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AN OUTPOST IN THE DESERT

At the turn of the twentieth century, the American southwest was still the stuff of legend. Rowdy saloons and gambling houses maintained a steady clientele, while stagecoach robberies and train holdups were frequent enough to lend an air of danger. The cattle town of Tucson, the largest city (population 7500) in the territory of Arizona, was as rough and raw as any other young American settlement. Though it boasted a university and an agricultural experiment station, it was a place where gentlemen still carried pistols. By rail, New York City was four days away.

One day in January 1903, two young botanists stepped off the train into this desert outpost. Daniel Trembly MacDougal and Frederic Vernon Coville, both established scientists in their mid thirties, were no strangers to the desert. Coville had been the botanist for the US Department of Agriculture (USDA) expedition to Death Valley in 1891 and nine years later made a trip across the stock ranges of Arizona investigating the effects of sheep grazing on the watershed of the Salt River Valley. MacDougal had been a member of another 1891/1892 USDA expedition to Arizona and Idaho, and a few years later had undertaken a plant-collecting trip by himself in the Navajo territory. This trip had ended in near disaster. His Indian guide had deserted him, taken all the horses, and left him to fend for himself.[1]

Though this 1903 journey was, like their earlier expeditions, to be of an exploratory nature, it was not plants that MacDougal and Coville were investigating, but real estate. The newly established Carnegie Institution had sent them on a search to find a suitable place to build a desert botanical laboratory. In 1902, the year the Institution was founded, the Carnegie trustees had pledged $8000 for construction and one year's operation of such a facility. The ideal site, according to the Institution's Advisory Committee in Botany, would provide a distinctly desert climate, flora as plentiful and varied as possible, easy accessibility, and some degree of habitability. MacDougal and Coville may have had Arizona in mind right from the beginning; a month before they began their journey, MacDougal had written to Robert Forbes, the director of the university's agricultural experiment station, asking for the names of an architect and builder in Tucson. MacDougal added that he had the "'Arizona habit' pretty deep seated."[2] But in checking all the options, the two intrepid botanists (dubbed a "board" by the Institution) spent five

weeks traveling by train, horseback, and wagon all over the southwest, from California to the Grand Canyon to Mexico's Chihuahuan Desert.[3]

Only Tucson met all the criteria. Its vegetation was among the most diverse of any arid part of the United States, it averaged only 11.74 inches of rainfall a year, and it was readily accessible by the Southern Pacific Railroad.[4] Furthermore, it evidenced some degree of civilization. Coville and MacDougal found not only that the town was run by "progressive Americans," but that a provision store there "would have done credit to a metropolis."[5] Though its climate would take some getting used to, Tucson was already in 1903 becoming a world-famous mecca for sun lovers and health seekers. A pamphlet advertising the city's virtues would state a few years later that this land of sunshine had "no fleas, no cyclones, no fogs, and no sunstrokes."[6]

Tucson's Chamber of Commerce showed genuine hospitality at the prospect of hosting a laboratory of the new Carnegie Institution. (Just a year before they had welcomed a Carnegie library.) They offered subsidies for 40 acres of land on Tumamoc Hill, a slight, undisturbed rise about two miles outside the town, and later arranged to install – free of charge – water, telephone, light, power, and, not the least, a road. The total cost of this gift was not insubstantial; the Chamber valued it at nearly $3000.[7] Agreeing to the conditions pending approval by the Institution, MacDougal and Coville left Robert Forbes in charge and returned to Washington.

Approval came in March. Things happened fast after that. Once the road was finished and the architect's design approved, construction began.[8] As the small, one-story building rose from the volcanic stones that covered the hill, Coville and MacDougal kept a close watch from afar, suggesting improvements and cost-cutting measures through their correspondence with Forbes. By September, the building was finished (Fig. 1.1) and the Desert Laboratory – the first facility anywhere devoted to desert studies – was ready to begin its work.

A trial run

Though MacDougal would – in a few years – become director of the Laboratory, Coville was the dominant force behind its birth. It was Coville, in fact, who chaired the Carnegie Institution's Advisory Committee on Botany. Though only 33 years old in 1902, he was chief botanist at the USDA and curator of botany at what would later become the US National Herbarium. Ever since his travels with the 1891 Death Valley Expedition, he had harbored the dream of building a laboratory devoted to the study of desert plants. He had been particularly intrigued on that expedition by the spacing of desert plants. He wrote in his report: "The scantiness of the desert vegetation possesses more significance than has ever been attributed to it. Except in rare instances the shrub is separated from its nearest neighbor by a distance of

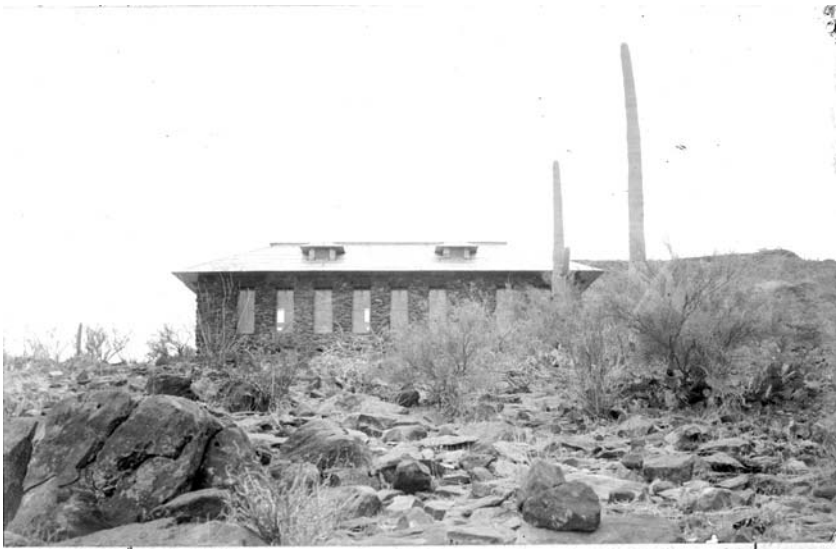

Figure 1.1. The Desert Laboratory building shortly after construction.

several meters." He was also fascinated by the seeming lack of competition in the desert. "Never do [shrubs] stand so close together as to crowd or shade each other . . . It is evident therefore that desert shrubs essentially present in their environment that anomaly of a struggle for existence, not against other plants, but against nonorganic physical forces alone. This fact makes the study of their adaptation especially interesting and instructive . . ."[9]

Coville's duties at the USDA and the Herbarium prevented him from undertaking any subsequent desert studies. He is much better known today for his role in the cultivation of the blueberry than he is for desert research. Nonetheless, his status and visionary outlook appealed to the Carnegie founders and Coville became a trusted advisor for the new Desert Laboratory.[10]

In deciding how to handle the open-ended largesse of their benefactor's generosity, the Institution's founders had turned to recognized experts for advice and counsel. At their first meeting in December 1901, the Executive Committee formed 18 advisory committees, mostly in scientific subjects. Four well-known botanists were on the Advisory Committee in Botany. Besides Coville, there were Nathaniel Britton, founder and chief of the New York Botanical Garden; John M. Macfarlane, professor of botany at the University of Pennsylvania; and Gifford Pinchot, chief of the US Department of Agriculture's Division of Forestry, forerunner of the Forest Service.

Britton's presence on the committee was undoubtedly due to his dominance in the field of botany. (Some 70 species of living and fossil plants were

then dedicated to him.) Certainly his working relationship with Andrew Carnegie, who was at the time vice-president of the Botanical Garden board, had not hurt. Macfarlane was an eminent botanist originally from Scotland who had founded the Pennsylvania Botanical Society in 1897. With his interests in cell structure and histology, Macfarlane's presence on the board was perhaps seen as a way to add diversity. (It is also possible that he was simply friends with Coville or some of the Carnegie trustees.) Pinchot was a rising star not only in the botanical but also in the political firmament of the times. He was later to become one of Teddy Roosevelt's chief advisors. Pinchot's status as forester, about as pragmatic a profession as the botanical sciences yielded, could also be seen as a tilt toward practicality. Though known right from the start for its attention to basic science, of which founder Andrew Carnegie believed the United States to be deficient, the Institution was attuned to the spirit of practicality that was so much a part of the American ideal – and of Mr. Carnegie's own philanthropic leanings.

German institutions had been dominant throughout the nineteenth century and served in many cases as role models for American educational establishments. But whereas German universities tended to be elitist, American schools were more egalitarian. According to science historian Nathan Reingold, "American universities were viewed largely as an extension of the democratic thrust to provide a responsible electorate."[11] Even the ivory tower schools of New England saw their role as being both educational and service-oriented. The Carnegie Institution distanced itself from the university world, and, in fact, was modeled more on the Royal Institution, a British research organization where teaching was not practiced.[12] But practical concerns were important in living up to the directive Andrew Carnegie delivered to his trustees in 1902: "to encourage in the broadest and most liberal manner, investigation, research and discovery, and the application of knowledge to the improvement of mankind."[13] Throughout its history, as its thrust grew more and more towards basic science, the Carnegie Institution would continue to strive to reconcile – and justify – this directive.

The reality of a burgeoning population was, in fact, a reasonable justification for a desert laboratory. In its written report to the Institution's trustees, the Advisory Committee on Botany stressed the practical. "The economic ground for the establishment of such a laboratory is the enormous development of population and industries that is bound to take place in our arid region during the next hundred years."[14] Two other, ultimately unfunded, proposals suggested by the committee were also given pragmatic slants. One suggested that the Institution fund a study exploring the forest with relation to atmospheric moisture, with the goal to learn if the national forest reserves were helping protect the water supply in the arid and semi-arid west. The other was to establish a laboratory in the tropics, an area of increasing commercial interest of the United States.[15]

The Desert Laboratory would be the first of what would become a network of Carnegie research departments. But in the beginning, the trustees voted to fund the Laboratory only on a temporary basis, for a five-year trial run. As it grew, the Institution came to see itself as a pioneering organization, opening up new fields for scientific study. Indeed, over the years, it played this role many times. But in its early departmental endeavors, the Institution was still a bit tentative, tending to support mainstream scientific subjects at civilized urban centers. Ecology was an infant science and Arizona was a long way from the civilizing influences of a big city. In this respect, the Desert Laboratory was considered an experiment. Even in its early organization it was an experiment, for at the outset it had no director, no "exceptional man," to guide the research.

The Advisory Committee's report envisioned that the Laboratory's research would center around water relations. This was to be expected. In the early years of the twentieth century, research into the water requirement for plants was a top priority.[16] Water was, of course, the critical limiting factor for desert plants. The future development of arid regions had at its base, the report noted, the development of agriculture, both with and without irrigation. Information about how desert plants grew with so little water was necessary so that the botanists of agricultural experiment stations in arid states would be in a position to put that information to practical use. A few years later, the Institution's president, Robert Woodward, would reiterate the Laboratory's practical foundation: "I look forward to the time when we may turn over the knowledge which we may gain at that Laboratory to the Department of Agriculture or some department of the government for utilization."[17]

An understanding of how plants use water was indeed to be a critical part of the studies emerging from the Desert Laboratory. But it was not toward the practical science of agriculture that the work of the Desert Laboratory pioneers would necessarily be directed. Rather it was toward a theoretical understanding of plant adaptation and distribution. Much of the scientific rationale for this effort would come from the new science of ecology, a field that was at the time just beginning to find expression in America.

The roots of ecology

Ecology is the study of patterns in nature. It explores the complexity of relationships between plants, animals, and their physical environments. Its practitioners are concerned with the distribution of organisms, the competition among them, and the causal factors underlying their local adaptations. In 1859, Charles Darwin marveled at nature's "web of complexity" in his classic book *On The Origin of Species*. His example of the entangled bank, "clothed with plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the

damp earth," remains a strong metaphor to this day.[18] Though he never called himself an ecologist (the word would not be coined until 1866), Darwin is considered by many to be one of the first and greatest ecologists.

Darwin's theory of evolution by natural selection – the idea that nature selects those random variations within an organism that are useful for survival, much as an artificial breeder selects for desirable traits – has, in fact, been called an ecological theory. Underlying the struggle for existence inherent in natural selection is the concept that nature is finely balanced. Not only limitations in the physical environment but also competition between and among species prevents populations from increasing to their full potential. The complex balance between the environment and its web of inhabitants can be easily upset. Change, even small change, can as easily lead to speciation (with a whole population taking advantage of a new place, or niche, in nature) as to extinction (with a population unable to adapt to new circumstances). Although Darwin did not have the knowledge to figure out the mechanism by which natural selection worked, he felt that evolution could only be understood within nature's tangled mesh of interrelationships.

While Darwin's theory of evolution provided the rationale behind the science of ecology, the publication of his *Origin of Species* was not accompanied by a sudden explosion of ecological research. As historian Eugene Cittadino has written, "nineteenth-century botanists did not read the *Origin* and then dash out into the field searching for interrelationships."[19] In fact, after an initial surge of popularity, Darwinism, especially its emphasis on natural selection, lost favor in the latter years of the nineteenth century. At least 30 years intervened between the appearance of the *Origin* and the accumulation of a substantial body of ecological literature, and even more years before ecology would become an accepted field of scientific study. There were other forces at work in the late years of the nineteenth century in America.

The decades around the turn of the century were, in fact, pivotal to the development not just of ecology but to all of biology. It was during these years that biology began to splinter into distinctive disciplines, mirrored by the concurrent formation of professional societies. Though botany, too, was breaking into subdisciplines, most of its practitioners continued to emphasize the naturalist tradition.

This was hardly surprising. Given the wealth of new species obtained on the many government-sponsored collecting trips of the mid to late 1800s, botany education emphasized anatomy, morphology, and taxonomy – disciplines necessary for systematic classification. But a small group of American botanists wanted more. They looked for guidance to the European plant geographers, who were concentrating on the study of the distribution and adaptation of whole-plant communities. Here was a significantly different way of looking at plants – not as individual organisms but as parts of larger

communities. In this was a dynamic approach to botany that was largely lacking in America.

According to historian Garland Allen, the turn of the century was a time when many biologists, not just the ecologists, turned away from the traditional subjects of morphology and taxonomy.[20] Rather than focus on structure, many of these scientists wanted to study how individual parts functioned within the organism. With this attention to function came a greater stress on experimentation. Young biologists were being trained with an increased emphasis on laboratory methodology at all levels of instruction, from high school to graduate school. The new techniques brought new rigor and discipline to biology, and gave it greater scientific authority in an age where physics and chemistry were ascendant.

To what extent this "revolt from morphology" fractured the biological sciences remains a topic much debated in the historical literature. Most historians would agree, however, that in distancing themselves from the natural history tradition, the early ecologists came to align themselves with the experimental science of physiology. Physiology, much more than natural history, suggested the study of processes and structural–functional relationships. It also brought to mind a laboratory setting – exactly what the early ecologists were seeking. Cittadino wrote: "These turn-of-the-century botanists had in mind the functional response of the whole plant to its external conditions. It was a logical next step to extend this point of view to the plant, or plant community, in its natural setting."[21] Experimentation in the outdoors thus became a new paradigm.

The first professional use of the word ecology came in 1893 during a meeting of the American Association for the Advancement of Sciences Madison Botanical Congress. Borrowing the term from the writings of the morphologist Ernst Haeckel, who had coined it 27 years earlier, the congress adopted the word to separate the new physiological emphasis on plant interrelationships from the older, traditional meaning of physiology. Despite the prestige that comes with a name, however, many scientists, including those favoring the "new botany," were not impressed.

Many believed ecology to be nothing more than glorified nature study. Charles Bessey, a prominent botanist at the University of Nebraska and author of one of the first high school and college textbooks extolling the virtues of laboratory study, saw much of what was then passing for ecology as a waste of time. He called it a "fad."[22] While the literature was full of ecologically inspired studies in the years following the Madison Botanical Congress, Bessey's perceptions were at times justified. A good many of these studies were not rigorous or experimental and could only remotely be considered physiological. Most of the very early work in ecology was, in fact, descriptive. Though ecology at this stage went beyond the simple floristic inventories characteristic of the older naturalists, it still had not developed a concern for models, method, nomenclature, and theory that would mark

its passage to a mature science. This would not begin to happen until the University of Chicago's Henry Cowles and the Carnegie Institution's Frederic Clements entered the field. Clements, a student of Bessey's, would eventually come to dominate ecology during the early years of the twentieth century.

Lasting value

By its very name, it is clear that the Desert Laboratory was born firmly within the experimentalist tradition. Physiological field studies would define its work from the beginning. Daniel MacDougal evidenced a strong bias in favor of a physiological approach. In 1908, he wrote: "Botanical science in its technical and applied branches has reached a stage of development in which it has become plainly evident that adequate progress in research in physiology, in comprehension of life-histories, and in formulating the general principles governing the origin, environic relations and distributional movements of plants may be expected only by experimental methods in the field or in actual contact with the types of plants under consideration under normal environmental conditions."[23] The stage was thus set for an attack on physiological desert ecology at the Desert Laboratory.

Less clear was a role for evolution in the founding of the Desert Laboratory. As Darwin made clear, the concepts of adaptation, competition, and geographical isolation and distribution that are integral to ecology are also integral to an understanding of evolution. In fact, just as the theory of evolution by natural selection has been called an ecological theory, ecology has been called the study of short-term evolution.[24] By the turn of the century, this was conceptually understood by many scientists. While an attack on evolution was implied in the Desert Laboratory's focus on adaptation, however, early research at the Laboratory was not consciously directed toward an understanding of evolutionary processes. Though there were a few exceptions (most notably the work of MacDougal), ecology would play the dominant role, with evolution limping along as a kind of afterthought. A case in point is a letter written to MacDougal in November 1903 on the occasion of a planned visit by the geneticist Charles Davenport, director of Carnegie's new Station for Experimental Evolution in Cold Spring Harbor, New York. "I have a sneaking suspicion that Davenport's proposed visit to the Desert Laboratory has some significance beyond what would appear on the surface. When you write to Cannon [the Laboratory's first resident investigator], ask him to be particularly receptive, responsive, and suggestive regarding the utilization of the Desert Laboratory as a locus for evolutionary experimentation."[25] It would only be many years later, in the 1930s and 1940s, that the department's seminal role in evolution would emerge.

There is no doubt, however, that the Desert Laboratory was a landmark in America's scientific adventuring, for it was one of the first facilities where the

new science of ecology could find creative expression. William G. McGinnies, a scientist at the University of Arizona who knew many of the individuals who worked at the Desert Laboratory in its later years, wrote of the Laboratory's legacy in 1981: "Despite difficult working conditions, climatic discomforts, and almost impassable roads in Arizona and Sonora, Laboratory personnel made discoveries of lasting value. The modern traveler can still rely on these early studies in botany, physiography, soils, and climate to illuminate what he or she sees while speeding over the paved highways of the region."[26] Let us now turn to those early ecology pioneers for whom the desert was a thing of beauty and inspiration.

2

EARLY YEARS AT THE DESERT LABORATORY

The first investigator to take up residence at the Desert Laboratory was actually not an ecologist at all – nor was he especially interested in desert plants. William A. Cannon was a plant anatomist who had been employed most recently as an assistant at the New York Botanical Garden. Undoubtedly, he had been selected for the Carnegie job by his boss at the Garden, Daniel MacDougal, then director of the Garden's laboratories.[1] (Cannon had also received one of the first extracurricular grants from the Carnegie Institution, $500 for work on a cotton hybrid.) A late bloomer, Cannon had earned his bachelor's degree at the age of 28 from the University of Michigan, and his doctorate three years later from Columbia University. While working towards a master's degree at Stanford University, he had dabbled in the plant geography of giant kelp and the evolutionary ecology of redwoods, and was thus, according to ecologist/historian Janice Bowers, who has written extensively on the Desert Laboratory, at least familiar with the thought patterns of ecologists.[2] A decade later, he would be thoroughly indoctrinated, becoming, in 1915, a charter member of the Ecological Society of America.

Cannon had just received his Ph.D. when he was offered the Carnegie job. He was inexperienced and impressionable. His task, however, was formidable. Starting work with little more than an invitation to be useful, he held the future of the Laboratory in his hands. His meager instructions from MacDougal were to inquire into the "morphology, physiology, habit, and general life-history of the species indigenous to the deserts of North America."[3] This must have been heady stuff for a young botanist most recently confined to a laboratory and now surrounded by miles of uninterrupted desert. The opportunities must have seemed as endless as the landscape.

Tumamoc Hill rises 800 feet above Tucson and the surrounding Santa Clara valley. (The word Tumamoc is from the local Papago Indian language; it means 'horned toad.') When Cannon arrived in August 1903, only the town and the rugged mountains rimming the valley provided relief from the scrubby desert landscape. Dominating the valley scene were creosote bushes (*Larrea tridentata*), interspersed with several species of prickly pears, or choyas (*Opuntia*), and joint pine (*Ephedra trifurca*). Present in the drainage areas were mesquite trees (*Prosopis*) and cat's claw (*Acacia greggii*). Upon the foothills, in addition, could be seen armies of the desert plant perhaps most