SHIMSHON AVRAHAM AMITSUR (1921–1994)
with fellow Honorary Member Nathan Jacobson on his right

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# OBITUARY

## SHIMSHON AVRAHAM AMITSUR

Shimshon Avraham Amitsur, who died on 5 September 1994, was a leading algebraist whose work in many areas of algebra had a decisive influence. He had been an honorary member of the London Mathematical Society since 1989.

Shimshon Avraham Kaplan (he later hebraicized his name to Amitsur) was born on 20 August 1921 in Jerusalem, in the old City, to Jacob and Rashke Kaplan. His father was a printer by profession, and a poet and writer by vocation (he left behind a long diary, written from boyhood in 1912 until his death in 1967). Shimshon's great-grandparents on both sides had emigrated from Russia in the 1870s and had settled in Jerusalem, earning a modest living and at the same time pursuing biblical learning.

Shimshon's talent and flair for mathematics was noticed by his secondary school teachers, who persuaded him to go to University (rather than become an accountant, as he had intended) and even obtained a stipend for him. He began his studies at the Hebrew University in Jerusalem in 1938, reading mathematics and physics, and graduated in 1941/2. He then joined the British Army (Jewish Brigade) and served for four years in the Artillery Unit, where his mathematical expertise was put to good use. There he also acquired experience as a radio operator and technician, which was to prove useful later in the defence of Mt Scopus during the War of Independence. It was at this time, in the late 1940s, that he changed his name, taking 'ami' and 'tsur' from the names of the Patriarchs of the tribes of Israel. He married Sarah, née Frankel, and they had three children (and now seven grandchildren, ranging in age from 22 to 3 years).

Returning to the Hebrew University in 1947, he received an MSc degree and the Jabotinsky Prize for research. His research in algebra, under the direction of Jacob Levitzki, led to a PhD in 1949. In 1950, Amitsur and Levitzki jointly published what has become one of the standard theorems on polynomial identities, the Amitsur–Levitzki theorem **[8]**: The ring of $n \times n$ matrices over a commutative ring satisfies the standard identity of degree $2n$. (This was known to be the lowest possible degree, by ⟨**11**⟩.) In 1953 they shared the first Israel Prize in the Exact Sciences. In conversations with Shimshon, it was clear what an important role Levitzki had played in his professional formation. It is sad that Professor Levitzki died three years later, in 1956, and in 1974 Amitsur organized a Memorial Number of the *Israel Journal of Mathematics* in his honour ([**74**]; see also [**38**]).

Amitsur spent almost all his working life (except for overseas visiting appointments) at the Hebrew University, Jerusalem, as research assistant from 1947, instructor from 1954, lecturer from 1954, associate professor from 1956 and full professor from 1960. He was Chairman of the Mathematics Institute at the Hebrew University from 1960 to 1962.

One of Amitsur's first and lasting interests was the topic of polynomial identities in rings. The subject had received its initial impetus in 1948 when Kaplansky proved his PI-theorem ⟨**9**⟩: A primitive algebra satisfying a polynomial identity of degree $d$ is simple of finite dimension $n^2$, where $2n \leqslant d$. Building on this, Amitsur extended

*Bull. London Math. Soc.* 28 (1996) 433–439

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his work with Levitzki by proving **[13]**: Any semiprime PI-ring can be embedded in a matrix ring over a commutative reduced ring. In later papers **[16, 18]**, he generalized and strengthened these results, and put them in a more general context. As interesting by-products, he showed that (i) every integral domain satisfying a polynomial identity can be embedded in a finite-dimensional division algebra **[25]**, (ii) every finite-dimensional division algebra can be generated by two conjugate elements $a$, $u^{-1}au$ **[24]**, (iii) every $T$-ideal (that is, admitting all endomorphisms) in a free algebra is primary **[26]**. In **[59]** and **[66]** he returned to this topic by extending the PI-theorem to general coefficient rings in an optimal way.

A significant breakthrough, which changed our perception of PI-theory, was the introduction of generalized polynomial identities (GPIs), that is, identities where the variables fail to commute not only with each other but also with the coefficients. As a first result in this field, Amitsur in **[54]** proved his GPI-theorem, a surprising analogue to Kaplansky's PI-theorem, this time without a bound on the dimension: A primitive ring satisfies a GPI if and only if it is isomorphic to a dense ring of linear transformations, with non-zero socle, over a skew field finite-dimensional over its centre. The proof is an ingenious but complicated induction; later, a simpler proof was found by Martindale ⟨**12**⟩ (see also Rowen ⟨**16, 17**⟩). Amitsur went on in **[58]** to consider rational identities; in the non-commutative case it is by no means obvious how rational expressions should be defined, and this is not the place to go into detail. His main result was that (i) a rational identity which holds in a division algebra infinite-dimensional over an infinite centre holds universally, and (ii) a rational identity which holds in a division algebra of dimension $n^2$ over an infinite centre, for all $n$, holds universally. As a consequence, he obtained a construction for the 'universal' skew field of fractions of the free algebra $F$ (here 'universal' is to be understood as 'having all other skew fields of fractions of $F$ as specializations'; see ⟨**4, 5**⟩). In his later work he frequently returned to the topic of PI-rings, and also took up the topic of central polynomials, for example in **[71]**, where he used central polynomials to give a simple proof of M. Artin's characterization of Azumaya algebras (see also **[77, 78]**).

I. N. Herstein in ⟨7⟩ made a study of the finite subgroups of skew fields, where he proved that every such subgroup of odd prime power order is cyclic, and he conjectured that this holds for any subgroup of odd order. In **[28]** Amitsur gave a complete solution (incidentally refuting Herstein's conjecture) by observing that such groups act without fixed points (that is, they have a representation $\rho$ for which $\rho(g)$ $(g \neq 1)$ leaves no non-zero vector fixed) and then using the classification of such groups begun by Burnside and Zassenhaus ⟨**20**⟩. This reduces the problem to determining the existence of certain division algebras, using class-field theory. This was an astonishing *tour de force*; even more so, the fact that the problem was solved at the same time (in essentially the same way) independently by J. A. Green (who had already submitted his paper, but withdrew it when Amitsur's work appeared).

Division algebras formed another subject to which Amitsur made major contributions. It was the topic of his thesis, and at this time he proved that two central simple algebras have the same splitting fields if and only if each is similar to a power of the other in the Brauer group. In the proof, generic splitting fields play an important role. By a generic splitting field of a central simple algebra $A$ of degree $n$ over the base field $k$, one understands a field $F(A)$ such that a field $E$ splits $A$ if and only if the composite $EF(A)$ is purely transcendental of degree $n-1$ over $E$ (or, equivalently, there is a $k$-place of $F(A)$ in $E$). Such fields were studied by Witt for the

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special case of quaternion algebras ⟨**19**⟩, and Chatelet in ⟨**3**⟩ made a study of algebraic varieties, the Brauer–Severi varieties, whose function fields are in effect generic splitting fields of of certain algebras. Amitsur in [**23**] was the first to define generic splitting fields for arbitrary central simple algebras, describe their properties and give methods of construction for them. Today they play an important role in the study of central simple algebras (see ⟨**14, 13**⟩). In [**29**] Amitsur solved a particular case of a question raised by Jacobson ⟨**8**⟩, by proving that a countable-dimensional algebra over an uncountable field has a nil Jacobson radical. (He told me that he noticed this fact while lecturing on complex function theory.)

One of the key questions about division algebras concerns their representability as crossed products. In 1929 Brauer proved ⟨**2**⟩ that every division algebra is similar to a crossed product, and he asked whether perhaps every division algebra is isomorphic to a crossed product. A. A. Albert ⟨**1**⟩ showed that this was so in degree 4, and, with older results, this provided a positive answer for degrees $n = 2, 3, 4, 6$ and 12; but the general question remained open for over 40 years, until in 1971 Amitsur was invited to contribute to a 65th birthday celebration volume for A. A. Albert. (Sadly, by the time it appeared, it was as a memorial volume.) Shimshon felt that this called for something special; he thought of the old problem of whether every central division algebra is a crossed product. And he succeeded in finding the solution: in [**69**] he constructed for any $n$ divisible by 8 or the square of an odd prime, a division algebra of degree $n$ that is not a crossed product. The proof is an ingenious combination of properties of generic matrix algebras and particular properties of power series rings, and it stimulated much of the recent research on division algebras.

Amitsur has been described as a 'bare-hands mathematician', but he managed to do a lot with his bare hands, as is shown by the many hard problems he solved. However, he also turned his hand to building theories. In a series of papers [**14, 19, 20**], he laid the foundations of a general theory of radicals in rings. Kurosh ⟨**10**⟩ had done the same independently, at about the same time, and it formed the basis of most subsequent treatments (see Szász ⟨**18**⟩); it also had significant implications for torsion theories.

In [**42**] Amitsur introduced a complex for a field extension $F/C$, soon to become known as the Amitsur complex, which for Galois extensions with group $G$ led to the cohomology of G; he found a link with the Brauer group of $C$ even for purely inseparable extensions. This work was generalized and simplified (with some errors corrected) by Rosenberg and Zelinsky ⟨**15**⟩, and it eventually became part of Cech cohomology in Grothendieck's super-generalization of topological spaces (sites), but it took someone of Amitsur's mathematical acumen to realize the usefulness of this complex (see also [**50, 53**]). He followed this up in joint papers with J.-P. Tignol [**93, 94, 95**], in which information on the Galois group of the minimal Galois splitting fields of universal division algebras of a given degree is obtained, leading to an evaluation of how far the universal division algebra is from being a crossed product. He also gave a treatment of derived functors in an abstract setting, in [**49**].

Amitsur used algebraic methods to good effect in other fields. Using the algebra of generating functions, he obtained results on asymptotic behaviour that led to simpler proofs of several results in number theory, including a proof of the prime number theorem ([**39**]; see also [**45, 47, 51**]). His earliest work was on linear differential equations, which he viewed as linear differential operators [**4**]; later, he applied these results to the study of cyclic Galois extensions of skew fields in [**21**], extending the work of Dieudonné in the quadratic case ⟨**6**⟩.

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On a personal level, Amitsur was very approachable, and when confronted by a mathematical question, would combine his wide knowledge with some quick reflection to give a constructive reply, which would always be practical and down-to-earth. He was also very knowledgeable about biblical history, as well as modern archaeology, and it was a pleasure to follow one of his conducted tours, a pleasure he obviously shared.

He was a frequent visitor at universities in the USA and elsewhere. He was also much in demand as a speaker at conferences, and he wrote a number of illuminating survey articles [**55**, **65**, **67**, **68**, **75**, **80**, **83**, **84**, **88**, **90**], but sadly no books. When I first met him in 1958 at the International Congress in Edinburgh, my little book on Lie groups had just appeared, and on being introduced, he said to me: 'I was sure you were an old man, because you had written a book'. But he very much kept up his research until the end. In 1969 he was awarded the Rothschild Prize for Mathematics, and he became a member of the Israel Academy of Sciences and Humanities. In 1989 our Society elected him an Honorary Member. In 1990 he received the Dr *Honoris Causa* of Ben Gurion University. He was also on the Editorial Board of numerous mathematical periodicals.

Amitsur took a keen interest in mathematical education. From 1961 to 1972 he was Director of a new experimental programme in 'New Math' in Israel, and from 1967 to 1973 he was Advisor and Writer for Instructional Television in Israel. Since 1963 he had represented the Mathematical Union of Israel at ICMI. Since 1975 he had been a member of the Committee for High School Mathematics in Israel, and since 1976 coordinator of the project of the new programme on High School Mathematics in Israel. Since 1984 he had been Director of the Education Center of the Hebrew University.

I am greatly indebted to Dr Oded Irshai, Shimshon's son-in-law, for providing me with information about the family. I should also like to thank his many friends and colleagues who have helped me in the writing of this obituary, in particular G. M. Bergman, M. P. Drazin, E. Formanek, J. Golan, A. W. Goldie, J. A. Green, I. Kaplansky, A. Mann, J. C. Robson, L. H. Rowen, J.-P. Tignol and D. Zelinsky (who kindly supplied the photograph).

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