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WILLIAM HENRY CHANDLER

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A Biographical Memoir by

JACOB B. BIALE

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"BECAUSE OF THIS RESERVE OF DORMANT BUDS," said W. H. Chandler, lecturing during the dark days of World War II, "a tree is more dependable in a destructive world. It can be broken to pieces pretty badly and will grow new parts to replace the lost ones" (1944,1).

Trees with buds at rest, keeping the secrets of dormancy; trees with buds bursting to bloom and to fruit; trees of different climates and of varied behavior fascinated Chandler and served as his dependable companions throughout a long, productive, and humane life. Delving into their complex functioning, he unraveled the story of their response to internal and external environment. Esteemed worldwide for transforming horticulture from an art into a science, he—with his reservations about the validity of classifying horticulture or agriculture as distinct sciences—would surely have rejected any such claim. But his original research papers and books, filled with knowledge and deep insight, continue to bring him international recognition.

In addition to advancing the field of horticulture generally, Chandler helped elucidate the mechanism by which frost kills plant tissue. He was the codiscoverer of the fact that zinc deficiency causes a number of physiological disorders, including little leaf and mottle leaf. He introduced a system of pruning that resulted in maximum yield. He developed hybrids of temperate zone trees that grow, flower, and produce fruits satisfactorily in climates with mild winters.

The university community, experiment station workers, and extension staff all valued Chandler's ideas on research, teaching, and communicating results. He inspired promising investigators, then helped place them where they could contribute the most to horticulture and plant physiology. Anyone who had the good fortune to know him—whether professionally or socially—was left with the impression of a man of sturdy character, mild manner, and no pretensions. His convictions were strong, yet he was open to others' views. He was cultured, appreciating history, poetry and novels. Not blind to human shortcomings, he yet had an idealistic trust in the future of mankind.

EARLY LIFE AND EDUCATION

Bill Chandler, the oldest of eight children, was born in Butler, Missouri, in a little log house where the dog went in and out freely through the open door. Many years later he recalled that, during his childhood, all eight children slept in a single room in trundle beds that were stored away under larger beds during the day.

His father, who came from the hill country bordering Virginia and Tennessee, disliked farming and often allowed weeds to displace planted crops. When Bill was ten years old, the family moved to a somewhat larger house and smaller farm, incurring a large debt. They lost the property three years later, and from then on the family was forced to live on rented farms. From the age of fifteen, the responsibility for maintaining his family through farming rested on Bill with the help of a younger brother.

Seriously restricted in the time he could devote to schooling, Bill attended the country school only during the six months of autumn and winter. The remainder of the year he worked full-time on the farm. At eighteen he went to stay with his uncle at the county seat, where he studied for two semiannual periods at the Academy. From 1898 to 1901 he taught in a single-room country school, while aspiring at the same time to study farming at the University of Missouri College of Agriculture. When he divulged his ambitions to his uncles, who were successful farmers, they ridiculed the young dreamer. "It isn't what I don't know that loses me money," one told him. "It's what I know and don't do."

Chandler disregarded the advice of his relatives and enrolled in agriculture at the University in the fall of 1901. The five-year course led to the B.S. degree in 1905, and a year later he received the M.S. degree. Partly due to the influence of Dr. J. C. Whitten, then head of the Department, he specialized in tree horticulture, though—in later years—he regretted that the program of study had not included required courses in physics and chemistry.

As a student, Chandler was inspired by the teaching of plant physiologist B. M. Duggar. For his doctoral dissertation topic he elected to study the killing of plant tissue by low temperature, a major problem in agriculture in Missouri as well as in many other regions, which continued to interest him throughout later appointments as assistant (1906–1908), instructor (1908–1909), and assistant professor (1910–1913) in horticulture. Due to a technical regulation, he was not officially awarded the Ph.D. until 1914, when he was no longer affiliated with the University of Missouri.

In 1913, Chandler was invited to join the faculty of the College of Agriculture at Cornell University as professor of pomology. Better pay and research support, the presence of Liberty Hyde Bailey as dean of the College, and the greater distinction of the University made the offer extremely attractive, and he accepted. Once there, he found that the climatic conditions and the widespread growing of apples in New York State stimulated his interest in winter injury to fruit trees, and he extended his observations to the relation of winter frost damage to growth responses during the preceding summer.

Local farmers cooperated willingly with the research and extension staff of Cornell's agricultural experiment station. Yet not everyone was equally enthusiastic about the program. "It's the farmer's conservatism that saves him," a skeptical Dean Bailey was reported to say. "If he'd done everything that you [the research men] recommend, he'd be ruined."

Chandler shared Bailey's respect for the innate intelligence and good sense of the farmer. Working on field plots with New York growers, he found their attitude to farm life more wholesome than that of farmers in Missouri, so that the area remained relatively free of land speculation and real estate promotion. "You could not buy a farm at any price," he remarked at the time, "from a man who had a son to take his place."

Like Bailey, too, he was skeptical about the quality of knowledge imparted by teachers of agriculture and the worthiness of certain agriculture research projects. L. H. MacDaniels, a Cornell graduate student at that time, reported that when Chandler arrived he was assigned to teach a course in the culture of nut trees that a number of football players took to lighten their load. After delivering a half-dozen lectures, he dismissed the class for the rest of the semester, saying that he had covered all that was known about the subject that was backed by evidence.

Chandler insisted that the pomology program be related to plant physiology and the basic sciences, arguing that preparation for trees research should lead to a Ph.D. in plant physiology or in another related field that could serve as a background for horticulture. He often directed his graduate students to study under other professors, and—though many investigators credit him for inspiring and directing their horticultural or physiological research—chaired, in fact, only one doctoral committee, that of A. J. Heinicke.

During his decade at Cornell, Chandler chaired the Department of Pomology from 1915 to 1920 and, as vice-director for research, administered research funds from 1920 to 1923. This last task, at times frustrating because of the limited funds supporting a number of meritorious projects, allowed him to broaden his contacts with his colleagues. He enjoyed his dealings with members of the general faculty on campus and life in the small, charming community of Ithaca.

During this period, he also established his professional standing as the pomologist best able to analyze and understand the complex responses of fruit trees. This ability found its fullest expression in *Fruit Growing*, a textbook written and revised with great care and precision during his Cornell years, though published after he left there permanently for the West.

In 1922, Chandler was invited to tour various regions of California in connection with the dedication of a building of the University of California at Davis. Once there, he observed a wealth of horticultural problems that did not exist in New York, where fruit trees had grown for hundreds of years and many of the intricacies of their culture were known. California, on the other hand, with its great range of climatic zones and wide spectrum of horticultural materials, was unique. In addition to the innate interest to an agriculturalist, C. B. Hutchison, an administrator in the College of Agriculture at Davis who had been Chandler's associate at Missouri and Cornell, also played a major role in his decision to transfer.

Chandler came to California in 1923 as professor of pomology and chairman of the Department at both Berkeley and

Davis, with headquarters in Berkeley. He later considered his fifteen at Berkeley highly, both professionally and personally, crediting his accomplishments in part to D. R. Hoagland, professor and chairman of the Division of Plant Nutrition.

Hoagland's Division was noted for its research on the nutritional requirements of plants, and especially their need for trace nutrients: copper, zinc, molybdenum, manganese, and boron. Using special laboratory apparatus free of contaminating elements, the Division staff developed a procedure for purifying chemicals to a high degree.

In this atmosphere, Chandler investigated physiological disorders known as "little leaf" in peaches, "rosette" in apples and pears, and "mottle leaf" in citrus. His training in both horticulture and plant chemistry enabled him to identify a zinc deficiency as the cause of all of these disorders, thereby solving a problem that had baffled fruit growers since the beginning of the century. Chandler viewed these zinc-deficiency studies as the most significant economic and scientific contribution of his career. He attributed his gratifying results to the combined efforts of his team members, whose diverse talents allowed them to focus on the problem from different angles, and to methodical experimentation using advanced procedures of purification and analysis.

As a result of this cooperative venture, Chandler and Hoagland established a long-lasting friendship. They shared similar outlooks on research and university affairs and advocated harmonious interaction between applied and basic research. Both men had unusual personal qualities that inspired those students and colleagues who had the good fortune to be associated with them.

In 1938, with the zinc work partially completed, Chandler was persuaded to accept the assistant deanship of the University of California's College of Agriculture and to establish his headquarters on the Los Angeles campus of the University. Administrative duties held no great attraction for him, but he yielded to the urgent pleas of C. B. Hutchison, then statewide dean of the College.

As assistant dean, Chandler's function was to harmonize relations between the Los Angeles and Riverside Departments of the College and to strengthen UCLA's program in plant science. He also identified profitable directions for research in plant biology within the constraints imposed by field work on a campus in an urban setting. He focused on studies not requiring much land that could be conducted in greenhouses and in laboratories, and on plants with rapid growth rates, as the most suitable for graduate thesis work. He was, consequently, instrumental in establishing a Department of Floriculture and Ornamental Horticulture at UCLA.

Knowing, from past experience, the benefits of administrative association between botany and agriculture, he further made a special effort to transfer the Botany Department from the College of Letters and Sciences to the College of Agriculture. This action was later credited with enriching UCLA's offerings in plant science, particularly at the graduate level. Arranging this transfer was Chandler's last major administrative act before he relinquished the deanship in 1943. He continued on at UCLA as a professor of horticulture until he officially retired in 1948.

During retirement, Chandler thoroughly revised his two textbooks, *Deciduous Orchards* and *Evergreen Orchards*. To collect source materials for his books he traveled to the West Indies, Trinidad, and Central America. UCLA's unofficial advisor for campus landscaping, he maintained his interest in plant physiology and regularly attended seminars.

In 1966, the Chandlers moved from Beverly Hills to Berkeley so that they could live closer to their three daughters. In November 1969, he suffered a mild stroke and a year later died at the age of 92.

Chandler and his wife of sixty-three years, Nancy Caroline, were married in 1905 when he was starting his graduate studies at Missouri. The Chandler home exuded a spirit of tranquility, hospitality, and good comradeship. In his affection for his wife, Chandler named a wisteria after her and dedicated to her several of his books.

Mrs. Chandler died in Berkeley in 1968. Their son, William Lewis (wife Eleanor), a microbiologist, established his home in Altadena. Their daughters, Carolyn Geraldine Cruess and Ruth Steele Lewis, live in Berkeley, and Mary Martha Honeychurch has her home in Orinda, California. Chandler is survived by four children, eleven grandchildren, and ten great-grand-children.

William Henry Chandler was awarded many honors during his lifetime. He was elected president of the American Society for Horticultural Science in 1921, member of the National Academy of Sciences in 1943, and Faculty Research Lecturer at UCLA in 1944. He won the Wilder Medal of the American Pomological Society in 1948 and, in the same year, was named one of three outstanding American horticulturists by the *American Fruit Grower* magazine. The American Society of Plant Physiologists bestowed on him the Charles Barnes Life Membership in 1951. In 1949 he received the honorary LL.D. degree from UCLA.

He held membership in the American Association for the Advancement of Science, American Society for Horticultural Science, American Society of Plant Physiologists, Botanical Society of America, and Sigma Xi.

TREES IN TWO CLIMATES

On March 21, 1944, four years before his retirement at the age of seventy, Professor Chandler delivered a talk on this subject as the annual UCLA Faculty Research Lecture (1945,2). By that time, he had spent two decades in the mild climate of California, with the last six years in the subtropical environment of the southern region of the state. Growing conditions and responses of fruit trees in the West differed dramatically from those he had observed during the first two decades of his career in Missouri and New York. The time was ripe for him to summarize his rich experiences with fruit trees of various climatic zones and to analyze the effects of temperature on cellular events as the major factor determining their growth.

Death by Freezing

Chandler was searching for the mechanism of cellular death by freezing. The killing of plant tissue by low temperature had been the subject of his dissertation at the University of Missouri, while in California he had been attracted to the problem of why certain fruit trees required these same chilling temperatures to grow.

Shortly after transferring from Missouri to Cornell, Chandler began observing the response of deciduous fruit trees to extremely low temperatures. In the early morning hours of January 14, 1914, the temperature of –34°F (–36.7°C) was recorded in an orchard in upstate New York in which Northern Spy apples were grown. Several days earlier ice had begun to form at the outer surfaces of some cells.

From his own research and the work of others, Chandler knew that the gradual lowering of temperature facilitated the movement of water from the interior of cells to the intercellular spaces where ice crystals were formed. He further discovered that, although water expands as it freezes, air in these spaces gave way to ice so that the frozen tree actually shrank. He estimated that seventy to eighty percent of the water in the tree was converted to ice and that a third or more of the weight of the above-ground portion of the tree was ice.

Microscopic observation showed, furthermore, that shrunken cells as protoplasm became a thin layer between flattened walls. The pressure of ice particles present in the intercellular spaces appeared to cause distortions of a magnitude that suggested severe injury. As judged from the luxuriant growth during the spring and summer following the severe winter, however, this was not the case, and the tree's survival suggested that these had been, in fact, the proper conditions for hardening.

Through field observations and laboratory tests Chandler discovered a decreasing order of resistance to freezing temperatures in the various tissues of hardened trees. Most resistent was cambium, which, when not well-hardened, turned out to be as sensitive as other tissues; then came bark, sapwood, and pith. He further observed that above-ground portions of a tree were more resistant than roots; that flower buds, generally more sensitive than vegetative buds, were less sensitive when trees were not fully mature; that resistance diminished in some species whose flower buds reached an advanced stage of differentiation by the beginning of winter.

With great precision, he described how frost resistance developed, singling out two ways—"maturing" and "hardening"—deciduous trees and shrubs became resistant to cold. Maturing of wood and buds begins after growth ceases in the summer. It is characterized by the accumulation of carbohydrates, decline of water content, increase in osmotic pressure, thickening of cell walls, and a marked drop in the succulence of newly formed tissues. At the end of the maturing process—the time of natural leaf abscission—some deciduous trees can withstand temperatures of –17° to –25°C.

Hardening of mature wood occurs with exposure to freezing or near-freezing temperatures, with immature wood requiring a longer time to harden. Once hardened, some varieties can withstand temperatures ten degrees lower. Even a relatively short warm period can undo this increased resistance, but it can be regained—unless growth started during the warm spell—with repeated exposure to low temperatures.

Chandler found that internal tissue changes during hardening included increased osmotic pressure (from starch hydrolysis) and greater holding capacity for unfrozen water at temperatures above the eutectic point. In some hardy species, vacuolar sap also contained colloids that held water against freezing and osmotic activity, while, in other species, expansion of cytoplasm and the consequent reduction of the vacuoles might accompany hardening.

The most resistant, living cells in well-hardened deciduous wood turned out to be nonvacuolated, meristematic cells in leaf buds and cambium. These cells in hardened plants could survive more shrinkage and the loss of a larger proportion of their water to ice masses than could cells of unhardened plants. The protoplasm of hardened cells, furthermore, seemed less easily ruptured than that of unhardened cells.

These extensive observations on the responses of plants and plant parts to temperature stress led Chandler to probe the fundamental question of how freezing kills plant tissue. Well aware of the variety of centuries-old opinions on the subject, he compiled a list of established facts regarding plant death by freezing.

Foremost was the phenomenon of ice formation—in tender tissue primarily within cells and, in cold-resistant material, in intercellular spaces—subjected to relatively slow temperature fall (the case during a normal cold wave). Rapid temperature drop, on the other hand, caused ice to form within the cells and raised the temperature at which death occurs. Ice formation and death occurred rapidly at killing temperatures, unlike other chemical changes, which were markedly suppressed under such conditions.

Death by freezing can best be seen in thawed tissue, which darkens and takes on a water-soaked appearance coupled with a rapid rate of evaporation. In most tissues the rate of thawing does not influence the level of the killing temperature, but some tissues show symptoms of death before thawing begins. Ice formed in the plant is pure water, while the solution left in the cells is highly concentrated. Sap solutes tend to hold some water unfrozen at temperatures below the eutectic point. Such concentrated sap may be toxic to protoplasm at room temperature but is a source of protection at freezing temperatures; it also often contains water-binding colloids. Chandler also noted that bacterial spores, seeds, and pollen grains in the proper state of dehydration could withstand temperatures of liquid hydrogen and remain viable.

Any explanation of the mechanism of freezing to death would have to account for these observations, as well as for supercooling as a means of protecting tissue from injury at freezing temperatures so long as ice formation did not occur. After examining the various hypotheses concerning the mechanism of death by freezing (including disorganization of protoplasm through water loss and toxicity through concentration of the sap), he arrived at the conclusion that plants were most probably killed by the pressure of the ice masses on plasma membranes.

The Rest Period

When he moved to California, Chandler's concern with low temperature as a limiting factor in the growth of fruit trees took a different turn—rather causing losses from freezing, low temperatures in fall and winter were necessary to some California plants if they were to develop normal shoot and flower buds the subsequent spring. In a subtropical as opposed to a harsh climate, the limiting factor for growing apples, pears, apricots, peaches, and plums was the absence of sufficient days at moderately low temperatures to "break the rest," a condition known in horticulture as the "chilling requirement."

In three of his four textbooks and in several special papers Chandler described the phenomenon of the "rest period" precisely. In the spring a hormonal substance produced in the tip prevents newly formed buds along the shoot from growing. Early in the season, if this apical inhibitor is removed, these buds will grow. Later in the summer, however, the buds enter the rest period and absence of the apical inhibitor does not cause growth. Rest period is, therefore, the period when the plant, or a portion of the plant, will not grow even when temperature, moisture, and nutrient conditions are favorable for growth. It is different from "dormancy," a state of inactivity brought on by any cause. An apple tree, for example, might be said to be *dormant* in February because the temperature is too low for growth, or it might fail to grow in December, not because of the temperature, but because it is in the *rest period*.

In some fruit trees this rest period is attained as early as five to seven weeks after the start of spring growth. In the warm winters typical of the coastal regions of California, on the other hand, buds on some varieties of deciduous trees do not grow until the middle of the following summer, and even then only a small percentage will grow.

To demonstrate his point, Chandler used the striking example of a Northern Spy apple tree in Berkeley that had experienced a rest period in which no buds grew for two seasons. Yet, Chandler maintained, if the same tree had been put at 5°C in the fall of the first year, its rest period could have been reduced from two years to six months. Placing a number of branches of a cherry tree at 0°C for two months, he showed that their buds opened a month earlier than buds on the unchilled tree.

In another experiment, he subjected peach trees to temperatures ranging from –1° to 0°C for two and one-half months during the fall, then transferred them to a warm greenhouse (15°C), keeping control trees continuously at the higher temperature. The chilled buds grew as much in fourteen days as the unchilled buds in 133 days.

Chandler's experiments showed that emergence from rest was a function of both temperature and time; that spring growth was more rapid when buds were previously subjected to temperatures of 5° to 10°C for fifty to sixty days; that the more vigorous and later the growth during the preceding summer, the greater the chilling requirement. He found that insufficient chilling caused some buds to open before others, and many to fail to open altogether. Inadequate chilling, furthermore, affected flower buds as much as leaf buds, causing many to fall off before they had fully opened. In some trees, flower initials died in the buds before opening, while apple and pear trees, whose buds are mixed (consisting of both flower and shoot initials), insufficient chilling led to the production of leafy shoot only, or of leafy shoots with a reduced number of flowers. As for the biological role of the rest period, he pointed out that delay in spring budding lessened the danger from spring frosts and opening to occur in weather more favorable for pollination and fruit setting.

Seeking the cause of the rest period in trees, Chandler suggested that a hormonal substance might be involved and cited changes in ether-extractable auxins in buds upon emergence from the rest. Treatments with rest-breaking substances such as ethylene chlorhydrin tended to reduce the auxin levels in plant tissue. Fully acknowledging the lack of verifiable data, Chandler advanced the idea that a bound form of auxin might be responsible for keeping buds from growing during the deep part of the rest, and that the rate of retardation of bud opening was determined by the balance between the bound and free forms.

FRUIT TREE NUTRITION—THE ZINC STORY

Regarding the nutritional requirements for optimal growth and yield in fruit trees, Professor Chandler's investigations ranged from experiments with specific nutrients to analysis of a complex biological system dependent on minerals derived from a highly variable medium.

Before Chandler, experiment station researchers tended to concern themselves with annuals. In their orchard-fertilizer experiments, they applied different quantities and combinations of required elements over a number of years, then analyzed the results statistically.

Chandler questioned the reliability of field trials where experimenters seeking to minimize error increased the size of their samples, necessarily using larger and more variable soil plots. He also called attention to errors caused by such frequently overlooked variables as bud variation, differences in the vigor of seedling stock growth, the cumulative effect of injuries sustained with age, and—in measuring growth and yield—the number of branches with which a tree started. He pointed out that the outbreak of disease (as happened when mottle leaf blighted certain experimental citrus trees) could vitiate years of carefully planned fertilizer experimentation that depended on uniformity of plots to test differential treatments.

Cognizant of these difficulties, Chandler designed a new approach to field testing with fruit trees. Shortly after he arrived in California, orchards in a variety of climatic zones both inland and along the entire Pacific Coast suffered great losses from a tree disease known since the beginning of the century. This disease, affecting both deciduous and evergreen trees (and walnuts and grapes as well), is called "little leaf" in stone fruits—almond, apricot, cherry, peach, plum; "mottle leaf" in citrus; and "rosette" in apples and pears.

The disease is most dependably characterized by stiff, narrow leaves—about five percent of normal size—that appear in the spring. Each of the small tufts, or rosettes, of these abnormally small leaves originates from a bud that would normally produce a shoot. Leaves are also mottled, with yellow streaks and splashes between veins, while the veins themselves, and some adjoining tissue, are green. These symptoms are most conspicuous in spring. Later in the season, healthy shoots may grow from buds lower on the branch. In severe cases, distorted yellow leaves form even late in the summer. Fruit size in all species is reduced and, in some, the fruit is also strikingly distorted. Moderately affected pome and stone fruits may live for many years producing fruit of inferior quality and yield. In some soils trees grow well for the first few years but then develop symptoms rapidly and die.

Chandler undertook to study this problem together with two members of Berkeley's Plant Nutrition Division—plant physiologist and soil chemist D. R. Hoagland and chemist P. L. Hibbard. Before starting trials of treatments he carefully observed conditions in various districts of California. He sought out the experiences of farm advisors, extension specialists, and orchardists. He noted that while trees in deep, well drained, sandy soils with low clay content were the most readily affected by the disease, in some regions little leaf also affected trees in loam soils. He paid special attention to orchards on land formerly used as corrals for livestock. On these soils, with high nitrogen content, the disease was rampant.

Quickly ruling out deficiencies of nitrogen, phosphorus, potassium, calcium, and magnesium, Chandler proceeded to test for iron. A preliminary mid-winter trial with large quantities of a commercial grade of ferrous sulphate resulted in normal leaves in summer.

Chandler first thought the iron sulphate worked by reducing the alkalinity of the soil, but other pH-lowering substances such as sulphur had no effect. When he then applied chemically pure ferrous sulphate, the results were equally negative, and it was immediately apparent that an impurity in the commercial grade of ferrous sulphate might account for its effectiveness. Chemical analysis showed that the sulphate contained one percent of zinc and several other elements in small amounts. Further tests with zinc sulphate gave positive results, though the amounts required varied widely and a broader range of trials seemed called for.

Chandler decided against concentrating his efforts in a single area, opting instead for a wide range of soils—twenty-six locations in ten counties. Leaving several severely diseased trees in each locality as controls, he treated some 2,000 others. It soon became evident to him that the degree of correction was a function of the solubility and dosage of the zinc compounds used. Yet extreme variability in the effectiveness of the treatment also suggested significant differences in the zinc sulphate.

To find out whether zinc was essential to fruit tree nutrition or had a secondary, soil-related function (such as correcting for undesirable flora), it was necessary to circumvent the soils and apply zinc directly to the trees. This Chandler accomplished in a variety of ways. He put dry zinc sulphate in gelatine capsules in holes in tree trunks, getting earlier, longer-lasting benefits than from soil treatments. He found that trees would absorb zinc from metallic zinc nails driven into the trunk or branches, and—though this treatment caused some injury to the wood—injured areas usually filled with callous tissue if the nails were not too close together. Trees cured of zinc deficiency symptoms by these direct methods, moreover, remained healthy for six years or more after a single application, though with certain citrus and stone-fruit trees, spraying trees with a zinc sulphate solution got the earliest beneficial results.

Chandler favored the idea that zinc, a nutrient required in minute amounts, acted as a catalyst for some biochemical process. In view of his observation that the demand was greatest when respiration was likely to be most rapid, he suggested that this catalysis might be an essential step in the respiratory pathway.

REFLECTIONS, CONVICTIONS, AND FAITH

I cherish the privilege of having had Professor Chandler as my teacher and mentor during my student days at Berkeley and as my colleague and friend after his move to UCLA. During the decade preceding his retirement, and for a considerable time thereafter, he expressed many thoughts (often unorthodox) on matters within and outside his immediate professional interests. He was particularly concerned with the position of the university in society, the role of the investigator and teacher in agricultural schools, and the responsibilities of scientists—both as citizens and as members of the human race. Many of these opinions were delivered in speeches to meetings of faculty, students, extension workers, and fruit growers. Copies of Prof. Chandler's speeches, which I was privileged to receive, serve as the main background for the comments in this section.

To Chandler, work for an institution of higher learning where scholars joined together in the attempt to find truth was a great cause deserving of the highest loyalty. For loyalty to survive the confusing vicissitudes of life, he added, its object had to be too important to be blamed for failures. "I may serve my cause ill," he quoted the philosopher Josiah Royce. "I may conceive it erroneously. I may lose it in the thicket of world transient experience. My every human endeavor may involve a blunder. My mortal life may seem one long series of failures. But I know that my cause liveth."

Chandler singled out universities as the greatest cooperative enterprise the world has ever known, for the investigator—engaged in solving a problem of his choosing—collaborated not only with his contemporaries but with generations of seekers of knowledge from the past as well. Chandler's own work, for instance, depended on that of those brave, "determined souls" of the Dark Ages who recorded unorthodox findings at their own peril.

From this historical view of communication's significance to science, Chandler particularly emphasized precise and careful reporting as essential to the great cooperative enterprise of learning. He remarked that, as methodology becomes more refined and thinking more rigorous, the presentation of data becomes more concise. "Where opinions are published in the most words and where there is most argument," he observed, there is the greatest accumulation of ignorance most likely to be found.

Chandler admired the brief, precise reports—targeted to a specific audience and unencumbered by lengthy discussions—common to the physical sciences. By contrast, agricultural experimentalists often failed to address their most interested readers, being more concerned about a paper's reception in peripheral scientific fields than its usefulness to other horticulturists. They published too often, he maintained, in too much detail, included exhaustive reviews of the literature, and got lost in wordy theoretical explanations.

He particularly objected to experimental stations publishing special editions of technical papers, which tended to be lengthy, cumbersome, costly, of limited reader access, and poorly edited. He favored, rather, publication in society journals, which had a wide circulation and were reviewed by peers capable of independent judgment.

The issue of priority of authorship in scientific publishing also failed to impress Chandler. Since, he said, investigators were rarely responsible for the same data in a paper, priority played little role in their professional standing among their peers. For all that he admonished his colleagues to be especially vigilant in fully crediting their research associates—including assistants and graduate students—for their contributions.

Finally, Chandler cautioned agricultural experiment stations against possessiveness with regard to research projects. While major responsibility and funding should go to the best qualified investigators, he contended, others should be encouraged to test promising leads.

Researchers should also welcome the cooperation of county farm advisors and extension specialists. These people, who knew local conditions best, could help by testing laboratory results on the farm or arranging for the use of outside growers' field plots.

Chandler further advised laboratory people to present their findings to farmers through agricultural agents rather than direct contact. He saw no discredit in a researcher attending so diligently to his research that he had no time to learn applied aspects of the work necessary for giving the best practical advice. He himself had intimate personal knowledge of working with trees that yielded publishable data but rarely and practical advice for growers even less.

In real life, according to Chandler, farmers "harassed by a whole range of nature's reactions" posed challenging questions to horticultural researchers. Yet attempts to solve a problem with fruit trees required the convergence of several disciplines, and those who "discovered" a practical remedy might be no more deserving of credit than the many earlier researchers whose earlier experiences had suggested the solution. It was often, he contended, a matter of good fortune to come to a problem when just a few added experiences were needed to supply the solution.

In a dinner talk delivered in 1941 to the western section of the American Society for Horticultural Science (1942,2), Chandler reflected on the merits of studying plants.

"The material we work with has character," he stated, considering himself fortunate in both the trees and the people with whom he had worked. Citing literary references to the sturdy character and earthy beauty of the apple tree, he went on to say that to him fruit and vegetables were not merely a mass of materials but a collection of individuals. Trees and plants, furthermore, were not merely objects worthy of admiration, they also exerted an influence on the behavior of the people who tended them. "As the apple tree is among the trees of the wood," he quoted from the *Song of Songs*, "so is my beloved among the sons. I sat down under his shadow and his fruit was sweet to me."

Chandler suggested that Thomas Jefferson's ability to endure the rigors and criticism of political life might be attributed to the comfort and encouragement he derived from the extensive time he spent on his farm working with his trees. Chandler discovered that, in the Scandinavian countries perhaps more than anywhere else, the beauty of flowers and trees, both ornamental and fruit-bearing, was associated with efforts for the general good that he himself called "effective human love." When he visited Denmark he was told that preference in police recruitment was given to horticultural school graduates who were known for their even tempers. In Sweden, trained agriculturalists were put in charge of urban housing projects in recognition of the importance of plants for social contentment.

Chandler expressed his faith in the Tree of Knowledge and in humankind in the following words:

"The God of Nature reveals his laws, I believe, very rarely to the propagandist or to the pompous, or even to the merely zealous, but rather to him who trains diligently in the technique and the records of a system of knowledge, who records his own observations clearly and briefly for the benefit of all workers, who reviews and reorganizes his knowledge frequently in the light of new discoveries, who consults as frequently as possible with workers in his field and related fields, hoping for a vision that points to a safe advance in human welfare, and who is meek enough to see a vision unobscured by projects of himself.

"Truth discovered by research enters into the lives of the people and its beauty is recorded for all time in literature and art; the drudgery of the laboratory today becomes beauty in the soul of humanity tomorrow. Because our discoveries enter the basic part, the masonry of the soul of humanity, we should report them with modest reverence. We want a foundation not of spongy lava thrown up by workers—each anxious to strut about the biggest pile, even if it is the trashiest—but rather of dressed stone, each piece placed carefully where it belongs in the structure.

"We can have faith in the triumph of good in humanity in spite of the evil we know exists; in fact, life is richer because of the imperfections in it. I liked the part in one of George Bernard Shaw's plays where the Bishop advised people always to give the devil a chance to state his case, for I have come to believe that the devil has a rather strong case. He stands for selfishness, and a degree of selfishness is socially necessary for the most diligent care of each individual. Furthermore, we need something to struggle against. If in man the instinct of self-preservation, selfishness, and the group instinct, human love, were so nicely balanced that there would be no conflict, so that we could just enjoy our goodness comfortably like pigs enjoy their fatness, would life be very interesting?

"Perhaps the richest part of life is knowledge of the great people that have been in it. If selfishness were no problem, we should never have heard of the thundering righteousness of the Hebrew prophets or of Jesus; they would have been just other nicely balanced men. And what use would we have had for Thomas Jefferson or Lincoln or Horace Greeley, or for the thousands of supporters who made their work possible, dormant-bud Jeffersons and Lincolns and Greeleys out among the people? The only changes I want to see in man are those he makes himself—struggling upward in response to the soul of humanity and his group instinct.

"The emblem of my faith is the tree and its system of dormant buds that can grow only if buds that happen to be in more favorable positions for growth are removed. If ends of branches are removed, shoots will grow out of the older wood from buds that have grown each year only enough to keep their tips in the bark. Then when their opportunity comes, they grow vigorously. Because of this reserve of dormant buds a tree is more dependable in a destructive world. It can be broken to pieces pretty badly and will grow new parts to replace the lost ones.

"This condition in the tree symbolizes my faith in humanity, my conviction that society, at least in those countries that have been able to maintain order without despotism most of the time, cannot long change in any direction except toward a richer life for the average person: For I know there are many dormant buds in human society also."

William Chandler shared his sturdy faith in humanity with the renowned fellow-botanist Liberty Hyde Bailey. Both lived to a ripe and productive old age, and I include, in conclusion, a stanza from "My Great Oak Tree," a poem by Bailey that Chandler greatly cherished:

"And thrice since then far over the sea
Have I journeyed alone to my old oak tree
And silently sat in its brotherly shade
And I felt no longer alone and afraid;
I was filled with strength of its brawny-ribbed bole
And the leaves slow-whispered their peace in my soul."

SELECTED BIBLIOGRAPHY

1904

Result of girdling peach trees. West. Fruit Grower, 15: 191.

1907

The winter killing of peach buds as influenced by previous treatment. Mo. Agric. Exp. Stn. Bull., 74:1–47.

1908

Hardiness of peach buds, blossoms and young fruits as influenced by the care of the orchard. Mo. Agric. Exp. Stn. Circ., 31:1–31.

Instructions for spraying. Mo. Agric. Exp. Stn. Circ., 34:1–16.

1911

Cooperation among fruit growers. Mo. Agric. Exp. Stn. Bull., 97:3–58.

1912

Combating orchard and garden enemies. Mo. Agric. Exp. Stn. Bull., 102:237–90.

1913

The killing of plant tissue by low temperature. Mo. Agric. Exp. Stn. Res. Bull., 8:141–309.

Commercial fertilizers for strawberries. Mo. Agric. Exp. Stn. Bull., 113:297-305.

1914

Sap studies with horticultural plants. Mo. Agric. Exp. Stn. Res. Bull., 14:491–553.

Some problems connected with killing by low temperature. Proc. Am. Soc. Hortic. Sci., 11:56–63.

Osmotic relationships and incipient drying with apples. Proc. Am. Soc. Hortic. Sci., 11:112–16.

1915

Some peculiar forms of winter injury in New York State during the winter of 1914–15. Proc. Am. Soc. Hortic. Sci., 12:118–21.

1916

Influence of low temperature on fruit growing in New York State. Cornell Countryman, 13:373–77.

1918

Influence of low temperature on fruit growing in New York State. N.Y. State Fruit Grow. Assoc. Prod., 16:186–94.

Winter injury in New York State during 1917–18. Proc. Am. Soc. Hortic. Sci., 15:18–24.

1919

Pollination. Ind. Hortic. Sci. Trans. for 1918:11–120, 173–75.

The effect of the cold winter of 1917–18 on the fruit industry. Ind. Hortic. Sci. Trans. for 1918:91–103.

Pruning—its effect on production. Ind. Hortic. Sci. Trans. for 1918:137–45, 156–61.

Some results as to the response of fruit trees to pruning. Proc. Am. Soc. Hortic. Sci., 16:88–101.

1920

Winter injury to fruit trees. Mass. Dep. Agric. Circ., 24:11.

Some preliminary results from pruning experiments. N.Y. State Hortic. Soc. Proc., 2:77–84.

Some responses of bush fruits to fertilizers. Proc. Am. Soc. Hortic. Sci., 17:201–4.

1921

The trend of research in pomology. Proc. Am. Soc. Hortic. Sci., 18:233–40.

1922

The outlook of agricultural research. (Address delivered at the dedication of the Dairy Industry and Horticulture buildings, University Farm, Davis: 24–37.)

1923

Results of some experiments in pruning fruit trees. N.Y. Agric. Exp. Stn. Cornell Bull., 415:5–74.

1924

The advantages and disadvantages of organization and standardization in horticultural research. Proc. Am. Soc. Hortic. Sci., 21:259–63.

1925

Fruit Growing. Boston: Houghton Mifflin Co.

Polarity in the formation of scion roots. Proc. Am. Soc. Hortic. Sci., 22:218–22.

With A. J. Heinicke. Some effects of fruiting on growth of grape vines. Proc. Am. Soc. Hortic. Sci., 22:74–80.

1926

With A. J. Heinicke. The effect of fruiting on the growth of Oldenburg apple trees. Proc. Am. Soc. Hortic. Sci., 23:36–46.

1928

North American Orchards, Their Crops and Some of Their Problems. Philadelphia: Lea & Febiger.

1931

Freezing of pollen: evidence as to how freezing kills plant cells. Am. J. Bot., 18:892.

With D. R. Hoagland and P. L. Hibbard. Little leaf or rosette of fruit trees. Proc. Am. Soc. Hortic. Sci., 28:556–60.

1932

With D. R. Hoagland and P. L. Hibbard. Little leaf or rosette of fruit trees. II. Effect of zinc and other treatments. Proc. Am. Soc. Hortic. Sci., 29:255–63.

With D. R. Hoagland. Some effects of deficiencies of phosphate and potassium on the growth and composition of fruit trees under controlled conditions. Proc. Am. Soc. Hortic. Sci., 29:267–71.

1933

With D. R. Hoagland and P. L. Hibbard. Little leaf or rosette of fruit trees. III. Proc. Am. Soc. Hortic. Sci., 30:70–86.

With W. P. Tufts. Influence of the rest period on opening of bud of fruit trees in spring and on development of flower buds of peach trees. Proc. Am. Soc. Hortic. Sci., 30:180–86.

1934

The dry matter residue of trees and their products in proportion to leaf area. Proc. Am. Soc. Hortic. Sci., 31:39–56.

With D. R. Hoagland and P. L. Hibbard. Little leaf or rosette of fruit trees. IV. Proc. Am. Soc. Hortic. Sci., 32:11–19.

1935

With A. S. Hildreth. Evidence as to how freezing kills plant tissue. Proc. Am. Soc. Hortic. Sci., 33:27–35.

With D. R. Hoagland and P. L. Hibbard. Little leaf or rosette of fruit trees. V. Effects of zinc on the growth of plants of various types in controlled soil and water culture experiments. Proc. Am. Soc. Hortic. Sci., 33:131–41.

1936

With D. R. Hoagland and P. R. Stout. Little leaf or rosette of fruit trees. VI. Further experiments bearing on the cause of the disease. Proc. Am. Soc. Hortic. Sci., 34:210–12.

With M. H. Kimball, G. L. Philp, W. P. Tufts, and G. P. Weldon. Chilling requirements of opening of buds on deciduous orchard trees and some other plants in California. Calif. Agric. Exp. Stn. Bull., 611:3–63.

1937

Zinc as a nutrient for plants. Bot. Gaz., 98:625–46.

1938

The winter chilling requirements of deciduous fruit trees. Blue Anchor, 5:2–5.

Our work. (Address to the Synapsis Club of the Citrus Experiment Station at Riverside, California, October 3, 1938, pp. 1–13.)

Rolling of leaves on Oriental plum trees, apparently caused by cool summers. Proc. Am. Soc. Hortic. Sci., 26:259–60.

1940

Some problems of pruning, with special application to shade trees. In: *Proc. Seventh Western Shade Tree Conference*, pp. 50–64.

Teaching in a college of agriculture. (Address before the annual conference of the Agricultural Extension Service, January 2, 1940, pp.1–8.)

1942

Deciduous Orchards. Philadelphia: Lea & Febiger.

Forty years of helping the farmer with knowledge. Science, 95:563–67.

Sermons. (Address before the Western Section of the American Society for Horticultural Science, June 20, 1941.) Proc. Am. Soc. Hortic. Sci., 41:387–97.

1943

Some responses of trees in a few subtropical evergreen species to severe pruning. Proc. Am. Soc. Hortic. Sci., 42:646–51.

1944

Sturdy faith and dormant buds. (Address before joint meeting of the Synapsis Club, Citrus Experiment Station, and the American Society for Horticultural Science. January 3, 1944, pp. 1–6.)

1945

Trees in two climates. (Faculty Research Lecture, University of California, Los Angeles, March 21, 1944. Univ. of Calif. Press, Berkeley and Los Angeles, pp. 1–22.)

1946

With D. R. Hoagland and J. C. Martin. Little leaf or rosette of fruit trees. VIII. Zinc and copper deficiency in corral soils. Proc. Am. Soc. Hortic. Sci., 47:15–19.

With D. Appleman. Little leaf or rosette of fruit trees. IX. Attempt to produce corral injury with constituents of urine. Proc. Am. Soc. Hortic. Sci., 47:25.

1949

Pruning trials on wisteria vines. Proc. Soc. Hortic. Sci., 54:482–84.

Evergreen Orchards. Philadelphia: Lea & Febiger.

1951

Deciduous Orchards, 2d ed. Philadelphia: Lea & Febiger.

With D. S. Brown. Deciduous orchards in California winters. Calif. Agric. Ext. Serv. Circ., 179:3–39.

1952

With R. D. Cornell. Pruning ornamental trees, shrubs, and vines. Calif. Agric. Ext. Serv. Circ., 183:1–44.

1954

Cold resistance in horticultural plants: A review. Proc. Am. Soc. Hortic. Sci., 64:552–72.

1955

Twenty-five years' progress in California fruit production. (Address delivered at University of California, Davis, October 29, 1955, pp. 1–15.)

1957

Deciduous Orchards, 3d ed. Philadelphia: Lea & Febiger.

1958

Evergreen Orchards, 2d ed. Philadelphia: Lea & Febiger.

1959

Plant physiology and horticulture. (Prefatory chapter.) Annu. Rev. Plant Physiol., 10:1–12.

1961

Some studies of rest in apple trees. Proc. Am. Soc. Hortic. Sci., 76:1–10.

1965

Reminiscences. Oral History Program. University of California, Los Angeles, pp. 1–39.