Eric E. Conn

1923–2017

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
J. Clark Lagarias

NATIONAL ACADEMY OF SCIENCES

ERIC EDWARD **CONN**

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Eric Edward Conn was a pioneering plant biochemist whose contributions to our understanding of plant secondary metabolism by leveraging radioisotope tracer methodology. His research illuminated the path to the subsequent isolation of many genes involved in plant defense that are critical targets of ongoing agricultural improvement efforts. He also mentored a generation of investigators, who shared his passion in the fields of cyanogenesis metabolism and phenylpropanoid biochemistry.

Eric E. Conn

By J. Clark Lagarias

Early Life

Eric was born in Berthoud, Colorado, on January 6, 1923. He grew up in Belaire, Kansas, in the midst of the Great Depression and experienced the dust-bowl years and their effects on the Great Plains. After his parents lost most of their assets, the family moved to Fort Morgan, Colorado, where Eric went to high school. That small town had an excellent high school, and Eric did well academically, sufficiently so to win a four-year scholarship to the University of Colorado at Boulder in 1940, the first of his family to attend college. Eric was taken under the wing of Reuben Gustavson, a steroid chemist whose introductory biochemistry course inspired Eric's early interest in biochemistry. Gustavson arranged for Eric to be hired by the Manhattan Project during his senior year. At Oak Ridge, Eric associated with Daniel Koshland and others whose career trajectories had also been sidetracked by the war. In 1946, Eric was accepted as a graduate student in the laboratory of Birgit Vennesland at the University of Chicago, where he first embraced higher plants as his research focus.

Graduate and Postdoctoral Research

Owing to Vennesland's interests in "carbon dioxide fixation" mediated by TPN-dependent malic enzyme and other such "dark fixation" enzymes, Eric spent his first year in her lab attempting to isolate coenzyme II or TPN+, as NADP+ was called in those days, from 50 pounds of hog liver. Eric followed a procedure published in 1935 by Warburg (the discoverer of TPN+) in *Biochemische Zeitschrift*. The procedure involved precipitation of the coenzyme as a mercury salt followed by removal of the mercury with hydrogen sulfide. Further purification as a barium salt was followed by removal of the barium with sulfate, procedures Eric recounts as "miserable failures." Not wishing to repeat this method more than he had to, his second attempt resulted in isolation of 150 mgs of TPN+ that was 15 percent pure. Along with another student, Eric subsequently devised a makeshift "counter-current" purification process to increase the purify of NADP+ purity to 77 percent.

In order to follow the yield of the coenzyme during purification, Eric used a manometric procedure of Warburg's involving glucose-6-phosphte dehydrogenase and "old yellow enzyme." Both enzymes were obtained from spent brewer's yeast, which necessitated visits to a brewery behind the Chicago stockyards to collect the discarded yeast. When the coenzyme was sufficiently pure, it could be assayed by the characteristic absorption of its reduced form at 340 nm. Fortunately, Vennesland's lab had a new Beckman DU spectrophotometer—commercially available only after World War II. Its power supply consisted of two 6-volt car batteries. Imagine, nowadays one can easily purchase NADP+ from multiple commercial suppliers. Indeed, it was a hearty soul who chose biochemical research in the days when it required preparation of all the reagents needed for assays.

In his own understated words, Eric's graduate research was "not particularly distinguished." Entitled "Triphosphopyridine Nucleotide Enzymes in Higher Plants," his dissertation provided the first data on the properties of the malic enzyme in several plant species and the enzymatic reduction of oxidized glutathione in wheat germ extracts by TPNH. At this time, Eric had the only supply of TPN+ in the United States and consequently was the first to learn that plant homogenates contain enzymes (nucleotidases) that degrade TPN+ and those that oxidize its reduced form, TPNH. While not surprising today, in those early days little was known about the metabolism of this redox cofactor.

After finishing his Ph.D. in 1950, Eric stayed on at Chicago as a postdoctoral fellow at the urging of Vennesland, who asked him to co-supervise her graduate students while

she juggled with "other" administrative duties. During this time, Eric also taught the introductory biochemistry course in the Biological Sciences Survey series, an integrated biology sequence of five courses in the University College. This gave him valuable teaching and administrative experience that was important later when he applied for faculty positions. During those postdoc years in Vennesland's lab, Eric was able to participate at the beginning of a research problem that later became textbook material, that is, the demonstration of the direct enzymatic transfer of hydrogen atoms between substrates and pyridine nucleotides catalyzed by alcohol dehydrogenase (ADH) enzymes.

This subject was Harvey Fisher's research project initiated with Vennesland. For that project, Fisher had to synthesize dideuteroethanol (CH_3CD_2OH) to use as a substrate and sought advice concerning its synthesis from Frank Westheimer of the University of Chicago's Chemistry Department. Eric provided the crystalline ADH and helped Harvey with the MS measurements. The results were unambiguous,[1] and such studies initiated a decade of collaboration between Westheimer and Vennesland that significantly advanced knowledge of the stereochemistry of pyridine nucleotide dehydrogenases.

Discovery of Phenylalanine Aminotransferase

After the two-year postdoctoral position in Chicago, Eric took a position as an instructor in the Department of Soils and Plant Nutrition in the College of Agriculture at the University of California, Berkeley (UCB). His biochemical interests were welcomed in that department, made famous for studies on plant nutrition by Dennis Hoagland. Two years later, an exchange suggested by Paul Stumpf, then chair of the Department of Agricultural Biochemistry at UCB, resulted in Eric's transfer into that department, thereby increasing their ranks to four faculty. Stumpf warmly welcomed Eric, and their relationship deepened into a lifelong professional association and personal friendship. The two colleagues collaborated in writing the *Outlines of Biochemistry*, first published in 1963, and in editing the *Biochemistry of Plants* treatise in 1981.

At UCB, Eric initially continued with work involving pyridine nucleotide enzymes and soon demonstrated that lupine mitochondria could carry out oxidative phosphorylation with the same efficiency, that is, the same P:O ratios as animal mitochondria.[2] Eric's first graduate student, Tsune Kosuge, sought training in plant biochemistry in order to apply that discipline to plant pathology. Kosuge was familiar with the role of coumarin as a precursor of dicoumarol in spoiled sweet clover hay, as studied by the legendary K. P. Link at the University of Wisconsin, and proposed investigating the enzymes involved in the biosynthesis of coumarin. Kosuge's thesis research,[3] together with work

carried out after he joined the Department of Plant Pathology at the University of California Davis (UCD), is probably the first example of a multistep biosynthetic pathway for a plant natural product—coumarin—characterized at the enzymatic level.[4]

Eric Conn in his UC Berkeley days backpacking.
(Photo credit Conn Family Files.)

Eric Conn is credited with the discovery of phenylalanine ammonia lyase (PAL), the first committed enzyme of the phenyl propanoid pathway.[5] This discovery was presaged by Arthur C. Neish, a distinguished Canadian plant biochemist who had already completed an impressive body of work on the biosynthesis of lignin from phenylalanine and tyrosine. Neish had proposed that PAL's trans-cinnamic acid product might be formed by transamination of phenylalanine, reduction of the keto acid to phenyllactic acid, and dehydration to form cinnamic acid. Because Kosuge's dialyzed sweet clover extracts catalyzed the formation of detectable amounts of cinnamic acid from phenylalanine, Eric believed there had to be another reaction. He proposed a single enzyme catalyzing deamination instead, by analogy to bacterial aspartase, which did not require a NAD(P)H cofactor. This turned out to be the case. Today, PAL is considered one of a few key enzymes that enabled the transition of aquatic plant ancestors to terrestrial habitats.

Following this discovery, Eric was often asked about follow-up studies on PAL—an enzyme that gained prominence in plant secondary metabolism and plant defense compounds. Because it was derived from Kosuge's initial work, Eric selflessly urged his protégé continue with studies on PAL and TAL, the analogous tyrosine-dependent enzyme involved in p-coumarin biosynthesis. This was typical of Eric's mentoring ability and humility, which made him a beloved mentor and teacher. Despite the scoop from Eric, Kosuge wound up working on other problems in plant pathology. Kosuge, later a colleague when Eric joined the UCD Department of Plant Pathology, ultimately became an internationally recognized leader in the field of plant pathology and was elected to the National Academy of Sciences (NAS) in 1988. Tragically, this was shortly before Kosuge died prematurely from colon cancer. Later, Eric learned that Kosuge was told a few days before his death that both were to be elected to the NAS that year.

Early Studies on Cyanogenic Glycosides at UCB

In 1957, Eric had first applied for and received a three-year grant (for $12,000 per year) from the U.S. Public Health Service for a proposal entitled "Metabolism of Aromatic Compounds in Plants." This project was subsequently renewed in five-year intervals for a total of twenty-nine years, and the final year totaled $120,000, some of which had to accommodate for inflation over those three decades. About fifteen years along, when the National Institutes of Health (NIH) decided that it would no longer fund plant research, someone at NIH deleted the last two words in the grant title. Rather than complain about that decision, Eric took "the coward's way out"—in his own words—and accepted the renewal because he was supporting the salaries of multiple investigators through that grant.

Coincident with Kosuge's tenure as a graduate student, Eric initiated studies on the biogenesis of cyanogenic glycosides, which became the field of research for which Eric Conn is best known.[6] Cyanogenic glycosides (cyanogens for short) are chemical compounds found in plants that release hydrogen cyanide when chewed or digested. The act of chewing and subsequent digestion leads to their hydrolysis, releasing cyanide as a byproduct. Owing to this property, cyanogenic glycosides elicit anti-herbivory responses in animals that survive attempts to feed on them. More than 2,500 plant species produce these compounds, including some that are used as human food sources. Cyanogens notably accumulate in seeds of the stone fruits, such as apricots, cherries, peaches, and plums—so please do not eat the seeds of these plants! In this regard, Eric participated in a public-service study on the toxicity of laetrile in the late 1970s, then touted as a cancer cure in the alternative news media.[7]

Eric fondly described his situation during these early research years at UCB as a period of "limited resources" that affected the choice of both employees and plants as experimental subjects. Fortunately, with the help of Takashi Akazawa, a visiting graduate student from Japan, Eric soon discovered that sorghum seedlings provided ideal tissue for studying the biosynthesis of dhurrin, the β-D-glucoside of hydroxy-(S)-mandelonitrile, a cyanogen derived from tyrosine in sorghum.[8] Although sorghum seed contains only traces of dhurrin, making it a palatable forage grain, days-old sorghum seedlings contain about 5-10 percent dhurrin per dry weight. Because tyrosine was the obvious precursor, they fed ^{14}C-tyrosine to such seedlings as a radiotracer and observed a relatively large incorporation (5-10 percent of the activity fed) into the glycoside.

Eric reported their results at the Federation of American Societies for Experimental Biology (FASEB) meeting in April 1958 and was surprised, albeit somewhat chagrined, to hear another researcher describe almost the same experiments in a subsequent talk. Eric invited this researcher to Berkeley, where the two worked hard to identify intermediates between the amino acid and the cyanogen product. With that large amount of incorporation, they both thought that it would be a simple matter to find a few spots on chromatograms, identify them, and sort out the pathway. Such was not the case, and it eventually took another decade to establish these intermediates. At the end of the summer, the visiting researcher returned to his home campus, published a short paper, and stopped working on the problem. Eric's progress on this project was delayed by his move to UCD in the fall of 1958 and a deferred sabbatical in England in 1960.

Research Network Formation at UCD

In the mid 1950s, the Regents of the University of California approved a major expansion of the university system that included conversion of Davis to a "full-service" campus. Paul Stumpf was summoned to set up a general biochemistry department at Davis, but only Eric agreed to go with him. The other two members of their department, Horace A. Barker and William Z. Hassid, who had had long and distinguished careers at UCB by then, declined to move to "the University Farm," as the Davis campus was known in Berkeley. The prominence of plant sciences at Davis and an infusion of new resources to start the new department proved very attractive to Eric. Thus, in September 1958, Eric moved with Stumpf to UCD to initiate the new Department of Agricultural Biochemistry in the College of Agriculture. Both left their students behind in Berkeley because the new department's facilities would not be ready until the following summer.

That first fall, Eric taught introductory biochemistry to sixty students. At the time, the total UCD campus enrollment was 2,300 students, the population of Davis was circa 8,300, and there were no stoplights. By the following fall, there were more than 100 students in Eric's biochemistry class. Eric was lecturing to classes approaching 400 students by the end of the 1960s! Fortunately, the increased teaching loads justified adding additional faculty to the department, by then housed in the new Hoagland Hall. This facilitated development of a well-rounded selection of biochemistry courses. The name of the new department evolved to Department of Biochemistry at the outset, apparently due to Stumpf's intervention with the sign painter, who was told to drop the name "Agricultural" from its name. When rumors of the formation of a Biophysics Department emerged soon after, the department's name was changed to Biochemistry

and Biophysics in 1960 and remained so until July 1992, later evolving to its current name— Department of Molecular and Cellular Biology.

Eric's first sabbatical leave in fall 1959 was spent with Tony Swain at the Low Temperature Research Station at the University of Cambridge in the United Kingdom. He had hoped to learn more about plant phenolics from Swain. Eric performed a few experiments on one of Swain's projects, and the two published a brief note indicating that gallic acid could also be formed from glucose without phenylalanine as an intermediate, implicating gallate's origin via the shikimate pathway.[9] It was many years later that this conclusion was validated experimentally.

At the end of his sabbatical in Cambridge in June 1960, Eric left for Germany to meet with Hans Grisebach in Freiburg—the first of numerous visits in later years to that beautiful city. Eric had met Grisebach in Berkeley when Grisebach was a postdoc with Melvin Calvin gaining experience in the use of radiotracers in metabolism. Grisebach often attended seminars in Eric's department at UCB and eagerly followed Kosuge's enzyme work on coumarin. At that time, Grisebach was a docent in the Chemistry Institute, later to ascend to head his own institute at the University of Freiburg, where he trained an entire generation of plant biochemists. Eric often lectured in his graduate plant biochemistry course on the elegant research done at Grisebach's Institute. Eric wrote that he "was indebted to Hans for advising some of his students to obtain some experience with enzymes in our group." The first person to do so was Klaus Hahlbrock, another trailblazer in plant biochemistry and molecular biology who came to Davis in 1967.

The sabbatical in Cambridge also cemented new relationships with colleagues in the Phytochemical Society, with whom Eric enjoyed reciprocal sabbatical exchanges over the years. One of these colleagues was New Zealander Graham Butler, who was working on cyanogenesis in flax seedlings. This connection resulted in Butler spending a year's leave in Davis in 1961–62, and in Eric taking his next sabbatical at Massey College at Palmerston North on the North Island of New Zealand. As will be noted later, Eric's connection with researchers "down under" was deep and long-lasting.

When he returned to Davis after his sabbatical, Eric was eager to set up his teaching and research. Although he had performed his share of service on university committees at Berkeley, his primary commitment at Davis was to the students and postdocs in his lab and to the undergraduates in the courses he taught. Indeed, the hallmark of Eric's career was his dedication to a healthy work-life balance and to his two passions: teaching and research. Throughout his career, Eric received numerous teaching awards, including the

Academic Senate Distinguished Teaching Award in 1973, the Faculty Research Lecturer in 1977, and ultimately, the UC Davis Prize for Undergraduate Teaching and Scholarly Research in 1990— the highest teaching honor designated by UCD alumni. Despite Eric's outstanding scholarly achievements in research, he never stopped teaching larger enrollment undergraduate courses even up to his retirement in 1993 and even after his induction to the NAS.

The Golden Years of Cyanogenesis Research

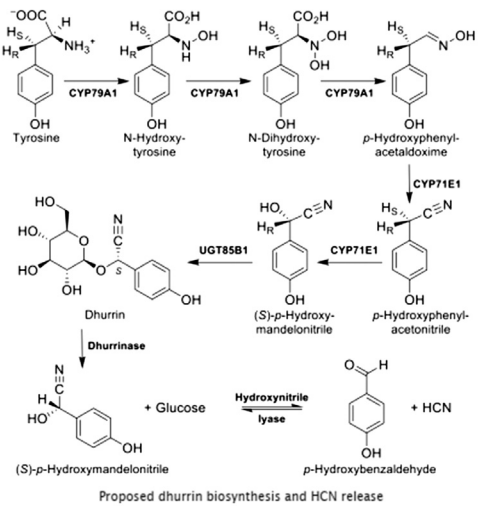
In the early 1960s, Jane Koukol, a postdoc in Eric's laboratory, showed that the carbon bond between the α and β carbons in the side chain of tyrosine was not severed during the conversion of the amino acid to the cyanogen. Koukol also showed that the α-carbon atom of tyrosine, labeled with ^{14}C, gave rise to labeled HCN, whereas the β carbon remained in the phydroxybenzaldehyde moiety of the cyanogen.[10] Several years later, Eric's graduate student Ernie Uribe, using tyrosine labeled with ^{14}C in the α position and with ^{15}N in the amino nitrogen, showed that the bond between those two atoms was not severed during dhurrin's synthesis.[11] This important result meant that all intermediates in the pathway had to contain nitrogen derived from the parent amino acid. Many years later, based on experiments by Harold Zilg, another visiting scientist from Freiburg, the glucosyl-linkage oxygen atom was shown to be derived from molecular oxygen.[12] These results implicated a mixed-function oxidase to be responsible for the conversion of the amino acid to the cyanohydrin precursor of the glycoside.

During his sabbatical in Eric's lab, Graham Butler made several important contributions to this early research. In an off-the-wall experiment, Butler and Shula Blumenthal fed ^{14}C-labeled HCN to sorghum seedlings in a closed system for several hours and then examined extracts for any labeled products. To their great surprise, a single, heavily labeled compound, quickly identified as asparagine, was observed.[13] Later work by others showed that many, and probably all, plants contain a mitochondrial β-cyanoalanine synthase that catalyzes the replacement of the -SH group of cysteine with -CN to form β-cyanoalanine.[14] Although it was easy to understand why cyanogenic species might have this enzyme, it was surprising to find that non-cyanogenic species contained it as well, albeit in lower amounts. This anomaly was later solved by Shang-Fa Yang, another notable colleague at UCD, and his student Galen Peiser, who showed that one molecule of HCN is formed in the last step of ethylene biosynthesis when ACC (1-aminocyclopropyl-1-carboxylic acid) is oxidized by ACC oxidase. In their experiments, they did not detect HCN but showed that the ^{14}C-labeled carbon atom bearing the nitrogen atom in

ACC was converted to labeled asparagine in nearly stoichiometric amounts (70-percent yield). Thus, any plant tissue that produces ethylene also produces an equivalent amount of HCN.

While at UCD, Butler also demonstrated the remarkable efficiency of young flax seedling shoots in converting labeled valine to the cyanogenic glucoside linamarin.[15] Remarkably, flax shoots converted 35 percent of labeled valine to linamarin within seven hours. Various experiments were also designed to detect intermediates in the conversion, but again none were detected. Experiments with ^{15}N showed that the nitrogen atom in valine was retained as valine is converted to linamarin, analogous to the conversion of tyrosine to dhurrin in sorghum seedlings.

Butler's student Brian Tapper was the first to show that oximes are intermediates in the biosynthesis of cyanogenic glucosides. A labeled compound that had the properties of an oxime glycoside accumulated in flax seedlings fed ^{14}C-valine and O-methyl-threonine, a metabolic inhibitor of valine. He prepared the oxime of ^{14}C-labeled isobutyraldehyde, administered it to flax shoots, and found that it was converted to linamarin nearly as efficiently as labeled valine. By contrast, isobutyraldehyde itself was not converted.[16] Because an oxime can be dehydrated to form a nitrile, the former was proposed to be oxygenated to form a cyanohydrin. Tapper's results suggested this biosynthetic sequence: amino acid ->aldoxime -> nitrile-> a-hydroxynitrile (i.e. cyanohydrin) -> cyanogenic glycoside, all of which contain one nitrogen atom as shown in the following Scheme. This work presaged the isolation and cloning of all of the enzymes of this pathway some years later.



Biosynthetic pathway of the cyanogenic glycoside, dhurrin.
(Photo Credit: Eric E. Conn.)

After Klaus Hahlbrock arrived in Davis in 1967 as a postdoc under Eric, he prepared nitriles and cyanohydrins that corresponded to the proposed intermediates in the biosynthesis of linamarin and prunasin, cyanogens derived from valine and phenylalanine, respectively. When fed to appropriate tissues (flax shoots and petioles of cherry laurel leaves, respectively),

Hahlbrock found that the nitriles were incorporated into the final glycoside. While the aliphatic cyanohydrin was readily converted to linamarin, the aromatic cyanohydrin proved toxic. These findings for the plausible biosynthetic pathway cited above were first published in a joint note with Tapper and Butler.[17] Hahlbrock soon demonstrated the last step in the pathway by detecting and purifying a UDPG-ketone cyanohydrin glucosyltransferase from flax seedlings.[18] This enzyme was equally active on the cyanohydrins of acetone and butanone, forming linamarin and lotaustralin respectively. In subsequent work, he concluded that the flax enzyme is responsible for formation of both cyanogenic glucosides in flax, a fact confirmed years later using a cloned enzyme.

A major advance in cyanogen biosynthetic work occurred when Ian McFarlane visited from Australia in 1974. By that time, numerous studies in animal tissues, and in some plants, had shown that microsomal enzyme systems catalyzed C-hydroxylation reactions. Eric suggested that McFarlane examine sorghum microsomes for their ability to catalyze the oxidation of p hydroxyphenylacetonitrile to p-hydroxymandelonitrile in the presence of NADPH and oxygen. McFarlane found that tyrosine was oxidized by the particles to form p-hydroxybenzaldehyde and HCN. Moreover, this reaction was more rapid than oxidation of p-hydroxyphenylacetonitrile. The particles also utilized the aldoxime as a substrate about as well as the amino acid. The properties of this microsomal system were then extensively studied by MacFarlane and Edith Lees, a faculty member on study leave from the University of Sydney.[19]

Because the conversion of tyrosine to p-hydroxyphenylacetaldoxime constitutes a four-electron oxidative decarboxylation, an intermediate in that conversion was likely. Earlier work on glucosinolate biosynthesis in Ted Underhill's group at the National Research Council of Canada in Saskatoon strongly implicated N-hydroxyaminoacids as intermediates between amino acids and aldoximes in the biosynthesis of glucosinolates. Fortunately, just as MacFarlane and Lees were finishing up their studies, Birger Møller from the University of Copenhagen arrived in Davis. Møller then perfected the synthesis of N-hydroxytyrosine (NHT), prepared the ^{14}C-labeled compound, and established its efficacy as a substrate along with five other compounds that proved to be intermediates between tyrosine and its aldoxime, such as tyramine, N hydroxytyramine, and p-hydroxyphenylpyruvic acid oxime.[20] Soon after, Møller established that the biosynthetic sequence catalyzed by the microsomes was highly channeled, explaining our inability to detect intermediates in earlier studies.[21] Møller returned to Denmark after two years and initially worked at the Carlsberg Institute on aspects of photosynthesis. In 1985, when he was appointed chair of Plant Biochemistry at the Royal Agricultural and Veterinary

University, Eric encouraged him to continue with his biosynthetic work. Applying the tools of molecular biology to that and related problems, Møller and his group have greatly advanced our understanding of this subject.

Other problems, usually related to cyanogenesis, attracted the interest of workers in Eric's lab from the 1970s until his retirement in 1993. Harold Zilg, Kevin Famden, and Mark Rosen, an undergraduate student, studied various stereochemical aspects of cyanogen biosynthesis. Adrian Cutler, Wolfgang Roesel, and Margaret Sternberg examined metabolic channeling during biosynthesis in arrow grass and flax.[22] Wendy Swenson and Joe Olechno described new cyanogens from *Acacia sutherlandii and Nandina domestica*. Mary Seely, Gary Kuroki, and Lang-Lai Xu studied the properties of o-hydroxynitrile lyases in several species, and Dirk Selmar concentrated on the physiological role of that enzyme. The β-cyanoalanine synthase of lupine was studied by Harland Hendrickson, and Peter Castric and Kevin Famden described a new enzyme that hydrolyzes β-cyanoalanine to asparagine, thereby explaining how the nitrogen in cyanogenic glycosides is retained by plants rather than being lost as HCN.

Compartmentation of cyanogenic glycosides and their catabolic enzymes attracted the interest of Jim Saunders, Susan Thayer, Eve Wurtele, and Marco Frehner. Jonathan Poulton, Kazuko Oba, and Alain Boudet extended such work to enzymes and intermediates of coumarin biosynthesis in sweet clover, and Mineo Kojima extended these studies to chlorogenic acid and enzymes involved in its metabolism. Wolfgang Hösel and Ingrid Tober characterized the β-glucosidases, establishing the high substrate specificity of the plant enzymes.

Another interest of Eric's concerned the role of the nonaromatic amino acid arogenic acid in the biosynthesis of tyrosine and phenylalanine in sorghum. Earlier work by Roy Jensen had shown that tyrosine is formed in mung beans, maize, and tobacco by transamination of prephenic acid to form arogenic acid ("pretyrosine"), followed by oxidative "aromatization" of the six-membered ring to form tyrosine. Because of the large flux of carbon into the cyanogenic glycoside dhurrin in sorghum, as well as the formation of many phenylpropanoid compounds in all plants, it seemed important to learn more about the final steps of phenylalanine and tyrosine biosynthesis in sorghum. Jim Connelly and Dan Siehl showed that sorghum contains prephenic transaminase that utilizes glutamate as amino donor to form arogenate, as well as arogenate dehydratase and arogenate dehydrogenase required for aromatization of arogenate and formation of phenylalanine and tyrosine.[23] Although they could not detect the dehydratase and dehydrogenase that

aromatizes prephenic acid, Bijay Singh and Gary Kuroki were able to purify and characterize the regulatory properties of chorismate mutase in several species.[24] By the late 1980s, this avenue of research came full circle back to plant pathology with Kent McCue's demonstration of the induction of DAHP synthase by a fungal elicitor from the oomycete *Phytophthora megasperma*.[25]

The Conn Lab 1984. Lang-lai Xu (left), Dan Siehl, Kent McCue, Ingrid (Tober) Gennity, Billy Gabriel, John Dunn, Eric Conn, Adolf Nahrstedt, and Bijay Singh. (Photo credit Conn Family Files.)

An Acacia Species Named for Eric Conn

Owing to a collaboration with David Seigler in the Plant Biology Department at the University of Illinois in the mid-1970s, Eric's became interested in the distribution of cyanogenesis in plants. At a 1972 meeting, the two investigators discussed the older literature reporting that some South African species of acacia contained cyanogens derive from valine and isoleucine, whereas those in Australian species are derived from phenylalanine. At that time, this was the only example of aliphatic and aromatic cyanogens occurring in the same genus. David, who taught plant taxonomy at Illinois, informed me of the taxonomic complexity of the genus, and the two decided to check out the earlier work. After confirming those studies, Eric started testing acacias in the UCD arboretum, as well as herbarium specimens, for cyanogenesis. Leaf material of any positive species was then obtained, extracted, and worked up to identify the cyanogen. This project resulted in the discovery of several new cyanogenic glycosides.

While testing acacias in California gardens, Eric also started looking at eucalyptus. Because there was only one documented report of cyanogenesis in that large genus—prunasin in *E. cladocalyx*—Eric reasoned there should be some additional cyanogenic species of eucalyptus. Initially Eric found two additional cyanogenic species in California, which led to his last sabbatical in Australia in 1981–82. In space provided in the laboratory of Brian Coombe at the Waite Research Institute at the University of Adelaide, Eric examined more than 300 species of eucalyptus in the university botanic garden. The two colleagues then started visiting botanic gardens in Adelaide, Brisbane, Canberra, Melbourne, Hobart, Sydney, and Perth, with Eric arranging permission to test the eucalyptus and acacias species in those gardens for cyanogenesis.

While in Perth, Eric met Bruce Maslin, an authority on the 1,000-plus Australian species of acacia, most of which are native to Western Australia. Maslin was interested

in his project, and Eric mentioned one western Australian species that he had previously determined to be cyanogenic. Because of his taxonomic knowledge of the genus, Maslin quickly produced herbarium specimens of several related species that we tested. During that first afternoon, the two had identified more cyanogenic species than Eric had managed to find during several months of work in gardens. Such results from herbarium specimens require that live species be located in the field, tested for cyanogenesis, and if positive, sampled and processed for identification of the cyanogen. This led to several productive collecting trips with Maslin in subsequent years.

Papers in *Phytochemistry, Kingia*, and *Western Australian Herbarium Research* Notes present results of tests on 96 percent of the described species of the genus *Acacia*. This work showed that cyanogenic species in pantropical subgenus *Acacia*, found mainly outside Australia, contain only aliphatic cyanogens, whereas cyanogenic species in the two other subgenera, *Phyllodineae* and *Aculeiferum*, contain aromatic cyanogens. These data support traditional taxonomic evidence that the subgenus *Aculeiferum*, distributed mainly in Africa and Asia, is more closely related to the predominantly Australian subgenus *Phyllodineae* than to the pan-tropical subgenus *Acacia*. The work on eucalyptus involved testing about 1,400 individual plants representing 348 species, 22 of which were cyanogenic. R-prunasin, derived from phenylalanine, was identified as the cyanogen in 10 of those species. Owing to his extensive work on acacias, one species, *Acacia conniana*, is named in honor of Eric. This species and many other acacias can be viewed in the Eric E. Conn Acacia Grove in the UCD Arboretum in Davis, California.

Eric Conn with Bruce Maslin and Acacia conniana in bloom. (Photo credit Conn Family Files.)

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