

BENJAMIN SILLIMAN JR.'S 1874 PAPERS: AMERICAN CONTRIBUTIONS TO CHEMISTRY

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To mark the centennial of the discovery of oxygen by Joseph Priestley (1733-1804) on August 1, 1774, H. Carlington Bolton of the Columbia College School of Mines suggested a gathering of American chemists be held to celebrate this event. A suggestion was made by Rachel Bodley of the Women's Medical College of Pennsylvania that an appropriate place would be Northumberland, Pennsylvania, where Priestley had settled in 1794 after being hounded out of England for his radical views. Organizing the event was a group of New York chemists. About 70 chemists attended for the daylong event, which featured a series of four papers and visits to the Priestley house and grave site (1).

The papers read at the meeting were "The Life and Labors of Priestley," by H. H. Craft of the University of Toronto; "The Century's Progress in Theoretical Chemistry," by T. Sterry Hunt of MIT; "A Review of Industrial Chemistry," by J. Lawrence Smith of the University of Louisville; and "American Contributions to Chemistry," by Benjamin Silliman Jr. of Yale University.

Silliman's two 1874 papers, totaling 57 pages and covering the

content of his address in Northumberland, are the subject of this analysis, which it is hoped will enlighten readers on the state of American chemistry on the eve of the centennial of the founding of the United States and the birth of the American Chemical Society (2). Thackray and coworkers have produced an extensive study of American chemistry from 1876-1976 (3). The current paper is a modest attempt to fill in the period prior to 1876 as viewed by Silliman. Silliman's papers appeared in two installments with different titles (August/September and December (4, 5) in the *American Chemist*, the journal founded and edited by the brothers Charles F. Chandler and William H. Chandler (6, 7).

Few people were as qualified as Benjamin Silliman Jr. (1816-1885) (Fig. 1) to survey the history of chemistry in America. Silliman Sr. and Jr. had served as Professors of Chemistry at Yale College from 1806 to 1870 (8). Benjamin Silliman Sr. founded the *American Journal of Science* in 1818 (9), and his son began almost immediately assisting him in the editing of the journal. He assumed the editorship of the journal in 1841 and continued his association with it

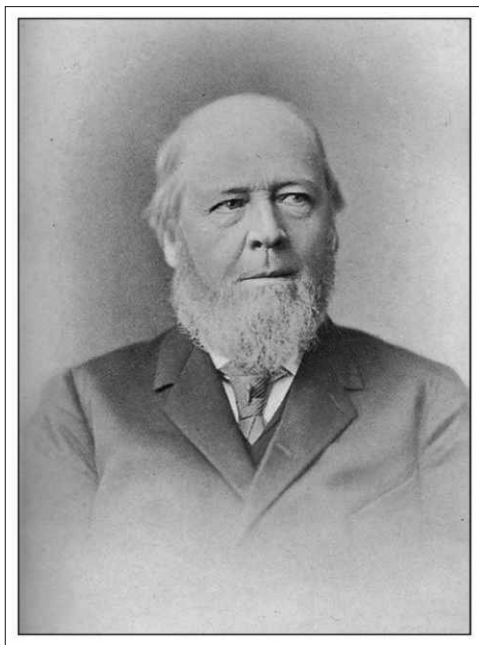


Figure 1. Benjamin Silliman Jr. Courtesy Oesper Collection, University of Cincinnati.

until his death in 1885. The committee could not have picked a more able person to discuss the development of American chemistry.

The title of Silliman's first paper has an asterisk and the following qualifying statement by the author (10):

In attempting to comply with the invitation of the committee in charge of the Chemical Centennial at Northumberland to prepare an "Essay upon American Contributions to Chemistry" in an address to be delivered on that occasion, I found the "Essay" insensibly and almost unavoidably assuming the historical form, and taking a wider range than may seem consistent with a strict rendering of its title. But such as it became it is now presented as a slight contribution toward a more elaborate historical discourse which yet remains to be prepared.

Silliman indicates the importance of the centennial of the discovery of oxygen to the development of modern chemistry as follows (10):

The emancipation of our science from the dominion of phlogiston, with its seductive but false philosophy, may be likened to the overthrow of aristocratic traditions, and monarchical supremacy, under which our ancestors were held, and the building up of the American system of self-government in their place.

In the view of Silliman there were two important periods in American chemistry, those that occurred before 1845 and those that occurred afterwards. By 1845 it had been almost two decades since Liebig "threw open wide the doors of access to the laboratory at Giessen and welcomed cordially all students without distinction of nationality to his scientific hospitality" (11). This was

a seminal event in the history of American chemistry, according to Silliman.

In 1846 the Smithsonian Institution was organized in Washington, DC, "opening wider and yet more freely the various paths of scientific research" (11). The American Association for the Advancement of Science in 1848 began publishing its own journal *Proceedings* which offered another venue for publication and according to Silliman was another landmark for American science.

The establishment of several scientific schools at some of the oldest and most prestigious American colleges was also a major event that took place in the late 1840s. Among the most important was the Sheffield Scientific School (1847) at Yale College, in which Silliman played a major role (12), and the Lawrence Scientific School (1847) at Harvard in which Liebig's student Eben Horsford was a major force (13).

The names in Table 1 are arranged in the order as presented by Silliman in his paper. Silliman does not provide any rationale for his listing as it is not strictly chronological or alphabetical. Several others have been omitted because their contribution or connection with chemistry seemed marginal at best. I have provided background material on the chemists mentioned by Silliman prior to 1845. Biographical information was gathered from Silliman's paper, internet searches, and the compilations of Miles and Gould (14) and various other sources such as the Chemical Heritage Foundation. Where a doctoral degree was earned, this is listed with the institution, year, and mentor when possible (14).

Table 1. Leading American chemists active before 1845.

NAME	DATES	CHEMICAL TRAINING	PROFESSIONAL CAREER	RESEARCH INTERESTS AND OTHER PROFESSIONAL DISTINCTIONS	OTHER ACCOMPLISHMENTS
Joseph Priestley	1733-1804	Self-educated	Tutor and Unitarian minister	Inorganic and physical chemistry	Discoverer of more new gases than any of his contemporaries
Benjamin Thompson (Count Rumford)	1753-1814	Self-educated	Inventor and government official	Physical chemistry and thermodynamics	Cofounded Royal Institution in 1799; endowed Rumford professorships at Harvard

NAME	DATES	TRAINING	CAREER	INTERESTS	OTHER
John Maclean	1771-1814	Glasgow	Princeton (1796-1812), William and Mary (1812-1813)		Opposed phlogiston theory; foremost proponent of the new chemistry in US
Parker Cleaveland	1780-1858	Harvard	Bowdoin College (1805-1853)	Mineralogy	
Benjamin Rush	1745-1813	Princeton, Edinburgh Medical School	Penn. Medical School		Produced the first chemistry textbook in America
James Hutchinson	1752-1793	Penn. Medical School	Penn. Medical School (1789-1793)		Revolutionary War Surgeon
James Woodhouse	1770-1809	Penn. and Penn. Medical School	Penn. Medical School (1796-1809)		
Aaron Dexter	1750-1829	Harvard Medical School	Harvard Medical School (1783-1816)		
Samuel Latham Mitchill	1764-1831	Columbia, Edinburgh Medical School	Columbia (1792-1820)		Congressman and Senator (1804-1813); first to teach Lavoisier's new chemistry in US; editor of <i>Medical Repository</i>
Robert Hare	1781-1858	Penn.	Penn. Medical School (1847)	Inorganic and physical chemistry	Developed the improved blow pipe for analysis
Archibald Bruce	1777-1818	Columbia, Edinburgh Medical School	College of Physicians and Surgeons, Columbia (1807-1812); Rutgers Medical School (1812-1818)	Mineralogy	
Benjamin Silliman Sr.	1779-1865	Yale	Yale (1804-1853)		One of the most eminent of American teachers of natural science; founder of <i>American Journal of Science</i> (1818)
Adam Seybert	1773-1825	Penn. Medical School; studied in Paris, Edinburgh, Göttingen	Operated a laboratory for drug preparation; seller of chemicals and equipment	Eudiometric analysis of air	Congressman (1809-1815, 1817-1819)
William James McNevin	1763-1841	Vienna Medical School	Professor of Medicine and Chemistry at College of Physicians, Columbia (1808-1826) and Rutgers Medical School (1829-1829)	Toxicology	First person to offer laboratory instruction in chemistry as part of curriculum

NAME	DATES	TRAINING	CAREER	INTERESTS	OTHER
John Gorham	1783-1829	Harvard and Harvard Medical School; studied in Paris, London, Edinburgh	Harvard (1809-1827)		One of the founders of <i>New England Journal of Medicine</i>
James Freeman Dana	1793-1827	Harvard and Harvard Medical School	Harvard, Dartmouth (1816-1827)	Analytical chemistry	Considered by his contemporaries to be unrivalled in his experimental abilities
Samuel Luther Dana	1795-1868	Harvard	Chemical manufacturer	Agricultural chemistry	"Muck Manual of Manures;" one of the first writers in the US to present an approach to agriculture based on chemistry
John Griscom	1774-1852		Private school teacher; also Rutgers Medical School		For 30 years he was acknowledged to be one of the best teachers of chemistry; popularized view of state-supported higher education
Thomas Cooper	1759-1839		Dickinson College, Penn., Univ. South Carolina		
Thomas Clemson	1807-1888	Sorbonne, École des Mines	Manufacturing chemist, mining engineer	Agricultural chemistry	Driving force in establishing USDA; his bequest led to founding of Clemson Univ.
John Redman Coxe	1773-1864	Penn. Medical School	Professor of chemistry Penn. Medical School, professor of pharmacy		Helped establish first college of pharmacy in US
James Cutbush	1788-1823	Penn.	Chemical manufacturer and lecturer		
Julius Ducatel	1796-1849	St. Mary's College (Baltimore), Paris	Maryland and Maryland Medical School		
Lardner Vanuxen	1792-1848	École des Mines (Paris)	Columbia College (SC) (1819-1826), consultant geologist (1826-1848), West Point (1824-1828)	Mineralogy	
John Patton Emmet	1796-1842	College of Physicians and Surgeons, Columbia			
John Torrey	1796-1873	College of Physicians and Surgeons, Columbia	College of Physicians and Surgeons (1827-1855), Princeton (1830-1854)	Mineralogy, botany	Prolific writer and investigator of the flora of America

NAME	DATES	TRAINING	CAREER	INTERESTS	OTHER
Samuel Guthrie	1782-1848	College of Physicians and Surgeons, Penn. Medical School	Manufacturer of alcohol, vinegar, potassium, chlorate, mercury fulminate		First to make chloroform
George T. Bowen	1803-1828	Yale, Penn. Medical School	Univ. Nashville (1826-1828, 1829-1850), chemical manufacturer	Mineralogy	
Gerard Troost	1776-1850	Leiden, Amsterdam		Mineralogy	
Denison Olmsted	1791-1859	Yale	North Carolina (1817-1825), Yale (1825-1859)	Mineralogy, meteorology, astronomy	One of the earliest to study meteors
William Williams Mather	1804-1859	West Point	West Point (1829-1835), Ohio Univ. (1842-1859)	Geology, mineralogy	First American to determine an atomic weight of an element
Lewis C. Beck	1798-1853	Union College, College of Physicians and Surgeons, Columbia	Rensselaer Polytechnic Inst. (1824-1829), Rutgers (1831-1853), New York Univ. (1836-1838), Albany Medical College (1840-1853)	Industrial chemistry, mineralogy	
Jacob W. Bailey	1811-1857	West Point	West Point (1838-1857)	Botany	First professor of chemistry at West Point
Alexander Dallas Bache	1806-1867	West Point	Penn. (1828-1843), US Coastal Survey (1843-1867)		First president of National Academy of Sciences; great grandson of Benjamin Franklin
J. E. Teschmacher	1791-1863	Privately educated in England	Self-employed entrepreneur in Boston	Mineralogy	
John Pitkin Norton	1822-1852	Yale, Agricultural Chemical Association laboratory (Scotland)	Yale	Agricultural chemistry	Influenced the founding of the agricultural experimental station system
Evan Pugh	1828-1864	D.Phil. under Wöhler, Göttingen 1856	Penn. State College (1859-1864)	Agricultural chemistry	President, Penn. State
Charles M. Wetherill	1825-1871	Penn., Paris, D.Phil. under Liebig, Giessen 1848	USDA (1862-1863), Smithsonian (1863-1865), Lehigh (1866-1871)	Agricultural chemistry; mineralogy	First chemist to serve in USDA

Analysis of American Chemistry, Pre-1845

In this period we find many American chemists who are purely homegrown products, and the study of chemistry abroad is the exception rather than the rule as it will be later. Instruction in chemistry was provided in undergraduate institutions beginning in 1767 at Columbia and amounting to about 50 in total by 1839 according L. C. Newell (16). This instruction varied greatly in quality and continuity. The medical schools were the most prominent chemical centers and produced the vast bulk of American chemists. The most important of these were the College of Physicians and Surgeons at Columbia University in New York and University of Pennsylvania Medical School. Approximately 25% of those listed attended one or the other. Among collegiate institutions the choice was fairly narrow with Harvard, Yale, Pennsylvania, and West Point the dominant ones, 38% of the group having attended one of these. Laboratory instruction was the exception and not the rule; often it was obtained by the eager young student through private instruction at additional expense.

Some American chemists chose to study abroad in this time period, with Paris being the most likely destination. A few Americans in the early 1840s started the trend to go to German universities, particularly Göttingen and Giessen, where, respectively, Wöhler and Liebig welcomed American students. These graduates who returned with their D. Phil. degrees were among the best trained in the United States in both theory and practice (17).

Research was generally not expected of academic chemists. One of the reasons for this was that laboratory space was either nonexistent or extremely limited if it was available. Institutional support for research was minimal at best; and given the high cost of equipment and chemicals which for the main part had to be imported from Europe, one can see why it required Herculean effort to begin and sustain a research program. Lecturers were paid on the basis of the number of students they taught. Many chemists of this period, in order to support themselves, held two or three positions, which often involved considerable travel and absence from their families for months at a time. This was particularly true of those teachers of chemistry in medical schools with only a four-month academic term. This very likely led to an uneven quality of instruction.

There was not much prestige associated with fundamental research and thus most of the chemical work that was done was centered on practical applications. Public service was also performed by many of these early chemists, mainly in the form of analysis of materials associated with public health.

One of the most significant aspects of this period according to Silliman was the large number of inspiring teachers who set the stage for a vast expansion of American chemistry in the post-1845 period. Among this elite group were John Maclean (Princeton); James Woodhouse and Robert Hare (Penn); Benjamin Silliman (Yale); and Samuel Latham Mitchill (Columbia).

Table 2. Leading American chemists post-1845.

NAME	DATES	CHEMICAL TRAINING	PROFESSIONAL CAREER	RESEARCH INTERESTS AND PROFESSIONAL DISTINCTIONS	SIGNIFICANT ACCOMPLISHMENTS
Charles Upham Shepard	1842-1915	Yale, Göttingen	South Carolina Medical School (1867-1885), South Carolina private analytical laboratory	Analytical and industrial chemistry	First person in US to grow tea as a commodity
Augustus Hayes	1886-1882	Dartmouth	Consultant and analyst	Industrial chemistry	
Lewis Feuchtwanger	1805-1876	Jena D.Phil. (1829)	Pharmacist and metallurgist	Mineralogy	First to suggest using nickel alloys in minting small coins
Robert Peter	1805-1894	Rensselaer Polytechnic, Transylvania Medical College	Transylvania Medical College (1838-1857)	Analytical chemistry	
John William Draper	1811-1882	Penn. Medical School	Hampden Sydney (1836-1838), New York Univ. (1838-1882)	Physical chemistry	Made some of the first Daguerreotypes in US; first president of the ACS

NAME	DATES	TRAINING	CAREER	INTERESTS	OTHER
Robert E. Rogers	1813-1884	Penn. Medical School	Virginia (1842-1852), Penn. Medical School (1852-1877), Treasury Department consultant (1877-1884)	Physiological chemistry	Introduced student laboratory instruction in medical school
John Johnston	1806-1879	Bowdoin	Wesleyan (1835-1873)	Physical chemistry	Prolific author of textbooks in chemistry and physics
James C. Booth	1810-1888	Penn., Göttingen	Private consulting chemist, chemical teaching laboratory, ran refiner for US mint (1849-1887)	Industrial chemistry	Founder of oldest chemical consulting business in US
Charles T. Jackson	1805-1880	Harvard Medical School	Analytical consulting laboratory in Boston	Industrial chemistry, mineralogy	Suggested ether as an anesthetic in 1846
James Blake	1815-1893	Univ. College London, Medical School	Univ. California Medical School	Analytical and inorganic chemistry	Studied periodic relationships based on physiological effects of elements
O. Wolcott Gibbs	1822-1908	Columbia and Columbia Medical School, Berlin, Giessen, Paris	City College of NY (1849-1863), Harvard (1863-1887)	Inorganic and physical chemistry	One of the founders of the National Academy of Sciences.
John Lawrence Smith	1818-1883	Medical College of South Carolina, Paris, Giessen	LSU (1850-1852), Virginia (1852-1854), Univ. Louisville (1854-1866)	Analytical chemistry	First American student of Liebig
Traill Green	1813-1897	Penn. Medical School	Lafayette College (1837-1841, 1849-1891), Marshall College (1841-1848)		
Martin H. Boyé	1812-1909	Copenhagen, Polytechnic Univ., Penn. Medical School	Assistant to Robert Hare, Penn. Central High School	Geology, mineralogy, inorganic and organic chemistry	Synthesis of ethyl perchlorate
Benjamin Silliman Jr.	1816-1885	Yale	Yale	Analytical and industrial chemistry	Helped establish American oil industry by analysis of Pennsylvania rock oil; one of the first members of National Academy of Sciences
Fredrick A. Genth	1820-1893	Heidelberg, Giessen, Marburg (D.Phil. 1845 under Bunsen)	Private chemical consultant, Penn. (1872-1888)	Analytical and inorganic chemistry	One of the most respected analytical chemists in America in his time
Eben Horsford	1818-1893	Rensselaer Polytechnic, Giessen	Rumford Prof. at Harvard (1847-1863); chemical manufacturer (1863-1893)	Agricultural and food chemistry	Developed the baking powder industry in America; student of Liebig but did not earn degree
Thomas Sterry Hunt	1826-1892	Yale	Geological Survey of Canada (1847-1872), MIT (1872-1878)	Mineralogy, organic chemistry	First to propose climate change due to carbon dioxide concentration changes
John W. Mallet	1832-1912	Trinity College (Dublin)	Univ. Louisiana Medical School (1865-1868), Virginia (1868-1912)	Atomic weights, toxicology	Superintendent of the Confederate States ordnance laboratory

NAME	DATES	TRAINING	CAREER	INTERESTS	OTHER
William P. Blake	1826-1910	Yale	Professional geologist; professor of geology School of Mines, Univ. Arizona (1896-1905)	Mineralogy	First to introduce western mining technology in Japan (1861)
William H. Brewer	1828-1910	Yale, Heidelberg, Munich	Washington College (1858-1860); Geological Survey of California (1860-1864); Sheffield Scientific School, Yale (1864-1903)	Agricultural chemistry, botany	One of the persons to recommend the purchase of Alaska in 1867
John M. Ordway	1823-1909	Dartmouth		Mineralogy	
George J. Brush	1831-1912	Yale, Munich, Freiberg School of Mines, Royal School of Mines (London)	Industrial chemist, MIT, Tulane (1884-1904)	Civil engineering, biology	
Henry Wurtz	1828-1910	Princeton	George Washington Univ. (1858-1861), private laboratory for consulting (1856-1900)	Metallurgy, petroleum technology	
Samuel Johnson	1830-1909	Yale, Leipzig, Munich, London	Yale (1856-1900)	Agricultural chemistry	Father of American agricultural research
John L. Leconte	1818-1891	Georgia, New York College of Physicians and Surgeons	Georgia (1846-1855), South Carolina (1856-1869), Univ. California (1869-1891)	Physics	President of Univ. California (1876-1881); measured speed of sound and showed that flames are sensitive to sound
Charles A. Joy	1823-1891	Union College, Göttingen (D.Phil. 1852 under Wöhler), Berlin, Paris	Union College (1854-1857), Columbia (1857-1877)	Mineralogy	
Charles A. Goessmann	1827-1910	Göttingen (D.Phil. 1852 under Wöhler)	Industrial chemist (1857-1861), Rensselaer Polytechnic (1862-1864), Univ. Massachusetts (1868-1907)	Inorganic and agricultural chemistry	"Not a better practical chemist in the United States," in opinion of his contemporaries
Eugene W. Hilgard	1833-1916	Heidelberg, Royal School of Mines (Freiberg), Zürich, Heidelberg (D.Phil. 1854 under Bunsen)	Smithsonian Institution, Mississippi, Michigan, Univ. California	Soil science	
John M. Maisch	1831-1893	Hanau	Pharmacist (1850-1859), New York College of Pharmacy (1859-1866), Philadelphia College of Pharmacy (1866-1893)	Pharmaceutical chemistry	Editor of <i>American Journal of Pharmacy</i> (1871-1893); assay of adulterants in food and medicine; participant at Priestley celebration
Theodore G. Wormley	1826-1897	Dickinson College, Philadelphia College of Medicine (M.D.)	Starling Medical College; Penn. Medical School (1877-1897)	Toxicology	

NAME	DATES	TRAINING	CAREER	INTERESTS	OTHER
John C. Draper	1835-1885	New York Univ.	New York Univ (1858-1871), City College of NY (1863-1885)		
Alexander Means	1801-1883	Transylvania Univ.	Emory (1838-1848), Medical College of Georgia (1840-1853), Atlanta Medical School (1855-1867)	Medicinal chemistry	President of Emory(1854-1855); first person to demonstrate an electric light in America
Josiah P. Cooke Jr.	1827-1894	Harvard	Harvard (1850-1894)	Atomic weight measurements	Physical chemistry textbook
John Addison Porter	1822-1866	Yale, Giessen	Delaware (1844-1847), Brown (1850-1852), Yale (1852-1864)	Agricultural chemistry	Helped in founding of Sheffield Scientific School at Yale, which awarded the first Ph.D. degree in America
Newton Spaulding Manross	1825-1862	Yale, Göttingen (D.Phil. 1852 under Wöhler)	Self-employed mining engineer and inventor (1853-1861), Amherst College (1862)		Died at Battle of Antietam, 1862
Matthew Carey Lea	1823-1897	Self-educated	Private laboratory	Photochemistry, analytical chemistry	
Charles F. Chandler	1836-1925	Harvard, Göttingen (D.Phil. 1853 under Wöhler and Rose)	Union College (1854-1857), Columbia (1857-1877)	Industrial chemistry	Chairman of the Priestley Centennial Celebration and publisher of <i>The American Chemist</i>
Henry Bradford Nason	1831-1895	Amherst College, Göttingen (D.Phil. 1857 under Wöhler)	Rensselaer Polytechnic (1858-1895)	Mineralogy	
Frank H. Storer	1832-1914	Harvard, Heidelberg, Freiberg, Paris	Industrial chemist (1857-1871), MIT (1865-1870), Harvard (1870)	Industrial and agricultural chemistry	
Charles Gilbert Wheeler	1836-1912	Nuremberg	Chicago, Chicago Medical College (1868)	Organic and physiological chemistry	
Cyrus Moors Warren	1824-1891	Harvard, Paris, Heidelberg, Munich, Berlin, London	Chemical manufacturer, MIT (1866-1868), private laboratory (1868-1891)	Petroleum chemistry	
Frederick Hoffmann	1832-1904	Berlin, Jena (D.Phil. 1859)	Pharmacy owner, publisher of the <i>Pharmaceutical Review</i>	Dye chemistry, analytical chemistry	
Maurice Perkins	1836-1901	Columbia College of Physicians and Surgeons, Heidelberg, Göttingen, Tübingen	College of Physicians and Surgeons (1862-1864), Harvard (1864-1865), Union College (1870-1901)		Founding member of the ACS
James M. Crafts	1839-1917	Harvard, Freiberg, Heidelberg, Paris	Cornell (1867-1870), MIT (1870-1874, 1891-1907), Paris (1879-1891)	Inorganic and organic chemistry	Friedel-Crafts reaction discovered in 1877; President of MIT (1898-1900)

NAME	DATES	TRAINING	CAREER	INTERESTS	OTHER
Samuel P. Duffield	1833-1916	Michigan, Munich, Giessen (D.Phil. 1858)	Founder of Parke, Davis, and Co. (1866), Detroit Medical School (1868-1881)	Pharmaceutical chemistry	Received M.D. in 1872 and practiced medicine along with teaching and running a pharmaceutical business
Gideon E. Moore	1842-1895	Yale, Wiesbaden, Leipzig, Heidelberg (D.Phil. 1870 under Bunsen, Kirchhoff, Kopp)	Consultant in New York City		Editor, <i>J. Am. Chem. Soc.</i> , Vol. 2 (1880)
H. Carrington Bolton	1843-1903	Columbia, Paris, Heidelberg, Göttingen (D.Phil. 1866 under Wöhler), Berlin	Columbia (1872-1877), Trinity College (1877-1887)	History of chemistry, bibliography of chemistry	Driving force behind Priestley Centennial and one of the first lecturers on the history of chemistry in the US
Le Roy C. Colley	1833-1916	Union College	New York State Normal School (1861-1874), Vassar (1874-1907)		Leading writer of text books in chemistry and physics for secondary schools in the 19th century
Samuel T. H. Endemann	1842-1909	Marburg (D.Phil. 1866 under Kolbe)	New York City Board of Health (1867-1880), consultant (1880-1909)	Medicinal chemistry, sanitary chemistry	Founding member of the ACS, Editor, <i>J. Am. Chem. Soc.</i> , 1879, 1881
Stephen P. Sharples	1842-1923	Penn. State College, Harvard	Consultant	Analytical chemistry	
George F. Barker	1835-1910	Yale, Albany Medical School	Wheaton College, Albany Medical School, Pittsburgh, Yale Medical School, Williams College, Penn.	Physical chemistry, toxicology	Expert on chemical patents and witness in criminal trials involving poisons
Samuel F. Peckham	1839-1918	Brown	Brown, Washington and Jefferson, Maine, Minnesota	Petroleum chemistry	
Paul Casamajor	1831-1887	École centrale, Paris	Chemist, American Sugar Co. (1867-1887)	Carbohydrate chemistry	
Frank W. Clarke	1847-1931	Harvard	Boston Dental College (1867-1873), Howard Univ. (1873-1874), Univ. Cincinnati (1874-1883), US Geological Survey (1883-1924)	Mineralogy, geochemistry, atomic weight determination	Analysis of minerals; determination of atomic weights
William H. Chandler	1841-1906	Union College, Columbia	Lehigh (1871-1906)		Co-publisher of <i>The American Chemist</i> .
Henry Morton	1836-1902	Penn.	Philadelphia Dental College (1863-1870), Stevens Institute (1871-1901)	Spectroscopy	President, Stevens Institute (1870-1902)
Albert B. Prescott	1832-1905	Michigan (M.D.)	Michigan (1865-1895)	Toxicology, organic chemistry	Founder and Dean of the College of Pharmacy at Univ. Michigan

NAME	DATES	TRAINING	CAREER	INTERESTS	OTHER
Samuel Sadtler	1847-1923	Gettysburg, Harvard, Heidelberg, Göttingen (D.Phil. 1871 under Wöhler)	Gettysburg, Penn.	Industrial chemistry	Established oldest continual industrial research and consulting business in US
Charles E. Munroe	1849-1938	Harvard	Harvard (1871-1874), US Naval Academy (1874-1886), Naval Torpedo Station (1886-1892), George Washing Univ. (1892-1918)	Analytical chemistry, explosives	Developed the shape charged explosive
Albert R. Leeds	1843-1902	Haverford, Harvard, Berlin, Columbia; College of Physicians and Surgeons, Munich	Stevens Institute (1871-1902)	Mineralogy, photochemistry, sanitary chemistry	Founding member of the ACS
Ira Remsen	1846-1927	Göttingen (D.Phil. 1870 under Fittig), Tübingen	Williams College (1872-1875), Johns Hopkins (1876-1913)	Organic chemistry	Established the German model of graduate education in the US; editor of the <i>American Journal of Chemistry</i>
Edward Morley	1838-1923	Amherst College	Western Reserve Univ.	Physical chemistry, atomic weights of oxygen and hydrogen	Michelson-Morley experiment of 1887; completed theological studies at Andover Theological Seminary (1860-1863)

The Post-1845 Period

In Table 2 are listed those American chemists Silliman viewed as noteworthy in the post-1845 period. This list follows the order in which they are mentioned by Silliman and is as complete as possible. Of the 47 chemists for which I have been able to gather information, one can see a quantum leap in their formal training in chemistry and the beginnings of a tradition of original chemical research. Study abroad now became more the norm rather than the rare exception. Germany was the prime destination and almost half of the listed chemists studied there for some period of time. Depending upon their financial and personal circumstances, many were able to stay long enough to complete the doctoral degree. By visiting and working at several universities, they succeeded in gaining a diversity of research experience. In the pre-1845 group of 37 only 12 had studied abroad and only two obtained a degree. The universities chosen for study were Gießen, where Liebig welcomed American students, as well as Göttingen, where Wöhler offered similar hospitality.

Bunsen in Marburg and later in Heidelberg also had many American students.

After 1845 chemistry moved increasingly from medical schools to institutions devoted to instruction in the natural sciences. In the pre-1845 group 16 of 38 received their chemical training in medical schools followed in four cases by study abroad.

In the 19th century Americans were drawn to the study of mining at the École des Mines in Paris and the Royal School of Mines in Freiberg, Germany. Given the vast natural resources of the United States this seemed to be a logical choice. Schools of mines were only established in the 1850s in the United States. This wealth of natural resources and the interest in knowing the content of minerals contained shows up in the recurring research interests by many of the chemists that Silliman listed.

One of the accomplishments of Silliman in preparing this paper was to assemble a bibliography of the papers published by the persons he cited. One can see

the spectacular growth in American chemistry by the sheer increase in volume of papers published. Forty-two of the persons listed in Table 2 published at least 10 papers, and several had as many as 40 or more. Among this elite group were J. W. Draper (46 papers); Wolcott Gibbs (47); B. Silliman (48); J. M. Maisch (52); and M. C. Lea (43). What is remarkable is that most of these papers were authored without collaborators. Although for the most part the work appeared in American journals, some were published abroad—notably in German journals. While many American chemists individually were highly productive, there was a lack of continuity as contrasted with the German model of the chemical institute and the emphasis on research. Eventually the German system was adopted in America, through the efforts of German-trained chemists such as Ira Remsen at Johns Hopkins in the late 1870s (18).

Silliman's review of American chemistry has been described by E. H. Thomson in the *Dictionary of Scientific Biography* as an "important publication not supplanted to this day" (19).

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