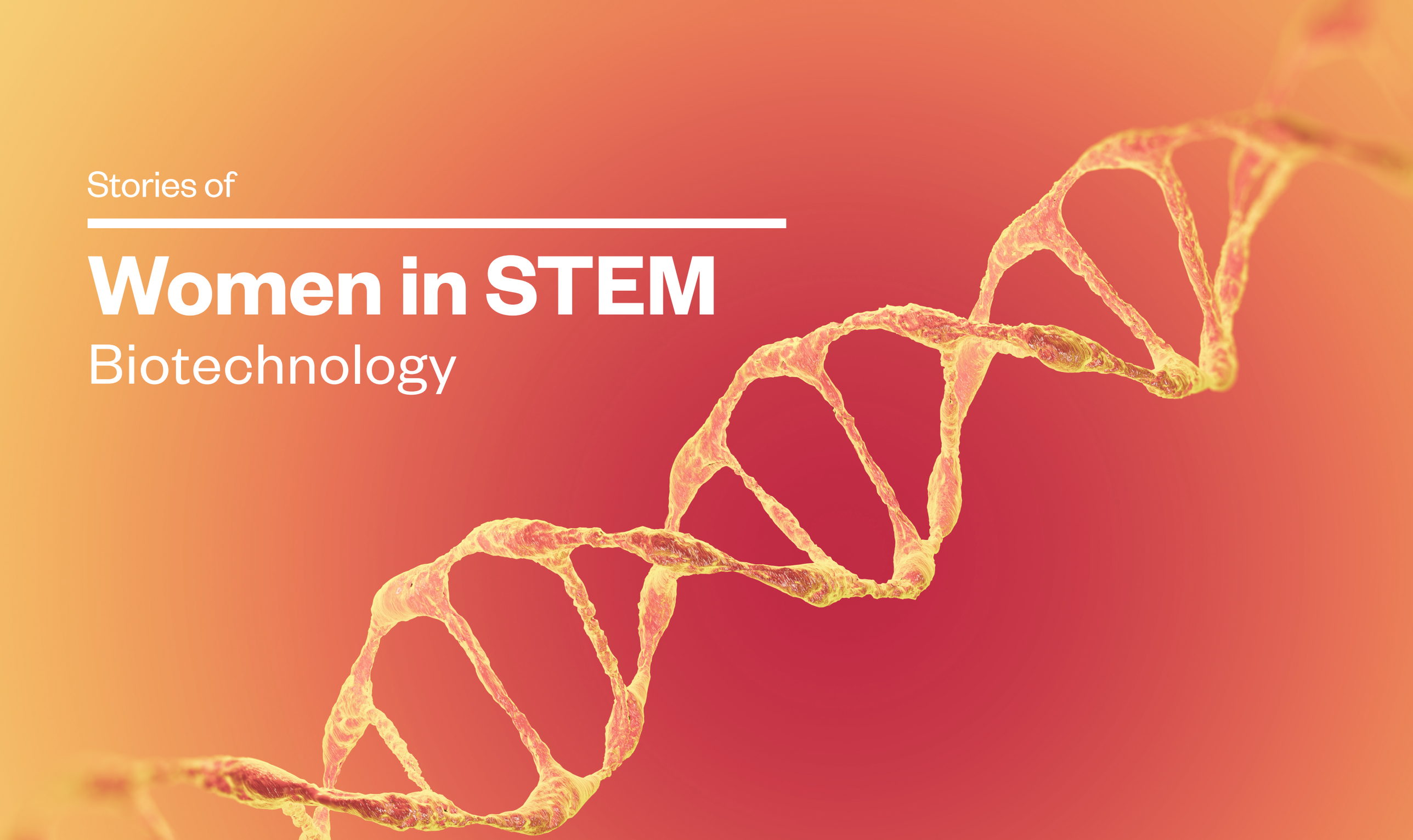
Stories of

Women in STEM

Biotechnology



Smithsonian
Science Education Center

STEM²D .org

The Smithsonian Science Education Center (SSEC) is an education organization within the Smithsonian Institution. The SSEC's mission is to transform *K-12 Education Through Science*™ in collaboration with communities across the globe. The SSEC promotes authentic, interactive, inquiry-based K-12 STEM teaching and learning; ensures diversity, equity, accessibility, and inclusion in K-12 STEM education; and advances STEM education for sustainable development. The SSEC achieves its goals by developing exemplary curriculum materials and digital resources; supporting the professional growth of K-12 teachers and school leaders; and conducting outreach programs through LASER (Leadership and Assistance for Science Education Reform) to help schools, school districts, state education agencies, and ministries of education throughout the world implement inquiry-based science education programs.

The Smithsonian Institution was created by an Act of Congress in 1846 "for the increase and diffusion of knowledge…" This independent federal establishment is the world's largest museum, education, and research complex and is responsible for public and scholarly activities, exhibitions, and research projects nationwide and overseas. Among the objectives of the Smithsonian is the application of its unique resources to enhance elementary and secondary education.

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Introduction

Dr. Carol O’Donnell

Director
Smithsonian Science Education Center

Growing up in inner city Pittsburgh in the 1960s and 70s, I was always tinkering—designing something new and putting my "inventions" in a little notebook. I also loved observing the world around me. In my small backyard, I was always experimenting—studying native plants during the day and observing the stars at night. I didn't know much about what it meant to study science, technology, engineering, or math (STEM) back then. I just knew that I loved making, testing, experimenting, inventing, and solving problems.

In high school, I got my first job at a library as a "Page." I would put books back on the shelf when people returned them, fix books that were broken, and help people find book titles that interested them. Books played such an important part in my life. And it was through books that I was first introduced to what it meant to be a "real scientist."

I don't recall having any women scientists in my life, though. At least not until I went off to college. That's when I got my first job at a museum—the Carnegie Museum of Natural History in Pittsburgh. They had just built the Benedum Hall of Geology and the Hillman Hall of Minerals and Gems. I fell in love with the history of our planet, and went on to get a Masters Degree in Geosciences with a focus on planetary geology.

I also had a second full-time job in college working in the Gastroenterology Lab at the hospital (yes, I worked a lot back then). Mary Mylo was the lab's Director, and I will never forget her. Other than my mother, Mary Mylo was my first "real mentor." One day, while working in the lab, I met a famous liver transplant surgeon, Dr. Thomas Starzl. When people were sick with liver disease, he would "transplant" (or put into their body) a liver from someone who had died. But our bodies tend to fight off new organs. So Dr. Starzl experimented with a new drug—Cyclosporine. I worked with him by administering the drug to patients and recording their side effects. Dr. Starzl knew that if he could get that drug to work right, it would help the body "accept" the new liver. And that could save the person's life.

Cyclosporine is produced by microorganisms and is one example of biotechnology. Biotechnology is the use of biological processes, organisms or systems to produce products that are anticipated to improve human lives.

Cyclosporine was a new technology back in the 1980s. But it isn't today. People didn't think it could work. But it did. Yet it wasn't always easy. Who would get the drug? How much would it cost? The questions were hard. Sometimes, it is difficult to imagine all the ways science, technology, engineering, math, and biotechnology can help improve our lives.

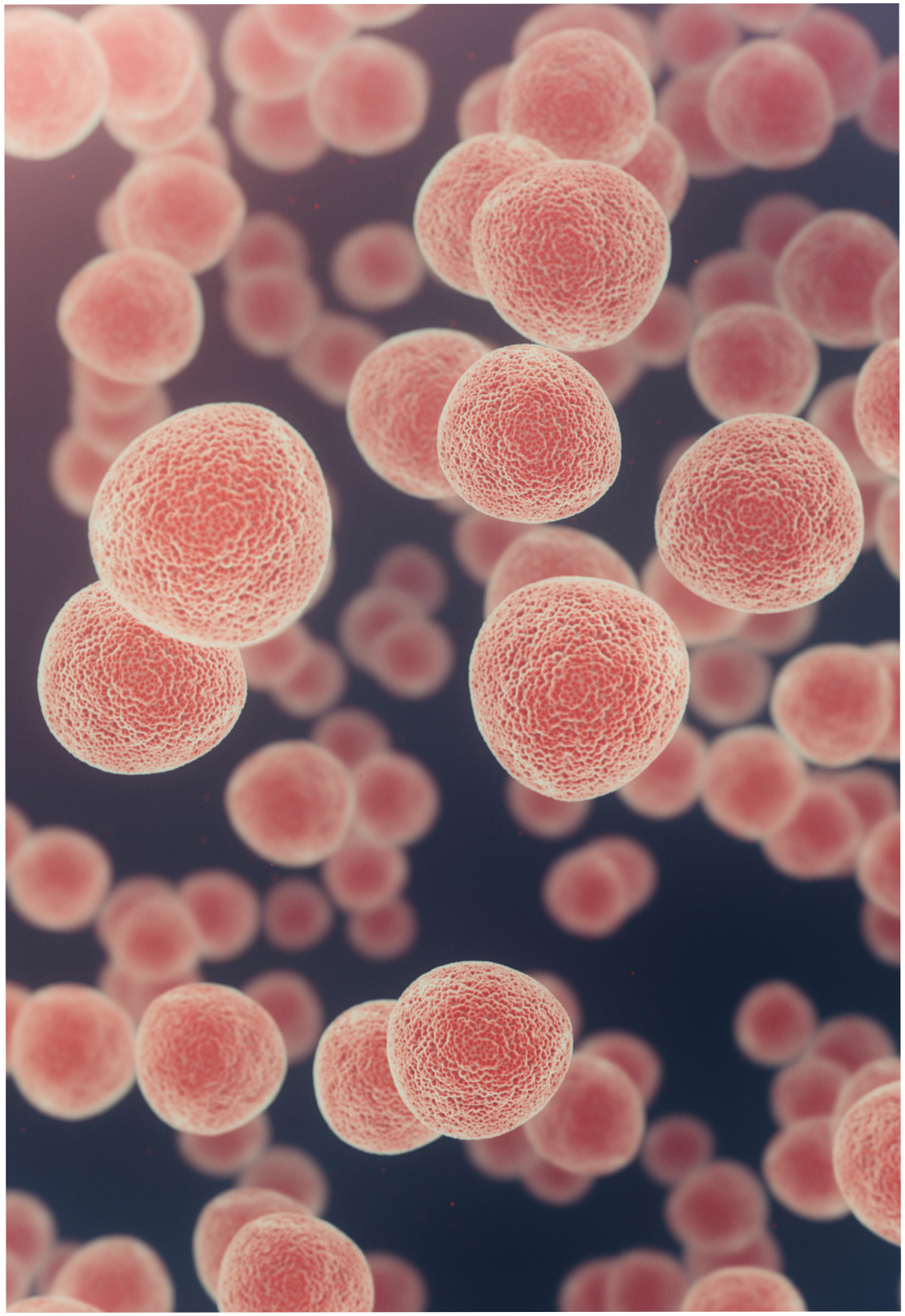
Who knows? One day, you might be like Jennifer Doudna, or Nucharin Songsasen, or Mary Beth Monroe, or Tara McHugh, or Felister Makini, or Carolyn Mordas, or Irene Xagoraraki and "do" STEM, too.

I am so glad that I had these experiences when I was young. They have shaped who I am today. Now, I direct the Smithsonian Science Education Center at the Smithsonian Institution. The books and the stories of women in STEM, the STEM mentors and role models I met along my journey, and hard work—they all helped me to achieve my goals.

As a young girl, it is so important to see yourself in the role models around you and in the stories you read. Some people call this the "See/Do" theory. If you can see yourself in others, then you will believe you can do it, too. That is the purpose of this book.

I hope when you read the stories of these amazing women in biotechnology, you can "see" your future self. Then, strive to be the best you can be.

Who knows? One day, you might be like Jennifer Doudna, or Nucharin Songsasen, or Mary Beth Monroe, or Tara McHugh, or Felister Makini, or Carolyn Mordas, or Irene Xagoraraki and "do" STEM, too.



Jennifer Doudna

Jennifer Doudna

“We need to encourage more women to pursue careers in science… Science is a field where women can thrive and where we belong.”

Women in science have played a major role in Dr. Jennifer Doudna’s career. She worked in a research lab while she was in high school in Hilo, Hawaii, in the United States. While there, she saw a female scientist talk about her research on cancer cells. It was the first time she heard the word “biochemistry.” This experience was important in helping her decide to be a scientist.

“You didn’t see professional women scientists in popular culture at the time,” Jennifer said. “I remember thinking right then that I wanted to do what she does.”

Jennifer Doudna

Jennifer's father also exposed her to science. He gave her a book called "The Double Helix," written by James Watson. He was a biologist who worked with Francis Crick, a biochemist. In 1953 they found the spiral staircase structure of the DNA molecule, called a double helix. They won the Nobel Prize—but they were not the only people involved in the discovery.

Rosalind Franklin was a key part of the process. She used X-ray crystallography images to show DNA's helical shape. X-ray crystallography is the study of crystals and their structure using X-rays. But Rosalind did not get the credit she deserved. Jennifer did not want this kind of thing to keep happening to women scientists.

Jennifer worked in a lab during her sophomore year in college. She worked under Sharon Panasenko, her biochemistry professor. The lab was trying to find a way for bacteria to grow without nutrients. "I experimented with growing bacteria in large baking pans instead of Petri dishes," Jennifer said. "And I succeeded."

Her professor published Jennifer's work in a scientific paper in the Journal of Bacteriology. "This was the first time my name appeared in a scientific journal," Jennifer said. "It made it possible to have a career in science seem very real."

Jennifer started working at Yale University in 1994. She became an assistant professor and led a lab there. She taught molecular biophysics and biochemistry. Then in 2002 she became a professor at the University of California, Berkeley. She was a part of the College of Chemistry.

At Berkeley Jennifer became famous for her discovery of CRISPR-Cas9 enzymes. CRISPR-Cas9 is a technology that can edit DNA. "We've learned to make copies of DNA, read it, and understand its function in many cases," Jennifer said. "But we haven't been able to fix mistakes or make changes. CRISPR makes this possible."

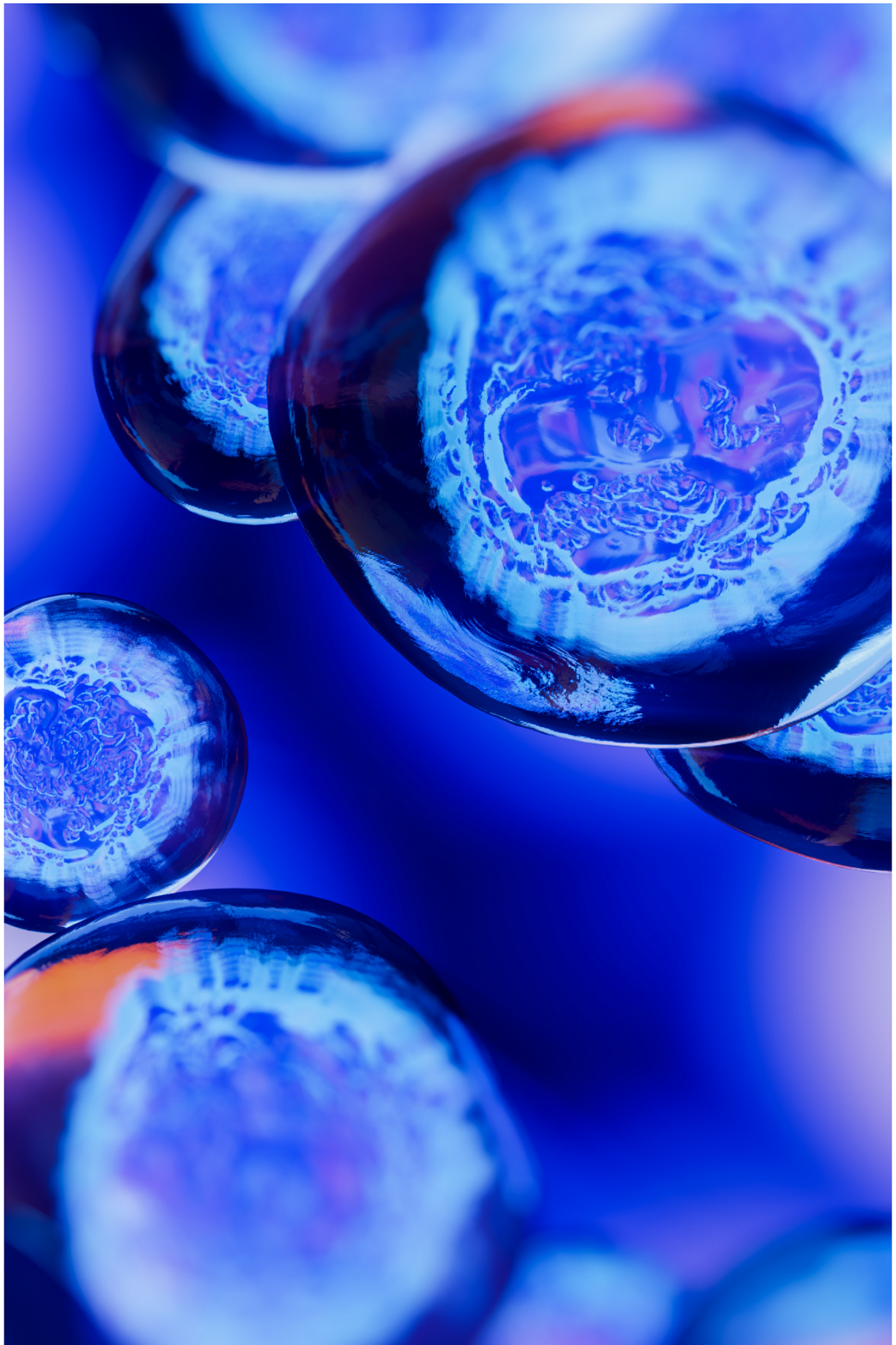
Jennifer founded the Innovative Genomics Institute at Berkeley. Her research lab looks for ways CRISPR technology can be used to solve health, climate, and agricultural problems around the world. For her work on CRISPR, she was awarded the Nobel Prize in Chemistry in 2020.

Jennifer Doudna

“We are applying genome editing to climate change,” Jennifer said. “Most people don’t think of CRISPR and climate change as being connected, but it can play an important role. We need to use every tool at our disposal.”

Genome editing is also called gene editing. Gene editing is used to change DNA in a live being. DNA can be added or removed in this process. It can be used to treat genetic diseases. But gene editing can also help reduce the impact of climate change on food supplies.

“There’s been a lot of focus on the medical applications of CRISPR,” Jennifer said. “But addressing the biggest threat to the health of the planet is an even more powerful way to impact human health.”



Jennifer Doudna

With so many important projects underway, Jennifer believes this is the right time for women and girls to get more involved in STEM. When she was interested in science growing up, she didn't get support from everyone in her life. She doesn't want that to be the case for girls and women in this generation.

"The most important advice I ever got was from my high school guidance counselor," Jennifer said. "She told me not to pursue science because 'Girls don't do science.' That advice was so clearly wrong that it made me want to do the exact opposite."

Jennifer believes the work of women in STEM needs to be celebrated more. She says it's important for young girls and women to be able to see themselves as scientists.

"We need to encourage more women to pursue careers in science," Jennifer said. "Science is a field where women can thrive and where we belong."

Nucharin Songsasen

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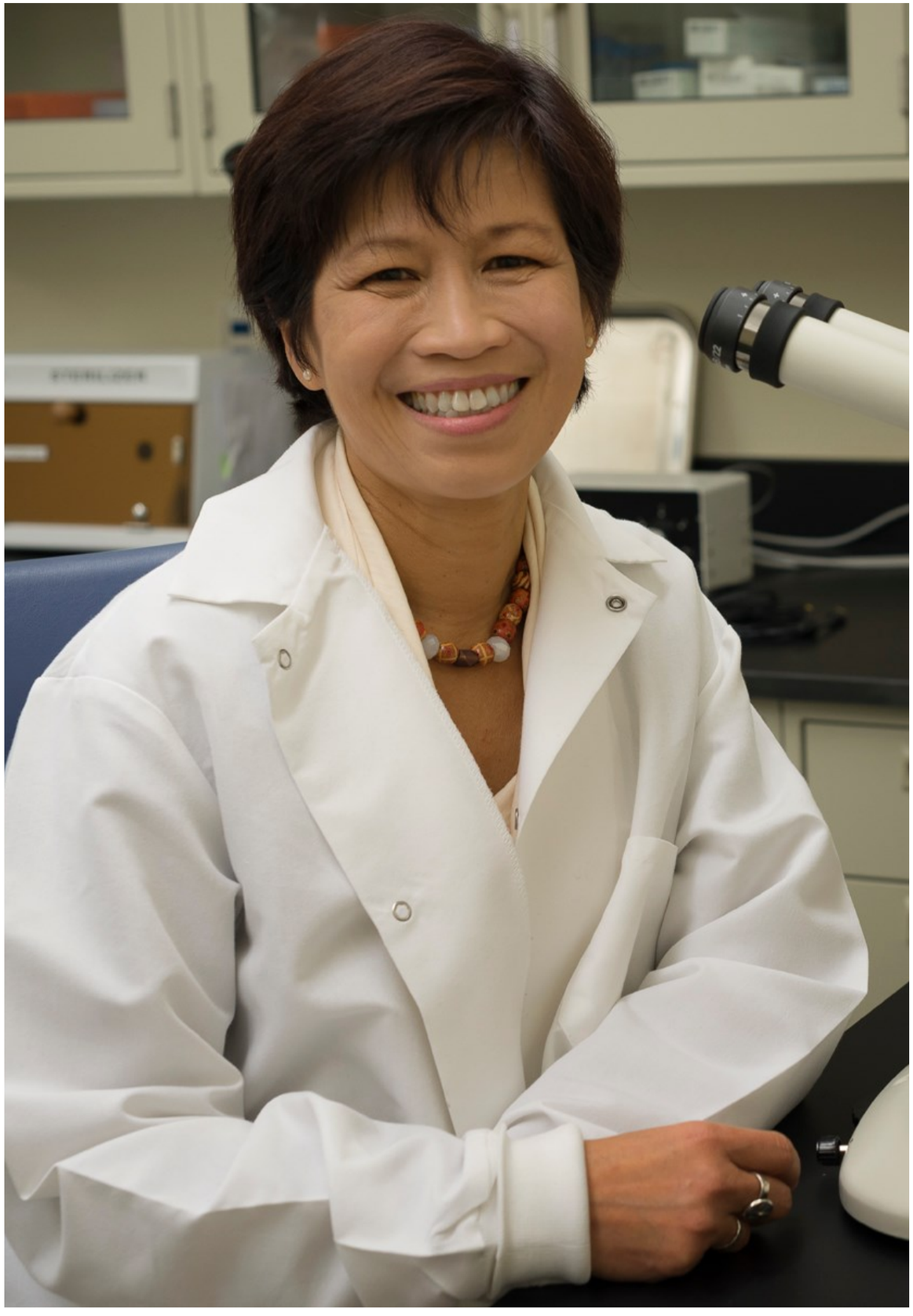
“Follow your heart and passion. Do not let anyone tell you that you cannot do it because you are a girl.”



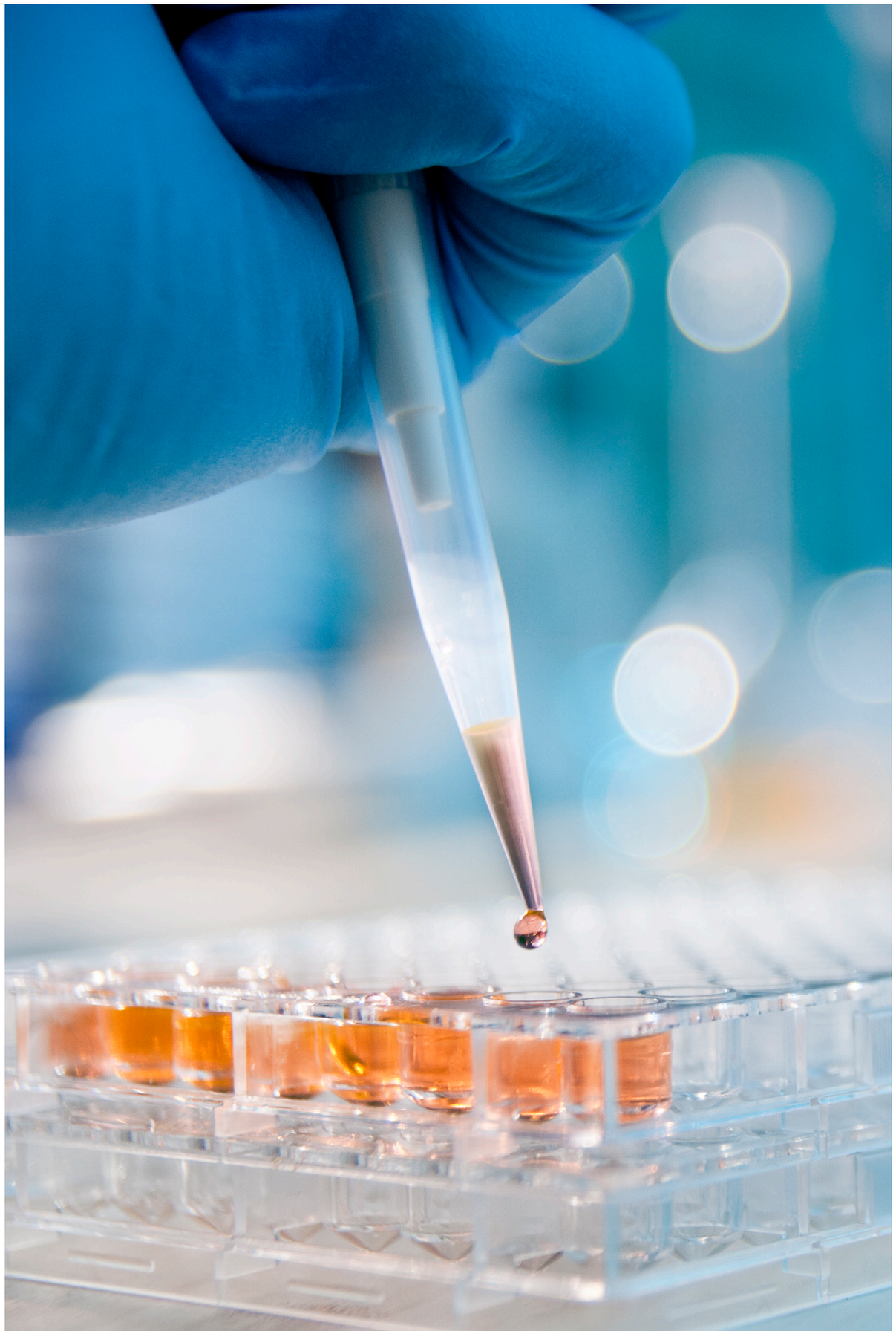
As a child, Dr. Nucharin Songsasen would follow her father at work. They lived in Thailand. Her father was a veterinarian. He took her to farms to treat sick and injured animals. These trips became some of her first memorable experiences in STEM. They gave her a lifelong dream of being a veterinarian. Nucharin spent time with her father in his small animal practice. She dreamed of becoming a veterinarian, too. Nucharin spent weekends helping her father in his practice. She watched him with his animal patients.

Nucharin Songsasen

Nucharin learned a lot from mentors like her father. She took care of her many pets. Her path in STEM was not always easy though. Nucharin wanted to go to veterinary school. But there were only two in Thailand. Both veterinary schools only allowed women to be 10% of the class. Nucharin had to work very hard to prepare for the school exam. Nucharin was admitted to veterinary school. She received her veterinary degree. When Nucharin became a veterinarian, she was sad when she had animal patients who were dying. She realized she did not want to be a veterinarian. Nucharin changed her work. She switched to something she had enjoyed at school. She studied reproduction. Reproduction is the process of making a copy of something. She joined a government agency working with farmers to solve a problem in dairy cattle. The problem was infertility. This means the cattle had trouble having babies.

Later Nucharin went to graduate school in Canada. Nucharin again overcame a barrier. English was not her first language. In Canada she found her passion in research. She earned her doctorate and became “Dr. Songsasen.” Nucharin went back to Thailand. She worked for the government again. After a while, Nucharin left Thailand to pursue her career in the United States. She started working at the Audubon Center for Endangered Species. It was in New Orleans. She also reconnected with Dr. David Wildt whom she met in graduate school. He offered her a post-doctoral position. Her job was to develop a conservation program for mammals. The mammals were in the dog family called canids. This is where Nucharin found her calling.

Nucharin came to the Smithsonian Institution in 2002. She studied the reproductive biology of carnivores. Carnivores are animals that eat other animals. She developed the Global Canid Conservation Program. Nucharin used biotechnology to aid conservation in the United States and abroad. Nucharin is now a research biologist. She is also the head of the Center for Species Survival at the Smithsonian. She’s a leading expert in carnivore reproduction. Nucharin’s research is very important. Many large carnivore species are threatened in the wild. These species are kept in zoos or breeding centers. This helps prevent extinction. (Extinction is when a species dies out.)



Nucharin Songsasen

To maintain diversity in their genes, she studies their biology. Nucharin's research can help ensure successful breeding. She saves the genes of animals that die. She puts them in a “gene bank.” The genes can be used in the future. Her work is not only important to animals. Some characteristics of carnivores, especially cats, are similar to humans. Technologies that Nucharin and her colleagues make can be adapted to address human health.

Nucharin followed her passion for animals to earn a Doctor of Veterinary degree. She also earned a special doctorate called a Ph.D. She became a research scientist. Nucharin has a message for the next generation of women in biotechnology. Nucharin says, “Follow your heart and passion. Do not let anyone tell you that you cannot do it because you are a girl.”

Mary Beth Monroe

Mary Beth Monroe

“I always loved math, making new things, reading, and writing growing up… And I knew that I wanted a career where I could help people.”

Dr. Mary Beth Monroe loved adventure and exploring new subjects and ideas. Her curiosity was an early sign of what she planned to do as a career. “I always loved math, making new things, reading, and writing growing up,” Mary Beth said. “And I knew that I wanted a career where I could help people.”

Mary Beth took challenging courses and participated in several activities in middle and high school. She was a member of her high school’s dance team. She became the lieutenant on her dance team her junior year. She was a captain in her senior year. She says these leadership roles helped her grow as a person.

“These leadership experiences taught me so many skills that I still use today. I am committed to a team. I have a strong work ethic. I like to build friendships. And I like memorizing things and teaching,” she said. Mary Beth found her love of engineering while in a math class at Trinity University. Trinity is in San Antonio, Texas.

Mary Beth Monroe

In her final year of college, she studied how people move when using artificial legs. She also attended the Society of Women Engineers national meeting in Baltimore. This led to her interest in biomedical engineering.

Mary Beth graduated with a bachelor's degree in Engineering Science. Then she pursued her doctorate in Biomedical Engineering at Texas A&M University. Her advisor, Dr. Elizabeth Cosgriff-Hernandez, became her mentor. Mary Beth says that her guidance helped set an important example for her as a young woman. It was not easy to be studying at a university with a family.

"Her passion for mentoring, research, and service were inspiring. It set the tone for how I run my research group in many ways," Mary Beth said.

Mary Beth worked in Dr. Cosgriff-Hernandez's lab. She was supported by the National Science Foundation Graduate Research Fellowship. She developed materials for use in man-made blood vessels. These synthetic blood vessels could be used for patients with heart disease.

Mary Beth graduated with a doctoral degree in biomedical engineering. This means she became "Dr. Monroe."

Mary Beth engineered proteins used to heal wounds. She worked with these proteins in the body and outside of the body. Dr. Magnus Hook in the Texas A&M Health Science Center guided Mary Beth. This work was funded by the National Institutes of Health Postdoctoral Fellowship.

After this experience, she returned to Texas A&M as a research scientist. Dr. Monroe began working as a lab manager at Dr. Duncan Maitland's Biomedical Device Lab. In this role Dr. Monroe built knowledge on medical devices that use "smart materials." These materials are made out of polymers that can remember a primary shape and return to it.

"Polymers, or plastics, are long chains of molecules bound together," she said. "Because they are so large you can change their shape. We do this by changing the molecules' mechanical, physical, and biological properties." Polymers are used in many everyday products. This includes cars, clothing, packaging, computers, and phones. In biomedical engineering, polymers can be used to clean, cover, and protect wounds (cuts) from the outside environment. Polymers can also be used to redirect blood flow from one area of the body to another. They can even be used to deliver drugs to specific parts of the body.

Mary Beth Monroe

Mary Beth has been an assistant professor in Biomedical and Chemical Engineering at Syracuse University since 2018. Her research at The Monroe BioMaterials Lab designs new biomaterials for healing.

There are many ways biomaterials can be used for healing. They can stop bleeds from traumatic wounds. (Traumatic wounds damage both the skin and underlying tissue.) Biomaterials can heal an abnormal connection between two body parts, such as from Crohn's disease. They can also reduce infections in chronic wounds. (Chronic wounds have not gone through the stages of normal healing.) Mary Beth hopes these biomaterials will eventually be used in first-aid kits for the public.

Outside of helping individuals heal, she also loves to spend time with her family. They love hiking, visiting parks around Syracuse, and hosting people at their home. She also likes to read fiction stories and embroider in her free time.

Mary Beth Monroe

“Creative hands-on experiences… could be an important way to encourage girls to pursue STEM.”

Mary Beth believes it is important to have a support system in your life. Her family and peers pushed her to follow her passions. She wants to provide this same experience to others.

“The best part of my job is mentoring. My greatest successes are often tied to the successes of the people I mentor,” Mary Beth said. “It is a huge privilege to work with someone as they develop into an independent researcher. I get so much joy from watching the process.”

She is creating activities for middle and high school students that explain polymer chemistry using cooking.

“I envision that this program will draw in new students who may not think that they like chemistry, but who enjoy cooking,” she said. “Creative hands-on experiences like that could be an important way to encourage girls to pursue STEM.”

Tara McHugh

Tara McHugh

“These experiences as a food scientist helped me see that I had the capacity to excel in STEM.”

When Dr. Tara McHugh was a child, she was very good at math and science. But she had trouble finding inspiration outside of school. A big influence on Tara was her father. “He was a biochemist. I would visit his lab when I was young,” she explained. “I didn’t have any other mentors. During the 1980s, mentorship programs were rare.”

In college Tara was inspired by a leader she worked with during an internship. “I had an internship with the National Institutes of Standards and Technology. My supervisor was a Black woman,” she said. Tara worked in a protein crystallography lab. She used powerful microscopes to “see” the atoms of the proteins. “This was my first memorable experience. I pictured myself having a career in STEM.” This inspired Tara to mentor young scientists, too.

Tara McHugh

Tara's early experiences helped plant the seeds for growing her passions into a STEM career. She earned her doctorate in Food Science from the University of California, Davis. She became “Dr. McHugh.”

Dr. McHugh started out working for two private food companies. But instead of selling food, she wanted to solve agricultural problems. “I realized that I did not want to work for a company whose primary mission was to make money. Instead, I wanted to work for the government and USDA,” she said.

The USDA is the United States Department of Agriculture. Agriculture is the science or practice of farming. This includes cultivating soil to grow crops. It also includes raising animals to provide food, wool, or other products. “These experiences as a food scientist helped me see that I had the capacity to excel in STEM,” Tara said. “USDA provided me with the freedom to develop a research program that brought my passions as a scientist together with USDA’s mission.”

During her time with the USDA, Tara invented a new process to produce the world’s first 100% fruit bars.

“Many communities in our country are food insecure and/or nutrition insecure. This means they do not have full access to nutritious foods,” she said. “One way to address this is to provide shelf-stable healthy food to these communities. Many of the products we have developed can be consumed to improve nutrition.”

The fruit bars are now widely available. The process invented by Dr. McHugh is now providing convenient nutrition and improving health worldwide.

Felister Makini

Felister Makini

“It’s the women that prepare the food for the family. Most farm operations are undertaken by them…”

Dr. Felister Makini enjoyed math and science when she was growing up. Math and chemistry were her favorite subjects. “I loved math and used to take my time to get the answers,” Felister said. “I loved chemistry lab experiments.” She also liked to dissect frogs. It was scary and hard for her at first, but she came to enjoy the process because she learned so much. This is where her love for biology began.

Her family and teachers in Kenya supported her interests and encouraged her to work hard. Felister graduated from the University of Nairobi. She then got a master’s degree in plant pathology from Georgia State University in the United States.

Felister Makini

She also got a PhD from the University of Greenwich in Britain. Plant pathology is the study of diseases in plants. The diseases can be caused by environmental conditions.

In 1983 she started working for the Regional Research Center in Mtwapa, Kenya in the plant pathology section. Felister is most concerned with how farming is affected by climate change. This is very true for how women in Africa are impacted by the climate crisis. “It’s the women that prepare the food for the family. Most farm operations are undertaken by them,” Felister said. “When drought hits, the family lacks food. This affects them the most.”

Felister later moved to Nairobi where she became deputy director, General Crops, in the Kenya Agricultural and Livestock Research Organization (KARLO). Felister’s job is to help farmers in Kenya prevent food shortages.

She is in charge of crop research, including developing and teaching others new technologies for farming.

Felister believes better technology is the answer to the climate change crisis. She is working to advance genetically modified crop technology. Genetically modified crops are plants in which the DNA is changed to give them certain useful traits. This is done using gene editing technology. Gene editing can add or remove DNA to change a plant. This process is completed in a lab. The changed plants are then grown on farms.

Felister is also a motivational speaker and has spoken to many students. She understands how important STEM is to better futures for women and girls. She hopes more of them will get involved in STEM careers.

Carolyn Mordas

Carolyn Mordas

“I was so passionate about learning that I also became passionate about teaching.”

When she was young, Dr. Carolyn Mordas was interested in math and science. She remembers receiving a chemistry set for her birthday. “That was so interesting to me,” Carolyn said. “It got me very curious about science. I wanted to understand the ‘why’ behind everything.”

In school, Carolyn was involved in hands-on lab tests. She was also a part of a Mathletes club. This helped Carolyn meet students from other schools. She took part in STEM competitions. She learned the importance of teaching and mentorship.

Carolyn Mordas

“I was so passionate about learning that I also became passionate about teaching,” she said. “I did not choose to be a professor. But I was able to find plenty of teaching opportunities. I did this by mentoring new employees at the company where I work.”

Carolyn is the vice president of Ethicon Biosurgery R&D at Johnson & Johnson. (R&D means research and development.) In her role she handles a large collection of biomaterials. These materials are used during surgery. Her team develops safety measures for the lab. They also make sure it’s safe before and after clinical studies.

Johnson & Johnson has helped Carolyn advance in her career in biotechnology. She started as an intern at the company. She did this while pursuing her graduate degree in chemistry at Princeton University. She also worked in the consumer and medical technology fields at the company.

Carolyn has enjoyed her time at Johnson & Johnson. She did not have much confidence starting out in STEM. She believes having great support is key. This is one of the reasons why she supports more diversity in STEM. “Many people have already established themselves in their STEM careers. But they should try to create a welcoming environment for new employees. Many new employees may not feel included,” Carolyn said.

Carolyn believes more females in STEM will attract more girls to get involved in STEM. Early exposure to STEM opens new doors to career opportunities. Many young people may not know that these opportunities are around.

Carolyn loves her job. She travels to many different countries thanks to her career. She has seen medical technology change over the years. She feels like she is making a difference. And she is excited about what is to come.

Irene Xagoraraki

Irene Xagoraraki

“Understanding science and its practical applications was the best way to make a difference for others.”

Dr. Irene Xagoraraki grew up on the island of Crete. This is in Greece. Irene was fascinated by the nature around her. She loved the flow of water. She loved the sound of waves. She saw the changing colors through the day and night. And she could smell and taste the land. Irene was in awe of the magic of nature. “I decided at a young age I could explain the miracle of nature. It was a mixture of God-action, biology, chemistry, physics, and some math,” she said. Her STEM career path started with a desire to understand this miracle.

“I wanted to make a difference in the lives of the people I loved,” Irene said. “Understanding science and its practical applications was the best way to make a difference for others.”

Irene Xagoraraki

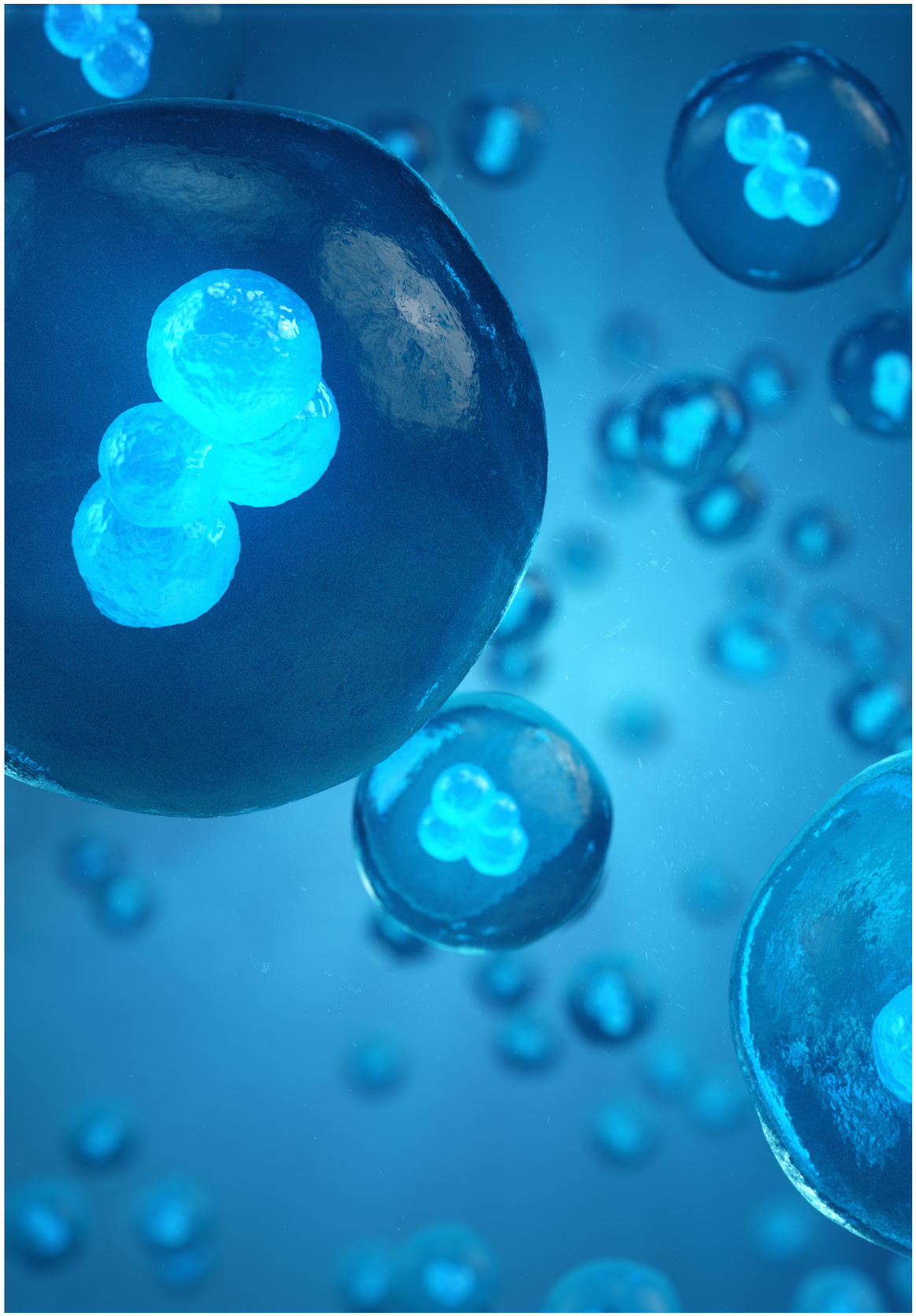
“My career path was inspired by people that surrounded me. A very supportive family and great teachers made it all possible,” Irene explained.

Back then, middle schools and high schools in Greece did not have labs or technical equipment. Irene had teachers with great imaginations. They helped her picture what could be done. And her family supported her and valued education. They gave her the confidence to believe she was smart enough to be a successful scientist. But she would have to work hard. In her family, she was not encouraged to travel outside of Greece just for fun. But she was allowed to travel the world for research and education. And that’s exactly what she did!

“I was fascinated by engineering, microbiology, and public health,” she explained. “My research projects focused on water quality engineering. I also studied the protection of public health and prevention of waterborne disease.” Irene is now a Professor of Environmental Engineering at Michigan State University in the United States. Irene uses her knowledge of STEM to help people around the world.

Doctors may not know a disease is spreading in their community until people show up sick in their offices. If medical professionals know a disease is spreading before that happens, they might be able to help stop the spread. They can also prepare to better help people with the disease. During the Covid-19 pandemic, Irene used a new way of identifying when viral disease was spreading in the community. She studied wastewater! Wastewater is the combined water and waste produced from using toilets, showers, sinks, dishwashers, and washing machines. It also contains things that cause disease, like viruses.

Irene Xagoraraki



Irene used technology to analyze the viruses found in community wastewater to predict when the number of COVID-19 cases would go up. This was also used for other viral diseases. Her work enabled her community to be more prepared to fight COVID-19.

First, she started using wastewater to identify and predict disease outbreaks near her in Detroit, Michigan. Now she also works with teams around the world to identify outbreaks in their locations. Many places do not have medical systems that are able to detect disease outbreaks early. Irene's work helps everyone she works with keep their communities healthier.

Another way Irene is making a difference is by passing on her skills and knowledge to others. She wants to build the next generation of STEM professionals. "Working with talented graduate students is among my most satisfying accomplishments," she said.

Irene Xagoraraki

“In science, no barrier can be imposed by others. If you believe in hard work, then nothing can stop you. Nothing can block solid scientific findings.”

“Discoveries are made. People are shaped – people who will keep on going after I won’t be able to anymore. The awards and successes of my graduate students make me happier than my own honors and successes.”

Irene has some words of advice for young people, especially girls. “In my early career years in the United States, I observed that sometimes some people may have had a misperception. That a young woman with an accent may not be as worthy of respect as an older scientist born in the U.S. But later I realized that the only barriers were in my mind. In science, no barrier can be imposed by others. If you believe in hard work, then nothing can stop you. Nothing can block solid scientific findings.”

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