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The Russians Are Coming! Part 1. The Red-Hot 100 Soviet Scientists, 1973-1988

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There has been increased interest in Soviet science and technology as a result of *glasnost* and *perestroika*. A study of Soviet papers based on 1973-1988 data from the ISI® *Science Indicators* file was undertaken. Part 1 examines the 100 most-cited Soviet scientists. The data indicate that nonmembers of the USSR Academy of Sciences were cited more frequently than members. During this period Soviet physics dominated, with secondary emphasis in chemistry and life-sciences research. Soviet biochemist and science historian Zhores A. Medvedev, National Institute for Medical Research, Mill Hill, London, UK, explains why physics research and physicists dominate Soviet science.

Soviet Science Under Gorbachev's *Glasnost*

In many ways 1989 was a watershed year for the Soviet Union. The changes, swept along by *perestroika* (restructuring) and *glasnost* (openness), would not have been predicted just five years ago. And activities that have already taken place in early 1990 indicate that this year may be even more eventful. Who would have thought it possible that a multiparty system, the creation of a Western-style presidency, and a cabinet system of government would be suggested by the general secretary of the Soviet Communist party? And that these unprecedented suggestions would be enacted by the Communist party Central Committee?[1]

Glasnost and *perestroika* have raised hopes not just for improved political and economic conditions, but also for more openness and freedom in Soviet science. Indeed, over the past 24 months, a number of new scientific links have been established between the USSR and the West, but especially between the Soviet Union and its cold war rival, the US. The unprecedented arrival of a top level delegation—led by USSR Academy of Sciences vice president Konstantin V. Frolov—to the annual American Association for the Advancement of Science meeting in Boston in February 1988 marked a new chapter in the US/USSR scientific dialogue.[2] Since then, exchange agreements have been reached between various USSR science delegations and the US National Academy of Sciences (NAS), the US Institute of Medicine, the American Society of Mechanical Engineers, the American Chemical Society, and other associations.[3,4]

In 1989 the increasing number of links between the US and the USSR turned from exchange agreements towards science cooperation pacts. In March an agreement was signed between the University of Michigan, Ann Arbor; the Massachusetts Institute of Technology, Cambridge; the Brookhaven National Laboratory, Upton, New York; and the USSR Academy of Sciences-affiliated Institute for High Energy Physics, Protvino, where 15 American and 15 Soviet physicists will conduct a joint experiment at a Soviet accelerator in mid-1991.[5] In August the US Geological Survey, the Incorporated Research Institution for Seismology, and the USSR Academy of Sciences agreed to collaborate on earthquake detection, including setting up further monitoring stations in both countries.[6] The NAS and the USSR Academy of Sciences put together plans in December for a joint com-

mittee to study global ecology,[7] and NASA and USSR space officials reached agreement on efforts to initiate cooperative biomedical research on both the US space shuttle and the Soviet modular space station *Mir*.[8] In March 1990 Vice President Dan Quayle announced that the US would provide ground-based hardware and services for a Soviet radiotelescope to be launched in the mid-1990s.[9]

Within the past 12 months, the influence of *glasnost* has resulted in unprecedented disclosures of previously unknown aspects of the Soviet science and technology establishment. These include information on failed or disastrous state-sponsored projects (such as their manned lunar[10-12] and nuclear energy[13-15] programs), as well as the first release of detailed economic data on how the Soviet Union spends its rubles on science. According to figures released last September by the USSR's minister of finance, Valentin Pavlov, the government has earmarked 11 billion rubles (which would compare to about 17.34 billion US dollars) for civilian research in the budget for 1990, compared with just 7.3 billion (or about 11.5 billion dollars) in 1989. This represents a boost from 1.5 percent to 2.3 percent of total state spending. The Soviets are going to lay particular stress this year on the fields of biomedicine and health.[16]

It remains to be seen how *glasnost* will affect the publication output of Soviet scientists, but there are potentially encouraging signs that freer and wider circulation of research is indeed possible in the USSR. The Supreme Soviet (parliament), for example, has passed a law allowing private ownership of photocopying machines, and the government is in the final stages of allowing the unregulated sale of uncensored Western periodicals and newspapers across the country.[17]

A recent example of the new publishing environment is the recently launched Soviet journal *Biomedical Science*.[18] The journal is a joint venture between the USSR Academy of Sciences, the British Royal Society of Chemistry, and the UK scientific publisher Pion. This English-language, international journal will no doubt increase the awareness—and prestige—of Russian life-sciences research not only in the West, but also among the Soviets themselves. Indeed, the same consortium has announced plans for another journal entitled *Mendeleyev Communications*, according to recent Soviet visitors Elia Moiseev and Mark Volpin, whom I had a chance to meet in mid-April when I visited Cornell University, Ithaca, New York.

Even before the Gorbachev era, ISI® acted to increase exchanges in information science by hosting Soviet visitors to Philadelphia. Physicist Sergei P. Kapitza (son of Nobelist Pyotr L. Kapitza), Institute for Physical Problems, Moscow, was the first Soviet scientist to accept an invitation and was here in March 1987.[19] Others included marine biologist Alexander I. Pudovkin, Institute of Marine Biology, Vladivostok (November 1987-April 1988);[20] mathematician Vladimir V. Nalimov, Laboratory of Statistical Methods, Moscow State University (October-December 1988);[21] and information scientist Valentina A. Markusova, chief, Information Department, Far-East Branch of the USSR Academy of Sciences All-Union Institute for Scientific and Technical Information, Moscow (September 1989-January 1990).[22] Markusova gave much invaluable input towards the development of this essay. More recently, information scientist Irinia V. Marshakova-Shaikevich (who independently discovered "co-citation analysis" with Henry Small, director of ISI's Corporate Research Department[23,24]), Institute for Philosophy, USSR Academy of Sciences, Moscow, was our guest.

With the USSR today generating so much interest, and considering that the last time a study of highly cited Soviet papers appeared in *Current Contents*® (*CC*®) was nearly 15 years ago,[25] we decided that a more up-to-date citation analysis of Soviet science was appropriate. This is not to say we and others have totally ignored Eastern Europe, but for obvious reasons their work has had limited impact in our usual studies of international high impact research.

Methodology and the Question of Institutional Affiliations

While a study limited to the last few years would give a more current perspective on Soviet science, we decided to examine the Soviet scientific literature for a period of 15 years. This provides the best oppportunity to identify high impact Soviet papers and authors. The data used to do this study comes from ISI's *Science Indicators* file. This file, which covers 4.5 million cited papers published between 1973 and 1988, is a subset of ISI's entire 1945-1988 *Science Citation Index®* (*SCI®*) database. The papers identified in the file were cited at least once. Nearly 3,830,000 source items in the *SCI* were never cited in this period. For this study we retrieved 180,000 cited articles published by Soviet scientists from 1973 through 1988. From these, we selected 892 high impact papers cited at least 50 times for analysis and discussion here. The analysis is based on all-author data; it is not limited to first authors.

It should be stressed that Soviet scientists who published highly cited articles before 1973 will not show up in the file. For example, physicist and Nobel laureate Lev D. Landau was ranked second in a study of the 250 most-cited primary authors in the 1961-1975 *SCI*.[26] However, Landau (who died in 1968) published papers from the 1930s up through the mid-1960s and therefore does not appear in our sample. A fascinating review of his relationship to Nobelist Kapitza appears in a recent book review.[27]

An additional caveat is that Soviet scientists were identified solely when their home institutional address was provided. That is, any time an institution from the USSR was listed by any coauthor, the paper was credited to the Soviet Union. But if a Soviet scientist happens to have been abroad on a research exchange and listed an address outside the USSR, the paper would not be credited as being Soviet. A case in point is a paper authored by the influential Soviet mathematician and academician Ludwig D. Faddeev, "Operator anomaly for the Gauss law," which examines anomalies of low-strength magnetic fields.[28] The article was published in 1984 and was cited nearly 160 times through the end of 1988. But Faddeev's listed address was the Scuola Normale Superiore di Pisa, Italy, where he had been working at the time.

However, this type of address problem for Soviet scientists is not as annoying as having no author address at all. *CC* readers are well aware of our campaigns to get journals to list authors' addresses.[29,30] Indeed, although many Soviet journals covered by the *SCI* and *CC* do have authors' addresses, many still do not. It is commonly said that national security considerations or secrecy laws have prevented and continue to prevent many of the authors from listing their institutional affiliations and even their names on occasion. Soviet science historian and biochemist Zhores A. Medvedev, National Institute for Medical Research, Mill Hill, London, UK, expands upon this theme:

> One of the main reasons why there are no addresses is the simple fact that many secret institutes simply do not have real geographical addresses and names. They are known only as a post-office box number. For example, the very large nuclear-energy research complex near Kyshtym where the main Soviet center of plutonium production is located, as well as a biological reservation and experimental agricultural station, is only known as *Post Box Chelyabinsk-40*.... The whole "atomic" town near Kyshtym has no name, but has about 100,000 residents.... However, the censorship which still exists to prevent the [publication] of classified information does not allow articles with such addresses.[31]

One may ask, why bother to publish at all if the authors are not free to discuss their work through correspondence or other personal contact?[32] I can only hope that *glasnost* allows *all* Soviet scientists who publish papers in the future to list not only an address, but even telephone and fax numbers.

The problem of missing or uninformative author addresses complicates our efforts to identify the most-cited Soviet scientists. This

makes it particularly difficult to distinguish between homographs—that is, different authors with the same last name and initials. Usually, most homographs can be quickly resolved by examining the journals of publication—if they are in widely divergent fields, such as immunology and petroleum engineering, we can differentiate between the two or three authors in question. However, if the homographic authors publish in the same set of field-specific journals, we rely on institutional affiliations to sort them out. Obviously, this strategy is less effective in dealing with potential Soviet homographs if there are no addresses. Short of contacting every known author listed and requesting complete bibliographies—a time-consuming and expensive undertaking—there is no guarantee that the homograph problem is completely solved. We have, of course, made every effort to ensure the accuracy of our list of most-cited Soviet scientists and are confident that the homograph problem has been kept to a minimum.

The Soviet 100—Whither the Academy Members?

Table 1 lists the top 100 scientists who were most cited for their publications in 1973-1988. The columns of tabular data show, in order from the left, 1973 through 1988 citations, number of papers in the 15-year period, average number of citations per paper ("impact"), and 1988 citations for each author. Members of the USSR Academy of Sciences are identified by an asterisk, and corresponding members by a dagger.

The Academy of Sciences is the principal coordinating body for science, technology, and production in the Soviet Union. Under the Council of Ministers of the USSR, the academy directs the research of all academies of the 15 Union republics and other scientific institutions, including universities. At the present time, the academy controls the operation and funding of more than 260 institutions, university and government laboratories, naval institutes, observatories, research stations, and scientific societies.[33]

Membership in the academy is by election and is basically of two types—academicians and corresponding members. Despite the different appellations, there is really not much difference between the two, other than a bonus the scientist receives. For an academician, it is 500 rubles over his salary; for a corresponding member, 250 rubles. In fact, the difference is so negligible that discussions are now under way to dispense with the corresponding member designation. (However, according to Medvedev, full academicians are also entitled to a state *dacha* in prestigious country villages.[31])

Considering the influence of the USSR Academy of Sciences in determining science and technology policy, one would expect that academy members would be quite prominent in a study of the highest impact Soviet scientists. But this is not the case. The four most-cited scientists are neither academicians nor corresponding members: physicists V.S. Letokhov, V.I. Zakharov, M.A. Shifman, and A.I. Vainshtein. And only 35 of the top 100 Soviet scientists belong to the academy. Three of the academicians—biochemist Yuri A. Ovchinnikov, chemist Anatoli N. Nesmeyanov (former president of the academy), and nuclear physicist Yakov B. Zeldovich—are deceased. There is also another deceased scientist on our list, V.M. Zhdanov, who was a member of the Academy of Medical Sciences.

On the topic of academy representation in Table 1, I think that—in all fairness—it should be noted that we cannot say that members of non-Soviet academies are universally highly cited. When we studied the 1,000 most-cited authors in 1981, only 240 of the 736 identified US scientists were members of the NAS.[34]

A Who's Who of Soviet Science: Physicists Dominate

Of the 100 most-cited Soviet scientists in Table 1, roughly a third (35) of the authors listed are physicists. They are followed by life scientists (32), chemists (30), and space-science researchers (3). These scientific dis-

Table 1: The 100 most-cited Soviet authors. Data are from the ISI® *Science Indicators* file, 1973-1988. A=1973-1988 citations. B=cited papers by this author. C=average citations per paper. D=citations received in 1988. Members of the USSR Academy of Sciences are indicated with an asterisk (*); corresponding members are indicated with a dagger (†).

		A	B	C	D
1.	**Letokhov V S** Institute of Spectroscopy(A) Troitsk	4,575	270	16.9	248
2.	**Zakharov V I** Theoretical and Experimental Physics Institute(A) Moscow	4,401	129	34.1	14
3.	**Shifman M A** Theoretical and Experimental Physics Institute(A) Moscow	4,268	101	42.3	303
4.	**Vainshtein A I** Theoretical and Experimental Physics Institute(A) Moscow	4,181	78	53.6	64
5.	***Ovchinnikov Y A** M.M. Shemyakin Bioorganic Chemistry Institute(A) Moscow	4,082	113	36.1	286
6.	†**Polyakov A M** L.D. Landau Theoretical Physics Institute Moscow	3,980	20	199.0	576
7.	***Kochetkov N K** N.D. Zelinskii Organic Chemistry Institute(A) Moscow	3,326	329	10.0	241
8.	†**Voronkov M G** Institute of Organic Chemistry(A) Irkutsk	3,290	624	5.3	263
9.	***Prokhorov A M** Institute of General Physics(A) Moscow	3,177	490	6.5	52
10.	***Georgiev G P** V.A. Engelhardt Molecular Biology Institute(A) Moscow	3,140	123	25.5	69
11.	**Linde A D** P.N. Lebedev Physics Institute(A) Moscow	2,777	53	52.4	329
12.	***Korshak V V** A.N. Nesmeyanov Organoelemental Compounds Institute(A) Moscow	2,626	617	4.3	25
13.	**Berezin I V** M.V. Lomonosov State University Department of Chemistry Moscow	2,432	220	11.1	110
14.	†**Pudovik A N** A.E. Arbuzov Organic and Physical Chemistry Institute(A) Kazan	2,389	548	4.4	116
15.	***Zefirov N S** M.V. Lomonosov State University Department of Chemistry Moscow	2,188	253	8.6	210
16.	***Nesmeyanov A N** A.N. Nesmeyanov Organoelemental Compounds Institute(A) Moscow	1,997	226	88.4	375
17.	***Kostyuk P G** A.A. Bogomolets Physiology Institute(U) Kiev	1,924	55	35.0	247
18.	**Lippmaa E** Chemical and Biological Physics Institute(E) Tallin	1,887	72	26.2	102
19.	†**Skulachev V P** M.V. Lomonosov State University A.N. Belozerskii Laboratory of Molecular Biology and Bioorganic Chemistry Moscow	2,681	135	19.8	123

20.	**Struchkov Y T** A.N. Nesmeyanov Organoelemental Compounds Institute(A) Moscow	3,303	464	7.1	24
21.	†**Sunyaev R A** Space Research Institute(A) Moscow	1,877	35	53.6	87
22.	**Martinek K** M.V. Lomonosov State University Department of Chemistry Moscow	1,842	118	15.6	208
23.	**Kiselev A V** M.V. Lomonosov State University Department of Chemistry Moscow	1,763	182	64.6	178
24.	**Altshuler B L** B.P. Konstantinov Nuclear Physics Institute(A) Leningrad	1,813	36	50.4	393
25.	***Reutov O A** M.V. Lomonosov State University Department of Chemistry Moscow	1,733	206	8.4	48
26.	***Zeldovich Y B** Institute of Physics Problems(A) Moscow	1,732	91	19.0	952
27.	**Bergelson L D** Cardiology Research Center(M) Moscow	1,708	176	66.5	64
28.	***Kabanov V A** A.V. Topchiev Petrochemical Synthesis Institute(A) Moscow	1,622	224	7.2	51
29.	**Shashkov A S** N.D. Zelinskii Organic Chemistry Institute Moscow	1,597	171	9.3	38
30.	†**Privalov P L** Institute of Protein Research(A) Pushchino-on-Oka	1,590	61	26.1	218
31.	†**Fradkin E S** P.N. Lebedev Physics Institute(A) Moscow	1,652	76	21.7	388
32.	***Basov N G** P.N. Lebedev Physics Institute(A) Moscow	1,544	199	7.8	316
33.	***Ivanov V T** M.M. Shemyakin Bioorganic Chemistry Institute(A) Moscow	1,478	90	16.4	23
34.	**Belov N V** M.V. Lomonosov State University Department of Physics Moscow	1,475	409	3.6	45
35.	†**Larkin A I** L.D. Landau Theoretical Physics Institute Moscow	1,475	55	26.8	23
36.	**Novikov V A** Theoretical and Experimental Physics Institute(A) Moscow	1,463	56	26.1	62
37.	***Razuvaev G A** N.I. Lobachevskii State University Chemical Research Institute Gorki	1,454	220	52.1	85
38.	**Aronov A G** B.P. Konstantinov Nuclear Physics Institute Gatchina	1,449	54	26.8	45
39.	**Spitsyn V I** Physical Chemistry Institute(A) Moscow	1,397	293	4.8	96
40.	†**Tsvetkov V N** Institute of Macromolecular Compounds Leningrad	1,367	143	9.6	185

41.	**Shklovskii B I** A.F. Ioffe Physical Technical Institute(A) Leningrad	1,347	51	26.4	131
42.	***Bayev A A** Institute of Molecular Biology Moscow	1,338	77	17.4	14
43.	***Goldanskii V I** Chemical Physics Institute(A) Moscow	1,309	136	9.6	167
44.	**Zamolodchikov A B** L.D. Landau Theoretical Physics Institute(A) Moscow	1,295	38	34.1	188
45.	†**Petrov A A** Physical Technical Institute(A) Moscow	1,280	283	4.5	47
46.	**Magi M** Institute of Chemistry and Biological Physics(E) Tallin	1,251	40	31.3	21
47.	***Plate N A** M.V. Lomonosov State University Department of Chemistry Moscow	1,220	131	9.3	108
48.	†**Bunkin F V** General Physics Institute(A) Moscow	1,197	137	8.7	121
49.	**Shuryak E V** Novosibirsk Nuclear Physics Institute(A) Novosibirsk	1,196	40	30.0	232
50.	**Krishtal O A** A.A. Bogomolets Physiology Institute(U) Kiev	1,192	30	40.0	35
51.	†**Bystrov V F** M.M. Shemyakin Bioorganic Chemistry Institute(A) Moscow	1,185	55	21.5	76
52.	**Kuzmin V A** Chemical Physics Institute(A) Moscow	1,181	148	8.0	58
53.	**Drachev L A** M.V. Lomonosov State University A.N. Belozerskii Laboratory of Molecular Biology and Bioorganic Chemistry Moscow	1,179	54	21.8	34
54.	**Akhrem A A** Institute of Bioorganic Chemistry(B) Minsk	1,170	213	5.5	68
55.	**Minkin V I** Rostov State University Physics and Organic Chemistry Research Institute Rostov	1,170	198	5.9	66
56.	***Sagdeev R Z** Space Research Institute(A) Moscow	1,168	119	9.8	117
57.	**Bakayev V V** Novosibirsk Medical Institute Novosibirsk	1,149	22	52.2	6
58.	**Shuvalov L A** Institute of Crystallography(A) Moscow	1,141	181	6.3	17
59.	**Petrovskii P V** A.N. Nesmeyanov Organoelemental Compounds Institute Moscow	1,135	137	8.3	0
60.	**Efros A L** A.F. Ioffe Physical Technical Institute(A) Leningrad	1,119	57	19.6	94
61.	**Dmitriev B A** N.F. Gamaleya Epidemiology and Microbiology Institute(M) Moscow	1,117	89	12.6	29

62.	*Gorkov L P L.D. Landau Theoretical Physics Institute(A) Moscow	1,116	54	20.7	111
63.	Belavin A A L.D. Landau Theoretical Physics Institute(A) Moscow	1,114	18	61.9	235
64.	Lipatov Y S Institute of the Chemistry of Macromolecular Compounds(U) Kiev	1,112	196	5.7	134
65.	†Zakharov V E L.D. Landau Theoretical Physics Institute(A) Moscow	1,109	61	18.1	275
66.	Ryskov A P Molecular Biology Institute(A) Moscow	1,090	51	21.4	4
67.	Shuvalov V A Institute of Soil Science and Photosynthesis(A) Pushchino-on-Oka	1,089	54	20.2	4
68.	Tseytlin A A P.N. Lebedev Physics Institute(A) Moscow	1,087	41	26.5	51
69.	Nametkin N S A.V. Topchiyev Petrochemical Synthesis Institute(A) Moscow	1,082	125	8.7	0
70.	Levanyuk A P A.V. Shubnikova Crystallography Institute(A) Moscow	1,072	73	14.7	59
71.	Nefedov V I N.S. Kurnakov General and Inorganic Chemistry Institute(A) Moscow	1,063	105	10.1	70
72.	Skryabin K G Molecular Biology Institute(A) Moscow	1,062	40	26.6	9
73.	Davankov V A A.N. Nesmeyanov Organoelemental Compounds Institute(A) Moscow	1,040	84	12.4	34
74.	Shibaev V P M.V. Lomonosov State University Department of Chemistry Moscow	1,039	108	9.6	53
75.	Zhdanov V M D.I. Ivanovskii Virology Institute(M) Moscow	1,035	138	7.5	34
76.	Klimov V V A.N. Bakh Biochemistry Institute(A) Moscow	1,021	67	15.2	55
77.	Lutsenko I F M.V. Lomonosov State University Department of Chemistry Moscow	1,001	191	5.2	20
78.	Abdulaev N G M.M. Shemyakin Bioorganic Chemistry Institute(A) Moscow	997	37	27.0	12
79.	Kumakhov M A M.V. Lomonosov State University Institute of Nuclear Physics Moscow	990	50	19.8	35
80.	Voloshin M B Theoretical and Experimental Physics Institute Moscow	987	44	22.4	62
81.	Yermakov Y I Institute of Catalysis(A) Novosibirsk	982	95	10.3	36
82.	Orlov S N Central Research Laboratory Ministry of Public Health USSR Moscow	969	67	14.5	43

83.	**Boreskov G K** Institute of Catalysis(A) Novosibirsk	964	109	8.8	46
84.	**Postnov Y V** Central Research Laboratory Ministry of Public Health USSR Moscow	957	47	20.4	79
85.	***Spirin A S** Institute of Protein Research(A) Pushchino-on-Oka	952	60	15.9	65
86.	***Knorre D G** Institute of Bioorganic Chemistry(A) Novosibirsk	937	76	12.3	34
87.	**Ptitsyn O B** Institute of Protein Research(A) Pushchino-on-Oka	932	57	16.4	48
88.	***Chazov E I** Moscow Cardiology Center Moscow	932	42	22.2	118
89.	**Kachanov V A** Serpukhov High Energy Physics Institute Serpukhov	925	82	11.3	0
90.	**Feigina M Y** M.M. Shemyakin Institute of Bioorganic Chemistry(A) Moscow	924	23	40.2	0
91.	**Osipov O A** Rostov Don University Physical and Organic Chemistry Institute Rostov Don	923	178	5.2	31
92.	**Sokolov V I** A.N. Nesmeyanov Organoelemental Compounds Institute(A) Moscow	919	117	7.9	40
93.	**Shakura N I** Shternberg Astronomy Institute Moscow	916	14	65.4	77
94.	**Makarov G N** Spectroscopy Institute(A) Troitsk	908	41	22.1	1
95.	**Brandt N B** M.V. Lomonosov State University Department of Physics Moscow	903	124	7.3	115
96.	**Saks V A** Cardiovascular Surgery Institute(M) Moscow	902	51	17.7	33
97.	**Rubin A B** M.V. Lomonosov State University Department of Biophysics Moscow	902	125	7.2	13
98.	**Samoson A** Institute of Chemical Physics and Biophysics(E) Tallin	897	21	42.7	31
99.	**Kaulen A D** M.V. Lomonosov State University A.N. Belozerskii Laboratory of Molecular Biology and Bioorganic Chemistry Moscow	897	33	27.0	2
100.	**Frankkamenetskii M D** Institute of Molecular Genetics Moscow	880	32	27.5	44

(A) = Academy of Sciences
(M) = Academy of Medical Sciences
(E) = Academy of Sciences EsSSR
(U) = Academy of Sciences UkSSR
(B) = Academy of Sciences BeSSR

cipline determinations are, for the most part, made solely by institutional affiliation; however, if the discipline could not be ascertained by affiliation, the journals in which the scientist published were examined to help us.

Among the 35 physicists listed, 10 are academy members: corresponding members Fedor V. Bunkin, Efim S. Fradkin, Anatoli I. Larkin, Aleksander M. Polyakov, and Vladimir E. Zakharov; and academicians Nikolai G. Basov, Vitalii I. Goldanskii, Lev P. Gorkov, Nobelist Aleksander M. Prokhorov, and the late Zeldovich. All work at institutions based in Moscow. Nonacademy members overwhelmingly had institutional affiliations in Moscow as well (16), but there was representation from other cities as well—Leningrad (3), Tallin (2), Gatchina (1), Novosibirsk (1), Serpukhov (1), and Troitsk (1).

Medvedev believes the prominence of Soviet physicists in our list would be even more evident had nuclear scientists been able to publish their results abroad. Furthermore, he points out that many prominent figures working in nuclear physics (as well as other subjects that are defense-linked) are not even allowed to publish in Soviet journals (undoubtedly comparable statements could be made about Western defense-linked researchers):

> Even names of some great Soviet scientists are never mentioned—like academician Sergei P. Korolev (space technology), who was anonymous before he died. Others, like the late academician V. Legasov (or academician Evgeny P. Velikhov, now director of the I. Kurchatov Institute in Moscow) have published very few papers, because they mostly prepare "closed" reports.... The late academician Andrei D. Sakharov is hardly known as a nuclear scientist if you read the journals.[31]

Of the 32 life scientists in Table 1, the four most-cited researchers are members of the academy. They are biochemist Ovchinnikov, now deceased; molecular biologist Georgi P. Georgiev, a *Citation Classic*® commentator;[35] physiologist Platon G. Kostyuk; and corresponding member and biochemist Vladimir P. Skulachev. Further down the list, we find academicians Vadim T. Ivanov (biochemistry); Aleksander A. Bayev (molecular biology); Aleksander S. Spirin (molecular biology), also a *Citation Classic* commentator;[36] D.G. Knorre (biochemistry); Evgeny I. Chazov (physiology); and corresponding members Pyotr L. Privalov (biophysics and polymers) and Vladimir F. Bystrov (biophysics). Ivanov, Bayev, Bystrov, Chazov, Georgiev, and Skulachev work in Moscow; Kostyuk in Kiev; Knorre in Novosibirsk; and Privalov and Spirin in Pushchino-on-Oka. Of the other 21 life scientists, 16 work in research centers in Moscow, 2 in Pushchino-on-Oka, and 1 each in Kiev, Minsk, and Novosibirsk.

Of the 30 chemists, 12 are academy members: corresponding members Mikhail G. Voronkov, Anatoli A. Petrov, Arkadiy N. Pudovik, and V.N. Tsvetkov; and academicians Viktor A. Kabanov, Nikolai K. Kochetkov, V.V. Korshak, the late Nesmeyanov, Nikolai A. Plate, Georgi A. Razuvaev, Oleg A. Reutov, and Nikolai S. Zefirov. Tsvetkov works in Leningrad, Voronkov in Irkutsk, Pudovik in Kazan, and Razuvaev in Gorki, while the others have Moscow addresses. The other chemists in our most-cited list are located at institutions in the following cities: Moscow (11), Novosibirsk and Rostov-on-Don (2 each), and Kiev, Tallin, and Troitsk (1 each).

The three space-science researchers we identified are corresponding member Rashid A. Sunyaev, academician Roald Z. Sagdeev, and N.I. Shakura. All have Moscow addresses. Sagdeev has been instrumental in the ongoing efforts to restructure the academy, and his views appear later in this essay.

Overall, the institutional affiliations of the top 100 Soviet researchers reveal that 71 are situated in Moscow, 4 each in Leningrad, Novosibirsk, and Pushchino-on-Oka, and 3 apiece in Kiev and Tallin. Figure 1 is a map of the USSR showing all cities that published at least 250 papers in 1989. The number of papers per city is given below the map. In 1989 the *SCI* covered over 3,200 journals,

Figure 1: Soviet cities that generated 250 or more publications in 1989. A = city in which research was conducted. B = number of papers published in 1989.

A	B
Baku	263
Chernogolovka	409
Donetsk	413
Dubna	289
Erevan	255
Gorki	327
Irkutsk	429
Kazan	374
Kharkov	884
Kiev	3,106
Leningrad	3,414
Lvov	346

A	B
Minsk	995
Moscow	14,044
Novosibirsk	1,265
Odessa	326
Pushchino-on-Oka	316
Riga	274
Rostov-on-Don	325
Sverdlovsk	678
Tashkent	420
Tbilisi	292
Tomsk	491
Ufa	261
Vladivostok	321

of which 127 were Soviet journals in Russian or in English translation.

Factors Affecting Soviet Citation Counts

While reviewing this essay, Medvedev noticed that most of the citations to the majority of the authors in our list are to Soviet publications, and very few are from US or Western journals. Medvedev also noted that the most-cited and most-prolific authors—Letokhov and Voronkov—have significant percentages of self-citations. Medvedev provided some further insights as to why some of the names possibly appeared on our list:

In the USSR it is nearly compulsory to cite so-called "classics" and scientists who are very influential. For example, Evgeny I. Chazov was also a minister of health of the USSR (he was dismissed in early April). [M]any references in 1988 were due to his ministerial position.... [For example], even Chazov's short interview in the general media tabloid *Argumenty i Facty* is included among his list of works, [although it is not a research article]. This [instance] is due to the fact he was the minister of health, not because of his research achievements. [In 1985 Chazov, along with the American Bernard Lown, accepted the Nobel Peace Prize on behalf of the International Physicians for the Prevention of Nuclear War.]

Furthermore, some scientists receive preferential citation treatment in the USSR

because they are editors-in-chief of certain journals. [For example], Vladimir P. Skulachev [is] editor of *Biokhimiya*, and the late professor V.M. Zhdanov, former editor of *Voprosy Virusologii*.... [And it is a] Soviet rule that publication of a scientific paper [is] allowed only if it is officially presented by the institute director. Without a formal letter from the director, the paper will not even be considered by Soviet scientific journals. [Thus], the directors and their deputies are ensconced in privileged positions....[31]

The Highest Impact Soviet Scientists Are Not Necessarily the Most Prolific

The highest impact Soviet author during the 15-year span, 1973-1988, is nuclear physicist Polyakov, an academy corresponding member. His 20 papers received about 4,000 citations for an average of 200 citations per paper. Crystallographer N.V. Belov has the lowest impact (3.6) of the 100 scientists listed. Their average impact is 23.3. The cited average for academy members is 24.6. However, if one factors out Polyakov's "superstar" citation number, the impact for academy members is 19.4. After Polyakov, the next six scientists with the highest impact are: the late Nesmeyanov (88.4); cardiologist L.D. Bergelson (66.5); astronomer Shakura (65.4); physicist A.V. Kiselev (64.6); and physicist Vainshtein and space scientist Sunyaev (53.6 each).

The most-prolific authors in Table 1 are physicists and chemists—Voronkov, with 624 papers; Korshak (617); Pudovik (548); Prokhorov (490); Y.T. Struchkov (464); Belov (409); and Kochetkov (329). By the way, in a study of the highest cited Soviet scientists that appeared in *The Scientist®*, it was erroneously reported that Kochetkov was deceased.[37] We received letters from both Goldanskii and Kochetkov himself informing us of this fact.[38,39] (Apparently, Kochetkov was confused with a K.A. Kocheshkov, who died 12 years ago.)

Fifty-three of the scientists in Table 1 authored 100 papers or less that were cited at least once, while 30 authored 101 to 200 papers. Seventeen authored more than 200 papers, 11 of whom are academy members. Most of these papers included one or more coauthors.

Physics Predominance: A Sign of Soviet Militarism?

Physics has been an area of science in which the USSR has been known to conduct world-class research for over 50 years. Soviet physicists are respected, influential, and have been at the forefront of world science for many decades. The data presented here corroborate this: of the 100 most-cited scientists, 35 are physicists. Typically, life-sciences researchers and publications tend to dominate undifferentiated citation lists. The reverse has been the case in the USSR.

We asked Medvedev to comment on this. He suggests that in the past the Soviet Union's military establishment focused the nation's scientific efforts on physics-based projects—such as the development of nuclear weapons:

> Physics received top priority in the Soviet Union when Stalin spent most rubles to create the atomic bomb. As a consequence, physics received favored treatment and unlimited governmental support, and physicists were able to develop anything they liked. Physicists also had the most funds of any branch of Soviet science.
>
> They were also spared the same type of ideologically motivated interference which had such a disastrous impact on biology (the Trofim Lysenko affair), on chemistry (the rejection of Linus Pauling's theories), and cybernetics.
>
> Since World War II, the majority of the elected presidents of the Academy of Sciences have been [nuclear] physicists. [Since] the academy was dominated by physicists, [they became] the privileged elite.
>
> But today, I don't think Soviet physicists have leading positions in world science as they did in the 1950s and 1960s—essentially because of the problems of obtaining modern computers. Due to this, Soviet progress in physics today is much more modest than in the past.[40]

According to Nobelist Roald Hoffmann, Department of Chemistry, Cornell Univer-

sity, militarism is only one reason for the dominance of physics in Soviet science. He suggests another major factor is the tradition of highly regarded scientists in Russian history: "Role models are very important in Soviet (and Russian) society. Three great physicists—Landau, Ilya I. Frenkel, and Pyotr Kapitza—shaped Soviet science, not only physics, but also guided [Soviet] youth to physics. [These men's] eminence and prestige *predated* the World War II period."[41]

Soviet excellence in physics is borne out when one looks at the Nobel Prizes. Of the 10 Nobel Prizes that have been awarded to Soviet scientists, 7 have been in physics. The 1958 prize was awarded to Ilya M. Frank, Igor E. Tamm, and Pavel A. Cherenkov. Landau won in 1962 for his work in the field of condensed matter, especially liquid helium. And Basov and Prokhorov with the American Charles Townes won in 1964. (Prokhorov is ranked ninth on the list of most-cited Soviet scientists in Table 1.) Pyotr Kapitza, who shared the 1978 Nobel physics award with Americans Arno Penzias and Robert Wilson, was recognized for his inventions and discoveries in low-temperature physics.

An interesting trend among Soviet physics Nobelists is that the 1958 and 1964 awards went to activity relating to lasers. Tamm and Frank found an explanation for why some liquids fluoresced when irradiated by gamma rays, a phenomenon discovered by Cherenkov. This discovery, which later proved important for laser technology, was recognized by the 1958 prize.[42] Prokhorov, Basov, and Townes's efforts dealt with the development of lasers and won the 1964 award.[43] The top-cited Soviet scientist in ISI's *Science Indicators* file—Letokhov—is a pioneer in the field of laser spectroscopy.

Conclusion

In concluding the first part of this essay on Soviet science, it is worth noting a recent interview by academician Sagdeev, former director of the Space Research Institute, Moscow, who gave an assessment of the USSR Academy of Sciences. According to Sagdeev the academy has become little more than a rubber stamp for huge, national-prestige projects after decades of control by an aging bureaucracy. Only in 1988 were elections for the top academy posts revamped, and age caps have been placed on active members.[44]

Sagdeev further asserts that *perestroika* has come late to the academy and greater efforts will be required for meaningful restructuring. He said: "The academy was too sleepy in the beginning.... It began to overhaul itself only as a result of demands from the public and from individual scientists.... As long as top officials [of the academy] are nominated by the [Communist] party or through party bosses like Yegor Ligachev, *perestroika* in the academy will be a phantom."[44]

In Part 2, we will examine the most-cited papers, institutes, research fronts, and journals.

* * * * *

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