

## Remembering Dan Rudolph

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Dan Rudolph died on 4 February 2010, following a long struggle with ALS (amyotrophic lateral sclerosis – ‘Lou Gehrig’s disease’). He was one of the world’s leading ergodic theorists, and combined mathematical brilliance with an extraordinary positivity and generosity of spirit.

### 1. *Early years (1949–1972)*

Dan was born in 1949 in Sheridan, Wyoming, the middle of three sons. Early in his life, the Rudolphs moved to Fort Collins, Colorado. There; Dan was raised on the family farm. He was very active in high school (Chemistry Club, Physics Club, Computer Club, Flying Club, Student Council, Westinghouse Science Talent Search Semifinalist).

Dan graduated from Fort Collins High School in 1968. He went to Cal Tech with a Sloan Scholarship, planning a career in theoretical physics. Instead, he committed himself to mathematics. Before graduating in 1972, he won Cal Tech’s Bell Prize for Undergraduate Mathematics Research.

### 2. *Graduate study at Stanford (1972–1975)*

Dan arrived at Stanford in a period when it was an epicenter of revolutionary work in ergodic theory, following Don Ornstein’s proof that Bernoulli shifts of equal entropy are measurably isomorphic (*Advances in Mathematics*, 1970). Visitors and students congregated at Stanford, especially over the summers, developing the new methods, solving old problems and creating new ones, with long daily lunches in the sunshine outside the Student Union. Dan gravitated to the excitement, and wrote his Ph.D. thesis under Don Ornstein.

It is hard to overestimate Ornstein’s influence in setting the direction of Dan’s mathematics. Ergodic theory for decades had been dominated by functional analysis. The complementary style of ergodic theory in the Ornstein school was measure theory with deep combinatorial insight and barehanded invention. This style seemed for Dan as natural as breathing, and it was the core of his mathematical work.

### 3. *Postdoctoral years (1975–1981)*

The Institute for Advanced Study at Hebrew University in Jerusalem, in its inaugural year, held a program in ergodic theory, attracting most of the world's very best. Dan was a postdoctoral fellow (August 1975–August 1976) at the Institute for this program. It was after that year, Ornstein said, that he realized what a formidable mathematician Dan was. In particular, Dan solved one problem ('When are two-point extensions of Bernoulli shifts also Bernoulli shifts?') which was central to several things on which people were working, and which had resisted Ornstein and others. In the solution of this problem Dan developed the method of 'nesting', which evolved into a very powerful tool. It was also there that Dan began his studies in the varieties of orbit equivalence.

Dan was subsequently a Fellow of the Miller Institute at U. C. Berkeley (1976–1978) and an assistant professor at Stanford University (1978–1981). He spent the fall of 1979 away from Berkeley at the University of Maryland, which was holding a Special Year in dynamics. One center of activity was the 'Ergodic House' where Dan and three fellow dynamics visitors (Bruce Kitchens, Brian Marcus and Laif Swanson) lived, and others (such as Doug Lind and Andres del Junco) often congregated.

### 4. *The Maryland years (1981–2004)*

It was during this major period of his career that Dan developed into one of the world leaders in ergodic theory. In addition to his many activities in Maryland, he made several long trips abroad to France, Poland and Israel, where his influence is still felt today. He organized many meetings and special year events at Maryland and turned it into one of the leading centers for research in classical ergodic theory.

4.1. *Awards.* Dan's excellence was recognized in some formal ways during the Maryland years. He was awarded a Sloan Fellowship in 1981. Each year, the University of Maryland elevates five faculty members to the status of 'Distinguished Scholar Teacher'; in 1987, Dan achieved this status. He was an outstanding teacher at all levels. In 2002, he gave a 45-minute invited lecture at the Beijing International Congress of Mathematicians.

4.2. *Style.* Whether giving a mathematics talk or teaching a mathematics class; Dan was a performer. He was dynamic, in motion, on a stage. Perhaps leaning far forward on one foot, or pulling forward on a mime's invisible taut rope or striking a pose. This physical expression reflected his other life in modern dance.

His relentless positivity was humbling and inspiring. In a problematic colleague, he would see the part to admire; with a problematic student, he would find some path to success. Dan did not write people off. He brought out the best in the people he knew.

Dan was an early riser: a farm boy gets up and does his chores. For a while, he kept a sign up in his Maryland office: 'Eat problems for breakfast'. At a conference, he might wander off early to a coffeehouse and six (!) shots of espresso, and return to meet groggy colleagues with a theorem.

While some of Dan's papers were difficult to read, in person he expressed the insight and ideas elegantly.

4.3. *Students.* Dan was very committed to his students. He directed nine Ph.D. theses at Maryland, and a tenth at Colorado State.

- (1) Janet Kammeyer (1988) A complete classification of the two-point extensions of a multidimensional Bernoulli shift.
- (2) Aimee Johnson (1990) Measures on the circle invariant for a nonlacunary subsemigroup of the integers.
- (3) Wojtek Bulatek (1993) Smooth, weakly mixing, weakly isomorphic but not isomorphic flows.
- (4) Ayşe Şahin (1994) Tiling representations of  $\mathbb{R}^2$  actions and alpha-equivalence in two dimensions.
- (5) Deborah Hecklen (1997) Decreasing sequences of  $\sigma$ -algebras in ergodic theory.
- (6) Florence Newberger (1998) The ergodic theory of the Bowen–Margulis measure.
- (7) Karen Ball (2002) Entropy and sigma-algebra equivalence of random walks on random sceneries.
- (8) Chao-Hui Lin (2002) Kakutani shift equivalence for uniformly dyadic endomorphisms.
- (9) David McClendon (2006) Orbit discontinuities and topological models for Borel semiflows.
- (10) Eric Holt (2009) A ratio ergodic theorem for Borel actions of  $\mathbb{Z}^d$  and  $\mathbb{R}^d$ .

His students remembered a number of features of Dan’s advising. He did not suffer foolishness lightly. He was demanding, but very supportive. He was respectful and supportive of their individual goals. For training, he believed in focusing and honing skill and eventually expanding expertise. But within this work he always showed the context and helped develop the big picture. He was humorous. He was generous with time and with friendship.

4.4. *Service.* Dan was a stalwart of service in Maryland’s mathematics department. He was chair of the graduate program and acting chair of the department. He was a leader in developing a Treisman-style calculus program. He founded and directed the SPIRAL program, an intensive six-week preparation for graduate study in the mathematical sciences, developed in close coordination with a group of minority-serving colleges and universities. This program was acknowledged by the AMS with its 2008 Award for Mathematics Programs That Make a Difference.

Dan served three years as graduate chair, and for an additional year was acting chair of the department. In the ‘VIGRE’ period, with different colleagues, Dan led the department’s application for an NSF VIGRE Grant five times, and succeeded on the fifth. (It may require some background to appreciate the pain of that process.) Dan wasn’t much for quitting.

4.5. *Before marriage.* Although Dan had taken dance classes already as a Cal Tech undergraduate, it was at Maryland, initially inspired by Alvin Mayes, that he became a serious modern dancer. Time demands were no problem; he found the dance activity improved his mathematics. Dan was a regular performer in different years with Alvin Mayes, Jan Taylor, Sharon Wyrick and others. In 1991, Alvin choreographed a duet ‘For Bill and Johnalou’, dedicated to Dan’s parents, and performed for them by Dan and Susan Barnett.

Dan's days were at the University. Evenings were for dance and friends (for example at the Brins', playing charades). Dan's pets were . . . turtles.

4.6. *Marriage and family.* Dan Rudolph and Michelle Hyde married in 1991, and went on to have three children (Beatrice, Jonah and Layton). Dan was a completely devoted father and husband. The evenings at play and the dance were gone. He was home early for dinner and family, back to mathematics after the children were asleep.

#### 5. *Colorado (2005–2010)*

In 2005, Dan and Michelle moved their family from the suburbs of Washington DC to the open space and mountains of Dan's old home town Fort Collins, where he assumed the Albert C. Yates Endowed Chair in Mathematics at Colorado State University.

In Colorado, as worrisome symptoms progressed into serious illness, Dan was diagnosed with the ALS. He met the disease with that remarkable positivity. At one ALS website, a member posted a list of 100 things that made his life worth living, which he was losing one by one; he said he would kill himself when only 50 remained. Dan said, when he lost one, he would find another one to put on the list.

ALS or no, Dan was working as hard as ever at Colorado. Though some physical activities became impossible, he continued to teach and do major department service. He directed the Ph.D. thesis of Eric Holt, and was supervising the thesis work of Bethany Springer and Niketa Salvi when he died. (They are finishing their Ph.D. work under Andres del Junco and Ayşe Şahin, respectively.) With the Yates Chair funds, Dan supervised postdoctoral students, and began a regional dynamics conference at Pingree Park, which attracted mathematicians much more widely. With a middle school teacher, Martha Cranor, he began a Math Circle for middle school girls. Colorado State University later extended this to a summer Math Circles camp, for middle school girls and boys.

As always, the mathematics was there for him. One of his final papers, the joint *Annals of Mathematics* paper with Matt Foreman and Benjamin Weiss, culminated years of work.

#### 6. *Conclusion*

Dan Rudolph was a remarkable mathematician and person, taken too early, sorely missed by those who knew him, but gratefully remembered.

*Acknowledgements.* For help with the preparation of this article, we thank Joe Auslander, Michael Brin, Aimee Johnson, Bruce Kitchens, Doug Lind, Nelson Markley, Jim Rudolph, Ayşe Şahin and Bethany Springer.