Physics research in Israel—A preliminary bibliometric analysis

Subbiah Arunachalam, M.K. Dhirendra Rao * and Praveen K. Shrivastava **
Publications and Information Directorate, New Delhi 110 012, India.

Received 19 March 1984
Revised 20 July 1984

The impact of physics research carried out in Israel on the international literature is assessed from data on publication and citation counts. We have considered in this analysis all papers published from Israel and covered under six of the ten major sections of INSPEC's *Physics Abstracts,* January–June 1977 (covering condensed matter physics, nuclear and particle physics, atomic and molecular physics and biophysics and physical chemistry) as well as citations to these papers as seen from five annual editions of *Science Citation Index,* 1977–1981. An analysis of these data permits us to identify: (i) areas of research in which Israel is strong, (ii) highly cited publications, (iii) the distribution of citations over the years, and (iv) how quickly the papers get cited. Israel accounts for less than 1% of the world's physics publications, but undeniably physics done in Israel is an integral part of the mainstream of world physics. Israeli physicists place almost all their work in foreign journals, most of them published from the United States, the Netherlands and the United Kingdom. Many of these journals have a good standing as seen from their high impact factors and immediacy indices. Nearly all papers in our sample have originated in eight institutions, indicating that Israel is free from the common Third World malady of spreading the butter of R&D budget too thinly. Overall, Israeli physics appears to be productive in condensed matter physics, nuclear physics and atomic and molecular physics. However, chemical physics tops the list if one considers both the number of papers published and the cognitive impact these papers have had. Two areas where Israel did not publish much and yet had a few publications of high impact are: (i) special theories, interaction models and particle systematics, and (ii) biophysics. Surprisingly for a nation interested in both the military and civilian applications of nuclear energy, Israel's publications in nuclear physics are not as well cited as her publications in many other subfields of physics.

* Permanent address: National Physical Laboratory, New Delhi.
** Present address: Department of Physics, India Institute of Science, Bangalore.

North-Holland
Journal of Information Science 8 (1984) 185–195

Scientific journals published in Australia, Canada, India and Israel, in general, make a relatively low cognitive contribution to the mainstream international research activity [3]. This, however, can not be taken to mean that scientists from these countries do not make important contributions to the generation of new knowledge in the sciences, for many of them publish their work—often their more important work—in international journals published from the advanced countries. For instance, a little over half of the papers published from Indian laboratories in the fields of physical, chemical, mathematical and earth sciences (as seen from the appropriate editions of *Current Contents*) appear in non-Indian journals [1]. This is particularly true as far as physics research in Israel is concerned: there is no physics journal in Israel and almost the entire publication output of Israeli physics appears in foreign journals.

Of late, there has been a spurt in interest in quantifying national contributions to the world's scientific efforts. Much of this scientometric literature is devoted to scientific enterprises in the advanced countries and precious little is written about science done in the rest of the world. Notable exceptions are the work of Davidson Frame on measuring scientific activity in lesser developed countries [7], that of Garfield on Third World science [10] and the efforts of Tibor Braun and co-workers at the Hungarian Academy of Sciences [4], [12]. Braun and his co-workers talk about middle-sized countries and cover Israeli science. Apart from these papers, we do not know of any other work on Israeli science, particularly work on Israel's share of the world's scientific literature and on the impact of Israeli physics on world science.

In this paper, we have attempted to evaluate the contribution of Israeli physics and its cognitive impact on the international literature of science from data on publication and citation counts. Studies on national contributions to the literature of physics are not many. Vlachý has estimated contributions made by different nations to physics literature as a whole [14] as well as to different

subfields of physics [15]. Chang and Dieks [6] have estimated the productivity of Dutch research efforts in physics.

There are reasons to believe that Israeli science —and physics in particular—ought to be of a high standard. Among the people who came to form Israel, as well as among those who came later on, were many scientists of proven merit. The proportion of Israeli scientists and engineers engaged in R&D in the natural sciences, agriculture, medicine and engineering is one of the highest in the world —about 30 full time equivalents for each 10000 population in 1977, as against 25 in USA and 24 in Japan [11]. Even in absolute numbers, Israel approaches the relatively small developed countries such as Holland, Belgium and Sweden [13]. Also, the proportion of researchers in academic institutions (in contrast to the productive or industrial sector) is higher in Israel than in the USA, Japan and Western European countries. Thanks to the enormous emphasis placed on higher education, the number of academic degree holders in Israel is growing twice as fast as the population since 1961. Currently, Israel tops the list in the award of second and third degrees in natural sciences per million population (136 as against 124 in USA). Thus the most important element of the infrastructure needed to build a productive scientific enterprise, *viz.* trained people, has all along been in plentiful supply. And, in fact, Israel, in spite of its small population, stood sixteenth among the more than 160 nations considered in the number of publishing scientists in 1977. According to *Who is Publishing in Science*, 1978, there were no less than 3310 publishing scientists in Israel who have authored at least one research paper or a book article in 1977. This makes Israel first, with respect to the number of articles published proportional to the country's population (10.2 per 10000 population, as against 9 in USA). The potential scientists and engineers in Israel were estimated to be 28516 per million population (in 1978), out of which 3991 were engaged in R&D. Also, Israel allocates a considerable sum of money for R&D —the 1981 figure pertaining to natural sciences and engineering R&D was more than $533 million. According to a press release of the Israeli Ministry of Science and Development released in December 1982, Israel's gross expenditure on R&D was over 2.5% of her GNP in 1980–81. This is of the same order as is found in the advanced countries of the OECD.

Although Israel, according to the World Bank [16], is a middle-income economy with a GNP *per capita* of $4500 (in 1980, *The Economist*, London, estimated that Israel's GDP was $5160 in 1981), it has the potential and infrastructure necessary to become a scientifically advanced country. Some socioeconomic indicators of Israel are given in Table 1. The high life expectancy at birth (72 years, 1980), the high adult literacy rate (84% as early as 1960, and claimed to be 90% in 1980), the relatively high investment in education and health, the large number of physicians and nurses for a

Table 1
Some social and economic indicators of Israel

Area, km^2	20770
Under tillage, hectares (1978–79)	4 million
Population in Dec. 1980	3.902 million
Population density in 1982, per sq. mile	472
Crude birth rate per thousand (1980)	24
Crude death rate per thousand (1980)	7
Population growth rate (average 1970–80), %	2.6
Life expectancy at birth (1980), years	72
Total fertility rate (1980)	3.4
Infant mortality rate (0–1 year, 1980)	14
Gross domestic product (1980), million US $	15340
Per capita GNP, $	4500
Annual growth rate, %	3.8
Adult literacy, % (1980)	> 90
No. of TV Sets per 1000 people (1980)	150
No. of newspapers sold daily per 1000 people (1979)	227
No. of foreign visitors (as % of population) (1979)	26.7
No. of telephones per 1000 people (1981)	293
No. of cars per 1000 people (1982)	125
6–11 year olds in primary school, %	96
12–19 year olds in secondary school, %	68
20–24 year olds in higher education, %	26
No. of doctors per 1000 people (1980)	3.3
Population per physician (1977)	310
Per capita energy consumption, kg equiv. coal (1979)	3513
Percentage of population between 15 & 64 years	59
Percentage of labour force in agriculture (1980)	7
in industry (1980)	36
in services (1980)	57
Unemployment rate (% of total labour)	5.1
Potential scientists/ engineers/technicians in 1978 per million population	28516
S-T personnel actually deployed in R&D (1978) per million population	3991 (14%)
No. of publishing scientists (1981 ISI data)	4227
No. of cities with at least 100 publishing scientists	10

Sources:
(1) *World Development Report*, 1982; (2) *The Economist*, London 24 December 1983, 53–59; (3) Current Bibliographic Directory 1981 (ISI, Philadelphia).

given population and low infant mortality rate, the large percentage of the labour force engaged in the 'service' sector as distinct from the 'agriculture' and 'industry' sectors, the high level of *per capita* energy consumption (3500 kg coal equivalent in 1979), *etc.* are clear indicators pointing to a society well geared to perform good science.

Methodology

The bibliometric method used in this study combines a comprehensive abstracting service (*Physics Abstracts*) and the *Science Citation Index (SCI)* and is similar to the technique used by Arunachalam *et al.* [2] for studying the impact of India's contribution to reproductive endocrinology on the world literature using *Biological Abstracts* and *SCI*.

We scanned twelve consecutive numbers of *Physics Abstracts* (January–June 1977, Vol. 80, No. 1055–1066) for abstracts of articles originating from Israel. We did not, however, scan the entire collection of abstracts, but only those appearing under Sections 10 (Physics of elementary particles and fields), 20 (Nuclear physics), 30 (Atomic and molecular physics), 60 (Condensed matter—structure, thermal and mechanical properties), 70 (Condensed matter—electronic structure, electrical and magnetic and optical properties), and 80 (Cross-disciplinary physics and related areas). We noted down all the entries originating from Israeli addresses, and checked, for each of them, the citations in subsequent literature as seen from the Citation Index sections of the annual cumulations of *SCI*, 1977–1981. Thus, our data consists of two parts:

(i) the bibliographic data on all papers from Israel covered by the chosen sections of *Physics Abstracts* in the first half of 1977, and

(ii) the citations received by each one of them in the international literature over five years.

In the data collected from *Physics Abstracts,* there were some papers which bear a publication date of 1975 or 1976. For such papers, citation index sections of the 1975 and 1976 editions of *SCI* were also consulted.

The Israeli physics papers (as seen from *Physics Abstracts*) were classified by institution, by subject class (following the INSPEC Classification Scheme used by *Physics Abstracts*) and by journal. The number of citations won by each paper over 5 years was counted and the highly cited papers were identified. Self citations (by first author) were noted.

One might ask: "Is it possible to draw valid conclusions from a simple randomly chosen six-month sample of *Physics Abstracts*?"

Conceivably, publications in a given six-month period could be affected by the state of major experimental facilities in the preceding year or so. Productivity in physics laboratories could be affected by conditions totally outside the control of physicists (war, change in government policy, closure of laboratories due to any reason, fluctuations in funds available for R&D, etc.). Another possibility: some unforeseen difficulty at INSPEC may affect the coverage in *Physics Abstracts.*

Ideally, one would have liked to look at papers published by Israeli physicists in two or more sampling periods, preferably spaced 12–18 months apart. With such data, not only would one validate (or invalidate) some conclusions drawn from a single six-month sample, but one could even attempt to see the evolution (or changes in direction) in Israeli physics. Unfortunately, for such an exercise one would need access to the computer-retrievable versions of *Physics Abstracts* and *SCI.* We neither have access to such databases nor have the funds necessary to get the searches made. Hence, we had settled for the laborious and time-consuming manual search. While we are fully aware that an analysis based on such limited data may attract criticism, we believe that the technique we have used is a valid and interesting application of bibliometrics, and that this study has led to several valuable insights into Israel's contribution to physics research.

Analysis

In the six major subject groups we covered in the twelve issues of *Physics Abstracts,* there were 26 593 papers worldwide, out of which Israel's share was 251, amounting to a little over 0.94%. This is close to the 0.89% share of Israel, determined by a number count based on all sections of *Physics Abstracts* over a larger period by Vlachý [14,15] and quoted by Braun and Nagy [5]. This, in a way, is an assurance that our sample is free from any bias. The distribution of Israeli and world

Table 2
Israeli research contribution to different subfields of physics (As seen from *Physics Abstracts, Vol. 80,* Jan.–June 1977).

Subject Area	Sections in Physics Abstracts	Israel's Contribution	World Contribution	% in World
Physics of elementary particles & fields	10–14	23	1933	1.19
Nuclear physics	20, 21, 23, 24, 25, 27, 28 & 29	51	3905	1.31
Atomic & molecular physics	30–36	36	2768	1.30
Condensed matter: structure, thermal & mechanical properties	60–68	26	4177	0.62
Condensed matter: electronic structure, electrical, magnetic and optical properties	70–79	73	7269	1.0
Cross-disciplinary physics and related areas	80, 81, 82 & 87	42	6541	0.64
Total		251 *	26593	0.94

* Includes, 229 research papers published in primary periodicals, 21 papers published in conference proceedings and 1 book article.

contributions to physics by subject is shown in Table 2. Israel appears to be relatively more productive in nuclear physics and atomic and molecular physics, areas in which her share exceeds 1.3% of the world's literature as against 0.89% in all of physics, and 0.91% in all of science as seen from *SCI* 1973 [10]. Although, following [5], we have given numerical values of percentage contributions of Israel with an apparent precision of 0.01%, values are only indicative of an order of magnitude, and not much statistical significance need be attached to the absolute values.

Table 3 provides data on the contributions made by different institutions in Israel to the literature of physics classified under sub-specialities. The Weizmann Institute of Science, Rehovot, tops the list followed by Tel Aviv University. A significant fact is that, unlike in most Third World and developing countries, Israel does not seem to spread its R&D funds too thinly on too many institutions. Less than half a dozen institutions account for three-fourths of Israeli physics publications.

The policy-makers in Israel have clearly understood that theirs is a small country in a world of big science, and therefore they have to be choosey and careful if they want to get more returns per dollar spent on R&D. Their strategy includes setting up and encouraging a few centres of excellence, and extending their scientific resources through growth and international collaboration [11]. The strategy appears to be sound and many less developed countries could adopt it profitably.

In the distribution of papers among different sub-specialities (Table 3), 'Magnetic properties and materials' (Section 75 under 'Condensed matter physics') comes out first with 22 papers, which include contributions mainly from the Technion Institute, the Weizmann Institute, the Nuclear Research Centre, and Bar-Ilan University. Section 33 (Molecular spectra and interactions with photons) is represented by 19 papers of which the Weizmann Institute's share is five. Biophysics and allied areas (Section 87) accounts for 18 papers, contributions coming mainly from Tel Aviv and Hebrew Universities and the Weizmann Institute.

Table 3
Contribution of Israeli institutions by subject

Section numbers as in *Physics Abstracts*, 1977	Weizmann Institute, Rehovot	Tel Aviv University	Hebrew University, Jerusalem	Technion Institute	Ben-Gurion University,	Negev Nuclear Research Centre	Soreq Nuclear Research Centre	Bar-Ilan University	Total
11	–	4	1	1	1	–	–	–	7
12	4	3	–	–	–	–	–	–	7
13	2	4	–	2	–	1	–	–	9
21	6	4	1	–	1	–	–	–	12
23	–	–	–	–	–	–	2	–	2
24	1	–	1	–	–	–	–	–	2
25	4	4	1	1	–	4	1	–	15
28	–	–	3	–	3	–	1	–	7
29	4	1	–	1	2	2	2	–	12
31	–	–	–	1	–	1	–	1	3
32	–	–	1	–	–	–	1	–	2
33	5	2	3	1	3	1	2	2	19
34	2	–	6	2	–	–	–	–	10
36	–	–	–	–	–	–	–	1	1
61	3	1	–	2	3	1	–	–	10
63	–	–	–	–	–	–	1	2	3
64	–	–	–	1	–	1	–	–	2
65	–	–	–	1	–	–	–	–	1
66	–	–	–	–	1	–	–	–	1
67	1	1	–	1	–	–	–	–	3
68	–	–	1	3	–	–	–	1	5
71	–	–	2	1	1	–	–	–	4
72	–	3	–	–	1	–	–	1	5
73	–	–	1	2	–	–	–	1	4
74	–	3	1	1	–	–	–	–	5
75	4	3	1	5	1	4	–	4	22
76	2	1	3	3	–	2	2	–	13
77	–	1	–	3	1	–	1	–	6
78	2	2	4	1	1	–	2	2	14
81	–	–	5	3	–	–	1	–	9
82	3	–	3	2	–	1	2	–	11
87	5	7	4	2	–	–	–	–	18
Total	48	44	42	40	19	18	18	15	244

Section 25 (Specific nuclear reactions and scattering) accounts for 15 papers, with the Weizmann Institute, Tel Aviv University and the Negev Nuclear Research Centre contributing four each.

Journal use by Israeli physicists

The journals used by Israeli physicists, showing country and type of publisher, are presented in Table 4. All the Dutch journals used are produced by for-profit publishing firms. Out of the 32 US journals used, 10 from commercial publishers accounted for 15 papers and the rest (77 papers) appeared in 20 society journals and 2 run by universities. Thirteen commercial journals from the UK accounted for 26 papers and 6 society journals from the UK published 18 Israeli physics papers.

Also indicated in this table are the impact factors and immediacy indices of these journals as seen from *Journal Citation Reports*, 1977 [8]. These two indices are useful in judging the average quality, citability and the time taken for a paper published in a journal to get quoted in the international literature.

In the sample considered, which consisted of

Table 4
Distribution of physics papers by journal

Title of Journal	Publisher type	No. of Israeli papers	Impact factor (1977 JCR)	Immediacy index (1977 JCR)
USA				
1. Phys. Rev. B	Soc.	17	3.035	0.591
2. J. Chem. Phys.	Soc.	14	3.222	0.630
3. Phys. Rev. D	Soc.	7	3.059	1.010
4. Phys. Rev. A	Soc.	6	2.858	0.703
5. Phys. Rev. Lett.	Soc.	6	6.353	1.820
6. Phys. Rev. C	Soc.	4	1.969	0.533
7. J. Electrochem. Soc.	Soc.	4	1.504	0.338
8. J. Appl. Phys.	Soc.	3	1.674	0.349
9. J. Low Temp. Phys.	Com.	3	1.501	0.585
21 Other journals	–	27		
Total USA		91		
Netherlands				
1. Chem. Phys. Lett.	Com.	20	2.206	0.518
2. Nucl. Phys. A	Com.	15	2.460	0.497
3. Nucl. Instrum. & Methods	Com.	9	1.011	0.183
4. Chem. Phys.	Com.	7	2.721	0.648
5. Nucl. Phys. B	Com.	7	2.815	0.798
6. Phys. Lett. A	Com.	7	1.158	0.249
7. Phys. Lett. B	Com.	3	3.239	0.800
8 Other journals	Com	11		
Total Netherlands		79		
Great Britain				
1. J. Phys. C	Soc.	6	2.515	0.521
2. J. Phys. F	Soc.	6	2.887	0.496
3. Solid St. Commun.	Com.	6	1.916	0.427
4. Ferroelectrics	Com.	4	0.608	0.164
5. Nature	Com.	3	4.957	0.928
17 Other Journals		22		
Total Great Britain		47		
Total (USA + Ned + UK)		217		
Other Journals		12		
Grand Total		299 *		

* This excludes 1 book article & 21 conference papers. Soc = Society; Com = Commercial.

229 journal articles authored by Israeli physicists, there were 92 papers in US journals (59 of them in journals of the American Institute of Physics), 79 papers in journals published from the Netherlands and 47 papers in British journals. Also, 57 of these papers (or 25% of the journal articles considered) appeared in journals with impact factors greater than 3, and 132 papers in journals of impact factor greater than 2. Nearly one-fifth of the sample (47 papers) appeared in letters journals: 20 in *Chemical Physics Letters,* 6 each in *Physical Review Letters* and *Solid State Communications,* and 10 in *Physics Letters* (Sections A and B).

There are at least 41 articles published in journals which have the words 'chemical physics' in their titles. About 35 papers were published in journals whose titles contain the word 'nuclear'. These are indicative of Israel's thrust in physics research (Table 6).

Almost all the journal articles were published in English language periodicals. There were 12 papers in journals published from countries other than the USA, UK and the Netherlands, but none in journals published from the Soviet bloc countries, Australia, Canada, India and Japan. These were published in journals from Belgium, West

Germany, Italy and Switzerland.

It is instructive to compare the choice and use made of journals by Israeli physicists with those by Indian and Egyptian physicists. In a study comparing the participation in selected journals by foreign authors, Braun and Nagy [5] have shown that Israel's share in *Physical Review A* (published by American Institute of Physics) whose impact factor as seen from *JCR* 1977 is 2.858, was 1.9%, which is more than twice the contribution of Israel to world physics literature. On the contrary, India's share of publications to four physics journals increased in inverse proportion to the impact factors of the journals: 2.4% in *Physical Review A* (impact factor 2.858), 2.8% in *Helvetica Physica Acta* (impact factor 1.038), 6.1% in *Czechoslovak Journal of Physics* (impact factor 0.598), and 31.2% in *Acta Physica Hungarica* (impact factor 0.165). Thus India's share in the first two journals whose impact factors exceed 1.00 is less than her contribution to the world literature of physics, *viz.* 2.94%, and much higher in the other two journals whose impact factors are rather low. Egypt's share to the world literature of physics is about 0.113% and her share in *Czechoslovak Journal of Physics* and *Acta Physica Hungarica* were 0.3 and 15.6% respectively, as against practically nothing in *Physical Review A* and *Helvetica Physica Acta*.

Citedness of Israeli physics papers

The 251 papers in the sample were cited 1530 times in the five year period 1977–1981, for an average of 1.22 citations per paper per year. Table 5 gives data on how many papers were cited how many times. Sixty of these papers went uncited. These include 17 of the 20 conference papers in the sample and 5 articles published in letters journals. Out of the 34 papers which were cited just once in the five years, five were published in letters journals. Four out of the 27 papers which received two citations in the five years were published in letters journals.

As many as 177 papers were cited 5 times or less (including uncited ones) in the 5-year period, and 40 papers were cited between six and ten times. 16 papers were cited more than 25 times each out of which three had received more than 85 citations each.

Of the 14 papers in *Journal of Chemical Physics* which in all won 212 citations, only one went uncited, and five won ten or more citations; among these, three won more than 25 citations each. The seven papers in *Chemical Physics* accounted for 55 citations, two of them winning more than 14 citations each. Only two of the twenty papers published in *Chemical Physics Letters* went uncited and the other 18 amassed 192 citations. In all, the 41 papers published in journals bearing the term 'chemical physics' in their titles accounted for 459 citations for an average of 2.24 citations per paper per year. If we omit the very highly cited paper by Mukamel (No. 1 in Table 7), the average turns out to be 1.8 citations per paper per year. This is clear

Table 5
Citedness of Israeli physics papers

No. of times cited (1977–81) (A)	No. of papers (B)	No. of citations (A)×(B)
0	60	0
1	34	34
2	27	54
3	28	84
4	16	64
5	12	60
6	7	42
7	13	91
8	9	72
9	6	54
10	5	50
11	3	33
12	7	84
13	2	26
15	2	30
16	2	32
17	1	17
19	1	19
27	2	54
28	1	28
29	2	58
31	2	62
35	3	105
36	1	36
38	1	38
40	1	40
87	1	87
97	1	97
99	1	99
Total No. of papers	251	
Total No. of Citations		1550

Average = 1.235 Citations per paper per year.

evidence of the strength of Israel in chemical physics. Most of these chemical physics papers were classified in *Physics Abstracts* under Molecular spectra and interaction with photons (Section 33) and Atomic and molecular collision processes and interactions (Section 34).

Of the 22 papers published in *Nuclear Physics* Sections *A* and *B*, two went uncited, 13 received between 1 and 4 citations and three received ten or more citations. The 32 papers published in journals on nuclear physics (not including *Nucl. Phys. B*, which is devoted to elementary particle physics) received 125 citations, for an average of a little less than 0.8 citation per paper per year, which is considerably lower than the average Israeli physics paper's record. Even if we consider the one nuclear physics paper published in *Physics Letters B* (which has won 9 citations), the average goes to 0.81. Thus, Israel seems to be publishing a large number of papers in nuclear physics but they are not cited exceptionally well. When we say this, we are not guided by absolute numbers of citations received by Israeli's chemical physics and nuclear physics papers in our sample. That could be misleading, as citation habits in different branches of physics, may vary. But we say this on the basis of a comparison of the average number of citations received by Israeli papers in a subfield and the impact factors of selected international journals in that subfield (See table 6). One notices that al-

Table 6
Journals devoted to chemical physics, nuclear physics and letters used by Israeli physicists (1977 Physics Abstracts).

Journal title	Impact factor (1977 JCR)	No. of papers	No. uncited	No. of citations
Chemical Physics				
J. Chem. Phys. (USA)	3.222	14	1	212
Chem. Phys. (Ned)	2.721	7	0	55
Chem. Phys. Lett. (Ned)	2.206	20	2	192
		41	3	459
	(Average greater than 11 citations per paper in 5 years or 2.24 citations/paper in 1 year)			
Nuclear Physics *				
Ann. Nucl. Energy (UK)	0.259	1	0	2
Nucl. Phys. A (Ned)	2.460	15	1	57
Nucl. Instrum. Methods (Ned)	1.011	9	0	36
Nucl. Sci. Eng. (USA)	1.087	2	2	0
Nucl. Track Detection (UK)	NA	1	0	4
Phys. Rev. C. (USA)	1.969	4	0	26
		32	3	125
	(Average about 4 citations/paper in 5 years)			
Letters Journals				
Solid St. Commun. (UK)	1.916	6	0	50
Commun. Phys. (UK)	N.A.	1	0	4
Phys. Rev. Lett. (USA)	6.353	6	0	79
Appl. Phys. Lett. (USA)	3.272	1	1	0
Chem. Phys. Lett. (USA)	2.206	20	2	192
Lett. Math. Phys. (Ned)	0.407	1	1	0
Phys. Lett. A (Ned)	1.158	7	2	16
Phys. Lett. B. (Ned) **	3.239	3	2	9
Lett. Nuovo Cimento (Ita)	0.760	2	0	5
		47	8	355
	(Average greater than 7.5 citations/paper in 5 years)			

* *Nucl. Phys. B* (impact factor 2.815) published 7 Israeli papers, one of which was not cited in the 5-year period 1977–81. The other 6 amassed a total of 122 citations. But this journal is largely devoted to elementary particle and high energy physics.
** The two uncited papers are on elementary particle physics and the one cited paper is on nuclear physics.

Table 7
Distribution of citations for highly cited papers * over a five year period

No.	First Author	Location	Total No. of citations	Citation spread				
				1977	1978	1979	1980	1981
1.	Mukamel, S. (Tel Aviv Univ.)	J. Chem. Phys. 65 (1976) 5204	99	16	21	31	16	15
2.	Veneziano, G. (Weizmann Inst.)	Nucl. Phys. B, B117 (1976) 519	97	15	19	23	27	13
3.	Borochov, H. (Weizmann Inst.)	Proc. Nat. Acad. Sci. USA, 73 (1976) 4526	87	8	17	30	6	26
4.	Klein, M.W. (Bar-Ilan Univ.)	Phys. Rev. B 14 (1976) 5008	40	1 ** + 4	4	14	9	8
5.	Zakai, N. (Hebrew Univ.)	Nature, 263 (1976) 696	38	4	18	7	6	3
6.	Aharony, A. (Tel Aviv Univ.)	Solid St. Commun. 20 (1976) 899	36	9	7	4	8	8
7.	Aharony, A. (Tel Aviv Univ.)	Phys. Rev. Lett. 37 (1976) 1587	35	3	10	11	8	3
8.	Banks, T. (Tel Aviv Univ.)	Phys. Rev. D 15 (1977) 111	35	10	2	11	5	7
9.	Shapiro, M. (Weizmann Inst.)	Chem. Phys. Lett. 46 (1977) 442	35	3	8	8	7	9
10.	Goldschmidt, C.R. (Hebrew Univ.)	Biophys. J. 17 (1977) 179	31	1	5	9	9	7
11.	Levine, R.D. (Hebrew Univ.)	J. Chem. Phys. 65 (1976) 3302	31	1 ** + 6	7	10	4	3
12.	Tamir, M. (Soreq Nucl. Res. Cent.)	Chem. Phys. Lett. 46 (1977) 208	29	1	7	13	4	4
13.	Glatt, I. (Weizmann Inst.)	J. Am. Chem. Soc. 98 (1976) 7087	29	1 ** + 5	8	5	3	7
14.	Yogev, A. (Weizmann Inst.)	Chem. Phys. Lett. 46 (1977) 290	28	6	4	6	2	10
15.	Korenstein, R. (Weizmann Inst.)	Biophys. Struct. and Mech. 2, (1976) 267	27	3	2	7	5	10
16.	Procaccia, I. (Hebrew Univ.)	J. Chem. Phys. 65 (1976) 3284	27	2 ** + 9	7	6	0	3
17.	Pollak, E. (Hebrew Univ.)	Chem. Phys. 21 (1977) 61	19	3	8	5	2	1
18.	Shechter, H. (Technion Inst.)	Phys. Rev. B 14 (1976) 1876	17	3	2	2	8	2
19.	Freeman, J.R. (Weizmann Inst.)	Nucl. Phys. B B120 (1977) 477	16	4	1	6	4	1
20.	Webman, I. (Tel Aviv Univ.)	Phys. Rev. B 14 (1976) 4737	16	3	3	6	3	1
21.	Halavee, U. (Nucl. Res. Cent.)	Chem. Phys. Lett. 46 (1977) 35	15	2	0	8	1	4
22.	Halavee, U. (Soreq Nucl. Res. Cent.)	Chem. Phys. 21 (1977) 105	15	2	2	4	2	5
23.	Marconinsky, Y. (Racah Inst. Phys.)	Appl. Phys. 47 (1976) 3868	13	2	1	7	2	1
24.	Wilson, A.D. (Bar-Ilan Univ.)	Chem. Phys. Lett. 43 (1976) 539	13	4	2	6	0	1
	Total		828	131	165	239	141	152

* Includes those papers with minimum 13 citations during the period 1977–81.
** Citations in 1976.

though the average impact factor of nuclear physics journals is less than that of chemical physics journals, the difference between the average no. of citations per year won by Israeli nuclear (0.8) and chemical physics (1.8) articles is much larger.

Israeli physicists have also published three papers in *Nature* during the period covered (which have won 51 citations in the five-year interval), one in *Proceedings of the National Academy of Sciences, USA* (87 citations), one each in *Journal of the American Chemical Society* (29 citations), *Biophysical Journal* (31 citations) and *Biophysical Structure and Mechanism* (17 citations), all of which find a place in the list of papers cited at least ten times. This is indicative of their strength in biophysics and related areas (Section 87). Out of the 17 Israeli journal papers in Section 87, seven were uncited but the others won 215 citations!

Other areas in which Israel has received many citations per paper are: Specific theories, interaction models and particle systematics (Section 12), 159 citations to 7 papers; Molecular spectra and interaction of photons (Section 33), 262 citations to 19 papers; Atomic and molecular collision processes and interactions (Section 34), 121 citations to 10 papers; Magnetic properties and materials (Section 75), 183 citations to 20 papers; and Physical chemistry (Section 82), 107 citations to 13 papers.

Significantly, most of the citations to Israeli work in physics appear in international journals in papers written by non-Israeli scientists. Out of the 251 papers considered, only 83 had self-citations (by first authors) and these first author self-citations (123 out of 1530) accounted for about 8% of all citations. This again is a clear indication that Israeli physics does not suffer from the intellectual island effect [3]. In contrast, that part of research done in India which is published in Indian journals gets cited by the authors of these papers and other Indian scientists to a much larger extent [3].

Another point worth noting is that of the 24 highly cited papers which were cited at least 13 times (Table 7) most were published in truly international journals of high impact devoted to subfields of physics. Only three papers—one each in *Nature, Proceedings of the National Academy of Sciences, USA* and *Journal of the American Chemical Society*—appeared in journals which are either multidisciplinary or devoted to a whole subject area. This may well be an indication that the Israeli physics community is sharply divided into groups working in well-defined sub-specialities. This is also in tune with the current tendency in science publishing wherein journals devoted to narrow areas are becoming more and more popular at the expense of journals devoted to whole disciplines.

An analysis of the 24 highly cited papers (Table 7) shows that the Weizmann Institute (319 citations from 7 papers) is easily the best physics research centre in Israel, followed by Tel Aviv University (221 citations from 5 papers) and the Hebrew University (146 citations from 5 papers). Again, Israel's strength in chemical physics is obvious: 10 of the 24 highly cited papers were published in journals devoted to chemical physics.

How quickly are these papers cited?

The distribution of citations to the highly cited papers as a time series over the five-year period 1977–1981 reveals that, on the whole, the papers receive a good number of citations in the first year itself. The citedness increases rapidly over the next two years and falls subsequently. Nothing more can be said, as we do not have data on citations over a longer period of time, say 10–15 years.

Conclusions

In any case, the evidence we have is enough to conclude that physics done in Israel is of a high order. It is otherwise impossible to get so many papers published in high impact journals in which they have actually been published. Nor would these papers have received so many citations as they have actually done. Israeli work in chemical physics is particularly noteworthy both in terms of number of publications and citation impact.

Israel, because of its close political and economic ties with the West, has certain advantages. Not only does she receive all the economic benefits that such ties ensure, but her scientists get ample opportunities to collaborate with fellow researchers in very well equipped laboratories in the United States and Western Europe. For instance, out of the 105 most highly cited 1980 articles (most cited in 1980 and 1981) in the physical sciences excluding chemistry, three were authored

by Israeli physicists, and all the three were written in collaboration with scientists outside Israel (from Denmark, France, West Germany, UK and USA). The Israeli author(s) of two of these papers hailed from the Weizmann Institute and the third from the Hebrew University, Jerusalem. One of the three papers was in experimental elementary particle physics, another in theoretical elementary particle physics and the third in quantum field theory [9].

To put these findings in perspective, we are now making a similar study of physics research in other middle level countries whose scientific enterprises are comparable to those of Israel, *viz.* India, Australia and Canada, and the results will soon be reported in this journal.

Acknowledgement

We are grateful to an anonymous referee and Professor Michael J. Moravcsik for constructive criticism.

Dr. Shlomo Herskovic of the National Council for Research and Development, Jerusalem, was kind enough to give us two valuable books on scientific research in Israel, and Dr. Eugene Garfield gave us a preprint of his Ranganathan Memorial Lecture.

We have pleasure in dedicating this paper to Jan Vlachý of Czechoslovakia, bibliometricist *par excellence,* whose productivity and depth of analysis we would like to emulate.

References

[1] S. Arunachalam and S. Hirannaiah, Journal preferences of Indian researchers in the physical and chemical sciences, Proceedings of the Seminar on primary Communication in Science and Technology in India, 4–8 December 1978, Bangalore, Publications and Information Directorate, New Delhi (1981) 141–148.

[2] S. Arunachalam, B.C. Kashyap and P.S. Shankar, Impact of Indian research in reproductive endocrinology on world literature, Proceedings of the Seminar on Primary Communication in Science and Technology in India, 4–8 December 1978, Bangalore, Publications and Information Directorate, New Delhi (1981) 205–210.

[3] S. Arunachalam and S. Markanday, Science in the middle-level countries: a bibliometric analysis of scientific journals of Australia, Canada, India and Israel, *Journal of Information Science 3* (1981), 13–26.

[4] T. Braun, W. Glanzel and A. Schubert, Scientometric indicators. Comparative analysis of the scientific publication activity of Austria, Czechoslovakia, Finland, Israel, Poland, Hungary and New Zealand (1976–1980), *Tudomanyos es Muszaki Tajekoztatais 30* (1983) 1–12 (In Hungarian).

[5] Tibor Braun and J.I. Nagy, A comparative evaluation of some Hungarian and other national biology, chemistry, mathematics and physics journals, *Scientometrics 4* (1982) 439–455.

[6] K.H. Chang and D. Dieks, The Dutch research effort in physics: its productivity in numbers, *Nederlands Tijdschrift voor Natuurkunde 41* (3) (1975) 28–32.

[7] J.D. Frame, Measuring scientific activity in lesser developed countries, *Scientometrics, 2* (1980), 133–145.

[8] E. Garfield, ed., *SCI Journal Citation Reports, Vol. 13,* (Institute for Scientific Information, Philadelphia, 1977).

[9] E. Garfield, The 1980 articles most cited in 1980 and 1981–1982. Physical sciences, *Current Contents 23* (20) (May 1983) 5–16.

[10] E. Garfield, Third World research, Parts 1 and 2. *Current Contents 23* (33/34) (August 1983).
See also: E. Garfield, Mapping science in the Third World, *Sci. Publ. Policy 10* (3) (1983), 112–127. For a more recent version, refer to his Ranganathan Memorial Lecture, 1983 (to be published).

[11] L. Lester, ed., *Scientific Research in Israel 1982,* (National Council for Research and Development, Jerusalem, 1982) 19.

[12] A. Schubert, W. Glanzel and T. Braun, *Scientometric indicators: A 32-country comparative evaluation of publishing performance and citation impact* (Hungarian Academy of Sciences, Department for Informatics and Science Analysis, 1982).

[13] E. Tal, N. Arnon and Y. Dudai *Science and Technology in Israel 1975–76.* (National Council for Research & Development, Jerusalem, 1977).

[14] J. Vlachý, Publication output of world physics, *Czech. J. Phys. B 29* (1979) 475–480.

[15] J. Vlachý, Publication output in physics subfields, *Czech. J. Phys. B 29* (1979) 829–836.

[16] *World Development Report 1982,* published for the World Bank by Oxford University Press, (1982).