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TECHNICAL REPORT
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MATHEMATICAL ACTIVITIES IN ISRAEL

BY

BERNARD EPSTEIN

30 August 1966

MATHEMATICAL ACTIVITIES IN ISRAEL

INTRODUCTION

Israel is, both in the political and the scientific sense, an isolated singular point. It is almost certainly no exaggeration to assert that there is not a single major field of scientific activity in which Israel's four hostile neighbors, which hem her in on three sides against the Mediterranean, are as productive, in combination, as this small and harassed nation of less than three million. Indeed, one must go quite far in any direction before reaching another nation with a comparable level (either gross or per capita) of scientific accomplishment. Although the picture is far from one of unalloyed optimism -- as is quite clear from the subsequent material in this report -- it is quite proper to begin by describing my overall impression, based on a recent visit, as one of astonishment and awe.

The economic, political, and military stresses which torment Israel, as well as the extremely trying problems associated with the attempt to weld a nation out of immigrant groups, drawn from a hundred different nations, with dozens of different native languages, cultural backgrounds, and degrees of religious commitment, need not be dwelt on here, but they should be kept constantly in mind when trying to assess the accomplishments, failures, and prospects of this unique nation.

It will almost certainly be found helpful to read this report in conjunction with reports ONRL-23-66 and ONRL-24-66, written by colleagues who have also recently visited Israel.

The Universities of Israel

At the present time Israel contains four universities: the Hebrew University of Jerusalem; the Technion (Israel Institute of Technology), which is located in Haifa; the University of Tel-Aviv, which is actually located in the suburb of Ramat-Aviv; and Bar-Ilan University, located in Ramat-Gan, a rather large outer suburb of Tel-Aviv. The first three of these institutions are distinctly secular in nature, although the Hebrew University supports a serious scholarly effort in Jewish history and philosophy. Bar-Ilan, on the other hand, has been established by the orthodox community with the intention of demonstrating that serious secular scholarship can be carried out successfully in a milieu of devoutness; perhaps the desire to shield religiously-inclined young people from the rather free-thinking attitudes manifested at the other universities also played an important role in the decision to found

Bar-Ilan. (However, some pious students are also to be seen at the other universities.)

In addition to these four universities one must also list the remarkable ("fabulous" is a more accurate term) Weizmann Institute of Science, located in Rehovoth, some fifteen miles southeast of Tel-Aviv. While primarily a research organization of outstanding quality, it also provides instruction, and grants master's and doctor's degrees, in mathematics and some of the sciences. However, as the nearby University of Tel-Aviv becomes more firmly established, it is planned that Weizmann will gradually cease to award degrees. Nevertheless, it will undoubtedly continue to attract young people who will find in their work at the Institute suitable subject matter for dissertations to be submitted to their own university faculties.

The financing of these institutions is not a simple matter. A large fraction of the initial capital costs has been provided by philanthropists from many different nations. Almost every building seems to be named after some donor, organization, or foreign (i.e., non-Israeli) city which has provided the needed funds. Thus, the mathematics department in Jerusalem is housed in the Manchester (England) building, the chemistry department of the Technion is housed in the Canada building, etc. Running expenses appear to be largely the responsibility of the Israeli government, although Bar-Ilan appears to be more nearly a "private" institution in the American sense than the others. The financial burden on the government is severe, and the financial status of each of the institutions is, to say the least, precarious. Yet somehow they struggle along from year to year, adding continually to a most remarkable record of accomplishment achieved in the face of extreme adversity.

I was informed that the fixed salary attached to a professorship is 25,000 IL (Israeli pounds) per year. (3 IL = $1.) The top portion of such a salary (which I was told, exceeds that of a cabinet minister) is subject to an income tax of 59%.

The language of instruction is principally Hebrew, which has been revived and modernized so as to be a viable language adequate both for daily life and academic needs. However, newcomers to the faculties who may have recently arrived from abroad are quite free to lecture in English. Although some texts have been written in (or translated into) Hebrew, the great majority of courses employ English-language texts, and almost all students appear to be reasonably at ease with English, French, and German, at least for reading.

A tendency that disturbed me considerably was that of trying to expand too rapidly in too many directions. While in Haifa, I was informed that a strong movement is under way to establish a new university there, entirely separate from the Technion, which will stress the humanities. Similarly, the city of Beersheba (where an ultra-modern new town of 80,000 has grown up in less than two decades next to the picturesque run-down remains of the ancient city) is seeking to establish its university. It is difficult for me to see how this small nation, however talented and avid for learning its citizens may be, can support such a huge educational plant. It appears to me that, at least for some decades to come, the country would be better advised to use its universities and great talents to build up a viable economy heavily slanted towards those technological activities where "know-how" can compensate for the isolation, small size, and limited natural resources. Obviously, there is no simple way of reconciling great intellectual aspirations with the harsh realities.

Comments on Individual Departments

As stated above, this writer has visited each of the five mathematics departments in Israel. We attempt to give below some indication of the activities in each of these departments, and in one or two cases we also report briefly on visits that were made to other departments.

Bar-Ilan University

Mathematics at Bar-Ilan is much less developed than at the other institutions. Prof. S. Yeshurun, who obtained his doctorate in Budapest in the 1920's, has been serving as acting chairman for some years, but it is quite clear that he has not made any serious attempt to build up the Department beyond the level of undergraduate instruction. It was evident during my visit that he was anxious to be replaced by a younger, more vigorous man, and he appeared quite pleased at the fact that a young number-theorist, Aviezri Frankel (nephew of the distinguished set-theorist Abraham Frankel, recently deceased), currently at the Weizmann Institute, was expected to assume the chairmanship in the fall of 1966. Also, I was informed that several very new PhD's from the United States were expected to join the Department at the same time. However, subsequently, I learned that Frankel had not yet definitely accepted the appointment, and that serious difficulties had arisen over the failure of the financially hard-pressed administration to furnish adequate assurances of its readiness to support the development of a capable staff of research-minded mathematicians. To the best of my knowledge, the matter remains up in the air at the time of writing (July 1966); even if this impasse is resolved, I cannot help feeling that other crises will arise.

In brief, the prospects for mathematics at Bar-Ilan, in contrast to the other institutions, impressed me as being quite dim; and I must confess that I left Israel with the strong feeling that the very existence of Bar-Ilan constitutes an unnecessary drain on Israel's secularly-oriented universities.

University of Tel-Aviv

This, the newest of Israel's universities, had its origins as an appendage of the Hebrew University, established for the purpose of providing part-time instruction on the university level in Israel's most densely settled area. A very impressive campus has already been established, once again largely as the result of outside philanthropy. It would appear that much credit must go the University's president, the American-born George Wise, an extremely intense, hard-driving man who has evidently channeled his abilities, which in the past brought him great success as a major business executive, into his scarcely concealed ambitions to bring Tel-Aviv to the dominant position among Israel's universities. He has frequently been at loggerheads with his faculty, many of whom claim he is degrading the nature of the University by his insistence on developing disciplines which will provide quick and tangible returns to the nation. Wise has submitted and retracted resignations a number of times; this observer hesitates to venture a guess on how long the game can continue without damaging the University beyond repair. Nevertheless, a very substantial staff has been established; if it can be held together, it may indeed serve as the nucleus of an outstanding faculty.

The Department of Applied Mathematics is, in fact, responsible for all mathematics at the University, applied and otherwise. The staff numbers almost 30, about half of whom hold the doctorate, while a dozen are teaching assistants working on their doctorates. The Department is headed by S. Abarbanel, formerly of MIT's Department of Aeronautical Engineering. Among the other staff members we may mention A. Jakimovski, formerly of the Hebrew University, who has published extensively in summability theory, and N. Geffen, a Cornell PhD who has published a number of papers in problems of magnetohydrodynamical wave propagation.

Abarbanel is particularly interested in problems of kinetic theory, especially in connection with processes of combustion and explosion, and he provides guidance for a number of research students along these lines. Two short but interesting papers which give a good idea of his interests will be found in Israel Journal of Technology, 4, No. 1 (1966), pp. 77-81 and 82-86 (the latter written jointly with G. Zwas). In the former paper, Abarbanel studies the deformation of the walls of a cylinder loaded with explosive material under the influence

of a detonation-wave proceeding down the tube with uniform velocity. This work is intended as an improvement over earlier work, based on a one-dimensional theory formulated by G.I. Taylor, published by F.E. Allison and J.T. Schriempf, J. Appl. Phys. 31 (1960), pp. 842-845 and 846-851. The recent publication employs a Prandtl-Meyer expansion, rather than the one-dimensional model, and also permits the walls to be compressible. For very thin or very heavy walls the results agree quite well with experimental results reported by Allison and Schriempl. In the other paper cited above the authors refine earlier studies of the problem of analyzing the properties of combustion products immediately behind the front of a spherical self-similar detonation wave. The equations of continuity, momentum, and state lead to a pair of non-linear equations for the velocity of the combustion product and the speed of sound behind the front (as functions of the distance from the center of the explosion relative to the radius of the shock front). This sytem is singular at the shock front, where the "initial" data is prescribed, so that numerical integration to determine the solution behind the front cannot be undertaken immediately. Instead, in the absence of an analytic solution to the problem, it is necessary to employ an analytical argument to get an accurate approximation to the solution immediately behind the shock front; then it is possible to employ numerical integration to determine the behavior of the solution still further behind the front. The analytical argument is carried out more completely in this paper than in earlier papers by several other authors, and results which are probably much more reliable are thus obtained.

In addition to boasting a good-sized "permanent" staff, the Department has appointed at least three valuable people as visitors during the coming academic year: A. Friedman, noted for his work in partial differential equations, who will be visiting from Northwestern University; I. Greber, hydrodynamicist from MIT; and B. Kaufman, formerly an assistant to Einstein at Princeton and presently at the Weizmann Institute.

A recent development at the University reflects, on the one hand, the strong impulse of Israel's academic community to undertake an ever-increasing load of activities, while, on the other hand, it constitutes what may very well be a serious threat. In memory of Saul Kaplun, Caltech fluid dynamicist who died quite young several years ago, his father made a substantial contribution to establish an "Institute of Applied Mathematics and Space Physics" at the University. While this Institute will undoubtedly provide a comfortable environment for Abarbanel's department, the question of what to do in order to justify the latter part of the Institute's title seems to be unresolved. A capable young physicist, Dr. U. Shafrir (trained at UCLA), has been appointed to direct this effort, but it would appear that

the gifts of the founder and other contributors have provided no resources for actually acquiring staff and equipment for any sort of research program that can justify the title of "space physics." In this writer's opinion, the gifts, generous though they were, may well prove to be a millstone rather than a buoy to Israeli science.

The Technion

This institution, the one technological university of Israel, which opened its doors in 1924 as a small technical training school, now occupies a magnificent heavily wooded 300-acre campus overlooking the beautiful city of Haifa. It enrolls 3300 full-time undergraduates, 1100 graduate students, while over 10,000 others take part-time courses at various technical levels. Like the other universites, the quality of its staff and splendor of its buildings contrast starkly with the grimness of its financial difficulties.

The rather large Department of Mathematics, which provides instruction for all the other departments and faculties as well as for its own majors, is headed by Prof. E. Netanyahu. The writer, while impressed with the caliber of the members of this Department, was quite surprised and disturbed to find little if any interest in problems of physical significance. For example, Netanyahu himself publishes rather extensively on the theory of univalent functions (extremal coefficient problems, region of variability of coefficients, etc.), B. Schwarz writes on extremal problems in Euclidean spaces and their generalizations to normed linear spaces, and M. Reichaw (previously Reichbach) works actively on problems dealing with normed linear spaces, metric spaces and also more general topological spaces. [I found the latter's paper in Proc. AMS 13, pp. 17-23 (1962) particularly interesting. Here he determines the number of topological types of zero-dimensional subsets (of a separable metric space) which are, respectively, open, closed, and G δ's; the answers are 2, $2^{\aleph_0}$, $2^{\aleph_0}$.] However, while I may simply have missed any contact with applied mathematicians, it seemed to me that the orientation of this Department was not best for the overall welfare of the Technion or the nation's scientific community.

On the other hand, the Technion evidently contains some mathematically able people outside the Department. I was told that Prof. I. Cederbaum, Dean of the Faculty of Electrical Engineering, has developed some useful techniques in circuit analysis and synthesis, while C. Elata and several colleagues in the Faculty of Civil Engineering, partially supported by ONR, work on various problems of viscous flow; while the mathematical techniques employed are scarcely profound, a considerable competence is demonstrated. In a recent paper, available to me

only in preprint form, Elata and M. Bentwich study, mathematically and experimentally, the formation of eddies in the region bounded by a stationary outer cylinder and a rotating eccentrically-mounted inner cylinder; in another recent paper, Elata and two colleagues investigate the highly significant question of the reduction of frictional resistance to solid bodies in turbulent shear flow of a fluid in which extended polymer molecules are dissolved.

The Technion has one of Israel's largest and best-equipped (IBM 7040) computing centers; so far as I could learn from a very brief visit, it fills a service role to the entire University with great competence, but it does not engage in any significant instructional or research activities.

The Hebrew University

This University, whose establishment about 1925 may be considered as a major step in reviving the Hebrew language and encouraging its modernization as a vehicle of secular scholarship, is in every sense a major university, with a faculty including many world-famed scholars in a wide variety of disciplines. The campus, in addition to being ultra-modern and exceptionally handsome (in the writer's opinion, at least), possesses a dramatic setting in the Judean hills, very close to the Jordanian border. The original campus is located on a tract of land which is Israeli territory, according to the 1948 agreement, but completely surrounded by Jordanian territory; only a limited maintenance staff is allowed to visit this area, accompanied by a UN team, and for all practical purposes its splendid library and other facilities are lost to Israel.

The Mathematics Department possesses remarkable strength in a diversity of fields, although each seems to claim only a small number of specialists. Thus, M.O. Rabin and Y. Bar-Hillel (the latter is, in fact, a member of the Philosophy Department) are beyond doubt among the most capable and original workers in the theory of automata, both deterministic and probabilistic; similarly, R.J. Aumann, M. Maschler and several colleagues are engaged in a long-term project of axiomatizing an important aspect of the theory of games, namely the formation of coalitions. (See, for example, Mathematics of Computation, 19, pp. 531-551, 1965.) Both of the above groups are partially supported by ONR contracts. Operator theory in linear space is ably represented by S. Foguel and J. Lindenstrauss, probability theory by A. Dvoretzky, algebra by S. Amitsur, and partial differential equations, particularly elliptic boundary value problems, by S. Agmon. The exceptionally able H. Furstenburg was a visitor, on leave from Minnesota, during this past year, and has apparently accepted a permanent appointment.

A large computing center is attached to the Department, but until now it has performed only a service function.

During my visit to Jerusalem, I was give a fairly detailed, and somewhat disappointing, picture of the undergraduate and graduate curricula in mathematics. It may be worthwhile to present a few details. Students enter the University at 20 or 21, after completing military service, which is mandatory, with few exceptions, for all able-bodied men (26 months) and unmarried girls (18 months). The undergraduate program takes three years at all universities except at the Technion, where an additional year is required. Students planning to specialize in either mathematics or physics are supposed to know the elements of calculus from their high-school training. The first two years are divided about evenly between mathematics and physics, then in the third year a definite choice is made: there is little work outside these two subjects during the entire three-year period.

In the fall of 1965 about 270 students entered the joint mathematics-physics program, and I was given the following estimates, based on previous history: About 140 will survive the first year, and 120 the second year. Of these, about 70 and 50 will choose physics and mathematics, respectively, and almost all will receive the BA. The terribly high failure rate in the first year is a cause of deep concern, one possible explanation is the long break between the end of high school and the beginning of university work. In any case, everyone to whom I spoke about the matter was both baffled and distressed.

The undergraduate program in mathematics appears to be rather severe, resembling the concentrated English pace rather than the more leisurely and spread-out American approach. Thus, by the end of the second year the student has usually had a fair introduction to the theory of analytic functions, existence theory of ordinary differential equations, functions of several variables, and several of the following: set theory, point-set topology, Lebesgue measure and integration, probability, differential geometry, linear and modern algebra, logic. In the third year the student will take three lecture courses and two seminars at a rather sophisticated level.

The MSc, which is a prerequisite for the PhD, takes $1\frac{1}{2}$ years, and consists of a rather intense program of courses and seminars plus a thesis which, while not expected to demonstrate creativity, should indicate that the student is able to read recent literature in the chosen topic. The doctorate, on the other hand, requires little in the way of course work, the thesis is the essential item. I was told that about 25 students begin the MSc program each year with 15 to 20 succeeding, three

or four doctorates are conferred annually. The question which no one could answer to my satisfaction was that of what the recipients of advanced degrees do with them. (High-school teaching is a favorite occupation for BA's and some of the MSc's who do not proceed further.) One humorous answer, with some truth, was that PhD's are a major export to the US, but it is hoped that somehow Israel can attract some of them back. Actually, of course, temporary appointments in the US are urgently desired, and the wish is realized in a very large number of cases.

The Weizmann Institute

This institution, consisting of almost twenty departments covering a remarkably broad spectrum of the physical and biological sciences, is by any meaningful standard one of the marvels of the contemporary scientific world, particularly in view of the smallness of the nation and (again!!) its repeated practice of combining deficit financing with appeals for assistance.

The Department of Applied Mathematics is a very large and powerful group, headed by J. Gillis, an English-born Cambridge PhD who has been at Weizmann for about 15 years. My very brief visit was frustrating in that I had scarcely any opportunity to speak to anyone except my splendid, highly able, and interesting host. Gillis is, in my opinion, an excellent example of an applied mathematician in the best sense of that expression. Among the subjects in which he has worked in recent years one may cite: A series of very "pure" papers on random walks on plane and higher-dimensional rectangular lattices was followed by a most interesting paper (Proc. Phys. Soc. 85, pp. 625-644 (1965)) in which Gillis and two co-authors, C. Domb and G. Wilmers, estimate the distribution of length of polymeric molecules by employing a model of a self-avoiding random walk. The self-avoiding condition imposes considerable complications and it leads to considerable deviations from the Gaussian nature of the distributions that usually appear when this condition is not imposed. Some interesting computations, carried out on the CDC-1604 at Weizmann, are tabulated; these were based on enumerating all plane and cubic self-avoiding walks of lengths of up to 18 steps (over 10^8 walks) and 13 steps (almost 10^9 walks), respectively. Gillis has also studied many specific problems of viscous flow, with a great deal of computation, as a means of gaining insight into the behavior of flows which until now have not been solved analytically. In this connection we cite Initial Flow in the Entrance of a Straight Circular Pipe (with M. Shimshani, Jour. Royal Aero. Soc., Feb 1966). In a quite different direction, we cite a brief paper, written with G. Weiss, appearing in Mathematical Tables ... 14 (1960)

[now re-named Mathematics of Computation]. Here an interesting problem of special functions is solved, namely that of expanding the product of two Laguerre polynomials, $L_r(x)L_s(x)$, as a (finite) series of Laguerre polynomials, $\sum C_{rst}L_t(x)$; taking account of orthogonality, one is led to the problem of evaluating the integrals

$$C_{rst} = \int_0^\infty e^{-x}L_r(x)L_s(x)L_t(x)dx,$$

involving the product of three, rather than the more usual two, polynomials.

A large number of papers, stimulated by seismological studies, have been written by a group of Institute members, including C. Pekeris, Z. Alterman, M. Shimshoni, and P. Kornfeld. This work seemed particularly important several years ago when there were considerable hopes for locating valuable oil deposits in the southern desert region (Negev), but to date these hopes have not been realized.

There is also considerable interest in mathematical problems of quantum mechanics. Pekeris and various colleagues have carried out very accurate computations of eigenfunctions and eigenvalues of two-electron atoms and ions; several such computations appeared in the Physical Review during the past few years.

Finally, we mention the remarkable computing center, directed by P. Rabinowitz, which possesses two large machines, the CDC-1604 mentioned earlier and the "Golem," which was entirely Israel-produced except for the memory. There is, I am told, some thought to building a Golem II as a commercial proposition.

Miscellaneous Remarks

While perhaps not strictly called for in a report of this nature, some brief notes based on the writer's observations of the contemporary Israeli scene may be of help in forming some impression of the nation's problems and prospects. The topics have been chosen almost randomly, and could be extended almost ad infinitum.

(a) Despite its own economic difficulties, Israel plays a significant role in helping to train a scientific cadre for some of the African nations. The Technion conducts first-year courses for students from these nations in English and French; after the first year, they must attend lectures given in Hebrew, but are permitted to write all their examinations in one of the two aforementioned languages.

(b) Practially every faculty member has spent some time in the United States and/or western Europe, even if he has earned his degrees in Israel. A year's leave of absence in the US every four or five years appears to be quite commonplace. In addition to helping the scholars keep up-to-date with the most recent advances in their disciplines, this practice enables Israel to maintain a larger staff of scholars than she could hope to keep otherwise.

(c) An attitude of boldness and confidence is manifested everywhere in the nation. An outstanding example is furnished by the decision, made after the loss of the original campus on Mount Scopus, to rebuild the Hebrew University in a location within point-blank artillery range of the Jordanian border. The new Parliament building is similarly located. A number of people expressed to this writer the opinion that ordinary "common sense" is not applicable in Israel's situation, and that only by engaging in such seemingly foolhardy gestures will she gain security.

(d) The problem of integrating an incredibly polygot community staggers the imagination. Nevertheless, it appears that, while the adults are often too "set" in their ways (especially those from North Africa and western Asia), the youngsters are quite amenable and seem to mix well with their peers of other backgrounds. I was told that sociologists are confident that in two generations a satisfactory degree of social and cultural integration will have been accomplished, with "western"values and philosophy dominant.

(e) There is a dangerous tendency to political fragmentation, reminiscent of French politics at its most confusing. Even the religious element of the population is split several ways, ranging from those who, while of unquestioned piety, are anxious to get along with their unbelieving or "lukewarm" brethen to a small but violent group of fanatics who refuse to recognize the existence of the State of Israel, give their children no secular education, and consider the use of the Hebrew language in any non-religious activity to be desecration. (The government apparently finds discretion to be the better part of valor, and refrains from compelling this community to submit to the school laws or to perform military service.)

(f) The lot of the Arab community, numbering about one-tenth of the nation, has both its bright and dark sides. Their economic, educational, and health level is probably better than it is anywhere else in the Arab world. (Israel is the only country in the predominantly Arabic part of the world where an Arab woman can vote!) Nevertheless, it must be

admitted that they are to some extent second-class citizens. For example, they must receive permission to travel from one part of the country to another; they are not subject to military service, which is compulsory for the Jewish community, and I believe that they cannot even volunteer. It is not hard to understand why such restrictions are imposed, but many members of the Jewish majority, who have themselves often been the victims of discrimination in other countries, are deeply distressed over the ethical aspects of this problem and are not satisfied by the argument that this discrimination could cease once the neighboring nations drop their policy of violent hostility to the very existence of Israel.

(g) The inflationary situation almost defies the imagination. A medium-sized British car, which sells for about £800 ($2240) in London, costs $7000 in Israel. The installation of a private telephone costs $280 plus months of waiting. The nation lives largely on philanthropy and from the German reparations. On the one hand, many people (this writer included) feel that the support goes for a worthwhile cause, that of conducting a unique experiment in reviving a talented community and rehabilitating a neglected corner of the world, and that this consideration outweighs all others. On the other hand, one may wonder how long this support can continue.

Conclusions

Israel maintains a level of mathematical activity which is quite remarkable, both in quality and quantity. However, the writer believes that the nation, and ultimately mathematics as well, would be better served if the mathematical talents which exist in such abundance were channeled into a few well-chosen directions that could help the nation's economic advancement, without doing harm to the principle of freedom of research. The mathematical groups at the University of Tel-Aviv and the Weizmann Institute, with their strong "slant" toward applied mathematics of high quality, appear particularly deserving of encouragement on this score. Jerusalem's department, while quite differently oriented, also appears to this writer to be deserving of substantial encouragement.

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13. ABSTRACT

This report surveys current mathematical activities in Israel at the Hebrew University, Technion, University of Tel Aviv, Bar-Ilan University and the Weizmann Institute of Science.

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