IN MEMORIAM

RAPAHAEL MITCHELL ROBINSON (1911 - 1995)

Rapahael Mitchell ROBINSON died on 27 January 1995. He was born on 2 November 1911 and was Professor Emeritus at the University of California at Berkeley.

Among Robinson's colleagues at Berkeley was Alfred Tarski, who, wrote Robinson's sister-in-law Constance Reid, "had great respect for Raphael and often talked with him about problems" (p. 273, D.J. Albers, G.L. Alexanderson & C. Reid (editors), *More Mathematical People* (Boston/San Diego/New York, Harcourt, Brace, Jovanovich, 1990)).

Robinson was interested in number theory and worked on applications of logic, especially recursion theory, to problems in number theory. Some of his publications included "The Theory of Classes, a Modification of von Neumann's System" in *The Journal of Symbolic Logic* **2** (1937), 29–36, "Primitive Recursive Functions", *Bulletin of the American Mathematical Society* (1) **53** (1947), 925–942, "Recursion and Double Recursion", *Bulletin of the American Mathematical Society* (1) **54** (1948), 987–993, "Arithmetical Definitions in the Ring of Integers", *Proceedings of the American Mathematical Society* (1) **2** (1951), 279–284, "Arithmetical Representation of Recursively Enumerable Sets", *Journal of Symbolic Logic* **21** (1956), 162–186, which was translated into Russian in *Matematika* **8**, no. 5 (1964), 23–47, and "Some Representation of Diophantine Sets" *Journal of Symbolic Logic* **37** (1972), 572–578, "Restricted Set-theoretical Definitions in Arithmetic", *Proceedings of the American Mathematical Society* (1) **9** (1958), 238–242; with Tarski and Andrzej Mostowski, he contributed to the book *Undecidable Theories* (Amsterdam, North-Holland, 1953). It was also a discussion in 1948 between Tarski and Raphael Robinson that led Raphael's former student and then wife, Julia Robinson, to her work on Hilbert's tenth problem (p. 273, D. J. Albers, G. L. Alexanderson & C. Reid).

HAO WANG (1921 - 1995)

Hao WANG (who was also sometimes known by the more traditional Chinese form of his name, as Wang Hao) died of lymphoma in New York City on Saturday, 13 May 1995. He is survived by his wife, a daughter, two sons, and two grandchildren. He was born in China on 20 May 1921. He made several lecture trips to China during his life, including for a period in the Winter of 1945-46. Thus, for example, his book *Popular Lectures on Mathematical Logic* (*1981*) grew out of six lectures he gave at the Chinese Academy of Science in October 1977. His former colleague Willard Van Orman Quine (*1985*, 306) called him "a gifted mathematical logician."

Professor Wang was one of few confidants of Kurt Gödel. He was one of the founding members of the Gödel Society, and its first president, from 1987 to 1989. His book *Reflections on Kurt Gödel* (*1987*), along with lesser papers "Kurt Gödel's Intellectual Development" (*1978*) and "Some Facts about Kurt Gödel" (*1981*) shares the intellectual fruits of his personal contacts with Gödel. He had a lively interest in the history of logic. His *Popular Lectures on Mathematical Logic* (*1981*; 1993 edition) begins, for example, with a ten-page survey of "One Hundred Years of Mathematical Logic" and in his (*1965*) paper on "Russell and His Logic" he delved in significant detail into Russell's contributions to mathematical logic, writing (*1965*, 1) that "professional mathematicians tend to regard [Russell] as an outsider, although in terms of intellectual power he is widely ranked with the best among scientists and mathematicians", adding (*1965*, 1–2) that "one feels slightly embarrassed when Russell writes that, having done all he set out to do in mathematics, he turned his attention to other matters in about 1910".

He wrote or contributed to the writing of some of the introductions in Jean van Heijenoort's *From Frege to Gödel*, and sometimes assisted with the translation of some of the German texts for the book. In particular, van Heijenoort tells us in the "Preface" to *From Frege to Gödel* (*1967*, viii) that Wang was among those who "generously contributed their time in helping me to select the texts" and "also lent a hand with clarifying passages in the originals or smoothing out phrases in the translations," and that Wang wrote the introduction to van Heijenoort's translation to 1925 Kolmogorov's "On the Principle of Excluded Middle" (Wang *1967c*).

Wang was an active participant at meetings. He attended the Cornell Summer Institute in Symbolic Logic in 1957, at which Alonzo Church, Haskell Brooks Curry, Burton Dreben, Solomon Feferman, Stephen Cole Kleene, Georg Kreisel, Charles D. Parsons, Willard Van Orman Quine, Abraham Robinson, John Barkley Rosser, Alfred Tarski, and Jean van Heijenoort were also present, but which his friend Gödel did not attend. In 1966 he began organizing an informal discussion group in logic in the mathematics department of Rockefeller University (see his (*1989*) letter to Anellis), where he arrived that same year and which then served as his home institution for the remainder of his academic life. These occasional meetings were attended by many of the leading logicians in the vicinity of New York City. Prior to moving to Rockefeller University, he was at Harvard University, where he had taken his doctorate.

In 1983, he attended the American Mathematical Society's annual meeting that was held in Denver, Colorado from 5 to 9 January. At the Special Session on Proof Theory organized by Irving H. Anellis and Grigorei E. Mints, he spoke on "Gödel's and Some Other Examples of Problem Transmutation"; and at the Special Session on Automated Theorem Proving: After 25 Years" organized by W. W. Bledsoe and Donald W. Loveland, he spoke on "Automatic Theorem Proving and Artificial Intelligence." Both talks were published, the latter in (*1984*), the former not until (*1991*). During the Denver meeting, Wang was awarded the first Milestone Prize for his pioneering work in automated theorem proving in the early years of research in that field. Otherwise, Wang's presence at the Denver meeting was enlivened by a minor accident: leaning forward on a table perched precariously close to the edge of the speaker's platform during his talk at the special session on proof theory (the most well attended of the special session after Henkin's), he very nearly knocked over the table (catching the table at just the last moment), as a consequence of which, however, the overhead projector was knocked over and a pitcher of water fell off the table, broke, and spilled its contents and shards of glass at the feet of Anellis and Gaisi Takeuti.

The "Citation for Hao Wang as Winner of The Milestone Award in Automated Theorem-Proving" (in Bledsoe & Loveland *1984*, 49), signed by Martin Davis (Chairman), David Luckham, and John McCarthy list the following contributions which Wang made "to the founding of the field" of automated theorem proving:

> 1. He emphasized that what was at issue was the development of a new intellectual endeavor (which he proposed to call "inferential analysis" which would lean on mathematical logic much as numerical analysis leans on mathematical analysis;
>
> 2. He insisted on the fundamental role of predicate calculus and of the "cut-free" formalisms of Herbrand and Gentzen;

3. He implemented a proof-procedure which efficiently proved all of the over 350 theorems of Russell and Whitehead's *Principia Mathematica* which are part of the predicate calculus with equality;

4. He was the first to emphasize the importance of algorithms which "eliminate in advance useless terms" in a Herbrand expansion;

5. He provided a well-thought out list of theorems of the predicate calculus which could serve as challenge problems for helping to judge the effectiveness of new theorem-proving programs.

As Solomon Feferman (*1993*, 383) has said, Herbrand's Fundamental Theorem has "been used in recent years as the basis for one approach to automated deduction." This connection dates back to at least to the late 1950s, when Hao Wang (*1957*, 91; *1970*, 157) declared that

> A fundamental result of Herbrand has the effect that any derivation of a theorem in a consistent axiom system corresponds to a truth-functional tautology of a form related to the statement of the theorem and the axioms of the system in a predetermined way. This and the possibility... of viewing axiom systems as proof-grinding machines to the investigation of the question of derivability in general, and inconsistency (i.e. derivability of contradictions) in particular of axiom systems.

This led Wang, working at IBM and then AT&T's Bell Laboratories in the following three years (1958, 1959–1960) to develop three programs (Wang machines), based upon Gentzen-Herbrand methods, for automated theorem proving for propositional logic (*1960*), for a decidable fragment of first-order predicate logic (*1960a*), and for all predicate calculus (*1961*). The latter program proved some 350 theorems of *Principia Mathematica*, albeit admittedly rather simple theorems of pure predicate calculus with identity; but this work became the benchmark for testing the abilities of other theorem provers that would be developed. (This work is recalled in Wang's (*1984*).) More specifically, the work was based, Wang (*1960*; see *1970*, p. 228) wrote, on cut-free formalisms of the predicate calculus initiated by Herbrand (*1930*) and Gentzen (*1934*)," with ideas borrowed from Hilbert and Bernays (*1939*), Dreben (*1952*), Beth (*1957*), Hintikka (*1955*; *1955a*), and Schütte

(*1956*), among others. (For a discussion of logical aspects of the history of automated theorem proving from 1957 to 1982, including in particular a survey of the work of Wang and the related work of Paul C. Gilmore and of John Alan Robinson, and a consideration of the general background for the development of Robinson's resolution method, see Donald W. Loveland (*1984*), especially pp. 6–8, and Jack Minker (*1986*), pp. v–viii; also see especially Daniel J. O'Leary (*1991*, 49–51) for a sketch of the work of Wang's automated theorem proving techniques for proving theorems of *Principia*, along with examples of two proofs using Wang's program.)

Wang also had an impact on work in 'pure' logic, most notably showing how to repair a problem arising in Quine's treatment of ordinal numbers in the first (1940) edition of *Mathematical Logic*; the problem was that Rosser showed in October 1941 that the Burali-Forti paradox could be derived in the set theory of *Mathematical Logic*. Calling this the "B40 diasater", Quine (*1985*, 146) recalled that Wang showed "what should have been done," namely:

> If the sets of *Mathematical Logic* were really not to exceed the classes of "New foundations," the bound variables in their membership conditions should be limited to sets for their values. Such was Wang's neat repair of *Mathematical Logic*, occasioning the revised edition, 1951.

Quine (*1985*, 146) also notes that the NF system still "retained interest, for Wang proved that *Mathematical Logic* as revised is consistent if and only if" NF is consistent.

Wang's interest in pure logic was exemplified also in his writings, mostly from the 1950s and '60s, on formal systems of logic, including, for example, a joint paper with John Barkley Rosser on nonstandard models of formal logic. His interest in set theory was reflected by a number of papers, written largely during that same period, on the set-theoretical axiomatization of number systems.

Quine's (*1985*, 306) assessment of Hao Wang's life during the period when Quine knew him best, 1942 to 1966, reflects on the personality of the man. For those of us who did not know him can help us to understand his difficult life. Quine writes:

> ...His was a persistently unhappy life amid success and good fortune. When I first heard from him, in 1942, he was unhappy in China and wanted to be brought to America. As a brilliant graduate student at Harvard he was unhappy in his insecurity. Publication and a Ph.D., he felt, would make all the difference. Both were forthcoming, as well as a

> Junior Fellowship in the [Harvard] Society of Fellows. Unhappy in his celibacy, he married an attractive and capable young geologist, Yenking. He was again unhappy, and they separated. He spent the third year of his Junior Fellowship at Zurich with Bernays, and from there he wrote me that any hope of happiness hinged on a post in philosophy at Harvard. We appointed him He was not called on to teach anything off his beat, but he was unhappy. He arranged a year's leave to work at Burroughs and see how he liked the computer industry. At length he accepted a readership at Oxford. He and Yenking, reunited, were perhaps happy there, but after some years he was lured back to a chair at Harvard in computer theory. Such was his post in the spring of 1964, when we collaborated briefly on neat ways of generating infinite ordinals. By then he was outspokenly bitter about the West and staunch for Red China. His move to Rockefeller University was still to come.

I do not know whether Hao Wang found happiness, or at least finally contentment, at Rockefeller University. But certainly in his last years at Harvard, during his stints at IBM and then at AT&T's Bell Laboratories, and through much of the rest of his career, he conducted work in automated theorem proving and on the logical foundations of computer science that by themselves alone more than amply justified Quine's assessment of him as "a gifted mathematical logician."

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CHRISTOPHER JOHN ASH

Christopher John ASH died in February 1995. He was 50 years old and had been on the faculty of Monash University in Australia. He had studied at Oxford under John N. Crossley and moved to Monash with Crossley. He was best known for his work in recursive structure theory, which grew out of joint work that he had carried out with Anil Nerod. Examples of his research can be seen in his paper "Categoricity in Hyperarithmetical Degrees", *Annals of Pure and Applied Logic* **34** (1987), 1–15 and in his joint paper with Rod G. Downey, "Decidable Subspaces and Recursively Enumerable Subspaces", *Journal of Symbolic Logic* **49** (1984), 1137–1145. He participated with Crossley, C. J. Brickhill, J. C. Stillwell, and N. H. Williams in writing *What Is Mathematical Logic?* (Oxford University Press, 1972; reprinted: Dover, 1990), based on a popular series of lectures for non-mathematicians which he and Crossley organzied at Monash University and the University of Melbourne in the autumn and winter of 1971.

JOHN VINCENT ATANASOFF (1903 – 1995)

John Vincent ATANASOFF died of a stroke at his home in Frederick, Maryland on 15 June 1995 following a prolonged illness. He was born in Hamilton, New York on 4 October 1903.

In the first months of 1937 that he conceived the idea of combining electronics, binary arithmetic, and Boolean algebra to build an electronic digital computer, using binary arithmetic for computation, Boolean switching-relay circuitry for machine logic, and electricical and electronic components for machine hardware.

The Editor