27 October 1978, Volume 202, Number 4366 SCIENCE

How Valuable Are Scientific Exchanges with the Soviet Union?

Loren R. Graham

Exchange and cooperation programs between the United States and the Soviet Union in areas of science and technology have been under way for almost two decades, with a marked expansion occurring since 1972. As these programs have become more prominent and expensive and as U.S.-Soviet relations have become more complicated, their value has frequently been questioned. Scientists have often wondered about the scientific quality of the programs. Decisions about continuation or modification of projects sometimes rest on the question, "Should the exchanges and bilateral agreements be judged strictly in terms of scientific or technical merit, or should diplomatic or political goals also be considered?" Several reservations about the programs have been expressed by persons who fear that the Soviet Union is achieving access to American technology and expertise potentially useful in mititary applications. The arguments about scientific cooperation have been further complicated by questions of human rights, often voiced by American scientists who have learned of the plight of some of their Soviet colleagues who are not permitted to travel abroad because of their backgrounds or political views. These Americans ask, "Should we cooperate with official exchange programs if they are being used by Soviet authorities as reward systems for politically orthodox scientists?"

During the last year or so several new studies of U.S.-Soviet science and technology exchanges and cooperation have been published (*1*-*5*). Together they provide far better information about the value of scientific interchange with the Soviet Union than was available before, although they cover only a portion of all the present programs. One of these reports, that of a panel of the National Academy of Sciences chaired by Carl Kaysen, is the first attempt made by qualified American scientists to evaluate Soviet science and a U.S.-Soviet exchange program systematically (*6*). The Kaysen report was the most important source of information for the present analysis, but information from other reports was also used (*7*).

In this article I describe the scope of present cooperation in science and technology between the two countries, summarize the most important results of the recent evaluations of the programs, analyze several of the main criticisms of the agreements that have appeared in the press, and, finally, suggest ways in which the programs can be made more effective.

Scope of Scientific Cooperation

The formal channels of U.S.-Soviet scientific and technological cooperation and exchange can be summarized in a list of 12 agreements (*8*). Two of these agreements antedate the period known as détente and have been in existence for 19 years. These two are administered on the U.S. side by nongovernmental organizations: the National Academy of Sciences (NAS) and the International Research and Exchanges Board (IREX). Only the first of these is a true science and technology exchange, since the IREX exchange is dominated on the "outgoing" side by American social scientists and humanists, although Soviet scientists and engineers predominate on the "incoming" side. Between 1959 and 1977 the interacademy exchange provided between 44 and 275 "man-months" of exchange visits each year, with the average being about 180 man-months. On this program, about 30 American scientists went to the Soviet Union each year for extended research visits. This program is continuing, as is the IREX exchange.

The pace of exchange and cooperation was accelerated in 1972 by the signing of the first bilateral agreements at the Moscow summit meeting in that year, and by additional bilateral agreements in 1973 and 1974. These agreements are usually administered on the U.S. side by governmental organizations, the "executive" or "lead" agencies (see Table 1). Many of the bilateral programs are in applied science, whereas the interacademy exchange concentrates on fundamental science.

Under these bilateral programs, the total number of participants who have made visits to the opposite country has varied from a low of 508 in 1972 to a high of 2284 in 1975 (Table 2). In the last 2 years the total has dropped to 1425, a decrease that reflects increasing political difficulties between the two nations, the passing of the exploratory phase of technical cooperation, and the winnowing of nonproductive projects. Further statistical data concerning these programs are shown in Tables 3 to 5.

The type of activity going on under these agreements is indicated in Table 5, which gives the details of visits by Americans to the Soviet Union in fiscal years 1976 and 1977 for seven out of ten working groups under one bilateral agreement, the Agreement on Scientific and Technical Cooperation. These seven working groups are all supported by the National Science Foundation (NSF).

Evaluation Methodology and Results

The Kaysen panel focused on the quality of fundamental science in the Soviet Union and on the interacademy exchange program. During a 2-year period it gathered information from the following sources: (i) all the reports written for the NAS since 1960 by American scien-

The author is professor of the history of science in the Program on Science, Technology and Society, Massachusetts Institute of Technology, Cambridge 02139.

0036-8075/78/1027-0383$02.00/0

Table 1. Bilateral agreements between the United States and the Soviet Union, and the agencies assuming primary responsibility for them.

Agreement	Responsible agency
Environmental protection	Environmental Protection Agency
Space cooperation	National Aeronautics and Space Administration
Scientific and technical cooperation	Office of Science and Technology Policy*
Medical science and public health (includes the earlier separate agreement on artificial heart research)	Department of Health, Education, and Welfare
Agriculture	Department of Agriculture
Transportation	Department of Transportation
Studies of the world oceans	National Oceanic and Atmospheric Administration
Peaceful uses of atomic energy	Department of Energy
Energy	Department of Energy
Housing and other construction	Housing and Urban Development

*The scientific and technical cooperation agreement contains a variety of topics, and designation of the responsible agency is more complicated than in the other areas; the agreement itself lists the Office of Science and Technology Policy as the responsible agency, but the executive secretariat is in the State Department, while seven of the ten working groups are supported by NSF; the remaining three (water resources, forestry, and metrology) are supported by other governmental agencies (Bureau of Reclamation, National Forest Service, and National Bureau of Standards, respectively).

tists who returned from exchange visits to the Soviet Union; (ii) questionnaires, designed for computer tabulation and analysis, sent to all past American participants in the exchange; (iii) questionnaires sent to American hosts of Soviet participants in the exchange during the last 5 years; (iv) letters soliciting evaluation of the various fields of Soviet science sent to eminent American scientists familiar with Soviet work in their fields; and (v) conversations with scientists and exchange administrators in both the Soviet Union and the United States.

The Kaysen panel invited the Soviet Academy of Sciences to send similar questionnaires to Soviet scientists in the U.S.S.R. who had participated in the interacademy exchange or hosted American scientists. The Soviet Academy, however, declined to conduct a similar poll, citing its desire to avoid "interference in the internal affairs of the National Academy of Sciences."

The questionnaire sent to American participants contained more than 100 questions. For the 350 questionnaires sent out, the response rate was about 80 percent (*9*). Here I will concentrate on the answers to those questions bearing most directly on the value of the exchange. Several of the questions about the value of the exchange experience are reproduced in Table 6 together with the gross response rate.

The results of these questions can be read in several ways, but it seems accurate to say that American participants in the interacademy exchange are fairly positive about the value of the program, with three-quarters of them rating their experience in the Soviet Union as outstanding or very good. Most of them believe that the exchange program is of definite value, scientifically speaking, to the United States. On the other hand, these participants are aware of the existence of political controls over science in the Soviet Union and believe that the exchanges suffer because of these controls.

In recent talks to university audiences, I have cited these new data; the reaction has been mild surprise that American scientists are as positive as they are about the scientific value of the exchanges. It would be interesting to have the results of recent public opinion polls (scientists and nonscientists) on these questions to compare with the attitudes of participating scientists (*10*).

It is possible that the answers given by participants in the interacademy exchange are misleadingly positive. Arguments in that direction include the following: (i) The participants in this exchange may be biased; after all, they went on it, and they may not want to admit they wasted their time or had bad judgment. (ii) The participants in the interacademy exchange may not be, scientifically speaking, the best-qualified judges of the quality of Soviet science; although distinguished scientists have participated, it is generally agreed that the very best American natural scientists rarely apply; and it is further agreed that the quality of applicants has declined somewhat in recent years.

Table 2. Personnel exchange under the bilateral agreements listed in Table 1.

Year	Participants in bilateral agreements		
	United States to Soviet Union	Soviet Union to United States	Total
1972	262	246	508
1973	404	273	677
1974	837	844	1681
1975	1170	1114	2284
1976	983	853	1836
1977	761	664	1425

In order to take such possible biases of participants into account, it is helpful to examine the results of the questionnaire that was sent to the American hosts of Soviet scientists who came to the United States during 1972 to 1977 on the interacademy exchange. These hosts were American scientists who had Soviet exchangees working under their guidance for extended periods. The American hosts were, on the average, rather different from the American participants who went to the Soviet Union; they were usually more senior and distinguished, and they had not committed themselves to the idea of U.S.–Soviet exchanges to the same degree. Most of them had never been to the Soviet Union on a scientific exchange. In many cases, the Soviet scientist who came to work in the host's laboratory was just one of several foreign scientists present, all of them attracted by the research program under way there.

The total number of questionnaires mailed out to hosts was 150, and the response rate was, again, about 80 percent. This questionnaire was less detailed than that sent to exchange participants, and some of the questions bearing directly on scientific quality are listed in Table 7.

Hosts of Soviet scientists also gave fairly positive evaluations of Soviet science and Soviet scientists, 80 percent of them rating the visiting scientists as equal to or better than visiting scientists from other countries (including, of course, Western Europe). Yet the American hosts were also restrained in their enthusiasm for Soviet science, probably more so than the exchange participants. In informal communications, for example, only very few of them indicated that they would recommend that their "best postdoc" spend a year in the Soviet Union. This reluctance to have their leading students go to the Soviet Union undoubtedly stemmed from a variety of considerations, including such factors as scientific quality, instrumentation and supply difficulties, living conditions, language difficulties, and the political situation.

While the majority of American scientists who were polled believed that scientific exchange with the Soviet Union is a worthwhile and significant endeavor, they considered the United States to be ahead of the Soviet Union in most scientific fields. In some areas of mathematics and physics, on the other hand, the

American scientists who assisted the Kaysen panel in drawing up "field-by-field" surveys of Soviet science said that exchange between the two countries was entirely mutual, with both countries at the forefront of research. In most other fields, however, the United States is ahead of the Soviet Union, according to the respondents; some of the evaluations of individual fields [see (*2*) for details] were critical of Soviet performance. In the section on chemistry, for example, the Kaysen report concluded, "It is not apparent that the U.S. has a great deal to gain from Soviet chemical research as it is now practiced, although there are a few exceptions." In the section on biomedical sciences, the report observed that "There was also near unanimity in stating that young American graduate students and postdoctoral fellows would benefit very little from training opportunities in the Soviet Union except for fields such as membrane biology, protein chemistry, and the chemistry of natural products." Such statements can be compared to the observation in the section on mathematics that "Today, the Soviet Union is one of the world's leading mathematical powers." Soviet science is obviously a heterogeneous collection of subfields of varying performance, and general statements about "Soviet science" conceal enormous field-by-field differences.

While a few leading American scientists believed that little would be gained scientifically by having exchanges in their particular fields, the majority of them maintained that fruitful exchange was still possible even in those areas where the Soviet Union lagged behind the United States. Taking all the fields of science together, it seemed apparent to the members of the Kaysen panel that the United States was the stronger nation scientifically, and in that sense the United States has more to teach than to learn in scientific interchanges with the Soviet Union. However, the panel warned against concluding from this assessment that the exchanges were not valuable to the United States in a scientific sense: "In the interchange of ideas—scientific or other—neither side parts with any of its initial stock, but adds to what it receives. . . . In the process of intellectual interchange, two plus two often equals six." In another section of the report, the panel continued:

> We conclude that on the whole we have been and are currently teaching the Soviets more in the course of the exchanges than we are learning from them. It would be an error, however, to draw from this the further conclusion that we are therefore conferring on the Soviet Union a benefit at our own expense. We learn even when we are teaching, and the "expense" of time and energy put into the exchanges is not simply a cost.

After considering all evaluations of scientific quality, the panel concluded that the interacademy exchange was justified on a scientific basis alone, but noted that cultural and political factors should also be included in an overall evaluation. The most difficult question, however, is "justified relative to what?" Few people would claim that a dollar spent on a U.S.-Soviet science exchange program could not be better spent, from a strictly scientific standpoint, on American research programs selected on the basis of normal peer review. To decide on that basis, however, to withdraw support from the exchange programs would mean ignoring their political and cultural effects. The Kaysen panel has shown that the interacademy program is also producing some good science, even if the political and cultural questions are still the most important.

Table 3. Short-term (less than 60 days) personnel exchange under the bilateral agreements, 1977. Abbreviations: I, individuals; D, delegations.

Agreement	From United States		From Soviet Union		Total	
	I	D	I	D	I	D
Health	105	12	104	15	209	27
Space	23	4	32	5	55	9
Environmental protection	164	48	135	36	299	84
Atomic energy	75	14	57	14	132	28
Agriculture	27	8	31	10	58	18
World oceans	32	8	36	7	68	15
Science and technology	134	21	94	22	228	43
Transportation	23	5	21	6	44	11
Energy	93	15	58	11	151	26
Housing	56	11	57	14	113	25
Total	732	146	625	140	1357	286

Table 4. Long-term (more than 60 days) personnel exchange under the bilateral agreements, 1977. Abbreviations: I, individuals; M-M, man-months.

Agreement	From United States		From Soviet Union		Total	
	I	M-M	I	M-M	I	M-M
Health	7	16.3	12	26.7	19	43
Space	0	0	0	0	0	0
Environmental protection	7	21	10	26	17	47
Atomic energy	4	9	5	33	9	42
Agriculture	1	3	0	0	1	3
World oceans	0	0	1	2.5	1	2.5
Science and technology	11	43	11	53.5	22	96.5
Transportation	0	0	0	0	0	0
Energy	0	0	0	0	0	0
Housing	0	0	0	0	0	0
Total	30	92.3	39	141.7	69	234

Table 5. Details of visits by American scientists to the Soviet Union in fiscal years 1976 and 1977 for seven out of ten working groups under one bilateral agreement, the Agreement on Scientific and Technical Cooperation.

Group	Number of		Number of travelers		Length of stay (days)	Average number of institutions visited
	Individual trips	Group visits	Average per group	Total		
Chemical catalysis	21	1	29	50	7 to 150	3
Computer applications	8	8	14	120	14 to 35	8
Electrometallurgy	2	6	10	63	14	5
Microbiology	1	5	11	57	9	7
Physics	4	2	10	23	3 to 20	3
Science policy	1	3	8	25	8	7
Scientific and technical information	0	2	4	8	12	7

Political and Cultural Benefits

If we now include cultural and political issues in the interacademy exchange, the responses given by American participants are considerably more positive than the responses about scientific benefits alone. Indeed, the participants indicated that the most important goal of the exchange program should be "fostering the development of the international scientific community" (72 percent of them considered this goal of "vital importance" or "very important"). The generation of new scientific knowledge ranked less high in their priorities (only 35 percent of them said that "building U.S. science" was a vital or very important goal of the interacademy exchange, and only 51 percent gave the same high ratings to the goal of "building world science"). The American hosts of Soviet scientists also said that "fostering the international scientific community" was the area where the interacademy exchange was performing best; they gave the exchange a 3.48 rating on a scale of 4.0 in this area, whereas they rated the exchange at 1.89 in the area of "building world science."

The emphasis which American scientists have put upon personal, political, and cultural goals in their interactions with Soviet scientists raises a number of interesting questions: How do we know the impacts in these areas are as significant and important as the American scientists seem to believe? Is it possible that questions about "cultural impact" are "motherhood" questions to which all respondents automatically give high ratings?

Formal exchange programs with the Soviet Union play a role quite different from that of exchange programs with countries in Western Europe and much of the rest of the world. West European and American scientists have a variety of ways of getting together, but for all practical purposes the only opportunity available to a Soviet scientist for spending an extended period of time in a foreign country is through the formal exchange programs. Western veteran world travelers accustomed to making their own travel arrangements frequently do not appreciate the significance of the formal programs for their Soviet colleagues.

On hearing how important the official programs are to Soviet scientists, some Americans are tempted to reply, "The programs are not that important to us; the Soviets should change their system of travel regulations to one that is easier for us if they wish to have close contacts." Such a brusque response ignores the fact that there is little chance that the Soviet Union will change in this regard, because its attitude toward scientific cooperation is part of a much broader and long-standing policy toward international contacts.

Is there any evidence that cooperation between the United States and the Soviet Union is actually significant from a political and cultural standpoint (aside from the scientific standpoint already discussed)? A useful way to approach this question is to compare the present level of personal knowledge and communication between the scientific communities of the United States and the Soviet Union with what it was 20 years ago. In the 1950's, before exchanges began, there were few American scientists who knew very much about Soviet scientists on a personal level and who were familiar with the conditions under which they work. Now, on the faculties of almost

Table 6. Questions sent to 350 U.S. scientists about the value of the interacademy exchange, and the gross response rates shown as percentages in parentheses.

A. Overall, how would you rate your experience in the USSR?

1. Outstanding	(32.4)
2. Very good	(42.3)
3. Satisfactory	(18.8)
4. Fair	(4.8)
5. Poor	(1.8)

B. Please indicate the extent to which you agree or disagree with each of the following statements concerning the scientific nature of the exchange:

	Strongly agree	Agree	Disagree	Strongly disagree
1. Scientifically, the US gains a lot by individual exchanges to the Soviet Union	(13.7)	(44.9)	(35.9)	(5.5)
2. The exchange program results in little new scientific knowledge	(3.2)	(32.4)	(50.2)	(14.2)
3. I was able to gain access to the best facilities the USSR has to offer my field	(20.3)	(53.4)	(20.3)	(6.0)
4. Because the Soviet Union is not very advanced in my field, little scientific benefit for the US results from the exchange program	(7.6)	(13.3)	(47.7)	(31.4)
5. The scientific productivity of the exchange is hampered by the political situation in the Soviet Union	(25.4)	(47.3)	(24.2)	(3.1)

Table 7. Questions bearing on scientific quality that were sent to 150 American hosts of Soviet scientists on the interacademy exchange, and the gross response rates shown as percentages in parentheses.

A. All told, how well did this visitor rate against other scientists you have known at comparable stages in their careers?

Compared to:	American scientists	Visiting scientists from other countries
He was better	(10.2)	(25.0)
About the same	(57.4)	(55.8)
He was weaker	(32.4)	(19.2)

B. Do you feel that you and your institution benefitted from this scientist's visit?
(Yes, 78.9) (No, 20.2) (No response or don't know, 0.9)

1. If you feel that you and your institution benefitted from this scientist's visit, to what extent do the following statements describe that benefit?

	Strongly agree	Agree	Disagree	Strongly disagree
a. The scientist is an expert in his field; he suggested new research procedures, introduced new ideas or imparted new knowledge	(8.1)	(65.1)	(22.1)	(4.6)
b. Although his training and capabilities were lower than we usually expect of a professional in our field, he contributed to our work on a technical level	(4.8)	(28.3)	(38.5)	(28.3)

every large university in the United States there are scientists who have either had Soviet scientists working with them in this country or who have studied or done research in the Soviet Union. Within several subfields—particularly in mathematics and physics—there now exist invisible colleges linking researchers in the two countries, based on communication networks and friendships that are both formal and informal, but which are in many instances derived from earlier exchange visits.

These links do have political effects that are desirable from the standpoint of the American scientific community. To give one example: 20 years ago if a mathematics researcher at the Steklov Institute in Moscow were arrested, Americans might learn about it 6 months later, a year later, possibly never. Today, if such a researcher is arrested or incarcerated we will learn about it within several days, and the chances are high that someone in the United States will know that individual personally. The response of the international scientific community to repression is no guarantee of security to Soviet scientists, but there is much evidence that the awareness of the international community is a contributing factor to Soviet restraint. Almost all Soviet scientists have favored the improvement of communications, and the dissidents, in particular, have stressed that their security is greater because of their links to the West.

Some American scientists have criticized exchanges with the Soviet Union because of repressive political conditions there; the irony in this situation is revealed when we notice that these same Americans are often dependent on the exchanges for acquisition of information about those conditions. It seems clear that the worst fate for unorthodox Soviet scientists would be to lose their contacts with the West.

A few people might interpret the exchanges as an attempt to subvert the Soviet political system. Such an interpretation would be erroneous. Almost no Americans believe the exchanges and bilateral agreements could ever have impacts of such magnitude, and most consider such a goal entirely improper for a scientific program. Furthermore, Soviet authorities have been somewhat successful in containing the dissident movement. They probably know better than anyone else what the effects of the exchanges have been; the fact that they still favor scientific cooperation indicates that fear of political effects internally is not strong enough to override their desires for the exchange of scientific and technical information and for the continuation of détente.

The nonscientific gains achieved by scientific exchanges and cooperation sometimes go beyond the issue of helping Soviet scientists working under repressive conditions. The level of cooperation and personal friendship reached by a few Soviet and American scientists has probably helped at several junctures in penetrating and eventually overcoming difficult obstacles to better relations between the two powers, obstacles that were simultaneously technical and political. For example, the Soviet Union at first refused to agree with American arms control specialists that antiballistic missile weapons could be "destabilizing." A series of discussions between Soviet and American scientists helped clarify this issue, and the Soviet Union eventually agreed to the inclusion of antiballistic missiles in the talks. Several American scientists involved in these discussions believe that without the earlier contacts with their Soviet colleagues on narrow scientific issues the level of confidence and respect necessary for intimate discussion of a very different and broader type of problem might not have been present.

It is a mistake to insist that scientific exchanges with other countries—including the Soviet Union—be evaluated only on the basis of scientific and technical gains for the United States. The original exchange agreements with the U.S.S.R. were signed two decades ago in an effort to alleviate the Cold War; they still can serve such a purpose. Our attitude toward other countries is similar in the sense that we seek goals broader than mere exchange of scientific information; we have science exchanges with underdeveloped countries from which no one expects the United States to be a significant beneficiary in a scientific sense. We are currently moving toward scientific exchanges with China from which the prospect for significant scientific gain for the United States is small.

In the current phase of the cooling of relations between the United States and the Soviet Union the maintenance of some lines of communication between the two countries is more important than ever. The cancellation of scientific trips to the Soviet Union by Americans offended by Soviet actions toward dissidents is understandable. Nonetheless, we need to ask what the ultimate results of our actions will be if we angrily spurn contacts with the Soviet scientific community. If joint programs no longer existed, what would irritated American scientists have left to walk out on? The creation of a situation in which no contacts remained between the two scientific communities would obviously result in a loss of all political and cultural influence.

Technology Transfer

Analyses of cooperation between the two countries in science and technology often raise the question of whether the Soviet Union is not engaging in the programs primarily for the purpose of gaining access to superior American technology (*11*). Some critics have suggested that the exchanges are actually a "ripoff" of American technological secrets by Soviet exchangees, who are pictured as intently scooping up such information while giving up nothing of real value in return.

There is a broad spectrum of different types of science and technology contacts between the two nations; some of these contacts are in areas of fundamental science far removed from technology, others are in a middle range where both science and technology are involved, while yet others—particularly the contacts between United States firms and Soviet ministries—revolve almost entirely about technology of many different types. The interacademy exchange, which has been studied most thoroughly, is the farthest removed from technology of all the formal science and technology channels between the two countries. This program consists largely of visits and conferences among academic scientists.

The results of the evaluations of the interacademy exchange show that the description of Soviet scientists as people who "scoop up information and give nothing in return" is incorrect. (Although there are individual Soviet scientists who conform to this description.) The majority of American hosts of Soviet scientists on that exchange stated that the visiting Soviet scientist was an expert who "suggested new research procedures, introduced new ideas or imparted new knowledge." The American scientists most intimately involved with the interacademy exchange do not see it as a one-way street, but as a true interchange of ideas.

In the other exchanges and contacts (the bilateral agreements and particularly the commercial ventures) the significance of technology transfer is greater, but even there the total amount of actual technology transfer in important areas is

probably smaller than often imagined. An early effort by the Soviet Union to have a bilateral program for the study of computer technology was deflected by the U.S. government negotiators into a program on "Computer Usage in Management," and in that way avoided an exchange involving computer design and manufacture.

There is, of course, some technology transfer involved even in the noncommercial exchanges and bilateral agreements. In fundamental science exchange some technology transfer occurs, for example, in scientific instrumentation and in such areas as semiconductors and lasers. In the last two fields the gaps between fundamental and applied research are small. Furthermore, an important part of the transfer of knowledge is making the other side aware that something is possible, even if the details or exact mechanisms are not transferred.

The amount of significant technology transfer that occurs through the interacademy exchange and most of the bilateral programs is sufficiently restricted, however, that the problem can be adequately handled by more insistence by the American administrators on reciprocity in exchange, particularly in fundamental science, where the potential for American benefit is greater. On all the exchanges and agreements the United States should insist on its legitimate commercial interests, including copyright as well as patent rights, areas where the Soviet Union has accepted international conventions. Additional controls over strategically significant technology are inevitable and proper elements of an unfortunately hostile world.

By carefully differentiating between the commercial, applied, and fundamental aspects of U.S.–Soviet science and technology contacts, further exchanges between the two countries are possible without introducing government controls over academic science. On the commercial side, trade in nonstrategic technology between nations traditionally antagonistic is an entirely laudable and commercially beneficial goal.

Ways to Improve the Exchanges

The exchange program between the NAS and the Soviet Academy of Sciences has usually been based on individual visits and research, not collaborative projects or symposia. In the early years of the exchange, when the effects of the Cold War were still manifest and when American knowledge of Soviet science was somewhat superficial, the individual approach was much easier than arranging joint projects. The NAS simply announced that an exchange program was in existence and invited applications from interested and qualified American scientists. A selection of the best scientists was then made from those who applied, and these scientists went to the Soviet Union, where their expenses were paid by the Soviet Academy. The Soviets similarly selected their nominees to go to the United States, relying on their own criteria. Either side could refuse the nominees of the other side, but the record of cooperation has been good (although the applications of approximately 30 Americans and 10 Soviets have been turned down by the receiving sides).

This system of exchange was asymmetrical because of the great differences between the two countries and their science organizations (for example, the fundamental organizational differences between the Soviet Academy of Sciences and the NAS and the greater importance of political factors in nomination by the Soviet authorities). American scientists going to the Soviet Union usually worked in the institutes of the Soviet Academy, while Soviet scientists coming to the United States usually were placed in universities. This asymmetrical arrangement was often satisfactory to both sides, since the best fundamental research in the Soviet Union is predominantly in the Academy, while such research in the United States is frequently in universities.

Individual exchanges of this type still have an important role even today, 20 years after they began. They continue to be the main avenue of long-term exchange. More than 50 percent of the Americans going to the Soviet Union on the interacademy exchange stay more than 3 months; only a very small fraction of Americans going on the bilateral programs stay there that long (less than 3 percent in 1977). As a result, as many Americans go for extended periods to the Soviet Union on the interacademy exchange as on all the bilateral programs put together.

Individual exchanges also have limitations. Usually neither the Americans nor the Soviets know who will be coming from the other side until they receive the nomination letters or lists from that side a few months before the exchangees commence their travel. The ruling principle here is "sending side nominates"; the possibility for scientists from one country to invite scientists from the other to come to work with them is still very limited. Invitations have worked on occasion, but the present system makes such interactions difficult and makes true collaborative research a rarity on the interacademy exchange.

Some Americans have been so irritated by this feature of the interacademy exchange that they have suggested that the NAS require that all participants in symposia and perhaps even the regular exchange be invited by the receiving side. If the Americans were to make such a demand, however, it would surely backfire. The Soviets, who are sensitive on this issue, could respond by calling for a symposium on, say, nuclear physics to be held in Tashkent to which the only Americans invited were the ten best-known nuclear physicists in the United States. Few of the American physicists would accept (they have better things to do), and the Soviets could then justly reply that the Americans do not care for the invitational principle either. Furthermore, even if invitations did work, few Americans would like to give the Soviets complete choice over who goes to the Soviet Union on exchanges.

Upon examination, we see that achieving exchanges that work entirely by invitation is an unrealistic goal. What is a realistic and valuable goal is to create a combination of modes of exchange. Some of these would depend on individual initiative by the participants from the sending side; some would be based on mutual agreement on lists of participants by both sides; and some would originate by invitation from the receiving side. This mix of modes of exchange should be a goal of both the interacademy exchange and the bilaterals, since both have distinct contributions to make.

The bilateral agreements signed in 1972 and subsequent years have not notably improved the opportunity for issuing invitations, but they have significantly augmented the opportunities for collaborative research. These programs are not based on the principle of individual exchange but on problem areas, such as "environmental protection," "chemical catalysis," and "electrometallurgy." Productive work has been reported in some of these areas (*12*). Furthermore, the bilateral agreements have opened to American scientists and engineers Soviet industrial and agricultural institutes (in organizations ouside the Soviet Academy of Sciences) which earlier were poorly known.

However, after 6 years of experience with the bilateral agreements it has become obvious that they, too, have serious defects. First, they contain much deadwood, topics on which the benefit for the United States (and probably for

the Soviet Union) is negligible. An example was the water resources project under the science and technology bilateral agreement, several aspects of which were criticized in the Garwin report (*3*) by its American participants for providing little useful information. The bilateral programs have included large elements of "scientific tourism," much more even than the interacademy exchange. Traveling delegations, sent out by the lead agencies (usually departments or organizations of the U.S. government) spend more time on scientifically unproductive jaunts through four or five Soviet cities and six or seven research institutes than anyone wants to admit. A cynic would say, with some justice, that the wheel is constantly reinvented as one more American delegation learns about the basic organizational features of Soviet research and education but little of scientific or technical value. Last, the financial arrangements for the bilateral programs are clearly unsatisfactory; Congress has not voted appropriations to fund them, so the lead agencies are usually forced to take money from other programs. Naturally, the agencies are not eager to reveal where these funds came from, since it would then be clear that some domestic programs were being deprived of support.

Even if these organizational and financial problems were eased, the bilateral agreements would not give the American scientific community access to the best quality Soviet research. The bilateral agreements are almost entirely devoted to applied science projects (there are a few interesting exceptions, such as high energy physics research under the science and technology agreement); the strongest fields of Soviet science are in fundamental areas. The desires of fundamental scientists for collaborative projects are not often being met by the bilateral cooperative agreements. There is no bilateral agreement covering mathematics, for example, and this is probably the single strongest discipline in Soviet science.

A major problem facing the interacademy exchange is the refusal of the National Science Board, governing body of the National Science Foundation, to permit NSF funds to be used to pay for NAS collaborative research projects with the Soviet Union. According to some sources, the position of the National Science Board is that NSF cannot with responsibility delegate its authority to award funds for research. The use of NSF funds for joint research projects agreed upon by NAS and the Soviet Academy would represent a delegation of such authority to a more significant degree than the present individual exchanges do. In addition, the National Science Board is evidently worried about the pressure that would be exerted on NSF by NAS and the Soviet Academy to continue to support costly joint projects once they were under way.

Since the interacademy exchange has been dependent on NSF for financing its program, this NSF policy effectively prevents NAS from moving in one of the important directions recommended by the Kaysen panel and favored by the people who are most familiar with the interacademy program. Conceivably, the funds necessary for such collaborative projects could be sought outside NSF, but the prospects for success in this endeavor are dim.

If these administrative and financial problems can somehow be solved, the interacademy exchange program could be markedly improved by supplementing the individual exchanges with more joint symposia on selected topics and with a number of collaborative research projects, primarily in fundamental science (*13*). The goal here is to make contact with areas of Soviet excellence more effectively than the present system does, to shift from a passive to an active mode of exchange. As a result of our almost two decades of experience with Soviet exchanges and of the recent field-by-field evaluations, we now know much better than ever before what the areas of Soviet excellence are, and we should target our efforts toward them.

Summary and Conclusions

Soviet science is a heterogeneous collection of disciplines and fields in which the levels of achievement and competence vary widely. In a few areas, such as mathematics, some aspects of theoretical physics, and several subfields of engineering, Soviet scientists and engineers are equal to the very best in the world, and cooperation between the United States and the Soviet Union should be equally attractive to both sides. The present exchange programs and bilateral agreements are, however, somewhat cumbersome, contain too much tourism, and do not provide for enough collaborative research in fundamental science. Dealing with the Soviet bureaucracy is difficult, living conditions in the Soviet Union are not attractive, and Soviet political policies, particularly toward dissidents, offend many American scientists.

However, even with all these difficulties, the majority of knowledgeable American scientists believes that the present programs are valuable, and could be made even more valuable if a number of changes were made, such as: (i) providing funds for the interacademy exchange to develop more joint symposia and collaborative research in addition to the existing individual exchanges, which might even be curtailed slightly if the new modes prosper; these new efforts should be directed toward areas where Soviet science is strongest; (ii) conducting qualitative evaluations of the bilateral agreements, eliminating the unproductive ones, and supporting the successful ones with funds specifically allocated for that purpose; (iii) negotiating with the Soviet Union to obtain more fruitful cooperative mechanisms. American negotiators should tell their Soviet counterparts that the United States is not interested in expanding contacts in science and technology beyond the present level unless some of the newer modes of cooperation can be more fully supported, including modes which permit more reliance on invitations and on interchange, well in advance, of lists of participants.

If some of these modifications in U.S.-Soviet scientific cooperation were made, the programs could serve better than they have in the past the furtherance of science in both countries, the maintenance of good relations between the two governments, and the strengthening of the international scientific community.

References and Notes

1. Two recent reports specifically on science and technology exchanges were the Kaysen report (*2*) and the Garwin report (*3*). Also, see J. R. Thomas and U. M. Kruse-Vaucienne, Eds., *Soviet Science and Technology: Domestic and Foreign Perspectives* (National Science Foundation, Washington, D.C., 1977). Two other reports of exchanges, but ones which did not devote adequate attention to science and technology, are *The Raised Curtain: Report of the Twentieth Century Fund Task Force on Soviet-American Scholarly and Cultural Exchanges* (Twentieth Century Fund, New York, 1977) and Byrnes (*4*). Also, see Report No. 6 (*5*), and *A Progress Report on United States-Soviet Union Cooperative Programs by the Comptroller General of the United States* (Washington, D.C., 1975).
2. C. Kaysen, chairman, *Review of U.S.-U.S.S.R. Interacademy Exchanges and Relations* (National Academy of Sciences, Washington, D.C., 1977).
3. R. L. Garwin, chairman, *A Review of Cooperation in Science and Technology between the US and the USSR* (National Academy of Sciences, Washington, D.C., 1977).
4. R. F. Byrnes, *Soviet-American Academic Exchanges, 1958-1975* (Indiana Univ. Press, Bloomington, 1976).
5. *Review of U.S.-U.S.S.R. Cooperative Agreements on Science and Technology: Special Oversight Report No. 6* (Committee on Science and Technology, U.S. House of Representatives, Washington, D.C., 1976).
6. The members of the Kaysen panel were C. Kaysen (Massachusetts Institute of Technology), L. R. Graham (Columbia University), L. Bers (Columbia University), P. M. Doty (Harvard University), J. F. Gilbert (Scripps Institute of Oceanography), E. L. Goldwasser (Fermi Na-

tional Accelerator Laboratory), J. P. Hartnett (University of Illinois), A. H. Kassof (International Research and Exchanges Board, New York), M. F. Hawthorne (University of California, Los Angeles), N. Holonyak, Jr. (University of Illinois), I. M. London (Harvard University and Massachusetts Institute of Technology), I. J. Bennett (New York University), E. Ginzton (Varian Associates), L. Knopoff (University of California, Los Angeles), S. Udenfriend (Roche Institute), and, ex officio, D. Pines (University of Illinois), R. Roy (Pennsylvania State University), and A. Rich (Massachusetts Institute of Technology). C. Trumbull of NAS provided staff support.

7. The author of this article served as rapporteur for the Kaysen study, and was involved in several of the other recent evaluations, but the analysis presented here was written after the publication of the reports and is entirely a private, individual endeavor.
8. See *Background Materials on U.S.-U.S.S.R. Cooperative Agreements in Science and Technology* (Committee on Science and Technology, U.S. House of Representatives, Washington, D.C., 1975). There were 13 agreements earlier, but in 1977 the agreement on artificial heart research and development was combined with the agreement on medical science and public health.
9. For further information contact the Commission on International Relations, National Academy of Sciences, 2101 Constitution Avenue, NW, Washington, D.C. 20418. Identities of respondents, unknown to the administrators of the poll, cannot, of course, be supplied.
10. In 1963 a Louis Harris national poll indicated that only 34 percent of the American public favored exchanges of scientists and engineers with the Soviet Union and 54 percent opposed them. These data are too old, however, to be helpful today; furthermore, we do not know why such a large percentage was opposed to exchanges (for example, low opinion of Soviet science, or fear of giving away American scientific knowledge) [see R. F. Byrnes (*4*, p. 47)].
11. See, for example, *An Analysis of Export Control of U.S. Technology—A DOD Perspective* (Office of the Director of Defense Research and Engineering, Washington, D.C., 1976), and *U.S.-Soviet Commercial Relations: The Interplay of Economics, Technology Transfer, and Diplomacy* [Committee on Foreign Affairs, U.S. House of Representatives (prepared by J. P. Hardt and G. D. Holliday), Washington, D.C., 1973].
12. See Report No. 6 (*5*). Reports on progress in the bilateral agreements were given 13 February 1978 at the American Association for the Advancement of Science meeting in Washington, D.C. See *Abstracts of Papers of the 144th National Meeting* (AAAS Publication 78-2, Washington, D.C., 1978), pp. 96–97. Other reports on the bilateral agreements were presented at the International Studies Association Meeting in Washington, D.C., on 25 February 1978. See *19th Annual Convention Program* (International Studies Association, Washington, D.C., 1978), p. 231.
13. The National Science Board policy has been interpreted as prohibiting collaborative research on the interacademy program, but not joint symposia. Many joint symposia have been held in fields such as condensed matter, radio astronomy, partial differential equations, biological pyridoxal catalysis, nucleic acids, biological membranes, and protein chemistry. One of the most successful symposia series is described in C. Herring and D. Pines, "Theory of condensed matter; the joint symposia," *Phys. Today* **28**, 46 (November 1975).
14. This work was conducted while the author was professor of history at Columbia University.

Peptides in the Brain: The New Endocrinology of the Neuron

Roger Guillemin

Brain Peptides Controlling Adenohypophysial Functions

In the early 1950's, data from several groups in the United States and Europe showed that the endocrine secretions of the anterior lobe of the hypophysis—well known by then to control all the functions of all the target endocrine glands (thyroid, gonads, adrenal cortex) plus the overall somatic growth of the individual—were regulated by some integrative mechanism located in neuronal elements of the ventral hypothalamus (*1*). Because of the peculiar anatomy of the junctional region between ventral hypothalamus (floor of the third ventricle) and the parenchymal tissue of the anterior lobe of the pituitary (Fig. 1), the mechanisms involved in this hypothalamic control of adenohypophysial functions were best explained by proposing the secretion of products from (uncharacterized) neuronal elements of the ventral hypothalamus. Such products would somehow reach the adenohypophysis by way of the capillary vessels that appeared to join the floor of the hypothalamus to the pituitary gland. The concept of neurosecretion, or the ability of some hypothalamic neurons to secrete proteins related to the posterior pituitary hormones, had been proposed earlier by E. Scharrer and B. Scharrer (*2*).

The concept of a humoral hypothalamic control of adenohypophysial functions was ascertained by means of simple experiments with combined tissue cultures of fragments of the pituitary gland and of the ventral hypothalamus (*3*). Attempts to characterize the hypothetical hypothalamic hypophysiotropic factors started then. Simple reasoning and early chemical confirmation led to the hypothesis that these unknown substances would be small peptides. After several years of studies in several laboratories in the United States, Europe, and Japan, it became clear that characterizing these substances would be a challenge of originally unsuspected proportions. Entirely novel bioassays would have to be devised for routine testing of a large number of fractions generated by the chemical purification schemes, and enormous amounts of hypothalamic fragments (from slaughterhouse animals) would have to be obtained if we were to have available a sufficient quantity of starting material to attempt a meaningful program of chemical isolation. The early pilot studies had indeed shown the hypothalamic substances to be extremely potent and, on the basis of simple assumptions, to be present in each hypothalamic fragment only in a few nanogram quantities.

Essentially one, then two groups of investigators approached the problem with enough constancy and resolution to stay with it for the 10 years that it took to provide the first definitive solution, that is, the primary structure of one of the hypothalamic hypophysiotropic factors. My own group, then at Baylor College of Medicine in Houston, Texas (with an episode at the Collège de France in Paris), organized the collection over several years of more than 5 million sheep brains, handling in the laboratory more than 50 tons of hypothalamic fragments. Schally and his collaborators, after he had left my laboratory at Baylor, collected also very large numbers of porcine hypothalamic fragments. Late in 1968, from 300,000 sheep hypothalami, Burgus and I isolated 1.0 milligram of the first of these hypothalamic hypophysiotropic peptides, the thyrotropin-releasing factor (TRF), the molecule by which the hypothalamus regulates through the pi-

The author is Research Professor and Chairman of the Laboratories for Neuroendocrinology at the Salk Institute, La Jolla, California 92037. This article is based on the lecture he delivered in Stockholm, Sweden, on 8 December 1977 when he received the Nobel Prize in Physiology or Medicine, a prize which he shared with R. S. Yalow and A. Schally. This article is published here with the permission of the Nobel Foundation and will also be included in the complete volume of *Les Prix Nobel en 1977* as well as in the series Nobel Lectures (in English) published by Elsevier Publishing Company, Amsterdam and New York. Dr. Yalow's lecture appeared in the 16 June issue of *Science* and that of Dr. Schally in the 6 October issue.

0036-8075/78/1027-0390$02.00/0