RECURSOS SUGERIDOS

George Urbain:

- May, L., The Lesser Known Chemist-composers, Past and Present, *Bull. Hist. Chem.*, 2008, *33*, 35-43;
- Georges Champetier and Charlotte H. Boatner, George Urbain, *Journal of Chemical Education*, 1940, 17 (3), 103;

GEORGES URBAIN[1]

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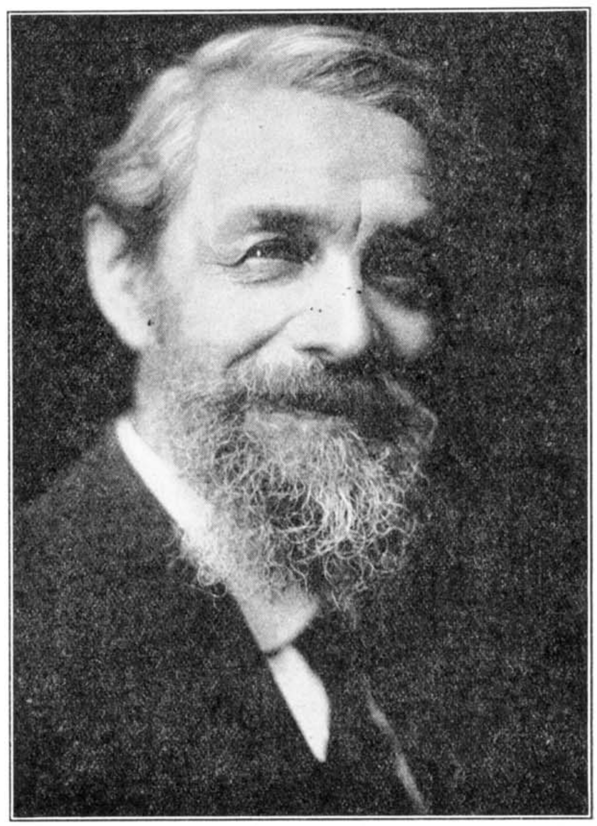
SCIENCE has lost one of its most illustrious figures in the death of Georges Urbain, Member of the Institute of France, Professor at the University of Paris, Director of the Institute of Chemistry of Paris. It was the privilege of one of us (C. H. Boatner) to work with him too short a time, one year at the Institut de Biologie Physico-Chimique; to the other of us (G. Champetier) was accorded the greater privilege of a longer association extending over a period of ten years, first at the Institut de Biologie Physico-Chimique and later at the Institut de Chimie. We welcome this opportunity to bring to American chemists an appreciation of the life and work of this great man.

Georges Urbain was born in Paris in 1872. His father, Victor Urbain, was an assistant to Frémy and professor at the Ecole Supérieure Lavoisier. He occupied his spare moments in drawing. Georges Urbain thus developed in a home which provided him with a scientific training and a taste for art. Following his father's wishes, Georges Urbain entered the Ecole de Physique et de Chimie de Paris, from which he graduated first in his class in 1894. His short term as assistant in the laboratory of mineral chemistry of this school brought him in contact with Pierre Curie. It was Pierre Curie who revealed to Georges Urbain the beauty and the greatness of scientific discovery. From this moment his course was determined, and a friendship both personal and scientific was begun which was to endure a lifetime. With his characteristic ardor Georges Urbain consecrated himself from this moment to research.

He then entered the laboratory of Charles Friedel as instructor and there confirmed his ability in research. He was named Assistant Professor of Analytical Chemistry in 1906, Professor of Mineral Chemistry in 1908, and Professor of General Chemistry, Director of the Institut de Chimie de Paris, and Co-Director of the Institut de Biologie Physico-Chimique in 1928.

He had soon built the Institut into the mecca of all good chemistry students in France. The young student who was able to get into the Institut took it as a mark of his superiority and furthermore felt assured that he would be prepared at the end of his courses there to take his place in his chosen field of chemistry whether it be teaching, industrial chemistry, or research. At the same time M. Urbain, first as Professor of Mineral Chemistry, and then as Professor of General Chemistry at the Sorbonne, was conducting a brilliant series of lectures. These courses were not only superior intellectual and pedagogical efforts, but they were immensely popular with the students with whom his courses had the reputation of being not only



Courtesy of Dr. R. E. Oesper

GEORGES URBAIN

[1] Presented before the Division of History of Chemistry at the ninety-seventh meeting of the A. C. S., Baltimore, Md., April 5, 1939.

good, but interesting. In 1930, anyone who did not go early to his lectures in general chemistry was fortunate if he found a seat in the gallery of the large amphitheater. M. Urbain's popularity with the students was impressive in view of the fact that obtaining a certificate in general chemistry, for which M. Urbain's course was required, was considered extremely difficult. The students rose in a body when he entered the room, they listened with such complete attention that there was not a murmur to be heard in the class of three hundred fifty students. The attention of the students bordered on perfection, but it was seldom that the perfect silence was maintained for a full hour. It rarely happened that at least once in every hour M. Urbain did not so beautifully demonstrate some important point, or let drop some so irresistibly facetious but always appropriate remark that a spontaneous burst of applause rose from the students. In 1928 M. Urbain was appointed Director of the Chemical Service of the Institut de Biologie Physico-Chimique. There he had his own research laboratory, as well as other laboratories in which chemical research was carried on under his direction or inspiration. Here, as in his research laboratories at the Sorbonne the daily appearance of "le patron" was the most important event of the day. An inspiring teacher, he knew how to communicate to his collaborators his faith in science, but above all he was to his students "le patron" who advised, who encouraged, who helped overcome difficult moments, who furnished moral and sometimes material support. His personal laboratory at the Institut de Biologie Physico-Chimique had become the center of constantly renewed discussions in which scientists of all fields in the Institut participated. Those who profited by these conversations and acquired through them a taste for general ideas are indeed numerous. Among his many students may be listed: P. Job, Professor at the University of Paris; Tourneux, Dean of the Faculty of Besançon; Chauvenet, Director of the Institute of Chemistry of Caen; Bourion, Honorary Professor at the University of Nancy; Dhar, Rector of the University of Hallahabad (India); Heyrovský, Professor at the University of Prague; Lortie, Professor at the University of Montreal; and Sarfaar, Professor at the University of Calcutta.

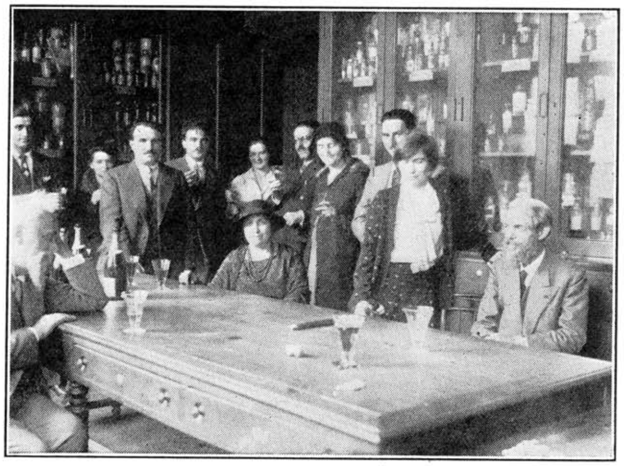
MEDAL STRUCK IN COMMEMORATION OF THE SCIENTIFIC JUBILEE HELD IN HONOR OF GEORGES URBAIN IN PARIS IN 1938

In addition to his artistic talents and tastes, Urbain had a deeply philosophic turn of mind. The study of the history of science fascinated him; he loved nothing better than to follow the development of ideas, or to watch the conflict of the "positive" and the "speculative." In the lectures given by him in a series entitled *Orientation actuelle des sciences* in 1930 one gets the impression of a philosopher reveling in large general ideas and theories; one sees revealed again his passion for speculation. He tells us in this lecture that in his youth he was even more devoted to speculation. And yet he chose the rare earths as his field of research. Of all possible lines open to him at the time, this was the most purely technical. After twenty thousand recrystallizations, one might hope to develop one law of small scope. This choice of a research problem, in view of his talents and his tastes, is one of the most remarkable examples of complete self-discipline that one could find. But, he tells us, "If imagination is necessary in science, more perhaps than any place else, it is no less necessary to discipline it." In fact, his whole bearing, his whole personality, his whole behavior were expressions of a man of force, intelligence, and deep sensibilities and yet of a man completely master of himself.

The fine spirit of the man is shown in these sentences taken from a report of his work on the rare earths, presented on the occasion of the dedication of the Sterling Chemical Laboratory. He deplores the fact that there were so few chemists engaged in research on the rare earths at the time he undertook his study of them, and this, he says, ". . . despite the attraction of the veritable unknown." His was a scientific curiosity of the highest order. This unquenchable thirst for truth led him at the age of twenty-three into a field in which the greatest chemists had become badly confused. His perseverance and self-discipline kept him working at a research program which covered a period of twenty-five years, and which included a number of fractionations in excess of two hundred thousand. The results of this work are of tremendous importance. He was able to completely clear up the confusion existing in the chemistry of the yttrium series of the rare earths by effecting the rigorous separation of samarium, europium, gadolinium, terbium, dysprosium, and holmium, and finally the scission of Marignac's ytterbium into ytterbium and lutecium, a previously unknown element. In this work he reduced the number of the first members of the yttrium group from twenty possibilities to four actually isolated elements. His determinations of the atomic weights of all of these elements were accepted by the International Committee on Atomic Weights and led to his membership on that committee of which he was later president. Later, in 1911, he recognized the presence of still another element, celtium, not of the rare earth family. This element was thought by Moseley to be the missing element number 72, but upon investigation, the X-ray evidence was found to be inconclusive. Finally in 1922, after a long interruption due to work in the war, M. Urbain again took up his work with the rare earths, and submitted the suspected sample to Dauvillier for examination by means of de Broglie's improved X-ray method. This indicated the presence of element number 72. The element was isolated in larger concentrations by von Hevesy and Coster in 1922. Although the name by which they called it, hafnium, is the one most often employed, the International Committee on Atomic Weights has accepted two names, celtium and hafnium, and two symbols Ct and Hf.

M. Urbain did a great deal toward the improvement of experimental procedures for the separation of rare earths by adding the ethyl sulfates as derivatives which lend themselves more readily to fractionation and by introducing the use of bismuth salts as agents of separation of two adjacent rare earths. As the result of his work, he could announce the Law of Seriation of Rare Earths: all salts of rare earths fall in the same order of solubility, except the ethyl sulfates and the nitrates. He used the phosphorescent spectra and the coefficients of magnetism of the rare earths as means of following their separation. M. Urbain's work was not merely manual, nor was his contribution only to the technic of separation. He was the first to emphasize the importance of following the separations by both physical and chemical means, and he recognized the limits of purification which necessitate the use of several procedures for complete fractionation.

M. Urbain disliked excessive specialization. He describes the situation of a specialist in a most amusing way.[2] "The specialist works in a pit. The details of his specialty absorb him to the point where he thinks he is making science, but most often he is making only erudition. He has a mania for document and leaves to others the task of coördinating that which he collects and with which he encumbers his special publications." Although M. Urbain, himself, might be thought to have specialized excessively, since he was engaged almost solely in research on the rare earths for a period of twenty-five years (at that, the rare earths represent one-sixth of the known elements), this specialization is only apparent and not real. We note that he took time to do extensive work on absorption spectra, emission spectra, and phosphorescence spectra. His contributions to the study of cathodic phosphorescence spectra were of particular importance. He perfected the technic of phosphorescent spectra, finally created order from chaos, and announced the laws governing this extremely complex phenomenon.



SCENE IN THE LABORATOIRE DE CHIMIE GENERALE OF THE SORBONNE. SEATED LEFT TO RIGHT: M. JEAN PERRIN, MME. RAMART-LUCAS, M. GEORGES URBAIN. (THE AUTHORS ARE STANDING NEXT TO M. URBAIN)

One might think that those numerous jobs, Director of the Institute of Chemistry, Professor of Mineral Chemistry, and then Professor of General Chemistry, Director of the Chemical Service at the Institut de Biologie Physico-Chimique, President of the Société de Chimie, member of the International Committee on Atomic Weights, during the war from 1914 Director of the Chemical Laboratory of the Technical Section of the Artillery, in 1916 member of Inspection des Etudes et Expériences Chimiques de Guerre, then at the death of Charles Moureu, President of the Comité Scientifique des Poudres et Explosifs and of the Commission des Substances Explosives, along with his time-consuming research on the rare earths and spectro-chemistry would have left him little spare time; yet M. Urbain found time to write four excellent texts: "Introduction à l'étude de la spectro-chimie" (1911), "Introduction à la chimie des complexes"—Urbain et A. Sénéchal (1913), "L'énergétique des réactions chimiques" (1925), "Traité de chimie générale"—G. Urbain, P. Job, G. Allard, et G. Champetier (1939).

The "Introduction à l'étude de la spectro-chimie" does not pretend to be an exhaustive treatise on spectro-chemistry. It is presented as an introduction to young chemists of the methods of spectral analysis, but it does

[2] "Les disciplines d'une science. La chimie," p. 30.

include some new methods, particularly for phosphorescence spectra. As usual, M. Urbain has included a careful historical survey of the subject. The theoretical matter is clearly presented and is accompanied in each chapter with explicit practical instructions. In this book, M. Urbain presents the method of spectral analysis by means of visual comparison of the spectrum of the unknown metal with that of iron as a standard. This method has obvious advantages for the chemist over the method of identifying each line by direct measurement. In an accompanying elaborate series of charts of the emission spectra of iron and of a large number of other metals he presents the means of applying this excellent method of identification of elements by spectral analysis. M. Urbain's interest in this visual comparison method of spectral analysis led to the publication by a student and collaborator[3] of an excellent and elaborate series of plates of the arc spectra of a great many elements, including iron, with intensities and wave-lengths indicated.

The "Introduction à la chimie des complexes" of G. Urbain and A. Sénéchal is an exhaustive treatise of four hundred sixty-eight pages. It is based in part on a course developed over a period of years by M. Urbain at the Sorbonne. When it was rewritten for publication, a preliminary introduction of the fundamental relations of inorganic chemistry was added. This is a particularly clear and thorough presentation of the basic concepts of physical and inorganic chemistry. The second part of the book is a critical exposition of Werner's theory of complexes, and the third part is a monograph on the complexes of platinum, cobalt, copper, and chromium with extensive bibliographies. This book should make a superb basic text for an advanced course in inorganic chemistry, and it should prove of value to any chemist interested in the field. It is not only an annotated bibliography and compilation of the work of others; it represents the results of the personal experience of the authors, of their experimental research, of their reflections and meditations in the laboratory, and of their scientific publications in the field of complex compounds. Georges Urbain and his school have made important theoretical and experimental contributions to the chemistry of complexes.

M. Urbain's third text, "L'énergétique des réactions chimiques," published in 1925, is a theoretical introduction to the energetics of chemical reactions. This, too, is based on a course given by M. Urbain at the Sorbonne for several years. As the author writes, he recognized the need of chemists of a relatively complete treatise on chemical thermodynamics written not from the point of view of a physicist or of a mathematician, but from the point of view of a chemist. As a pure chemist, from his own experience in mastering the subject, he could recognize the points difficult for chemists to grasp which neither physicists nor mathematicians would deign to emphasize. He has stressed the functions of state of greatest chemical importance, he has avoided overstressing mechanics, and he has used significant chemical illustrations wherever possible. The achievement of the book is that it is easy for the "atomistically" trained chemist to understand, and yet it has remained true to the spirit of thermodynamics.

Georges Urbain's last text, "Traité de chimie générale," written with P. Job, G. Allard, and G. Champetier, was published after his death. The major part of this book is the work of Georges Urbain. It represents his course in general chemistry at the Sorbonne in the state of near perfection to which he had developed it by constant improvement and constant change in order to keep it completely up-to-date over the period of thirty years during which he lectured on the subject of general chemistry. In this book, as in all of his texts, Georges Urbain writes not only an excellent textbook on general chemistry but he includes much of a fundamental philosophical nature, and a tremendous amount of historical material since he feels, as he tells us in the introduction, that general chemistry by its very nature signifies chemical philosophy.

And yet, Professor Urbain says, "The greatest scientists are those who have given science new methods of thinking; the others are merely good workers." Georges Urbain was not merely a good worker. As he remarks, somewhat ironically, during the years of his slow and tedious separation of the rare earths he had a great deal of time for reflection. The concentrated fruits of his reflection are published in three purely theoretical treatises: "Les disciplines d'une science. La chimie"; "Les notions fondamentales d'élément chimique et d'atome"; "La coördination des atomes dans la molécule. La symbolique chimique."

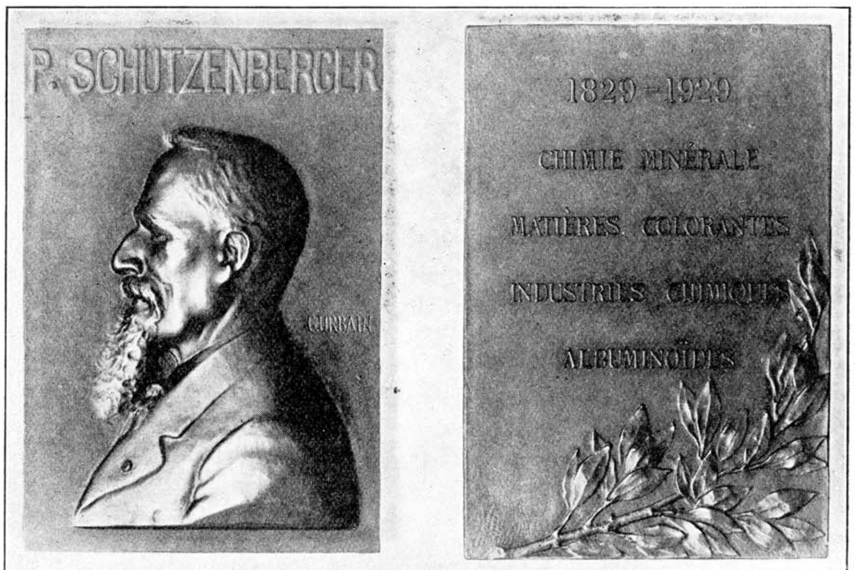
It would be difficult to estimate the value of M. Urbain's contributions to theoretical chemistry. He developed specifically the concept of homeomerism and contributed to the extension of the coördination theory of Werner. The concept of homeomerism can be explained as follows, more or less in Urbain's own words. Although by isomorphism most chemists understand syncrystallization, isomorphism is really a broader relation. Isomorphic compounds are those with identical energy coefficients, such as coefficients of magnetism and coefficients of thermal expansion. The concept of isomorphism is extremely interesting, but it is limited to the crystalline state. M. Urbain proposes a concept which would include all possible states of matter by dropping only the condition of equality of interfacial angles; he calls this concept homeomerism. Thus two substances are homeomeric when they have equal molecular coefficients of energy. As he points out, the usefulness of this concept lies in the fact that the quantities with which it is concerned are actually measurable. This can lead, among other things, to a rigorous definition of isotopes as elements which are rigorously, or almost rigorously, homeomeric. In this way one can take into account the equality of the properties of isotopes which are measurable in terms of energy, and one can explain their identical chemical behavior.

[3] "Atlas de Spectres d'Arc," Jacques Bardet, Doin, 1926.

Deeply interested in philosophy, Urbain was also a student of the history of the development of chemistry. His book, "Les disciplines d'une science. La chimie," is, in the opinion of Paul Job, a magnificent monument of chemical philosophy which can be compared only to the immortal lessons of Jean-Baptiste Dumas. He could, moreover, just as keenly analyze the development of contemporary science. He could search out the fallacies and inconsistencies in our present views. His last book on the coördination of atoms in the molecule and chemical symbolism is a challenging book which would interest particularly an organic chemist. It disturbs the complacency with which most of us now accept, without much thought, such well-established concepts as the quadrivalence of carbon and the double bond. In his introduction to chemical thermodynamics he remarks that although the partisans of thermodynamics as the perfect science claim that it is free of assumptions, he has found, after careful consideration, that at least a half-dozen postulates and axioms have crept into the science, and, he remarks facetiously, he is sure that he has missed a few.

As Professor Urbain's knowledge of the whole field of chemistry broadened, he became more and more impressed with the lack of unity in the ideas of chemistry in its various fields. In "Les disciplines d'une science. La chimie" an attempt at coördination of inorganic and organic chemistry leads him to the idea that the fundamental difference in the two is that in the former we are dealing with equilibrium conditions, whereas in the latter we are dealing mainly with metastable conditions which he conceives as due to a "chemical restraint." We may say that a substance is in a state of chemical restraint when a dissociation which is possible is nevertheless not produced. Later, as he restudies the situation in "La coördination des atomes dans la molécule. La symbolique chimique," he cannot believe that there is enough fundamental difference between organic and inorganic reactions, between organic and inorganic molecules, to justify the vastly different treatment of them which is the current practice. The importance of unity cannot be too greatly stressed, and its realization should be possible, particularly if some of the useless hangovers from discredited theories could be discarded from each field. M. Urbain has gone far in ferreting out a large number of these hangovers and in pointing a way toward the unification of chemistry by means of a modification and extension of Werner's coördination theory.

No discussion of Georges Urbain could pretend to be complete without some mention of his attainments in the arts. His father, Victor Urbain, communicated to him his taste for the arts. It would appear that this taste was always supreme in Georges Urbain, and that he undertook science only at the insistence of his father. He always regretted his choice somewhat, and believed that his life would have been more beautiful, if not more glorious, had he consecrated himself to sculpture or even to music which always gave him the greatest spiritual satisfaction.



Courtesy of Dr. Tenney L. Davis

CENTENARY PLAQUETTE OF PAUL SCHUTZENBERGER WHICH WAS DESIGNED BY GEORGES URBAIN. IT WAS USED IN CONNECTION WITH THE SCHUTZENBERGER CELEBRATION AT PARIS IN DECEMBER, 1929

Georges Urbain was a born musician.[4] Endowed with an exquisite sensibility, he found in music not only repose from his prodigious intellectual activity but the realization of noble aspirations and sometimes consolation and hope.

He played the piano from childhood, but soon abandoned formal lessons, finding them monotonous and preferring to play as he pleased. However, he was a serious student of music and studied its evolution attentively. Having read most of the didactic works on music and having assimilated the classics, he found the compositions of Johann-Sebastian Bach the most satisfying to his intellect. Richard Wagner and César Franck exercised a strong influence on his artistic orientation. Later, the rare harmonies of Claude Debussy enchanted him.

Georges Urbain's book, "Le Tombeau d'Aristoxène. Essai sur la musique," published in 1924, is an exposition of the thesis proposed by him that music is more intellectual than sensuous, that we find certain sounds disagreeable not simply because they are false and displeasing to the senses, but because they are not com-

[4] This account of Georges Urbain's contribution to music is taken largely from a memoir, "Georges Urbain, Compositeur," by Henry Mesmin.

prehensible to the intelligence. On this basis music can be the object, if not of a true scientific study, at least of a methodical study; and he makes a two hundred thirty-four page analysis of music and of its development in order to sustain this thesis. As Claude Seymart[5] points out, what makes the interest of this study is that the scientific proof presented by the author is given in a clear and truly elegant style. It is not one of those heavy volumes of weighty and tedious demonstrations but a suggestive essay presenting original and interesting ideas.

The musician, Georges Urbain, could not long remain contented with a philosophy. He created. He wrote in 1921 his first important compositions: "A la veillée" and two melodies on the poetry of Verlaine, "Chanson d'Automne" and "Sur l'herbe"; and in 1922, the "Magagnose and Dyonisos" theme in six brilliant variations.

He then freed himself of the Franckist school; he sought movement, atmosphere, imagery. But the artist was not satisfied, he found his writing too dense; he needed air and space, so he had to use a large and rather elaborate counterpoint. In this period he wrote several suites for the piano and several pieces of a grave and rich character for the organ. In a later period he purified his lines and composed pieces of a greater simplicity. These pieces composed in the period 1928–1932 represented the full flowering of his talent. Finally in the last years of his life he went back to his original compositions, retouching them, seeking perfection.

Thus we see that Georges Urbain was not a mere dilettante, that he contributed something of real value to music just as he contributed much of real value to science. His is probably one of the very few scientific jubilees for which the compositions of the scientist being feted could serve as the musical background of the program.

In addition to his talents as a pianist, composer, and musicographer Georges Urbain was a gifted painter and sculptor, gifts which were served by an astonishing visual memory and a rare manual dexterity.[6]

[5] Seymart, "G. Urbain: Le Tombeau d'Aristoxène," *La Revue Musicale*, **79**, 179–80 (1924–1925).

[6] This account of Georges Urbain's artistic achievements is a translation of a memoir, "Georges Urbain, Peintre et Sculpteur," by Pierre Urbain, his son.

His paintings were almost exclusively landscapes, particularly between 1900 and 1914, a period during which he sought in a variety of processes the means of rendering the various aspects of forest and sea. Strongly influenced by the impressionist school he first used the technic of pointillism, which he later abandoned for the palette knife, preferring to work in thicknesses and large surfaces. From this period date some good canvasses executed in the forest of Sénart, at Saint-Cast, and at Veulesles-Roses. After 1910 frequent sojourns at Barbizon induced him to modify his manner once more. He returned to the brush and sought to utilize all of its resources; he strove, as his father Victor Urbain had done, to arrive at effects of delicacy by using transparent strokes obtained by means of highly diluted colors. This technic, which approaches the effect of water color, was to be his to the end of his life. He has left interesting sketches executed in the forest of Fontainebleau, in Portugal, in Corsica, in Algeria, and in Morocco. His last were executed in Provence, during the summer of 1938, during the months of short happiness which preceded his brutal death.

His friends usually preferred his sculpture to his painting. They did not remember all that he risked in portraiture, palette in hand. He took his revenge with clay and chisel. His first striking work was a bust of his father whose serene wisdom and kindness he rendered in a masterly fashion. From the same epoch dates a bust of his master, Friedel, which is now in the Secretariat of the Faculty of Sciences of Paris, and a bust of his life-long friend, Jean Perrin, full of youthful enthusiasm. Both are treated with boldness and without hesitancy. Later, Georges Urbain became attached, in sculpture as in painting, to a more minute technic, and he turned to the medal; we have from him portraits of eminent savants and doctors who were his masters or his friends: Paul Schutzenberger, Georges Stodel, René Wurmser, Paul Langevin. His last work was a portrait of Doctor Henri Minet, which he had time to finish and to give to the molder; his premature death deprived him of the pleasure of seeing this medal reduced and struck.

The ability, the gifts, the accomplishments of such a man leave one overwhelmed with admiration. Endowed with a high culture, philosopher, encyclopedist, Georges Urbain formed several generations of chemists. With him disappeared a great figure in French science.

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THE LESSER KNOWN CHEMIST-COMPOSERS, PAST AND PRESENT *

Leopold May, The Catholic University of America

The most prominent chemist-composer was Alexandre P. Borodin (1833-1887), organic chemist, about whom much has been written (1). The chemistry and music of another chemist-composer, Lejaren A. Hiller, Jr., (1924-1994), polymer chemist, have been the subject of several publications (2). In addition to Borodin and Hiller, there were four previous chemist-composers, George Berg, amateur chemist-composer, Sir Edward W. Elgar, amateur chemist-composer, Georges Urbain, inorganic chemist-composer, and Emil Votoček, organic chemist-composer. There are also three contemporary chemist-composers, E. L. Bearer and Morris Kates, both biochemists, and Carlo Botteghi, industrial chemist. Their chemistry, music, and short biographies will be presented.

Previous Chemist-Composers

George Berg, Amateur Chemist-Composer
(~1720-1775) (3-5)

Although the exact date is not known, George (or Georg) Berg was born about 1720 and as some sources suggest in Germany. He was an organist and a teacher of violin and harpsichord. At the Ranelagh Gardens in the late 1750s he probably played either the organ or the violin. He was elected a member of the Royal Society of Musicians in 1763, and was listed in Thomas Mortimer's *The Universal Director* as 'composer & teacher on the harpsichord, Lincoln's Inn Fields.' In the same year he won a gold medal from the Gentlemen and Noblemen's Catch Club (5). Although publication of his songs continued into the nineteenth century, the last book of his music appeared in 1769. He was elected a member of the Society of Arts in 1769 and served on the Polite Arts, Mechanical Arts, and Chemistry committees. By 1771 he was organist at St Mary-at-Hill, Billingsgate, London, where he remained until his death.

He was a composer of instrumental and vocal music, including a collection of songs, especially those he wrote for entertainments performed at the Marybone, Ranelagh, Spring Gardens, and other pleasure gardens (entertainment complexes) in London. He published six books of Ranelagh songs; but nothing survives of his operas, his oratorio, *The Cure of Saul*, or of his ode, *The Invitation*. In 1763 he won a prize with one of his glees, *On Softest Beds*. A glee is an unaccompanied song for three or more solo voices in harmony (4). In 1759 he was the first to use the word sonatina in his *Twelve Sonatinas or Easy Lessons* (6). His galant works are considered cliché (5). Galant is a musical style featuring a return to classical simplicity after the complexity of the Baroque era. He was best known for his catches and part-songs, many of which were published in anthologies. Catch is a type of round in which the lines of music often interact so that a word or phrase is produced that does not appear if it is sung by only one voice (4). Part-songs written for multiple voices may be performed with or without instrumental or orchestral accompaniment. He also wrote an opera *Antigno* that was performed at Spring Gardens in London in February, 1764.

His more than 672 experiments in glassmaking were described in his "Experiment Book" (3,4). He was interested in learning chemistry, as it appears that he had no formal education in chemistry or glassmaking. Other objectives of the experiments were to prepare a clear glass melt, produce colored glass, some of which would be imitations of natural gemstones, and make glasses for enameling metals. He was able to make colored glasses that could be ground and used to color enameled wares. He made gem-like glasses, either for the carved or molded "cameos and intaglios" that imitated antique stones or for the more prosaic false stones set into buckles, jewelry, picture frames, or other small metal wares. The Falcon, Salpetre Bank, and Whitefriars glasshouses allowed him to use their muffle or wind furnaces. These furnaces were found in the workshops of goldsmiths, watchmakers, and other artisans who might regularly use enameling colors. He probably used a smaller version, a kiln, for most of his experiments. For some of his products, he calculated the proportional gravity ratio of weight of glass in air to its weight in water for some of his products in 1766. In 1765, Delaval (7) suggested that proportional gravity or specific gravity was related to the color of glass. Perhaps Berg did not find this helpful as he did not use it after this year (3).

Berg died in 1775, between April 17 and May 4 (3).

Sir Edward William Elgar, Amateur Chemist-Composer (1857-1934) (8-10)

Edward W. Elgar was born on June 2, 1857 in Broadheath, England. His father, who with his uncle owned a musical instrument shop, played the organ at the local Catholic Church. In addition to the organ, Edward played the bassoon, piano, and violin as well as being a conductor. When he was eleven, he wrote tunes for a play staged with his siblings, which were later published as *Wand of Youth Suites*. Ten years later, he composed *Harmony Music Four and Five Intermezzos*. In 1879 he became the conductor of the Worcester Amateur Instrumental Society and bandmaster to the Attendant's Orchestra at the Worcestershire County Lunatic Asylum in Powick. During the 1880s he played Popular Concerts in Birmingham, was a soloist at violin recitals for clubs, and taught violin to young middle-class ladies. In 1889 he married one of his pupils, Caroline Alice Roberts. One year later he composed a religious composition, *The Dream of Gerontius*, Opus 38, based on the poem of the same title by Cardinal Newman, a Catholic theologian. It relates the journey of a pious man's soul from his deathbed to his judgment before God and his settling into purgatory. In 1899 he completed the score for *Enigma Variations*. This was the work that finally secured his reputation as a composer of national and international standing. In this piece, fourteen people and one dog are featured. The first two *Pomp and Circumstance Marches* were composed in 1901 and the fifth and last in 1929. About the first march, he appreciated its worth and is quoted as saying: "I've got a tune that will knock 'em - knock 'em flat! … a tune like that comes once in a lifetime …" Elgar had 'arrived' (9).

Sir Edward William Elgar

His interest in science, prompted by new technology of the gramophone, led him to be the first major composer to record one of his own works in 1914. He conducted his composition, *Carissima*, in his first recording at the Gramophone Company on the "His Master's Voice" label, generally referred to as HMV. The company's London studios were located on an upper floor to minimize the effect of traffic noise and vibrations. The music was played with only a few instruments that could be clustered close enough to the recording horn. During World War I he wrote patriotic pieces such as *WWI*. He received many honors, including being created Knight Commander of the Victorian Order (K.C.V.O) in 1928. After this event, he was known as Sir Edward Elgar.

One of his other interests was chemistry (11). At his Hereford house, Plas Gwyn, he set up a small laboratory in the basement. His manuscript of the *Prelude to The Kingdom*, dating from January 1906, bears the stains of his chemistry experiments. In August, 1908 he moved his laboratory to part of an outhouse. It was called The Ark because of the nesting of doves in the shed, and it had a telephone link to the house. A story about Elgar's hobby was related by W. H. Reed (12):

> One day he made a phosphoric concoction which, when dry, would "go off" by spontaneous combustion. The amusement was to smear it on a piece of blotting paper and then wait breathlessly for the catastrophe. One day he made too much paste; and, when his music called him, and he wanted to go back to the house, he

> clapped the whole of it into a gallipot, covered it up, and dumped it into the water-butt, thinking it would be safe there.
>
> Just as he was getting on famously, writing in horn and trumpet parts, and mapping out wood-wind, a sudden and unexpected crash, as of all the percussion in all the orchestras on earth, shook the room, followed by the "rushing mighty sound" he had already anticipated in The Kingdom. The water-butt had blown up; the hoops were rent; the staves flew in all directions; and the liberated water went down the drive in a solid wall.
>
> Silence reigned for a few seconds. Then all the dogs in Herefordshire gave tongue; and all the doors and windows opened. After a moment's thought, Edward lit his pipe and strolled down to the gate, andante tranquillo, as if nothing had happened; and the ruined water-butt and the demolished flower-beds were pre-historic features of the landscape. A neighbour, peeping out of his gate, called out, "Did you hear that noise sir: it sounded like an explosion?" "Yes," said Sir Edward, "I heard it: where was it?" The neighbour shook his head; and the incident was closed.

When he moved to London in 1912, he turned to microscopes to satisfy his scientific curiosity.

Hydrogen sulfide (H_2S), known from alchemical times and variously named sulphur water or "Holy Water'" (13), stinking sulphurous air (14), hepatic air (15), and—by Lavoisier—as "unknown combination" (16), became recognized as an important reagent for inorganic qualitative analysis (17). Elgar was one, although an amateur chemist, who produced a device to generate this important reagent, which he knew as sulphuretted hydrogen. As he wrote in a letter to August J. Jaeger, dated November 11, 1908 (10):

> You will perhaps be amused - I hear that the 'new Sulphuretted Hydrogen Machine designed by Sir Edward Elgar' is to be manufactured & called the 'Elgar S.H. Apparatus'!! I will not offer to send you my invention - you would soon tire of it - although a nice toy.

This toy was "about as small as a hand (finger tip to wrist)." There is an inner chamber with a small hole at the top connecting it to the outer vessel. "The bottom of the outer vessel is perforated with a series of about 15 small drilled holes" (12, 18). It was made by the firm of Philip Harris (12, 18), and one is kept at Elgar's birthplace (19). His godsons, Atkins (20) and Kennedy (21) have written that it was patented. Atkins stated that it was "in regular use in Herefordshire, Worcestershire, and elsewhere for many years" (20).

Elgar died on February 23, 1934. He and his wife had one daughter.

Georges Urbain, Inorganic Chemist-Composer (1872-1938) (22,23)

Georges Urbain was born on April 12, 1872 in Paris, France. While he was studying` at the École de Physique et Chimie de Paris, he was an assistant in the mineralogy chemistry laboratory where he met Pierre Curie, who inspired him to make chemical research his life work. In 1894, after he graduated as an Ingenieur-chimiste, he entered the Faculté des Sciences de Paris, where he started research in rare earths in the Laboratory of Organic Chemistry of Charles Friedel. Four years later he received the DSc. After six years in industry, he was appointed Assistant Professor of Analytical Chemistry at the Insitut de Chimie, Sorbonne, Paris. In 1908 he was promoted to Professor of Mineral Chemistry. During World War I he was Director of the Chemical Laboratory of the Technical Section of the Artillery, a member of Inspection des Etudes et Expériences Chimiques de Guerrre, and President of the Comité Scientifique des Poudres et Explosifs and the Commission de Substances Explosives. In 1928 he became Professor of General Chemistry, Director, Institut de Chimie de Paris, and Codirector and Director of the Chemical Service, Insitut de Biologie Physico-Chimique.

Georges Urbain from (24)

He was very popular with the students who "rose in a body when he entered the room" and "listened with such complete attention that there was not a murmur to be heard in the class of three hundred fifty students" (23). For his war service, he was made Chevalier la Legion d'Honneur in 1918 and Commandeur in 1933. In 1921 he was elected to the Académie des Sciences. He was an Honorary Member of the Chemical Society of London and Corresponding Member of the National Academies of Belgium, Spain, and the USSR. He served as president of the French Chemical Society, Société de Chimie, and Société de Minéralogie.

Urbain was also a musician who played the piano and composed. Some of his compositions included, *A la veillée, Chanson d"Automne, Sur l'herbe,* and *Magagnose et Dyonisos*. In 1924, he wrote the book *Le Tombeau d"Aristoxéne. Essai sur la musique*, in which he applied the scientific method to the study of music (25). In addition, he was a painter and sculptor.

In 1879 Lars F. Nilson separated Marignac's ytterbia into scandia and a new ytterbia, which Urbain then separated into neoytterbia and lutecia (ytterbium and an unknown element) in 1907. In the same year, K. Auer von Welsbach reported the spectra and atomic weights of two elements in ytterbia, which he named after the stars aldebaranum and cassiopium. Urbain named the element lutecium (Roman name for Paris), which was later changed to lutetium. Between 1895 and 1912 he worked on the rare earths and performed more than 200,000 fractionations to afford the elements samarium, europium, gadolinium, terbium, dysprosium, and holmium. In 1911 Urbain had studied element number 72, which he called celtium. The discoverers, D. Coster and G. von Hevesy, however, named it hafnium in 1923. He also discovered the law of optimum phosphorescence of binary systems and carried out research in isomorphism. He converted an analytical balance into a thermobalance before Kotaro Honda and discovered the law governing efflorescence of hydrates in a dry atmosphere. He also served on the International Commission on Atomic Weights.

Urbain wrote several books dealing with various chemical topics, spectrochemistry, 1911 (26), chemistry of complexes with A. Sénéhal, 1913 (27), chemical reactions, 1925 (28), and a general chemistry text with P. Job, G. Allard, and G. Champetier, 1939 (29).

Urbain died on November 5, 1938.

Emil Votoček, Organic Chemist-Composer (1872-1950) (8, 31-32)

Emil Votoček was born in Arnau (Hostinné nad Labem), Bohemia, on October 5, 1872. After graduating from the gymnasium, he attended the School of Commerce in Prague where he developed an interest in chemistry. So, he transferred to the School of Chemistry (now the Prague Institute of Chemical Technology) of the Czech Technical University. In 1893 he received a diploma with the degree of Ingenieur (33). Then he continued his studies in Germany, first at Mulhouse in Alsace-Lorraine, and a year later at Georg-August University in Göttingen. He returned to the Czech Technical University as an Assistant in 1895 and was promoted to Docent in 1905. One year later he was appointed Extraordinary or Associate Professor of Organic Chemistry and was promoted to Ordinary (Full) Professor of Inorganic and Organic Chemistry in 1907. He served as Rector of the University during 1921-1922, and in February, 1939 he was forced to retire by a decree from the Department of Education. However, he enrolled as a student so that he could continue his research. After the conquest of Czechoslovakia by the Germans, the universities were closed by order of the German occupation officials on November 17, 1939, until the country was liberated in 1945.

Emil Votoček as Rector of the Czech Technical University from (32)

Although he was regarded as a learned and respected professor, he was often hot-tempered and irritable. His research laboratory was known as "Devil's Island," which represents the appearance and the mood in the laboratory (32). He lectured in both inorganic and organic chemistry and wrote textbooks in both fields. K. Preis and he wrote the inorganic text with Jaroslav Heyrovský (34). In the organic text (35) he introduced a new classification of organic chemicals dependent upon whether a compound was derived from the original hydrocarbon by substitution on one, two, or more carbon atoms. He also wrote a laboratory manual and a book of exercises in organic chemistry (36).

Votoček received honorary doctorates from the Czech Technical Universities of Prague, 1948 and Brno, 1927, the Universities of Padua, Nancy, and Toulouse, 1929, and from the Sorbonne. He was an honorary member of the Polish, Italian, Spanish, and Romanian chemical societies, the Société de Chimie Industrielle, and the Société Chimique de France, which awarded him the Le Blanc Medal; and he was named Officier de la Légion d'Honneur and Officier de l'Instruction Publique. Other honors included the Ordine Corona d'Italia and Commander of Poland's Order of Polonia Restituta, 1932. He was nominated for the Nobel Prize in Chemistry in 1933, a year in which it was not awarded (32). However, one of his students, Vladimir Prelog, received the Nobel Prize in 1975 for his research into the stereochemistry of organic molecules and reactions, which he shared with John Cornforth for his work on the stereochemistry of enzyme-catalyzed reactions. On the centenary of his birth, 1972, a commemorative medal was minted and is awarded by the Rector of the Prague Institute of Chemical Technology as the highest recognition of scientific activity,

He played the double bass in addition to being a musicologist and composer. Among the 70 songs and works for piano and ensembles he wrote are *Allegretto grazioso*, 1932, *Thema con variazioni for piano and Soprano Voices*, 1934, *Trio for Piano, Violin, and Violoncello*, 1938, *Serenade for French Horn and String Quartet*, 1943, *Czech Polka*, 1944, *From Dawn to Dusk of Life*, 1945, and *The May Fairy Tale*, 1949. In 1946 he published the book, *Musical Dictionary of Foreign Expressions and Phrases* (37).

Among his many literary achievements were several chemical dictionaries for different languages: *Shorter German-Czech and French-Czech Chemical-Technical Dictionary* with B. Setlík, 1906 (38); *Czech-German-French-English-Italian-Latin Chemical Dictionary*, 1941 (39). He also published several for other sciences: *Czech-French-Terminological and Phraseological Dictionary for Chemistry, Physics and Related Sciences*, 1924 (40); *Polish-Czech Chemical Dictionary with Partial Regard to Mathematics, Physics, Geometry and Mineralogy,* 1931 (41). Two dictionaries dealt with the Czech and French languages: *Czech-French Conversation and Phraseology*, 1939 (42) and 1924 (40). He published two volumes containing all postmarks used in Bohemia up to 1918 (43). In 1929 he started the journal *Collection of Czechoslovak Chemical Communications* with Jaroslav Heyrovský, who received the Nobel Prize in Chemistry in 1959 for work in polarography. They also served as the editors until the journal ceased publication in 1939. When the journal resumed publication after World War II in 1947, Heyrovský continued as sole editor (44).

Votoček's research on artificial dyestuffs, carbohydrates, and analysis of natural products was published in 300 articles. One of his main research interests was saccharides, especially methylpentoses. This interest was developed during his stay in Göttingen, where he worked with Bernard C. G. Tollens, who was noted for his research of the chemistry of saccharides. He studied the derivatives of rhammose, L- fucose and its D-isomer, which he named rhodeose. To describe two sugars that can be converted into each other, he invented the term epimers and the term epimerization for the reaction. He introduced the use of nitrous acid in the oxidation of sugars and synthesized a number of saccahrides and saccahride acids and alcohols. Some of his efforts were devoted to nomenclature in carbohydrates and (with Alexander Sommer-Batěk) in inorganic compounds. He also served on the IUPAC Commission on the Nomenclature of Organic Chemistry. One of his studies on the derivatives of carbazole led to its application as an analytical reagent (Votoček's reagent) for the determination of sulfite in the presence of thiosulfate and thionate. He also introduced the use of sodium nitroprusside as an indicator in mercurimetric titrations. A more comprehensive account of his chemical work can be found in Ref. 32.

On February 17, 1906, he married Libuše, the daughter of an Austro-Hungarian minister; they had two sons and a daughter. He died October 11, 1950 in Prague.

Contemporary Chemist-Composers

The tradition of chemist-composers continues to the twenty-first century as illustrated by the activities of three contemporary chemist-composers, E. L. Bearer, Morris Kates, and Carlo Botteghi.

E. L. Bearer, Biochemist-Composer (8, 45)

Elaine L. Bearer was born on April 1, 1949 in New Jersey. Her early education began at age 6, and by age 9, the first performance of one of her compositions took place. After studies at Juilliard Prep School, she matriculated at Carnegie Institute of Technology, where she studied both music and computer science. Composition studies were with Carolos Surinach, Virgil Thompson, Don Wilkins, and Nicolai Lopatniff. She left Carnegie Tech after two years to travel to Paris, where she worked with Nadia Boulanger, the famed composition teacher. Returning to New York, with an interest in computer "algorhythms" to generate sound, she completed a B. Music in 1970 from the Manhattan School of Music. From 1970 to 1973 she was an instructor in music history and appreciation at Fairleigh Dickinson University. Then she was recruited to San Francisco by Lone Mountain College as an Assis-

Elaine L. Bearer

tant Professor of Music in 1973, after having withdrawn from the Ph.D. program at NYU, which awarded her an M. A. in Musicology in the same year. After teaching composition at Lone Mountain, SF State University, and the San Francisco Conservatory, she decided to attend medical school. While preparing at Stanford University, she was a postgraduate research assistant in neuroscience with John Nicholls and a teaching assistant for Donald Kennedy. She was the first graduate from the M.D.-Ph.D. program at University of California, San Francisco in 1983. Then she served a residency in pathology there for two years. After a year at the Centre Medial Universitaire, University of Geneva, Switzerland, she returned for a postdoctoral fellowship in biochemistry with Bruce M. Alberts. In 1991 she joined the Department of Pathology and Medicine of Brown University as Assistant Professor. One year later she was appointed Adjunct Assistant Professor in the Department of Music. After six years, she was promoted to Associate Professor in both departments and Professor in 2004 in the Department of Pathology and Medicine and in 2005 in the Department of Music and in 2006 in the Division of Engineering. Since 1993 she has served as Director and Codirector of The San Lucas Health Project, which provides the indigenous Maya of the San Lucas Toliman, Guatemala region with free year-round primary health care.

One musical composition, *The Nicholls Trio: A Musical Biography of a Scientist***,** is dedicated to her mentor, John Nicholls (45, 46). The final movement was inspired by electrical patterns in the neurons of leeches, which Nicholls studied. The piece was premiered at the annual meeting of the Society for Neuroscience in 1994. Her *Magdalene Passion* (45, 46), an hour-long oratorio for chorus, orchestra, and five soloists, was premiered in 2000 by the Providence Singers under Julian Wachner

In her research in molecular biology of actin-cytoskeleton, Bearer investigates dynamic cellular behavior. Presently, she uses a range of microscopic imaging and molecular techniques to understand the mechanisms of these dynamics by using model systems, including squid giant axon, transport of Herpes simplex virus, and human blood platelets. Some of her recent studies address fundamental questions pertaining to learning and memory. She has published 45 papers on her research and is the editor of *Cytoskeleton in Development* (47) and co-editor of *Nature and Nurture* (48).

Carlo Botteghi, Industrial Chemist-Composer (1938-2002) (49,50)

Carlo Botteghi was born in La Spezia, Italy, on March 5, 1938. In 1963 he graduated in chemistry from the University of Pisa. He continued there as a Lecturer of Organic Chemistry in the Faculty of Engineering until 1968. Then he took a research position at ETH (Polytechnic Institute) in Zürich, Switzerland, as Forschungsassistent and Oberassistent. He was also Lecturer in Organic Chemistry in the Faculty of Engineering and Director of the high pressure laboratory. In 1975 he became Professor of Industrial Chemistry at the University of Sassari, Italy, and Director of the Institute of Applied Chemistry. After ten years he became Professor of Industrial Chemistry at the Università Ca' Foscari di Venezia (University of Venice), Italy. In addition to teaching various courses in the area of industrial chemistry, he served as Director of Department of Chemistry for two 3-year terms.

Carlo Botteghi from (50)

He studied piano and music composition privately and has been registered in the Music Section of the Italian National Register of Authors since 1960. As a musicologist, he concentrated mainly on Pietro Mascagni (1863-1945), who was one of the important Italian composers at the turn of the 20th century, best known for his first masterpiece *Cavalleria Rusticana*. He was a noted Mascagni scholar or Mascagnano and the head of the Centro Studi Mascagnani of Livorno. In 1995 he wrote the music for the song *Mascagni* with words by Luigi Biagioni. It may be found on a CD entitled *Cieli* *di Toscana* (Tuscan Heavens) performed by the popular Italian singer, Andrea Bocelli. In 1981 Carlo Botteghi wrote *Magari tu and Una giornata senza te* with words by Antonio Strinna. His book, *Le Suggestioni della Musica* (The Splendor of Music) was published in 1992 (51). In 1997 he published an essay on the opera, *Parsina*, entitled *Parisina –il dramma musicale di Gabriele D'Annunzio e Pietro Mascagni* (Parisina-the musical drama by Gabriele D'Annunzio and Pietro Mascagni) (52).

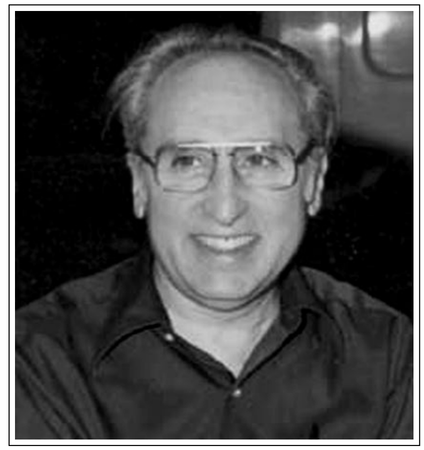
Botteghi published 150 papers in organic chemistry, homogeneous catalysis, hydroformylation, and carbonylation. One of his interests was conservation of buildings, and he did research in the synthesis of polymeric materials for this use. From 1995 to 1998 he also taught Conservation of Materials in Historical Buildings at the Architecture University Institute in Venice.

Botteghi died suddenly on September 19, 2002 and was survived by his first wife, Maria Grazia Bacci, and their two sons and his second wife, Vera Bellagamba, and their son.

Morris Kates, Biochemist-Composer (53,54)

Born in Galati, Romania, on September 30, 1923, Morris Kates was brought to Ottawa, Canada, one year later. He received a B.A., 1945, M.A., 1946, and a Ph.D., 1948 from the University of Toronto. After receiving his doctorate, he continued at the University as a postdoctoral fellow and then moved to the National Research Council of Canada, where he was first a Postdoctoral Fellow (1950-1951), and then a research scientist until 1968. In that year, he transferred to the Department of Biochemistry, University of Ottawa, as Professor, where he remained until he retired in 1989 as Professor Emeritus. During his tenure at the University of Ottawa, he served as Chairman of the Department of Biochemistry (1982-1985) and Vice-Dean (Research), Faculty of Science and Engineering. In 1995 he was named the Morton Lecturer, an award by the Biochemical Society to a lecturer who has made an outstanding contribution to lipid biochemistry. He also received the Supelco Award for lipid research from the American Oil Chemist Society in 1981. An issue of *Biochemistry and Cellular Biology* in 1990 was dedicated to him in honor of his valuable contributions to biochemistry in Canada (55).

Kates developed his twin passions for science and music during his youth and began studying violin at the age of 11. By the time he was in high school, he began composing music and exploring the world of laboratory science. During his university studies he took courses in music harmony, counterpoint, and composition and played in the University of Toronto Orchestra. When he was at the National Research Council, he played in orchestras and string quartets in Ottawa. His first formal composition in 1946 was *Theme and Variations for Piano*, which was revised for strings in 1964. In 1990 he composed *Columbus* for baritone and full orchestra, and two years later, *Festive Suite for Brass Quintet and Strings*. His composition for choir and string quartet *Water—Source of Life* was released in 2000. He is an Associate Composer with the Canadian Music Centre and a member of the Canadian League of Composers.



Morris Kates from (53)

Kates has published about 220 articles on the analysis, structure determination, biosynthesis, and membrane function of cellular phospholipids, the nutritional value of lipids, and the production of biodiesel fuel. One of his research projects was the discovery and study of a new class of glycerol-diether lipids in bacteria named *Archaea* that live in extreme environments. He is currently associated with the Ottawa Biodiesel Research Group in the Department of Chemical Engineering at the University of Ottawa, whose "main objective is to produce biodiesel in a cost-effective way by overcoming several barriers to biodiesel profitability"(56).

His books include *Techniques of Lipidology: Isolation, Analysis, and Identification of Lipids*, which is now in the second edition (57). In 1980 he and Arnisa Kuksis edited *Membrane Fluidity: Biophysical Techniques and Cellular Regulation* (58), and four years later, with Lionel A. Manson, he edited *Membrane Fluidity – Biomembranes*, Vol. 12 (59). In 1990 he edited *Glycolipids, Phosphoglycolipids, and Sulfoglycolipids*, which is volume 6 of the *Handbook of Lipid Research* (60). Three years later he coedited *The Biochemistry of Archaea (Archaebacteria), New Comprehensive Biochemistry*, Vol. 26, with D.J. Kushner and A.T. Matheson (61).

Kates is married to Pirkko Helena Makinen, and they have three children and seven grandchildren.

Observations

The chemist-composers described above are experimental chemists; two amateur chemist, two biochemists, an industrial chemist, an inorganic chemist, two organic chemists, and a polymer chemist, but none is a physical or theoretical chemists. In performing experimental work, one sometimes involves "hunches" in solving problems, which may be more similar to the brain processes used in composing music than the abstract reasoning needed in solving problems in physical or theoretical chemistry. This does not apply to chemist-performers because some are physical chemists (e.g., Wilhelm Ostwald). Nor does it apply to several of the scientist-composers who are also mathematicians and physicists (62). It may be that the sample of nine chemist-composers is too small to derive any correlation between the area of chemistry pursued by the chemist-composers and their music.

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