Professor Solomon Marcus' Axioms

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Axiom 0. Be a language theorist

I remember the day I recognized Professor Solomon Marcus while walking down the street. I forget which Romanian city I was in – neither Bucharest nor Iasi nor Bacau. It may have been while vacationing at the Black Sea, perhaps in Eforie Nord or Mamaia. I was a college student at the University Alexandru Ioan Cuza in Iasi. I knew his face from his TV appearances; he was the leading scientist in Romania in the area of research I was interested in: formal languages and automata theory. On that street, I got brave and approached him, introduced myself, and mentioned that I wanted to show him a theorem I just proved about Chomsky grammars. He invited me into his house and we discussed mathematics. I guess I made a good first impression, as he invited me to come to Bucharest to continue our discussions. Four years later, at the University of Bucharest, I defended my Ph.D. thesis in the area of formal languages. The advisors for my thesis, "Context-Sensitive Languages: Applications to Program Semantics and Number Theory," were the extraordinary Professors Solomon Marcus and Sergiu Rudeanu.

From Professor Marcus I learned that Language is beautiful and deep. As a computer scientist, my studies in formal languages and automata theory gave me the greatest insight of all. My research in the theory of computation, programming languages, program semantics, logic of programming, algorithms, graph theory, derandomization, the human genome, the regulatory genome, protein folding, statistical mechanics -- all were built on insights from mathematical language theory.

Axiom 1. Be a first-class scientist in at least one of the disciplines of your interdisciplinary research

In 1998, my son Lee, who was finalist at the Mathematics Olympiad being held in Albuquerque, N.M., told me that famed mathematician Paul Erdos would be addressing the finalists. I was working at Sandia National Labs at the time and eagerly asked Erdos' hosts, the University of New Mexico, for permission invite him to Sandia Labs and to host him for one full day. The colleagues from UNM granted me the pleasure, but not before asking whether I was aware of the fact that he

needed constant "supervision," as he is in his world of proving theorems and has attention for nothing else. The first thing he said when he got to my office was "I have to call Francoise Ulam and we should write a postcard to Solomon Marcus." I do not have Erdos [paper] number 1, but the postcard we coauthored gave me *Erdos postcard number 1*.

At the time I was working on the construction of universal traversal sequences. I had been thinking about them for 10-plus years having completed (about 100 page long proof for) the solution to for 2-regular graphs, and working on the generalization to 3-regular graphs, the general case [and still work on it now]. I asked him two questions. His answers were memorable. Q1. Do very long and involved proofs eventually simplify? A1. *No*. Q2. When do you give up working on a problem? A2. [His expression was shocked, and with all his strength he yelled] *"Never! I solved a problem after 20 years – once you start working on the problem, the brain continues working subconsciously."*

In the area of computational biology where I have been working since 1992, interdisciplinarity is essential. I learned from Professor Marcus, whose life work is a model of interdisciplinarity, that you need to be a first-class scientist in at least one of the component sciences of your interdisciplinary work. The fields of computational biology and bioinformatics are now going through growing pains. Hard-core computational biology, defined as first class in algorithmic methods or in statistical methods when combined with biology to yield an effective hybrid, is a rare find. Unfortunately an alarming bunch of soft-core bioinformatics research is taking place. There's a term for that, coined by some eloquent biologists: "computational biology without biology." And the analogous "without computer science."

Axiom 2. Be a mathematician of the continuous and discrete

I was a member of a wonderful group of students admitted to the University Al I Cuza's first class of *Informatica* (Computer Science). Some of my classmates had studied at the well-known Negruzzi High School devoted to mathematics (my wife's high school, in fact). I was the small-town boy from Tg. Neamt, Judetul Neamt, and Iasi, where the university was located, was the first big city I lived in. One university course that looked formidable yet enticing was set theory. Though the big-city Negruzzi grads had already studied set theory, I was the one of those who got the highest grade (10). Proudly, I went to the post office to send a telegram home to my parents: "Am luat 10 la teoria multimilor," which was received back in Tg. Neamts as "Am luat 10; dar teoria multumitor" ("I got 10; but theory satisfactory"). This place – where I could study mathematics 24 hours a day if I chose, and surround myself with math books, the only place where I can find many American/English, French and Russian books – was heaven. I spent a lot of time studying in this beloved Seminarul Matematic "Alexandru Myller". Though I graduated *summa cum laude*, I was forbidden to be an assistant professor because of my relatives in the U.S. and Israel but I was able to get a position as researcher at Centrul de Calcul al Universitatii. Its Computing Center and its then-beautiful new building became,

through the lifetime work of Professors Adolf Haimovici and my beloved mentor and Professor Calin Ignat, the Department of Computer Science/Facultatea de Informatica. Today in the entryway, just below my former office, there is a statue of Grigore Moisil a world class mathematician and logician. His career was an integral part of historic record of achievements in mathematics and computer science at both Universities of Iasi and Bucharest. He was the founder of computer science in Romania. Few professors are school-building professors with a large number of their students becoming, in turn, professors and researchers and continuing the master teacher's research vision. Professor Moisil had such a legendary following in the school that he built around him at Iasi and Bucharest. Inheriting this rare talent, Professor Marcus, a most distinguished member of the Moisil school, is himself a school builder professor of highest stature. Distinguished members of the Marcus school are my two "academic brothers," professors Cristian Calude and Georghe Paun.

In 2005 I was interviewing at Texas A&M University - an intense 4-day interview for a Chair Professorship position in the Department of Computer Science. When I looked over the interview schedule, to my pleasant surprise, I saw Ciprian Foias, Distinguished Professor of Mathematics, without question the most famous Romanian mathematician in US. Winner of the Norbert Wiener Prize in Applied Mathematics awarded every five years by the American Mathematical Society jointly with the Society for Industrial and Applied Mathematics for a most influential body of work of most general impact for entire mathematics. He has been the leading expert in the most notoriously difficult area of *Turbulence;* he wrote *the* book on the Navier-Stokes equations of turbulence. I met him for the first time in New Mexico when he was the Ulam Scholar at Los Alamos National Laboratory and I was a scientist at Sandia National Laboratories. I went to his office and he immediately started talking about Solomon Marcus, his academic brother, and his admiration for professor Marcus' deep insights into both continuous and discrete mathematics. He then said that he wants to show me a problem he has been stuck with for years. He said that he read about my work on the three-dimensional Ising model -- where in a continuous mathematics, statistical mechanics model, I proved an impossibility theorem based on an underlying discrete mathematics (NP-completeness) structure and this for *every* three dimensional model. He was wondering if I could see a similar phenomenon in his functional analysis problem. That was a memorable day for me: Ciprian Foias asked me for help with a problem in turbulence! Hydrodynamical turbulence was a problem that fascinated von Neumann!

I remember how, during one of my visits to Bucharest to work with Professor Marcus, he introduced my to Professor Moisil. It was part of a gathering and we did not do too much talking, but I remember the handshake. So I have Moisil handshake number 1. The *handshake number*, similarly defined as the well-known Erdos number, was introduced by John Conway, the John von Neumann Professor at Princeton, who I am proud to have as a collaborator and good friend. What is your von Neumann handshake number? Through John Conway, my Wittgenstein

handshake number is 3 (via his dentist). Through Professor Marcus my Leibniz handshake number is 13 and my Euler handshake is 9, and through my Brown colleague and Nobelist Leon Cooper, my Einstein handshake number is 2.

Axiom 3. Be an intra-math, inter-sciences, and cross-cultures scientist.

In 2009 the world celebrated the 50th anniversary of C. P. Snow's book "The Two Cultures and the Scientific Revolution." Its author talked about a breakdown of communication between the sciences and humanities and issued a severe warning about the negative consequences of this. Professor Marcus has been building a bridge between these two cultures with a prolific output of papers in mathematical analysis, mathematical and computational linguistics and computer science, poetics, linguistics, semiotics, philosophy and history of science and education. He taught us from his castle built on a foundation of two cultures. He revealed to us insights gleaned from both worlds.

No more than six months after a major surgery Professor Marcus arrived at Brown in the summer of 2008 for a month-long research visit. In the middle of his stay, with an energy that was amazing for someone who had just undergone major surgery, he exclaimed*: I am at age zero!* The environment offered by the centuries-old Ivy League scholarship had stimulated his creativity and empowered him to give eight amazing lectures. (Their videos are available on my website.) I plan to edit Professor Marcus' "The Brown Lectures" as a volume in the near future. This year, in 2011 he spent another three weeks at Brown and gave another four lectures. Though the environment was less serene during this visit (Hurricane Irene showed her fury and delayed his departing flight by three days), Professor Marcus' energy and lecturing power and zest for research was as amazing as it was in 2008. I think I found the secret of life: "tinerete fara batrinete si viata fara moarte." It is: Mathematics!

Axiom 4. Be the guardian of high standards

The Ph.D. advisor genealogy – or Ph.D. advisor "handshake," if you will – lists for professor Marcus 8 such "handshakes" to Euler in the 17th century just about when Brown University was established, and 11 handshakes to Leibniz in the 16th century: Solomon Marcus (1956), Miron Nicolescu, Paul Montel, Henry Lebesgue, Emile Borel (1893), Gaston Darboux, (Michel Chasles, Simeon Poisson), Joseph Lagrange, Leonhard Euler (1726), Johan Bernoulli, Jacob Bernoulli, Gottfried Leibniz (1666).

Axiom 5. Know a lot - really a lot - of mathematics

John von Neumann argued in 1947 about the different structure of mathematics "that falls into a great number of subdivisions, differing from one another widely in character, style, aims, and influence" vis a vis "the very opposite of the extreme concentration of theoretical physics." He concluded that "a good theoretical physicist may today still have a working knowledge of more than half of his subject. I doubt that any mathematician now living has much of a relationship to more than a quarter." [1] The last sentence refers probably to himself, of course. It is without

question that Professor Marcus has a working knowledge of a quarter of mathematics in 2011! And his encyclopedic knowledge communicated with an infectious technical strength, as in the 12 Brown lectures, has infected many of us since graduate school. The joy of instincts and intuitions in multiple sciences is *marcusism*.

Axiom 6. Be a storyteller (povestitor)

Professor Marcus has written 50 books and hundreds of articles. He encourages us to write our papers, to publish our books and to express our scientific opinion, to address difficult questions and to share some of the battles in our scientific work on how truth is won. I have difficulty writing – it takes me a long time to polish papers. And only when I arrived at Brown did I start writing non-technical papers. [2, 3, 4] Both Professor Marcus and Nobel Laureate in Economics, Ken Arrow (Dear Sorin, It was a pleasure to meet and talk with you. I enjoyed very much your article in CONDUIT, with its light, yet penetrating touch into some deep thoughts on computing. I hope we have another opportunity to exchange ideas.) sent encouragements about my non-technical writing. Professor Marcus, Professor Dijkstra, Professor Michael Waterman and the wonderful letters of John von Neumann were my initial inspiration. Their delightful articles/letters enticed me to share my stories. Last year, in my visit to Bucharest to attend Professor Marcus' 85th celebration sponsored by the Romania Academy of Sciences, Professor Marcus told me that storytelling is in the genes: *Moldovenii sint poverstitori* (People from Moldova [the northern Romanian province] are storytellers.) Like both of Professor Arrow's parents, we are born in Moldova: Professor Marcus was born in Bacau, I in Tg. Neamt.

Here are Professor Marcus' Axioms:

Axiom 0. Be a language theorist

Axiom 1. Be a first-class scientist in at least one of the disciplines of your interdisciplinary research

Axiom 2. Be a mathematician of the continuous and discrete

Axiom 3. Be an intra-math, inter-sciences, and cross-cultures scientist

Axiom 4. Be the guardian of high standards

Axiom 5. Know a lot - really a lot - of mathematics

Axiom 6. Be a storyteller (povestitor)

But these seven axioms (with the "language" replaced by "automata" in Axiom 0) are also John von Neumann's axioms. The two come from the group of mathematicians of highest stature, universal mathematicians of unprecedented mathematical power and scholarly output whose work inspired many of us to tackle the hardest

problems. I am very privileged and honored to have optimal handshake numbers for both of them: Von Neumann 2 and Marcus 1.

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