Candace Haigler

How did your career get started?

I was a first-generation college student, a descendant of two immigrant families of farmers (Thomas and Haigler/Hagler) who settled in North Carolina in the mid-1700s. My ancestors survived for generations through cleverness, hard work, and strong values, traditions that continue today among many extended family members. My future was strongly influenced by my parents (Everette and Geraldine Haigler) who, before I was born, moved to the outskirts of Charlotte to find city jobs. As I grew up there, I learned from many diverse teachers and friends in the community, at school, and in church. I am grateful that my parents encouraged and supported my education through the PhD degree.

As a young person with orthopedic challenges, I enjoyed reading and schoolwork, especially in the humanities. I was exposed to synthetic and analytical thinking in an experimental public junior high school where we learned in themes instead of specific subject matter courses. In 10th grade, I became disinterested in science after a biology class involving animal dissection. However, Mr. Paschal, an excellent chemistry teacher at East Mecklenburg High School, revived my scientific interests so that I enrolled in and graduated from Wake Forest University with a B.A. in Chemistry. Attending Wake Forest was possible for me because of a Carswell Scholarship, and I greatly benefitted from Wake Forest's small classes, challenging curriculum, and caring professors. My B.A. degree (instead of a B.S.) reflected my progressively diminishing interest in pure chemistry for my long-term career, and it also allowed me to take additional liberal arts courses that I greatly enjoyed.

In my senior year at Wake Forest, I had my first undergraduate research experience, studying nitrogen fixation in lichens with Dr. Veryl E. Becker, which helped me realize I liked lab work and plant research. While I was still trying to decide on my next step after graduation, Dr. Becker arranged for me to accompany a graduate class taught by Dr. Mary Beth Thomas on a visit to the laboratory of Dr. R. Malcolm Brown, Jr. in the Department of Botany at the University of North Carolina-Chapel Hill. I also applied for a technician's job in the UNC-CH medical school—the interviewing professor shaped my career by not hiring me while also saying that I needed to go to graduate school!

I am grateful to Dr. Brown, who offered me a funded graduate research assistantship in his lab, even though I had taken only two biology courses in college. Dr. Brown fostered my career through a productive project, stimulating peers, opportunities to travel to meetings, and connections with other leaders and mentors in the field of cellulose synthesis research, including Dr. Moshe Benziman, Dr. Henri Chanzy, and Dr. Debby Delmer. My fellow graduate student and future husband, Dr. Richard L. (Larry) Blanton, also fostered my career through his constant encouragement that I could finish the journey to a PhD degree and continue in an academic career.

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

My scientific career started on a high note, given that my first publication was in *Science* and featured on the cover! This paper described the disruption of cellulose crystallization during its biosynthesis by adding a fluorescent brightener to the culture medium of a cellulose-synthesizing bacterium, then called *Acetobacter xylinum*. This finding was expanded in collaboration with several co-workers during my graduate career in Dr. Brown's lab, and it resulted in papers that established key principles about cellulose microfibril formation. The first principle is that cellulose polymerization and crystallization are coupled processes, but there is a temporal gap between them that allows microfibril properties to be modified through the amount and composition of cellulose-binding polymers present during biosynthesis (for example, plant cell wall matrix polymers). I named the second principle 'hierarchical, cell-directed, self-assembly', which summarizes the idea that the arrangement of cellulose synthases in the plasma membrane helps to control how the microfibrils will crystallize and assemble into larger aggregates.

As a postdoctoral research associate and Assistant Professor, I shifted my research emphasis to plants. After joining Texas Tech University, I worked with my students on tracheary element differentiation in cell culture, revealing a role for calcium in secondary wall differentiation. Another key discovery was that microtubules are only required to help establish the pattern of the secondary cell wall; they are not required to sustain continuing cellulose synthesis in the same pattern. Cotton is a major crop in Lubbock, Texas, which led to opportunities to expand my group's research areas. Over the years, I've especially appreciated the long-term support of our cotton research by Cotton Incorporated, a not-for-profit company that promotes knowledge and use of cotton. Students, technicians, and postdocs at Texas Tech worked together to elucidate the strong temperature dependence of secondary wall synthesis in cotton fibers and showed that the amount of intracellular sucrose was greatly reduced under cool temperatures. Working with Dr. Debby Delmer, we provided evidence that sucrose synthase (misnamed because it degrades sucrose) is involved in secondary wall synthesis in cotton fibers and tracheary elements. This led to consideration of how changes in intracellular carbon recycling could potentially make cellulose synthesis more environmentally resilient. Very early in the era of cotton biotechnology, we made transgenic plants to test this idea (in collaboration with Dr. Norma Trolinder, the pioneer in transgenic cotton) and isolated and tested a secondary wall promoter that was useful in cotton fiber.

Upon moving to NC State University as a Professor, my lab's studies on cotton fiber expanded into other areas. I vividly remember the moment I realized that a graduate student had not made a mistake while doing transmission electron microscopy. His images showed that cotton fibers do not elongate as single cells; instead, they secrete a special cell wall layer that conjoins the fiber population into a single 'tissue'. Together with collaborators, including Dr. Niki Robertson's group, we demonstrated the capacity of virus-induced-gene silencing to provide more efficient testing of gene function in cotton. With the continuing support of Cotton Incorporated, we began to work toward the possibility of generating superior cotton fibers (like Pima cotton produced by *Gossypium barbadense*) on the commonly grown, high yielding, Upland cotton (*G. hirsutum*). To this end, with the support of the NSF we developed and published a rigorous transcriptomic and metabolomic data set that illustrated how cotton fiber has mainly shut down lignification, how the 'transition stage' between primary and secondary wall synthesis is developmentally distinct, and how mitigation of oxidative stress is a major key to enhancing cotton fiber elongation. Recently, we showed that, despite being single cells, cotton fibers are not all alike: a population of young Upland cotton fibers contains narrow and wide cells. Through multi-disciplinary collaborations embracing computational biology, breeding, genomics, and computer vision, we are currently exploring the implication of this finding for mature fiber quality.

While at NC State, I greatly benefitted from becoming part of the multi-institutional, multi-disciplinary, Center for Lignocellulose Structure and Formation (CLSF), an Energy Frontier Research Center. CSLF was funded by the U.S. Dept of Energy, Office of Science, Basic Energy Sciences and led for many years by Dr. Daniel Cosgrove. Within CLSF, I stimulated a protein modeling colleague (Dr. Yaroslava Yingling) and her group members to generate a *de novo* computational model of a plant cellulose synthase before a bacterial template existed. We used the model, in combination with freeze fracture electron microscopy, to provide evidence that a plant cellulose synthesis complex contains 18 cellulose synthases, which was only half of the number assumed for several decades previously. Computational protein structure prediction remains useful because some regions of plant cellulose synthases are intrinsically disordered and do not yet have solved structures. Recently, our collaborative group has generated and used complete 'hybrid' structural' models that blend information from solved structures and *de novo* modeling. With other collaborators (including Dr. Alison Roberts, who was my first graduate student), we were pioneers in making hypothesis-driven point mutations or small domain swaps in plant cellulose synthases, followed by testing of protein functionality *in vivo* through mutant complementation. We are continuing to explore how a 'gating loop' and the transmembrane polymer translocation channel help to regulate cellulose synthesis.

There have been many compelling questions and interesting research outcomes in the many years that I have studied cellulose synthesis, secondary wall formation, and cotton fiber development. It has been particularly gratifying to see many others around the world pick up these lines of investigation and make important further discoveries!

What impact did ASPB have on your career?

I remember attending an ASPB meeting early in my graduate career. The meeting was held on a university campus, everyone stayed in dorms, and talks were given in classrooms. I don't have a record of an abstract from that meeting, but it was an early exposure to the larger community of scientists and a motivation to want to become an accomplished researcher and join them. Four years after I began as an Assistant Professor at Texas Tech University, I began to take my own graduate students to ASPB meetings, a pattern that continued after I moved to North Carolina State University. The ASPB meetings had special value through welcoming all areas of plant research and through including stellar symposia that were helpful for general education, research, and teaching. I've also appreciated knowing that ASPB advocates on policy matters important to plant science.

What advice would you offer a young person considering a career in plant biology?

Many things come to mind, some of which I've done well and some where I could have done better! Be willing to learn from anyone. Always go above and beyond what is required. Learn key fundamental knowledge, for example plant anatomy, as that will enhance all your research efforts. Become a true scholar—read deeply and analytically in your field, including historical literature. Find the supporting data and assess its rigor before asserting something to be true. Internalize that scientific research progressively reveals the truth, so don't worry about being 'wrong' if you've done your experiments thoughtfully and rigorously and evaluated the results objectively. Maintain high expertise in a technical area while you also embrace new methods and collaborators. Work on important questions in crop plants with the mindset of a biologist. Foster, acknowledge, and celebrate the successes of your students and other trainees. Choose a scientific society in which you exert leadership over many years. Strive to live, work, and treat others at a high ethical standard so that you will have no regrets once your fascinating journey as a plant scientist and educator comes to an end.

Academic Family Tree:
https://academictree.org/cellbio/peopleinfo.php?pid=649253