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In Memoriam

Garrett Birkhoff

January 10, 1911–November 11, 1996

Mathematics has lost a superstar in Garrett Birkhoff. The son of a famous mathematician, George David Birkhoff, Garrett showed tremendous brilliance in mathematics already at an early age, and his contributions in various areas of mathematics are well known. A member of the prestigious Society of Fellows at Harvard (1933–1936), he spent almost all of his professional life at Harvard University. He is probably most famous for his early work in lattice theory and on universal algebras, and for the epoch-making book, "Survey of Modern Algebra," which he wrote jointly with Saunders Mac Lane. But his research contributions ranged from abstract algebra to the numerical solution of elliptic PDEs to fluid flow and reactor calculations to spline approximation. Because of his interest in splines and their use in approximation theory, he was asked to join the founding editorial board of the *Journal of Approximation Theory* in 1968, remaining as an editor until 1990.

To describe more carefully Garrett's contributions in the area of spline approximations and their applications, Garrett began his consulting work with General Motors Research in 1959. One of the problems posed there was the mathematical representation of automobile surfaces in order to exploit the then new numerically controlled milling machines for the cutting of dies; these dies were needed for stamping of the outer and inner panels of automobiles. Garrett was quick to recommend the use of cubic splines (i.e., piecewise cubic polynomials with two continuous derivatives) for the representation of smooth curves. (He was familiar with their use in ship design through his earlier contact with the David Taylor Model Basin.) In [4], Garrett and Henry Garabedian developed a bivariate generalization of cubic spline interpolation which was capable of interpolating a C^1 surface to a given rectangular mesh of cubic splines. This method eventually led Carl de Boor to the now standard method of bicubic spline interpolation.

Garrett Birkhoff published several papers, some listed below, dealing with various aspects of splines; the survey paper [3] provides a very good record of his many and wide-ranging ideas and results. It is also important to add here that in [2] he proposed what was probably the first spline

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quasi-interpolant, i.e., a fundamental method of approximation which is local and stable and aims only at reproducing all polynomials of a certain degree (rather than at matching function values). Birkhoff's method is now treated more generally in terms of the de Boor–Fix quasi-interpolant.

His honors were many, among them membership in the National Academy of Sciences and the American Academy of Arts and Science, six honorary degrees, and a Guggenheim Fellowship.

In the many obituaries written recently for Garrett Birkhoff, one item has not been mentioned: he had, at Harvard University, 50 Ph.D. students, many of whom have become leaders in their own fields. This is, to us, a significant part of Garrett Birkhoff's legacy in mathematics, and we give below the complete list of these students.

We shall truly miss him.

PH.D. STUDENTS OF GARRETT BIRKHOFF (1936–1978)

1936	Joel Brenner (finite groups)	University of Arizona (retired)
1940	John Dyer-Bennet (free real algebra)	Carleton College
1941	Philip Whitman (free lattices)	Rhode Island College (retired)
1942	Murray Mannos (vector lattices)	Mitre Corp.
1945	Richard Arens (general topology)	U.C.L.A.
1945	Jeremiah Certaine (1-groups)	United Nuclear
1946	Pesi Masani (product integration)	University of Pittsburgh
1947	Thomas Caywood (potential theory)	Caywood–Schiller Associations
1947	Frank Stewart (product integration)	Brown University
1948	George Mostow (Lie groups)	Yale University
1948	Marion Heineman (kinetic theory/ physics)	
1950	Bruce Crabtree (derivatives in hypercomplex algebras)	Stevens Institute of Technology
1950	Chandler Davis (1-semigroups)	University of Toronto
1950	William A. Pierce (free mobility axioms for geometry)	Lyndonville, Vermont
1950	John Sopka (Reynolds operators)	Boston College
1951	Lawrence J. Markus (ordinary DEs)	University of Minnesota
1951	David Young (numerical analysis)	University of Texas–Austin
1953	Martin Abkowitz (submarine dynamics/physics)	
1953	Samuel Kneale (hydrodynamics) (operational research)	(retired)
1956	James Howland (potential theory)	University of Ottawa

1959	Thomas Mullikin (C_o-semigroups)	Purdue University
1960	Martin Leibowitz (neutron slowing down/applied math)	SUNY at Stony Brook
1961	John Bennett (numerical analysis/ applied math)	United Aircraft
1962	Thomas Brown (ordinary DEs)	RAND Corp.
1962	Tyrrel Rockafellar (convex programming)	University of Washington
1963	Robert E. Lynch (numerical analysis/ applied math)	Purdue University
1963?	Uta Merzbach (history of math)	Smithsonian Institution
1965	Jose Canosa (reactor dynamics/ physics)	IBM Research, Palo Alto
1965	Martin Schultz (numerical analysis)	Yale University
1966	I. Abu-Shumays (neutron theory/ physics)	Westinghouse–Bettis Lab.
1966	Kirby Baker (free vector lattices)	U.C.L.A.
1966	Henry Wente (Plateau problem)	University of Toledo
1967	S. Nagpaul (lubrication theory/ applied math)	St. John's College, India
1968	George Fix (numerical analysis/ applied math)	University of Texas–Arlington
1968	Walter Taylor (ultraproducts, etc.)	University of Colorado
1969	Bernie J. Hulme (numerical analysis/ biharmonic DE)	Hulme Math.
1969	Emmett Keeler (mathematical economics)	RAND Corp.
1969	John Lipson (flowgraphs/applied math)	University of Toronto
1970	Donald Rose (sparse matrices/ applied math)	Duke University
1970	Vern Poythress (universal algebra)	University of California–Davis
1970	Gary Wakoff (numerical analysis/ applied math)	Bell Telephone Co.
1971	Richard Goodman (numerical analysis)	University of Miami
1971	Arthur Priver (computer graphics/ applied math)	U.S. Department of Transportation
1971	Alan G. Waterman (university of algebra)	
1971	Jerry Bona (statistically well-set Cauchy problems)	University of Texas–Austin

1973	Gerald Edgar (general topology)	Ohio State University
1973	George Markowsky (lattices)	University of Maine, Orono
1976	Vassilios A. Dougalis (numerical fluid dynamics)	University of Athens
1976	Peter Olver (groups and DEs)	University of Minnesota
1978	Barbara Epstein (Tokamak reactors)	Sandia Labs.

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4. G. Birkhoff and H. L. Garabedian, Smooth surface interpolation, *J. Math. Phys.* **39** (1960), 258–268.
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