# NOYES LABORATORY, AN ACS NATIONAL CHEMICAL LANDMARK: 100 YEARS OF CHEMISTRY AT THE UNIVERSITY OF ILLINOIS

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Ten Nobel Prize winners and, in the past 80 years, almost one out of every four presidents of the American Chemical Society (ACS) have studied or worked in the William Albert Noyes Laboratory of Chemistry at the University of Illinois in Urbana-Champaign (1). So have an estimated 12,000 other chemists, more than in any other structure in the United States and a significant proportion of the American Chemical Society's membership. On September 14, 2002, the ACS celebrated the centennial of Noyes Laboratory by designating it an ACS National Historic Landmark.

A. W. Palmer

The early history of Noyes Laboratory suggests several reasons for its remarkable success. Chemistry was important to the University of Illinois from its beginnings in 1867 as the Illinois Industrial University. Only a handful of U.S. institutions had even a rudimentary chemical laboratory at the time (2), yet in 1868 the school's first president declared in his first annual report, "It is especially important that an appropriation should be made to fit up, at once, a chemical laboratory (3)."

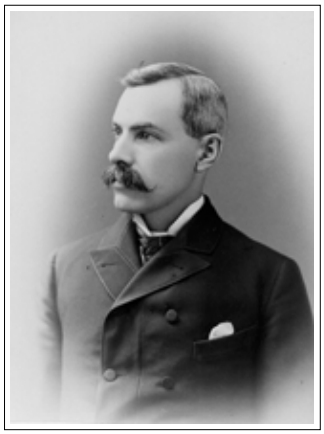
At first, the chemistry department was housed in the basement of Illinois Industrial's only building, without gas, electricity, water, or central heat. Bench space was limited so students worked in shifts. Within a decade, however, chemistry became the first department on campus to move into its own building, Harker Hall, a $40,000 structure with both gas and water. During the 1880s, when Illinois Industrial University changed its name to the University of Illinois, federal aid for land grant education doubled the university's budget; and Arthur William Palmer became the first of five chairs who–with only two breaks–would lead Illinois' chemistry department for the next century.

Under Palmer, Illinois' chemistry department became an interdisciplinary entity devoted in large part to helping the state of Illinois. Palmer was born in England but educated at Illinois and Harvard and in Germany (4). After a typhoid epidemic, the legislature established the Illinois State Water Survey to analyze local water supplies and appointed Palmer its first director. The State Water Survey remained in the department for 44 years (5). Illinois' unusual combination of chemistry and chemical engineering originated when Samuel Wilson Parr joined the department, and the two men divided the workload. Chemical science stayed with Palmer, and industrial chemistry-later called chemical engineering-went to Parr (6). Parr helped Illinois' bituminous coal compete with Eastern Appalachian coal (7) by developing an alloy and various processes and fuel testing devices, including the Parr bomb.

Notwithstanding these successes, when lightning struck and badly damaged the chemistry building in 1896, it took Palmer four years to convince the Illiinois Legislature to appropriate $100,000 for a new structure. Palmer's E-shaped building, the western half of the structure that still exists, opened in 1902. It was supposed to provide enough space for chemistry for 25 years (8).

Harker Hall

Despite the recent fire, Palmer's building was wooden-framed. Its fireproofing consisted of 12 inches of sand between floors and ceilings (9), and wooden beams stretched through the flues. In addition, the building's hoods never functioned properly, and Illinois chemists worked with inadequate ventilation until a major renovation in 1941 (10). Moreover, the university and particularly its chemistry department were growing quickly. Within a decade, the building was overcrowded.



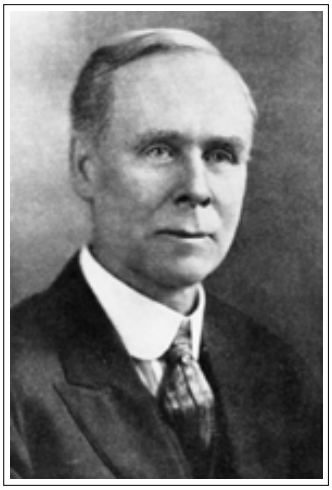
S. W. Parr

Palmer died in 1904 at the age of 43, apparently of overwork. The university hired a new chemistry head, William Albert Noyes, for whom the chemistry building was named in 1939. Noyes built Illinois' department into one of the most prestigious in the United States. He also doubled the size of its building and made it the largest and most modern chemistry laboratory in the world. How could Noyes succeed where the politically astute, workaholic Palmer could not?

First, Noyes was nationally known as the discoverer of the definitive structure of camphor, the former chief chemist at the National Bureau of Standards, the editor of the prestigious Journal of the American Chemical Society, the founder of Chemical Abstracts, and one of the founders of Chemical Reviews (11).

Second, chemical research was the basis for Germany's growing industrial and military power, and anything seemed possible with chemistry. Speakers in Noyes Laboratory dreamed of turning cornstarch into India rubber; of using the "emanations" from radium to transform copper into potassium (for fertilizer) (12); and of mining seawater for potash, again for fertilizer. An Illinois chemistry professor declared in 1916, "Don't say it can't be done, for it is being done by miles of seaweed (13)."

Most important, Noyes was asking for money to expand the chemistry building during the military buildup preceding World War I. As an Illinois chemistry department brochure explained at the time, the sudden exclusion of German products from U.S. markets "opened the eyes of the whole country to our inferior and dependent position in many lines of chemical manufacture and to the importance of establishing such industries on a better footing in America (14)."

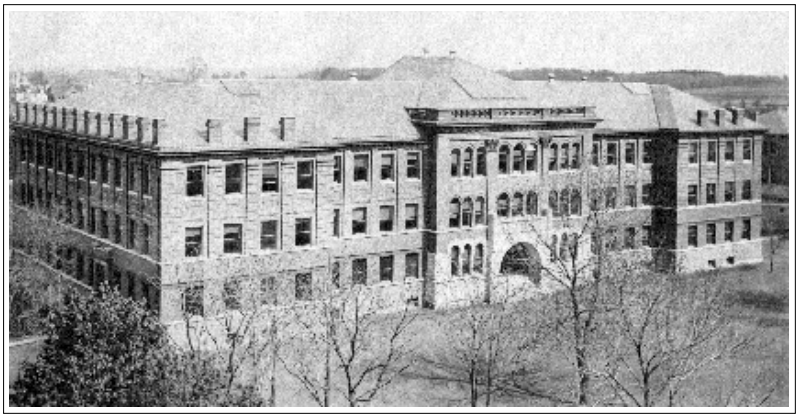


W. A. Noeyes

Enrollment in Illinois' chemistry courses multiplied more than six times in 15 years (15). Growth in graduate education was particularly rapid. By the beginning of World War I, more U.S. students were earning Ph.D.'s in chemistry than in any other science (16). As

a result, Noyes was able to secure the first state appropriation made to a state university specifically for graduate work (17) and $500,000 to enlarge the chemistry laboratory. New construction enclosed Palmer's E-shaped building to form a hollow square with almost four acres of working space-twice as much as before. The addition had many unique features: distilled water, compressed air, piped-in hydrogen sulfide, steam, a special vacuum system, and 150 electric wall plugs. It was finally fireproof, and its ventilation system was supposed to exchange the air six to eleven times an hour (18).

The addition opened for business in 1915, but its dedication was delayed a year to give the Twin Cities of Champaign and Urbana time to build a hotel. The 1916 ACS spring meeting was held in conjunction with the building's inauguration, and 729 visitors came, more than to any previous ACS convention (19). There were not enough organic chemists, however, to fill a 35-seat classroom (20).



Noyes Laboratory

The 1916 dedication of Noyes Laboratory celebrated chemistry's coming of age in the United States and the highpoint of women's participation until the late 20th century. Women made up 8 % of chemistry's instructional staff (21); but, banned from the all-male chemistry club and fraternities, women faculty and students had formed a sorority (22). At the convention banquet, the sorority served refreshments to the men. As the department grew in size and prestige under Noyes and later Roger Adams, women's participation declined markedly. During the Adams years, there was a "definite feeling," as one observer put it, that "a graduate student should have neither wife nor car (23)." The chemistry department hired its first tenure-track woman in 1985 (24).

If the Department overlooked women chemists, it chose its men well. One of Illinois' early Ph.D.'s was St. Elmo Brady, the first African-American Ph.D. chemist in the United States. Of his years in Noyes Lab, Brady said, "They began with 20 whites and one other and ended, in 1916, with six whites and one other (25)."

As chair, William Noyes also hired important men, especially Roger Adams and the nucleus of division heads who would constitute the department's establishment for a quarter century between 1926 and 1954. Under Noyes, the university hired, in chronological order, B. Smith Hopkins, Roger Adams, Carl S. (Speed) Marvel, Worth H. Rodebush, William C. Rose, and G. Frederick Smith.

As Roger Adams emphasized, military research during World War I gave chemistry a big boost. Adams figured that the Chemical Warfare Service "brought together 80 % of the chemists [in the U.S.] (26). " He himself directed a poison gas research laboratory, studied arsenic compounds, and worked out a simple way to make tear gas.

Marvel remained in Noyes Laboratory to run a financially self-supporting project called "Summer Preps." Graduate students earned summer salaries by manufacturing in Noyes' sweltering attic various organic reagents for the American military, manufacturers, and medical and university researchers. By then, Noyes Laboratory suffered from an almost complete lack of ventilation; one professor could joke that fire was not a danger because the air in Noyes would not support combustion (27, 28). Black smoke often filled the Preps room; students' hands became black with chemicals; and "a certain aroma that wafted from each worker became the mark of the preps chemist (29)."

As Speed Marvel described the work (30):

> Various government groups needed materials, especially for the new chemical warfare which had been introduced by the Germans.... Many of the requests for chemicals were for prospective chemical warfare agents, and it was quite a task to make such materials in the university laboratories which had rather poor ventilating hoods.

Rogers Adams, by then a major in the chemical warfare program (30):

R. Adams

> ...used us to furnish needed chemicals on a rush basis. We had many experiences with toxic materials ... Some accidents occurred because safety regulations had not yet come to university laboratories.

Such attitudes about safety were typical of generations of macho chemists. Marvel claimed, for example, that he could identify 500 compounds by smell alone (31 It was not until 1980 that Illinois' organic chemists developed, as department head Herbert S. Gutowsky reported (32):

> ..a new laboratory safety program which for the first time has been able to encourage a set of laboratory safety practices comparable to those commonly encountered in industrial chemical laboratories.

During the 1920s and 1930s, between the two World Wars, organic chemistry at Illinois entered what has been called "the Golden Age of Roger Adams." Adams, who arrived in Illinois in 1916, was a man of particular charm and force, buoyant and gregarious at the same time that he was intellectually brilliant, pragmatic, and extremely tough (33). Ten years later, he was unanimously chosen head of a very young department; only one faculty member was more than 40 years old (34).

Adams spent 56 years at Illinois, 28 of them as department head. He developed the platinum oxide catalyst that hardens liquid vegetable oils into solid fats for soap and shortening and analyzed several biologically active compounds, including a natural oil used to treat leprosy, a toxic constituent of cottonseed meal, and the active ingredients in marijuana. Adams published 425 scientific papers.

Under Adams and Marvel, Illinois became the country's largest producer of organic chemists, particularly Ph.D. chemists. Between the wars, Adams guided 21% of Illinois' Ph.D. chemists, many of whom became important in industrial research and management, in universities, and in the ACS (35).

Adams' student Wallace Hume Carothers was perhaps the single most important product of the University of Illinois' chemistry program. Carothers arrived at Illinois for graduate school in 1920 after six desperate years spent in his father's secretarial school and working his way through college. Carothers also struggled, without modern medications, with both thyroid disease and bipolar mood disorder, formerly called manic depression. Despite his health problems, Carothers earned a Ph.D. and taught for two years in Noyes Laboratory before going to Harvard for another two years and then to Du Pont's Experimental Station in Wilmington, Delaware, for nine more years. Throughout his life, Carothers maintained ties to Noyes Laboratory and the friends he made there (36).

Carothers and Marvel

While at Du Pont, Carothers conducted the first fundamental scientific research in the American chemical industry. He showed that-surprisingly-polymers are long but otherwise normal molecules held together by normal bonds. Then Carothers invented Neoprene, a synthetic rubber, and nylon, the first commercially marketable synthetic fabric and the beginning of the modern era of plastics and synthetics. Within days of arriving at Du Pont in February, 1928, Carothers outlined the research project that would start the field of polymer chemistry and culminate in nylon. In his plan, Carothers predicted that, if it succeeded, it would be an "important factor in the great success of the work in organic chemistry at the University of Illinois (37)." A few months later on March 1, 1928, Carothers submitted a detailed research plan to Du Pont and wrote at the top (38):

> Copies to: Dr. Adams: University of Illinois; Dr. Marvel: University of Illinois.

Adams and Marvel had become consultants at Du Pont (39), and at one point, Carothers wrote a friend about Adams (40):

> I think his visit will put about $5,000 worth of pep into some of the chemists around here.

Marvel, who had been Carothers' instructor in Noyes Laboratory, went on to start at Illinois the first major polymer research program in an U.S. university. Marvel said, years later, after Carothers' suicide (41):

> I learned most of my polymer chemistry at Du Pont from Carothers.

The high point of Adams' tenure as head of the chemistry department occurred, he thought, during the 1930s when the American chemistry establishment consisted largely of Illinois and some other Midwestern state universities with a sprinkling from Harvard, Columbia, Princeton, Caltech, and a few other chemists. According to the so-called Illinois system, small groups of graduate students from different backgrounds were expected to do research "fraternally." Illinois' undergraduates went to other midwestern universities for their postgraduate education, and those midwestern universities, in turn, sent their best students to Illinois for graduate school. More undergraduates in chemistry went on to graduate school from Illinois than from any other institution in the U.S. Illinois chemistry offered social mobility to generations of able and ambitious young men of limited means for whom medical school would have been too costly (42).

Ironically, despite the reputation of Illinois' organic program before World War II, the most famous figures in the department were an inorganic chemist and a biochemist. In 1926, rare earth chemist B. Smith Hopkins announced that he had discovered a tiny amount of the long-sought Element No. 61. Hopkins named it "Illinium" for the state and university. It became a departmental embarrassment because, although it was learned after World War II that Illinium was not an element after all (43), it lived on in campus charts of the periodic table and in textbooks, including one that Hopkins edited, as late as 1956 (44).

In 1935, a decade after Hopkins' Illinium, biochemist William C. Rose discovered threonine, the last of the eight essential amino acids that people need but must get from food because our bodies cannot make them or cannot make enough of them. Rose eventually calculated the minimum daily requirement for each essential amino acid (45). Rose began his feeding experiments, involving rats and more than 42 graduate students, in 1930. Today they would not be permitted because they could have jeopardized the health of his students (46). But Rose wanted to make a synthetic diet for patients who could not digest proteins or who had to be fed intravenously. At the time there was no complete synthetic diet for them; nor was there any way to characterize and separate one amino acid from another in a protein. Feeding studies had long played a quite honorable role in science, and Rose regarded them as his only choice. In any event, the work of both Hopkins and Rose demonstrated that Illinois was far more than just an organic chemistry department, even under Roger Adams.

W. C. Rose

During World War II, Marvel coordinated from Noyes Laboratory two interdisciplinary research efforts-one of them larger than the Manhattan Project-that produced a usable synthetic rubber within a year and chloroquine, in time for its use in the Pacific against malarial mosquitoes. After the war, during the 1950s, Marvel explained that (47):

> With the new synthetic rubber program, the big surge in synthetic textiles, and the growth of the automobile industry and its needs for new materials, the chemical industry profited in the fifties and sixties. Research laboratories expanded and new ones started up. The demand for chemists reached new peaks.

Illinois, which had played key roles in the development of both synthetic textiles and rubber, was ready for the post-war growth. Within one year between 1953 and 1954, the department underwent a massive generational upheaval as Roger Adams and most of his divisional leaders retired or moved to other jobs. Nonorganic chemistry emerged from under the pre-war shadow of organic chemistry, and Adams was succeeded first by biochemist Herbert Carter and then by physical chemist Herbert S. Gutowsky.

H. E. Carter

Carter not only replaced most of the department division heads with younger men but also expanded the senior faculty-because of growing enrollments-by 35 percent (48). In addition, as mathematics and quantum physics became increasingly important to chemistry, Illinois developed strong programs in inorganic, physical, and analytical chemistry to balance its organic work.

Gutowsky's application of nuclear magnetic resonance spectroscopy to chemistry is indicative of these new directions. Gutowsky said that Roger Adams hired him "accidentally" in 1948 to do infrared spectroscopy for Illinois' organic chemists (49). Gutowsky came to Illinois as a young instructor, however, convinced that the magnetic vibrations of protons could reveal what was happening inside a molecule. So Gutowsky

H. S. Gutowsky

gambled his career. With the help of a graduate student in chemistry and an undergraduate in electrical engineering, he rigged up an NMR apparatus (50). With this device, he discovered and explained the phenomenon of spin-spin coupling, which allows scientists to determine the relative locations of neighboring atoms. He also predicted and then discovered the phenomenon of chemical exchange, which chemists use to understand how atoms and molecules move (51).

Gutowsky's monumental work on NMR and Rose's essential amino acid studies are regarded as Noyes Laboratory's greatest scientific and medical discoveries. Gutowsky later chaired the chemistry department and the School of Chemical Sciences and built and staffed what he regarded as "revolutionary" service centers to operate NMR spectrometers, mass spectrometers, X-ray equipment, and computers (51).

How did the inhabitants of Noyes Laboratory become such a significant force in chemistry? Several aspects of its history are particularly striking. First, Noyes' interdisciplinary, organic, graduate orientation began before World War II. Second, leading scientists-not just skilled administrators-chaired the department and provided scientific vision. Third, Noyes Laboratory scientists not only conducted research that benefited the State of Illinois and a broad region around it; they also gave their constituents' children social and economic mobility. Finally, Noyes nurtured the long-term careers of its students, sending undergraduates on to graduate schools and placing graduate students in academia and industry.

## ACKNOWLEDGMENTS

Dr. Vera Mainz made this article possible by assembling historical data about the history of Noyes Laboratory for the American Chemical Society's National Historic Landmarks Program and by answering the author's many questions. Many documents are accessible in a website

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## ABOUT THE AUTHOR

Sharon Bertsch McGrayne, the author of Prometheans in the Lab: Chemistry and the Making of the Modern World (McGraw-Hill, 2001), gave the keynote address about the history of Noyes Laboratory when it was designated an ACS national historic landmark on September 14, 2002. McGrayne lives in Seattle, Washington. Her web page address is http://www.McGrayne.com.