Daniel Schachtman

How did you spend your career?

I was an active kid growing up, and then in one year, at age 13, I broke my arm and then my leg. During that time stuck at home after school, I started watching a gardening show on PBS hosted by Thalassa Cruso. That simulated my interest in indoor plants and then vegetable gardening. I was lucky that my mom supported my hobby of growing indoor plants, and my dad let me plant small gardens all over our suburban yard and have a compost pile.

My interest in plants eventually led to my career in plant science, but not without a big detour. Coming from a suburb of Chicago, I had this idea that a city kid needed go into business, and so I obtained my first degree in agricultural economics from the University of California (UC), Davis. After graduation I traveled for a year and returned to no job and no career. Figuring out the next step wasn't easy, but I eventually landed in the Vegetable Crops Department at UC Davis and did a master's degree with Arnold Bloom and Jan Dvorak. I found I really enjoyed plant research, was good at doing experiments with plants, and enjoyed reading scientific literature.

Eventually this led me to do my PhD in Australia on salt tolerance in wheat at CSIRO and Australian National University. This suited my love of travel, and I ended up in what was the most wonder-

ful work environment I've found in my career. During that time, we showed that sodium exclusion was important for salt tolerance in wild species related to wheat. Rana Munns and I developed a quick method for accurately measuring sodium exclusion capabilities in wheat lines, and we used that method to screen a large germplasm collection of the wild D genome progenitors of bread wheat. That material was then used to try to identify genes related to sodium exclusion using RFLP mapping with Rudi Appels and Evans Lagudah. In addition, I also tested the hypothesis that root ion channels differed in their selectivity between salt-tolerant and salt-sensitive wheat varieties. Those studies were the first to patch clamp plant root cells and helped me gain experience with electrophysiology. That work was done with my colleague Stephen Tyerman in Adelaide.

After my PhD in Canberra, we moved to UC San Diego, where I pursued the molecular basis of sodium exclusion in wheat roots with Julian Schroeder. I had the best bike ride commute to work imaginable, from Del Mar to the UC San Diego campus, partially along the coast. The work in Julian's lab provided a couple of seminal findings, including characterization in frog oocytes of the first plant inwardly rectifying potassium channel that was very selective for potassium versus sodium and the cloning of two other transporters using yeast complementation. I was lucky to be acquainted with Wolf Frommer, who coached me through the yeast system, and Marty Yanofsky, who helped me learn more molecular biology. One of the transporters I cloned was called HKT1. As it turned out, 20 years later Rana Munns showed that HKT1 in durum wheat was essential for sodium exclusion. So the story came full circle from our initial work identifying sodium exclusion as an important trait, to the cloning of HKT1 in my postdoc, to work by my PhD supervisor showing that HKT1 genes are important determinants of salt tolerance in durum wheat.

After my postdoc we moved to Adelaide, Australia, and spent the next 7.5 years raising two children. During that time, I worked at CSIRO and the University of Adelaide on HKT1, tolerance to zinc deficiency in barley, and salt tolerance in grapevine. Again, some of the people who oversaw my work at CSIRO left a formative impression on my science. Mark Thomas taught me the importance of a methodical approach to troubleshooting and of

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having the confidence to overcome any scientific hurdle.

In 2001 I left Australia to take up a position at the new Danforth Plant Science Center in St. Louis, Missouri. It was very exciting to be one of the founding PIs in a new plant science research institute, thanks to Roger Beachy. There we started several different projects, three of which were highly productive. We pieced together a signal transduction pathway for root response to low potassium and showed for the first time that reactive oxygen species was pivotal to plant root response to low nutrients. That work also identified a kinase, an MYB transcription factor, ethylene, and another transcription factor that were all part of the signaling pathway in response to low potassium.

We also conducted the most thorough characterization of maize xylem sap constituents at the time and identified other compounds important in stomatal closure under drought. Finally, together with two other PIs at the Danforth Center, we did some pioneering work on transport proteins and their function in nematode giant cells. One of them turned out to be an auxin transporter. Using the skill I gained working with oocytes, we clearly showed for the first time that this transporter moved auxin across plant membranes. Even though these transporters had been identified many years earlier, their function was a bit controversial until our work.

In 2008 I took a job at Monsanto, where I spent three years searching for genes that increase the nitrogen use efficiency of maize and two years trying to innovate on the maize transgenic testing pipeline for the yield projects. In 2011 I closed my Danforth lab but continued to work at Monsanto. During this final period in my Danforth lab, we showed that overexpression of zinc transport proteins increased the zinc content in cassava tubers but threw the plant zinc homeostasis out of balance, leading to zinc-deficient leaves. Being at Monsanto was a tough time for me scientifically because it was largely unproductive, but it forced me to grow as a person in many ways and taught me a huge amount about leadership, inspiring the people around you, and emotional intelligence.

Toward the end of my time at Monsanto, I was involved in an interesting strategy team that was tasked to study the ways in which Monsanto could move into the field of biological inoculants. In 2014 I moved to the University of Nebraska as a tenured professor. Through the work on the inoculant strategy team at Monsanto, I realized how little rigorous science had been applied to the study of most of the bacteria and fungi in agricultural fields. I also became aware of the exciting advances in culture-independent approaches using new sequencing technologies. As a result, I decided to embark on a new research direction with strong emphasis on soil microbe–root interactions. So in the past four years I have developed a laboratory that studies plant tolerance to abiotic stress and soil microbe–root interactions and the intersection of these two topics. The leap into the microbial world has been challenging, to say the least, and required that the laboratory personnel learn microbiology, ecology, and bioinformatics. Jumping into a completely new area of science at 54 years of age has been difficult, but having the support of my very bright and skilled wife, Ellen, with me at the bench made this transition possible. She has been very supportive of my career, and we have worked together for at least 20 years. The contributions Ellen has made to our science has been a critical factor in my career.

One of the things I love about the scientific career are the challenges, the variety of work, the discovery, and the environment where you can constantly be learning. My research career has been varied, with impact in a number of different areas, but with a strong focus on roots and plant response to abiotic stress. Together with many awesome mentors and colleagues, my career research has ranged from genes, to proteins in membranes, to whole plants, and now to field-based research on microbes associated with roots. We have been very lucky to have been supported over the years by funding from NSF, DOE, USDA, several foundations, industry, and the Australian Research Council. I've made many scientific friends over the years and feel that being a scientist is a privileged position in society. Even though it has had its moments of great difficulty, stress, and despair, I could not have imagined a more rewarding, interesting,

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and fun career, which has allowed me to work closely with some of the most amazing people and organisms on Earth.

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

The following contributions are among my most important:

- 1990—contributed new knowledge to the physiological basis of salt tolerance in wheat
- 1992—characterized in oocytes the first inwardly rectifying potassium channel in any organism
- 1994—cloned and partially characterized HKT1
- 2005–2012—elucidated multiple components of the Arabidopsis root nutrient signaling pathways in response to low potassium
- 2006—demonstrated that AUX1 transported auxin using oocytes
- 2005–2008—contributed new knowledge to our understanding of the composition of the maize xylem sap under drought-stressed conditions
- showed that the below-ground microbial communities respond to water deficit and are shaped by decades of maize hybrid breeding.

When did you become a member of ASPP/ASPB?

In early 1990.

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

ASPB was formative for me because at my first ASPB conference, I found my postdoc position advertised. This was before the Internet, and so finding a place in the Schroeder lab really changed how I viewed science and my career. ASPB has also provided strong journals in which to publish my work and a community for me where I could interact with excellent colleagues.

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

Don’t be afraid to fail. If you don’t take risks, especially in science, your work will be ordinary and lack impact. But realize that when you fail, it is not the end of the world, and you need to keep moving forward. Find a supportive environment with strong colleagues whom you can bounce ideas off and collaborate with. If you get stuck in a rut on one topic, move on to something else. There are many important questions to answer in plant biology. It is important to know when to drop ideas and when to pursue them. Holding on to ideas too tightly can cause problems, but it is also tricky to know when to stop working on certain projects