# My Career in Mathematical Biology
# A Personal Journey

## Leon Glass

When I was a young boy, I used to spend hours watching the shenanigans of my ovoviviparous guppies and rearranging my fish tanks. On one notable occasion I siphoned the water from a 10 gallon tank into a 5 gallon tank, much to the dismay of the downstairs neighbor.

After graduating from high school I headed to Brooklyn College as a pre-med major. An encounter with comparative vertebrate anatomy (What is the gestation period of an aardvark?) led me to change my major to psychology. But I ran into problems in both normal psychology (What are the three characteristics of a normal personality?) and abnormal psychology (How do you interpret a dream of a girl riding a horse?). So I switched to chemistry.

After graduating from college in 1963 I went to graduate school in Chemistry at the University of Chicago. I worked with Stuart Rice, an extraordinary scientist who himself had gone to Brooklyn College a decade earlier. My first project dealt with spectroscopy and energy transfer in compounds with multiple benzene rings. But after ruining several high quality UV cuvettes, I switched to statistical mechanics of liquids. During the last year of my thesis work, I attended seminars that were organized by Jack Cowan, who had just been hired to revitalize the Committee of Mathematical Biology at Chicago.

When I finished my PhD in 1968, I obtained an NIH fellowship to work in the newly formed Department of Machine Intelligence and Perception in Edinburgh. My mentor, Christopher Longuet-Higgins suggested that I study geometric illusions. Since I knew nothing about illusions, I started reading, but this was discouraged since "reading rots the mind". A decisive step took place when Longuet-Higgins showed me a demonstration discovered by physicist Erich Harth in Syracuse. Take a blank paper and make a copy of it using a Xerox machine. Then keep iterating, always taking a copy of the last copy. Soon a stable dot pattern emerges (Beware - it no longer works!). To study the spatial autocorrelations of the dot pattern, I made a transparency to project on a bull's eye pattern. In the process, I superimposed the copy with the original and discovered striking circular images when the two images were slightly rotated with respect to each other. Under Longuet-Higgins' guidance, I managed to write up the description before leaving Edinburgh.

Jack Cowan had invited me to return to Chicago when I was done in Edinburgh. Although I had initially planned to keep working on vision, I was intrigued by results from Stuart Kauffman, one of Cowan's new recruits. Kauffman had shown that randomly constructed Boolean switching networks could fall into a small number of asymptotic behaviors. This was Kauffman's picture of how lots of genes could lead to a much smaller number of cell types. But I was bothered by the fact that Kauffman's models called for discrete states and discrete updating, and I worked to develop nonlinear equations that embodied the logical structure of the discrete time systems. This was my first contact with nonlinear dynamics, and I greatly appreciated the geometric approach. During my time in Chicago, I also had the good fortune to be inspired by seminal studies that were being carried out by other Chicagoans including Art Winfree, John Tyson, Hugh Wilson, Stuart Newman, and Jack Feldman.

In 1972 I migrated to Elliot Montroll's group in Institute for Fundamental Studies at the Department of Physics and Astronomy at the University of Rochester. In Rochester I followed up on several projects that emerged from my earlier studies on vision, pattern formation, and dynamics in model gene networks in collaboration with Ronald Shymko, Rafael Perez Pascual, and Joel Pasternack.

While in Rochester, I realized that it was essential to have more contact with experimentalists. I had met Michael Mackey at Gordon Conferences in Mathematical Biology in the early 1970s. Mackey was a young faculty member in the Department of Physiology at McGill and was searching for someone to build up mathematical physiology with him. This was the opportunity I had been seeking and I accepted the job enthusiastically.

At about that time in the summer of 1975, I attended a workshop in Aspen where I learned about "chaos", i.e., aperiodic dynamics in deterministic systems. Returning back to Montreal, Mackey and I posed the question, "Could physiological systems display chaotic dynamics." We wrote a team grant to the Natural Sciences and Engineering Council of Canada, which was funded for the remarkable sum of $7000/year. We developed time delay differential equations for physiological control including one that displayed chaos. We also used the term "dynamical disease" to refer to abnormal pathological dynamics arising as a consequence of a bifurcation in the underlying physiological control system. This work set the theme for the rest of my career.

Was it possible that complex dynamics in physiological systems could be identified with chaotic dynamics? Early mathematical studies showed that chaotic dynamics could be found by periodically forcing nonlinear oscillators. Translating this to physiological experiments, graduate student Gino Petrillo studied mechanically ventilated cats in collaboration with respiratory physiologist Teresa Trippenbach. This was shortly followed by graduate student Michael Guevara who suggested searching for chaos by carrying out periodic pacing of the heart. This became feasible when the cardiac electrophysiologist Alvin Shrier was recruited to McGill. Guevara's massive thesis carried out extensive analysis on the resetting and entrainment of periodically forced chick heart aggregates and demonstrated (to my satisfaction at least) chaotic dynamics over limited ranges of stimulation amplitude and phase.

Guevara's enthusiasm for cardiac arrhythmias was contagious, and a major part of my work has continued with the analysis of mechanisms of cardiac arrhythmias in biological and mathematical models as well as in people. But I have also managed to continue studies in dynamics in other biological systems including genetic networks, vision, and motor systems. Throughout I have had the great fortune to collaborate with a remarkably talented group of colleagues and students including Alvin Shrier, Jacques Bélair, Daniel Kaplan, Jim Keener, Anne Beuter, Jim Collins, Ary Goldberger, Rod Edwards, Ted Perkins and many, many more (apologies for not naming all).

I am struck by how convoluted my path has been, and how much it has been affected by what appears to me to be chance decisions. Although, I am now honored to be the Isadore Rosenfeld Chair in Cardiology at McGill, during my PhD and the following seven year period, it was not clear if I would be able to find a job.

It is a rare privilege to be a scientist and to have the opportunity to think about interesting problems every day and to teach students about ideas I find fascinating. Through the community of scientists I have met fascinating people and have made many lifelong friends. I have been honored by colleagues in three different professional societies (APS, SIAM and SMB) to have been elected to serve in executive positions or committees.

For those at an early stage of their careers I have two suggestions: "Have confidence that what you are doing now will work out, and the tenacity to make sure that it does," and "Look at the data!"

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