Preface

The present issue of *Linear Algebra and Its Applications* is dedicated to Alan J. Hoffman, its founding editor-in-chief, on the occasion of his sixty-fifth birthday. The double volume issue forms one of the largest special issues of LAA with nearly 50 contributions from his many friends and colleagues. The included papers range from linear algebra to combinatorics, graph theory, and linear programming, as does Hoffman's own work.

Alan J. Hoffman was born on May 30, 1924 in New York City. He graduated from George Washington High School in 1940 and entered Columbia College on a Pulitzer Scholarship. His intention to make his career in mathematics was reinforced by inspirational teachers such as J. F. Ritt and G. A. Pfeiffer. Equally inspiring was the friendship of an extremely talented young graduate student—Ernst Straus. In particular, Straus introduced Hoffman to combinatorics, an area that was to become one of his main research interests.

Hoffman left college early in 1943 to enter the U.S. Army. He eventually served in England, France, Germany, Philippine Island and Japan, most of the time in the Signal Corps, but at least in his first year of service maintained his interest in mathematics. The first progress in what later became his dissertation was made during basic training; and Straus sent long letters with research problems in combinatorics, most of which Straus had already solved.

In 1946 Hoffman returned to Columbia and graduated on his birthday the following year. But he did not attend the graduation ceremony, for on that day he married Esther Atkins Walker. They had been introduced to each other by Hoffman's army friends Joel Wyman and Alex Walker, Esther's brother. Their marriage lasted forty-one years, ending with Esther's death last summer.

Hoffman continued at Columbia as a graduate student, receiving his Ph.D. in 1950, with a dissertation "On the Foundations of Inversion Geometry". His advisor was E. R. Lorch; H. S. M. Coxeter of Toronto and fellow student Hing Tong were also helpful in preparing the dissertation.

He next spent a year as a temporary member of the Institute for Advanced Study in Princeton. During that year, Hoffman "fell in love" with the Bruck-Ryser-Chowla Theorem, which concerns the integers that can be orders of finite projective planes. The theorem serves as an example of one of the "edges" of the "triangle" of Hoffman's mathematical interests. The "vertices" of this triangle are combinatorics (including graph theory), linear

655 Avenue of the Americas, New York, NY 10010 0024-3795/89/$3.50

inequalities and programming, and matrix theory (especially eigenvalues). The above theorem is combinatorial in nature, but its proof depends on matrix theory.

After the year at the Institute, Hoffman went to work at the Applied Mathematics Division of the National Bureau of Standards in Washington, D.C., where he spent the following five years. These were the early days of computers and linear programming, and his principal assignment was to participate in the Bureau's linear programming efforts. He learned linear programming through essentially private lessons from George Dantzig. Hoffman was an excellent student, and one outcome of this tutoring was the first example of cycling of the simplex method [10]. He also organized comparisons of the simplex method with potential competitors, the account of which [7] is still viewed as a model for reporting computational results.

Hoffman's immediate supervisor at the National Bureau of Standards was the well-known numerical analyst, John Todd. Also, Olga Taussky-Todd was a regular consultant at the Bureau. She had an important long-term influence on Hoffman as she got him seriously interested in matrix theory. She encouraged him, she challenged him and she helped him. Hoffman still views her as the model of the way senior people should help and look after their juniors. Other visitors whom Hoffman met at the Bureau and who influenced him were Ky Fan, Alexander Ostrowski, Helmut Wielandt and James Wilkinson. At the Bureau, Hoffman reached the "interior" of his research triangle with the Hoffman-Wielandt Theorem [6], which concerns the variation of the spectrum of a normal matrix. The proof of this matrix-theoretic result is based on linear programming and the combinatorial Birkhoff Theorem that a doubly stochastic matrix is a weighted sum of permutation matrices. Another paper of this period that corresponds to the interior of the triangle is [24], jointly authored with J. Kruskal. This classic paper is about integral boundary points of convex polyhedra. The paper touches on the three vertices of the above triangle as it establishes a combinatorial existence result by studying a system of linear inequalities and examining the determinants of the underlying matrices. Together with the transportation-simplex algorithm one can view this work as the early foundation of integer programming.

During the early fifties, the community of Washington mathematicians was relatively small, and the Applied Mathematics Division of the Bureau was intellectually exciting and socially congenial. There was a sense of being "present at the creation" of developments with big futures (though Hoffman says his personal vision of the futures of computing and of linear programming was very short of the mark). Esther worked as a labor economist with the Wage Stabilization Board until the birth of their daughter Eleanor in 1954.

Hoffman left the National Bureau of Standards in 1956 to become a Scientific Liason Officer at the Office of Naval Research in London, and returned the next year to accept a position with the General Electric Company at its headquarters in New York. He has said that part of the motivation for joining G.E. was sociological: having Military, Government and University, he thought it would be interesting to see Business. The job involved teaching operations research to students from various departments of General Electric and helping them in their subsequent activities. But the lure of mathematics proved more powerful than business or sociology. For example, his first papers on the eigenvalues of graphs were written during the years at G.E. So in 1961 he joined the Mathematical Sciences Department of the T. J. Watson Research Center of IBM at Yorktown Heights, with which he is still affiliated.

The atmosphere he found at the Research Center was reminiscent of what he encountered at the Bureau of Standards a decade earlier, and he found a similar collegiality and stimulation. Hoffman's contributions and stature were recognized by IBM in 1977 when he was designated an IBM Fellow.

Most of Hoffman's professional career has been with research groups in government and industry. Still, he always had the desire to share his energy and enthusiasm for mathematics with students. He continuously held adjunct appointments at various universities, including the Technion—Israel Institute of Technology (1965), City University of New York (1965–1976), Yale University (1976–1985) and Stanford University (1980–to date). Further, Hoffman was involved in the dissertation research of many students and served as the principal advisor for a number of them.

Hoffman was the founding editor-in-chief of *Linear Algebra and Its Applications*. His editorial statement in the first issue of LAA reads in part as follows: "The editors and publisher hope that *Linear Algebra and Its Applications* will become the journal of record of important research on theoretical and numerical aspects of the subject." His vision, as expressed by this statement, determined the tone and the focus of the journal and continues to guide the editors to date.

In addition to serving as the editor-in-chief of *Linear Algebra and Its Applications* for four years and being the managing editor of *Naval Research Logistics Quarterly* for one year, Hoffman held a variety of editorial responsibilities in *SIAM Journal of Applied Mathematics*, *Journal of Combinatorial Theory*, *Combinatorica*, *Mathematics of Computation*, *International Computing Center Bulletin*, and *Transportation Science*. Furthermore, he is currently on the editorial boards of *Mathematics of Operations Research* (advisory editor), *Discrete Mathematics* (advisory editor), *Naval Research*

Logistics Quarterly, *Discrete Applied Mathematics*, *SIAM Journal on Discrete Mathematics* and of course *Linear Algebra and Its Applications* (founding editor).

Hoffman was elected in 1982 to membership in the National Academy of Sciences of the United States. He is also a fellow of the American Academy of Arts and Sciences (since 1987) and the New York Academy of Sciences (since 1975). In 1986 Hoffman was awarded an honorary doctorate by the Technion —Israel Institute of Technology.

Above and beyond his scholarly and professional contributions, Hoffman has unparalleled ability to enjoy everything he does. He enjoys singing, ping pong, puns, witty stories, and—possibly as much as anything else—doing mathematics. Curtis Eaves tells the story of an occasion in which he saw Hoffman sitting in a parked car on a freeway. He had stopped to offer his help and was invited to participate in the solution of a mathematical problem.

As mentioned earlier, Esther Hoffman—Alan's wife and companion for over forty years—died last summer, while this issue honoring Alan Hoffman's sixty-fifth birthday was being put together. We are very sorry that she cannot share this occasion with us and we send Alan our deepest and sincerest condolences.

Alan Hoffman has two daughters, Eleanor Hoffman and Elizabeth Perry (married to Michael Perry). He has one grandson, David Jennings Perry, who was born in February of 1987. Anybody who talks to him briefly finds out how much he enjoys his grandson. We all wish Alan Hoffman many more healthy and creative years with a lot of enjoyment from mathematics and much joy with his family.

URIEL ROTHBLUM

Publications of Alan J. Hoffman

PUBLISHED PAPERS

1. On the foundations of inversion geometry, *Trans. Amer. Math. Soc.* 17:218–242 (1951).

2. A note on cross ratio, *Amer. Math. Monthly* 58:613–614 (1951).

3. Chains in the projective line, *Duke Math. Journal* 18:827–830 (1951).

4. Cyclic affine planes, *Can. Jour. Math.* 4:295–301 (1952).

5. On approximate solutions of systems of linear inequalities, *J. Research Natl. Bureau Stds.* 49:263–265 (1952).

6. The variation of the spectrum of a normal matrix, *Duke Math. Journal* 20:37–40 (1953) (with H. W. Wielandt).

7. Computational experience in solving linear programs, *Jour. Soc. Ind. Appl. Math.* 1:17–34 (1953) (with M. Mannos, D. Sokolowsky and N. Wiegmann).

8. On a combinatorial theorem, *Natl. Bureau Stds.* Report 2377 (1953).

9. On an inequality of Hardy, Littlewood and Polya, *Natl. Bureau Stds. Report* 2977 (1953).

10. Cycling in the simplex algorithm, *Natl. Bureau Stds. Report* 2974 (1953).

11. A characterization of normal matrices, *J. Research Natl. Bureau Stds.* 52:17–19 (1954) (with O. Taussky).

12. On a theorem of Ostrowski and Taussky, *Archiv der Mathematik* 5:123–127 (1954) (with R. Bellman).

13. Lower bounds for the rank and location of the eigenvalues of a matrix, Contributions to the Solution of Systems of Linear Equations and the

Determination of Eigenvalues, *Appl. Math. Series* No. 39:117–130, Washington (1954) (with K. Fan).

14. On the solution of the caterer problem, *Nav. Res. Logist. Quarterly* 1:223–229 (1954) (with J. Gaddum and D. Sokolowsky).

15. Smooth patterns of production, *Management Sci.* 1:86–91 (1954) (with W. Jacobs).

16. A remark on the smoothing problem, *Management Sci.* 1:92–95 (1954) (with H. Antosiewicz).

17. Some metric inequalities in the space of matrices, *Proc. Amer. Math. Soc.* 6:111–116 9 (1955) (with K. Fan).

18. How to solve a linear programming problem, *Proc. Second Linear Programming Symposium*, 397–424, Washington (1955).

19. SEAC determines low bidders, *Research Reviews*, 11–12 (April, 1955).

20. Linear programming, *Research Reviews*, 23–27 (August, 1955) (with G. Voegeli).

21. Linear programming, *Applied Mechanics Review* 9:185–187 (1956).

22. The number of absolute points of a correlation, *Pac. Jour. Math.* 6:83–96 (1956) (with M. Newman, E. Straus and O. Taussky).

23. On systems of distinct representatives and linear programming, *Amer. Math. Monthly* 63:455–460 (1956) (with H. Kuhn).

24. Integral boundary points of convex polyhedra, *Annals of Mathematics Study* 38:223–241, Princeton (1956) (with J. Kruskal).

25. Dilworth's theorem on partially ordered sets, *Annals of Mathematics Study* 38:207–214, Princeton (1956) (with G. Dantzig).

26. On systems of distinct representatives, *Annals of Mathematics Study* 38:199–202, Princeton (1956) (with H. Kuhn).

27. Generalization of a theorem of Konig, *Jour. Wash. Acad. Sciences* 46:211–212 (1956).

28. Systems of inequalities involving convex functions, *Proc. Amer. Math. Soc.* 8:617–622 (1957) (with K. Fan and I. Glicksberg).

29. Geometry, Chapter 8, 97–102, *Handbook of Physics*, McGraw-Hill (1958).

30. Linear programming, *McGraw-Hill Encyclopedia of Science and Technology* 7, 522–523 (1960).

31. Some recent applications of the theory of linear inequalities to extremal combinatorial analysis, *Proc. Symp. in Applied Mathematics, Amer. Math. Soc.*, 113–127 (1960).

32. On the uniqueness of the triangular association scheme, *Annals of Mathematical Statistics* 31:492–497 (1960).

33. On the exceptional case in a characterization of the arcs of a complete graph, *IBM J. Res. and Dev.* 4:487–496 (1960).

34. On Moore Graphs with diameters 2 and 3, *IBM J. Res. and Dev.* 4:497–504 (1960) (with R. Singleton).

35. Extreme varieties, concave functions and the fixed charge problem, *Communications in Pure and Applied Mathematics* 14:355–369 (1961) (with W. Hirsch).

36. Block design games, *Canadian Journal of Mathematics* 13:110–128 (with M. Richardson).

37. On unimodular matrices, *Pacific Journal of Mathematics* 12:1321–1327 (1962) (with I. Heller).

38. Finding optimal combinations, *Science and Technology*, 26–33 (July, 1962) (with R. Gomory).

39. On the polynomial of a graph, *American Mathematical Monthly* 70 (1963).

40. On the convergency of an integer-programming process, *Naval Research Logistics Quarterly* 10:121–123 (1963) (with R. Gomory).

41. On simple linear programming problems, *Proc. Symposia in Pure Mathematics VII*, 317–327, *Amer. Math. Soc.* (1963).

42. Dynamic programming, 5th IBM Medical Symposium, *Endicott* (1963).

43. On the duals of symmetric partially balanced incomplete block designs, *Annals of Mathematical Statistics* 34:528–531 (1963).

44. On symmetric bimatrix games, *IBM Research Report RC 959* (1963) (with J. Griesmer and A. Robinson).

45. Shortest path, assignment and transportation problems, *Naval Res. Logistics Quarterly* 10:375–379 (1963) (with H. Markowitz).

46. Large linear programs, *Proceedings IFIP Congress* 1962, 173–176.

47. A characterization of comparability graphs and of interval graphs, *Canadian Journal of Mathematics* 15:539–548 (1964) (with P. Gilmore).

48. On abstract dual linear programs, *Naval Research Logistics Quarterly* 10:369–373 (1964).

49. Linear inequalities and analysis, *American Mathematical Monthly* 71:416–418 (1964) (with M. McAndrew).

50. Some properties of the rank and invariant factors of matrices, *Canadian Mathematical Bulletin* 7:85–96 (1964) (with R. Gomory and N. Hsu).

51. The line graph of the complete bipartite graph, *Annals of Mathematical Statistics* 35:883–885 (1964).

52. Some properties of graphs with multiple edges, *Canadian Journal of Mathematics* 17:166–177 (1965) (with D. Fulkerson and M. McAndrew).

53. The polynomial of a directed graph, *Proc. Amer. Math. Soc.* 16:303–309 (1965) (with M. McAndrew).

54. On the line graph of a projective plane, *Proc. Amer. Math. Soc.* 16:297–392 (1965).

55. On the line graph of a finite affine plane, *Canadian Journal of Mathematics* 17:687–694 (with D. Ray-Chaudhuri).

56. On the line graph of a symmetric balanced incomplete block design, *Transactions Amer. Math. Soc.* 116:238–252 (1965) (with D. Ray-Chaudhuri).

57. The nonsingularity of real matrices, *Mathematics of Computation* XIX, No. 89:56–61 (1965).

58. On the nonsingularity of real partitioned matrices, *International Journal of Computation and Applied Mathematics* 4:7–17 (1965).

59. On the nonsingularity of complex matrices, *Pacific Journal of Mathematics* 17:211–214 (1966) (with P. Camion).

60. On nonterminating stochastic games, *Management Science* 12:359–370 (1966) (with R. Karp).

61. Ranks of matrices and families of cones, *Transactions New York Academy of Science* 29:375–377 (1967).

62. Three observations on nonnegative matrices, *Journal of Research, National Bureau of Standards* 71b:39–41 (1967).

63. The eigenvalues of the adjacency matrix of a graph, *Proc. Symposium on Combinatorial Mathematics*, 578–584, Univ. North Carolina (1967).

64. Some recent results on spectral properties of graphs, *Beitrage zur Graphentheorie* (Proceedings of an International Colloquium), 75–80, B. G. Teubner, Leipzig (1968).

65. Estimation of eigenvalues of a matrix and the theory of linear inequalities, *Proc. AMS Lectures in Applied Mathematics*, II, part 1, Mathematics of the Decision Sciences, 295–300 (1968).

66. Bounds for the rank and eigenvalues of a matrix, *Proc. IFIP Congress* 111–113 (1968).

67. A special class of doubly stochastic matrices, *Aequationes Mathematicae* 2:319–326 (1969).

68. The change in the least eigenvalue of the adjacency matrix of a graph under imbedding, *SIAM Journal of Appl. Math.* 17:664–671 (1969).

69. On the covering of polyhedra by polyhedra, *Proc. Amer. Math. Soc.* 23:123–126 (1969).

70. On unions and intersections of cones, *Recent Progress in Combinatorics*, 103–109, Academic Press, New York (1969).

71. Two remarks on copositive matrices, *Linear Algebra Appls.* 2:387–392 (1969) (with E. Haynsworth).

72. Generalizations of Gersgorin's theorem, Lectures given at Univ. California, Santa Barbara (1969).

73. When is a team "mathematically" eliminated?, *Proc. Princeton Symposium on Math. Programming*, 1966, 391–401, Princeton (1970) (with T. Rivlin).

74. On the variation of coordinates in subspaces, *Annali Di. Mat. Ser. IV* Vol. LXXXVI:53–59 (1970).

75. Patterns of dependence in generalizations of Gersgorin's theorem, *SIAM J. on Numerical Analysis* 7:571–574 (1970) (with R. Varga).

76. $-1-\sqrt{2}$?, Combinatorial Structures and Their Applications, 173–176, Gordon and Breach, New York (1970).

77. On eigenvalues and coloring of graphs, *Graph Theory and its Applications*, 79–91, Academic Press, New York (1970).

78. On eigenvalues and colorings of graphs II, *Proc. International Conference for Combinatorial Mathematics, Annals of the New York Academy of Sciences*. 175, 238–242 (1970) (with L. Howes).

79. Combinatorial aspects of Gersgorin's theorem, *Recent Trends in Graph Theory*, 173–179, Springer-Verlag, New York (1970).

80. On vertices near a given vertex of a graph, *Studies in Pure Mathematics*, 131–136, Academic Press, New York (1971).

81. Eigenvalues and edge partitionings of graphs, *Linear Algebra Appls.* 5:137–146 (1972).

82. On finding all shortest distances in a directed network, *IBM J. Res. and Dev.* 16:412–414 (1972) (with S. Winograd).

83. On limit points of spectral radii of nonnegative symmetric integral matrices, *Graph Theory and its Applications*, 165–172, Springer-Verlag (1972).

84. Some applications of graph theory, *Proceeding Third S.E. Conference on Combinatorics and Computing*, 9–14 (1972).

85. Sparse matrices, *Proc. Second Manitoba Conference on Numerical Mathematics* (1972).

86. On spectrally bounded graphs, *A Survey of Combinatorial Theory*, 277–283, North-Holland (1973).

87. Complexity bounds for regular finite difference and finite element grids, *SIAM Journal on Numerical Analysis* 10:364–369 (1973) (with M. Martin and D. Rose).

88. On copositive matrices with $-1,0,1$ entries, *J. Combinatorial Theory* A14:302–309 (1973) (with F. Pereira).

89. Lower bounds for the partitioning of graphs, *IBM J. Res. and Dev.* 17:420–425 (1973) (with W. Donath).

90. Self-orthogonal latin squares of all orders $n \neq 2,3,6$, *Bulletin Amer. Math. Soc.* 80:116–118 (1974) (with R. Brayton and D. Coppersmith).

91. On eigenvalues of symmetric $(+1, -1)$ matrices, *Israel Journal of Mathematics*, 17:69–75 (1974).

92. A generalization of max flow-min cut, *Mathematical Programming* 6:352–359 (1974).

93. On balanced matrices, *Mathematical Programming Study* 1:120–132 (1974) (with D. Fulkerson and R. Oppenheim).

94. Eigenvalues of graphs, Studies in Graph Theory, Part II, 225–245, *Mathematical Association of America* (1975).

95. Linear G-functions, *Linear and Multilinear Algebra* 3:45–52 (1975).

96. On the spectral radii of topologically equivalent graphs, *Recent Advances in Graph Theory*, 273–282, Czechoslovak Academy of Sciences (1975).

97. Applications of Ramsey style theorems to eigenvalues of graphs, *Combinatorics*, 245–260, D. Reidel Publishing Company, Dordrecht (1975).

98. Spectral functions of graphs, *Proceedings of International Congress of Mathematics* 1974, Vol. 2, 461–464, Canadian Mathematical Congress (1975).

99. On convex cones in C^n, *Bulletin of the Institute of Mathematics*, Academia Sinica 3:1–6 (1975).

100. On spectrally bounded signed graphs, *Proc. 21st Conference of Army Mathematicians*, 1–6, El Paso (1975).

101. Self-orthogonal latin squares, *Colloquio Internationale sulle Teorie Combinatorie, Tomo II*, 509–517, Accademia Nazionale Dei Lincei (1976) (with R. Brayton and D. Coppersmith).

102. Total unimodularity and combinatorial theorems, *Linear Algebra Appls.* 13:103–108 (1976).

103. On graphs whose least eigenvalue exceeds $-1-\sqrt{2}$, *Linear Algebra Appls.* 16:153–166 (1977).

104. On the line graph of the complete tripartite graph, *Linear and Multilinear Algebra* 10–25 (1977) (with B. Jamil).

105. A theorem on inverses of convex sets of real matrices, with application to the worst-case DC problem, *IEEE Transactions on Circuits and Systems* CAS-24:409–415 (1977) (with R. Brayton and T. Scott).

106. On signed graphs and grammians, *Geometrie Dedicata* 6:455–470 (1977).

107. On partitions of a partially ordered set, *J. Combinatorial Theory* B 23:3–13 (1977) (with D. Schwartz).

108. On limit points of the least eigenvalue of a graph, *Ars Combinatorica* 3:3–14 (1977).

109. Linear programming and combinatorial problems, *Proceedings of a Conference on Discrete Mathematics and its Applications*, 65–92, Indiana University (1976).

110. Nearest $\mathscr{S}$-matrices of given rank and the Ramsey problem for eigenvalues of bipartite $\mathscr{S}$-graphs, *Colloques Internationaux* C.N.R.S. 260, Problemes Combinatoire et Theorie des Graphes, 237–240 (1977) (with P. Joffe).

111. Multicoloration dans les hypergraphes unimodulaires et matrices dont les coefficients sont des ensembles, *Colloques Internationaux* C.N.R.S. 260, Problemes Combinatoire et Theorie des Graphes, 27–30 (1977) (with C. Berge).

112. On the distance matrix of a graph, *Journal of Graph Theory* 1:85–88 (1977) (with R. Graham and H. Hosoya).

113. Local unimodularity in the matching polytope, *Annals of Discrete Mathematics* 2:201–209 (1978) (with R. Oppenheim).

114. On lattice polyhedra, *Proceedings 5th Hungarian Colloquium on Combinatorics*, 593–598 (1978).

115. Polyhedral Combinatorics, *Mathematical Programming Study* 8, North-Holland (1978) (M. Balinski, Co-editor).

116. D. R. Fulkerson's contributions to polyhedral combinatorics, *Mathematical Programming Study* 8:17–23 (1978).

117. On lattice polyhedra III: blockers and anti-blockers of lattice clutters, *Mathematical Programming Study* 8:197–207 (1978).

118. Helly numbers of some sets in R^n, *IBM Research Report* RC7319 (1978).

119. Some greedy ideas, *IBM Research Report* RC7279 (1978).

120. The role of unimodularity in applying linear inequalities to combinatorial theorems, *Annals of Discrete Mathematics* 4:73–84 (1979).

121. On the mixed achromatic number and other functions of graphs, *Graph Theory and Related Topics*, 105–119, Academic Press (1979) (with F. Buckley).

122. Linear programming and combinatorics, *Proc. Symposia in Pure Mathematics* 34, 245–253, American Mathematical Society (1979).

123. Binding constraints and Helly numbers, *Annals of the New York Academy of Sciences* 319, 284–288 (1979).

124. Polyhedral aspects of discrete optimization, *Annals of Discrete Mathematics* 4:183–190 (1979) (with F. Granot).

125. Maximum degree in graphs of diameter 2, *Networks* 10:87–96 (1980) (with P. Erdos and S. Fajtlowicz).

126. Matroid intersections, *Combinatorica* 1:43–47 (1981) (with H. Groflin).

127. Ordered sets and linear programming, *Ordered Sets*, 619–654, D. Reidel Publishing Company (1981).

128. On bounds for eigenvalues of real symmetric matrices, *Linear Algebra Appls.* 40:217–223 (1981) (with E. Barnes).

129. Lattice polyhedra II: construction and examples, *Annals of Discrete Mathematics* 15:189–203 (1982) (with H. Groflin).

130. Two remarks on the Mendelsohn-Dulmage theorem, *Annals of Discrete Mathematics* 15:171–177 (1982) (with D. Gale).

131. Extending Greene's theorem to directed graphs, *J. Combinatorial Theory* A34:102–107 (1983).

132. On the relationship between the Hausdorff distance and matrix distance of ellipsoids, *Linear Algebra Appls.* 52:301 313 (1983) (with J. Goffin).

133. On greedy algorithms in linear programming, *Proc. 4th Japanese Mathematical Programming Symposium*, 1–13, Kobe (1983).

134. Partitioning, spectra and linear programming, *Progress in Combinatorial Optimization*, 13–26, Academic Press (1984) (with E. Barnes).

135. A fast algorithm that makes matrices optimally sparse, *Progress in Combinatorial Optimization*, 185–196, Academic Press (1984) (with S. McCormick).

136. Aspects of the Traveling Salesman Problem, *IBM J. Res. and Dev.* 28:476–486 (1984) (with M. Held, E. Johnson and P. Wolfe).

137. On the spectral radius of (0,1) matrices, *Linear Algebra Appls.* 65:133–146 (1985) (with R. Brualdi).

138. Path partitions and packs of acyclic digraphs, *Pacific Journal of Mathematics* 118:249–259 (1985) (with R. Aharoni and I. Hartman).

139. Triangulations (tilings) and certain block triangular matrices, *Mathematical Programming* 31:1–14 (1985) (with G. Dantzig and T. Hu).

140. On transportation problems with upper bounds on leading rectangles, *SIAM Journal on Algebraic and Discrete Methods* 6:487–496 (1985) (with E. Barnes).

141. Totally balanced and greedy matrices, *SIAM Journal Algebraic and Discrete Methods* 721–730 (1985) (with A. Kolen and M. Sakarovitch).

142. Line sum symmetric scaling of square nonnegative matrices, *Mathematical Programming Study* 25:124–141 (1985) (with B. Eaves, U. Rothblum and H. Schneider).

143. Minimizing a unimodal function of two integer variables, *Mathematical Programming Study* 25:76–87 (1985) (with P. Wolfe).

144. History of Traveling Salesman problem, *The Traveling Salesman*, 1–15, John Wiley (1985) (with P. Wolfe).

145. On a conjecture of Kojima and Saigal, *Linear Algebra Appls.* 71:159–160 (1985).

146. On greedy algorithms that succeed, *Surveys in Combinatorics*, 97–112, Cambridge University Press (1985).

147. On the cone of nonnegative circuits, *Discrete and Computational Geometry* 1:229–239 (1986) (with C. Lee).

148. A generalization of the Eckart-Young-Mirsky matrix approximation theorem, *Linear Algebra Appls.* 88/89:317–327 (1987) (with G. Golub and G. Stewart).

149. Greedy packing and series-parallel graphs, *J. Combinatorial Theory* A47:6–15 (1988) (with A. Tucker).

150. On greedy algorithms for series parallel graphs, *Mathematical Programming* 40:197–204 (1988).