2012

Profiles in Science: John Bennett Fenn

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Abstract

"Don't ever try to be a scientist or engineer!" Had John Bennett Fenn listened to this advice given by his ninth grade teacher, he might not have gone on to pursue a career in analytical chemistry which would culminate in the attainment of the Nobel Prize in 2002. Gathered from interviews, publication analyses, glowing tributes, and his reminiscences, this paper outlines the academic and professional life of John Fenn from childhood through the end of his career in 2010.

Keywords: John Bennett Fenn, analytical chemistry, professor, Nobel Prize, Virginia Commonwealth University, Yale University

Running Title: Profiles in Science John Bennett Fenn

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Introduction

John Bennett Fenn was a professor of analytical chemistry in the Department of Chemistry at Virginia Commonwealth University (VCU) from 1994 until his death in 2010. He was also an affiliate professor of chemical engineering at VCU's School of Engineering. Fenn began his academic career at Princeton in 1952 until 1967 when he moved to Yale. Fenn was on the faculty at Yale from 1967 to 1994. He is best known for his award winning work on electrospray mass spectrometry which "has been used in chemistry laboratories around the world to rapidly and simply reveal what proteins a sample contains, revolutionizing the development of new medicines."(Buckley 2010) For his work in the development of soft desorption ionization methods for mass spectrometric analyses of biological macromolecules, Fenn received the 2002 Nobel Prize in Chemistry. Fenn was not only one of the most influential and well-respected scientist in world, he was a beloved colleague, friend and mentor at VCU. This paper profiles Fenn's life, education, and career.

Early Life and Education

John Bennett Fenn was born on June 15, 1917 in New York, NY to Herbert Bennett Fenn and Jeanette Dingman Fenn (Grayson 2011). Herbert and Jeanette met while working for the Presbyterian Mission Board at the Sheldon Jackson Mission School in Sitka, Alaska. Herbert graduated from Rutgers in 1910, majoring in electrical engineering and Jeanette graduated from Columbia the same year with a degree in home economics and nutrition. The Presbyterian Mission Board hired Herbert as a handyman and to keep the school's generator operational. Fenn's mother taught home economics at the school.

In an interview, Fenn recounts his parent's story of how the Chairman of the Mission Board introduced the two new hires and warned Herbert and Jeanette not to fall in love. He followed his warning with an offer. The Chairman told the two that if they fell in love and got married, he would provide a home for the couple for the duration of their stay in Sitka (Fenn 2002). The two did indeed fall in love and marry. During a vacation cruise in 1996 Fenn visited the Mission School in Sitka and toured what he dubbed his parent's "Honeymoon Cottage," the same home offered to the wedded couple by the Mission Board Chairman.

After miscarrying her first child, Jeanette's physician informed her that her pelvic structure would necessitate that any future babies be delivered by Caesarian section. Though the couple enjoyed living in Sitka, Caesarian sections were not performed there during that time period. Fenn believed his parents would have remained in Sitka, but because they wanted to have children they decided to move to Hackensack, New Jersey (Fenn and El-Shall 2009). There, Fenn's father obtained a position as superintendent of a waterproofing factory in the nearby town of Lodi, New Jersey. The factory specialized in producing water-resistant cotton duck cloth called Metacloth.

John was born in 1917 while the couple lived in Hackensack. Three and a half years later the couple had another son, Norman. In what Fenn described as a "treasured" Saturday trip with his father to the waterproofing factory, Fenn received his first and what he called an "abrupt introduction" to chemistry when he lifted a cover off a tank and recoiled at the smell of cuprammonium solution (Fenn 2002). In an

interview, Fenn described the incident: “I still recoil at the memory of that ammoniacal, and demoniacal, assault on my eyes and nose. It was a startling revelation on how and why a whiff of smelling salts can often revive people from a dead faint!”(Fenn 2002) When Fenn was eight to nine years old, his parents bought him the “Book of Knowledge,” a twenty volume science encyclopedia for children. Fenn recalled spending hours looking over the volumes (Fenn 2002).

During the Great Depression, in 1927, the waterproofing factory was sold and Fenn’s father lost his job (Fenn and El-Shall 2009). Although Fenn’s father began working at the Fokker Aircraft Company as a temporary draftsman, his reduced income could not pay for the house purchased just before he lost his job at the waterproofing factory. As the family’s finances dwindled, the family lost their new home to foreclosure in 1928 (Fenn 2002).

When Fenn was eleven years old, his family moved from Hackensack, New Jersey to Berea, Kentucky. Berea, an Appalachian town, located forty miles south of Lexington, had a population of 3500 people at that time. Fenn’s father was offered a position teaching auto mechanics and practical electricity at Berea College, the same institution where Fenn’s aunt taught (Fenn and El-Shall 2009). Despite the frustrations of losing a job and home in Hackensack and an automobile accident on their journey to Berea, Fenn described their life in Berea as, “rich and rewarding beyond what any of us had dreamed” and said, “To this day my brother and I share those sentiments and count ourselves especially privileged to have been reared in what was a truly remarkable community.”(Fenn 2002)

Fenn’s colleague David Muddiman credits Fenn’s college educated parents with instilling in Fenn, “the critical importance of education”(Muddiman 2011, 160). In the fall of 1928 after the family’s arrival in Berea, Fenn attended the Foundation Junior-High School, one of four schools comprising the institution known as Berea College; later he went on to enter Berea’s Academy and then College (Fenn and El-Shall 2009). The school did not charge the students tuition, however, the students were required to provide at least two hours of labor a day performing duties such as yard work, office duty, or working in the dining

hall, on-site bakery, broom factory, dairy, garden, sheep farm, or furniture making shop, weaving center (Fenn 2002).

Fenn recalled a day from ninth-grade algebra when the teacher returned Fenn's algebra exam with the message, "Don't ever try to be a scientist or engineer!" written in red ink. Redeeming himself, Fenn completed the algebra class with a final grade of a B. He later successfully completed plane geometry, advanced algebra, and solid geometry with trigonometry earning an A in each class. Despite his grade redemption, Fenn believed he lacked mathematical skills which resulted in a substantial handicap throughout his career (Fenn 1996).

In 1932, Fenn Graduated from Berea Academy, at the young age of fifteen. His parents thought he was much too young to enter into college, so Fenn enrolled in an extra year at the Academy. During this extra year he completed courses in mechanical drawing, shorthand, and piano.

Fenn began Berea College with the class of 1938. He enrolled in an introduction to chemistry class his first year since he had enjoyed his chemistry class at the Academy. Fenn described his professor, Julian Capps, as, "A wonderful teacher who made his subject live."(Fenn 2002) Fenn goes on to explain, "I was so seduced that Chemistry became my major even though Gravimetric Analysis gave me fits in my sophomore year"(Fenn 2002). Because Fenn attended summer school in 1936 in order to graduate the same year as a woman he fell in love with, Fenn was able to complete all but two class requirements and was granted a provisional membership in the class of 1937. His relationship with the woman ended just months later (Fenn 2002).

Although he graduated in the spring 1937 commencement, Fenn completed course requirements at Purdue University during a summer session to receive his degree (Fenn 2002). At Purdue, Fenn completed classes in physical chemistry and chemical microscopy. In addition to chemistry classes, Fenn had the opportunity to attend a four week course in welding at the Lincoln Electric Company in Cleveland. Recognizing the importance of a trade after his father's experience working as a draftsman to support the

family after losing his job, Fenn became a certificated master welder. Fenn described those weeks of welding classes as more educational than the chemistry courses he completed that summer (Fenn 1996).

After graduation in 1937 from Berea College, Fenn was offered admission to Yale and Northwestern University. He was initially inclined to attend Northwestern because of the chemistry department's outstanding reputation and Northwestern offered a much more generous fellowship. After a conversation with a persuasive next door neighbor, Fenn changed his mind and decided to attend Yale. His decision was affirmed when he was offered a ride to college by the treasurer of Berea College who had a son starting at Yale as well. Fenn's decision to attend Yale delayed his meeting Malcolm Dole, a professor at Northwestern who in 1968 reported on experiments on electrospray ionization that would later change Fenn's scientific life (Fenn and El-Shall 2009).

Once at Yale, Fenn was in awe of the architecture and the splendor of the Yale campus. In his free time at Yale he explored the nooks and courtyards of the campus, while also spending many hours exploring the stacks at Sterling Library. He had to be frugal with recreational expenses because his assistantship only paid $850 for nine months with $350 of the amount budgeted for paying tuition and fees (Fenn 2002). To save money he fasted for three consecutive meals every week, which enabled him to save $1.15. This along with other frugalities enabled him to afford all of his out of pocket expenses (Fenn 1996).

Fenn's academic career was initially shaped by the ranking faculty member of the department, Herbert Harned, saying to him, "Fenn, you might as well go with Gus." "Gus" was Dr. Gosta Akerlof, who became Fenn's advisor and friend during his time at Yale. Upon being assigned to Akerlof's group, Fenn said he felt neither joyful nor apprehensive since he had little understanding of what graduate study and research entailed. Most of the research in the department focused on the properties of electrolyte solutions with preference towards greater dilution. Dr. Akerlof's research differed slightly from that of his department colleagues, focusing on concentrated electrolyte solutions. Under Akerlof's tutelage, Fenn

took courses, oversaw undergraduate labs, and spent the rest of his time working on what would become his dissertation research (Fenn 2002).

Dr. Ackerlof and his wife made their home a “home away from home” for the students he mentored. Fenn witnessed the Akerlofs’ hospitable nature in his third year at Yale. After his second year at Yale, Fenn did not receive a fellowship to continue his research. This left him without financial support and needing a way to help pay for his expenses while still being able to conduct his research. His solution to this dilemma was to marry Margaret (Magee) Wilson, who was ten years his senior and had been his supervisor when he was a student laborer in the Registrar’s Office at Berea. Fenn stated in an interview, “She was a beautiful woman by whom I (then in the tenth grade!) was smitten the first day she started work as Assistant Registrar” (Fenn 1996, 1-41). His wife supported him during his third year by doing odd jobs earning 50 cents an hour. While Dr. Akerlof was not in favor of graduate students getting married, he and his wife took the new couple under their wings. In fact he later told Fenn that he thought marrying Magee was the smartest thing Fenn ever did. It was a sentiment that Fenn said was echoed by many of his friends over the years. Fenn and Magee were married for 53 years. She passed away in 1992 at the age of 85 as the result of injuries sustained in a car accident (Fenn 2002).

Starting a Career in Industry

Fenn graduated from Yale in 1940 with a Ph.D. but had a greatly diminished love of or interest in conducting academic research from the experience. This disillusionment led him to look for work in the private sector with the research department of the Phosphate Division of the Monsanto Chemical Company in Anniston, Alabama. His starting salary was $2700 and he once remarked to his mother that he did not know how he would spend so much money. The plant was known for the production of food grade acid and PCBs (polychlorinated biphenyl).

A year after being at Monsanto, Fenn met and befriended James W. Mullen II, who was an organic chemist from Princeton. Each was growing increasingly discontent with their careers and had a

real desire to move in a different direction. Mullen insisted that he eventually was going to start his own research company and wanted Fenn to join him. While they did not immediately partner to start a research firm, they both resigned from the Anniston plant on the same day. Fenn took a position at Sharples Chemicals in Wyandotte, Michigan and Mullen began a job at Bell Labs in New Jersey. Their separation only lasted until June 1945 when Fenn received a letter from Mullen saying he had started a company in Richmond, Virginia and urged Fenn to join him. By this time Fenn had two young daughters, Marianne and Barbara, and was expecting a son; he was intrigued enough by the research that Mullen was conducting that he decided to move to Richmond (Fenn 1996, 1-41).

Mullen's company, Experiment, Inc., was working with the U.S. Navy on Project Bumblebee, a missile program, and had been granted a subcontract by the Applied Physics Laboratory of Johns Hopkins University focusing on ramjet power. Fenn found that he increasingly enjoyed research and felt he might one day like to be on a college faculty (Fenn 1996, 1-41).

Transfer to Academia

Fenn's long and distinguished career in academics began at Princeton. In 1952, his work with the Navy led to a job as director of Project SQUID, a U.S. Navy program based at Princeton. Project SQUID involved applied research related to jet propulsion (Fenn and El-Shall 2009). That year, he became a professor of aerospace and mechanical sciences. In 1955, he travelled to London to serve a one year term as Liaison Officer for the Office of Naval Research, London branch (ONRL) in the areas of combustion and propulsion. This allowed him to work with other scientists in the field rotating in and out of the ONRL office in Europe. In London his academic study underwent a major change; he started thinking about reactive scattering experiments with molecular beams on any chemical reaction. From 1959 to 1963, he served as a professor of mechanical engineering at Princeton. From 1963 to 1966, he held the position of professor of aerospace science (Arnaud 2010).

When Yale was expanding its engineering department, Art Ross, a friend of Fenn's, invited him to join the faculty of the Department of Engineering and Applied Science. Yale wanted to design a program similar to Project SQUID and needed Fenn's expertise. Fenn initially rejected the offer because Princeton offered a better environment for his work with combustion, but Ross was persuasive (Fenn and El-Shall 2009). Fenn joined the Yale faculty in 1967. From 1967 to 1980, he worked as professor of applied science and chemistry at Yale. In the mid-1970s, Fenn started to explore work in electrospray. This resulted in his appointment as a professor of chemical engineering from 1980 to 1987. He became a senior research scientist at Yale after being named emeritus in 1987 due to Yale's mandatory retirement age of seventy. This ranking resulted in diminished laboratory space and funding which meant that Fenn had to pay for his own lab and equipment. This circumstance greatly limited his ability to conduct research. At the age of seventy, he felt that he still had a lot more he could accomplish (Fenn and El-Shall 2009).

While researching at Yale in 1989, Fenn filed a patent under his name for an invention in the field of mass spectrometry, U.S. Patent No. 5,130,538; it was granted in 1992. Fenn did not agree with the

70/30 share of royalties that Yale demanded, especially since at this time, as an emeritus he had to pay for his own lab. Fenn patented the technology in his own name and sold licensing rights to Analytica, a company which he partly owned and earned royalties. This violated Yale's patenting policy which stated "any patentable inventions resulting from a faculty member's research conducted at Yale belongs to Yale and not the faculty member unless Yale expressly releases its interest in such invention." (Fenn v Yale Univ. 2005) Yale first learned of this patent when a company made an inquirey to the Yale Office of Cooperative Research (OCR) about the possibility of licensing the patent in 1993. This resulted in multiple correspondences between the OCR and Fenn, where Fenn refused to reassign the patent to Yale. Yale circumvented Fenn by entering into a licensing agreement with the company Analytica.,

The two parties were never able to come to an agreement regarding this patent. Fenn filed a lawsuit "alleging conversion, theft, tortuous interference with a business relationship and violations of the Connecticut Unfair Trade Practices Act (CUTPA), regarding a patent for an invention" in 2003. Yale "asserted counterclaims for breach of contract and fiduciary duty, fraud, negligent misrepresentation, conversion, theft, and CUTPA violations." (Fenn v Yale Univ. 2005) In 2003, the Connecticut court found that Fenn deceived Yale into thinking the invention represented little scientific or commercial value. Fenn's patent for his invention would have to be turned over to the university and Fenn was ordered to compensate Yale for the net royalties due in regards to the patent policy of the University. Fenn appealed the Connecticut court decision and again lost at the United States Court of Appeals for the Second Circuit in 2006. Some people in academics, including academics from Yale, did not agree with this treatment of a Nobel Prize recipient and distinguished professor (Moran 2005).

During his academic career, John Fenn had many opportunities to become a visiting scholar. He was a visiting professor at Trento University in Italy (1976), University of Tokyo (1979), Indian Institute of Science at Bangalore in India, Chinese Academy of Science in Beijing (1987) and a distinguished lecturer at several other institutions (Office of Public Affairs and Communications 2010).

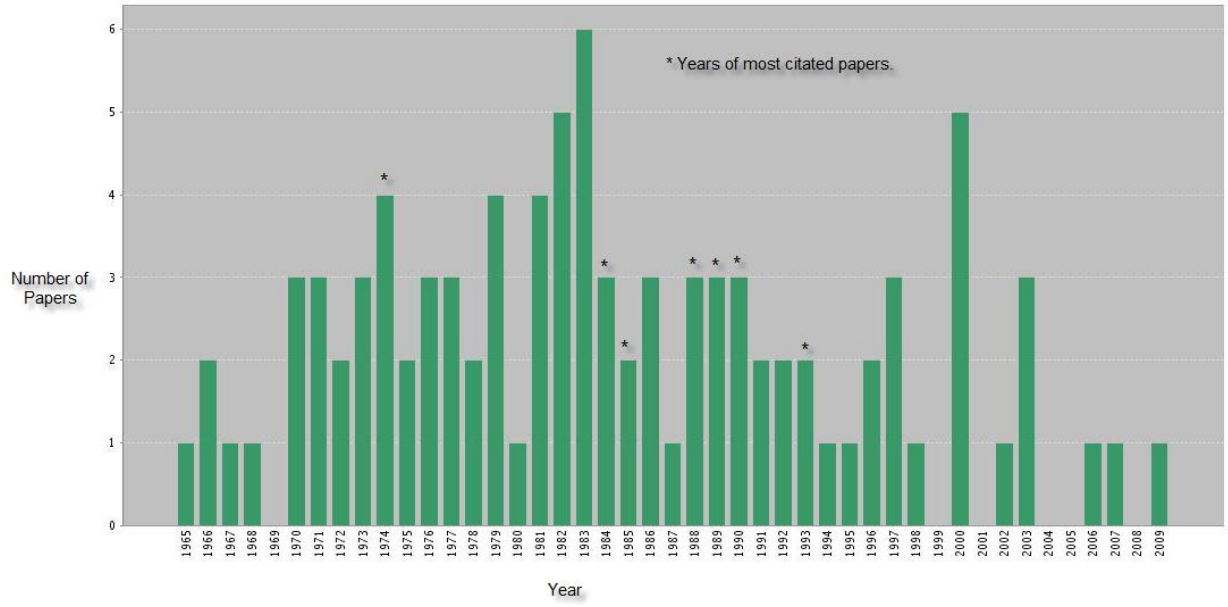
Fenn remained at Yale because his wife, Magee, wished to remain in New Haven. After she died in 1992, he was free to leave Yale. While visiting friends in Richmond, VA, he again met Freda Mullen, the widow of his friend and colleague, Jim Mullen, and eventually married her. At about the same time, Fenn was invited to Virginia Commonwealth University (VCU) in Richmond for a seminar. Fenn asked Vicki Wysocki, an Associate Professor in VCU's Department of Chemistry, if there was a possibility of joining the faculty at VCU. He needed a lab which would allow him to continue his research which had been interrupted by his mandatory retirement from Yale and his diminished lab privileges (Fenn and El-Shall 2009). In 1994 Fenn was appointed as professor of analytical chemistry in VCU's Department of Chemistry. He was also appointed affiliate professor of chemical engineering in VCU's School of Engineering. Fenn continued his work on electrospray. Some of his research at VCU was funded by the National Science Foundation (NSF); it involved measuring the affinity of molecules for water and on analyzing particulate matter in an effort to see how the latter causes disease (Buckley 2010). In his nineties Fenn continued to work regularly. While at VCU, Fenn received the Nobel Prize in Chemistry in 2002 based on his work at Yale. Fenn worked at VCU until his death at the age of 93 on December 10, 2010.

In one of his interviews in 2009, Fenn expressed strong sentiments about the way students are taught science in college. He thought that instead of teaching students to memorize plenty of facts, professors ought to teach the students how to think so that they can continue to learn on their own as information continues to proliferate (Fenn and El-Shall 2009; Wynne 2011).

Publications

John B. Fenn published regularly throughout his career, except during a few transition periods. In all he wrote and published over 100 journal articles, editorials, conference papers and two books.

Figure 1. Papers per Year (analysis based on the 94 papers in Web of Science).



Articles by Fenn are well cited. Of the 94 papers and conference abstracts in Web of Knowledge (all databases, including MEDLINE, BIOSIS and Zoological Abstracts, as of August 1, 2011), there were a total of 11,407 citations, only 139 of which were self-citations. The average citations per item is 121.35, and the average citations of John B. Fenn's works per year is 247.98. Fenn's top 10 articles account for 9040 of the citations of his articles.

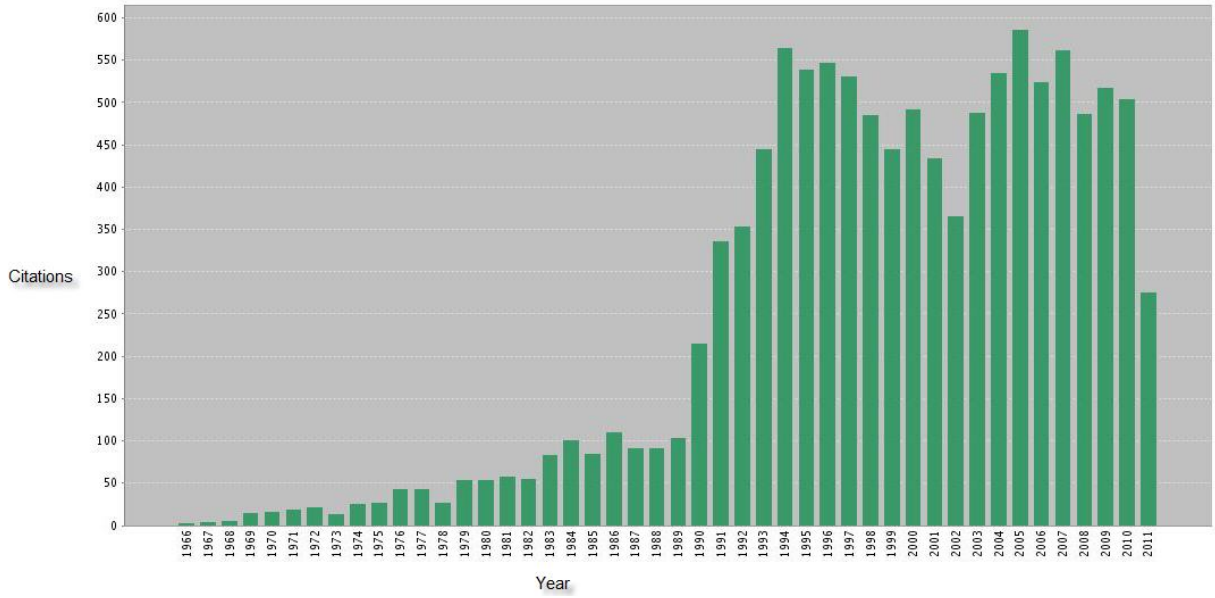
Table 1. Top 10 Articles by Total Citations (all databases in Web of Knowledge)

Article	Times cited
Fenn JB, Mann M, Meng CK, Wong SF, Whitehouse CM. 1989. Electrospray ionization for mass-spectrometry of large biomolecules. Science 246(4926):64-71.	3726
Fenn JB, Mann M, Meng CK, Wong SF, Whitehouse CM. 1990. Electrospray ionization-principles and practice. Mass Spectrom Rev 9(1):37-70.	1192
Yamashita M and Fenn JB. 1984. Electrospray ion-source - another variation on the free-jet theme. J Phys Chem 88(20):4451-9.	1061
Whitehouse CM, Dreyer RN, Yamashita M, Fenn JB. 1985.	987

Electrospray interface for liquid chromatographs and mass spectrometers. Anal Chem 57(3):675-9.	
Mann M, Meng CK, Fenn JB. 1989. Interpreting mass-spectra of multiply charged ions. Anal Chem 61(15):1702-8.	447
Anderson JB and Fenn JB. 1965. Velocity distributions in molecular beams from nozzle sources. Phys Fluids 8(5):780-7.	391
Yamashita M and Fenn JB. 1984. Negative-ion production with the electrospray ion-source. J Phys Chem 88(20):4671-5.	389
Fenn JB. 1993. Ion formation from charged droplets - roles of geometry, energy, and time. J Am Soc Mass Spectrom 4(7):524-35.	343
Wong SF, Meng CK, Fenn JB. 1988. Multiple charging in electrospray ionization of poly(ethylene glycols). J Phys Chem 92(2):546-50.	274
Searcy JQ and Fenn JB. 1974. Clustering of water on hydrated protons in a supersonic free jet expansion. J Chem Phys 61(12):5282-8.	230

The graph of citations over time (Figure 2) shows the effect of receiving a Nobel Prize on a person's citation history. There was a jump from the 1989 Science paper starting in 1990, but just as the citations started to dip in 2002, the announcement of the Nobel Prizes late in 2002 increased interest in Fenn's work. Citations for 2011 include only six months of the year, so it appears as though the 2011 citation number may be as high or higher than in 2010. Fenn's death, with the following obituaries that summarized his work, could be contributing to a renewed interest in his work, especially due to a New York Times obituary, in addition to memorials in science journals.

Figure 2. Citations to Fenn's papers over time (Web of Science citations only).



An analysis of the subjects of citing papers before and after the Nobel Prize (Figure 3) is thought provoking as well. Electrospray mass spectrometry is obviously important in chemistry and physics, but it is interesting to see the pattern change in numbers of papers citing Fenn's work before and after receiving the Nobel Prize, a time at which his work would have been noticed by subject areas outside his specialties. Biochemistry & molecular biology, pharmacology & pharmacy, and materials science citations increased. Some subject areas fell out of the top 25 but new areas like polymer science, neurosciences & neurology, genetics & heredity, and even nutrition & dietetics, moved into the top 25 subject areas.

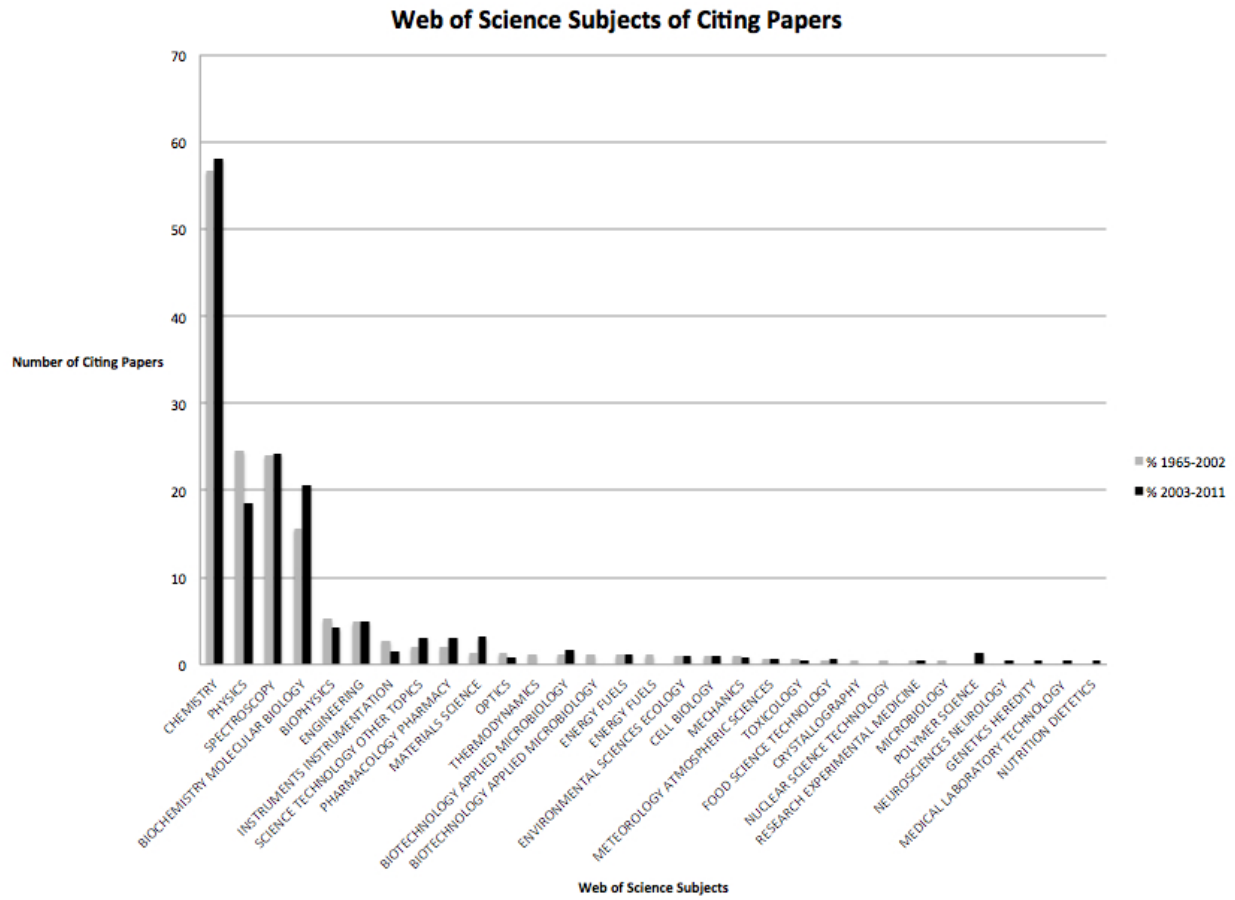


Figure 3. Subject categories of papers citing JB Fenn before and after Nobel Prize in 2002.

Fenn was also an inventor of many U.S. and other patents world-wide. A review of some of his U.S. patents (Table 2) with the number of times they have been cited shows his influence on technology in the United States. His two newest patents, also in Table 2, show how his work is used in new areas of research.

Table 2. Selected US Patents (USPTO) of JB Fenn.

Inventors	Assignee	Title	Year Awarded	US Patent No.	# times referenced in USPTO database
Labowsky MJ, Fenn JB, Yamashita M, inventors	Yale University USA, assignee.	Method and apparatus for the mass spectrometric analysis of solutions.	1985	4,531,056	95
Whitehouse C, Fenn JB, Yamashita M, inventors	Yale University USA, assignee.	Process and apparatus for changing the energy of charged particles contained in a gaseous medium.	1985	4,542,293	88
Fenn JB, Meng CK, Mann M, inventors	Now assigned to Yale.	Method of producing multiply charged ions and for determining the molecular weight of molecules by use of the multiply charged ions of molecules.	1992	5,130,538	27
Whitehouse CM, Fenn JB, Shen S, Smith C, inventors	Analytica of Brandford, Inc., USA, assignee.	Method and apparatus for improving electrospray ionization of solute species.	1994	5,306,412	75
Fuerstenau SD and Fenn JB, inventors	USA, assignee.	Method for detection and analysis of inorganic ions in aqueous solutions by electrospray mass spectrometry.	1996	5,523,566	27
Fenn JB, Meng CK, Mann M, inventors		Method for determining molecular weight using multiply charged ions.	1996	5,581,080	4
Fenn JB, Meng CK, Mann M, inventors		Composition of matter of a population of multiply charged ions derived from polyatomic parent molecular species.	1997	5,686,726	6
Fenn JB, Meng CK	Analytica of Brandford, Inc.	Multiply charged ions and method for determining the	2000	6,118,120	4

inventors		molecular weight of large molecules.			
Fenn JB, inventor		Method and apparatus for electrospray ionization.	2001	6,297,499	14
Bango JJ and Fenn JB, inventors	Ocugenics LLC, USA,	Method for stromal corneal repair and refractive alteration.	2009	7,579,442	0
Fuerst R, Bango J, Fenn JB, Dziekan ME, inventors	Ocugenics LLC, USA,	Fabrication of improved contact lens utilizing polymer electrospinning.	2009	7,563,396	0

Research Areas

Fenn's interest in bench research began somewhat inauspiciously during his time as a graduate student in chemistry at Yale University. Under the supervision of Gosta "Gus" Akerlof, Fenn's work focused on electromotive force in concentrated solutions and the effects of varying concentrations and temperatures. Fenn described the work as "a boring chore with few redeeming features. The results contained no surprises and nothing of much interest to anyone, least of all me."(Fenn 2002) He felt his dissertation reinforced this fact because it was 45 pages of tables and only three pages of text (Fenn 1996). After graduating, Fenn took jobs in the private sector, first with Monsanto Chemical Company in Anniston, Alabama in the phosphates division, then with Sharples Chemicals in Wyandotte, Michigan working with amyl chloride (Fenn and El-Shall 2009). He eventually became disenchanted with work in the private sector as well, finding that he disagreed with the way things were run (Fenn 2002).

Fenn's first real excitement for the research process came years later when he moved to Richmond, Virginia with his former coworker, Jim Mullen, to work at Experience, Inc.(Fenn 2002). Upon joining Mullen, Fenn became involved in the Project Bumblebee endeavor. The project was an effort by the U.S. Navy to develop a ramjet-powered antiaircraft missile for its fleet. Experiment, Inc. was granted a subcontract by the Applied Physics Laboratory of Johns Hopkins University to focus on the combustion and high speed flow issues of ramjet power. Through his work on Project Bumblebee and a number of other research and development contracts, Fenn was introduced to new areas of research surrounding

compression flow, jet propulsion and combustion (Fenn 2002). It was during this time that Fenn published his first research paper, focusing on ignition in high-speed flow with coworkers including Jim Mullen (Mullen, Fenn, and Irby 1949). Fenn found that he increasingly enjoyed research and felt that he might one day like to be on a college faculty (Fenn 1996).

As a result of his growing notoriety in the field of combustion, Fenn gained the attention of those in the academic community who were pursuing research in jet propulsion and combustion. During this time, the U.S. Office of Naval Research partnered with Princeton to start Project SQUID, which was a program to support basic and applied research in combustion, fluid flow and heat transfer in relation to jet propulsion (Fenn 2002). After the initial director of the program resigned, Fenn was offered the job and immediately went to London to work as the ONRL Liaison Officer (Fenn and El-Shall 2009, 1-11). The position entailed frequent travel to visit laboratories and conferences, but Fenn also learned a great deal about the complex nature of combustion reactions and developed curiosity that would shape his future research interests (Fenn 2002).

Primarily, he became interested in whether combustion reactions could be studied through molecular free jet beam scattering experiments (Fenn 2002). He was eager to become more directly involved in research in the area, but without faculty status at Princeton, Fenn was unable to act as a Primary Investigator. His ideas generated enough interest that colleagues in the chemical engineering department agreed to take on the project, listing Fenn as a consultant; the proposal to study free jet nozzles for molecular scattering experiments was funded by the U.S. National Science Foundation in 1960 (Fenn 2002). Fenn continued with research in combustion thermodynamics, propulsion and molecular beams at Princeton for nearly another decade. In one interview, Fenn remarked that due to the complex and progressive nature of his work with free jet beam scattering, he and his colleagues “had the whole field to [themselves] for several years”(Fenn and El-Shall 2009, 1-11).

After seeing the success of Project SQUID at Princeton, Yale decided to start a similar program, and invited Fenn to join their faculty in applied science and chemistry in 1967 (Fenn and El-Shall 2009, 1-

11). Fenn continued to be interested in studying combustion by looking at the products of molecular beam collisions. Without the use of mass spectrometry, he found that velocity analyses allowed him to study the differing acceleration of heavy and light molecules after the beam collisions. Fenn became interested in the work of Malcolm Dole at Northwestern University, who was using electrospray technology to study acceleration and vibration rates of gas molecules (Fenn and El-Shall 2009, 1-11). Throughout the 1970s and 1980s, Fenn continued to develop techniques to study vaporized biomolecules in mass spectrometry (Daintith 2009). While valuable, these techniques did not extend to large molecules that could not be vaporized; this limitation led to the development of a new method which eventually won Fenn the Nobel Prize in chemistry (Daintith 2009). Electrospray ionization or ESI is a method of mass spectrometry that produces charged droplets of protein solutions in a vacuum chamber, and when the water evaporates protein ions are left behind. Fenn found that applying a charge to these molecules kept them from sticking to the chamber walls and allowed them to "fly" (Wynne 2011). The mass of these molecules could then be determined by measuring the time it took them to move a fixed distance across an electric field (Daintith 2009).

In the late 1980s, Fenn started collaborating with Joseph J. Bango, Jr., President of Connecticut Analytical Corporation. Their collaboration led to many applications of Fenn's work, including jet spray propulsion of satellites (Fenn 2004a) and an electrospinning variation of electrospray used to create nano fibrils that can replicate the human cornea (Bango and Fenn 2003).

After retiring from Yale and finding a place at Virginia Commonwealth University, Fenn's research included NSF-funded work measuring the affinity of molecules for water and analyzing particulate matter, which could help to relate atmospheric pollutants to disease epidemiology (Buckley 2010), and continuing research with Bango and Connecticut Analytical Corporation on propulsion and nano fibrils. He also continued to advocate for good science education. Colleague Fred Hawkridge commented: "He would often comment that teachers do little to foster thinking in their students; rather, information was taken from the lecture notes of the professor and transferred to the notes of the student without going through the brains of either person. John had an open office door habit at VCU and he loved engaging in

conversation with students who stopped to say hello and meet a Nobel Prize winner. He invested his time wisely." (pers. comm.)

Membership and Awards

Fenn was a member of the American Chemical Society for 69 years. He was affiliated with a number of other scientific organizations during his career including the American Society for Mass Spectrometry, Sigma Chi, the American Association of University Professors and the Alexander von Humboldt Association of America (Office of Public Affairs and Communications 2010).

Prior to being named a Nobel Laureate, Fenn was recognized for his groundbreaking and significant research. In 1977, he was the honorary president of the International Symposium on Molecular Beams and in 1985 became the first fellow of the International Molecular Beam Symposium. The Alexander von Humboldt Foundation awarded him the U.S. Senior Scientist Award in 1982. During his tenure at Yale, Fenn was also presented the Award for Distinguished Contributions in Mass Spectrometry by the American Society of Mass Spectrometry. This award is given to a person who has "made a contribution that has had a significant impact on the fundamental understanding and/or practice of mass spectrometry." (American Society for Mass Spectrometry)

After moving to Virginia Commonwealth University (VCU) in 1994, Fenn continued to be honored for his contributions in chemistry. The American Chemical Society gave him the Award for Advancements in Chemical Instrumentation in 2000. In the same year, he received the Thomson Medal from the International Society of Mass Spectrometry. This award pays homage to Sir J. J. Thomson who, over a century ago "was responsible for the first mass spectrograph, a parabola instrument that used magnetic and electrostatic deflection and which foreshadowed many features of modern instruments."(International Mass Spectrometry Foundation) Also in 2000, Fenn was named a Fellow of the American Academy of Arts & Sciences.

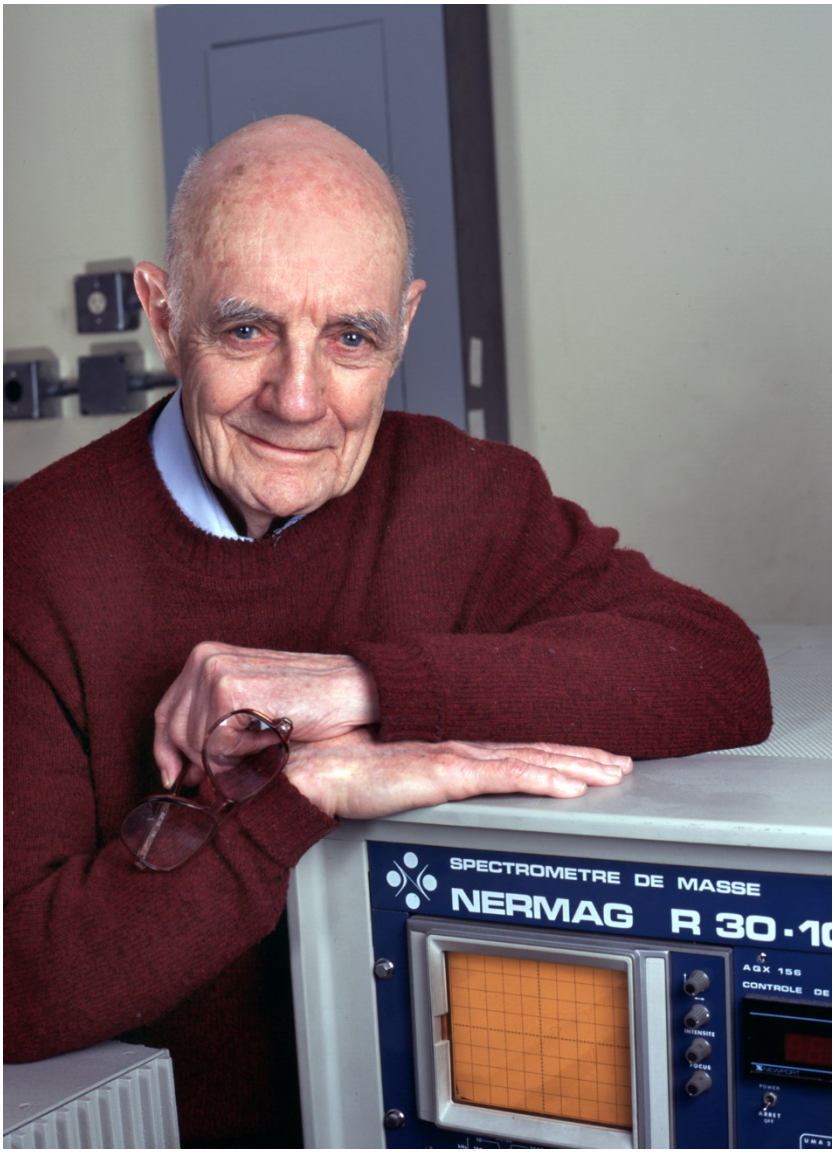
Early on the morning of October 9, 2002, Fenn answered the phone call from the Royal Swedish Academy of Sciences informing him that he was receiving the Nobel Prize in Chemistry. This award was shared with Koichi Tanaka of Japan for "their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules"(Nobelprize.org 2002). Fenn and Tanaka shared the award with Kurt Wuethrich of Switzerland. On December 8, 2002 Fenn gave his Nobel lecture entitled "Electrospray Wings for Molecular Elephants" at Aula Magna, Stockholm University (Fenn 2003). Months after receiving the Nobel Prize, Fenn was elected to the National Academy of Sciences in 2003.

In addition to being a brilliant researcher, Fenn was a beloved student and teacher and this is reflected in the awards and celebrations given him during the major academic phases of his life. The Berea College Alumni Association awarded him the Distinguished Alumnus Award in 1987. The September 1984 issue of The Journal of Physical Chemistry was dedicated to him and captured the proceedings of a conference called "Nozzle Molecular Beams -- A Fennfest"(Kolb and Herschbach 1984). This conference in his honor was organized by the Department of Chemical Engineering at Yale University in 1983 and featured Nobel Laureates who noted his contributions to their research and successes. Yale University also honored him with the Science and Engineering Award for Distinguished Contributions to Basic and Applied Sciences in 1999 and later, in 2003, the Wilbur Cross Award for distinguished Yale Graduate Alumni. In 2007, Virginia Commonwealth University held the **Fenn 90** symposium to honor his 90th birthday and to note developments in chemistry and mass spectrometry. The University established the John Fenn Chair Professorship in Chemistry to recognize his contributions in research (Office of Communications and Public Relations).

Conclusion

The long and varied career of John B. Fenn and the multidisciplinary nature of much of his work are a testament to his excellence as a scientist. The resilience and flexibility he learned from his parents are obvious from the many jobs and interests Fenn had throughout his life. Despite all his contributions to science, he continued to credit his parents and teachers, "In sum, for me – and probably for most other

people who have been fortunate enough to taste some of the fruit of what passes for success – it has been my parents and my teachers, from kindergarten on, whom I must salute. They molded the raw material." (Fenn, 2004b)



References

Fenn v. Yale Univ. Civil Action No. 3:96 CV 736 (CFD) (Lead Case), 3:96 CV 990 (CFD), 3:96 CV 1647 (CFD) *Fenn v. Yale Univ.* , LEXIS 1827 (UNITED STATES DISTRICT COURT FOR THE DISTRICT OF CONNECTICUT 2005).

American Society for Mass Spectrometry. 2011. Distinguished contribution in mass spectrometry. American Society for Mass Spectrometry. Accessed August 15, 2011. http://www.asms.org/Awards/DistinguishedbrContribution/tabid/299/Default.aspx

Arnaud, C. 2010. John Fenn dies at 93. *Chemical & Engineering News*. 85(51):(December 15), http://pubs.acs.org/cen/news/88/i51/8851news3.html.

Bango, J. J., and J. B. Fenn. 2003. *Method for stromal corneal repair and refractive alteration.* Patent Application Country: Application: US; Patent Country: US; Priority Application Country: US Patent US; 20030193118, filed 2003, and issued 1016; Patent Application Date: 20030416.; Priority Application Date: 20020416.

Buckley, A.2010. Nobel laureate John Fenn, VCU professor of chemistry, dies at 93. Virginia Commonwealth University. Accessed July 2011, http://www.news.vcu.edu/news/Nobel_Laureate_John_Fenn_VCU_Professor_of_Chemistry.

Daintith, J.(ed.) 2009. Fenn, John B. *Biographical Encyclopedia of Scientists.* 3rd ed.:237.

Fenn, J. B. 2004a. *Wick injection of colloidal fluids for satellite propulsion.* Patent Application Country: Application: US; Patent Country: US; Priority Application Country: US Patent US; 20040226279, filed 2004, and issued 1118; Patent Application Date: 20030513.; Priority Application Date: 20030513.

———.2004b. How did I get from here to there? In *One hundred reasons to be a scientist*., The Abdus Salam International Centre for Theoretical Physics (ICTP). Trieste, Italy:86-89.

———. 2003. Electrospray wings for molecular elephants (Nobel lecture). *Angewandte Chemie-International Edition* 42 (33): 3871-94.

———. 2002. Autobiography. Nobelprize.org. Accessed July 26,2011. http://nobelprize.org/nobel_prizes/chemistry/laureates/2002/fenn.html

———. 1996. Research in retrospect: Some biograffiti of a journeyman chemist. *Annual Review of Physical Chemistry* 47 : 1-41.

Fenn, J. B., and M. S. El-Shall. 2009. A conversation with John B. Fenn. *Annual Review of Analytical Chemistry* 2 : 1-11.

Grayson, M. 2011. John Bennett Fenn: A curious road to the prize. *Journal of the American Society for Mass Spectrometry*(8) (Aug 01): 1301-8.

Hawdridge, F.M. 2011. *Personal Communication.*

International Mass Spectrometry Foundation. "Thomson medals." International Mass Spectrometry Society. Accessed August 16, 2011. http://www.imss.nl/awards/thomson06.html.

Kolb, CE, and DR Herschbach. 1984. John Bennett Fenn. *Journal of Physical Chemistry* 88 (20): 4447-51.

Moran, K. 2005. Nobelist loses to Yale in lawsuit. *Yale Alumni Magazine.* May/June, http://www.yalealumnimagazine.com/issues/2005_05/l_v.html.

Muddiman, D. C. 2011. Retrospective. John Bennett Fenn (1917-2010). *Science.* 331 (6014) (Jan 14): 160.

Mullen, J. W.,II, J. B. Fenn, and M. R. Irby. 1949. The ignition of high velocity streams of combustible gases by heated cylindrical rods. *Symposium on Combustion and Flame, and Explosion Phenomena* 3 (1): 317- 329.

Nobelprize.org.2002. The Nobel prize in chemistry 2002. Nobelprize.org. Accessed August 18,2011. http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2002/

Office of Communications and Public Relations. 2007. Fenn 90 symposium. VCU News Center Accessed August 16, 2011. http://www.news.vcu.edu/news/Fenn_90_symposium

Office of Public Affairs and Communications. 2010. In memoriam: John B. Fenn *Yale Daily Bulletin.* December 15, 2010 Accessed August 16, 2011. http://dailybulletin.yale.edu/article.aspx?id=8107

Wynne, K. J. 2011. John Fenn obituary *Guardian.co.uk*, Thu, 13 Jan, 2011. Accessed August 16, 2011. http://www.guardian.co.uk/science/nobelprizes.