

# Chaos Math, Brain Science, and Mind Philosophy

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## **Abstract**

Since 1960 at least, I have been sharing chaos thinking with my brother Fred, and reciprocally, learning about brain research from him. This is a brief reminiscence of those early years.

**Dedicated to Walter Freeman (1927–2016)**

## **1. Introduction**

After my freshman year in engineering at the University of Vermont, I moved to the University of Michigan for a developmental trajectory from electrical engineering to experimental particle physics, applied math, then finally pure math. In 1960, with a fresh PhD, I moved to Berkeley for my first job. The math department there had just expanded into a major international center. I met and began joint work with Steve Smale and a large and changing group on dynamical systems theory. Meanwhile, Fred had finished his PhD at Illinois and moved to UCLA in 1962.

## **2. Chaos math, the early years**

During my first year in Berkeley, 1960-61, my group included Steve Smale, Moe Hirsh, Mauricio Peixoto, Bob Williams, René Thom, Chris Zeeman, and other mathematicians of note, some of whom became main figures in chaos theory and catastrophe theory as the 1960s unrolled. The next year, 1961-62, Steve moved to Columbia university, and the following year I followed him there to facilitate our joint work. After that year, in 1963, he returned to Berkeley, while I remained at Columbia, and then moved to Princeton in 1964. These were golden years for mathematics, while the world around us suffered the Bay of Pigs, the Cuban Missile

Crisis, the assassinations of JFK, RFK, MLK, and Malcolm X, and the fights for civil rights and to end the Vietnam war.

As for dynamical systems theory, our work, sometimes called the Smale program, was devoted to the basic ideas of generic properties, structural stability, and bifurcations. Eventually, some of our optimistic predictions were foiled by clever counter examples, and the experimental discovery of chaotic behavior by Yoshi Ueda in 1961, and Ed Lorenz in 1963.

After a summer-long summit conference in Berkeley in 1968 our group splintered as people returned to the drawing board, browsing various sciences for fresh ideas. And I left Princeton to return to California. In the first half of 1968-69, my conversations with Fred resumed, and contact with Steve Smale as well. The second half of that year I spent at Chris Zeeman's new institute, the Maths Research Centre, at the University of Warwick in Coventry, UK. Most of the dynamics gang reconvened there, in a sort of wake for our failing program, and desperate search for new directions, Thom's catastrophe theory leading the way.

In the following years, catastrophe theory fell by the wayside. Dynamical systems theory became known as chaos theory after influential articles by Robert May in 1974, and Li and Yorke in 1975. In the early 1980s, my dynamics picture book, joint with Chris Shaw, became a learning opportunity for scientists in various fields, including the neurosciences. Fred leveraged this work into texts specially tuned for psychology, and these became influential, along with his Society for Chaos Theory and Psychology.

After a short wave of popularity around 1987, chaos theory followed catastrophe theory into the twilight.

### **3. Brain science, primitive thoughts**

Fred meanwhile had created a large lab at the BRI devoted to EEG analysis involving human brains as well as simpler organisms. I was excited by ideas involving large scale synchronization of electrical and chemical activity. At this early time, around 1971, I identified physical states of the biological neural network with mental states and thoughts, and tried to apply ideas of chaos and catastrophe theories to these states.

Besides Fred's influence in the early 1970s I had made the acquaintance of Walter Freeman, who had arrived in Berkeley in 1959. Computer graphic technology became available at UCSC in 1974. With this new technology I created images and animations of chaotic behavior for my classes, and for science conferences in the US and Europe. Dan Sunday, a mathematician with computer graphic skills, came to

Santa Cruz to work with me, and then moved on to Berkeley to work with Walter. Together they made computer graphic animations of Walter's EEG data showing waves of electrical activity on the olfactory cortex of cats or rabbits, which were very stimulating to my fantasies of chaotic dynamics in neural networks. These would be around 1980 I believe.

## 4. Mind philosophy, some experiments and fantasies

After teaching catastrophe theory in Amsterdam, 1971-72, I spent the rest of 1972 in India. There, through experiments with LSD and meditation in the Himalayan ambience of the guru, Neemkaroli Baba, I began to think of the mind as distinct from the brain, and but still behaving as a complex dynamical system. These ideas followed from my studies of Sanskrit literature such as *Yoga Vasistha* and other classics of Vedanta such as were provided by Neemkaroli's ashram. The ideas in this tradition included dynamical metaphors such as vibration and resonance, that I latter found fully expressed in Kashmiri Shaivism.

As I followed the evolving ideas of Walter Freeman and his joint work with Christine Skarda in the 1980s, I felt there was a convergence of chaos theory and mind philosophy that epitomized the potential benefit of mathematics to the science and philosophy.

## 4. Conclusion

If I am correct in this thinking, then the courageous use of chaos theory by Fred and Walter are precious examples of the best of applied math. Hopefully these developments will continue in future, to advance the life sciences, to inspire young scientists to follow new mathematical discoveries, and to apply them creatively in their work.

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