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Formative Influences

I consider myself lucky to have been born in the United States at the end of 1946, the leading edge of the post-war baby boom. Women born five years earlier didn't have the chance to become university professors; people born five years later faced a limited job market and fierce competition in science.

I grew up in a family that prized education and science. My father, Lester Kuhn, was a chemist who developed propellants during World War II and afterwards pioneered the use of infra-red spectroscopy to reveal the shapes of molecules in solution. My mother, Marcia Goldys Kuhn, seemed frustrated to be a homemaker in the 1950s. She served on dozens of civic committees and was a founding member of a book club. As children of immigrant families who suffered during the Depression, both parents saw education as a way to enrich our lives both economically and culturally. They encouraged my pursuit of music and science fairs. They were delighted when I was selected to the "Top 40" of what was then the Westinghouse Science Talent Search. These early successes gave me a sense of promise that sustained me during my undergraduate years at Harvard and early in my career when women were not evident as role models for career scientists. Another formative influence was the countryside surrounding the homes in our small town. After school, my brother Steven and I would change into blue jeans and sneakers and race off to climb trees, swing on vines, explore streams and ponds, and braid cattails from the marshes. We read Boy Scout magazines in a secret hideaway in a thicket on a ridge above a pond.

At Harvard, three out of the 300-some undergraduate majors in Applied Mathematics were girls. I felt overwhelmed. I did not do well academically. I gravitated to Biology where there were more women, and I enjoyed a senior project with tutor Bill Bossert, a mathematical biologist who seemed to take my interests and ambition seriously. During my senior year, I had a whirlwind romance with a young astronomer, Joseph Silk. We married in August after graduation, and I followed Joe to his postdoc in Cambridge, England. There, I landed a job at the fabled Laboratory of Molecular Biology, where Watson and Crick had envisioned the double helix. My boss, protein crystallographer David Blow, was impressed at my training in math and biology. He enthused that I would be able to work with the theorists in the morning and in the laboratory in the afternoons. It was an exciting time to be in protein chemistry, as X-ray crystallography had recently revealed that proteolytic enzymes from very different life forms all had the same configuration of amino acids around their active sites. Alas, the theory part of my job turned out to be typing my boss's computer cards and ferrying them to the IBM 360 computer in another building. The laboratory work was using computer output, a measuring stick, protractor, and plumb bob to build a ball-and-stick model of the chymotrypsin molecule. My mind wandered. The positive outcome was that graduate school seemed an appealing avenue after all. Perhaps with more training I could find an opportunity for more creative work.

Luckily, Joe moved to Princeton so that I was able to accept a fellowship at the University of Pennsylvania. There, I had the great good fortune to study with Paul Green and Ralph Erickson, who kindled my interest in plants. My time at Penn was cut short by another career move for Joe, this time to Berkeley. But by then I had accumulated some academic successes and was accepted into Russell Jones' lively laboratory, where I did my doctoral research on the gibberellin response in lettuce hypocotyls. Russell made me aware of the importance of publishing ("five figures make a paper"). In the Jones lab I enjoyed interacting with my articulate lab mate, Linc Taiz, and I loved the exchange of ideas at research seminars at both Berkeley and Stanford, where Paul Green had moved. I had my first child in 1971, during my first year at Berkeley. Faculty would come up to me in the hall and remark, "We are so sorry to see you are leaving our program. You were one of our more promising students." And indeed, I thought I might be leaving the program. No tenured women were on the faculty, and no young children were evident at graduate social events. However, Russell Jones encouraged me to continue with my research project, part time at first. My infant son seemed to thrive with care from two parents and a babysitter. A women's consciousness-raising group and the publication of the first issue of Ms magazine were formative influences. And so, I persisted.

I was thrilled when I received a post-doc offer with Ralph Erickson back at Penn to resume work on mathematical aspects of botany, and Joe agreed to a sabbatical at nearby Princeton. At Penn, I was startled to get a letter inviting me to apply to develop a program in quantitative aspects of plant-environment interactions in the Department of Land, Air, and Water Resources at UC Davis. I knew few female professors, and I had family responsibilities and limited geographic mobility. I had thought my postdoc might be my last opportunity to do research in plant physiology. However, in 1976 Title IX (now known as the Patsy T. Mink Equal Opportunity in Education Act), was requiring that universities receiving federal funding interview women in proportion to their representation in the doctoral pool. I learned that Ted Hsiao, as chair of the UCD hiring committee, had scoured the CVs filed by job seekers at ASPB (then ASPP). Fortuitously, I had left a few paragraphs at an annual ASPP meeting. To the surprise of Erickson, my future colleagues, and myself, I was offered an interview and then a position---commuting distance to my husband's job at Berkeley! I was the first woman hired into tenure track in a department of 45 individuals. Two years later, I was the first faculty person on campus to apply for maternity leave. It was denied. But my chair encouraged me to "work from home for a while," and my department loyally supported my promotion to tenure in 1982.

At Davis, I enjoyed a long and fruitful career endowed with talented students and postdocs and dedicated colleagues, with a vast array of disciplinary interests and opportunities. Being at a large public university facilitated winning grants from the National Science Foundation and the United States Department of Agriculture.

My Contributions to Plant Biology

In my formative post-doc, Erickson suggested I analyze the curvature of lettuce hypocotyls, The mathematical definition of curvature, symbolized κ, differs from the "angle of curvature" favored by botanists since the time of Darwin. In contrast, κ is the rate of change of the local angle θ along a curve. This can be understood by noting that at every point along a hypocotyl image one could fit a circle; the reciprocal of the radius of the fitting circle is the local curvature. Visually, we see that a small fitting circle indicates large curvature, while a region with zero curvature, fit by a circle of infinite radius, is straight. Using the mathematical definition allows one to describe the spatial distribution of curvature along the hypocotyl and to compare this to the spatial pattern of physiological properties including local elongation rates and lignification. In contrast, the "angle of curvature" is a global property that does not allow analysis in terms of underlying physiology or genetics. The use of κ has permitted understanding of the different ways in which organisms produce curved forms including hypocotyls, ruffled fronds, and bent stems. I developed computer-assisted numerical methods to determine the curvature pattern along the hypocotyl hook. At the same time, I used a Bolex 16-mm movie camera to get time lapse records of the growth of some marked hypocotyls. In the movies, we saw that marks placed on the apical, straight side of the hook, appeared to move through the curved region. Apparently, the hook, which remains stationary a few millimeters behind the apex, is produced by a parade of tissue elements each of which first curves and then straightens. Erickson and I recognized the analogy to fluid structures, such as rivers and boat wakes. The fluid structures, like growing regions of plants, may appear unchanging in time, but they are produced by material elements (water droplets or cells) that move through them and experience continuing change. I came to see the hypocotyl hook as a paradigm for plant growth. Reviewing concepts and numerical methods from fluid dynamics, I realized they are powerful tools for analyzing plant development and plant-environment interactions. I coined the term "plant growth kinematics" to refer to these quantitative approaches to morphogenesis. Most generally, this approach allows us to understand spatial and temporal relationships in growing parts of plants.

At UCD, my laboratory used the kinematic approach to quantify effects of environmental variation (water stress, salinity, temperature perturbation, nitrogen availability, oceanic drag, heavy metals) on aspects of plant growth, form and biochemistry. Later, we looked at the reciprocal influence of the plant on the environment, especially nutrient cycling and soil stability. Root studies were extended to understand growth-sustaining water potentials, rhizosphere development, and pH in the rhizosphere. Younger colleagues including Bob Sharp, Donie Bret-Harte, Bruno Moulia, Achim Walter, Jiyan Shi, and Lionel Dupuy spent time in my lab and went on to have science careers that eclipsed my own. On sabbaticals in France and Australia and at Harvard and Berkeley, I learned new approaches to science and lifestyle. Sabbatical colleagues Tobias Baskin, Mimi Koehl, Michele Watt, Maha Mahadavan, and Missy Holbrook inspired projects in biomechanics.

My teaching responsibilities at UCD included quantitative skills for plant biology, introductory hydrology, and plant-environment interactions. In mid-life with encouragement from musician Ron Goldberg, my second husband, I returned to music-making for joy and community. In the classroom, I addressed the anxiety or boredom that science can provoke. Students who took the course "Science and Society 42,"Earth Water Science Song," heard me lecture on environmental science. Then they wrote songs and performed a musical in a local art gallery to teach our larger community about the natural world. These students worked hard, learned a lot, and showed an increase in self-esteem, rare in a science class.

Advice to a young person considering a career as a plant scientist

As our human population has grown, we need renewable energy and eco-friendly products, manufacturing processes, and public policies. We need to tell the public about the scientific method and teach youth about natural history. Young scientists, please, please, please persist. We need you more than ever before in the course of human history. Keep at it-- Keep at your bench work, your field work, your modeling; but also try to reach out and march for science.

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