELL IF WE JUST LISTEN

STUDENTS GET THE OPPORTUNITY to investigate the science that Dr. Jahren discusses in her videos. In the first activity, students explore Dr. Jahren’s love of trees as they work with a tree ring simulation, analyze tree ring data, and create a model to demonstrate what they have learned about paleoclimates. In the second activity, students analyze climate data from sites around the world to understand how climates are defined. Then they connect climates and biomes using satellite imagery. Students examine NASA data and read an article about current changing rates of photosynthesis. Finally, students have the opportunity to design and conduct an experiment where they investigate different plant stressors.

NGSS CONNECTIONS:

- **Science and Engineering Practice:** Analyzing and Interpreting Data, Developing and using models
- **Crosscutting Concepts:** Systems and system models, Patterns

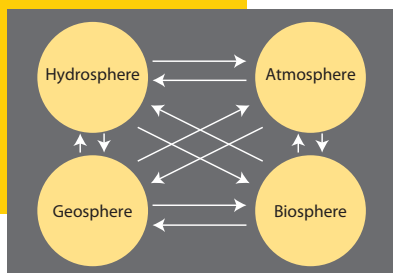


MAP OF EARTH'S BIOSPHERE FROM GLOBE.GOV; TIMELINE GRAPHIC: AGI.



HOPE JAHREN'S CAREER has included a wide variety of experiences and work settings.

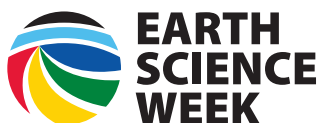
**THE CARBON CYCLE
AND YOUR TOWN —
MODELING ENERGY
AND MATTER FLOW
WHERE YOU LIVE**



JOURNEYING THROUGH THE CARBON cycle, students will move from one simulated reservoir to another as they practice systems thinking skills. A visit to their school campus provides new opportunities for students to make place-based observations and categorize them into the four spheres: geosphere, hydrosphere, biosphere, and atmosphere. Developing a visual model supports students as they consider interactions between and among the components of the spheres they identified, and build their systems thinking skills. As students wrap up the lesson they return to their personal timelines to explore how their thinking has changed related to their talents and STEM.

NGSS CONNECTIONS:

- **Science and Engineering Practice:** Developing and using models
- **Crosscutting Concepts:** Systems and system models



EDUCATION CONTENT: AIDA AWAD, CHERYL MANNING, LAURA HOLLISTER. TWO LEFT PHOTOS BY MATT CHING. RIGHT PHOTO COURTESY OF HOPE JAHREN. FOUR SPHERES DIAGRAM: AGI.



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

Just Think.

We promote science, education, and the literary arts to expand public understanding of fundamental questions of scientific inquiry and their connection to culture. Through the creation of print, electronic, and visual media of the highest quality and depth, NautilusThink seeks to connect science to our everyday lives and explore the frontiers of scientific, mathematical, and philosophical inquiry and the human spirit.

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Jess Cramp
IF/THEN Ambassador

Shark Researcher &
Marine Conservationist

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.

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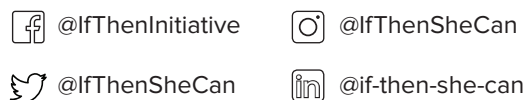


Photo by Andy Mann

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