האוניברסיטה העברית בירושלים
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MICHAEL MASCHLER: IN MEMORIAM

by

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Working with Mike

Mike and I worked together for half a century. To date, I've had some twenty-five collaborators—coauthors of joint papers and books; there's no question that Mike is the premier one. He and I wrote three joint papers—the original Bargaining Set paper (21), the one on the Minimax Principle (38), and the Talmud paper (50)—and one joint book (64), about repeated games of incomplete information. These works are among my own most important, and perhaps among Mike's, too. To be sure, each of us also did other things, but these stand out.

Our collaboration started in the late nineteen-fifties, two or three years after I'd come to the math department of the Hebrew University. Mike was working in complex function theory, in which he had done his thesis; I had already made the switch from my thesis topic—knots—to games. One autumn afternoon I spoke at the mathematics colloquium, a weekly gathering of the whole department where a faculty member or guest gives a talk that's supposed to be of general interest to any mathematician, not only a specialist. I decided to speak about the von Neumann–Morgenstern (N–M) "solution," a.k.a. stable set. This is a very subtle and beautiful solution notion for coalitional games; at the time, I myself did not fathom its full beauty and subtlety, which became apparent only after subsequent work with Mike. During the question period after the lecture, Mike asked several questions that challenged its appropriateness. As the discussion lengthened, I suggested continuing in private, which we did. I did what I could to explain the N–M notion, but could not satisfy Mike. At last, a little exasperated, I said, Well, let's see if you can come up with something better. He said, Okay, give me a couple of days. That started a lifetime of friendship and collaboration.

Mike indeed came up with a proposal after a few days, which I promptly "shot down." That is, I constructed a "counterintuitive example": a game in which the proposed definition yields unacceptable results. This process continued for many months—Mike would propose a definition, and I would shoot it down. Finally, as the academic year was drawing to a close, Mike came up with a definition that I could not "shoot down." I didn't like his definition, and told him so; it seemed overly complex and arbitrary, lacking elegance and simplicity. There wasn't even a general existence theorem; it was, indeed, sometimes empty. But, I could not shoot it down.

Shortly thereafter, I left Israel for an extended trip to the United States, and occupied myself with other matters. To my surprise, some time later I received a manuscript from Mike entitled "The Bargaining Set for Cooperative Games"—containing Mike's definition, some worked-out examples, and some additional analysis—by R. J. Aumann and M. Maschler! I wrote to him that this was 100% his work, that all I had done was to shoot down previous attempts at a definition, and that there was absolutely no justification for including me as a coauthor—all the more so as I really did not like the definition. But Mike was a stubborn guy, he insisted, really kept at me for weeks and months; and finally, out of sheer exhaustion, I capitulated.

That paper has been cited many hundreds of times; it became one of my—and no doubt Mike's—most popular works. Mike's stubbornness really paid off. Moreover, the paper led to a very large literature, it was truly seminal. Later offshoots—one might say descendants—of that original concept were the Maschler–Davis Bargaining set $M^{(1)}$, for which there *is* an existence theorem (with a beautiful, highly nontrivial proof), and which is altogether more pleasant to work with, as well as the Kernel and Schmeidler's Nucleolus; taken together, these concepts constitute one of the richest, and yes, most elegant chapters of game theory, with a great many applications yielding beautiful insights. Much of this theory was developed by Mike, alone or in collaboration with game theorists such as Davis, Peleg, Shapley, G. Kalai, Owen, Curiel, Tijs, Granot, Potters, Zhu, and others.

Mike was good not only at theory, but also at applying it. Here's that story: I spent the academic year 1960–61, on sabbatical from Jerusalem, with Oskar Morgenstern's outfit—the Econometric Research Program—at Princeton University. In October of '61—as my stay was drawing to a close—there was a conference at Princeton entitled "Recent Advances in Game Theory," sponsored by Morgenstern and Harold Kuhn. All the luminaries of Game Theory came, including Shapley, Shubik, Scarf, Morgenstern and Kuhn themselves, and even Henry Kissinger—later to become Secretary of State of the United States—who was analyzing Cold War games. Mike spent the year '61–62 with Morgenstern, and was given the task of putting together the conference proceedings. In March of '62, in Jerusalem, I received a telegram (does anybody still remember what that was?) from Mike, informing me that the deadline for sending in papers had passed, that all the other participants had sent their papers in, and that if mine was not in within one week, he would go to press without it. I immediately dropped everything else, worked around the clock to get my paper written and typed, and rushed it off to him. Sure enough, the proceedings came out in April, right on time.

Afterwards, it transpired that when Mike sent that telegram, he sent similar telegrams to *all* the other speakers. *Not a single paper had come in yet*. And it worked! The conference proceedings came out on schedule, and became a game-theory classic.

During 1964–65, I was again on sabbatical, this time at Yale. Mike, who was back at home, suggested that we sponsor a game-theory workshop in Jerusalem in the summer of 1965. I agreed; perforce, Mike did almost all the preparatory work, raising money, making the reservations, and so on. This workshop was quite different from previous—and for that matter, subsequent—workshops and conferences. There were only 17 or 18 participants, and the workshop was spread out over three weeks. Thus there was only one presentation per day, lasting perhaps an hour or so. *All* the rest of the time was devoted to informal discussions in small groups. We even rented a room in the hotel, with coffee and cake available, where people could talk informally in the evenings whenever they wanted. The participants included Harsanyi, Selten, Shapley, Shubik, Joachim Rosenmüller (who at that time was a young student), and others.

The results were spectacular. Selten's perfect equilibria—which led to the whole enormous refinement literature—as well as Harsanyi's games of incomplete information were initially promulgated at this workshop. It's of course possible that the authors had already thought of these things before coming to Jerusalem in 1965,

but there is no doubt that the discussions at the workshop had an important early formative effect on these developments.

One of the most exciting periods of my life—and probably of Mike's, too—was the late Sixties, when we were working with the US ACDA, the United States Arms Control and Disarmament Agency. This was a US government agency whose job was to conduct nuclear arms control negotiations with the now-defunct Soviet Union. A consulting outfit based in Princeton called Mathematica, whose principals were Oskar Morgenstern and Harold Kuhn, had contracted with the ACDA to bring some game theory to bear on these negotiations. The work began in 1964–65, when a team that included Mike, Harold Kuhn, Frank Anscombe and others examined the game theory of nuclear weapons inspections; the question was, what provisions to write into the treaties to provide reasonable assurance that treaty provisions were being kept. This team wrote a report that became famous in the inspection literature, the star items being Mike's papers on the "Inspector's Non-Zero Sum Game" (25, 32).

In 1965, the emphasis changed from inspection to other aspects of the negotiations, including the effects of repetition; the negotiations were drawn out over many years, creating a repeated-game effect. At that time the team changed; Anscombe and some others left, and on board came a more game-oriented crew: Gerard Debreu, John Harsanyi, Reinhard Selten, Herb Scarf, Jim Mayberry, and the writer of these lines. Maschler and Kuhn stayed. Later, Dick Stearns joined the team. Between 1965 and 1968, we met three or four times a year for several days each time, usually in the Washington area. The agency was represented by Tom Saaty, an American OR specialist of Lebanese origin, very likable, capable, and knowledgeable. These meetings were extremely intense; for sixteen hours a day we would brainstorm with each other, meet with the agency staff, report on what we had done individually since the last meeting. Between meetings, back in Jerusalem, Mike and I—occasionally joined by Dick—would work very intensely, sometimes until three or four in the morning. And, we got results.

One time—it must have been in '67 or '68—we were working in my flat in Jerusalem in the wee hours of the morning. On my previous trip to the States, I had brought back one or two delicious kosher beef salamis, of a kind that was impossible to obtain in Israel. As we were getting a little hungry, I decided to serve sandwiches with my prized salami; it made an immediate hit with Mike. When he had finished one sandwich, I asked if he would like another one. Sure, he said, but don't bother with the bread. He always liked to get to the meat of things.

It was in this atmosphere that the theory of Repeated Games with Incomplete Information was born. To illustrate its relevance to the work of the ACDA, suppose that the US and SU (Soviet Union) are considering a treaty that provides for the destruction of a stated number of nuclear bombs on each side. Of course, what concerns the parties is not the number of bombs destroyed, but the number not destroyed, the number remaining; but it is much easier to verify that a bomb has been destroyed than that it remains. So we have a game of incomplete information: the payoff is in the number of bombs remaining, which can only be guessed at; thus the players do not know the payoffs, even their own. Harsanyi's theory of games of incomplete information had just been born and was very much in the air; Mike and I

decided to apply it to the repeated games context that was inherent in the repeated Arms-Control negotiations between the US and the SU.

The theory created in those years was initially written up in four reports (30, 34, 35, 36); they started a large, rich and mathematically deep literature, to which dozens of people contributed, that continues to develop to this day. For years, it was very difficult to get one's hands on the reports; bootlegged copies were secretly handed from one researcher to the other. Finally, in 1995, the reports were edited and issued in book form (64), with "postscripts" detailing what had happened in the area since the Sixties. The publication of this book is a saga in itself, to which we return below.

It is difficult to convey the palpable excitement of those years. We felt that we were unraveling secrets of nature, like in the natural sciences. The questions asked were indeed very natural; they were also difficult, and it was very exciting to get a result after weeks and sometimes months of working on it.

Throughout our many decades of joint work and interaction—which extends far beyond the jointly published work—we had many sharp disagreements, which sometimes even degenerated into shouting matches; some of them had conceptual or scientific substance, whereas others were about matters of presentation, including even the minutiae of printing. One disagreement with conceptual substance occurred when we were writing the paper about the minimax principle (38). To resolve the matter and go to publication, we finally hit on the idea of writing, "Some people feel that ... Others disagree, holding that ..." (Section 6). Of course, the "some" referred to one of us, the "others" to the other one. I don't remember now which was which; but I do remember that at the time, it seemed as if Western civilization would stand or fall on this issue.

In the year '80–81, while on sabbatical at Stanford, a paper by Barry O'Neill entitled "A Problem of Rights Arbitration in the Talmud" crossed my desk. The idea that there was something of game-theoretic interest in the 2,000-year-old Talmud fascinated me; I sent the paper to my eldest son Shlomo, then studying at a Talmudical academy in Jerusalem. Shlomo wrote back, laconically, "Dad, look at Ketuvot 93a" (a standard form of reference to one of about 5,000 folio pages in the Babylonian Talmud). I did look, and found a passage that was indeed related to O'Neill's work, but that was nonetheless extremely puzzling. The Talmud considers three cases of bankruptcy—with debts to three creditors totaling 600 and assets of 100, 200, and 300 respectively—but the payouts that the Talmud decrees do not seem to follow any fixed rule. I could not make sense of it.

After returning to Jerusalem in the fall of '81, Mike and I sat down to try to figure out what is going on in that passage. We put the nine relevant numbers on the blackboard in tabular form (50, Table I) and gazed at them mutely. There seemed no rhyme or reason to them—not equal, not proportional, nothing. We tried the Shapley value of the corresponding coalitional game; this, too, did not work. Finally one of us said, let's try the nucleolus; to which the other responded, come on, that's crazy, the nucleolus is an extremely sophisticated notion of modern mathematical game theory, there's no way that the sages of the Talmud could possibly have thought of it. What

do you care, said the first; it will cost us just fifteen minutes of calculation. So we did the calculation, and the nine numbers came out precisely as in the Talmud!

Needless to say, that was only the beginning of the research. As we'd said earlier, the sages of the Talmud could not possibly have known of the nucleolus. Rather, we figured, the nucleolus probably has some general property that corresponds to a principle that *was* within the sages' reach.

Where would one look for such a principle? Well, a natural place is in an axiomatization. At the time, we didn't know of any axiomatization of the nucleolus; but a literature search revealed that several years earlier, the nucleolus had been axiomatized by a Russian mathematical game theorist by the name of Sobolev. The central axiom was *consistency*; roughly, that if you give some of the players the amounts that the nucleolus assigns them, and consider a new game among the remaining players for the remaining money, then the nucleolus of the new game gives the remaining players precisely what it gave to those same players in the old game. I.e., for the nucleolus, it doesn't matter whether the payouts are made in stages or all at once. This principle, as applied to the bankruptcy problem, *was* indeed within the sages' reach.

It took many more months to unravel the puzzle completely, but consistency did turn out to be the key. The full story is told in (50), which became widely known not only in game theory circles but to the general public as well—especially that with some interest in the Talmud.

In June of 1982, my son Shlomo—the one who had first called attention to the apparently strange Talmudic passage—was killed in action while doing military reserve duty in "Operation Peace for Galilee." Mike was distraught. As soon as he heard the news, he rushed over to my house and sat on the stairs, unable to talk. During the "shiv'a"—the seven traditional days of mourning—he must have visited at least half a dozen times.

At some time in the mid-Eighties, we were approached by MIT Press to bring the old ACDA reports up to date and publish them in book form. We readily agreed to this proposal, and it came to fruition with the 1995 publication of "Repeated Games of Incomplete Information" (64), which won the Lanchester prize for the best OR book of that year.

Why did the production of this book take almost ten years, though all the research was already in place and indeed had been written up even before we began? Perhaps the major reason is that Mike had become a Tex afficionado shortly before, and insisted that the typesetting be done under his direct supervision, at the math department of the Hebrew University. I tried to tell him that we are mathematicians, and to some extent writers, but certainly not typesetters; the typesetting should be left to the publisher, who would do it for nothing, no doubt better than we possibly could. But when Mike had set his mind on something, there was no moving him. He insisted, and I capitulated. A typist was hired, and over the course of almost ten years, we spent some fifty thousand dollars of research money to pay her for the typesetting, not to speak of hours spent on endless discussions of the minutiae of Tex and of printing.

Above, I mentioned some advantages of Mike's stubbornness; but I do think that this particular project of his was crazy.

In a lighter vein is the following story. By the late Eighties, I still had not learned to work with computers. But when a favorable deal became available, I decided to invest in a "small" (ten kg) computer for use at home. I liked it, so when several months later, Mike proposed that we spend some research money to buy computers for use in the office, I readily agreed. And then Mike told the following (politically incorrect and chauvinistic) story: Computers are like women in three ways: (i) You tell them to do one thing, and they do something else; (ii) you can't manage with them, and you can't manage without them; and (iii) after you have one at home for a few months, you want one in the office, too.

And while on the subject of stories, Hanna—Mike's widow—relates the following: In addition to his work in complex variables, Game Theory, and experiments, Mike was a marvelous teacher at all levels. Indeed, he wrote several textbooks in general math for seventh and eighth grades (in addition to high school and university texts in game theory), which were, for a long time, *the* texts generally used in Israeli schools. One September day, Hanna was visiting a bookstore in downtown Jerusalem, and heard one young girl say to another, perhaps you have at home a used Maschler in good condition? Whereupon Hanna intervened and said, I do, but I'm not selling.

Mike's outstanding characteristic was his total honesty and straightforwardness. If he did not understand something, he would tell you right out; if he disagreed with you, he would tell you right out—and even insist, to an unreasonable degree, as mentioned above. If he refereed a paper and had a question or remark, he would write straight to the author, without any attempt to hide his identity. His stubbornness was, I think, associated with this extreme honesty.

Another outstanding characteristic was his generosity, which was also extreme, and which is also mentioned above. A minor chance remark regarding a paper would be enough to make him offer you joint authorship; and he was always extremely scrupulous in assigning credit.

Altogether, working with Mike for fifty years was exciting, fun, and a true privilege. I think we made some real progress, and am sorry it has come to an end.

Robert J. Aumann

A Mathematics Teacher

Michael Maschler was a game theorist, but deep down he was a mathematics teacher. He had the consciousness of a mathematics teacher and one can say that as a teacher the student was always before his eyes. Over the years he wrote mathematics textbooks for junior high school students and he was very deeply involved in all that was going on in mathematics teaching in high schools. He was a member of various professional committees in the Education Ministry and had a lot of influence on the role of mathematics teaching in the schools.

In this capacity he was active in the Science Teaching department of the Hebrew University in developing mathematics textbooks and as an instructor for graduate students and Ph.D. students. It was here that I made my acquaintance with him. In the 1980s, while searching for a Ph.D. subject in science teaching, or to be more specific, mathematics teaching, it occurred to me to write a high-school level book in game theory. The potential basis for it was a curriculum with an option of elective course offerings. I believed, and still do, that by teaching game theory there is a possibility of exposing the student to an alternative mathematical experience. With this in mind, it was natural for me to ask Michael to be my guide in this research, and he agreed. That was the starting point of a long journey of collaboration, always interesting if not always easy.

At the beginning I was a bit afraid of working with him because he was known as a tough guy to work with, but I discovered that he was tough in a soft way. I was afraid that he would force his ideas on me, but I discovered an amazing openness. All along he said that it was my thesis and he was at hand just to guide me. He taught me that in writing a textbook or in teaching one needs to be sensitive to the difficulties of the learner.

Several years after I finished my Ph.D. the head of the Science Teaching Center suggested that I write a book in game theory based on my Ph.D. thesis that could be introduced into the high school curriculum. He asked whether I would like Michael to be my coauthor or advisor. I said that I would prefer him to be my adviser and not my coauthor and to my surprise he refused. He said he did not want to be my traffic cop, but that he was ready to write it together with me, with the option of quarreling and discussing issues, but I would have the final say since I had experience in teaching the book and it was mostly my work. That was Michael. He knew how to give credit to his students; as I said, he was really oriented toward his students.

I accepted and respected his wishes and together we wrote the book. Unfortunately, the book was not used much in Israel and so, at the initiative of Robert Aumann, it was translated into English. Again we embarked on a long journey of collaboration, the fruit of which is to be published soon by Cambridge University Press. In this endeavor too I learned from Michael to heed any suggestion by anonymous or non-anonymous readers.

I'll end with an anecdote that describes how sensitive Michael was to the learner. In the course of the translation we had an argument with the translator Mike Borns about a specific sentence that was quoted from a paper by Gale and Shapley. The debate was sharp enough that the three of us agreed that Robert Aumann would be the judge. In this meeting Aumann decided that we were right and the sentence should remain in the original form. As we left the meeting Michael said to me, "You know, if Mike didn't understand the sentence, then the potential student probably won't either, so let's try to phrase it in another way." We did, and Mike was happy with the outcome.

That was Michael, always sensitive to the learner.

Ein-Ya Gura

Michael's Questions

"What do you mean by 'continuous probability'? Is it 'non-atomic,' or continuous in some topology? And can you extend your results to measures with countably many atoms?" Even today I vividly remember Michael Maschler's questions when I presented my master's thesis at the Game Theory and Mathematical Economics Research Seminar in Jerusalem. It was my first time at that famous seminar (I was then a student at Tel Aviv University), and I was surprised how such a distinguished person could ask such "simple" questions. Didn't he understand? But that was Michael. He wanted to get right to the bottom of things, and leave as few stones unturned as possible. Michael was always the true scholar.

In time I came to appreciate Michael more and more, both as a scientist and as a person. He made path-breaking contributions to game theory; stimulated and excited many people, all over the world, with his ideas and suggestions; and did so, above all, in a most unassuming way. He was a very open and friendly person, with a keen sense of humor (I have a good collection of jokes that he e-mailed me over the years).

Maschler was a strong believer in his work, not necessarily following the latest "fashions" (and yes, these exist in science as well). Bob Aumann once fondly said that there are three kinds of game theory: cooperative game theory, noncooperative game theory, and … "Maschlerian" game theory (many probably recall Michael's arguments such as "player 1 owes this amount to player 2, who owes that amount to player 3, and so on—and in the end everything clears and the right solution obtains!").

When I came to the Hebrew University of Jerusalem, Michael's support and valuable suggestions were instrumental in the establishment of the Center for the Study of Rationality. When the Game Theory Society was founded, Maschler served on its First Council. Again and again, most characteristically, he never sought the limelight. Yet one could always count on him—extremely helpful, supportive, and full of new ideas.

Michael Maschler will be sorely missed.

Sergiu Hart

My Joint Work with Michael Maschler

In 1962 I was writing my Ph.D. thesis under the supervision of R. J. Aumann. In one of my meetings with him Aumann had given me a preprint, coauthored by M. Davis and M. Maschler, on the Davis–Maschler bargaining set. That preprint contained an open problem that I succeeded in solving. I sent my solution to Maschler who was visiting Princeton at that time. Maschler's answer was very kind and enthusiastic. As far as I recall that was my first contact with Michael.

When Maschler returned to Jerusalem in 1963 our collaboration began. Our first project yielded two major results: 1) an algebraic existence proof for the kernel of a coalitional game; 2) a precise formula for the (maximum possible) dimension of a kernel of a game. Additional by-products of our first paper were the investigation of the desirability relation for coalitional games and of separating collections of coalitions; see (28). We continued our investigation of the kernel in (33), where we introduced the (general) concepts of reduced games and intermediate games. With the help of these concepts we analyzed the structure of the kernel of a coalitional game. We were both very excited when we obtained the precise star-shaped form of the kernel of the seven-person projective game during our investigation of the kernel of general projective games. In (42) we investigated (discrete and autonomous) set-valued dynamic systems in metric spaces. We arrived at sufficient as well as some necessary conditions for stability of points and sets of points. Our main tools were vector-valued Lyapunov functions and stable sets were characterized as inverse images of Pareto minimal points. As an application we offered concise proofs of the results on stability and asymptotic stability of the kernel and nucleolus.

The collaboration with Maschler led to two joint papers with L. S. Shapley. In (39) we characterized the kernel and the bargaining set for convex games and in (46) we investigated some geometric properties of the kernel and the nucleolus. Our last joint project was a paper in honor of Shapley on his sixty-fifth birthday. That was a joint work with G. Owen on a dynamic system that leads to the Nash bargaining set of smooth bargaining games; see (54).

Maschler helped P. Sudhölter and me very much when we were writing our book *Introduction to the Theory of Cooperative Games*, which appeared in 2003. He kindly supplied many handwritten remarks on several chapters of our manuscript that improved our presentation. After that he kindly agreed to review our book for *GEB* and used it, among other sources, in his lectures on cooperative games at the Center for the Study of Rationality. As a result of his lectures he used to come to my office to discuss our writing and offer further improvements. His suggestions were very helpful in preparing the second edition of our book, which appeared in 2007.

My cooperation with Michael was an intellectually challenging and instructive experience. I shall always remember our collaboration and the many days we spent together investigating the theory of cooperative games.

Bezalel Peleg

Michael Maschler at the Center for the Study of Rationality

I first met Michael Maschler nineteen years ago, at the inception of the Center for the Study of Rationality. I will always remember him as a warm and friendly soul, with a wonderful sense of humor. At all times, and even in his difficult last days, he would entertain us with a witty joke that not only made us laugh, but also conveyed a shrewd insight into the situation.

As part of my job as the Center's administrative director, I handled his budget and often had to discuss it with him. Usually he made wise and pointed comments, but sometimes he simply said "I don't understand."

It was a pleasure to see students coming out of his classroom excited and inspired by his thought-provoking lessons and crystal-clear explanations.

I feel honored and privileged to have known Michael Maschler.

Hana Shemesh

Teacher, Colleague, and Coauthor

I feel privileged for having come a long way with Michael Maschler: over fifty years of collaboration and friendship, which I would like to highlight here. He was my challenging high school teacher of mathematics, and clearly influenced my decision to major in mathematics in college. In high school he taught me the basic notions of topology, including a simplified, two-dimensional proof of Brouwer's fixed point theorem. The mathematical puzzles he presented us with have been passed down to my children and students.

In graduate school I was on Maschler's team to supervise the teaching of his mathematics textbooks in middle schools. My role consisted of giving instruction courses to the teachers on the new material and supervising their performance in classrooms around the country. Maschler's high standards and involvement in mathematics education at all levels were a valuable example for me.

At the same time Maschler became an important role model also as a teacher and prominent game theorist. In one advanced graduate course, while teaching Harsanyi's incomplete information theory, he gave a homework exercise in which we were asked to find all possible belief types when two players face uncertainty about the state of nature that can be α or β. About fourteen years later, when the Mertens–Zamir paper on the construction of the universal belief space was completed, he called me up and said, "I heard that you answered the question I gave in class." His pioneering and seminal research with Bob Aumann on repeated games with incomplete information became the research topic of my Ph.D. under the supervision of Aumann. Later Maschler refereed my first published paper (he insisted on being identified to the authors whose work he refereed in order to establish a dialogue with them). By then I realized that his role as my teacher and educator had extended far beyond what I could have imagined in high school. Our professional activities crossed again when I was working on inspection games and I found out soon enough that Maschler's works were the most cited, pioneering works in the field. As usual, Maschler was most supportive, always encouraging and truly interested in others' work. In addition to being a leading researcher in cooperative game theory, on the personal level Maschler was the most cooperative game theorist.

About three years ago, when Eilon Solan and I started to write a textbook on game theory (in Hebrew), we found it quite natural to ask him to join us and contribute his enormous educational talent and experience. He became totally dedicated and committed to the project and was engaged in reading and making comments and suggestions, in between his repeated hospitalizations, literally up to his last days of consciousness. He missed by less than a month the delivery of the manuscript to the publisher. The publication of this book, coauthored by Michael Maschler and dedicated to him, is expected shortly.

These comments and thoughts would be rather incomplete without saying a few words about the pleasant personality of Michael Maschler. His friendly and sincere attitude towards everybody around him, regardless of their age, grade, or status, was

rather remarkable. He became a friend to everyone he worked or interacted with. He was fond of certain jokes that he selected and delighted in telling. I still remember the last one he told me over the phone just before his last hospitalization. I will greatly miss him as a teacher, colleague, collaborator, and friend.

Shmuel Zamir

II. Scientific Contributions of Michael Maschler: An Overview

Professor Michael B. Maschler, a prominent and distinguished member of the game theory community, a leader and architect of the theory of games as it is known today, passed away on July 20, 2008, at the age of 81. His prolific scientific activity extended over 56 years, from the first paper he published at the age of 25 to the last two books he coauthored, published in the months after his death.

Born in Jerusalem on July 22, 1927, he got his Ph.D. from the Department of Mathematics at the Hebrew University in 1956; upon submission of his thesis on the theory of functions of complex variables, he joined the department as an instructor. His meeting with Robert J. Aumann, a newly recruited young lecturer in the department, was a turning point in his career as he was "converted" to game theory and became one of the small group of people who developed and shaped game theory in the early Sixties. This was the beginning of the remarkable Aumann–Maschler collaboration, which extended over many decades and had a great impact on the foundations of game theory. Both men were research associates in the Econometric Research Program at Princeton University in the years 1961–1963, where much of the "action" in game theory took place. A few years later, in 1967–1968, both were members of a group of specialists who advised the U.S. Arms Control and Disarmament Agency (ACDA) in Washington, D.C., to which the theory of games with incomplete information owes its origin.

Michael Maschler's greatest impact is on cooperative game theory. He originated the bargaining set for cooperative games (in collaboration with R. J. Aumann) and then its conceptual derivative, the kernel (in collaboration with M. Davis and B. Peleg), which in turn inspired D. Schmeidler to introduce the next conceptual derivative, the nucleolus. The extensive studies of these concepts and their wide variety of applications constitute one of the three major approaches to cooperative game theory, the others being the core and the Shapley value. Maschler's numerous studies, in collaboration with B. Peleg, G. Owen, L. Shapley, M. Potters, S. H. Tijs, and others, explore the relationships between all these concepts as well as the Nash bargaining solution. His work on the Nash bargaining problem led Maschler to introduce, in collaboration with M. Perles, the subtle and original superadditive solution, which was further investigated by several authors. In studying the cooperative game solution concepts, Maschler developed the notions of consistency and reduced game due to Sobolev, and studied their role, relevance, and applications to various solution concepts (see, e.g., his work with G. Owen on the consistent Shapley value and his work with J. A. M. Potters and S. H. Tijs on the general nucleolus). A beautiful piece of work making original use of cooperative game theory—and, specifically, the notion of consistency—is Maschler's joint work with R. J. Aumann on a bankruptcy problem from the Talmud, in which they relate an ancient problem and its ancient solution to a modern game-theoretic solution concept, namely, the nucleolus. Another contribution of Maschler was in applying cooperative game theory to network games, which he did in collaboration with D. Granot, A. van den Nouweland, S. H. Tijs, and H. Reijnierse. Still within his contributions to cooperative game theory and its applications, Maschler recently got interested in the dynamics of voting systems, a

line of research that he developed in collaboration with S. Barberà, D. Granot, and J. Shalev.

One of the most important events in the mid-Sixties was the development of the theory of games with incomplete information, and Maschler was part of it. This happened while he was a member of a group of specialists (including R. J. Aumann, G. Debreu, J. Harsanyi, H. Kuhn, H. Scarf, R. Selten, and R. Stearns) that was formed to advise the U.S. Arms Control and Disarmament Agency in Washington, D. C., during the negotiation between the U.S. and the Soviet Union over an arms reduction agreement (the SALT agreement). The pioneering works of Aumann and Maschler on repeated games with incomplete information became a starting point and a cornerstone of a rich and still growing field of research and, because they largely inspired the breakthrough result of Mertens and Neyman, had a major impact on the related field of stochastic games as well. A testimony to the importance of the seminal work of Aumann and Maschler on repeated games with incomplete information is the fact that these works, written in 1967–1968, and for almost three decades available only as classified ACDA reports, were published, due to their growing relevance, in 1995 as an MIT Press book which won the Lanchester Prize Citation for that year. The Aumann and Maschler work on repeated games with incomplete information was a central element in the Nobel Prize Committee announcement that awarded the 2005 Nobel Prize in Economics to Robert J. Aumann.

A by-product of Maschler's involvement in several consulting projects, such as the ACDA, the U.S. Air Force office of Scientific Research, and the Office of Naval Research, was his important contribution to the theory of inspection games. His two papers published in those years are basic references in any work in this field.

An important aspect of Maschler's professional contribution was his extraordinary talent as an educator. He was an excellent teacher at all levels. His game theory lecture notes were published at the Hebrew University (1970), at the IMSSS at Stanford University (1973), and at the Institute for Advanced Studies in Vienna (1978). But his role as an educator started much earlier, as I can personally attest: Maschler was my high school mathematics teacher, a most challenging and effective one. In this capacity, he became one of the first "experimental game theorists," as he ran experiments in class on the formation of coalitions in games with an empty core. The results of these experiments were published in 1962, long before experimental economics and game theory became so widespread.

For years he was an active and central figure in the Israeli education system. He chaired curriculum committees for mathematics in elementary, middle, and high schools. He delivered a lecture on mathematics curriculum for humanistic studies at the International Congress of Mathematicians in Stockholm (1962) and on the exponential and logarithmic functions in the new high school curriculum at the Israel Mathematical Union Conference in Tel Aviv (1987). Maschler authored many textbooks that were widely used all over the country. Here again I happened to have a privileged look, as I was involved in the instruction and supervision of the schoolteachers using his textbooks. Michael Maschler supervised Ein-Ya Gura in a rather unique Ph.D. project involving teaching selected topics in game theory to middle school students. The project was successful and they both coauthored a book

in Hebrew on the subject. This book is forthcoming in English by Cambridge University Press. Another book expected to be published within a month or two is a textbook on game theory for undergraduate and graduate level students by Michael Maschler, Eilon Solan, and myself. The Hebrew version by the Magnes Hebrew University Press is expected next month. The English version by Springer Verlag will be out hopefully within a year.

Let me conclude by saying a few words about the pleasant personality of Michael Maschler. He was most supportive, encouraging, and truly interested in others' work. His friendly and sincere attitude to everyone around him, independently of their age, grade, or status, was rather remarkable. He became a friend who was fun and a pleasure to be with, to anyone whom he worked or interacted with. He was a valuable and much-beloved member of the game theory community, who will sorely miss him.

Shmuel Zamir

III. List of Publications of Michael Maschler

1. “Sur une transformation généralisee de série en série,” *Comptes Rendus des Seances de l’Accademia de Sciences, Paris* 235 (1952a), 769–770 (Abstract).
2. “A generalized series to series transformation and its use to find an analytic continuation,” M.Sc. thesis, The Hebrew University of Jerusalem, 1952b.
3. “Prolongement analytique par la méthode de la transformation généralisee de série en série,” *Comptes Rendus des Seances de l’Accademie de Sciences, Paris* 236 (1953), 883–885 (Abstract).
4. “Properties of minimal domains,” Abstract from the *Proceedings of the International Mathematical Congress*, Amsterdam, 1954, pp. 139–140.
5. “Minimal domains and their Bergman Kernel function,” *Pacific Journal of Mathematics* 6 (1956a), 501–516.
6. “Minimal domains and representative domains,” *Bulletin of the Research Council of Israel* 5A (1956b), 50 (Abstract).
7. “Domain functions and conformal mapping with applications to extremal problems,” Ph.D. thesis, The Hebrew University of Jerusalem, 1956c (in Hebrew, English summary).
8. “*M*-minimal domains,” *The Bulletin of the Research Council of Israel*, Section F: Mathematics and Physics 7F (1957), 42 (Abstract).
9. “Classes of minimal and representative domains and their kernel functions,” *Pacific Journal of Mathematics* 9 (1959a), 763–782.
10. “Analytic functions of the classes *L*2 and *l*2 and their kernel functions,” *Rendiconti del Circolo Matematico di Palermo* 8, Ser. II (1959b), 1–15.
11. “Why do students fail in mathematics in high school?,” *Atti Del Sesto Congresso Dell’Unione Matematica Italiana, Tenuto a Napoli nei Giorni 11–16 Settembre 1959*, Edizioni Cremonese, Roma, 1960, pp. 483–484.
12. “Classes of square integrable analytic functions and their kernel function,” *Atti Del Sesto Congresso Dell’Unione Matematica Italiana, Tenuto a Napoli nei Giorni 11–16 Settembre 1959d*, Edizioni Cremonese, Roma, 1960, pp. 323–324.
13. “Bargaining in *n*-person cooperative games of pairs,” *Recent Advances in Game Theory*, Papers delivered at a meeting of the Princeton University Conference, October 4–6, 1961, M. Maschler, ed., Princeton University Press, Princeton, NJ, 1962a, pp. 161–169.
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15. “Immune coalition-structures for *n*-person cooperative games,” Abstract of short communications, International Congress of Mathematics, Stockholm, 1962c, p. 163.
16. “Mathematics curriculum for humanistic studies,” Abstract of short communications, International Congress of Mathematicians, Stockholm, 1962d, p. 209.
17. “An experiment in *n*-person games,” *Recent Advances in Game Theory*, Papers delivered at a meeting of the Princeton University Conference, October 4–6, 1961, M. Maschler, ed., Princeton University Press, Princeton, NJ, 1962e, pp. 49–56.
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19. “The power of a coalition,” Management Science 10 (1963b), 8–29.

20. “A non-zero-sum game related to a test ban treaty,” *Applications of Statistical Methodology to Arms Control and Disarmament*, Report of the U.S. Arms Control and Disarmament Agency/ST-3, Washington, DC, 1963c, pp. 237–287.

21a. “The bargaining set for cooperative games” (with R. J. Aumann), *Advances in Game Theory*, M. Dresher, L. S. Shapley and A. W. Tucker, eds., Annals of Mathematics Studies, No. 52, Princeton University Press, Princeton, NJ, 1964a, pp. 443–476.

21b. “The bargaining set for cooperative games” (with R. J. Aumann), *Classics in Game Theory*, H. W. Kuhn, ed., Princeton University Press, Princeton, NJ, 1997, pp. 140–169.

22. “Stable payoff configurations for quota games,” *Advances in Game Theory*, M. Dresher, L. S. Shapley and A. W. Tucker, eds., Annals of Mathematics Studies, No. 52, Princeton University Press, 1964b, pp. 477–499.

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24. “The kernel of a cooperative game” (with M. Davis), *Naval Research Logistics Quarterly* 12 (1965a), 223–259.

25. “The inspector’s non-constant-sum game: Its dependence on one detector,” *The Application of Statistical Methodology to Arms Control and Disarmament*, Report of the U.S. Arms Control and Disarmament Agency/ST-37, Chapter IX, Washington, DC, 1965b, pp. 231–267.

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35. “Repeated games of incomplete information: The zero-sum extensive case” (with R. J. Aumann), *The Indirect Measurement of Utility*, Report of the U.S. Arms Control and Disarmament Agency/ST-143, Chapter III, Washington, DC, 1968a, pp. 37–116.
36. “Repeated games of incomplete information: An approach to the non-zero sum case” (with R. J. Aumann and R. E. Stearns), *The Indirect Measurement of Utility*, Report of the U.S. Arms Control and Disarmament Agency/ST-143, Chapter IV, Washington, DC, 1968b, pp. 117–216.
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39. “The kernel and bargaining-set for convex games” (with B. Peleg and L. S. Shapley), *International Journal of Game Theory* 1 (1972b), 73–93.
40. Lectures on Game Theory, A series of lectures given at the Seminar of the Institute for Mathematical Studies in the Social Sciences, Stanford University, Stanford, CA, 1973. Compiled by L. Guasch, J. Meyer, M. Okuno, and K. Yun.
41. “Asymptotic stability and other properties of trajectories and transfer sequences leading to the bargaining set” (with G. Kalai and G. Owen), *International Journal of Game Theory* 4 (1975), 193–213.
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45. Lectures on cooperative *n*-person game theory, Lectures given at the Institute for Advanced Studies, Vienna, Compiled by M. Winkler, 1978.
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65. “The kernel/nucleolus of a standard tree game” (with D. Granot, G. Owen and W. R. Zhu), *International Journal of Game Theory* 25 (1996), 219–244.
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67. “The reactive bargaining set: Structure, dynamics and extension to NTU games” (with D. Granot), *International Journal of Game Theory* 26 (1997), 26–75.
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76. “Voting for voters: The unanimity case” (with D. Granot and J. Shalev), *International Journal of Game Theory* 31 (2003), 155–202.
77. “Encouraging a coalition formation” (also in: *Theory and Decision* 56 (2004), 25–34), *Essays on Cooperative Games in Honor of Guillermo Owen*, Theory and Decision Library, Series C: Game Theory, Mathematical Programming and Operations Research, G. Gambarelli, ed., Kluwer Academic Press, Boston, 2004, pp. 25–34.
78. *Game Theory* (with E. Solan and S. Zamir), Magnes Press, Jerusalem, 2008 (in Hebrew).
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81. “The nucleolus of a standard tree game revisited: A study of its monotonicity and computational properties” (with J. Potters and H. Reijnierse), submitted to *International Journal of Game Theory.*

Hebrew Publications of Michael Maschler

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2. *מתמטיקה* (עם ב. מאיר), בית הספר התיכון ליד האוניברסיטה העברית, ירושלים, 1961, 1962, 1965.
3. *מתמטיקה לשנת הלימודים השמינית* (עם ע. סקידל), ועדת החינוך הבין-קבוצית, ירושלים, 1966.
4. *אלגברה לשנת הלימודים השביעית*, עם עובד, תל אביב, 1969, 1972; הקיבוץ המאוחד, תל אביב, 1976.
5. *אלגברה לשנת הלימודים השביעית מדריך למורה*, (עם צ. אלטשולר, מ. קורן),.פרקים א-ח, 1970, 1979; פרקים ט- יד, 1971; (עם צ. אלטשולר,א. רימון), פרקים טו-כ, 1973, המרכז הישראלי להוראת המדעים על שם עמוס דה-שליט, האוניברסיטה העברית, ירושלים.
6. *אלגברה מדריך למורה* (עם צ. אלטשולר,מ. קורן), המרכז הישראלי להוראת המדעים האוניברסיטה העברית ומכון ויצמן למדע, ירושלים ורחובות, 1973-1970.
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9. *אלגברה לחטיבת הביניים כיתה ט'*, חלק א'- ג' (עם מ. הרשקוביץ, מ. קורן), האוניברסיטה העברית, ירושלים, 1971.
10. *אלגברה לשנת הלימודים התשיעית*, עם עובד, תל אביב, 1971.
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15. *אלגברה לשנת הלימודים התשיעית מדריך למורה*, פרקים טו-כ (עם צ. אלטשולר, א. רימון, ר. אלדורי), האוניברסיטה העברית, ירושלים, 1973.
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18. *אנליסה שתיים ושלוש יחידות לימוד* (עם ד. קטורזה ואחרים), המרכז להוראת המדעים על שם עמוס דה-שליט, האוניברסיטה העברית, ירושלים, 1979.
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