

## KENNETH BRYAN RAPER, 1908–1987

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Kenneth B. Raper, one of the great figures in American mycology, died January 15, 1987, at the age of 78. He is survived by a sister, his wife, one son, three grandchildren and two great-grandchildren. Raper's major contributions, spanning more than half a century, belong in three distinct areas of mycological research: the biology of the Acrasiomycetes, the systematics of *Penicillium* and *Aspergillus* and the production of penicillin. The quality and originality of his research assure him a place of eminence in the history of mycology. He will be remembered by his colleagues also for his fluent writing style and extraordinary dedication to scientific endeavor. On a personal level, he was a warm, outgoing, constructive person who had many friends.

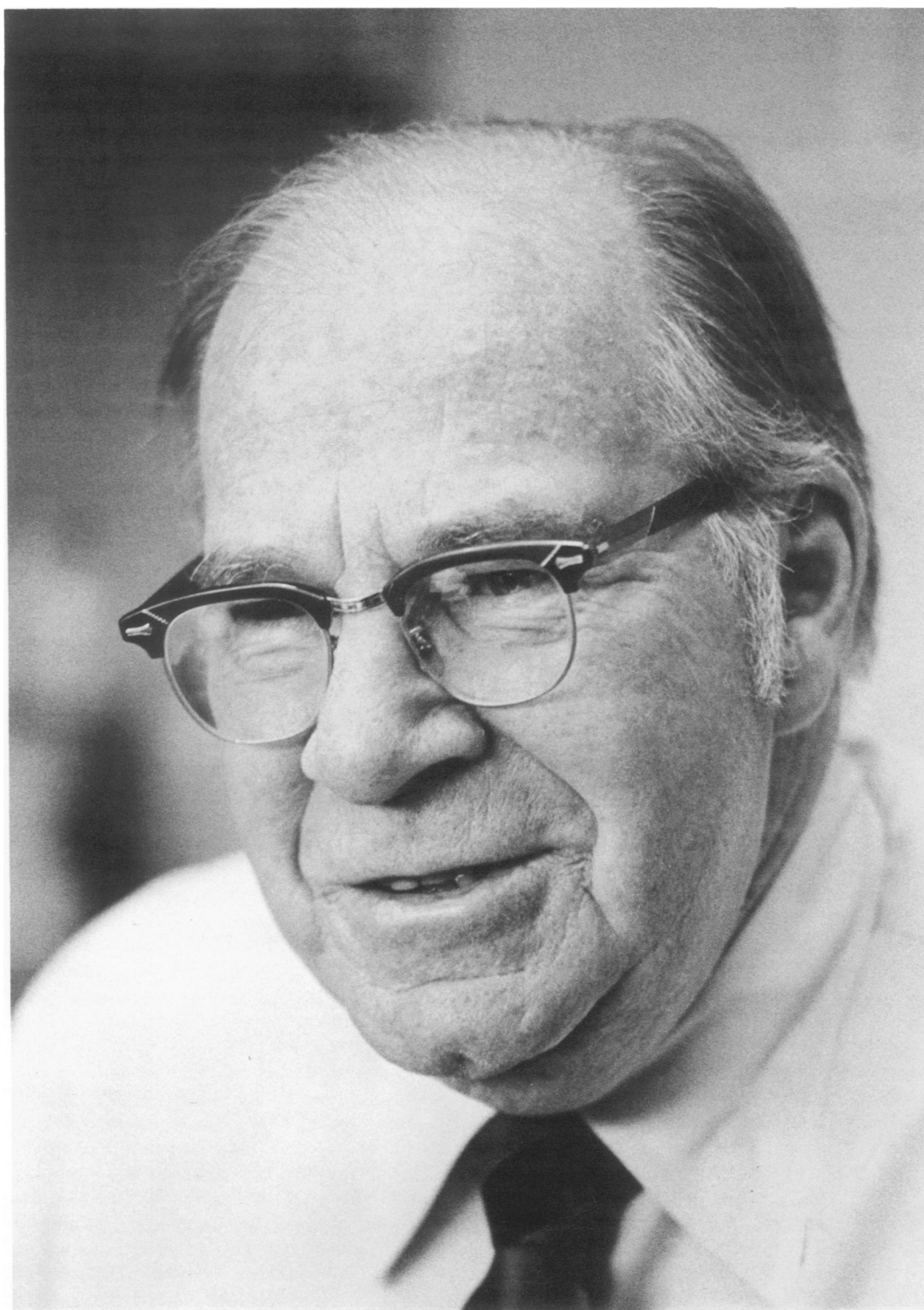
Kenneth Raper was born on July 11, 1908, into a family whose paternal antecedents had lived on a farm near Welcome, North Carolina, for several generations. Kenneth was the seventh of eight children. His nearly constant childhood companions were the next older sibling, Blanche, and his younger brother, John. John was to become a Harvard professor well known for his studies on the sex hormones of fungi and mating type patterns in basidiomycetes.

Ken always looked back with fondness to the years spent on the family farm. In an autobiographical sketch written late in life, he recalled with particular pleasure the untouched woods and magnificent old trees that were on the farm when he was a boy. With his family, Kenneth was active in two Moravian churches in the Winston-Salem area. Later he liked to recall that mu-

sic had occupied a prominent place in Moravian worship and that listening to good choral or instrumental music, live or recorded, had been a "continuing pleasure" in his life. His parents valued education and obviously conveyed that feeling to their children. Despite limited financial resources, all eight children went to college, several earned master's degrees and three completed Ph.D.s.

As an undergraduate at the University of North Carolina in Chapel Hill, Ken was financially hard pressed and earned money during his freshman year, in 1925–1926, by waiting on tables in the college dining room and selling felt pennants at ball games. It is interesting and instructive now to look back and to examine the scientific beginnings of the young college student who was to become one of the great figures in mycology and microbiology. In his very first year at North Carolina he met three botanists—W. C. Coker, H. R. Totten and John N. Couch—who stimulated his interest in the scientific study of plants and launched him on his professional career. These men soon recognized his talent and drive and offered him an undergraduate assistantship at a stipend of \$260 for the school year. Years later he wrote that no offer he ever received subsequently pleased him more than that one.

Although only an undergraduate, Ken was given work space in the laboratory where Professor Couch was conducting research on the symbiotic relationship between scale insects and fungi of the genus *Septobasidium*. That bench became an important focus of Ken's life on campus, and he was to write later that the stimulus and privilege



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of working alongside Professor John Couch played an important part in shaping his subsequent career.

His first research experience was in Dr. Coker's course in mycology. At Coker's suggestion, he conducted a survey of water molds of the family Saprolegniaceae by sampling plots selected from field and forest areas. He was 20 when he published his first paper, a description of the genera and species he had isolated. The paper appeared in the *Journal of the Elisha Mitchell Scientific Society*, the official journal of the North Carolina Academy of Sciences.

Just before graduating from North Carolina in 1929, Ken applied for a Civil Service position as Junior Mycologist with the USDA in Washington, D.C. The position was to be under Dr. Charles Thom, who was Mycologist in the recently created Division of Soil Microbiology. Following a visit by Dr. Thom to Chapel Hill, Ken received the appointment, and the two began a close collaboration that continued in one form or another until Thom's death in 1956.

When he was hired in 1929, Ken was 21 and Charles Thom was 57. Dr. Thom, internationally known for his studies on *Aspergillus* and *Penicillium*, was a scientist of exceptionally wide interests and great ability. Ken's primary responsibility under Thom was to maintain the culture collection. The task not only taught the younger man the usefulness of collections, but also provided the opportunity for him to develop his skills in handling cultures. The conservation of microbes was always an important concern of his in later life.

In Washington, he met many outstanding biologists who visited Charles Thom's laboratory. Among them was Dr. R. A. Harper, from whom Ken heard about the interesting attributes of a then relatively obscure group of soil organisms, the cellular slime molds. Soon after Harper's visit, Ken and Dr. Thom began systematically searching for cellular slime molds which they had already seen occasionally developing from soil fragments placed on hay infusion agar. It was in 1933, when he was 25 years of age, that Kenneth Raper made a discovery that was to affect his own career profoundly, and give rise eventually to a new field of inquiry into the way in which multicellular organisms develop. In North Carolina on a brief vacation, he collected some forest leaf mold while hiking in the Craggy Mountains in the western part of the state. From this ma-

terial he isolated a spectacular new species of cellular slime mold belonging to the genus *Dictyostelium*. He named the new species *Dictyostelium discoideum* and described it in the *Journal of Agricultural Research* in 1935. The forest habitat at about 4000 feet in the western North Carolina mountains is still one of the best localities for finding that remarkable and now well-known species of dictyostelid. In fact, one is virtually assured of finding it in almost every sample, whereas it turns up only rarely in agricultural soils.

Consistent with another of his outstanding traits—his intuitive sense of discovery—Raper realized that a number of unusual structural and behavioral features exhibited by his new species would make it especially attractive for experimental work. In particular, he recognized that *Dictyostelium discoideum* differed from other species of the Acrasiumycetes known at the time in that after the cells stream together, they migrate as a pseudoplasmodium before cooperatively rearing up into a delicate fruiting body. Furthermore, he was to find that the pseudoplasmodia are strongly polarized, with more or less pointed anterior ends that receive stimuli and from which movements of the whole pseudoplasmodia are controlled.

It was a credo of Charles Thom's that his younger colleagues should be given the opportunity for additional education, even though their leaves of absence often caused him inconvenience. Thus Dr. Thom urged Ken to go to Harvard to work on a doctoral degree under the famous Professor William H. ("Cap") Weston, and arranged for Ken to take a leave of absence for that purpose in 1933. With Weston's blessing, Ken elected to study *Dictyostelium discoideum* for his Ph.D., which was completed in 1936. Ken later recalled that when he proposed to "Cap" that he work on *D. discoideum*, Weston replied, "If you're game, I am!" Ken later showed that same preference for spotting interest and letting it develop in his own students and associates. Like many others, Ken considered Weston to be a "great teacher" and "wise and thoughtful counselor."

In his doctoral research, Raper explored the behavior of *D. discoideum* in an extensive series of ingenious experiments that laid the groundwork for the later adoption of this organism as a model system to investigate on a more primitive, approachable level the sorts of intercellular communications and controls that operate in

multicellular organisms. Despite his many years of devoted and meticulous work on industrially important molds, this early work on *D. discoideum* [see *J. Elisha Mitchell Sci. Soc.* **56**: 241–282 (1940)] almost certainly would have headed a list of the creative endeavors that gave him the greatest personal satisfaction.

It is worth noting that Kenneth Raper by his mid-twenties had already won the respect and support of three of the great personalities among the mycologists of that period: John Couch of Chapel Hill, Charles Thom of the USDA and “Cap” Weston of Harvard. All three became his good friends and remained so for life. During his years in Washington and Cambridge, he also met and married Louise Montgomery Williams, who became, as he later put it, his “beloved companion and counsel, and benevolent critic of succeeding years.” She is remembered as a gracious hostess and friend by the many students and colleagues who were to enjoy her hospitality at the Raper home in later years.

Following Ken’s return to the USDA in 1936, further investigative work on cellular slime molds was largely postponed, owing first to the urgent need for intensive work to be done on the taxonomy of isolates in the industrially important genera, *Aspergillus* and *Penicillium*, and then to his involvement in the great effort to boost penicillin production. In 1940, he was appointed Microbiologist at the new Northern Regional Research Laboratory established by the USDA in Peoria, Illinois, and so in that year, at the age of 32, he moved to Peoria with Louise and son Charles. His innovative work with industrially important microbes in the years immediately following played a major role in the recognition of the Peoria laboratory through the 1940s and early 1950s as a preeminent microbiological center, both for the characterization of *Aspergillus* and *Penicillium* cultures and for the development of industrially efficient strains and fermentation methods.

While working on industrially important forms, Raper established the NRRL Culture Collection of molds, yeasts, bacteria and actinomycetes, focusing particularly on microbes of known or potential usefulness. In one instance, while seeking to develop a high-yielding itaconic acid-producing culture of *Aspergillus terreus*, he invoked a valuable lesson already learned: go back to nature and search for additional strains. This led to the discovery of an isolate from soil collected

in Texas that produced itaconic acid at higher yields than the induced mutants on hand.

He had been at Peoria less than a year when Howard Florey and Norman Heatley arrived on an urgent visit from England. They were seeking help in boosting the production of penicillin, which then was available only in minuscule amounts for the many World War II casualties and others in need. They had called first on Charles Thom, who sent them on to the laboratory at Peoria. Kenneth Raper’s important role in the great “penicillin saga” is well known [his own account appeared in *Amer. Soc. Microbiol. News* **44**: 645–654 (1978)]. Briefly, he embarked on an intensive search for strains in the *Penicillium chrysogenum* series yielding high levels of penicillin, while others at the NRRL studied media and methods for promotion of growth and production of the antibiotic in submerged culture.

Of the hundreds of strains screened, the best isolate was obtained from a moldy cantaloupe brought to Raper’s laboratory from a Peoria grocery in July, 1943. Designated *Penicillium chrysogenum* NRRL 1951, this was the strain supplied by Ken to numerous mycologists and biochemists involved in the penicillin effort around the country. Using NRRL 1951, Myron P. Backus and John F. Stauffer at the University of Wisconsin systematically exposed spores to ultraviolet radiation and eventually obtained the very high-yielding mutant, Q176, the strain adopted generally by the pharmaceutical industry in the 1940s.

Other major accomplishments of Kenneth Raper during the years of the “penicillin project” of the 1940s were publication of the *Manual of the Aspergilli* by Thom and Raper in 1945, application of the lyophil process as a means for the preservation of molds, and publication of the *Manual of the Penicillia* by Raper and Thom in 1949. The classic 1945 and 1949 Manuals and the 1965 Monograph, *The Genus Aspergillus*, by Raper and Fennell, are known and used throughout the world. Indeed, because of the commonness of species in those genera and their industrial importance, their toxin-producing capacities and their usefulness as basic tools in genetics and biochemistry, the Raper Manuals undoubtedly rank among the best known mycological references by any American author. Raper was an inveterate “plant hunter” who isolated from nature at every opportunity. Together, the Manuals

contain descriptions of 46 new species and 23 new combinations or new varieties. They represent the fruition of Kenneth Raper's work with *Aspergillus* and *Penicillium* over a period of more than 30 years.

In 1952, at the age of 44, Raper was offered and accepted appointment to the faculty of the University of Wisconsin at Madison. Prior to that, he had taught an industrial mycology course at the University at Illinois each spring for six years and found that he enjoyed a university atmosphere. Through service in national scientific organizations and work on the penicillin project he had already become acquainted with many of the individuals who would become his colleagues in the years ahead, including E. B. Fred, the prominent University of Wisconsin bacteriologist who served as President of the University from 1945 to 1958, and E. M. Gilbert, Myron Backus, L. R. Jones and Elizabeth McCoy. He and Louise soon found Madison, where the forest meets the prairie, a wonderful place to live and work and they became confirmed "Badgers," as he put it.

The Rapers were to remain in Madison for the rest of his life. There, both Ken's interests and his title, Professor of Bacteriology and Botany, were interdisciplinary and, accordingly, he accepted students whose interests ranged widely within basic and applied natural science. He continued to work with industrially important microbes, completed *The Genus Aspergillus* with Dorothy Fennell in 1965, identified species in *Aspergillus* and *Penicillium* sent to him by workers worldwide and maintained a collection of several hundred cultures for teaching, reference and distribution.

The university setting also provided Ken the opportunity to realize his long-held desire to return to active research on the cellular slime molds. He and a succession of students published a long series of papers exploring the occurrence, structure and behavior of dictyostelids and acrasids. During the last 30 years of his career, approximately three-fourths of the articles he authored or co-authored were on acrasiomycetes.

Retirement in 1979 allowed him to devote full time to what was to prove to be one of his finest accomplishments, a beautifully written and illustrated monograph of the dictyostelids prepared with the collaboration of Ann Worley Rahn. This book, an achievement of meticulous scholarship, consists of two parts, the first on the bi-

ology of the Class Acrasiomycetes and the second on the systematics of the Subclass Dictyostelidae. It was a monumental undertaking which took six years to complete, two years longer than he had expected at the outset. We can only have deep admiration for a man who, in his seventies, would have the sense of purpose and the self-discipline to see such a demanding task through to completion. It must have been satisfying, indeed, for him to be able to lecture, as he did in 1985 at Ohio University and in Amsterdam, on a half century of research with the dictyostelids. His concern was that others might also come to know, appreciate and be stimulated to study these organisms. Consistent with his belief that culture collections should be in the hands of investigators who will use them, in 1983 he donated his lyophilized collection of dictyostelids to J. C. Cavender at Ohio University and his lyophilized collection of species of *Aspergillus* to Martha Christensen at the University of Wyoming.

Ken Raper had a keen appreciation of the soil and leaf mold environment, and a special talent for exploring its natural history, especially that of the dictyostelids with their incredible morphogenetic processes and behavior. Working as he did with diverse organisms, often near the interface between fungi, animals and plants, he was a mycologist, a microbiologist and a botanist more or less simultaneously. Writing in a reflective moment, he said he had sometimes felt that his efforts were being spread too thinly—that he should have focused them more sharply. But he realized that if his interests had been less broad he would not have discovered and explored *Dictyostelium discoideum*, or written the books on *Aspergillus* and *Penicillium* or found the molds yielding higher levels of penicillin during World War II.

During his career, Raper published numerous reviews and 129 research papers, including 48 articles on *Aspergillus*, *Penicillium*, culture collections and industrial preservation, uses of molds and the development of penicillin. He was author or co-author of 71 articles on cellular slime molds. In 1954 he was conference chairman and consulting editor of *Speciation and Variation in Asexual Fungi*, published by the New York Academy of Sciences. He will be best remembered, however, for his four books on *Penicillium*, *Aspergillus*, and the dictyostelids. As all users are aware, each of those works is a comprehensive treatment of the named specific group

of fungi—a “biology” in the truest sense of that word. The biosystematics focus in each is consistent with the author’s conviction that description is an essential precursor to experimentation and that a frame of reference which in its time is both reasonable and practical is an essential fundamental.

Raper served as President of the Mycological Society of America in 1951 and was awarded the Society’s Distinguished Mycologist Award in 1981, just 50 years from the date of his having joined as a Charter Member. Over the years he helped with the organization of forays and symposia and served on various committees within the Society. It was he, for example, who proposed both the Newsletter and Annual Lecture, when he was a member of an ad hoc committee chaired by Leland Shanor. The committee’s charge was to consider means for enhancing interest in the science of mycology and in the MSA. At a meeting held at the University of Illinois, Raper formally proposed that the Society issue a newsletter on a regular basis and that it sponsor a yearly lecture to be given by a distinguished biologist at the annual meeting.

Among other contributions to the community of biologists as a whole, he served as trustee of the American Type Culture Collection for 14 years, as an officer and member of the Board of Trustees for Biological Abstracts (now Biosciences Information Service) for 6 years, as Chairman of the American Delegation to the General Assembly of the International Union of Biological Sciences (IUBS) in 1958 and 1964, as a charter member of the Society for Industrial Microbiology and President of that Society in 1953, as a Fellow of the American Association for the Advancement of Science and member of its council for 5 years, as Vice President and U.S. Chairman for the XI International Botanical Congress in 1969 and as a member of various committees appointed by the National Academy of Sciences and National Research Council.

Kenneth Raper was widely admired for what he achieved professionally by devotion, industry, enthusiasm and high intelligence, and much liked for his helpfulness, good will and unflinching courtesy. He was honored on many occasions by both national and international organizations. He was a recipient, along with others on the “penicillin team,” of the Lasker Award in 1946 and a Distinguished Service Award from the U.S. Department of Agriculture in 1947. He was elected

to the National Academy of Sciences and the American Academy of Arts and Sciences in 1949, and he became a member of the American Philosophical Society in 1958 and a member of the Council of the National Academy of Sciences in 1961. He was awarded a Certificate of Merit by the Botanical Society of America in 1960, and received an honorary D.Sc. from his undergraduate alma mater, the University of North Carolina, in 1961. He was elected to honorary memberships in the American Society for Microbiology in 1983, and the British Mycological Society in 1984. In 1977, he and Louise were guests at an international symposium on cellular slime molds held in his honor on the island of Sardinia. The conference publication (*Development and Differentiation in the Cellular Slime Molds*, edited by P. Cappuccinelli and J. M. Ashworth) was dedicated to Kenneth B. Raper with appreciation for his “significant contributions” and “pioneering work in this field.” He supplied the National Academy Sciences with an autobiographical sketch in 1986 and deposited his scientific papers in the archives of the American Philosophical Society.

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<sup>1</sup> A complete list of publications is available from the authors.

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