ASPB Pioneer Member

Jerry Cohen

The beginning: My very early life was on a small farm near Half Moon Bay, California, where my parents primarily raised flowers commercially and my father supplemented the family income by teaching agriculture to WWII veterans at San Mateo Junior College. For a toddler, farm life was idyllic, climbing trees, playing with our dog, Duke, and eating watercress from the stream behind the house, but it was difficult to make a living this way, so my dad took a job with the USDA just before I started kindergarten. From first grade through high school, we lived in Dixon, California, where I was educated to the standards of a small farming community. Outside of school, I enjoyed doing many of those things now thought too dangerous for kids to do. While Dixon lacked many of the educational opportunities found in larger places, I discovered early that the library could show me the world. I loved science fiction, and from there found the world of science, which opened my mind to those things that fiction only teased about.

Higher education: Based on high SAT scores, I was admitted to the University of California, Riverside (UCR) early, and this allowed me to enroll in metal shop in high school, a class otherwise reserved for vocational students. I picked UCR because it had a major in microbiology, and I had developed a fascination for single cell life. In addition, Riverside was far from where I was raised, and I liked desert climates. While my parents and my previous jobs helped me with the initial college expenses, it was clear from the beginning I would need to fund my own education. Working one's way through college has many disadvantages, but I was lucky and with the help of sympathetic faculty, I always had a research job and that had important advantages for a future research scientist.

Although I think my early experiences in the lab shaped the trajectory of my career, it would be an incorrect characterization of my early college life. I studied in the UC system during the era of the Vietnam war, and like many UC students I was super active in the antiwar movement and student activism. I was also a student leader; I organized an early version of course evaluations, served as a student representative at faculty meetings and was involved in the Chancellor's campus-student-community retreats. While I took difficult courses, I was not a top student in them – I was far too involved with social and movement activities to give full attention to my studies. It was not until sometime after my 21st birthday that I made the personal decision to focus on science. I was able to stay employed and an undergraduate student for a fifth year of study while I waited for Sue, now my wife of 52 years, to finish her degree and us to get married.

Graduate education (MS): Finding graduate education for Sue and me that wouldn't separate us hundreds or even thousands of miles apart was complicated. While a postdoc at UCSD, Kenneth D. Johnson had taught a course at UCR that Sue had taken, and I had an opportunity to meet him. At the time of my graduation, Ken had taken a position at San Diego State University (SDSU), and I became his first graduate student and worked for my MS while Sue worked on an MS in mycology. Because of Ken and his joy for discovery, it was an exciting place to be, but there was also David L. Rayle and occasionally Michael J. Dowler working together in one laboratory. Although the Botany Department at SDSU was small, the graduate students helped each other, and we learned from each other as well. My thesis, "Relationship between cell wall glycosidases and cell extension in *Avena* coleoptiles", was completed in 18 months, and I presented my results at the ASPP meeting at Cornell that summer. With the advice and support of Ken Johnson, I was off to Michigan State for continued graduate studies.

Quest for the Ph.D.: Michigan State in 1974 was arguably one of the best places in the nation to study plant physiology/biochemistry. Many of the people I interacted with there, from the faculty to undergraduate students, have become leaders in the field during my lifetime. During my first year in the graduate program I was supported on a TA and did laboratory rotations with Derek Lamport, Ken

Nadler, and Bob Bandurski. The rotation project in Ken Nadler's lab, developed in discussion with Norm Good, resulted in a publication in Plant Physiology. I ultimately joined Bob Bandurski's lab and started on a project to use indolo-α-pyrone fluorescence for analysis of auxin. Despite trying lots of variations and pretty much proving it was not going to work, it took the intervention of a postdoc, Axel Ehmann, and a senior graduate student in the lab, Greg Dilworth, to convince Bob the problem was the project and not me! While Bob was an excellent mentor, it was really Greg Dilworth and Axel Ehmann who were responsible for my entry into the technology necessary for success. What Greg and Axel taught me was how to broaden my scientific vision, be meticulous in my lab approaches, and interact with Bob. My Ph.D. thesis, "The physiology and analysis of indole-3-acetic acid and its *myo*-inositol esters" could still be a thesis topic in 2024, and that project was far more successful than my first one. I was funded on a fellowship from the Michigan Agricultural Experiment Station, but our lab was largely NSF supported.

Many things during my studies stand out, but I fondly remember several people. First, our NSF program director, Eli Romanoff, who would call the lab, and if Bob was not there would ask "...so what have you been working on?", followed by a long discussion with much excellent advice. Similarly, if I went to the Dean's office, I might be summoned into Dick Byerrum's office for another "tell me some science" discussion. I did not know then how truly remarkable these experiences were until I experienced contrasting styles throughout my career. Jane Shen-Miller, then at the Argonne National Laboratory, served as an 'external advisor' and I also learned a great deal about hormone physiology from her that complimented the biochemical focus of my guidance committee.

In our tribute to Bob Bandurski, we (Greg Dilworth, Peter Felker, Dennis Reinecke and I) noted that he cultivated a great lab family environment, with holiday dinners at his home, long bicycle trips, canoe lab outings, as well as lunch and in-lab celebrations. Bob had high expectations for us as scientists, but he set an even higher bar for us as thoughtful humanists with a world vision.

I cannot list here all the great lifetime friends I made in graduate school and my postdoctoral years at Michigan State, but the impact that group has had on plant science research and in higher education throughout my career is truly amazing. Several international scientists, including Ephraim Epstein, Lech Michalczuk, and Yoshi Momonoki, influenced my research and have been friends for all these many years. After graduation, I stayed at MSU working in Bob's lab, while also working to expand the MSU/NIH mass spectrometry facility in Biochemistry, where Chuck Sweeley had obtained funding from the Michigan Agricultural Experiment Station. During this time, I also became a father with the birth of my son Aaron. The opportunity to have hands-on mass spectrometry experience has been valuable throughout my career and has guided my own graduate and postdoctoral educational philosophy.

The next career step: Following my two years as a postdoc, I was looking for new opportunities and was especially interested in advanced mass spectrometry. I wrote to Clinton Ballou at UC Berkeley and after an interview was offered an ideal postdoctoral position. Life, however, has the potential to change our directions. That summer I attended the ASPB meeting at Laval University. While there, Morris Lieberman dined with Bob Bandurski and Mark Brenner, explaining to them his dilemma of leading a plant hormone laboratory while lacking the expertise to measure most hormones. Upon meeting me at the posters, Morris said, "I think I want to hire you, when can you come to Beltsville to see if we are good enough."

It was a great opportunity, and I made the choice to move to Maryland and begin an independent research laboratory at the USDA in the Plant Hormone Laboratory (PHL). Unfortunately, Morris passed away less than 3 months after I started, and his wise guidance was thus short lived and not replicated. While the Plant Hormone Lab never reached its potential, my laboratory grew quickly with good people. Krystyna Bialek had been hired into the PHL by Morris, and she soon joined our group. Janet Slovin and I had met at an ASPB meeting in 1980, and we shared a common vision of understanding plant hormones, especially auxins, by using molecular biology, mutant genetics coupled with advanced analytical and biochemical methods. Janet joined the lab in 1983 to head the molecular vison for our research. Both Janet and Krystyna were fully capable of running their programs without me, but the three of us were

more productive together. We had important successes and we had fun. We decided early to focus on reference species, first using Lemna, then corn and somewhat later Arabidopsis, often with begrudging USDA tolerance. We had some marginal independence, because we had grant support, first from USDA-CRGO and then the molecular analysis work that Janet led was soon well funded by the NSF and later by the DOE.

Education of graduate students, postdocs and others: The University of Maryland (UMd) is only two miles from the USDA labs, but in the 1980s few USDA scientists interacted on a regular basis with colleagues at UMd. My first UMd interaction was hiring students to work in my lab. However, Larry Vanderhoef was UMd provost, and we were both colleagues as well as friends. Larry recruited our lab's first graduate student, Kai-Hsien Chen, while on a visit to Taiwan. While Larry later left for UC Davis, well before Kai finished his degree, Larry remained both financially and personally engaged. Anita Nina (Miller) Azarenko, formally advised by Chris Walsh at UMd, made the transition from chainsaw to mass spectrometer in a week and became the second graduate student in the lab. Victoria Yorke was hired as a temporary technician and Bruce Baldi, while working on his MS on aflatoxins was our student technician. Victoria left after one year for medical school. Bruce, however, was bitten by the plant biochemistry bug; he moved to Washington State for his Ph.D. and returned to the lab a few years later as a postdoc.

During the decade of 1983-1993, we had many international activities, including visiting scientists, such as Ephraim Epstein and Nehemia Aharoni (Israel), Lech Michalczuk (Poland), Arild Ernstsen (Norway), Rubén Bottini and Patricia Piccoli (Argentina). A particularly fortuitous interaction was a visit to my office by Prof. Pasquale Rosati from Italy, who established a long-term interaction between my lab and the Consiglio Nazionale delle Ricerche (CNR) in Bologna, Italy. This association began with visits by Rita Baraldi to my lab and my visits to Italy starting in 1985 and continuing through to a longer-term visit by Francesca Rapparini more than a decade later.

While Kai and Anita started our lab's involvement with graduate education, it was the development of a close scientific friendship with Todd Cooke at UMd that made graduate education in collaboration with UMd a more frequent activity. Thus, in subsequent years, Yuen Yee Tam and David Ribnicky (1996); Jyh-Ching Chou, Ester Sztein, and Nebjosa Ilić (1999) were able to do research jointly with both labs and complete their UMd degrees. Some of Todd's students, such as Roxanne Fisher and Carol Auer, also benefited from our lab interactions. Carol later joined our group as a USDA-funded postdoctoral fellow.

Scientifically, the first decade saw the development of new strategies for using stable isotopes to study phytohormone metabolism, important improvement in analytical methods and employing the use of genetic mutants to approach biochemical questions. The first of our workshops on methods started during this time. Perhaps more importantly, our ideas about pairing mutant genetics coupled with advanced analytical and biochemical methods came to enhanced fruition with collaborations with M. Gerald Neuffer and Gerald R. Fink on tryptophan auxotrophic mutants. Visiting postdocs from their labs, including Allen D. Wright and Jennifer Normanly, also enriched these studies. Visiting scientists, such as Ellen Sutter, Volker Magnus, and Tom LaRue, as well as several postdocs, including Bruce Baldi, Anders Östin, Mridula Iyer, Gary Kuleck, and Seijin Park allowed us to expand this work by moving in several new directions. USDA was not without important colleagues as well; especially memorable were our collaborations with J. George Buta, George W. Pittarelli, Jeffrey S. Karns, Walter W. Mulbry and, of course, with Janet Slovin once she built her independent USDA research group.

An oddity of federal employment was the high priority equipment list – a wish list of aspirational equipment desires rarely realized. In 1986, the federal government went through an across-the-board budget cut that was highly disruptive for research. However, only at the USDA can budget cuts lead to extra funding for equipment and our aspirational desires suddenly became reality. We went from a lab working with small bench-top mass spectrometers to having a high-resolution magnetic sector machine that was state of the art. We also hired a bright young chemist, Barbara Maher, to run the system. This was an important step in establishing our firm foundation in the area of research mass spectrometry and built connections to other labs pushing the frontiers of small molecule and peptide analysis.

Krystyna Bialek first discovered that

an auxin conjugate in bean was a small peptide and Seijin Park found a larger IAA modified bean protein. An international student exchange with Jutta Ludwig-Müller in Germany brought Alexander Walz to our lab, and he cloned the gene for that protein following mass spec proteomic sequencing. Alexander and Seijin helped bridge the transfer of my program to Minnesota.

Research or administration? In 1991, I received an appointment as acting Research Leader for the Plant Hormone Laboratory. Although I had headed my own USDA-ARS program, served on various committees and task forces, this was my first administrative position. This assignment was followed by being selected as one of a dozen or so scientists nationally to be part of a two-year USDA-ARS program for education in scientific administration. Part of this program was an administrative internship, but because of changes at the USDA this was delayed until 1998, when, following excellent advice from Machi Dilworth, I went to the NSF. I first was a program director in Cell Biology, but six months into this program, I was selected to become Deputy Division Director for Molecular and Cellular Bioscience. Thus, I stayed at NSF for an additional year. The situation at the USDA remained problematic with new organizational changes, so while at NSF I interviewed for two different positions at the University of Minnesota (UMN). I returned to USDA only long enough to pack up my laboratory and office and leave before Y2K arrived.

An academic life: When I informed MCB Division Director Maryanna Henkart that I had two possibilities of positions at UMN, a department head and an endowed chair, she was only excited about the endowed chair possibility. After very careful soul-searching, I made the decision that my future was in a university laboratory with a direct role in the education of graduate students and postdoctoral scientists. As was usual, like in so many of my experiences with Maryanna while at NSF, we also agreed on this – what the next step in my career would involve.

The move to the University of Minnesota (UMN): In my interview for the Gordon and Margaret Bailey Endowed Chair in the Department of Horticultural Science at UMN, I asked the group of very senior faculty what they thought an endowed chair should do and they agreed on "set a good example" – simple but it could be difficult, I remember thinking. The Department Head, Gary Gardner, extended an offer to me in the summer of 1999, and we set my start date for January 1, 2000 – the exact time of the Y2K millennium bug, a worry for many but the start of a new phase for my science.

When I left USDA-ARS many people asked me 'why did you leave?' There were many reasons. First was the realization that my program had grown to near the limits of USDA size and staying at the USDA meant that my science future would look like my present. The second was the realization that USDA scientists can never be truly independent, and thus I faced the undesirable expectation that "you cannot stay at the bench" for your entire career. Third, and of critical importance, was the discrimination, both subtle and overt, at the USDA. Such discrimination extended from the way support people were treated, to difficult situations with postdocs, and clearly biased scientist hiring policies. The ramifications of this tended to disadvantage many people who tried to improve on diversity and opposed discriminatory policies. My experience at NSF, a government agency with an environment devoted to funding great science but with a keen eye to diversity and opportunity, made a return to USDA seem personally difficult. These issues all suggested that both my research and my concerns for social justice would thrive in a more academic environment.

My move to the UMN proved to be an excellent decision, giving me the opportunity to expand my science in new and sometimes unexpected directions. The move also resulted in interactions with colleagues who are devoted to improving educational opportunities for the next generation of scientists and improving our own research capacities. Minus the stress of working in the USDA-Beltsville lab, my chances to interact with the students and postdocs improved and the opportunities to teach and develop courses has been delightfully easier and very rewarding. I was privileged to be able to return to the NSF in 2004-5 as Deputy Division Director of MCB, and for several months in 2008 I was an Intermittent Program Director for Plant Genome Research.

Dr. Seijin Park moved to the UMN with me, and we set up a functional laboratory with help from two very hard-working undergraduate students. Alexander Walz initially stayed at Beltsville, luckily able to continue working in Janet Slovin's lab

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for a year, and then moved to the UNM to join us and to set up the molecular biology components of our still growing group. Dr. Yunde Zhao was our first UMN visitor and did IAA analysis on yucca mutants. Dr. Julie Tillman next joined the lab and began our serious quest to automate auxin measurements. When Julie left with her husband, Steven J. Seybold, for California, Dr. Lana Barkawi, who had received her Ph.D. in the Seybold lab, continued the development of advanced analytical technology and its applications. My first UMN graduate student, Angela Hendrickson Culler, soon joined the lab and worked on *in vitro* studies of tryptophan-dependent IAA biosynthesis in maize. Dr. Minsang Lee, funded by a contract with Renessen LLC, joined the lab to study developing seeds that over expressed a gene encoding anthranilate synthase. Together with Jyh-Ching Chou, who re-joined the now relocated lab as his second postdoctoral experience, we began to think about our work using the framework of a metabolic systems biology approach.

UMN is a large university with almost unlimited opportunities for collaborations. Early on, I joined with Gary Gardner and his lab's postdoc Gerard Engelen-Eigles on efforts in the Plants and Human Health initiative. That interaction expanded across the campus to many other departments and centers. This has been an enduring collaboration throughout my time at UMN. Similarly, my interactions with the Department of Chemistry, starting with collaborations with Pete Carr, have been important for our analytical studies, as have our interactions with Biochemistry, Molecular Biology and Biophysics, mostly through the Center for Metabolomics and Proteomics.

My NSF experiences changed the evolution of my thinking about science and how I would approach new research problems. One concept that intrigued me, expanding on thoughts dating from my 1980 paper with Ephraim Epstein, was how to measure dynamic processes, extending from metabolites to protein turnover. This soon expanded into new ways to look at the proteome and, based on my experience with auxin metabolism, the metabolome. Bill Gray and I were funded by NSF to study protein turnover and Drs. Xiaoyuan Yang and Wen-Ping Chen joined us as postdocs working on this project. UMN hired Adrian Hegeman as a new faculty member in Horticultural Science to fulfill our campus efforts to expand metabolomics campus-wide. Adrian joined with Bill and me to expand our ideas on turnover and the development of measurement and modeling approaches.

The ethics of both graduate education and postdoctoral studies have been a keen interest of mine since events during my own graduate experiences, as well as during my years at the USDA. From 2005-2009 I was able to serve as the Associate Director for Graduate Studies and Director of Graduate Studies for the Plant Biology Graduate Program at UMN. This was a rewarding experience and some important changes in the program came about during this time. I was able to establish a good working relationship with the postdoctoral group on campus, and in 2013 UMN recognized these and other activities with the award for "Outstanding Contributions to Postbaccalaureate, Graduate, and Professional Education, University of Minnesota."

The activities of the lab in the 21st century have been exciting, and working in the environment of a major research university has been both productive and enlightening. Our group has been able to advance research on three fronts: analytical advances, metabolomics/proteomics, auxin biochemistry, and bioinformatics. The analytical studies have been important from the beginning, but the advances in instrumentation changed things as our lab moved from conventional technologies to triple quadrupole mass spectrometers and then to high-resolution orbitrap systems. These transitions were facilitated by excellent postdocs, including Lana Barkawi, Paul Boswell, Daniel Abate-Pella, Mikel Roe, Nathan Tivendale, Dana Freund, Evan Larson; and graduate students, including Xing Liu, Peng Yu, Molly Tillmann, Yuan Xu, Qian Tang and Daniel Bacher. Our ventures into proteomics and metabolomics would never have progressed without close collaboration with Adrian Hegeman. Our studies in these areas were also only possible with a mix of technical employees, including Will Menzel, Mark Esler, Calvin Peters, and the postdocs and graduate students. In addition, Mike Wilson's work on plant resins, studies we did in collaboration with Prof. Marla Spivak, and the efforts of two students advised by Adrian Hegeman or jointly with Adrian and Bill Gray, Kai-Ting Fan and Erin Evans, contributed importantly of our expanding efforts in these omics fields. Using a somewhat novel approach, we developed chambers for

growing plants fully enriched in ^{13}C and/or ^{15}N for our use in metabolic studies (13carbon.com).

Our studies on auxin biochemistry benefitted from the conceptual framework of metabolomics. The work has progressed from studying a single target compound to where we try now to look at questions with a systems biology or network approach. This began with the studies of both Xing Liu and Peng Yu. Molly Tillmann then combined the technology with a chemical biology approach to look at IAA biosynthesis. Qian Tang employed Peng Yu's methods to isolate auxin conjugates, and she went on to study their function to yield IAA for growth. Qian also developed methods for very fast kinetic analysis of stable isotope tracers. Modern approaches require a deeper dive into statistical approaches, and we have benefitted from early collaborations with Aaron Rendahl, Arthur Eschenlauer and others, but more recently with previous graduate students, especially Yuan Xu and Kevin Murray.

The world of science is small: My international involvement did not stop with my move to UMN, and I have continued with such activities. I was elected President of the International Plant Growth Substances Association (IPGSA) in 2007 and helped organize meetings in Tarragona Spain (2010) and Shanghai China (2013). Trine Hvoslef-Eide (Norway) visited in 2009-10, and Rubén Bottini and Patricia Piccoli (Argentina) returned to visit us in 2011. Trine and Rubén were both funded on individual Fulbright awards. Nokwanda "Nox" Makunga (South Africa) visited Adrian and me in 2018 on another Fulbright. Alexander Walz, co-advised by Dr. Jutta Ludwig-Mueller, obtained his Ph.D. at Technische Universität Dresden in 2003, and Luz Gabriela Muñoz Sanhueza received her Ph.D. from the Norwegian University of Life Sciences while co-advised by Prof. Trine Hvoslef-Eide. For the last seven years I have had a collaboration with Prof. Marjorie Marianela Reyes Diaz at Universidad de La Frontera in Temuco, Chile as well as with her former graduate student, Dr. Jorge González-Villagra, and her current and past students, post docs and collaborators.

Closing thoughts: My career has allowed me to track my love for science and to enjoy interacting with others that share that commitment. My two main goals, discovery of new knowledge and education of a new generation, are important. However, these goals are bolstered by a keen understanding of the personal and community needs for science to ultimately be for societal good and increase our understanding of the world in which we live.
Many people can do experiments, but I believe a fundamental goal should be to design each study to be excellent science that probes a little deeper and represents an effort to seek out that special beauty of creativity. In recent years, I see a community-wide over-reach in attempts to define 'translational research'- a kind of fundamental research with an applied end. It is, however, critically important to continually promote the value of pure curiosity-based research and educate the public about how counterproductive were it to be restricted.