In Memoriam: Olga Taussky-Todd

Edith H. Luchins and Mary Ann McLoughlin

Olga Taussky-Todd passed away in her sleep on Saturday, October 7, 1995, at the age of 89, at her home in Pasadena, California, where she was Professor Emeritus of Mathematics at the California Institute of Technology. She is survived by her husband of 57 years, the mathematician John (Jack) Todd, also Professor Emeritus of Mathematics at Caltech. He reported that her death, a consequence of a broken hip from which she had not fully recovered, was swift and peaceful. It is a profound loss for Jack, for Caltech, and for the worldwide mathematics community.

Olga Taussky-Todd was a distinguished and prolific mathematician who wrote about 300 papers. Throughout her life she received many honors and distinctions, most notably the Cross of Honor, the highest recognition of contributions given by her native Austria. Olga's best-known and most influential work was in the field of matrix theory, though she also made important contributions to number theory. Perhaps Olga herself can best describe her mathematical tastes and motivations, as she did in a 1985 memoir:

> [For a large part] of my life all I wanted to work in was number theory. But this was frustrated through many circumstances. In fact, it took a long time before I could return to my dream subject. But apart from the complications in my career, I developed rather early a great desire to see the links between the various branches of mathematics. This struck me with great force when I drifted, on my own, into topological algebra, a subject where one studies mathematical structures from an algebraic and from a geometric point of view simultaneously. From this subject I developed a liking for sums of squares, a subject where one observes strange links between number theory, geometry, topology, partial differential equations, Galois theory, and algebras.
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> The theses written under my guidance reflect the main areas of my own research. At present these are: commutativity and generalized commutativity of finite matrices, which includes the difficult problems concerning eigenvalues of sums and products of matrices, and on the other hand, integral matrices… These two subjects sound quite different, but they have important intersections, a fact on which I am working very hard, with some success, interpreting facts in number theory via facts in matrix theory, which involves

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> noncommutativity. This is nothing new in principle, but has not been exploited sufficiently until recently. Some facts in modern number theory have been better understood by considering numbers as one-dimensional matrices, and then generalizing to matrices of higher dimension, thus giving more meaning to the original results. I became interested in these methods as soon as I heard of them. Some go back to Poincaré who had great ideas in more subjects than people realize. I have gone my own way on this kind of work.
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> —*Olga Taussky-Todd [17]*

This memorial article offers reminiscences written by students and colleagues about Olga Taussky-Todd and her mathematics and ends with a biographical sketch of her long and eventful life.

Remembering Olga Taussky-Todd

From Charles Johnson, College of William and Mary:

Olga Taussky-Todd often said that number theory was her first love, but in many ways she had the greater impact on her second love: matrix theory. She was involved with many of the major themes of twentieth century research in matrix theory, and the vast majority of her Ph.D. students were in matrix theory, several being major developers of the field in the latter half of the century. Perhaps most important she had an aesthetic sense and taste for topics that served to elevate the subject from a descriptive tool of applied mathematics or a by-product of other parts of mathematics to full status as a branch of mathematics laden with some of the deepest problems and emblematic of the interconnectedness of all of mathematics. Her influence on what people do and how well they do it will continue to be felt for some time.

Olga had an almost motherly love of several enduring topics in matrix theory, including Gershgorin's theorem, Lyapunov's theorem (these two thrust upon her, in part, by her and Jack's assistance in the war effort), the L-property, matrix commutators, the generalized Cayley transform $A^{-1}A^*$, the field of values, and "cramped" matrices.

Gershgorin's theorem is one of those remarkable mathematical facts that has maximum utility, yet is relatively simple and beautiful. If $A = (a_{ij})$ is an n-by-n complex matrix, then all the eigenvalues of A lie in the union of the discs $\{z \in C : |z - a_{ii}| \le \sum_{j \ne i} |a_{ij}|\}$. The fact, discovered independently by many authors over the years, long pre-dates Olga, but she did the most (beginning with her 1949 *American Mathematical Monthly* article "A recurring theorem on determinants" [7]) to popularize it and begin mathematical study of fine points, such as the occurrence of eigenvalues on the boundaries of the discs. In the meantime the subject has developed rapidly with many dozens of papers, including generalizations to other implicit functions of a matrix, such as the field of values, singular values and permanental roots, and enough material to constitute the book that Olga once planned to write.

Caltech Ph.D. Students of Olga Taussky-Todd

1960	Charles Hobby
	Robert C. Thompson
1964	Lorraine L. Turnbull Foster
1966	Edward A. Bender
	Fergus Gaines
1969	Daniel L. Davis
	Donald Maurer
1972	Charles R. Johnson
	Raphael Loewy
	Frank D. Uhlig
1976	Joseph A. Parker Jr.
1979	Helene Shapiro
1981	Philip J. Hanlon

Lyapunov's basic theorem relates general matrices whose eigenvalues lie in the right half plane to positive definite matrices (whose quadratic forms lie in the right half plane). All eigenvalues of the n-by-n complex matrix A have positive real part if and only if there are positive definite (Hermitian) matrices P and H such that $PA + A^*P = H$. In particular, if H is taken to be the identity (or for any fixed positive definite H), there is a unique and positive definite solution P to the above equation exactly when A is as described. Again, Olga both popularized and spearheaded mathematical investigation of the fundamental idea of this beautiful fact. The beauty lay, Olga realized, in the relation between the inertia of the quadratic form of P and the radial distribution of the spectrum of A, and this was the source of some of the early generalizations. Since then, the subject has become a major industry in inertia theory/eigenvalue localization, matrix equations, operator theory, and numerical analysis.

Olga was always fascinated with McCoy's theorem. If two n-by-n matrices A and B are simultaneously (upper) triangularizable by similarity, then there is an ordering $a_1, \ldots, a_n$ of the eigenvalues of A and $b_1, \ldots, b_n$ of the eigenvalues of B so that, given any polynomial $p(x, y)$ in noncommuting variables, the eigenvalues of $p(A, B)$ are the numbers $p(a_i, b_i), i = 1, \ldots, n$. McCoy showed the converse: if every (!) polynomial exhibits the correct eigenvalues in a consistent order, then A and B are simultaneously triangularizable. How much may the requirement of "all polynomials" be weakened? Two matrices A and B are said to have the "L-property" if the above polynomial condition holds for

Olga Taussky-Todd (foreground) at the time of her retirement in 1976, flanked by former Ph.D. students (left to right) Charles Johnson, Robert Thompson, and Daniel Davis.

all linear (!) polynomials in A and B. This was studied by Motzkin and Taussky [10], and it turns out to be weaker than simultaneous triangularizability, except under additional hypotheses, such as normality.

The above are a small sample of Olga's tastes and influences in matrix theory. Further examples of what motivated her interests in matrix theory are given in Olga's own words in her 1988 *Monthly* article "How I became a torchbearer for matrix theory" [19].

As a student of Olga's I have many fond recollections of her idiosyncracies as well as inspirations and kindnesses. For example, she had rather particular ideas about mathematical writing. No pictures or diagrams were allowed, and, much as I wanted to write "$n \times n$" to describe the dimensions of a matrix in my thesis, it had to be "n-by-n". I, and my students, still write "n-by-n". At the time I was a student, Caltech used an oral Ph.D. qualifying exam. Mine was to be mid-morning on a Monday. Somehow, Olga felt I was unduly nervous about the event (perhaps because I'd recently seen the Elliot Gould movie "Getting Straight") and called me up over the weekend to tell me that she and John would take me to the beach on Sunday to relax. The exam went fine, partly because one of the examiners, David Boyd, came an hour late—leaving Marshall Hall to ask me about group theory and the Riemann zeta function.

From Robert Guralnick, University of Southern California:

I first met Olga Taussky in spring 1977, a few months before I started a two-year appointment as a Bateman Research Instructor. Olga arranged that I get an office next to hers and as soon as I arrived asked me to referee a paper for her. Over the next two years, I learned an enormous amount of matrix theory from her and through her seminar. I was very impressed by some of Olga's early matrix theory papers. In particular, her joint paper with Motzkin [10] (if $\lambda A + \mu B$ is diagonalizable for all values of λ and μ, then $AB = BA$) in the mid-1950s was a tour de force and really introduced some new ideas; for example, they used algebraic geometry to study properties of matrices.

Olga was very helpful to me throughout my career. She introduced me to many well-known mathematicians. She helped me in my appointment at USC, and I am sure she was contacted about promotions. I would generally go to Caltech once a week to see Olga and attend her seminars.

Olga was a very good friend as well. Every time I would visit her in her office she would offer me some candy: either some European chocolate or a Kit Kat bar.

She was an amazing lady—very frail looking but quite tough. I recall that she went on the Oberwolfach hike in 1984 and kept up with the group, at age 78.

From Helene Shapiro, Swarthmore College:

On my first day at Caltech as a new graduate student, Olga came over to me in the lecture hall, introduced herself, and welcomed me to Caltech. I had arrived in January 1976 and felt somewhat out of place starting in the middle of the academic year; this warm welcome from Professor Taussky-Todd meant a great deal to me.

In my second year at Caltech I took the advanced matrix theory course with Olga. The topics included McCoy's theorem about simultaneous triangularization of sets of matrices, work on commutator relations and other results involving generalizations of commutativity, theorems about cramped matrices, and some work on integral matrices. These were topics of particular interest to Olga, and the course was a wonderful introduction to matrix theory as a research area of mathematics. Most of this material would not be found in textbooks, and so this course really helped introduce me to mathematics as it appears in journals and papers rather than in standard courses and texts. In this course I began to see how theorems in matrix theory, and their proofs, were related to many other areas of mathematics.

Because of this course, I decided I wanted to work in matrix theory and was delighted when Olga agreed to be my thesis advisor. She met with me once a week while I was working on my dissertation. Her knowledge of the literature was amazing—it seemed that whenever I asked about something, she could direct me to specific papers dealing with that problem. I felt very fortunate to have this chance to work with someone who had such a command of the field. She insisted that I always give the original source for known results, even those that could be found in textbooks. This was an important lesson for me.

Jack and Olga Todd were so kind and gracious to us—I remember a wonderful brunch for the

graduate students which they had in their lovely home, and Olga sometimes brought me lemons and kumquats from their garden. Olga had a very special way of expressing herself, so that her stories and advice made a vivid and long-lasting impression. I often think of the sign Olga kept on her desk: "It's nice to be important, but it's more important to be nice".

From Tom Apostol, Caltech:

Although her initial appointment as research associate did not specifically require any teaching duties, Olga voluntarily taught one course or seminar every year. These were intended primarily for graduate students, but many undergraduates attended them as well. Thirteen Caltech Ph.D. students wrote their theses under her direction, and she was proud of the fact that two of them were women.

Olga interacted regularly with young postdoctoral appointees and junior faculty, often doing joint work with them. She was also instrumental in bringing to Caltech many distinguished visitors who shared her research interests—people such as Drazin, Frölich, Hlawka, Macbeath, O'Meara, Paul, Roquette, Varga, Wielandt, and Zassenhaus. She had frequent contacts and mathematical discussions with senior members of the Caltech mathematics faculty, notably Bohnenblust, DePrima, Ryser, and Ward.

I first met Olga when she attended a number theory conference at Caltech in 1955. After she and Jack joined the Caltech faculty, we became colleagues and close friends.

All of us here at Caltech were proud of the fact that someone of her stature and reputation joined our faculty. She was of course the first woman faculty member of the Caltech mathematics department and also the first woman to receive tenure at Caltech.

She was always active in research. Although Olga and I never worked together on any mathematics problems, we jointly organized many seminars related to number theory. I had enormous respect for her mathematical talents and for her sensitivity as a kind and caring human being.

I recall her uncanny ability to tell instantly the number of letters in any word or name that was mentioned to her. When I first told her that the Greek origin of my own last name was Apostolopoulos, she immediately said that it had 14 letters. I asked her several times how she did this, but she never revealed her secret. Jack claimed that this remarkable ability clinched their job offer at Caltech, when then-president Lee DuBridge asked for the number of letters in the Institute's full name and Olga shot back the answer.

From Fergus Gaines, University of Dublin:

I came to Caltech as a graduate student in the fall of 1962. All the first-year graduate students in mathematics were required to take part in the elementary seminar which met once a week throughout the academic year. That year the seminar was directed by Olga and her husband, Jack, and each week one of the students had to lecture on a paper from the literature, while another student was required to write up the lecture. The topic for the year was matrix theory, and Olga and Jack were extremely helpful to all the students, guiding and encouraging them. I recall a social evening in the Todds' house to which all the first-year graduate students were invited. Also present was a bright, young staff member with his wife—they had only recently arrived at Caltech—and the wife said to Olga, "One of the problems in being married to a mathematician is that I can't really talk to my husband about his work. I don't understand it at all. Do you understand your husband's work?" With excellent tact, Olga answered with her characteristic smile, "A little"!

My interest in matrix theory was aroused by the elementary seminar, and during my first summer at Caltech Olga gave me a small problem to work on—justifying the National Science Foundation grant I held. That resulted in a small paper. As a result of that summer working with Olga, she became my thesis advisor, and I graduated with my Ph.D. in 1966.

Olga was a superb advisor, encouraging, cajoling, and always there to help. She insisted that I call to see her for one hour every Friday morning to discuss my progress for each week, whether there was any progress or not! She was always kind and encouraging and a great support.

Olga had a very wide knowledge of mathematics and, of course, of matrix theory in particular. She put this down to the fact that during her years in the National Bureau of Standards she was required to read every journal that came in to them. She was always very keen to assign the right priority to the discoverer of some theorem, and she had a well-nigh encyclopedic knowledge of the literature in linear algebra. This knowledge is exemplified in her famous paper, "A recurring theorem on determinants" [7]. She had many hundreds of correspondents around the world, most of whom wrote to her with queries about matrix problems because they had seen her name on one of the many papers she wrote. They all got an answer!

She was always interesting to talk to, particularly when she reminisced about her time in Göttingen. She introduced me to many well-known mathematicians. One piece of advice she gave me: "When you are working on a problem,

do not discuss it with other people until it is finished!" The reason she said this was because once she discussed a problem with a well-known mathematician while she was still working on it, and he completed it before she did. She was quite hurt by that, but in her usual kind way she forgave him, saying, "His brain is so active, he couldn't help but think about it until he had solved it."

My own view is that her greatest contribution to matrix theory was that she made the subject so well known: by posing problems to talented mathematicians to solve; by writing superb survey articles, which introduced so many people to the subject; by her inspiring lectures, both at conferences and at the many short courses on special topics that she organized at Caltech. I do not know which part of her work she herself was most proud of, but she always had a soft spot for that area of mathematics which combined linear algebra and number theory.

When I studied at Caltech, her position was research associate. We graduate students used to wonder why this was so, and why she was not a full professor at that time.

Olga was a great advisor, but she was also kind to me and my wife in many other ways. We were frequent visitors to the Todds' home. It was not unusual for them to take us for a Sunday afternoon drive to some scenic spot, and we still treasure the gift she gave us for our wedding.

From Richard Varga, Kent State University:

Olga was always interested in students, and she brought out the very best in her pupils and her postdoctoral fellows, such as Morris Newman and Alan Hoffman.

I was first introduced to Olga and Jack in 1954 at the Bureau of Standards, shortly after I finished my Ph.D. degree at Harvard. Then later at a meeting in Los Alamos in 1955 I had a chance to chat with her during a stroll in the Bandelier National Monument, where we did indeed "talk shop". I was totally unprepared to be able to speak technically with such an already-famous person, but she was extremely kind, and she quickly led the polite conversation to a discussion of technical questions in matrix theory related to the Perron-Frobenius theory of nonnegative matrices and to ideas related to the Gershgorin circle theorem. This lengthy discussion had a decisive impact on me, as these topics became an integral part of my first book, *Matrix iterative analysis* of 1962. It was as though she was attempting to create a "research fire" for these ideas, and she was, in truth, totally successful here!

Over the years the lives of Olga and Jack have intertwined with my life and the lives of my family, as a consequence of our many visits to Caltech. Olga was not only a great mathematician—surely one of the world's most outstanding women mathematicians—she was a part of our extended family. Her death was very sad for us, and we will sorely miss her.

From Frank Uhlig, Auburn University (paraphrased from a 1995 letter to Jack Todd):

I remember how dedicated Olga was to her note pad, which she took to every math lecture to jot down notes, to do her own math, and which kept her so productive. From my times in Pasadena, [at] her conference visits, talks, and lectures, I carried away a high esteem for any mathematical thought or idea and a dogged determination to plug away at it.

I feel that mathematics has come around to claim me totally. I wake up to do math and go to sleep (or not) thinking about it. So this was the long-term effect of knowing Olga.

From Philip Hanlon, University of Michigan:

Probably the thing I remember most vividly about Olga is what a kind and sensitive person she was. She could be difficult for sure on professional matters, but when it came to personal (or personnel) matters, particularly those involving families, she was very sensitive and understanding.

As an advisor Olga was very dedicated. She was unusual in that she felt obliged to train me in the subject areas as well as direct my research. We met at least once a week, at which time she would ask me to report on readings that she'd given me earlier. Often this reading was off the subject of my dissertation work—just something I should know.

Often she would report with great satisfaction that someone else had taken one of her results and generalized it considerably. I was puzzled by her attitude towards this situation. Finally I worked up the nerve to ask if she didn't feel disappointed not to have been the one to have stated and proved the result in its full generality. I remember her answer distinctly: "We mathematicians are too quick to credit the developer and forget the explorer."

The Life of Olga Taussky-Todd

The Early Years

Olga Taussky was born on August 30, 1906, in Olmütz in the Austro-Hungarian Empire under the rule of Franz Josef. Olmütz (which after World War I became Olomouc in the Czech Republic) had a strong tradition of learning and music.

Olga was the second of three daughters of Julius David and Ida Pollach Taussky. Her father

was an industrial chemist, who together with his father, Samuel Taussky, wrote a text on vinegar in 1903.

> My mother was a country girl. She was rather bewildered about our studies and compared herself to a mother hen who had been made to hatch duck eggs and then felt terrified on seeing her offspring swimming in a pond…She was educated to be a housewife and she made a nice home for all of us. Some evenings when I did not fall asleep readily I heard my parents in the kitchen making a late supper for themselves and the relaxed tone of their voices made me feel good. In some ways she was less old-fashioned than my father. The idea of us children using our education later to earn our living seemed all right to her, but not to him.
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> —*Olga Taussky-Todd [17]*

Her father preferred that, if his daughters had careers, they be in the arts, but they all went into the sciences. Ilona, three years older than Olga, became a consulting chemist in the glyceride industry, and Hertha, three years younger than Olga, became a pharmacist and later a clinical chemist at Cornell University Medical College in New York City.

In 1909 the family moved to Vienna and, in the middle of World War I, to Linz, a small town in upper Austria where her father was director of a vinegar factory. Recognizing her mathematical ability, her father assigned her the challenge of figuring out how much water to add to mixtures of various vinegars to attain the acidity level required by law. She set it up as a mixture problem and solved the resulting Diophantine equation in positive integers. Her solution was posted in the factory. Her father died during her last year in the *gymnasium*, leaving the family devastated, emotionally and financially. Olga increased her tutoring load and consulted for the vinegar plant.

Higher Education and Beyond: Göttingen, Vienna, Bryn Mawr

Despite some concern about funds for college, with her family's approval Olga followed her older sister to the University of Vienna. She first majored in chemistry ("a wonderful subject," [17, p. 315]) but then changed to mathematics. Kurt Gödel was a fellow student and friend [18]. The first year she took a course on number theory, taught by Philipp Furtwängler, as well as his seminar on algebraic number theory in her second year. Olga wrote her thesis just as class field theory was being invented. A result that had just been proved is that given an algebraic number field F with ring of integers O, there is a naturally defined unramified, normal extension field H of F, called the Hilbert Class Field, in which the lifting of all ideals in O become principal. Moreover, the Galois group of H over F is the class group G, the group of ideals in O modulo the principal ideals. Because of that last fact, the intermediate subfields between H and F correspond to the subgroups M of G. An obvious conjecture was that for an intermediate field K, the corresponding subgroup M can be described in terms of the ideals coming from F which are not yet principal in K. Furtwängler had proven this result when the class group is $Z^2 \times Z^2$.

Photograph of portrait made by Caltech archives.

Portrait of Olga Taussky in 1939 by Clara P. Ewald.

> The problem that Furtwängler assigned to me then concerned odd prime numbers. He had already solved it for the prime number 2 but did not show this to me. . . After some struggle, I did indeed solve it for 3. While trying to generalize it for prime numbers larger than 3, . . . I found that every prime number p behaves differently.
>
> —*Olga Taussky-Todd [17]*

In 1930 she received the doctoral degree, and in 1932 her thesis was published in the *Journal für die Reine und Angewandte Mathematik* (the *Crelle Journal*) [1].

Together with Hans Hahn, Olga wrote a review of B. L. van der Waerden's *Moderne Algebra*, Volume I (the review of Volume II appeared under her name alone) [2]. Hahn recommended Olga to Richard Courant, who was looking for an editor of Hilbert's *Werke* to be published by Springer-

Verlag. When Olga was hired as an assistant at Göttingen for 1931–1932, her major task was to edit the first volume devoted to number theory; the co-editors were two other young mathematicians, Wilhelm Magnus and Helmut Ulm.

Olga also took shorthand notes of Emil Artin's 1932 lectures in class field theory and edited them; they have since been translated into English by Robert Friedman in [23]. Emmy Noether ran a seminar in class field theory precisely because Olga was there and gave her opportunities to lecture. Moreover, Olga agreed to be the assistant in Courant's differential equations course, even though it required much effort. "Her wanderings began in the autumn of 1932, after Courant had advised her in writing not to return to Göttingen in view of the growing political tension at the University" [25, p. 180]. Olga returned to Vienna for the academic year 1932–1933. Tutoring supplemented her small salary.

Among other visitors at Göttingen in 1931–1932 were Oswald Veblen and his wife, who were very kind to Olga. He spoke about her to Anna Johnson Pell Wheeler, professor and head of the mathematics department at Bryn Mawr, who then offered her a fellowship for the academic year 1933–1934. In the meantime Olga had obtained a three-year research fellowship from Girton College, a women's school in Cambridge, which permitted her to spend the first year of the fellowship at Bryn Mawr, primarily because Noether was there. Sometimes Olga went along on Noether's weekly trips to Princeton—a dream come true for Olga, who made many friends there and wrote a paper on topological algebras with Nathan Jacobson [3]. Bryn Mawr invited her to stay another year, but Olga felt obligated to spend the remaining two years of her fellowship at Girton College.

The Todds, World War II, London and Belfast

In June 1935 (after Noether's death) Olga left the United States for Girton College in Cambridge. Concerned about having Olga supervise a student who wanted to work with her in algebraic number theory, an administrator invited a male colleague to take on the task. He refused on the grounds that Olga was better qualified; accordingly, the student's application for admission was rejected. The University of Cambridge awarded her an M.A., *ad eundem*, in 1939 after the rules were changed by an act of Parliament to permit women to be degree recipients.

With the assistance of G. H. Hardy and the head of Girton College, Olga obtained a junior-level teaching position at a women's college of the University of London in 1937. At an intercollegiate seminar she met John (Jack) Todd, who worked in analysis and taught at another London college. Jack brought to Olga's attention a problem that he thought should be solved: If M is a normal subgroup of the group G and if N is a normal subgroup of M, then for what class of groups is N a normal subgroup of G? It became a reason—if one was needed—for Olga and Jack to get together. The Jewess from Austria and the Presbyterian Northern Irishman were married in London on September 29, 1938, when Neville Chamberlain proclaimed "peace in our time." Over fifty years later Olga remarked, with a contented smile, "My life and my career would have been so different if my Irishman had not come along" [30, p. 7].

War was declared in 1939. The Todds moved eighteen times during the war. Jack was given a leave of absence from his college to take a war job, but until it materialized the Todds went to Belfast to live in his parents' home. One of Jack's former high school students, the young theologian Ernest Best, worked with Olga on the problem that Jack had brought to her, and they solved it [5]. Olga also worked on two problems that subsequently formed large parts of her research program: generalizations of matrix commutativity and matrices with integer coefficients. She and Jack wrote a joint paper [4] on matrices of finite period.

Olga resumed teaching in her college, which had moved to Oxford to be safer from air raids. In 1942–1943 she supervised the D. Phil. thesis at Oxford University of Hanna Neumann, who wrote on combinatorial group theory. Jack was a member of the Royal Navy Volunteer Reserve Team that went to the Mathematical Institute of Oberwolfach in Germany. He is credited with saving it from possible looting and burning in 1945, thereby earning the title, "The Savior of Oberwolfach".

While on leave of absence from the University of London, Olga took a position at the National Physical Laboratory in Teddington, near London. She worked there from 1943 to 1946 in the so-called Flutter Group under the direction of Robert A. Frazer. Assigned to work on a boundary value problem for a hyperbolic differential equation arising from flutter at supersonic speed, Olga "realized the beauty of research in differential equations" [17, p. 326] and also developed a strong interest in the stability of matrices.

NBS and Caltech

In September 1947 Olga and John traveled on a Liberty ship with one hundred war brides. They went to work at the National Bureau of Standards' (NBS) National Applied Mathematics Laboratory, headed by John H. Curtiss. Initially they spent some time at the Institute for Advanced

Study, working in the Electronic Computer Project directed by John von Neumann.

Jack was asked to help in promulgating the use of high-speed computers for problems involving huge numbers of mathematical computations. Olga's title was "consultant in mathematics". She did a great deal for the NBS and its Institute of Numerical Analysis (INA). "Her wide knowledge of mathematics and mathematicians played an important part in the development of the NBS-INA" [31, p. viii]. She refereed papers, responded to cranks, invited distinguished visitors, and recruited promising graduate students and postdocs as NBS employees, research associates, or fellows. She supervised the Ph.D. thesis of Karl Goldberg at American University in Washington, DC, while he was at the NBS. As part of the semicentennial celebration of the NBS, in 1950–1951 she organized a symposium, now widely regarded as a forerunner of the Gatlinburg-Householder Symposia. Olga contributed number theory problems (and their solutions) for the computers. She has been described as a "computer pioneer…who provided significant contributions to solutions of problems associated with applications of computers" [34].

But Olga and Jack missed teaching. They were ready when in 1957 the California Institute of Technology invited both of them. The invitation may have had its beginnings when Olga was invited in 1955 to a number theory conference at Caltech. Jack was offered a full professorship and Olga—according to the letter of appointment—"a research position of equal academic rank, called here [at Caltech] a Research Associate appointment." Translating from her German:

> Before me no women had ever taught at the university, so it was no easy matter to find the right appointment for me. It was decided that I should have a research appointment, with the permission but not the obligation to teach.
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> After many years of work mostly with applied mathematics, I was in the beginning rather uncertain about the teaching. But again it was the students who came to my assistance [as in the college in London]. It was clear to them that I had much mathematics to give them and they forced it out of me.
>
> —*Olga Taussky-Todd [20]*

Having left a tenured position at the NBS, Olga wanted tenure at Caltech and was pleased when it was granted in 1963. "I was happiest, though, when (in 1971) my appointment was changed from research associate to full professor" [30, page 6]. She was the first woman at Caltech with this academic rank (ibid).

At the mandatory retirement age of 70, Olga was retired. In 1977 she received the title of Professor Emeritus of Mathematics. Technically Emeriti are not supposed to supervise doctoral students, but Olga did, the provost wisely ruling that rules were made to be overruled.

Olga was pleased that she had brought to public attention certain mathematical contributions that might otherwise have been overlooked, e.g., through her papers [8, 9] that referred to the work of Arnold Scholz and to a theorem by Kenjiro Shoda. Her publications thanked those who helped her with the germ of an idea and those who urged her to publish. Her remembrances and autobiographies expressed her indebtedness to her teachers, her associates, and her students. She spoke and wrote about Emmy Noether [14,16]. Her Noether Lecture, sponsored by the Association for Women in Mathematics, was published in extended form as "The many aspects of the Pythagorean triangles" [15]. It seemed to her that both in her work, as well as in the work of others, she looked "for beauty and not only for achievement" [17, p. 336].

Awards and Honors

Many honors and awards came her way. Her paper on sums of squares in the *Monthly* won the Ford Prize of the Mathematical Association of America in 1971. She was elected Corresponding Member of the Austrian Academy of Sciences in 1975 and of the Bavarian Academy of Sciences in 1985. The highest scientific award of the government of Austria, the Cross of Honor in Science and Arts, First Class, was bestowed upon her in 1978. The University of Vienna renewed her doctorate in 1980, awarding her the Golden Doctorate. An honorary Doctor of Science degree was granted to her by the University of Southern California in 1988. In 1991 she was elected a Fellow of the American Association for the Advancement of Science.

Olga was on the Council of the London Mathematical Society in 1946–1947. She was a member of the Council of the American Mathematical Society for six years, beginning in 1972, and served as vice-president in 1985. The Todds spent a semester at the Courant Institute for Mathematical Sciences in 1955. A decade later under Fulbright Professorships they spent a semester at the University of Vienna. In 1963 she was selected as one of nine Women of the Year by the *Los Angeles Times*, which pleased her, since it made Jack happy and would not make her (then all male) colleagues envious.

In 1976 *Linear Algebra and its Applications* [27] and *Linear and Multilinear Algebra* [26] published special issues dedicated to Olga. She was a founding editor of the first and an editor of both journals. She was also an editor of the *Journal of Number Theory* and of *Advances in Mathematics*. For several years she was editor of the Research Announcements section of the *Bulletin of the AMS*. *Number theory and algebra*, a book edited by Hans Zassenhaus, was dedicated to Olga (and also to Henry Mann and Arnold E. Ross); it contains her own technical survey of some of her work and her bibliography to date [12]. Her publications for the next ten years are included in a chapter on Olga in *Women of mathematics* [29].

The Olga Taussky–John Todd Instructorships in Mathematics for young mathematicians with strong research promise were established by Caltech in 1990. Colleagues, friends, and students of the Todds contributed to the establishment in 1993 of the Olga Taussky–John Todd Lecture Program, through which the International Linear Algebra Society every three or four years invites talented mathematicians in linear algebra to talk about their research. Helene Shapiro gave the first lecture in March 1993, and Robert Guralnick will give the next one this year. Both were also speakers at a memorial conference held in Olga's honor at Caltech in April; the other speakers were Benedict Gross, Philip Hanlon, and Kenneth Ribet.

Dennis Estes, who worked as a postdoc with Olga in 1966, reminisced that she used to call her male Ph.D. students and postdocs her "boys" (cf. "Noether's boys," [14, p. 83]) and her "bad boys" if they did not contact her for a month or so. He presented a talk about her life and work at the AMS sectional meeting at Baton Rouge in spring 1996. Bruce Reznick, an undergraduate at Caltech, wrote a survey paper on Hilbert's 17th problem, which he dedicated to the memory of Olga and of Raphael Robinson, both of whom contributed significantly to the topic and both of whom unfortunately died in 1995. Robert C. Thompson, Olga's early Caltech Ph.D., whom she considered among her best students, died on December 10, 1995, only about two months after his mentor, compounding the profound loss suffered by the mathematical community.

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