# Eleanore T. Wurtzel

## How did you spend your career?

I grew up in New York City as the daughter of World War II refugees who inspired me to follow my dreams. My father was a civil engineer who came to this country for graduate education. My mother was a stay-at-home mom with a high school education. When she turned 40, she returned to school, and at 50 we both celebrated our PhDs in biology, although in different fields and via unique paths. As many scientists in the making, I treasured my chemistry set. I enjoyed learning advanced math from my father, while I negotiated space with two younger brothers in the back seat of the car on family outings. My home was filled with multiple languages, and I learned the importance of education and making a meaningful difference in the world. I was lucky, because many young women were steered away from math and science, passions which led me to the Bronx High School of Science. In high school, my interests in molecular biology and gene regulation were ignited when I discovered "The Lactose Operon" (published in 1970), an intriguing book which I read to develop my term-paper writing skills for an English class. I went on to study biochemistry at SUNY Stony Brook, after considering math and chemistry, subjects for which I could not find adequate applications. As an undergraduate, I volunteered in the lab of Masayori Inouye, an expert in the field of prokaryotic gene regulation. It was there that I became hooked on research and decided to pursue a PhD in Inouye's lab and a career as an academic scientist. During this period in the mid-1970's, the very early days of molecular biology, we developed new experimental protocols and created home-made reaction "kits". There was no internet to Google, nor a methods text to which we could refer. The science was exciting, creativity and collaboration were encouraged, and I became proficient in molecular biology, biochemistry, and genetics. My doctoral research led to the isolation of the first genes for two-component signaling through innovation of a novel gene-tagging method. I was fortunate to publish extensively on this research, which later birthed an entire signaling field that expanded to eukaryotic systems, including plants. At the tail end of these glorious days of concocting new ideas just to isolate a gene, I became a joyful mother of my son Joel, who also loved math and even discovered what to do with it. Today, my son is an actuary, financial analyst, and proud father of two. Thus, my days of juggling career and home paid off!

When I was ready to choose a postdoc in 1982, I strove to prepare for a future career as an independent scientist and professor with my own lab. I explored diverse fields, seeking to develop a research niche in a promising area with great potential for expansion. I planned to translate my expertise from working on prokaryotes to studying eukaryotic gene regulation. To do the best science then, I sought a discipline with a solid foundation of genetics. I considered virology, but it was a hot field too competitive for starting a successful career. I contemplated neurobiology, which was much in its infancy, but I had no background. Yeast genetics was attractive as a step up from working on bacteria, but I was not convinced that this was enough of a leap. And then there was plant biology- important for so many reasons. However, this was uncharted territory with few molecular biologists. I contacted Benjamin Burr and his wife and partner Frances Burr, maize geneticists at the Brookhaven National Laboratory. Maize genetics would be perfect to support my studies on plant gene regulation. However, I had no plant background, except for my first experience planting seeds in kindergarten in a little garden next to an expanse of concrete sidewalk in New York City. This unfamiliarity with plant biology left me a little unsure, especially as I was leaving a successful research path behind. Ben suggested that I speak to his

*continued on next page*

**ELEANORE WURTZEL *continued***

collaborator, Barbara. Who was Barbara? Well, she was Barbara McClintock, the Nobel Laureate and maize geneticist who discovered controlling elements, also known as transposons. I decided to call her, and we embarked on a life-changing conversation. First, she suggested that I consider Drosophila, a powerful model system to investigate gene regulation and development, and on which she had also published. No, I was not convinced. Then, we began discussing the opportunities of moving into plant biology. I realized that this could be my niche, and that I could always go back to bacterial systems to study gene regulation. The decision of moving into an emerging field, while bringing along my research expertise, established for me a lifelong pattern of engaging in new areas of research and embracing interdisciplinary collaboration.

I was fortunate that the National Science Foundation (NSF) was looking for people like me who were trained in other fields and willing to jump headfirst into plant biology. Here was a field with tremendous growth potential but limited scientific engagement with available cutting-edge technology. I never looked back, and in fact my doctoral research came in handy when I decided to use bacteria for testing ideas for metabolic engineering of plant biosynthetic pathways, and later for purifying plant enzymes. Maize was amenable for plant molecular biology research, because of the ability to use genetics for testing hypotheses; the simpler Arabidopsis model system was not yet established, and genome-wide transcriptomic data were a future dream. The Burr lab was focused on isolating plant genes. However, I spent my PhD isolating genes and finally I wanted to be able to study gene regulation. The NSF postdoctoral fellowship, funded by my first grant, proposed lofty ideas to study the effect of transposons on chromatin structure and gene regulation. Having my own funding meant I could work on my own ideas, while accessing the maize genetics expertise in the Burr lab. I developed methodology and then conducted early studies of plant chromatin structure, research that was ground-breaking then and is still a very hot topic today. The NSF funding supported me to attend and present my novel methods and research findings at a Gordon Research Conference (GRC) on Plant Molecular Biology (this meeting spawned many later topical plant meetings) and my first Maize Genetics conference; later, I discovered the wonderful American Society of Plant Biologists (ASPB) meetings. At these meetings, I met many new friends and collaborators in the plant community. However, I also discovered that big labs in Europe were initiating similar chromatin structure studies in plants. I realized that it would be a struggle to successfully compete with a 50-person lab, as European labs were structured. I also felt that I needed further training in plant biology before setting up my own lab. And so, after two years at Brookhaven National Laboratory, I began searching for other opportunities. I discovered that not far away, at Cold Spring Harbor laboratory, there was a group using tomatoes to investigate the regulation of carotenoid biosynthesis, then a poorly studied field. I immediately recognized the opportunity for establishing a research program on carotenoids in maize and other major food crops, since carotenoids were not only important in photosynthesis, but also important for human nutrition. I also realized that I could again transfer my skill set to establish a research program investigating gene regulation related to carotenoid biosynthesis in maize. It turned out that Don Robertson and other maize geneticists were using the seed phenotype associated with the yellow carotenoid pigment to identify many interesting seed and plant carotenoid mutants, a collection that served me for many years in gene discovery related to the carotenoid biosynthetic pathway. It was within this one-year stay at Cold Spring Harbor Laboratory that I initiated my lifelong research program on carotenoids. In this brief period, I was also offered my dream position in academia as a tenure-track assistant professor at Lehman College of the City University of New York (CUNY). As I was completing this second postdoc, my daughter Laura was born; she was destined to become an orthodontist and mother of two. So, with a bit more juggling, I began my academic career as an assistant professor.

In 1987, I arrived at Lehman College, one of 20 campuses of The City University of New York.

*continued on next page*

**ELEANORE WURTZEL *continued***

Lehman College is a Predominately Undergraduate Institution (PUI), Minority-Serving Institution (MI), and Hispanic-Serving Institution (HSI). Today, Lehman College is ranked first in the nation among HSIs for helping students improve their academic standing through education, and fourth among all four-year colleges for social mobility. In the 1980's, Lehman College showed potential, but still awaited further growth that came later in the CUNY "Decade of Science". Lehman was also home to the CUNY-New York Botanical Garden collaborative PhD program in Plant Sciences. The New York Botanical Garden was filled with botanists who were discovering new plant species and guiding evolutionary studies. My job interview included being vetted by the world-famous botanist Arthur Cronquist, of the New York Botanical Garden, who was known for developing an important classification system for flowering plants. The New York Botanical Garden represented a rich haven of potential research collaborators, wonderful botanical library, world-class herbarium and other resources, as it serves to this day. In 1987, my department was transitioning from a teaching-only environment to one that also integrated research. I was "the molecular biologist" hired to fill this disciplinary need of the department. I saw this as an opportunity to build interdisciplinary collaborations both within my university and beyond. While my start-up funds were minimal, my ideas were plentiful, and as always, I would have a "plan". It was essential that I create a career plan to build an active research program at an institution with limited resources, but with significant encouragement for building a research culture. My plan encompassed many grant applications needed to build and sustain a serious research lab, while networking in the university and New York Botanical Garden to establish productive research collaborations. Meanwhile, my lab would advance foundational research on carotenoids, beginning with the isolation of genes encoding the biosynthetic enzymes in maize and other crops in the Grasses. The NSF again came to the rescue through my first grant as a faculty member. NSF funded the bulk of the instrumentation needed to outfit a comprehensive research laboratory, making up for my paltry start-up funds. This funding facilitated serious interdisciplinary research in molecular biology and biochemistry, which catapulted my research and enabled the careers of other faculty and students in our minority-serving institution. The lab ultimately required much more space to fit all of the NSF-funded equipment, necessitating construction that was funded by industry and the National Institutes of Health (NIH), which has continued to support my plant research for over 25 years. I drafted plans for my lab using the high school drafting skills that I never expected to apply. Thus, we were able to move to a beautiful new lab constructed with limited college resources. More recently, the College built a state-of-the-art teaching and research building that houses my lab and greenhouse, together with the labs of other faculty and students engaged in plant biology research. Although I was in the middle of the Bronx, New York City, plant research was and continues to be alive and well. Not far from the #4 subway in the Bronx, I created a corn field on campus for conducting our maize genetics research, with the intent of also introducing living plants to our diverse urban students, faculty and community. I continued to attend various plant-related conferences, where we discussed ongoing carotenoid research among a handful of interested faculty and students; all we needed were a few chairs to make a small circle. However, that was soon to change.

In the early 1990's, I knocked on the door of the Rockefeller Foundation to share my research on maize carotenoids and to suggest that funding of my research could help solve the global vitamin A deficiency of 250 million children in the rice-eating, developing world. Somehow, they already knew of me and so the director, Gary Toenniessen, asked me for a grant proposal, which led to eight years of funding by the Rockefeller Foundation International Rice Biotechnology program. Following this funding request, the Rockefeller Foundation organized the first workshop in 1993 ("Potential for carotenoid biosynthesis in rice endosperm") to discuss the feasibility of developing a sustainable solution to vitamin A deficiency through creation of

***continued on next page***

**ELEANORE WURTZEL *continued***

provitamin A carotenoid-enriched rice. The scientific community had the tools for rice transformation and the genes encoding carotenoid biosynthetic enzymes. We were a small group of the leading carotenoid biochemists, including George Britton (UK), Peter Beyer (Germany), Bilal Camara (France), Joseph Hirschberg (Israel), Norihiko Misawa (Japan), Rodney Ausich (USA), John Hearst (USA), and me, Eleanore Wurtzel (USA), all of whom were invited to share ideas in this closed meeting, together with rice transformation expert Ingo Potrykus from the ETH in Switzerland, and Lawrence Bogorad (USA), an expert on photosynthesis. I suggested that they also include a vitamin A expert, Jim Olson (USA), who they invited as well. I would later realize that translation of science to solving real-world problems also requires engagement of societal stakeholders, in order to avoid the backlash that we were stunningly surprised to witness when "Golden Rice" was developed using GMO technology, the only technical solution for this crop. I shared two messages at this pivotal workshop. One, if the project works, then we will need greater foundational knowledge to support introgression of this trait into cultivars that carry other agronomically valuable traits. Two, if the project fails, research will also be needed to understand why and to be able to solve the problem. Thus, I convinced the Rockefeller Foundation to support my lab's basic research on carotenoid biosynthesis in Grasses, including corn and rice, research that accompanied rice transformation at the ETH, which was needed to produce the provitamin A-carotenoid enriched, "Golden Rice". Over the years, my lab was also funded by NIH, the American Cancer Society, USDA, DOD, industry, New York State, CUNY, and the McKnight Foundation, which supported risky plant biology research with transformative potential. With the incredible work of my research group and support of my institution, I was able to miraculously amplify $35,000 in start-up funds to ~$8 million in funding for research at a primarily undergraduate and Minority/Hispanic-serving institution. These early beginnings also launched my extensive travels world-wide and fueled my lab's longstanding interdisciplinary research on provitamin A carotenoid biosynthesis needed to enable sustainable solutions for eliminating global vitamin A deficiency.

The value of reaching across disciplines to advance scientific understanding cannot be underestimated. Therefore, we seized on interdisciplinary opportunities to discover the regulatory mechanisms controlling carotenoid biosynthesis and accumulation in plants. I invited scientists to join my lab who were not necessarily plant biologists, but who possessed novel expertise, thereby forging collaborations with scientists who could contribute expertise beyond that of my lab. Consequently, we were able to take advantage of diverse fields, including bioinorganic chemistry, cell biology, bioinformatics, systems biology, structural biochemistry, classical and association genetics, comparative genomics, metabolic engineering, synthetic biology, and protein biochemistry. For example, we exploited the genetic variation of diverse germplasm to elucidate pathway control points and develop molecular markers for breeding maize with high-provitamin A carotenoids. We discovered gene families encoding the carotenoid biosynthetic pathway enzymes and characterized their roles in controlling carotenoid accumulation. We also advanced understanding of how carotenoid biosynthetic enzymes are organized into functional complexes. Most recently, the Wurtzel laboratory discovered Z-ISO, a new carotenoid enzyme that is essential for biosynthesis of all plant carotenoids, including provitamin A carotenoids. This breakthrough led to discovery of a new prototype function for heme proteins, uncovered a novel means for regulating carotenoid biosynthesis in plants, and redefined the carotenoid biosynthetic pathway in plants. These advances in fundamental knowledge, necessary for development of sustainable solutions to global vitamin A deficiency, could not have been achieved without the extensive research of students and visiting scientists in my lab and labs of my collaborators, to all whom I am ever grateful.

### What do you consider to be your most important contributions to plant science?

I believe that as scientists, our contributions should go well beyond our published papers, from the minds we mold to our manifold roles in the scientific community, all of which are

*continued on next page*

personal and professional choices of how we spend our time. I hope to think that my contributions have encompassed not only my research and that of my research group, but also my impact in the scientific community, present and future. So where has this scientific journey taken me?

**Contributions of foundational research on carotenoid biosynthesis.** Our longstanding research on carotenoid biosynthesis in plants has supported the ongoing development of provitamin A carotenoid-enriched crops, which are necessary for region-specific, sustainable solutions to eliminate global vitamin A deficiency, a problem affecting the health and mortality of 250 million children world-wide. For these contributions, I was elected an AAAS Fellow by the American Association for the Advancement of Science and honored for "pioneering research on provitamin A carotenoid biosynthesis and for founding and organizing the first GRC on Plant Metabolic Engineering". I was recognized as a Fellow of the American Society of Plant Biologists for "distinguished and long-term contributions to plant biology", and I was honored as a Fellow of The International Carotenoid Society, which recognizes "members whose consistent contributions to the Society, the scientific community, and the general public demonstrate a commitment to excellence, leadership, and sound ethics".

**Catalyzing thinking in emerging fields.** To advance emerging fields, I have brought together scientists with complementary interests and expertise. For example, when plant metabolic engineering was a fledgling field that lacked a venue to fuel discussions, I founded and chaired the first GRC on Plant Metabolic Engineering, now an ongoing meeting for over 15 years. As chair of the Carotenoids GRC, I made a controversial move to incorporate discussions of carotenoid cleavage products, which have turned out to represent a plethora of new hormones and bioactive compounds in plants and animals, and now a regular part of the meeting. I served on the GRC Board of Trustees, where I fostered interdisciplinary research in many scientific communities, including plant biology, and influenced new strategic initiatives. More recently, I organized a Banbury meeting at Cold Spring Harbor laboratory to brainstorm the potential transformative application of synthetic biology to revolutionize agriculture to meet the challenges of food insecurity destined to occur with a growing world population. The intense discussions in this closed meeting, of ~30 scientists from around the world, began an important conversation that evolved into our "Perspective" article in Nature Plants; new research and further meetings on this topic are ongoing.

**Enhancing diversity and gender balance in plant biology.** I have been committed to promoting diversity and gender balance in the scientific community and expanding opportunities for young scientists. For example, I serve on the GRC advisory committee for developing programs at GRC conferences that address challenges women face in science and engineering. I have also served on the ASPB Women in Plant Biology Committee and the ASPB Minority Affairs (renamed EDI) Committee. I founded the GRC Seminar on Plant Metabolic Engineering and the GRC Seminar on Carotenoids to create communities for early career scientists. Lastly, in my role as a professor, mentor and senior faculty member in a minority-serving institution with a significant female population, I have introduced plant biology and research to advance the careers of scores of underrepresented minority and women students. My laboratory in plant biology, with all its multidisciplinary flavors, has been the impetus for my many students to go on to successful careers in plant biology as well as to other fields, such as in the case of one Latino undergraduate, the first in his family to attend college. I like to say that this student developed his passion for research in a corn field- actually in our maize genetics field and research lab, pivotal experiences that inspired his trajectory to become a Professor of Neuroscience at Dartmouth.

**And the usual.** Over the years, I have done my share of advising on multidisciplinary projects, grant review panels, ad-hoc grant reviewing, journal article reviewing, including advising on multi-institutional projects to improve provitamin A in other plants beyond rice, co-editing of journal focus issues, chairing the CUNY-New York Botanical Garden PhD program in Plant Sciences, and currently serving as Graduate Advisor for our master's degree

*continued on next page*

ELEANORE WURTZEL *continued*

program, an important diversity pipeline. Although the time commitments have been significant, the benefits for personal growth have been greater.

### When did you become a member of ASPP/ASPB?

I became involved with ASPB after my move into plant biology over 30 years ago.

### How did the Society impact your career, and what motivated you to become a Founding Member of the Legacy Society?

ASPB provided a place to explore the multifaceted realm of plant biology, well beyond my own research. The society has provided opportunities for the next generation of plant scientists. ASPB initiatives to promote gender balance and diversity have been important to me and to my students. As a result of these efforts, I was able to bring my underrepresented minority students to annual meetings to benefit from the diverse plant biology community. As a Monitoring Editor of the ASPB journal, Plant Physiology, I contribute to the impact of this excellent peer-reviewed journal. ASPB has been a catalyst in the plant biology community, facilitating discussions of emerging research opportunities and resources needed for plant biology to meet our future global challenges.

### What important advice would you give to individuals at the start of their career in plant science?

1. Identify your personal and professional goals and plan on how to make it all fit.
2. Always have a short-term and long-term plan with flexibility for each stage of your career.
3. Build on your skill set.
4. Choose research that will make a difference in the world and for which you have a great passion.
5. Embrace interdisciplinary collaborations and include open discussions of authorship to protect your students and postdocs.
6. Be open to new ideas and novel approaches, even when suggested by a seemingly inexperienced student.
7. In establishing your lab, think about bringing in students or postdocs that expand the breadth, diversity, and capabilities of your group. Everyone benefits.
8. Move in new directions to take advantage of opportunities.
9. Learn to communicate what you do and why it is important, as this skill will open doors.
10. Serve on review panels and/or volunteer as an *ad hoc* reviewer- you get better from reading and critiquing the research and papers of others.
11. Seek out a mentor; be a mentor.
12. Network; volunteer; get involved in ASPB, where you will make great connections and meet lifelong colleagues and friends.
13. Go to conferences and look for opportunities to network and get new ideas.
14. Don’t be afraid of failure-always use these opportunities to learn and to grow.

These suggestions were written prior to the COVID-19 pandemic, which has forever changed all of our lives, and revealed the ephemeral nature of our being. Use your time wisely. One thing that I have learned throughout my career is the importance of flexibility, back up plans, being prepared for the unexpected, and being open to change and new opportunities.

**Academic family tree:**
http://academictree.org/chemistry/tree.php?pid=399794&pnodecount=4&cnodecount=2&fontsize=1