Wilfred Kaplan has been associated with the University of Michigan since 1940. After completing his Ph.D. at Harvard in 1939 under the guidance of Hassler Whitney, he spent a year at the College of William and Mary before accepting T. H. Hildebrandt's bid to come to Ann Arbor. His research has concerned the topology of curve families, dynamical systems, and complex function theory. He is the author of influential textbooks on mathematics for engineering students, including Advanced Calculus, Ordinary Differential Equations, and Operational Methods for Linear Systems. *For many years he has played an active role in the AAUP, serving for a time on the national Executive Committee.*

Mathematics at the University of Michigan

WILFRED KAPLAN[1]

INTRODUCTION

This article is confined to the story of the Mathematics Department in Ann Arbor. For the period up to 1940 an excellent history appeared in [2]. This provides much detail about the professors and curriculum. Because of the availability of this source, the early period will be treated rather concisely.

THE PERIOD TO THE END OF WORLD WAR II

The first hundred years. The University of Michigan traces its beginning back to 1817, when a Catholepistemiad of Michigan was created in Detroit [4, Chapter 1]. The primitive conditions, however, prevented realization of the plan until 1837, when regents were appointed for an institution in Ann Arbor. It took four more years before buildings could be erected and five professors appointed. On September 25, 1841 instruction began, with seven students in classes taught by two professors: the Reverend George P. Williams for mathematics and science, the Reverend Joseph Whiting for Greek and Latin.

[1]The present article has been prepared, in accordance with advice from the editors, as a shortened version of an article on file at the departmental office in Ann Arbor, including a list of all faculty from 1841 to 1988.

By 1854 there were sixty-three freshmen and a comparable number in the three higher classes and Professor Williams was being assisted by professors from other disciplines. The curriculum covered algebra, geometry (Legendre), trigonometry, analytic geometry, calculus.

In 1863 Williams became Professor of Physics and Edward Olney was appointed Professor of Mathematics. Until 1872 Olney and one instructor did the teaching. From 1872 to 1877 the staff gradually rose to five. The curriculum expanded slightly, with encouragement to those who wished to pursue topics such as quaternions, calculus of variations and calculus of finite differences. Olney wrote several textbooks for the courses. By 1887 there were courses on projective geometry and the theory of functions, including elliptic functions.

The University's library had started with 3707 volumes (purchased for $5000), covering many fields. It offered little in mathematics and grew very slowly. A major improvement came in 1881 when a complete set of Crelle's Journal was donated.

From 1888 on the department expanded steadily. Notable additions were Alexander Ziwet and Frank N. Cole (Ph.D. Harvard, 1886), the first Ph.D. in mathematics to join the department. Both were much involved with the New York Mathematical Society, which became the American Mathematical Society (hereafter referred to as the Society) in 1894.

Cole was inspired by Felix Klein, whose seminar in Germany he attended in 1883–1885. In 1885–1886, as a graduate student at Harvard, he lectured on the new geometric function theory. He came to Michigan in 1888 and remained until 1895, when he went to Columbia. His years at Michigan were especially productive, yielding eight papers on group theory and a translation of E. Netto's *Theory of Substitutions.* This work stimulated further important work in the field. While in Ann Arbor, Cole had as student and colleague G. A. Miller, who later had an active role in the Society and a distinguished career in group theory. From 1896 to 1920 Cole was secretary of the Society. Concerning his career one is referred to [1], especially pp. 100–103.

Alexander Ziwet was on the publication committee of the Society from 1898 to 1912 and was vice-president in 1903–1904. His career at Michigan lasted from 1888 to 1925. He did much to improve the courses and the library, donating a large personal collection of books. He also left a bequest of about $20,000 to the University. The Ziwet Fund has supported a series of Ziwet lectures by outstanding mathematicians, beginning in 1936. From the obituary in the *American Mathematical Monthly* (vol. 36, 1929, p. 240), we quote: "Professor Ziwet was outstanding as a scholar and teacher. His range of knowledge was not limited to mathematics, especially from the applied point of view, but extended to many sections of pure mathematics, history of mathematics and the humanities. As a linguist he was perhaps unsurpassed

by any member of the University faculty.... He was a potent influence in the University, not only for high ideals in connection with engineering education, but also in the promotion of graduate work and research."

Another important figure was James W. Glover (Ph.D. Harvard, 1895), who was in the department from 1895 to 1937. In 1902 he offered the first courses in actuarial mathematics and over the years did much to build a strong program in this area. The interest in insurance mathematics had arisen much earlier: John E. Clark and Charles N. Jones were department members from 1857 to 1859 and 1875 to 1888, respectively, who later had careers with insurance companies.

We also mention Walter B. Ford (Ph.D. Harvard, 1905), who wrote on asymptotic series and summability theory; he was active in the Society, holding various posts; he was in the department from 1900 to 1940, but continued to be active in research until his death in 1971 at the age of 96. He was concerned about the college-level curriculum, wrote several textbooks for it, and was a great supporter of the Mathematical Association of America (MAA), of which he was president in 1927–1928. Early investments in IBM made him very wealthy and he gave generously to many philanthropies, as well as to the Chauvenet Fund of the MAA. In 1973, after his death, his son Clinton B. Ford gave a large sum to the MAA to create the Walter B. Ford Lecture Fund. The obituary (*Amer. Math. Monthly*, vol. 78, 1971, pp. 1094–1097) refers to his high standards for exposition: "A doctoral candidate under his supervision could always expect to prepare at least twenty drafts of his dissertation before its linguistic format would be approved."

Louis C. Karpinski (Ph.D. Strasbourg, 1903) was in the department from 1904 to 1948 and had a distinguished career in history of mathematics. Clyde E. Love joined the department in 1905 and had wide influence through his textbooks.

By 1908 the department had grown to twenty: four professors, two junior professors, five assistant professors, nine instructors. The curriculum included Fourier series and spherical harmonics, ordinary and partial differential equations, theory of substitutions, theory of numbers, theory of invariants, potential theory, courses for teachers.

In 1909 Theophil H. Hildebrandt (Ph.D. Chicago, 1910) joined the department and remained until 1957. A student of E. H. Moore, he did important work in functional analysis and integration theory. For example, in 1923 he gave the first general proof of the principle of uniform boundedness for Banach spaces, before the work of Banach and Steinhaus (1927). In 1928 he published a basic paper on the spectral theory of completely continuous transformations (compact operators) on Banach spaces, completing earlier work of F. Riesz. His pioneering research in these developing areas of analysis is

described by Dunford and Schwartz, *Linear Operators, Part I* (*Interscience*, 1958).

Tomlinson Fort was in the department from 1913 to 1917; he was active in the Society for many years. Harry Carver joined the department in 1916 and had a distinguished career in statistics; he was in many ways a pioneer in the development of this field in the U. S., having personally started the *Annals of Mathematical Statistics* and taking a leading part in the founding of the Institute of Mathematical Statistics. He remained until his retirement in 1961.

Beginning in 1901 there was a gradual separation of mathematics instruction for engineering students, with Ziwet in charge. This lasted until 1928, when the engineering department was absorbed in the original Mathematics Department in the college of arts and sciences. It should be remarked that at the University of Michigan, as at many other universities, the question of who should teach mathematics to engineering students has remained a bone of contention over all the years; many Engineering College professors have taught "engineering courses" indistinguishable from mathematics courses.

Around 1920 the curriculum expanded by introduction of courses in applied mathematics: vector analysis, hydrodynamics, elasticity, celestial mechanics; also courses in infinite series and products, divergent series, history of mathematics, graphical methods.

Wooster W. Beman functioned as chairman of the department from 1887 to 1922. He was succeeded by Joseph L. Markley, who held the title for only four years, when Glover became chairman. During Markley's term, there were several important additions to the staff: James A. Shohat, Ruel V. Churchill, Cecil C. Craig, Ben Dushnik. Shohat made important contributions to analysis, including a book on the moment problem written with J. D. Tamarkin; he was in the department from 1924 to 1930. The other three remained in the department until retirement. Churchill did much for the applied mathematics program and had wide influence through his books on applied analysis. Craig did important work in statistics. Dushnik was active in set theory.

Glover also brought in some new talent: George Y. Rainich and Raymond L. Wilder in 1926; Walter O. Menge in 1925; William L. Ayres and Arthur H. Copeland in 1929. Rainich, in relativity theory, and Wilder, in topology, did much to strengthen the teaching program and research, especially through seminars. Ayres was also an outstanding topologist and was active in the Society; he left the department in 1941. Menge strengthened the actuarial program; he remained until 1937. Copeland made important contributions to probability theory.

In many ways Hildebrandt, Rainich and Wilder brought the department to a higher level of breadth and seriousness. Each had appreciation for mathematics far beyond his special field and encouraged students and younger staff in all fields.

Most of Rainich's papers and his greatest achievements were on the theory of relativity. In a series of papers in the 1920s he showed that the mathematics of the general theory which Einstein had made to supply a model for gravitation, also supplied one for electromagnetism. Rainich ran an "orientation seminar" for advanced undergraduate and beginning graduate students, covering a broad spectrum of topics; he had a remarkable talent for building enthusiasm of the young students and encouraging them to make careers in mathematics. He and his wife, Sophie, often entertained new and old members of the department at their home and thereby did much to bring the new ones into the life of the department. As émigrés from Russia they brought cultural breadth to university life.

Wilder was a topologist of first order, a product of the R. L. Moore school and (as seemed to follow axiomatically) a superb teacher, using the Socratic method to let the students do the discovering. He had twenty-five Ph.D. students. Wilder was a pioneer in the development of the topology of manifolds. By methods of algebraic topology, he extended to higher dimensions many of the results of set-theoretic topology in the plane and 3-space. Some of his best achievements are found in his AMS Colloquium Publication *Topology of Manifolds* (vol. 32, 1949). He had very broad interests in topology and hence could recognize new talent of great variety. He also promoted interest in logic and foundations through a very popular course. He was president of both the Society (1955–1956) and the MAA (1965–1966).

Hildebrandt did much to encourage work in the rapidly developing area of functional analysis. He was very active in the Society and in the MAA, serving as president of the Society in 1945–1946. In 1929 he was the first recipient of the Chauvenet Prize, given for a 1926 paper on "The Borel theorem and its generalizations." In recognition of his leadership as chairman over twenty-three years, the T. H. Hildebrandt Research Instructorships (later Assistant Professorships) were introduced in 1962. He also had a great interest in music, acquiring a degree in that field in 1912 with the organ as specialty. A testimonial to him after his death in 1980 stated: "He was more than an outstanding scientist and enthusiastic expositor of mathematics; he was a leader who took a deep interest in the personal as well as the mathematical growth of his students and colleagues."[2]

In 1934 Hildebrandt became chairman and further appointments were made: Edwin W. Miller in 1934, specializing in set theory—he died of a

[2]The testimonial is from the minutes of a meeting in Fall 1981 of the faculty of the College of Literature, Science and the Arts of the University of Michigan. The memorial was drafted by George E. Hay and Cecil J. Nesbitt.

heart attack in 1942; Paul S. Dwyer in 1935, working in statistics; Sumner B. Myers in 1936, in differential geometry; Robert M. Thrall and Cecil J. Nesbitt, algebraists, and Robert C. F. Bartels in applied mathematics, in 1937–1938; Herman H. Goldstine in 1939, in functional analysis. The last five named had noteworthy career changes: Myers turned to functional analysis, Thrall to operations research, Nesbitt to actuarial mathematics, Bartels in 1967 became the first director of the University's computing center, Goldstine went on leave in 1941 but did not return, having been drawn into basic research on digital computing with John von Neumann (see his article "A Brief History of the Computer," which has appeared in Part I of *A Century of Mathematics in America*, American Mathematical Society, 1988, pp. 311–322).

Over the years 1922–1941 courses were steadily added, so that at the close of the period all the main branches of mathematics were covered, with a fair number of courses at the graduate level. The department had its first Ph.D. in 1911: W. O. Mendenhall, who wrote on divergent series under the guidance of Ford. By 1922, eleven doctor's degrees had been granted; by 1941, ninety. Among the recipients were Ralph S. Phillips and Charles E. Rickart, both students of Hildebrandt in functional analysis.

As a fitting climax at the end of the first 100 years, the department sponsored a two-week Topology Congress in June 1940, with Wilder and Ayres as organizers. The speakers included S. Eilenberg (who then joined the department), E. Van Kampen, S. Lefschetz, H. Whitney, S. Mac Lane, C. Chevalley.

The war years. As elsewhere, World War II had a devastating effect on the University and, in particular, on the mathematics program. Enrollments diminished and some faculty took leaves for military research. There were several military training programs on campus, such as the Air Force Meteorology Program and the Navy's V-12 Program.

The department did add a few professors at the time: Edward F. Beckenbach, in analysis, who remained only two years; Wilfred Kaplan, who had come for the Topology Congress; George E. Hay, in applied mathematics, who later became chairman (1957–1967); Erich Rothe, in functional analysis; the topologists Samuel Eilenberg and Norman E. Steenrod.

There were also several Ph.D. students finishing up, who helped to sustain interest in research. Among these were L. J. Savage, who went on to a career in statistics, and S. Kaplan in topology.

One unusual by-product of the war was a seminar on meteorology, bringing together several professors including G. Y. Rainich, the physicist G. Uhlenbeck, the geologist R. L. Belknap, the aeronautical engineer A. Kuethe. A motivation was to work on a topic that might have practical applications and help the war effort.

Those who were on leave for military research and those who joined the department after the war, having done such research, gained breadth by the

experience and their subsequent research and teaching showed a better understanding of such topics as control systems, operations research, applied statistics, communication networks.

Immediately following the war the enrollments shot up and soon the returning GIs appeared, bringing a highly motivated group of students.

Research discussion groups. There were many formal and informal gatherings to discuss research. A Mathematics Club meeting monthly has existed for about 100 years; according to Jones [**3**, p. 9], this began prior to 1891 in Prof. Ziwet's parlor. In [**1**, p. 50], Cole in 1891 referred to a "Mathematical Society of the University of Michigan." In [**6**, p. 3], Wilder tells of a secret mathematics club of about twelve members, including professors from physics and philosophy, meeting during the period 1927–1934. The writer also recalls a similar club organized by S. Eilenberg about 1940, called "The Gauss Group."

Eventually the secrecy was abandoned. In the 1940s regular colloquia were held and research seminars arose in ever-increasing numbers.

The Postwar Years

The professional staff and research activities. Under Wilder's leadership, the University of Michigan quickly grew to be a major center of topology, with such leaders as Eilenberg,[3] Steenrod, Bott and Samelson. There were many Ph.D.'s in the field, including S. Smale in 1957 (winner of a Fields medal in 1966). In real and functional analysis Hildebrandt and Myers provided strength; they were followed by E. H. Rothe, L. Cesari, P. Halmos and many others. Complex analysis took on great vigor following a two-week international conference in 1953; this was the beginning of an important "Finnish connection," involving many visits of faculty to and from Finnish universities—F. Gehring, who joined the department in 1955, became a leader in this enterprise. Number theory was fostered by W. J. LeVeque, D. J. Lewis and others. Applied mathematics had a strong old tradition in the department. Statistics continued as a strong interest, but a separate department was formed in 1969. Logic was promoted by Wilder through a very popular course and book on foundations; the program was sustained by R. Lyndon and others. A small group, including P. Jones and C. Brumfiel, ran a program for the training of secondary-school teachers of

[3] Major joint work of Eilenberg and Mac Lane was a by-product of Ziwet lectures given by Mac Lane in 1941. During one of these lectures (on group extensions) Eilenberg suddenly left the room! The audience wondered whether something was wrong, but later learned that he had just then realized the important connection between group extensions and topology. In the following days Eilenberg and Mac Lane were often found conferring intensely.

mathematics. In algebra and algebraic geometry strength gradually developed, with R. Brauer in the department from 1948 to 1952. Actuarial mathematics had an ancient tradition, created by Glover; this was continued by Nesbitt, A. L. Mayerson, C. H. Fischer and D. A. Jones. For some years Michigan's program in actuarial mathematics was generally considered the strongest in the country.

The instructional program. The table below gives basic information on the growth of the department and of mathematics instruction up to 1985. In column 2 the count is made at the beginning of the fall term and includes visitors but excludes regular staff on leave. The count is affected by the creation of a Computer Science Department in 1965 (later, in 1983, attached to the Electrical Engineering Department) and of a separate Statistics Department in 1969. For column 5 comparable figures are not available for 1940–1960. Although large lecture sections have been used for some second- and third-year courses, the freshman calculus course has been taught only in small sections, generally by teaching assistants, with some coordination by professors.

Growth of the Department, 1940–1985

1	2	3	4	5	6
Year	Departmental Roll		Under-	Graduate	Ph.D.s
	Staff	Teaching Fellows	graduate Majors	Students	Granted in Previous 5 years
1940	35	8	53		29
1945	35	11	32		21
1950	48	20	80		24
1955	61	34	56		56
1960	63	71	165		43
1965	84	116	290	303	66
1970	65	112	281	250	105
1975	64	80	114	165	101
1980	64	81	74	123	63
1985	66	92	111	131	61

The scope of the undergraduate program has broadened over the years to reflect increasing use of mathematics in engineering and the sciences, especially the social sciences, and the revolution in computing. The following are typical: courses in advanced mathematics for engineers, linear programming, algorithms, operations research, numerical analysis at various levels, mathematics for the social sciences. The concern for K–12 mathematics education has led to expanded offerings in teaching of mathematics, including summer institutes and in-service programs for teachers.

In order to meet the needs of gifted students, two special sequences of courses were introduced in the post-Sputnik era: one proceeding somewhat

more rapidly through calculus and differential equations; the other an honors sequence over the first three years. The enrollments in these sequences in 1970 and in 1985 were: rapid sequence: 1970, 218 and 1985, 196: honors sequence: 1970, 73 and 1985, 20. In 1970, 152 students graduated with majors in mathematics; in 1986, 64 did so.

A general master's degree has been offered for many years. Recently specialized programs were introduced in applied mathematics, secondary mathematics education and scientific computing. The number of degrees granted in 1970 was 101 and in 1985 was 24.

The actuarial program produced about 400 graduates from 1903 to 1940, about 300 from 1940 to 1960 and about 200 in each succeeding decade. Among these is the distinguished mathematician T. N. E. Greville, who received a Ph.D. in 1933. (See a forthcoming history of the actuarial profession in North America, titled *Our Yesterdays*, by Jack Moorhead.)

The Ph.D. program has been a major interest of the department. Since 1940 it has been supervised by a committee which has considered entrance requirements, progress of candidates and evaluation of dissertations.

Among those receiving the Ph.D. at Michigan are many who have gone on to successful careers in mathematics. These include W. Feit, 1955, M. Jerison, 1950, D. J. Lewis, 1950, J. R. Munkres, 1956, R. Phillips, 1939, F. Raymond, 1958, S. Smale, 1957, L. J. Savage, 1941, J. R. Schoenfield, 1953, E. H. Spanier, 1947, F. L. Spitzer, 1957.

Since 1960, the Sumner B. Myers Prize has been awarded to those whose dissertations have been deemed outstanding.

Other aspects of department life. Various endowed lecture series have brought outstanding mathematicians to the department for a week or more. The oldest of these is that named after Alexander Ziwet; the first lecturer was Edouard Čech in 1936 and the series has provided twenty-six visits up to 1986. The series named after George Y. Rainich has had three speakers: Lipman Bers in 1983, Michael H. Freedman in 1986, Richard M. Schoen in 1988.

During the academic year there has long been a tradition of a weekly colloquium speaker, very often a visitor. In addition fifteen or more specialized seminars have flourished, from beginning graduate to advanced research levels.

The Mathematics Club has long preserved special customs. The meetings are held in the evenings and are also social occasions, with refreshments served. The talks are expository, aimed at a broad audience, and are often followed by vigorous discussions. Each meeting opens with a reading of the minutes of the previous meeting. Then come unannounced "three-minute talks," presented by staff or students, on some novel ideas found in research or teaching. Finally (and this may be an hour later) the announced speaker

is allowed to take over. The informality and spirit of fun at these evenings have done much to build *esprit de corps.*

In 1952 the *Michigan Mathematical Journal* was initiated, under the leadership of Rainich. He became an early fan of "desktop publishing" when he discovered that the new departmental typewriter could justify margins; what better way to exploit this than in a new mathematics journal? (The machine was very primitive by modern standards, and the result was unattractive. A better printing process was soon found which did not, however, justify margins.) From 1954 to 1975 George Piranian was editor; his high standards and dedicated labor put the journal on firm ground. He was succeeded by Peter Duren (1976–1977) and by James Kister and Carl Pearcy with some alternation in the following years.

In 1964 *Mathematical Reviews* moved from Providence to Ann Arbor. Its presence has brought other mathematicians to the area and provided a lively association with the department.

The department has generally avoided being embroiled in political matters. However, one member of the faculty, H. Chandler Davis, was a victim of the "McCarthy period" of the 1950s. He cited the First Amendment to the Constitution as a basis for refusing to testify to a congressional committee investigating communism. He was dismissed from the University in 1954 by action of the regents. There was widespread faculty criticism of this step. A later investigation by AAUP led to a censuring of the University. Davis has described the events of this period in his article "The Purge", which has appeared in Part I of *A Century of Mathematics in America* (American Mathematical Society, 1988), pp. 413–428.

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